GUANGZHOU/ GUANGDONG
ENVIRONMENTAL STATUS REPORT

Contribution from the Working Group
on Pollution Prevention

Disclaimer  This report contains preliminary findings on the basis of
information obtained from reports prepared by the Chinese experts from
the WG on Pollution Control on the environment in Guangzhou, and
from discussions with Chinese experts from Guangzhou City, Chengdu
City, Guangdong Province, South China Institute of Environmental
Protection and Guangzhou Research Institute of Environmental Protection.
Remaining questions of the experts of the Netherlands are written in the
text between square brackets.

1. INTRODUCTION

Under the umbrella of the “China Council for International
Cooperation on Environment and Development” the Working Group
on Pollution Control is developing a policy plan for the major urban
and industrial areas of the People’s Republic of China. The first years
of the Working Group's 5 year action plan priority is given to the col-
lection and assessment of the necessary information e.g. by describing
the State of the Environment of key regions within China’s rapid de-
veloping industrial areas. A key region should comprise of: one or
more larger cities, (part of) a river-basin, one or more industrialised
areas in combination (if applicable) with a large agricultural supply re-
region. The State of the Environment should be assessed based on ex-
isting and to be collected data. After discussion with the relevant
Chinese authorities it was decided by the Working Group to select as
its first study areas (in order of priority):
* the Province of Guangdong with the City of Guangzhou as focal
  point
* the area around the confluence of the Yangtze and Jialing rivers
with the City of Chongqing as its focal point
* the area around the City of Shenyang

In order to assess the feasibility to assemble the information necessary to write a State of the Environment Report in China, an Expert Team from the National Institute of Public Health and Environmental Protection conducted from May 17-23, 1994 a pilot study in Guangzhou (and its surroundings).

This report represents the results of the first phase of this pilot study. The full pilot study will be completed before the Council Meeting in 1995.

1.1 Background Information

More than 22% of the world population lives in China. Although the average GDP per capita (about 350 $ / capita in 1992 prices and exchange rates) is still lower than the world average, China has a fast growing economy with a growth rate of 10% per annum or more, from the beginning of economic reform in 1978 onwards. Especially in Southern China a further boom in production is expected in the near future. China with 22% of the world population uses about 10% of the energy used by the whole world. The energy use per capita is thus still low: in the Netherlands the use of energy per capita is 10 times higher. Energy use could increase by 3-4% per year. In order to avoid harmful impact caused by the increase of the amount of energy usage and pollutant discharge on the local and even on the whole global environment, China should take effective measures to control pollution. The developed countries should offer assistance in technology and finance in order to keep pollutant discharge to a reasonable level under the situation of rapid economic growth in China. The energy resources in China (114bn tons of coal and more than 1.1 trillion m$^3$ of gas according to 1992 World Energy Council data) do not seem to be a limiting factor for the projected growth in the next decades. China has ratified the UN Framework Convention on Climate Change and is willing to help prevent global warming “provided that financial and technical assistance is made available” (World Resource Institute, World Resources 1994-95).

Local air and water pollution and the disposal of (hazardous) in-
Industrial and domestic waste are among the most urgent environmental problems, although depletion (and pollution) of water resources and degradation of cropland due to intensive farming are growing problems, which are already visible in some regions. The challenge for the future will be to combine the urbanization and industrialization process with a sustainable use of both soil and water resources. This could require changes in agricultural practices in order to maintain the soil productivity in the long run and to reduce the losses of nutrients and pesticides to ground water resources. Such changes could however lead to lower yields in the short run. The challenge will become even bigger when the use of renewable energy sources (biomass and hydropower) will increase as is to be expected. Photochemical smog may become a new problem in urban areas, as NO\textsubscript{x} and HC (hydrocarbons) emissions will rise sharply due to the growing number of vehicles. Emission standards for vehicles, regular car inspections and integration of an efficient public transport system in the design of new towns and suburbs would be important means to prevent this problem. The irreversible loss of forests, coastal wetlands and wildlife habitat, together with acidification damage to crops and sensitive ecosystems could get more priority in the future when income levels become higher.

In the period 1991–1995 0.85% of projected GDP will be spent on environmental protection. In the period 1986–1990 this was 0.67%. According to the World Bank at least 1.5% of GDP will be required just to stabilize the current environmental degradation. Because of this restricted financial leeway, priority setting on the basis of an comprehensive approach, such as the comparative risk analysis, could be an important element in environmental planning in China.

2. DEMOGRAPHIC AND ECONOMIC DEVELOPMENTS

Guangdong Province in Southern China covers about 2% of the total Chinese area, but contains more than 5% of the Chinese population and almost [20%] of its GDP. Guangzhou is, with more than 6 M inhabitants, the main city of Guangdong. After Beijing and Shanghai, Guangzhou is the largest economic power in China, Guangdong is one of the fastest growing economies in S.E. Asia. Its main city
Guangzhou is expected to become an international megalopolis in the next decade, with more than 8.3 M people living in the greater Guangzhou area in 2005. At this moment, still 71% of the area of Guangzhou consists of agricultural land. It is expected that urban and industrial area will be more than doubled in the next decade. The rural areas around Guangzhou city are urbanized and industrialized at a much higher speed than was planned in the original 15-year Modernization Programme of 1984. At that time industrial production in this area was expected to grow from 15 bn yuan in 1985 to 45 bn yuan in 2000 (in 1990-prices). In 1993 the industrial production already appeared to be more than two times higher than the projection for 2000! In the period 1991–1993 GDP grew with about 20% per year, surpassing the target of 12% in the long term plan. In Guangzhou GDP per capita was 11,490 yuan, more than 2.5 times higher than the national average.

In Guangzhou heavy industry (petrochemical industry, cement, iron and steel) is still the fastest growing sector. Industry is gradually being moved to satellite zones. Currently a new Long Term Plan is prepared by the municipal planning department that sets new targets for population growth and economic growth up to the year 2005. This new long term plan is now in the process of approval by the provincial and national planning councils. The plan contains an average annual growth of industrial production of about 12% from 1990 on, which will more than triple the current (1993/94) production level. Energy use is expected to increase by 8% per year and water use by about 10% per year.

Industrial production growth rates reached record heights in the past decade. In contrast to other regions in China large government owned petrochemical, steel and power plants contribute considerably to the government incomes. Only 20% of firms in Guangzhou need subsidy. These are mainly the older medium sized textile, bicycle and machinery factories. The average labour-productivity in industry increased by more than 30% in the last 3 years. Industry now employs more than 2 M people.

The largest growth occurs in the designated "free economic zones" with help of large amounts of foreign investments. Especially cleaner manufacturing industries, such as electronic and pharmaceutical
industries are expected to grow fast in this region. In some cases older plants are closed in the inner city, while modernized and cleaner plants are built in suburban areas.

All new plants and extensions of existing plants require an environmental assessment report. Minimum pollution requirements are set by the national government, but the local authorities may apply stricter standards depending on the economic and environmental situation. In Guangzhou for new plants "1980" and sometimes "1990" best available technology is requested, which is on average 40-50% more efficient and cleaner than the technologies applied in most existing plants (with "1960" or even "1940" technology). At this moment about 50% of the industries operate with "old" technology. Large plants are planned to be modernized and moved to suburban areas. Excellent examples of these modern facilities with efficient pollution reduction technologies have been demonstrated during the visit of the Expert Team to Guangzhou City.

The high population density and rapid economic growth give Guangdong characteristics that are comparable to Taiwan and Singapore in the 1970's. It would probably be one of the regions within China where environmental concerns will lead to pleas for a stricter environmental policy at the national level (see Table 2.1). In Guangzhou for several substances emission reduction targets of 75% have been formulated in the city area, and of 25% (on average) in the suburban areas. For large point sources considerable efforts have been made to reduce dust emissions and waste water discharges. Pollution control for the large amount of small scale sources will become a major challenge in the near future. Also policies for NOx and VOC have to be developed because, due to the expected increases in motorized traffic, photochemical smog may become an important threat in the future. Motorized road traffic roughly doubled in the last five years, leading to congestion, noise and urban air pollution.

The economic structure is expected to shift gradually towards lighter and HiTech industries and services. This will lead to a lower energy intensity of the economy. Together with technological efficiency improvements a "delinkage" will occur between economic development and energy use. In 1986 5.3 tons of Coal equivalents were necessary to produce 10,000 yuan GDP in Guangzhou. In 1990 this was 2.8
tons per 10,000 yuan. In 2005 the energy efficiency is expected to be 1.5 tons per 10,000 yuan. Nevertheless energy use is expected to grow to 30 Mkg of coal equivalents in 2005. In 1990 energy use was 8.5 Mkg of coal equivalents. In Guangdong the total installed power plant capacity is expected to grow from 13,000 MW in 1993 to 80,000 MW in 2010, of which 40,000 MW will be coal, 15,000 MW nuclear and 25,000 MW hydropower.

Guangdong uses - in comparison to other parts of China - relatively clean coal for its electricity generation (1% sulphur) and Guangzhou plans to use more gas for domestic purposes. Although Guangzhou electricity is produced with a rather high conversion efficiency (36% in the newest plant), besides coal moulding no measures have been taken to reduce sulphur emissions. Dust from large point sources in Guangzhou (petro-chemical industry and power generation) are removed with electrostatic precipitators, which can reach a removal rate of 99.5%. In the future more small scale electricity turbines will be build in order to keep up with the fast growing electricity demand (of more than 20% or 500 MW per year in the past 5 years). As energy prices are quit low (for domestic use 0.5 yuan for one kWh and 2.3 yuan for a litre of gasoline, the incentive to use energy more efficient or more rational is not very high.

The same is true for water use. At this moment the water price is 0.5 yuan per m³. Water consumption per day per capita is 0.45 m³, which is the highest in China. Water use in Guangzhou is expected to increase with 5% per year. Waste water discharges are also expected to increase with 5% per year [this could be 2% per year if drainage of water is to be increased]. Waste water treatment capacity is planned to be extended in view of with the population growth of Guangzhou. At this moment 12% of the domestic waste water is treated with an efficiency of [...] for BOD.

The total environmental expenditures in Guangzhou are more than 2% of GDP, but in this figure also the costs of fuel gasification is incorporated. The environmental costs in Guangdong Province are 0.87% of GDP, which is the China average. Thus far no cost calculations (and environmental effect studies) have been made for alternative policy scenarios.

The environmental policy of Guangzhou incorporates relocation
of the pollutant sources to specific areas outside of the City. Efforts are made to apply newer pollution abatement techniques and to promote efficient use of energy. Proper siting is aimed at in locating the so-called first, second and third industrial categories. New enlarged and reconstructed projects and facilities pass through an Environmental Impact Assessment, including suggestions for pollution prevention techniques. The government urges seriously polluting enterprises to control pollution in a short time: imposing high pollutant discharge fees on enterprises that discharge pollutions above the existing national standards. Also Admission Certificates for pollutant discharge are issued to enterprises that are the main polluters. Some of the policies are tentative. For example, some enterprises, especially power plants which are burning coal, reduce sulphurous dioxide emissions by increasing the height of the stacks. Although these countermeasures can abate local pollution, it cannot solve long-term and profound problems (such as acidification, climate change). Furthermore, it may affect the surrounding areas.

For long range problems, such as acidification and climate change, an environmental policy strategy will have to be designed in cooperation with other regions and the national government (that plays a key role in the definition of minimum standards and of fuel taxes and pollution fees).

Emissions of energy related substances like \( \text{SO}_2 \) and \( \text{NO}_x \) could easily be doubled in the next 10 years. Only to stabilize emissions at the current level new industrial plants, power plants and vehicles would have to be 75% cleaner than the current plants and vehicles. For emission reductions relatively expensive best available technologies such as flue gas desulphurization, coal-gasification and catalytic reduction would be necessary in all new plants and vehicles. The faster energy use will grow the higher the pollution abatement costs will be if one also wants to improve the environmental quality and reduce long term environmental risks to ecosystems.

**Recommendation**

It is recommended that alternative scenarios for energy use, energy prices, fuel mix, traffic planning and application of abatement techniques are developed in order to assess the costs and environmental ef-
fects of such policy alternatives. In order to curb increasing water use and waste water discharges comparable water-policy alternatives are to be developed (as is proposed in the Dongjiang River Project).

On the basis of such a comprehensive scenario study, costs and effects of alternative policies can be assessed. This could be the basis for rational environmental planning and priority setting. Preferably such scenarios are to be developed in cooperation with the planning department and the departments responsible for energy planning, traffic planning and agriculture and industry, as to incorporate all participants in the policy discussions into the planning process. Because in a number of cases the national government is responsible for the use of certain instruments (such as discharge fees and energy prices), it is recommended that representatives of the national government participate in such a policy process. The risk of limiting the scenario-study to one region is that much emphasis is given to local and visible environmental problems, while long range problems and “future” problems that are caused by a gradual depletion of resources and accumulation of pollutants in the environment are not taken into account. Water problems can only be solved when all provinces in a catchment area work together to find a solution that is acceptable for all.

Literature
Mark Barrett, Environmental impacts of fossil fuels, in K.V. Ramani. Peter Hills and Grace George (eds), Burning Questions, Environmental Limits to Energy Growth in Asian-Pacific Countries during the 1990’s, WWF, [1993]


Qu Geping, China’s dual-thrust energy strategy, economic development and environmental protection, in: Energy policy, June 1992, p 500-506

World Resource Institute, China, in: World Resources 1994-95

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Table 2.1   Environmental load factors per km$^2$*

<table>
<thead>
<tr>
<th></th>
<th>Guangzhou</th>
<th>Guangdong</th>
<th>China</th>
<th>Netherlands</th>
<th>dimension</th>
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<tbody>
<tr>
<td>population</td>
<td>823</td>
<td>363</td>
<td>126</td>
<td>452</td>
<td>pop / km$^2$</td>
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<tr>
<td>GDP</td>
<td>9,658</td>
<td>1,288</td>
<td>240</td>
<td>50,873</td>
<td>1,000 yuan / km$^2$</td>
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<td>industrial production</td>
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<td>592</td>
<td>108</td>
<td>25,437</td>
<td>1,000 yuan / km$^2$</td>
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<tr>
<td>energy use</td>
<td>1,143</td>
<td>293</td>
<td>139</td>
<td>4,518</td>
<td>ton coal equivalents / km$^2$</td>
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<tr>
<td>vehicles</td>
<td>67</td>
<td>34</td>
<td>11</td>
<td>301</td>
<td>vehicles / km$^2$</td>
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<tr>
<td>cattle</td>
<td></td>
<td>368</td>
<td></td>
<td>555</td>
<td>per km$^2$ arable land</td>
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<tr>
<td>SO$_2$</td>
<td>24</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>ton per km$^2$</td>
</tr>
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</table>

* see Annex 1
<table>
<thead>
<tr>
<th>Area</th>
<th>Guangzhou</th>
<th>Guangdong share (%)</th>
<th>China</th>
<th>Netherlands dimension</th>
</tr>
</thead>
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<tr>
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<td>76%</td>
<td>60%</td>
<td>6%</td>
<td>31%</td>
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<tr>
<td>energy intensity</td>
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<td>6%</td>
<td>31%</td>
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<tr>
<td>energy intensity</td>
<td>192</td>
<td>227</td>
<td>6%</td>
<td>6%</td>
</tr>
<tr>
<td>cattle</td>
<td>500</td>
<td>8</td>
<td>6,000</td>
<td>4</td>
</tr>
<tr>
<td>arable land per capita</td>
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<tr>
<td>water use</td>
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<td>4,900</td>
<td>4</td>
</tr>
<tr>
<td>BOD discharge</td>
<td>500</td>
<td>8</td>
<td>4,900</td>
<td>4</td>
</tr>
<tr>
<td>domestic waste per capita</td>
<td>200</td>
<td>8</td>
<td>4,900</td>
<td>4</td>
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<tr>
<td>domestic waste per production</td>
<td>200</td>
<td>8</td>
<td>4,900</td>
<td>4</td>
</tr>
</tbody>
</table>

Annex 2.1 General data 1992

a. Reference year 1990 data from Qiu and Chan (1992); not clear whether this refers to first, coarse or total fraction.
b. No data on HC is given, methane probably included in HC.
c. No data on HC is given, methane probably included in HC.
Fig 2.1  GDP development Guangzhou

Fig 2.2  Industrial output Guangzhou
3. EMISSIONS

3.1 Emission of air pollutants

3.1.1 Emissions in Guangzhou

For the city of Guangzhou emission inventories have been made for a number of pollutants, see tables with general data in appendix I. Emission estimates are calculated using statistical information on industrial activities and emission factors according to the standard procedures provided by NEPA. Validation of the emission data by direct measurements of concentrations in exhaust gases has only been done for one of the major point sources (Huangpu Power Plant). Data presented in Appendix I refer to 1992. The increase in energy consumption during the last years, leads to a steady increase in SO\(_2\) emissions. It is expected that until 2000 SO\(_2\) emissions will increase with approx. 6.4% per year. NO\(_x\) and hydrocarbon (HC) emissions will sharply increase in the near future due to the strong increase in the number of cars (20% / year).
The NO\textsubscript{x} emissions for 1988 given by Qin and Chan\textsuperscript{©} are probably strongly underestimated. Recent estimates (1992) for the Huangpu Power Plant alone give an emission of 38 kton/year. For Shanghai NO\textsubscript{x} emissions from industrial and domestic fuel combustion have been estimated to be 127 kton/year for the base year 1983. Assuming a similar emission density per capita for Guangzhou and assuming a traffic contribution of 22%\textsuperscript{©} total NO\textsubscript{x} emissions are estimated to be 165 kton/year.

The major source of SO\textsubscript{2} emissions is the industrial combustion of sulphur-containing coal and oil. Largest point source in the city is the Huangpu Power Plant with a total capacity of 1,100 MW; SO\textsubscript{2} emission of this plant is 58 kton/year.

For the city and its surrounding area a gridded emission inventory (reference year 1987) is available with a spatial resolution of 2×2 km for SO\textsubscript{2}, NO\textsubscript{x}, CO and dust. The large changes in emissions makes an update for a more recent year necessary.

3.1.2 Emissions in Guangdong

The consumption of coal in Guangdong in 1988 and 1992 increased from 18.2 Mton to 25.9 Mton respectively. Oil consumption increased in the same period from 3.3 Mton to 4.2 Mton. The sulphur content for coal and oil is 1% and 1.4% respectively. The cement industry uses 15% of the coal. On the basis of this information SO\textsubscript{2} emissions can be computed to be about 440 and 110 kton for coal and oil respectively. Therefore, the total SO\textsubscript{2} emission in the region is 550 kton in 1992. Furthermore it was stated that 60% of the regional emissions originate from combustion power generation.

In Guangdong six large point sources are located as described in chapter 6. One of these sources that was visited by the expert group, is Huangpu. During the visit it was stated that 58 ktons of SO\textsubscript{2} were emitted by the power plant in 1993, that the sulphur content of the coal used by the power plant is 1.04% and that of oil 1.46%.

\textsuperscript{©} Qin Y. and Chan L. Y. (1993) Traffic source emission and street level air pollution in urban areas of Gangzhou, South China (P.R.C) Atmospheric Environment 27B, 275 – 282.

\textsuperscript{©} UNEP(19..) Urban air pollution in megacities of the world, WHO and UNEP.
It was not established what the emissions of \( \text{SO}_2 \) are in the other five large point sources. Therefore in the following tentative calculations, assumptions are made. It is assumed that emissions of the other five power plants range between 30 and 50 ktons. The consequence of this assumption is that total emission from all six large point sources in Guangdong ranges between 208 ktons and 308 ktons. This is 37% and 56% respectively in relation to the total \( \text{SO}_2 \) emissions of 530 ktons, established in the previous section. As mentioned above, Chinese experts claim 60% of \( \text{SO}_2 \) emissions in the region to be attributable to power generation.

These magnitudes seem to be different from the shares which are established for the whole of China. Chinese \( \text{SO}_2 \) emissions are about 18000 ktons of which about 3,000 kton is allocated to the generation of electricity, i.e. only about 16%. If shares of large point source emissions in Guangdong (assumed in the above to be ranging between 208 and 308 ktons) total \( \text{SO}_2 \) emissions in the region could exceed 1,000 ktons.

There seems to be a considerable gap between the contribution to \( \text{SO}_2 \) emissions from electricity generation in China and Guangdong respectively. It is recommended to pay further attention to \( \text{SO}_2 \) emissions from other sources than those established in relation to the six large point sources in Guangdong.

For the province emission data for \( \text{NO}_x \), HC, CO and dust have not been discussed during the task force meeting.

3.1.3 Other air pollutants

Emission data on other components are not known both for the province and the city. In the city relatively high levels of heavy metal emissions can be expected from traffic (leaded petrol) and the (metallurgic) industry. When the composition of coal and oil is known, the heavy metals emissions related to the combustion of coal and oil can

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be estimated according to procedures described in the literature\(^\circ\).

In the province the usage of pesticides form an important source of air toxics.

Data on ammonia and the greenhouse gases (CO\(_2\), N\(_2\)O, CH\(_4\)) have not been presented during the meeting.

3.1.4 Emission standards

National emissions standard are set by NEPA for the following sectors:

- industry: SO\(_2\)
- traffic: gasoline cars: CO, HC
diesel: smoke
motorcycles: CO, HC

No emission standards are set for NO\(_x\).

3.1.5 Recommendations

- develop emission standards for NO\(_x\) for large combustion sources and traffic
- prepare emissions inventories for NO\(_x\) both for Guangzhou and Guangdong
- emission inventories for Hydrocarbons (HC) and methane should be made separately
- make a first survey of heavy metals emissions using the available statistical data on industrial activities, consumption of leaded petrol etc. and emission factors (see for example the PARCOM-ATMOS emission manual\(^\circ\) for European emission factors).

3.2 Emissions to surface water

The river and water systems of Guangzhou and the Province of Guangdong are contaminated by industry and urban domestic waste water, as well as by agriculture and cultivation.

Locations and information about waste water discharges of impor-

tant point sources of pollution (industries) are available for the urban area of Guangzhou. This also applies for domestic waste water.

In the period 1988–1990, the city developed a master plan for water pollution control for the municipality. The sewage treatment facilities are not sufficient at the moment. In 1992 only 11.7% of municipal waste water was treated (0.3 Mm³/day). An existing sewage plant is being expanded and a new plant, with a capacity of 0.7 Mm³/day, will be ready within 5 years.

Most of the larger sources of industrial waste water are treated separately. In 1992 about 60% of the treated waste water met the emission standards. From the main industrial activities (food production, textile, machinery, electronics, refinery, paper, chemical and metallurgical) more than 17 Mm³ per day is discharged.

The total discharge of waste water is expected to increase by 2% on an average annual basis. [In view of the increase in drinking water supply (5% per year) this seems to be a rather low figure.] By 2005, it will be 34.6% more than that of 1990.

It is to be expected that a number of municipal waste water treatment plants with a total daily handling capacity of 2.2 Mm³ will be necessary in the near future.

3.3 Solid wastes

3.3.1 Industrial solid wastes

In the Guangdong Province the amount of solid waste generated by industry has grown from 10.8 Mton in 1980 to 17.6 Mton in 1992. The percentage of reuse increased from a low 21% to about 48%. The main part however, still is “stored”; which probably means deposited at the industrial sites. No information is available about the exact storage locations, the storage conditions and the possible leakage of substances to the surroundings. The amount of industrial waste that is landfilled under controlled conditions has decreased considerably from 0.4 Mton in 1985 to 0.2 Mton in 1992. The available information on industrial waste generation is far from enough to assess the state of affairs at the provincial level.

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①China statistical yearbook, 1993
The information available about industrial solid waste generation in the urban area of Guangzhou provides a good first impression of the magnitude of the waste problem. The total amount of generated industrial waste is about 3.2 Mton/a. The reuse percentage is higher than the provincial average: 65.7% in 1992. This leaves about 1.1 Mton/a with the destination landfill. [This number is not in conformity with the provincial numbers.]

In the Guangzhou report 4 categories of industrial waste are distinguished: hazardous organic and inorganic and non-hazardous organic and inorganic. It is recommended to use the definitions of the Basel Convention(UN) if this is not already the case.

Hazardous waste is registered, treated and finally disposed of in specially designated pits. The locations of these pits should not be too close to rivers in case of seepage of leachate to the river. The regulations concerning these disposal facilities have been set at the national level. Within the Guangzhou area there are no special hazardous waste disposal facilities.

The major part of industrial waste that has to be landfilled at the moment is formed by the residues of power generation (about 50% of 1.5 Mton/a) and metallurgical wastes.

With an increase in power production of 500 MW/a on top of the 2,600 MW already produced in Guangzhou City, and under the assumption that the increase will be in coal fired plants, the residues from power generation by coal combustion will increase from about 1.5 Mton/a to about double this amount by the year 2000. The assumption in the reports is that 50% will be reused, but it can be doubted that there will be enough reuse possibilities in time for this quantity of coal residues. Part of a possible solution might be that the production of building materials with these residues is taken up by the power producers themselves. Care has to be taken that the products made with these residues meet leaching standards (especially for heavy metals). It is also known that some of the coal that is used has a rather high percentage of radiative material. This is concentrated in the residues when coal is burnt. An assessment of the risks is necessary when reuse of residues as building bricks is considered in order to avoid future health problems. Another part of the solution is already mentioned in the Annual Report of the Industry Pollution Control Strate-
gy & Policy Study for Guangzhou: use ashes in large infrastructural projects.

The remaining coal residues have to be landfilled. Space however is becoming more and more scarce in the direct vicinity of Guangzhou so it is advisable to push for increased reuse of coal residues.

For the province the coal fired power generation at the moment is about 6,100 MW. This capacity will increase to about 40,000 MW in the year 2010. Using the same waste factor as in Guangzhou City this leads to an estimate of coal residues of about 3 Mton / a for the province as a whole; increasing to 20 Mton / a in 2010. It will be a major effort to find reuse possibilities for such quantities. Landfilling will rapidly become impossible in view of the scarcity of suitable places in the vicinity of the power plants, Transportation over large distances is expensive. A comprehensive assessment of this item at the provincial level is recommended.

With the industrial development that is planned in the City of Guangzhou a substantial number of industries will contribute to the solid waste problem. Some of the development regions plan to house industries with substantial waste generation. The EIA's needed for these factories have to include an assessment of the waste generation and have to contain solutions for reuse and/or final disposal based on best available techniques.

In the Guangzhou area only a treatment plant has been noticed for organic wastes for a limited capacity. A treatment plant with a capacity of 1000 ton / day has been planned in the south-eastern part of the area in 1998.

3.3.2 Domestic and commercial waste

Generally speaking domestic waste does not form a serious problem in rural areas. Therefore this aspect will only be considered for the more densely populated area of Guangzhou.

Every day 11,000 men collect in total 3,300 tons of waste in the City of Guangzhou. This means about 1.25 Mton / a collected from the urban areas of the city or 200 kg per person per year (which about 50% of the domestic waste generation per person in the Netherlands). Next to this collected waste there exists intensive recycling of materials. When the prosperity of the population increases — as is one
of the goals of the development schemes for China — it is to be expected that the recycling will become less efficient unless the municipal government provides economic incentives to keep this intact.

The annual increase in the amount of domestic waste over the past years is about 10%. It is predicted that by the year 2000 the amount will be doubled.

At the moment these wastes are landfilled at two sites in the urban area: one in the northern part with a capacity of 2.8 Mm³ which started in 1992. This site is used at a rate of 1,400 ton/day, which means that it can only be used for about 4 more years. The second one is in the southeastern part of the area. The present capacity is 1.7 Mm³ which will be enlarged this year to 4.2 (see also map in Annex 3.3.1). At this site 1200 to 1,400 ton/day is landfilled. A new site is planned for 1997 east of the Guangzhou urban area.

In the past a large part of these wastes were inorganic (domestic coal burning). The composition has rapidly been changed because of the use of propane and electricity in households. [The heat value now 1,200 kcal/ton makes it advisable to look for incineration as an alternative for the landfilling that is used at present.] This is already under consideration in the city. Energy recovery at the incineration plant (12MW) is a small part of the power generating system of the city. In Europe and the USA incineration plants have caused dioxin problems. At the moment technology is available enough to prevent this.

4. AIR QUALITY

4.1 Introduction

All over the world it was for a long time believed that air pollutants were diluted to negligible low concentrations. However, measurements taken during the last decades have shown this belief to be erroneous. Air pollution may lead to a variety of adverse environmental effects on local, regional and even global scale. Distances over which an air pollutant is transported depends on its atmospheric residence time (determined by deposition losses and chemical conversion), the meteorological situation and the release
height. Building higher stacks may bring some local relief but it shifts pollution problems to more regional scales.

One pollutant may play an important role in a range of environmental effects. For example, pollutants originating from the usage of fossil fuels (sulphur dioxide, nitrogen oxides) together with ammonia, mainly originating from agricultural practice, cause major problems including acidification (chapter 6), eutrophication and contamination of soil and surface waters. This may have strong consequences for the diversity and conditions of ecosystems including forests and crops.
In combination with hydrocarbons (more commonly called Volatile Organic Compounds, VOC) the nitrogen oxides are also involved in the photochemical formation of ozone at ground level. Ozone is a highly reactive gas which causes health effects and damage to agricultural crops and natural vegetation.

4.2 Urban air quality in Guangzhou

A growing number of people in China live in urban areas: in 1990 the urban population was estimated to be 297 million (approx. 26% of the total population), an increase of nearly 90 million since 1982. Many urban activities (e.g. industrial production, power generation, traffic) are accompanied by emissions into air yielding elevated concentrations of pollutants. This is especially important when a large number of activities are concentrated together, as in an urbanized region.

Urban air pollution is the source of a range of problems: health risks mostly associated with inhalation of gases and particles, accelerated deterioration of building materials, damage to buildings and to vegetation within and near the cities. For an assessment of these problems and for regulatory decision making it is necessary to characterize urban air quality by using tools like monitoring, data analysis and modelling.

4.2.1 Monitoring system

In the City of Guangzhou an automatic monitoring system is installed. This system consists of one central station and 12 sub-stations. Measurements of SO$_2$, NO$_x$, CO, HC, O$_3$ and TSP are carried out on a semi-continuous way (15 days / month; 24h / day). Next to the automatic network, there is a manual by operated network covering the whole city. This manual system consists of 37 stations; measurements are made of SO$_2$, NO$_x$, CO, TSP, sulphate, dust deposition and heavy metals in dust fall. In general 80 samples (every season four samples per day during five days) are analyzed. Sampling and analysis methods are in agreement with the standard procedures of NEPA.
4.2.2 Ambient levels

Guangzhou is located in the southern subtropical zone and has a marine monsoon climate. Meteorological conditions (annual averaged wind speed of 1.9 m/s, relatively low mixing height) are not favourable for dispersion. Concentration in the city will largely be determined by emissions in the urban area as is indicated by analyses of the monitoring data. However, during spring and summer the prevailing wind direction is south east and concentrations may be influenced by emissions in Hong Kong. A more quantitative insight in the origin of the pollution levels in Guangzhou and of the contribution of the various economical sectors can be obtained by application of atmospheric transport models + appendix 4.2. Models can also be used to quantify the impact of the urban emissions on the air quality in Guangdong Province. According to the information obtained during the meeting, the input data required for such model studies are available.

4.2.2.1 Concentrations in air

The averaged concentration of SO$_2$ measured at all monitoring stations increased from approx. 60 $\mu$g/m$^3$ in 1983 to approx. 100 $\mu$g/m$^3$ in 1990. In the more rural parts of the city yearly values of approx. 40 $\mu$g/m$^3$ are measured. In the industrial/commercial districts levels are [150]-170 $\mu$g/m$^3$ indicating that the third class AQ standard (see appendix) is violated. The WHO guidelines of 40-60 $\mu$g/m$^3$ is exceeded at nearly all stations.

NO$_x$ concentrations, averaged over the city, are doubled during the last decade: increasing from 60 $\mu$g/m$^3$ in 1983 to 100 $\mu$g/m$^3$ in 1990. Yearly averaged concentrations in streets may be as high as 340 $\mu$g/m$^3$, the third class NO$_x$ short-term standard of 300 $\mu$g/m$^3$ is frequently exceeded in a number of streets.

The annual averaged CO concentration (1993 data), averaged over the whole city is 2.8 mg/m$^3$; highest concentrations are found in traffic areas (4.9 mg/m$^3$) whereas in more residential and commercial areas yearly concentrations range from 1.2 to 3.4 mg/m$^3$. Effects of CO are associated with the short-term exposure to high concentrations. WHO guidelines are therefore defined as maximum 1h or 8h averaged concentrations. Based on the yearly averaged data, an evaluation of the exceedances of CO guidelines is not possible. Timeseries of CO were not presented during the meeting but it is ex-
pected that CO, similar to NO\textsubscript{x}, has shown an increase during the last ten years.

For TSP an yearly averaged value of 280\(\mu g / m^3\) was reported as city averaged value in 1992 which indicates that the WHO guidelines are exceeded in the whole city. The concentrations of TSP showed no clear trends during the last years. As a result of the growing dust emissions from traffic and the introduction of electrostatic precipitators in industry, an increase in the contribution of smaller, inhalable particles is expected.

Data on ozone concentrations are scarce. There are indications that the third class standard for ozone of 200 g / m\textsuperscript{3} is violated. The forecasted increase in NO\textsubscript{x} and VOC emissions (e.g. because of the growth in the number of vehicles) can be expected to increase the ozone production. This might present a serious problem to Guangzhou and the downwind areas.

Analyses of heavy metal fraction in dust fall is reported but measuring data have not been made available for this report. A first survey, including emission estimates and application of atmospheric transport model has to be made in order to assess the relevance of heavy metal pollution.

4.2.2.2 Concentrations in precipitation

In southern China acid deposition is a growing problem. In the city measured pH values are low (4.2–4.4); in the provinces the region over where low pH values are measured is increasing.

Research done in USA and Europe indicates that determination of the total load of sulphur and nitrogen could considerably improve the description of acidification of soil and surface water. The total load of S and N compound is the sum of the wet deposition (= concentration in rain times the amount of precipitation) and dry deposition (= deposition velocity time air concentration). Close to major source areas dry deposition gives the most important contribution to the total deposition; in remote areas, wet deposition will dominate. Acidification is further discussed in chapter 6.

4.2.2.3 Indoor air quality

Data on indoor air quality has not been discussed during this Task Force Meeting. Indoor air pollution is highly relevant when the human exposure to air pollution is considered and it should be in-
cluded in future work on human health risk analysis.

4.2.3 Effects
4.2.3.1 Health effects

Studies on the effect of air pollution on health of the citizens of Guangzhou were not available for this report. The current air pollution levels exceed the WHO long-term guidelines for SO₂ and TSP; Although no information on daily levels of SO₂ and TSP has been presented, it is expected that they exceed the short-term air quality guidelines. The observed levels are associated with chronic pulmonary disease in ageing populations and in susceptible individuals. The presented data is insufficient to estimate the increase in morbidity for respiratory diseases and mortality.

4.2.3.2 Exposure of materials, buildings to air pollution

Air pollution in urban and industrial areas increases the deterioration of many buildings and construction materials. For the city of Chongqing economic losses caused by air pollution has been estimated to 3.2% of GDP of which 0.8% must be attributed to material damage. When this number is applied to Guangzhou, an economical loss of approx. 570 million yuan is estimated. However, as the air pollution climate in Guangzhou not as bad as in Chongqing this number might be an overestimation.

4.3 Air quality in Guangdong

In the major cities in Guangdong SO₂, NOₓ and TSP are measured. In general it can be stated that Guangzhou is the most polluted region in the province. SO₂ concentrations in the other cities range from 12g/m³ in Zhuhai to 102g/m³ in Shaoguan. The lower limit of the WHO guideline value of 40g/m³ is exceeded in Shaoguan and Fushan.

In the city of Shenzhen a NOₓ concentration of 108g/m³, comparable to the concentration in Guangzhou is measured. In the remaining cities the reported NOₓ data do not exceed 70g/m³. TSP concentrations exceed the WHO guideline value of 90g/m³ in all cities: in Jiangmen, Meizhao and Zhaoqin a threefold exceedance is measured.
The concentration in air and precipitation in the more rural areas will not only be the result of emission in the province itself but also by emissions in surrounding regions. In the western part of the province, the impact of emissions around Wuzhou is expected; emissions from Hongkong will be transported over the central part of the province.

4.4 Recommendations

1) Representativeness of data from the manual network: which study uncertainties are introduced by the discontinuous sampling procedure (per year total sampling time is 80 hours or less); study the intercomparability of manual and automatic network.
2) Evaluation of dustfall measurements: how are these measurements used in assessment studies? Deposition of dust depends on meteorological conditions, the size distribution of the aerosol and the air concentration. Deposition to artificial surfaces is generally not a good measure for deposition on soil or surface water. More (effect-relevant) information will be obtained by direct measurement of PM10 concentrations; air quality standards are set for PM10, see Annex 4.2.
3) Re-evaluation of the precipitation data: analyses of the wet deposition fluxes of sulphate, nitrate and ammonia.
4) First survey of heavy metals concentrations using emissions estimates and transport models.
5) Initiate exploratory measurements of ozone.
6) Monitoring, data analysis, modelling etc. constitute fundamental building blocks for assessment of problems and regulatory decision making. Therefore, a series of training workshops to train teachers who will rapidly propagate relevant information and technology is advisable.
7) Application of atmospheric transport and dispersion models for SO$_2$ and NO$_x$.
   + check on the consistency between emission estimates and measuring data
   + assessment of the contribution to ambient levels of various economical sectors
   + evaluate the impact of emission in Guangzhou on the prov
ince and vice-versa

Appendix 4.1

Table 1. Chinese National Ambient Air Quality Standards (in g/m³)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging Time(h)</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
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<tr>
<td>O₃</td>
<td>1</td>
<td>120</td>
<td>160</td>
<td>200</td>
</tr>
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<td>CO</td>
<td>24</td>
<td>4,000</td>
<td>4,000</td>
<td>6,000</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>10,000</td>
<td>10,000</td>
<td>20,000</td>
</tr>
<tr>
<td>NO₂</td>
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<td>100</td>
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<tr>
<td></td>
<td>1</td>
<td>10</td>
<td>150</td>
<td>300</td>
</tr>
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<td>SO₂</td>
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<td>20</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>24</td>
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<tr>
<td></td>
<td>1</td>
<td>150</td>
<td>500</td>
<td>700</td>
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<tr>
<td>Dust(a)</td>
<td>24</td>
<td>50</td>
<td>150</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>10</td>
<td>500</td>
<td>700</td>
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<tr>
<td>TSP(b)</td>
<td>24</td>
<td>150</td>
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<td>500</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>300</td>
<td>1,000</td>
<td>1,500</td>
</tr>
</tbody>
</table>

(a) Aerodynamic diameter less than 10 μm; (b) Total Suspended Particulates

WHO Air Quality Guidelines (in g/m³)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging Time</th>
<th>AQG</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
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<td>100-150</td>
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<tr>
<td>NO₂</td>
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<td>150</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>400</td>
</tr>
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<td>CO</td>
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<td>40-60</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>100-150</td>
</tr>
<tr>
<td>TSP</td>
<td>Year</td>
<td>60-90</td>
</tr>
<tr>
<td></td>
<td>98-percentile</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>of daily values</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4.2

The CAR model

The CAR model (Calculation of Air pollution from Road traffic) is a simple parametrized model for the determination of air quality alongside roads, including street canyons, in cities. In the Netherlands, the model supports the implementation of air quality guidelines decrees under the Air Pollution Act by provincial and municipal authorities.

By analysis of measured concentrations in streets and an extensive program of wind tunnel experiments the relation between emissions and concentration was investigated for a large number of configurations which differ with respect to dimensions, distances and shapes of streets, its buildings and trees. Based on these studies parameters with the largest influence on the concentrations were selected. A decision was made to distinguish five type of streets, see Figure 4.1.

In the CAR model the calculations are performed in the following way:

1) Calculation of the local street emission from speed-class-dependent emission factors for light duty and heavy duty cars, the traffic density (number of cars per day) and the fraction of heavy duty traffic in the street.

2) Calculation of the street specific concentration from the traffic emissions and the street-type specific dispersion parameter which was empirically determined based on the wind tunnel experiments. The value of this dispersion parameter depends on the selected street type.

3) Calculation of street level air quality by adding a city background concentration (e.g. the upwind concentration in a more rural area).


Preliminary calculations with the CAR model are made for three
streets in Guangzhou, see Figure 4.2 and 4.3. The measured NO$_x$ and CO concentrations and information on traffic density, street configuration and emissions are taken from Qin, Y. and Kot, S. C. (1993) Dispersion of vehicular emission in street canyons, Guangzhou, South China, Atmospheric Environment, 27B, 283-291. Although not all necessary input data could be extracted from this paper, the model performs well in predicting the air pollution levels in different types of street canyons in Guangzhou. Using the available road maps and traffic intensity maps for the city, the model could be applied to assess air quality in Guangzhou's busy streets.
Figure 4.1  Street types and their dilution function as defined in the CAR model

The CAR model

Street types in the CAR model

Type 1
$\phi_1 = 0.75 \times 10^{-6} S^2 - 0.70 \times 10^{-3} S + 0.17$
Road in open terrain. No buildings or trees within a distance of 100 m (or so few that roughness length is not affected).

Type 2
$\phi_2 = 3.10 \times 10^{-4} S^2 - 1.82 \times 10^{-2} S + 0.33$
Basic street type, all roads not defined by 1, 3a, 3b or 4.

Type 3
$\phi_3 = 3.25 \times 10^{-4} S^2 - 2.05 \times 10^{-2} S + 0.39$
Street with buildings (at least 3 m high) on both sides; no gaps larger than 25 m and at least 75 m buildings per 100 m street. The ratio between height of buildings and distance of these two road axes is from 1.5 to 3 on one side and less than 3 on the other.

Type 3b
$\phi_3 = 4.88 \times 10^{-4} S^2 - 3.08 \times 10^{-2} S + 0.39$
Special case of street type 3a, the above mentioned ratio is less than 1.5 for both sides of the road.

Type 4
$\phi_4 = 3.00 \times 10^{-4} S^2 - 3.16 \times 10^{-2} S + 0.57$
Street with buildings (at least 3 m high) on one side, with the ratio building-height/road-axis-distance less than 3; the other side has no buildings or a ratio much greater than 3 (preferably greater than 10).

1 With exception of street type 2, the definition is only valid if the street has the same configuration of at least 100 m. S: distance to roadaxis.
Figure 4.2 CAR model results for 3 streets in Guangzhou, CO(China)

![Graph showing calculated vs measured concentration for CO]  

Figure 4.3 CAR model results for 3 streets in Guangzhou, NO\textsubscript{x} (China)

![Graph showing calculated vs measured concentration for NO\textsubscript{x}]
5. SUSTAINABLE MULTIFUNCTIONAL USE OF WATER RESOURCES

5.1 Introduction and problem statement

The numerous rivers in Guangdong have large flow rates, little silt content, long high-water seasons and wide hydro-electric power potentials. The Pearl River delta consists of alluvial deposits, has many water ways and fertile soils. The Pearl River system drains half of Guangdong's total area.

Today, the Province of Guangdong and especially the City of Guangzhou and its surrounding urban area is facing enormous environmental problems, caused by its high population densities and its rapid economic development. This puts a high pressure on the water systems. The river and water systems of Guangzhou are contaminated by industry and urban domestic waste water, as well as agriculture and cultivation. Because Guangzhou is located at a crossroads of different rivers, with their junctions in its urban area, flowing southwards as the Pearl River to Deep Bay and the South Chinese Sea, it has a tremendous potential impact on the aquatic environment in the whole Pearl River delta. The water is used by different, often conflicting, interests like population (water supply and waste water), industry, navigation, power generation and irrigation.

At the moment, the area has a.o. a problem with its drinking water supply because of pollution of surface water resources.

To be able to serve all water functions in the region (also downstream of Guangzhou), and to safeguard these functions for the future, a stage of sustainable multifunctional use of the water has to be reached. This can only be achieved by integrated water management, taking into account all relevant factors and their mutual relationships. The best way to implement this concept is to evaluate all functions and their requirements as to water quantities, water levels and water quality at the river basin scale, and to describe the situation along the line of pressure-state-impact and societal response(Figure 5.1). Priority setting by the authorities determines the allowable use of the water system by the different functions. Linking different river basins produces the picture for a whole region.
The above statement implies that optimal sustainable solutions with regard to water problems can only be achieved at a river basin scale and that solutions for smaller units within a river basin (like cities) can only be reached within that context. A proper tool to analyze and evaluate the water related problems in a river basin and to move to sustainable water use, is the integrated assessment methodology as described in an annex.

Potential outcomes of applying this methodology are:
- overview of functions and functional requirements to the water system;
- coherent information on the state of the water system;
- identification of problem areas (bottle necks);
- starting points for sustainable multifunctional use.

The Dongjiang River project that is being carried out at the moment is conceptually an excellent example of this approach and could be a model for other river basin studies in China.

In the next sections, a diagnosis will be given as to available and essential information for generating a status report on the water systems in the Province of Guangdong. A lumped approach will be followed rather than a detailed evaluation as to single factors. The analysis aims to produce a first impression, based on information available to the expert team.

5.2 Water use and state of the water systems in the municipality of Guangzhou

Water quality

In 1974, the city began systematic monitoring of the aquatic environment. Ten monitoring sites are in operation since then. The network was optimized in 1988, which resulted in nine sites (three are national monitoring sites). Shortly after 1988 six monitoring sites were added along the Dong River. The water pollution pattern is affected by tidal effects and type of season (wet or dry). The monitoring results show that organic pollution is very important. Trend analysis since 1985 points out that NH$_3$-N and DO were the parameters which most frequently did not meet the standards.

A clear picture exists of the impact of the city of Guangzhou on
the water quality of the Pearl River because upstream, urban and
downstream information is available. Dynamic effects caused by the
season and the tides can be seen in the data. Quite a long distance of
the first part of the Guangzhou River section has turned dark and
smells badly because of lack of dissolved oxygen. At the sites far from
the downstream area the water quality meets the highest quality
standard due to the strong tidal influence.

Water pollution with heavy metals and hazardous organics is not
considered a serious problem anymore, due to the tight control on the
industrial pollution sources of these pollutants. Compared to 1985, the
discharged heavy metal pollutions by industries decreased
substantially. However in the opinion of the expert team, a decreasing
trend of heavy metal concentrations cannot be seen in the period
1989-1992. Moreover Hg and Cd concentrations seem to be rather
high. Recently, the city put much effort in the monitoring and control
of hazardous organic pollutants. The concentrations have been found
to be not alarming. [This cannot be confirmed by the Expert Team due
to lack of information.] Information concerning Cl (important for
drinking water supply purposes), P (with regard to eutrophication) ex-
ists through monitoring. For Cl, no national standard exists. Lacking
information concerns pollutants from diffuse sources (mainly
pesticides). Occurrence of pesticides can be expected because 72.3% of
the landuse of the municipality of Guangzhou is agricultural. [Also
lacking is information on the microbiological water quality. Finally,
neither information on the quality of river sediments nor no ground
water quality is available.]

- **Effects**
  Aquatic organisms seem to be monitored as well. [Information on
effects was not available.]

- **Water quantity**
  Information is available on rainfall amounts, evaporation and
  river discharge. In 1988 Guangzhou was the second largest in total
  water consumption and per capita consumption nationally. In recent
  years, water supply increased by about 5%. The ruban areas of
  Guangzhou are supplied with surface water (population, industry as
  well as irrigation) from eight water plants supplying 3.08 Mm³ per
day. Industrial water supply amounts to about 5.4 Mm³ per day. The
amount of water supply per capita per year is the lowest in China. The city does not have much water resources from the localities. 70% of the supplied water comes from Xi Channel and its upstream of Liu Xi River. The drinking water resources are protected. Quantitatively spoken, the surface water resources are sufficient, because of the location of Guangzhou in a network of rivers, but the city is facing shortage of drinking water supply because of water pollution.

Lacking information concerns especially the ground water (aquifers, flow directions, flow rates) and the interaction with surface water.

- Other functions

The river system is rather intensively used for transport (4.7 Mtons are transported per year to and from Guangzhou; for the whole region this is about 25 Mtons per year). This transport means a potential risk to other functions like drinking water supply.

Also hydropower and irrigation are important water functions, that also influence drinking water supply.

- Perspectives and recommendations

As industry and city are developed further, the environment will suffer from a higher pressure. The fast growing economy and progress of science and technology will provide the environment with economic and technological instruments for its protection and improvement. But, at the same time, the expectation is, that water pollution will remain a problem in the future. Water quality will decline if the plan is not followed to build a number of municipal waste water treatment plants.

The future water demand has been estimated to 3.8 Mm³ per year in 1995. The municipal government has planned to develop new water supply sources in the south of the city. Sustainable supply from surface water resources can only be achieved if substantial extra capacity for treatment of sewage water to prevent pollution with organic pollutants becomes available as soon as possible. The water supply from the Liu Xi River will not be sufficient for the future. Besides demand management, the potentials of water supply from ground water may be investigated. The state and the perspectives of the water in the urban area of Guangzhou have to be evaluated, with respect to all relevant functions, in the context of the scale and the problems of the Pearl
River basin, its delta and the coastal zone as a whole.

5.3 Guangdong region and abroad

- River basin approach for management of water resources

As stated in the introduction an integrated approach at river basin scale is necessary to achieve sustainable multifunctional use of water. Within the Province of Guangdong, the Xijiang, Dongjiang and Beijiang are the largest rivers, its drainage basins are covering the greater part of the province.

For the Dongjiang River basin, an integrated study is being carried out, taking into account quantity and quality of surface water under different water regimes. With the rapid economical and population growth as well as the economic structure change from agriculture-dominant to industry-dominant, excessive exploitation of water resources has led to more and more serious water pollution. Water demand on the Dongjiang River is increasing rapidly. Without efficient control measures, it is expected that sooner or later the river will face a serious shortage of fresh water. Based on the project proposal it can be expected that the study will provide most of the necessary information for an adequate management plan for the river basin. However, to complete the information and to be able to achieve optimal solutions with the management plan, the (deep) ground water has also to be taken into account, as a necessary additional water supply resource. Ground water, being a potentially reliable and clean source, has to be taken into consideration (its occurrence, vulnerability and possibilities for supply from a standpoint of sustainability ) as a structural factor in the research, planning and management of the water resources in the river basin. [Because of lack of any information on ground water issues, it has not been possible for the Expert Team to make a first estimate as to the possible quantities for supply.] It is urgently recommended to carry out comparable studies for the river basins of the Xijiang and the Beijiang Rivers, to complete the picture for the whole region and to be able to relate the water quality in the outflow area (the Pearl River delta and the Deep Bay) to the upstream situation and activities. Only then, a sufficient and adequate management plan can be formulated to achieve sustainable multifunctional
use of water, not only in the river basins, but also for the Pearl River delta and the linked coastal zone, where wetlands are seriously being threatened by industrial activities and pollution.¹

— Recommendations

For the future it is recommended to study the basins of the large rivers in different provinces and probably even at the national scale in a comparable way, enabling:

• classifications as to the state of the water systems, the pressures on the environment and the expected future development;
• priority setting in the context of a pollution reduction strategy.

In this context, joining of the UNEP study on global fresh water resources, to be carried out in the near future, might be worthwhile.

Finally, coordination and exchange of data and expertise between different water research and water policy institutions and departments in a region is absolutely necessary for a successful accomplishment of integrated river basin studies and for creating a basis for adequate management plans.

Figure 5.1 A generic environmental management cycle from a systems analysis perspective

¹ "Refugees" Flock to Mai Po, Window, May 6, 1994.
6. ENVIRONMENTAL IMPACTS EMPHASIZING ACIDIFICATION

6.1 Introduction

Air pollution compounds lead to a great variety of environmental effects on broad regional scales. For example, emissions of sulphur dioxide, nitrogen oxide and ammonia cause acidification, damaging natural systems and materials including cultural heritage. Nitrogen oxides and ammonia may cause eutrophication of soils and catchments. Emissions of volatile organic compounds in combination with nitrogen oxide cause tropospheric ozone which causes health effects. The sources of the emissions causing the wide range of effects are very disperse. Combustion of energy resources such as coal and oil in power plants and in industry is largely responsible for emissions of acidifying compounds except for ammonia which, for example, in Europe is largely due to agricultural practice. Volatile organic compounds originate in industrial production processes and from traffic, that also is the source of nitrogen oxides.

From the information obtained from regional counterparts emphasis is put on acidification. It was reported\(^1\) that acid rain occurs in Guangzhou. Therefore this section emphasizes acidification and where appropriate other environmental effects are mentioned. A treatment of health effects can be found elsewhere (see chapter 3).

Basically two kinds of environmental effects can be distinguished, i.e. direct and indirect effects. Direct effects occur through direct contact of air pollutants (sulphur dioxide, nitrogen dioxide, ozone) with surfaces (e.g. stems and leaves) of vegetation and materials. Indirect effects are caused as a consequence of proliferation of the original pollutants through a number of chemical reactions in soils and surface waters ultimately leading to (geo-) chemical changes in the environment which increases the probability of damage. This process may

\(^1\) Guangzhou group, Pollution control expert sub-committee, International Cooperation Committee, Environment in Guangzhou, 29 October 1993.
take many years and depending on the dispersion of the pollutants and
the kind of receptors occurs over broad regional areas. Recently, a risk
based scientific methodology based on the concept of direct and
indirect effects has been developed allowing comprehensive policy as-
cessments of different alternatives of emission reduction. This
methodology provides tolerable limits of pollutant loads, so called crit-
ical loads. A critical load is a quantitative estimate of an exposure to
one or more pollutants below which significant harmful effects on
specified sensitive elements of the environment do not occur according
to present knowledge. The term critical level is used with respect to
tolerable limits related to direct effects of air concentrations.

Information was provided that environmental policy in
Guangzhou was based on the assessment of tolerable limits. However
it was not established how tolerable limits are obtained. In the next
section an overview of facts is presented including findings on impacts
by Chinese experts from Guangzhou. In chapter 3 results are presented
which have been obtained through a project of the World Bank and
Asian Development Bank by Chinese experts from the Academy of
Sciences and counterparts from elsewhere.

6.2 Methods and data

In Guangzhou, according to the report acid rain was very serious
in the spring and in the summer of 1986 and 1987. Evidence is provi-
ded for a steady decrease of the pH in rain from more than 5.2 to less
than 4.4. Indeed this pH is low and is likely to contribute to a steady
decrease of the pH in soils which ultimately may lead to the occurrence
of indirect effects. However, development of soil pH also depends on
the buffering capacity of soils. The decrease of pH and the annual in-
crease of the period over which the pH remains low, noted in the re-
port, points to an increase of acidifying pollutants such as SO₂ and
NOₓ and/or a decrease of the emissions and depositions of base-
cations. It is necessary to obtain a transparent overview of the
dispersion of these compounds over Guangzhou as well as over
Guangdong in order to establish the full impact of the increase of the
pollutants. Chinese experts have mentioned that damage was found to
vegetables. It cannot be excluded that this damage is not only due to
the indirect effect of acidification. In this context it seems appropriate to assess the possible occurrence of direct effects of concentrations of pollutants to crop as well as to other vegetation. In Table 6.1 critical levels are provided which have been scientifically established.

**Table 6.1 Critical levels**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Critical level $\mu g / m^3$</th>
<th>Vegetation or dose specifics</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_2$</td>
<td>20.29</td>
<td>forest, natural</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>30.44</td>
<td>agricultural crops</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>29.95</td>
<td>adverse eco-physiological effects$^b$</td>
</tr>
<tr>
<td>O$_3$</td>
<td>10,800</td>
<td>AOT 40$^c$ crops</td>
</tr>
<tr>
<td></td>
<td>10,000</td>
<td>AOT 40 forests (daylight, 6 months)$^d$</td>
</tr>
</tbody>
</table>

a Derived from work done in the frame work of UN/ECE–LRTAP(1993)
b Expressed as NO$_x$ in combination with the annual mean of SO$_2$ and/or exposure of O$_3$ below their critical level.
c Accumulated Exposure Over Threshold (AOT) of 40 ppbh ($80 \mu g / m^3$) over all daylight hours during three months of the growing season. The critical level of 10,800 $\mu g / m^3$ thus defined is assumed in Europe not to cause more than 10% crop loss. Daylight is defined as the period during which global radiation exceeds 50 Watt.

d Further knowledge of concentrations and depositions of acidifying pollutants, especially sulphur dioxide which seems to prevail, and a detailed overview of damages and impacts is necessary. In the next section very preliminary results on impacts$^e$ are presented with emphasis on Guangdong. The results are part of a project of acid rain and emissions in Asia of which the deliverable will be an integrated model quantifying the relationship within and between Asian regions of emissions (i.e. sulphur dioxide), transport and impacts. The Research Center for Eco-environmental Sciences (RCEES) in Beijing is the

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$^e$ exact definition to be communicated by Dutch expert.

Chinese counterpart in this project.

6.3 Preliminary application of critical loads in Guangdong

Figure 6.1 provides a tentative and preliminary overview of critical loads in Guangdong. The preliminary assessment of critical loads in the region have been obtained using a low estimate of base cation deposition (BCD). Improved knowledge of the deposition of base cation deposition in the area is required since these compounds contribute to alleviation of acidifying effects. Figure 6.1 shows areas of high sensitivity (between 0 and 200 equivalents per hectare) in the north of Guangdong and in dispersed areas around Guangzhou and along the eastern coast. Sensitive areas (between 200 and 500 eq / ha) cover a wide area within Guangdong. Areas with moderate or low sensitivity to acidification are dispersed in the north and in the southern peninsula of Guangdong.

The assessment of the current risk of damage requires knowledge of the deposition and dispersion of sulphur. For this information is required on (1) total emissions in the regions from large point sources as well as from diffuse sources, (2) the dispersion of these emissions within the region and the exported and imported amounts, and (3) the deposition of acidifying compounds.

Figure 6.2 shows the dispersion of wet SO$_4^{2-}$ deposition over Guangdong in 1988. Comparing Figure 6.2 to Figure 6.1 by subtracting the critical loads from the wet deposition provides an indication of the fact that the critical load may be exceeded over wide areas in Guangdong. Maximum excess could range beyond 6000 mg / m$^2$.

In Figure 6.3 the critical load map is shown together with the geographical location of six large point sources (exceeding 300 MW) in

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① 1 equivalent of acidity per hectare is equal to 0.0016 grams per square meter of sulphur or 4.8 mg per square meter of SO$_2$ and 0.0014 grams of nitrogen. The unit equivalent is used to allow for summation of different acidifying compounds.

② Information about the project RAiNS–ASIA can be obtained from the World Bank, Dr. Jitu Shah, from the Asian Development Bank, McAli Azimi, and from Prof. Zhou Dianwu at RCEES in Beijing.
Guangdong. Three power plant are located around Guangzhou, one in the north and two in the peninsula. From Figure 6.3 it can be seen that the power plant in the north and around Guangzhou are located close to sensitive areas. The two power plants in the south of Guangdong are located in areas which have preliminary been identified as less sensitive (higher than 1,000 eq/ha). However, considering the emissions of these powerplants of which one (Huangpu) is identified as 58,000 ton/a (see chapter 3 on emissions) it is to be expected that the dispersion is wide thus contributing to an increased risk of indirect and direct effects in a broad area of Guangdong.

6.4 Conclusions and recommendations

The major conclusion is that acidification effects occur around Guangzhou and there is indication that risk of damage is increasing in Guangdong. For a more definite conclusion knowledge is required of the distribution of SO₂ and NOₓ depositions (wet and dry) over the region including contributions from other regions around Guangdong. A detailed review of critical loads which have preliminarily been established in the framework of the RAINS ASIA project needs to be further elaborated in close collaboration with local experts.

An integrated assessment of emissions, air pollution transport, depositions and concentrations of acidifying compounds is required to allow scientific support of current and future policies with respect to the growth and location of energy combustion sources and other pollutant sources such as those of nitrogen oxides. It is not to be excluded that direct effects, possibly including those due to excessive ozone concentrations, have an important contribution to the damage which has been identified to agricultural crop (vegetables) in the region. It is recommended to establish a detailed overview of the actual environmental effects in the region.
7. RECOMMENDATIONS

7.1 General Recommendations

1) Integrated environmental policy

It is recommended not to treat emissions, transport of pollutants and resulting environmental and other effects as independent components. Sources, pollutants and effects require a consistent overall integrated analysis of the interrelationships and the manner by which emissions propagate via air, soil and water into environmental impacts. Dealing with air pollution, water pollution and waste removal separately could easily lead to suboptimal solutions or even a shift of environmental problems from one compartment or region to the other. An integrated approach covering all economic activities leads to more cost-effective solutions. A comprehensive scenario approach can be useful to detect common causes of environmental problems and to design consistent environmental policy strategies. Common causes are e.g. the squandering of energy in the economy, the fact that material
Figure 6.3

Critical Loads
Low BCD
and
Locations of Power plants

Preliminary:
© RIVM: Hettelingh
SEI: Chadwick
RCEES: Zhou
"RAINS-ASIA"

Equiv/ha yr

<table>
<thead>
<tr>
<th>Equivalent</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>0~200</td>
<td>Light grey</td>
</tr>
<tr>
<td>200~500</td>
<td>Grey</td>
</tr>
<tr>
<td>500~1000</td>
<td>Dark grey</td>
</tr>
<tr>
<td>1000~2000</td>
<td>Dark grey</td>
</tr>
<tr>
<td>&gt;=2000</td>
<td>Black</td>
</tr>
</tbody>
</table>

Locations:

Guangdong-Hainan region

May 1994
cycles in the economy are not closed, and that little attention is paid to improvement of the quality of goods and services. Energy conservation and a rational use of energy-intensive products such as fertilizers, plastics and cars are measures that could solve several environmental problems at the same time and therefore have a high cost-efficiency. So are the prevention and re-use of waste and the redesign of products which will lead to an improvement of the quality (in stead of the quantity) of goods and services. In addition to overall integration also linkages within and between socio-economic systems become important for the consistent development of emission abatement alternatives. The role of economic instruments such as taxes, levies and subsidies can be used to obtain an improved use of resources and the application of appropriate abatement techniques. Measures which lead to increased energy efficiency, for example, may decrease the necessity to apply abatement techniques further down the production process. Generic instruments such as energy prices and water prices can be efficient policy tools to implement such strategies. Especially in a situation with fast economic growth long-term integrated environmental management plays an important role, because the share of new investments in the total capital stock will be large. When environmental measures are taken early a larger part of the capital stock will consists of (industrial) facilities with relatively clean technology.

2) Mass balance approach

Potential (irreversible) environmental problems can be detected while preparing mass balances of the economy in a country or region as a whole and follow where materials come from and where they go to. Economic developments will only be sustainable in the long run when the input in the economic system will not lead to depletion of natural resources and when the output will not lead to (irreversible) accumulation of materials in air, soil and water. A mass balance approach can therefore be an useful instrument in the design of a sustainable development strategy.

3) Comparative Risk Analysis in Environmental Priority Setting

Comparative risk analysis is an analytical process and a set of tools by which decision-makers can identify their environmental prob-
lems with the highest risks. Comparative risk analysis provides a common basis for evaluating the net benefit and costs of different strategies for reducing or preventing those risks. Thus, comparative risk can provide an important input to the priority setting and budget process when possible reduction and prevention strategies are considered in the context of other relevant non-risk concerns, such as economic viability, technological feasibility and social equity.

Currently, comparative risk analysis is considered to be the best available tool to help set environmental risk management priorities. The reason for the success of this approach is that it utilizes available data and best professional judgement to consistently evaluate a set of environmental problems. Once characterized with a common yardstick, a ranking of the risks can be established.

For these reasons, risk managers in all levels of government, industries and communities must acquire the knowledge and skills to perform comparable risk analysis for cost-effective environmental risk management.

In the context of a dynamic environmental management system comparative risk analysis often becomes “integrated scenario assessment” which includes potential future risks and priorities that are expressed into a long-term policy plan, comprising environmental measures that have to be taken within a period of 10–25 years.

### 7.2 Specific Recommendations for the WG on Pollution Control

1) It is recommended that alternative scenarios for energy use, energy prices, fuel mix, traffic planning and application of abatement techniques are developed in order to assess the costs and environmental effects of such policy alternatives. These scenarios are to be developed in cooperation with the planning department and the departments responsible for energy planning, traffic planning and agriculture and industry, as to incorporate all participants in the policy discussions into the planning process. Because in a number of cases the national government is responsible for the use of certain instruments (such as discharge fees and energy prices), it is recommended that representatives of the national government participate in such a policy process.
2) It is recommended that comparable water-policy alternatives are being developed in order to curb increasing water use and waste water discharges. A plan should be made to construct a number of additional municipal waste water treatment plants during the coming decade.

3) It is recommended that adequate attention is given to the groundwater resources around Guangzhou. Although quantitatively the surface water resources are sufficient, the city is facing shortage of drinking water supply because of water pollution and the potential of water supply from ground water could be investigated.

4) It is recommended to study the basins of the large rivers that supply Guangdong and Guangzhou of the necessary water resources. In particular support should be given to the Dongjiang River Project and the Pearl River Delta Study. Care should be taken that next to the multifunctional systems approach, enough high quality information (including adequate measurement data) is gathered so that a proper analysis and evaluation can be made of the risks for the environment and the priorities that have to be set by the appropriate authorities. Coordination and exchange of data and expertise between different water research and water policy institutions and departments in a region (water catchment area) is absolutely necessary for a successful integrated river basin study and for the creation of an adequate water management plan.

5) It is recommended to develop and introduce (national) NO x emission standards for large combustion sources and traffic.

6) It is recommended to carry out emission inventories for SO 2 , NO x , Hydrocarbons (HC) and methane for both Guangzhou as well as Guangdong.

7) It is recommended to study the representativeness of the data from manual monitoring networks within the Province of Guangdong with emphasis on Guangzhou.

8) It is recommended to start measurements of PM10 concentrations because of their effect relevance.

9) It is recommended to optimize [or start] measurements of hazardous organic pollutants both in water and air especially in Guangzhou and its surroundings.

10) It is recommended to assess the contribution to ambient pollu-
tion levels of various economical sectors using transport and dispersion models. For this application several models can be made available.

11) It is recommended to prepare a detailed overview of the actual environmental (ecosystem) effects in the region (Province of Guangdong) and establish tolerable limits (critical loads) at which the risk of damage is decreased. Close collaboration in existing scientific projects can be considered.

12) It is recommended to establish a framework that enables the successful deployment of training workshops. The major subjects of the different workshops that could be held in a group of indicated cities of interest are:

- comparative risk assessment [see Annex 2]
- policy planing
- monitoring and data analysis (including modelling exercises)

ANNEX 1 INTEGRATED ASSESSMENT METHODOLOGY FOR RIVER BASINS (DRAFT)

1. Introduction

In past decades a considerable number of river basin studies has been carried out, addressing all kinds of water related issues. However, very few studies have been set up with the perspective of multifunctional and sustainable use of all water within the river basin. In some cases an overall conceptual framework has been developed, but there is no general guiding concept on how to select the relevant interrelated factors within a specific river basin and on how to develop appropriate solutions as to multifunctional sustainable use of water.

In this document, an integrated assessment methodology for river basins is presented. The integration involves the items mentioned in section 2. This methodology consists of a stepwise guidance to the assessment of the state and the longterm development of fresh water resources, directed towards multi-functionality and sustainability. With this methodology it is possible to select from the conceptual framework (Figure 1.) the system (i.e. a (sub-) set of interrelated factors),
Figure 1. Conceptual framework
which is relevant to the specific river basin at hand. It is a help to select promising scenarios and interventions, based on problem definition and selection of interactions which are of primary importance to the considered problem.

The main characteristics of the methodology are:

- it has been developed for river basins with conflicting interests;
- it is a generic approach, primarily meant for the river basin scale;
- it is applicable in data poor and data rich situations.

Indicators, operating in a function-related pressure–state–impact framework, are given a prominent role in this methodology, as to characterizing the present situation and its evaluation. When this assessment methodology would be applied widely, the results might also be used to rank river basins in a region or in the world according to pressures upon its water systems, or to vulnerability of its ground water to pollution, etc..

2. The different steps

The different steps of the approach are described below.

Step 1

The outcome of this step is the water-related physical characterization of the river basin, the availability of its water resources and the description of the reference situation. It is mainly a qualitative evaluation.

Hydrological characterization of the river basin

First of all, the hydrological system has to be identified, because it plays a key role in the assessment of fresh water resources.

Important aspects to be addressed are:

- determination of river basin boundaries (to be derived from elevation maps or isohypses);
- geomorphological features and river morphology characteristics (elevations, river dimensions, etc.);
- amounts / pattern of rainfall;
- evapotranspiration;
- surface water: type of hydrograph; to be derived from discharge
information;
- groundwater: type of subsoil (unconsolidated sediments, hardrock, etc.), aquifer type, isohyposes and flow directions; to be derived from hydrogeological information and ground water levels; fresh-brackish water interfaces;
- relationship between river and ground water; to be derived from ground water levels and/or geo-hydrochemical information;
- tidal/coastal impacts/flooding;
- assessment of renewable fresh water resources (at actual landcover).

*Hydrochemical and biological characterization*

This issue addresses the *natural* quality of surface water and ground water in the river basin (determined by rainfall composition, soil properties, natural processes and flow regime) and the description and valuation of *aquatic ecosystems* (including the coastal zone) without anthropogenic influence (reference situation).

Pollution is considered as a pressure (step 2).

This step also involves a meta-description of the available information, with an eye to step 3.

**Step 2**

The output of this step is an *overall picture of the demands of all relevant socio-economic sectors (users and claims) as to the different functions of the water in the river basin and a listing of the related requirements and pressures* in terms of quantity and/or quality and/or level of the water table.

The current state has to be described here (characterization of current level of pressures) and the future situation at autonomous development ("business as usual"), per sector.

This includes population, agriculture, ecosystems and conservation, industry and also hydropower dams, etc. For example: the population uses the water as drinking water (a function). This implies requirements as to quantity and quality (health aspects). A relevant question, for example, is: Which type and amounts of emissions are or may be produced by agriculture and industry that may cause problems for the drinking water function? On the other hand, the population
uses the surface water to discharge waste water (a pressure) which may have its influence on the water quality if it is not purified (state and impact). Water abstraction means also the use of a portion of the water resources. In general, agricultural claims can be expressed in terms of quantity, quality and water levels. Impacts concern the use of a portion of the water resources and sometimes water quality (diffuse water pollution in case of using pesticides, for example). Industry uses water for production processes or for cooling purposes. In the first case, the water has to meet certain quality standards. The impacts can be expressed in terms of quantity (claim to water resources) and quality (emission of waste water in cases of absence or insufficient purification or discharge of water with a higher temperature).

Also, anthropogenic impacts that play a role but cannot be influenced at the river basin level have to be addressed here (acidification, potential climate change and related impacts on the hydrological system, etc.).

A first indication of potential problem areas can be obtained by overlaying the availability figures from step 1 and the users' claims and their quantitative requirements and impacts from step 2. For example, a comparison of renewable fresh water resources with the current and/or claimed use of fresh water (different users) shows whether there are, or may arise, problems in this area.

Step 3

This step consists of the assessment of the physical boundaries and the selection of major issues to be addressed (together called the system), the structure of the system and its quantification.

Systems definition

This is a discriminating ordering step. Based on site specific information (steps 1 and 2) and the chosen objective (the assessment of state and future of fresh water resources), the total system of interrelated factors to be investigated has to be selected, to be described as pressure-state-impact-chains (see Figure 5.1). Basic questions here are: Which sectors and functions are taken on board? Which temporal and spatial scales are going to be applied? Which schematizations are chosen?
Starting-point here is the own responsibility of the authorities of the river basin. It's their business to decide upon which interests they take on board and to set priorities in this area. The integrated assessment methodology enables them to make informed decisions and provides them with the proper tools. In this respect, even sustainability is a relative notion.

Systems identification and diagnosis

Systems identification is the study of the structure and the functioning of a system. It includes the analysis and quantification of the different pressure-state-impact-response chains (called sub-systems) and their interrelationships. The relationships within a specific chain can be described in two ways (two types of models):

* a mathematical description (formulation of systems equations)
* empirical (if no systems equation is, or can be, applied).

Identification of required datasets has to cover all parameters, necessary to quantify the pressure-state-effect-chains such as soil characteristics to quantify ground water flow, hydraulic properties to quantify river flow, etc. The selected system dictates which data are needed and how to use them.

The output of this step is the quantitative description of the current situation and the future situation at autonomous development (given the actual functions), of the selected system. Valuations of these situations in terms of sustainability have to be given and (potential) conflicts identified. The different functions have to be evaluated separately, in the context of the actual state of the water systems (being the integrated result of all pressures). For example, the suitability of the water as to the function “drinking water” has to be evaluated. The level of expected changes in satisfying the different demands (given the autonomous development) has to be indicated (diagnosis).

These activities may be done descriptively, for separate components (for example a map of a certain aspect of ground water quality), or can involve analysis and quantification (mathematical or empirical) of causal relationships (pressure-state-impact chains). Also evaluation of the performance of current policies has to be addressed here.

An important aspect, in general, is the description of the quality of the river sediments. Sediments are an important sink for
hydrophobic pollutants. Consequently, former discharges of persistent pollutants may limit specific functions in downstream areas for decades.

All this information will be expressed in terms of environmental indicators (for pressure, state, impact and response).

Each user will be evaluated as to its impact on the system, to the background of current policies. This produces a user-related description as well as an overall view.

**Step 4**

*Development and analysis of scenarios*

Different scenarios (internally consistent sets of projections) can be evaluated, based on different policy options, restricted to one user demand or for a set of users or for all users together. For these projections, the same indicators and models as applied in step 3 will be used. The outcome is pressure-state-impact-information in terms of indicators and the most promising scenarios. Projections must be based on the *present stage of development* of a country. In the future, a country may develop, for example, from an agricultural character into the direction of industrialization. Then, mutual valuation of sectors and functions may be change. This is up to the authorities and has to be expressed in the scenarios.

**Step 5**

*Selection of promising interventions*

The overall results of the analyses of steps 3 and 4 have to be translated into *meaningful actions*.

This step involves the development and analysis of potential promising (effective) interventions (within the context of the most promising scenarios) to make progress as to multi-functional sustainable use of water, considering all users and demands and impacting factors on the system. These interventions may involve basin wide development plans, management strategies, reallocation, sanitation, regulation, reservoir construction, demand management, etc.
ANNEX

Models
Different existing models can be used within the overall multidisciplinary framework, in combination with GIS-tools where relevant. For example for hydrology, simple lumped water balance models up to and including complex grid based ground water-surface water models are available. Selection of the models will be based on the identified specifications per case.
These models will be included in the toolbox of the methodology.

Data
The methodology must allow to operate with different data categories and in data rich as well as data poor situations. The three data categories to be considered are:
- measured data (input data, parameter values), directly useful (or via interpolation);
- data derived from the literature and/or based on expert judgement (like soil characteristics related to types of aquifer material);
- data extrapolated from other regions (where the underlying information is available). An example is the estimation of withdrawals based on population density and water use per capita.

Furthermore, a database with environmental indicators directed to water has to be involved. Selections are dictated by water functions and region-related problems.

ANNEX 2 WORKSHOP ON COMPARATIVE RISK ANALYSIS AND ENVIRONMENTAL PRIORITY SETTING

1. Introduction
Risk assessment usually deals with the analysis of specific substances or a problem area. Another way to use risk assessment as a
tool is to compare risks from multiple problems at the state, regional, national or global level. This comparative risk assessment process involves the following steps:

1) Listing of all problem areas in the region, state or country.
2) Ranking the problems on the basis of risk (human health, ecology, and welfare or quality of life); this ranking is based on an analysis of available data specific to the problem in that region, state, or country, and
3) Developing an action plan to address the problem areas, based on the risk ranking and other factors (e.g. technology options, economic considerations, public opinion, etc.)

2. Workshop objectives

The proposed workshop intends to provide a good mechanism for an international sharing of ideas and experiences on using risk analysis as a tool for environmental risk management priorities, and thus contributing to a cost effective implementation of public policy.

The workshop will be designed as:

1) A systematic training exercise to share historical perspectives of successes as well as failures of environmental risk management.
2) Trainers and trainees will jointly work through a set of typical environmental issues and problems to analyze the magnitude of hazards, compare them, and rank them in a step-by-step approach.
3) Communication of comparative risk analysis to regulatory decision makers and to the public.
4) Provide management tools for the definition and measurement of national and local environmental goals.

3. Workshop participants

Approximately 30 participants in each session would be convenient, however, up to 50 could be accommodated. The initial series of 2 or 3 sessions are intended to "TEACH the TEACHERS", so that TEACHERS can, in turn, teach many more officials and students.

4. Target audience (who should participate)

- regulatory agencies, officials at various levels
public policy officials including national planning and budgeting (the involvement of the economic and social development sector is critically important)

- academic community
- industrial sector: national / private
- NGO community

5. Workshop organizers
NEPA
Local / regional organization (host)
Toni Schneider, National Institute of Public Health and Environmental Protection, The Netherlands
Si Duk Lee, United States Environmental Protection Office

6. Workshop sponsors
NEPA
US EPA
US-Asia Environmental Partnership
Asia Development Bank
UNIDO, UNDP
Air and Waste Management Association
China Programme, Simon Fraser University

7. Host
NEPA
Local / regional organization

8. Proposed date first workshop
spring 1995

ANNEX 3 EXPERIENCES WITH ENVIRONMENTAL FORECASTING AND PLANNING IN THE NETHERLANDS

1. The National Environmental Policy Plan of the Netherlands was prepared in 1989 under the responsibility of the ministers of envi-
rontment, agriculture, transport and economic affairs (the latter has the main responsibility for energy policy). The report contains quantitative goals for pollution and the use of resources (water and energy) for the long term, from which short and medium term intermediate targets and 249 specific actions for the period 1990-1994 were derived. These goals and actions form an operational definition of sustainable development as perceived by the Dutch government. During the process of making the Environmental policy plan non-governmental stakeholders (from industry, farmers, retailers, consumers and environmental groups) were involved as to create a broad consensus on the targets and actions, some of which were related to changes in life styles (e.g. less use of energy, water, packaging materials and private cars) and production methods (e.g. waste recovery, good housekeeping, extensification of agricultural practices).

2. Quantitative goals and priorities in actions were based on the scientific data that were compiled in the first Environmental Outlook "Concern for Tomorrow" (1988). This report was made by the National Institute for Public Health and Environment (RIVM) at the request of ministries involved in the National Environmental Policy Plan. The respective ministries put forward the topics that had to be addressed in the outlook, but gave RIVM a free hand in adding other issues and in the scientific "elaboration". The environmental outlook contains not only a description of the current state of the environment but also an quantitative outlook on possible future states, given the alternative policy actions that can be taken (e.g. "current policy" or "business as usual", "application of best available end-of-pipe techniques" and "structural changes in production methods and life styles"

3. The main conclusions of the first environmental outlook were that 70-90% reduction of most types of pollution was necessary in order to obtain a sustainable use of resources (e.g. forests, biodiversity, ground water) and a safe air and water quality). These reductions can only be met through application of clean technologies and structural changes in life styles. The socio-economic consequences of such drastic measure would not be prohibitive according to estimates of the eco-
onomic Central Planning Bureau.

4. It was made clear in the outlook that although some problems were not yet visible (e.g., pollution of ground water and climate change) they would occur if current practices were continued. It was also made clear that due to time lags in the environmental system timely actions should have to be taken in order to prevent such problems. Waiting until these problems would be visible in monitoring systems, would mean that it would take decades to solve them.

5. The environmental outlook was produced in cooperation with national institutes specialized in such fields as water resources, energy, transport, agriculture. The (economic) Central Planning Bureau was responsible for estimating the socio-economic effects of the different policy scenarios. During the production process of the first environmental outlook as much scientific consensus as possible was build on the issues that had to be addressed in the environmental policy plan. Uncertainty margins were presented when no complete consensus was possible. A wide scientific review was used as to commit scientist of universities and non-governmental institutes to the main findings of the outlook.

6. The impact of the report on both the general public and the policy makers was high. Even the prime minister and the queen expressed their concern about the future of the environment. As there were little or no scientific dissidents the report was accepted by all ministries involved as the scientific basis for negations and priority setting within the government.

7. After the environmental policy plan was published RIVM was asked to monitor and evaluate the implementation of the actions and their future developments. Thusfar two new volumes of the environmental outlook were produced (number two in 1991 and number three in 1993). In order to evaluate the effects of the actions laid down in the National Environmental Policy Plan monitoring the current environmental quality is not enough. Monitoring of current trends in the society (e.g. population growth, changes in production, mobility, cattle, energy use and even energy prices) were added to the traditional data that were monitored. The main messages of the new environmental outlooks were that trends in population growth, production and energy use are “worse” than was expected when the first environmental outlook was made and that subsequently more meas-
ures would be necessary to reach the long term goals that were laid down in the Environmental Policy Plan. The current low energy prices and the high growth rates in the energy intensive sectors would make it very difficult to meet all of the targets. On request of the ministries involved in process of making a second Environmental Policy Plan (for the period 1995-1999) RIVM elaborated its decision support system so that policy makers can get instantaneous insight in the costs and effects of additional policy measures. In the future the evaluation process will be integrated into the national budget planning cycle. Trade offs between environment and economy will be available on a yearly basis.

8. About 150 scientists are involved in the production of an environmental outlook (adding up to 40 full time years per outlook). The production time takes about 2 years, but this will be brought back to one year. The coordination and integration of all the contributions is done by a multi-disciplinary core group of 7 persons. Persons in the core-group have the ability to communicate with all the specialized scientists involved (most of them physical engineers, chemists, biologists, toxicologists, but also economists and social scientists). This group of generalists also form the interface between policy makers and science. They interpret the desires of policy makers and translate the outcomes of research and model calculations into policy recommendations.

9. There are other examples of processes were scientific consensus is build in order to facilitate political negotiations, e.g. the International Panel on Climate Change (IPCC) and the scientific task forces that support the negotiations under UN-Convention on Long Range Transboundary Air Pollution. However there are also examples of successful environmental surveys where scientific consensus was not a top priority, but were the start of a consensus process. RIVM supported the 5th Environmental Action Plan of the EC and the Environmental Action Plan for Central and Eastern Europe as the start for a consensus process. Initiative not always has to be the government. It can also be the World Bank (as in Central and Eastern Europe and in the Acid Rain Program for South East Asia), or even a non-governmental organization as the IUCN in Pakistan.