Chapter S7 Air Dispersion Simulation

Contents

Tables and Figures

7.1 Outline of Air Dispersion Simulation

Air dispersions were simulated for three periods as in the following a), b), and c) for each area, and the calculated results were compared with the corresponding air quality monitoring data.

a) Summer air quality monitoring period (around one week)

Area	Period
Buenos Aires	From March 8th to 15th
San Nicolas	From February 5th to 12th
Lujan de Cuyo	From February 13th to 25th

b) Winter air quality monitoring period (around one week)

Area	Period
Buenos Aires	From July 13th to 18th , and 20th to 21st
San Nicolas	From July 27th to August 3rd
Lujan de Cuyo	From June 27th to July 4th

c) Recent period with the existing air quality monitoring data

Area	Period	Source of the Existing Monitoring Data
Buenos Aires	1998	Laboratorio Vigilancia Atmosferica
San Nicolas	2000, April	CTSN (UTN)
Lujan de Cuyo	2000	Gobierno Mendoza

The ISCST3 dispersion model was applied for the simulation, which has been used in some EIAs in Argentina (#33, #134) and has been frequently used in the world.

The targeted pollutants were SO_2, NO_x as NO_2 and PM. Hourly meteorological data were used for calculation of pollutant concentration. The necessary input data for air dispersion model are meteorological data and pollutant source data.

7.2 Meteorological Conditions

Hourly data of wind direction, wind speed, temperature, atmospheric stability, and mixing height are at least required for the calculation with the ISCST3 model. Atmospheric stability and mixing height were estimated by the Argentine method (#28). Recommendations for improvement of the simulation model are included in Article 7.5 in this Chapter S7.

7.2.1 Meteorological Observation Data

For the simulation during the periods, the following meteorological data and estimation methods were used as in **Table 7.2.1**. The JICA Team purchased some of the meteorological data from Servicio Meteorologico Nacional (SMN).

Table 7.2.1 Meteorological Observation Data

Buenos Aires			
Period	Summer	Winter	Year 1998
Wind Speed, Wind Direction	Nuevo Puerto Power Plant	Same as to the left	Aeroparque (SMN)[1)]
Temperature	Same as to the above	Same as to the left	Costanera
Cloud Amount, Cloud Height	Aeroparque (SMN)[1)]	Estimated from Weather types at Aeroparque (SMN)[2)]	Aeroparque (SMN)[1)]
San Nicolas			
Period	Summer	Winter	Year 2000
Wind Speed, Wind Direction	UTN (University)	Same as to the left	Rosario airport (SMN)[1)]
Temperature	UTN (University)	Same as to the left	Same as to the left
Cloud Amount(CA), Cloud Height(CH)	Rosario airport (SMN)[1)]	Estimated from Weather types at Rosario airport[2)]	Rosario airport (SMN)[1)]
Lujan de Cuyo			
Period	Summer	Winter	Year 2000
Wind Speed, Wind Direction	Observed by Gobierno Mendoza	Same as to the left	Mendoza airport (SMN)[1)]
Temperature	Same as to the above	Same as to the left	UNC (University)
Cloud Amount(CA), Cloud Height(CH)	Mendoza airport (SMN)[1)]	Estimated from Weather types at Mendoza airport[2)]	Mendoza airport (SMN)[1)]

1) Purchased, 2) Downloaded from the web site

7.2.2 Estimation of Mixing Height and Atmospheric Stability

1) Mixing Height

The ENRE manual estimates the mixing height h (m) under the neutral condition by

$$h = \frac{\alpha \cdot u_*}{f}$$

Under the unstable conditions by

$$h = \frac{\alpha \cdot u_*}{f} \cdot \left| \frac{u_*}{fL} \right|^{1/2}$$

Here, f (Coriolis parameter)= $|2\Omega \sin\Phi|$ (Φ : latitude)、u_*(friction velocity)、L(Monin-Obukhov length).

An ultrasonic anemometer is usually used for observation of the friction velocity. As the velocity was not observed in this study, the u_* and L were calculated with the meteorological data pre-processor, PCRAMMET, and the meteorological observation data.

The flow of the estimation of u* and L by PCRAMMET is as follows.

1. A solar elevation angle is calculated with the latitude and longitude, and a solar radiation amount is calculated by experimental formulae with cloud amounts and the calculated solar elevation angle.
2. Adding to the calculated solar radiation amount, a net radiation amount is calculated with temperature, cloud amounts and the noon time Albedo value.
3. Adding to the calculated net radiation amount, a sensible heat flux is calculated with the Bowen ratio, fractions of the net radiation absorbed by the ground, and anthropogenic heat flux.
4. The u_* and L at each observation site are calculated by the following formulae
5. The u_* and L at the target point (ex. power plant) are calculated.

The calculation formulae for u_* and L under the unstable conditions (in the daytime) are;

$$u^* = \frac{kU}{\ln\left(\frac{z_{ref}}{z_0}\right) - \Psi + \Psi_0}$$

$$L = \frac{\rho c_p T u_*^3}{kgH}$$

Anyway,

$$\Psi = 2\ln\left(\frac{1+\mu}{2}\right) + \ln\left(\frac{1+\mu^2}{2}\right) - 2\tan^{-1}(\mu) + \frac{\pi}{2}$$

$$\Psi_0 = 2\ln\left(\frac{1+\mu_0}{2}\right) + \ln\left(\frac{1+\mu_0^2}{2}\right) - 2\tan^{-1}(\mu_0) + \frac{\pi}{2}$$

$$\mu = \left(1 - 16\, {z_{ref}}/{L}\right)^{1/4}$$

$$\mu_0 = \left(1 - 16\, {z_0}/{L}\right)^{1/4}$$

H: Sensible Heat Flux at Ground Surface (Wm^{-2})

ρ : Density of Dry Air (By $P = \rho RT$)

k: von Karman Constant

c_P: Specific Heat Capacity at Constant Pressure ($1004 Jkg^{-1}deg^{-1}$)

U: Wind speed (ms^{-1})

T: Temperature (K)

z_{ref}: Anemometer Height above Ground (m) g : Gravitational Acceleration （$9.81 ms^{-2}$）

z_0 : Surface Roughness Length at Observation Site（m）

Under stable conditions (In the nighttime)

$$u_* = \frac{C_D U}{2}\left(1+\left(1-\left(\frac{2u_0}{C_D U}\right)^2\right)\right)$$

$$L = \frac{T u_*^2}{k g \theta_*}$$

Here, β m is non-dimensional constant(=4.7), and N is cloud amount

$$\theta_* = 0.09\left(1-0.5N^2\right)$$

$$u_0 = \sqrt{\frac{\beta_m z_{ref}\, g\theta_*}{T}}$$

$$C_D = \frac{k}{\ln\left(\frac{z_{ref}}{z}\right)}$$

Especially, when $\frac{4u_0^2}{C_D^2 U^2} > 1$, $u_* = \frac{C_D U}{2}$

The reference values for input parameters are included in the user’s manual of the PCRAMMET (#238).

2) Atmospheric Stability

Atmospheric stability is estimated with the following tables (**Table 7.2.2** and **Table 7.2.3**).

Table 7.2.2 Definition of Atmospheric Stability

Wind Speed at 10 m (m/s)	Daytime			Nighttime	
	Solar Radiation Index			4/8<=Cloud Cover<=7/8	Cloud Cover <=3/8
	Strong	Moderate	Weak		
<2	A	A – B	B	F	F
2 – 3	A – B	B	C	E	F
3 – 5	B	B - C	C	D	E
5 – 6	C	C – D	D	D	D
6<=	C	D	D	D	D

Table 7.2.3 Definition of Solar Radiation Index

Cloud Cover(CC) Cloud Ceiling Height(CH)	Solar Elevation Angle (A)		
	15<A<=35	35<A<=60	60<A
CC<=4/8 or 4800m<CH	Weak	Moderate	Strong
5/8<=CC<=7/8 and 2100m<CH<4800m	Weak	Weak	Moderate
5/8<=CC<=7/8 and CH<2100m	Weak	Weak	Weak

7.2.3 Meteorological Conditions during the Periods

Meteorological conditions during the simulation periods are summarized in **Table 7.2.4.**

For annual average data, the meteorological characteristics in each area are described as follows.

In Buenos Aires, the wind is strong and it contributes the dilution of pollutant in its area. However, the major wind directions are north and east, which means the direction from the river-side power plants toward the city urban area although the contributions from the power plants are relatively small compared with the other pollutant sources. Around the half of the stability is estimated as the neutral condition and the annual average mixing height is more than 10,000 meters.

In San Nicolas, although the wind is around 3 m/s, the calm frequency is as high as 18 %. The major wind directions are south and east. The east wind blows from the power plant toward the residential area, and the south wind brings the pollutant over the Parana river. The frequency of the neutral stability condition is below 40%, and the frequency of stable and unstable conditions are relatively high. The annual average mixing height is more than 9,000 meters.

In Lujan de Cuyo, the wind is weak and the calm frequency is very high as 25%. The major wind directions are south and southeast, and the directions are different from the ones towards the Mendoza city center. The frequency of the neutral condition is low, and the stable and unstable conditions show high frequencies because of weak wind. The annual average mixing height is more than 11,000 meters.

Table 7.2.4 Meteorological Conditions during Monitoring Period

Buenos Aires			
Period	Summer	Winter	Year 1998
Average Wind Speed (m/s)	4.1	2.4	4.6
Major Wind Direction[1)]			
First (%)	N (29.2)	W (31.9)	E (26.3)
Second (%)	E (23.2)	N (19.4)	N (15.4)
Calm (%)	0.0	0.0	3.1
Average Temperature. (℃)	24.5	12.8	17.8
Atmospheric Stability (%)			
A	0.0	0.0	0.2
B	17.9	19.4	8.0
C	30.4	15.6	21.5
D	41.1	33.1	50.9
E	4.8	11.2	9.0
F	6.0	20.6	10.4
Average Mixing Height (m)	11807.4	5629.4	10721.7

San Nicolas				
Period	Summer	Winter	Year 2000	Year 2000 Apr.
Average Wind Speed (m/s)	2.2	2.8	3.1	2.6
Major Wind Direction				
First (%)	N (27.4)	N (40.9)	S (19.3)	E(26.7)
Second (%)	S (15.5)	E (18.3)	E (19.2)	S(15.9)
Calm (%)	17.3	7.3	17.6	18.4
Average Temperature. (℃)	26.4	13.8	18.4	18.0
Atmospheric Stability (%)				
A	1.2	0.0	0.3	0.0
B	30.4	18.9	13.2	10.0
C	9.5	25.0	19.9	18.3
D	31.0	18.9	38.7	41.3
E	3.0	11.0	6.7	6.7
F	25.0	26.2	21.2	23.2
Average Mixing Height (m)	12989.1	6219.2	9349.0	7673.0

Lujan de Cuyo			
Period	Summer	Winter	Year 2000
Average Wind Speed (m/s)	3.2	2.4	2.1
Major Wind Direction[1)]			
First (%)	E (35.0)	W (37.8)	S (18.2)
Second (%)	W (25.8)	E (17.7)	SE (18.1)
	0.0	0.0	25.4
Average Temperature. (℃)	23.9	7.3	17.4
Atmospheric Stability (%)			
A	0.0	0.0	0.3
B	19.2	7.3	24.7
C	36.7	29.9	19.9
D	9.2	15.2	22.9
E	5.8	15.9	3.5
F	29.2	31.7	28.6
Average Mixing Height (m)	11981.5	4747.3	11891.37

1) In eight wind directions

7.3 Emission Source Condition

7.3.1 Pollutant Source Condition

Data necessary to simulate the air dispersion of pollutants from power plants are facility outlines, stack data, and emissions from each stack. Each type of fuel consumed by each facility, its operation condition, and flue gas rate and gas temperature at each stack are different at any time. Therefore, it is essential to collect these data in details.

As flue gas flow rate and velocity are not measured each hour of operation usually at power plants, these values have to be estimated by the following methods. The pollutant concentration is monitored when the sample gas temperature is cooler than its original one in the stack. Therefore, the most of moisture originally contained in the sample gas has condensed before the measurement. The gas is thought as very close to dry state. This is the reason to use dry calculated amounts of flue gas by fuel, rather than wet calculated amounts of flue gas by fuel for fuel to gas conversion. Calculated dry gas flow rate from each fuel burnt (Table 3.3.1 in the Main Report) is used. If another reliable flue gas rate per fuel burnt is available, the data can be used.

$$\text{Dry Gas } (m^3_N/h) = \sum_{fuelType} \text{Fuel Consumption} \times \text{Calculated Dry Gas by Fuel}$$

$$\text{Emission Rate (g/sec)} = \text{Dry Gas } (m^3_N/h) \times \text{Concentration } (g/\,m^3_N) \div 3600 \text{ sec/h}$$

Velocities of wet flue gases at the exhaust temperature and at the stack top are calculated using calculated amounts of wet flue gas by fuel (Table 3.3.1 in the Main Report).

$$\text{Wet Gas } (m^3/h)$$

$$= \sum_{fuelType} \text{Fuel Consumption} \times \text{Calculated Wet Flue Gas by Fuel} \times \frac{(T_{actual} + 273.15C)}{273.15C}$$

$$\text{Gas Velocity (m/sec)} = \text{Wet Gas } (m^3/h) \times \text{Stack Area } (m^2) \div 3600 \text{ sec/h}$$

The JICA Team requested for hourly fuel consumption, flue gas concentration, and gas temperature of power plants in each model area. The hourly data are used to set up hourly flue gas velocity, and emission rate, etc. for the monitoring period. For stacks where hourly generated power, and daily or monthly concentration or fuel consumption were obtained, the hourly flue gas velocity and emission rate, etc. were estimated by ratio of hourly versus daily or monthly sum of power generation. For the cases of daily fuel consumption is obtained instead of hourly data, an initial step needed is shown as equation in the followings. If monthly fuel consumption is obtained, it is necessary to change the daily power generation to monthly power generation.

Hourly Fuel Consumption =

$$\text{Daily Fuel Consumption} \times \text{Hourly Power Generation} \div \text{Daily Power Generation}$$

(m³/h or ton/h) *(m³/d or ton/d)* *(MW/h)* *(MW/d)*

For cases that have no hourly generation data obtained, a similar pattern has to be mobilized for the calculation. An example of an average 24 hour NO_x emission pattern for Stack 2 of Costanera is shown in **Figure 7.3.1**. A similar individual pattern is used for calculation of the hourly generation data of each power generation unit. **Table 7.3.1** shows the cases the own pattern is used for.

Figure 7.3.1 Example of Average 24 Hour NO_x Emission of Costanera Stack 2

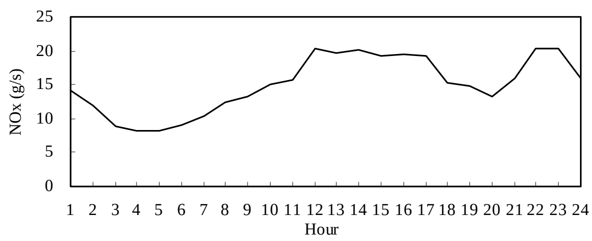


Table 7.3.1 Data Pattern Used

Power Plant	Summer	Winter	Annual
Central Puerto	×	O	O
Central Costanera	O *1	O	O
San Nicolas	O	O	O
Mendoza	×	O	O

Note O : Hourly values obtained or estimated for all of the stacks.
*1 : Except Stack 1
× : No utilization of the similar pattern with the one in Fig. 7.3.1.

For most of the time, the above methods are used except 2 cases. Although the summer monitoring was in February 2001, average concentration of February 2000 and average fuel consumption of February 1998 are used for Central Puerto. Also for the summer monitoring data of Centrales Termicas Mendoza, average concentration and fuel consumption of February 2000 are used. This is because only data available was of different years, and the data will be more representative if monthly average rather than of hourly values are used. For these exceptions, hourly concentration and fuel consumption patterns are estimated as explained below.

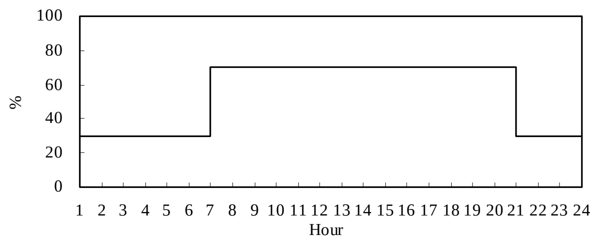
For stacks where hourly concentration and fuel consumption cannot be estimated by the previous method (Central Puerto, Mendoza and Stack 1 of Central Costanera), the 24 hour operation pattern of **Figure 7.3.2** is used. Such case arises where concentration or fuel consumption is not hourly and power generation values are not in hourly. If the obtained fuel consumption was in daily values, the following steps were applied to find hourly emission rate.

1) Set hourly fuel consumption by making an assumption of hourly operation pattern of 70% daytime and 30% night time (**Figure 7.3.2**).

2) Assume daytime operation starts at 7:00am and fuel consumed every hour as set in 1), to evenly distribute the daily fuel consumption into 14 hours.

3) Find gas velocity and emission rate from hourly flue gas calculated from hourly fuel consumption and unit flue gas amounts by fuel (Table 3.3.1 in the Main Report).

Figure 7.3.2 Surveyed Mean 24 hour Operation Pattern



In the cases where only daily or monthly concentrations are available, the concentration is used as it is. For winter monitoring period, daily concentration were obtained from 2 stacks of Central Termica San Nicolas and all of Centrales Termicas Mendoza. Also for the annual data, daily concentrations were obatined from Central Costanera, and monthly concentrations were obtained from Centrales Termicas Mendoza.

7.3.2 Monitoring Period

1) Buenos Aires

There are 4 power plants in Buenos Aires with total 14 stacks. Central Puerto (Nuevo Puerto and Puerto Nuevo Power Plants) can burn natural gas and fuel oil, and Central Costanera does natural gas, fuel oil, and gas oil. Central Buenos Aires, which is located within Costanera (hereinafter included in Costanera), consumes natural gas only.

A Summer

For Central Puerto, concentration of March in year 2000, and fuel consumption of March in year 1998 were used as the base because no other data were presented to the JICA Team, and they are summarized in **Table 7.3.2**.

Table 7.3.2 Operation Rate, Emissions, and Flue Gas at Central Puerto Power Plant in Summer Monitoring Period[*1]

Stack 5 (Unit5)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	--- g/s
		SO_2	--- g/s
		PM	--- g/s
	Average Flue Gas during Operation		357.16 $\times 10^3 m^3_N/h$
Stack 6 (Unit6)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	14.99 g/s
		SO_2	--- g/s
		PM	0.17 g/s
	Average Flue Gas during Operation		463.19 $\times 10^3 m^3_N/h$
Stack 7 (Unit7+8)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	10.91 g/s
		SO_2	1.36 g/s
		PM	7.40 g/s
	Average Flue Gas during Operation		743.72 $\times 10^3 m^3_N/h$
Stack 8 (Unit9)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	17.62 g/s
		SO_2	--- g/s
		PM	0.10 g/s
	Average Flue Gas during Operation		495.25 $\times 10^3 m^3_N/h$

Note [1*]: Concentration of year 2000 and fuel consumption of year 1998 were used because no data was presented for the monitoring period.

Data of 4 stacks of Costanera Power Plant were obtained. The details are as shown in **Table 7.3.3**. The operation rate of the stack 3 is below 50% but has the largest average flue gas during this period.

Table 7.3.3 Operation Rate, Emissions, & Flue Gas at Costanera Power Plant in Summer Monitoring Period

Stack 1 (Unit1+2)	Operation Rate		67.3 %
	Emission Rate at Average Operation Rate	NO_x	4.88 g/s
		SO_2	0.30 g/s
		PM	0.66 g/s
	Average Flue Gas during Operation		175.83 $\times 10^3 m^3_N/h$
Stack 2 (Unit3+4)	Operation Rate		82.7 %
	Emission Rate at Average Operation Rate	NO_x	14.91 g/s
		SO_2	0.39 g/s
		PM	1.53 g/s
	Average Flue Gas during Operation		370.45 $\times 10^3 m^3_N/h$
Stack 3 (Unit6)	Operation Rate		45.2 %
	Emission Rate at Average Operation Rate	NO_x	47.39 g/s
		SO_2	0.48 g/s
		PM	6.84 g/s
	Average Flue Gas during Operation		636.16 $\times 10^3 m^3_N/h$
Stack 4 (Unit7)	Operation Rate		6.5 %
	Emission Rate at Average Operation Rate	NO_x	2.10 g/s
		SO_2	0.00 g/s
		PM	0.50 g/s
	Average Flue Gas during Operation		194.80 $\times 10^3 m^3_N/h$
Stack 5[*1] (CBA)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	14.25 g/s
		SO_2	280.61 g/s
		PM	33.33 g/s
	Average Flue Gas during Operation		717.19 $\times 10^3 m^3_N/h$

Note [*1]: 24 hour pattern of **Figure 7.3.2**, and data of year 2000 is used because no data obtained for monitoring period.

Table 7.3.4 shows emissions from power plants and mobile and stationary sources during monitoring period in Buenos Aires. Power plants emitted NO_x the most and PM the least, whereas mobile and other stationary sources emitted NO_x the most and SO_2 the least. Most of the SO_2 emission is due to data of year 2000 for Costanera Stack 5.

Table 7.3.4 Emission During Summer Monitoring Period in Buenos Aires

Unit:ton

	NO_x	SO_2	TSP
Power Plant	70.1	22.1	7.9
Other Stationary	5.6	0.0	0.0
Mobile	1,200.2	124.6	313.2

Note: Not all stationary sources are included

B Winter

Data of 6 stacks of Central Puerto and 5 stacks of Costanera Power Plant were obtained. The details are as shown in **Table 7.3.5** and **Table 7.3.6**. The gas rates are very small for the stack 7 of Central Puerto and the stacks 1, 2, and 4 of Costanera because they had small amount of fuel consumption, which resulting in small amount of flue gas during operation.

Table 7.3.7 shows emissions from power plants and mobile and stationary sources during winter monitoring period in Buenos Aires. Power Plants emitted NO_x the most and PM the least, whereas mobile and other stationary sources emitted NO_x the most and PM the least.

Table 7.3.5 Operation Rate, Emissions, & Flue Gas at Central Puerto Power Plant in Winter Monitoring Period

Stack 6 (Unit6)	Operation Rate		61.7 %
	Emission Rate at Average Operation Rate	NO_x	5.38 g/s
		SO_2	8.60 g/s
		PM	0.19 g/s
	Average Flue Gas during Operation		375.12 $\times 10^3 m^3_N/h$
Stack 7 (Unit7+8)	Operation Rate		1.9 %
	Emission Rate at Average Operation Rate	NO_x	0.22 g/s
		SO_2	0.00 g/s
		PM	0.01 g/s
	Average Flue Gas during Operation		36.11 $\times 10^3 m^3_N/h$
Stack 8 (Unit9)	Operation Rate		85.8 %
	Emission Rate at Average Operation Rate	NO_x	23.20 g/s
		SO_2	5.04 g/s
		PM	0.08 g/s
	Average Flue Gas during Operation		348.73 $\times 10^3 m^3_N/h$
Stack 11 (Unit11)	Operation Rate		98.1 %
	Emission Rate at Average Operation Rate	NO_x	0.00 g/s
		SO_2	9.54 g/s
		PM	0.38 g/s
	Average Flue Gas during Operation		1,006.92 $\times 10^3 m^3_N/h$
Stack 12 (Unit12)	Operation Rate		98.10 %
	Emission Rate at Average Operation Rate	NO_x	0.00 g/s
		SO_2	7.09 g/s
		PM	0.63 g/s
	Average Flue Gas during Operation		1,006.92 $\times 10^3 m^3_N/h$

Table 7.3.6 Operation Rate, Emissions, & Flue Gas at Costanera Power Plant in Winter Monitoring Period

Stack 1 (Unit1+2)	Operation Rate		46.8 %
	Emission Rate at Average Operation Rate	NO_x	0.00 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		0.47 $\times 10^3 m^3_N/h$
Stack 2 (Unit3+4)	Operation Rate		80.1 %
	Emission Rate at Average Operation Rate	NO_x	0.00 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		0.58 $\times 10^3 m^3_N/h$
Stack 3 (Unit6)	Operation Rate		1.0 %
	Emission Rate at Average Operation Rate	NO_x	17.14 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		368.46 $\times 10^3 m^3_N/h$
Stack 4 (Unit7)	Operation Rate		46.8 %
	Emission Rate at Average Operation Rate	NO_x	0.01 g/s
		SO_2	0.02 g/s
		PM	0.32 g/s
	Average Flue Gas during Operation		13.97 $\times 10^3 m^3_N/h$

Table 7.3.7 Emission During Winter Monitoring Period in Buenos Aires

Unit:ton

	NO_x	SO_2	PM
Power Plant	11.3	10.8	0.3
Other Stationary	4.6	0.0	0.0
Mobile	1,012.6	105.1	264.3

Note: Not all stationary sources are included

2) San Nicolas

In San Nicolas, only one central power plant exists, i.e. San Nicolas Power Plant, and it has 5 stacks. Two stacks are not in use. The rest in use, where 2 of the 3 stacks are in use from July 2001, just in time for the winter monitoring period.

A Summer

The details of the estimated average are shown in **Table 7.3.8**.

Table 7.3.8 Operation Rate, Emissions, & Flue Gas at Central Termicas San Nicolas in Summer Monitoring Period

Stack 5 (Unit5)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	37.18 g/s
		SO_2	37.49 g/s
		PM	4.06 g/s
	Average Flue Gas during Operation		646.21 $\times 10^3 m^3_N/h$

Note: 24 hour pattern of **Figure 7.3.2** used.

Emission from the power plant and mobile and other stationary sources in San Nicolas during summer monitoring period are shown in **Table 7.3.9**. Non-power plant sources emit more NO_x and PM, and emit less SO_2. SO_2 is emitted from burning coal in the power plant

Table 7.3.9 Emission During Summer Monitoring Period in San Nicolas

Unit:ton

	NO_x	SO_2	PM
Power Plant	25.1	20.4	1.9
Other Stationary	6.9	7.2	291.7
Mobile	40.5	4.6	11.2

Note: Not all stationary sources are included

B Winter

Data of 3 stacks of San Nicolas Power Plant were obtained. The details are as shown in **Table 7.3.10**. As the stacks 6 and 7 have just started their operation, the measured values may be fluctuated. For the stack 5, data of hourly concentration and power generation, and daily fuel consumption were obtained.

Emission from power plant and mobile and other stationary sources in San Nicolas during winter monitoring period are shown in **Table 7.3.11**. Non-power plant sources emit more PM and less SO_2. The emission of PM from non-power plants are due to the large industrial area with steel plants, cement factories, etc. SO_2 is emitted from burning coal in the power plant, and the value is 2.7 times more than of summer period.

Table 7.3.10 Operation Rate, Emissions, & Flue Gas at Central Termicas San Nicolas in Winter Monitoring Period

Stack 5 (Unit5)	Operation Rate		67.9 %
	Emission Rate at Average Operation Rate	NO_x	85.48 g/s
		SO_2	158.61 g/s
		PM	5.84 g/s
	Average Flue Gas during Operation		613.55 $\times 10^3 m^3_N/h$
Stack 6[*1] (Parana)	Operation Rate		37.6 %
	Emission Rate at Average Operation Rate	NO_x	1.79 g/s
		SO_2	0 g/s
		PM	0 g/s
	Average Flue Gas during Operation		704.34 $\times 10^3 m^3_N/h$
Stack 7[*1] (Parana)	Operation Rate		36.4 %
	Emission Rate at Average Operation Rate	NO_x	2.19 g/s
		SO_2	0 g/s
		PM	0 g/s
	Average Flue Gas during Operation		1,384.92 $\times 10^3 m^3 N/h$

Note[*1] : Operation of Parana started in July of year 2001.

Table 7.3.11 Emission During Winter Monitoring Period in San Nicolas

Unit:ton

	NO_x	SO_2	PM
Power Plant	29.9	54.2	1.7
Other Stationary	6.0	6.2	250.7
Mobile	34.8	3.9	9.7

Note: Not all stationary sources are included

3) Lujan de Cuyo

One power plant, Centrales Termicas Mendoza with 6 stacks is in the Lujan de Cuyo model area.

A Summer

The monthly average concentration, and fuel consumption, and hourly power are used to estimate emission during summer monitoring period.

Table 7.3.12 Operation Rate, Emissions, & Flue Gas at Centrales Termicas Mendoza in Summer Monitoring Period

Stack 12 (Unit11+12)	Operation Rate		66.7 %
	Emission Rate at Average Operation Rate	NO_x	2.97 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		257.33 $\times 10^3 m^3_N/h$
Stack 21 (Unit 21)	Operation Rate		66.7 %
	Emission Rate at Average Operation Rate	NO_x	5.28 g/s
		SO_2	0.06 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		91.01 $\times 10^3 m^3_N/h$
Stack 22 (Unit22)	Operation Rate		66.7 %
	Emission Rate at Average Operation Rate	NO_x	0.00 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		88.74 $\times 10^3 m^3_N/h$
Stack 23 (Unit23)	Operation Rate		66.7 %
	Emission Rate at Average Operation Rate	NO_x	6.55 g/s
		SO_2	0.17 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		81.91 $\times 10^3 m^3_N/h$
Stack 24 (Unit24)	Operation Rate		3.6 %
	Emission Rate at Average Operation Rate	NO_x	0.00 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		91.01 $\times 10^3 m^3_N/h$
Stack 25 (Unit 15+25)	Operation Rate		3.5 %
	Emission Rate at Average Operation Rate	NO_x	4.18 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		88.74 $\times 10^3 m^3_N/h$

Note: 24 hour pattern of **Figure 7.3.2** used.

Emission from the power plants and mobile and other stationary sources in Lujan de Cuyo during monitoring period are shown in **Table 7.3.13**. Non-power plant sources have larger emission in all NO_x, SO_2, and PM.

Table 7.3.13 Emission During Summer Monitoring Period in Lujan de Cuyo

Unit:ton

	NO_x	SO_2	PM
Power Plant	11.5	0.1	0
Other Stationary	5.3	13.1	67.8
Mobile	247.9	26.6	69.6

Note: Not all stationary sources are included

B Winter

For winter monitoring period, daily concentration, fuel consumption and power generation data were obtained. The values are summarized in **Table 7.3.14**. The emissions and flue gas flow rates are very small.

Table 7.3.14 Operation Rate, Emissions, & Flue Gas at Centrales Termicas Mendoza in Winter Monitoring Period

Centrales Termica Mendoza

Stack 23 (Unit23)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	0.01 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		5.47 $\times 10^3 m^3_N/h$
Stack 24 (Unit24)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	0.01 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		5.44 $\times 10^3 m^3_N/h$
Stack 25 (Unit15+25)	Operation Rate		100.0 %
	Emission Rate at Average Operation Rate	NO_x	0.02 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		16.16 $\times 10^3 m^3_N/h$

Note: 24 hour pattern of **Figure 7.3.2** used.

Emission during winter monitoring period, the power plants that the values did not show in the **Table 7.3.15** had very minimal emissions.

Table 7.3.15 Emission During Winter Monitoring Period in Lujan de Cuyo

Unit:ton

	NO_x	SO_2	PM
Power Plant	0	0	0
Other Stationary	4.6	11.2	58.3
Mobile	213.0	22.9	59.8

Note: Not all stationary sources are included

7.3.3 Annual Estimation

1) Buenos Aires

Annual operation in Buenos Aires is summarized in **Table 7.3.16** and **Table 7.3.17**. The recent existing air quality data obtained for simulation was of the year 1998. Therefore, for Central Puerto, the concentration, fuel consumption and power generation of the year 1998 were obtained. But for Costanera, the data of 1998 were not available in the electronic data form. Instead, the data of July 2000 to August 2001 were obtained.

Table 7.3.16 Operation Rate, Emissions, & Flue Gas at Central Puerto Power Plants

Stack 5 (Unit5)	Operation Rate		94.1 %
	Emission Rate at Average Operation Rate	NO_x	14.00 g/s
		SO_2	31.60 g/s
		PM	0.50 g/s
	Average Flue Gas during Operation		283.32 $\times 10^3 m^3_N/h$
Stack 6 (Unit6)	Operation Rate		87.6 %
	Emission Rate at Average Operation Rate	NO_x	26.80 g/s
		SO_2	33.20 g/s
		PM	0.70 g/s
	Average Flue Gas during Operation		361.44 $\times 10^3 m^3_N/h$
Stack 7 (Unit7+8)	Operation Rate	Unit 7	52.6 %
		Unit 8	95.0 %
	Emission Rate at Average Operation Rate	NO_x	23.60 g/s
		SO_2	54.40 g/s
		PM	0.80 g/s
	Average Flue Gas during Operation		606.60 $\times 10^3 m^3_N/h$
Stack 8 (Unit9)	Operation Rate		86.1 %
	Emission Rate at Average Operation Rate	NO_x	18.50 g/s
		SO_2	18.00 g/s
		PM	0.50 g/s
	Average Flue Gas during Operation		366.84 $\times 10^3 m^3_N/h$

Table 7.3.17 Operation Rate, Emissions, & Flue Gas at Central Costanera Power Plants

Stack 1 (Unit1+2)	Operation Rate	Unit 1	12.6	%
		Unit 2	25.3	%
	Emission Rate at Average Operation Rate	NO_x	6.50	g/s
		SO_2	18.30	g/s
		PM	0.50	g/s
	Average Flue Gas during Operation		278.28	$\times 10^3 m^3_N/h$
Stack 2 (Unit3+4)	Operation Rate	Unit 3	38.1	%
		Unit 4	43.0	%
	Emission Rate at Average Operation Rate	NO_x	6.60	g/s
		SO_2	18.60	g/s
		PM	0.80	g/s
	Average Flue Gas during Operation		275.76	$\times 10^3 m^3_N/h$
Stack 5 (CBA)	Operation Rate		71.4	%
	Emission Rate at Average Operation Rate	NO_x	16.80	g/s
		SO_2	---	g/s
		PM	---	g/s
	Average Flue Gas during Operation		1,412.28	$\times 10^3 m^3_N/h$
Stack 3 (Unit6)	Operation Rate		43.1	%
	Emission Rate at Average Operation Rate	NO_x	18.10	g/s
		SO_2	5.00	g/s
		PM	0.90	g/s
	Average Flue Gas during Operation		565.20	$\times 10^3 m^3_N/h$
Stack 4 (Unit7)	Operation Rate		14.7	%
	Emission Rate at Average Operation Rate	NO_x	6.10	g/s
		SO_2	1.20	g/s
		PM	0.40	g/s
	Average Flue Gas during Operation		476.28	$\times 10^3 m^3_N/h$
Stack 6[*1] Stack 7[*1] (Unit8+9+10)	Operation Rate	Unit 8	81.5	%
		Unit 9	84.3	%
		Unit 10	92.7	%
	Emission Rate at Average Operation Rate	NO_x	62.40	g/s
		SO_2	---	g/s
		PM	---	g/s
	Average Flue Gas during Operation		3,170.88	$\times 10^3 m^3_N/h$

Note: [*1] Half of the noted value is used for each stack.

Table 7.3.18 shows estimated emissions in Buenos Aires. The large NO_x emission is from mobile sources as in **Figure 7.3.3**. The large traffic volume, which is commonly seen in large cities causes large NO_x emission. The large emission of SO_2 is from large consumption of fuel oil in Power Plants in the year 1998.

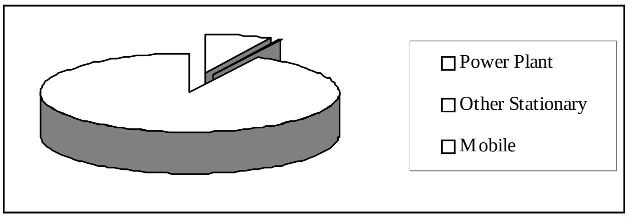
Table 7.3.18 Emission in Buenos Aires

Unit:ton/y

	NO_x	SO_2	PM
Power Plant	4,223.0	5,069.4	94.7
Other Stationary	240.5	0.0	0.0
Mobile	54,757.9	5,683.2	14,290.3

Note: Not all stationary sources are included

Figure 7.3.3 NO_x Emission in Buenos Aires



2) San Nicolas

Operation summary of the year 2000 of Central Termica San Nicolas is shown in Table 7.3.19. Stack 5 burns natural gas and coal, which results in large emission of SO_2.

Table 7.3.19 Operation Rate, Emissions, & Flue Gas at Central Termica San Nicolas

Stack 1 (Unit1+2)	Operation Rate	Unit 1	21.6	%
		Unit 2	86.1	%
	Emission Rate at Average Operation Rate	NO_x	4.50	g/s
		SO_2	1.70	g/s
		PM	1.20	g/s
	Average Flue Gas during Operation		139.68	$\times 10^3 m^3_N/h$
Stack 3 (Unit3+4)	Operation Rate	Unit 3	14.4	%
		Unit 4	8.2	%
	Emission Rate at Average Operation Rate	NO_x	3.80	g/s
		SO_2	3.60	g/s
		PM	0.60	g/s
	Average Flue Gas during Operation		184.68	$\times 10^3 m^3_N/h$
Stack 5 (Unit5)	Operation Rate		74.8	%
	Emission Rate at Average Operation Rate	NO_x	63.90	g/s
		SO_2	127.30	g/s
		PM	14.80	g/s
	Average Flue Gas during Operation		798.84	$\times 10^3 m^3_N/h$

All emission from power plants and non-power plants is shown in Table 7.3.20, and SO_2 emission is separately shown in Figure 7.3.4. The SO_2 emission is large in power plants as a result of burning large amounts of coal. Great emission of PM from other stationary is from the large industrial park in the east of Central Termica San Nicolas. Within the model area, a cement factory, steel plants, chemical factories etc. are included. The obtained emission data were summarized below. The actual values might be much greater.

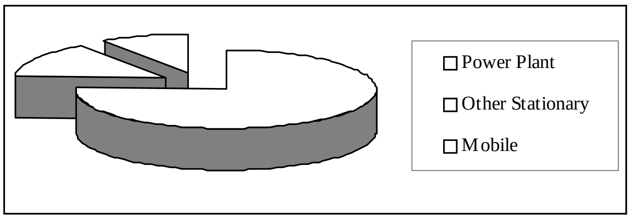
Table 7.3.20 Emission in San Nicolas

Unit:ton/y

	NO_x	SO_2	PM
Power Plant	2,978.5	1,639.2	382.3
Other Stationary	316.4	326.6	13,310.4
Mobile	1,849.6	207.6	512.5

Note: Not all stationary sources are included

Figure 7.3.4 SO_2 Emission in San Nicolas



3) Lujan de Cuyo

Operation and emissions data in Centrales Termicas Mendoza in the year 2000 were obtained from its monthly report, and the summary is shown in Table 7.3.21. Emission in Mendoza and Lujan de Cuyo are shown in Table 7.3.22. About 90% of NO_x are emitted from mobile sources as in Figure 7.3.5.

Table 7.3.21 Operation Rate, Emissions, & Flue Gas at Centrales Termicas Mendoza

Stack 11 (Unit11+12)	Operation Rate	Unit 11	28.5 %
		Unit 12	31.6 %
	Emission Rate at Average Operation Rate	NO_x	12.90 g/s
		SO_2	1.60 g/s
		PM	0.10 g/s
	Average Flue Gas during Operation		215.28 $\times 10^3 m^3_N/h$
Stack 25 (Unit15+25)	Operation Rate	Unit 15	81.8 %
		Unit 25	83.1 %
	Emission Rate at Average Operation Rate	NO_x	11.00 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		372.60 $\times 10^3 m^3_N/h$
Stack 21[*1] Stack 22[*1] (Unit14+21+22)	Operation Rate	Unit 14	37.6 %
		Unit 21	35.8 %
		Unit 22	35.4 %
	Emission Rate at Average Operation Rate (Stack 21)	NO_x	9.70 g/s
		SO_2	0.10 g/s
		PM	0.00 g/s
	Emission Rate at Average Operation Rate (Stack 22)	NO_x	0.00 g/s
		SO_2	0.00 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		117.72 $\times 10^3 m^3_N/h$
Stack 23 (Unit23)	Operation Rate		94.8 %
	Emission Rate at Average Operation Rate	NO_x	11.80 g/s
		SO_2	0.40 g/s
		PM	0.00 g/s
	Average Flue Gas during Operation		254.52 $\times 10^3 m^3_N/h$
Stack 24 (Unit24)	Operation Rate		97.4 %
	Emission Rate at Average Operation Rate	NO_x	---[*2] g/s
		SO_2	---[*2] g/s
		PM	---[*2] g/s
	Average Flue Gas during Operation		---[*2] $\times 10^3 m^3_N/h$

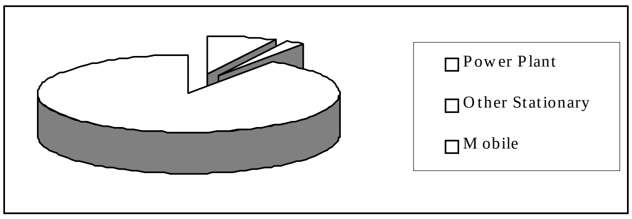
Note: [*1] Half of the noted operation rate is used for each stack.
[*2] Power generation data and concentration were obtained but fuel data were not obtained, so emission rate were unable to calculate.

Table 7.3.22 Emission in Lujan de Cuyo

Unit:ton/y

	NO_x	SO_2	PM
Power Plant	926.0	31.3	1.1
Other Stationary	242.1	597.2	3,095.3
Mobile	11,308.2	1,215.5	3,173.9

Figure 7.3.5 NO_x Emission in Mendoza and Lujan de Cuyo



7.4 Calculation Results

The ISCST3 model was used for calculation of periodical averages of SO_2, NO_x and PM under the meteorological and pollutant source conditions mentioned before.

7.4.1 Buenos Aires

1) Summer and Winter Monitoring Period

The air dispersion simulation with the ISCST3 model was conducted for the summer and winter monitoring periods, and the calculated values are the periodical averages. The monitored values of NO_x and SO_2 are averages of 6 data of hourly base per day and the TSP monitored values are averages of 24 hours sampling values. The calculated values are compared with the monitored values as in **Table 7.4.1** and **Table 7.4.2**.

In summer, the calculated values of NO_x are around five or ten times over-estimated, and the calculation of SO_2 shows under-estimation with around 5 or 10 % of the measured values. The estimation of PM is relatively better, but under-estimated with around 10 to 40 % of the monitored values. The largest contributions of the power plants are 2.6 $\mu g/m^3$ at Site 1 for NO_x, and 1.3 $\mu g/m^3$ at Site 5 for SO_2 .

In winter, the general features are similar as the ones in summer. NO_x is over-estimated, and SO_2 and PM are under-estimated. PM estimation shows 40% to 123% of the monitored value and it seems relatively good estimation of concentration level, but the R^2 value is only 0.183. The contributions from the power plants are very small and lower than 1 $\mu g/m^3$.

Table 7.4.1 Comparison of Monitored and Calculated Values (Buenos Aires, Summer)

NO_x	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	6.9	38.1	2.6	5.52
Site 2	9.0	96.4	1.3	10.67
Site 3	8.1	54.3	1.7	6.71
Site 4	8.1	55.3	1.9	6.85
Site 5	7.4	80.7	2.0	10.94
Site 6	6.6	80.1	0.8	12.21
Site 7	7.3	64.9	0.7	8.90
SO_2	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	141.5	3.8	0.1	0.027
Site 2	110.5	10.0	0.1	0.090
Site 3	138.6	5.5	0.1	0.040
Site 4	89.6	5.5	0.0	0.062
Site 5	108.9	9.4	1.3	0.087
Site 6	99.2	8.8	0.6	0.089
Site 7	111.7	6.7	0.2	0.060
TSP	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	93.1	9.3	0.1	0.100
Site 2	58.1	24.8	0.0	0.426
Site 3	63.3	13.7	0.1	0.216
Site 4	64.7	13.9	0.0	0.215
Site 5	72.4	20.7	0.2	0.285
Site 6	73.4	20.8	0.1	0.283
Site 7	55.9	16.2	0.0	0.290

Unit: $\mu g/m^3$

Table 7.4.2 Comparison of Monitored and Calculated Values (Buenos Aires, Winter)

NO_x	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	33.3	121.6	0.21	3.65
Site 2	28.5	262.3	0.11	9.21
Site 3	30.6	187.8	0.35	6.15
Site 5	31.8	288.8	0.05	9.08
Site 6	25.0	271.5	0.04	10.87
Site 7	26.6	212.5	0.22	7.98
Site 8	39.9	142.7	0.08	3.58
Site 9	40.9	145.3	0.35	3.56
Site 10	36.2	272.6	0.07	7.54
SO_2	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	84.1	12.9	0.33	0.15
Site 2	80.7	27.4	0.19	0.34
Site 3	73.1	19.8	0.36	0.27
Site 5	95.0	29.9	0.07	0.31
Site 6	75.3	28.1	0.06	0.37
Site 7	74.5	21.7	0.16	0.29
Site 8	98.0	14.9	0.16	0.15
Site 9	147.5	15.1	0.19	0.10
Site 10	124.1	28.2	0.11	0.23
TSP	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	78.4	31.7	0.0	0.40
Site 2	57.3	68.4	0.0	1.19
Site 3	47.4	48.8	0.0	1.03
Site 5	64.9	75.0	0.0	1.16
Site 6	57.3	70.5	0.0	1.23
Site 7	74.4	54.3	0.0	0.73
Site 8	88.9	37.2	0.0	0.42
Site 9	53.6	37.5	0.0	0.70
Site 10	57.9	70.6	0.0	1.22

Unit: $\mu g/m^3$

2) Existing Monitoring Data

In Buenos Aires, the Laboratorio Vigilancia Atmosferica of the city government conducted air quality monitoring at the cross of Las Heras avenue and Oritz de Ocampo avenue in city center. The JICA team collected the monitoring data of year 1998. Among the pollutants, the most frequently monitored pollutant, NO_x is used for the comparison of the calculated results (**Table 7.4.3**).

In this case, the calculations are estimated under the monitored values, and the ratios are from 24 to 62%, and the R^2 value is also relatively good as 0.654.

Table 7.4.3 Comparison of Monitored and Calculated Values (Buenos Aires, Year 1998)

	Measured	Calculated	Calc./Meas.
January	-	43.9	-
February	201.7	61.4	0.30
March	292.5	71.6	0.24
April	180.4	72.5	0.40
May	242.4	83.1	0.34
June	260.7	98.3	0.38
July	271.6	87.6	0.32
August	254.4	90.3	0.36
September	183.0	78.0	0.43
October	138.4	53.9	0.39
November	92.4	47.3	0.51
December	92.0	57.3	0.62
Annual	200.7	70.5	0.35

Unit: $\mu g/m^3$

7.4.2 San Nicolas

1) Summer and Winter Monitoring Period

The calculated values are compared with the monitored values as in **Table 7.4.4** and **Table 7.4.5**.

In summer, The calculated values of NO_x around two or seven times over-estimated, and the calculation of SO_2 shows under-estimation with around 4 or 9 % of the monitored values. Although the estimation of PM is relatively better, the estimation is under with around 5 to 55 % of the monitored values except Site 9. The contributions of the power plants are small and below 1 ug/m^3.

In winter, the calculated NO_x data shows similar level of the monitored values. However, R^2 value is only 0.01. The SO_2 values are under-estimated and are only 7 to 16 % of the monitored values. The PM values are also under-estimated to be 11 to 75 % of the monitored values except Site 8. The relatively large contributions are from the power plant to Site 7 of NO_x , and to Sites 4 and 7 of PM.

Table 7.4.4 Comparison of Monitored and Calculated Values (San Nicolas, Summer)

NO_x	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	5.7	14.5	0.39	2.53
Site 2	4.9	26.6	0.07	5.42
Site 3	4.7	32.4	0.07	6.90
Site 4	4.3	30.1	0.32	6.95
Site 5	4.2	27.1	0.12	6.47
Site 6	4.7	13.2	0.26	2.83
Site 7	4.3	11.8	0.83	2.73
Site 8	4.0	13.3	0.53	3.33
Site 9	5.7	10.1	0.00	1.79
SO_2	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	32.0	2.4	0.24	0.076
Site 2	41.7	3.3	0.05	0.079
Site 3	43.3	3.9	0.04	0.091
Site 4	48.3	3.8	0.30	0.078
Site 5	63.8	4.0	0.37	0.062
Site 6	41.1	1.6	0.08	0.038
Site 7	38.7	1.7	0.24	0.043
Site 8	48.9	2.1	0.02	0.043
Site 9	32.4	1.5	0.00	0.046
TSP	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	78.9	43.7	0.038	0.554
Site 2	112.3	14.2	0.005	0.126
Site 3	100.1	15.9	0.006	0.159
Site 4	99.1	27.3	0.045	0.276
Site 5	155.4	27.6	0.016	0.177
Site 6	109.7	5.2	0.002	0.047
Site 7	98.3	11.7	0.073	0.119
Site 8	128.8	48.9	0.057	0.379
Site 9	85.0	163.4	0.000	1.923

Table 7.4.5 Comparison of Monitored and Calculated Values (San Nicolas, Winter)

NO_x	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	11.5	7.0	0.52	0.61
Site 2	13.5	22.7	0.37	1.68
Site 3	13.7	27.2	0.37	1.99
Site 4	12.9	28.6	0.71	2.22
Site 5	10.8	24.9	0.44	2.31
Site 6	11.4	12.4	0.03	1.09
Site 7	14.5	8.1	2.43	0.56
Site 8	12.3	7.4	0.01	0.60
Site 10	12.3	4.8	0.00	0.39
SO_2	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	44.7	2.9	1.67	0.06
Site 2	56.4	3.8	1.16	0.07
Site 3	33.0	4.3	1.16	0.13
Site 4	47.7	5.5	2.20	0.12
Site 5	23.7	3.8	0.75	0.16
Site 6	30.0	1.6	0.03	0.05
Site 7	34.9	5.4	4.27	0.15
Site 8	45.7	1.6	0.00	0.03
Site 10	41.4	1.0	0.00	0.02
TSP	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	67.4	47.7	0.03	0.71
Site 2	80.7	9.1	0.02	0.11
Site 3	83.0	11.1	0.02	0.13
Site 4	55.6	41.8	0.01	0.75
Site 5	162.0	16.1	0.03	0.10
Site 6	112.7	16.5	0.00	0.15
Site 7	82.1	33.8	0.08	0.41
Site 8	108.1	137.6	0.00	1.27
Site 10	81.3	46.5	0.00	0.57

Unit：μ g/m^3

2) Existing Monitoring Data

The JICA team collected the air quality monitoring data from National Univ. of Technology. NO_x, SO_2, and SPM were monitored at Rentas and Pombo stations in April of the year of 2000. The Rentas station located in the city center and the Pombo station is close to the power plant in a few kilometers. The comparison is shown in **Table 7.4.6**.

At the Rentas station, the calculation is under-estimated and the estimations compared with the monitoring at Pombo are much different for each pollutant.

Table 7.4.6 Comparison of Monitored and Calculated Values（San Nicolas, April 2000）

Rentas	NO_x	SO_2	SPM
Measurement	60.4	7.8	79.2
Calculation	18.3	2.0	5.2
Calc./Meas.	3.308	3.829	15.193
Pombo	NO_x	SO_2	SPM
Measurement	160.7	2.1	41.3
Calculation	15.9	2.7	21.1
Calc./Meas.	0.099	1.278	0.512

Unit: $\mu g/m^3$

7.4.3 Lujan de Cuyo and Mendoza

1) Summer and Winter Monitoring Period

The calculated values are compared with the monitored values as in **Table 7.4.7** and **Table 7.4.8**.

In summer, the calculated values of NO_x are around two or three times over-estimated at the most stations. The calculation of SO_2 shows under-estimation with around 2 or 4 % of monitored values, and the estimation of PM is under-estimation with around 1 to 22 %. NO_x contributions from the power plant to Sites 2 and 8 are relatively large.

In winter, the calculated NO_x shows similar level as monitored with a little under-estimation. The SO_2 and PM values are under-estimated and they are 1 to 8 % and 2 to 13 % of the monitored values. The contributions from the power plant are very low in winter.

Table 7.4.7 Comparison of Monitored and Calculated Values (Lujan de Cuyo, Summer)

NO_x	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	4.7	13.6	0.06	2.93
Site 2	6.4	17.2	4.17	2.71
Site 3	6.0	13.4	0.00	2.22
Site 4	6.6	6.8	0.03	1.02
Site 5	6.1	4.5	0.60	0.74
Site 6	5.8	21.1	0.67	3.65
Site 7	5.9	17.8	0.25	3.02
Site 8	5.8	17.2	1.56	3.00
Site 9	5.8	15.0	0.47	2.57
SO_2	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	87.5	3.6	0.00	0.04
Site 2	63.2	2.6	0.13	0.04
Site 3	61.4	2.5	0.00	0.04
Site 4	68.4	1.5	0.00	0.02
Site 5	66.1	1.1	0.03	0.02
Site 6	61.9	2.4	0.02	0.04
Site 7	70.6	2.2	0.01	0.03
Site 8	72.2	1.9	0.07	0.03
Site 9	67.0	2.1	0.02	0.03
TSP	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	144.2	32.7	0.00	0.23
Site 2	278.2	7.4	0.00	0.03
Site 3	172.0	19.3	0.00	0.11
Site 4	151.8	1.8	0.00	0.01
Site 5	177.0	7.5	0.00	0.04
Site 6	232.0	8.5	0.00	0.04
Site 7	190.4	5.3	0.00	0.03
Site 8	175.0	7.8	0.00	0.04
Site 9	205.2	5.9	0.00	0.03

Table 7.4.8 Comparison of Monitored and Calculated Values (Lujan de Cuyo, Winter)

NO_x	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	22.4	14.8	0.000	0.66
Site 2	20.3	13.7	0.045	0.68
Site 3	21.3	14.6	0.000	0.69
Site 4	23.2	5.7	0.000	0.24
Site 5	21.9	1.6	0.000	0.07
Site 6	21.1	24.6	0.004	1.17
Site 7	22.4	20.4	0.002	0.91
Site 8	22.1	18.7	0.002	0.85
Site 9	19.4	16.4	0.006	0.85
SO_2	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	50.4	2.3	0.000	0.05
Site 2	73.9	2.0	0.000	0.03
Site 3	45.2	2.1	0.000	0.05
Site 4	35.9	0.8	0.000	0.02
Site 5	53.0	0.3	0.000	0.01
Site 6	33.7	2.8	0.000	0.08
Site 7	33.2	2.4	0.000	0.07
Site 8	44.5	2.4	0.000	0.05
Site 9	35.4	2.1	0.000	0.06
TSP	Measured	Calculated	Power Plant	Calc./Meas.
Site 1	75.9	10.0	0.000	0.13
Site 2	165.0	10.3	0.000	0.06
Site 3	164.0	8.7	0.000	0.05
Site 4	119.6	2.5	0.000	0.02
Site 5	119.0	2.0	0.000	0.02
Site 6	91.1	9.3	0.000	0.10
Site 7	102.0	7.4	0.000	0.07
Site 8	101.6	7.2	0.000	0.07
Site 9	107.1	6.6	0.000	0.06

2) Existing Monitoring Data

Seven air monitoring stations exist in the private area of YPF and one in CTM. Because of unknown locations of the seven stations in the YPF plant, all stations of YPF are assumed to be at the center of the YPF and the monitored value is the average of the seven stations. The comparison is shown in **Table 7.4.9.**

All of the calculations show under-estimations and the results for NO_x are better than the ones for SO_2. R^2 value for NO_x at YPF is relatively high and 0.576.

Table 7.4.9 Comparison of Monitored and Calculated Values (Lujan de Cuyo, Year 2000)

CTM	SO_2			NO_x		
	Calculated	Meausred	Calc./Meas.	Calculated	Meausred	Calc./Meas.
January	3.7	9.9	0.369	16.2	14.6	1.109
February	2.9	4.4	0.657	13.2	17.9	0.736
March	3.0	14.6	0.207	17.3	25.1	0.688
April	2.8	7.1	0.398	18.2	25.3	0.720
May	2.4	14.3	0.170	17.1	19.4	0.877
June	2.1	10.9	0.191	15.8	16.9	0.933
July	2.2	16.8	0.132	17.4	19.3	0.902
August	2.6	20.2	0.130	17.3	24.5	0.707
September	2.4	16.3	0.144	13.3	29.0	0.460
October	2.3	6.6	0.346	11.8	20.7	0.570
November	2.6	18.0	0.145	10.8	19.1	0.567
December	3.4	9.7	0.353	12.3	22.2	0.554
Annual	2.7	12.7	0.215	15.0	21.3	0.703

YPF	SO_2			NO_x		
	Calculated	Meausred	Calc./Meas.	Calculated	Meausred	Calc./Meas.
January	1.4	4.5	0.321	13.1	11.1	1.181
February	1.2	8.3	0.141	10.8	18.8	0.572
March	1.5	5.1	0.295	14.3	21.6	0.664
April	1.7	4.9	0.343	15.6	29.6	0.526
May	1.6	9.2	0.169	14.6	33.5	0.436
June	1.4	7.0	0.206	14.0	37.0	0.377
July	1.7	10.2	0.164	15.5	44.2	0.352
August	1.6	11.9	0.131	14.6	26.0	0.561
September	1.2	5.6	0.205	10.8	18.1	0.595
October	1.0	5.5	0.189	9.6	9.9	0.971
November	0.9	5.6	0.166	8.5	12.8	0.661
December	1.1	4.9	0.220	9.8	18.5	0.528
Annual	1.3	5.6	0.239	12.5	23.8	0.525

Measured: Average of seven stations

7.4.4 Evaluation of the Calculation Results

Although some of the comparisons (like NO_x around the Las Heras avenue, NO_x at YPF etc.) showed the relatively good results, the level of the calculated concentrations showed large difference with the monitored data. Generally, the results for NO_x showed over-estimation and the ones for SO_2 and PM showed under-estimation.

Main reasons of this discrepancy may come from lack and inaccuracy of pollutant sources information. Much effort was made on data gathering from other stationary and mobile pollutant sources during the course of the Field Works. The Argentina Counterpart Team keenly tried and succeeded to obtain the useful information from the other official agencies, even though the authority of the Team is limited mainly to the energy sector.

The ENRE manual introduces the two approaches for the background concentrations: (1) monitoring especially for the purpose and (2) an approach based on the pollutant source data of power plants and the others. It may be difficult for ENRE to collect the other pollutant source data with sufficient accuracy for the dispersion calculation, because both teams tried to collect them for this Study and found it to be very difficult. The approach tried in this section is to estimate the contributions from the other pollutant sources (the backgrounds) by the dispersion calculation, and is categorized in a variation of the approach (2).

The ISCST3 model has been widely used for EIA in the world and the US-EPA has endorsed the capability of the model. The calculation for target power plants has certain reliability with this model and with the detailed information collected for the target power plants.

As a conclusion, the ISCST3 model is used to simulate the contributions from the target power plants, and the monitored air quality data are used to estimate background concentrations from the other emission sources, for the establishment of local emission standards, as in **Section 5.3** of the Main Report.

For an additional information, Enrique Puliafito et. al. of Mendoza University has been working on the regional simulation in the Mendoza city and Lujan de Cuyo for years and improving his simulation (#184). When his study is finalized, the results will be useful for establishment of the emission standards in this region.

Some of the concentration distributions of pollutants by the target power plants are shown in **Figure 7.4.1** to **Figure 7.4.14**.

In annual average concentrations of Buenos Aires, the high concentrations occurred at the east of the power plants. The high concentrations occurred at the west and south-west of the power plant in San Nicolas, and occurred at the north and north-west of the power plant in Lujan de Cuyo. The relative locations of the high concentrations match with the major wind directions in Buenos Aires and Lujan de Cuyo. On the other hand, the locations do not directly match with wind directions in San Nicolas because the wind speed in the directions and the atmospheric stability also affect the concentration pattern (from **Figure 7.4.1** to **Figure 7.4.9**).

In summer averages of Buenos Aires, the high concentrations of NO_x and SO_2 occurred at the south of Costanera power plant (**Figure 7.4.10**, **Figure 7.4.11**). In winter average of San Nicolas, the high concentration of NOx and SO_2 plumes spread towards the south of the power plants (**Figure 7.4.12**, **Figure 7.4.13**). In summer average of Lujan de Cuyo, the high concentrations of NO_x occurred at the west of the power plants (**Figure 7.4.14**).

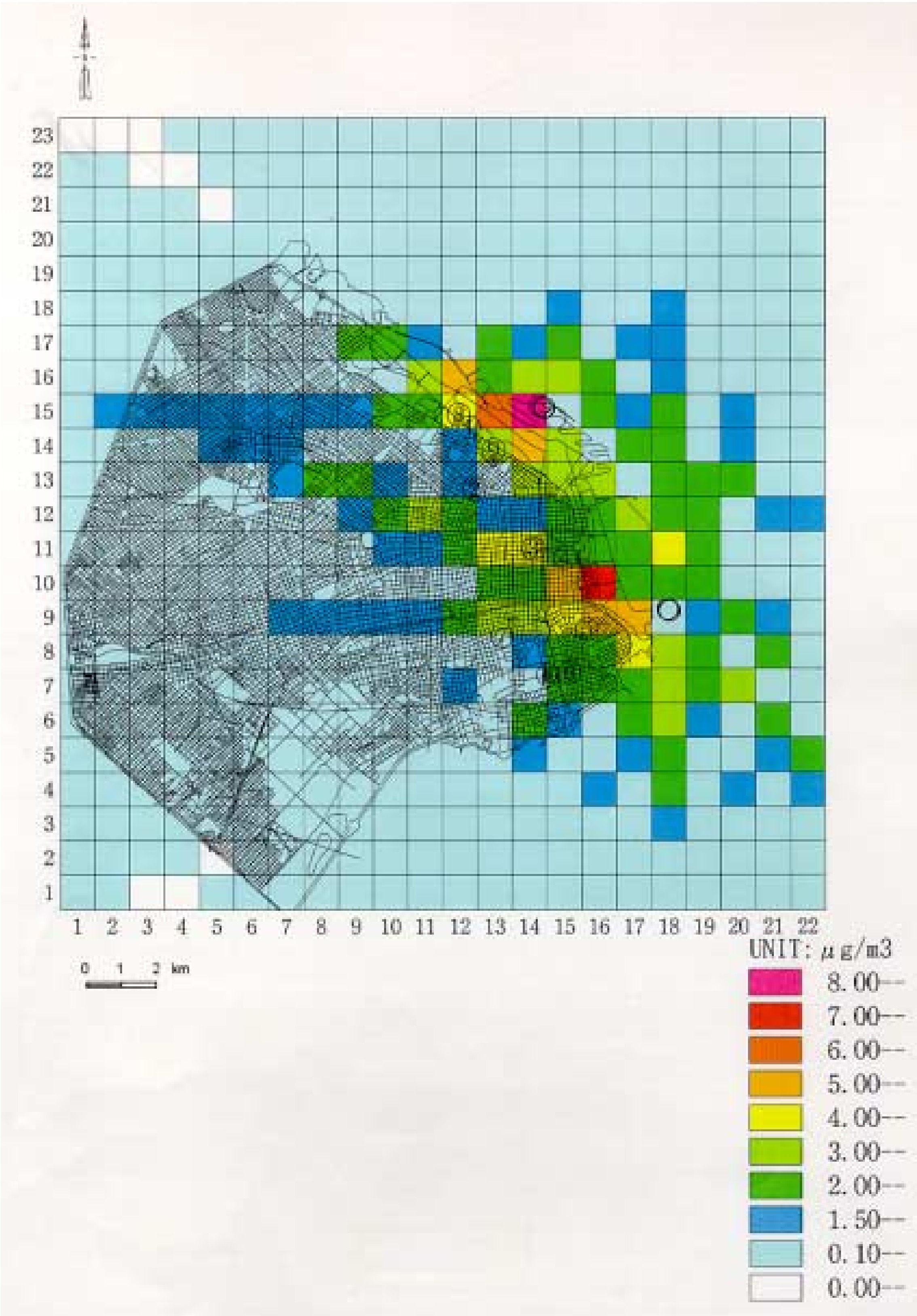


Figure 7.4.1 Buenos Aires Year 1998 Annual Average NO_x, Power Plant

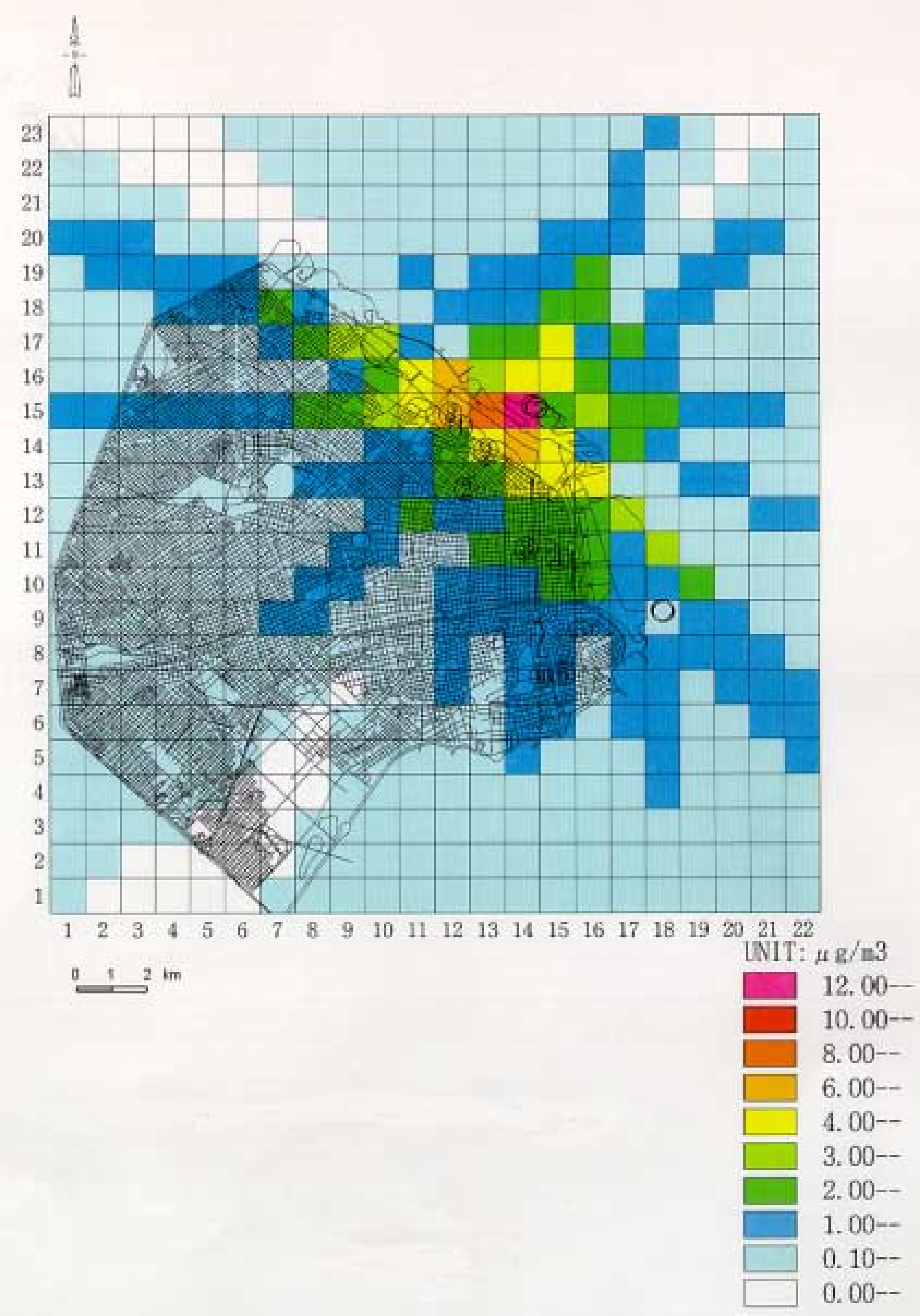


Figure 7.4.2 Buenos Aires Year 1998 Annual Average SO_2, PP

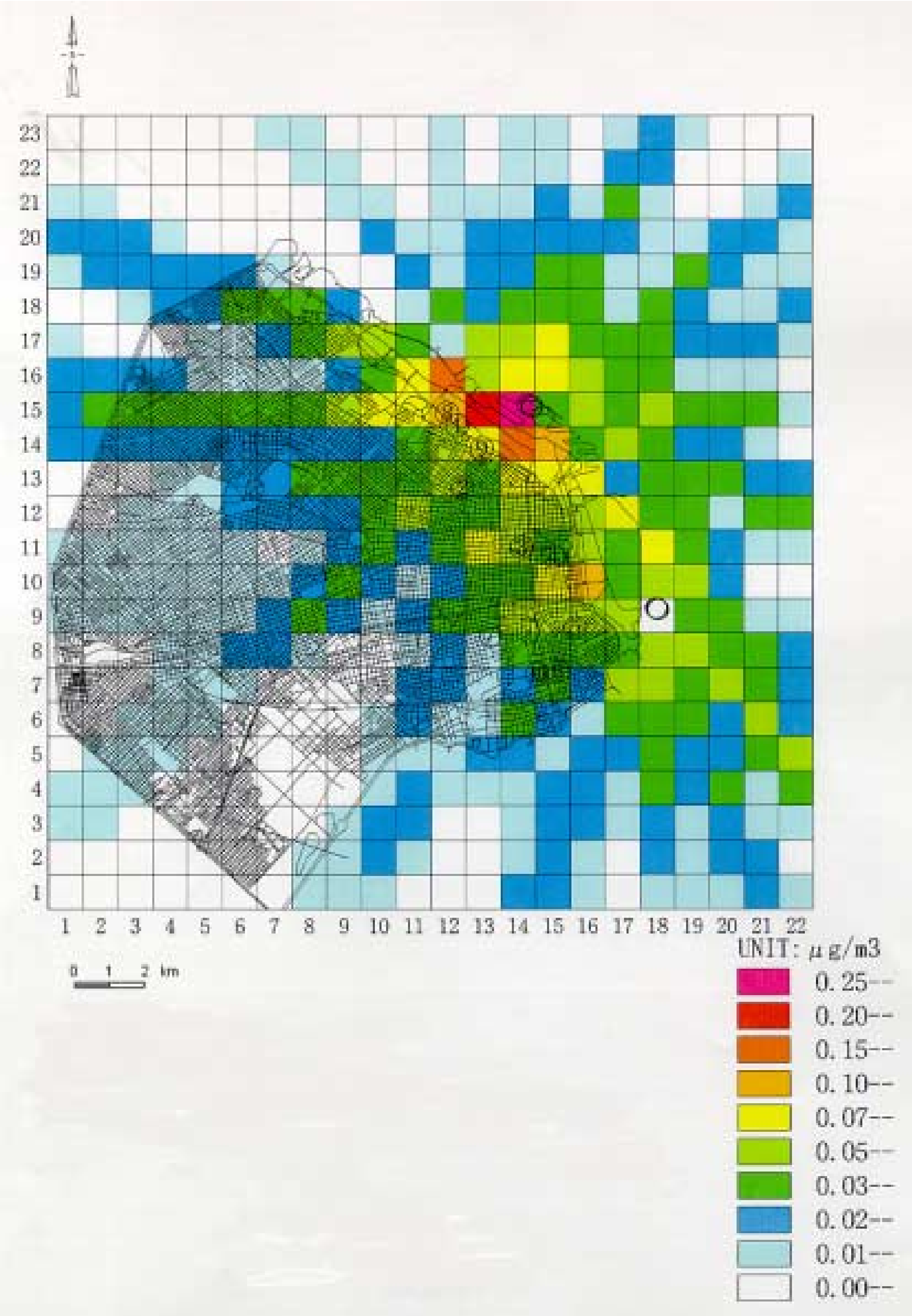


Figure 7.4.3 Buenos Aires Year 1998 Annual Average PM, PP

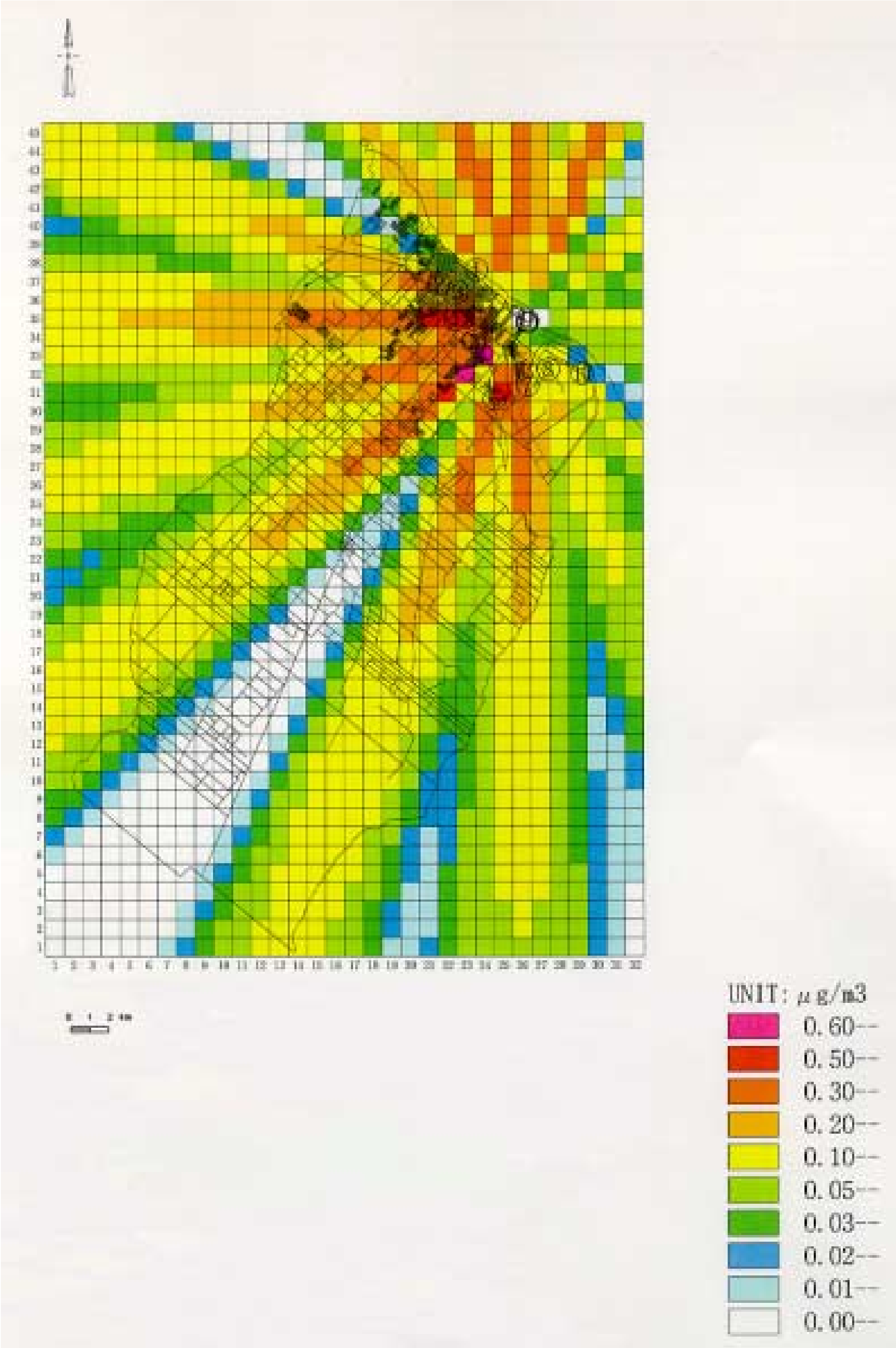


Figure 7.4.4 San Nicolas Year 2000 Annual Average NO_x, PP

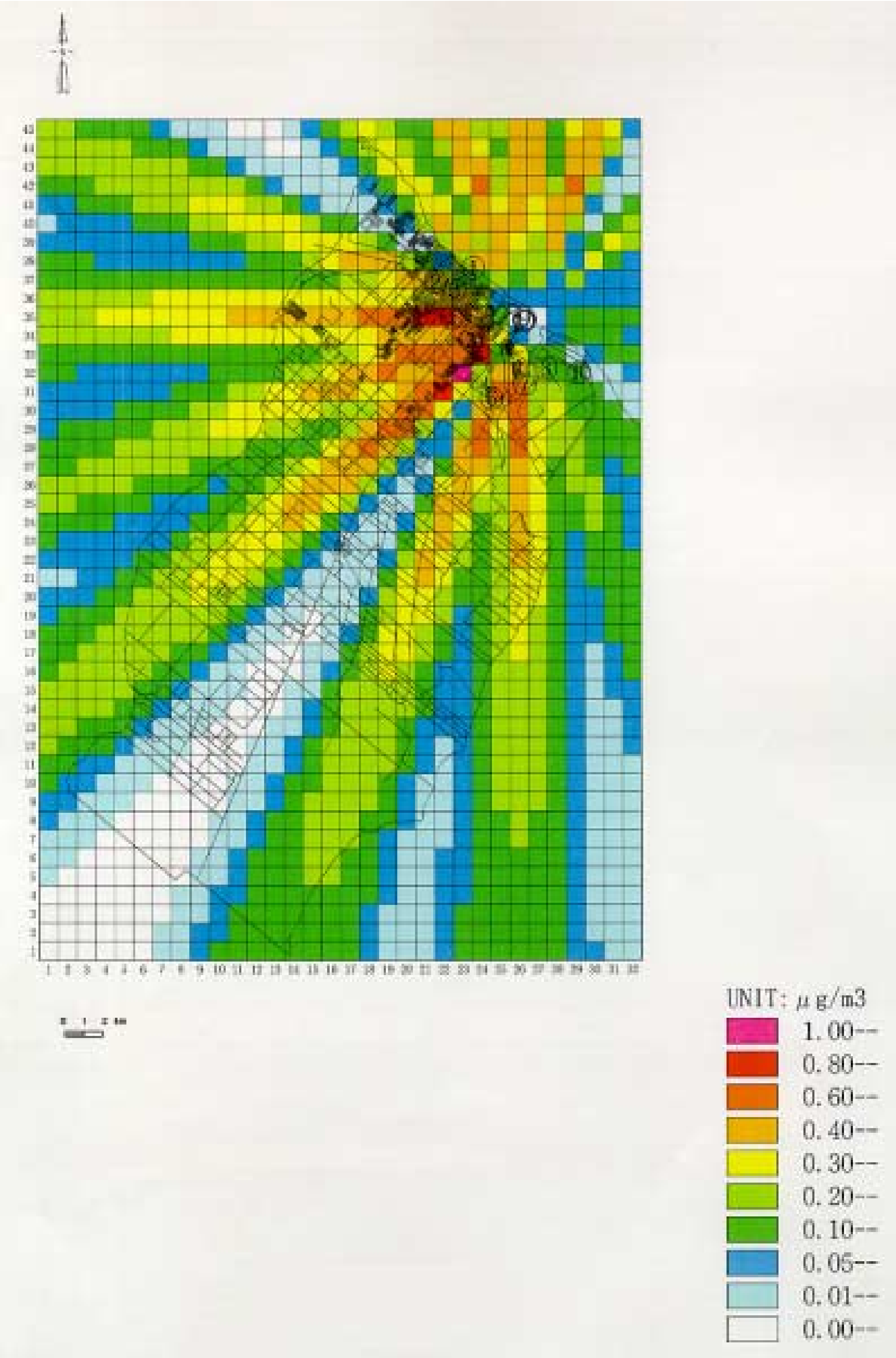


Figure 7.4.5 San Nicolas Year 2000 Annual Average SO_2, PP

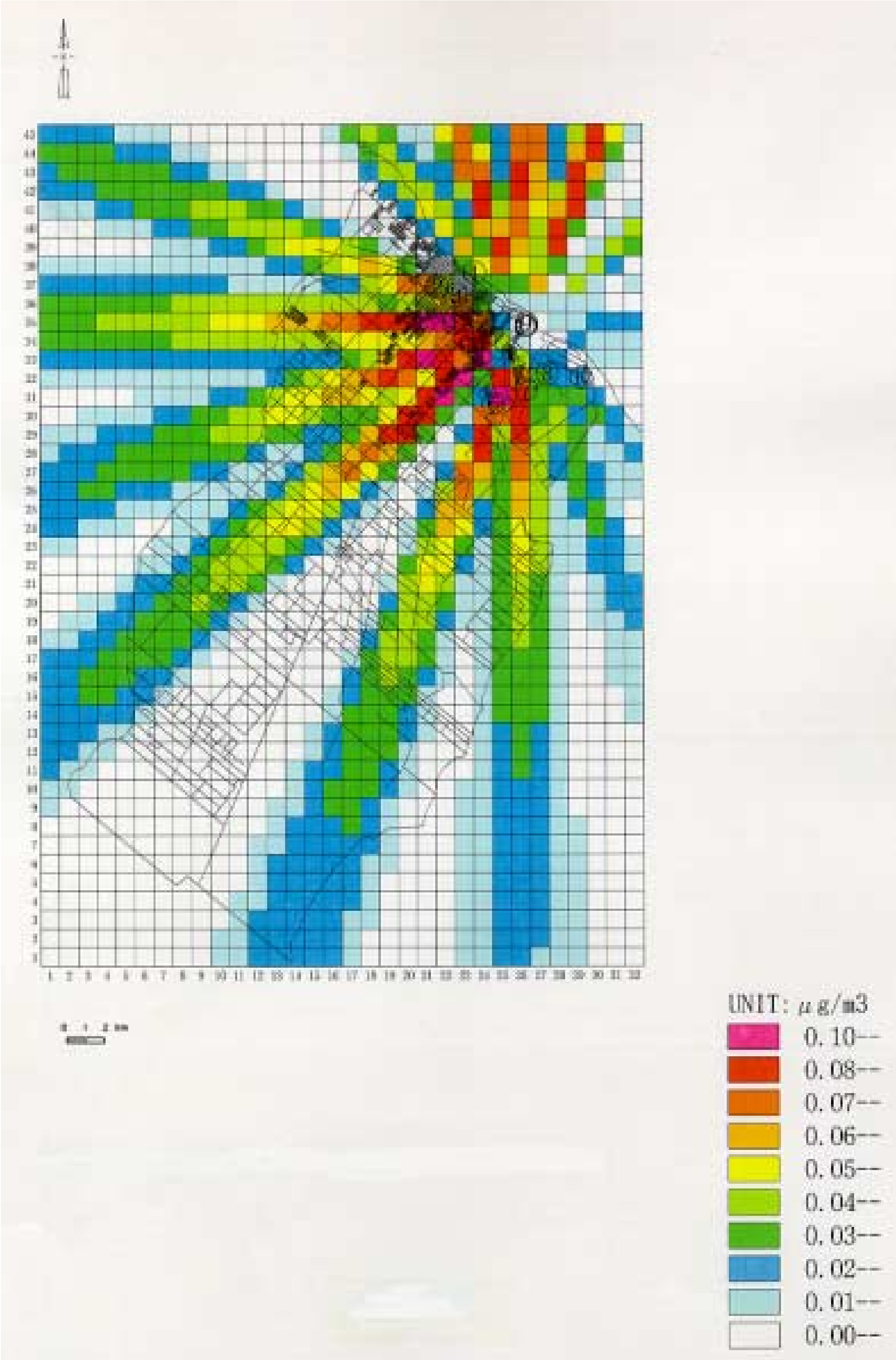


Figure 7.4.6 San Nicolas Year 2000 Annual Average TSP, PP

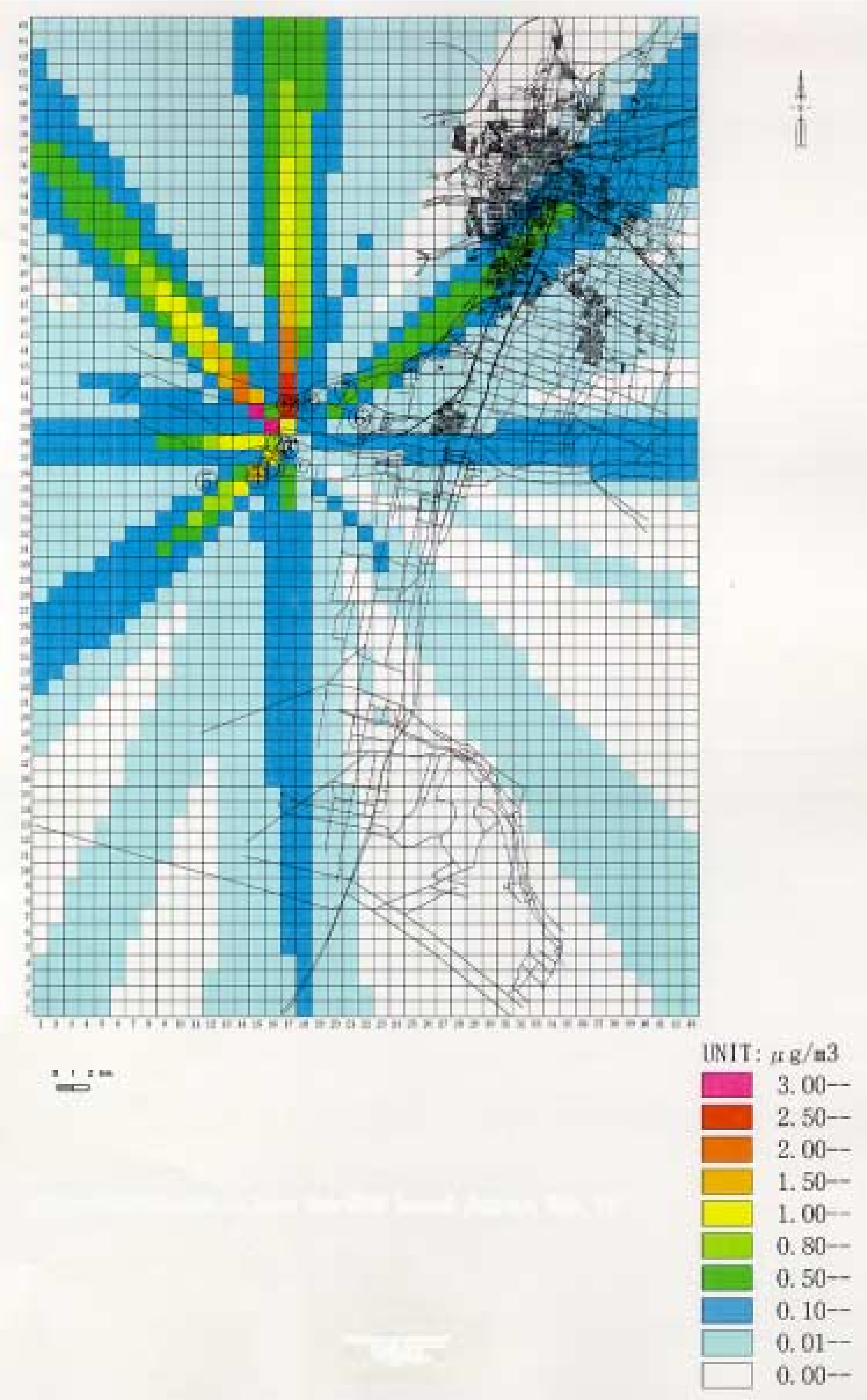


Figure 7.4.7 Lujan de Cuyo Year 2000 Annual Average NO_x , PP

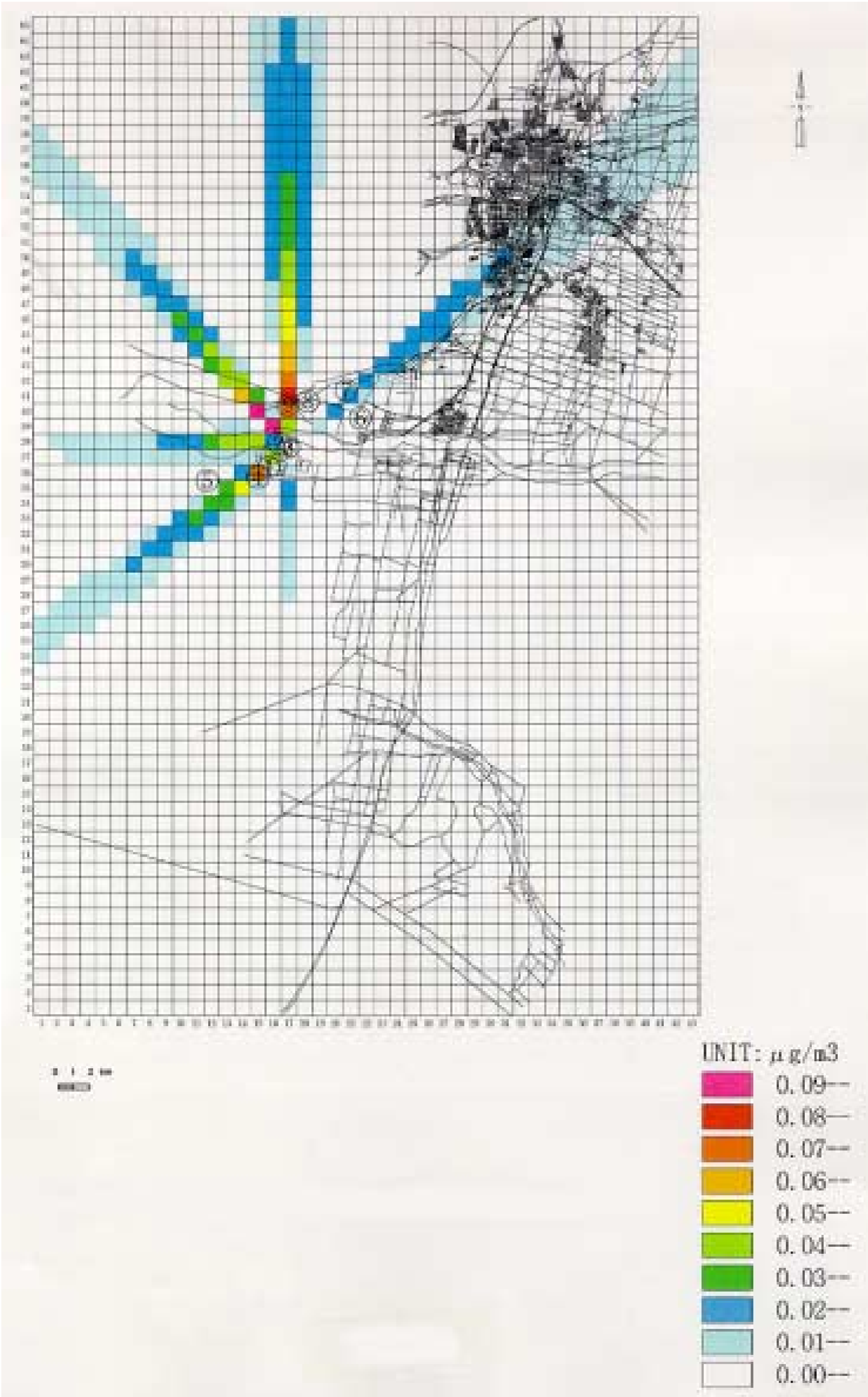


Figure 7.4.8 Lujan de Cuyo Year 2000 Annual Average SO_2, PP

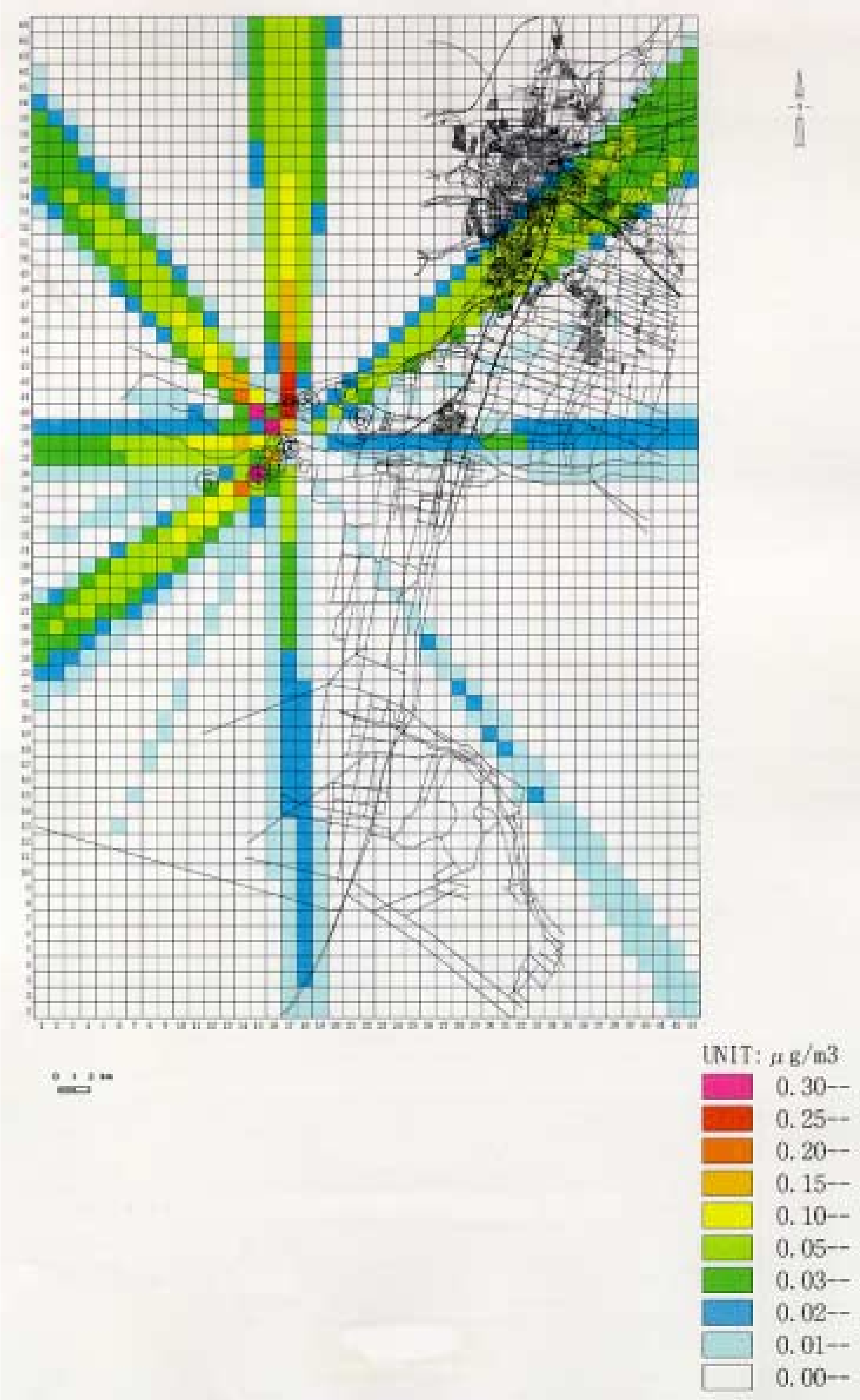


Figure 7.4.9 Lujan de Cuyo Year 2000 Annual Average TSP, PP

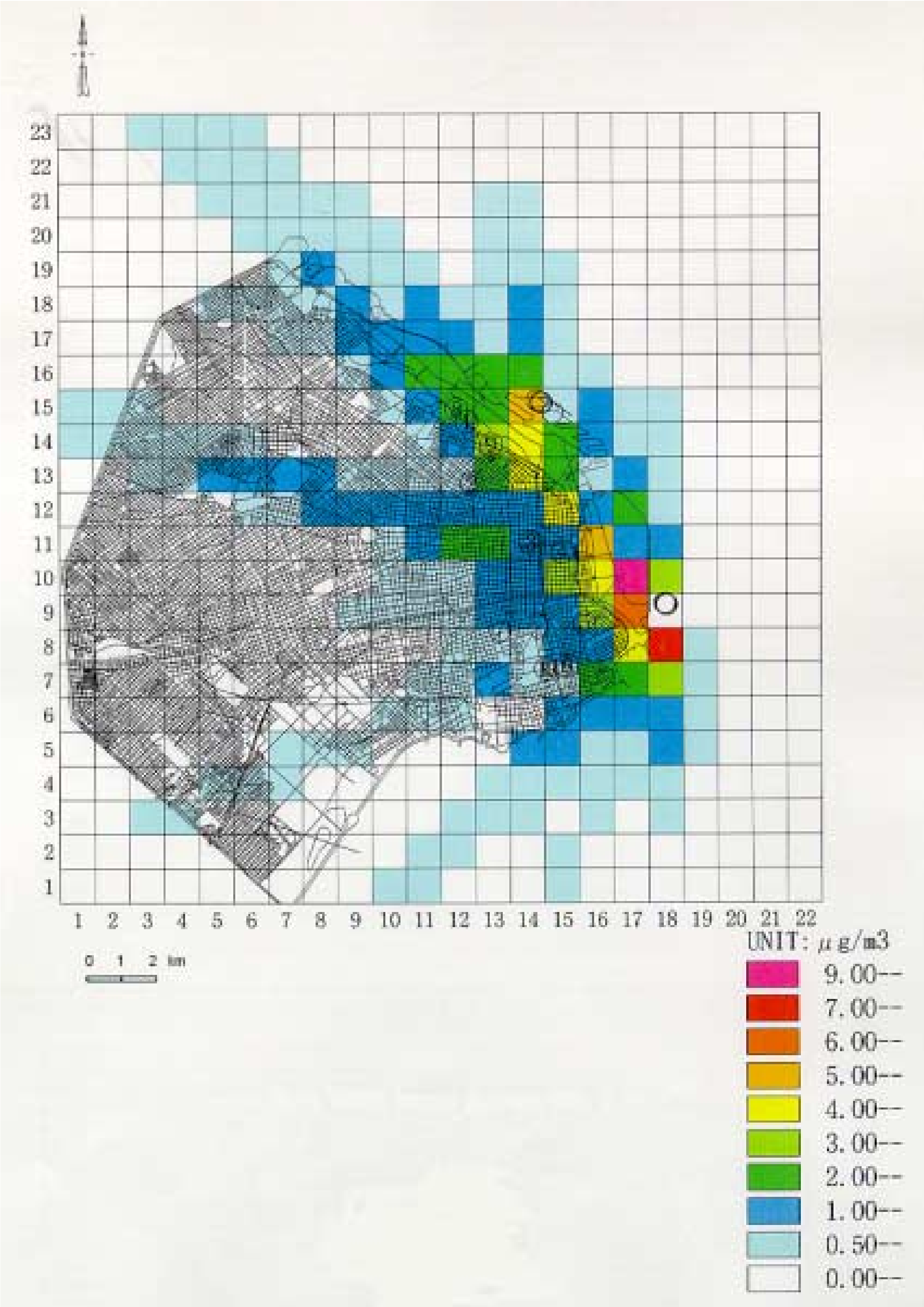


Figure 7.4.10 Buenos Aires Summer Average NO_x, PP

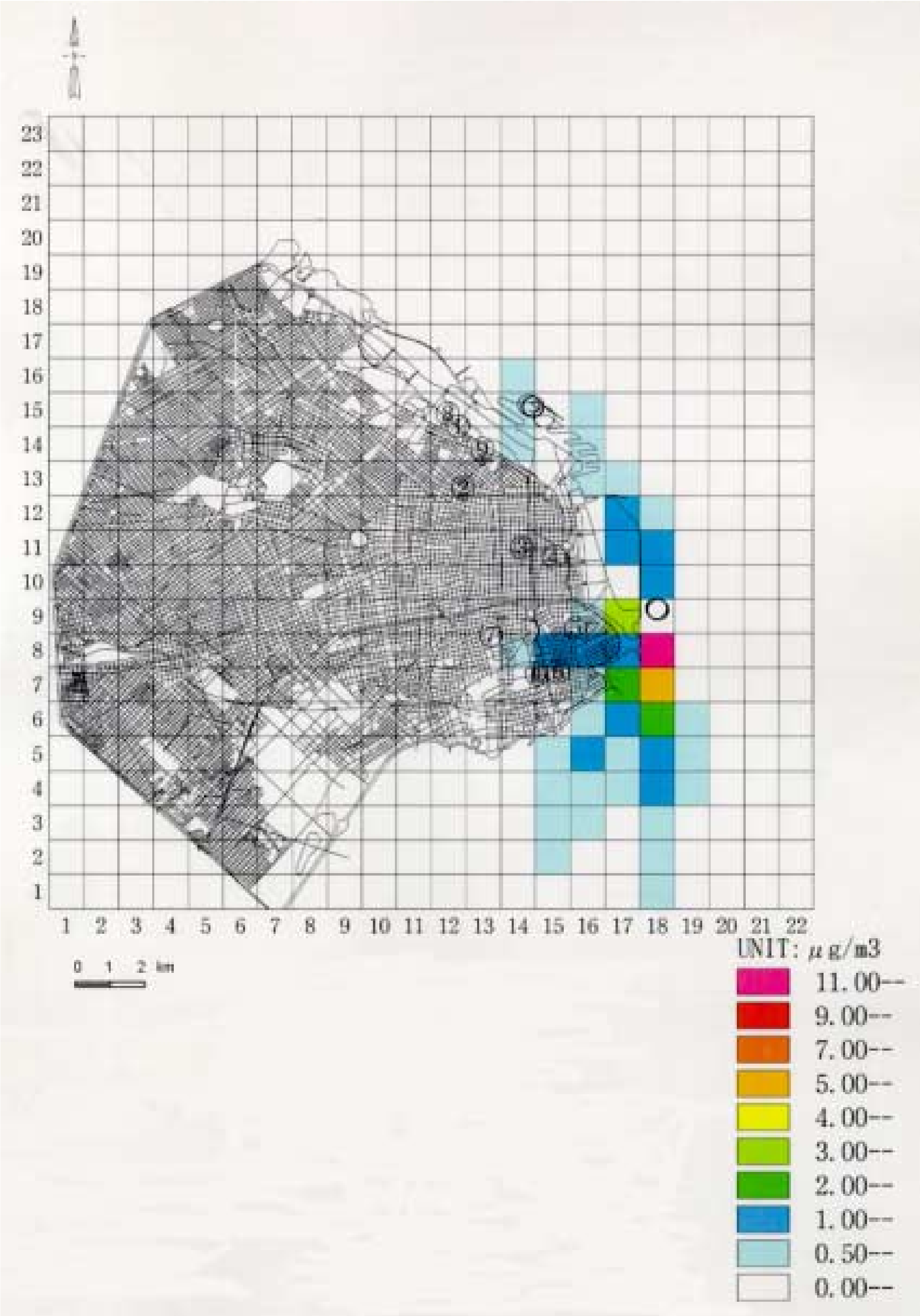


Figure 7.4.11 Buenos Aires Summer Average SO_2, PP

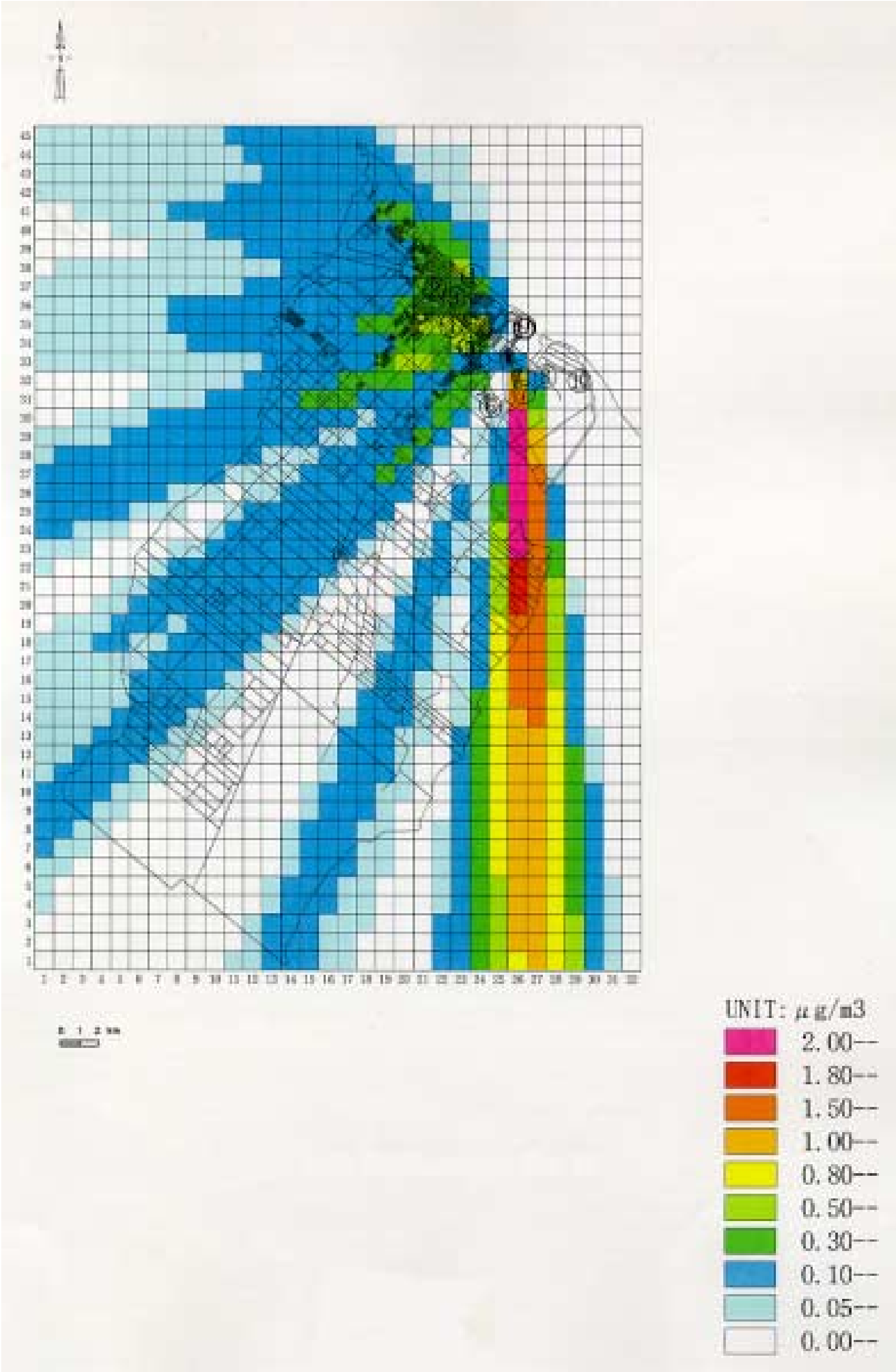


Figure 7.4.12 San Nicolas Winter Average NO_x, PP

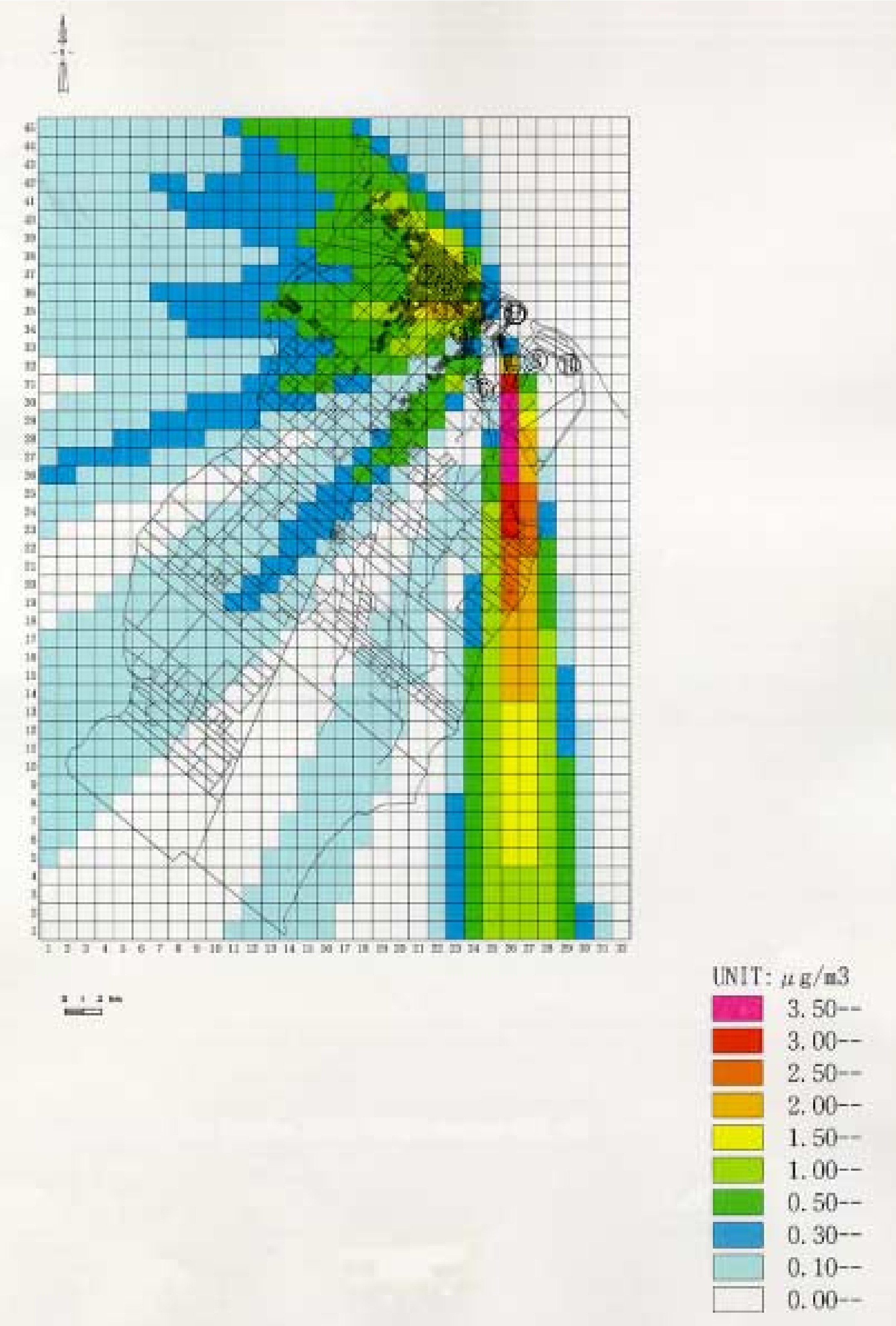


Figure 7.4.13 San Nicolas Winter Average SO_2, PP

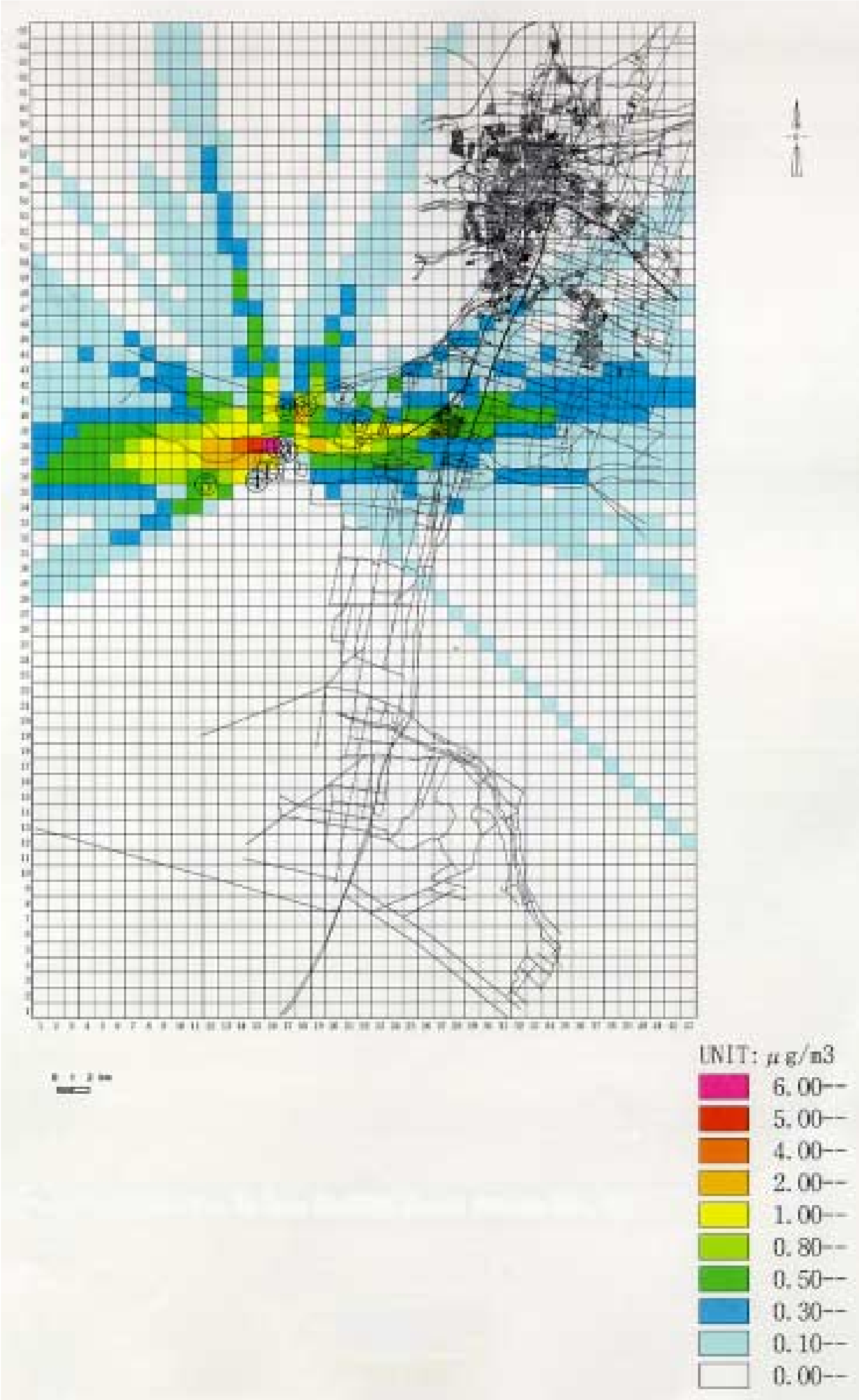


Figure 7.4.14 Lujan de Cuyo Summer Average NO_x, PP

7.5 Recommendations for Air Dispersion Simulation

7.5.1 Mixing Height

1) Mixing Height Estimation

In the dispersion simulation in this report, the mixing height estimation method by the ENRE manual was adopted because of limitation of the available data and consistency of the method. The ENRE manual also adopted the method because of the limitation of the available data. However, the estimated heights seem rather higher than usually expected and are more than several thousand meters.

An example of the alternative method in Japan use solar radiation data at surface. Gamoo et al. (#241) made the estimation formulae for the mixing height by the analysis of the observation data in Tokyo, Japan.

$$H = 76.8 \times I^{0.499}$$

H : Daily Maximum Mixing Height (m)

I : Integral Solar Radiation Amount (cal/cm^2)

In Buenos Aires, mixing height was assumed to reach its maximum at 14:00 o'clock and the daily maximum mixing height was obtained with integral solar radiation amount from the sunrise to 14:00 o'clock. On the other hand, this formula has the weak point and cannot estimate the minimum mixing height. Therefore, the 350 meters height was set as the minimum mixing height based on the technical experience. Adding to the estimations of daily maximum and minimum mixing heights, interpolation algorithm caused around 1200 meters of the summer averages mixing height in Buenos Aires. This equation is made on the meteorological observation in Tokyo and conducting this kind of investigations in Argentina is the one of the approaches for the improvement.

Using another literature (#102), the estimated mixing heights in Buenos Aires based on the morning temperature profile are as follows (**Table 7.5.1**).

Table 7.5.1 Example of Estimated Mixing Heights in Argentina

Time Season	9	10	11	12	13	14	15	16	17	18
Summer (Dec-Feb)	549	670	824	934	1082	1170	1165	1165	1099	951
Autumn (Mar-May)	363	478	604	709	764	824	808	753	676	566
Winter (Jun-Aug)	261	328	400	478	533	589	578	544	478	417
Spring (Sep-Nov)	467	589	678	789	850	889	883	850	761	656

Unit: meters

This method is another way to investigate and to set default values of the mixing heights.

2) Vertical Temperature Profile in Argentina

Vertical temperature profile data at the Ezeiza airport of only two days were purchased from SMN. They were one monitoring data in summer (1998/Feb./16/9:00) and two data in winter (1998/Aug./15/21:00, 1998/Aug/16/9:00). The vertical profiles are shown in **Figure 7.5.1**. There seem some lower inversions.

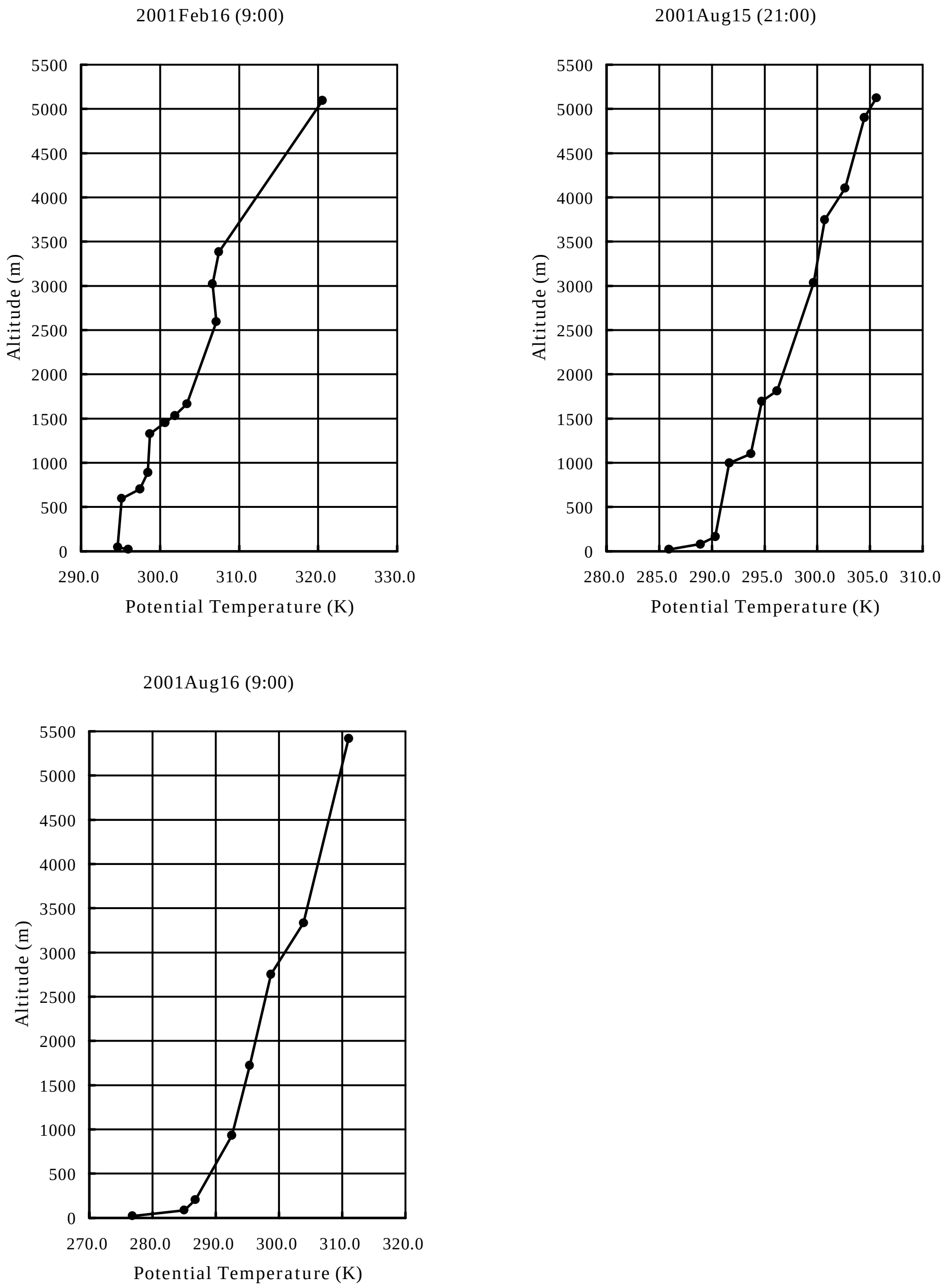


Figure 7.5.1 Vertical Temperature Profile

7.5.2 Calm Condition and Puff Equation

Basically, the ISCST3 is the steady-state plume model and cannot calculate pollutant concentrations under the calm condition (wind speed = 0). Under the calm condition, the maximum concentration theoretically occurs around the stack itself and gradually decrease by distance from the stack according to the puff equation used in Japan.

$$C(R,z)=\frac{Q_p}{(2\pi)^{3/2}\gamma}\left\{\frac{1}{R^2+\frac{\alpha^2}{\gamma^2}(H_e-z)^2}+\frac{1}{R^2+\frac{\alpha^2}{\gamma^2}(H_e+z)^2}\right\}$$

R: Distance from stack to calculation point (m)

Qp: Emission Rate (g/s)

He: Effective Stack Height (m)

z: Receptor height (m)

α : Diffusion Parameter in Horizontal Direction

γ : Diffusion Parameter in Vertical Direction

The diffusion parameters α and γ are as shown in .

Table 7.5.2 Diffusion Parameters of Puff Equation

Stability	α	γ
A	0.948	1.569
B	0.781	0.474
C	0.635	0.208
D	0.470	0.113
E	0.439	0.067
F	0.439	0.048

The JICA Team recommends that this approach should be tried where the calm conditions are prevailed.

7.5.3 AERMOD

The ISCST3 used in this study is one of the preferred air quality models for specific regulatory purposes endorsed by the US-EPA. In the document in the year 2000 (#276), the AERMOD model would replace the ISCST3 model in many assessments. However, in the air quality guideline of the year 2001 edition (#277), the AERMOD model has not been registered as the preferred model, nor appeared in the document. The ISCST3 model is still registered as the preferred model.

AERMOD has been developed by the AERMIC (American Meteorological Society / Environmental Protection Agency Regulatory Model Improvement Committee) established in 1991. The committee has made effort to incorporate the concept of planetary boundary layer (PBL) into AERMOD based on ISCST3 model.

The dispersion calculation is conducted with AERMOD (Dispersion Calculation Program), AERMET (Meteorological Data Preprocessor), and AERMAP (Terrain Preprocessor). In AERMET, PBL parameters used in AERMOD are calculated from the meteorological data.

The AERMOD model basically followed the ISCST3 model, with incorporation of some of new or improved algorithms as the followings (#278).

- Dispersion in both convective boundary layer (CBL) and stable boundary layer (SBL)
- Plume rise and buoyancy, plume penetration into elevated inversions
- Computation of vertical profiles of wind, temperature, and turbulence
- Adjustment for the urban boundary layer
- Treatment of receptors on all types of terrain from the surface and up to and above the plume
- Further development for new or improved algorithms dealing with building downwash, dry and wet deposition was underway at this time

A general overview of the most important features of AERMOD is described below.

AERMOD is a steady-state plume model. In the stable boundary layer (SBL), the concentration distribution is assumed to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), horizontal distribution is assumed to be Gaussian, but the vertical distribution is described with bi-Gaussian probability density function. Additionally, AERMOD teats “plume lofting”, whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into elevated stable layer, and allows it to re-enter the boundary layer if appropriate.

AERMOD incorporates current concepts of complex terrain. Where appropriate, the plume is modeled as either impacting and/or following the terrain. This approach is designed to be physically realistic and simple to implement while avoiding the need to distinguish among simple, intermediate, and complex terrain.

One of the major improvements incorporated with AERMOD is its ability to characterize the PBL. AERMOD constructs vertical profiles of meteorological variables based on the measurements and extrapolations of those measurements using similarity-scaling relationships. Vertical profiles of wind speed, wind direction, turbulence, temperature, and temperature gradient are estimated using the minimum number of observed meteorological parameters. AERMOD requires only a single surface measurement of wind speed, wind direction, and temperature and also needs cloud cover. However, AERMOD also requires the full set of morning upper air sounding data as inputs and surface characterization like surface roughness, Bowen ratio, and albedo.

AERMOD is the more sophisticated model, but it needs some input data for simulation and is not registered as the regulatory model by the US-EPA at present. AERMOD is one of the candidates for improving the EIA method in Argentina and it is valuable to investigate AERMOD technically and scientifically. However, it likely takes some more time to adopt the AERMOD as an EIA tool.