Open File Envelope No. 12,895

NATIONAL ENERGY RESEARCH DEVELOPMENT AND DEMONSTRATION COUNCIL PROJECT 590:

UNDERGROUND GASIFICATION OF LEIGH CREEK COAL

REPORTS ON FIELD INVESTIGATIONS AND GEOTECHNICAL STUDIES

Submitted by
Shedden Pacific Pty Ltd, Golder Associates Pty Ltd, Amdel Ltd and SADME
1985

Enquiries: Customer Services
Resources and Energy Group
7th Floor
101 Grenfell Street, Adelaide 5000

Telephone: (08) 8463 3000
Facsimile: (08) 8204 1880

Government of South Australia
Department of State Development

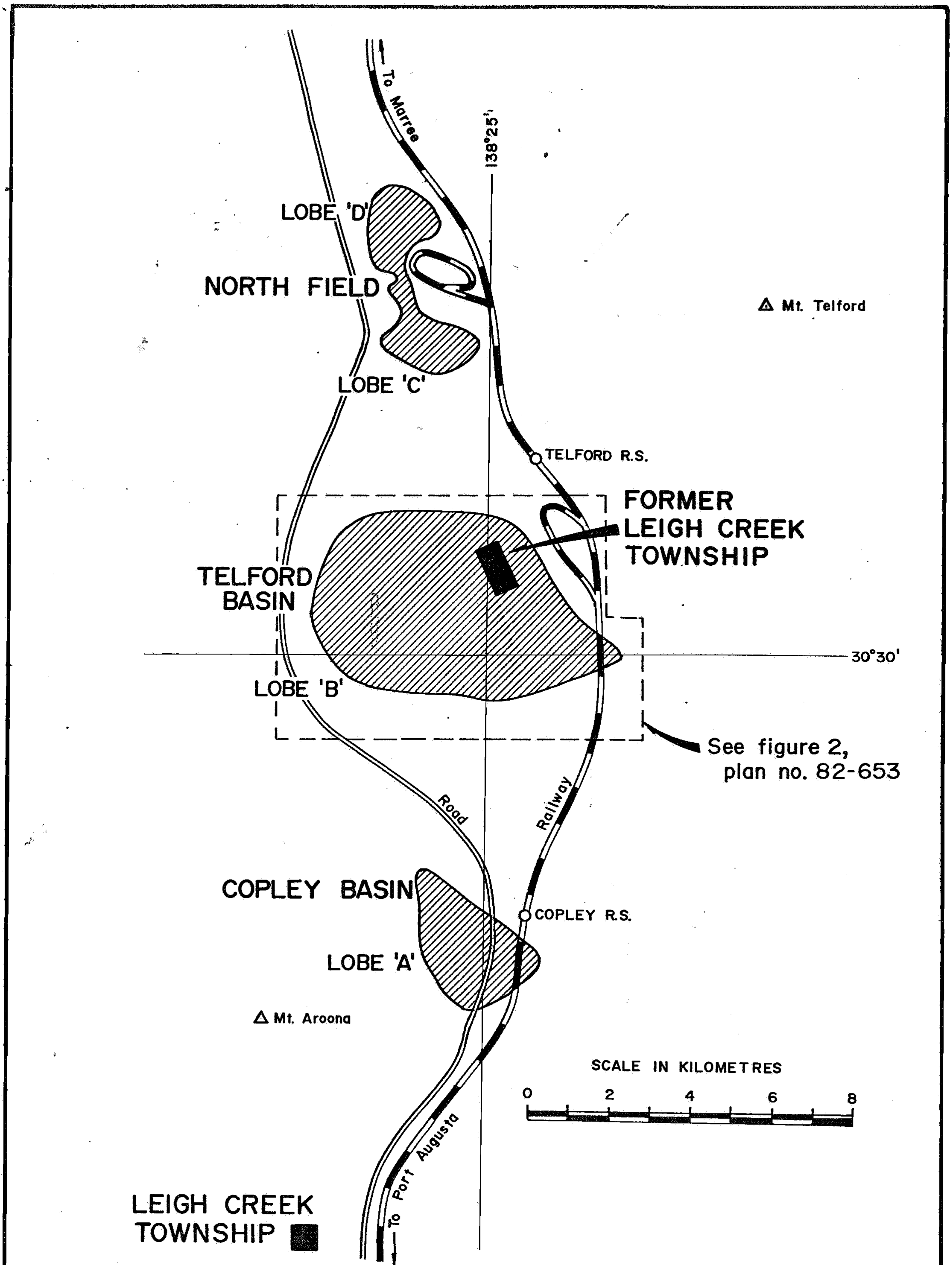

FIG. 1

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

LEIGH CREEK COALFIELD
UNDERGROUND GASIFICATION OF INACCESSIBLE COAL MEASURES
LOCALITY PLAN

COMPILED C. M. W.	C.D.O 9-2-83 DATE
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DATE DEC.' 1982	PLAN NUMBER S16504
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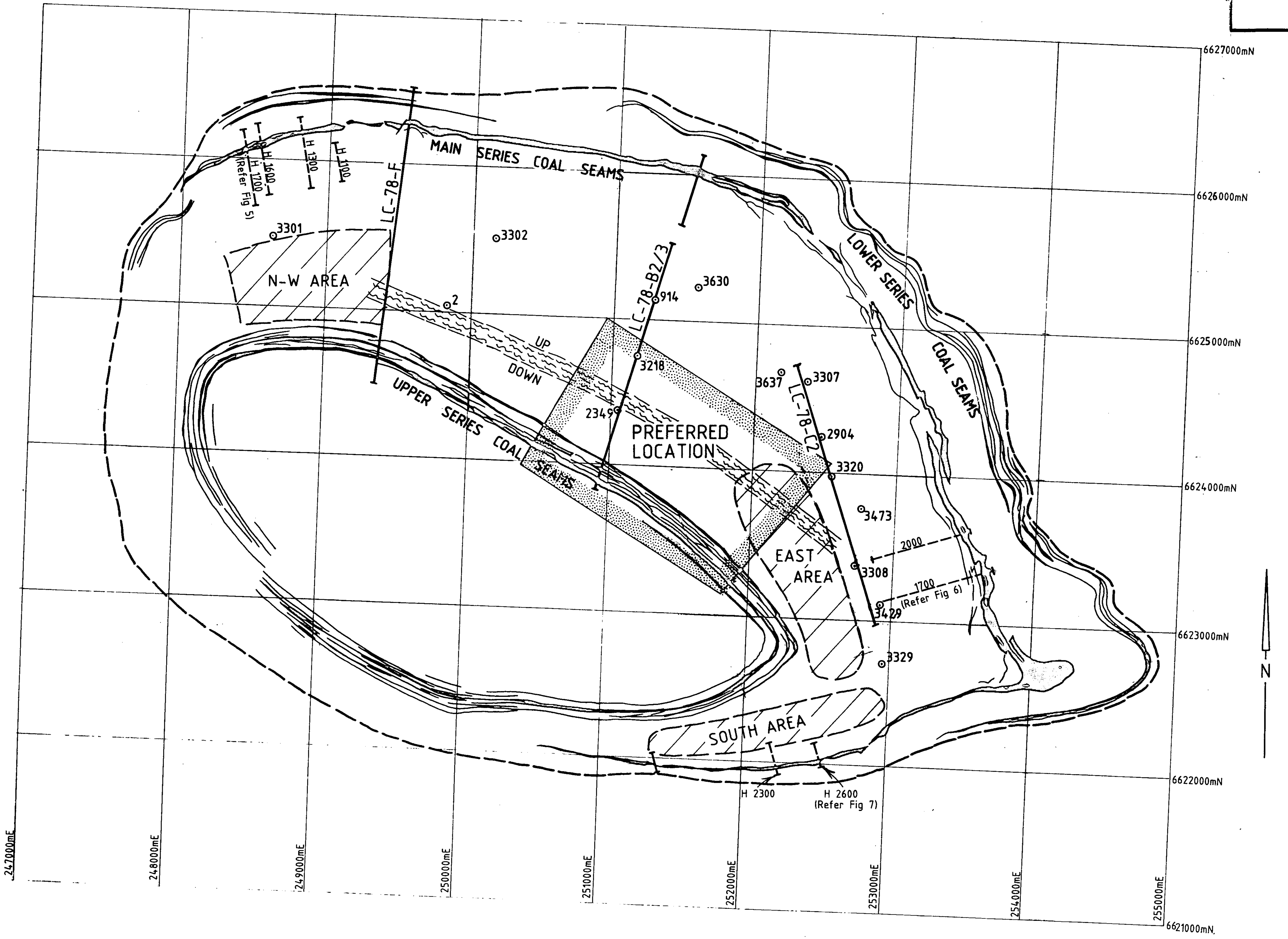
LOBE 'B' - LOCATION PLAN.

FIGURE



LEGEND

- LIMIT OF COALFIELD
- SUB-OUTCROP OF COAL SEAM
- LINE OF SECTION
- 3630 BOREHOLE
- SEISMIC TRAVERSE
- INFERRED FAULT (50m displacement)

SCALE 1:25000

REFERENCE: S.A.D.M.E. PLAN No. 83.86 FEB 1983

GOLDER ASSOCIATES

OPEN FILE ENVELOPE:

This Envelope contains technical data relating to the "**Field Investigation and Geotechnical Studies for U.C.G. Feasibility Study, Leigh Creek**", undertaken in 1984 by Golder Associates.

The study was part of the National Energy Research Development & Demonstration Council (NERDDC). NERDDC Project No 590. 'Underground Gasification of Leigh Creek Coal', but also some funding from the State government and SENRAC.

SPECIAL NOTE: Some of the data is missing or incomplete. The search for records is ongoing and any extra data located will be added to this Envelope.

82 2353

TODD TO INSERT THIS REPORT INTO ENV 12895 28/3/17.

ment of Mines and Energy
South Australia

PRE - FEASIBILITY STUDY
UNDERGROUND COAL GASIFICATION
LEIGH CREEK
SOUTH AUSTRALIA

VOLUME 1 of 2

Shedden Pacific Pty. Limited

Melbourne
August 1983

Q665.112 STEW 1983 V.1

SHEDDEN PACIFIC PTY. LIMITED

Project Managers and Engineers

Telephone: 690 6055
Telex: AA38110 Spplml

18-20 Thomson Street,
P.O. Box 324,
South Melbourne,
Victoria, 3205.
Australia

Your Ref:

Our Ref: GNR:aw:1117

October 7, 1983

The Chairman,
The National Energy Research,
Development and Demonstration Council,
National Energy Office,
Department of National Development and Energy,
P.O. Box 5,
CANBERRA. ACT. 2600.

Dear Sir,

1982 Application for Support Grant
In-Situ Gasification of Coal for Power Generation
Submitted by S.A. Department of Mines
and Energy & E.T.S.A.

Please find enclosed 12 copies of our report Pre-Feasibility Study, Underground Coal Gasification, Leigh Creek, SA, which has been prepared for the SA Department of Mines and Energy.

DME, SA have instructed us to forward these copies to you to assist in your evaluation of their 1982 Support Grant Application.

Yours faithfully,
SHEDDEN PACIFIC PTY. LIMITED

G.N. ROOSEN
SENIOR PROJECT ENGINEER

DoN 5c6 182/99

SHEDDEN PACIFIC PTY. LIMITED

PRE-FEASIBILITY STUDY
UNDERGROUND COAL GASIFICATION

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

1.1 Background

Shedden Pacific Pty. Limited, with the assistance of Professor I. McC. Stewart and Golder Associates Pty. Ltd., was commissioned to undertake a technical and economic pre-feasibility study of Underground Coal Gasification (UCG) at Leigh Creek for the South Australian Department of Mines & Energy (DME) and the Electricity Trust of South Australia (ETSA). This study was funded by a grant from the National Energy Research, Development and Demonstration Council (NERDDC) as part of its programme to promote more effective use of existing energy resources, particularly coal.

1.2 Geology & Hydrology of the Leigh Creek Coal Deposits

The geological review of the Leigh Creek deposits indicated that there are reserves in Lobe B of some 120 million tonnes of coal potentially recoverable by UCG. These reserves are unlikely to be economically recoverable by open pit or underground mining methods, and would support a 250 MW power station for approximately 25 years.

The Lobe C reserves which are also considered potentially recoverable by UCG were estimated to be in the order of only 8 million tonnes. These reserves were limited by seam thickness and shallow overburden cover. As a result, Lobe B was selected as the site for the initial UCG development programme.

A preliminary assessment of roof stability in the gasification zone indicated that a ground surface settlement of up to 80% of the coal thickness would be likely after completion of gasification. However, because the depth of gasification was selected as 200m minimum, it is considered most unlikely that gas will leak to the surface.

There is limited available information on groundwater levels and rock permeability. A preliminary assessment has indicated that the permeability may be relatively high. If these data are correct there may be high seepage flows with consequent desaturation of the roof rock. A contingency allowance has been made in the estimate for groundwater monitoring and recharging.

1.3 Technology for Underground Coal Gasification

The UCG technology selected by Professor Stewart for the particular configuration of the Leigh Creek coal measures is based on bringing together elements of UCG experience in USA, Russia and UK, his own laboratory research and data acquisition and current oil and gas field drilling technology. The gasification panel design on which this study is based, is believed to involve only a modest extension of existing overseas technology. The proposed development programme (Ref. Section 1.4) aims at adapting and verifying the selected technology for the specific characteristics of the Leigh Creek deposits.

The underground configuration comprises 80 metre wide gasification panels each with 2 production boreholes and 1 blast air borehole drilled 230 mm and 180 mm diameter respectively, for a distance of 400m, within the lower half of the coal seam. At the lower end of the panels, vertical ignition boreholes, 70 mm diameter, are drilled at 20 metre spacing. Linkage air equipment is provided so that the ignition boreholes can be linked to create the initial combustion cavity connecting the blast air and production boreholes. Six panels are required in operation at any one time. These panels burn out (and need to be replaced) at an average rate of 1.65 and 2 per year depending on the gas turbine ratings for the respective gas cleaning cases.

The selected system operating pressure is 1650-1400 kPa (abs) through the reaction zone and the gas quality will be maintained at approximately 3500 kJ/kg on a dry basis. A dual trunk main (600 mm and 550 mm dia.) carries the product gas to the gas cleaning and power generation facilities.

Two gas cleaning cases have been studied - i.e. wet scrubbing and dry cleaning. Wet scrubbing utilises a dual train system with wash box, wash column and desalination column in each train. Water treatment facilities are provided for tar and oil removal, gas stripping and waste water/solids disposal. Dry cleaning utilises a dual train system with cyclone separator and electrostatic precipitator and provides for the handling and disposal of the tar/solids residue.

The power generation plant comprises 2 x 35 MW nominally rated gas turbine alternators. A dual unit station was selected to minimise product gas wastage during generator shutdowns. This would otherwise result from the limited turndown capability of underground gasifiers. The station size was selected as being appropriate for the current Leigh Creek load and transmission facilities. After derating these units for the low calorific value gas produced by UCG, the respective qualities of the wet scrubbed and dry cleaned gases and after allowing for power consumption within the

CONTENTS

Leigh Creek Underground Coal Gasification Project

INTRODUCTION

Following preliminary evaluation of the potential for UCG for the known South Australian coal deposits, it was concluded that the deeper measures of the main series in the Telford Basin of the Leigh Creek coalfield could be appropriate for more immediate investigation. The known geology for the deposit with its seams dipping at 10-15° appeared to be suitable for UCG, while causing economic limitations on the extent of current open-cast mining operations. In addition, existing infrastructure and local demand for electricity could provide an effective basis for a pilot plant and demonstration plant, generating electricity from the gas using gas turbine generators.

Consultants were engaged to perform a preliminary feasibility study for UCG at Leigh Creek, with a view to generating about 50MW in a pilot scale plant and 200 MW in a demonstration plant, should feasibility be confirmed.

Prefeasibility Study

The geological review of the Leigh Creek deposits indicated that there are reserves in Lobe B (Telford Basin) of about 120 million tonnes of coal potentially recoverable by UCG, which are unlikely to be economic using conventional mining techniques. The coal considered was selected at a minimum depth of 200 m at which depth, based on the limited information available, it was considered that roof stability and sealing characteristics would be adequate. There was somewhat more uncertainty with regard to groundwater seepage and an additional contingency was introduced into the feasibility study to allow for this.

The technology selected for the particular configuration of Leigh Creek was based on elements of the UCG experience in USA, Russia and UK, brought together by Professor I. Stewart of the University of Newcastle, NSW, whose laboratory facilities were used in some testing programmes for the coal. The underground configuration thus selected comprises 80 m wide gasification panels each with 2 production boreholes and 1 blast air hole drilled 230 mm and 180 mm diameter respectively for a distance of 400 m within the lower half of the coal seam. At the lower end of the panels, vertical ignition boreholes, 70 mm diameter are drilled at 20m spacing. Linkage would be by directional drilling. Six panels would be required in operation at any one time (nominal 50 MW plant) which would burn out at a average rate of about 2 per year. The selected operating pressure was 1 650 kPa, airblown.

The study considered the available options for gas cleaning and performed a preliminary costing for the 50 MW scale plant which led to a levelised cost of electricity generated of 4.5 to 5.5 ¢/kWh. It may be projected that for a 200 MW plant this cost would reduce to 3.4 to 4.3 cents/kWh.

On these grounds, it was concluded that UCG applied to Leigh Creek coal for local electricity generation could be both technically and economically feasible providing various necessary assumptions could be confirmed, leading to a proposal for an ongoing testing and development programme.

Testing and Development Programme

This programme has been designed to further evaluate the suitability of the Leigh Creek deposit for UCG and to implement a staged assessment of the technical and economic feasibility of this technology.

From the start it was recognised that a staged development would be necessary to maximise the probability of success and minimise the cost. The programme shown in Figure 1 was therefore derived. Table 1 illustrates current intentions for funding the stages of development up to the construction of the pilot plant. Departmental funding is assured and applications for SENRAC (State Energy Research Advisory Committee) and NERDDC (National Energy Research Development and Demonstration Council) grants have been made.

Phases I and II have been completed, phase III being the prefeasibility study previously discussed.

Phase III involves drilling a fully cased and fully cored hole from 30 metres above the coal to determine hydrological factors in the coal and in the interval immediately above it, to establish the permeability of the coal and of the roof strata, and to determine other geotechnical information relevant to UCG.

This will be followed by 6-8 holes over two years fully logged, to confirm projected reserves, establish the projected continuity of the coal seam and probability of significant faulting, and provide further confirmation of hydrological and permeability factors. Departmental resources will be applied to this phase with some consultant assistance for interpretation specifically related to UCG.

Phase IV

The results of Phase III will be evaluated and compared with projections used in the prefeasibility study and any variations assessed for their impact on the feasibility.

On the assumption that the project is still considered to be feasible, two fully cased holes will be drilled, linked and a test burn performed.

The results of that test burn will be evaluated, if necessary with further modelling tests performed in the University of Newcastle test rig, to ascertain the conditions necessary for performing a full panel burn.

Finally a full feasibility study will be performed involving expertise from organisations with operating experience with UCG, and a pilot panel design produced, with final design of the above ground pilot scale gas cleaning and gas turbine generator plant following on feasibility being confirmed.

Phase V

Although no specific funding has yet been arranged for this stage, it is anticipated that if final costing is as currently projected Electricity Trust involvement, either as the developer or as a contracted purchaser of electricity or of clean gas, would be justified. Private sector involvement and other government sources of funding may also be sought to progress this stage.

On the economics determined by the prefeasibility study, the electricity generated, even at pilot-scale, would be competitive with alternative sources of supply for the location, particularly since the timing would coincide with an increasing need to reduce natural gas consumption for base load electricity generation in the State, and local supply would allow an equivalent amount of power from the coal fired Northern Power Station to be transmitted to the Metropolitan load centre.

Figure 1 : Leigh Creek Underground Coal Gasification Project

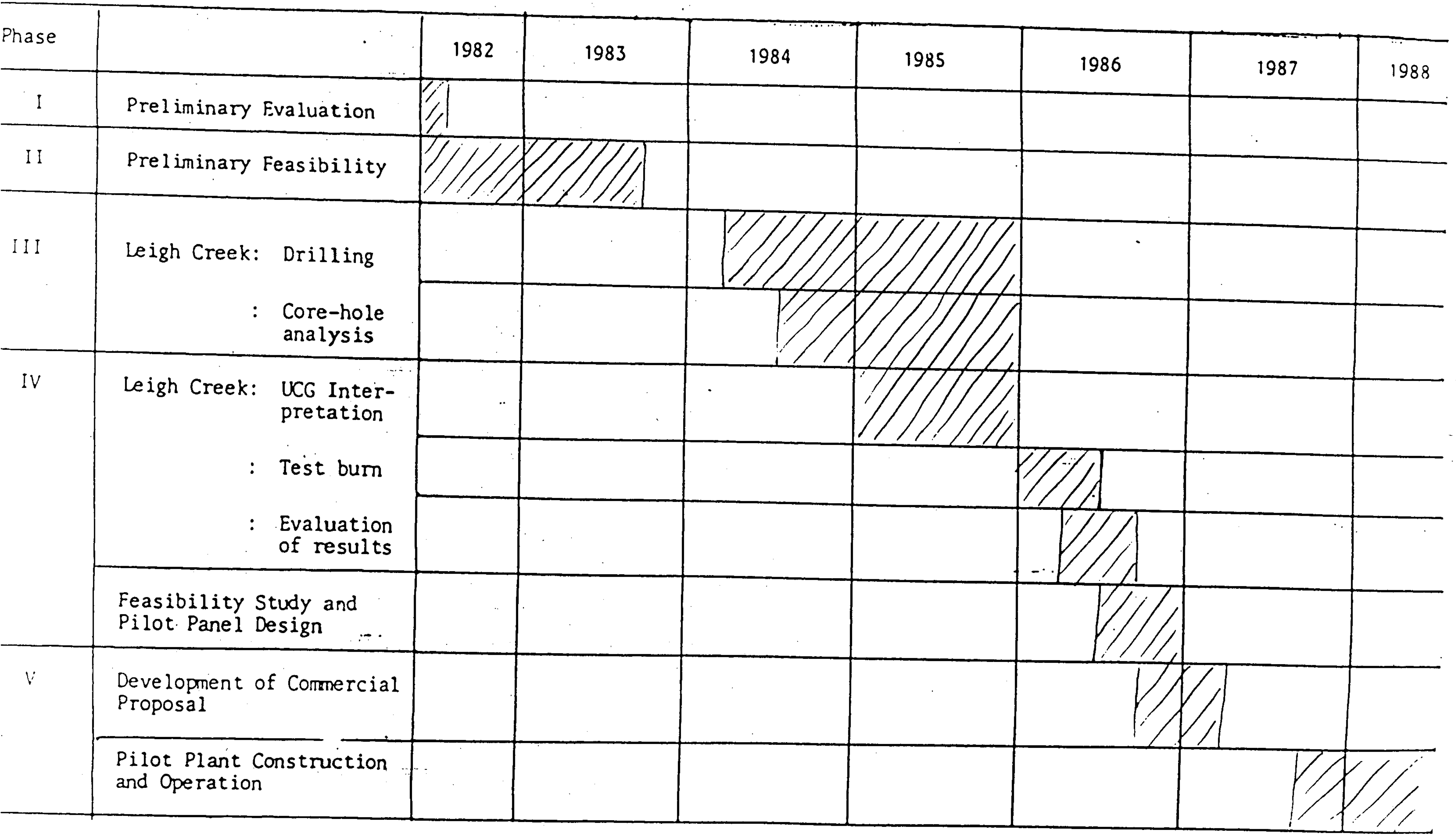


Table 1 Leigh Creek Underground Coal Gasification Project

Proposed Funding

	Dept of Mines & Energy, ETSA *	SENRAC	NERDDC
Phase I			
Preliminary Evaluation of Technology, Deposits (1979-81)	$20 000	-	-
Phase II			
Preliminary Feasibility Study of Leigh Creek (1982-83)	$5 000	-	$55,000
Phase III			
Drilling and Geotechnical Evaluation			
1983-84	-	$50 000	-
1984-85	$120 000	$50 000	-
1985-86	$120 000	-	-
Phase IV			
i) Interpretation of Deposit Characteristics for UCG and preparation for test (1985)	-	-	$70 000
ii) Test burn (1985-6)	-	$60 000	-
iii) Final feasibility and pilot plant design (1986)	-	-	$100 000
TOTAL	$265 000	$160 000	$225 000

Phase V

Commercial pilot plant — Private funding to be sought

* NOTE: Does not include cost of staff responsible for the UCG project.

UCG 85/5

FLP 4049

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

REPORT

TO

SHEDDEN PACIFIC PTY. LTD.

ON

FIELD INVESTIGATION AND
GEOTECHNICAL STUDIES

FOR

U.C.G. FEASIBILITY STUDY
LEIGH CREEK

MAY 1985

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GOLDER ASSOCIATES PTY LTD.
25 BURWOOD ROAD HAWTHORN VIC 3122 AUSTRALIA
MELBOURNE
TEL (03) 819 4044
TELEX AA33616

May 15, 1985

82612075

TABLE OF CONTENTS

LIST OF FIGURES

SUMMARY

Following an initial appraisal of the U.C.G. potential at Leigh Creek, a field investigation has been undertaken to provide quantitative data on the strength and permeability characteristics of the geological profile of the Main Series in Lobe B. The principal concerns for development of a gasified system relate to the potential drawdown of the water table, and resulting groundwater inflow into the burn cavity, and the stability of roof rocks as the cavity expands.

During preparation for the field programme, additional investigation data was obtained from D.M.E. in Adelaide which indicated that a significant fault, with a displacement exceeding 50 metres, passed through the area previously defined for gasification. Following extensive discussion, it was agreed that a redefinition of the area to be gasified in Lobe B was required, if required reserves of some 30 million tonnes were to be obtained. The area selected was updip of the fault, but restricted by the ultimate highwall of the Main Series open cut. The investigation programme was planned for this area.

Investigation Programme

Three partly cored boreholes were drilled to depths of 260.2, 396.8 and 403.7m on two seismic lines crossing the area of study. Two shallow holes were also drilled for installation of near surface piezometers. Permeability testing and geophysical logging were undertaken in the deep holes and sealed piezometers installed for water level measurement. Permeability values were determined for roof and floor rocks and the coal seam. Indentor tests were used to assess rock strengths.

The investigation generally confirmed the thickness and continuity of the Main Series coal seam, established by previous work, with good agreement being achieved between seismic and drillhole data. An average coal thickness of about 14m, with dips varying from 16^{o} to 22^{o} were determined.

Approximate estimates place the reserves in the defined area of study at about 36 million tonnes, significantly in excess of that required. However initial use of these reserves does have significant implications on the development of the complete Lobe B resource.

Geotechnical Evaluation

Computer analyses have been used to simulate the response of groundwater to the progressive burning of a 500m wide cavity, using data obtained from field results. The values for permeability (1 to 5 x 10^{-9} m/s) are significantly lower than those indicated in previous reports and used in the preliminary appraisal in 1983.

Despite the significant assumptions required for the analysis, the results suggest that both groundwater inflow and groundwater drawdown will be acceptable. The estimated inflow suggests that the ratio of average water flow to coal production should be in the range 1:10 to 1:100, which will be readily handled by the gasification process. The groundwater drawdown should maintain a cover of about 100m of water except perhaps near the end of the mine life, depending on the parameters assumed. The long-term situation can only realistically be assessed after obtaining data from the early years of operation.

With respect to roof stability, calculations suggest that complete closure will not occur until the full seam length has been gasified, with the caved zone extending perhaps 25 to 50m above the cavity. Ground settlements long-term in the range 10-13m might be anticipated.

Overview of Lobe B Resource

An initial appraisal has been made of the complete resource in Lobe B, with the purpose of assessing the best technical approach to its development. Total reserves of approximately 200 million tonnes in the Main Series seam, and 80 million tonnes in the Lower Series seam are considered possible, although data below 500m is very limited. While the Main seam appears to maintain excellent thickness, the Lower seam is variable and banded, and although an average of 3m of coal has been assumed, some difficulties may exist in maintaining a continuous burn because of changing coal thickness.

If total reserves of around 250 million tonnes are present, it is reasonable to consider the effect of developing the proposed area on the development of the complete deposit. It is evident that the current proposal would create technical difficulties in developing downdip in the Main Series, and in gaining access to the Lower Series, because of problems of drilling through broken ground.

If development of Lobe B in its entirety is contemplated, it is clear that an initial programme of seismic work and deep drilling would be essential to define reserves and gasification potential below 500m depth.

GOLDER ASSOCIATES PTY. LTD.
per:

L.K. Walker

L.K. Walker

I.M. Gibson

I.M. Gibson

LKW/IMG/blh

1. INTRODUCTION

In April 1983, Golder Associates presented a report entitled "Geotechnical Aspects of U.C.G. Feasibility Study, Leigh Creek". The report collated and reviewed existing data relevant to the development of an underground coal gasification scheme utilizing the Leigh Creek coal measures which are inaccessible to open cut mining.

The report considered a number of alternatives for development including the three main coal seams (Upper, Main and Lower Series) of Lobe B. Lobe C was also considered, but detailed study deferred due to lack of suitable long-term reserves for the required power supply. The most likely area for development of 60 MW of produced power with a plant life of 20 years was considered to involve a high pressure system using Main Series coal from Lobe B. Reserves of about 30 million tonnes were inferred to exist between the upper series outcrop line and the long-term high wall of the Main Series open pit. Coal to the north-west and south-east of this area was considered unsuitable due to likely faulting at depth. Apart from the general geological environment, the report considered three key factors in detail, given the limited data available in the preferred area.

- coal seam characteristics (reserves, thickness and continuity)
- roof stability
- influence of groundwater.

The Main Series seam showed an acceptable average coal thickness of about 13m, without evidence of significant faulting which would affect the continuity of the gasification process. The roof rock was considered to be of sufficient strength to provide controlled caving without suppressing the coal burning process.

An evaluation of groundwater effects on gasification was made using limited rock permeability data provided by D.M.E. The analyses predicted high seepage flows, with desaturation of the roof rock after a number of years of working. Although it was felt that the permeability values quoted were unreasonably high, and the predictions were unduly conservative, it was recommended that a contingency item be included in cost estimates in the event that some recharging of aquifers was required during the mine life.

Following completion of this initial report, it was felt that further progress of the feasibility study required quantitative field data on roof and floor rock strength and permeability, existing water levels, and coal seam permeability and continuity. Various discussions ensued with D.M.E. in Adelaide during 1984 concerning the most efficient use of resources, and the extent to which the Department could assist by providing drilling services. During this period, additional geological information was provided by the Department which indicated that a significant fault passed through the area previously defined for gasification.

A meeting was held in Adelaide on September 7, 1984, to resolve finally the approach to be taken to the execution of a limited geotechnical programme to better define existing uncertainties. The meeting was attended by Prof. I. Stewart and representatives of Golder Associates and D.M.E. It was agreed that the presence of the fault required a redefinition of an area of reserves to supply about 30 million tonnes. A possible area updip of the fault was defined, and the investigation programme set out in detail.

This report describes the field work performed, the rock parameters obtained, and presents the current interpretation of

- coal seam thickness, reserves and continuity
- geotechnical parameters as they affect groundwater pressures and flow, and stability of the roof in the gasified zone.

2. INVESTIGATION PROGRAMME

2.1 Existing Information

The location plan for Lobe B is presented as Figure 1, showing the outcrop of the Main and Upper Series coal seams. Also shown on the plan are locations of previous boreholes and seismic traverses. This data consists of

- a seismic traverse line AA with three correlation boreholes (BHL3027, 3382 and 1576)
- a seismic traverse line BB with two correlation boreholes (BHL914 and BHL3218) plus one borehole entirely in rock (BHL2349)
- one additional borehole (BHL3630)
- available cross-sections within open cut region of Main Series.

Cross-sections along the seismic traverse lines have been drawn up to show the inferred continuity of the Main Series coal seam (Figures 2 and 3). These sections indicate that the coal seam maintains its thickness and continuity to the maximum interpreted depth of about 450m-500m when a major fault is encountered. The throw of the fault is inferred to be 52m on Section AA and 60m on Section BB. Although the seismic traverses picked up minor faults at shallower depths, the coal seam displacements appear to be less than half the seam thickness and should therefore have little effect on the continuity of the gasification process.

Existing drillhole results show a reasonable correlation of the intersected coal seam updip of the fault with that inferred from the traverses. The absence of coal in borehole L2349 on Section BB also confirms the presence of a substantial fault in the area defined by seismic work, although the borehole suggests that the throw of the fault is greater than interpreted. Data from the sections and from coal exposures in outcrop have enabled an inferred zone of influence of the fault to be defined on plan (refer Figure 1). Although positive confirmation of the fault by intersection of the coal seam down-dip of the fault is not available, sufficient certainty of its presence exists to require reconsideration of the originally proposed gasification procedure.

Normal gasification procedure would involve the progress of a burn updip in panels. Collapse of the roof would occur progressively as the panel was burnt out. Obviously the burn would start at the fault, and would require to be restarted if coal at lower levels was to be burnt. There are two main obstacles to the successful restarting of the process - the cost of drilling deep new ignition and recovery holes, and the need to drill through previously caved roof rock. In view of these difficulties it was determined that investigation work should concentrate on coal within an area updip of the fault governed by

- the inferred fault location
- the long-term high wall for the open cut (updip).

Within these boundaries (outlined on Figure 1) it was determined that reserves of approximately 30 million tonnes could be recovered.

2.2 Field Programme

After agreement on the area of investigation, a limited drilling programme was undertaken during the period October-December, 1984. The main purposes of the programme were

- to establish continuity of the Main Series coal seam to give confidence to proposed gasification panel layouts, and to inferred coal reserves

- to establish basic strength and permeability characteristics of the coal seam, and roof and floor rocks, to be used in assessing the consequences of panel development on water flows and rock stability.

The drilling work was undertaken using D.M.E. equipment and personnel, under the direction of Mr. I. Gibson, a senior engineering geologist from Golder Associates. Borehole locations were restricted to existing seismic lines on Sections AA and BB so that calibration of the results could be achieved.

Three partly cored deep boreholes (numbered L3964, L3966 and L3967) were completed, with shallow holes being drilled alongside the first two holes for installation of near-surface piezometers. Borehole L3964 was drilled on Section AA, while L3966 and L3967 were drilled on Section BB to the north-west of the site.

Boreholes L3964 and L3967 were drilled by open hole methods to a predetermined level, and then lined with steel casing prior to commencement of coring. Rising head permeability testing was performed using a wireline pneumatic double packer system. Upon completion of coring, boreholes were geophysically logged for a range of nuclear, electrical and acoustic properties using equipment supplied and operated by S.A.D.M.E.

After geophysical logging, a piezometer was installed within the coal seam interval in these two boreholes. The interval between the upper grout seal and the base of the steel casing may also be regarded as providing a means of measuring piezometric head at this level. Details of the piezometer installations are shown on Figure 4. A supplementary shallow observation bore (L3965) was completed adjacent to L3964.

Borehole L3966 was intended only to correlate with the seismic data and was drilled open-hole into the coal before coring. No in-situ testing was performed, however the upper section of the borehole can be used to monitor groundwater levels. A shallow observation bore (L3968) was completed adjacent to L3966.

Table 1 summarizes the detailed information for each hole - its depth, cored interval, coal intersection, and location of permeability test intervals. Core recovered over the indicated depths was photographed in colour, and then logged in detail for geotechnical purposes, including:

- rock type
- estimated strength
- bedding dip
- joint dip
- fractures per metre.

TABLE 1

SUMMARY OF BOREHOLE DETAILS

Borehole No.	Depth (m)	Cored Interval (m)	Coal Intersection (m)
L3964	403.7	349.1 - 403.7	371.1 - 389.9
L3965		Observation Borehole	
L3966	260.2	241.0 - 260.2	227.0 - 242.9
L3967	396.8	312.4 - 396.8	373.2 - 384.7
L3968		Observation Borehole	

Borehole No.	Permeability Test Interval (m)	Permeability (m/s)	Strata
L3964	350.0 - 368.1	1×10^{-9}	roof
	368.4 - 389.9	2×10^{-9}	coal
	389.7 - 403.7	1×10^{-9}	floor
L3967	315.0 - 335.8		roof
	315.0 - 359.4	4×10^{-9}	roof
	372.0 - 396.8	100×10^{-9}	coal
	384.0 - 396.8	2×10^{-9}	floor

Strength estimates were backed up by a limited field testing programme consisting of Point Load Strength Index testing and Rock Core Hardness Indentor tests. Detailed borelogs and test results are presented in Appendix A to this report. Core photographs are included in Appendix B.

Water levels have been monitored in each of the piezometers/standpipes since the completion of drilling in late December 1984. Table 2 lists all results reported to date, it being noted that the piezometers were flushed out in early February 1985 and have subsequently restabilized.

2.3 Materials Testing

The strength of roof and floor rocks was determined in the field using Point Load Index testing and Rock Hardness Indentor testing. The Point Load Index (I_s) is obtained by testing pieces of core 50mm long, and correlations between unconfined compressive strength (u.c.s.) in MPa and I_s have been established, viz.

$$u.c.s. \approx 25\ I_s.$$

For low strength rocks, it is often difficult to obtain suitable specimens for laboratory testing, and under these conditions the Indentor, which simulates the loading of a small circular footing, can be used to obtain an estimate of unconfined compressive strength. For low strength rocks ($\phi = 25^0$) a correlation exists between u.c.s. and indentor reading which is linear. As rock strength increases, the relationship becomes non-linear.

The rock strength test data are summarized on Figure 5, which shows

- the correlation curve between Indentor reading and u.c.s.
- the correlation between Point Load Index and u.c.s.
- test data showing Point Load Index strength plotted against Indentor reading. Locations of individual tests are shown on the borelogs in Appendix A.

TABLE 2

LEIGH CREEK
U.C.G. FIELD PROGRAMME
GROUNDWATER MEASUREMENTS

DATE	L3964			L3966		L3967	
	3/4" GAL. COAL	6" STEEL ROOF	L3965 PVC SHALLOW	6" PVC ROOF	L3968 SHALLOW	3/4" GAL. COAL	6" STEEL ROOF
20/12/84	11.28	18.80	DRY	8.84	15.12	11.08	38.83
2/1/85	10.47	18.26	DRY	8.80	15.18	10.72	16.03
4/1/85	10.46	18.00	DRY	8.81	15.19	11.03	15.79
7/1/85	10.47	17.68	DRY	8.81	15.20	11.54	15.60
8/1/85	10.51	17.66	DRY	8.83	5.22	12.36	14.88
10/1/85	10.42	17.62	DRY	8.82	5.25	12.41	15.55
14/1/85	10.41	17.61	DRY	8.82	5.26	12.50	15.60
16/1/85	10.39	17.62	DRY	8.81	5.27	12.59	15.67
18/1/85	10.37	17.61	DRY	8.82	5.27	12.58	15.71
21/1/85	10.37	17.60	DRY	8.81	5.28	12.68	15.76
23/1/85	10.36	17.60	DRY	8.81	5.29	12.79	15.80
24/1/85	10.45	17.61	DRY	8.83	5.31	12.86	14.81
25/1/85	10.48	17.60	DRY	8.82	5.32	12.76	14.75
28/1/85	10.40	17.54	DRY	8.81	5.33	12.79	14.60
30/1/85	10.34	17.52	DRY	8.82	5.35	12.82	14.54
31/1/85	10.35	17.52	DRY	8.81	5.32	12.84	14.52
4/2/85	12.94	17.60	DRY	8.83	5.36	12.88	14.39
6/2/85	12.34	17.57	DRY	8.67	5.37	12.97	14.32
8/2/85	14.41	19.13	DRY	8.78	5.33	12.59	14.30
11/2/85	13.26	18.81	DRY	8.77	5.33	12.81	14.21
13/2/85	13.16	18.69	DRY	8.77	5.36	12.65	14.17
6/3/85	13.68	16.64	DRY	8.71	5.38	13.22	13.89
11/3/85	13.63	16.50	DRY	8.70	5.41	13.07	13.88
13/3/85	13.65	16.44	DRY	8.70	5.40	13.31	13.84
15/3/85	13.68	16.39	DRY	8.69	5.42	13.02	13.86
19/3/85	13.58	16.26	DRY	8.68	5.44	13.11	13.80
22/4/85	13.59	14.81	DRY	8.67	5.51	12.91	13.63

It can be concluded from the results that the Leigh Creek rocks are generally of medium strength (i.e. outside the linear range of the Indentor correlation curve), and are uniform with a relatively small scatter in test data.

2.4 Permeability Test Data

The six rising head permeability tests were undertaken after completion of borehole drilling, and were run for approximately one hour. Water level recoveries over this period varied from 0.06 to 4.5m, with five of the tests producing rises of less than 0.6m due to the relatively low rock permeabilities. While the changes in level for most of these tests are small, a result of time limitations on site, the permeabilities calculated are considered to give a reasonable estimate of the in-situ value for the purposes of the feasibility study. Variations in the static water level, as shown by the measurements reported in Table 2, do not have a significant effect on the calculated permeability. Permeabilities for each of the six tests undertaken are listed on Table 1.

3. COAL SEAM CHARACTERISTICS

3.1 Geology

The general geology of the Main Series coal seam in Lobe B was summarized in the April 1983 report. Previous investigation work, apart from that summarized on Figures 1-3, has been concentrated in areas likely to be mined by open-cut methods, i.e. at maximum depths in the range 150-200m. Detailed examination of geophysical logs resulted in the separation of the seam into upper and lower splits separated by a middle parting of 1-2m thickness comprised of mudstones, often carbonaceous. Some improvement in coal quality down-dip was anticipated.

Average coal thicknesses were assessed in different areas as follows:

N-W area, dip 15^{0}-20^{0}, 13.3m coal in 15.8m seam
E area, dip 10^{0}-15^{0}, 13.4m coal in 15.2m seam
S area, dip 30^{0}-40^{0}, 8.2m coal in 10.7m seam.

An assessment was made of faulting, and it was concluded that only the southern area of the seam was likely to be affected by faulting to an extent which would significantly interrupt the gasification of coal to depths of about 500m.

3.2 Seam Thickness and Continuity

Coal intersections of 15.9m (L3966), 11.5m (L3967) and 18.8m (L3964) were obtained from the three boreholes drilled in this investigation. There was no evidence of intermediate partings over these intervals. These intersections are consistent with the data inferred from previous reports, and from interpretations of the seismic traversing shown on Figures 2 and 3. The results thus give considerable confidence to the maintenance of seam thickness to depths of around 500m.

These intersections have been plotted on Figures 2 and 3 to enable a reassessment of seam continuity to be made. It is evident that good correlation exists between the boreholes and seismic traverse, confirming the good continuity of the seam down to the major inferred fault. The strata dip at an angle of about 16^{0} at borehole 3964 on Section BB, increasing to 22^{0} at 3967 on Section AA.

With respect both to seam thickness and continuity, the additional data obtained for the report gives substantial additional evidence of the suitability of the Main Series coal seam for gasification. The existence of a fault at about 500m depth with a throw greater than 50m does however demand that consideration be given to the best means of utilizing the entire resource in the seam, since gasification updip of the fault has obvious implications if recovery downdip is to be pursued. These broader considerations are discussed further in Section 5.

3.3 Reserves

The principal purpose of the April 1983 report was to confirm reserves sufficient to produce 60 MW actual of power using a high pressure system with a plant life of 20 years. Revised estimates of coal usage gives a calculated requirement for 30 million tonnes of coal. It is obviously important to estimate the reserves existing within the area bounded by the inferred fault and longterm location of the crest of the open cut high wall, assuming a face slope angle of 45^o.

The area for reserve calculation is indicated on Figure 1, while the length of coal seam which can realistically be worked, given geometric constraints, is indicated on the cross-sections (Figures 2 and 3). Approximate calculations of reserves within the bounded area, to an accuracy consistent with the limited field data available, may be summarized as follows.

Plan area within boundaries = 1.9×10^6 m^2

Average dip = 18^o, average coal thickness = 14m

.. reserves in-place

$$= \frac{1.9 \times 10^6}{\cos 18^o} \times 14m$$

$$= 28 \times 10^6 \ m^3$$

Assuming a density of 1.3 tonne/m^3 gives reserves of about 36 million tonnes, significantly in excess of the required tonnage. However it must be pointed out (refer Section 5) that use of these reserves for initial power production may have detrimental effects on development long-term of the total Lobe B resource.

It is evident that the reserve calculation will be redone when details of a gasification procedure is defined, particularly with respect to detailing of the drilling of deviated holes from the high wall of the open cut. However it is sufficient at this stage of the study to indicate that the required reserves are present to support the feasibility of the proposed plant.

4. TECHNICAL ANALYSIS OF GASIFICATION

4.1 Groundwater Analysis

In the April 1983 report, a simplified analysis of the effects of the gasification process on groundwater levels was made using a finite element groundwater computer package developed by Golder Associates. A computer model was developed to simulate the progressive gasification of a 600m working face at a rate of 100 m/year. This analysis used permeability values provided in a previous report by Coffey and Partners, which were considered at the time to be unrealistically high.

Although permeabilities in the roof and floor rocks obtained in the field programme are relatively uniform, a wide range of values was obtained for the coal. A detailed analysis would thus require a range of permeability values to be used to determine the sensitivity of water inflow and water table drawdown to variations in permeability of the various layers. Other factors to be considered in the analysis are the gas pressure in the cavity and the increased permeability which will result in the caved zone above the cavity. Given the limited scope of this study, a preliminary analysis has been undertaken using the following parameters

- roof permeability 2×10^{-9} m/s
- coal permeability 3×10^{-9} m/s
- floor permeability 1×10^{-9} m/s
- cavity pressure 15 atmospheres
- effect of caving ignored.

The finite element analysis was used to predict the response of groundwater for the case of a 500m wide burn excavation progressively introduced over a 20 year period. The model was based on the section shown on Figure 6. The coal seam (15m thick) treated in the analysis was restricted to 100m updip of the fault and 200m from the toe of the open cut. The two-dimensional model assumed an extensive burn along strike (i.e. >2000m).

The analysis for the open cut mining phase indicates an average groundwater inflow rate of 23 ML/year for 1 km face length of the pit, with the phreatic surface after 20 years indicated on Figure 7.

The effect of underground coal gasification (years 20 to 40) was simulated by applying a constant mine inflow rate from nodes within the excavated area. The inflow rate was selected by trial and error to be compatible with initial and final pressure states in the cavity, given that progressive mining will occur updip. An average inflow rate of 45 ML/year for a 1 km face length was adopted, and five time increments in the gasification of the seam were adopted.

Figure 7 presents the distribution of water pressure head across the burn section at the completion of the burn. The uniform fluid pressure of about 150m water head in the excavation results from the assumed cavity gas pressure of 15 atmospheres. The water table, which was lowered about 25m at the updip end of the seam during open pit mining, is lowered to 40m after completion of the burn, i.e. about 200m above the seam.

The limited scope of this study has meant that more detailed analyses varying input parameters has not been possible. However inferences have been made from the results obtained as follows.

A lower cavity gas pressure would increase groundwater inflow rates during excavation. It is estimated that zero fluid pressure at the end of gasification would cause an average inflow of 90 ML/year per 1 km length. Lowering of the water table is estimated to increase from 40m to 100m, which would still leave a minimum groundwater cover of about 140m over the top end of the excavation area.

If a higher permeability dislocation zone was introduced over the burn area in the latter stages of excavation, this would cause a marginal increase in groundwater inflow rates, but a significant increase in groundwater table lowering, particularly for the low fluid pressure case. In the extreme case of zero fluid pressure in the cavity, the groundwater cover at the updip end might be close to zero in the latter part of the gasification period.

The coal seam permeability used in the analysis is at the low end of the range measured. If a significantly higher value was adopted, this would result in slight increases in groundwater inflows and water table lowering during underground mining. In addition, higher groundwater inflows and more extensive depressurization of the coal seam would occur before underground mining commences.

4.2 Roof Stability

A preliminary evaluation of roof stability was made in the April 1983 report, using experience derived from the U.K. involving overburden which was typically well-bedded sedimentary strata. It was estimated that the expected maximum possible settlement might be in the range 0.7 to 0.9 of the seam thickness. For the average coal thickness of 14m used in the ore reserve calculation, this implies a ground settlement in the range 10-13m. The drill core and strength testing showed a mudstone of relatively uniform medium strength, which is consistent with the U.K. rock types from which the data were derived. The projections of maximum ground settlement are therefore considered realistic.

With respect to caving of the coal seam roof, observations of subsidence suggest that the mining width at which closure occurs is about 1.4h (where h is the mining depth below ground surface). For an average mining depth of about 350m, the mining width for closure is thus 490m, i.e. the full width of the burn.

The height of caving above the gasified zone is estimated from experience at about 0.07 to 0.14h, i.e. between 25m and 50m, or about 1.7 to 3.3 times the seam thickness. It should be noted that the height of the caved zone is restricted by the bulking of the caved material. With a bulking factor of between 1.2 and 1.3, the extent of bulking is limited to between 3 and 5 times the seam thickness before roof support is achieved.

Beyond the caving height, a zone of lesser dislocation will exist within which there will be an increase in rock permeability to a height estimated at up to 10 times the mining height. This effect will of course reduce with distance above the cavity.

4.3 Implications on Gasification Process

The field investigation programme has enabled a better definition of rock strength and permeability characteristics, and of groundwater levels. These parameters have enabled more relevant analyses to be made of groundwater response to creation of the gasified cavity, and of roof stability and surface settlement.

Despite the significant assumptions required to be made for the preliminary analysis undertaken, the results suggest that both groundwater inflow and groundwater drawdown will be acceptable. The estimate of water inflow is 45 ML/year per 1 km of face. The rate of gasification indicates that a full face length (along the strike of the seam) of about 4 km will be mined in 20 years, i.e. 200 m/year. The estimated inflow is thus 9 ML/year, or 9000 m^3/year. This compares with a rate of coal production of about 30 million tonnes in 20 years, or about 1 million m^3/year. The ratio of average water flow to coal production is thus about 1:100. This is a relatively low flow, and even with localized higher coal permeabilities the ratio should not exceed say 1:5, which will be readily handled in the gasification process.

With respect to groundwater table drawdown, the analyses suggest that with the most unfavourable assumptions, a groundwater cover should be maintained above the coal seam to prevent gas leakage except perhaps at the end of mine life. Given the limited accuracy of all parameters, it can sensibly be concluded that a significant pressure head over the cavity is likely for most of the mine life, and that the long-term situation can only realistically be assessed after data from the early years of operation are obtained.

Conclusions as to roof stability are not significantly changed from those presented in the April report. The calculations of roof stability suggest that complete closure will not occur until the full seam length updip has been gasified. The caved zone will extend perhaps 25 to 50m above the cavity but should have a limited effect on the gasification process because of its development late in the gasification of a particular panel.

5. OVERVIEW OF LOBE B RESOURCE

The preliminary studies of underground coal gasification on Lobe B were based on the requirement to provide 70 MW of power over a life of 20 years. Main Series coal was selected as most suitable for this purpose, with a high pressure system forming the basis of the feasibility study.

Following discussions with ETSA on development of Lobe B, it was considered desirable to assess the overall reserves in this deposit, rather than part of one particular seam. Comments below on each of the Lower, Main and Upper Series coal seams are extracted from the April report, modified by limited additional information. The relative positions of the three coal seams are shown on Figure 8. With the relatively shallow depth of the Upper Series, and the possibility of developing the open cut to at least 200m, it is probably realistic to ignore the possibility of recovering coal from these seams by gasification. The obvious possibility involves recovery from the Main and Lower Series over the full seam length.

Both of these seams appear to terminate in the south-west area of the basin, possibly along a major inferred fault structure. The vertical separation between the seams, to the extent that it is defined, appears to be roughly constant at about 150m-200m.

Based on a very preliminary assessment of deep seismic survey data, the Main Series seam downdip of the area proposed for gasification appears to maintain its thickness and continuity. Knowledge of the nature of the seam to a depth of 400m can thus be extrapolated to depth with some modest likelihood of applicability.

The composition of the Lower Series seam is relatively complex, being made up of variably interbedded coal and mudstone according to the limited data available at shallow depth (<200m). The coal bearing interval is comprised typically of an upper and lower split separated by 10m to 20m of mudstone. The overall coal content exhibits considerable range in both splits, as does the thickness of the major coal bands, which range from 2.5m to 8.0m in the north-eastern area and from 1.7m to 3.6m in the southern areas. The upper split contains several coal bands in excess of 3m thickness, but those in the lower split rarely exceed 1.5m.

In attempting to achieve a realistic assessment of total reserves, it would appear reasonable and perhaps conservative to adopt an average seam thickness of at least 10m in the Main Series and a total of 4m in the Lower Series. A rough seam length of 3500m and a width of about 4500m can be obtained from current knowledge of the basin geology. The reserves which result from these dimensions are

Main Series - 160 million m^3 or 200 million tonnes

Lower Series - 60 million m^3 or 80 million tonnes.

The limited accuracy of these estimates should be evident from previous discussion.

If the total gasifiable resources of Lobe B are put at around 250 to 300 million tonnes, i.e. ten times the amount being considered for development in the present study, it is reasonable to consider the impact of the proposed 60 MW scheme on development of the complete deposit.

Two major factors requiring consideration in determining the best method of developing the complete resource are

- the need to define reserves at depth (>500m)
- difficulties in developing the Lower Series seam if the Main Series is gasified first.

The latter point results from the problems of drilling through caved ground within and above the Main Series seam in order to install ignition holes at lower levels.

The problem of adequately defining coal seam thickness, reserves, and continuity at depth is obviously of great significance in determining the maximum potential of Lobe B for gasification. This is particularly true for the Lower Series, due to the variable thickness of the seam in the splits.

There is little doubt that an initial programme of seismic investigation and limited deep drilling would be necessary to support any long-term plan to gasify both Main and Lower Series seams to maximum depth.

APPENDIX A

LOCATION	
SURFACE ELEVATION (R.L.)	DATUM
INCLINATION VERTICAL	AZIMUTH
DRILL TYPE / METHOD HOTT	DATE

BORE HOLE L 3964

FIGURE A1

SHEET 1 OF 7

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. ▼ DEPTH ▲ metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm) 1 4 16 64	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
	OPEN HOLE Surf. - 349.09								
MUDSTONE F	dark brey, moderately weak, massive, some banding evident, low angle dip 6° to 8°		349 .460 .390 .420			100	1 1 0 1	349.09 bedding dip 6°, clean, rough, planar 349.38 bedding dip 8°, clean, rough, planar 349.56 bedding dip 8°, clean, rough, planar 349.95 drilling 10°, irregular, stepped, rough	

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	HQTT	DATE	

BORE HOLE L 3964

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A1

SHEET 2 OF 7

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	GRAPHIC LOG	R.L. / DEPTH (metres)	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)	ROCK INDENTOR VALUES (I_s=POINT LOAD STRENGTH)
MUDSTONE F	dark grey, moderately weak, massive, low bedding angle to 10°		350				1	350.23 bedding dip 10°, slight curve, smooth, clean	460
							1	350.36 bedding dip 4°, clean smooth planar	470
							0		450
							1		470
			351			100	1	350.84 bedding dip 10°, clean, smooth, planar	460
							0	351.10 bedding dip 4°, clean, smooth, planar	470
							0		485
							2	351.91 bedding dip 10°, clean, rough, planar	440
			352	352.10			0	352.02 bedding dip 10°, clean, rough, planar	440
							0	352.50 to 352.58 hard bar	500
						100	0		520
									460
			353				1	353.00 bedding dip 10°, clean, rough, planar	460 (I_s = 1.10 MPa)
							0	353.37 drilling B3 10°, clean, rough, planar	500
							1		500
							0		510
			354				1	353.72 bedding dip 10°, clean, rough, planar	500
							2	354.23 B3 dip 10°, clean, rough, planar	510
								354.30 B3 dip 9°, clean, rough, planar	460
			345	34			0		460
							0		
			355				1	354.84 bedding dip 6°, discoloured, rough, planar	460
							0	355.29 bedding dip 9°, discoloured, rough, planar	460
	minor bedding plane trace, SILTY horizons (?)					100	1	355.57 to 355.60 hard bar, irregular, small, slickensides developed on bedding planes 12° to 16°	460
							2	355.80 bedding dip 9°, discoloured, rough, planar	460
			356				1	356.04 drilling - bedding dip 9°	460 (I_s = 0.81 MPa)
							0		460
							0		510
							0		460
			357				1	356.98 bedding dip 9°, discoloured, rough, planar	470 (I_s = 0.56 MPa)
				357.26			2	357.06 bedding dip 8°, discoloured, rough, planar	
							1	357.13 bedding dip 9°, discoloured, rough, planar	460
							1	357.40 drilling 9°, clean, rough, planar	460
								357.54 drilling 9°, clean, rough, planar	
			358				0	357.65 hard bar 25mm, bedding 10° at 120° to other faces	460
							0		460
							0		460
							1	358.72 bedding dip 5°, discoloured, rough, planar, iron-stained	440
			359			100	0		480
							1	359.22 bedding dip 8°, discoloured, rough, planar	470 (I_s = 0.86 MPa)
							1	359.31 bedding dip 7°, clean, rough, planar	480
				359.90					470
			360						

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	HQTT	DATE	

BORE HOLE L3964

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A1

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	GRAPHIC LOG	R.L. / DEPTH (metres)	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)	ROCK INDENTOR VALUES (I_s = POINT LOAD STRENGTH)
MUDSTONE F	dark grey, moderately weak, massive, uniform		360				0		450
							0		440
							1	360.51 drilling 8°, clean, smooth, planar, minor leaf impression	450
							1	360.95 drilling 10°, clean, rough, planar	460
			361				1	361.04 drilling 9°, clean, rough, planar	470
							0		450
							1	361.60 drilling 10°, clean, rough, planar	440
							1	361.90 bedding 12° minor slicks, smooth planar	440
	well developed banding throughout, often several cycles of upwards filling		362 / 362.06				0	361.91 to 362.10 hard bar; 361.92 bedding 16°, slicks, smooth, planar	500
							3		460
							0		470
							0		460
			363				3	363.21 drilling 10°, clean, smooth, planar	430, 470 (I_s = 0.88 MPa)
						100	3		470
							1	363.80 drilling 11°, clean, rough, planar	470
			364				1	364.04 drilling 6°, clean, rough, slightly curved	460
							1	364.18 drilling 8°, clean, smooth, planar	450
							0		460
							1		460
			365				0	365.03 to 365.04 driling breaks from catcher	460
			365.14				2	365.23 bedding 6°, clean, smooth, planar	430
							7	365.48 bedding 7°, clean, smooth, planar; 365.49 bedding 7°, slickensides down dip polished planar	420
							4	365.30 to 365.80 many bedding planes with 9° dip, minor slickensides very smooth, planar, slicks often small striations sub-parallel to bedding direction.	500, 355
			366				2		430
							1	356.70 irregular slicked fragments	
							0	365.79 to 365.86 hard bar	440
						100	0	366.05	420
			367				1	366.92 bedding dip 6°, clean, rough, planar	440 (I_s = 0.63 MPa)
							0	367.29 bedding dip 6°, minor slicks, rough, planar	380
							3	267.44 bedding dip 5°, very small crush zone paralled bedding	450
							4	367.47 several sub-parallel sub-vertical discontinuous fractures	430
							1	367.62 bedding 8°, clean, rough, planar	460
			368 / 368.14				5	367.86 bedding 10°, clean, rough, planar; 368.13 joint dip 65°, clean, rough, planar passes downhole into zone of sub-vertical sub-parallel fractures	
							4		
			368.64				1		
							0		
			369				0	369.06 to 369.83 several sub-vertical drilling induced fractures due to re-drilling	
							1		
							2		
			370				1		

3864

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	HOTT	DATE	

BORE HOLE L3694

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A1

SHEET 4 OF 7

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	GRAPHIC LOG	R.L. / DEPTH metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)	ROCK INDENTOR VALUES
MUDSTONE F	grey and dark grey, moderately weak		370				0	370.37 drilling very minor grinding	430
							1		465
						100	1		450
							0	370.74 drilling	390
			371						460
COAL F	black, vertical		371.07						
			371.69						
			372						
			373			NA			
			374						
	MAIN SERIES COAL SEAM 371.07-389.87		374.72						
			375			NA			
			376			NA			
			377						
			377.77						
			378						
			379			NA			
			380						

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	HOTT	DATE	

BORE HOLE L3964

FIGURE A1

SHEET 5 OF 7

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. ▼ DEPTH ▲ metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
COAL F	black, very weak to weak		380						
			380.82						
			381						
			382			NA			
	MAIN SERIES COAL SEAM 371.07 - 389.87		383						
			383.87						
			384				NA		
			385			NA			
			386						
			386.84						
			387						
			388			NA			
			389						
			389.87						
			390						

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	HQTT	DATE	

BORE HOLE L3964

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A1

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	GRAPHIC LOG	R.L. / DEPTH (metres)	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)	ROCK INDENTOR VALUES (I_s = POINT LOAD STRENGTH)
MUDSTONE F	grey and dark grey, moderatley weak		390 – 392.66			100	0, 0, 0, 0, 0, 1, 0, 0, 0	391.03 very thin hard bar 5mm 391.31 bedding dip 6°,clean,rough,plan planar No breaks	430, 440, 430, 460, 420, 460-500, 450, 480 (I_s = 0.50 MPa), 440
			392.66 – 394.72			100	1, 0, 0, 0, 0, 0, 0, 0, 0	392.66 bedding dip 6°, slicked crush zone 3mm intact 393.5 to 394.4 irregular fracture at about 15° Increased dip between two crush zones 392.66 and 395.08	440, 470, 410, 460, 430, 430, 450, 460 (I_s = 0.53 MPa), 440, 450
near CLAYSTONE			394.72 – 397.72			100	0, 2, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1	395.08 to 395.10 bedding dip flat, irregular, high slicked,very smooth slightly curved 395.74 bedding dip 4°,clean,rough, planar 395.95 bedding dip 6°,clean,rough, planar 396.43 bedding dip 4°,clean,rough, planar 396.96 to 397.11 hard bar 397.55 bedding 4°, possibly crush zone, very thin	450, 450, 460, 500, 520, 450, 500, 460, 475, 460, 440, 450, 460
			397.72 – 400			100	0, 0, 0, 1, 0, 2, 1, 1, 0, 0	398.46 bedding (?) dip 2-3° clean, rough, planar 398.77 bedding 7°,clean,rough,planar 398.96 to 399.08 hard bar 398.96 contact to hard bar dip 3°, highly polished, smooth, planar 399.12 bedding 4°, clean,very rough, planar 399.36 bedding 6°,clean very rough, planar	430, 440, 420, 500, 460, 460, 460, 460

BORE HOLE L3964

FIGURE A1

SHEET 7 OF 7

LOCATION

SURFACE ELEVATION (R.L.) DATUM

INCLINATION VERTICAL AZIMUTH

DRILL TYPE / METHOD HQTT DATE

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. / DEPTH metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	ROCK INDENTOR VALUES
MUDSTONE F	dark grey, massive		400				0		460
							0		460
			400.72				0		430
							0		460
			401				1	401.0 minor grinding 401.07 bedding dip 3°, very rough, clean, planar	500
							0		430
							0		460
			402			100	0		450
							0	slickensides, msooth, slightly curved, hard bar at 402.65 15mm thick, slicken-sides, smooth, planar	450
							2		430
							0		470
			403				0		480
							0		450
							1	403.50 bedding dip 4°, clean,rough, planar	480
							0		460

END OF BOREHOLE
@
403.72M

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	PORTADRILL -H Q T T	DATE	14.12.84

BORE HOLE L3966

PROJECT SHEDDEN/ U.C.G./LEIGH CREEK

FIGURE A2

SHEET 1 OF 2

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. ▼ DEPTH ▲ metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
	OPEN HOLE (SURF - 241m)		240						
COAL F	black, very weak		241 242					bedding contact angle 10°	
SILTSTONE F SANDY	grey, moderately weak, rare coal bands and blebs		242.95				0 1 2	at coal base very fine grained silty sandstone 15mm 243.4 sub-vertical in fill structure	
SANDSTONE F GRADING VERY SILTY	light grey-brown, very fine grained ?		243.80 244				4 0 2	244.3 bedding dip 8°, clean, rough, planar	
			244.61 245				1 3 5		
GRADING SANDY	light brown and grey						2 3		
COAL			245.78 246				1 2 3		
MUDSTONE F WITH COAL BANDS	dark grey, weak		246.65				2 3		
MUDSTONE F	grey, moderately weak, massive minor banding evident		247.00 248				1 3 3 7 4 8 5	247.10 bedding dip 2°, clean, rough planar 247.18 bedding dip 7°, clean, rough planar 247.25 bedding dip 4°, clean, rough planar 247.33 bedding dip 5°, clean, rough planar 247.5 to 248 many bedding planes dip 4° to 16°, clean, rough, planar 247.95 hard bar 26mm intact bedding dip 6° clean, rough, planar	
(?CLAYSTONE)	light grey, moderately high strength		249				8 5 4 5 6	248.95 hard bar 10mm 249.82 and 249.88 bedding dip 8° clean, rough, planar	
			250						

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	PORTADRILL -H Q T T	DATE	14.12.84

BORE HOLE L3966

FIGURE A2

SHEET 2 OF 2

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. / DEPTH metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
MUDSTONE F	grey and dark grey, moderately weak, massive		250				1, 1, 2, 2	250.80 bedding dip 8° clean,rough,planar 250.95 bedding dip 5°clean, rough,planar	
			251				4, 2, 2, 3	251.14 hard bar intact 251.48 SLTST band, yellow-brown, moderately weak Bedding disrupted at top and bottom, no slickenside 251.92 bedding dip 11°clean,rough,planar	
			252				3, 3, 5, 4	252.48 hard nodule, parallel bedding 252.80 bedding dip 8°clean,rough, irregular, planar	
			253				2, 3, 2, 1	253.50 to 253.60 hard bar intact 253.96 bedding dip 8° clean,rough,planar fossil trace	
			254				3, 3, 4, 3	254.22 bedding dip 4° clean,rough, irregular, planar 254.37 bedding dip 5°clean,rough,planar 254.73 joint dip 20°grooved down dip, smooth,planar,dip normal to bedding dip 254.83 hard bar, thin, weak	
			255				4, 5, 3, 3	255.06 to 255.21 development of several thin hard bars- sandy bedding dip 8° clean, rough, planar	
			256				3, 5, 3, 2	256.00 bedding dip 8°clean,rough,planar 256.20 bedding dip 4°clean,rough,planar 256.26 bedding dip 15°clean,rough,planar 256.43 to 256.46 hard bar, thin, weak bedding dip 8°, clean, rough, planar	
			257				3, 3, 3, 4	257.19 to 257.26 sandy siltstone, bedding dip 8°, clean, rough, planar	
			258				5, 3, 2, 4, 2	258.0 to 258.38 several bedding planes dip 4° to 15°, clean, rough, planar 258.68 to 260.0 many bedding planes dip 6° to 10° clean, rough, planar	
CLAYSTONE (?)	banded light grey and grey		259				4, 5, 6, 7, 3	259.30 to 259.46 hard bar, high strength	
			260						

END OF BOREHOLE
@
260.20M

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	Portadrill - HQTT	DATE	

BORE HOLE L3967

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A3

SHEET 1 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	GRAPHIC LOG	R.L. / DEPTH (metres)	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)	ROCK INDENTOR VALUES (I_s = POINT LOAD STRENGTH)
	OPEN HOLE SURFACE - 313.60M		310 – 313.60						
MUDSTONE F	dark grey, moderately weak, rock, massive low angle bedding		313.60 – 314.44				0, 1, 2	314.52 joint dip 12°, very smooth, clean, planar, horizontal to bedding direction	460, 470, 490
			314.44 – 316.40				0, 0, 1, 1, 0, 2, 3	315.45 bedding dip 15°, clean, rough, planar; 316.02 bedding dip 10°, clean, rough, planar	480, 470, 490, 480, 490, 480
			316.40 – 317.85				2, 3, 0, 1, 1, 0		490, 480, 480, 520 (I_s = 0.6 MPa)
			317.85 – 319.70				0, 0, 2, 0, 1, 1, 1, 1		450, 470, 430, 420, 460, 470, 480
			319.70 – 320				1		

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	Portadrill - HQTT	DATE	

BORE HOLE L3967

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A3

SHEET 2 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	GRAPHIC LOG	R.L. / DEPTH (metres)	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)	ROCK INDENTOR VALUES (I_s=POINT LOAD STRENGTH)
MUDSTONE F	dark grey, moderately weak rock massive, low angle bedding		320 – 322.05			100	0, 1, 1, 0, 0, 1, 1, 1, 1, 1		480, 470, 500, 480, 460, 490, 490, 440, 450 (I_s = .86 MPa), 440
			322.05 – 324.58			100	0, 1, 0, 0, 0, 0, 1, 1, 0, 0, 1	324.25 bedding dip 22°, pyrite (?), rough, planar	500, 460, 470, 520, 560, (I_s = .78 MPa), 460, 480, 500, 470
			324.58 – 327.70			45	1, 2, 1, 2, 3, 2, 2, 3, 4, 8, 6, 0, 1	324.58 joint dip 17°, slickensided, highly polished, very smooth, planar 325.47 tp 325.76 several joints dip 8° to 15° normal to bedding direction, Each highly polished, very smooth, planar, slicks generally parallel to bedding dip direction 326.75 to 327.10 numerous flat dipping joints and bedding. all approx paralled to bedding, each highly polished, very smooth, planar to slightly curved	520, 490, 400, 480, 460, 480, 490, 470, 480, 470, 470
			327.70 – 330			100	0, 1, 1, 2, 1, 2, 0, 0, 3, 1		490, 480, 480, 460, 470, 470 (I_s = 1.32 MPa)

Depth markers: 320, 321, 322, 322.05, 323, 324, 324.58, 325, 326, 327, 327.70, 328, 329, 330

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	Portadrill - HQTT	DATE	

BORE HOLE L3967

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A3

SHEET 3 OF 11

Columns: ROCK TYPE AND DEGREE OF WEATHERING | DESCRIPTION (COLOUR, HARDNESS, etc.) | GRAPHIC LOG | R.L. / DEPTH (metres) | CORE RUN AND TYPE | CORE LOST | R.Q.D. (%) | FRACTURE LOG (PER 250mm) | DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE) | ROCK INDENTOR VALUES (I_s = POINT LOAD STRENGTH)

Depth interval: 330 – 340 metres

Rock type: MUDSTONE F

Description: dark grey, moderately weak rock massive, low angle bedding

Core run boundaries: 330.48; 332.69; 335.76; 338.08

R.Q.D. (%): 98; 98; 65; 90

Fracture log (per 250 mm, top to bottom): 0, 2, 2, 1, 1, 1, 2, 0, 2, 0, 1, 0, 2, 1, 1, 1, 2, 2, 2, 2, 1, 2, 2, 1, 2, 2, 2, 3, 3, 4, 1, 3, 4, 0, 1, 1, 1, 1, 0, 2

Discontinuities:

- 333.83 to 333.89 hard bar
- 335.15 to 335.32 hard bar, irregular nodules
- 337.32 joint dip 25° to 30°, discontinuous, polished, very smooth, curved
- 337.22 joint dip 50° normal to bedding, polished, very smooth, planar
- 337.60 joint dip 60° normal to bedding, polished, very smooth, planar
- 338.0 joint dip 65°, curved and polished, very smooth, planar

Rock indentor values (top to bottom): 460, 440, 480, 450, 450, 420, 450, 440, 450, 450, 490, 480, 460, 460, 480 (I_s = .82 MPa), 480, 510, 480, 480, 440, 470, 460, 490, 470, 450, 460, 470 (I_s = .88 MPa), 440, 440, 420, 500, 460, 460, 460, 460, 470, 450 (I_s = .33 MPa), 450, 430, 460

LOCATION				BORE HOLE L3967	FIGURE A3
SURFACE ELEVATION (R.L.)		DATUM			
INCLINATION	VERTICAL	AZIMUTH			
DRILL TYPE / METHOD	Portadrill - HQTT	DATE		PROJECT SHEDDEN/U.C.G./LEIGH CREEK	SHEET 4 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. / DEPTH metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	ROCK INDENTOR VALUES (I_s=POINT LOAD STRENGTH)
MUDSTONE F	dark grey, moderately weak rock, massive, low angle bedding		340				0	339.90 two parallel joints dip 60°, highly polished, very smooth, planar, normal to bedding	460
							0		470 (I_s = 1.30 MPa)
							2		470
							3		480
			341				1		
	DEPTH CHECK REVEALED ERROR IN DRILLING DEPTH. BASE OF BOREHOLE ACTUALLY AT 339.84M DEPTH ERROR 1.24M TOO DEEP								

LOCATION			
SURFACE ELEVATION (R.L.)	DATUM	# BORE HOLE L3967	FIGURE A3
INCLINATION VERTICAL	AZIMUTH		
DRILL TYPE / METHOD Portadrill - HQTT	DATE	PROJECT SHEDDEN/U.C.G./LEIGH CREEK	SHEET 5 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. DEPTH metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm) 1 4 16 64	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
			330						
			331						
			332						
			333						
			334						
			335						
			336						
			337						
			338						
			339						
	REPORT NOTE - SHEET 4 DEPTH CHECK ETC.								
			340						

BORE HOLE L3967

FIGURE A3

SHEET 6 OF 11

LOCATION	
SURFACE ELEVATION (R.L.)	
DATUM	
INCLINATION	VERTICAL
AZIMUTH	
DRILL TYPE / METHOD	Portadrill - HQTT
DATE	
PROJECT	SHEDDEN/U.C.G./LEIGH CREEK

ROCK TYPE AND DEGREE OF WEATHERING: MUDSTONE F

DESCRIPTION (COLOUR, HARDNESS, etc.): dark grey, moderatley weak rock, massive, low angle bedding

GRAPHIC LOG

R.L. / DEPTH (metres): 340, 341, 342, 342.84, 343, 344, 345, 345.90, 346, 347, 348, 348.90, 349, 350

CORE RUN AND TYPE: runs at 342.84, 345.90, 348.90

R.Q.D. (%): 30, 50, 75

FRACTURE LOG (PER 250mm): 1, 4, 5, 5, 3, 4, 4, 2, 3, 5, 5, 3, 0, 3, 2, 2, 2, 2, 2, 5, 5, 2, 4, 1, 2, 2, 0, 2, 1, 3, 3, 1, 3, 2, 3, 1, 1, 1, 0, 3

DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE):

340.4 to 341.2 several flat dipping joints, normal to bedding, highly polished, very smooth,slightly curved surface,normal to bedding dip

340.64 joint dip 65°,highly polished, very smooth,slightly curved surface, normal to bedding dip

340.8 joint dip sub-vertical curved, highly polished and slickensided,very smooth,normal to bedding dip

341.75 joint dip 55°,highly polished and slickensided,very smooth,planar

342.0 to 342.4 several slightly curved joints dipping in same directions as bedding. Each highly polished,slickensided,very smooth

342.84 two parallel joints dip 60°, highly polished, slickensided,planar, normal to bedding

344.24 joint dip 60°,polished, very smooth,planar, dip same direction as bedding

344.55 joint dip 65°,polished,smooth, planar, normal to bedding

345.30 to 345.90 several bedding planes, dip 12° to 15°, clean, rough,planar, often trace pyrite

348.45 several sub-parallel joints,dip 55° to 65°,highly polished,very smooth, slightly curved

348.75 bedding dip 16°,clean,rough, planar, joint dip 35° to 40°,slickensides,very smooth,slightly curved, normal to bedding

349.75 joint dip 65° normal to bedding, closed slickensided,very smooth,planar

ROCK INDENTOR VALUES (I_s=POINT LOAD STRENGTH):

440, 450, 470, 490, 470, 440, 470, 470, 480, 460, 430, 480, 470, 470, 440, (I_s = .38 MPa), 460, 360, 380, 480, 470, 450, 460, 460, 470, 460, 440, 440, 460 (I_s = .59 MPa), 460, 470, 460, 470, 440, 460, 440, 470, 480, 470, 460, 480

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	Portadrill - HQTT	DATE	

BORE HOLE L3967

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A3

SHEET 7 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	GRAPHIC LOG	R.L. / DEPTH (metres)	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)	ROCK INDENTOR VALUES (I_s=POINT LOAD STRENGTH)
MUDSTONE F	dark grey, moderately weak rock, massive, low angle bedding		350			30	3, X		
							4, 2	350.7 to 351.0 several flat-dipping joints highly polished, very smooth, planar	460, 529
			351				5, 3, 4	351.3 intersecting joints dip 50° and 60°, polished smooth, planar, normal to one another, onwards bedding decreases from 15° to approximately 6° to 8°	470, 440, 450
			352			45	2, 2, 2, 3	352.25 joints dip 60°, normal to bedding, polished, smooth, planar	460, 460, 470, 460
			353				3, 5, 2		470, 450, 440
			353.5				1		470
			354			65	1, 1, 2, 2, 2		460 (I_s = .92 MPa), 440, 470, 420
			355				1, 1, 2	355.7 joint dips 35°, polished, very smooth, dip parallel to direction of bedding	430, 450, 450, 440, 440
			356				2, 4		420, 440
			356.5				2, 3		430
			357			20	2, 2, 3, 4	357.0 bedding dip 5°, clean, trace pyrite, rough, planar 357.12 bedding dip 5°, clean, trace pyrite, rough, planar 357.30 bedding dip 4°, clean, rough, planar	460, 430, 460, 450
			358				3, 5, 2, 3	357.98 bedding dip 3°, clean, rough, planar 358.10 bedding dip 3°, clean, rough, planar	470, 470, 440, 440
			359				2, 5		440, 440 (I_s = .78 MPa)
			359.4				2, 0, 1		465, 440
			360						

LOCATION	
SURFACE ELEVATION (R.L.)	DATUM
INCLINATION VERTICAL	AZIMUTH
DRILL TYPE / METHOD Portadrill - HQTT	DATE

BORE HOLE L3967

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A3

SHEET 8 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. / DEPTH metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
MUDSTONE F	dark grey, moderatley weak rock, massive, low angle bedding		360				3, 5, 0, 1	360.13 and 360.20 Bedding dip 2°, clean, rough, planar 360.4 Shattered band above thin hard bar, minor grinding at base	
			361			80	2, 3, 2	361.22 Bedding dip 4°, clean, very rough, planar 361.31 Bedding dip 4°, clean, rough, planar 361.55 Bedding dip 4°, clean, rough, planar, light grey claystone/mudstone bar 75mm thick	
			362 362.10			100	2, 1, 1, 1, 1		
minor silty banding evident			363 363.13			45	2, 1, 2, 0, 6, 2, 1, 1, 1, 1, 3, 2	363.0 Bedding dip 4°, clean, rough, planar 363.13 Shattered hard bar, minor slickensides on some surfaces 363.66 Joint dip 80°, partly open, discontinuous 363.72 Joint dip 60°, fault contains 8mm thickness of healed fragment, joint surface is highly polished, very smooth, planar 363.98 Intersecting, discontinuous joints normal to each other, 50°, highly polished, slickensided, very smooth, planar	
			364					364.26 Joint dip 50°, discontinuous highly polished, very smooth, planar. Also three joints sub-parallel to bedding dip 10°, 15° and 25° to 35° Each slickensided, highly polished, down dip, very smooth, slightly curved to curved 364.36 Similar zone, two joints sub-parallel to bedding. Slickensided across dip, highly polished, very smooth, planar 364.36 to 366.00 Extensive disruption evident across thin hard bands 364.60 Hard bar with several open joints dip 55° normal to bedding, calcite in fill, also dark crystal growth 364.80 Joint dip 20°, dips normal to bedding direction, slickensided, highly polished, very smooth, slightly curved 364.82 Joint dip 75°, normal to bedding direction Striated, slickensided, smooth, planar	
			365					365.40 Joint dip 60°, parallels bed dip direction, slickensided, highly polished, some healed fragments, very smooth, planar	
			366 366.13			95	2, 1, 1, 1, 1, 1, 3, 0		
			367					367.1 this light grey baning, dip 12°	
			368				2, 1, 1, 0, 4	368.05 joint dip 65°, clean, rough, planar 368.80 bedding planes dip 6°, polished, very smooth, several intact closed curved planes	
	thin brown mudstone bands		369 369.11				0, 0, 0, 0		
			370						

LOCATION	
SURFACE ELEVATION (R.L.)	DATUM
INCLINATION VERTICAL	AZIMUTH
DRILL TYPE / METHOD Portadrill - HQTT	DATE

BORE HOLE L3967

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

FIGURE A3

SHEET 9 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. ▼ DEPTH ▲ metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
MINOR SANDSTONE BAND, TO 5MM			370			90	0, 2, 1, 1	370.22 joint dip 55°,clean,rough, slightly curved 370.3 joint dip 60°,closed,irregular, curved 370.52,370.63,370.85 bedding dip 8°, clean, rough, planar	
			371				15, 2, 1, 1	371.04 bedding dip 8° 371.04 to 371.31 10 parallel joints,sub-parallel to bedding,each discontinuous, slickensides,polished,planar,bounded by two stepped joints,dip normal to bedding at 70° and 55° 371.31 joint dip 15°,clean, very smooth, planar	
			372				1, 1, 0, 2	371.50 two intersecting joints dip 40° and 35°,discontinuous, slickensides, polished,smooth,planar 371.71 joint dip 30°, normal to bedding clean,smooth,planar 371.80 joint dip 40°,clean, smooth, planar	
			373 373.14				2		
COAL F	weak, black and brown, irregular banding		373.20				4, 2		
			374				1, 2, 5, 1	374.0 to 374.7 several sub-parallel, discontinuous near vertical joints	
			375				1, 1, 2, 3, 3	375.4 to 375.75 three sub-parallel, discontinuous near vertical joints 375.85 joint dip 70° to 90° curved at top, extended to 376.4, joint has strike normal to bedding dip direction, i.e. parallel of strike of bedding	
			376 376.09				1, 2, 2, 2		
			377 377.14				3, 2, 2, 1		
			378				4, 2, 1	378.08 joint dip 70° to 90° curved at top 378.85 joint dip 60° to 90° curve at top	
			379				8, 3, 5, 1, 1		
			380						

BORE HOLE L3967

FIGURE A3

LOCATION	
SURFACE ELEVATION (R.L.)	
DATUM	
INCLINATION	VERTICAL
AZIMUTH	
DRILL TYPE / METHOD	Portadrill - HQTT
DATE	
PROJECT	SHEDDEN/U.C.G./LEIGH CREEK

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION (COLOUR, HARDNESS, etc.)	CORE RUN AND TYPE (end depth, metres)	R.Q.D. (%)
COAL F	weak banded, irregularly black and brown	383.14	NA
SILTSTONE F F	grey, moderately high strength, moisture, irregular coal blebs throughout	385.38	NA
COAL F	black and brown, weak		NA
SILTSTONE F MINOR COAL BANDS	grey, moderately weak, massive, minor coal blebs throughout	386.46	98
COAL F	black, weak	388.48	
MUDSTONE F CARBONACEOUS IN PART	dark grey, moderatley weak	388.90	
SILTSTONE F	grey and dark grey, moderately weak	389.29	100

Depth: metres, 380 to 390

DISCONTINUITIES (JOINTS, BEDDING, SEAMS, FAULTS) DESCRIPTION (SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE)
dip of all banding in the range 25° to 30°
381.61 stone band, hard SLTST
381.87 stone band, hard SLTST
382.30 stone band, hard SLTST
382.39 stone band, hard SLTST
384.66 sharp contact SLTST/COAL
384.89 joint dip 55°, clean, rough planar
384.95 to 385.13 several sub-horizontal blebs
385.00 small fault zone, minor shearing on joint with 60° dip
386.7 to 388.6 Each fracture is irregular, near planar, sub-parallel to bedding
387.35 to 387.92 Minor thin COAL
388.48 to 388.80 COAL transitional at base
389.91 to 389.96 COAL band

LOCATION			
SURFACE ELEVATION (R.L.)		DATUM	
INCLINATION	VERTICAL	AZIMUTH	
DRILL TYPE / METHOD	Portadrill - HQTT	DATE	

BORE HOLE L3967

PROJECT SHEDDEN/U.C.G./LEIGH CREEK

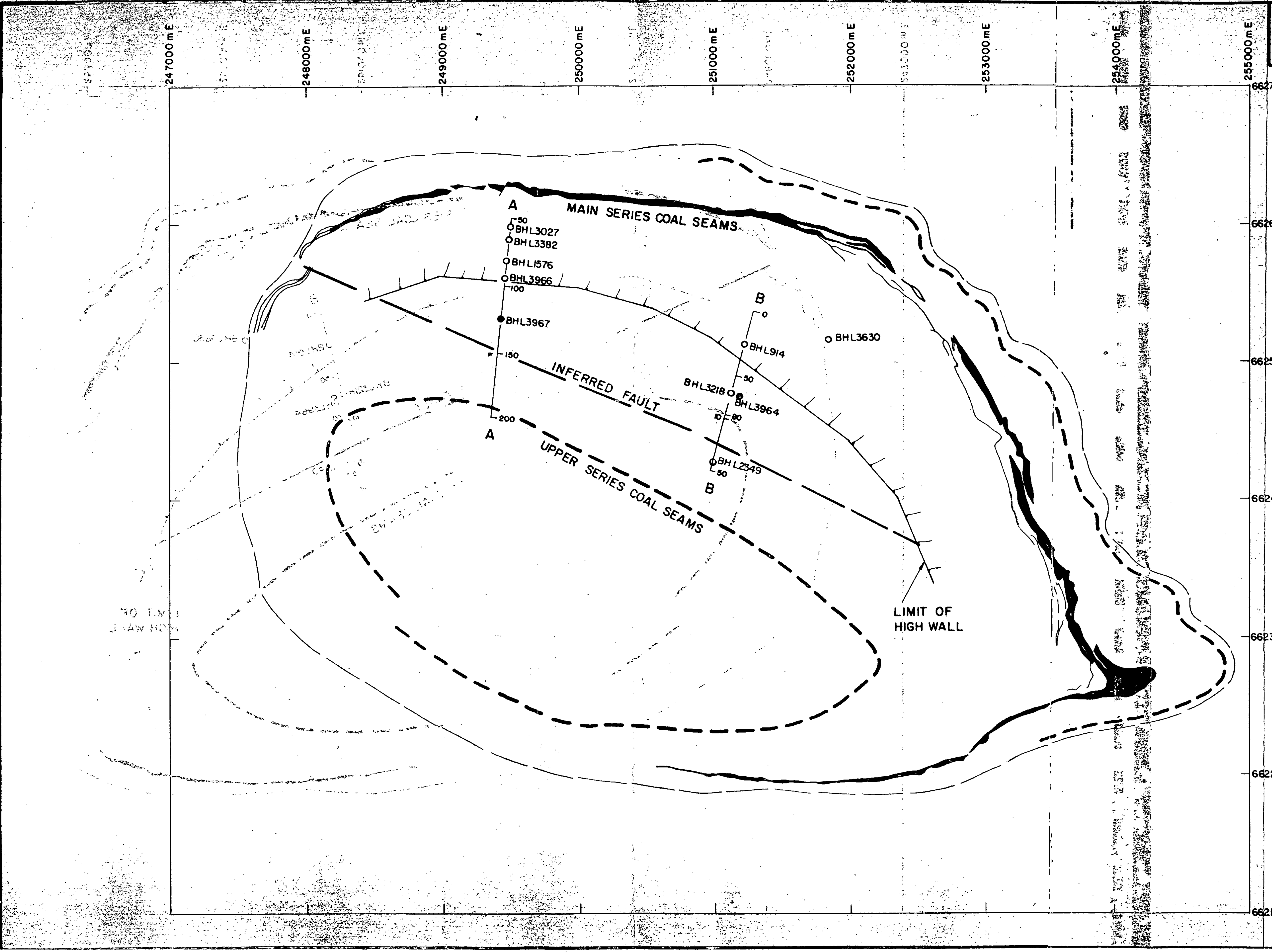
FIGURE A3

SHEET 11 OF 11

ROCK TYPE AND DEGREE OF WEATHERING	DESCRIPTION COLOUR, HARDNESS, etc.	GRAPHIC LOG	R.L. / DEPTH metres	CORE RUN AND TYPE	CORE LOST	R.Q.D. (%)	FRACTURE LOG (PER 250mm)	DISCONTINUITIES JOINTS, BEDDING, SEAMS, FAULTS DESCRIPTION SPACING, ATTITUDE, SMOOTHNESS, FILLING, COATING, APERTURE	REMARKS
SILTSTONE F	grey and moderately weak		390				0, 0	Bedding dip 15 - 20°	
COAL F	black and brown banded		390.55				3		
COAL AND CARB MUDSTONE F	dark grey - black, weak		390.85 / 391			100	1, 1		
MUDSTONE F	dark grey, moderately weak		391 / 392 / 393	391 62			0, 3, 0, 0, 1, 0, 0	391.45 - 391.52 Coal Bright conchoidal fractures	
CARB AND MUDSTONE F			393.26				0		
COAL F	black, weak		393.32 / 394			100	0, 0, 0, 0		
SILTSTONE F	grey (blue) moderately high strength, massive		394.45 / 395 / 396	394 60		100	0, 2, 0, 1, 0, 1, 1, 1, 1, 1		
	END OF BOREHOLE AT 396.75M								

LOBE B - LOCATION PLAN

FIGURE 1



LEGEND

LIMIT OF COALFIELD

SUB - OUTCROP OF COAL SEAM

GEOPHONE LOCATIONS B —50— B LINE OF SECTION

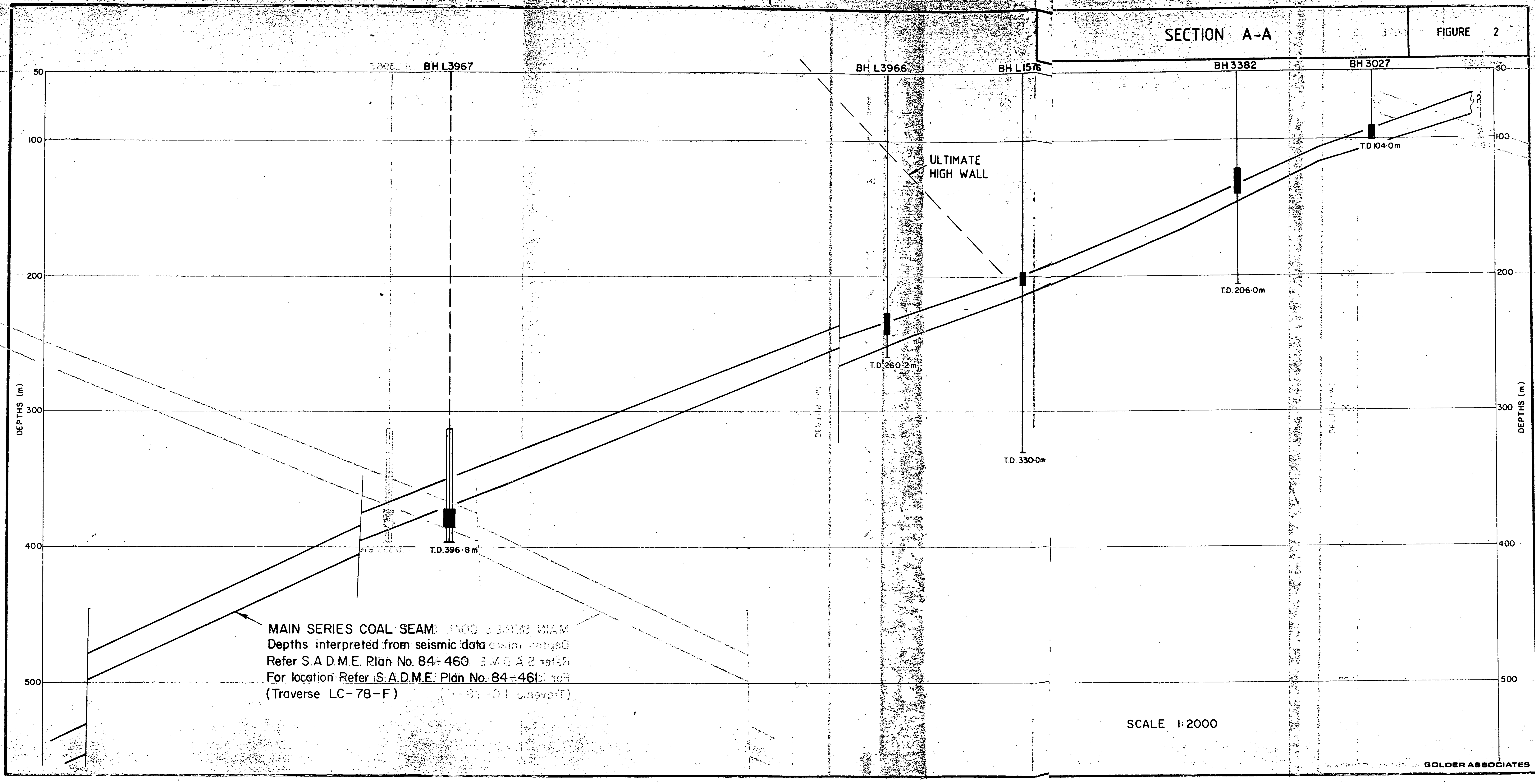
● BOREHOLES (GEOTECHNICAL)

○ BOREHOLES - OPEN

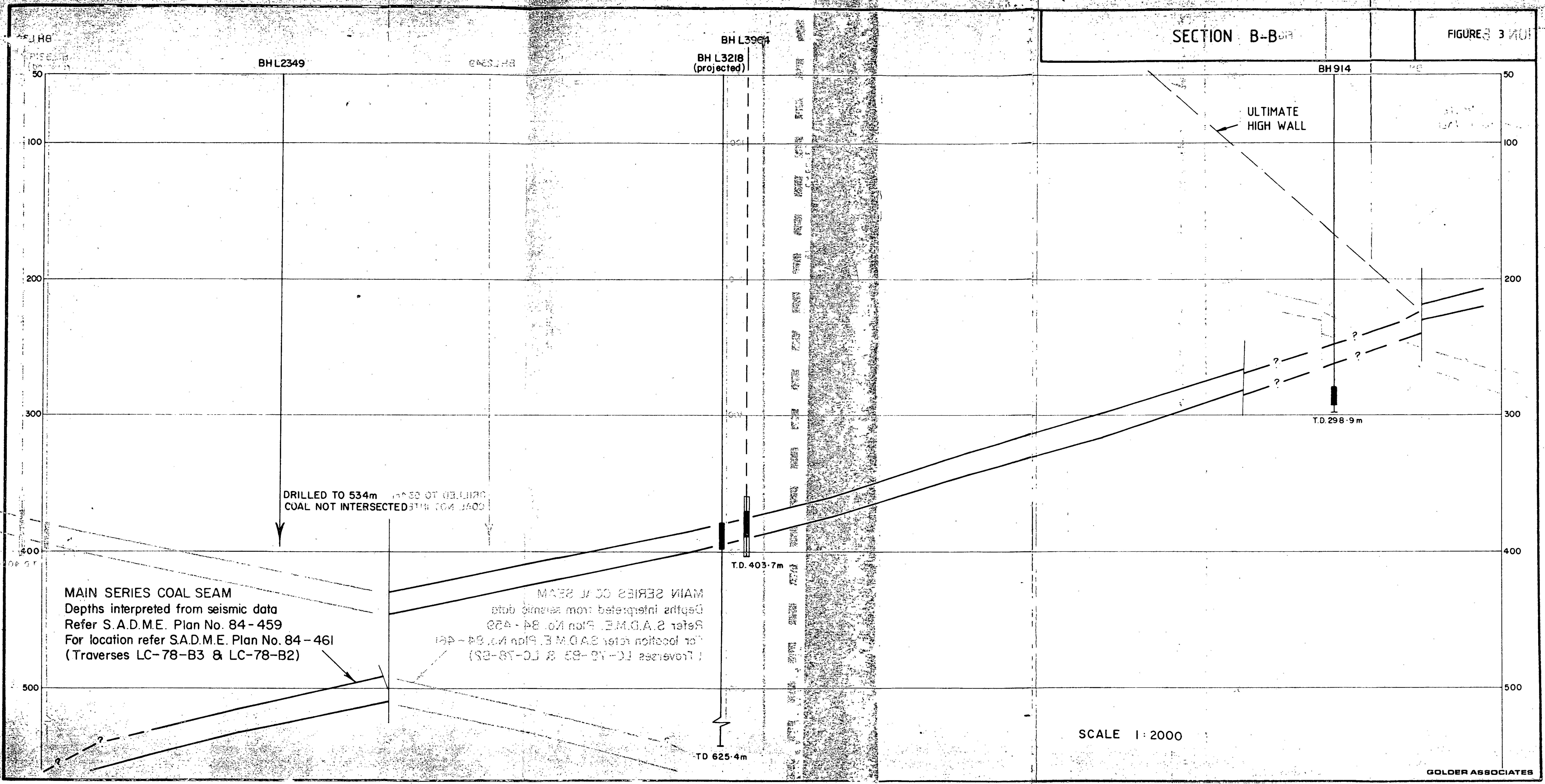
SCALE 1 : 25000

REFERENCE: S.A.D.M.E. PLAN No. 83.86 FEB. 1983

GOLDER ASSOCIATES



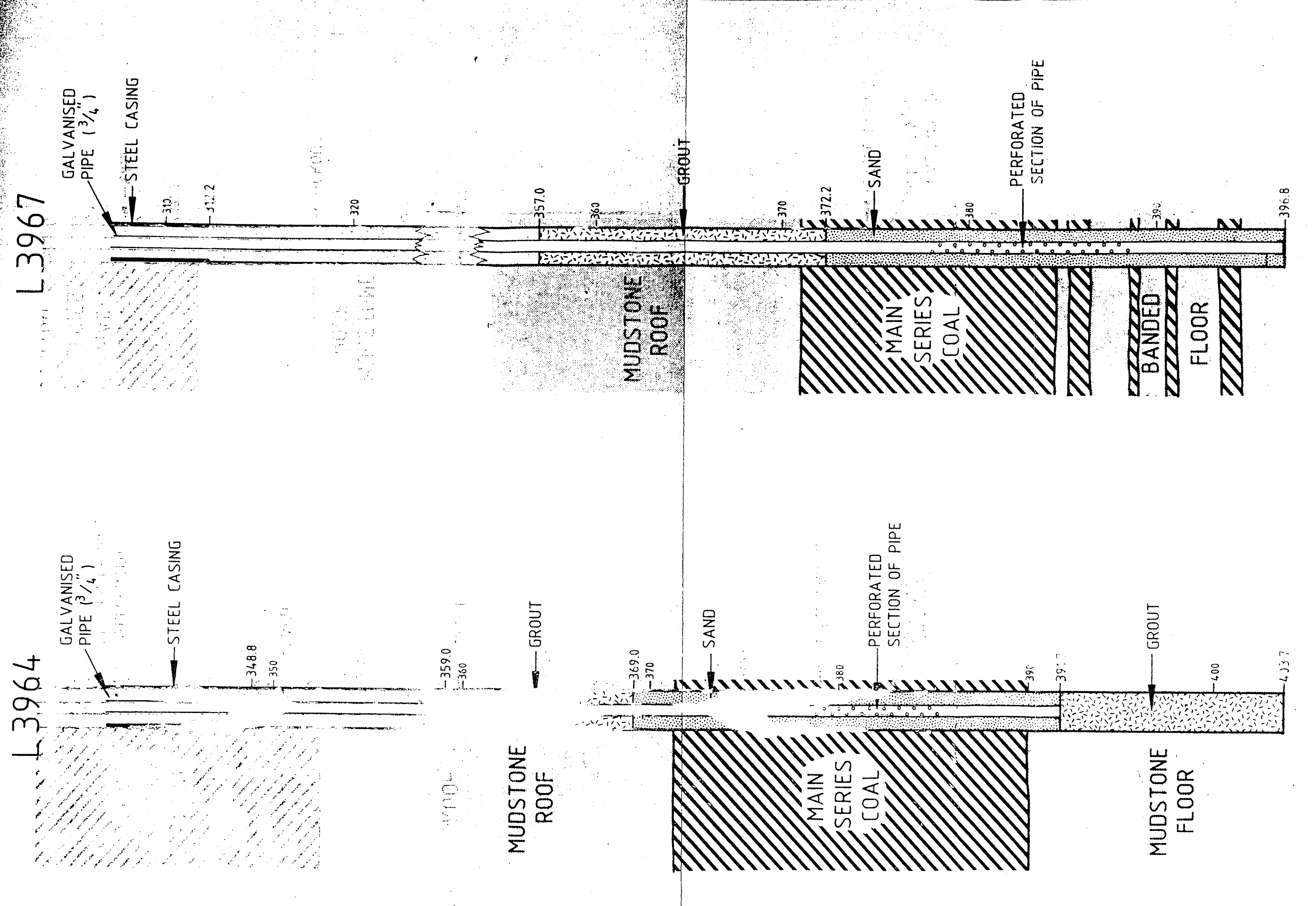
SECTION A-A
FIGURE 2
BH L3967
BH L3966
BH L1576
BH 3382
BH 3027
ULTIMATE
HIGH WALL
T.D. 396·8 m
T.D. 260·2 m
T.D. 330·0 m
T.D. 206·0 m
T.D. 104·0 m
DEPTHS (m)
50
100
200
300
400
500
MAIN SERIES COAL SEAM
Depths interpreted from seismic data
Refer S.A.D.M.E. Plan No. 84-460
For location Refer S.A.D.M.E. Plan No. 84-461
(Traverse LC-78-F)
SCALE 1:2000
GOLDER ASSOCIATES



SECTION B-B
FIGURE 3
BH L2349
BH L3904
BH L3218
(projected)
BH 914
ULTIMATE
HIGH WALL
50
100
200
300
400
500
DRILLED TO 534m
COAL NOT INTERSECTED
T.D. 403·7m
T.D. 298·9m
TD 625·4m
MAIN SERIES COAL SEAM
Depths interpreted from seismic data
Refer S.A.D.M.E. Plan No. 84-459
For location refer S.A.D.M.E. Plan No. 84-461
(Traverses LC-78-B3 & LC-78-B2)
?
SCALE 1:2000
GOLDER ASSOCIATES
CHECKED
BY

PIEZOMETER INSTALLATIONS
BOREHOLES L3964 AND L3967

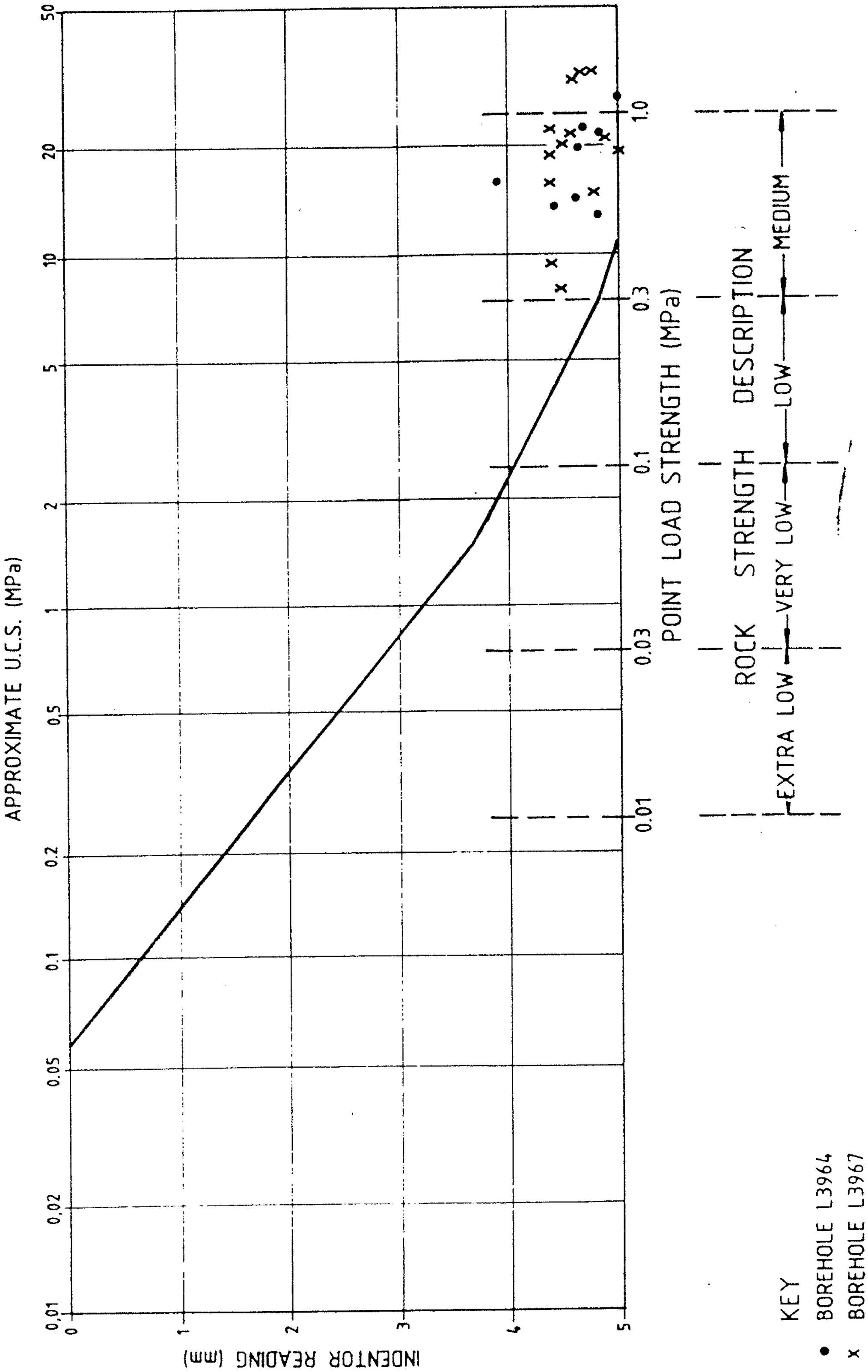
FIGURE 4



VERTICAL SCALE 1:200

ROCK STRENGTH TEST DATA

FIGURE 5



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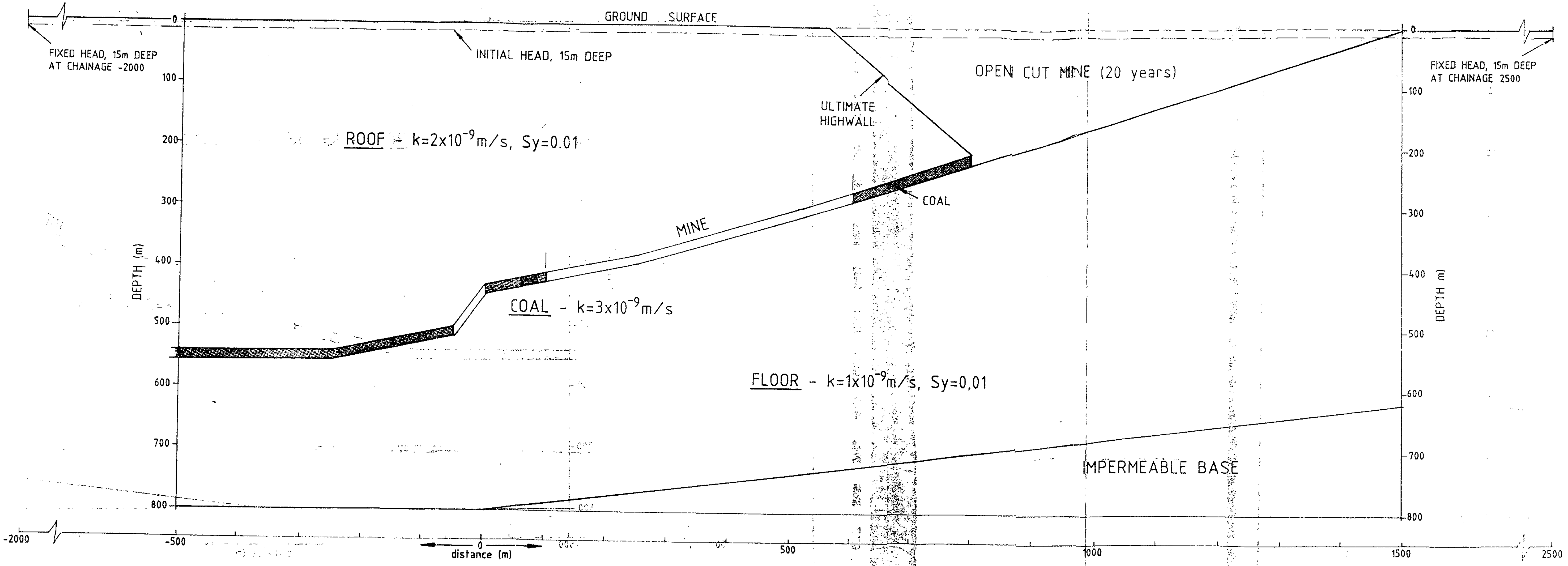
GROUNDWATER ANALYSIS
ASSUMED SECTION

FIGURE 6



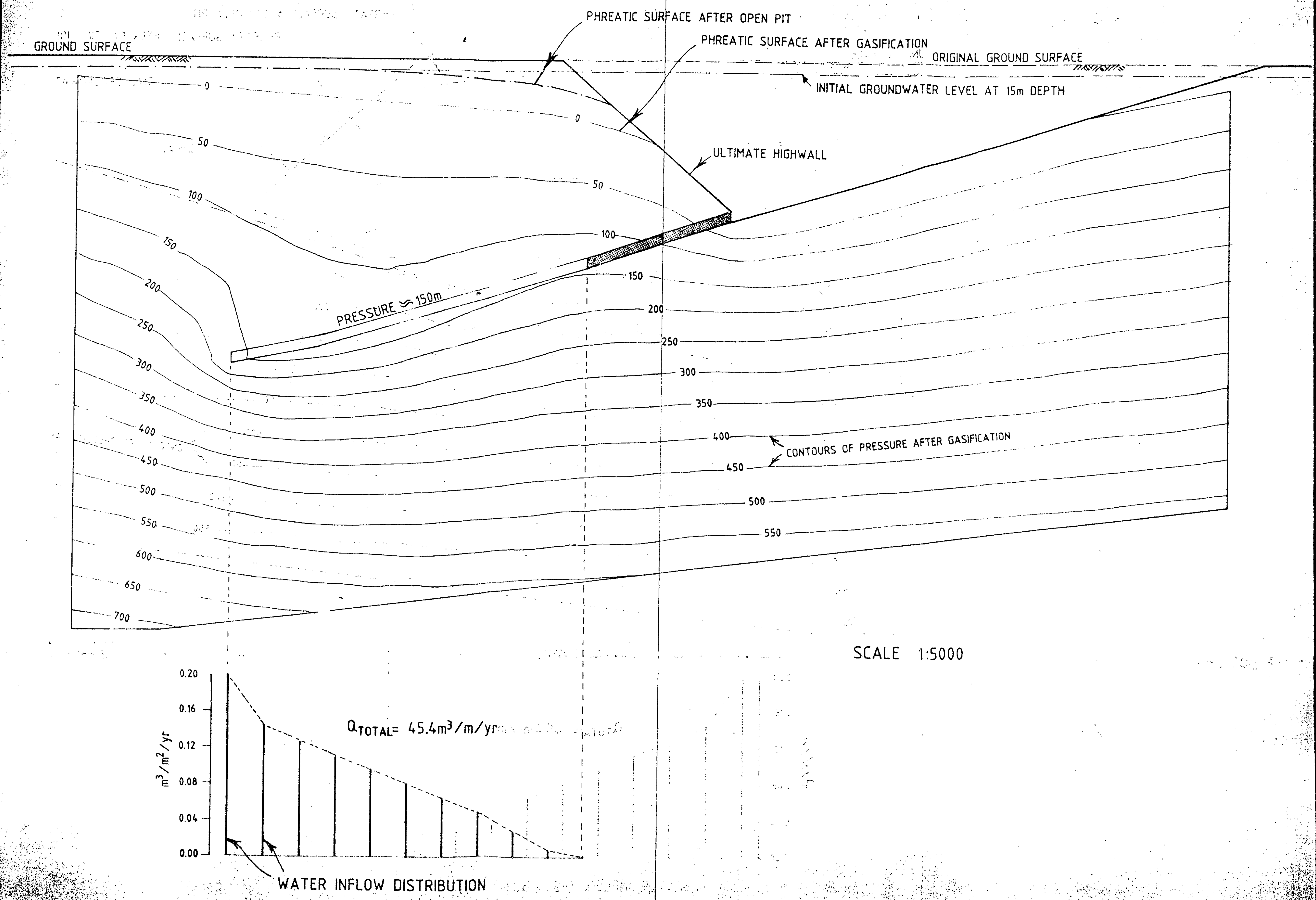
NOTES

(a) 20 YEARS TO CREATE OPEN CUT MINE $Q = 23m^3/m/year$

(b) DEPRESSURIZATION OF 500m WIDE MINING STRIP OVER 20 YEARS OF MINING $Q = 45.4m^3/m/year$

PREDICTED DRAWDOWN AFTER GASIFICATION

FIGURE 7



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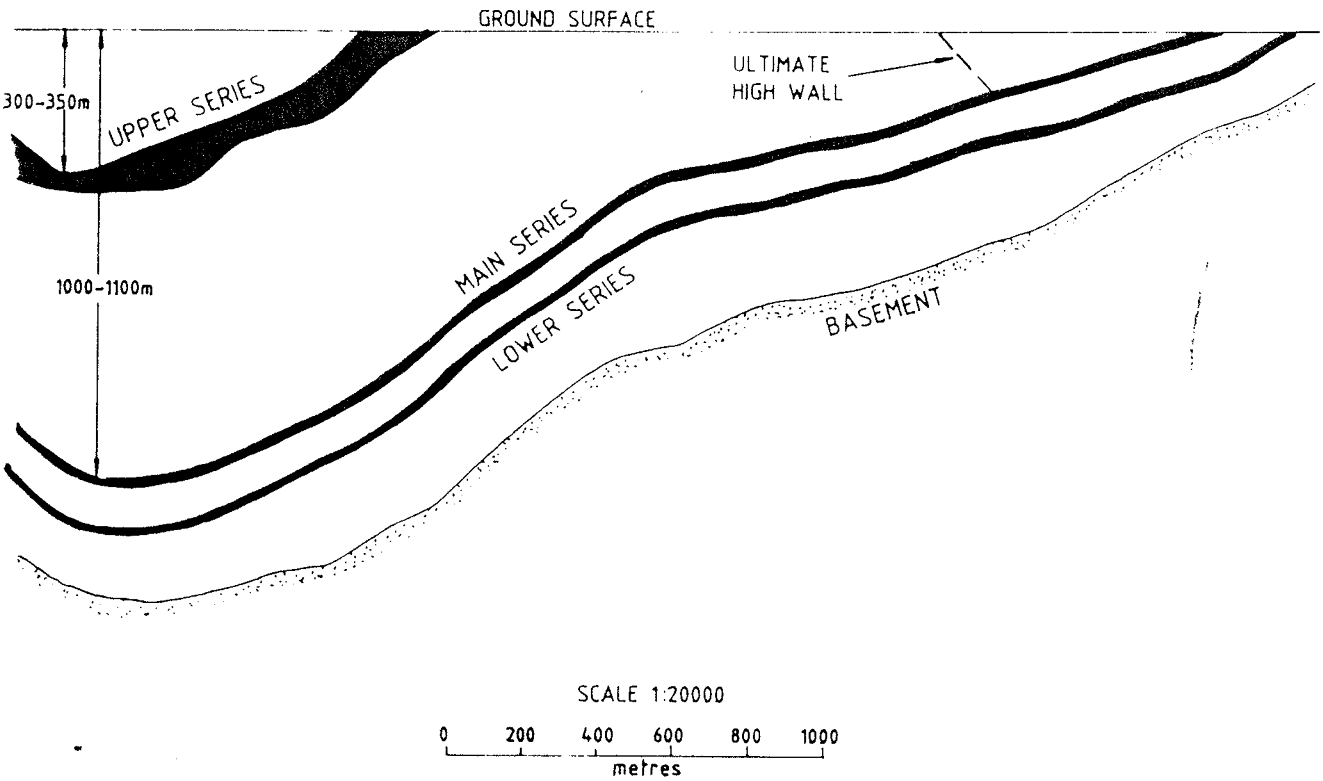
LOBE B - INFERRED BASIN PROFILE

FIGURE 8



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DRILLHOLE DETAILS

Hole Name	L 3964	L 3966	L 3967
Unit Number	6537 — ?	6537 — ?	6537 — ?
Core Library Number	6537 — 130	6537 — 129	6537 — 128
Classification	Stratigraphic	Stratigraphic	Stratigraphic
Tenement	ETSA — Leigh Creek Mine	ETSA — Leigh Creek Mine	ETSA — Leigh Creek Mine
Operator	Golder Associates DME Energy Division	Golder Associates DME Energy Division	Golder Associates DME Energy Division
Commodity	Coal	Coal	Coal
Location:			
▪ **Coordinate Source**	ETSA — Survey	ETSA — Survey	ETSA — Survey
▪ **Datum**	GDA 94	GDA 94	GDA 94
▪ **MGA Easting**	251347.47	249584.34	249557.87
▪ **MGA Northing**	6624858.50	6625795.00	6625498.00
▪ **MGA Zone**	54	54	54
▪ **Elevation (metres)**	191.50	186.92	186.63
Date Drilled	5/11/84	11/11/84	14/12/84
Depth Drilled (metres)	403.72	260.20	396.75
Dip	Vertical	Vertical	Vertical
Cored Interval (metres)	349.09 — 403.72	241.00 — 260.20	312.40 — 396.75
Cored metres	54.63	19.20	84.35
Drilling Rig	PORTADRIL	PORTADRIL	PORTADRIL
Drilling Company	DME Drilling Services	DME Drilling Services	DME Drilling Services
Site Geologist	I. Gibson (Golder Associates)	I. Gibson (Golder Associates)	I. Gibson (Golder Associates)
Geophysical Logging	Yes	Yes	?
Geophysical Logging Contractor	DME	DME	?

FU SR 29/1/85

Paper to be presented at the New Zealand Coal Research Conference, October 1985.

DEVELOPMENT IN BOREHOLE SYSTEMS FOR IN-SITU GASIFICATION OF COAL FOR PRODUCTION OF SYNTHESIS (OR POWER) GAS

Hon. Professor Ian McC. Stewart
University of Newcastle, N.S.W.
Australia

ABSTRACT

In-situ gasification of coal has been demonstrated on a small commercial scale for many years in U.S.S.R. and by recent field tests in U.S.A. In both places major emphasis was placed on the Russian "linked-vertical well" system, very suitable for thick beds of low-rank coal at modest depths (to say 300m). For Australian conditions a system of horizontal in-seam boreholes, drilled from the surface is applicable to a great range of resources not economically mineable by conventional means because of thickness, quality, ash content, depth and other conditions. Where the depth is great cost considerations require a wide spacing of such boreholes. The Research project at the University of Newcastle has been largely concerned with aspects of such a system. The control of a blast-borehole drilled in coal was investigated by bench-scale and numerical experiments. It was discovered that small proportions of liquid water injected with either air, or oxygen-steam blast, would give adequate control. A detailed economic study was made for a 60MW demonstration plant for Leigh Creek in South Australia for electricity generation. This looks commercially viable. A corresponding field test was designed. The most recent work has been the development of a computational model of a complete system - the results agree tolerably well with the scant data available and indicate that the high mass flows possible with pressure gasification (2 to 6 kg oxygen/sec per borehole) in seams of 2m thickness or more lateral spacing to 150m is feasible without significant loss of performance and raw gas costs can be kept below $A1.0 per GJ.

INTRODUCTION

The in-situ gasification programme at the University of Newcastle (1) over the last ten years was undertaken from the premise that the system had the potential for economic recovery of coal resources, not commercially mineable by conventional means because of high sulphur, high ash, excessive stress or depth. The environmental advantages are that there is negligible surface disturbance, that (for a borehole system) very little surface access is required, that sulphur is much more readily removed from a combustible gas than from coal or the products of its combustion, and the dust associated with surface handling and storage of coal and ash is eliminated.

A survey was made of appropriately located resources in Australia with the limitations of at least 2m coal thickness, and cover at least 40m plus 3 seam thicknesses. Very large otherwise unrecoverable resources were identified in W.A., S.A., N.S.W. and Queensland, with an excellent site for the first operations in the country at Leigh Creek in South Australia. The particular long-term advantage was seen to be low cost of synthesis gas for the production of liquid fuels.

Gasification under pressure requiring cover of 200m or more offers many technical advantages. Most of the suitable Australian resources are deep. Examination of the requirements for economic deep seam gasification became the main thrust of the work.

2 HISTORIAL DEVELOPMENT OF IN-SITU GASIFICATION

The commercial feasibility of the gasification of coal 'in-situ' was established in the U.S.S.R. prior to World War II. (2) The great achievement was the development of 'reverse combustion linkage' whereby an initial channel is burned between two vertical boreholes by establishing a small flow of air through interstices in the seam, igniting at the outlet borehole and burning back against the flow. Once the channel is established a burning front forms at the inlet and spreads laterally. As this 'producer' burns out it may be extended by a similar linkage process. The system is conveniently designated as *"Linked Vertical Well" (LVW)*. A commercial station installation (about 60 MW electrical) has operated for over 27 years at Angren in Turkestan. Seams of sub-bituminous ('lignite') coal from 2m to 22m thick were gasified at depths of from 40m to over 200m using air-blast. Conditions were difficult with a high water make to the gasification zone through the seam and associated strata. Consistent gas quality was maintained at about 850 kcal/nm^3 with about 70% gasification efficiency and 70% coal utilization. The system works well for low rank coals which shrink on drying. It has formed the basis of several successful trials in the U.S.A. over the last ten years.

There are several disadvantages. It is not generally suitable for higher rank coals. The maximum distance for linkage appears to be about 25m. The result is a multiplicity of boreholes with high costs at depths of more than 200m and with a great potential for gas leakage. This will limit operation to close to atmospheric pressure with associated high blast-compression costs. Maximum energy output/borehole was about 10MW (thermal) (3MWe).

The steeply-dipping seam system was also developed in U.S.S.R. (at South Abinsk in S.E. Siberia). The coal was high-volatile bituminous in seams from 2m to 9m thick at a dip of about 55° from a surface outcrop. Product boreholes were drilled in the seam; blast boreholes below the seam were deviated to meet the seam at the bottom of the gasifier (140 to 350m); a firefront was established in a horizontal channel linking several boreholes. The gasification front moved upwards. Operating conditions were difficult with a high water make and a district heading load which varied by about 3:1 between winter and summer. Consistent gas quality was maintained at about 20% higher specific energy than from Angren. Oxygen-steam gasification from a single borehole by Gulf R & D at Rawlins in Wyoming (USA) in 1980-1982 produced very high quality gas from an 11m seam dipping at about 70°.(3)

The parallel-borehole horizontal seam system. The National Coal Board of Great Britain, for their final trial at Newman Spinney in 1959, drilled four holes at 23m spacing from a heading in a thin seam (0.8m) for a distance of about 130m. They were intersected at the far end by vertical production boreholes, ignited at the heading and gasified until completion at 120 days. The gas quality though poor at 500-700 KJ/mm^3 (50-70 BTU/ft^3) was considered reasonable because of the very thin seam. The test represented a new concept and provides the only data we have on the shape of the burn-out cavity and long-term performance of a parallel borehole system.

3 A PARALLEL BOREHOLE DEEP SEAM SYSTEM

For an economical system high output per borehole is important, requiring operation at pressure. Preliminary mining as used at Newman Spinney is not acceptable for this except under special conditions. Deviated directional drilling for oil production for methane drainage and for mineral exploration has developed to enable long in-seam boreholes to be produced at depth by drilling from the surface. To optimise costs the maximum possible coal should be won from each borehole - i.e. long boreholes at wide spacing. With a target for total field costs below $A1 per GJ the requirement for a 2m seam at 1000m depth would be about 100m lateral spacing for 700m length (m coal), achievable readily with current drilling technique.

Russian experience was mainly at about 25m spacing and holes to 400m. Lateral spacing of 40m was used successfully with thick seams.

Two questions arise;

- How will wide spacing affect the gasification performance of a system?
- How can the integrity of blast and production boreholes in a large system be maintained against subsidence?

The latter was addressed first.

System integrity : the in-seam blast borehole

In the steeply dipping seam system of U.S.S.R. a wide ignition front was established. The vertical wells used for ignition were not effective for very long because of damage by subsidence. Blast boreholes were drilled in the rock below the coal and deviated to intersect the seam near the ignition line. At times auxiliary blast holes were drilled from below after gasification had been partially completed. For more nearly horizontal seams at any appreciable depth this procedure is not very practical.

Our proposal is to drill the blast borehole in coal parallel to the production borehole. The layout is shown in Figure 1 below. The blast borehole should preserve its integrity and burn back as fast as the burning face retreats, delivering the oxidant close to the burning face with a very satisfactory distribution pattern. However, it is known that at some flow rates the flame front may burn back against the oxidant stream and establish a combustion front in the wrong place. The first experimental and computational programme explored and developed a solution to this problem. It was clear ignition would not travel back in an adequately wetted tube, with indications that only a small molal proportion of water to oxidant would achieve this. The bulk of our research effort was devoted to this. We dmonstrated both in the laboratory and with detailed computer modelling that this was so. An Australian patent has been granted. (4)

It should be noted that a borehole outlet controlled in this way and delivering to an adjacent face will in fact retract as fast as the face burns back, thus ensuring a desirable air distribution with some concentration towards the face. Although only small water proportions are required it appears from analyses of test data from U.S.A. that with oxygen gasification the correct operation may be to mix water rather than steam with the oxygen.

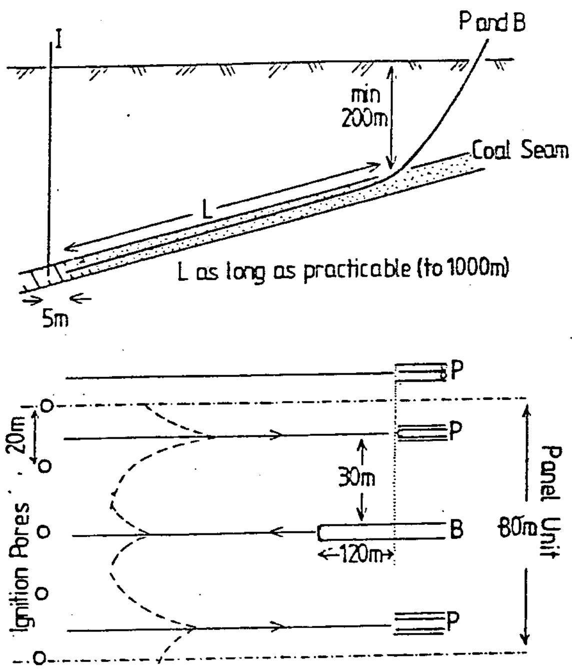

Figure 1   Parallel boreholes for Leigh Creek

The Lawrence Livermore team in U.S.A. started work about the same time and for a different objective on blast outlet control. (5) They have tested and patented a positive but more expensive system - "CRIP" - in which the whole length of the blast borehole is lined with light steel casing which is burned off as required by a retractable small propane lance ignited by Silane.

4 THE LEIGH CREEK PROPOSAL

The resources study established that the most attractive site for an initial installation would be at Leigh Creek in South Australia. A thick seam (11 - 13m) of sub-bituminous coal dips, initially gently at about 15°, from the most optimistic open-cut limit of 200m cover. About 300 million tons of coal are available below this limit (to 1000m). Infrastructure and electrical load are available. The layout proposed for Leigh Creek(6) illustrates the features of the system. (Fig.1) Parallel production boreholdes are drilled in coal at 40m equivalent spacing and cased only until they are well within the seam. A blast borehole is drilled between and cased for a short distance into the seam. An initial combustion front across the panel at its lower end is established by reverse combustion between vertical wells. When this is developed blast and product lines will develop towards the dotted shape.

The thickness and the moderate moisture content (31%) of the seam fully warrant the assumptions that, for continuous operations a slightly higher gas quality and borehole spacing can be obtained than at South Abinsk.

The South Australian Department of Mines and Energy and the Electricity Trust sponsored a NERDDC proposal to make a pre-feasibility study of an initial small power-generation project by Shedden Pacific Ltd., in association with the writer. (6) A steady load of 60MW (MCR) was specified with gasification at 17 at supplying standard 35MW Brown Boveri gas turbines with burners modified to LCV gas; no waste heat recovery. With proper allowance for contingencies, and particularly for gas cleaning for such a little-known system, the overall capital cost including all services for gas production and the initial borehole system came to less than $A1500 per kW and the 'levelized' cost of electrical energy sent out to less than 4.5 to 5.4¢/kWh - comparable with generating costs in that State and very attractive for so small a plant. The total cost of raw gas was estimated at less than $1/GJ and cleaned at less than $1.60/GJ. With experience, and a larger plant, the unit cost of gas cleaning should be much less and overall cost of units sent out about 3¢/kWh.

This does indicate that in conjunction with combined cycle gas turbine-steam turbine generating plant there can be a real future for electricity generation from in-situ gasification of thick deep coal. However, the most attractive prospect is for production of synthesis gas by oxygen gasification. It has been demonstrated in recent trials in U.S.A. that 'in-situ' gasification with oxygen-stream is more efficient and no more difficult than with air, can produce gas of comparable quality with that from surface gasifiers and at considerably less cost. (3)

5 COMPUTATIONAL MODEL OF A BOREHOLE SYSTEM

At the outset of the programme a model of a plane reacting coal face was developed (Fig.2). Computer studies were made of reaction conditions in a well-stirred cavity (8). It was shown that once a substantial ignition temperature was reached (generally over 1400K) the face would burn as fast as oxygen reached it (within the range of commercial practicality). For considering the potential of wide borehole spacings a good model must cover the behaviour of a wide system over most of which there will be massive roof-break and must adequately model also transfer in an open-cavity, wide with respect to its height.
Spot calculations for the Newman Spinney system shewed that neither dispersive nor turbulent transfer could account for even the comparatively poor results which were achieved there but that the very strong natural convection forces due to the high temperature differences at the face could. Heat transfer appeared the limiting mechanism and the radiant component was significant. Five distinct zones would be identified:-

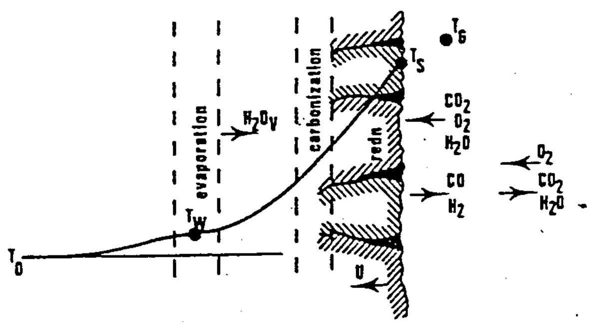

Figure 2 Face model-temperature and reactant distribution.

"Packed-bed" combustion zone due to roof break
"Packed-bed" reduction zone due to roof break
Open reduction zone with vertical coal walls, stone roof
Open reduction zone completely surrounded by coal
Long "tail" close to borehole diameter

The wide "packed bed" systems. A very simple convection model assumed a stream of width 0.1β x total face height transferring heat at the face. The difference between the mean temperature of this stream and the mean temperature of the bulk gas provides the driving force to move the stream over an average path length of face height plus half the system width. Some experiments with a water-bath packed with glass spheres and cooled at one end showed that (when calculated for this case for laminar flow) expression derived with $\beta = 1$ gave a very close approximation for average transfer rate.

For the combustion zone the top temperature of the stream was taken as zone exit temperature. The hot gas was assumed to stratify, gradually filling the void and reducing the available gravity head with zone end-point arbitrarily taken as 90% filling. The packing was taken as 20cm cubes at 33% voids, which from observation in coal mines would seem as good an approximation as any. The incoming oxidant stream is assumed uniformly distributed across the system width and enters a bounded space.

In the reduction zone the face temperature is determined by rate of reaction. Only radiant heat transfer is considered between the gas-stream and the face - from the layers of gas between stone lumps, both direct and re-radiated from solid faces. The resulting pair of heat transfer and mass flow equations are solved iteratively.

The open-reduction zones. Three heat transfer mechanisms, natural convection, forced convection and gas radiation are of different relative values according to system conditions. All three are evaluated and added. An adjustable term has been added to allow for transfer resistance due to an ash layer on the coke surface in all zones.

Heat losses. In the three vertical face zones lateral conduction losses were calculated by a method due to Loison (9) in which the face and part of the roof of a steadily advancing face are represented as an isotherm of an advancing line heat source. [This is not valid where moisture has to be evaporated from the coal seam. The error is believed to be small in relation to total heat flux].

Roof and floor losses for that portion of the roof not included above are obtained by integrating the loss to a slab exposed to constant temperature in terms of the time of exposure.

For the two zones entirely in coal an expression is used based on the classical expression for temperatures in an infinite body surrounding a cylinder at constant heat flux. This should allow the effect of time of exposure and of carbonization at a faster rate than burn-away and, with considerable approximation, the effect of liquid water ingress (by reducing the 'sink' temperature in terms of the latent heat load). The results are not entirely satisfactory.

Reaction rate. Data have been used from Cruz and Kirov (10) for reaction of oxygen, water vapour and CO_2 on lump high-temperature coke, adjusted in terms of a plane surface area. First order reaction is assumed. This probably over-estimates rates at high pressure but better data for this purpose is not available. To simplify the computational system the partial pressures of CO_2 and H_2O are added, reacted at a mean rate constant with stoichiometry based on CO_2 and final gas analysis adjusted to water gas equilibrium at 1000K. Very little error is expected.

Mass transfer. Resistance to mass transfer has been neglected. Spot checks have shown that this introduces very little error except at the high temperature end of the reduction zone. The effect is similar to reduction in reactivity (see Section 6).

The computational system. It would be desirable to follow real phenomena, i.e. start with a cylindrical borehole and compute its burnaway, step-by-step along the borehole and in time. Experience with our ignition-burnback programme, which does just this for a carbon tube with very limited burnaway, indicated that the programming time to allow for all the parameters to be investigated would be beyond our available manpower resources and that computer running time could be inordinately long.

The computational system assumes a quasi-stable cavity shape at any specified outlet temperature and determines the conditions for the long-term steady shape *and* the development time required. At an axial rate of advance, s, any section of width W at a distance ℓ from the start of combustion, relative to axes moving at a rate s has an inclination to the axis:-

$s \frac{dw}{d\ell} = u$, where u is the rate of advance of the face by reaction normal to itself.

Also at any time after an initial transient, for a system width W1, combustion zone end of width W2, then s is proportional to M/(H x (W1-W2)) where M is oxygen mass flow rate and H the seam height. The rate of coal consumption by reduction between two widths W3 and W4 is equal to s x (W3 - W4) x H. For any real system the system width W1 is known and the roof-break boundary W3 and the end of the exposed roof W4. To avoid the infinite 'tail' an arbitrary and width W5 is taken (H/20 + 2WO) and to calculate $\frac{dw}{d\ell}$ an adjacent width W6 = 2WO (where WO is the original borehole diameter).

The width W2 is the measure of the gasification efficiency of the system and for any given outlet temperature T5 may be calculated by iteration from the condition that the gas temperature resulting from the heat balance over the system must equal T5. For the final (infinite time) state conditions at W5 must satisfy the gradient equation above.

The computational system converges rapidly and has been developed to give numerical stability over a very wide range of input conditions.

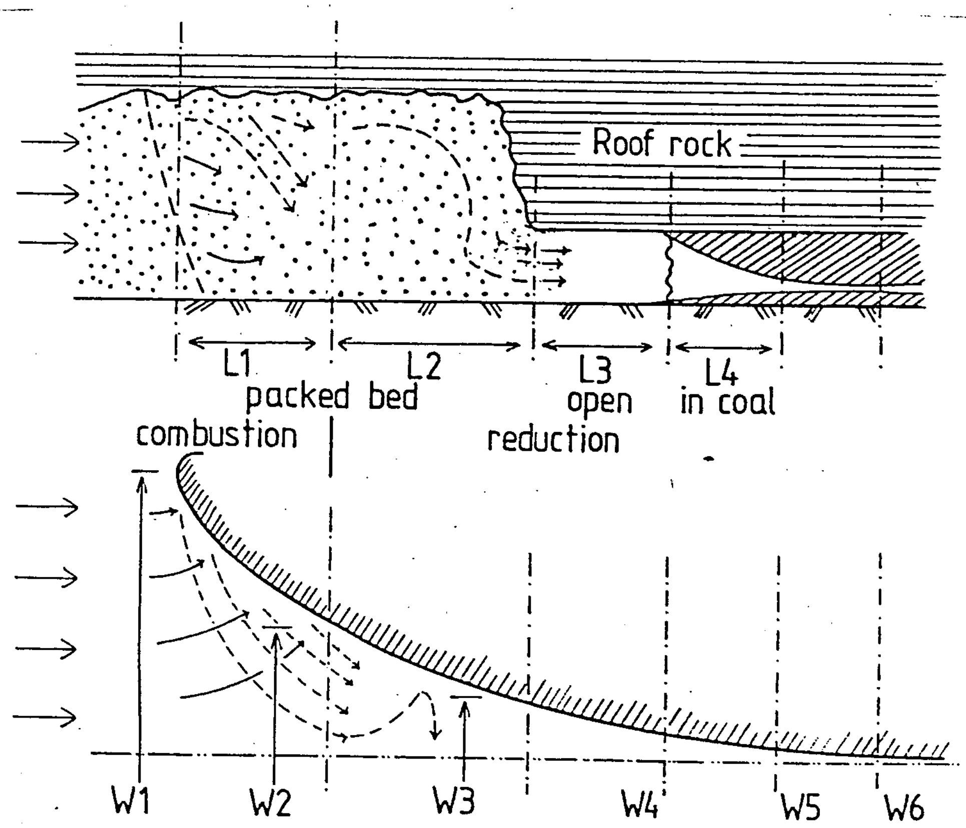

Figure 3 Diagram of borehole system model

6 RESULTS OF THE COMPUTATIONAL PROGRAM

6.1 Nature and Limitation of the Solutions

The 'infinite time' solution shows a cavity, tapering in plan fairly rapidly to a diameter of about half the seam height and then exponentially approaching the borehole diameter at an infinite distance.

Initially computed lengths L, are to an arbitrary small diameter equal to H/20 + 2WO.

A practical 'breakthrough' length L^1 is the diameter at which gasification efficiency has fallen by 2% and above which falls rapidly.

The main combustion and reduction zones approach the final shape very rapidly.

The program assumes carbonization behind the face is at the same rate as fixed carbon consumption. Real systems carbonize at a greater rate in the early stages, giving a richer gas and higher efficiency initially, and poorer performance as a borehole is burned out. This is less significant in wide systems than in narrow.

Water can be allowed for as either steam or water in the blast, as a coal moisture content and as leakage (aquifer) water. The method of allowing for the latter needs further examination.

6.2 'Calibration' of the Program

The only data available in detail for individual boreholes were for the Newman Spinney P5 trial (11), the Gulf R & D Co trials at Rawlins and the writer's small box tests. Sensitivity tests, tabulated below, were made for the P5 average conditions, dry air blast at 333 gm.02/sec, seam 80 cm thick, boreholes 20cm at 23m spacing, bituminous coal, at 40% volatile, 7.5% moisture (d.a.f. basis), leakage water 7.5% on d.a.f. coal.

SENSITIVITY - BASIS P5 TEST			
Parameter	Ash resistance ≡ 2cm.ash	Coke reactivity x 0.3	Moisture add 21% d.a.f.
Gas Spec.Energy	Small increase	-10%	-12%
Gasification Efficiency	Small increase	- 6%	- 8%
Exit gas temp.	-50°	+70°	-10°
Full system length, L	+50%	small	small

The assumed changes in reactivity and in transfer resistance due to ash only produced modest changes in system performance. The small reactivity effect justifies the omission of mass-transfer resistance. The substantial effect of water ingress is notable.

Newman Spinney

Water vapour load in the gas was not measured at Newman Spinney. However, various notes in the published report indicate wet strata conditions. The higher moisture load basis was used for comparison with test figures as follows:

NEWMAN SPINNEY P5 TEST			
	Test average	Calculated	
		27 days	60-100 days
Gas S.E.cal/mm^3	57	69	72.3
Gasification effic.	<60	52	53
CO_2 %	15.2 *	13.2	12.9
CO %	8.0 *	11.2	11.8
H_2 %	8.8 *	7.9	8.2
CH_4 %	0.9 *	0.7	0.7
Outlet temp.	High (N.D.)	1300K	1259K
Length L'm	<70		89

* Spot values day 28; avg. not reported

Calculated performance is a little better than reported. This is not surprising as in the test, organised under rush conditions, borehole 15 was short and problems with 14 were attributed to air by-pass through an abandoned borehole. There is substantial evidence that the burn had passed the 'breakthrough' length before the test finished, with corresponding loss in efficiency.

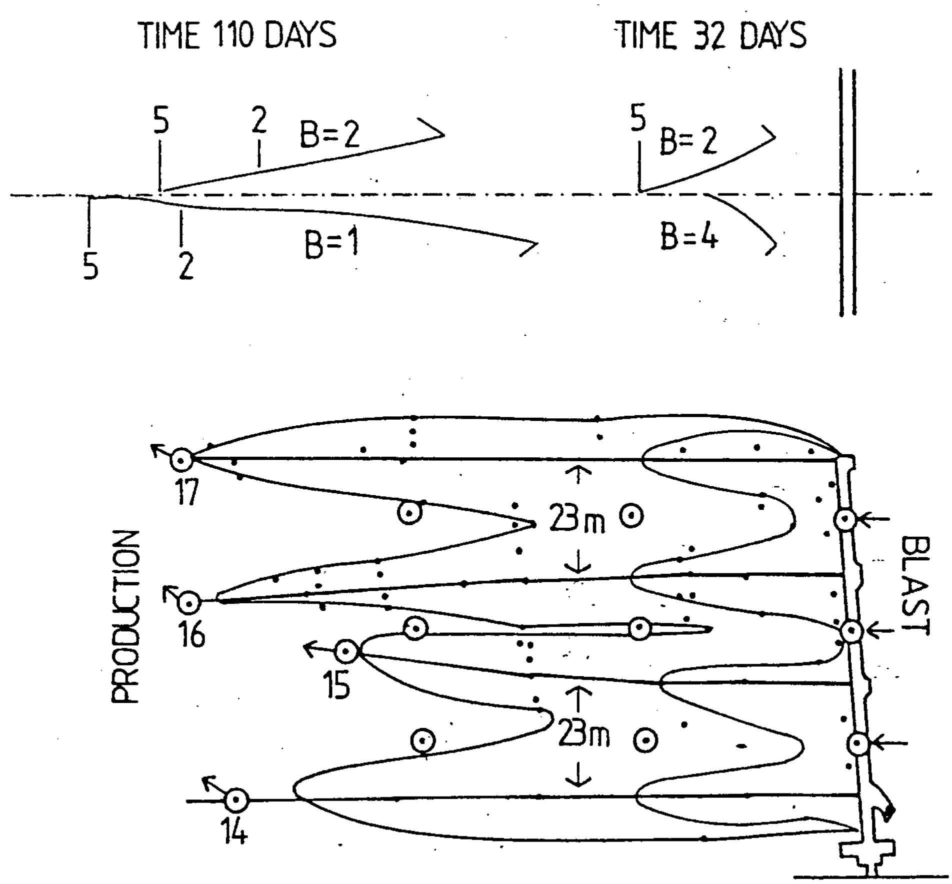

Figure 4 Cavity Pattern at Newman Spinney

The computed cavity shapes at 32 days and end of test are shown in Fig. 4. The report shapes suggest, as would be expected, that roof break had not occurred by day 32 but had certainly occurred and continued well into the tapering void by the end of test. A value of β of close to 1 describes the final cavity well. The open void at day 32 implies a high β; a value of 4 gives a fair fit.

Box-tests were made in Newcastle on a 22cm thick bed of bituminous coal, 1m wide and 2m long formed of large coal lumps with interstices packed with fines at maximum density. The calculated gas quality is much poorer than measured:-

Calculated	18 CO_2,	1.5 CO,	1.6 H_2,	0.3CH_4;	To 1689K
Measured	12→18,	8→1,	6→1,	1.0→0 ,	> 1400

At end of test the coal carbonized (not reacted) was comparable in quantity to the coal reacted, sufficient to account for the higher gas quality. It is expectable in a small system at low oxygen mass flow rates.

The transition from combustion to reduction zone was reasonably discernible at diameters of the order of the calculated value of 13 cms. It is encouraging that the program predicted, at least qualitatively, the poor performance of these tests and particularly the unexpected high exit temperature at the low flow rate of 4gm oxygen per second.

Calculation for a higher rate of 10gm per second showed exit temperature drop of 120K and specific energy increase from 132 to 412 kcal/nm^3.

Gulf trial at Rawlins. This was 67 days of oxygen-steam gasification in a 9m thick steeply dipping seam of sub-bituminous coal reported at 18% moisture on dry ash-free basis. From test results the total liquid water entering the system was calculated at 73% on d.a.f. coal. The oxygen mass flow rate at 486 g/sec. with a steam-oxygen ratio of 1.63 was small for the thickness of the seam. A very high specific energy of gas at 3113 kcal/m^3 with 16.4% methane was maintained. The data together with information from excavation of other small thick seam trials suggest that the whole cavity (about 35m x 17m) was filled with a loose pack of ash and broken coal, performing as an overfed gas producer in which the top layers of coal were hydrogen gasified. The borehole program is not applicable but it is of interest to note that it predicts that a total reaction cavity length of only 3.5m would be required. The predicted gas at 34.9 CO_2, 24.9 CO, 39.5 H_2 and 0.7 CH_4 would produce at the 900K and 7 ats pressure gas of the measured quality by hydrogen-gasification of the volatile component of broken raw coal.

More and better field data is needed to validate the program. However it is reasonable to claim that over a wide range of system size and coal type the predictions are in better than qualitative agreement with field data.

6.3 Wide-spaced Borehole Systems-Predictions

A number of runs have been made for bituminous coal at 17 at pressure air gasification (as for gas turbine application). Coal analysis as for Newman Spinney with total seam moisture at 15.5% on d.a.f. basis and heavy water injection at 0.5 mol/mol oxygen with the blast. A basic system was 3kg/sec O_2 (corresponding to about 60 MW(thermal) per well in a 4m seam, with blast variation at 1.5 and 6.0 kg/sec, system widths of 23, 100 and 150m and one run at 2m seam thickness.

Key results are shown in Figs. 5 and 6. For efficiency and specific energy the mass flow rate per unit seam thickness proved a useful parameter. It appears that performance falls off at mass flow rates less than 0.5 kg/sec/m and is fairly constant at rates above 1. More runs at other seam thickness are needed to confirm this. System width has very little effect and 100m appears an optimum width for 3kg/sec/m for a 4m seam. There is a clear fall-off in performance for a 2m seam, more runs are needed to establish performance. Computed specific energy is comewhat lower than that published for commercial operation in U.S.S.R.

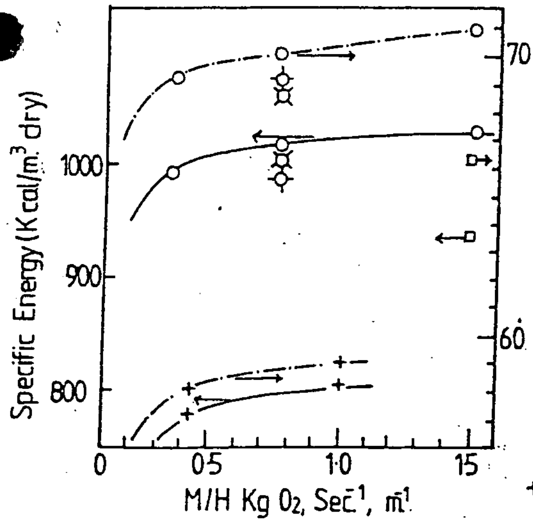

FIG. 5 EFFICIENCY AND SPECIFIC ENERGY

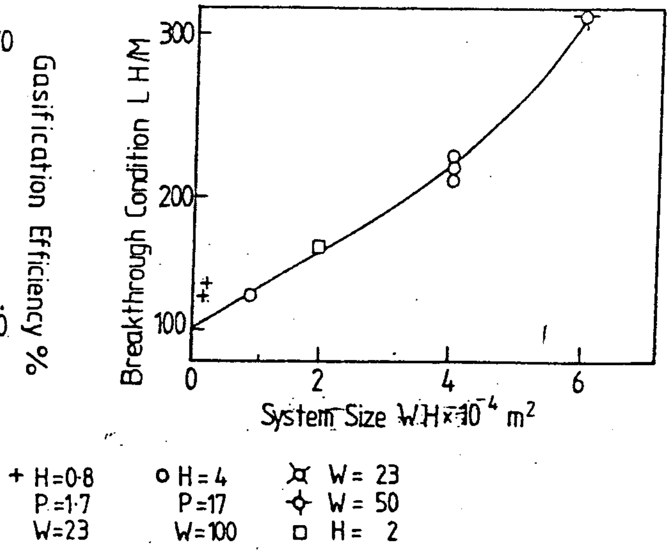

FIG. 6 BREAKTHROUGH LENGTH VS WIDTH BITUMINOUS COAL

In Figure 6 a "dimensionless" breakthrough length L'H/M is plotted against WH, the product of system width and seam height. The length falls as pressure is increased. Mass flow rate has surprisingly little effect over the range so far computed.

Sub-bituminous coals. A few runs were made using the same high-water make as at Rawlins. The results are generally in line with those discussed above but show a slightly lower efficiency and gas energy - a little lower than the reported commercial averages for Angren in USSR.

The computed system length is less than for bituminous coals under comparable conditions. The computed effect of water input is very great (in line with Russian generalizations). Further investigation is needed into the method of allowing for water influx and also the computation of the carbonization rate for high moisture coals.

Oxygen gasification. Some runs have confirmed that higher efficiencies than with air-blast are obtainable. Further runs will be made.

8 CONCLUSIONS

In-situ gasification by a borehole system has the potential for low cost production of synthesis gas or combined cycle electricity from deep coal seams (or otherwise not commercially mineable) of greater than about 2m thickness.

For economic operation long boreholes at a wide spacing are desirable. The simplified computation developed indicates that spacings to 150m are feasible without serious efficiency loss and that throughputs of 60 MW (thermal) per borehole (or more) are advantageous. Some useful and unexpected generalizations have been developed.

The computational tool predicts reasonably well the limited field data available and should be adequate for extrapolation of pilot trials on a particular seam to commercial conditions.

Further development of the program for water-make and carbonization rates is desirable.

9 ACKNOWLEDGEMENTS

Thanks are due to the Chemical Engineering Department of the University of Newcastle for services and facilities, to Dr. R. J. Gupta and Mr. Gulam Mohamed for work on ignition burnback and to Mr. Tariq Mahmud on the system model for computational work. The earlier work reported was supported by grants from the National Energy Research and Development Council with additional support from the South Australian Department of Mines and Energy and the South Australian Electricity Trust and Shedden Pacific Ltd. for the Leigh Creek investigations.

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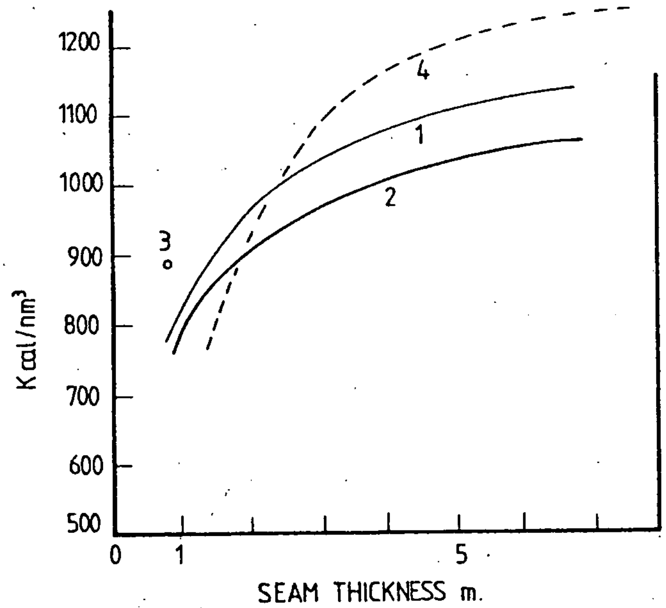
DEVELOPMENT OF BOREHOLE SYSTEM FOR IN-SITU GASIFICATION

SUPPLEMENTARY NOTE

Since writing the paper some more work has been done on two aspects:-

The effect of seam thickness on performance
The effect of liquid water, particularly for sub-bituminous coals.

Seam thickness. A number of runs have been made for various conditions. No dimensionless form of seam thickness has yet been found to correlate results. Results at one set of conditions (width 100m and mass flow 3kg per second 17 at. pressure bituminous coal) are shown in the figure below for the effect of seam thickness on gas specific energy. These are compared with published Soviet generalications from commercial performance at S.Abinsk with a somewhat higher water make and much lower mass air flows and pressures than we have used. The general agreement between reported and calculated performance is good - with calculated values generally lower than reported for comparable conditions.



1. W = 100m, M = 3 kg/sec; 2. W = 100m, M = 0.5 kg/sec
3. W = 25m, M = 0.5 kg/sec
4. South Abinsk at est. .33 gm/gm d.a.f. water

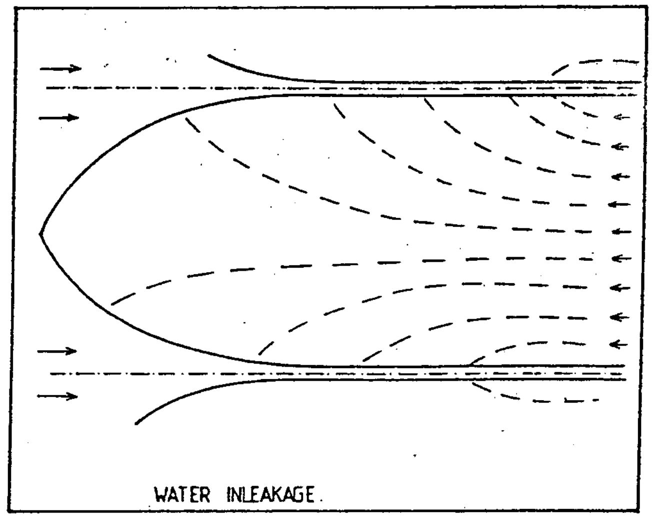
EFFECT OF SEAM THICKNESS ON SPECIFIC ENERGY

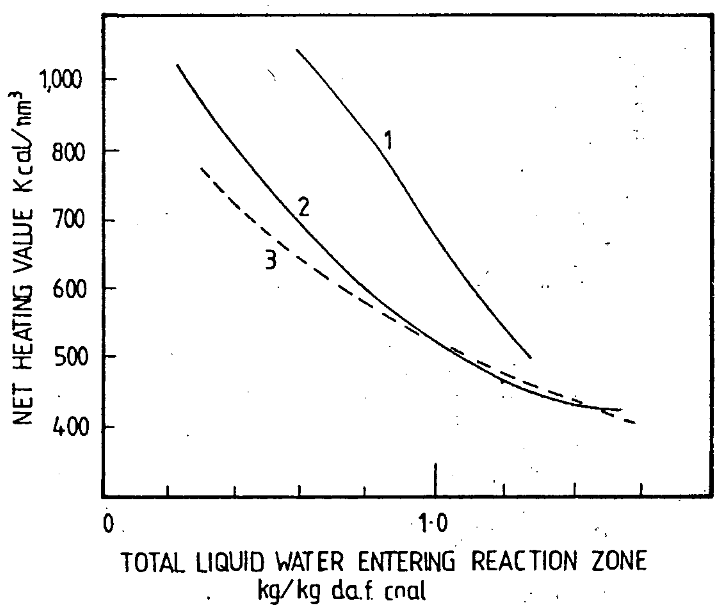
Water make. In an operating unit the water vapour load can only be measured in the outlet gas. In wet seams the reported temperature of this is from 100°C to 300°C, well below the temperature of about 600°C below which reduction reaction rates are negligible. Conduction heat loss can only account for a fraction of this temperature drop which must be due to evaporation of water downstream of the reaction zone. For forward gasification in a borehole system, if the coal seam is the main aquifer a sketch of probable flow lines confirms this.

Available Soviet publications show the effect on gas specific energy solely in terms of "inleakage water rates per tonne of coal gasified" (coal presumably in 'as fired' state). These showed a fall to 500kg/m³ for water makes of 5m³/tonne for sub-bituminous coal, about 1.5m³/tonne for the high moisture Angren 'lignite' as compared with our calculated less than 1m³/tonne (on the only simple calculational basis that water enters in proportion where the coal is consumed.

For lack of detailed data the assumption has been made that only 30% of the leakage water reaches reaction zones (70% is downstream of the reaction zone). Specific energy of gas is then plotted in the figure below against total liquid water entering reaction zone (i.e. liquid water in blast + bed-moisture in coal + leakage water to reaction zone per unit of d.a.f. coal). On that basis our calculations for a 13m seam at 31% moisture 17% ash as burned agree reasonably well with S.Abinsk at 7% moisture 8% ash. The Angren 'lignite' (35% moisture 12% ash) shows a higher specific energy. In every case the effect of water on gas specific energy is very great.

Sub-bituminous coals. For in-situ gasification the key characteristics appear to be considerable bed moisture and shrinkage on drying. Recent investigations in USA (LLL tests at Centralia) have established that, in the early stages of cavity growth at least, coal spalls from sides and roof filling the cavity with a loose assembly of coal and char lumps and loose ash - a highly efficient gasification medium. This behaviour could account for the better performance of Angren (which used a complex system) and as noted above at Rawlins. Such behaviour would not be expected from a wide tapered steadily advancing cavity with roof break, as postulated for a forward burning borehole system. However, the model computes for a wet 13m seam at the high width of 100m and high blast rate of 3kg O_2/sec that the total forward length of the main reaction zone will be only 13m. At this size we could expect a broken coal bed to form a reasonable proportion of the cavity with corresponding high performance.





Russian figures re-plotted on basis that only 30% of 'leakage' water enters reaction zone.

1. Angren 'lignite', modified LVW, bed-moisture 0.61 kg/kg d.a.f.
2. S. Abinsk, bituminous, steep-seam borehole, 0.08 kg/kg d.a.f.
3. Calculated 'lignite', bed-moisture 0.65 kg/kg d.a.f.

(all for seams 6-12m thick)

Oxygen gasification.
The water in blast is yet to be optimised. As an example the comparison for a 4m seam of bituminous coal at 3kg of oxygen/sec; 100m system, is:

Oxidant	Efficiency	System Length Factor	Kj gas/m³ oxygen
Air + 0.5 water	73.3	110	6960
Oxygen + 1.5 water	73.7	46	7270

Errata - original paper

p9 : Table last line test avg L^1 should read > 70m

p11 : Title Fig.6 - should read $WHx10^{-2}$

nomenclature ✧ W=50 should read 150

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

82612075
August 2, 1984

Department of Mines & Energy,
191 Greenhill Road,
PARKSIDE, S.A., 5063.

Attention: Mr. K. Plastow

Dear Sir,

RE: LEIGH CREEK - U.C.G. DRILLING PROGRAMME

At a meeting on July 13, 1984, between officers of the D.M.E. and Golder Associates, additional geological data relevant to the U.C.G. study was presented and discussed.

Although most of this data comprised descriptive logs from boreholes located near to the proposed 30 year mine limit around the north and east limbs of the coal basin, of most interest is the data obtained from Seismic Line LC-78-B2/3, which includes three correlation boreholes (refer Figure 1).

The seismic data clearly indicates a break in seam continuity, at a depth of around 500m, with the downdip block displaced by several tens of metres. This interpretation is partly confirmed by boreholes 914 and 3218, which intersect the coal seam on the updip block. Borehole 2349, which is located over the downthrown block, was terminated above coal, but does indicate downwards displacement in excess of 25m.

A review of additional uncorrelated seismic data on Seismic Line LC-78F suggests major seam displacement, once again at a depth of approximately 500m.

Past geological interpretations have inferred some form of axial faulting through the basin. It is possible that the major faulting indicated by the seismic data may be confirmation of this supposition.

The major faulting downdip within the currently proposed U.C.G. target area will have a considerable effect upon available long-term reserves and optimum panel layout.

The proposed investigation programme must therefore be directed not only towards evaluation of the geotechnical and hydrogeological properties of the coal seam and enclosing rocks, but should also provide more accurate definition of coal reserves and their actual location.

GOLDER ASSOCIATES PTY LTD
25 BURWOOD ROAD HAWTHORN VIC 3122 AUSTRALIA
MELBOURNE
TEL (03) 819 4044
TELEX AA33616
SYDNEY • BRISBANE • PERTH • CANBERRA • WOLLONGONG • MAROOCHYDORE • TRARALGON • CANADA • U.S.A. • U.K.

The overall aims of the programme will be structured to match the above requirements within budgetary constraints. The following revised proposals taken into account all available geotechnical data, and points made during discussion at the July 13 meeting.

We would propose drilling three boreholes as follows:

2 only partly cored boreholes	400m depth
1 only open hole borehole	650m depth

The partly cored boreholes would be utilized for hydrological testing and the core obtained would be logged and tested in detail to allow assessment of strength parameters and their effect on rock caving potential. These boreholes would be located updip of the inferred fault, and 100m east and west of the seismic line at borehole 3218.

The open borehole, which would be located downdip of the inferred fault, would be drilled to prove the suitability of the seismic method as a means of subsurface investigation at Leigh Creek. This technique could prove invaluable in delineation of faulted zones at depths of several hundred metres.

Each borehole would be geophysically logged to allow correlation of stratigraphy, and hence extrapolation of material parameters. It is also anticipated that piezometers would be installed, where practicable within the partly cored borehole, to allow long-term monitoring of groundwater levels.

At the completion of this programme analysis would be performed to allow better definition of roof rock structure and groundwater flow characteristics around a gasified cavity.

We are of the opinion that this modest programme will, together with detailed examination of existing data from the open-cut mining areas, provide a significant improvement in assessing the U.C.G. potential of inaccessible coal reserves at Leigh Creek. It will also confirm the value of seismic methods for definition of coal seam intervals and faulted zones.

We would welcome the opportunity to discuss this programme with officers of the Department, in order that we can jointly agree on timing, personnel and equipment requirements. We would anticipate that such discussions should include personnel from those areas from which direct programme support is to be provided, namely:

- Mr. G. Kwitko (geological supervision)
- Mr. J. Alvey (geophysical logging)
- Mr. M. Brennan (drilling services)

We have attached an outline of the overall field programme sufficient to allow recognition of possible technical/logistical problems. We believe this provides a reasonable basis for discussion of the upcoming drilling requirements.

Yours faithfully,
GOLDER ASSOCIATES PTY. LTD.
per:

L.K. Walker

L.K. Walker

I.M. Gibson

I.M. Gibson

IMG/LKW/blh

A. PRELIMINARY CONSIDERATIONS

1. OBJECTIVES

(i) Exploration - As a consequence of examination of data made available on Seismic Line LC-78- B 2/3, there is sufficient confidence in present geologic interpretation to forego exploration oriented drilling for the time being.

(ii) Targetting - The proposed drilling programme will quantify basic geotechnical parameters, and will also establish seam displacement across the interpreted fault. This will allow assessment of the value of future seismic work for exploration purposes.

(iii) Testing - The partly cored boreholes will be concentrated within an area suitable for future panel development purposes, and the data obtained, including long-term groundwater monitoring, will be directly relevant to a future test burn.

2. MODEL OF TARGET

The proposed programme is based around a model derived from existing data available from relevant boreholes and the seismic line, and includes consideration of geological, geophysical and geotechnical information.

Key information now required relates to more specific issues of hydrological, geotechnical and chemical nature of the coal and enclosing rocks. Information currently sought includes

- coal seam intersections, dip, quality, banding, parting, strength and permeability
- roof rock strength, permeability and structure
- possible stratigraphic correlation in coal and roof to allow extrapolation of data.

3. BUDGET-LIMITATIONS AND COSTS

The 1983-84 SENDRAC grant of $50,000 allows provision of $10,000 for drilling support services. The remainder will enable Golder/Shedden to perform updated geotechnical and feasibility studies.

The S.A.D.M.E. is understood to have made an allocation of $120,000 in additional drilling services, including a geologist to supervise field operations, and also, geophysical logging of the boreholes.

4. SITE CONDITIONS

It is understood that E.T.S.A. will provide assistance of a general nature with reasonable access to each drilling site, with specific assistance of on-ground survey facilities, meals and accommodation for drill crew and technical personnel, and also, a suitable 4WD vehicle at Leigh Creek for Golder Associates personnel.

We also understand that, if required, workshop facilities for equipment maintenance and repair would be made available.

5. DRILLING PROBLEMS

In order to allow for borehole size reduction at depth, it is recommended that the borehole be cased at a minimum 8" (200mm) through unconsolidated alluvial and into competent weathered rock. This casing should be cemented in and the plug drilled out, this being necessary to avoid failure of the casing and consequent problems with caving and flushing of the unconsolidated soils.

Open hole drilling at depth may encounter badly caving ground. Prior to any reaming out and setting of casing, the caved zone should be grouted and redrilled. This may avoid unnecessary size reduction.

Similar requirements would apply for caving problems in the cored intervals, but only as a last resort as permeability test results would be affected.

Open hole drilling may be carried out using air flush with V-notch weir on hand to monitor any significant water flows.

All coring should be done using water thus avoiding undue effects on permeability tests.

6. MINIMUM REQUIREMENT

In terms of the total programme an absolute minimum would be one cored borehole: with successful permeability tests and piezometer installations in the roof and in the coal seam, and, a deep open hole downdip of the fault to intersect the coal seam. Successful geophysical logging must be achieved in each cored borehole and in the deep open borehole.

Additional holes will be governed by the cost of drilling assessed by D.M.E. At this stage it is considered that a second cored hole can be executed with the D.M.E. budget.

7. ADDITIONAL INFORMATION

(i) Borehole Geophysics

It is understood that a logging service will be provided by D.M.E. personnel, and that the logging suite will include:

- caliper
- density
- gamma
- neutron
- sonic
- resistivity
- self potential
- dip meter (borehole deviation)
- microresistivity

Equipment must have a depth capability of 700m. Standardization of logging tools will be required.

We have had preliminary discussion with C.S.I.R.O. into possible logging trials of the ASH system. This system is in the marketing stage so some effort would be required to involve E.T.S.A. directly as a possible user of the ASH system.

It will be necessary to log the open hole section of partly-cored boreholes prior to reaming and/or casing installation.

(ii) Borehole directional surveys will be required to allow determination of deviation off vertical of each borehole. As past experience at Leigh Creek indicates a tendency to climb up dip, this aspect requires careful study for successful application of deviated drilling techniques but also for vertical development boreholes.

Although this data may be obtained from geophysical logging, we would like to see this complemented by use of a multi-shot borehole camera (Eastman) over the cored interval. Shots would be taken as rods are withdrawn at end of cored section.

(iii) Basic strata information can be derived from monitoring of drilling rates by recording time taken to penetrate each 6m interval (say). Data relating to drill rig mechanics → gearing, pump rate etc. should also be noted.

(iv) All core will be photographed in colour by Golder Associates. Core handling techniques should include sufficient care to ensure that core is not dropped, broken or lost through mishandling. Core will be transferred from metal splits into P.V.C. splits prior to logging and transfer into core boxes.

(v) As considerable chemical testing of core is envisaged by D.M.E., an outline of the proposed laboratory programme will be required to avoid clash with the Consultant's proposals. If necessary, individual partly cored boreholes may be sampled separately.

(vi) Laboratory testing of coal may require tests more relevant to metallurgical properties - possible fused slag and reduction of coal permeability etc. It may be necessary to omit testing which would normally require immediate sealing of samples upon recovery.

(vii) Hydrological testing of cored intervals will be carried out under the direct supervision of the Consultant. No special equipment is required to be supplied by the drilling section. Permeability testing can be performed in both 'N' and 'H' size boreholes. 'H' will be preferred size. Allow 4 hrs per test - 20 tests.

(viii) Geomechanical testing of core will consist of a combination of estimation of strength, non-destructive indentor testing, and, destructive point load index strength testing. Additional tests to determine moisture contents, plasticity and slaking characteristics will be carried out as necessary by the Consultant.

B. BOREHOLE DESIGN CONSIDERATIONS

(i) Minimum core size will be 'N', but at this stage it is required that core be recovered using 'H'-size wireline equipment. 'H' size is considered optimum for geological/geotechnical/structural logging, and also suitable for geomechanical/chemical testing.

Recovery of core is clearly vital, and we would stress the need for controlled drilling of cored interval. If necessary short core runs will be required if difficulties arise, such as bit blockages.

(ii) As with core size, geophysical logging will require minimum 'N' with optimum 'H', even in open hole intervals. If borehole size reduction is proposed, it will be necessary to run geophysical logs prior to reaming/casing.

It would be prudent to maintain a set drilling fluid chemistry for all geophysically logged intervals. All boreholes should be topped up with fluid prior to geophysical logging.

(iii) Permeability testing can be carried out at 'N' and 'H' size (see above).

(iv) If reduction in borehole size is required due to bad ground conditions geophysical logging must be carried out prior to casing installation. It may be necessary to drill open hole intervals at 100mm (4 inch), geophysically log that interval, then ream and case before further advance.

Discussion with Mike Brennan will be required to ensure correct selection of borehole drilling sizes. There are only two requirements by the Consultant - that is geophysical logging must be done without the hindrance of casing, and, the cored intervals should be drilled with water.

(v) The proposed drilling is relatively simple. The partly cored boreholes are to be open holed to approximately 30m above the coal seam (as estimated from available data at 3218). After geophysical logging, the borehole may be reamed and cased if necessary prior to commencement of coring.

Although we would be guided by experience gained by D.M.E. personnel previously involved in deeper drilling programmes at Leigh Creek, we would suggest that casing may not be required in partly cored boreholes, as the drill rods used for coring remain in place as the borehole is advanced.

We would also suggest that, in the event that casing is required, it may be unnecessary to cement the casing in the borehole, but rather to ream it down into the undrilled section to provide adequate seal.

(vi) The casing program and borehole completion requirements will necessitate additional materials being transported to site. We are in accord with D.M.E. personnel in that piezometer installations should be completed in the coal and roof rocks.

Our experience with piezometer installations at depths of several hundred metres indicates that successful completion will only be achieved utilizing ½" diameter galvanized water pipe.

This material has sufficient rigidity to allow accurate placement of the piezometer, filter sand, and, sealing materials through the drill rods.

An accurate costing should be prepared of time and materials based on placement of one piezometer only in each of the partly cored boreholes.

If severe difficulties are envisaged with piezometer placement through the H-drill rods, then casing would normally be required to maintain wall stability during the installation. We would anticipate that this casing could still be recovered after successful completion of the installation.

A short length of casing with a lockable top would be required to be installed at the surface to provide long term protection.

(vii) We would suggest that in the interval above the piezometer the borehole should be grouted up to the surface.

This aspect is probably covered by D.M.E. regulations on groundwater protection, but would also be required to prevent any possible future gas/water connection between the coal seam and overburden aquifers.

(viii) Upon completion of coring samples would be required for chemical testing (D.M.E.) and geomechanical testing (Golder Associates).

The Consultant's selection criteria are not critical at this stage, as existing data suggests relatively homogeneity about overburden.

The proposed sampling requirements, including any special protection, or time considerations (such as avoiding dryout out) should be discussed.

C. DRILLING COSTS

To allow the D.M.E. personnel to prepare a budget estimate we have included the following brief check list of items which will be a real cost to the job, or may require equipment/material provision.

(i) The basic cost per unit length/time for

- core
- non-core
- casing
- standby

at various borehole depths.

(ii) Any imposition on anticipated drilling rates as a result of requirement: keep borehole reasonably straight; achieve maximum core recovery; and similar issues.

(iii) Allowance for selection of bit type (diamond/tungsten) and associated bit wear/damage.

(iv) Borehole reaming for casing installation including selection of appropriate bit and casing sizes. It should be assumed that at the worst casing will be required, but we would anticipate it will be recoverable.

(v) Contingency for difficulty due to stuck rods or equipment downhole.

(vi) Provision of appropriate drilling muds (polymers or bentonite) and cementing materials, including need for accurate placement of latter.

(vii) Standby time associated with geophysical logging, hydrology testing, piezometer installation.

(viii) Materials cost for piezometers - say 700m of 12.5mm I.D. (½") galvanized pipe in 6m length. Bentonite pellets, sand filter materials, lockable surface casing installation (2 off).

(ix) Water haulage - estimated water volume requirements will be necessary to determine whether to use excavated sumps or recirculating tanks.

(x) A time estimate will be required for moving from one borehole location to the next, including rig dismantling and setting up time.

(xi) D.M.E. personnel have indicated a 6 day week, 10 hour day, single shift operation will operate. It is understood that E.T.S.A. will provide meals and accommodation for drill crew and technical personnel for the duration of the drilling programme.

We would ask that E.T.S.A. confirm their willingness to provide a suitable 4.W.D. vehicle for Golder Associates staff as required.

(xii) It is likely that minimal site preparation will be required, however reasonable track access should be confirmed, also the need for any site clearing and/or excavation of sumps.

D. TECHNICAL LIAISON

Following agreement on the proposed programme and setting of target depths for commencement of coring, on intersecting of coal, liaison will be between the Drilling Supervisor and Supervising Geologist (Kwitko).

A daily record will be kept of each shift including any drilling problems and variations to expected conditions. Prior to any borehole cementing or casing installation, Golder Associates' representative is to be notified to ensure that adverse consequences are avoided.

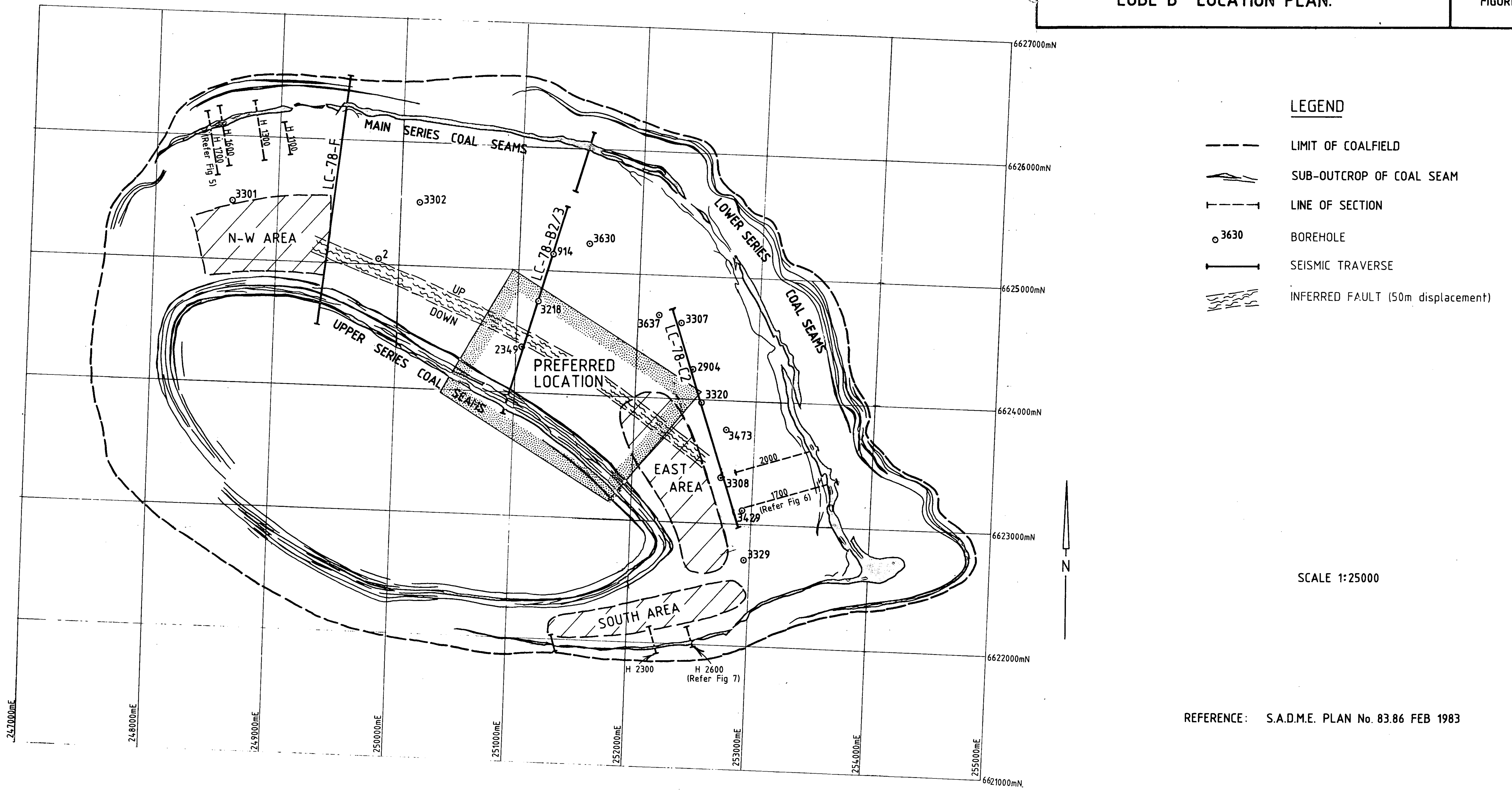
Golder Associates' representative will be on site during all coring operations and will be responsible for selection of hydrologic test intervals. The equipment required for this testing will be provided by the Consultant. We assume that bottled gases are available through a C.I.G. outlet at Leigh Creek. If not, industrial air bottles should be transported to site (minimum of 8 'E' size bottles).

The Consultant will review geophysical logs to ensure their suitability. It may be necessary to re-run some logs if problems due to excess mudding of the hole or other circumstances effect log quality.

Final selection of drilling equipment and its size will be made by Mike Brennan after discussion with the Consultant.

LOBE 'B' - LOCATION PLAN.

FIGURE



REFERENCE: S.A.D.M.E. PLAN No. 83.86 FEB 1983

GOLDER ASSOCIATES

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

RH AMARAL M KURZEME WA PECK
WN DAVIES KE MATHEWS KJ ROSENGREN
RG FRIDAY JR MORGAN IM SMITH
TN HAGAN RJ MORPHET HK SULLIVAN
PN HAYTER RJ PARKER LK WALKER

82612075
July 5, 1984

Department of Mines & Energy,
P.O. Box 151,
EASTWOOD, S.A., 5063.

Attention: Mr. K. Plastow

Dear Sir,

RE U.C.G. DRILLING PROGRAMME AT LEIGH CREEK - TECHNICAL REQUIREMENTS

We acknowledge having received from you notes summarizing the conclusions reached at a meeting of representatives of those sections of the Department which have the potential to contribute to the Leigh Creek U.C.G. project. As you are aware, various technical discussions have also been held between members of your staff and our senior engineering geologist responsible for the project (Iain Gibson), as a result of which additional geological data from the proposed U.C.G. area has been made available.

The purpose of this letter is to summarize our objectives, specify as best we can our requirements, and respond to comments raised by the Department. Following receipt of your verbal response to this letter, and given the availability of the drill rigs later this month, it is proposed that Mr. Gibson visit Adelaide to finalize all specific details of the programme.

Objectives

In the original SENRAC/NERDDC grant applications for 1983/84, there were two specific inter-related objectives

- to establish the existence and continuity of the Main Series coal seam to support the practicability of the proposed U.C.G. panel layouts

- to obtain quantitative geotechnical parameters for the coal seam and surrounding rocks, with particular emphasis on strength and permeability.

With subsequent approval of SENRAC funds only, it was decided to concentrate on drilling one hole and obtaining geotechnical parameters, i.e. the second objective above. The proposed hole was to be located on a section down-dip from existing borehole L3630. A specific location for this hole (6624700 MN and 251600 ME) was nominated in a telex to the Department dated April 16, 1984.

Since that date, the possibility for drilling additional holes has been provided by allocation of Department funds for field services. In addition, further geological information has been provided from existing boreholes 914, 3218 and 2349 and an associated seismic line running down-dip at the western end of the preferred U.C.G. area. This additional support should enable both of the above objectives to be achieved.

Given the limited information on the geological profile in the proposed U.C.G. area, and the limited funds currently available, the intention has always been to simplify field work to obtain the essential geotechnical and geological information, and hence minimize the possibility of cost overruns which might result from attempting more difficult down-hole testing. The techniques proposed have been

- detailed geological logging
- down-hole geophysical logging
- in-situ permeability testing
- borehole orientation
- piezometer installation for groundwater monitoring.

It was also anticipated that useful information on the geology and groundwater regimes in the area would be obtained from the current open pit geotechnical programme, to supplement the U.C.G. field data.

Following recent discussions on cost allocation, it is understood that the available funds will permit, as a minimum, one cored borehole for in-situ testing, and three open holes drilled primarily for strata identification.

Proposed Borehole Locations

Examination of additional data provided subsequent to our Preliminary Report of April 1983 indicates the possible existence of a major strike fault across the middle of the proposed U.C.G. area. With an inferred strata displacement of several tens of metres, this feature clearly represents a significant potential limitation upon panel development.

It is prudent that, in keeping with our initial proposal, coal seam continuity be determined by drilling of geophysically logged open boreholes across the inferred fault position. This will be required to establish the extent of downdip continuity and thickness of the coal seams.

It is anticipated that a minimum of three open boreholes would be required to resolve to some degree of satisfaction the nature of faulting. These boreholes would be located in the corners of the proposed U.C.G. area, with existing boreholes 3218/2319 providing guidelines for anticipated coal intersections.

It should be appreciated that, although locations may be specified with some accuracy, coal intersections can only be estimated. However, to eliminate cost overruns on the partly cored borehole, it is proposed that this borehole, which will include in-situ testing, be located immediately adjacent to existing borehole L3218.

Drill Hole Construction

Boreholes will need to commence at a diameter that will ensure suitable size at coal seam depth for geophysical logging to be carried out at H-size.

The experience of the Drilling personnel of the Department will be invaluable in selection of borehole drilling procedures. It may be necessary to pre-collar the borehole at a relatively large size through alluvium and weathered rock. This section would be cased off at, say 200mm, with P.V.C. It would seem prudent to allow for at least one reduction in borehole size due to possible drilling difficulties.

Within the proposed partly cored borehole it will apparently be necessary to case the borehole from the ground surface to the top of the cored borehole. The internal diameter of this casing will be a minimum of 100mm. Because of the requirement to accurately place and seal the casing into the base of the borehole, it will be necessary to use steel casing. It is anticipated that the borehole size over the cased interval be of the order of 175mm diameter. Dependent upon rig capabilities it may be possible to firstly drill the borehole at say 100mm diameter prior to reaming out to a larger size.

This approach may assist in maintaining the straightness of the borehole, while also virtually ensuring ease of casing installation.

It is our belief that once the technical requirements have been specified by the Consultant, the drilling details should be determined by Drilling personnel from the Department. The Consultant would review the proposed borehole construction details to ensure that the stated requirements can be achieved.

Borehole Geophysical Logging

Past experience dictates that each borehole should be geophysically logged for a maximum of parameters. Most coal logging suites include as a minimum:

- density (neutron-neutron)
- caliper
- gamma
- neutral

Additional logging should include:

- sonic
- resistivity
- self potential
- temperature

We understand that the Department has the facilities to perform this logging. We would require that details be provided to the Consultant as soon as possible of the range and nature of tools available.

We also understand that C.S.I.R.O. has some geophysical tools of an experimental nature. We would be keen to discuss with them possible trials at Leigh Creek.

Hydrological Investigation

At this stage of the Feasibility Study, relatively simple hydrological testing will be performed.

It is proposed to use wireline packers in the partly cored borehole to perform rising/falling head test. For the former it will be necessary to extract water from the drill rods by flushing with a high pressure air line. For the latter water would be added to the drill rods.

The measurements would essentially record the response time to return to a static water level situation. This aspect of the programme would be performed by Golder Associates personnel.

It is possible that water flows from the borehole induced by air flush drilling may provide useful data. We do, however, see some practical problems arising from the ultimate depth of the boreholes. It would be worthwhile persevering with this technique as long as practicable, with flow measurement across a V-notch weir being performed.

Drill Hole Abandonment

As potential gas/water leakage paths must be minimised, it will be necessary to cement boreholes upon completion. This aspect will almost certainly be covered by regulations promulgated by the Department in relation to either groundwater or possible underground mining (by conventional means).

Piezometer Installation

Dependent upon estimated costs it may be feasible to install piezometers within the cored interval of the partly cored borehole. We are looking further into this possibility and the associated costs.

Geotechnical Testing

At this stage it is envisaged that geotechnical testing will consist of

- Point Load testing
- Indentor tests
- Atterberg limits and moisture content.

It is understood this work can be performed on site.

We trust the above comments cover those queries raised within the Department. We would propose that a joint meeting of all parties involved be held in Adelaide in about one week's time to finalize all relevant details. We shall be in contact to arrange details for such a meeting.

Yours faithfully,
GOLDER ASSOCIATES PTY. LTD.
per:

L. K. Walker

L.K. Walker

LKW/blh

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

RH AMARAL M KURZEME WA PECK
WN DAVIES KE MATHEWS KJ ROSENGREN
RG FRIDAY JR MORGAN IM SMITH
TN HAGAN RJ MORPHET HK SULLIVAN
PN HAYTER RJ PARKER LK WALKER

82612075
June 26, 1984

Department of Mines & Energy,
P.O. Box 151,
EASTWOOD, S.A., 5063.

Attention: Mr. K. Plastow

Dear Sir,

RE U.C.G. DRILLING PROGRAMME AT LEIGH CREEK - COST ALLOCATIONS

Following the meeting between Messrs. Plastow and Walker on Friday, June 22, we write to summarize our understanding regarding the cost of drilling, geological and geophysical services to be provided by the Department to assist in maximizing the technical information to be gained from this stage of the U.C.G. programme.

We have agreed that the current programme of field work will consist of a minimum of four holes drilled within the proposed U.C.G. area. Of these holes, the first three are to be open-holed and the fourth cored below 300m. Technical details of drilling and testing requirements will be forwarded within the next few days.

It is our understanding that the Department will undertake to provide drilling services, geological supervision and geophysical downhole testing for these holes for an allocated sum not to exceed $140,000. Of this sum, $120,000 relates to funds allocated to the programme by the Department for the 1984/85 year, and $20,000 will be allocated by Shedden Pacific from the SENRAC grant approved for 1983/84.

This agreement will provide Golder Associates with funds from the SENRAC grant of about $20,000 to organize the field programme, supervise aspects of downhole testing in the cored hole, interpret all available data, analyse test results to reassess roof stability and groundwater flows, and prepare a written report to SENRAC. The availability of this sum is considered essential to provide progress in geotechnical evaluation of the site, since the first preliminary appraisal in April 1983, for which $5,000 was allocated, required about $10,000 for its execution.

It is understood that the Department will assess internal costs of this minimum field programme of four holes, and will advise if additional holes can be drilled within the agreed funds. Such additional holes would be used to check on the continuity of the coal seam down-dip, and the effect of the fault inferred to be present from recent surface geophysical work.

We trust the above adequately summarizes our joint understanding of cost allocations for the proposed drilling programme. Should you have any further queries we would be happy to answer them. Our understanding is that the rig is likely to be available to commence drilling in the latter part of July.

Yours faithfully,
GOLDER ASSOCIATES PTY. LTD.
per:

L. K. Walker

L.K. Walker

LKW/blh

DME 112

Minute Form DME No. 250/84

TO THE PRINCIPAL ENGINEER

COMPLETION REPORT - ROTARY DRILLING
LEIGH CREEK - U.C.G. PROJECT

Drilling, coring and piezometer installation on the above project has been completed.

WELL NO. LC3964 1st Deep piezometer.

The well was collared with 2m of 305mm OD steel pipe and drilled 290mm diameter to 14m into solid shale using blades and air circulation. 203mm PVC pipe was run to 14m and the shoe was cemented with Gyp Cement 60. Drilling proceeded 152mm diameter using a 4 way heavy duty unitized insert bit to 295m with air circulation, and water with liquid polymer from 295m to 349m. Small supplies of very saline water were intersected while air drilling.

The depth limitation using 250 psi air in this ground with 2.7/8 drill pipe is 250-300m. The conversion to water circulation was required due to the inability to clear the hole with air circulation and foam.

The bottom section of the hole was drilled with 2 x 4½ drill collars to reduce string weight.

The hole was electrically logged at 349m prior to running casing.

A string of 100mm HD galvanised S + S pipe was run to 349m, with one length of 152mm HD black pipe at surface to accomodate the 114mm diameter kelly. Adaptation of pipe was done using a 152-100mm black steel reducing socket.

A six metre plug of cement was dump bailed in the bottom using 2 x 3m lengths of HQ rod with dump shoe and bail. The type of dump shoe caused some problems by not remaining open when dumping under cement following the first run.

The casing was set on bottom and retained in partial tension by using a clamp at the surface. The clamp was left on the well at completion. Rotary drilling fluid was displaced with clear water before coring.

After setting casing the hole was cored HQ3 to TD of 403.78m using a 101.6mm TC, stepped lifter case, face discharge core bit. One bit was used to cut the section. The bottom hole section was electically logged on completion of coring.

Noted PE.

Noted

→ Dir Oil Gas + Coal — to note completion report of Leigh Creek U.C.G. Drilling.

noted

D2044

Penetration was slow in the grey shales, which were interbedded with hard stringers. The bit ran rough in the hard bands requiring a reduction in RPM. Penetration rates were faster in the hard sections than in the shale.

Full recovery was obtained over the section, however it was difficult to break the core in the shale sequences as it proved very tough in situ, and pulled through the lifters rather than breaking cleanly at base. Several modifications were made to the lifters however no one set design proved more effective in breaking the core.

This hole was cored approximately 14 metres into the floor below the coal and plugged back to 391.5m with cement placed with an NQ bailer (2 x 3m lengths). Problems were encountered with the dump shoe and partially set cement in hole by the time the last bailers were run. The time factor is too great to enable large cement plugs to be set at these depths using a dump bailer.

After plugging back, open end HQ pipe was run to bottom and the drilling water was displaced with clear water, the HQ rod was then retracted and positioned with the open end 10m above the top of the required gravel pack.

Heavy 20mm galvanised S + S pipe was run to 391.5m as a piezometer.

The bottom was plugged with a 6.5m blank sump. One length of perforated pipe was set from 378.5 to 385m.

Perforations were 3mm drilled holes at 200mm spacing offset 100mm at 90°.

The length of pipe immediately above the perforated length had four (4) 3mm holes drilled at 90° in a single plane 200mm below the top socket. These were designed as tell tale holes for the gravel packing process. After gravel packing this first piezometer the tell tale hole system was considered ineffective, and was not used in the second piezometer.

Reverse circulation was obtained up the piezometer pipe and down the HQ using a 50mm centrifugal pump. The yield was low approximately 0.2 litres a second and this decreased as the gravel packing proceeded. The sand used for packing was Steetley's 8-16 graded and washed sand. Sand was added slowly into the annulus between the 20mm pipe and HQ rod while reverse circulating, through a funnel attached to the HQ rod. Feed rate for the sand was approximately 20 litres per hour, and 170 litres was placed in the well, sufficient to fill 2 metres above the tell tale holes. Reverse circulation was maintained for one hour after final sand placement, and well was allowed to stand overnight before placing the cement plug.

Sufficient cement slurry to give a 10m plug on top of the sand was poured into the HQ rod and balanced with water. The HQ pipe was then removed.

This well was drilled with "fresh" water obtained from a creek after rain.

Three packer tests were carried out during coring using an inflatable packer, one test in the roof, another in the coal, and the final in the floor section.

The well was airlifted in the annulus and 20mm piezometer from 70m on the following dates 17-12-84, 1-2-85 and 6-2-85.

<u>WELL NO. LC3965</u> Adjacent LC3964

This well was drilled 152mm to TD of 11m with air circulation and completed as an observation well by casing with 80mm PVC pipe slotted from 5-11m. The casing was cemented at surface above a Linatex seal. The well was dry when drilled.

<u>WELL NO. LC3966</u>

The well was spudded 200m diameter to 16m into fresh shales with air circulation and 150mm Class 6 PVC pipe was set with shoe cemented with Gyp Seal 60.

Drilling continued 147mm diameter with air circulation to 241m using a 4 way unitized TC insert bit.

Coring HQ3 with a carbide bit was commenced at 241m and continued through the coal seam and into the floor. Coring ceased at 260m.

Following electric logging the hole was plugged back to 180m with cement and left as an observation well in the roof.

<u>WELL NO. LC3967</u> 2nd Deep Piezometer.

The general construction and drilling of this well was basically the same as in LC3964.

Ground conditions varied considerably from LC3964 and caused drilling problems and delays. Broken hard ground at 140m continually moved into the hole requiring two reaming trips before the hole could be logged. Casing was run to 312.5m and cement was dumped at the shoe with a bailer, however due to boulders and collapsed material in the hole the cement failed to make an adequate seal.

When attempting to core ahead of the casing, the rods jammed in the casing, rotating the bottom of the casing string and parting it in two places. The rods were freed and the casing was reconnected at one parting but could not be reconnected at 248m. The top casing was removed and two fishing trips were required to recover the remaining casing with a taper tap. After conditioning the hole with water and liquid polymer the casing was rerun and pressure cemented with 18 sacks of cement. The coal seam was expected to be shallower at this location, hence coring commenced at 312.5m. Coal was not encountered until 372.26m.

Two core bits were used in this hole - one HQ3 TC face discharge bit and one diamond HQ3 double dimple bit. The TC bit proved superior in penetration rate. The diamond cut the coal well but bogged down in the shales. Varying RPM and weight did not improve the penetration of the diamond bit. Both bits were subject to rough running in the hard stringers and broken sections.

Ground conditions were very fractured throughout the cored section. At 373-5m approximately one metre into the coal seam a major fracture was encountered resulting in complete loss of circulation and stuck rods. Circulation was regained by using heavy applications of Liquid Polymer to the pump suction and the rods were freed.

Coring ceased at 396.8m on advise of Geologist Mr. Ian Gibson of Golder and Associates.

No cement plug was required in the floor, and after electric logging 20mm pipe was set as a piezometer in a similar manner to LC3964.

No tell tale holes were used, and two lengths of perforated pipe were set from 377.3 to 390.3.

A 15 metre cement plug was set through the HQ rod above the gravel pack.

This well was drilled and completed using salt water from the open cut mine.

The annulus between the 20mm pipe and 100mm pipe and the inside of the 20mm pipe were airlifted once only from 70m using 25mm and 12mm poly pipe respectively on 19-12-84.

Four packer tests were run in this well, two in the roof, one in the main coal seam and one in the floor.

WELL NO. LC3968 Adjacent LC3966.

This well was drilled 152mm to TD of 10.5m and completed as an observation well by casing with 80mm PVC pipe slotted from 4.5 - 10.5 metres. The well yielded approximately 0.5 L/sec while air drilling.

WELL NO. LC9070W ETSA

A fishing operation involving one days work was carried out on this well for ETSA. A submersible pump attached to 8 x 6 metre lengths of 100mm FRP column was recovered together with 100m of 20mm nylon rope and 50m of 25mm electrical PVC conduit. Fishing required six trips using a C/T rope spear on drill rods.

WELL NO. LC3969

The well was spudded 200mm diameter and 150mm Class 6 PVC pipe was set at 10m with the shoe cemented with Gyp Seal 60 into fresh shale. Drilling continued 147mm diameter to TD of 271m using air circulation. The hole was filled with saline water prior to logging. One shift was lost due to breakdown of logging equipment. After logging the well was plugged at bottom with thirty sacks of cement.

Drill String - 6 x 4½" x 15ft Drill Collars
2 x 4½" x 15ft Ext. Flush Drill Pipe
2.7/8 x 15ft Drill Pipe - 2.7/8 IF T Joints
Compressor - Holman RO70VHP 700CFM @ 250 psi

Details -

Date commenced 15-10-84
Date completed 6- 2-85
Rig - Portadrill RD4
Driller - A. McIntyre
No. of Holes -6

Metres drilled - 1195
Metres cored - 158
Bore Serial Nos. LC3964, LC3965, LC3966, LC3967, LC3968, LC3969
121/85 155/85 156/85 157/85 158/85 162/85
Debit No. 136-F41
Approval $120,000

JMB:SJS
20-2-85

J.M. BRENNAN
ROTARY DRILLING SUPERINTENDENT

To G. Kwitko

The Australian
Mineral Development
Laboratories

Flemington Street, Frewville,
South Australia 5063
Phone Adelaide (08) 79 1662
Telex AA82520

Please address all
correspondence to
P.O. Box 114 Eastwood
SA 5063
In reply quote:

amdel

1/9/0 - AC 1036/86

1 October 1985

NATA CERTIFICATE

The Director General,
S.A. Department of Mines & Energy,
P.O. Box 151,
EASTWOOD S.A. 5063

REPORT AC 1036/86

YOUR REFERENCE:	EX-408, DME 250/84.
REPORT COMPRISING:	Cover Sheet Pages 1 - 2
DATE RECEIVED:	6 September 1985

D. Patterson

D. Patterson
Chief Chemist
Analytical Chemistry Division

(F)

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Head Office:
Flemington Street, Frewville
South Australia 5063
Telephone (08) 79 1662
Telex: Amdel AA82520
Pilot Plant:
Osman Place
Thebarton, S.A.
Telephone (08) 43 5733
Telex: Amdel AA82725
Branch Laboratories:
Melbourne, Vic.
Telephone (03) 645 3093
Perth, W.A.
Telephone (09) 325 7311
Telex: Amdel AA94893
Sydney, N.S.W.
Telephone (02) 439 7735
Telex: Amdel AA20053
Townsville
Queensland 4814
Telephone (077) 75 1377

ANALYSIS

AS RECEIVED

%

SAMPLE MARK	CARBON C	HYDROGEN H	NITROGEN N	SODIUM Na	CHLORINE Cl
A 297	13.8	1.94	0.39	0.10	0.08
A 309	45.9	2.53	1.14	0.20	0.10
A 314	8.4	1.36	0.24	0.09	0.08
Comp A	60.5	3.68	1.68	0.21	0.26
Comp B	52.9	2.98	1.40	0.21	0.13
Comp C	55.0	2.99	1.37	0.21	0.16
Comp D	57.4	3.10	1.46	0.21	0.16
Comp E	50.7	3.02	1.35	0.18	0.16
Method:	C4	C4	C9	C8	C7

ANALYSIS

AS RECEIVED

SAMPLE MARK	MOISTURE H_2O %	VOLATILE MATTER %	FIXED CARBON %	ASH %	TOTAL SULPHUR as S %	SULPHATE SULPHUR as S %	PYRITIC SULPHUR as S %	GROSS SPECIFIC ENERGY MJ/Kg
A 297	2.4	15.5	10.4	71.7	0.16	0.06	0.01	4.44
A 309	11.7	22.7	40.1	25.5	0.11	0.01	0.01	17.00
A 314	1.8	12.0	5.7	80.5	0.10	0.02	0.01	2.28
Comp A	13.1	31.4	49.4	6.1	0.21	0.01	0.01	23.56
Comp B	12.2	26.6	43.7	17.5	0.15	0.01	0.01	20.20
Comp C	12.3	27.2	45.9	14.6	0.12	0.01	0.08	20.96
Comp D	13.2	27.0	47.8	12.0	0.11	0.01	0.01	21.76
Comp E	11.5	26.0	41.6	20.9	0.19	0.01	0.10	19.44
Method:	C3	C3	C3	C3	C5	C18	C17	C16

Information Officers Copy

DMC 142

DEPARTMENT OF MINES AND ENERGY

191 GREENHILL ROAD,
PARKSIDE, 5063
P.O. BOX 151,
EASTWOOD, 5063
PHONE 2747500

APPLICATION FOR EXAMINATION OF SPECIMENS OR SAMPLES

Submitted to AMDEL for
- Analytical, Petrological, Other Examination.

INVOICES MUST BE RENDERED TO THE ACCOUNTANT, STATING THIS NUMBER. EX - 408

REPORTS MUST BE DELIVERED TO THE INFORMATION OFFICER STATING THIS NUMBER. DME 250/84 ~~[illegible]~~

2315F

Sample Number 1:100 000 sheet	Assay Numbers	Rock Name	Other Numbers (Drillhole, Aerial Photo etc.)	Geological Province	Stratigraphic Unit or Age	Details of work required	Price
6539	RS A297/85	COAL	BOREHOLE L39641	Leigh Creek	Triassic	Refer to AMDEL Rept. AC 4852/85	
	RS to			Coalfield		+ attached sheet	
	RS A 314/85						
	RS					ANALYTICAL WORK ON COAL PLY/COMPOSITES	
	RS						
	RS					CODE SAMPLE COMPOSITES + PLY	
	RS						
	RS					C3 ABCDE	
	RS					C4 ABCDE A297, A309, A314	
	RS					C5 " " " " " " " "	
	RS					C7 " " " " " " " "	
	RS					C8 " " " " " " " "	
	RS					C9 " " " " " " " "	
	RS					C16 " " " " " " " "	
	RS					C17 " " " " " " " "	
	RS					C18 " " " " " " " "	
	RS						
	RS						
	RS						
	RS						

Type of Samples (18): AMDEL ply samples from previous order...

Disposal of Samples: Return to Core Library
ACTION NOW COMPLETE

Name of Applicant: G. KUVITKO

DME Section: OIL GAS + COAL DIVISION

Signed: R.K. Johns per JN Director General

Date: 23.8.85

$ 2350 TOTAL

SAMPLING/ANALYTICAL INSTRUCTIONS TO ACCOMPANY ORDER

Refer to AMDEL Report AC4852/85 (June/July 1985).

Composite Sample Identification

A	=	ply samples	A298/85	&	A299/85.				
B	=	" "	A300/85	&	A301/85	&	A302/85.		
C	=	" "	A303/85	&	A304/85	&	A305/85.		
D	=	" "	A306/85	&	A307/85	&	A308/85.		
E	=	" "	A310/85	&	A311/85	&	A312/85	&	A313/85.

Use density determinations to prepare composites (attachment).

SAMPLE MARK	SPECIFIC GRAVITY	PLY THICKNESS metres
A297/85	2.36	1.00
A298/85	1.49	0.90
A299/85	1.47	2.30
A300/85	1.61	0.80
A301/85	1.55	0.65
A302/85	1.63	1.20
A303/85	1.55	1.80
A304/85	1.59	1.00
A305/85	1.61	0.80
A306/85	1.54	1.70
A307/85	1.54	1.20
A308/85	1.59	1.45
A309/85	1.72	0.60
A310/85	1.61	1.50
A311/85	1.58	1.45
A312/85	1.52	0.75
A313/85	1.77	0.40
A314/85	2.44	1.00

The Australian
Mineral Development
Laboratories

Flemington Street, Frewville,
South Australia 5063
Phone Adelaide (08) 79 1662
Telex AA82520

Please address all
correspondence to
P.O. Box 114 Eastwood
SA 5063
In reply quote:

amdel

NATA CERTIFICATE

1/16/0 - AC 4852/85

26 July 1985

REPORT COMPLETE

The Director General,
S.A. Department of Mines & Energy,
P.O. Box 151,
EASTWOOD S.A. 5063

REPORT AC 4852/85

DME 250/84

YOUR REFERENCE: EX-361, [illegible]-06-0233

REPORT COMPRISING: Cover Sheet
Page 1

DATE RECEIVED: 30 May 1985

D. Patterson
Chief Chemist
Analytical Chemistry Division

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Head Office:
Flemington Street, Frewville
South Australia 5063
Telephone (08) 79 1662
Telex: Amdel AA82520
Pilot Plant:
Osman Place
Thebarton, S.A.
Telephone (08) 43 5733
Telex: Amdel AA82725
Branch Laboratories:
Melbourne, Vic.
Telephone (03) 645 3093
Perth, W.A.
Telephone (09) 325 7311
Telex: Amdel AA94893
Sydney, N.S.W.
Telephone (02) 439 7735
Telex: Amdel AA20053
Townsville
Queensland 4814
Telephone (077) 75 1377

SAMPLE MARK	SPECIFIC GRAVITY
A297/85	2.36
A298/85	1.49
A299/85	1.47
A300/85	1.61
A301/85	1.55
A302/85	1.63
A303/85	1.55
A304/85	1.59
A305/85	1.61
A306/85	1.54
A307/85	1.54
A308/85	1.59
A309/85	1.72
A310/85	1.61
A311/85	1.58
A312/85	1.52
A313/85	1.77
A314/85	2.44

... REPORT NUMBERS 3·7·85 - 1/16/0 - ACH852/85 Part 1

APPLICANTS COPY DMC 142

DEPARTMENT OF MINES AND ENERGY
191 GREENHILL ROAD,
PARKSIDE, 5063
P.O. BOX 151,
EASTWOOD, 5063
PHONE 274 7500

APPLICATION FOR EXAMINATION OF SPECIMENS OR SAMPLES

Submitted to AMDEL for
- Analytical, Petrological, Other Examination.

INVOICES MUST BE RENDERED TO THE ACCOUNTANT, STATING THIS NUMBER. EX - 561A

REPORTS MUST BE DELIVERED TO THE INFORMATION OFFICER STATING THIS NUMBER. ~~11/06/02333~~ ~~11/06/0233~~

Sample Number 1:100 000 sheet	Number	Rock Name	Other Numbers (Drillhole, Aerial Photo etc.)	Geological Province	Stratigraphic Unit or Age	Details of work required DME	Price 250/84
6537	RSA 297/85	—	Drillhole L 3964	Leigh Creek Coalfield	—		
	RS	Leigh Creek Coal	↓	↓			
	RS						
	RS						
	RS		18.7.85			Service Fee	25
	RS		Note: ASTM method now applied			Code C1 (1/30 ... hour)	90
	RS		∴ cost is increased			Code C3 (18 samples)	270
	RS		to $30 per sample			M04.2.1 Specific Gravity	324
	RS		Total Cost = 30x18 = $540				
	RS						
	RS					NOTE: These results should	
	RS					be forwarded to SADME	
	RS					as soon as possible for	
	RS					designation of composite	
	RS					samples for detailed	
	RS					analysis	
	RS						
	RSA 314/85	—					
	RS						
	RS						

Type of Samples (18): HQ CORE

Disposal of Samples: Return crushed sample to Core Library

Name of Applicant: G. KNITKO

DME Section: OIL GAS + COAL

Signed: R.K. Johns per J.N. (Director General) Date 3.6.85

~~$709~~

TOTAL $1159

The Australian Mineral Development Laboratories

Flemington Street, Frewville,
South Australia 5063
Phone Adelaide 79 1662
Telex AA 82520

Please address all correspondence to
P.O. Box 114 Eastwood
SA 5063
In reply quote:

amdel

1/16/0 - AC 4852/85

28 June 1985

PART REPORT 1

The Director General,
S.A. Department of Mines & Energy,
P.O. Box 151,
EASTWOOD S.A. 5063

REPORT AC 4852/85

YOUR REFERENCE: EX-361A [illegible]-06-0233 DME 250/84

REPORT COMPRISING: Cover Sheet
Page 1

DATE RECEIVED: 30 May 1985

D. Patterson

D. Patterson
Chief Chemist
Analytical Chemistry Division

ij

Head Office:
Flemington Street, Frewville
South Australia 5063,
Telephone (08) 79 1662
Telex: Amdel AA82520
Pilot Plant:
Osman Place
Thebarton, S.A.
Telephone (08) ~~43 8053~~ 43 5733
Branch Laboratories:
Melbourne, Vic.
Telephone (03) 645 3093
Perth, W.A.
Telephone (09) 325 7311
Townsville
Queensland 4814
Telephone (077) 75 1377

ANALYSIS

SAMPLE MARK	AS RECEIVED TOTAL MOISTURE H_2O^-	AIR DRIED MOISTURE H_2O^-	AIR DRIED VOLATILE MATTER	AIR DRIED FIXED CARBON	AIR DRIED ASH
A297/85	9.7	2.6	15.4	10.3	71.7
A298/85	24.7	12.8	30.0	48.6	8.6
A299/85	26.0	13.9	32.6	49.6	3.9
A300/85	19.8	11.9	26.8	42.8	18.5
A301/85	23.9	13.8	27.5	45.7	13.0
A302/85	19.0	12.1	25.2	43.0	19.7
A303/85	23.0	13.1	28.0	47.7	11.2
A304/85	21.6	12.5	27.1	45.6	14.8
A305/85	21.4	12.3	26.1	44.3	17.3
A306/85	24.2	13.9	27.3	48.1	10.7
A307/85	18.5	13.8	28.1	48.0	10.1
A308/85	20.4	13.3	25.6	47.3	13.8
A309/85	17.9	11.8	22.6	40.0	25.6
A310/85	20.7	13.0	25.3	45.1	16.6
A311/85	22.0	12.5	27.3	44.8	15.4
A312/85	22.1	13.3	30.6	45.0	11.1
A313/85	17.1	9.2	21.4	32.3	37.1
A314/85	6.3	2.2	11.7	5.4	80.7
Method:	C1		C3		

INFORMATION OFFICER COPY DMC

DEPARTMENT OF MINES AND ENERGY

191 GREENHILL ROAD,
PARKSIDE, 5063
P.O. BOX 151,
EASTWOOD, 5063
PHONE 2747500

APPLICATION FOR EXAMINATION OF SPECIMENS OR SAMPLES

Submitted to AMDEL for
- Analytical, Petrological, Other Examination.

INVOICES MUST BE RENDERED TO THE ACCOUNTANT, STATING THIS NUMBER. EX - 361AK

REPORTS MUST BE DELIVERED TO THE INFORMATION OFFICER STATING THIS NUMBER. ~~11/106/02333~~ → 11/106/02233

DME/250/85

Sample Number: 1:100 000 sheet	Sample Number: Number	Rock Name	Other Numbers (Drillhole, Aerial Photo etc.)	Geological Province	Stratigraphic Unit or Age	Details of work required	Price
6537	RS A 297/85	—	Drillhole L 3964	Leigh Creek Coalfield	—		
	RS .	Leigh Creek Coal	↓	↓			
	RS .						
	RS .						
	RS .					Service Fee	25
	RS .					Code C1 ($30 per hour)	90
	RS .					Code C3 (18 samples)	270
	RS .					M04.2.1 Specific Gravity	324
	RS .						
	RS .						
	RS .					NOTE: These results should	
	RS .					be forwarded to SADME	
	RS .					as soon as possible for	
	RS .					designation of composite	
	RS .					samples for detailed	
	RS .					analysis.	
	RS .						
	RS A 314/85	—					
	RS						
	RS						

Type of Samples (18): HQ CORE

Disposal of Samples: Return crushed sample to Core Library

Name of Applicant: G. KNITKO

DME Section: OIL, GAS & COAL

Signed: R.K. Johns per J.N. (Director General) Date: 3.6.85

TOTAL: $709

DRILLHOLE L3964 COLLAR INFORMATION													
DHID	EASTING	NORTHING	ELEVATION	TD	AZI	DIP	CORE	QUALITY	GEOPHYSICS	SEAM	DATE	GEOTECH	CAMPAIGN
3964	251347.5	6624857.5	191.5	403.72			Y						Golder UCG Study

DRILLHOLE L3964 LITHOLOGY INFORMATION										
bore	from	to	thick	strat	mseam	rock	weath	bed	perc	cont
3964	0	349.09	349.09			OB				
3964	349.09	371.07	21.98			MS				
3964	371.07	389.87	18.8	Q	Q	CO				
3964	389.87	403.72	13.85			MS				

(277) 3585

S.A.D.M.E
COMPUTERISED BOREHOLE LOGGING

BOREHOLE NO. L3964

OPERATOR:	N. DUNSTAN
DATA LOG VER :	108203.01
DATA PLOT VER:	08202.01
DATUM ABOVE GROUND LEVEL	1.55 M.
CASING DEPTH	345.0 M.
VERTICAL SCALE	1:200
DEPTH LOGGED	402.82 M.
DATE LOGGED	31/10/84

S.A.D.M.E (U.C.G. PROJECT)
LEIGH CREEK COALFIELD AREA
PLAN NO.:
REPORT NO:
1:250,000 REF. SHEET NO.

LOGGING SPEEDS AND TIMEBASES:
DENSITY PROBE NO. 1 , 6 M/MIN 200 MSEC
NEUTRON PROBE NO. 1 , 6 M/MIN 200 MSEC
SONIC PROBE NO. 1 , 6 M/MIN 1000 MSEC
RESISTIVITY PROBE NO. 1 , 6 M/MIN 1000 MSEC

277
3586

S.A.D.M.E
COMPUTERISED BOREHOLE LOGGING

BOREHOLE NO. L3964

S.A.D.M.E (U.C.G. PROJECT)
LEIGH CREEK COALFIELD AREA
PLAN NO.
REPORT NO:
1:250,000 REF. SHEET NO.

OPERATOR: N. DUNSTAN
DATA LOG VER : 108203.01
DATA PLOT VER: 08202.01

DATUM ABOVE GROUND LEVEL 1.55 M.
CASING DEPTH 345.0 M.
FLUID LEVEL -1.5 M.

VERTICAL SCALE 1:200
DEPTH LOGGED 402.82 M.
DATE LOGGED 31/10/84

LOGGING SPEEDS AND TIMEBASES:
NEUTRON PROBE NO. 1 . 6 M/MIN 200 MSEC
S P P 100 MSEC
TEMPERATURE PROBE NO. 1 , 6 M/MIN 200 MSEC
DEVIATION PROBE NO. 1 , 6 M/MIN 5000 MSEC
RESISTIVITY PROBE NO. 1 , 6 M/MIN 1000 MSEC

SELF - POTENTIAL (M/VOLTS) (LEFT) FIL= 11 SKIP= 4 — -120 to 0
SHORT RESISTIVITY (OHM.M) FIL= 3 SKIP= 0 — 0 to 60
INCLINATION (*10) (DEGREES) FIL= 1 SKIP= 0 — 0 to 80
ABSOLUTE TEMPERATURE (DEGREES C.) FIL= 3 SKIP= 2 — 20 to 40
RESISTANCE OHMS FIL= 15 SKIP= 4 — 130 to 170
LONG RESISTIVITY (OHM M.) (DASHED) FIL= 3 SKIP= 0 — 0 to 20

INCLINATION (*10) (DEGREES) 0 80
ABSOLUTE TEMPERATURE (DEGREES C.) 20 40
RESISTANCE OHMS 130 170
LONG RESISTIVITY (OHM M.) (DASHED) 0 20
SELF - POTENTIAL (M/VOLTS) (LEFT) -120 0
SHORT RESISTIVITY (OHM.M) 0 60

3587 & 3588

S.A.D.M.E

COMPUTERISED BOREHOLE LOGGING

BOREHOLE NO. L3966

OPERATOR:	N. DUNSTAN
DATA LOG VER:	108203.01
DATA PLOT VER:	08202.01

DATUM ABOVE GROUND LEVEL	1.45 M.
CASING DEPTH	17.0 M.
FLUID LEVEL	-1.4 M.

VERTICAL SCALE	1:200
DEPTH LOGGED	257.48 M.
DATE LOGGED	11/11/84
DATE PROCESSED	22/11/84

S.A.D.M.E (U.C.G. PROJECT)
LEIGH CREEK COALFIELD AREA
PLAN NO.:
REPORT NO:
1:250,000 REF. SHEET NO.

LOGGING SPEEDS AND TIMEBASES:

DENSITY PROBE NO. 1 , 6 M/MIN 200 MSEC
NEUTRON PROBE NO. 1 , 6 M/MIN 200 MSEC
SONIC PROBE NO. 1 , 6 M/MIN 1000 MSEC
TEMPERATURE PROBE NO. 1 , 6 M/MIN 200 MSEC
DEVIATION PROBE NO. 1 , 6 M/MIN 5000 MSEC
RESISTIVITY PROBE NO. 1 , 6 M/MIN 1000 MSEC

.D.M.E

COMPUTERISED BOREHOLE LOGGING

BOREHOLE NO. L

VERTICAL SCALE 1:2

DEPTH LOGGED 258.73 M.

DATE LOGGED 11/11/84

DATE PROCESSED 22/11/84

S.A.D.M.E (U.C.G. PROJECT)

LEIGH CREEK COALFIELD AREA

PLAN NO.:

REPORT NO:

1:250,000 REF. SHEET NO.

OPERATOR: N. DUNSTAN

DATA LOG VER : 108203.01

DATA PLOT VER: 08202.01

DATUM ABOVE GROUND LEVEL 1.45 M.

CASING DEPTH 17.0 M.

LOGGING SPEEDS AND TIMEBASES:

DENSITY PROBE NO. 1 , 6 M/MIN 200 MSEC

NEUTRON PROBE NO. 1 , 6 M/MIN 200 MSEC

SONIC PROBE NO. 1 , 6 M/MIN 1000 MSEC

TEMPERATURE PROBE NO. 1 , 6 M/MIN 200 MSEC

DRILLHOLE L3967 COLLAR INFORMATION													
DHID	EASTING	NORTHING	ELEVATION	TD	AZI	DIP	CORE	QUALITY	GEOPHYSIC	SEAM	DATE	GEOTECH	CAMPAIGN
3967	249557.9	6625498	186.63	396.8			Y						Golder UCG Study

DRILLHOLE L3967 LITHOLOGY INFORMATION										
bore	from	to	thick	strat	mseam	rock	weath	bed	perc	cont
3967	0	373.2	373.2			OB				
3967	373.2	384.7	11.5		Q	CO				
3967	384.7	396.8	12.1			SH				