JAPAN INTERNATIONAL COOPERATION AGENCY

CENTRAIS ELETRICAS DO SUL DO BRASIL S.A.
COMPANHIA ESTADUAL DE ENERGIA ELETRICA-RS

THE STUDY
ON
EVALUATION OF ENVIRONMENTAL QUALITY
IN REGIONS UNDER INFLUENCE OF COAL STEAM POWER PLANTS
IN
THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT
(SUMMARY)

September 1997

SUURI-KEIKAKU CO., LTD.
TOKYO ELECTRIC POWER ENVIRONMENTAL ENGINEERING CO., INC.

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PREFACE

In response to the request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct the Study on Evaluation of Environmental Quality in Regions under Influence of Coal Steam Power Plants in the Federative Republic of Brazil and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Brazil the Study Team, led by Mr. Masaaki Noguchi of Suuri-keikaku Co., Ltd. (SUR) and organized by SUR and Tokyo Electric Power Environmental Engineering Co., Inc., to Brazil five times from June 1995 to July 1997.

The Team held discussions with the officials concerned of the Governments of Brazil and of related States, and conducted 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 future evaluation of environmental quality 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 and the States of Santa Catarina and Rio Grande do Sul for their close cooperation throughout the Study.

September 1997

Kimio Fujita

President

Japan International Cooperation Agency

September 1997

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir:

We have pleasure of submitting to you the Final Report of "The Study on Evaluation of Environmental Quality in Regions under Influence of Coal Steam Power Plants in the Federative Republic of Brazil". This report presents the monitored and evaluated influence by the three coal steam power plants located in the state of Santa Catarina or Rio Grande do Sul upon ambient air of the regions within 20 km of the plants, and proposes countermeasures drawn from the evaluation.

The report consists of the summary and the main volumes. The summary volume gives essences of the study results, and the main volume contains all the methods employed and results obtained. The main volume is attached with necessary information such as the detailed data, analytical and evaluative methods, etc.

On this occasion, we would like to express our deep appreciation and sincere gratitude to all those who extended their kind assistance and cooperation to the Study, in particular the officials from Centrais Electricas do Sul do Brasil S.A., Companhia Estadual de Energia Eletrica - RS, Fundacao do Meio Ambiente - SC, Fundacao Estadual de Protecao Ambiental - RS, Agencia Brasileira de Cooperacao, and Ministerio de Minas e Energia. We also would like to extend our acknowledgments to the officials of your agency, the Ministry of Foreign Affairs, the Ministry of International Trades and Industries, the Japanese Embassy in Brasilia, and the Japanese Consulate General in Porto Alegre.

We hope the report will realistically contribute to the development of the Brazilian coal steam power plants and Brazil itself.

Sincerely yours,

Masaaki Noguchi

Masaaki Noguchi
Study Team Leader

CONTENTS

LIST of ABBREVIATIONS

B/T	Brazilian Counterpart Teams
Cl	Chlorine
C max	Maximum concentration
CMB	Chemical Mass Balance
CO	Carbon monoxide
C/P	Counterpart(s)
De-NOx	Nitrogen Oxides Removal Plant or Process
De-SOx	Sulfur Oxides Removal Plant or Process
DF/R	Draft Final Report
E	East
EC	Electro-conductivity
EIA	Environmental Impact Assessment
EP or ESP	Electrostatic Prepicitator
FC	Fixed Carbon
FGD	Flue Gas Desulfurization
F/R	Final Report
HC	Hydrocarbons
He	Equivalent height
IC/R	Inception Report
I/M	Inspection and Maintenance
IT/R	Interim Report
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standards
J/T	JICA Study Team
N	North
Na	Sodium
n.a. or na	not available
NO	Nitrogen monoxide
NOx	Nitrogen Oxides (NO & NO_2)
NO_2	Nitrogen dioxides
O_3	Ozone
PM	Particulate Matter
ppb	Part per billion
RIMA	Environmental Impact Statement
ROM	Run of Mine
S	South
SOx	Sulfur Oxides (SO_2 & SO_3)
SO_2	Sulfur dioxides
SPM	Suspended Particulate Matter
S/W	Scope of Work
TEA	Triethanolamine
TSP	Total Suspended Particulates
U or u	Unit (usually with a numeral - indicating the plant unit number, ex. 3u)
ug or μg	micro gram
VC	Volatile Component
W	West
WB or W/B	World Bank
WHO	World Health Organization
X max	Maximum distance
¥	Currency unit of Japan: U.S.A. $1.00 = ¥120 in this Report

Chapter 1 Introduction

1.1 Background

Coal steam plants in Brazil are concentrated in the states of Santa Catarina and Rio Grande do Sul. They are necessary in order to supply electricity during the dry season and to maintain local industries. The Brazilian Ministry of Mines and Energy solicited assistance from the Government of Japan in evaluating the air quality of the regions surrounding the coal plants and in contributing to development of similar plants by transfer of related technologies. JICA as the executing agency organized the JICA Study Team to start its full-scale study in June 1995.

1.2 Study Overview

The study regions encompassed roughly 20 km around each of the three power plants shown in Fig. 1.1. The pollutants that the study concentrated on were sulfur dioxide, nitrogen oxides, and particulate matter in ambient air and stack gases. Also the main ion ingredients and acidities of rain and soluble dry precipitation were monitored at one point in each region and an additional place in Acegua. Table 1.1 is brief description of the power plants concerned.

Table 1.1 Units in Power Plants Studied

Name of Power Plant (Operator)	Unit Code	Rated Capacity	Year in Operation
Jorge Lacerda (ELETROSUL)	A Ⅰ-1	50 MW	1961
	A Ⅰ-2	50	1963
	A Ⅱ-3	66	1972
	A Ⅱ-4	66	1972
	B Ⅲ-5	125	1977
	B Ⅲ-6	125	1977
	Ⅳ	350	1/1997
Charqueadas (ELETROSUL)	1	18	1956
	2	18	1956
	3	18	1956
	4	18	1968
	Jacui 1	350	12/1999
Candiota (CEEE)	Ⅱ A-1	63	1974
	Ⅱ A-2	63	1974
	Ⅱ B-1	160	1986
	Ⅱ B-2	160	1986
	Ⅲ	350	(9/2003)

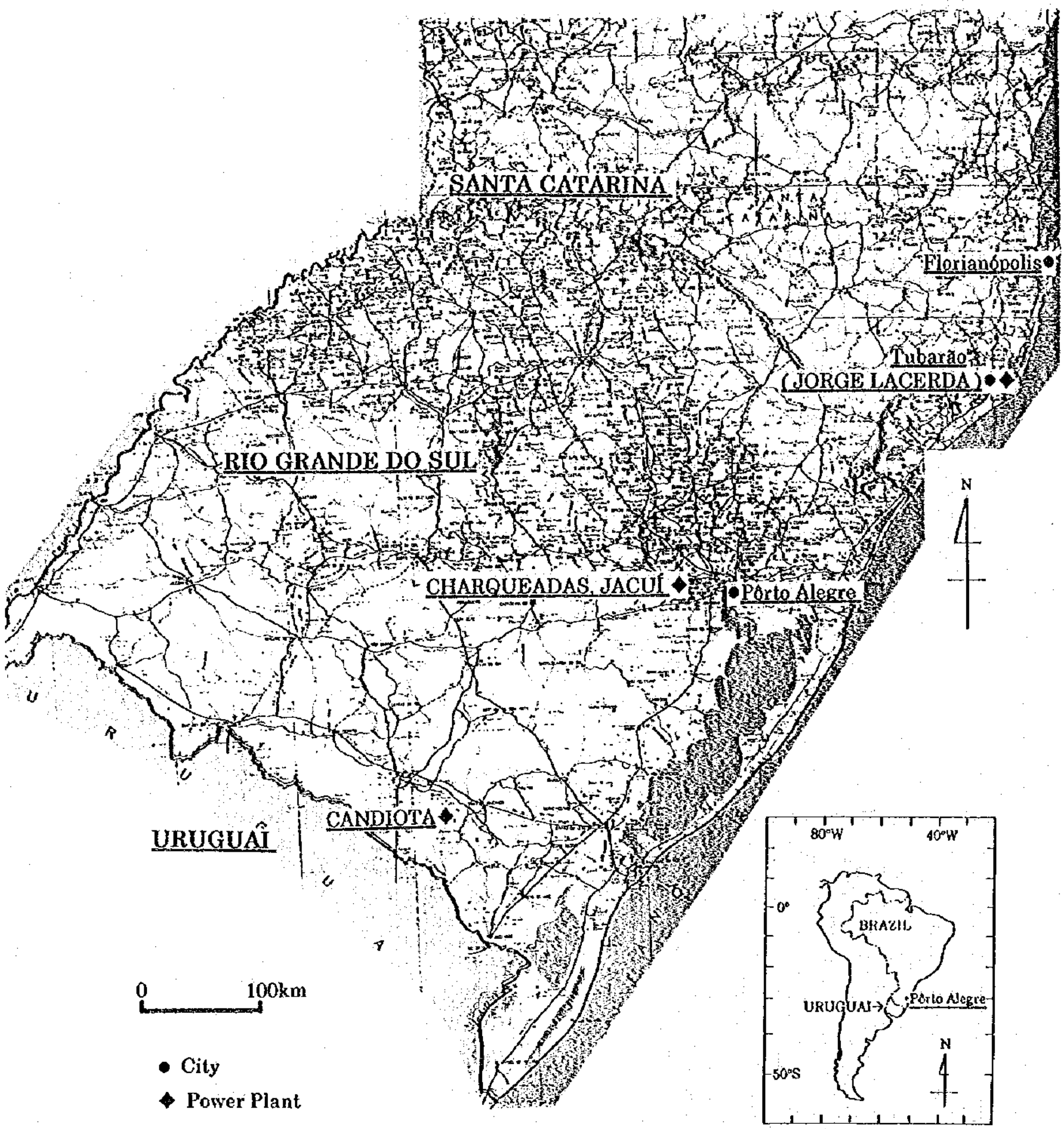


Fig. 1.1 Study Regions

As privatization and the introduction of natural gas had an impact on the electric sector, the expansion plan for the Candiota Plant was reduced from 2100 MW to 350 MW during the Study. The 350 MW expansion unit at the Jorge Lacerda Plant was into operation in January 1997.

Table 1.2 indicates the time schedule and major tasks accomplished in the Study.

Table 1.2 Major Tasks and Their Schedule

	Work Components	Schedule	Major Tasks
1	First Field Work	6~7/1995	Discussion of the Inception Report, and collection of data & information for inception of the Study
2	First Analytical Work	7~9/1995	Preparation for specifications of the JICA Equipment
3	Second Field Work	2~3/1996	Commencement of air and stack gas monitoring
4	Second Analytical Work	5~6/1996	Preparation of the Interim Report (IT/R)
5	Third Field Work	6~7/1996	Discussion of the IT/R and continuation of monitoring
6	Third Analytical Work	7~10/1996	Preparation of air dispersion model
7	Fourth Field Work	3/1997	Checking of the JICA Equipment and technology transfer of the dispersion model usage
8	Fourth Analytical Work	5~6/1997	Preparation of Draft Final Report
9	Fifth Field Work	7/1997	Explanation & discussion of DF/R; Holding seminars

Chapter 2 Socioeconomical Conditions pertaining to the Power Sector

2.1 Current Socioeconomics and Development Plans

Brazil won the fight against the hyperinflation by introducing a monetary stabilization policy and a new currency, the Real, on July 1, 1994. Its economy has been growing steadily ever since. One of the economic measures taken was adoption of a policy to privatize public industries. USIMINAS Steel Works Co. was the first public corporation to be privatized, in January 1991.

Free trade and open market policies stimulated the economy in Brazil, and it recorded an average growth rate in the Gross National Product per capita of 11.5% in two years from 1993 to 1995, increasing from US$ 2930 to $3640.

2.2 Current Power Sector and National Policies

Electricity generation in Brazil is given in Table 2.1 by sources, and in Table 2.2 in terms of installed capacity. Hydraulic source occupies 93% of the total supply of public and private power plants.

Table 2.1 Electricity Generation by Sources in Brazil (1994)

Sources	Public Plants		Private Plants	
	GWh	%	GWh	%
Natural Gas	0		416	2.76
Coal	3,105	1.26	214	1.42
Firewood	0		921	6.10
Bagasse	--		2,348	15.56
Black Liquor	--		1,807	11.98
Other Waste	--		1,752	11.61
Diesel Oil	1,841	0.75	319	2.11
Fuel Oil	1,389	0.57	2,017	13.37
Coke	--		543	3.60
Nuclear	55	0.02	--	
Hydraulic	239,203	97.40	3,714	24.61
Others	--		1,039	6.88
Total	245,593	100.00	15,089	100.00

Table 2.2 Installed Capacity of Electric Generation in 1994

	Thermal	Nuclear	Hydraulic	Total in MW
Public Plants	4,155	657	1)49,304	54,116
Private Plants	2,900	0	624	3,524
Total in MW	7,055	657	49,928	57,640

Note: 1) includes half of Itaipu Plant (total installed capacity 12,600 MW)

Power generation, etc. are planned and controlled by ELETROBRAS under National Department of Water and Electric Energy in the Ministry of Mines and Energy. ELETROBRAS is divided into four regional companies, one of which, ELETROSUL, has responsibility for the south. Each state has its own public corporation, and CEEE is the public corporation for the state of Rio Grande do Sul. ELETROSUL generates and distributes electricity , but does not sell it to end users. CEEE sells to end users electricity generated and distributed by itself, as well as that purchased from ELETROSUL. Table 2.3 indicates power generation by both companies. Coal is used for generation of about 10% of the ELETROSUL's power and about 40% of CEEE's.

Table 2.3 Power Generation by Counterpart Companies

	Installed Capacity in MW (1993)				Generation in GWh		
	Coal	Oil	Hydraulic	Total	Coal & Oil	Hydraulic	Total
ELETROSUL	554	66	2602	3,222	1,787	13,469	15,256
CEEE	446	--	820	1,266	2,483	3,758	6,241

All the coal produced in Brazil is used for power generation. Metallurgical coal is almost all imported. Known coal deposits are estimated to be about 17,100 million tons and are located in the two southern states. Rio Grande do Sul has around 89% of the known deposits. The state has plans to expand coal power production from 40% to 55% in the future, in order to stimulate local economy in the coal-related industries of mining, washing/dressing, transportation and power generation.

Brazil's basic economic stimulation policies, such as open markets, free importation, and privatization have affected the power industry. Natural gas is going to be imported from Argentine and used to generate electricity in Rio Grande do Sul with a capacity of 316 MW (or 450 MW in a combined cycle) in a joint venture between public and private interests. Gas power generation is certain to compete head-on with coal power. The Jacui and Candiota III units are looking for private partners openly. CEEE itself is ready to offer its shares with the approval by the legislative assembly of the state.

Chapter 3 Policies on Air Quality Preservation

3.1 National Policies on Environment

The key issue of Brazilian policy on the environment is the challenge of sustainable development, as voiced in the United Nations Conference (the Earth Summit) at Rio de Janeiro, 1992.

The special office for the environment was created in October 1973, and the first law stipulating a National Environmental Policy was established in 1981. After several institutional reorganizations, the National Environmental Council (CONAMA) was organized in 1984, and it has drawn up rules and standards compatible with environmental protection. In 1989, a new environmental program called Our Nature was launched just after the proclamation of the new constitution. The program seeks to defend still prevailed environment from deterioration caused by industrialization, loss of rain forests, etc.

Currently the Environmental and Renewable Natural Resources (IBAMA) under the Ministry of Environment is in charge of EIA report evaluation, issuance of construction and operation permission, and so on, for projects on the national level or multi-state projects. State agencies, such as FATMA or FEPAM, have responsibility for projects their respective states.

3.2 Regulations and Decrees on Air Quality

Table 3.1 gives the environmental air quality standards in Brazil published in March 1990. The values marked with a star * should not be exceeded more than once a year. Each state is responsible for assigning the area criteria under its jurisdiction. There is no such area assigned as the secondary criteria at present.

Table 3.1 Environmental Air Quality Standards in Brazil

Unit μ g/m^3

Pollutants	Averaging Time	Primary Criteria	Secondary Criteria	Measuring Methods given or equivalent approved by CONAMA
TSP	Annual	80	60	High-volume air sampler
	24 hours*	240	150	ditto
Smoke	Annual	60	40	Reflectance
	24 hours*	150	100	ditto
Inhalant	Annual	50	50	Inertial separation and filtration
Particulates	24 hours*	150	150	ditto
SO_2	Annual	80	40	Para-rosaniline
	24 hours*	365	100	ditto
CO	8 hours*	10,000	10,000	Non-dispersion infrared absorption
	1 hour*	40,000	40,000	ditto
O_3	1 hour*	160	160	Chemiluminescence
NO_2	Annual	100	100	Chemiluminescence
	1 hour	320	190	ditto

There are also national emission standards for power plants as shown in Table 3.2. Class I area is for national parks or similar areas. Class II and III are areas governed respectively by the secondary and the primary criteria of the environmental air quality standards.

Table 3.2 Emission Standards of Pollutants from Power Plants

Output	Less than 70MW		More than 70MW		Remarks
	Area Class		Area Class		
Pollutants (units)	I	II・III	I	II・III	..
TSP ($g/10^6Kcal$)	120	350(Oil) 1500(Coal)		120(Oil) 800(Coal)	..
Smoke(%)	20	25	No new plant approval	20	Ringelman
SO_2 ($g/10^6Kcal$)	2000	5000		2000	..
Limit of Fuel Oil	3000 t/Year	···		···	..

The national emission standards are applied to new or expanding thermal power plants, and do not to the existing units. However, as a condition of operational permission of their new or expanding plants, both power companies have concluded agreements with FATMA or FEPAM to control emissions of TSP, NOx, and SO_2 from their stacks. The agreed emission rates are as shown in Table 3.3.

Table 3.3 Agreement with State

Power Plants		Units	No.	Output MW	Limitations (mg/m³N)			Remarks
					TSP	NOx	SO_2	
Jorge Lacerda		AI	1	50	less emission than SO_2 burning 2.2% coal at rated capacities of total units			after 1/1997
			2	50				
		AII	3	66				
			4	66				
		BIII	5	125				
			6	125				
	New	IV	--	350				
Charqu-adas			1	18	80	400	400	by 2005
			2	18				
			3	18				
			4	18				
Jacui	New	I	-	350	140(@280MW) 85(@175MW)	680	1500	when in operation
Candiota		A	1	63	80	400	400	by 2004
			2	63				
		B	1	160	unknown	680	2100	by 2002
			2	160				
	New	III	-	350	265(@280MW) 100(@158MW)	un-known	2000	when in operation

As in Table 3.3, severer emission allowance rates are applied to the existing units than to the new or expanding units in Charqueadas and Candiota, although the existing units have smaller capacities. The small and old units require high cost for modification. Even if the concentration is high, small units influence less on the surrounding air. It is the emission amount to be considered on the influence. Therefore, its seems not rational to apply severer emission rates to the existing units than to the new and higher capacity ones.

The 10^6 kcal used in the national standards (Table 3.2) is equivalent to about 1,600 m³N of the amount of flue gas with residual O_2 concentration of 6%. Accordingly, TSP 800 g/10^6 kcal is equivalent to 500 mg/m³N, and SO_2 2,000 g/10^6 kcal to 1,250 mg/m³N, respectively.

Chapter 4 Current Air Qualities

4.1 Meteorology

The meteorology was observed from March 1996 to February 1997 for one year.

Calm frequency was high (11.5 %) and the average wind speed was 2.0 m/s at Jorge Lacerda. The wind was the weakest at Jorge Lacerda. On the other hand, the wind at Candiota was the strongest, and the calm frequency and the average wind speed were 3.7 % and 3.4 m/s respectively. At Charqueadas, the extent of wind speed was the middle of the other two regions, and the calm frequency and the average wind speed were 7.0 % and 2.3 m/s (Figure 4.1).

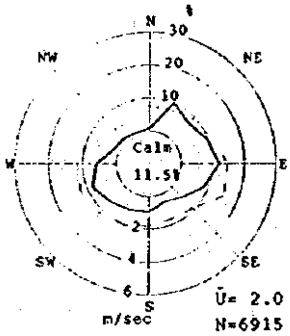
The atmospheric stability was determined from data on wind speed, solar radiation and net radiation. However, as the solar radiation data at Candiota showed abnormal values, the stability was determined from wind speed and net radiation there. General features of stability in these regions were high frequency of strong stable conditions(G) and strong unstable conditions (A to B). High frequency of strong unstable conditions has potential of high impact from the tall stack of power plants to the ground concentrations. The frequencies of strong unstable conditions were 19.4 % at Jorge Lacerda, 18.3 % at Charqueadas, and 13.3 % at Candiota, respectively (Figure 4.2).

In summary, the meteorological conditions at Jorge Laceda with the weakest wind and the highest frequency of unstable conditions tend to cause air pollution, and Candiota has the less possibility of air pollution because of the strong wind and the low frequency of unstable conditions.

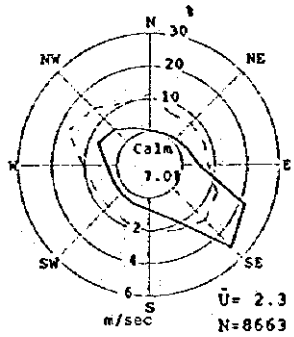
4.2 Automated Continuous Monitoring of Air Quality

Each three automated continuous monitoring stations were installed at Jorge Lacerda, Charqueadas, and Candiota. Sulfur dioxide (SO_2) concentrations were monitored at each three stations, and nitrogen oxides (NO_x, NO_2, and NO) concentrations at each one station in each region (Table 4.1).

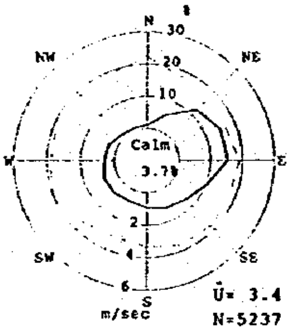
LACERDA



JACUI



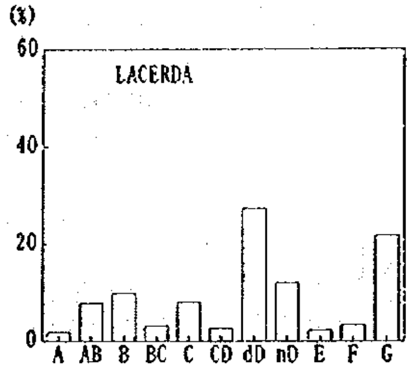
CANDIOTA



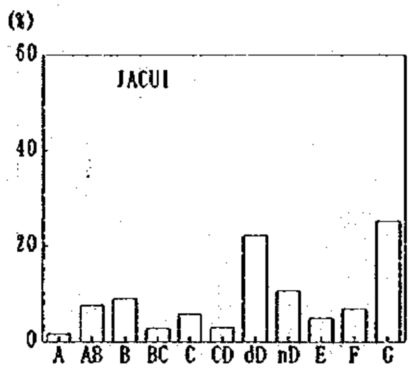
——— Frequency of Wind Direction
- - - Average of Wind Speed
Calm: Less than 0.5 m/sec
U=: Ave. of wind speed (m/sec)
N=: Number of sample

Figure 4.1 Wind Rose Year: 1996 (Mar. to Feb.)

Jorge Lacerda Power Plant



Charqueadas Power Plant



Candiota Power Plant

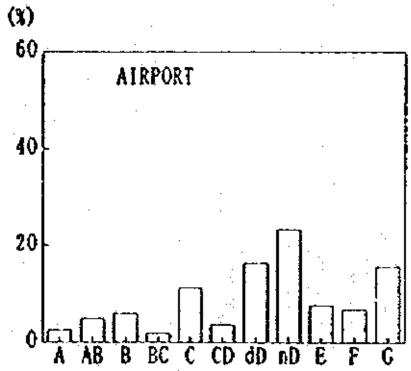


Figure 4.2 Stability Frequency Year 1996 Mar to 1997 Feb

Table 4.1 Results of Automated Continuous Monitoring

Item / Station	SO_2			NO_2		
	Average	Daily Max.	Hourly Max.	Average	Daily Max.	Hourly Max.
Capivari	6.1	35	336	5.7	11	44
Vila Moema	8.0	54	322	-	-	-
Sao Bernardo	5.2	63	438	-	-	-
DEPREC	1.9	11	120	3.0	11	37
Jacui	3.7	18	108	-	-	-
Arranca Toco	6.1	39	173	-	-	-
Airport	3.5	17	182	1.4	7	20
Candiota III	4.5	27	113	-	-	-
Tres Lagoas	4.2	16	129	-	-	-
Standard	30.56	139.44	-	53.15	-	170.08

Unit: ppb

All the values monitored were much lower than the National Primary Criteria for annual average (80ug/m^3=30.56 ppb) and 24 hours average (365ug/m^3=139.44 ppb). The annual average concentrations of SO_2 at Vila Moema of Jorge Lacerda was the highest among others to be 8.0 ppb. The maximum concentration of SO_2 daily averages was the highest at Sao Bernardo. Generally, SO_2 concentrations of Jorge Lacerda are higher than the ones in the other regions.

The annual average concentration of NO_2 and the maximum concentration of NO_2 hourly values were the highest at Capivari of Jorge Lacerda. The NO_2 concentrations in Jorge Lacerda and Charqueadas were almost in the same range, and the concentrations in Candiota were lower than the others. Maximum values of NO_2 were also much lower than the Primary Criteria for annual average (100 ug/m^3=53.15 ppb) and hourly value (320 ug/m^3=170.08 ppb).

TSP measurements were carried out using with existed high volume samplers at each three points in Jorge Lacerda and Charqueadas, and one point in Candiota. TSP concentrations at Capivari of Jorge Lacerda exceeded the Primary Criteria of 24 hours average (240 ug/m^3) twice out of sixty times measurements. TSP concentarations at Vila Moema in the same region also exceeded the criteria once.

Diurnal changes of SO_2 showed one peak during the daytime, and this phenomenon would be caused by the tall stacks of power plants because the atmosphere is unstable by solar radiation in the daytime. Accordingly, the effect from the tall stack could reach to the ground level, but contributions from ground-level sources like automobiles are weakened by dilution. On the contrary, diurnal changes of NO_x had two peaks in the morning and the evening which indicated the pattern to be related with traffics. The contributions from power plants to NO_x concentrations might be relatively low (Figure 4.3).

The analysis of average concentrations by wind directions at Candiota showed good coincidence between high concentration directions and upward directions of the power plant, although the concentrations were low. This indicates that the contributions from the power plant to the stations is relatively high at Candiota. Such kind of coincidence was not clear at Jorge Lacerda. Many other pollutant sources except the power plant would be there to contribute the pollutant concentrations at Jorge Lacerda.

The average SO_2 concentrations were relatively high under unstable conditions. The tall stacks would be the reason. The average NO_x concentrations were relatively high under stable conditions and may be caused by automobiles. However, the NO_x concentrations at Capivari also increased under unstable conditions and some contributions from the tall stacks should be considered.

As results, SO_2 and NO_2 concentrations are much below the criteria and not problematic at present. The power plants could contribute to SO_2 concentrations in all regions, and the contributions from the power plants to NO_x concentrations are relatively small compared with the ones from automobiles. The contributions from the power plants to TSP concentrations will be discussed based on the simulation results later.

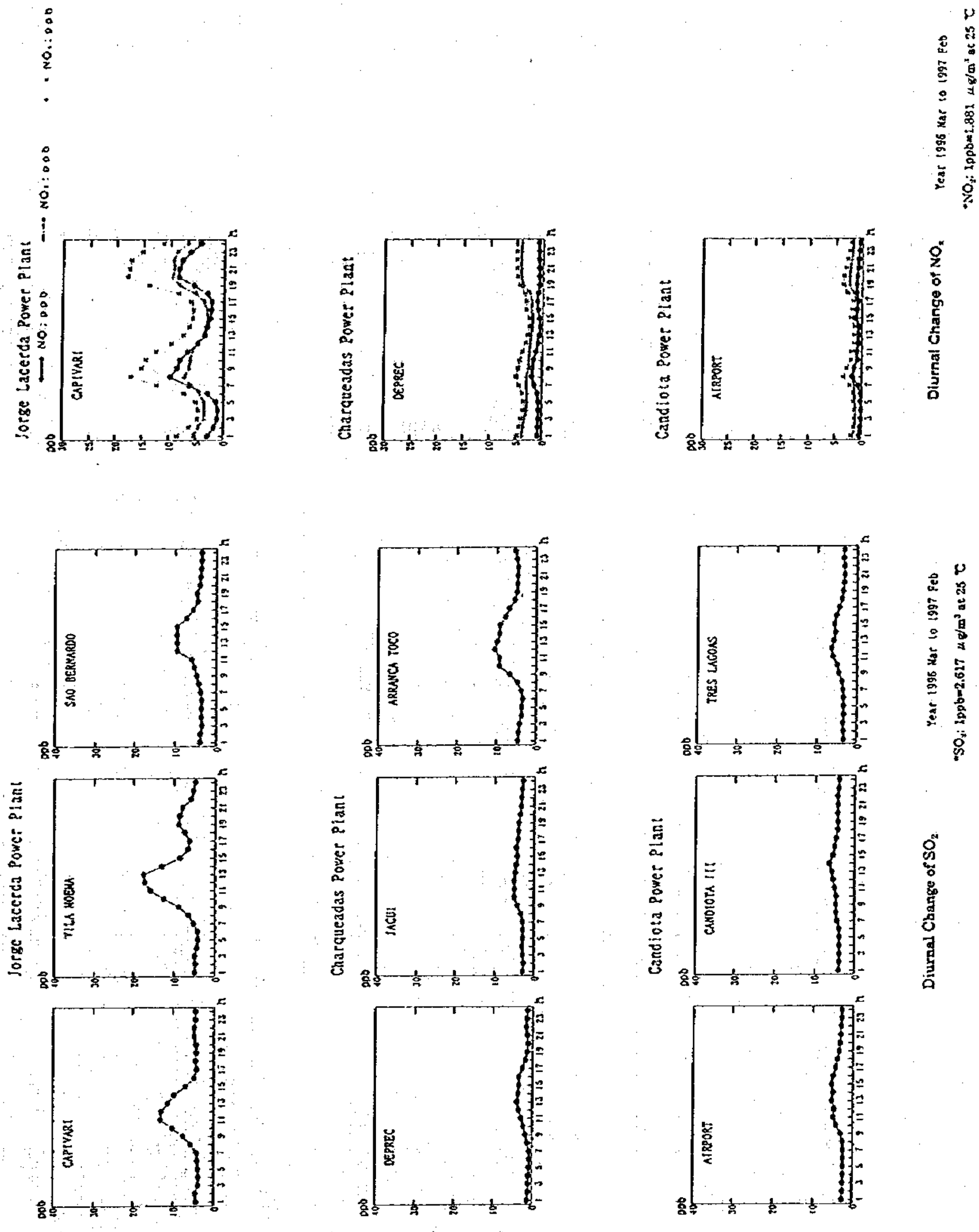


Figure 4.3 Diurnal Changes of SO_2 and NOx

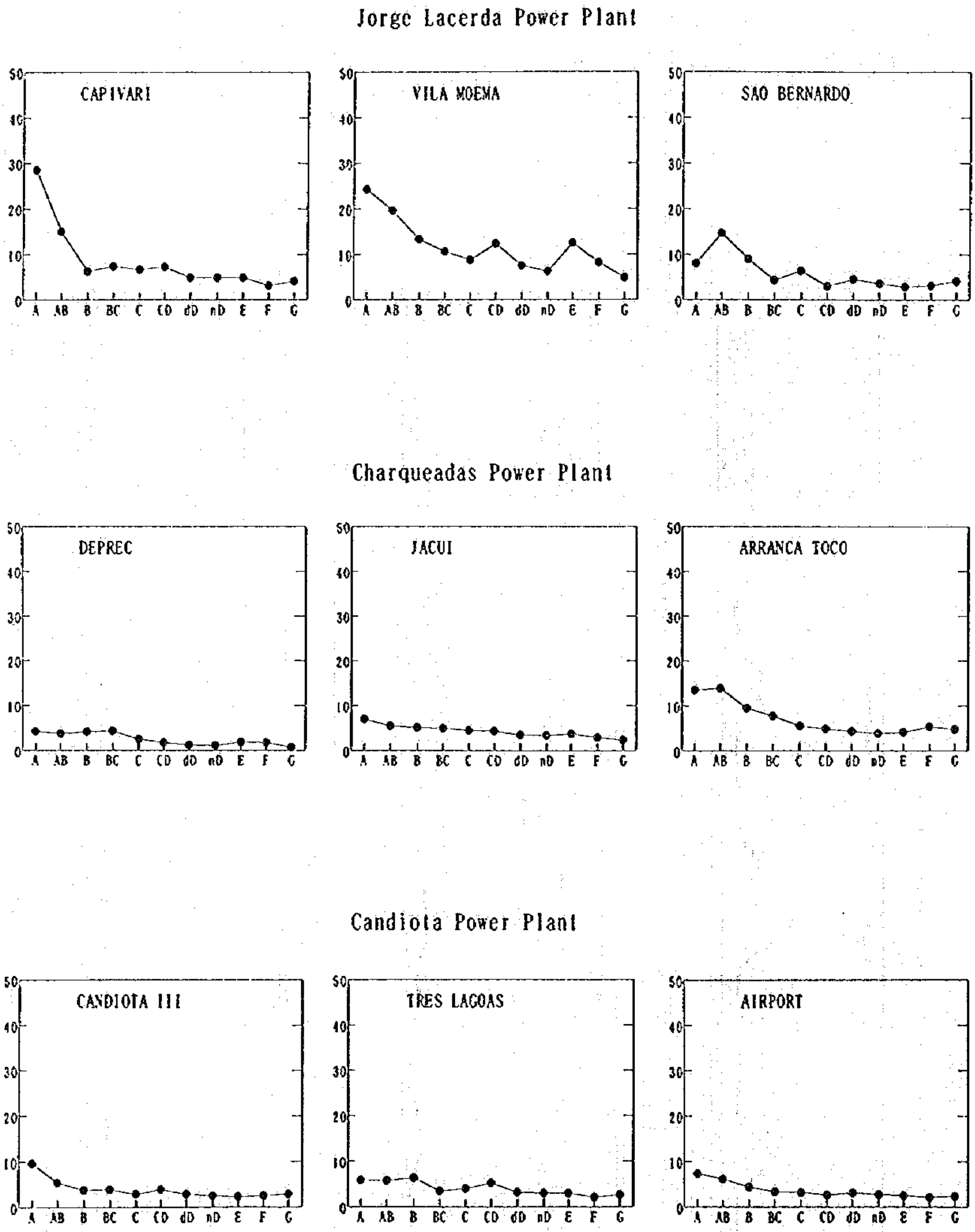


Figure 4.4 Average Concentration by Stability

Year 1996 Mar to 1997 Feb

4.3 Simple Method of Air Monitoring

A simple method was employed to support the fixed automated ambient air monitoring. Each twenty sampling points ere set in each region and the samplers were exposed for one month. The samplers were analyzed by TEA-Ion Chromatography method to measure the absorption amounts of SO_2 and NO_2. The absorption amounts were tried in vain to compare with the average concentrations of SO_2 and NO_2 at the automated continuous stations during the same periods. The absorption amounts were too small for the comparison. Therefore, SO_2 absorption amounts were directly evaluated.

The area with substantial SO_2 absorption amounts (0.4 μ g per month) spread in WSW to SW and with the distances of 5 to 15 km from the power plant at Jorge Lacerda. In addition, the wind frequency of E to NNW were high and the potential influence by the power plant should be considered. The areas of notable NO_2 concentrations (more than 5 ppb) were located at SW and E to NNW from the power plant.

In Charqueadas, there were two locations of notable amounts of SO_2 absorbed: the one at NW to W with the distance of 10 to 15 km from the power plant and the other at E to NEN with the distance of 1 to 10 km. The former may be influenced by the power plant because the main wind directions were SE to ESE. NO_2 concentrations was high at only one point near the power plant.

In Candiota, the areas with substantial amounts of SO_2 absorption widely spread in S with the distances of 1 to 20 km from the power plant, and NW to N with the distances of 5 to 15 km. The other unknown sources can be suspected. NO_2 concentrations were generally low.

Some of the local areas may be influenced by the power plants and also by other pollutant sources to their ambient air qualities. Pollutant sources should be considered for locations of monitoring stations, if the new network is planned for the air quality monitoring.

4.4 Chemical Analyses

In addition to the chemical analyses of samples from the simple method of air monitoring, the chemical laboratory at the Charqueadas plant analyzed several anions and cations, pH, and the electro-conductivity of rain and dry precipitation at the three power plants and Acegua. Also a local independent laboratory was asked to analyze eight chemical elements in airborne particulate and stack gas fly ash.

There is a question remained unanswered about the accuracy of pH and ion concentration measurements of rain samples. Very few data were in conformity with both measurements. Within this limitation, rain samples showed mild acidity in the pH range of 4.5 to 5.9, which were normal in Japanese rural areas. Continuous efforts to measure samples are recommendable using well maintained equipment by qualified people. Rain contained equivalent amounts of Na and Cl, which were surmised to have been fine salt particles from the sea or rock dissolved in it.

The elemental analyses by the local laboratory came up with different results (less nickel and high lead in every sample) from the data taken by the JICA Team from different samples. The analyses were repeated in Japan when the final project training was carried out. More nickel was found than lead in fly ash. Lead in airborne particulate may come from other sources than the power plants.

Chapter 5 Current Stack Gas Qualities

5.1 Coal Steam Plants

All three power plants employ pulverized coal boilers. They are equipped with electrostatic precipitators to remove fly ash (dust) from stack gases. They burn coal from nearby mines exclusively. The properties of the coal are generally low heating values with high ash content as shown in Table 5.1.

Table 5.1 Properties of Coal Used in Power Plants

Item (Unit)	Power Plants			
	Jorge Lacerda	Charqueadas	Jacui	Candiota
Caloric Value (Kcal/kg)	4300 - 4700	2945-3255	3600-3800	3027-3572
Fixed Carbon (wt%)	33-40	FC/VC<1.2	FC/VC<1.6	24.5-28.1
Volatile Component (wt%)	20-26	--	--	21.5-23.5
Ash (wt%)	39-44	53-56	45-48	49.1-53.5
Total Carbon (wt%)	43-50	--	--	28.0-30.0
Hydrogen (wt%)	2.7-3.1	--	--	1.8-2.4
Sulfur (wt%)	1.8-2.3	<1.3	0.7	0.8-1.5
Nitrogen (wt%)	1.0-2.1	--	--	0.4-0.7
Oxygen (wt%)	3.5-8.0	--	--	6.7-10.0
Water (wt%)	6-10	12-15	<15	10.0-18.4

5.2 Stack Gas Monitoring

Pollutant emission rates, such as SO_2, NOx, and dust, together with O_2 and moisture contents, temperature and gas velocity were monitored at each duct of all the boilers. The data given in Table 5.2 show fluctuation inherent in coal burning with the topmost dust loading, the ratio of maximum to minimum to be 15.

Table 5.2 Current Stack Gas Emissions @ 6% of O_2

	SO2 mg/m³	NOx mg/m³	Dust mg/m³
Jorge Lacerda	5,829~8,371	264~750	83~1,261
Charqueadas	3,257~5,429	196~368	81~1,081
Candiota	6,057~7,457	370~663	929~2,052

As mentioned in Chapter 3, the agreements with each state are the govern the emission limitation on the plants concerned. The Jorge Lacerda plant is to burn coal of sulfur content below 2.2% at its full-rated capacity. The plant can easily keep the agreement since it is currently using almost the same coal as that agreed upon. Other power plants, Charqueadas and Candiota, have been emitting more dust and SO_2 than the values agreed on with FEPAM as shown in Table 5.3. Emission controls on these pollutants must be in place before the year specified in the agreement (Table 3.3). Candiota AI and AII units may need to reduce NOx emission by installing low NOx burners or other devices.

Table 5.3 Ratio of Measured Emission Rates vs. Agreed Values

Power Plant	Unit	Dust	SO_2	NOx
Charqueadas	1	-	13.6	0.9
		5.0	9.1	0.9
		7.0	9.3	0.7
	2	--	12.7	0.6
		1.0	10.5	0.5
		1.4	11.1	0.6
		13.5	10.1	0.6
	3	6.5	12.1	0.9
		4.8	8.1	0.8
		5.7	8.2	0.8
	4	6.6	8.9	0.8
		7.9	9.9	0.8
Candiota	A 1	19.1	--	1.0
		12.5	18.6	0.9
	A 2	11.6	15.1	1.2
		11.3	15.3	1.3
	B 1	--	2.9	1.0
	B 2	--	3.0	0.7
		--	3.2	0.7
		--	3.3	0.9

According to Table 5.3, Charqueadas Unit 1 is emitting in 13.6 times of SO_2 amount agreed with FEPAM. The SO_2 reduction of $100 \times (13.6 - 1)/13.6 = 92.6\%$ is required in the future.

Chapter 6 Effect of Stack Gas on Air Quality

6.1 Outline of Impact Assessment from Stack Gas

The impacts of the stack gas emitted from the power plants to the surroundings were estimated with a dispersion simulation model. The model is based on Plume and Puff formulae, and annual averages, daily averages and hourly values of SO_2, NO_2, and SPM concentrations were simulated. The conversions from NO_x to NO_2 were conducted with the measured ratios of NO_2 to NO_x in each area. The usual NO_2 conversion models was not be applicable because of the lack of O_3 concentrations data and of only one monitoring station in each area.

The pollutant emission intensity, wet gas volume and so on were based on the results of the Stack Gas Monitoring, the specifications of stacks and annual electricity generation data.

The necessary meteorological inputs to the simulation model are wind direction, wind speeds and atmospheric stability. Wind speed data at the stack height were estimated from wind speed data with correction factors. The measured stability were shifted to neutral conditions to calculate diffusion parameters, because of the nature of the ambient air at high altitude.

6.2 Distribution of Annual Average Concentration

One year is divided into two seasons, winter as May to October and summer as November to April, and two time zones, daytime as 8 o'clock to 22 o'clock and nighttime as the remainders. Average concentrations of each season and each time zone were calculated and averaged to obtain annual average concentrations.

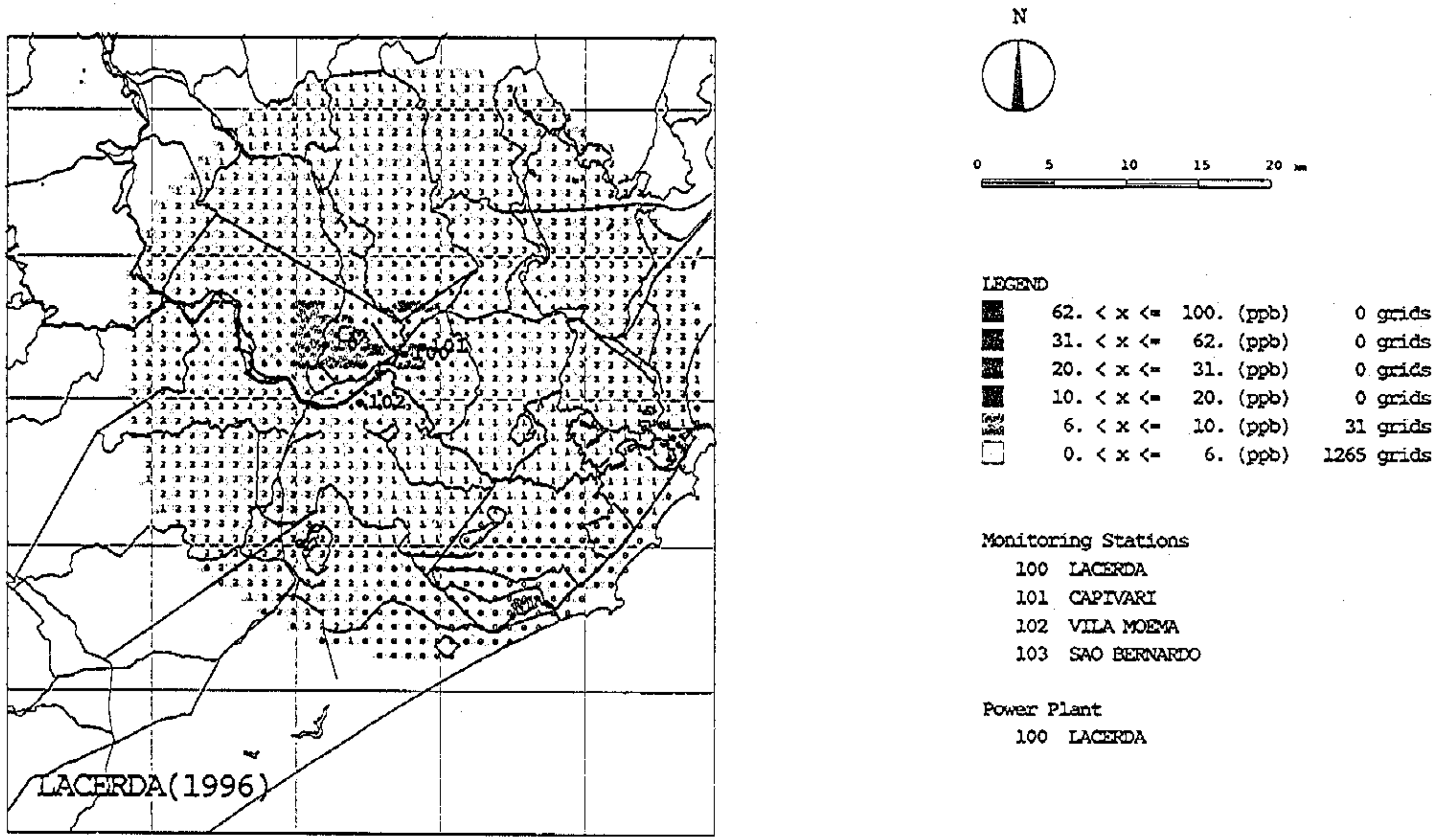
The basic data of pollutant emission intensities, such as SO_x, NO_x, Dust, and wet gas volumes, were converted to the values at each hour with the ratios of hourly electricity generation data and the electricity generation at the time of the stack gas monitoring. The obtained hourly data on pollutant emission intensities and wet gas volumes were averaged by each season and each time zone. Wet gas volumes were averaged for operation hours.

The calculations were conducted at the monitoring stations and center points of each grids with 1 km spans in the radius of 20 km from the power plants. The results were indicated as concentration maps. Figures 6.1A, B and C are the concentration maps of three regions.

The maximum concentration of the monitoring was 8.0 ppb at Vila Moema in Jorge Lacerda. On the other hand, the maximum concentration of SO_2 annual average was calculated to be 8.5 ppb at WNW with the distance of around 4 km from the stacks in Jorge Lacerda. The Jorge Lacerda power plant can be said to be the major source of SO_2 in the area. The maximum calculated NO_2 concentration was 1.0 ppb and much lower than the criteria (53.15 ppb). The monitored average of NO_2 at Capivari was 5.7 ppb and the diurnal change of the monitoring data indicated the influence of automobiles. The influence from the power plant is considered to be minor. The maximum SPM concentration calculated was 2.2 ug/m^3 and much lower than the criteria (50 ug/m^3). The power plant is the minor pollutant source for SPM in the Jorge Lacerda region.

The maximum calculated concentration of SO_2 in Charqueadas was 3.1 ppb, and occurred at NNW and with the distances of around 3 km from the stack. The concentration is much lower than the criteria, but about a half of the maximum concentration of the monitoring at Arranca Toco, 6.1 ppb. Charqueadas plant is said to be a major pollutant source for SO_2 in this area. The maximum calculated concentrations of NO_2 and SPM were respectively 0.4 ppb and 0.9 ug/m^3.

The maximum calculated concentration of SO_2 was 1.5 ppb in Candiota at WSW and with the distances of around 8 km from the stack. The concentration is low, but the stack may be major pollution source for SO_2 because the measured concentration in the area ranged 3 to 4 ppb. The maximum concentrations of NO_2 and SPM were very low to be respectively 0.2 ppb and 1.0 ug/m^3.



SO2 ppb Annual Average □C MAX= 8.5ppb

Figure 6.1 A Concentration Distribution of SO_2 (Jorge Lacerda, Present)

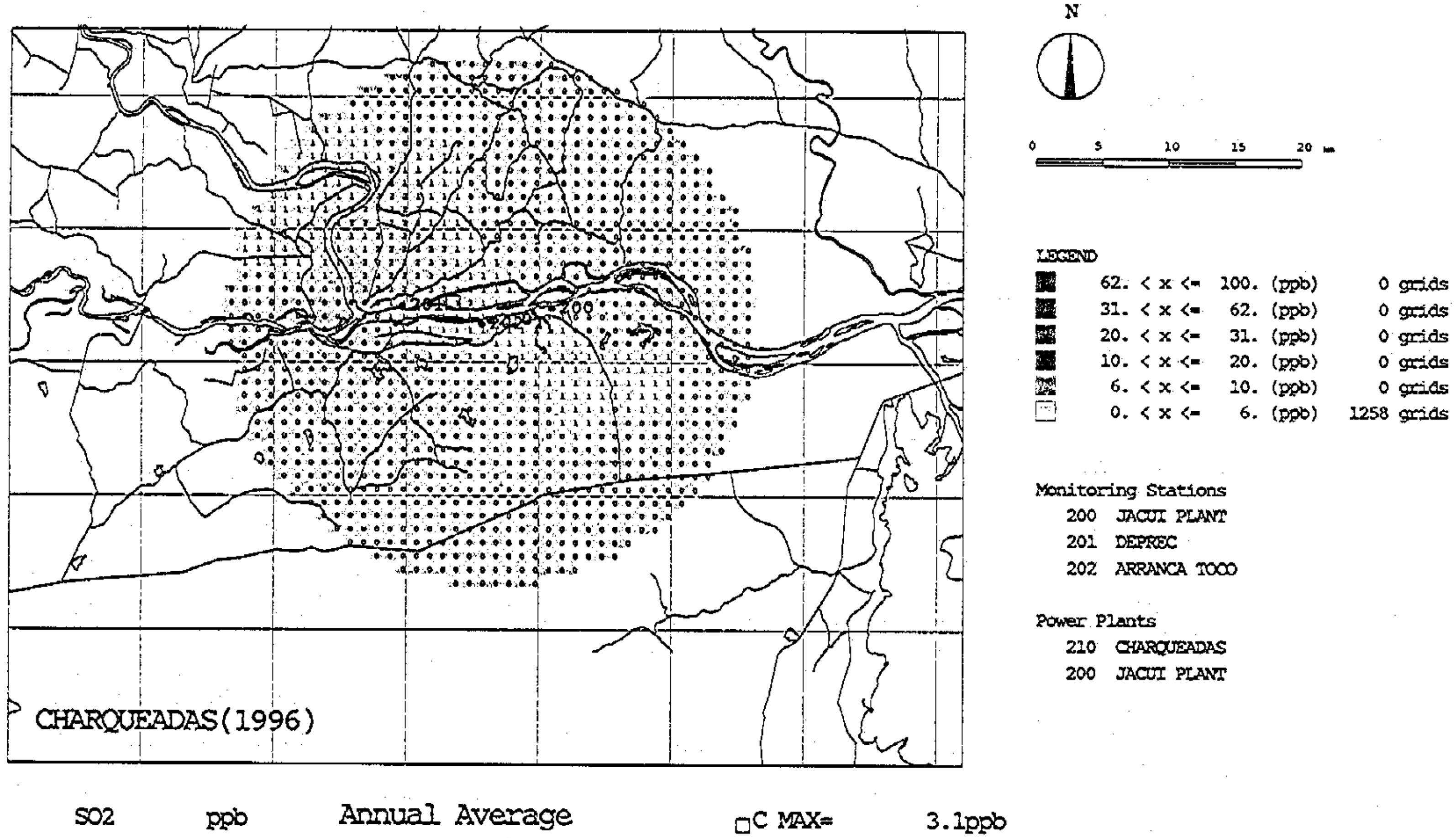


Figure 6.1 B Concentration Distribution of SO_2 (Charqueadas, Present)

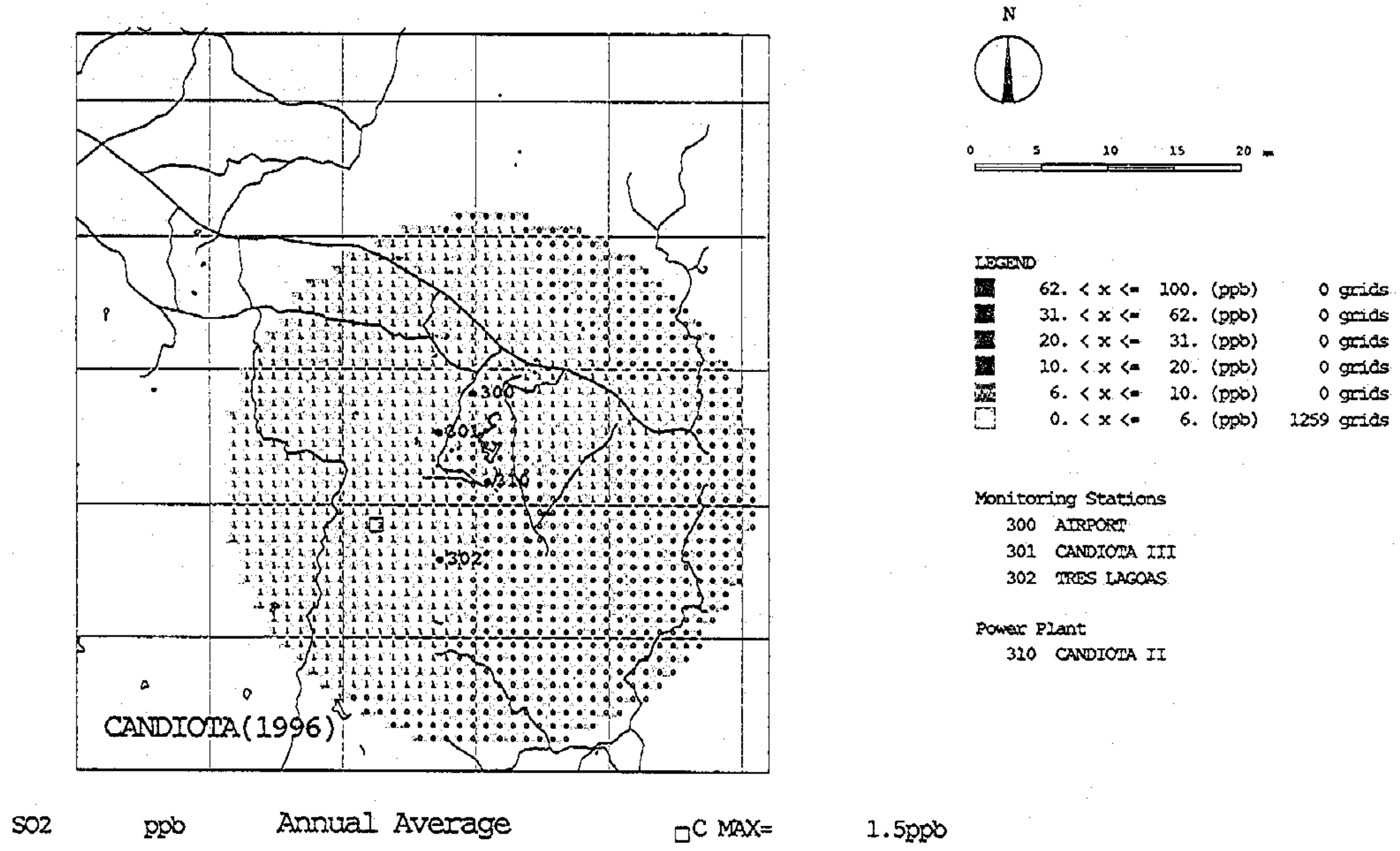


Figure 6.1 C Concentration Distribution of SO_2 (Candiota, Present)

6.3 Daily Averages and Hourly Values at Monitoring Station

Daily average concentrations and hourly concentrations were calculated based on the emission conditions and the meteorological conditions at the monitoring stations. The procedures were the same as for the annual average calculation.

The daily average concentrations and the hourly concentrations were much lower than the criteria as in Table 6.1.

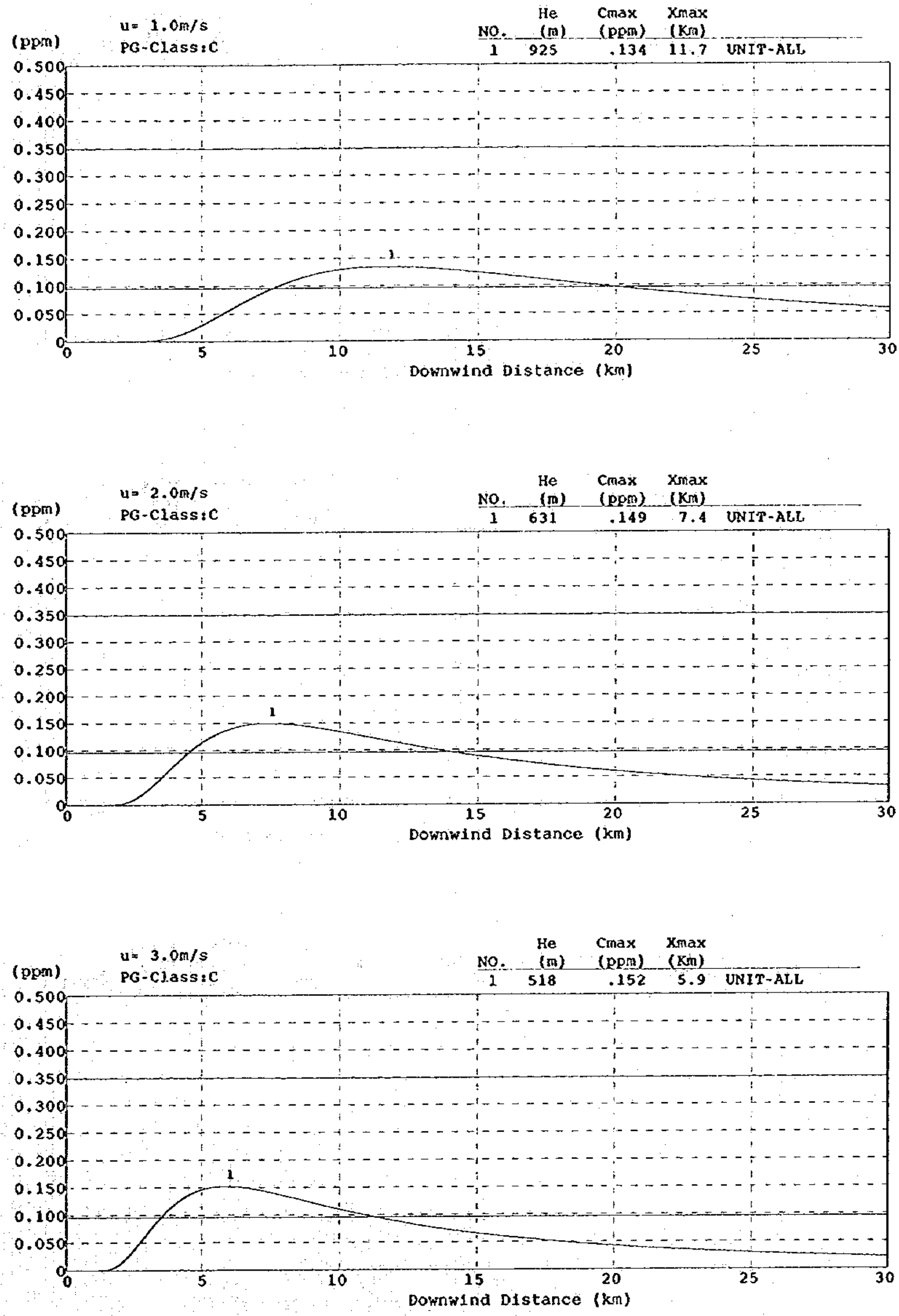
Table 6.1 Daily Average and Hourly Value at Monitoring Station

	SO_2 Daily	NO_2 Hourly	SPM Daily
Capivari	43.3	24	10.9
Vila Moema	17.7	29	4.6
Sao Bernardo	42.7	25	11.0
DEPREC	8.2	5	2.4
Jacui	5.4	6	1.6
Arranca Toco	12.0	4	3.5
Airport	14.3	9	14.7
Candiota III	19.0	9	20.3
Tres Lagoas	16.9	9	18.0
Standard	139.4	170.1	150.0
Unit	(ppb)	(ppb)	(ug/m^3)

6.4 Hourly Concentration Profile

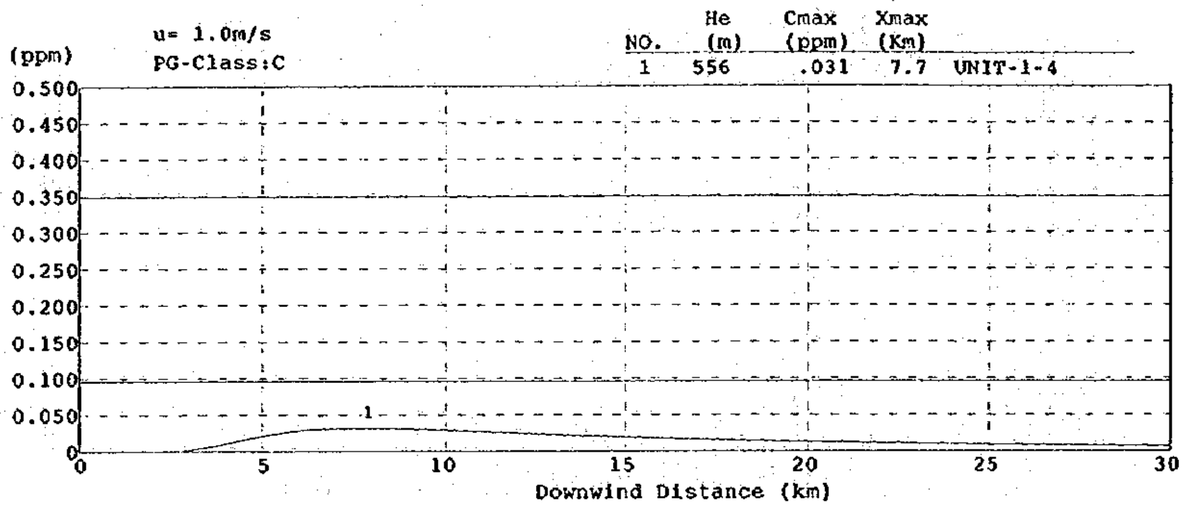
Hourly concentration profiles on plume center line to leeward from the stacks were calculated, assuming operation at the maximum load and all stacks located at the same point. Diffusion conditions were set from C to E because the stability at high altitude tend to be neutral. Six wind speed classes at most were set from 1.0 to 9.0 m/s.

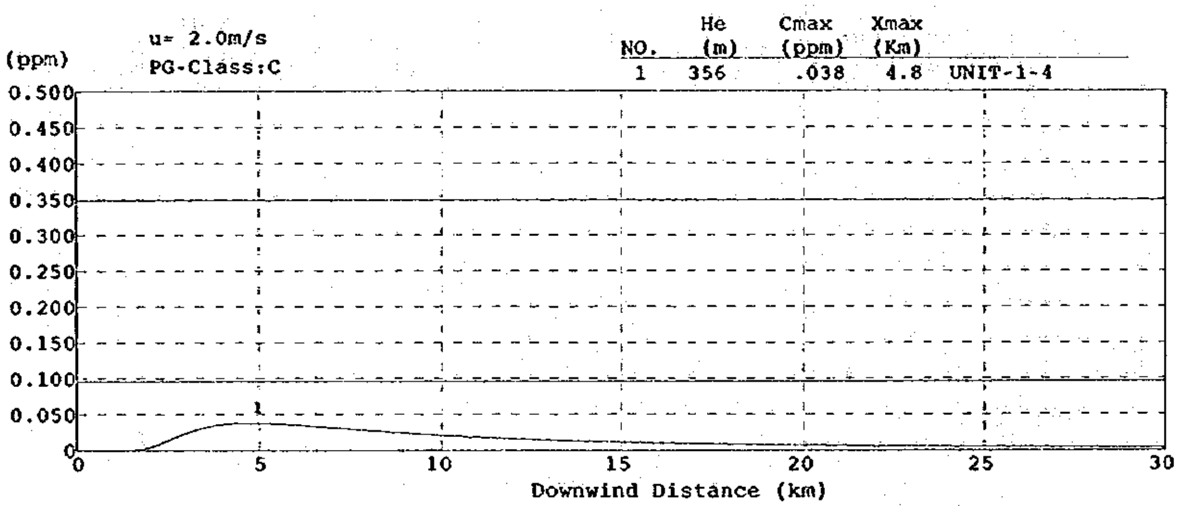
Figures 6.2 A,B and C are SO_2 concentration profiles at three regions. All maximum concentrations were calculated under the conditions of stability C and 3.0 m/s of wind speed. SO_2 maximum concentration was the highest among others at Jorge Lacerda to be 152 ppb. There is no standard for SO_2 hourly concentration in the national air quality regulation and its standard for 24 hours average is 139.4 ppb. The calculated maximum may be not problematic because hourly values is generally higher than the one for 24 hours average.

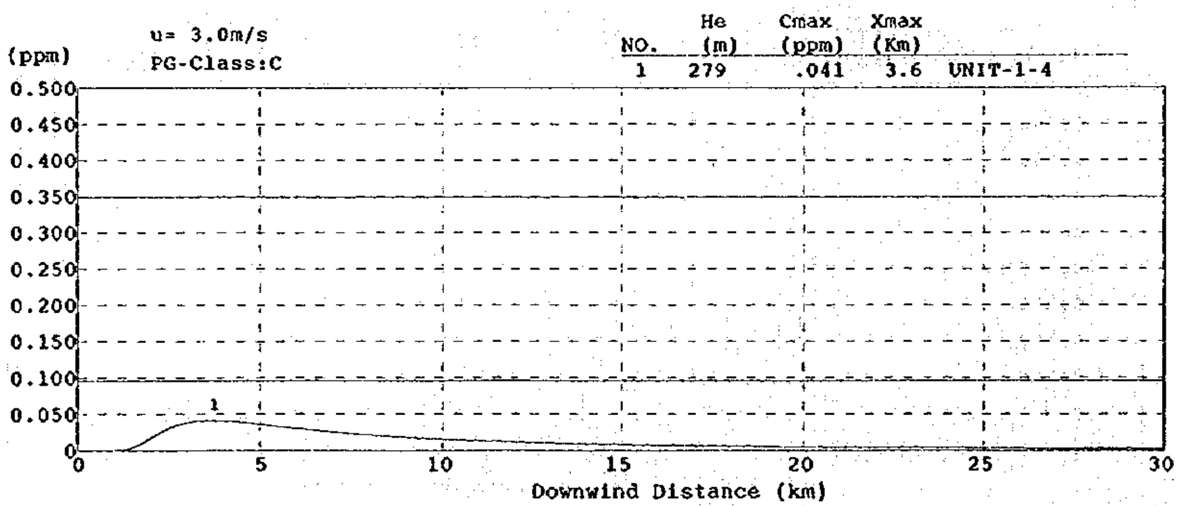


CONCAWE & Plume (SO2)

Figure 6.2 A Hourly Concentration Profile of SO_2 (Jorge Lacerda, Present)

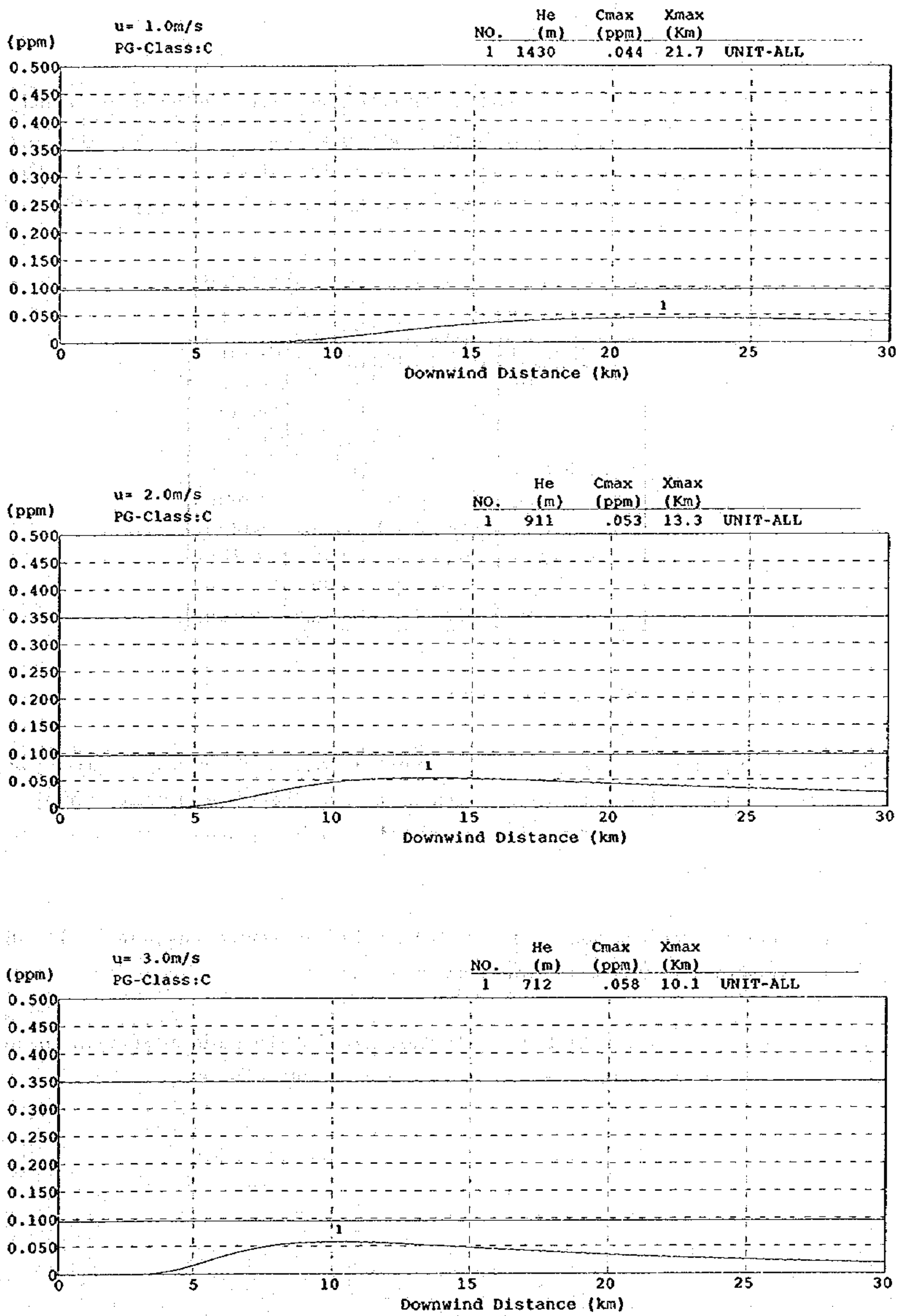






CONCAWE & Plume (SO2)

Figure 6.2 B Hourly Concentration Profile of SO_2 (Charqueadas, Present)



CONCAWE & Plume (SO2)

Figure 6.2 C Hourly Concentration Profile of SO_2 (Candiota, Present)

The calculated NO_2 and SPM maximum concentrations were also the highest among others at Jorge Lacerda to be respectively 32 ppb and 4 5 ug/m^3. The calculated NO_2 concentrations were much lower the national standard for hourly NO_2 of 170.1. The calculated SPM was lower than the national standard for 24 hours average of SPM.

Table 6.2 Maximum Concentration on Profile

Power Plant	Item	Maximum	Distance
Jorge Lacerda	SO_2	152ppb	5.9km
	NO_2	32ppb	5.7km
	SPM	45 μg/m^3	6.1km
Charqueadas	SO_2	41ppb	3.6km
	NO_2	7ppb	3.6km
	SPM	12 μg/m^3	3.6km
Candiota	SO_2	58ppb	10.1km
	NO_2	11ppb	10.1km
	SPM	36 μg/m^3	10.1km

6.5 Effect of Power Plant on Air Quality

The power plants are the major emission sources for SO_2 in all areas, and especially at Jorge Lacerda. Although nothing serious at present, there is a future possibility of SO_2 pollution in the Jorge Lacerda area, depending on the expansion of the power plant or any other SO_2 sources.

The influences from the power plants to NO_2 and SPM concentrations were small in all areas and the measured concentrations were also low.

24 hours concentrations of TSP at Capivari exceeded the national standard as in Chapter 4. However, the contribution from the power plant is low.

Chapter 7 Prediction of Future Air Qualities

7.1 Expansion Plans

ELETROSUL completed the construction of Jorge Lacerda IV unit, 350 MW, in 1996 and started its commercial operation from January, 1997. ELETROSUL has still suspended the construction of the Jacui Plant from 1991. CEEE reduced its expansion plan of Candiota Plant from 2100 MW to 350 MW. Both units, Jacui and Candiota, will start construction after finalized the privatization scheme.

7.2 Simulation of Future Air Quality

7.2.1 Condition of Simulation

Emission conditions are as-known basis currently with emission agreements in consideration.

The regulation for Jorge Lacerda limit the SO_2 amount from the consumption of the 2.2 % sulfur coal at rated load. However, the utilizing rate of the plant was around 50 % and sulfur contents of the used coal were below 2.2 %. It has been assumed that the agreement with the state has no influence to the current emission conditions and pollutant concentrations from the stack are the same as the current ones. Unit IV started from January, 1997 will be operated for full years in the future.

Pollutant concentration limits are determined for Dust, SO_x, and NO_x from the existing Charqueadas plant and the planned Jacui plant. Pollutant concentrations will be reduced to the limits of the agreement and the estimation of emission amounts in the future is changed accordingly. Although the pollutant concentrations limits are defined at 6 % O_2, the existing units will be operated at current actual O_2 concentrations. The limited concentrations values are converted to ones at the actual O_2 concentrations. The new plant will be operated at 6 % O_2. Gas volume and gas temperature are obtained from the design specifications.

For Candiota, pollutant concentrations limits are also set for Dust, SO_x, and NO_x from the existing and the planned units. Dust concentration for the existing units and NO_x concentrations for the planned units are not determined and these concentrations are assumed as same to the current ones. The existing units will be operated at the current actual O_2 concentrations, and the planned units at 6 % O_2.

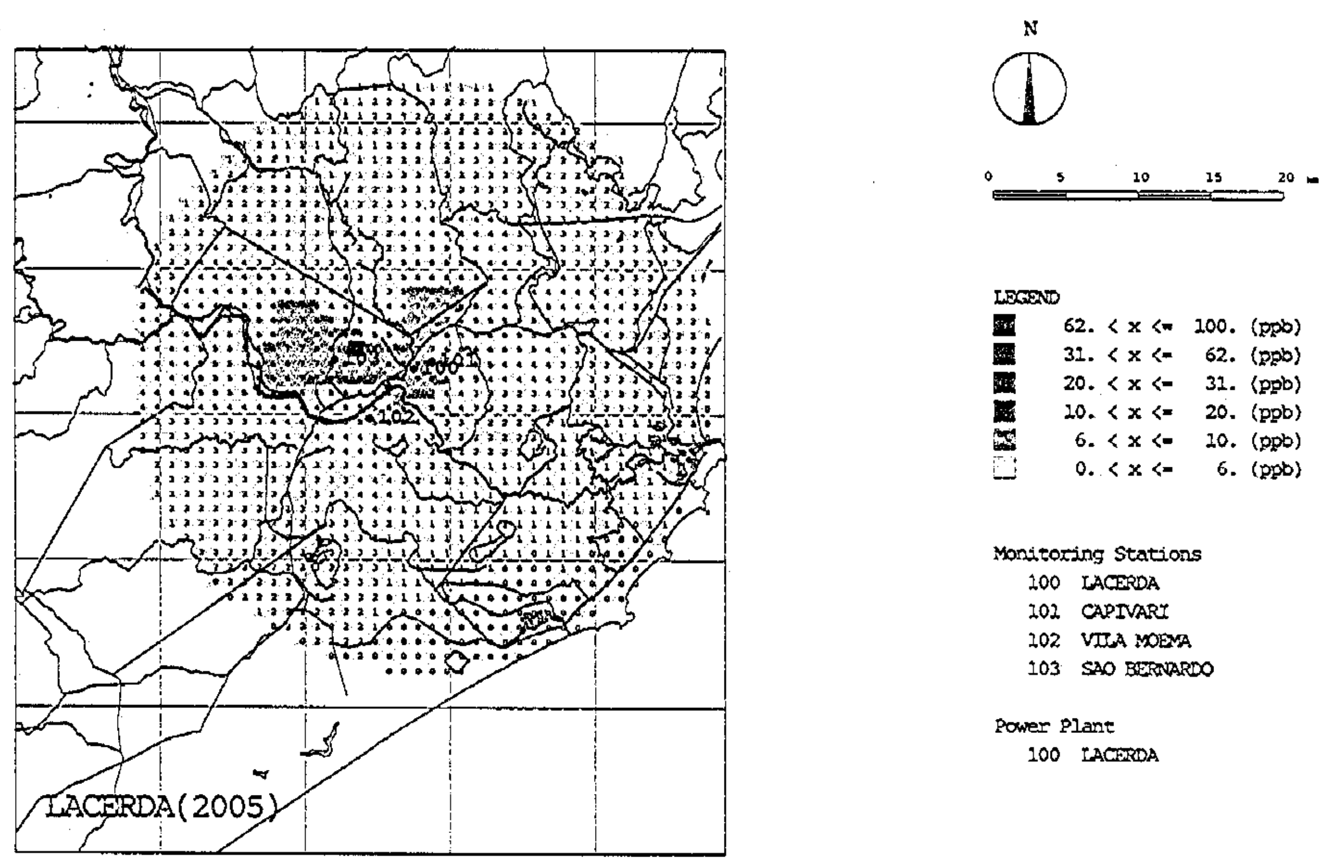
The flue gas temperature of all the units for which FGD will be installed is assumed as 100 ℃. Meteorological conditions are the same as the current ones.

7.2.2 Distribution of Annual Average Concentration

In the Jorge Lacerda region, the calculated maximum concentration of SO_2 annual average is increased to 10.0 ppb from 8.5 ppb of the current conditions. The position with the maximum concentration is the same as the current one. SO_2 concentration will be below the standard even after the expansion and one year operation of Unit IV (Figure 7.1A). The maximum concentration of NO_2 and SPM will increase to 1.2 ppb and 2.9 ug/m^3 respectively, and they will not be problem as well as at present.

Jacui plant will be constructed in the future in addition to the existing Charqueadas plant. However, the maximum concentration of SO_2 will be reduced to 1.4 ppb from 3.1 ppb under the current conditions because of the agreement for both of the plants (Figure 7.1B). Because the emission limits for NOx is higher than the current emission concentrations, NO_2 concentrations will increase to 1.2 ppb by construction of Jacui plant, but it will not violate the national standard. SPM concentration will be reduced to 0.5 ug/m^3.

In the Candiota region, the maximum SO_2 concentration will be reduced to 0.8 ppb from 1.5 ppb under the current conditions even after the expansion of Candiota III because the agreement is set for both of the existing and the planned units (Figure 7.1C). NO_2 and SPM concentrations will increase to 0.4 ppb and 1.3 ug/m^3, not exceeding the national criteria.



LEGEND

62. < x <=	100. (ppb)	0 grids
31. < x <=	62. (ppb)	0 grids
20. < x <=	31. (ppb)	0 grids
10. < x <=	20. (ppb)	1 grids
6. < x <=	10. (ppb)	70 grids
0. < x <=	6. (ppb)	1225 grids

Monitoring Stations
100 LACERDA
101 CAPIVARI
102 VILA MOEMA
103 SAO BERNARDO

Power Plant
100 LACERDA

SO2 ppb Annual Average □C MAX= 10.0ppb

Figure 7.1A Concentration Distribution of SO_2 (Jorge Lacerda, Future)

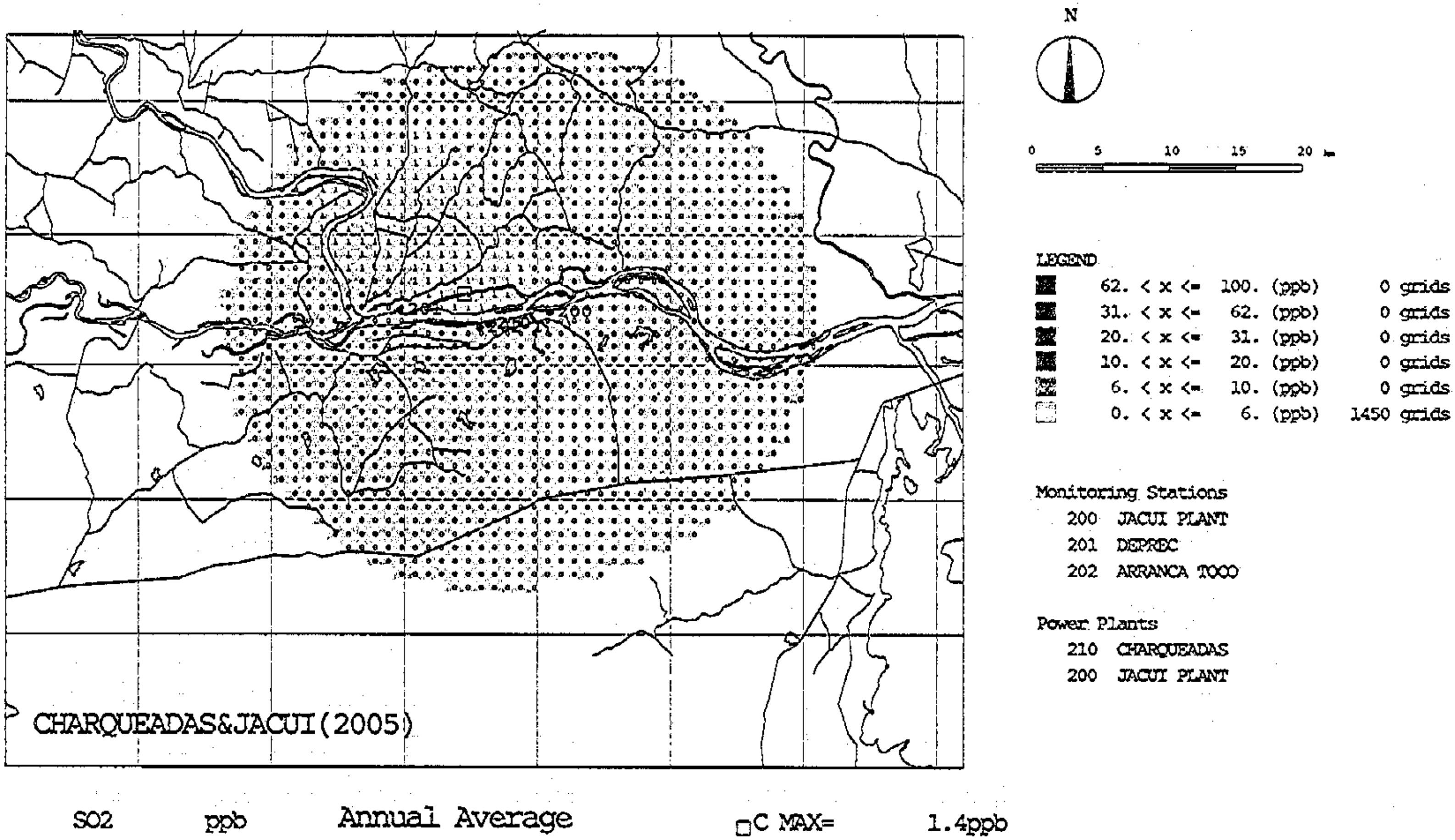


Figure 7.1B Concentration Distribution of SO_2 (Charqueadas&Jacui, Future)

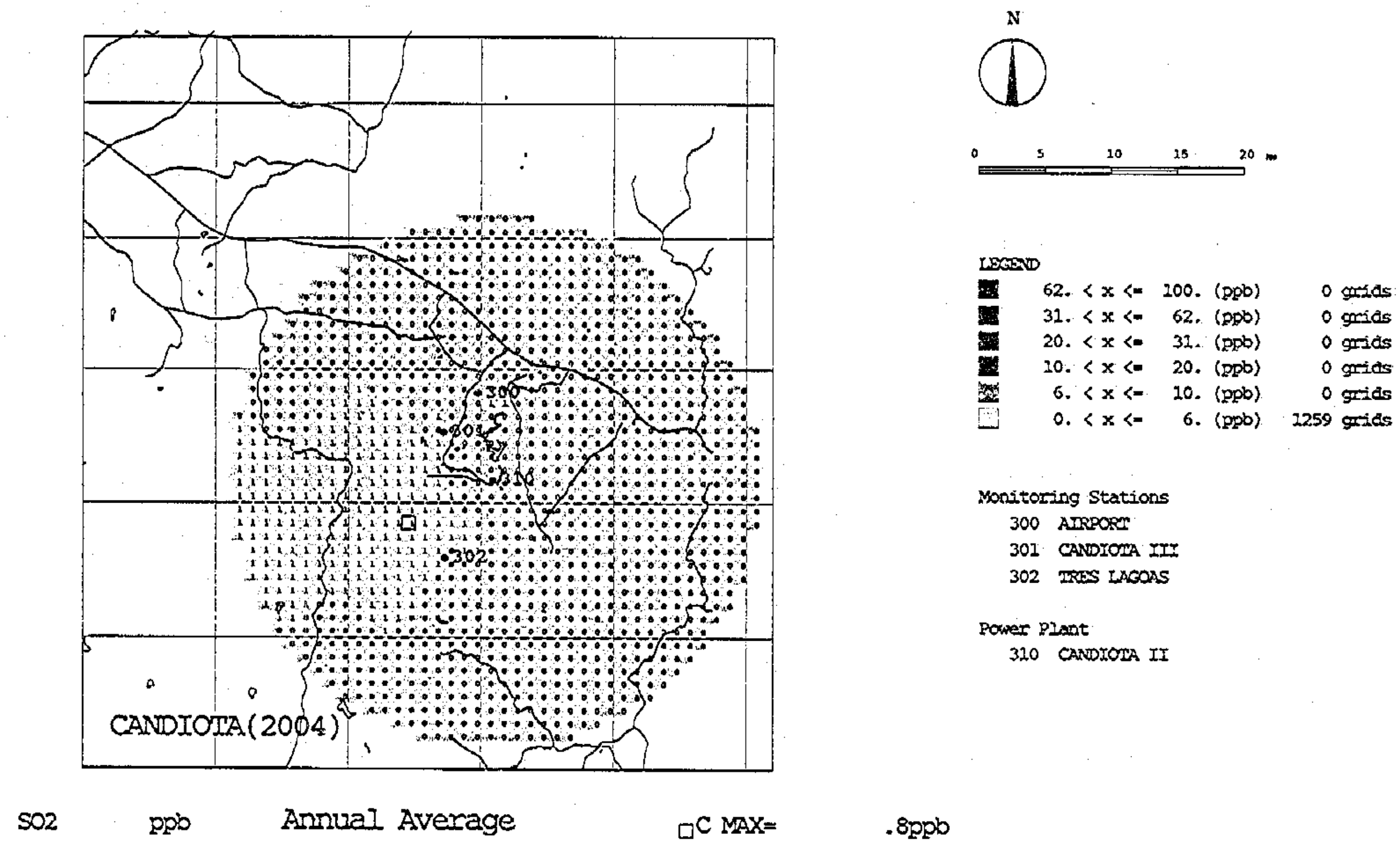


Figure 7.1C Concentration Distribution of SO_2 (Candiota, Future)

7.2.3 Daily Averages and Hourly Values at Monitoring Stations

Simulation procedure is the same as the one under the current conditions. Some of the calculated concentrations at certain stations will increase. However, they are lower than the national ambient air standards (Table 7.1).

Table 7.1 Daily Average and Hourly Value at Monitoring Station

	SO_2 Daily	NO_2 Hourly	SPM Daily
Capivari	64.7	33	19.3
Vila Moema	26.0	28	8.6
Sao Bernardo	43.7	25	11.4
DEPREC	7.1	29	2.2
Jacui	14.8	33	4.0
Arranca Toco	6.2	21	2.0
Airport	6.7	18	24.9
Candiota III	10.5	18	37.5
Tres Lagoas	7.6	18	28.3
Standard	139.4	170.1	150.0
Unit	(ppb)	(ppb)	(ug/m^3)

7.2.4 Hourly Concentration Profile

Most of simulation procedures are the same as the ones under the current conditions, except that the Jacui plant was placed at around 4.7 km far from the Charqueadas plant. Downwind direction is assumed from Jacui to Charqueadas.

Because emission conditions at maximum load never change for the future case at the Jorge Lacerda plant (the emissions from the new plant was included in the last part of the Study), the calculated maximum concentrations are the same. Although all maximum concentrations at all three regions were resulted under the conditions of stability C and 3.0 m/s of wind speed, the maximum calculated concentration for the Charqueadas and Jacui region was resulted under the conditions of stability C and 2.0 m/s of wind speed.

As in Table 7.2, SO_2 and NO_2 concentrations will be the highest at Jorge Lacerda in the future. SPM concentration at Candiota will increase and be the highest among the three. However, all the concentrations will be under the national standards.

Table 7.2 Maximum Concentration on Profile

Power Plant	Item	Maximum	Distance
Jorge Lacerda	SO_2	152ppb	5.9km
	NO_2	32ppb	5.7km
	SPM	45 $\mu g/m^3$	6.1km
Charqueadas	SO_2	25ppb	7.9km
	NO_2	28ppb	8.0km
	SPM	9 $\mu g/m^3$	8.1km
Candiota	SO_2	36ppb	7.6km
	NO_2	25ppb	7.7km
	SPM	47 $\mu g/m^3$	8.3km

7.2.5 Evaluation of Future Air Quality

The impact from the power plants to annual average concentration is estimated as 10ppb and is lower than the standard (30.56 ppb). However, there is a possibility of exceeding the national standard of SO_2 concentrations in the Jorge Lacerda region, because of the contributions from the other pollutant sources. Therefore, the ambient air quality monitoring should be continued.

The expansion plans for Jacui plant and Candiota III are relatively large ones, but the agreements were set for both of the existing and the planned plants. As far as the agreements are observed, no problem would happen even after the expansion, according to the simulation. Implementation of the countermeasure to satisfy the agreement are very important.

Chapter 8 Recommendations

8.1 Preface

Countermeasures to preserve air quality in the regions are proposed in this chapter based on evaluation of the current and future conditions of emissions and air qualities. For the stack gas emission controls, the agreements with each state were the basis of the proposal planning. The agreement also stipulated methods of stack gas monitoring at Charqueadas and Candiota Plants.

8.2 Air Pollution Control at Power Plants in General

There are three basic considerations in planning air pollution control measures at power plants: fuel conversion, facility renovation, and operational and management measures. The power plants concerned here are located at mine-mouths and there is not much possibility of changing the fuel to pollution-free coal.

The facility renovation is to add stack gas cleaning processes, to change over to low-NOx burners, to improve dust removal efficiency at precipitators and so forth. Operational and management measures promotes pollution control from the side. In contrast to the hardware of facility renovation, this is for software, including stringent combustion control aimed pollution control and fuel efficiency improvement, as well as expansion of monitoring capability.

8.3 Recommendations for Individual Plants

(1) Jorge Lacerda

Neither fuel conversion nor facility renovation is required. It is recommended that the plant check efficiencies of all electrostatic precipitators which seem to be having problems.

(2) Charqueadas

All the units in this plant are too small to renovate facilities. ELETROSUL shall consider the fate of the plant --whether to enlarge it by combining small four units into one or demolish it completely. If it is necessary to continue operations, two units of wet type SO_2 removal process having capacity equivalent to 36 MW are recommended for reduction of SO_2 and dust emissions in accordance with the agreement with the state.

(3) Candiota

Candiota AI and AII units should be renovated by replacing low NOx burners to meet the requirements of the agreement with the state.

Also in order to meet the agreement, all the existing units, including AI and II, should be provided with wet type SO_2 removal (95% for A and 70% for B) units to control both emissions of SO_2 and dust; one unit for AI and II combined and two units for BI and II. There is no space available to install separate SO_2 and dust removal processes.

The AI and AII units are too small to be renovated and accordingly require relatively too high investment cost for the renovations. CEEE shall study economically the best solution to comply with the agreement. Some of solutions are a) abandonment of the units' operation after the commencement of Candiota III, b) additional SO_2 removal at BI and BII (probably plus Candiota III) with equivalent to the amount to be removed at AI & II, and no installation of the FGD at AI & II and keeping operation of AI & II, or c) else.

The new Candiota III may have a more efficient electrostatic precipitator, since it is designed accordingly to the design specifications and not retrofitted later. Any type of reliable SO_2 removal process can accomplish the limitation specified by the agreement. However, from operational and management viewpoints and from giving safety margin to dust removal, installation of the wet type SO_2 removal plant is advisable.

(4) Jacui

Although Jacui needs to install a unit of low SO_2 removal (70%) and probably no additional dust removal unit to the already installed one, tt is recommendable to install one unit of wet SO_2 removal process from giving safety margin to dust removal.

8.4 Ambient Air Monitoring System

According to the monitored data and simulation results, there are no violations of national ambient air quality standards for SO_2 and NO_2 currently and in the foreseeable future. It is recommended that monitoring continue using the automated stations and that data be reported to the authorities and public as one of the social responsibilities of the power companies.

TSP concentration over the national primary standard was recorded three times at Capivari and rather high at Vila Moema in the Jorge Lacerda region. Therefore, it is recommended that SPM automated monitoring instruments be installed at both stations, and each one unit at each one monitoring station in Charqueadas and Candiota regions. CMB evaluation is proposed to identify contributions of emission sources in Jourge Lacerda region as a project by FATMA. There are several proposals to relocate monitoring stations to better places according to the simulation study.

The Charqueadas plant is included in the area of the Greater Porto Alegre Ambient Air Monitoring System planned by the State of Rio Grande do Sul. ELETROSUL should propose to the state that it includes three monitoring stations to be connected and managed as part of the system.

8.5 Stack Gas Monitoring System

The agreement with the state stipulated continuous monitoring of SO_2, NOx and dust emissions of stacks at Charqueadas from 2005, Jacui and Candiota III from the beginning of their operations, Candiota AI and AII from 2004, and BI and BII from 2002. Recommendations were given regarding the types, costs, and methods of maintenance for the continuous monitoring equipment. As the dust instrument can give only a relative value for dust concentration, batch monitoring as employed in the Study has to be carried out to confirm the actual value.

There is no statement available on Jorge Lacerda for stack gas monitoring. It is recommended that batch monitoring be carried out twice a year or occasionally when the kind of coal is changed or boiler operation conditions are changed.

Chapter 9 Conclusion

ELETROSUL and CEEE rely on coal for 10% and 40% of their power generation respectively. They are obliged to oversee operations of the coal power plants in meeting the national and local standards or agreements for environmental protection. Current monitoring results indicated no violation of the national ambient air quality standards, except one incident of TSP at Capivari which may not be impacted by the power plant emissions. Air quality in the foreseeable future is also within the standards according to the dispersion simulation study.

Table 9.1 summarizes proposed items to be carried out by the Brazilian side. Air quality should be continuously monitored using the existing automated stations with additional 4 SPM instruments: 2 in Jorge Lacerda and each on in other regions. CMB evaluation was proposed to be carried out in Jorge Lacerda region. The stations around Charqueadas may be included in the Greater Porto Alegre Ambient Air Monitoring System when it is implemented.

To observe the agreement with the state, wet SO_2 reduction plants have to be installed at the Jacui and Candiota plants. The Charqueadas plant also has to be provided with the same kinds of plants if it is to be kept in operation. Also, continuous stack gas monitoring systems have to be installed in the Charqueadas, Jacui, and Candiota plants.

All the member of the JICA Team are glad to have been involved in the Study and to have found our counterparts eager to learn sacrificing holidays in Carnival. We hope the cleanliness of the ambient air in the regions be preserved forever.

Table 9.1 Summary of Recommendations[1)]

No.	Items	Description	Background	Investment[2)]	Substitute Plan	Plan	Startup	Remarks
1	Power Plant	One train of wet FGD unit in Jacui	Agreement	$\$35 \times 10^6$	Separate SO_2 and Dust Removal	see Remarks	(E/1999)	Immediately to start design, depending on the start-up date
2	Power Plant	Decision of the fate of Charqueadas Plant	Small and Old Agreement	—	2 Wet FGDs	—	2005	Investment of the substitute plan: $\$ 12 \times 10^6$
3	Power Plant	One train of wet FGD in Candiota A	Agreement	$\$17 \times 10^6$	—	2001	2004	
4	Power Plant	Low NOx Burners in Candiota A	Agreement		Stack Gas Recycle	2003	2004	
5	Power Plant	Two trains of wet FGDs in Candiota B	Agreement	$\$64 \times 10^6$	—	1999	2002	
6	Power Plant	One train of wet FGD in Candiota III	Agreement	$\$40 \times 10^6$	Dry FGD	2000	(9/2003)	
7	Plant Management	Strict operation and maintenance management of boiler, ESP, etc. at all power units	Save Energy, Remove Dust	—	—	Always	—	
8	Stack Gas	Batch monitoring at all units until another monitoring system installed	Social Responsibility	—	—	Occasion -ally	—	
9	Stack Gas	Continuous monitoring of SO_2, dust, and NOx at Jacui	Agreement	$110,000	—	(1998)	(E/1999)	
10	Stack Gas	Charqueadas - see Item 2	—	—	Auto. Continuous Monitoring	—	2005	Investment of the substitute plan: $440,000
11	Stack Gas	Continuous monitoring of SO_2, dust, and NOx at Candiota A	Agreement	$220,000	—	—	2004	
12	Stack Gas	Continuous monitoring of SO_2, dust, and NOx at Candiota B	Agreement	$220,000	—	—	2002	
13	Stack Gas	Continuous monitoring of SO_2, dust, and NOx at Candiota III	Agreement	$110,000	—	—	(9/2003)	
14	Air Monitoring	SPM analyzers 2 in Jorge Lacerda Area, each one in other areas, total 4 units	Violation of TSP Air Quality	$120,000	—	1998	—	
15	Air Monitoring	CMB evaluation of SPM sources in Jorge Lacerda Area	ditto	see Remarks	—	1999	2001	FATMA's Project; Estimated total cost=$400,000 including analyses in Japan
16	Air Monitoring	Move monitoring stations slightly in J. Lacerada and Candiota; Change or add wind meters	Better Monitoring	—	—	—	—	4 sets of Wind meters $52,000
17	Air Monitoring	Transfer the monitoring system in Charqueads Area to the Greater Porto Alegre System	Cooperate with the State	—	—	—	Not Dis-closed	FEPAM's Project
18	Air Monitoring	Continue monitoring in all three regions and report the results to the public and authorities	Social Responsibility	—	—	Always	—	

Note: 1) Eliminated those items to be carried out in unknown future or ones related to undisclosed details of new or expanded units, such as ESP and low NOx Burners.

2) Japanese catalogue prices for hardware only; Conversion rate: $1.00=¥120

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