JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

SECRETARIA DE DESENVOLVIMENTO URBANO E
MEIO AMBIENTE DO ESTADO DE SANTA CATARINA (SDM),
FUNDAÇÃO DO MEIO AMBIENTE (FATMA),
THE FEDERATIVE REPUBLIC OF BRAZIL

THE FEASIBILITY STUDY ON RECUPERATION OF MINED-OUT AREAS IN SOUTH REGION OF SANTA CATARINA STATE, THE FEDERATIVE REPUBLIC OF BRAZIL

MAIN REPORT

MARCH 1998

MITSUBISHI MATERIALS CORPORATION
CHIYODA-DAMES & MOORE CO., LTD.

JAPAN

CURRENCY EQUIVALENT

Currency Unit	=	Real ($R)
US$1.00	=	R$1.08 (October 1997)

Note: The exchange rate used in this report is US$1.00=R$1.00 because it was the rate prevailing when research and groundwork for this report was done in late 1996 and early 1997.

WEIGHTS AND MEASURES

1 meter (m)	=	3.28 feet (ft)
1 kilometer	=	0.6214 mile (mi)
1 square meter (m^2)	=	10.7639 square feet (ft^2)
1 square kilometer (km^2)	=	0.3861 square mile (mi^2)
1 cubic meter (m^3)	=	35.3147 cubic feet (ft^3)
1 hectare (ha)	=	2.4711 acres (ac)
1 liter	=	0.2642 US gallon (gal)
1 metric ton	=	2,205 pounds (lb)

FISCAL YEAR

January 1 to December 31

PREFACE

In response to a request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct the Feasibility Study on the Recuperation of Mined-Out Areas in South Region of Santa Catarina State and entrusted the study to the Japan International Cooperation Agency (JICA)

JICA sent a study team, led by Mr. Yasuo Aida of Mitsubishi Materials Corporation and organized by Mitsubishi Materials Corporation and Chiyoda-Dames & Moore Co., Ltd. to Santa Catarina State in the Federative Republic of Brazil eight times from February 1996 to February 1998.

The team held discussions with the officials concerned of the Government of the Federative Republic of Brazil as well as the State Government of Santa Catarina and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the promotion of the plan and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Federative Republic of Brazil for their close cooperation throughout the Study.

March 1998

Kimio Fujita
President
Japan International Cooperation Agency

March 1998

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita:

Letter of Transmittal

We are pleased to submit to you the Feasibility Study on Recuperation of Mined-Out Areas in South Region of Santa Catarina State. The report includes the comments and suggestions of concerned authorities of the Government of Japan and your agency. Also included are comments made by FATMA during technical discussions on the draft final report held in Florianópolis, Santa Catarina.

The Study was also carried out with a view to formulating a comprehensive program aimed at ensuring that this severe pollution from coal mining and non-compliance with environmental regulations will not occur again in the future. The report consists of two parts: (i) Summary Report; and (ii) Main Text. The main text includes the following:

- ⇨ Section I. Sector Studies;
- ⇨ Section II. Technical Studies;
- ⇨ Section III. Cost-Benefit Study; and
- ⇨ Section IV. Strategy and Program for Recuperating Mined-Out Areas.

Section I analyzes the coal mining sector and formulates a strengthening program for Fundação do Meio Ambiente (FATMA), the state of Santa Catarina's agency in charge of environmental protection. Section II presents a feasibility-level study on remedying the four designated mined-out sites which are representative of the region's pollution problems and outlines an overall remedial plan, including an environmental measurement and monitoring system for the polluted rivers. Section III describes the environmental damages, quantifies the potential remediation benefits and estimates the remedial cost and the economic merits of the remediation program. Section IV proposes remediation strategy and implementation program.

In light of the very high concern of the affected population to recuperate the polluted areas in the region as shown in our Willingness to Pay Study in Section III, we recommend that the Government of Santa Catarina implement the remediation program proposed in the report as soon as possible.

We wish to take this opportunity to express our sincere gratitude to your agency, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry. We also wish to express our deep gratitude to FATMA, Departamento Natcional da Produção Mineral (DNPM) and many other authorities concerned for the close cooperation and assistance extended to us during our study.

Very truly yours,

相田康雄

Yasuo Aida

JICA Team Leader

The Feasibility Study on Recuperation of Mined-Out Areas in South Region of Santa Catarina State

ABBREVIATIONS AND ACRONYMS

AMREC	*Associação dos Municipios da Região Carbonífera,* (Association of Municipalities of the Coal Mining Region)
ARD	Acid Rock Drainage
BOD	Biochemical Oxygen Demand
BOM	US Bureau of Mines
CAEEB	*Companhia Auxiliar de Empresas Elétricas Brasileiras,* (Power Company)
CASAN	*Companhia Catarinense de Águas e Saneamento,* (Santa Catarina's Water and Sanitation Company)
CCC	*Conta de Consuma Combustível,* (A System of Purchasing Fossil Fuel for Power Generation)
CCU	*Companhia Carbonífera de Urussanga,* (Urussanga Coal Mining Company)
CE	*Carvão Energético,* (Calorific Value for Steam Coal: kcal/kg)
CEPAN	*Comissão Executiva do plano do Carvão Nacional,* (Executive Commission of the National Coal Plan)
COD	Chemical Oxygen Demand
CONAMA	*Conselho Nacional do Meio Ambiente,* (National Council for the Environment)
CONSEMA	*Conselho do Meio Ambiente,* (Santa Catarina's Council for the Environment)
CEPCAN	*Comissão do Plano do Carvão Nacional,* (Executive Commission of the National Coal Plan)
CPL	*Carvão Pré-lavado,* (Pre-Washed Coal)
CPRM	*Companhia de Pesquisa de Recursos Minerais,* (Company for Research in Mineral Resources)
CSMA	*Conselho Superior do Meio Ambiente,* (Higher Council for the Environment)
CSN	*Companhia Siderúrgica Nacional,* (National Steel Company)
DO	Dissolved Oxygen
GDP	Gross Domestic Product
DNPM	*Departamento Nacional de Produção Mineral,* (National Department for Mineral Production)
EC	Electrical Conductivity
EIA	*Estudo de Impacto Ambiental,* (Environmental Impact Assessment)
EPAGRI	*Empresa de Pesquisa Agropecuaria e Extensao Rural de Santa Catarina,* (Santa Catarina's Agriculture Secretariat)
FATMA	*FUNDAÇÃO DE MEIO AMBIENTE,* (Santa Catarina's Environment Agency)
FCE	*Formulario de Caraterização do Empreendimento,* (Project Identification Form)
FEPEMA	*Fundo de Proteção Especial ao Meio Ambiente,* (Santa Catarina's Special Fund for Environmental Protection)

FUCRI	*Fundação Educacional de Criciúma*, (Criciúma University)
FUNDEMA	*Fundação Municipal do Meio Ambiente*, (Municipality of Joinville's Environment Agency)
GTZ	Deutche Geselschaft für Technische Zusasammenasbeit
IBAMA	*Instituto Brasiliero do Meio Ambiente e dos Recursos Renováveis* (Brazilian Institute for the Environment and Renewable Resources)
IBRD	International Bank for Reconstruction and Development
ICC	*Indústria Carbonifera Catarinense*, (Coal Mining Company)
INPE	*Instituto Nacional de Pesquisas Espacia*, (National Institute for Space Research)
IPH FRGS	*Instituto de Pesquisas Hidráulicos da Universidade Federal do Rio Grande do Sul*
JICA	Japan International Cooperation Agency
LAVACAP	*Lavador de Capivari*, (Capivari Coal Washing Plant)
MINFRA	*Ministétio de Infra-Estrutura*, (Ministry of Infrastructure)
MME	*Ministério de Minas e Energia*, (Ministry of Mines and Energy)
MIS	Management Information System
MPN	Most Probable Number
MWH	Megawatt/hour
NNP	Net Neutralization Potential
NUPESE	*Núcleo de Pesquisas e Estudos Sócio-Econômicos*, (Unit for Socio-Economic Research and Studies)
NUPEA	*Núcleo de Pesquisas Ambientais* (Unit for Environmental Research)
NGO	Non-Governmental Organization
OB	*Orientação Básica*, (Project Description Document)
ORP	Oxygen Reduction Potential
PATS	Passive Anaerobic Treatment Systems
P-M	Particulate Material
PME	*Programa de Mobilização Energética*
RCA	*Relatório de Controle Ambiental*, (Environmental Control Report)
RIMA	*Relarótio de Impacto Ambiental*, (Environmental Impact Assessment Report)
ROM	Run of Mine
SEMA	*Secretária Especial do Meio Ambiente*, (Special Secretary for the Environment)
SDM	*Secretaria de Estado do DesenvolvimentoUrbano e Meio Ambiente*, (Secretary of Urban Development and the Environment)
SIECESC	*Sindicato das Indústrias de Extração de Carvão do Estado de Santa Catarina*, (Santa Catarina's Coal Mining Industry Union)
SISNAMA	*Sistema Nacional do Meio Ambiente*, (National Environmental Protection System)

SNIEC	*Sindicato Nacional das Indústrias de Extração de Carvão,* (National Coal Mining Industry Union)
SRB	Sulfate Reducing Bacteria
SS	Suspended Solids
TDS	Total Dissolved Solids
TVA	Tennessee Valley Authority
UNESC	*Universidade do Extremo Sul Catarinense* (University of Southern Santa Catarina)
UTE	*Usina Termelétrica,* (Coal-Fired Power Plant)

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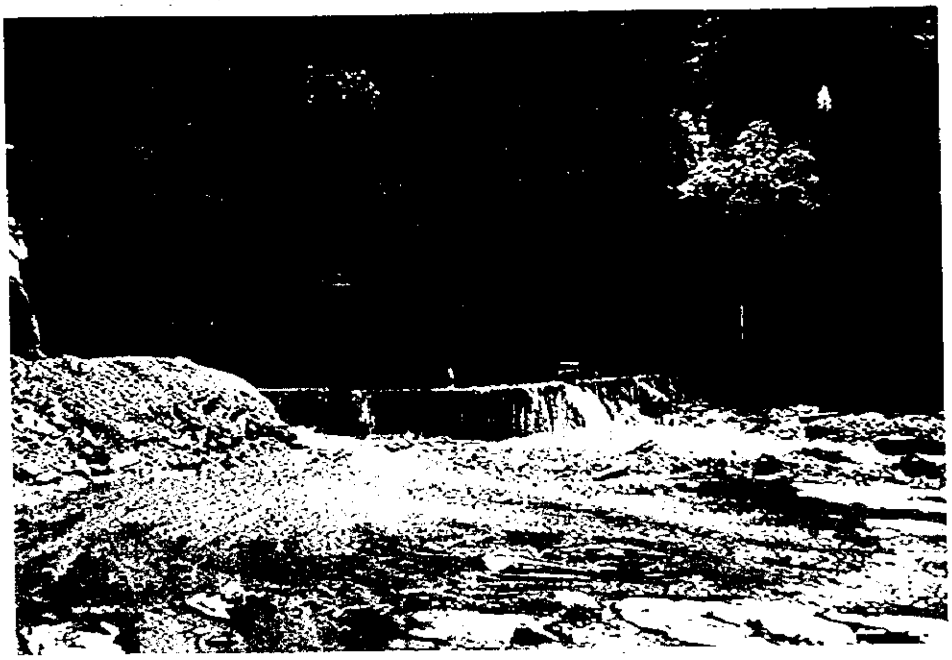
Localização de SANTA CATARINA no contexto do MERCOSUL
NICARÁGUA
COSTA RICA
PANAMÁ
TRINIDAD E TOBAGO
VENEZUELA
GUIANA
SURINAME
GUIANA FRANCESA
COLÔMBIA
EQUADOR
PERU
BOLÍVIA
BRASIL
PARAGUAI
URUGUAI
ARGENTINA
CHILE
SANTA CATARINA
OCEANO PACÍFICO
OCEANO ATLÂNTICO

Rio Fiorita FS Site

Rio Rocinha FS Site



Rio Carvao FS Site

Capivari FS Site

INTRODUCTION

A. BACKGROUND

1.01. Brazil has been mining coal since the late 19th century, originally for railroad fuel, then for power generation from the states of Santa Catarina and Rio Grande do Sul. Together, these two states account for 99% of Brazil's known coal reserves. Although Santa Catarina has less than 10% of the total known reserves, it produced almost as much as its southern neighbor Rio Grande do Sul because the deposits were easier to exploit.

1.02. The quality of the Santa Catarina's coal is relatively poor with a calorific power of between 3700 and 4500 kcal/kg (as compared to 6,400-6,700 for Polish and US coal, respectively). Its coal is also high in ash (between 47% and 58%) and sulfur (1.0%-4.7%) content. Finally, the recovery rate is extremely low, at less than 35%. This means that for every metric ton extracted, only a maximum of 350 kgs of salable coal could be recovered, while the remaining 650 kgs end up as waste.

1.03. Partly because of these characteristics and partly because of vague environmental laws and regulations and weak enforcement until the early 1980s, coal exploitation in Santa Catarina has resulted in an environmental disaster. There was practically no remediation of the mined-out areas, thus making more the 4,700 hectares of good land unusable for any purpose. Compounding the problem is the high level of pyrite contained in the waste which has been leaching through over the years, contaminating most of the southern Santa Catarina region's river basins and groundwater reserves. Many municipalities in the coal mining subregion (*Associação dos Municipios da Região Carbonifera* - AMREC) could not use the water for consumption and had to rely on other water sources in the neighboring municipalities, increasing the cost of living or doing business in the affected area. The pollution of the region's river system also limits the development of agriculture, especially of irrigated rice, prevents its use for recreation or other purposes and gives the region a bad image, constraining the development of its tourism potential. In 1980, the Federal Government decreed the region as the 14th national endangered region, allowing it to obtain special federal assistance to repair the damages done to the environment by past mining activities.

1.04. Following several attempts during the 1980s, in April 1991, the State Government of Santa Catarina set up a working group to prepare a comprehensive program to recuperate the areas polluted by coal mining and to improve the quality of life in southern Santa Catarina. The program called *Programa de Recuperação da Qualidade de Vida da Região Sul de Santa Catarina* (PROVIDA) envisaged a total investment of US$382 million to (i) repair urgent infrastructure (US$94 million); (ii) develop the road network (US$90 million); (iii) improve drainage and sewerage (US$102 million); and (iv) recuperate mined out areas (US$96 million). The program was approved by the Federal

Government in 1992.

1.05. However, finding financing to implement the program proved to be more difficult. At the request of the Brazilian Government, from August to October 1993 JICA (Japan International Cooperation Agency) seconded an expert to FATMA (*Fundação do Meio Ambiente*) to advise on ways to implement the PROVIDA program. The expert recommended that a comprehensive feasibility study be done on PROVIDA and in February 1994 Brazil requested JICA's assistance to carry out such a study. From August 1994 to November 1995, JICA sent a number of missions to prepare the terms of reference of the Study and to agree with the Brazilian authorities on the scope of work. Recognizing that it would not be realistic to tackle all the issues under the PROVIDA program, it was agreed with the Brazilian authorities that the Study should address in priority the remediation of mined-out areas.

B. OBJECTIVES

1.06. The objectives of the Study are two fold. First, (i) conduct a feasibility study on remedying a number of target mined-out sites in southern Santa Catarina; (ii) formulate an overall remediation plan and environmental measurements and monitoring system on the surrounding rivers polluted by coal mining and coal preparation activities; and (iii) transfer relevant technologies to Brazilian counterpart personnel in the course of the Study. Second, facilitate the involvement of bilateral or multilateral lending institutions in the financing of the remediation of mined-out areas. With that second objective in mind, it has been deemed necessary to expand the scope of the work to include improvement of coal mining operations and strengthening of environmental protection in Santa Catarina with a view to formulating a comprehensive program aimed at ensuring that this severe pollution from coal mining and non compliance with environmental regulations will not occur again in the future.

SECTION I

A. SANTA CATARINA'S COAL MINING SECTOR

1. IMPORTANCE OF COAL IN BRAZIL'S ENERGY SUPPLY

1. Coal has traditionally played a secondary but crucial role in Brazil's energy equation. Because of the country's immense hydraulic potential and the enormous investments already made to develop it, hydroelectricity will continue to be the main source of power. However, the role of coal is likely to remain important in the foreseeable future for the following reasons:

1. most of Brazil's hydraulic potential is located in the Amazon region, far from the country's major consumption centers of the south and south east;
2. the cost of hydropower projects is high and most of the investment is concentrated in the first years of execution, making it necessary to mobilize large amounts of resources in short periods;
3. the environmental impact of hydroelectric projects, particularly those involving major dam construction, has become more apparent and adds substantially to the investment cost; and
4. finally, the construction period of a hydroelectric complex is very long.

2. In Brazil, coal is found mainly in the states of Rio Grande do Sul and Santa Catarina. Together, these two states account for 99% of the 32.3 billion tons of known reserves. During the coal boom period of the late 1980s, production almost reached 9 million tons. Although Santa Catarina has less than 10% of the total known reserves, it produced almost as much as its southern neighbor Rio Grande do Sul because the deposits were easier to exploit. Since then, Santa Catarina's production has hovered around 1.9 million tons, or about 40% of Brazil's total coal production.

3. Both states produce mainly steam coal with a relatively low calorific power of between 3,700 and 4,500[1] (as compared to 6,400-6,700 for Polish and US coal, respectively). Brazilian coal is also high in ash (between 47% and 58%) and sulfur (1.0%-4.7%) content. Finally, extraction conditions are difficult given the location, disposition and shape of the deposits. All these problems make that Brazilian coal is only competitive under relatively favorable conditions of price and demand.

4. At present, thermal generation only accounts for 5% of Brazil's power production. However, Eletrobras expects that percentage to increase to 15% by the year 2015, as a result of continued

high power demand fueled by the country's strong economic growth. Thermal generation is also expected to continue playing an important role as an alternative source of power, relieving the system during peak periods or during crises.

5. The need to maintain a viable thermal power sector is most evidenced by the *Conta de Consumo Combustível* (CCC), a system whereby public utilities companies make mandatory contributions into an account managed by Eletrobras which uses the funds to help power generation companies purchase fossil combustibles (coal or oil) for their thermal plants. The rationale is to ensure the continued availability of thermal generation in Brazil as an insurance against crises of the hydrosystem. Table I-1 below shows that in 1995 two thirds of the CCC funds in the interconnected systems of the South/Southeast/Centerwest were used to buy coal and that Santa Catarina did well, obtaining 56% of the funds reserved for coal.

Table I-1

South/Southeast/Centerwest Interconnected Power Systems

A. Distribution of CCC Funds by Combustible, 1995

Combustible	US$ Million	Percentage
Fuel Oil	56.8	31.9
Coal	118.4	66.5
Diesel Oil	2.1	1.2
Natural Gas	0.9	0.5
TOTAL	178.2	100.0

B. Purchase of Coal by State, 1995

State	US$ Million	Percentage
Rio Grande do Sul	49.9	42.1
Santa Catarina	66.4	56.2
Paraná	2.1	1.7
TOTAL	118.2	100.0

6. Brazilian thermoelectric plants rely for about two thirds on domestic coal and will continue to do so, provided that it remains competitive with imported coal. This is a challenge that Santa Catarina's coal sector should meet.

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[1] Santa Catarina also produced coke with 17% of ash and 1.7% sulfur, but following the liberalization of the sector in 1991, production ceased because of competition from cheaper imported coke (mostly from China).

2. IMPORTANCE OF COAL IN SANTA CATARINA'S ECONOMY

7. Coal mining in Santa Catarina is more than 110 years old. During all that time, except for the last six years, the sector has existed and operated mostly for the Federal Government under its protection and control. Most of the coal produced was consumed by public enterprises (Eletrobras' power plants and public steel mills) at prices fixed by the Government. The Federal Government also set production levels and, through state-owned companies, controlled the whole production process from research and extraction to beneficiation and final consumption.

8. The Federal Government's interest in the sector was not motivated by the desire to foster the region's economic development. It was dictated by strategic considerations or prompted by international developments. During World War II, the Government's assistance to the sector was deemed necessary to ensure a regular source of energy, given the constant disruptions of import supplies. It was at that time that the Government created the *Conselho de Minas e Metalurgia* (Coal and Steel Council) to set coal prices and the *Companhia Siderúrgica Nacional* (National Steel Company) to exploit the Santa Catarina coal, the only one in Brazil suitable for steel mills. Government's intervention continued during the 1950s and 1960s with the establishment of the *Comissão Executiva do Plano do Carvão Nacional* - CEPCAN (Executive Commission of the National Coal Plan) to coordinate coal production, beneficiation, and distribution with a view to ensuring the expansion of the sector and improving its efficiency.

9. The 1960s also saw the installation of the first thermoelectric unit at the Jorge Lacerda complex and the creation of ICC (*Indústria Carboquímica Catarinense*) to exploit the pyrite wastes coming from coal beneficiation and removal of metallic elements from the mineral for sulfur extraction. During the oil crises in the 1970s, the Federal Government's interest in the sector intensified. Special incentives were granted to encourage the substitution of oil for coal. CAEEB (*Companhia Auxiliar de Empresas Elétricas Brasileiras*) was created in 1975 to directly ensure the commercialization of all the steam coal produced in Brazil. The company extended subsidies not only to coal producers (up to 90% of selling prices) but also to users who were willing to adapt their installations to use coal instead of oil. Production of steam coal jumped to a record 7.1 million tons in 1986, while coke reached 1.3 million tons, also a record representing about 24% of Brazilian steel mills needs. Recent sector developments are described below.

2.1 Recent Sector Developments

10. The period between mid-1970s and mid-1980s is known as the golden area of coal. The sector developed in a protective environment characterized by the obligation of Brazilian companies (particularly steel mills and power companies) to use at least 20% of local coal in their energy

consumption at prices set by the Government. During the 1970s, the Government adopted the cost + formula, a disastrous system which encourages inefficiency by rewarding companies with large costs and discouraging investments to improve productivity and control production costs. Incentives and subsidies were generously given both at the production and commercialization stages. The most common are those for investment, production and transport of coal. As shown in Table I-2 below, coal production increased substantially until 1988 when they started to decrease as subsidies and production incentives were gradually withdrawn.

Table I-2

Evolution of Coal Production, 1980-1995
(Thousand Tons)

	1980	1988	1990	1992	1995
Steam Coal					
RS	2,666	4,284	2,800	2,620	2,980
SC	1,840	2,993	787	1,684	1,978
PR	210	228	117	151	135
Sub-total	4,908	7,505	3,704	4,435	5,093
Coke					
SC	1,288	835	348	---	---
Other	273	421	64	171	80
TOTAL	6,469	8,762	4,116	4,626	5,173

Note: RS = Rio Grande do Sul; SC = Santa Catarina; PR = Paraná

11. All along that fast-growing period, coal mining companies operated without clear and enforceable environmental regulations. The revised Mining Code of 1967 (Decree Law No. 227) only stipulated that mining activity should "avoid water and air pollution". In Southern Santa Catarina, it was only during the 1980s that some specific legislation was issued to address a problem which has become serious:

=> Decree No. 85.206 of September 25, 1980 classifying Southern Santa Catarina as the 14th Critical Polluting Area (*Área Critica de poluição ambiental*).

=> Inter-ministerial Order No. 917 of July 6, 1982 requiring mining companies to submit proposals within 180 days for (i) effluent treatment; (ii) transportation, handling and disposal of solid wastes; and (iii) recuperation of mined-out areas;

=> Decree No. 97.632 of April 10, 1989 requiring environmental impact assessment (EIA) for new mining operations and submission of site remediation programs for new and existing mining concerns.

12. In the mid-1980s, the situation started to change. In 1985, the Government adopted a system limiting steam coal prices to a maximum of 80% of Eletrobrás fuel oil 2-A (a substitute for coal in thermal generation). As the price of that fuel is maintained artificially low for economic policy reasons, coal producers had difficulty keeping that parity without incurring losses. At the same time, subsidies and incentives were gradually withdrawn. They were completely eliminated in 1988.

13. In 1989, as part of its new deregulation program, the Government decided to withdraw from the sector. It took the following actions:

⇒ Abolition of CAEEB, which was responsible for the commercialization of all the coal produced in Brazil, leaving coal prices to be freely set between mining companies and coal users, including Eletrosul;

⇒ Abolition of CSN (through which the Federal Government has been producing coal for more than 40 years) and privatization of its subsidiary Carbonifera Prospera (which was completed in 1991), signaling that the Government will no longer be involved in coal production;

⇒ Removal of the obligation by national steel mills to use local coal; and

⇒ Closure of the Capivari washing station (*Lavador de Capivari* - LAVACAP), the existence of which was justified by the coke production from pre-washed coal.

14. As a result of these policy changes, coke production, unable to compete with imports, ceased in 1991, while steam coal production decreased drastically from their peak of 7.5 million tons in 1988 and stabilized at a level of about 4.4-5.0 million tons/year since 1992.

15. The Federal Government continues to be involved in the following coal-related activities: (i) transportation of coal from the mines to the Jorge Lacerda thermoelectric complex in Capivari de Baixo; and (ii) thermal generation through the Jorge Lacerda complex, which has an installed capacity of 482 MW (832 MW when the fourth plant is in operation in mid-1997).

16. The Federal Government also maintains the *Conta de Consumo Combustivel* (CCC) system. Finally, the Government retains the following tasks which are considered public sector responsibilities:

⇒ Granting of authorization for research, exploration and extraction of coal and other minerals (through the Ministry of Mines and Energy/DNPM);

⇒ Approval of mining projects, including monitoring of their implementation (through DNPM); and

⇒ Monitoring of mining projects' environmental impact (through CONAMA, IBAMA and FATMA).

2.2 *Impact of Coal Mining on Southern Santa Catarina's Economy*

17. Coal mining has played a dominant role in the economy of southern Santa Catarina, particularly in the 1970s when it represented up to 30% of the region's GDP. During the 1980s, the economy became more diversified with emerging industries such as ceramics, garment manufacturing, plastics and furniture making accounting for an increasing share of the region's production. However, coal mining remains important because of its indirect effects on the rest of the economy. Using national accounts input-output tables, a study by the Fundação Getúlio Vargas (*O Carão Nacional na Industriá Brasileira*) estimated that coal mining has a multiplier effect of 3.49 on the economy of southern Santa Catarina, i.e., the total impact of coal mining on the economy is 3.49 times its direct impact. Applying this coefficient to GDP figures shows that coal mining represented between 28.7% and 33.3% of southern Santa Catarina's economy in the 1980s. Even in the depressed years of the early 1990s, the sector still contributed between 20.4% to 25.6% to the region's GDP. Recent research by FUCRI indicated that in Lauro Müller and Siderópolis, two municipalities in the coal mining area (AMREC) which have not succeeded in diversifying their economy, coal mining still accounts for 85% and 73% of industrial production, while in the rest of AMREC, it averages 10%.

18. In terms of employment, in its prosperous days, coal mining employed nearly 11,000 workers and provided the main livelihood for more than 66,000 people. Its total impact is even larger, however, if account is taken of related activities, such as transportation (both rail and road), shipping, handling and other port services, commercialization and other services. Assuming that these activities are at least as labor intensive as mining (which is a safe assumption), the total employment impact of coal mining could be estimated at 38,000 jobs which supported more than 220,000 people.

Table I-3

Coal Mining Employment by Category of Job, 1984-95

	1984	1985	1987	1990	1993	1994	1995
Mining Engineers	46	44	37	30	20	24	17
Geologists	12	14	8	7	7	7	6
Sr. Technicians	112	126	72	70	66	63	60
Jr. Technicians	175	144	266	200	79	77	75
Mining Workers	9,970	9,561	8,242	4,200	3,858	3,300	3,200
Ad. Workers	583	647	504	450	263	163	160
Total	10,898	10,536	9,129	4,957	4,293	3,630	3,518

Source: DNPM/CPRM

2.3 *Prospects*

19. Coal prospects as an viable source of energy – particularly for thermal generation – depends, to a large extent, on the resolution of environmental problems associated with its use. While the environmental problems resulting from the extraction and washing of coal can be easily remedied through the application of relatively simple technologies, the control of P-M (particulate materials), SO_x and NO_x emissions in the production of energy requires the use of more advanced technologies recently developed in Europe and the US where coal accounts for more than 50% of the fuel used in electricity production. Japan is also using such technologies.

Available Technologies

20. At present, available technologies include those (i) allowing coal burning in the pre- or post-combustion phases; (ii) affecting the coal combustion process itself; and (iii) transforming coal into a liquid or gasified fuel.

21. In the pre-combustion phase, the technology aims at eliminating impurities, such as pyrite contained in the mineral, thus preventing the emissions of polluting gases during the burning process. Technologies that act directly on the combustion process itself are used more both in conventional and advanced processes. The main ones are described below:

➢ THERMOELECTRIC PLANTS WITH PULVERIZED COAL BURNER

1. Conventional combustion with low emission of NO_x using ROM coal
2. Conventional combustion with pre-combustion coal desulfurization and low emission of NO_x
3. Conventional combustion of ROM coal with low emission of NO_x and desulfurization of combustion gases

➢ THERMOELECTRIC PLANTS WITH ATMOSPHERIC FLUIDIZED BED COMBUSTION

➢ THERMOELECTRIC PLANTS WITH TOPPING CYCLE

1. Fluidized combustion at high pressure
2. Gasification and fluidized combustion in topping Cycle

22. Among processes considered the cleanest and most popular is the fluidized bed combustion system. It is also the most suitable to Brazilian coal. The process works as follows: The coal, reduced at an adequate temperature, is maintained in suspension in the furnace by air injection through an appropriate distributor located at the bottom of the burner. The desulfurization operation is done in a simple way through a reaction in the bed, producing sulfite of calcium which is extracted together with ashes.

23. The fluidized bed functions at controlled temperatures below the fusion point of ashes (about 850°), thus avoiding the formation and deposit of slags close to the inside parts of the burner, guaranteeing a perfect burning of the fuel. Given its low temperature, it reduces No_x emissions. The wide application of this new technology for thermal generation is due to its aptitude to burn cleanly bad quality fuels, i.e., those with high humidity, ash and sulfur content. There are plants currently using this process effectively and staying within established emissions limits. Table I-4 below compares the generation costs of a thermal unit of 125 MW, using four different processes.

Table I-4

Generation Cost of a Thermal Unit of 125 MW

Generation Process	Generation Cost ($ Thousand/kwh)				
	CE 1800 Waste	CE 3300 Candiota	CE 3300 Bonito	CE 3700 B. Jacui	CE 6500 Colômbia
Pulverized Coal	----	46.7	51.6	55.1	56.9
Pulverized Coal with Desulfurization	----	58.6	63.6	67.2	69.1
Topping Cycle with Gasification	----	-----	-----	69.8	71.4
Atmospheric Fluidized Bed	46.6	53.8	58.8	62.4	64.2

24. In Santa Catarina, the coal most suitable for fluidized bed combustion is that of Bonito (CE-3300 or CE-2800). The pulverized coal process is cheaper but is considered inadequate because it results in high emissions of large PM after combustion. The adoption of the fluidized bed combustion technology constitutes a breakthrough with regard to the compatibility between the economics of thermal generation and the requirements of air pollution control.

Brazil's Mineral Reserves Potential

25. According to MINFRA 1990 National Energy Survey, coal accounts for 2/3 of Brazil's non-renewable resources. In energy terms, this is equivalent to ten times identified petroleum reserves, three times that of nuclear energy and ten times that of bituminous schist and makes coal credible as a reliable source for electric energy generation. Eletrobrás's 2015 Plan seriously consider this scenario and recommends more research, studies and investments in thermoelectric plants to make a smooth transition from a predominantly hydroelectric program to a hydro-thermal system in the future.

26. Table I-5 below taken from Eletrobras' 2015 Plan shows the thermoelectric potential of Brazil, while Table I-6 projects the installation of 14 additional thermoelectric units of 125 MW each in Santa Catarina based on the likely exploitation of the Bonito seam (CE-4500 for the existing plant and ROM-2800 for the new units using AFBC (Atmospheric Fluidized Bed Combustion) process. It is therefore estimated that Santa Catarina will generate 2,582 MW by 2015 and would use 14.7 million tons of coal/year, which is equivalent to 7.3 times the current annual production.

Table I-5

Coal-Fired Thermoelectric Potential in Brazil
(In MW)

			POTENTIAL		
	Existing	**Planned**	**Measured/Indicated**	**Inferred**	**Total Potential**
R.G Sul	538	700	27,200	29,500	56,700
S.C	482	350	1,750	450	2,200
Paraná	20	--	260	--	260
TOTAL	1,040	1,050	29,210	29,950	59,160

Table I-6

Planned Thermoelectricity Expansion in Santa Catarina
(Coal: Thousand tons)

	1996	1998	2000	2005	2010	2015
Jorge Lacerda						
MW/h	482	832	832	832	832	832
CE-4500	1,320	2,900	2,900	2,900	2,900	2,900
NEW TEU*						
MW/h	___	___	(2) 250	(3) 375	(3) 375	(6) 750
ROM-2800	___	___	1,686	2,530	2,530	5,060
TOTAL						
W M/h	482	832	1,082	1,457	1,832	2,582
Coal	1,320	2,900	4,586	7,116	9,646	14,706

Source: Eletrobras - Year 2015 Plan and SIECESC
* Thermoelectric Unit (using Atmospheric Fluidized bed Combustion)

3. BRAZIL'S EMERGING COAL MINING POLICY

27. Until the wave of market policy reforms with its accompanying deregulation and privatization measures hit Brazil in the early 1990s, the country's coal mining policy was characterized by direct involvement of the Federal Government in all the phases of activity of the sector, from research and exploration to production and commercialization.

28. The 1990 Federal Deregulation Program (Decree No. 99.179) established the legal basis for the Government's disengagement, but did not define a policy for the sector. A 1994 multiannual plan for the development of the coal sector prepared by DNPM tried to fill the gap by recommending the following directives for the Government's actions in the sector:

⇒ Set well-defined commercial and operational rules for the use of coal by thermoelectric plants in Southern Santa Catarina, so as to permit planning for the long-term expansion of the sector. These rules must be applied to existing units as well as future ones and must establish minimum levels of production and sales compatible with the stability of the coal industry, given its importance in the country's long-term energy equation;

⇒ Define the structure and ownership of the company (public, private or mixed) which will be investing and managing the thermoelectric plants planned by the electric sector;

⇒ Avoid that prices of fuels produced by the public sector generate distortions in the domestic market, making impossible the planning for an efficient development of national energy resources; and

⇒ Support the coal industry's initiatives to develop cleaner technologies for the use of coal, such as gasification and fluidized bed combustion.

29. These recommendations, which mixed market concepts and interventionism, were mostly rejected and in 1995 the Ministry of Mines and Energy, with the collaboration of representatives of the coal industry, issued the following 12 guiding principles for the formulation of a national coal mining policy:

- Government should not interfere in coal mining exploration and commercialization
- Price subsidies to coal's alternative fuels (such as petroleum) should be avoided;
- Technology development programs should be introduced to improve open pit and underground mining;
- Government should support the development of clean technologies for coal burning;
- Resolution No. 08/90 of December 6, 1990 on licensing of mining activities should be revised but without affecting the environmental protection requirements;

- Workers' contracts should be consistent with the requirements of the legislation concerning safety and hygiene on mining work;

- Implementation of the planned investments in coal-fired thermoelectric plants and the coverage of coal production and sales by the *Conta de Consumo de Combustível* will continue to be conditioned on criteria of optimization of the electric system;

- Ministry of Mines and Energy (MME) will request the Ministry of Science and Technology priority for programs aimed at developing the production, beneficiation and utilization of coal;

- MME will support requests from the coal industry for financing of, and/or fiscal incentives for, actions aimed at improving its productivity;

- MME will study the possibility of promoting coal-fired thermal generation in the Mercrosul countries;
- MME will support the Santa Catarina state's efforts to mobilize external resources for the recuperation of mined-out areas; and

- MME will consider the inclusion of coal-fired thermal generation in the regulation of the electric sector as well as in the IPP (Independent Power producer) sector.

30. The Government disengaged itself from coal production and commercialization as stated, but did not keep its commitment to discontinue subsidizing diesel oil prices, a direct competitor of coal as an industrial fuel, because of the impact of such a measure on inflation. As a result, many coal mining companies are in difficult financial situation. In 1995, for example, they sold coal CE-4500 to Eletrosul at R$39.8/ton and coal for industrial use, such as CE-5200 and CE-5400 at about R$30/ton, while, according to a study carried out by the *Fundação Getúlio Vargas*, the average production cost of SIECESC's members was R$37.3. Including taxes and normal profit margin, they should have sold their coal at R$46.5 to remain profitable.

4. Legal and Institutional Framework for Coal Mining

31. Coal mining falls under the **Ministry of Mines and Energy** (MME), which is responsible for the following: (i) geology and mineral resources; (ii) hydraulic regime and sources of hydraulic energy; (iii) petroleum industry, electricity and nuclear energy; and (iv) mining and steel industry. The Ministry mainly relies on DNPM to carry out these tasks.

4.1 Departemento Nacional de Produção Mineral - DNPM

32. DNPM is located in MME and is directly responsible for all types of mining in Brazil. It operates as an autonomous agency (Law No. 8.876 of May 2, 1994), responsible for (i) promoting the planning and development of the exploration and exploitation of mineral resources; (ii) supervising

geological research and monitoring mining operation in all the national territory according to the Mining Code, Mineral Water Code and related regulation and legislation; and (iii) ensuring compliance with the mining code and related legislation and regulations.

33. In particular, the Department is responsible for:

⇒ Granting licenses for the exploration and exploitation of mineral resources;

⇒ Analyzing developments of the Brazilian (and international) mining sector and maintaining statistical data and information on the production and trade of mining products;

⇒ Monitoring the research, extraction, washing, and commercialization of mineral products. DNPM can impose sanctions and penalties for non-conformity to the dispositions of the mining legislation;

⇒ Enforcing compliance with environmental regulations, as well as hygienic and safety norms, together with public organisms responsible for these matters;

⇒ Supporting the development of small-scale mining enterprises;

⇒ Establishing areas and defining conditions for the constitution of individual or small mining companies; and

⇒ Issuing supplementary norms and, together with responsible organisms, enforcing compliance with environmental, safety and hygienic regulations.

34. DNPM has a legal personality and is administratively and financially autonomous. Its present structure dates from September 1993 when Congress adopted a national program for mining development. Besides entrusting DNPM with an autonomous framework, the program transformed CPRM (*Companhia de Pesquisa de Recursos Minerais*) into a public enterprise, amended the mining code, created a national program of basic geological surveys (*Programa de Levetamentos Geológicos Básicos do Brasil*) and established a working group to formulate a multiannual plan for the development of the mining sector in Brazil.

35. DNPM's resources mainly come from the federal budget. However, it also raises revenues from fines to mining companies, contributions foreseen in the mining legislation, sales of publications, inspections and supervision, donations, subsidies and other income established by law, regulations and contracts.

36. In the 1990 administrative reform DNPM lost most of its regional offices, the functions of which were transferred to the Mining Division of the Ministry of Infrastructure, now recreated as the Ministry of Mines and Energy. However, DNPM still maintains a strong presence in Santa Catarina. That office has a staff of 32, of whom 18 university graduates (12 geologists and 2 mining engineers). Its work program is enormous, consisting of the supervision and monitoring of 350 extraction concessions,

300 licensing, 1,300 research permits and 3,800 research requests. The office needs to be closer to its clients, as well as state and municipal organisms involved in mining exploitation, and develop a training and incentives program (including career planning) to improve the productivity of its staff. The southern region office located in Criciuma has four professionals (two Geologists and two assistants) seconded by CPRM.

4.2 The Mining Code

37. The present Mining Code was enacted by a Law-Decree No. 227 of February 28, 1967 which updated the old mining code of 1940. The Code covers all mining activities. There is no special code for coal mining.

38. The Code stipulates that "the Union [the Federal Government] is responsible for managing the country's natural resources and the industry dealing with the production, commercialization and distribution of mineral products.

39. To operate a mine in Brazil, a company must obtain an authorization delivered by the MME through DNPM (Articles 80 and 84 of the Mining code). Before extraction, a company must submit a research project to MME which will grant an exploration permit on the basis of DNPM's recommendation. Following exploration and verification of the existence of minerals in technical and economical conditions justifying exploitation, if the company decides to proceed with the exploitation phase, it needs to obtain an extraction permit, which is granted after review by DNPM of the proposal submitted by the company. If the exploitation request is accepted, the extraction permit is granted with a document signed by the President of the Republic according to Articles 36-59 of the Mining Code. The concession has no time limit and is free (i.e., no annual fees nor taxes). The company must, however, agree to DNPM's monitoring of its activities and must conform to the reporting requirements as stipulated by law. The company must also abide by the environmental regulations stipulated by the Federal Government, as well as the state and municipality in which it operates.

40. DNPM is entrusted by law with the necessary power to monitor all mining activities in Brazil. However, it needs more technical and human resources to efficiently play the role for which it was created.

4.3 The Sindicato da Industria da Extração de Carvão do Estado de Santa Catarina - SIECESC

41. Created to coordinate the actions of the individual mining companies and represent and defend the interests of the mining industry, SIECESC has become the official channel of communication between the industry and the authorities. It also represents the Santa Catarina mining companies in price negotiations with Eletrosul and other coal users.

42. SIECESC has been very active in promoting the importance of coal in thermal generation and helping its members adopt cleaner technologies and introduce environmental protection measures in their operations.

43. Since the coal mining crisis in 1990, SIECESC has lost some of its importance as many companies closed down under competition from cheaper import coal. The sector is now reduced to six companies with a total direct labor force of 3,500, as compared to almost 11,000 in the mid-1980s. The future of Santa Catarina's coal lays in the adoption by Eletrosul of clean combustion technologies of high ash and sulfur content coal and SIECESC's main task will be to help promote these technologies in Brazil.

4.4 The Sociedade de Assistência aos Trabalhadores do Carvão - SATC

44. Created in 1959 to assist mining workers, SATC provides training in coal mining techniques through its technical school and gives high school level classes to the workers' children. It is managed by SIECESC. The entity also has a lab and makes coal quality analyses for mining companies sending their production to Eletrosul in Tubarão and monitors the quality of water in washing plants for SIECESC members.

5. ENVIRONMENTAL REGULATION AND CONTROL OF COAL MINING

5.1 The Institutional Framework

45. In Brazil, enforcement of environmental regulations is the responsibility of state and local governments. The federal environmental agencies mainly issue norms and regulations, which are often supplemented by state directives according to their own environmental policy. However, in the case of coal mining, since it is a federal responsibility, both federal and state agencies are involved in the regulation and control of that activity.

(a) Federal Institutions

46. Brazil's basic environmental legislation is the law No. 6938 of August 31, 1981 (referred to as the *Ley do Meio Ambiente)*. That law defines Brazil's Environmental Policy, establishes the National Environmental system - SISNAMA (*Sistema Nacional do Meio Ambiente*) and allocates responsibilities for environmental protection among the three spheres of government (federal, state and municipal). At the federal level, the institutions forming SISNAMA are the following:

(i) *Conselho Superior do Meio Ambiente* - CSMA (Higher Council for the Environment)

47. The council advises the President of the Republic on the formulation of national policies and federal guidelines concerning the environment and the management of natural resources. CSMA meets periodically (about twice a year) and is composed of State Ministers, representatives of the *Ministerio Público Federal, Sociedade Brasileira para o Progresso da Ciência,* federal law makers, and five representatives of environmental NGOs. CSMA is chaired by the President of the Republic and the Minister of the Environment, Hydraulic Resources and the Legal Amazon serves as its Executive Secretary.

(ii) *Conselho Nacional do Meio Ambiente* - CONAMA (National Council for the Environment)

48. CONAMA is the executive support of CSMA. It prepares federal environmental policy directives, drafts norms and regulations and issues resolutions and implementation guidelines to clarify or apply environmental laws. CONAMA is composed of the State Minister for the Environment, Hydraulic Resources and the Legal Amazon (President), the Executive Secretary of the Environment Minister (Executive Secretary), one representative of each ministry and secretariats of the Presidency and of IBAMA, one representative of each state and of the Federal District, a representative of each of the following entities: national federations of industry, commerce and agriculture, national federations of workers, Brazil Steel Institute, *Associação Brasiliera de Engenhieria Sanitária - ABES, Fundação Brasiliera para a Conservação da Natureza - FBCN, Associação Nacional de Municípios e Meio Ambiente - ANAMMA),* two representatives of legally established associations for the preservation of natural resources selected by the President of the Republic, and one representative of legally constituted associations for the defense of civil rights whose actions are linked to the protection of the environment in each region of the country.

49. CONAMA meets in ordinary sessions every quarter in the Federal District and exceptionally when called by its President or when requested by 2/3 of its members. CONAMA can divide itself into technical committees to examine specific issues raised during plenary sessions. The terms of reference, composition, functioning of the technical committees are to be agreed by the plenary session that decides to create them.

(iii) *Ministério do Meio Ambiente , dos Recursos Hídricos e da Amazônia Legal e a Secretaria do Meio Ambiente da Presidência da República* (Ministry of the Environment, Hydraulic Resources, and the Legal Amazon and the Secretary for the Environment in the Office of the President of the Republic).

50. The Ministry is responsible for providing support to CONAMA's Executive Secretariat and its Technical Committees. Its main functions are to:

⇒ Obtain the collaboration of staff from federal organisms and entities, the Federal District and municipalities for specific periods to work with CONAMA;

⇒ Ensure adequate technical support to CONAMA meetings and functioning of the Technical Committees;

⇒ Coordinate the exchange of information between SISNAMA's different bodies through SINIMA (*Sistema Nacional de Informações sobre o Meio Ambiente)*; and

⇒ Promote the publication of CONAMA's resolutions.

(iv) *Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis* - (Brazilian Institute for the Environment and Renewable Natural Resources) - IBAMA

51. IBAMA is the executor of the Government's environment policy. It is established as an autonomous entity by law No. 7735 of February 22, 1989. Its main functions are as follows:

⇒ Acts as CONAMA Executive Secretariat;

⇒ Translates into operational terms the federal Government's environmental policy and ensure its implementation;

⇒ Supports actions related to the conservation and recuperation of polluted areas;

⇒ Ensures compliance with environmental legislation, norms and directives and provide technical assistance to federal, state and municipal entities when needed;

⇒ Promotes inspection of activities involving the exploitation of forestry, fauna, flora and hydraulic resources;

⇒ Applies the penalties defined by law in cases which are beyond the competence of the states and municipalities; and

⇒ Promotes the development of environmental education.

52. IBAMA maintains offices in most states. These offices report administratively report to IBAMA's President and technically to the (Regional) Directors. Their main purpose is to implement the Institute's regional plans and programs, including:

⇒ Developing programs and activities aimed at specific problems and issues;

⇒ Analyzing, evaluating, and presenting to the central administration proposals submitted by diverse segments of society and by state and municipal public institutions;

⇒ Developing at the state level other activities of a technical nature within the Institute's areas of responsibility; and

⇒ Articulating, together with the *Secretaria de Planejamento e Coordenação*, the Institute's actions with those executed by state and municipal organisms.

(v) *Fundo Nacional de Meio Ambiente* (National Environmental Fund)

53. The fund was created by the federal law No. 7797 of July 10, 1989, with the objective of financing projects promoting the rational and sustainable use of natural resources, including the maintenance, betterment and recuperation of the environmental quality with a view to improving the life quality of the Brazilian population. The following types of projects are considered priority by the Fund: environmental education, institutional strengthening, pollution control, environmental research, preservation, and forestry management.

54. The resources of the fund come from the federal budget, donations, and other revenues as defined by law. The Fund is managed by the Office of the Presidency's Secretaria of the Environment under directives fixed by the Council of the Government..

(b) State Institutions

55. At the state level, environmental policy and management are usually defined by state laws. In Santa Catarina, the law No. 5793 of October 15, 1980 sets the objectives and priorities of the state's environmental policy and establishes the institutional framework under which it will be carry out. The law created FATMA and entrusted it with the responsibility of executing the state's environmental policy. FATMA is discussed in a separate report. The other major environmental institutions are briefly described below:

(i) *Secretaria do Estado do Devolvimento Urbano e Meio Ambiente* - SDM (State Secretary for Urban Development and the Environment).

56. With regard to the environment, SDM is responsible for the following:

⇒ Coordination, formulation, and implementation of programs and projects supporting ecological sustainability;

⇒ Formulation and execution of the state's hydraulic resources policy;

⇒ Defense, preservation and improvement of the environment;

⇒ Coordination and promotion of environmental defense and conservation campaigns;

⇒ Assistance to municipal development;

⇒ Basic sanitation; and

⇒ Integration of the State Government's environmental actions with those of the Federal Government and the municipalities through its specialized organisms.

(ii) *Conselho de Meio Ambiente* - CONSEMA (Environmental Council)

57. CONSEMA is a consultative body whose main objective is to direct the environmental policy of the Santa Catarina state. CONSEMA is located in SDM. Its main responsibilities are to:

⇒ Help SDM formulate the state's environmental policy and develop/adopt clean technologies;

⇒ Establish norms and criteria to control the effects on the environment of activities supervised by the state;

⇒ Define norms and procedures regarding environmental protection;

⇒ Suggest modifications or adoption of guidelines aiming at harmonizing the state's environmental policy;

⇒ Propose directives for the formulation, evaluation and execution of environmental programs and projects;

⇒ Disseminate measures facilitating the flow of environmental information at the local, municipal, state and federal levels; and

⇒ Approve resolutions and administrative processes within its competence.

58. The council is composed of (a) the State Secretaries of Urban Development and the Environment; Education; Health; Agriculture; Planning and Finance; (b) the Director General of FATMA; and (c) six members appointed by the Governor.

(iii) *Fundo Especial de Proteção ao Meio Ambiente* (Special Fund for Environmental Protection)

59. The Fund has been created to receive fines and other penalties imposed by FATMA to enterprises and other predators for damages to the environment. It is administered by SDM. Funds are used by SDM and FATMA to purchase office equipment, publications books and accessories for environmental education programs carried out by municipalities on criteria fixed by the State Secretary of SDM. Revenues collected in the Fund vary from month to month, between $R5,000 to $R10,000/month.

(c) Municipal Institutions

60. It is at the municipal level that community pressures demanding solutions to environmental problems are first felt. However, it is also there that the institutions are the weakest. Among Brazil's four thousands municipalities, only a few have agencies or departments specifically assigned to work on environmental issues.

61. In southern Santa Catarina, besides Criciúma, no municipality has an environmental department adequately staffed. The municipality of Siderópolis, for example, has only one person in charge of the environment, while environmental problems are enormous. There is an urgent need to

strengthen municipalities in environmental management at least to deal with the following environmental issues which could not be delegated to the states:

⇒ *Land Use Planning.* Only municipal authorities can decide the use of its territory and define the areas which will be reserved for parks, ecological protection and recreation uses and those where commercial and industrial activities are permitted. Although the Constitution requires a master plan for municipalities over 20,000 people, very few such municipalities have;

⇒ *Environmental Impact Assessment (Relatórios de Impacto Ambiental - RIMA).* This is another area where the municipality has to get involved as projects requiring EIA generally have significant impact on the population living in the project area;

⇒ *Control and monitoring of pollution.* Control and monitoring of activities with potential negative impact on the environment and the quality of life are also responsibilities that municipal authorities can not be delegated; and

⇒ *Mining Exploitation.* Given its significant negative environmental impact on the community and the need to ensure that the exploiting company recuperate the mined-out areas as described in its approved project, the involvement of the municipality is indispensable.

5.2 The Legal Framework

62. The main legal texts regulating mining activity from an environmental point of view are the following:

⇒ *CONAMA Resolution No. 01 of January 23, 1986 and Federal Decree No. 97.632 of April 10, 1989* which spell out in detail the environmental obligations of mining companies as stated in the article 2 of the 1981 Environmental Law. The decree requires new mining companies to prepare and submit for approval to the appropriate environmental authorities (i) an Environmental Impact Assessment (*Estudio de Impacto Ambiental - EIA*) and the corresponding report (*Relatorio de Impacto Ambiental - RIMA*); and (ii) a plan for recuperating the areas which have been polluted by mining activity. Existing companies are requested to submit that plan within 180 days. The CONAMA resolution enumerates the activities for which an EIA is necessary, establishes the criteria and norms for its preparation and defines the minimum technical requirements of the EIA. However, state and municipal authorities can supplement and/or establish their own norms. This is a potential area of conflict and/or duplication and confusion. Generally, state and municipal authorities only adapt the federal norms to suit their local situation;

⇒ *CONAMA Resolution No. 09 of December 3, 1987* which makes mandatory public consultation and participation (*Audiência Pública*) in the EIA process whenever deemed necessary by the environmental authority or requested by a public entity or by more than 50 citizens. The local environmental authority is responsible for organizing and conducting the consultation; and

⇒ *CONAMA Resolution No. 09 of December 6, 1990* which spells out the licensing requirements (*Licenciamento*) for all mining research and extraction (with the exception of quarries for extraction of construction materials). Three types of licensing exist, depending on the phase of activity: (i) *Licença Prévia* (LP) delivered at the research phase following approval of the EIA; (ii) *Licença de Instalação* (LI) required by DNPM when it grants the extraction concession following submission by the mining company of its Environmental Control Program (*Plano de Controle Ambiental* - PCA); and (iii) *Licença de Operação* (LO) delivered by the environmental authority when the concession and the PCA are approved. In practice, this Resolution establishes a good operational articulation between the technical work linked to mining licensing for which DNPM is responsible and the environmental considerations for which FATMA must ensure compliance.

5.3 *The Enforcement*

63. In Santa Catarina, FATMA is responsible for enforcing environmental regulations. It mainly focuses on environmental licensing and EIA to monitor and control the activity of the mining sector and other potentially polluting industries.

(a) *Environmental Licensing*

64. This task occupies about 42% of FATMA's staff. As discussed above, environmental licensing is required for all "installation and expansion enterprises whose activities are included in the list of activities considered potentially harmful to the environment". To obtain the required environmental licensing, an enterprise goes through the following steps:

- **First step: Completion of the FCE** (*Formulário de Caracterizaçao do Empreendimento*-Project Identification Form) which contains the basic information on the project such as: description of the project, localization, type of activity, production, inputs used, etc. The FCE is reviewed by FATMA which should approve it and recommend the project for the second step of the process;

- **Second step: Preparation of the OB** (*Orientaçao Básica*), which includes: identification of the promoter, the project to be licensed, type of licensing, completion of administrative procedures (documents required by the municipality, authorization of DNPM, publication of the licensing request as per CONAMA resolution 006/82 of January 24, 1986, etc.), environmental impact assessment (EIA), if required and a pollution control plan to be prepared according to FATMA's guidelines. Coal mining projects involving extraction, beneficiation and use of coal should also submit an *Instruçao Normativa IN 01* which describes in detail (i) geological and geotechnical surveys done to help assess the risks of underground water pollution; (ii) surface water drainage system to be used in the project; (iii) proposals to collect, remove and treat underground mining water; and (iv) transport and disposal of wastes; and

- **Third step: Granting of the environmental licensing**. It is done by FATMA following a careful review of the request and related documentation (including EIA) and inspections and site visits to the project area. The inspection and control by FATMA do not exclude those of the municipality or other state and federal organisms. The licensing is always conditioned on the company realizing the project according to an agreed timetable and on its compliance with environmental regulations.

(b) *Environmental Impact Assessment*

65. Although municipalities are also allowed to conduct EIAs, these are normally carry out by FATMA with the assistance of the municipality concerned. By law, an EIA must include, *inter alia*, the following elements:

◊ Comprehensive survey of existing scientific literature and adequate legal reference, field work and investigation, and detailed lab analysis[2];

◊ Definition of the geographical limits of the project's direct and indirect impacts. In any case it should include the whole river basin where the project is located;

◊ Compatibility and consistency of the project with Government's plans and programs (CONAMA Resolution No. 001/86);

◊ Ex-ante study of the project area (before establishment of the project) covering the physical, biological (the natural ecosystems) and socio-economical (environmental diagnostic of the area) aspects (Decree No. 88-351/83 and Art. No. 6 of the Resolution 001/86). An initial description of the project site is an important element to objectively assess the merits of the project by comparing the with and without project situations;

◊ Identification and evaluation of all the possible impacts (positive and negative; direct and indirect; short, medium and long terms, temporary and permanent, their degree of reversibility as well as their cumulative or synergetic characteristics;

◊ Description of proposed measures aimed at correcting or mitigating the negative impact on the environment. CONAMA Resolution No. 0011/85 stipulates that the EIA should spell out the remedy measures, including a description of the control equipment and effluent treatment systems, together with an evaluation of their efficiency;

◊ Inclusion of proposed compensatory measures;

◊ Prevision of measures in case of catastrophe; and

◊ Estimation of the social costs and benefits. It is extremely important from a social point of view to know what segments of the population are going to benefits and which ones are going to lose as a result of the project.

66. The EIA should be done by a multidisciplinary team independent from the project sponsor. The team is technically responsible for the conclusions of the work.

67. As discussed above, by law, the public can follow, or assist in, the work of the EIA team to the extent that its participation does not affect the industrial secret to which the sponsor company is entitled to protect. In addition, the RIMA is widely advertised and published in the State Official Journal, as well as in a major regional or local newspaper. Access to EIAs is a constitutional right of the Brazilian citizen.

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[2] RIMA (*Relatorio de Impacto Ambiental*) is the report which summarizes the analysis and conclusions of the EIA. As such, RIMA is less comprehensive than EIA.

68. EIAs are prepared in two phases. *At the Comment Phase*, any person, institution, environmental association, or public ministry can make written comments to the team on the work being carried out.. *At the Public Audience Phase*, the preliminary results of the EIA are presented to the public in a meeting organized by FATMA. The comments (officially recorded) will be used by FATMA, together with the RIMA, to make a decision with regard to the project. The public audience is the last step in the EIA process.

69. For large projects, FATMA requests EIA with consultations with the affected communities in public audiences. It is also FATMA's policy to require EIA for all coal mining projects although none has been done so far since there is no new mining project since the EIA requirement was instituted in 1986. In 1995, FATMA requested the preparation of EIA for nine projects, including two gas projects, four road construction projects, a beer factory (Antártica), a tourism project (Porto da Barra da Lagoa da Conceiçao) and a hydroelectric project. For small projects, FATMA only requests a simplified form of EIA.

6. Technical Characteristics of Mining Operations

6.1 Open Cast Mining

(a) Characteristics of Mining Areas

70. Mechanized mining started in the Sidcrópolis area with open cast mines first by the *Companhia Siderúrgica National* (CSN) and then by Treviso, a privately owned company (Figure I-1). This type of mining was done in flat areas in the vicinity of rivers where the overburden rarely exceeded 30 m in height. The overburden was entirely extracted by shovels after blasting. All waste materials were dumped on the spot. The coal extracted was transported by trucks to the preparation plant. The method used was strip mining without any reclamation and generated a "lunar landscape" as a result of the waste piles.

71. In 1959, CSN decided to improve its production by introducing a heavy dragline MARION with a 23 m^3 bucket and 70 m of disposal arm length. This equipment was responsible for the devastation of more than 1000 ha of fertile land in CSN's 30 years of coal exploitation in the region.

72. The private company Treviso Coal Co. was also responsible for the destruction of a vast area. At that time, environmental regulations were non existent and no consideration was given to site remediation in mining projects. The areas were acquired by the mining companies which had no obligation to remedy the mined land. All the areas available for open cast mining were completely mined out, except for some strips of land located in areas of high topography where the overburden raised

abruptly, making surface mining difficult.

73. The areas where surface mining is possible rarely exceeds 60 m wide and are located along the sides of small valleys formed by natural drainage. Generally, at these locations, the rocks forming the overburden are partially altered, allowing the use of standard earthwork equipment. These areas are generally small and dispersed, making difficult to concentrate mining operations. They are also divided into small rural properties and are located in areas where woods and water sources still could be found.

(b) Equipment and Technology

74. The characteristics of the areas suitable for open cast mining generally do not justify heavy mechanization. The equipment used generally consists of bulldozers which perform the overburden removal and 2 m^3 bucket back excavators which extract the coal, loading it directly into dump trucks which transport it to the preparation plants. This extraction process is selective, taking the coal and rejecting the interburden or the sterile part between coal seams. (Figure I-2)

75. When explosives are necessary, a rotative drill is used. That machine is powered by a gasoline motor and is called CARDOX, which drills horizontal holes with 4.5 inches in diameter and up to 15 m long working over the top of the coal seam. Usually, nitroglycerinade explosives are used to break the rock and permit the bulldozers to do the work. This operation significantly raises the extraction costs.

76. Treviso is the only company which disposes of adequate equipment for surface mining. However, its Barro Branco reserves (the uppermost coal seam) are almost exhausted, forcing it to exploit its Bonito seam (the bottom coal seam) in its coal concessions in Lauro Müller. The equipment owned by Treviso are one MARION 5323 shovel excavator with 20 cyd bucket, a Bucyrus Erie 180 W dragline with 6 cyd bucket dragline, a Bucyrus Erie 54 B dragline with a 2.5 cyd bucket, some FIAT S-90 back excavators with 2 m^3 bucket and also some rear dump trucks for coal transportation to the preparation plant.

(c) Economic Aspects

77. Surface mining represents today less than 15% of the total coal produced in Santa Catarina and is practically all done by Treviso which possesses the necessary equipment for surface mining. Also, a few small contractors mine the Barro Branco seam in the Carbonífera Barro Branco concessions with their own earthwork equipment. In these cases, the concessionaire still takes legal responsibility for mining activity.

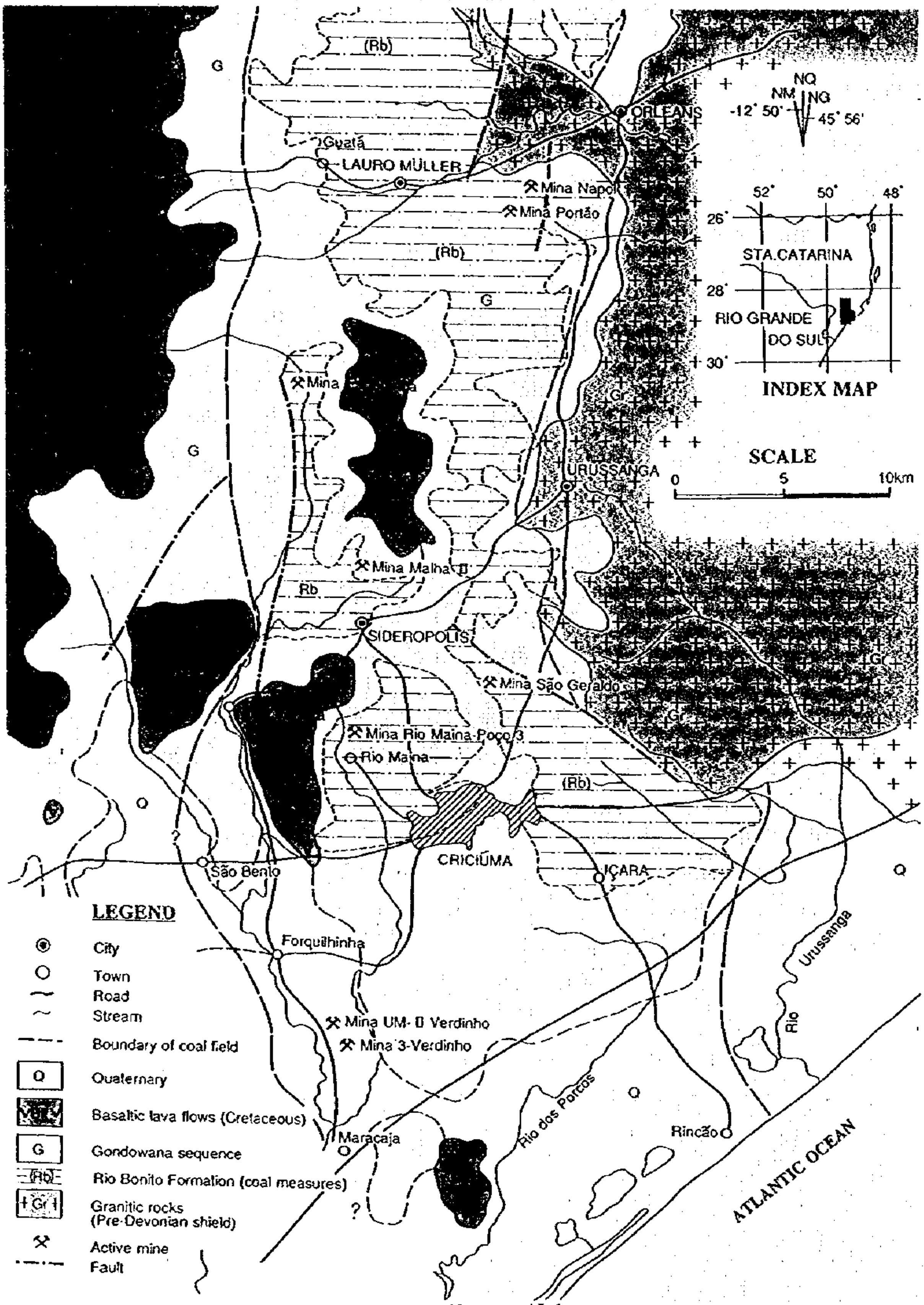

FIGURE I-1

SANTA CATARINA COAL FIELD

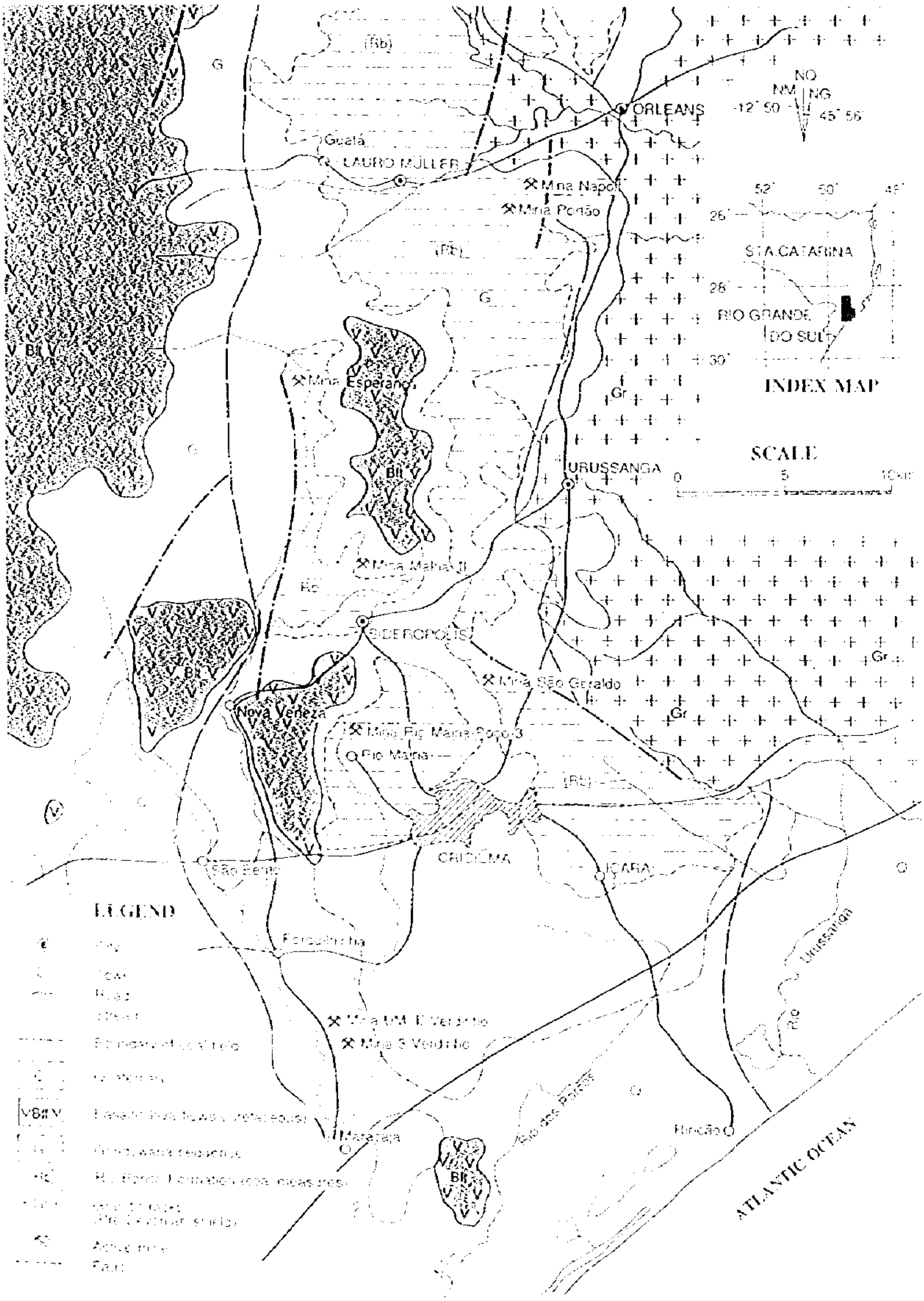

FIGURE I-1

SANTA CATARINA COAL FIELD

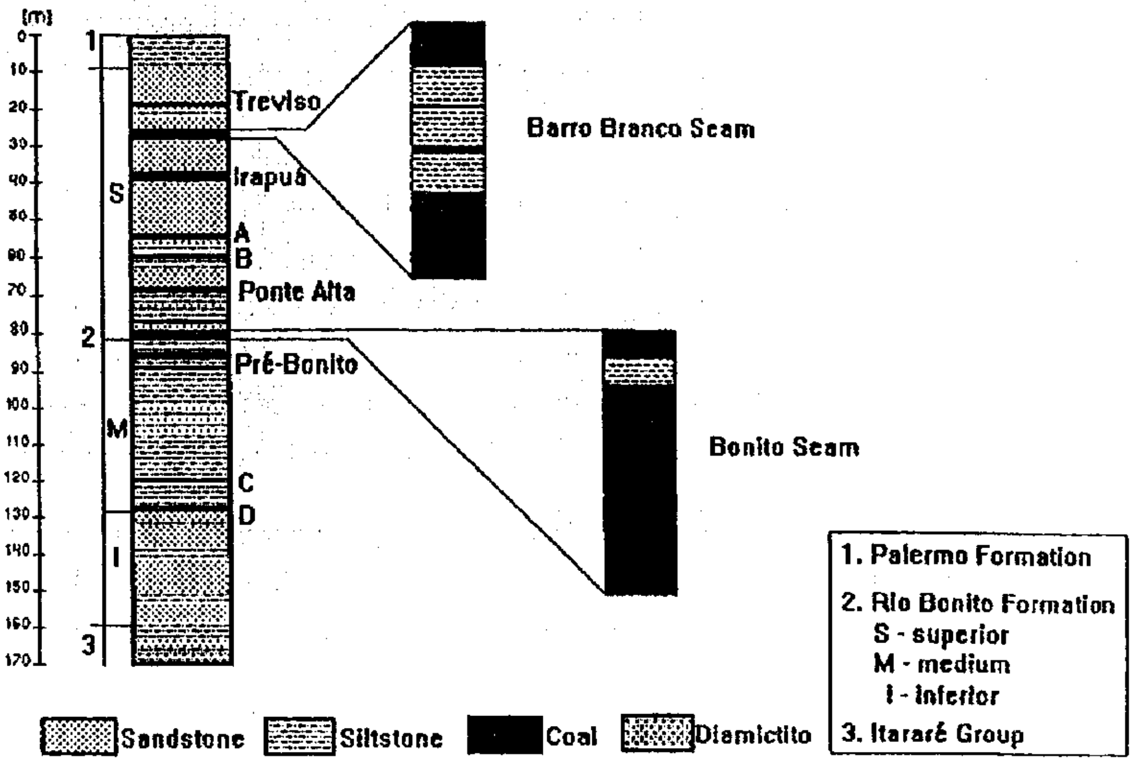

Figure I-2

Geological Profile of the Rio Bonito Formation

78. This type of mining is only profitable in low overburdens (less than 15 m), located near preparation plants and using already depreciated equipment.

6.2 Underground Mining

(a) Characteristics of Mining Areas

79. Underground mining takes place in the eastern part of the Paraná basin which is formed by gondwanic sequence. The main coal deposits: Barro Branco (upper seam), Irapua (middle seam) and Bonito (lower seam) are intercalated with Permian silt stones and sandstones in the superior portion of the Rio Bonito formation. The basin is elliptical in shape and is delineated on the West side by the Serra Geral hills, on the East side by the littoral elevations formed by Pre-Cambrian rocks, and on the South side by the Quaternarian plains.

80. The coal field is approximately 60 kms long and 20 kms wide. The coal beds show an average slope of one degree toward SE. There are regional faults in a regular pattern in two main directions: NE - SW and NW - SE. Subsequently, the region was affected by "trapp" type volcanism at Triassic age which generated extensive lava spreading which formed the Serra Geral hills. The lava intrusions cut coal seams forming dikes and sills, destroying or disturbing the coal in some portions of the basin. This volcanism is also responsible for the actual coal ranking, varying from high to low volatility.

81. The geologic structure makes it possible to find outcrops alongside the eastern side of the coal basin, and to have the Barro Branco seam 70 m above sea level on the North in Treviso and 70 m below sea level on the South in Criciúma. The fault pattern formed individual blocks which have different dips and strikes.

82. The geological structure is comparatively simple on the South side and more intricate on the Northeast part of the coal basin. The erosion dug deep valleys at hillside, and shallow ones at Siderópolis where intensive surface mining were conducted. In Criciúma, the coal seams are mainly extracted by underground mines. Surface mining is possible only in lifted blocks on the east part of the basin.

83. Although these deposits have been exploited for a long time and were the subject of many exploration projects by CPRM (*Companhia de Pesquisa dos Recoursos Minerais*), they are not very well known, particularly with regard to their origin and deposit patterns. Of all the drills carried out, only one reached the bottom without revealing the characteristics of the paleo relief. Given the lack of information and the near exhaustion of the Barro Branco seam, further research is necessary to:

=> Know better the areas West of the current mining areas;

=> Define the factors conditioning the sedimentation of the coal seams;

⇒ Define the erosion patterns in the region;

⇒ Identify the structure of the base rock and the thickness of the sediments; and

⇒ Find a possible link between the coal deposits in Santa Catarina and those in Rio Grande do Sul.

(b) Access to Coal Seams

84. Access to underground seams is done through galleries of medium slope from the outcrops along the high wall exposed after surface mining, or through inclined shafts or vertical shafts appropriately located from the surface to reach the deepest points of the deposit. The coal extracted is transported through belt conveyors installed in the galleries on the inclined shafts. The vertical shafts are usually used for ventilation and drainage. It is only at the Verdinho mine of Carbonífera Criciúma that the shaft is equipped with a hoisting system and cages allowing the transportation of materials and people.

85. The vertical shafts generally do not exceed 120 m in depth and are round in shape with diameter ranging from 4.50 m to 6.0 m. The walls of shafts are usually reinforced by concrete in the vicinity of their mouths where rocks are loose and the remaining part is supported by roof bolting. Most shafts are square with wooden support. A few ones are entirely made with concrete.

86. The size of the inclined shafts varies between 5.50 m to 6.50 m wide and between 2.20 m to 2.60 m high. The support is generally made of wood or concrete in the rectangular sections and of metallic arches in the semicircular sections. The inclinations vary from 10° to 16° in order to permit conveyor belt haulage. Only a few inclined shafts have concrete floors.

(c) Transportation of Workers and Materials

87. The transport system used in underground mines varies little between companies, given the general use of jeeps for the transportation of light materials and emergencies and of agricultural tractors (*Tratóres Transportadores Agricolas-TTAs*) with carts for the transportation of heavy materials. For conveyor belt assembling/disassembling and hauling, TTAs equipped with hoists are generally used. Miners usually walk from mine mouth to the mining face in distances which vary from a few hundreds meters to a few kilometers. Given the long distances, this practice forces the companies to pay for the extra time it takes to arrive at the working face so that miners actually work the regular six-hours/day.

88. Mining companies in the region also use electric locomotives for the transportation of materials and workers. However, this system presents more risks of accident due to the use of trolley wires of 380V DC to power the locomotives. In addition, the particularities of the inclination of the seams limit their flexibility and require the additional use of hoists in the inclined shafts.

(d) Mining Techniques

89. The mining method currently used is "rooms and pillars without pilar extraction." The extraction methods adopted are "conventional equipment" (full mechanization) and semi- mechanization with bobcats. Five out of the six mines in operation use bobcats and the last one uses conventional equipment. The Fontanella mine owned by Metropolitana will start production with LHDs instead of using loaders and shuttle cars.

90. The conventional equipment appears to be a more productive and economical method and is well adapted to the extraction conditions existing in the Barro Branco seam. However, it requires good organization and technical expertise in the company due to complexity of the equipment combination.

91. The semi-mechanized method with bobcats contributed to a productivity improvement in mines which were so far operating manually. However, this only represents a first step toward a full mechanization of mining operations, which was not achieved due to the general lack of investment funds and the inability of some companies to master the problems related to the complexity of the mechanization method. A natural evolution of the semi-mechanization method would be the use of LHDs. This was the mechanization pattern in the US and South Africa and appears to be perfectly adapted to the mining conditions in the Santa Catarina's deposits.

92. Mining is an highly technical activity. However, there is a general lack of planning and R&D in Santa Catarina's mining companies to such an extent that improvement of production processes becomes more difficult, if not impossible.

93. The need to exploit the Bonito seam (given the near exhaustion of the Barro Branco seam) requires an intensive research effort to identify the geological and mechanical characteristics of the seam in order to determine the possibilities and types of mechanization. Available information indicates (i) the possibility of mechanical extraction without blasting; and (ii) a major difficulty with roof support due to the height of the seam (up to 4 m) and the type of rocks which makes its roof. These are in addition to the already known difficulties of washing this coal in order to obtain a product with less than 50% ash.

<u>Blasting and Transportation Methods at Mining Face</u>

94. Coal is blasted by explosives. The consumption of explosives varies from 100 g per ton of ROM (Run of Mine) coal in conventional mines to 330 g/t in semi-mechanized mines which do not use coal cutters before blasting and practice what is called "*Fogo no Duro*." The explosive used in most mines is dynamite. CCU (*Companha Cabonifèra de Urussanga*)is the only company using emulsion-type of explosives developed with an explosive producer. This explosive does not have the same performance as nitroglycerinated explosives, but is economical and results in a lower extraction cost. The

use of explosives is determined by the characteristics of the Barro Branco seam which presents a high mechanical resistance due to the quantity of gray shale layers sandwiched between coal layers in the seam. The Bonito seam is different. It does not have as much intercalation, which makes possible mechanical extraction. Tests recently made by Metropolitana at the Fontanella mine show the viability of using "continuous miners" as principal mechanization in the Bonito seam.

95. Ignition of explosives is done with a fuse connected to a non-electric primer No. 8. This method is used without exception in all the mines of the region. Time delay between explosions is given by different length of the fuse. Despite the risks involved, this method still constitutes the most efficient and economical solution. Thus, the only innovation made in recent past consists in the partial substitution of the fuse with electric wires connected to a resistor capable of igniting the fuse. This solution was adopted by CCU, resulting in a reduction of the ignition cost and a diminution in the generation of gases in underground mines. This is a home made solution which needs to be tested and thoroughly analyzed to determine its safe utilization.

96. With regard to coal extraction techniques, there is a need to study more the following aspects:

⇒ Optimization of fire plans, including blasting pattern;

⇒ Development of non nitroglycerin-based explosives;

⇒ Economical alternatives to non electric detonator use;

⇒ Mechanical effects on the immediate roof rock by blasting; and

⇒ Use of mechanical extraction without explosives.

97. Blasting is an important step in mining extraction which merits more attention, given the fact that it is one of the most expensive and potentially dangerous phases and one of the least developed in Santa Catarina's mines.

98. Explosions produce many undesirable effects in the underground mine, including gas generation and roof disturbances. Another aspect to consider is the cost involved in activities such as cutting and drilling, which are integral parts of blasting.

99. Conventional mines use coal cutters, which make cuts in the lower third of the coal seam before drilling, generating a new free face and facilitating the effects of blasting. The dimensions of the cuts are generally 0.15 m high, 6.00 m wide and 2.70 m depth. In fully mechanized mines and in some semi-mechanized ones, drilling is done by hydraulic rotary perforating machines, which make holes with 42 mm in diameter and depth varying from 1.2 m to 2.8 m. Some semi-mechanized mines still use pneumatic manual drilling machines such as RH-571 Atlas Copco model with an integrated rod and bit

(not attachable) adapted to these mines. A metal pastille bit is taken off from rods and a newly cut edge of the rods is forged into a new bit for coal face drilling. This practice permits the reuse of bits already used in roof rock drilling.

100. In conventional mines, extracted coal is loaded by gathering arm loaders (Joy 14 BU type) and transported by shuttle cars (10 SC 22 B Joy type) through a distance of about 80 m to a belt feeder breaker which breaks the large blocks and discharges it into the belt conveyor. A typical conventional equipment consists of two loaders and three shuttle cars. The panel entries are formed by 9 to 11 parallel galleries of 6.0 m wide, interconnected by transversal galleries (crosscuts) which form square pillars of 7 to 15 m in width.

101. In semi-mechanized mines, loading and hauling are done by bobcats which collect coal at the mining face and discharge it directly into a belt installed in a nearby crosscut to reduce the bobcats' travel time and improve productivity. In some mines, bobcats are replaced by a equipment made in the region, based on the original bobcats, but with a larger bucket and faster and better maneuverability. This equipment, called MT-700, was developed by CCU and currently operates in the São Geraldo mine. The new machines permit a productivity gain since they have buckets with a capacity of 850 kg compared with 300 kg for bobcats. The typical panel in semi-mechanized mines consists of 11 to 17 parallel galleries with width between 4.5 and 5.5 m, interconnected by crosscuts with square pillars of seven to 15 m.

102. The productivity obtained in mechanized mines reach 250 tons per hour worked, against 120 t/h in semi-mechanized ones. In 1986, labor productivity was 6.2 to 9.9 tons of ROM coal per man-shift in mechanized mines and 2.6 to 7.1 tons of ROM coal per man-shift in semi-mechanized ones.

ROM Coal Haulage

103. In all mines, the conveyor belt system is used for coal transportation. The rope conveyor and tubular conveyor types are generally used because of their versatility in assembling and disassembling works. The width of the conveyors ranges from 36 to 42 inches and the speed varies from 1.5 to 2.5 m/s. Conveyors are mounted with one or two engines and are operated by a single operator who stays the whole shift at the conveyor head to deal with possible problems. Carbonifera Criciuma modified this system by introducing a remote control system based on camcorders and TVs strategically located to replace human supervision, thus saving on manpower. The system has been operating for two years at the Verdinho mine and constitutes a viable alternative for reducing extraction costs. The conveyor belt system brings the coal at mine mouth through inclined shafts or slope galleries. There, the coal is unloaded in piles of ROM coal from where it goes to feed the crushing and preparation plants.

Roof Support

104. Phase essential in the extraction of coal, roof support has, however, been an area of little development in the region. Most mines still use manual stoppers for roof drilling, which make the operation both dangerous and expensive. As a crucial step in the coal production process, roof support is a determinant factor of production because of the time-consuming nature of this activity.

105. The system used is steel roof bolts chemically anchored with polyester resins and wooden blocks or steel plates tensioned at between 10 to 15 kg per meter in toque. Introduced in 1986, this system is now adopted by all the mines in the region. The wooden blocks or steel plates work as tension distributor to the roof and as retention of small blocks which tend to fall. The function of these roof bolts is to reinforce the rock layer and minimize its deformation. Roof strengthening also maintain the galleries clear for easy movement of the equipment.

106. Wooden props are also used for roof reinforcement at unstable spots. The bolting density varies from mine to mine, even within a mine, but is in the range of 0.5 to 1.0 bolt per square meter. Mine roof is formed by massive silt stones or sandstones but, predominantly by laminated silt stones.

107. Roof control and optimization of roof support operations are currently mining experts' main focus of attention because the best coal extraction spots tend to be located in areas of unstable roof.

Coal Pillar Design

108. Virtually unknown until the end of the 1980s, pillar design became crucial since 1990 when DNPM prohibited pillar extraction. Pillar extraction, largely practiced until then, was mainly responsible for the pollution of surface water, the principal source of water supply in rural areas.

109. That issue was studied by the Technological Foundation of the Rio Grande do Sul state (CIENTEC). The objective was to determine the characteristics of Brazilian coal, as well as their roof and floor with a view to improving pillar design and utilization. The analysis of pillar failure cases as well as good pillar design cases, coupled with lab and in situ tests, resulted in the development of a methodology of pillar design adapted to Santa Catarina's deposits. The shallowness of the seams in the region, coupled with a pillar design tailored to the needs of Santa Catarina's mines, permitted a rational extraction of the seams without undue risks for surface water reserves and above ground structures.

110. Research on pillar reinforcement is currently being undertaken by Carbonífera Metropolitana and CIENTEC to determine the economic viability of exploiting deposits in 300-500 m in depth. This would substantially increase the coal reserves of the company.

(e) Mine Ventilation

111. One of the major myths (may be the most dangerous one) spread in the region regarding coal exploitation in Santa Catarina is the non-existence of methane gas in Brazilian coal mines. Given that belief, mine ventilation has been dismissed as a secondary issue by most mining companies. As a result of this negligence, nothing prevented a gas/dust explosion in the mine Plano II of CCU in Santana which killed 32 miners in 1984. Since that tragic accident, the authorities and mining companies have acted more effectively to better control ventilation in the region's mines. Besides the improvement of ventilation systems and fans, new rules and procedures were established for monitoring the presence of methane gas and norms were set for minimum acceptable levels of fresh air in mining faces.

112. Another important measure taken at that time to improve the ventilation conditions in underground mines was the obligation imposed by the Ministry of Labor and DNPM to suppress dust by spreading water during drilling activities. The dust suppression by water during drilling and the improvement of ventilation may result in a decrease in lung and other respiratory diseases in mining workers in Santa Catarina.

113. Ventilation in Santa Catarina's mines is made by suction, with the main fans installed on surface connected to return air entries. Air enters mainly through shafts or inclines and circulates in the mine through a system of fences built with bricks or cement plastered on one side, thus closing crosscut and forcing the air to move to the mining face. At proximity of the mining face (normally the last three crosscuts), the fences are made with plastic fixed in wooden structures, so that they remain flexible and can resist strong displacements of air caused by blasting.

114. Ventilation control is done through periodical visits, with visual inspections and air quality measurements in predetermined points along the circuit and at the mining face. Since 1986, following the explosion in the Santana mine, presence of methane gas is monitored daily per DNPM's instruction and the results sent to DNPM on a monthly basis. Other information on ventilation is noted in an appropriate register placed at mine mouth.

115. Other parameters of air quality, such as temperature, humidity, concentration of gases and dust, etc., are not controlled and therefore not taken into consideration in the design of ventilation in the mines.

116. In 1995, together with mining companies, SIECESC (*Sindicato das Indústrias de Extração de Carvão do Estado de Santa Catarina*) initiated a study on underground mining safety aimed at: (i) exchanging relevant experience among mining companies; (ii) determining the region's needs in mining safety; and (iii) finding adequate solutions. However, as a result of the tight financial situation in most

mining companies, many of the working group's recommendations and measures were not implemented. The continuation of the group's work was also affected by the sector's bad financial situation.

(f) Drainage and Effluent Disposal

117. All mines in activity today, with the exception of CBCA's No. 3 mine, which started production in 1990, have experienced land subsidence because of pillar extraction. Through these collapsed areas, large amounts of water get in the underground, polluting aquifers. The quantity of water drained by the mines varies significantly from mine to mine, depending on the size of the area already mined and the extent of the pillar extraction in each mine. It ranges from 2,000 m^3/day to 9,400 m^3/day (the Nova Próspera mine reaches 15,000 m^3/day).

Table I-7

Mine Water: Environmental Standards and Actual Situation

	Values Observed			Standards
pH	2.44	to	5.52	6.0 to 9.0
Solid waste (mg/l)	1925	to	1965	- *
Acid (mg/l $CaCO_3$)	102	to	905	-
Sulfate (mg/l)	1056	to	1126	1.0
Fe (mg/l)	36.87	to	89.82	15.0
Mn (mg/l)	5.11	to	5.83	1.0 **
Cu (mg/l)	0.059	to	0.19	0.5
Zn (mg/l)	0.00	to	2.85	1.0
Pb (mg/l)	0.00	to	0.00	0.5

* Sedimentable solid up to 1.0 ml / l in assay of one hour using the "Imhoff cone" method
** Mn^{+2} soluble

118. Part of the drained water is used in coal washing, part of it in dust suppression, and the rest (a large part) is pumped from the mining face to local pump stations often located within the underground working area itself and from there collectively to the main pump station and then to the ground.

119. The quality of the drained water is monitored on a monthly basis by the companies as stipulated in the Environmental Operating Permits (*Licenças Ambientais de Operação*) delivered by FATMA (*Fundação do Meio Ambiente*). The table I-7 above shows the range of values obtained directly from the companies:

(g) Financial Aspects

120. The financial analysis of underground coal mining is a complex matter because of the diversity of materials and services involved in the extraction process and because of wide range of

conditions prevailing in the different mines, as well within the same mine. Below is an estimate of the operating cost of a mechanized mine in difficult mining conditions. The calculation is made on the basis of a ROM coal production of 74,375 tons, which yields a CE 4500 production of 21,922 tons, given a recovery rate of 29.41%.

Table I-8

Typical Cost Structure of Santa Catarina's Mining Companies

	R$/month	R$/t ROM	R$/t CE 4500	%
Materials	285,108	3.83	13.00	34.77
Labor	336,210	4.52	15.34	41.03
Energy/water	81,100	1.90	3.70	9.90
Taxes	51,956	0.78	2.64	7.06
Overhead	37,270	0.50	1.70	4.55
Other	22,126	0.30	1.01	2.70
Total	819,770	11.02	37.39	100.00

Sale Price CE 4500: R$ 39.76/t.
Operational Result: R$2.37/t (5.96% of sale price)

6.3 Coal Washing

121. For a long time, coal washing was considered a secondary activity in the extraction process. Coal production was concentrated on CPL (*carvão pre-lavado*, or pre-washed coal), which was sent to the preparation plant at Capivari for washing and separation between metallurgical coal and steam coal. Coal fines recuperation only started in 1973. For more than 50 years, this product was discharged improperly polluting most of the region's river system.

122. At present, washing is a major activity since the loss of this product in the production process reduces profitability. Many enterprises specialize in only washing old coal waste generated by mining companies. They get enough coal out of the waste to make it a profitable activity.

123. Washing of the Barro Branco coal has been done since the 1960s when CSN built its first metallic jig in Siderópolis based on a design by American McNally. Since then a dozen jigs were made in the region as copies of the original McNally. In 1972, the federal government program for the mechanization of the Santa Catarina's mines also included the modernization of the washing plants. It was also at that time that the first Batac jig was imported from Germany by CBCA. It is still in operation.

124. The new mines established since 1980 and financed by a Government program called PME (*Programa de Mobilização Energética*) introduced a Polish technology, which is to this day still being used by most mines.

(a) *Main Technologies Used*

125. The washing technique used in Santa Catarina is gravimetric separation by jigs. The region has small washers with a capacity of 100 to 200 t/h made of wood, which are copies of the original McNally, as well as larger ones (500 to 600 t/h) made with steel and supplied by KOPEX, a Polish manufacturing company. These plants are all Baüm jigs. There is also a Batac jig of German technology supplied by Humdbolt -Wedag with a capacity of 500 t/h operating in the CBCA mine.

126. Currently, there are two inactive jigs: (i) a Baüm-type jig of 350 t/h capacity which will be used by Fontanella for washing the coal from the Bonito seam; and (ii) another Baüm jig installed in the A Sangão mine with a capacity of 600 t/h. Another Batac jig (500 t/h), which was used by ICC (Indústria Carboquímica Catarinense) for the concentration of pyrites, has been already dismounted.

(b) *Products and Recovery Rates*

127. Following the abolition of the requirement for the Brazilian steel industry to use local coal, mining companies switched to the production of the CE 4500 coal with 42% ash for use by the Jorge Lacerda thermoelectric power plant in Capivari de Baixo. This represents the main product of the region's mines. Other products include coal with ash content between 32% and 35% (CE 5200) which are sold to the cement, ceramic and food industries.

128. The flowsheet as illustrated in Figure I-3 shows the washing process. The coal characteristics and recovery rates of the main products are shown in Table I-9 below:

Table I-9

Recovery Rates and Ash Content

	t/h	Recovery (%)	Ash Content (%)
Coarse Coal			
Feed	3500	100.0	64
Waste R1	1166	33.3	81
Waste R2	808	23.1	81
Fines	424	12.1	58
CE 4500	1102	31.5	42
Fine Coal			
Feed	424	12.1	58
Waste	126	3.6	--
Mixes	56	1.6	45
Recirculated	161	4.6	--
Products	81	2.3	--

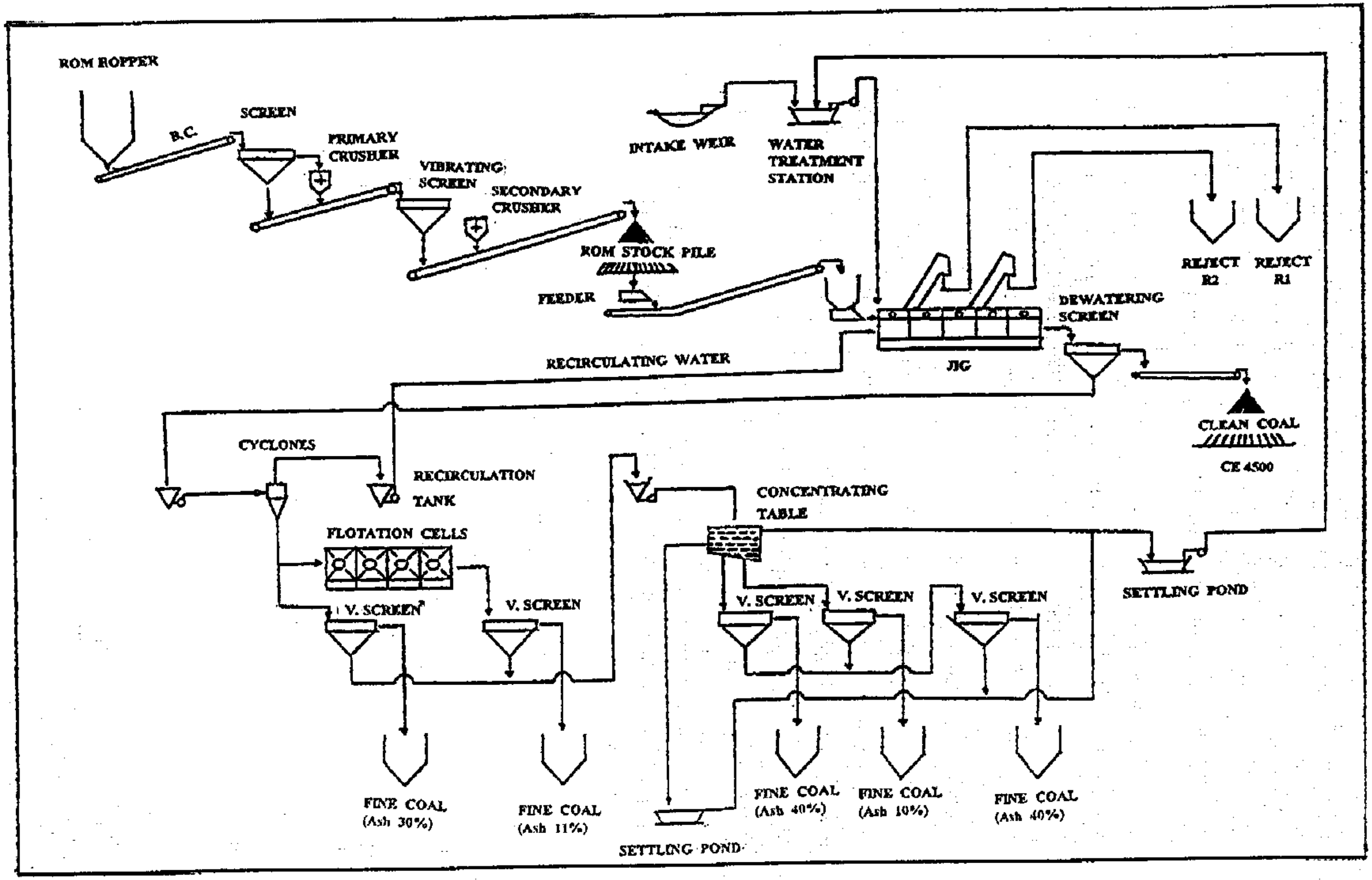

Figure I-3 Coal Washing Flow Chart

(c) Transportation, Handling and Storage of final Products

129. Coal produced for thermoelectricity generation (CE 4500) is stored in areas next to the washing plants in piles of 1,000 tons while waiting for analysis. Samples are collected by SATC (*Sociedade de Assistancia aos Trabahadores deo Carvão*) staff and analyzed in SATC lab. Following analysis, a certificate is issued indicating the coal qualities and giving clearance for delivery. The coal is then shipped by train or truck depending on the location of the mines to Caprivari de Baixo. Rejected coal are blended again and undergo another analysis.

130. The other products are stored in piles close to the washing stations or preparation plants waiting to be sold. These products are essentially CE 5200 and fines. The storage areas are generally located in well-drained and easy access places. Fine coal is usually stored in covered areas to reduce moisture.

131. Besides good drainage, the storage areas do not include any other measure to protect the environment. Transportation is made by dump trucks, which are allowed on federal and state roads provided that they are properly covered with sailcloth to avoid spilling any liquids on the road.

7. Environmental Aspects of Coal Mining Operations

7.1 Solid Waste Disposal

132. The way mining companies dispose of solid wastes is to stack them in piles and dump them in mined out areas, or in flat areas near washing plants. The regulation and control of waste dump areas as well as the methods of disposal, reclamation and revegetation have been defined in 1984 by ZETA and International Engineering SA, two consulting firms contracted by the mining companies. The work was done to comply with SEMA (*Secretária Especial do Meio Ambiente*)' s regulations concerning disposal of solid waste and treatment of effluents.

133. However, implementation of the project was extremely simplified. Some important measures were dropped, such as: (i) the obligation to treat the water leaching through the waste piles (deep drainage); (ii) the use of clay for impermeabilization; and (iii) the requirement to compact layers of waste with compactors. The regulation with regard to surface drainage was significantly simplified. On the other hand, the placement of waste in piles and the requirement to bench it every 10 m high were respected. In some cases, waste with clay recuperated from decantation ponds is used to make waterproof between lifts of waste, in substitution for clay. Compaction of waste piles is only done to facilitate the traffic of trucks which transport materials for the dump area. The slope angle of the waste piles is not

defined. Some companies shape the slope at less than 24° by bulldozers. Others leave it at the natural disposition angle (about 40°). The disposal method is called "*ponta de aterro*".

134. The final treatment consists of recovering taluses with clay. In some places, grass is planted; in others, taluses are simply covered with top soil containing roots and seeds, providing for spontaneous revegetation. Some companies plant eucalyptus trees on the taluses to reduce erosion. However, DNPM is now advising companies not to plant eucalyptus as their deep root systems tend to destroy impermeable clay layers. Steps or channels in concrete or made with sand are built to allow evacuation of rain water to the main drainage system.

135. In principle, inspection of waste disposal is the responsibility of the engineer of the washing plant with the assistance of the company's environmental staff. However, no environmental specialists have ever been employed in any of the mining companies. Control is rare and only focuses on drainage aspects. There is practically no control or monitoring of the structure or stability of the waste piles.

7.2 Effluent Disposal

136. Water from coal washing and storage, waste piles (generated by rain), as well as underground mining activities is sent to the decantation pond near the preparation plant. The various uses in the mine (washing activities, dust suppression during drilling, etc.) could not absorb all that water and the excess, which varies from company to company and ranges from 40 to more than 600 m^3/h, is discharged mostly untreated, contributing to the severe pollution of the region's rivers, particularly the Urussanga and Araranguá river basins.

Table I-10

Washing Plant Effluent Discharge: Environmental Standards and Actual Situation

	Observed Values			Standards
pH	2.940	-	3.390	6.0 - 9.0
Solid Waste (mg/l)	3.457	-	4.895	-*
Acid (mg/l $CaCO_3$)	452.2	-	1.470	-
Sulfate (mg/l)	2.159	-	3.044	1.0
Fe (mg/l)	108.1	-	311.6	15.0
Mn (mg/l)	11.16	-	16.86	1.0**
Cu (mg/l)	0.054	-	0.120	0.5
Pb (mg/l)	0.000	-	3.429	0.5
Zn (mg/l)	0.000	-	9.220	1.0

*Sedimentable solid up to 1.0 ml/l in assay of one hour using the Imhoff cone method.
**Mn^{+2} soluble

137. The quality of the wastewater discharged into the ground and river system is monitored regularly by the mining companies as stipulated in the Environmental Operating Permit.

138. The wastewater from the washing plants is channeled to the decantation pond for fine coal recuperation. Solid wastes in the water are settled before the water is discharged into the river system. In some cases, the decantation ponds function as filters where the water permeates leaving only the solid waste in the ponds. Some companies dispose of the solid materials remaining in the decantation ponds by dragging them together with coarse waste. Others cover the materials in the ponds with clay for revegetation and build new ponds for use. However, given the difficulty to find space for waste disposal, companies now tend to drag existing decantation ponds.

7.3 Issues

139. From a legal point of view, all companies have valid environmental operating licenses for their mines and preparation plants. They also try to comply to environmental regulations regarding site reclamation. However, they have never adopted a positive and active attitude in this matter, always alleging that the enormous financial difficulties of the sector prevent them from meeting their environmental commitments.

140. Companies use different measures to reduce the environmental impact of their mining and washing activities such as restricting truck traffic at night, watering roads to reduce dust formation, and covering trucks to prevent spilling. These measures are insufficient to prevent the damages caused by mining activity in the region over the years. The result is a general mistrust of the general population toward the industry, its workers and owners. Coal mining is seen as being against the people's interests whose benefits coming from that activity is small compared to the damages caused to the environment and the health of the workers.

141. Indeed, protection of the environment and health of the workers were neglected in the past, but not without the complicity of the enforcement authorities, entrepreneurs and the society itself, which for a long time considered coal mining a vital activity for the region and whose benefits largely exceeded the costs. Effective environmental laws and regulations are a recent reality, so is environmental conscientiousness. Finally, while coal mining is a major polluter, the environmental degradation in the region is also the result of the ceramics industry, intensive pig raising, deforestation, spontaneous settlements and improper land use.