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EXECUTIVE SUMMARY REPORT
LAKHRA COAL PROJECT
SIND PROVINCE, PAKISTAN

Prepared for

WATER & POWER DEVELOPMENT AUTHORITY

GOVERNMENT OF PAKISTAN

Sponsored by

USAID / PAKISTAN

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By

JOHN T. BOYD COMPANY

Mining and Geological Engineers

Pittsburgh, Pennsylvania, USA

Report No. 1800

Volume 1

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Subject: Executive Summary
Lakhra Coal Project Mining Feasibility
Volume 1

Dear Sirs:

In this cover is our summary of the Lakhra coal mine feasibility study which has required the concerted efforts of the John T. Boyd Company (BOYD) staff over the previous twenty-six (26) months. The objectives of the Lakhra Coal Mine Feasibility Study were to demonstrate the technical feasibility of modern mine development and to estimate capital and operating costs commensurate with the mine plan selected.

During the course of our investigation, we have:

(1) Completed two on-site field studies programs (totaling 106 drill holes and one bulk sample).

(2) Spent an aggregate of approximately 1,700 mandays in Pakistan supervising field exploration activity, assessing future mining requirements, and researching the present mining operations and industry capabilities.

(3) Prepared a 15-volume series of reports covering the technical aspects of the coal mine feasibility.

It is our opinion that the planned Lakhra mine operation can be developed in accordance with the projected mine plan capacities outlined in this study. The mine will serve as a dedicated fuel supply for the proposed on-site electrical generating station, which is the objective of the overall Lakhra Coal Mining and Power Generating Project (USAID Project No. 391-0478).

We wish to express our appreciation to GOP/WAPDA and USAID for our participation in the Lakhra Coal Mine and Power Plant Project and acknowledge the cooperation of Mr. G. M. Ilias, Chief Engineer, Coal Power Projects-WAPDA, and Messrs. M. C. Moseley, John R. Morgan, and Douglas W. Huber, Office of Energy and Environment, USAID/Pakistan.

Very truly yours,

JOHN T. BOYD COMPANY

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GENERAL STATEMENT

Background

"The goal of the Lakhra Coal Mine and Thermal Power Station 300 MW Project is to assist Pakistan to begin the large scale use of indigenous coal as an energy source and to develop the country's coal industry. The project's purposes are to assist the GOP and private sector to develop the Lakhra coalfield and assist WAPDA to design the first of a series of large scale power plants fired with Lakhra coal." (Source: USAID Project Paper, Energy Planning and Development Project 391-9478, July 1983.)

Shortages of electrical power, foreign exchange imbalance, and limited resources of gas and oil are three of Pakistan's most serious problems; therefore, it is in the national interest to increase generating capacity using domestic coal sources. GOP policy is to conserve declining domestic natural gas supplies and discourage the import of petroleum products.

Increased coal consumption will occur as the existing brick industry expands and cement plants are required to convert from natural gas to coal. Demand for coal by 1989-1990 is projected to be in the 6.2 to 6.7 million long ton range, including a 2.6 million long ton per year allocation to power generating and cement factories. (Source: PC-1 Scheme (revised 24-2-83): Development of Coal Mines at Lakhra, District Dadu (Sind), as prepared by PMDC.)

Current coal production in Pakistan is approximately 1.5 to 2.0 million long tons per year (with approximately 800,000 long tons produced in Sind). Current coal imports are limited to metallurgical coal for use by Pakistan Steel Mills Corporation, Karachi. Any large scale program to import steam coal is doubtful for political reasons (balance of trade, availability of domestic reserves, and national commerce) and due to limited ocean port facilities. Independent analyses of Pakistan's energy resources by both the International Energy Development Consultants (IEDC) and USAID/Pakistan concluded that "only domestic coal can be developed relatively quickly at modest levels of public expenditure and, over the next decade, provide an important contribution towards alleviating Pakistan's power crisis."

There are two general sources of coal production in Pakistan: public sector (government) mines, operated by Pakistan Mineral Development Corporation (PMDC, an agency of the federal Ministry of Petroleum and Natural Resources), and over 2,000 small privately owned mines. Unlike natural gas, petroleum, and electricity, the price of coal is not regulated by the government and varies by region according to mining and transportation costs, demand and available supply. Pakistan coal production has historically been constrained by lack of substantial committed markets, coal selling practices (independent agents assume responsibility for marketing using annual coal supply solicitations), lack of capital, inadequate infrastructure and, in the case of Lakhra, a

seasonal shortage of miners. All existing mines are underground operations using labor intensive, primitive mining methods. World competition, lower quality of Pakistan coal, inland location of the reserves, and inadequate transportation and port facilities prohibit coal exports.

Current Investigation

Over the last twenty (20) years, a series of lignite reserve and mine feasibility studies have been made on the Lakhra reserves, most notably, the JICA report in 1981 and the SWECO (Stone and Webster Engineering Co.) overview report in 1983.

In late 1983 the various donor agencies, USAID, World Bank, and Asian Development Bank (ADB), reviewed the available Lakhra feasibility studies and identified areas requiring further investigation.

Identified Donor Agency Areas of Concern

- Adequacy of the drill hole data base regarding reserve estimation and classification, continuity and correlation of the coal seams.
- Availability of low ratio surface mineable reserves.
- Reliability of existing coal quality data and estimates, particularly moisture content.
- Investigation of potential to upgrade coal quality through washing.
- Mining approach, inclusion of surface mine component, and associated economics.
- Project implementation schedule.
- Participation of private sector.
- Transportation systems (cost) to alternative power station sites.

The BOYD report, combined with results of the other five project contractors, is intended to enable potential lenders to appraise the technical, financial, and overall viability of the project. Following is a

listing of the six principal contractors retained by USAID and WAPDA to independently assess the feasibility of the Lakhra Coal Mine and Thermal Power Generating Project.

Field of Study	Contractor
Coal Mine Feasibility	John T. Boyd Company (BOYD)
Power Plant Design & Analysis	Gilbert Commonwealth International, Inc. (GCII)
Economic & Financial Analysis	ICF Incorporated (ICF)
Environmental Assessment	Environmental Sciences and Engineering (ESE)
Social Soundness	A. Helweg, I. Niazi, S. Vleer
Project Financial Packaging	Bank of America International Limited, London (BAIL)

During the course of our study, we regularly communicated with GCII and the other project contractors to coordinate work and maintain consistency between the various reports.

The goal of the BOYD final report is to address the concerns of the donor agencies, while completing an independent assessment of the technical feasibility and costs of mining coal from the designated Lakhra Coal Project study area. The individual project objectives and the methodology utilized to achieve the objectives follows:

Objective	Methodology
A. Define the geology of the deposit in the designated reserve areas.	Review of previous geological reports and drill hole data. Completion of a two phase drilling program (106 drill holes total) which, combined with previous drilling, completed a 500 m. square grid of drilling throughout the designated reserve areas. All BOYD drill holes were geophysically logged to insure complete and accurate drilling records. The entire seam drill hole data base was examined and three principal coal seam zones identified and correlated. Data on the uppermost Laki limestone, underlying Laki laterite, and major sand zones were also compiled. Geologic modeling was completed using BOYD's internal computer facilities, which are equipped with SEAMSYS geologic modeling software. Computer mapping was completed for each principal lignite seam including isopachs of mineable thickness and contour (elevation) structure isopleths.
B. Field Studies Program Phase I: Identify 42 million tonnes of recoverable reserves. Phase II: Confirm the presence of a reserve base of 120 million tonnes.	Following Phase I field studies program, individual seam sections were examined and mineable seam sections were determined according to surface mining and underground mining criteria selected by BOYD. Using the SEAMSYS computer modeling facilities, independent estimates of mineable reserves were completed based on surface mining recovery, and, secondly, underground mining methods. Phase II field studies program was planned to define reserves underlying the expanded reserve areas identified by Phase I studies. After incorporating Phase II results into the previous drill hole data base, final lignite reserves estimates were completed.

Objective	Methodology
C. Examine the quality of raw (as mined) and washed Lakhra coals.	Both the Phase I and Phase II field studies programs included comprehensive testing of the drill core samples recovered during the drilling process. To insure credibility of the analytical testing, all drill core samples were air freighted to the United States and analyzed at a major independent laboratory. (a) Individual seam samples were examined and subdivided into a series of coal (lignite) and parting (shale/clay) sections. Each coal or parting section was tested raw and washed (single specific gravity separation). A total of 414 separate core subdivisions were analyzed in Phase I and Phase II. (b) Using results of individual core analyses (step A), the net mineable seam section was determined to comply with prescribed engineering criteria for mining. (c) Multiple core samples (mineable seam sections) were composited by seam and area, and detailed coal washability (washing) testing was completed to fully evaluate the effects of washing. A total of 34 composite samples were completed under Phase I and Phase II programs. To properly examine the effects of out-of-seam dilution during mining (i.e., extraneous top and bottom rock recovered with the seam during mining), selected core samples of the roof and floor rock were analyzed (63 samples total). A bulk sample (estimated 1,800 kg) was recovered from an on-site test shaft and air shipped to the United States for detailed washability analyses. BOYD also assisted the power plant contractor (GCII) in completing a series of bulk samples to assess combustion properties of the Lakhra coals. To better define spontaneous combustion characteristics, three samples of Lakhra coals were tested for spontaneous heating properties. Analytical test data was entered into the BOYD internal computer facilities, and the following items completed: (a) graphic sections of each core seam showing the raw and washed coal analyses of the mineable seam, (b) composite raw and clean coal analysis by seam and mining area, (c) simulation of coal washing plant operation to evaluate operating efficiency and final quality of a washed coal product, and (d) in-seam raw coal quality mapping by seam--ash, sulfur, and thermal value (Btu/lb.).
D. Develop data on hydrology, environmental, and geotechnical issues.	As an integral part of the Phase I and Phase II field studies programs, on-site sampling (and subsequent laboratory testing) was completed to examine hydrology, environmental, and geotechnical aspects of future mining. Historical background data were compiled from published sources and visits to governmental agencies. (a) Background surface water information was compiled using Surface Water Hydrology Project (WAPDA) annual reports. (b) Ground water occurrence and depth were recorded in all BOYD drill holes and visits were made to nearby mining operations to survey ground water experience. Ground water monitoring wells were installed in three of the BOYD Phase I drill holes. (c) Water samples were collected from five water wells and seven flooded coal mines located in proximity to the Lakhra study area. Quality of the samples was determined by laboratory analysis. (d) Air quality and meteorological data were compiled from information published by the Pakistan Meteorological Department and other sources. (e) BOYD representative completed on-site noise surveys at Lakhra and at the nearby Khanot townsite. (f) Overburden core samples were collected from five Phase I drill holes and laboratory tested for total sulfur and neutralization potential. (g) In conjunction with the Soil Survey of Pakistan, an on-site soil survey was completed (10 sites were used for pit soil excavation/sampling).

Objective	Methodology
D. Continued	(h) The BOYD geotechnical investigation included a surface survey of the general area, physical inspection of subsurface core rock samples recovered during drilling, and laboratory rock mechanics testing of selected rock core specimens. An independent lineament study was completed for the Lakhra Coal Project study area using Landsat imagery.
E. Examine alternative mine designs (considering both surface and underground mining methods, various levels of mechanization, capability of existing labor, etc.).	BOYD engineers visited existing mining operations in Pakistan to survey mechanization, labor availability and practices, and develop an opinion of implementation requirements. During our inspection program a total of 13 active underground lignite mines operating in the Lakhra coalfield, ZealPak limestone quarry, PMDC Khewra Salt Mine, and PMDC Makarwal Coal Mine were visited. In order to evaluate the general industrial capability of Pakistan, visits were also completed to Pakistan Steel Mills Corporation and Pakistan International Airways. Three alternative surface mining approaches were studied--shovel/truck, dragline, and combination shovel/truck and dragline. Two alternative underground mining systems were evaluated--full mechanization, including longwall, and partial mechanization. Preliminary equipment prices were solicited from vendors in Pakistan and directly from the manufacturers. Labor staffing practices and compensation schedules were obtained from individual mining companies, WAPDA and other sources. When available, supply costs were compiled from mine operators and local vendors. Electrical rates are based on WAPDA tariffs.
F. Develop a detailed coal mine feasibility of the master mine plan and examine alternative mine sizes for fueling power plants of various generating capacities.	Using results of the field studies program and accompanying coal reserve and coal quality studies, the technical requirements of future mining were examined. BOYD's Volume No. 9A/9B presents our recommended master mine plan having an annual production level of 4.3 million tonnes (adequate to fuel an 800 MW generating station). The proposed plan relies predominantly on surface mining (4.0 million tonnes per year), with supplemental tonnage produced at a small underground mine (0.3 million tonnes per year). The following factors are critical in our selection of the master mine plan: (a) Reserve conservation and compatibility of the mining plan with known reserves. (b) Magnitude of scale results in increased generating capacity and mine size, while minimizing "unit cost" of capital and fixed operating costs. (c) Reliability of supply through use of proven surface mining methods, standardized and multiple use equipment selection, multiple mine fuel supply, and stockpile/inventory provisions. (d) Reduced risk from spontaneous combustion and less exposure to health and safety impacts of mining as observed in existing underground mines. (e) Introduction of advanced, but attainable, technology to promote the development of a modern mining industry. (f) Increased regional socio/political compatibility as local Sindi population is integrated into the predominantly surface mine labor force. Minimal labor disruption should occur to the existing private sector mines to the south. (g) Project attractiveness to recruit an experienced international mine manager. Surface mine equipment selection: (a) Surface mine is equipped with modern large capacity units. Principal earth-moving equipment includes three (3) to four (4) draglines, with multiple shovel/truck fleets working in advance to remove the uppermost overburden interval. (b) Standardization is planned in equipment manufacturers, models, sizes, and even engines where practical. (c) Preference is given to major established equipment manufacturers and to proven units of equipment. (d) Units are assigned multiple uses where possible. For example, large hydraulic backhoes are used for coal loading and interburden removal; off-highway trucks are used to transport both coal and overburden.

Objective	Methodology
F. Continued	(e) The use of electrical powered equipment was emphasized over Diesel fueled units. (f) Assigned equipment productivity was reduced by a factor of 20 to 25 percent below comparable U.S. rates to reflect the project location and working environment. Underground mining plan advances existing manual mining practices with the introduction of partial mechanization (Lakhra Upgrade approach): (a) Pneumatic picks to cut the coal (b) Diesel scoops, chain conveyors, and belt conveyors for coal haulage (c) Hydraulic props for roof control on longwall panels As compared to existing mines, the proposed underground mining system: (a) Permits a more reasonable mine production level (b) Increases labor productivity (c) Improves working conditions and worker health and safety by providing a modern ventilation system, improved roof control, reducing the physical demands of the job, and decreasing the risk of spontaneous combustion. Capital cost estimates for equipment are based on current manufacturer pricing, quoted for new units in the Asian market. (For example, large dragline units, as proposed for the Lakhra surface mine plan, are only manufactured in the United States; price quotes are based on United States equipment prices delivered to Pakistan. Mobile equipment is manufactured primarily in the United States and Japan. In this case competitive equipment prices were received for both sources, but are based on the Asian market in all cases.) All transportation costs, overseas and inland, are included. Initial training is assumed to be included in the purchase price. Costs are expressed in constant U.S. dollars as of mid-1985 and include a 10 percent contingency. We have not considered possible price reductions through fleet purchases, nor have we speculated on future market conditions or the ability through negotiation to obtain lower prices. Operating cash cost estimates include: (a) Labor (b) Operating supplies (c) Electrical power (d) Equipment replacement (expensed) (e) Other and 10 percent contingency Amortization cost has been included as a point of reference for report purposes: real interest rates of 5 and 10 percent per annum and a 30-year repayment term were used subject to future negotiation during the financial packaging process. Amortization covers initial capital, mine development expense, and interest during development and the loan repayment period. BOYD staff also completed studies of related technical areas required to fully evaluate the Lakhra Coal Project: (a) Training: a review was completed of existing labor practices and experience in Pakistan with the operation and maintenance of modern mining equipment. Visits were also made to regional technical schools and training facilities to evaluate future training requirements. (b) Transportation: a study of existing transportation infrastructure was completed to evaluate alternative transportation systems for possible shipment of future Lakhra mine production to two proposed off-site power plant sites - Khanot and Jamshoro. To provide local construction and related costing practices, work was performed in conjunction with a Pakistani civil engineering consultant (Engineering Consultants, Karachi).

Objective	Methodology
F. Continued	(c) Infrastructure: future mine and minesite colony infrastructure requirements were identified by BOYD and an independent assessment was completed in coordination with Engineering Consultants, Karachi. Items included under the infrastructure study were: water supply electrical service extension access road townsite (colony) development railroad (optional, depending on power plant site) Preliminary working drawings, construction schedule, initial capital costs and operating costs were developed for each infrastructure item.
G. Examine the option of an all underground mining plan.	Identified coal reserves amenable to underground mining recovery (see BOYD Volume No. 11) were examined and representative capital and operating costs applied based on underground mining cost projections estimated in Volume No. 9A and No. 9C. To assure reliability of supply under an all underground mining plan, we assume mines will produce coal two shifts daily with the third shift idle (non-production) and used for mine construction, maintenance, etc. This is considered normal and prudent scheduling when underground mining serves as the primary or sole source of power plant fuel.

Report Presentation

Our final report is presented in a series of volumes as summarized below:

Volume No.	Description
Phase I Reports	
1	Executive Summary
2	Lakhra Coal Field Overview
3A	Field Studies Program (Book 1 of 2)
3B	Field Studies Program (Book 2 of 2)
4	Lignite Reserve
5	Lignite Quality
6	Transportation Study
7	Environmental Assessment
8	Alternative Mine Design
9A	Mining Feasibility and Master Mine Plan
9B	Exhibits to Accompany Mining Feasibility and Master Mine Plan
9C	Conceptual Alternative Mining Cases
10	Health and Safety Guidelines for Future Mining Operations
Phase II Reports	
3C	Field Studies Program
11	Final Lignite Reserve/Quality

Following technical presentations of the BOYD and GCII reports at World Bank in January 1986, the various donor agencies participating in the sessions concluded that: (a) technical concerns relative to the previous feasibility reports were resolved, and (b) donor agency support for the Lakhra Project is warranted.

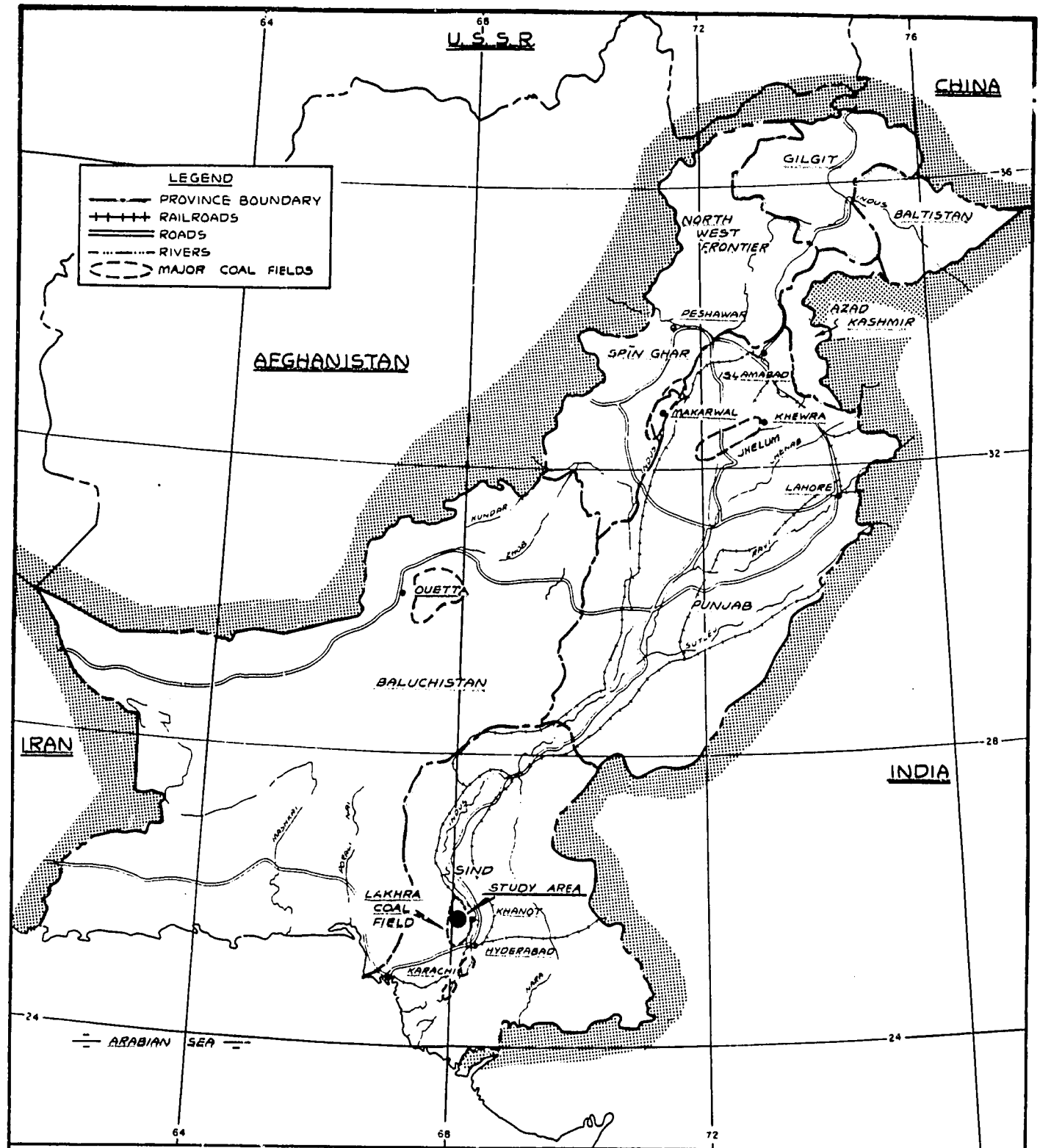
"It was agreed that the reports indicated a high standard of professional competence and were satisfactory. It was also agreed that the Project is attractive not only because it is consistent with GOP's overall strategy for the power subsector which calls for the diversification of fuel supply, use of domestic energy resources, and mobilization of the private sector, but also because it could, if successful, become a model for other projects." (Source: Joint Memoire - WAPDA, USAID/Pakistan, USAID/Washington, World Bank; PAKISTAN, PROPOSED LAKHRA COAL MINE AND POWER GENERATION PROJECT; Aide Memoire dated January 29, 1986.)

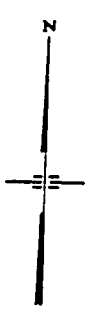
All estimates are expressed in metric tonnes, and costs are expressed in constant U.S. dollars as of July 1, 1985. In our opinion, there has not been any significant change in capital and operating costs, and the estimates shown in the BOYD reports are representative of current prices. As shown in this report, the terms "coal" and "lignite" are used synonymously.

Scope of reporting under this study is comprehensive and includes both technical reporting to demonstrate the feasibility of future mine development, and compilation of all basic source data (e.g., drill hole records and coal quality analytical laboratory reports) to permit any prequalified company to independently assess the Lakhra lignite reserves.

All findings of this report represent the professional opinion of BOYD. The viability of any mining venture is dependent on many technical aspects, as well as the qualification and performance of the mining company and the contractual agreements under which the venture operates. All reports are prepared using accepted engineering practices, with assumptions and procedures outlined in each report.

Following this page is Plate 1 showing the general location of the Lakhra Coal Project study area.





MAP OF PAKISTAN
SHOWING
LAKHRA COAL FIELD
SIND PROVINCE, PAKISTAN
FOR
USAID / PAKISTAN - WAPDA
CONTRACT Nº 391-0478-C-00-5006-00
SCALE 1:8,000,000 APPROX.

APRIL 1984

JOHN T BOYD COMPANY
MINING & GEOLOGICAL ENGINEERS

PLATE I

EXECUTIVE SUMMARY

Based on our company's established reputation in providing professional and independent consulting services both within the United States and internationally, staff expertise in all aspects of mining engineering and related disciplines, and participation in the 1983 review of the Lakhra Coal Mine and Power Plant Project, John T. Boyd Company (BOYD) was selected to complete an independent coal mine feasibility study of the Lakhra Coal Project reserves. Under the sponsorship of USAID, work began in November 1984 and will terminate December 1986. During this period BOYD staff has examined the project in detail, including an aggregate 1,700 mandays spent in Pakistan conducting field exploration, investigating the status of the national mining industry, and determining project implementation requirements.

Following are our principal findings and conclusions covering our independent technical assessment of the feasibility of coal mine development of the designated Lakhra Coal Project lignite reserves.

1. Lakhra Coal Project is the most fully explored coal deposit in Pakistan. Within the 79 square kilometer study area, 178 drill holes have been completed under exploration programs conducted by PMDC, JICA, and USAID/BOYD. Coal rights are presently controlled by PMDC under a mining lease from the Sind provincial government, who owns all the mineral. Surface ownership is reportedly divided between public and private control, with most held by public agencies. Based on the remote location, low land use, and the high priority placed on the Lakhra Coal Project, securing the coal reserves and surface within the study area is not considered a problem.

2. The geology of the deposit underlying the explored areas is well defined. The study area is located along the axis of a doubly plunging anticline known locally as the Lakhra Dome. Coal-bearing strata is essentially flat-lying with recoverable reserves located within the upper coal-bearing beds of the Lower Ranikot Formation (see Plate 2, Generalized Stratigraphic Section, following this text). A normal displacement fault bisects the property into East and West areas. Although (a) the multiple seam lignite reserves are relatively deep (ranging from 50 to 120 m, and averaging 65 m), (b) lignite seams are lenticular, variable over short distances, and interbedded with clay/shale partings, and (c) occurrence of unconsolidated sand zones in the overlying strata will make recovery of the lignite reserves more difficult, it is technically feasible to mine the coal by both surface and

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underground methods. Reliable correlation of the three principal lignite zones (No. 1, 2, and 3) of the upper coal-bearing beds was completed. Comprehensive mapping was completed to demonstrate the geology of the deposit and depict the lateral extent and thickness of the three principal lignite seams and the Laki Limestone member. Under BOYD supervision the Phase I and Phase II programs were completed on schedule and within budget. A new drilling performance standard was achieved for future commercial exploratory drilling in Pakistan. The previous drill hole data base was expanded by a factor of 150 percent, as summarized below:

Source	No. of Drill Holes	Aggregate Meterage Drilled	Date
GSP/PMDC	22	2,188	pre-1977
JICA	50	5,203	1979
Subtotal - pre-1984	72	7,391	
USAID/BOYD Phase I	65	6,988	1984/5
USAID/BOYD Phase II	41	4,040	1985/6
Subtotal - USAID/BOYD	106	11,028	
Total	178	18,419	

3. Depending on the mining methods used to recover the in-place lignite, estimated recoverable reserves range from 30.7 million ROM (run-of-mine, unwashed) tonnes under an all underground mining approach to 122.9 million ROM tonnes using a predominantly surface mining approach, with supplemental underground mining (see Plate 3, following this text). The master mine plan utilizes the latter approach, two large surface mines supplemented by a small underground mine.

Reserve findings following Phase I exceeded the 42 million tonne reserve objective and identified a reserve potential in excess of 100 million tonnes if a large scale surface mining plan were considered. Phase II program successfully confirmed the presence of a large reserve capable of supporting a mining level of 4 million tonnes per year for 30 years. The reserve deposit is well explored with all tonnage

estimates considered demonstrated and 90 percent of the reserve tonnage classified measured (i.e., the highest reliability category). Estimated lignite reserves using the master mine plan approach (i.e., predominantly surface mining) total 122.9 million tonnes:

Coal Seam No.	Coal Area (Hectares)	Average Mineable Seam Thickness (m)	Reserve Tonnes (000) In-Place (Mineable Seam)	ROM by Reserve Classification Measured	Indicated	Total	Average Strip Ratio
			West Pit Surface Mine				
3	469	1.0	6,602	6,165	165	6,330	35.5
2	1,086	1.7	24,830	22,346	1,198	23,544	21.5
1	974	1.8	24,451	21,971	1,181	23,152	4.2
			55,883	50,482	2,544	53,026	15.6
			East Pit Surface Mine				
3	146	0.7	1,326	1,174	89	1,263	57.6
2	1,386	2.1	40,227	32,658	5,526	38,184	21.9
1	1,303	1.4	24,772	20,859	2,424	23,283	5.0
			66,325	54,691	8,039	62,730	16.4
			Underground Reserves				
1	396	2.2	11,572	4,651	1,110	5,761	-
2	137	1.7	2,957	663	714	1,377	-
			14,529	5,314	1,824	7,138	-
			Total (Master Mine Plan)				
			136,737	110,487	12,407	122,894	

4. Based on our assessment of Lakhra coal quality data, both on a raw (unwashed) and clean (washed) coal bases, and experience at other lignite mines and power plants fueled by lignite, a ROM (run-of-mine, unwashed) lignite product will be produced having

the following estimated quality (BOYD master mine plan).

	Average Analysis*					
	Daily			Monthly		
	Average	High	Low	Average	High	Low
Ash, Dry (%)	31	41	21	31	37	30
Sulfur, Dry (%)	7.6	9.6	6.6	7.6	8.5	7.0
Thermal Value, Dry						
Btu/lb.	8400	9600	6900	8400	9000	7800
Kcal/kg	4670	5330	3830	4670	5000	4330
Moisture (%)	32	45	25	32	42	28

*Based on 95% of the samples falling within this range.

The comprehensive nature of the BOYD analytical testing program resulted in the most thorough analysis of the Lakhra coals ever completed. Reliable data was collected on moisture, raw and washed coal quality, spontaneous combustion properties, and combustion characteristics. Coal quality testing demonstrated that an acceptable power plant fuel could be produced on either a raw (ROM, run-of-mine) or washed coal basis. Mechanical washing improves coal quality but has been discounted for operating and economic reasons. Normal practice worldwide is to burn low rank coals on a raw basis. Projected improvements in coal quality do not warrant the substantial increase in fuel cost resulting from mechanical washing. Experience with Lakhra coals shows they are highly susceptible to spontaneous combustion. Laboratory testing confirmed that the Lakhra coals are moderately susceptible to spontaneous heating as compared to other lignite deposits. Lignite coals are successfully mined worldwide and procedures are incorporated into the future Lakhra Coal Project mine plan to minimize the risk of spontaneous combustion.

5. Based on our independent environmental assessment of the proposed mining plan (Volume No. 7), we do not anticipate any significant problems relative to surface water, ground water, air quality, noise, or overburden/soils. Geotechnically, the reserves study area has extensive fracturing (lineaments) throughout the area, although only one major displacement fault is identified. The occurrence of weakly cemented sand zones in the overburden will affect highwall stability, but the lack of ground water will assist in prolonging

the competency of the sands. Underground mining conditions are anticipated to be average to fair; future mining is restricted to areas overlain by shale or siltstone roof strata. Width of underground mine entries is restricted in the recommended mine plans.

6. BOYD Volume No. 8 presents our preliminary assessment of alternative mine designs. From this study the master mine plan mining systems were selected based on: (a) technical compatibility with the known Lakhra reserves, (b) capability of the available labor force, (c) reliability of continual coal supply, and (d) economics. The master mine plan includes two basic components, surface mine(s) utilizing a combination of shovel and truck equipment for advance stripping, followed by dragline overburden removal, and, secondly, underground mines using partial mechanization, representing an upgrade from existing manual mining practices. Other surface mining systems were reviewed and eliminated due to technical and/or economic reasons (e.g., a bucket wheel excavator system is considered unsuited due to the Laki limestone caprock and the high degree of mechanization involved in this highly integrated system).

7. Following completion of the Phase I coal mine feasibility report (Volume No. 9A/9B) and technical presentations to the donor agencies in January 1986, World Bank established sulfur emission guidelines which restricted the power plant size to 500 MW (two units at 250 MW each). This reduces the coal mine size from the proposed 4.3 million tonnes per year to approximately 2.7 to 3.0 million tonnes per year. To examine the effect of reduced mine size on coal mine capital and operating costs, conceptual mine plans were completed for a 1.4 million tonne per year operation and a 3.0 million tonne per year mine size. In addition general sensitivity curves were developed for various surface and underground mine sizes (see BOYD Volume No. 9C). Based on a study of the identified Lakhra Coal Project reserve quantity and quality, technical assessment of anticipated mining conditions, and examination of the existing Pakistan mining industry, we have developed detailed feasibility studies of the master mine plan. The final plan as now defined produces 3.0 million ROM tonnes per year and derives approximately ninety (90) percent of the total production from two surface mines, with the remaining tonnage produced at a single underground mine. A central administrative function and coal handling facility are considered common to the entire operation. Infrastructure is identified separately but is included in the total project planning and costs. Participation of the GOP and Sind Province should be investigated to defray all or a portion of the infrastructure costs. A mine site power plant location is used in all cases.

The following summarizes the detailed coal mine feasibility study of the master mine plan at an annual production level of 4.3 million ROM

tonnes per year; conceptual mine plans for two alternative mine sizes, 1.4 million ROM tonnes per year and 3.0 million ROM tonnes per year.

	Power Plant Capacity (MW)		
	260	560	800
Mine Size (ROM Tonnes-000/Yr.)			
Surface Mine(s)	745	2,700	4,000
Underground Mine(s)	655	300	300
Total	1,400	3,000	4,300
Estimated Labor Force (No. of Payroll Employees)			
Direct Mine			
Staff - Expatriate	12	32	32
- National	228	203	227
Worker	1,288	1,284	1,434
Subtotal	1,528	1,519	1,693
Infrastructure			
Staff - Expatriate	1	1	1
- National	24	23	23
Worker	175	191	191
Subtotal	200	215	215
Total	1,728	1,734	1,908
Productivity - Avg. No. of ROM tons Produced/Payroll Employee Day	2.7	5.7	7.5
Estimated Initial Capital - BASE CASE (US $-Millions)			
Direct Mine			
Equipment & Facilities	121.8	250.3	344.5
Development Expense	47.7	100.8	142.8
Interest During Const.*	41.9	76.8	112.3
Subtotal	211.4	427.9	599.6
Infrastructure			
Equipment & Facilities	32.4	33.8	33.8
Development Expense	3.9	2.7	2.3
Interest During Const.*	15.6	15.6	15.3
Subtotal	51.9	52.1	51.4
Total	263.3	480.0	651.0
Estimated Average Coal Cost - BASE CASE (US $/Tonne)			
Direct Mine			
Operating Cash Cost	19.85	22.15	21.11
Depreciation	4.05	3.90	3.78
Finance Expense*	11.85	10.90	10.73
Subtotal	35.75	36.95	35.62
Infrastructure			
Operating Cash Cost	1.25	0.40	0.40
Depreciation	0.85	0.40	0.28
Finance Expense*	3.05	1.45	0.96
Subtotal	5.15	2.25	1.64
Total			
Operating Cash Cost	21.10	22.55	21.51
Depreciation	4.90	4.30	4.06
Finance Expense*	14.90	12.35	11.69
Total	40.90	39.20	37.26
Sensitivity Range			
Estimated Average Coal Cost (US $/Tonne)			
Direct Mine Total Operating Cost	28.60-39.30	29.55-40.80	28.50-39.20
Infrastructure Total Operating Cost	4.65-5.65	2.05-2.50	1.45-1.80
Total Cost	33.25-44.95	31.60-43.30	29.95-41.00
Initial Development Period to Power Plant Start-up (Yrs.)	5 - 7	5 - 7	5 - 7

*Per World Bank guidelines estimated at 10% per year real interest (30-year loan repayment term assumed by BOYD).

Operating Cost: independent estimates of operating cash cost have been prepared. These estimates include labor, supplies, and other direct operating costs (including replacement of equipment and facilities). Costs are developed on an individual year basis; included in this volume are average operating costs during the 30-year mine production period (weighted on tons mined). External taxes and surcharges are not included (i.e., import duty and taxes, expatriate management fee, and provincial severance costs).

(a) Amortization is calculated at 10% real interest per year and includes financing for initial capital, development cost, and interest during construction. A 30-year term of repayment is used in this report.

(b) The technical findings and cost estimates developed in our mine feasibility report are considered realistic. We do believe that outstanding expatriate management could achieve up to a 20 percent reduction in capital and operating cost estimates and in the proposed project implementation schedule. Key factors relative to reduction of costs and shortening of the implementation schedule are:

- Higher equipment productivity and utilization.
- Training to achieve higher labor efficiency in operations and maintenance.
- Management control to eliminate waste and establish good control on maintenance spare parts, warehousing, and inventory.
- Negotiation of favorable equipment and operating supply agreements, including accelerated procurement and in-service time.
- Lower contingency factor.
- Recruitment of quality expatriate and national personnel.

(c) Our proposed implementation schedule to develop the coal mines and related infrastructure requires six (6) years from project commitment to achieving full mine production. It is based on a coordinated, phased buildup of mine activity which reflects the introduction of modern mining in Pakistan. We are aware that differences do occur between the implementation schedules of the power plant contractor (GCII) and ourselves. The BOYD schedule can be shortened to 4.5 to 5.0 years assuming an OUTSTANDING performance of the expatriate mine manager. Initial power plant start-up operation could begin in 1991 under the accelerated schedule.

(d) Through a strategy of minimizing the number of operating units, simplifying training requirements, and maximizing the level of technical support, we have optimized the probability of success.

8. Based solely on economics, an all underground mining approach appears rational, initial capital investment can be reduced, and average operating cost is substantially below the average of the base mine plan. There are several additional factors which also need to be considered when evaluating an all underground mine plan:

(a) Reserve conservation; as compared to available reserves recoverable under the recommended mine plan (122.9 million ROM tonnes), an all underground mine plan will recover only 30.7 million ROM tonnes with remaining reserves considered lost (see Plate 3, following this text).

(b) Lack of identified mineable reserves to support a mining level exceeding one million ROM tonnes per year (approximately 125-MW generating station).

(c) Reduced reliability of supply due to difficult physical mining conditions, increased exposure to spontaneous combustion, and introduction of new technology to the existing labor force. Under an all underground plan, mine production would be restricted to two shifts with the third shift used to provide excess capacity (i.e., third shift mining scheduled when other mines are idled due to adverse mining conditions, mine fire, or labor unrest), and perform maintenance and mine extension.

(d) Continued reliance on non-Sindi workers as the primary work force. Increased demand for available workers will place the proposed mines in competition with existing mines to the south. Predominance of outside workers could hamper the establishment of a permanent work force and may create socio/political problems in the region.

(e) Labor intensive requirements of the underground mining system will result in extensive training and increased project infrastructure requirements.

(f) Proposed mining methods involve limited mechanization and are intended to be compatible to prevailing mining conditions and ability of the existing labor force. Recruitment of a local mining company to manage and place equity in the mines will probably be required. None of the local companies are experienced at managing a major mining operation as proposed for Lakhra.

(g) Mining costs are projected to increase on a unit (cost per tonne) basis as mining is expanded to meet increased coal requirements. Increased cost results from two principal reasons: reduced operating efficiency and extension of mining into reserves having less favorable conditions.

Before an all underground mine plan is seriously considered, we recommend field testing of proposed mechanization systems (on-site underground demonstration mine) and further exploration to expand the known reserve base. A gradual, phased buildup of mine production is recommended to permit an orderly program of labor recruitment and training. Following are operating cost estimates for various scenarios of an all underground mining plan.

Case 1: BOYD Base Case assuming the identified underground reserves within the immediate Lakhra Coal Project study area are used as the source of future production. Costs become progressively higher as more favorable reserves are depleted and mining is extended into thinner, less productive reserves.

Case 2: Theoretical case assuming mining within the Lakhra Coal Project study area is limited to the better underground reserves (i.e., favorable thickness, reserve size, and mining conditions) and, secondly, new drilling outside the present study area identifies additional underground reserves having favorable thickness, mining conditions, etc. It is also assumed production is divided between four to five qualified mining companies to provide reliability of supply.

	Case 1	Case 2
Annual Production (ROM tonnes - 000)	1,400	1,400
Power Plant Capacity (MW)	250	250
Estimated Cost of Coal Production (US $/Tonne)		
Direct Mine		
Cash Cost	20.45	16.70
Amortization	9.65	7.50
	30.10	24.20
Infrastructure		
Cash Cost	2.15	2.15
Amortization	5.35	5.35
	7.50	7.50
Total (Base Case)	37.60	31.70
Sensitivity Range		
Direct Mine Total Cost	27.10 - 39.15	21.00 - 31.45
Infrastructure	6.75 - 8.25	6.75 - 8.25
	33.85 - 47.40	27.75 - 39.70

In the event that an all underground mine option is selected for implementation, BOYD recommends that consideration be given to development of sufficient reserves outside the designated study area in order to preserve the surface mineable areas of the East and West Pits for future surface mine development. Underground recovery would probably not yield over 20 million tonnes of coal from the identified surface mining areas, and this would be at the expense of "spoiling" nearly 100 million tonnes of Lakhra Coal recoverable by surface mining methods.

9. Based on sulfur emission guidelines of World Bank, the future power plant capacity is restricted to 500 MW (two units at 250 MW each). In addition to the primary supply of coal to the proposed 500 MW Lakhra power plant, the mine could produce additional lignite for existing regional markets and possibly for a series of small fluidized bed power plants which are being discussed for the Lakhra area (five units at 50 MW each). As a by-product of the surface mining operation, approximately 8 million to 15 million tonnes of limestone will be excavated each year. Random chemical analyses by BOYD indicate the Laki Limestone is suitable for primary feed in the manufacture of cement. Recovery of the limestone will require minimal change to the proposed mining plans and will result in only minor cost increases. Consideration should be given to the construction of an on-site cement manufacturing facility to utilize the available limestone and provide an additional market for the lignite.

Expansion of the mine size to the 4.3 million tonne per year level, as recommended in our master mine plan (Volumes Nos. 9A/9B), will lower the estimated unit cost of coal by 1.94 US $/tonne.

Mine Size (ROM Tonnes-Millions/Yr.):		3.0	4.3
Est. Total Cost of Coal (US $/Tonne)			
Direct Mine -	Cash Cost	22.15	21.11
-	Amortization*	14.80	14.41
		36.95	35.62
Infrastructure -	Cash Cost	0.40	0.40
-	Amortization*	1.85	1.24
		2.25	1.64
Total		39.20	37.26

*Calculated at 10% per year real interest, 30-year term.

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10. Although the Lakhra reserves are relatively deep and difficult to recover and low rank coal (lignite) is mined, coals of lower quality and in more complex deposits are actively being mined in other parts of the world.

(a) Comparison of Lakhra Coal Quality with Selected Lignite Deposits/Mines:

Location	As Received Basis			
	Moisture (%)	Ash (%)	Thermal Value Btu/lb.	Thermal Value Kcal/kg
Pakistan, Lakhra	32	21	5740	3190
India, South Arcot	56	3	4980	2765
India, Neyveli Mine	50	3	4410	2450
Greece, Drama	58	15	2235	1240
Greece, Sterea Ellas	45	14	4760	2640
Poland, Belchatow Mine			3420	1900
Turkey, Afsin-Elbistan	55	17	1890	1050
Germany, Hirschberg Mine	45	5	4860	2700
United States, Gulf Coast	31	14	5800	3220

(b) Comparison of geological setting of Lakhra Surface Mine with Selected Lignite Mines:

Location	Annual Production (Tonnes-Millions)	Lignite Thickness Mined (m)	Overburden Depth (m)	Appr. Strip Ratio	Mining Conditions
Pakistan, Lakhra	2.7 - 4.0	3 - 4	45 - 90	16	Multiple seam, flat lying deposit. Overburden contains some unconsolidated sand zones. Little ground water.
Spain, Arino Mine	0.3	4 - 6	30 - 80	15	Lignite seams steeply dipping, subject to intense folding. Overburden removed using mobile equipment.
Poland, Belchatow Mine	25	60	130 - 220	4	Deep coal reserve, numerous faults up to 40 m. displacement, high water table requires extensive dewatering program.
India, Neyveli Mine	4	0 - 18	60 - 150	6	Overburden predominantly sandstone (hard and abrasive); excessive ground water (20 tons of water are pumped for each ton of lignite mined); relatively deep deposit.
United States, Texas (Typical Mine)	4 - 10	2	10 - 40	7 - 14	Multiple seam deposit. Highwall stability problems resulting from unconsolidated sand zones being saturated with ground water.

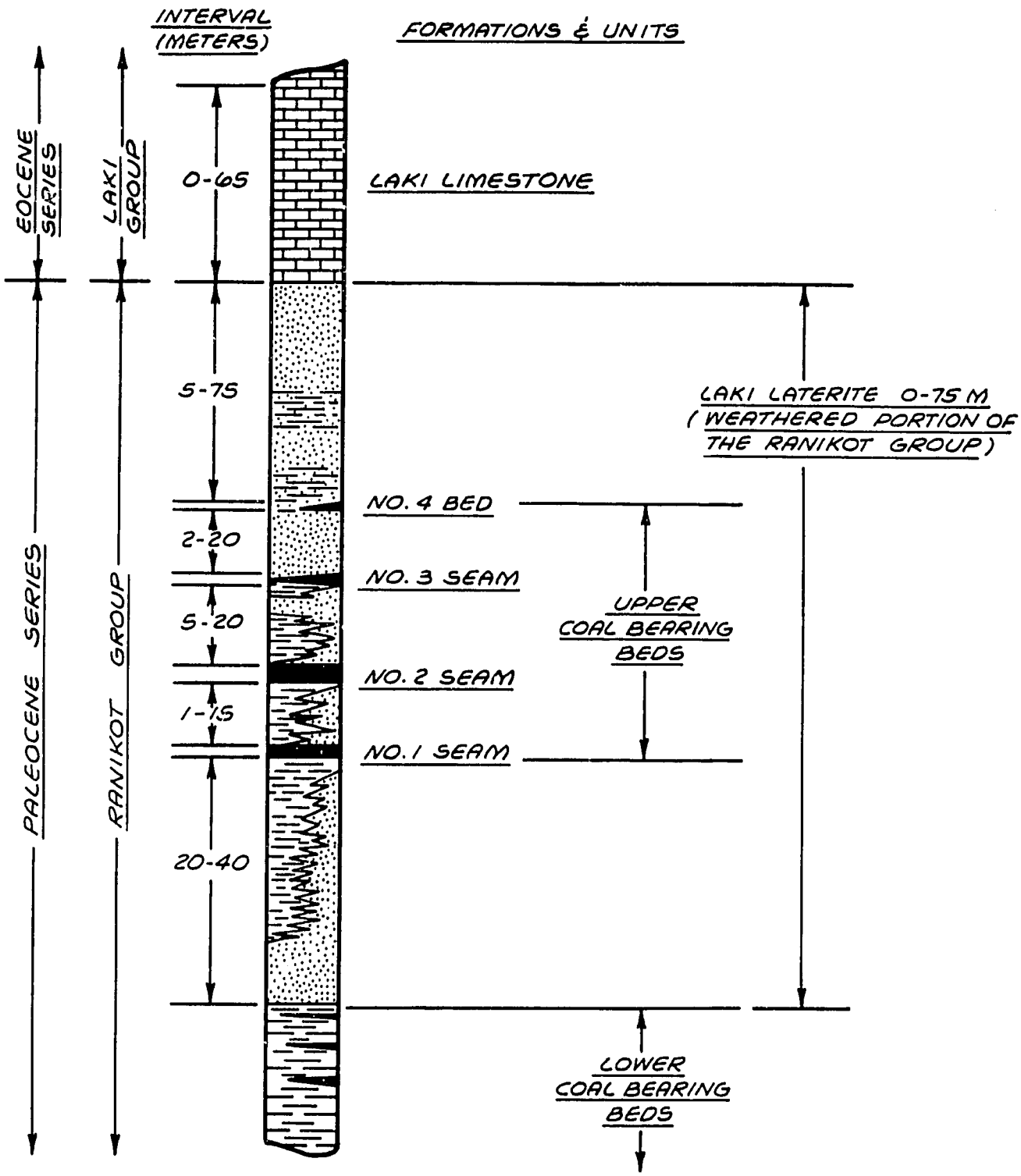
11. The mine plans, as developed in BOYD Volumes Nos. 9A, 9B, and 9C, are realistic considering the complexities of the multiple seam deposit, the arid climate and remote location, and the current capability of the mining industry in Pakistan. Plans are based on a well coordinated, phased buildup of mine activity to reflect the introduction of large scale, modern mining in Pakistan. With proper management, the proposed mine plans will develop a reliable source of fuel for the proposed mine-mouth power station.

Lakhra Coal Project lignite reserves are fully explored and comprehensively studied relative to their mineability and utilization as power plant fuel. They can be successfully recovered using modern mining methods to provide Pakistan a self-reliant source of fuel for new electrical generating capacity.

Based on prevailing conditions in the worldwide coal industry, now could be an opportune time to implement the Lakhra Coal Project. Prices on new equipment are very competitive and qualified expatriate mining companies have expressed interest in the project.

Following this text are:

Plates
- 2: Generalized Stratigraphic Section
- 3: Reserve Recovery Comparison
- 4: Map of Lakhra Coal Project Study Area showing Assigned Reserves - Master Mine Plan
- 5: Topographic Map of Lakhra Coal Project Study Area showing Extent of Exploration



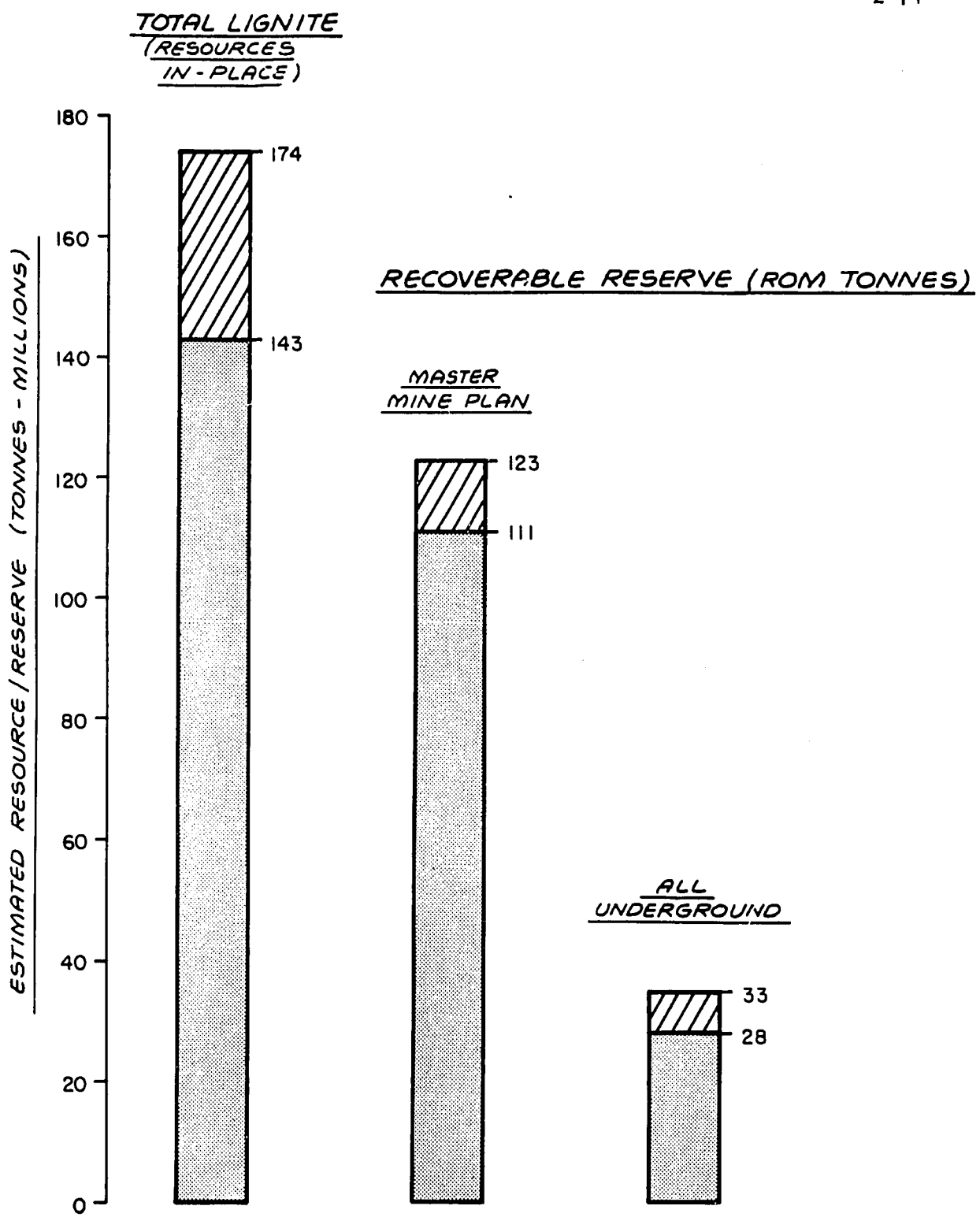
GENERALIZED STRATIGRAPHIC SECTION
LAKHRA COAL FIELD
Sind Province, Pakistan
For
USAID/PAKISTAN - WAPDA
CONTRACT NO. 391-0478-C-00-5006-00

Not to Scale

December 1986

John T. Boyd Company
Mining & Geological Engineers

PLATE 2



LEGEND

MEASURED

INDICATED

RESERVE RECOVERY COMPARISON
LAKHRA COAL PROJECT STUDY AREA
Sind Province, Pakistan
For
USAID/PAKISTAN - WAPDA
CONTRACT NO. 391-0478-C-00-5006-00

Not to Scale

December 1986

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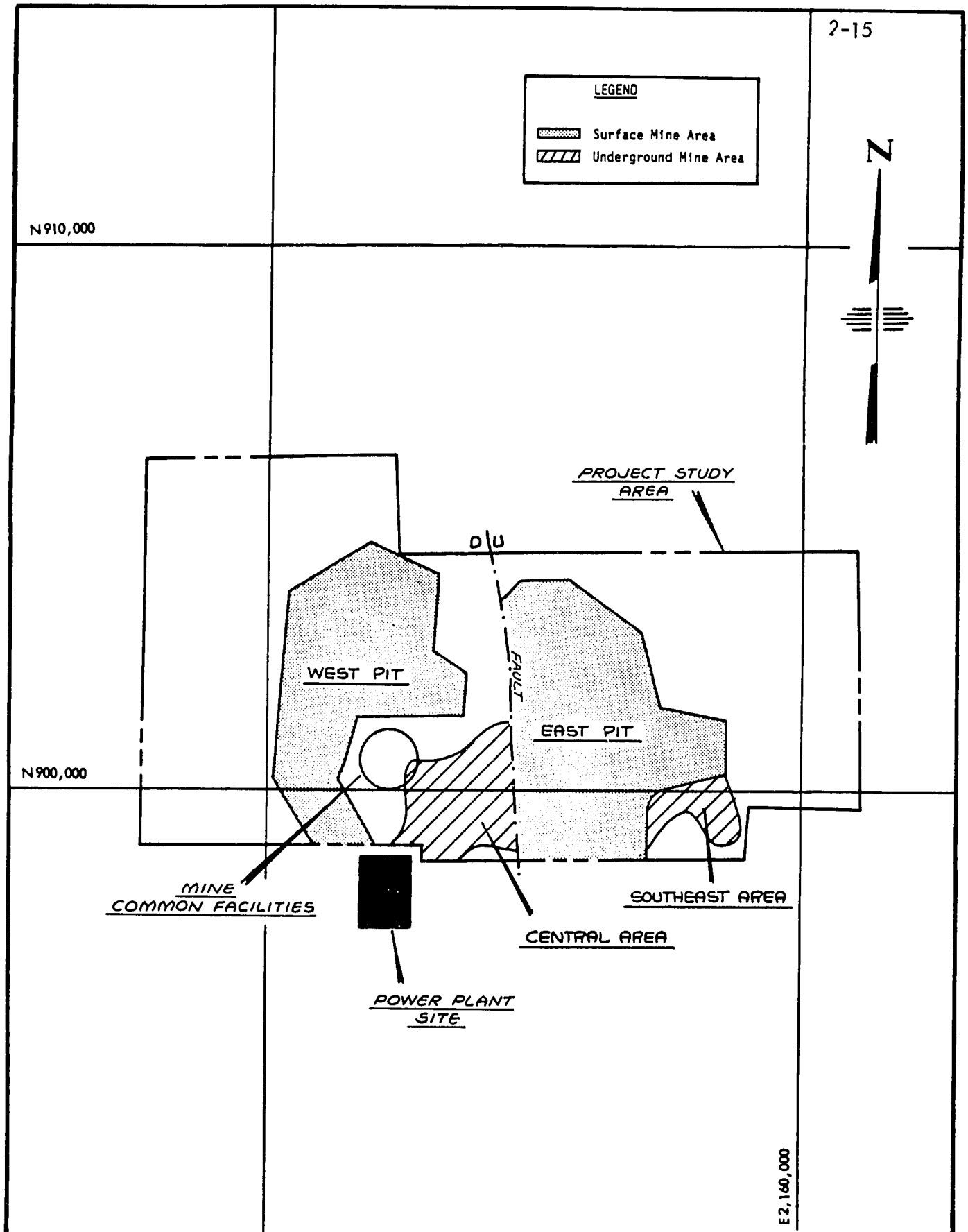
Mining & Geological Engineers

PLATE 3



MAP OF LAKHRA COAL PROJECT STUDY AREA
SHOWING ASSIGNED RESERVES
MASTER MINE PLAN
Sind Province, Pakistan

Scale: 1:100,000

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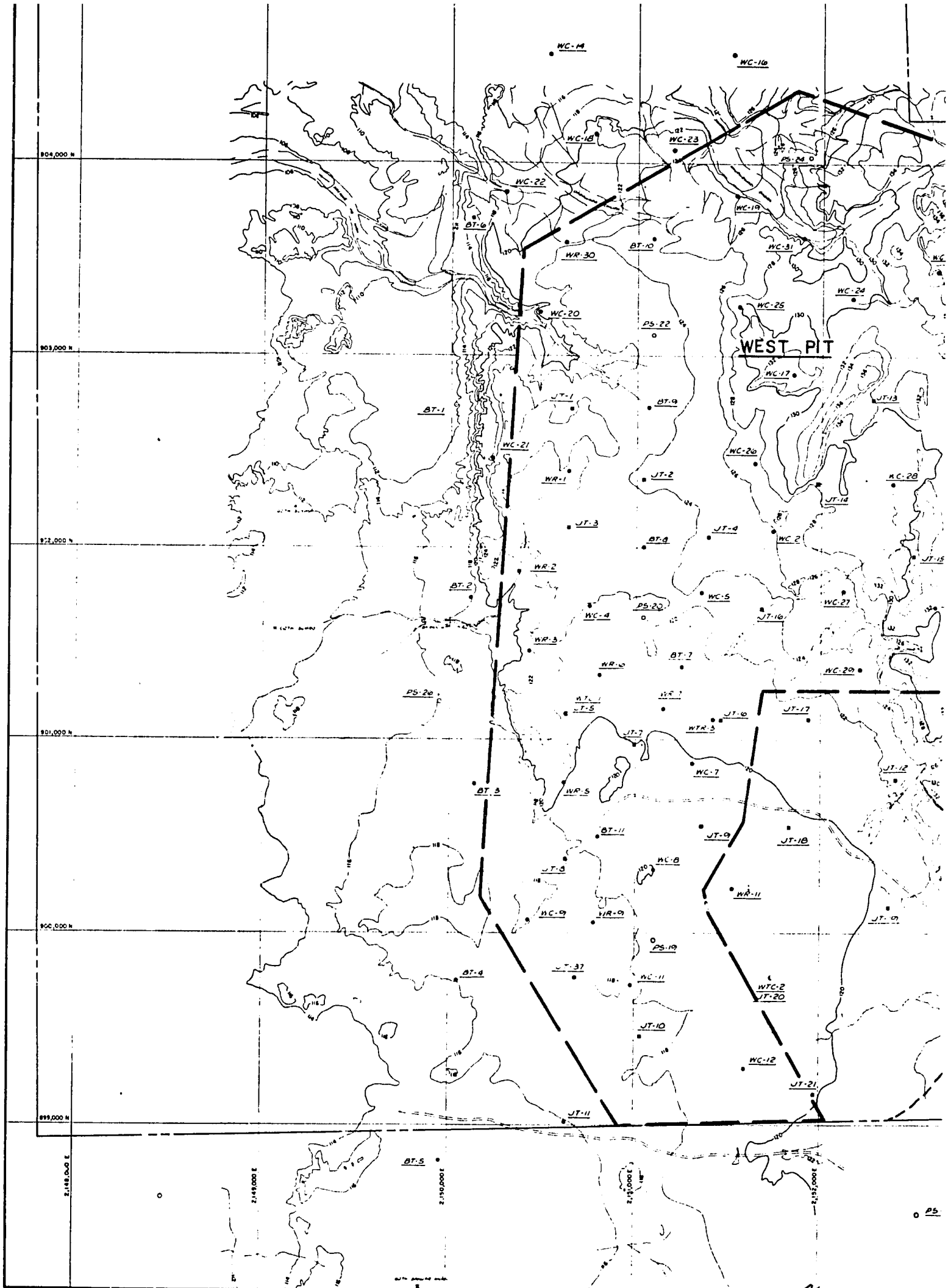
PLATE 4


WEST PIT
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WC-16
WC-18
WC-23
PS-14
WC-22
WC-19
BT-6
WR-30
BT-10
WC-31
WC-24
WC-25
WC-20
PS-22
WC-17
JT-13
BT-1
JT-1
BT-9
WC-21
WC-26
WR-1
JT-2
WC-28
JT-14
JT-3
BT-4
JT-4
WC 2
JT-15
WR-2
BT-2
WC-5
WC-27
PS-20
WC-4
JT-16
WR-3
BT-7
WR-6
WC-29
PS-26
JT-5
JT-17
JT-10
WTR-3
JT-7
WC-7
JT-12
BT-3
WR-5
BT-11
JT-9
JT-18
WC-8
JT-8
WR-11
WC-9
WR-9
JT-19
PS-19
JT-37
BT-4
WC-11
WTC-2
JT-20
JT-10
WC-12
JT-21
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BT-5
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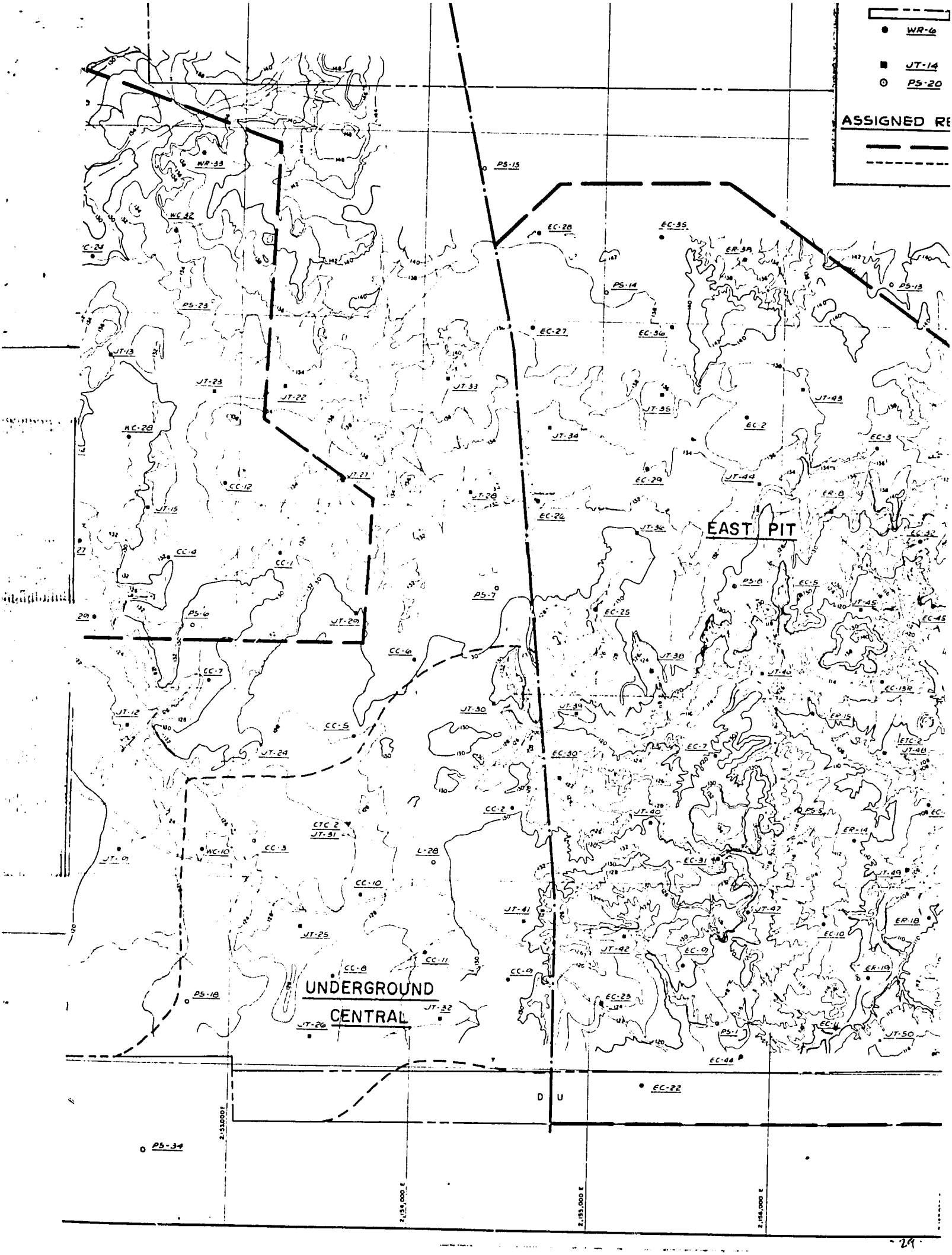
2,152,000 E

28


WR-6
JT-14
PS-20
ASSIGNED RE
EAST PIT
UNDERGROUND
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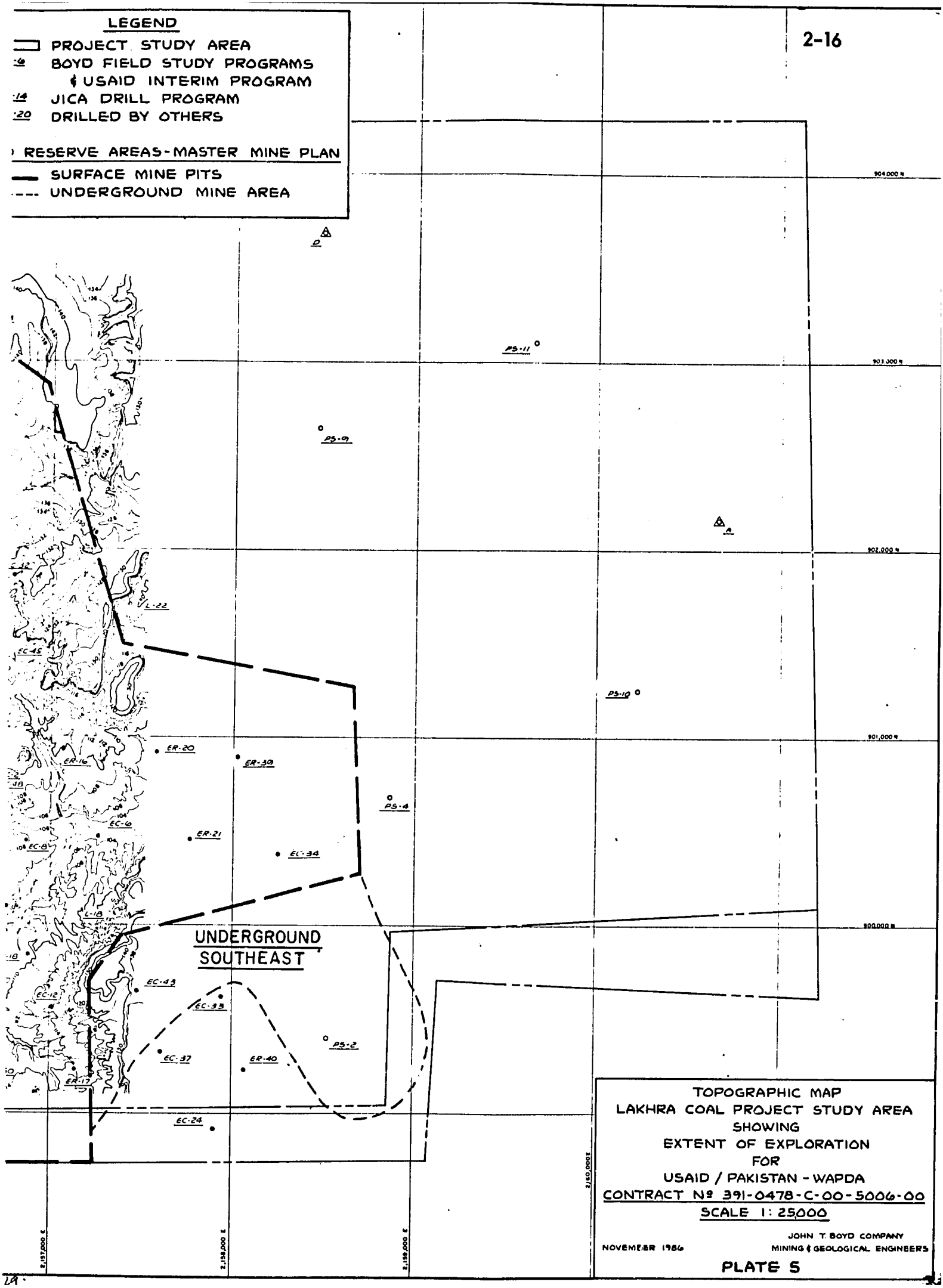

TOPOGRAPHIC MAP
LAKHRA COAL PROJECT STUDY AREA
SHOWING
EXTENT OF EXPLORATION
FOR
USAID / PAKISTAN - WAPDA
CONTRACT Nº 391-0478-C-00-5006-00
SCALE 1:25000

NOVEMBER 1986

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PLATE 5