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SHENZHEN ENVIRONMENT OUTLOOK

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FOREWORD

Executive Director
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The United Nations Environment Programme (UNEP) is mandated to regularly assess major environmental developments and trends. This mandate has been practically implemented through the Global Environment Outlook (GEO) process with global, regional, sub-regional, national and even city-level assessments. The GEO process is participatory, consultative and features capacity building at its core, which provides scientific accuracy, credibility and authority to provide information for environmental management and policy development to a wide target audience.

The capacity building programme of the GEO process has been highlighted in the Bali Strategic Plan for Technology Support and Capacity Building, an agreed intergovernmental framework to strengthen capacity to developing countries and countries with economies in transition. The implementation of the Bali Strategic Plan is an important opportunity for UNEP to work with partners to strengthen national city structures for environmental reporting as a basis for decision making.

The Shenzhen Environment Outlook report is one of the outputs of UNEP's capacity building programme. The report identifies key environmental issues for Shenzhen City, notably air quality, land and water resources. These issues have been analyzed by various stakeholders, including scientists, academics，government officials and civil society representatives, to determine their policy making implications. This broad-based participatory process brings environmental issues to the attention of different stakeholders and to the general public. I hope this report will provide a sound basis for decision making by Shenzhen Municipality in addressing environmental issues at the policy level and in advancing its sustainable development agenda.

In cooperation with China's State Environmental Protection Administration (SEPA), UNEP has also been assisting China to conserve the environment with collaborative activities on environmental management, capacity building and raising environmental awareness. I would like to express my gratitude to SEPA, all the Government and associated experts, especially Peking University for this fruitful collaboration.

I would like to congratulate Shenzhen Municipality for their continuous efforts in pursuing sustainable development, as witnessed by awarding "Global 500 Roll of Honour" issued by UNEP in 2002, and piloting city level Environment Outlook in Asia and the Pacific. I hope that Shenzhen City continues to press forward in exploring win-win approaches to environmental protection and socio-economic development.

Achim Steiner
United Nations Under-Secretary General and Executive Director
United Nations Environment Programme
July 2007

Preface

Urban development in China is close related to global environment. The success of its development mode needs to be examined in the process of global sustainable development. Global Environmental Outlook (GEO) is a UNEP's program aiming at understanding global environmental status. GEO urban environmental assessment method, as one of GEO methods has set up an effective platform for assessing in a scientific way the relations between urban environmental protection and sustainable development. At the same time, it also has provided a good opportunity for cities to get close to the world. Therefore, GEO China Coordination Center is the first institution to introduce GEO urban environmental assessment method into China. With case studies, it analyzes the relations between Chinese urban development and the environment to provide reference for scientific decision making of the government and actively promote international exchanges on sustainable urban development of China.

Shenzhen has grown from a small border town with only several tens of thousand population and several square kilometers into one of the biggest cities with over 10 million residents and 7 million square kilometers over the past two decades. The rapid industrialization and urbanization, along with its continuous struggle between development demand and the environment protection, makes Shenzhen a typical representation for the study of urban sustainable development mode and approach in China. Therefore, our workgroup chooses Shenzhen as the platform for the study on GEO urban environmental assessment work for the first time in China. Under strong support of Shenzhen Environmental Protection Bureau, Shenzhen Environment Outlook workgroup has compiled the *Shenzhen Environment Outlook*. Based on published data, the report analyzes environmental changes of Shenzhen during the past 20 years and its economic and social driving factors. With the idea of integrating the assessment, the report carries out comprehensive assessment on environmental status, impacts and action plans of Shenzhen and makes predictions and projections on future trend of environment and development of Shenzhen in different senarioes with the help of systematic dynamics simulation method.

The *Shenzhen Environment Outlook* complies with the PSIR assessment framework and methodology specified in the City Environment Assessment Working Manual written by the UNEP Regional Resource Centre for Asia and Pacific （RRCAP） with some adjustments of specific assessment indicators in accordance with the real situation of Shenzhen in order to reflect the practical situation and evident characteristics of urban environment and development of Shenzhen. PSIR assessment framework and method is a common tool of GEO assessment system, which includes Pressure-State-Impact-Response (PSIR). It defines the indicator groups on environmental status at various levels

(local, regional, national and global) and establishes the logic relations between various indicators. With these indicators, we could analyze the causality,impacts and responses of different stokeholders.therefore,we could use it to guide the assessment of the environmental status and development trend. The framework of the current report strictly complies with the structure of GEO urban environmental assessment report specified in the City Environment Assessment Working Manual.

The *Shenzhen Environment Outlook* serves for various readers,including government policy makers, foreign people who are concerned with Shenzhen,researchers ,NGOs and ordingary citizens as well.

The Shenzhen Environmentl Outlook is the first urban environmental outlook report in China under GEO assessment framework Meanwhile, it is also the first appilication of the GEO assessment procedure in Mainland of China.

As the first city in China compiling its environmental outlook report,Shenzhen is willing to accept the international challenges.

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Executive Summary

Shenzhen has grown from a small border town with only several tens of thousand population and several square kilometers into one of biggest cities with over 10 million residents and 7 million square kilometers over the past two decades. The rapid industrialization and urbanization process of the city reflects the process of seeking the balance between economic growth and environmental protection. Shenzhen mirrors the rapid urbanization process of China.

Overview

Rapid Economic Growth

Shenzhen has maintained rapid economic growth over the past 20 years. From 1979 to 2006, annual growth rate of Shenzhen's GDP is over 25% with comprehensive economic strength ranking the first group among all big and medium sized cities across China. In 2006, GDP of Shenzhen is RMB 581 356 million Yuan, up by 17.4% than that in 2005. Per capita GDP (based on residential population) is more than US$8 500, ranking No.1 among all big and medium sized cities of mainland China. Per capita disposable income of residents reaches RMB 23 000 Yuan. Total value of export reaches US$136 100 million, ranking No.1 for the 14th consecutive years and accounting for about one seventh of the total of China. Local municipal budgetary revenue is RMB 50 088 million Yuan and submits RMB 118 000 million Yuan revenue to the Central Government.

Accelerated Urbanization

In 2006, the registered unemployment rate of Shenzhen is controlled at 2.31%. There is the continuous improvement of Shenzhen in living standard after the completion of urbanization work in 2005. Shenzhen has established multi-level social security system with increasing coverage and guarantee level.

Challenge of Sustainable Development

Though having salient achievements in economic and social development as well as urban planning and construction, Shenzhen obviously confronts the bottlenecks for future development. This mainly reflects by the obvious pressure in the four aspects: land, resources, the environment and population.,including the limitation of land and space, energy and water shortage, pressure on population expansion and strained environmental carrying capacity. How to realize harmonious and healthy development under these constraints is a huge challenge Shenzhen is facing with.

Adjustment of Economic Growth Mode

Shenzhen Municipal Government has vigorously facilitated the adjustment of economic growth mode to overcome the development bottlenecks. On the one hand, it actively develops high-end industries, speeds up self innovation, upgrades and optimizes industrial structure so as to change from "Made in Shenzhen" to "Design in Shenzhen". On the other hand, it vigorously promotes circular economy, reduces energy consumption and pollution and changes the original extensive economic growth mode dependent on resources and shifts from "Shenzhen speed" to "Shenzhen benefits".

Environmental States and Policy Response

◆ Water

Though with rapid economic growth, Shenzhen relatively lags behind in the construction of sewage treatment facilities. Large amount of sewage directively flows into rivers without any treatment leading to serious water pollution. The quality of the mid and lower reaches of major rivers fails to meet Grade V National Standard for Surface Water Quality. On the whole, the quality of reservoir water is good with the concentrations of TN and TP beyond the standard leading to some eutrophication trend. The average impoundment of reservoir is only 15% of the total water resources in normal years. And existing capacity does not meet the requirements for reserving runoff.

With the impacts of pollution and water shortage, it is expected that Shenzhen will face severe water security problems within a long period in the future with shortage of 1 000-1 500 million m^3 in 2030.

Confronting water degradation and shortage, Shenzhen on the one hand makes more efforts in pollution control of the inflowing rivers to the reservoirs for domestic, as strengthening the construction of wastewater treatment facilities to improve the pipe network of sewage interception, and on the other hand regulates water supply and demand by various measures including “tapping new sources of supply and reducing consumption” to ease water shortage. In 2005, Shenzhen Municipal Government issued *the Regulations of Shenzhen on Saving Wate*r to enhance water saving in the city. At the same time, Shenzhen also actively carries out studies on recycling of waste water and utilization of water resources like rain water and sea water.

Existing parks in the city gradually employ reclaimed water, rain water and recycled waste water for vegetation and landscape. In addition, building materials with good permeability are gradually adopted to pave sidewalk, public square and parking ground in order to raise water conserving capacity of the city in an all round way and facilitate utilization of rain water.

◆ Atmosphere

The atmospheric environment of Shenzhen is subject to common influence of the regional pollution of the Peal River delta and local pollution. Main air pollutants are SO_2, NOx and respiratory particulates. Among them, SO_2 mainly comes from the electricity industry and NOx from vehicles and industrial point sources. The air quality of Shenzhen is going down which is reflected by the increase of the occurrence of haze and bigger acidity of acid rains. The frequency of haze has increased from over 80days in 1990s to 175 days in 2004. Average daily concentration of NO_2 and SO_2 in the air have increased compared with that of late 1990s.

The protection of the atmospheric environmental of Shenzhen follows the practice dominatedby the combination of regional cooperation with local pollution control. Shenzhen has commenced the studies on the control of regional air pulltionh since 1990s and put forward relevant countermeasures. In the control of localssss pollution, Shenzhen has issued a series of government documents targeting specific pollutants such as *the Plan for Air Pollution Control in Shenzhen,* and adopted

initiatives including the Clean Environment, Smooth Traffic, Quiet Neighborhood Project and Blue Sky Action to control the local emissions of pollutants.

◆ Land

Shortage of available land for construction severely contrains social and economic development of Shenzhen. By 2006, construction land has reached 719.88 km^2, which is over 90% of the total available land for construction. Up to the end of 2005, there has been only no more than 100 km^2 available land for construction remains outside the ecological control boundary. Within ten years, Shenzhen will have no available land for construction according to the exploitative intensity as 10 km^2 each year.

To enhance the management of land resources, Shenzhen focuses on how to develop both the incremental land and the reserved land. For the incremental land, Shenzhen adopts economic tools including land price to encourage intensive development and utilization of new industrial land to facilitate saving of land resources. For the reserved land, Shenzhen actively promotes the reform of old urban districts and raise land efficiency. Coping with the regional vulnerability in city, a series of documents have been issued as the *Outline of the Master Plan of Shenzhen on the Reform of Villages in Village-in-city* and *Suggestions of Shenzhen Municipal Government on Further Enhancement of Land Management and Promotion of the Conservation and Intensive Use of Land.*

◆ Biodiversity

With some improvement in the conservation of biodiversity, Shenzhen is facing serious situation in terms of the invasion of alien species. The Mangrove Nature Reserves near urban districts provides very good biotope for the migration and propagation of the birds in the region. There have been nearly 400 wild bird species living here by 2006, up by nearly 50 species than 7 years ago. Though with these improvement of biodiversity, Shenzhen is also still facing the invasion of alien species. At present, the area invaded by Mikania micrantha has reached more than 2600 ha in Shenzhen and the invasion of alien species including Mikania micrantha has caused relatively serious impacts on local ecological environment.

By 2006, Shenzhen has developed 4 5,300 ha ecological landscape forest, reformed 8 400 ha of landscape forest and developed 20 ha mangrove wetland ecological system. Forest coverage of Shenzhen is 43.2%, and the area of nature reserves accounts for 11.36% of the land area, which have provided good habitat for all species. Shenzhen is the first city in China identifying basic ecological control boundary, which covers 974.5 km^2, and provides strong support to the safety of urban ecosystem, where exploitive activities are strict limitied. In addition, Shenzhen authority attaches great importance to the invasion of Mikania micrantha and carries out prevention and control activities in an all round way. It has carried out trial work in some areas since 2006 and invested nearly RMB 6 million Yuan to prevent and control Mikania micrantha.

◆ Coastal and Marine Areas

There is evident spatial difference on the quality of coastal seawater. Seawaters show the trend of eutrophication with frequent occurences of red tide. Shenzhen has 229.96 km coastalline and four coastal

areas covering 1 145 km^2. The quality of seawater in eastern area is better than that in the western areas due to restriction in development. Because of the development of coastal areas and serious pollution of inland rivers, the concentrations of nutrients as N and P are beyond the standard, and coastal seawaters show a trend of eutrophication.

Coastal environment control project focuses on the prevention and control of land pollution sources. The authority will enhance the construction of sewage treatment facilities in the catchment area and the improvement of supporting network, actively carry out pollution control of inflowing rivers and greatly reduce water pollution load of rivers and coastal areas. Shenzhen has founded 5 sewage drainings to sea projects and sewage treatment systems that have effectively prevented water degradation of sea waters near Shenzhen. It has set up *the Shenzhen Marine and Fishery Environmnetal Monitoring Station*, which strengthens the monitoring and broadcasting of marine environment and effectively reduced the loss on aquaculture and beach tourism due to water pollution.

◆ Urban Vulnerability

The vulnerability of Shenzhen to environmental change mainly reflects by regional vulnerability and the low adaptation capacity of vulnerable population to environmental change. Regional vulnerability is mirrored by the existence of village-in-city. There are a total of 241 administrative villages in urban areas of Shenzhen. Among them, 91 are in special economic development zones and 150 are outside the special economic development zones. Many common problems such as high population density, concentrated buildings, lag-behind civil infrastructure, poor supporting facilities and sanitary conditions occur in such villages and people living in the villages are facing high environmental risks.

Vulnerable population refers to the low income population due to current industrial structure. Among the people under practical administration by Shenzhen authority, over 60% of the temporary working-age residents engage in labor-intensive low-end industries such as construction and house decoration, processing of imported materials or according to supplied samples, assembling of supplied parts, and compensation trade; business and trade. Low position in social, economic and cultural status of this vulnerable group causes inadequate public service resources and social security leading to low adaptation capacity to environmental change.

The existence of villages in urban areas occurred during rapid urbanization process brings about urban vulnerability with many aspects. To cope with the vulnerability, Shenzhen authority has issued the *Provisional Regulations of Shenzhen on Reform of the Villages in Urban Areas (Old Villages)* and *Outlines of the Master Plan of Shenzhen for the Reform of the Villages in Urban Areas (Old Villages)*. These documents have actively facilitated the reform of villages in urban areas (old villages) of Shenzhen in terms of specific implementation rules, government work arrangement and strategic plan.

Outlook 2008—2030

Targeting main development constraints Shenzhen are confronting, SZEO summarizes four scenarios based different development modes. These scenarios describe anticipated economic, social and environmental development of Shenzhen in the future. These development modes are the followings:

- **Business as Usual**
- **Environment-friendly First**
- **Resource Security First**
- **High-end Industry First**

Carrying out simulation estimate on the four development modes with the help of systematic dynamic model, we obtain the following scenarios and conclusions:

A Tale of Four Scenarios

Business as Usual

Continue the extensive development mode. Economic growth rate is the first priority while sustainability is ignored. The proportion of the secondary industry dominated by labor-intensive industries continues rising with big population pressure. Economic growth has the characteristics of high energy consumption and heavy pollution.

Environment-friendly First

Take the protection and improvement of ecological environment of Shenzhen as the top priority. Shenzhen will carry out whole-process control on environmental pollution. On the one hand, it will phase out large amount of enterprises with high pollution intensity and promote the development and utilization of new energy sources without considering the cost. On the other hand, it will employ various pollution control technology to treat pollution. Government will continuously increase the input in environmental protection. At the same time, it will strengthen its efforts in environmental management.

Resource Security First

It is a development mode targeting the resource shortage bottleneck (especially shortage of water and land resources Shenzhen confronts. Implementing the policy of tapping new resources of supply and reduce consumption to ensure sustainable use of energy. On the one hand, it increases available amount of new energy and reuses of resources. On the other hand, it will implement the security and saving strategy of resources and energy and raise their efficiency.

High-end Industry First

Change the industrial structure of Shenzhen and adjust economic growth mode from the traditional one mainly depending on capital and labor input into the one dominated by technological progress. Agricultural service industry will replace the traditional agriculture; its industry will shift to high and new technological industry with less energy consumption and low emissions.Traditional manufacturing enterprises will gradually be phased out.The tertiary industry will take the biggest proportion. With industrial restructuring, urban population pressure will be mitigated.

◆ Economic Growth

To maintain sustainable economic growth, it is necessary to shift economic growth mode. Business as usual development mode may maintain relatively high growth rate in short term, but in the long run, it will no longer work because it has high consumption of energy with heavy pollution. Development mode with environment-friendly as a priority will impose certain influence on economy due to the adoption of too strict environmental standard. As a comparison, resource security development mode and high-end industry priority development generate relatively good balance between economic and the environment.

◆ Resources

Imbalance between the supply and demand of water resources is the biggest threat Shenzhen confronting. Though all four development modes consider water saving and reuse of reclaimed water and sewage at some extent, only the development mode with resource security as top priority that comprehensively considers the utilization channels of other water resources (development and use of sea water and rain water, etc.) can reach the balanced supply and demand of water resources in all years. Therefore, to solve the issue of water shortage, it is important to develop innovative approaches for water resources apart from existing measures such as strengthening of water conservation and reuse of reclaimed water or sewage.

Because of the inflexibility of land supply, there is no big difference among the estimate results of the construction land of the four scenarios. With such measures as reclaiming land from sea and reform of old villages to expand land reserveand increase of land use efficiency, the upper limit of the land area of Shenzhen for construction is about 900 km^2. Shortage of land resources is the rigid constraint confronting the development of Shenzhen.

◆ Environment

Model simulation shows that under the development mode with environment-friendly as the first priority, most polluants will under effective control with the results evidently better than that of other development modes. Business as usual development mode will have the worst effect on pollution control. The simulation results show that as long as there is enough environmental investment, strict environmental standard with adequate strict enforcement, Shenzhen will put pollution under good control and improve the environment, but leading to relatively big adverse impacts on economic growth. As a comparison, resource security development mode focusing on raising energy efficiency and high-end industry development mode focusing on the enhancement of industrial restructuring could control environmental pollution with slight influence on economic growth.

◆ Population

Population pressure of Shenzhen mainly comes from the continuous inflow of drifting population. Therefore, controlling floating population is the most straightforward method to ease population pressure of Shenzhen. However, compulsory ideal population control target is difficult to meet in Shenzhen. So the practical way is controlling the demand sources of floating population -- labor intensive industries. So the authority will meet population control target by adjusting industrial structure, i.e. lower the proportions of labor-intensive manufacturing industry, thus reducing the demand for floating population.

Options for Action

With reflections on traditional development mode and the scenario analysis and simulation of improvement strategies, the author puts forward such recommendations and measures as industrial restructuring, resource recycling and effective use and establishment of regional environmental protection cooperation system to coordinate the relations among soecity, economy and the environment and meet the objective of sustainable development. They mainly include:

◆ Policy & Regulation Guarantee Strategy

Strong policy & regulation guarantee system is the prerequisite for the implementation of all strategic measures. With full utilization of its legislation right, Shenzhen shall gradually set up a well-establishged policy & regulation system to ensure smooth implementation of various other strategies.

1. Improve policies and regulations on energy and environmental protection
2. Strengthen policy and regulation circulation

◆ Industrial Restructuring Strategy

The simulation results of business as usual development mode show that existing industrial structure cannot meet the requirements for sustained economic growth. To realize rapid and healthy economic development, industrial restructuring is imperative. According to the predictions of the high-end industry development scenario, good industrial structure not only facilitates the mid and long term economic growth, but also shows good effects on releasing the pressure on population, energy and the environment.

1. Appropriately identify the pillar industries
2. Optimize industrial layout
3. Establish the industry withdrawal and access mechanism

◆ Population Regulation Startegy

The imbalance between the percentage of floating population (or temporary residents) and that of registered permenant population of Shenzhen is the important characteristics of the population structure of the city. In scenario A, the development mode dominated by traditional manufacturing industry leads to increasing expansion of the population. The analytical results of other scenariuos also demonstrate that, to meet the objective of harmonious urban development, urban populatioj must be controlled at appropriate level.

1. Control population size
2. Optimize population structure and layout

◆ Resource and Energy Security Strategy

Existing development of Shenzhen depends heavily upon resources. In the simulation analysis of four scenarios, only one could meet supply and demand balance of resources and energy. This reflects the restriction to future development caused by resources amd energy. To ensure the supply of resources and energy to Shenzhen is not only the pressing main task at present, but also a strategic issue that cannot be ignored in quite long period in the future.

1. Develop clean energy sources and adjust energy structure
2. Improve water resource guarantee system
3. Develop circular economy

◆ Effective and Intensive Spatial Distribution Strategy

The simulation estimate results of all the four scenarios in Chapter 5 show severe lack of land resources reserve of Shenzhen and near exhaustion of available land for future development. The key to addressing land shortage issue of Shenzhen lies in putting in place the following two measures at the same time:

1. Effectively expand available space

2. Enhance the management of land resources

◆ Eco-environment Harmony Strategy

Rapid development of past several decades has put relatively big pressure on ecoenvironment of Shenzhen. To facilitate sustainable development, Shenzhen authority should also take the development of good ecology into the agenda of the city while advocating the development of materials life and political and spiritual progress. To build Shenzhen into an environment-friendly city with harmonious ecology and good living conditions, more efforts should be made to combine environmental management with environmental control.

1. Strengthen environmental management

2. Carry out comprehensive environmental control

3. Enhance inter-city cooperation and control regional pollution

The above six strategies each with certain focus are complementary and constitute a well-established economy-resources-ecology guarantee system. They comply with the development orientation of efficient Shenzhen and harmonious Shenzhen; embody the urban spirit of pioneering, innovation and enterprising; facilitate sustainable development of ecology, economy and society and ensure the final realization of the urban development strategy：Shenzhen is going to be one of the advanced cities in the world！

Acronyms and Abbreviations

CEN	China Environment News
CES of PKU	Center of Environmental Sciences, Peking University
CITYU	City University of Hong Kong
CRAES	Chinese Research Academy of Environmental Sciences
EIA	environmental impact assessment
EMC	energy management contact
EPB	Environmental Protection Bureau of Shenzhen Municipality
GDP	gross domestic product
GdPG	People's Government of Guangdong Province
HDI	Human Development Index
MEA	Millennium Ecosystem Assessment
NBS	National Bureau of Statistics of China
SDM	system dynamics model
SEPA	State Environmental Protection Administration of China
SOA	State Oceanic Administration People's Republic of China
SzAFFB	Agriculture, Forestry and Fishery Bureau of Shenzhen
SzBLH	Shenzhen Municipal Bureau of Land Resources and Housing Management
SzBSTI	Shenzhen Bureau of Science Technology and Information
SzBTI	Shenzhen Bureau of Trade and Industry
SzBWS	Shenzhen Bird Watching Society
SzCA	Shenzhen Construction Administration
SzDRB	Shenzhen Development and Reform Bureau
SzEPMC	Shenzhen Environmental Protection Monitoring Center
SzFB	Shenzhen Finance Bureau
SzHWTS	Shenzhen Hazardous Waste Treatment Station
SzMB	Meteorological Bureau of Shenzhen
SzMSA	Shenzhen Maritime Safety Administration
SzOA	Shenzhen Ocean Administration
SzPB	Shenzhen Planning Bureau
SzPG	People's Government of Shenzhen
SZPKU	Shenzhen Graduate School of Peking University
SzPSB	Public Security Bureau of Shenzhen
SzSB	Statistics Bureau of Shenzhen
SzSEZ/SSE	Shenzhen Special Economic Zone
SzSZD	Shenzhen Special Zone Daily
SzTB	Shenzhen Traffic Bureau
SzUMB	Urban Management Bureau of Shenzhen
SzVA	Shenzhen Volunteer Association
SzWRB	Shenzhen Water Resource Bureau
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WWF	World Wildlife Fund

Scientific and Temporal Measurements

BOD	biological oxygen demand
COD	chemical oxygen demand
CPI	comprehensive pollution index
NH_3-N	ammonia-nitrogen
NO_2	nitrogen dioxide
NOx	nitrogen oxides
PAH	polycyclic aromatic hydrocarbon
$PM_{2.5}$	particulate matter of diameter 2.5 microns or less
PM_{10}	particulate matter of diameter 10 microns or less
SO_2	sulphur dioxide
Sox	sulphur oxides
TP	total phosphorus
TSP	total suspended particles

Chapter I Introduction

Established in 1979, Shenzhen is one of the earliest special economic development zones in China. As a cradle of China's reform and opening up policy, Shenzhen has developed from a poor border town near the South China Sea into a new, prosperous, beautiful and important modern city with full functions and legal system after rapid development in the past two decades, which plays an important role in national economic and social development. It has created a miracle in the history of world industrialization, urbanization and modernization.

Situated in southeast coastal area of Guangdong Province, Shenzhen borders Dongguan City and Huizhou City in the north, New Territories of Hong Kong in the south, Daya Bay and Dapeng Bay in the east and the Pearl River Estuary and Lingdingyang in the west. It is located at the 22°27′-22°52′N and 113°46′-114°37′ E. Its marine area is located at 22°09′-22°52′ N and 113°40′-114°39′ E, which connects the South China Sea and the Pacific Ocean. Total land area of the city is 1952.84 km^2. Among them, special economic zone has an area of 395.81 km^2. The coastline is 229.96 km long.

1.1 Geography and Climate

Figure 1.1 Location of Shenzhen

The topography of Shenzhen is high in southeast and low in northwest dominated by small mountains, smooth mesa and hilly land. Small mountains dominate the southeast area. Hilly land dominate the central and northwest areas with a few small mountains with height over 500 m, between the hills and small mountains are a range of alluvial plain. The southwest area is a large area of beach alluvial plain, accounting for 22.1% of the total land area of the city. The main rock is granite with relatively large area distribution of sand shale in eastern and northern areas.

Shenzhen falls into subtropical marine climate, which is mild with rich precipitation and long sunshine hours. Annual average temperature is 22.5℃ with the highest 38.7 ℃ and lowest 0.2℃, 355 days of frost-free period. Annual sunshine period is 1933.8 h with annual solar radiation 5 225 MJ/m^2. The period from May to October of most years is subject to tropical cyclones (typhoon).

Annual average precipitation of Shenzhen is 1 837 mm with average amount of rainy days of about 140. The annual average precipitation is over 2 200 mm in the southeast area and over 1 500 mm in northwest area. The wet season mainly occurs from April to September with the amount of rainfall accounting for 84% of the total. Among them, in pre-flood season (from April to June), it is mainly frontal precipitation and takes up 36% of the total precipitation. From July to September, it is mainly typhoon rain and takes up 48% of the total. Winter and spring have less rain with precipitation ranging from 150-200 mm. The annual average humidity of Shenzhen is 77%. Average monthly precipitation of Shenzhen is shown in Figure 1.2.

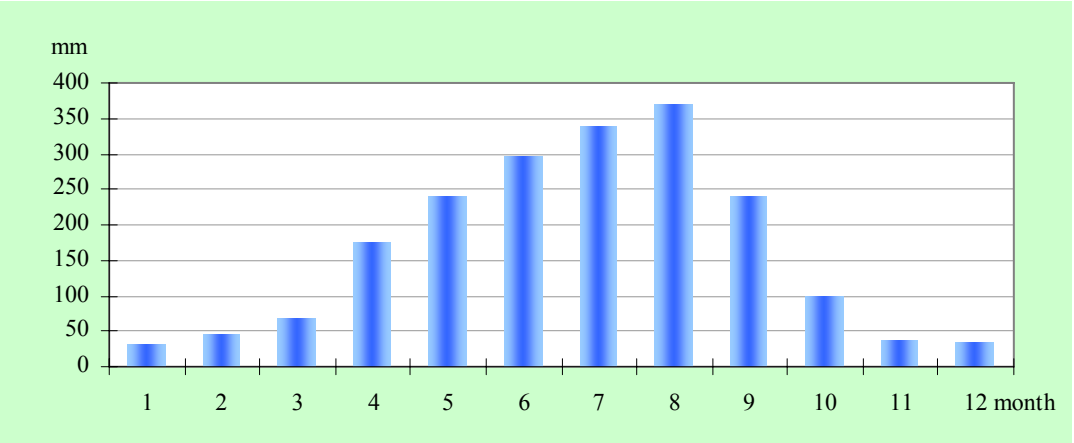

Figure 1.2 Average monthly precipitation of Shenzhen

(Source: SzMB b)

1.2 Natural Resources

Water Resources

Most rivers in Shenzhen are short and small due to topography and the source of flow comes from rainfall. There are only five relatively big rivers in Shenzhen.They are the Longgang River, Pingshan River, Guanglan River, Shenzhen River and Maozhou River.

Annual average surface runoff of Shenzhen is 980 mm deep with amount of 1 827 million m^3, and the amount of annual average runoff is 1 334 million m^3. Total groundwater resources of the city are 650 million m^3 per year. 242 reservoirs have been built with total capacity of 507 million m^3 and normal water reserves of 390 million m^3, but these can only meet 15% of water demand of the city. 85% water supply comes from the rivers outside Shenzhen.

Land and Mineral Resources

Total land area of Shenzhen is 1952.84 km^2.Among them, special economic development zone has 395.81 km^2. 719.88 km^2 are built land in Shenzhen, accounting for 36.869% of the total land area. (SzPB 2006)

Shenzhen has six soil categories, including crimson soil, red soil, yellow soil, rice soil, beach sandy soil and beach saline soil. Among them, crimson soil has the widest distribution, occurring in vast hilly terrans with altitude lower than 300 m. There are four soil categories with 14 kinds of soil. Among them, granite crimson soil has the widest distribution with the thickest parent materials. The parent material of sand shale is relatively thin. Organic matter level of topsoil is about 0.2%. The concentration of organic matters of the topsoil dominated by crimson soil, which is subject to serious soil erosion, is only 0.2-0.4%.

A total of 23 kinds of mineral resources have been found in Shenzhen occurred at 81 mines. Metal mineral resources mainly include iron, manganese, lead, wolfram and tin, etc. with relatively small reserve. Stone materials dominate non-metal mineral resources. Among them, granite has rich reserves and wide distribution.

Biological Resources

Because Shenzhen is located at the transitional region between tropical and subtropical area, mild climate and complex landscape provide good conditions for many species. Trees in Shenzhen are dominated by tropical ever-green rainforests. There are 2 854 wild and cultivated plant species across the city, falling into 1 262 genuses of 234 families. Among them, 2 142 species are wildvascular plants. And 20 species are protected plants or rare and endangered species. There are 8 animal species under national protection program, 31 species of amphibians, 73 species of reptiles, 387 species of birds, more than 200 species of wetland birds, 33 species of beast, over 40 species of high-quality coastal fishes, 8 species of shrimp and over10 species of shellfish. (EPB a).

1.3 Economic and Social Context

Benefiting from special economic policy and the advantage of neibouring HongKong, along with the guiding ideology as pioneering and innovation spirits, Shenzhen has obtained rapid economic and social development since established in 1979.

Annual GDP growth of Shenzhen keeps increasing by over 25% from 1979 to 2006. Its comprehensive economic strength quickly ranks the first group of big and medium sized cities in China. In 2006, GDP of Shenzhen is RMB 581 356 million Yuan, up by 17.4% than that in 2005. Per capita GDP (based on residential population) is more than US$8 500, ranking No.1 among all big and medium sized cities of mainland China. Per capita disposable income of residents reaches RMB 23 000 Yuan. Total value of export reaches US$ 136 100 million, ranking No.1 for the 14th consecutive years and accounting for about one seventh of the total of China. Local municipal budgetary revenue is RMB 50 088 million Yuan and submits RMB 118 000 million Yuan revenue to the central government. (SzSB 2007)

Shenzhen has set up a complete manufacturing and service industrial system with four pillar industries-namely the high and new technologies, finance, logistics and culture. The proportion of the aaded outcome of the four pillar industries exceeds 50% of the GDP of the city. Shenzhen has actively developed a national innovation city with steady rising contributions of science & technology, education and human resources. The added value of high and new technological products reaches RMB 180 800 million Yuan, accounting for 31.8% of the GDP. The research and development input of the city exceeds 3% of the GDP, much higher than the national average and close to the level of developed countries. At present, Shenzhen has many high-quality innovation resources and a great number of self-owned brands and many technical patents. It ranks No.1 among all big and medium sized cities in China in terms of the amount of national and international famous brands and has been awarded as the “City of Brands”. Shenzhen has basically established a well-structured modern financial system dominated by banks, securities and insurance with co-existence of various other financial institutions. Shenzhen Port is the hub with which South China connects to world market. The handling capacity of Shenzhen port reached 18.47 million standard containers in 2006, ranking for the fourth biggest container port in the world. Shenzhen airport is the fourth biggest airports in the mainland of China with passenger amount top 100 and cargo handling amount top 50 in the world (Top 81 and 37 respectively in 2005).

With rapid economic growth, Shenzhen has higher cultural development with increasing living standard. The average life expectancy of Shenzhen is 76.71 years, higher than that of some developed countries. In 2005, Shenzhen had completed its urbanization process and become the first city without villages and farmers in mainland of China. In 2006, the registered unemployment rate of Shenzhen was controlled at the low level of 2.31%. Per capita disposable income reached RMB 23 000 Yuan, ranking No.1 among all big and medium sized cities in the mainland of China. Shenzhen has established a multi-level social security system with increasing coverage and higher level. According to the findings of the 2007 Blue Paper on Urban Comprehensive Competitive Force of China, Shenzhen ranks the second place, second only to Hong Kong.

Table 1.1 Major indicators on economic development of Shenzhen and ranks among big and medium sized cities of China, 2006

Index	Unit	Shenzhen	China	Rank
GDP	RMB 100 million Yuan	5813.56	209407	4
Per capita GDP	RMB 10 000 Yuan	6.945	1.59	1
GDP/ km^2	RMB 100 million Yuan / km^2	2.98		
Per capita disposable income	RMB 10 000Yuan	2.2567	1.1759	1
Total value of import & export	$ 100 million	2374.11	17607	1
Total value of Export	$ 100 million	1361.08	9691	1
Local municipal budgetary revenue	RMB 100 million Yuan	500.88		3
Proportion of the primary, secondary and tertiary industries	—	0.1:53.2:46.7	11.8:48.7:39.5	—

(Source: SzSB 2006)

Awards of Shenzhen

As a new city with rapid development and emphasing ecoenvironmental protection and promotion of the harmony between man and nature, Shenzhen has always adhered to sustainable development strategy and basically realized the harmony among economic growth, urban development, resources and the environment. Shenzhen has won such awards as the first Urban Planning Award in Asian issued by International Construction Union, “Global 500 Roll of Honour” granted by UNEP, Garden City, National Sanitary City and National Garden City during the past few years. In 2006, Shenzhen was the first city in China winning the honour as National Demonstration City as Ecological Garden.

Chapter II Pressures

Pressure refers to the factors driving the change of the environment, which include economic growth and social development etc. They include not only the negative factors leading to environmental degradation, but also the positive factors facilitating environmental improvement. The functioning mechanism of the pressure is often very complicated with multiple influences on the environemnt. (UNEP 2001)

2.1 Rapid Economic Growth

From the very beginning, Shenzhen aims at extraordinary development mode with fast growth rate. This is determined by special historical background and function positioning. The GDP of Shenzhen went up from RMB 1960 million Yuan in 1979 to RMB 495 090 million Yuan of 2005 with average annual growth of 23.7%.[1] This growth rate is unprecedented in China and even the world as a whole.

Before reform and opening, Shenzhen had very weak industrial development. The industrialization of Shenzhen mainly originates from the "*Sanlaiyibu*"[2] which requires relatively low costs of land, labor and the environment. Up to the end of 1983, Shenzhen had introduced a total of 2 512 projects (including service industry) in relation to foreign investment, and 82% of them fell into the category of "*Sanlaiyibu*". In 1989, Shenzhen introduced 6 720 projects, while "*Sanlaiyibu*" projects took up 56.8% of them. From 1985 to 1998, the amount of industrial enterprises of Shenzhen had grown from 609 to 2 077, 2.4 times as before. The amount of workers was 2.6 times of that in 1985. And the investment in industrial fixed assets grew up by 3.3 times

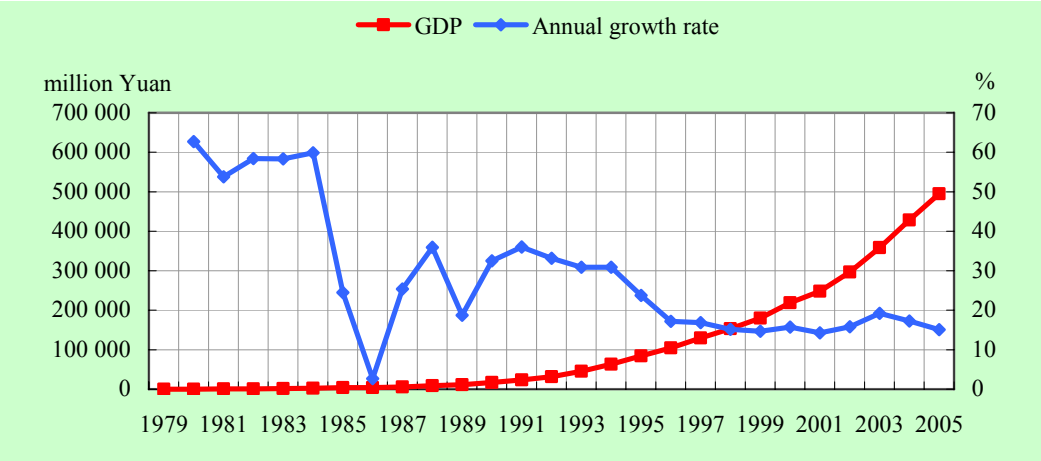

Figure 2.1 GDP and annual growth rate of Shenzhen
(Source: SzSB 2006)

1 From this chapter, all the related statistical data are up to the end of year 2005, which are imited to sources and veracity of data. But some certain data of states are updated to 2006.
2 "*Sanlaiyibu*"refers to the general term of 4 kinds of utilization of foreign capitals, namely processing of imported materials or according to supplied samples, assembling of supplied parts, and compensation trade.

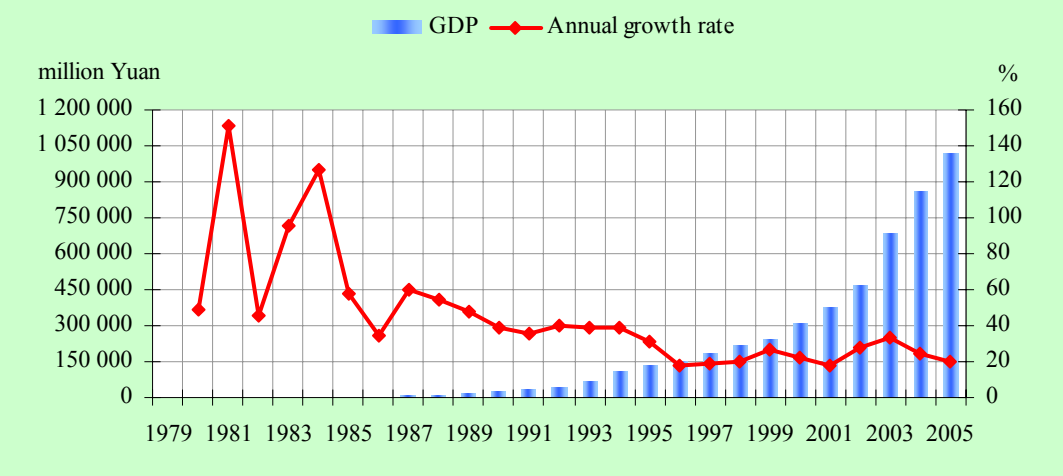

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Figure 2.2 Annual gross output value of industrial and annual growth rate of Shenzhen, 1997-2005

(Source: SzSB 2006)

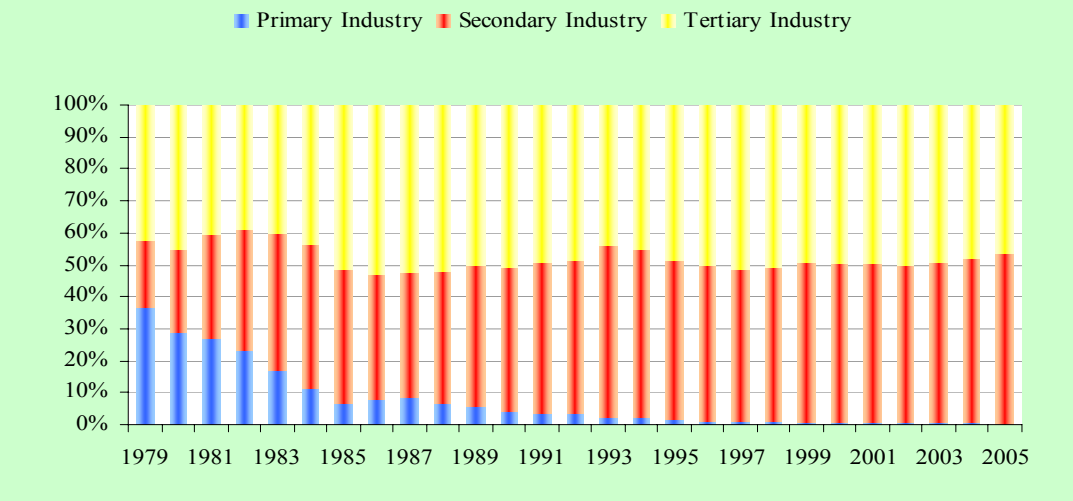


Figure 2.3 Annual composition of GDP by three industries of Shenzhen, 1997-2005

(Source: SzSB 2006)

Shenzhen has optimized its industrial structure at some extend since the beginning of mid 1990s. But it has not carried out a fundamental adjustment of its economic growth mode. Rapid economic growth means the consumption of large amount of energy and resources. The extensive economic growth mode has the following characteristics: sustained economic growth depending on more input of production elements or expansion of reproduction scale; high input of resources with high consumption. Though economy has evident growth, economic structure and growth mode are not rational. Economic growth is powered by the increase of capital and labor, rather than technological advances and higher productivity. This kind of growth mode and economic structure lead to over dependence and exploitation of the environmental resources of Shenzhen and are the main causes of urban environmental changes.

2.2 Acceleration of Urbanization

Urbanization of other cities at home and abroad usually experiences at least several decades or even longer. The fundamental characteristics of urbanizarion are the shift of rural population into urban population, enhanced urban concentration functions and the development of service industry as well as the relations between down town districts and surranding skirts, etc. However, Shenzhen has finished its urbanization just in 20 years. Studies show that the urbanization rate of Shenzhen[1] rapidly goes up from 23.81% in 1980 to 100% in 2005.

Accelerated urbanization is also coupled with rapid increase of the investment in urban capital construction. From 1979 to 2005, total investment of fixed assets of Shenzhen grew by 29.2% each year (average national growth rate is 11% in the same period). Among them, the investment of capital construction accounted for over 70% of total investment of fixed assets during 1979-1990, with the highest percentage of 91% in 1981.

Urban expansion and increase of built areas of Shenzhen heavily depend upon large scale development of land resources. The development rate of construction land of Shenzhen exceeds 30 km^2/y over the past two decades. At present, there are only 790 km^2 available land resources for construction, but 719.88 km^2 are under construction, over 90% of the total available area, indicating very limited land reserves.

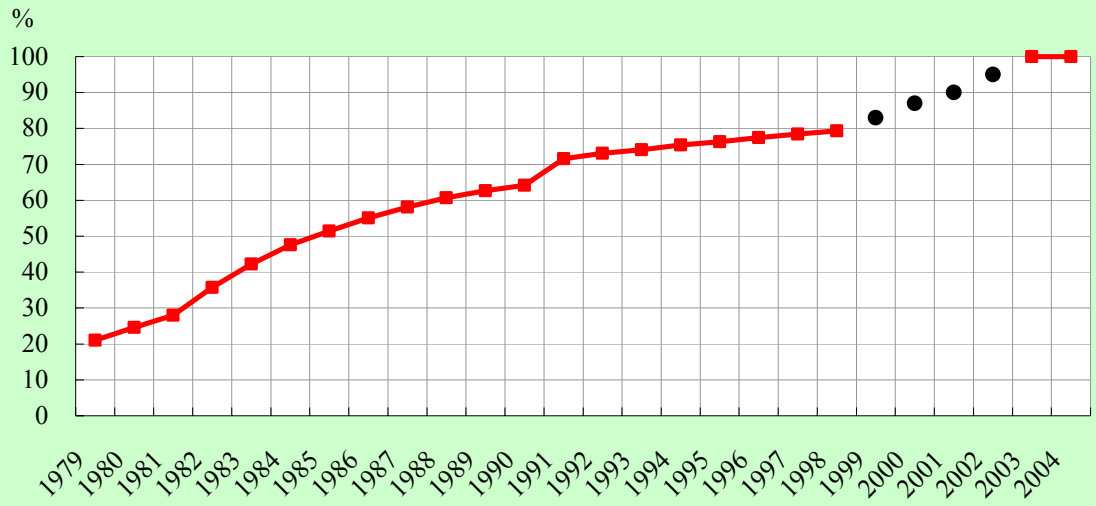


Figure 2.4 Urbanization of Shenzhen

(Source: SzSB 2006, Xiaoli Xu 2002)

1 Urbanization level is estimated by the percentage of non-farmer population with residence cards against the total population with residence cards.

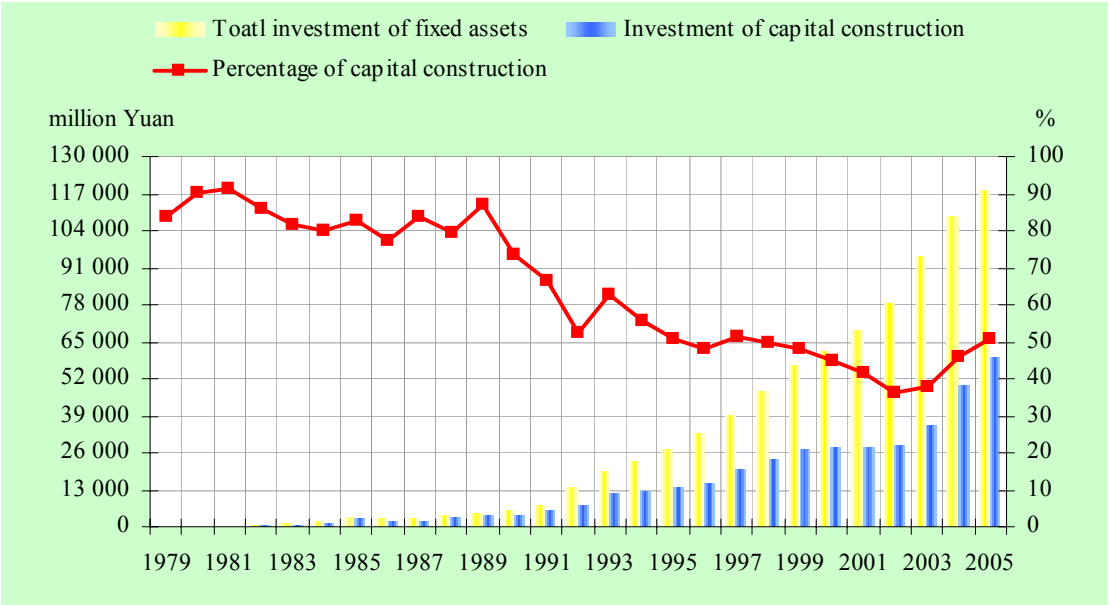


Figure 2.5 Annual investments of fixed assets and capital construction in Shenzhen

(Source: SzSB 2006)

2.3 Rapid Population Growth

The population of Shenzhen grows year by year. At present there are 8.46 million residential population[1] in Shenzhen, but more than 12 million actual managing population including the floating population. Population structure of Shenzhen appears as the following characteristics: relatively high population density as 4234 people/km^2 in 2005, higher than that of other big cities like Shanghai, Beijing and Guangzhou, but lower than Hong Kong Special Administrative Region. The average age of Shenzhen residents is quite young at about 31 years old. 73.5% of the population is under 35 and 1.22% of the population is over 65 years old. The population educational background shows highly polarized trend with relatively high percentages of both the talents with tertiary education background and migrant workers with low educational background.

The development of labor-intensive industries has attracted millions of migrant workers leading to the unique phenomenon of much higher percentages of temporary population and floating population against that of registered population in Shenzhen. From 1979 to 2005, residential population of Shenzhen had an explosive growth with annual average growth rate of 12.9%.

Table 2.1 Comparision of population structure among Shenzhen and other cities, 2005

	Shenzhen	Beijing	Shanghai	Guangzhou
The proportion of Population with residence cards and Population with non-residence cards	1:6.11	1:0.294	1:0.337	1:0.445

(Source: SzPSB 2006)

1 Residential population includes population with residence cards and temporary residence cards.

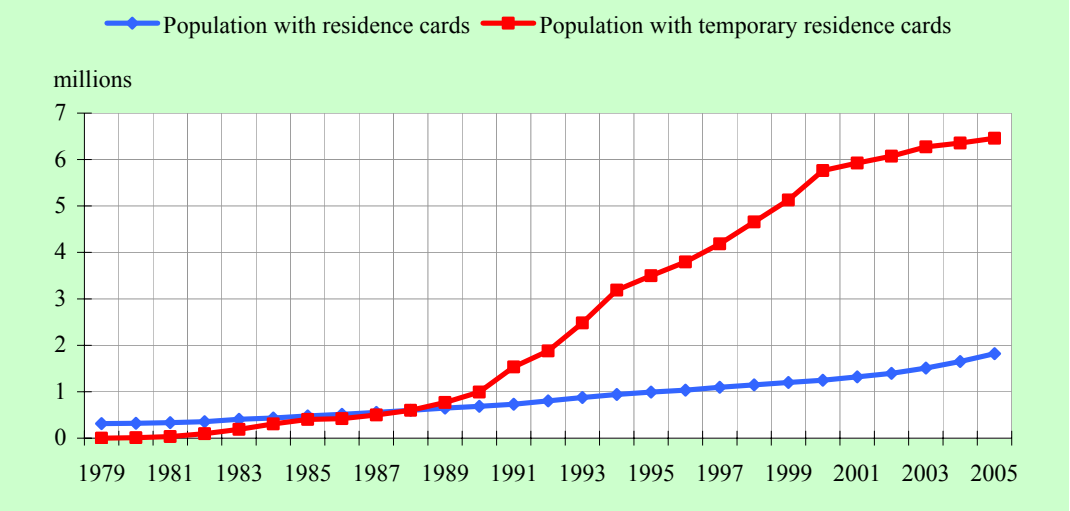


Figure 2.6 Annual population change of Shenzhen

(Source: SzSB 2006)

Rapid growth of floating population and the characteristics of population structure characteristics cause huge pressure on the development of Shenzhen. The pressure is mainly reflected by the following aspects: land resources of Shenzhen is under mounting pressure; pressure of domestic pollution sources due to population explosion on environmental quality especially water quality; long-term overload operation of middle and primary schools and service institutions including hospitals due to rapid population growth; imbalance between population structure and the development orientation of Shenzhen. All these are factors constraining further development of Shenzhen.

2.4 Development of Transportation

Shenzhen borders Hong Kong Special Administartive Region. This geographic location determines its rapid development in urban transportation and the construction of transportation infrastructure.

The total highway length Shenzhen is over 2 800 km. Among them, more than 1 400 km are open to the traffic with over 200 km of expressway. Highway density is 0.75 km/km^2. The high-speed road system of the special economic zone composed of expressway, high-speed urban road, urban main road and overhead road has reduced the passage time from Line 1 to Line 2 of the special economic zone to less than 30 minutes, and time required from Shenzhen to neibouring cities including Guangzhou to about 1 hour. At the same time, the amout of vehicles in Shenzhen is soaring. In 2004, the existing amount of motor vehicles of Shenzhen exceeded that of Hong Kong, reaching 660 000 with daily increase of 300-400 cars. Up to the end of March, 2007, the amount of motor vehicles of Shenzhen had exceeded one million, ranking No.2 in the mainland of China, second only to Beijing.

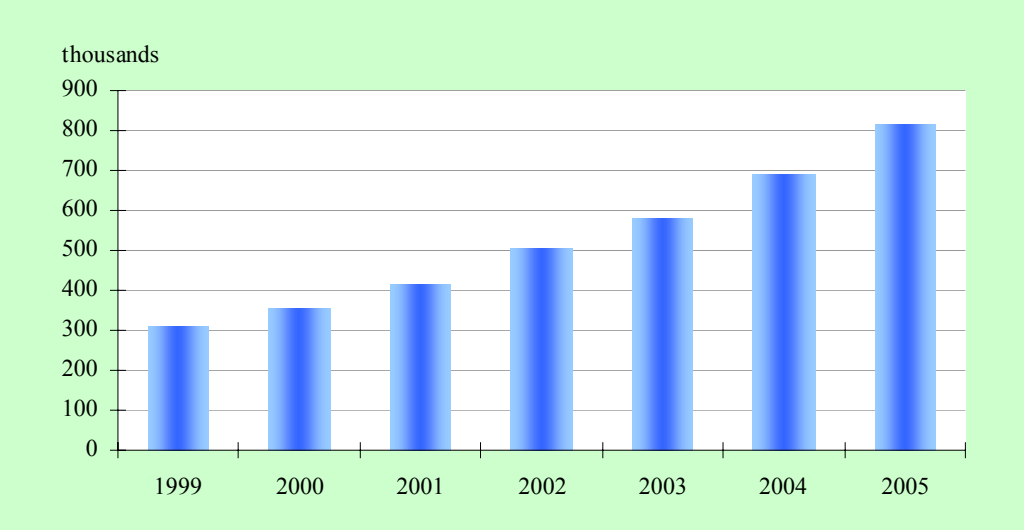


Figure 2.7 Annual change of motor vehicles in Shenzhen, 1999-2005

(Source: SzSB 2006)

The coastal line of Shenzhen is 229.96 km long with a total of 141 port berths, 53 of them have the capacity over 10 000 tonnes. As a hub connecting South China to world market, Shenzhen Port is No.4 biggest container port in the world and identified as a national key port. The coastal line of the port of Shenzhen is 15 km long. Nine commercial port areas including Shekou and Yantian have been built along the line with 141 berths with capacity over 500 tonnes. Among them, 53 are operational deep-water berths with capacity over 10 000 tonnes. Cargo handling capacity of Shenzhen seaports has grown rapidly. The container handling capacity has grown faster since 1988 (Figure 2.8). The ocean transportation shipment is 8 million tonnes each year, up by 37.9%. At the same time, both Shekou and Fushui passenger terminals have regular ships to Hong Kong Airport. Annual passenger volumn of Shenzhen is 3.45 million person times.

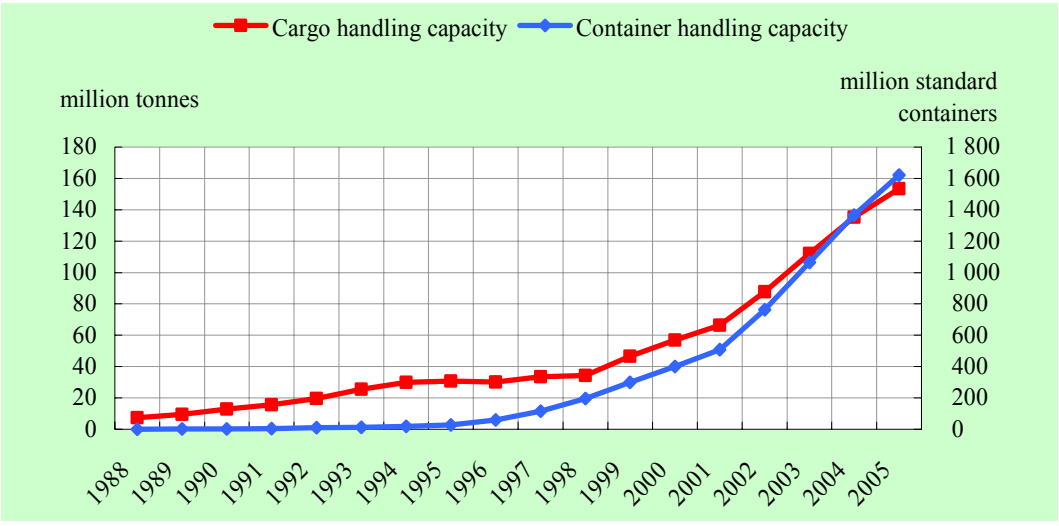


Figure 2.8 Annual handling capacity of cargo and container of Shenzhen seaports

(Source: SzSB 2006)

Amount of vehicles in Shenzhen ranks No.2 in China, second only to Beijing

(Source: www.sznews.com)

Shenzhen Bao'an International Airport is the fourth biggest airport in the mainland of China with passenger flow within top 100 and cargo flow within top 50 in the world. In 2004, there were 14.24 million person times of passenger flow in the airport, up by 31.4% than that of 2003. The cargo and postal handling capacity reached 495 400 tonnes, up by 21.8%.

Shenzhen has increasingly well-developed urban transportation system. On the one hand, it has strengthened the communications with neiboring areas and further facilitated economic growth. On the other hand, it has brought about continuous pressure on the atmospheric, acoustic, water, coastal and marine environment of the city.

2.5 Cluster Effect of Metropolitan Region

Shenzhen is located among the cities of the Pearl River delta. Each city of the Pearl River delta closesly links to other cities through the transportation network and resource network. So does the urban environmental problems. The environmental problem of the city cluster has evident regional characteristics. This is mostly reflected by more pressure on natural resources because of the utilization of same kinds of resource by those cities and the overlap of environmental pollution (Zhixue Jiang 1999).

Figure 2.9 Location of Shenzhen among the cities of the Pearl River Delta Metropolitan Region

(Source: CITYU)

Introduction of the Pearl River Delta Metropolitan Region

The Pearl River Delta Metropolitan Region is composed of Guangzhou, Shenzhen, Foshan, Zhuhai, Dongguan, Zhongshan, Huizhou, Zhaoqing and Jiangmen with total land area of 4 1,700 km^2 and population of 40.77 million (according to the 5^{th} National Population Census), accounting for 23.2% and 47.2% respectively of the total of Guangdong Province. It is the political, economic, cultural, scientific & technological, information and communication center of southern part of China (Mengyang Wang 2002).

Taking the geographical advantage of bordering Hong Kong and Macao and grasping the development opportunity of the world economic restructuring and industrial shift, the Pearl River Delta has developed an IT industrial cluster with "Guangzhou — Shenzhen" as the center dominated by such cities as Shenzhen, Dongguan and Huizhou on the estern bank of the Pearl River and electrical product industrial cluster dominated by Guangzhou, Foshan, Jiangmen and Zhuhai on the west bank of the River since China adopted reform and open-up policy in 1979. These cities have well established modern transportation infrastructure and smooth information network. With rapid reform of urban transportation, the Pearl River Delta has speeded up the integration of different cities. According to Urban Development Plan of Guangdong Province, the city cluster of the Pearl River Delta will realize "1-hour light railway traffic areas" after the establishment of inter-city rapid light-rail system in Pearl River Delta economic zone in 2020. This will make the Pearl River Delta into a mega urban area with much closer connections.

As one of the key cities in the Pearl River Delta Metropolitan Region, Shenzhen is inevitably subject to the overall influence of the cluster. This is mainly reflected in the following aspects as follows. (Shugong Wang 2003)

- The development of city cluster leads to the shortage of natural resources such as land and water. Urban population has a drastic increase due to the city conglomeration effect. Population growth increases the pressure on resources and the environment. The quality of the population limits the awareness of people in resource balance and environmental protection. In Shenzhen and even the whole Pearl River Delta, the constraining factors dominated by lack of water and land resources have increasing salient contradictions to rapid development of the city cluster.
- Inappropriate spatial layout of the city cluster leads to trans-regional overlap of air pollution. Pollution spread and mixture of pollutions sources of the region, between one city to another, between urban areas and suburbs or the fume effects among very big cities constitute large scale pollution diffusion and misture at regional level, resulting in far-distance transportation of pollutants and diffusion of secondary pollutants. With rapid economic growth, the emissions of air pollutants including SO_2 keep rising with heavier acid rain

pollution. The Pearl River Delta has become a big control area for acid rain. This has imposed significant impacts on air quality and ecosystems of the delta. And atmospheric environment of Shenzhen is inevitably subject to the impacts of regional pollution transportation and local emissions.

- The scale and economic growth of the city cluster leads to more salient problem of watershortage due to pollution and the conservation of water source areas. Dense water network of the Pearl River Delta belongs to Pearl River water system and is sensitive to tides. Because of rapid development of each city and poor coordination mechanism, most rivers flowing through the city cluster become the main drainage of urban sewage. Shenzhen is located at the lower reaches of the Pearl River.Therefore, the safety of water environment of the Pearl River basin is an important guarantee for sustainable urban development. However, the water environment of Shenzhen is under integrated impacts of both the pollution from the upstream cities and local sources, thus leading to shortage of water due to poor quality.
- Domestic waste caused by rapid urbanization becomes a new environmental problem. Population explosion and rising living standard lead to increasing amount of domestic garbage year by year. It has become a pressing problem for many cities in the cluster as how to dispose the garbage. In addition, hazardous waste is facing many problems in terms of transporation, treatment and disposal.
- Impacts of urbanization on the security of the environment and ecology. The Pearl River Delta has rich ecological and environmental resources. But continuous rapid urbanization, industrialization and economic growth have huge impacts on natural eco-system and the environment, which are mainly reflected by the following phenomena: reduction of both the amount and quality of arable land; shrinkage of forests, lower ecological benefits; degradation of urban natural landscape; continuous reduction of the amount and species of wild animals and plants; threats to biodiversity and widespread invasion of alien species representated by Mikania micrantha (Shihong Yang 1999). Cities of the Pearl River Delta cluster are quite concentrated. To prevent and control the invasion of alien species, the efforts of Shenzhen is far from enough. We need the cooperation of the entire region of the Pearl River Delta.

Chapter III State and Impacts

State refers to current status and change trend of the urban environment under various direct or indirect forces such as the economic, social and population influences. Impacts refer to the effects of urban environmental changes on urban ecosystem, economy and social system. Impacts have close relations with the state or status. The scientific and objective descriptions of the status of different elements of urban environment and their change results aims at enabling all stakeholders have object understanding of current features of urban environment and main environmental factors influencing urban development and helping decision makers to carry out strategic analysis and decision discernment, etc. (UNEP 2005)

3.1 Water

Shenzhen falls into the subtropical monsoon climate with annual average precipitation of 1837 mm. Annual average total water resources of Shenzhen is 1 872 million m^3. Based on the residential population of 8.28 million in 2005, per capita water resource is 226 m^3, only 1/8 of the national average. If based on the actual water consumption population of 10.71 million, the per capita water resource is 175 m^3, less than 1/10 of the national average. After about 10 years' continuous government efforts, Shenzhen has established a primary water supply network dominated by water transfer (accounting for 80%) from the Dongjiang River outside the city and supplemented by local reservoirs. This has basically met the demand of the economic development of Shenzhen for water resources.

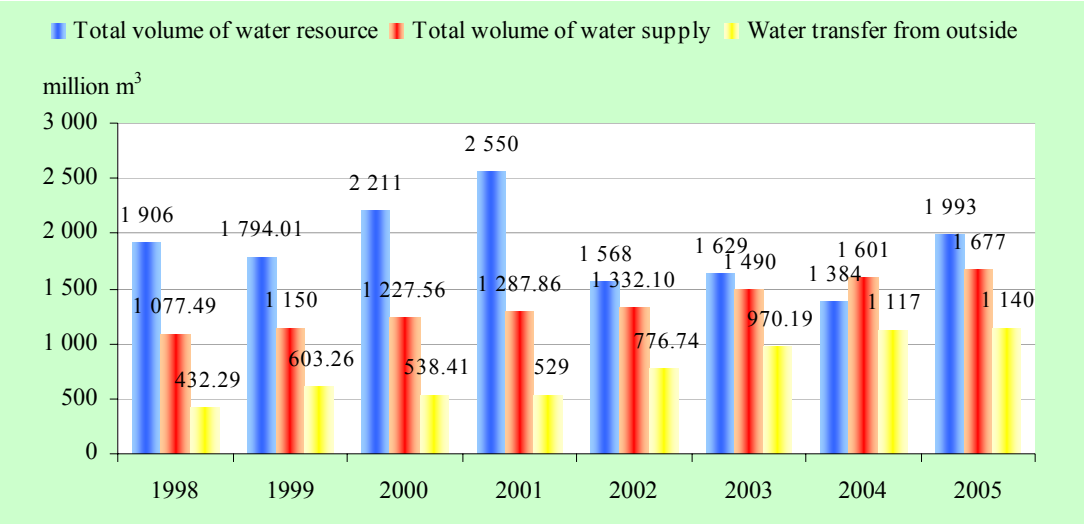


Figure 3.1 Annual change of water resource and water supply in Shenzhen, 1998, 1999-2005

(Source: SzWRB d)

Shenzhen has evident water shortage due to water pollution and lack of water conservancy projects. This is reflected by the fact that although there are quite many reservoirs, they have small capacity. In addition, the precipitation of Shenzhen has obvious seasonal characteristics; it is hard to conserve rain water. Though fast in economic growth, Shenzhen is relatively lag behind in the construction of sewage treatment facilities. As a result, large amount of sewage directly flow into rivers without any treatment, leading to serious water pollution (Haitao Huang et al 2005).

Shenzhen lacks groundwater resource with reserve of 192 million m^3. Not all of them can be mined in scale. The amount that could be supplied is about 60 million m^3 per year.

I Drinking Water

Drinking water of Shenzhen mainly comes from reservoirs. Because Shenzhen lacks water resources, the main sources of water of these reservoirs of Shenzhen come from the water of Dongjiang River through “East Water Supply Project” and “Dongjiang-Shenzhen Water Supply Project”.

All reservoirs in the city have small capacity with relatively weak water storage capacity. With no large reservoir, Shenzhen has 9 medium sized reservoirs (capacity over 10 million m^3), 65 Type I small reservoirs (capacity 0.1 - 10 million m^3) and 121 Type II small reservoirs (capacity 0.10 - 1 million m^3). So the main water supply reservoirs are medium sized with total capacity of 327.5 million m^3. The largest reservoir is Tiegang Reservoir with effective capacity of 49 million m^3.

According to the assessment result of the quality of reservoir water of Shenzhen in 2005, the general water quality of these reservoirs is quite good. Main pollutants with concentration beyond national water quality standard are TN and TP, showing a trend of eutrophication.

In general, the water quality of drinking water sources of Shenzhen is good, according with national quality standard for drinking water. From 1997 to 2006, up-to-standard of water quality of main drinking water sources was over 96% except lower in 2001.

II Surface Runoff

There are few big rivers in Shenzhen but with many small ones. There are only five river swith the basin area over 100 km^2 in the city, such as the Shenzhen River, Guanlan River, Maozhou River, Longgang River and Pingshan River, ten rivers with the basin area over 50 km^2, 310 rivers with the basin area over 1 km^2 and total length of 998.9 km.

Rivers in Shenzhen have the obvious characteristics of rain water dependence. Shenzhen falls into the subtropical monsoon climate. It has rich rainfall but with uneven

Table 3.1 Up-to-standard rate of water quality of the drinking water sources in Shenzhen, 1998-2005

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Up-to-standard rate	96.8	97.2	98.1	98.7	93.45	96.1	97.13	96.7	98.1	98.07

(Source: EPB d)

time and spatial distribution, leading to evident seasonal change of river flow. In dry season (October to March), the base flow is very small. While in wet season (April to September), the flow has great increase (Changxing Li, 2004).

Rivers play the roles in pollutants bearing and flood control. Most rivers in Shenzhen run through urban or town areas. Though with rapid economic growth, Shenzhen lags behind in the construction of urban sewage treatment facilities. This causes large amount of domestic sewage, industrial waste water and rainwater directly flowing into rivers by a confluent sewer system and leads to serious pollution. Pollution is especially severe in dry season, as most water in the rivers is waste water with only a small percentage of natural runoff. In wet season, large amount of rain water causes soaring flow in the rivers. Because relatively small drainage area in Shenzhen with weak capacity in flood control, flood easily break out. Apart from the main stem of the Shenzhen River that can reach the flood control standard for 100-year frequency can tolerate the flood one in 100 years, other four big rivers can only reach the flood control standard for 10 to 30 years frequency. This shows that flood control situation in Shenzhen is rather severe . (Wuhan Shi, 2006)

Rivers in Shenzhen have been seriously polluted. Because most rivers flow through urban areas with certain amount inflow of waste water added by small flows, rivers in Shenzhen have quite serious water pollution. The water quality of most mid and lower reaches of these rivers fails to meet Grade V national environmental quality standards for surface water, in which main pollutants are ammonia-nitrogen, TP and BOD. Though water quality of some certain rivers has improved, the overall water quality of rivers still shows a trend of degradation. (Xiaomao Yang et al 2005)

In general, Shenzhen is facing grim situation in terms of water resources and water environment. However, it is expected that the East Water Supply Project and Dongjiang-Shenzhen Water Supply Project as wel as the future development of sea water desalinization will ease the situation of water shortage. To improve the water environment, local government should put more efforts in the prevention and control of water pollution of rivers, reservoirs and coastal sea areas.

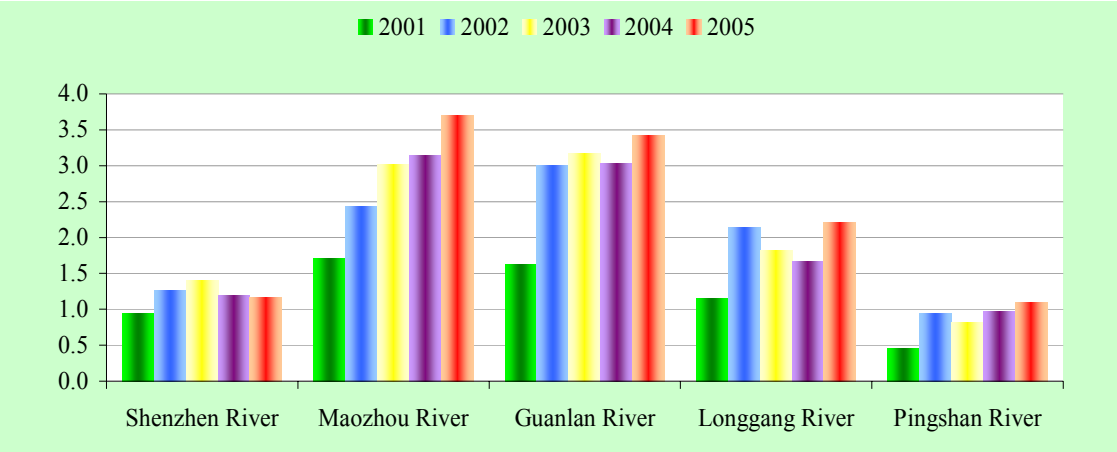


Figure 3.2 Comparison of the average comprehensive pollution index among the five major rivers in Shenzhen, 2001-2005

(Source: EPB a)

3.2 Atmosphere

At present, main air pollutants in Shenzhen are SO_2, NO_x and inhalable particulate. Figure 3.3—Figure 3.5 show annual change of the concentration of major air pollutants in Shenzhen during 1991-2005.

I Sulfur Dioxide (SO_2)

From 1991 to 1999, Shenzhen had rapid industrial development with evident acceleration of industrialization and expansion of energy consumption. Annual SO_2 emission had dramastic increase from 2 600 tonnes/y in 1991 to 29 000 tonnes/y in 1999, up by more than 10 times. At the same time, SO_2 concentration in the air went up from 0.004mg/m^3 in 1991 to 0.013 mg/m^3 in 1999. On the whole, SO_2 pollution in this period is not severe with the concentration basically meeting Grade I National Air Quality Standard (0.020 mg/m^3).

With rapid urban development, SO_2 emissions mainly come from the electricity industry. The installed capacity of thermal power generating sets of Shenzhen went up from 1.80 million kW in 1996 to 3.10 million kW in 2000. The expansion of the consumption of industrial fuels brings about the rise of SO_2 emissions. To control SO_2 pollution, Shenzhen has gained some achievements by taking such measures as further optimizing and adjusting industrial structure, rationalizing industrial layout, speeding up the development of gas industries, facilitating the application of clean energy and developing flue gas desulphurization facilities of existing power plants.

Annual SO_2 emissions grows from 38 400 tonnes/y in 2000 to 43 500 tonnes/y in 2005, but the growth rate has been under control. In general, SO_2 concentration of Shenzhen shows rising trend in recent years compared with that of 10 years ago. In 2000, 2001 and 2004, SO_2 concentration of Shenzhen went beyond Grade I National Air Quality Standard and only met Grade II Standard (0.060 mg/m^3). Daily average SO_2 concentration in the air in 2005 went up by 100% compared with that in 1999, leading to higher acidity of the acid rain.

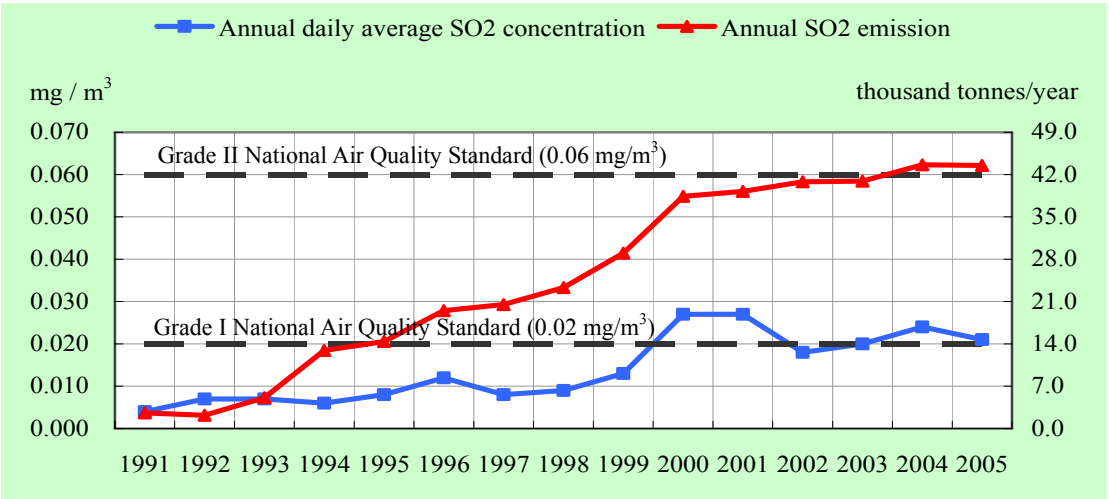


Figure 3.3 Annual SO_2 emission and annual daily average SO_2 concentration of Shenzhen, 1991-2005

(Source: EPB a, b, c)

II Nitrogen Oxides (NO_x)

Compared with SO_2 pollution, NO_x pollution in Shenzhen is rather serious. Figure 3.4 illustrates that annual daily average NO_x concentration of Shenzhen present an increased trend during 1991-2000. Among these years, there was a significant rise from 1991 to 1995, and the increase slowed down from 1996. Continuous increase of NO_x concentration in Shenzhen mainly attributes to vehicle exhaust emissions and the emissions of industrial combustion point sources. With the issuing of various national policies encouraging car consumption and the increasing of local residents` income, the amount of private cars is growing very fast. Meanwhile, with rapid economic growth and steady increase of export trade, the amount and trip volume of transit wagons and container trucks keeps growing. (Lingyan He 2005) In addition, industrial development leads to corresponding rising demand for fuel oils, which contributes the rising NO_x concentration in the air to some extent.

Although some changes happened to the statistic caliber of pollutant concentration after 2000, it still presents a fluctuant trend of NO_2 concentration in the air showing the increasing rate slowed down. It implies that positive measures such as enhanced management on vehicles, extension of clean fuels and application of exhaust purification devices, has played an important role in controlling NO_x concentration in the atmosphere.

III Particulate Matter (PM)

Shenzhen experienced rapid urban development and expansion in early 1990s with over 60% government financial expenditure for the investment in urban infrastructure (See Figure 2.5). The concentration of air particulates increases resulting from flying dust of land exploitation and construction sites due to rapid land development and big growth of construction activities. In addition, continuous increase of vehicle emission and influence of meteorological conditions also caused evident rise of the concentration of TSP in urban areas. With

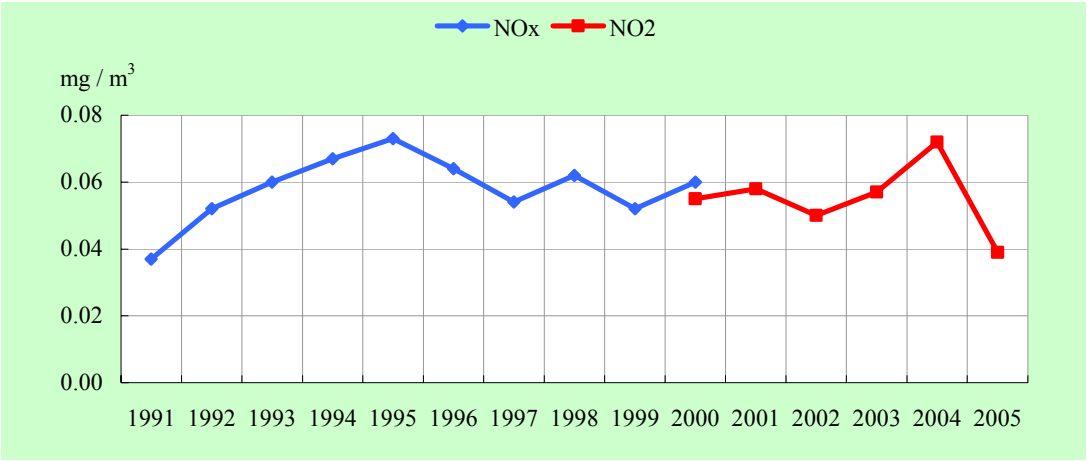


Figure 3.4 Annual daily average concentration of NO_x and NO_2[1], 1991-2005

(Source: EPB a, b, c)

1 From 1999, the statistic caliber is changed, shifting from NOx to NO_2.

increasing public concern on air quality, slowing of urban development, rising level of pollution control and continuous optimization of energy mix, the overall level of TSP in air is on downward trend. In 1999, annual daily average concentration went down and met National Grade I Air Quality Standard (0.080 mg/m^3), indicating that TSP pollution in the city has been mitigated.

After 2000, the national air quality standard has been improved and the statistical caliber has been changed, so the public pay further attention to the concentration of inhalable particles (PM_{10}). Because continuous construction projects including subway development, construction in central areas and sea reclamation projects in Shenzhen have been going on, there are long-term fugitive dust sources with gradual rising trend of PM_{10} concentration to a small extent. The PM_{10} concentration of Shenzhen peaked in 2004, the year with most haze days in the city, as high as 175 days.

IV Acid Rain and Haze Days

Shenzhen is one of the key cities in the Pearl River Delta Metropolitan Region. The air pollution characteristics of the region are the combination of urban with rural pollution, local pollution with regional pollution, primary pollution with secondary pollution. Air pollutants transport in the whole region with interactions, turning local pollution into regional pollution centering on cities. Therefore, air pollution of Shenzhen has the feature of regional pollution and its atmospheric environment is evidently subject to the impacts of regional transportation of air pollutants across the delta. And local acid rain and haze days are also atmospheric environmental issues resulting from the combination of regional pollution and local pollution.

Figure 3.6 illustrates pH change of the precipitation of Shenzhen during 1995-2006. It can be seen from this figure that the pH value of the precipitation of Shenzhen fluctuate from 4.5 to 5.0 in the past few years, lower than the acid rain critical value (pH=5.6), falling into slight acid rain category. The overall trend of the pH value shows downward trend each year. Research shows that long distance transportation of pollutants is one of the main reasons of the aggravation of acid

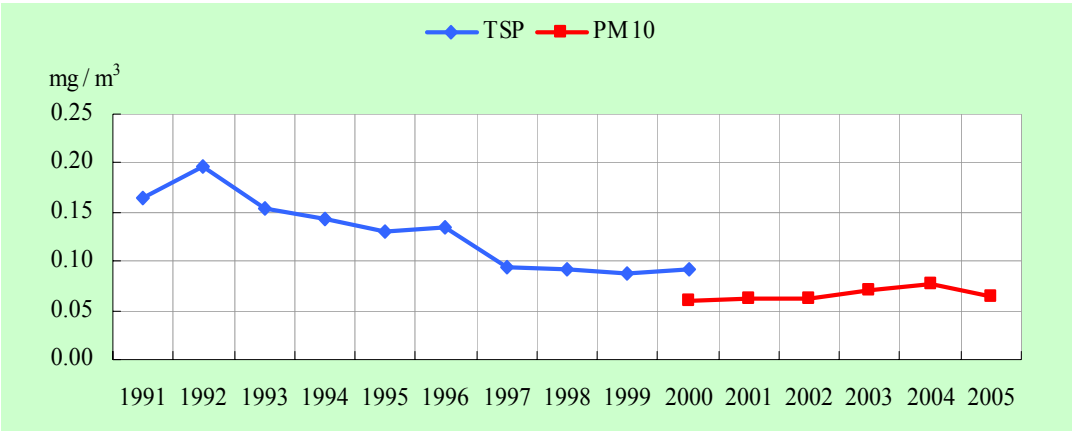


Figure 3.5 Annual daily average concentrations of TSP and PM_{10} in Shenzhen during 1991-2005[1]

（Source: EPB a, b, c）

1 From 2000, the statistic caliber is changed, shifting from concentration of TSP to PM_{10} level.

rain pollution in Shenzhen (Hongmei Li 2006). Among them, pollutants transportation in the Pearl River Delta, which is a national acid rain control area, impacts on Shenzhen significantly. With rapid increase of the amount of vehicles in the Pearl River Delta, NO_x emissions shows a rising trend year by year. As a result, the component of acid rain in Shenzhen has evolved from only SO_4^{2-} induced to the combination of both SO_4^{2-} and NO_x^-. In addition, this phenomenon is also subject to the emissions of local pollution sources of Shenzhen and meteorological conditions.

Figure 3.7 illustrates the change of haze days in Shenzhen during the year 1981-2006. In 1980s, there were 58 haze days in Shenzhen with average 6 days each year. In 1990s, the amount of haze days increased to 824 in 10 years with annual average of about 80 days. In the beginning of the new century, annual average haze days increased to 122 with the highest in 2004 being 175 days.

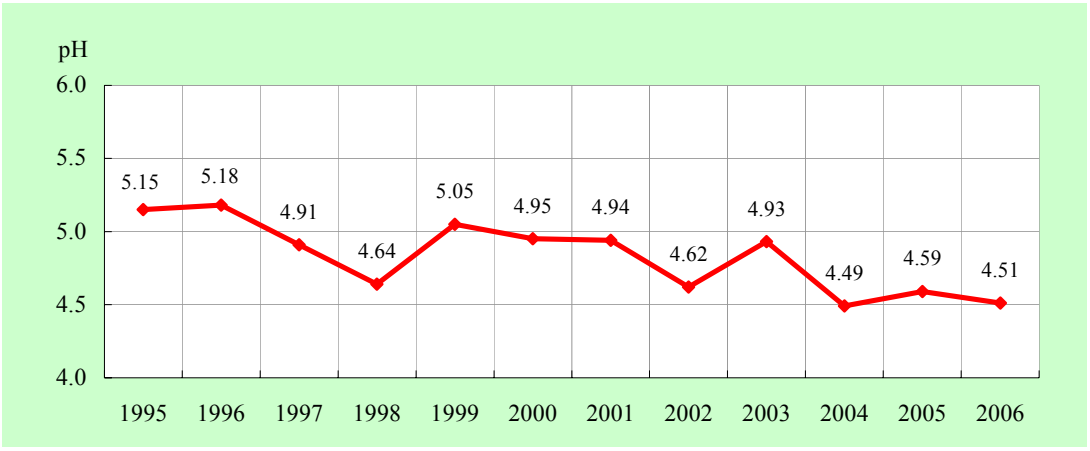


Figure 3.6 Annual average pH value of precipitation in Shenzhen, 1995-2006

(Source: EPB a, b)

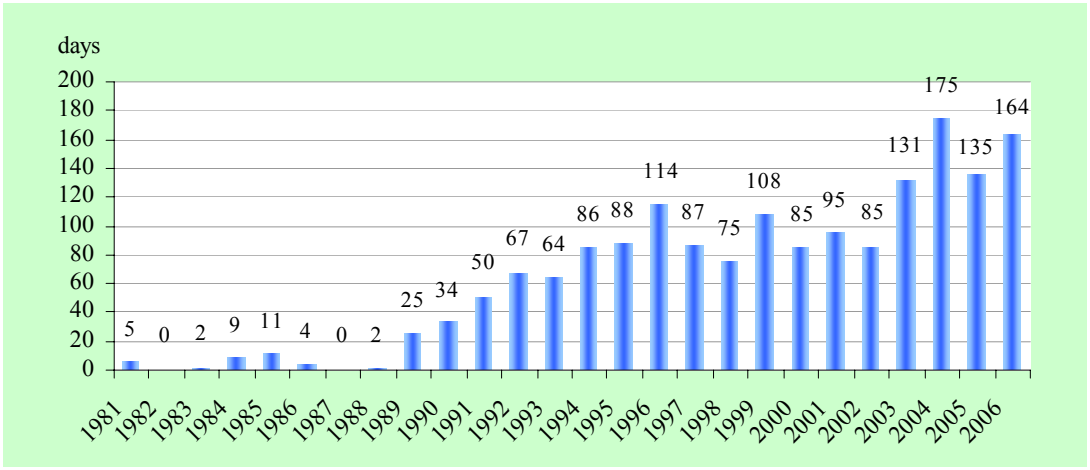
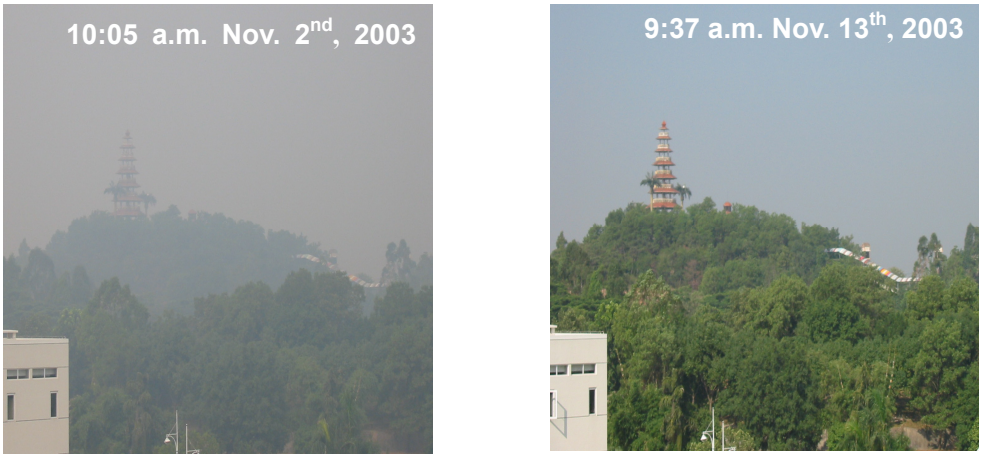


Figure 3.7 Annual haze days in Shenzhen, 1981-2006

(Source: CRAES 2005, SzMB 2006)



Comparision between haze day and normal day in winter, Shenzhen

(Photographer: Lingyan He)

The reasons for increasing of haze days in Shenzhen year by year are various. Apart from local meteorological conditions in Shenzhen, other causes include the transportation of pollutants at regional level, increasing exhaust due to continuous expansion of the amount of vehicles, and the increase of the concentration of surface air pollutants especially fine particles during urban development etc..

3.3 Land

Shenzhen shows the characteristics of the areas that are experiencing rapid urbanization in that there is an obvious trend in land uses, i.e., the fast growth in land uses for urban construction and constant reduction in agricultural lands, in particular, arable land. According to the *Construction Plan for the Near Future (2006-2010)* issued by SzPB, construction land has reached 719.88 km^2, which is over 90% of the total available land for construction., and the land resources in stock are quite limited.

Since 1980, there had been a sharp increase in buildings and residential housing construction, (Figure 3.8) at the same time the arable areas had fallen observably. (Figure 3.9)

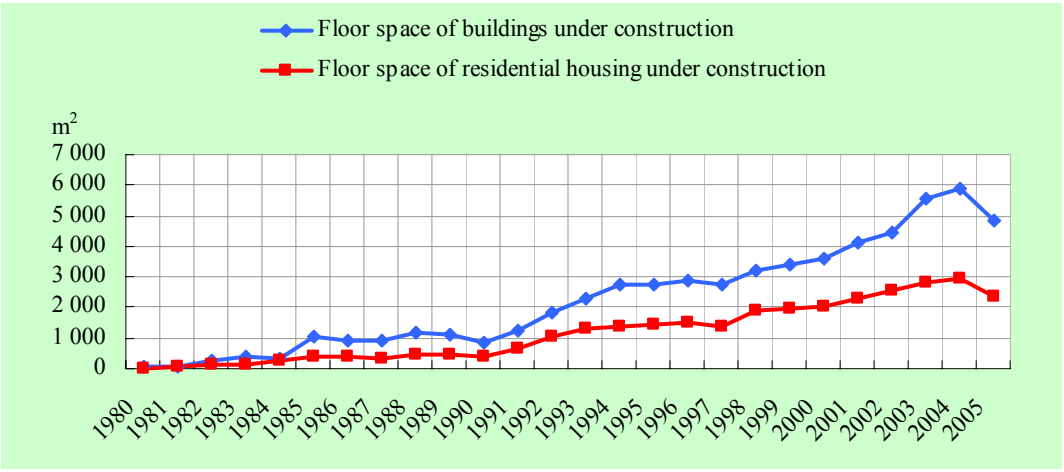


Figure 3.8 Floor space of buildings and residential housing under construction in Shenzhen, 1980-2005

(Source: SzSB 2006)

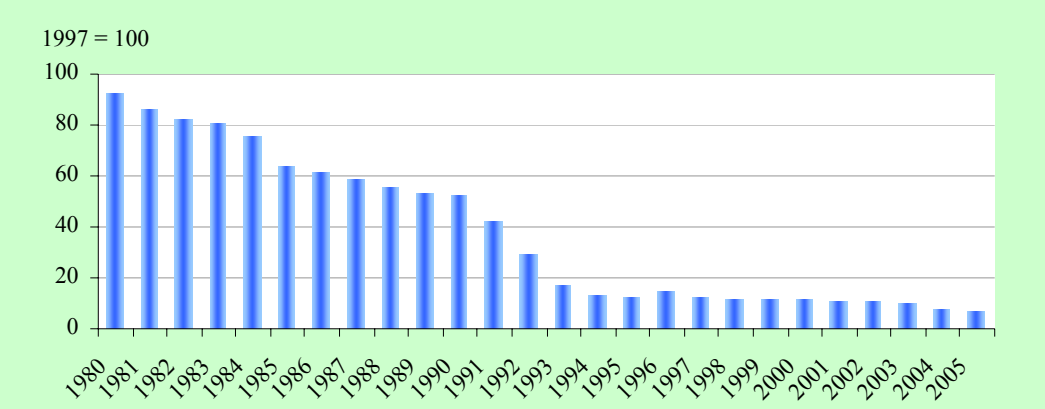


Figure 3.9 Indices of areas under cultivation in Shenzhen, 1980-2005

(Source: SzSB 2006)

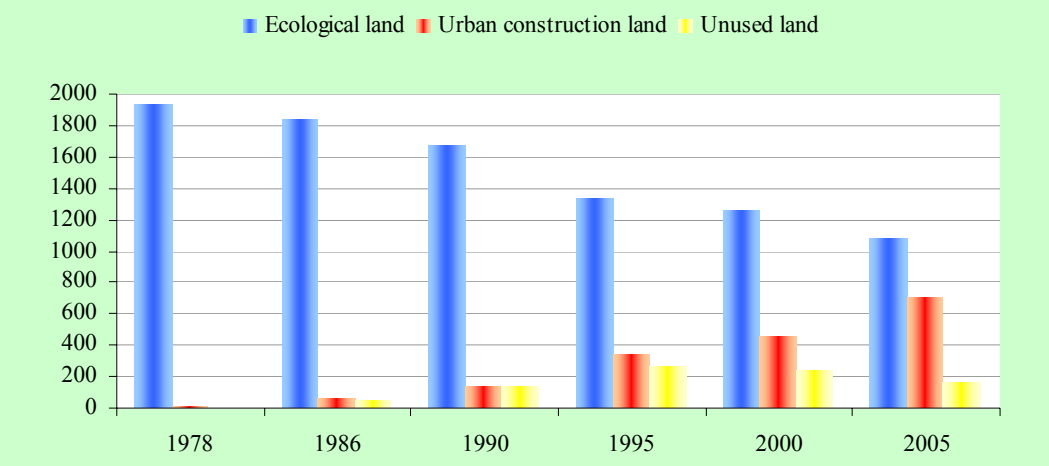


Figure 3.10 Changes of land use structure in Shenzhen

The rapid growth of the construction area of buildings (including the houses) has shrunk the land stock of this city. According to the reality of the land uses as well as the trends in the previous years, this is bound to impose impacts on the ecological environment and brings about immense pressure on the economic development. Since 1990s, Shenzhen has witnessed sharp increase in land areas for urban construction and gradual decline in ecological land. As a result, the ecosystem fragmentation is increasingly severe. (Changes in urban construction land, see Figure 3.11)

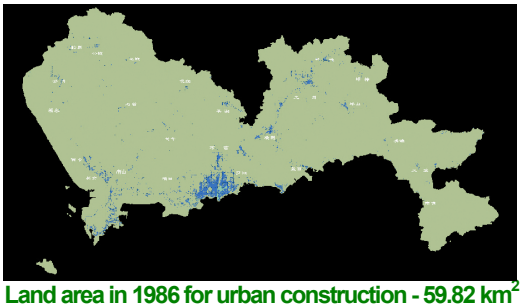
As the city expands and the land development activities intensify, construction activities have gradually extended to foot and slopes of mountains. More activities to cut and fill the slopes result in lots of side slopes, which, not only are unpleasant to the sightseeing, but also tend to cause soil and water loss, become hidden troubles for geological disasters and threat the life and property of city residents. The survey indicates that at present, the city has more than 40 000 man-made side slopes, including 6 951 dangerous ones, affecting up to 60 000 people and threatening 1.5 million m^2 of construction areas. Among these side slopes, 912 ones are around primary and secondary schools, 112 ones are adjacent to hospitals, and 6 555 ones are along roadsides. They are the primary hidden troubles of geological disasters in Shenzhen.

Exploitation of Quarries and Urban Environment

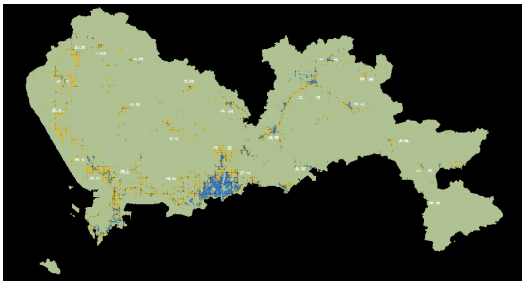
Barren quarries are the major cause of soil and water loss in Shenzhen City. While building and operating the quarries, trees are cut down, surface soils are peeled off, and mountains are cut through in order to fetch stones, which will cause soil and water loss. What's more, some of the enterprises operating the quarries pay little attention to soil and water loss conservation during their exploitation activities, and they fail to reforest the mountains, which aggravates soil and water loss.

At best, there're more than 600 sites exploiting stones, and as of 2004, 55 enterprises were still in operation. According to the analysis results of Hymap video in 2004s, the barren area of the quarries in Shenzhen city amounts to 9.4 km^2, causing about 5.45 million tonnes of the amount of soil and water loss every year. As efforts to regulate quarries began, by the end of 2006, there had had no productive quarries in Shenzhen. Apart from the 12 quarries intended for restricted exploitation, all the other quarries have being treated and reforested, and will be shut down upon the expiration of their permits.

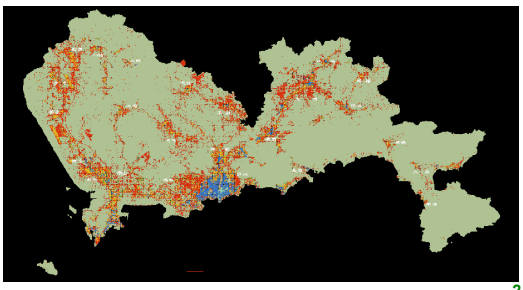
Land area in 1978 for urban construction - 2.81 km^2



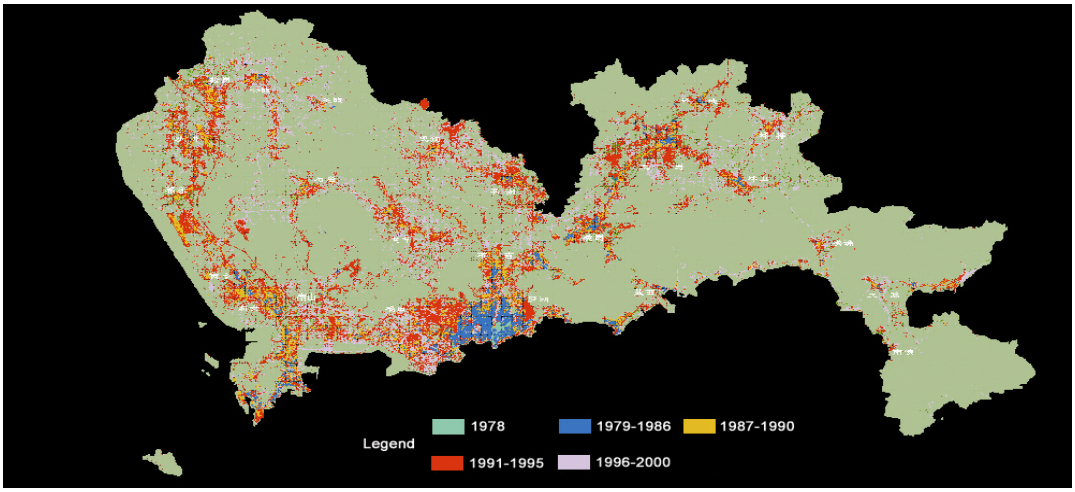
Land area in 1986 for urban construction - 59.82 km^2



Land area in 1990 for urban construction - 138.79 km^2



Land area in 1995 for urban construction - 341.87 km^2



Land area in 2000 for urban construction - 452.14 km^2

Figure 3.11 Changes of Urban Construction Land in Shenzhen

(Source: Research resluts provided by SZPKU, 2005)

The changes in the way to use lands affect soil and water loss in urban areas. With the rapid growth and urbanization process of this city, the impacts imposed by the development activities have been far beyond the self-conservation capacity of the soils. Meanwhile, fierce storms and large-scale human disturbances accelerated the rate of soil and water loss in this city, posing a threat to the sustainable socio-economic development. Since the late 1980s, Shenzhen has experienced a dynamic change in the amount of soil and water loss, from sharp increase (1987-1995) to obvious decline (1995-1998) to being under basic control (1998-2000). (Desheng Yang et al. 2002) From 1987 to 1995, Shenzhen was witnessing growth at an ultra-high speed. A large number of construction projects and lack of regulated policies aggravated soil and water loss. From 1995, Shenzhen paid attention to soil conservation, and as shown in Figure 3.12, the amount of soil and water loss is reducing in evidence. After that, the city saw inertial development and with less land usable for construction purposes and fewer construction projects, there was little change in the area of soil erosion. However, since 2000, soil erosion intensified again, mainly due to the increase in illegal construction activities that violated the law on soil conservation.

3.4 Acoustic Environment

Data on the environmental noise levels of Shenzhen in this decade and their up-to-standard rates are shown in Table 3.2. During 1996-2006, the average noise level of this city had declined year after year, and in general, Shenzhen suffered from slight noise pollution. Domestic noise and traffic noise are the main sources of noise pollution in the city.

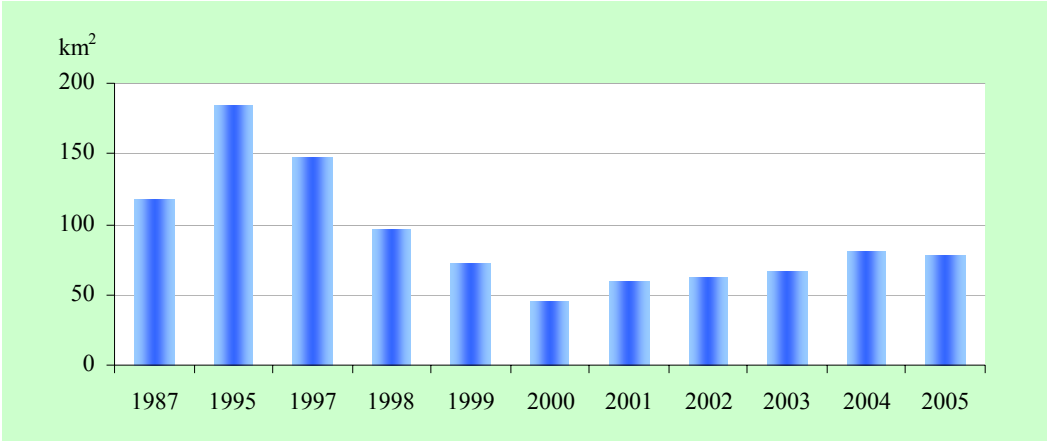


Figure 3.12 Changes of soil and water loss areas in Shenzhen, 1987, 1995-2005

(Source: EPB d, Desheng Yang et al 2002)

Table 3.2 The Average Noise Levels and the Up-to-standard Rates, 1996-2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Average dB (A) dB (A)dB（A）	58.0	57.2	57.2	57.1	57.0	56.1	56.0	56.0	56.1	56.2	56.5
Up-to-standard rate (%)	—	81.3	80.7	81.0	—	87.5	91.6	88.7	87.3	86.2	84.7

(Source: EPB a, b, d)

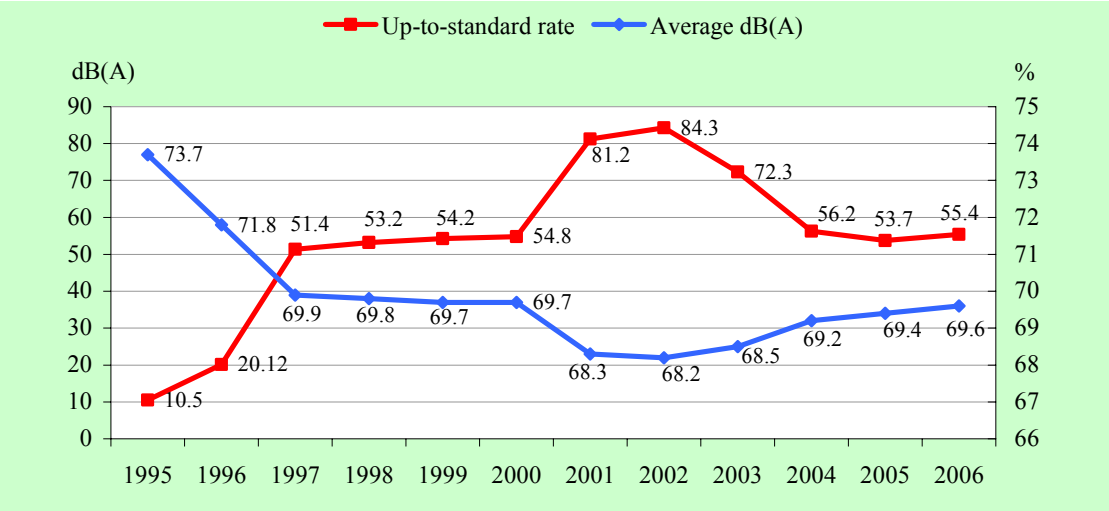


Figure 3.13 Average Traffic Noise Level and Up-to-standard Rates in Shenzhen, 1995-2006

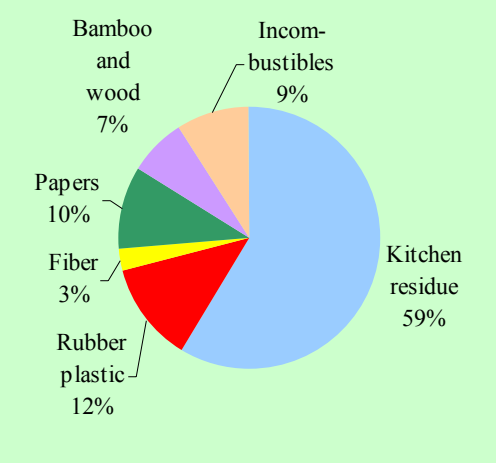
(Source: EPB a, b, d)

From 1995-2000, in order to hold down the noise pollution caused by traffic, Shenzhen regulated the traffic orders and improved the road facilities. As a result, the traffic noise level declined remarkably, and the acoustic environmental quality was improved due to lower vehicle density despite the increase in the number of vehicles. Since 2000, with the year-on-year increase in the number of in-service vehicles across the city, traffic noise level has risen again. In 2006, the average road traffic noise level in the city reached its peak, and the up-to-standard rate was the lowest. (Figure 3.13)

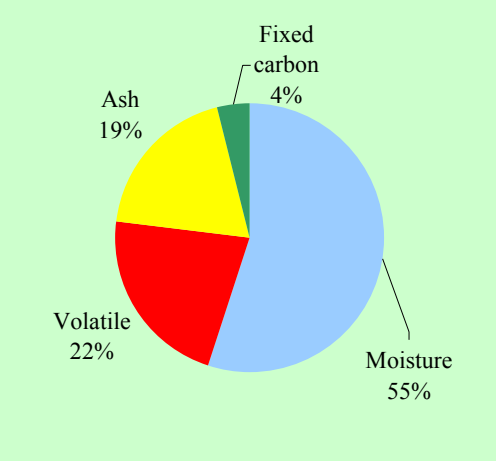
3.5 Solid Waste

Urban solid wastes fall into four categories, as domestic wastes, construction wastes, general industrial solid wastes and hazardous wastes. Since 1996, all of the four kinds of solid wastes have increased to varied degrees. In 2005, there were 3.33 million tonnes of domestic wastes in this city, 752 000 tonnes of which were incinerated. There were 563 500 m^3 of construction wastes and 830 000 tonnes of general industrial solid wastes. A total of 186 800 tonnes of hazardous wastes (32 kinds) were collected and disposed, and so did 2 864.11 tonnes of medical wastes.

The basic components of domestic wastes in Shenzhen and their respective proportions are shown in Figure 3.14, which reveals the major components and their caloric values. Among them, kitchen residues are the main urban domestic wastes, their low caloric value being up to 5 289 kJ/kg. Kitchen wastes mainly include solid wastes like residues and liquid wastes such as swill oil. Shenzhen has a well-developed catering industry. There are nearly 10 000 restaurants of a certain scale and more than 30 000 catering sites. Therefore, lots of kitchen wastes are produced, accounting for about 60% of the urban domenstic wastes. According to the estimates of UMB, around 2 380 tonnes of kitchen wastes are generated on a daily basis from hotels, restaurants and dining halls of this city.



Percentages of all wastes (by weight) (%)



Industrial Analysis Results (%)

Figure 3.14 Components of Domestic Wastes in Shenzhen

(Source: EPB a)

In addition, Shenzhen has lots of electronic wastes (known as e-wastes). In 2005, 200 000 or so computers were phased out across the city. Those wastes contain plenty of hazardous substances (e.g., Pb, Cd, Ni and other metals and their compounds) and some valuable metals (such as Cu, Au, Pd, Ag), so they will impe considerate ril the environment with considerate out proper disposal.

At present, eight facilities are built and operated for the harmless treatment of domestic wastes (five for incineration treatment and two for sanitary landfill). Four are under construction with the potential treatment capacity up to 5 200 tonnes/day. By the end of 2005, ten garbage transfer stations had been built up.

3.6 Coastal and Marine Areas

Shenzhen has 229.96 km of coastline, including 154.69 km in the east and 75.27 km in the west. The sea areas under its jurisdiction include four coastal areas, namely, northern part of Dapeng Bay, western part of Daya Bay, Northern part of Shenzhen Bay and Southeast of Pearl River Estuary, accounting for 1 145 km^2.

Affected by the development activities along the coastal zone as well as the inland rivers, water quality of the coastal areas presents spatial difference. In eastern coastal areas, development activities have been under rigorous control, so there's slight pollution, and the main sources of pollution are domestic garbage and land pollution sources in Yantian District. Water quality in this area comes up to national Grade II standard for seawater, the major pollutants including inorganic nitrogen, active phosphate, oils and COD have declined indistinctively, coliform has dropped sharply, and the overall water quality turns out to be a little better. Western coastal areas belongs to the Pearl River Estuary marine area. The Pearl River system sends plenty of sewage that is discharged along the banks to the Pearl River Estuary, causing serious pollution in the estuary. Pollutants from some areas of Hong Kong and those from Shenzhen River (Bay) and Bao'an District affect the water quality in the west as well. Water quality in this area is worse than Grade IV standard. The major pollutants including inorganic nitrogen, active phosphate and oils are in a downsliding

trend, coliform rises drastically, and the overall water quality is degenerating.

As inland rivers that run into the sea have abundant nutrients, which causes a rise in nitrogen, phosphor, and other nutrients in seawater, red tides have occurred sometimes in coast and marine areas. Among others, Dapeng Bay and Shenzhen Bay suffer from frequent red tides. According to incomplete statistics, in the 1980s red tides occurred once or twice every year in Shenzhen, whereas since 1990, the number has risen to four or five times almost every year and the coverage of red tides has grown as well. In June 2002, sea areas of 250 km^2 were affected by red tides in Shenzhen Bay. Up to now, 31 coastal observation stations have been established to monitor the occurrences of this phenomenon.

Table 3.3 Monitoring Results of the Coastal Seawater Quality in Shenzhen, 2001-2005

Unit: mg (Coliform: Unit/L)

Marine areas	Ye ar	COD_{Cr}	Active Phosphate	Inorganic Nitrogen	Hg.	Cu.	Pb	Petroleum materials	Coliform
Eastern	2001	1.55	0.002	0.230	0.00002	0.0013	0.0008	0.05	3 320
	2002	0.97	0.010	0.128	0.00002	0.0007	0.0008	0.03	370
	2003	0.65	0.003	0.056	0.00002	0.0015	0.0006	0.03	710
	2004	1.45	0.002	0.041	0.00002	0.0018	0.0006	0.03	310
	2005	0.83	0.003	0.066	0.00002	0.0015	0.0011	0.02	130
Western	2001	2.16	0.090	1.538	0.00002	0.0041	0.0010	0.05	7 100
	2002	1.36	0.071	1.571	0.00002	0.0020	0.0008	0.03	5 900
	2003	1.41	0.104	1.442	0.00002	0.0024	0.0011	0.03	4 400
	2004	1.72	0.069	1.448	0.00002	0.0040	0.0007	0.02	15 000
	2005	1.19	0.066	1.379	0.00002	0.0033	0.0009	0.03	58 000
National Grade II standard for sea water		3	0.030	0.300	0.0002	0.0100	0.0050	0.05	10 000

(Source: EPB a)

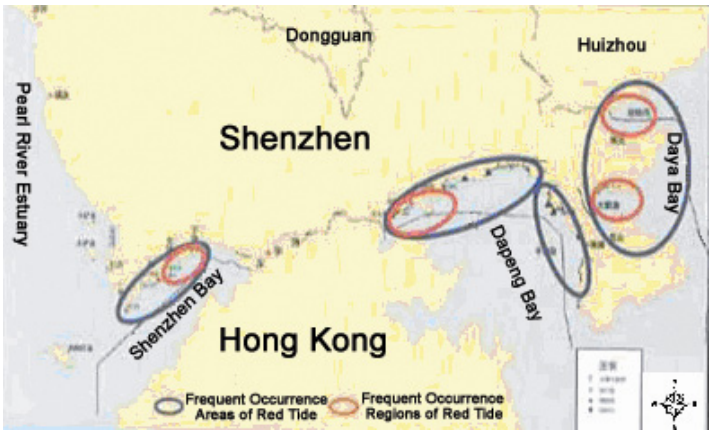


Figure 3.15 Sea Areas Frequented by Red Tides in Shenzhen

(Source: SzAFFB 2002)

Table 3.4 Frequency and affected areas of Red Tides in Shenzhen

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Frequency of red tides	1	0	7	1	6	10	7	10	6	0
Maximum area affected (km^2)	—	—	—	—	5	50	250	50	40	—

(Source: SzAFFB 2002, SOA a, b)

Water Environment of Shenzhen River (Bay)

Shenzhen River is the boundary river between Shenzhen and Hong Kong. Its drainage area is 313 km^2, and it flows towards southwest into Shenzhen Bay. With the rapid economic growth in the two cities, a lot of sewage water is discharged directly to the river, and the pollutant load far exceeds its self-purification capacity, so the water environment of Shenzhen River was badly affected. Water quality in the middle and lower reaches of the river is far from reaching the national Grade Ⅴ standard for surface water quality, and the river presents the phenomena of black color and odor.

Table: Changes of Water Quality of Shenzhen River

Unit: mg/L

Year	Permanganate Iindex	BOD_5	Ammonia-Nitrogen	Total Phosphorus	Volatile Phenols
2001	7.07	13.0	7.72	1.507	0.016
2002	9.93	16.7	10.64	1.353	0.024
2003	10.64	17.4	12.19	1.355	0.056
2004	8.34	11.9	11.10	1.269	0.012
2005	10.29	15.6	9.86	1.193	0.007

As a great deal of domestic sewage is discharged into Shenzhen Bay, it suffers from increasingly serious eutrophication. In recent years (except in 2005), Shenzhen Bay has witnessed red tides every year. Among others, red tides occurred in Shenzhen Bay and the east part of Pearl River Estuary, which were caused by Gyrodinium instriatum and Skeletonema costatum and affected 250 km^2 areas, on June 1, 2002.

Table: Frequency of Red Tides in Shenzhen Bay, 2001-2005

Year	1998	2001	2002	2003	2004	2005
Frequency of red tides	2	3	3	3	1	0

Confronted with the serious situation of the water environment in Shenzhen River (Bay), Shenzhen and Hong Kong governments have reached a consensus on harnessing the river, and by now three phases of the harnessing project have been finished, leading to an improvement. However, there remains arduous work in the cooperation on dredging the river, and the two cities will also act together to harness Shenzhen River mouth and the upper reaches of Shenzhen River (Liantang River) and to begin the river bottom sediment dredged project.

Dameisha Coastal Bathing Beach in Eastern Marine Area
(Source: EPB)

Nan'ao Red Tide in 2004
(Source: Xinhuanet)

3.7 Biodiversity

As the city expands gradually, and the coverage of the built areas grows constantly, human activities aiming for development have significantly disturbed the natural ecosystem. Urban ecological land gradually shrinks in the city, and the ecosystem has an increasingly fragmentation trend.

Urban construction activities once caused great damage to the mangrove ecosystem, resulting in substantial decline of the amount of birds and shrunk biodiversity. Among others, Futian Mangrove Nature Reserve, which is located in the margin of the built area, is threatened greatly.

According to the statistics in the end of 1994, up to 1.48 km^2 of areas in the nature reserve is occupied by various means, accounting for 48.8% of the area originally approved. Compounded with the impact of noise pollution, the species of land birds have declined by 36%, and their number has been down by 34.7%; the species of rare land birds have decreased by 38.5%, and that of rare waterbirds have shrunk by 54.4%; mangrove Bruguiera gymnorhiza is facing to extinction. (Bosun Wang et al 2002) During years of ecological construction, the ecological resources in this reserve were under effective protection, and the number of species rose up steadily. Right now, nearly 400 species of wild birds inhabit here, about 50 more than that of

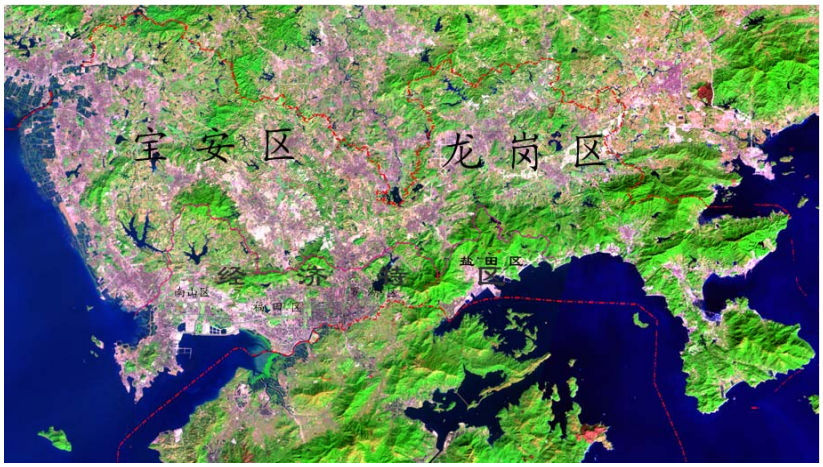


Figure 3.16 Map of Shenzhen by Remote Sensing Technology

seven years ago. The bird species are dominated by Pycnonotidae, aigret, gull, and Anatidae, and include more than 50 species of national key protected birds such as hawks, white stork, white aigret, and Chinese goosander and more than 10 species of endangered birds like glede, Black-Headed Gull and Platalea minor (Black-faced spoonbill). Platalea minor is one of the most rare bird species in the world. According to statistics from 1999 to the winter of 2000, only 702 Platalea minor lived on this planet, 178 of which were in Shenzhen Bay. From 2000 to the winter of 2001, the number of such bird reached 252 in Shenzhen Bay. During 2005 and the winter of 2006, the number reached a new high to 320-plus, accounting for more than 21% of the world total.

State of Futian Mangrove Reserve

Mangrove in Shenzhen

There's a national nature reserve in Shenzhen, as Neilingding Island-Futian Nature Reserve, which is composed of Neilingding Island Macaca mulatta Nature Reserve and Futian Mangrove and Bird Nature Reserve. The national reserve totals 9.22 km^2. Among others, Futian Mangrove and Bird Nature Reserve is the only and smallest national nature reserve located deep in city hinterland for the protection of forests and wild animals.

Futian mangrove forest is in the northeast bank of Shenzhen Bay, and divided by the water with Mifu Nature Reserve of Hong Kong Special Administrative Region. The two reserves create a wetland ecosystem that is of international significance in Shenzhen Bay. There are 16 species (falling into nine families) of mangrove plants in Futian Mangrove Reserve, mainly Kandelia candel, Bruguiera gymnorrhiza, Parmentiera cerifera Seem., Avicennia marina, Sonneratia caseolaris, etc.. The thick mangrove forest starts from Xinzhou River mouth in the east, and reaches the Coastal Eco-Park in the west, forming a "Green Great Wall" of nine kilometers along the coastline and covering about 3.68 km^2. More than 100,000 migratory birds preparing for long-distance migration made a stopover at Shenzhen Bay every year. The Bay is one of the important "transfer stations", "stopovers" and "fuelling stations" of the migration passage for migratory birds in the Eastern Hemisphere.

In order to protect the ecological balance of the mangrove forests and retain the birds' habitat, in 1997 when the Binhai Road was under construction, Shenzhen especially built a green land slope for sound insulation. It built more than 400 meters of sound-proof glass wall and opened ecological corridor such as culvert pipes. In 1999, the west end of the mangrove forests was built into a coastal eco-park. At the same time, a domenstration demonstration project was under way to restore the mangrove forest, and the project covered 1.4 km^2. With an estimated investment of RMB 360 million Yuan, the project fell into five sub-projects on water purification at the river mouth, the restoration remediation of the mangrove forest, popular science education base, transformation reconstruct of the patrol road and the mangrove theme park. It is scheduled to carry out the project to transform reconstruct the patrol road and purify the water at the river mouth in 2007, and finish by 2010. This project will greatly raise the overall ecological value of the mangrove nature reserve, and return a primitive original and beautiful coastal scene to Shenzhen citizens.

Another study indicates that the number of Macaca mulatta in the Neilingding Island Macaca Mulatta Nature Reserve increases at an annual rate of 8.8%, and the current number may be over 1 000.

Although the urban natural ecosystem are affected greatly by human activities, this city saw a sharp increase in the area of artifical green land due to effective measures and mild and humid climate. In 2006, 43.4% of the city was covered by forests, and 11.95% of it was nature reserves. There were 440-odd parks of various kinds across the city, over 100 more than that of seven years ago. 45.0% of the built area was forested, 39.1% of the built area was green land, and the per capita green areas reached 16.02 m^2, 1.82 m^2 more than that of seven years ago. (SzSZD 2007b)

As Shenzhen experiences rapid growth in the international trade, tourism, and transportation, the invasion of alien flora species has accelerated as well, causing damages to the local species, natural plant community, ecosystem, and landscape diversity as well as causing economic losses. At present, there are nine varieties of alien invasive species endangering Shenzhen most, including Mikania micrantha, Mimosa sepiaria, Eichhornia crassipes (Mart.) Solme, Ipomoea cairica (Linn.) Sweet, Lantana camara, Eupatorium catarium, Alternanthera philoxeroides, Wedelia trilobata, and Eupatorium odoratum. Among them, the spreading Mikania micrantha imposes the most serious impacts. (Yinong Li et al 2007)

Twenty years ago, Mikania micrantha was introduced into China as a kind of plant to protect the beach. However, in recent years, this plant has spread rampantly in the Pearl River Delta. 26 km2 of Shenzhen suffers from this, and 2.6 km^2 of forests suffer most. At present, Shenzhen is trying to control the damage by physical and chemical methods, in addition to the simple biological methods. But the results are not so satisfactory. (Zhifang Shao et al 2006)

3.8 Environmental Changes and Human Well Being

The welfare of city residents is affected by many factors, one of which is the environmental changes in the city. Environmental changes mainly influences living conditions of residents, including air quality, domestic water quality , inhabiting conditions, and green areas. (MEA 2005)

I Air Quality

A lot of international and domestic studies correlate pollutants in the air with people's diseases. Therefore, ambient air quality has great influence on people's health, and it is one of the important factors affecting the residents' welfare. Shenzhen enjoys good air quality, which meets national Grade II standard, and the number of days with good air quality has long been around 350 every year. However, despite good air quality at large, the concentrations of SO_2, NO_x, inhalable particulates and other air pollutants are still high, threatening the residents' health.

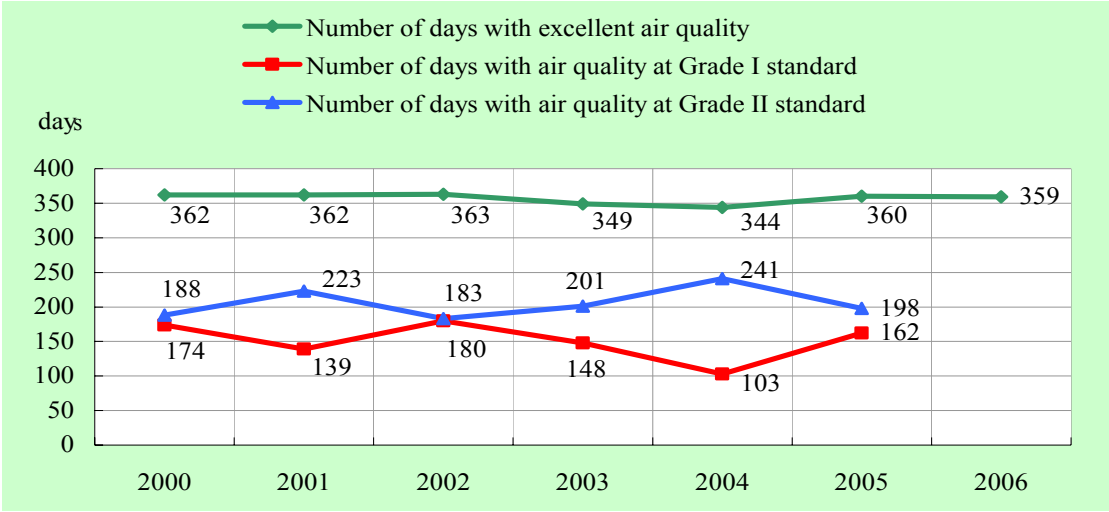


Figure 3.17 Air Quality of Shenzhen

(Source: EPB a, d)

II Domestic Water Quality

There's a sharp conflict between the supply and demand of water resources in Shenzhen. The quality of surface water fails to meet the needs of residents, so more than 80% of water is supplied from sources out of Shenzhen. Although water transfer from sources out of the city has increased the cost for water supply, objectively, this has ensured that urban residents have access to clean drinking water, and so the residents' health is affected little by polluted water. The popularization rate of tap water in Shenzhen rose up from 97% in 2000 to 99.8% in 2004, and the overall up-to-standard rate of tap water remained very high. Meanwhile, such rate of water quality at the drinking water sources has kept above 96% except lower in 2001. This has played a positive role in keeping the infective diseases that are caused by unclean drinking water from pervasion.

III Inhabiting conditions

Shenzhen sees increasingly expanding population, which has sustained demands for housing. This has accelerated the expansion of urban infrastructure to some extent. Compounded with the limited land resources and higher construction costs, the price of real estate has increased year by year. More commercial houses have resulted in the sustained increase of per capita housing area, which was up to 22.75 m^2 in 2004.

Table 3.5 Popularization rate and up-to-standard rate of tap water in Shenzhen

Year	2000	2001	2002	2003	2004	2005
Popularization rate of tap water (%)	97.0	—	98.5	99.8	99.8	99.8
Comprehensive up-to-standard rate of tap water (%)	—	99.60	99.60	99.60	99.8	—

(Source: SzSB 2006)

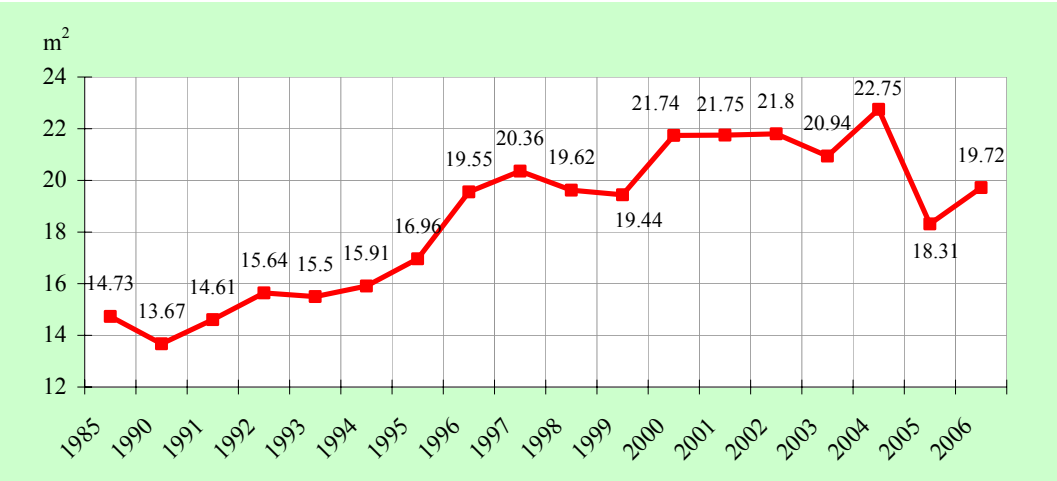


Figure 3.18 Changes of per capita housing area in Shenzhen, 1985, 1990-2004

(Source: SzSB 2006)

IV Green Areas

The urban natural ecosystem are gradually fragmentized, and the land used for ecological purposes decreases, but when the development activities has reached a certain degree and the city adopts effective measures like greening, the area of green lands grows year after year. As is shown in the decade's changing trends (1992-2002), in the built area where there're dense buildings, the areas of total public green lands and per capita public green areas see increase every year. In recent years, the public green lands all over the city have increased as well, so has the per capita number. In 2004, per capita public green areas came up to 16 m^2.

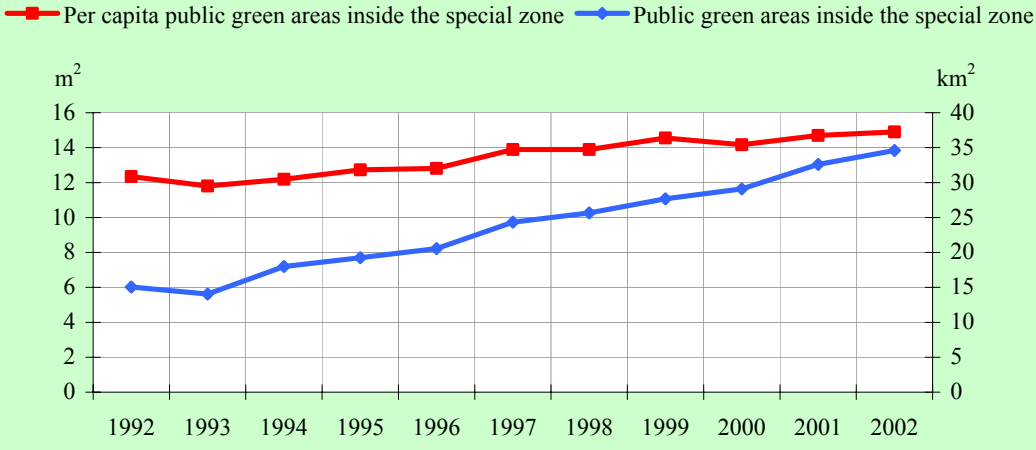


Figure 3.19 Changes in public green areas inside the special zone of Shenzhen, 1992-2002

(Source: SzSB 2003)

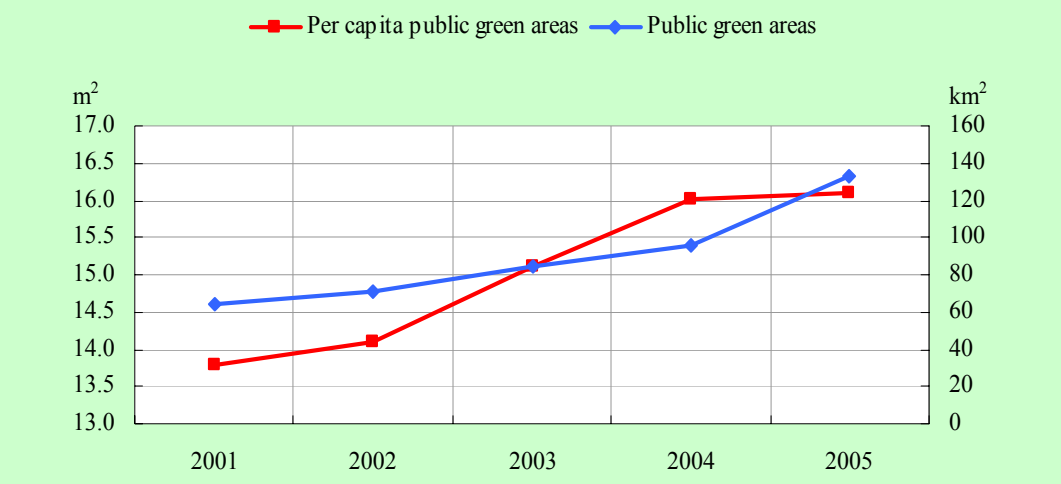


Figure 3.20 Changes in public green areas in Shenzhen, 2001-2005

(Source: SzSB 2006)

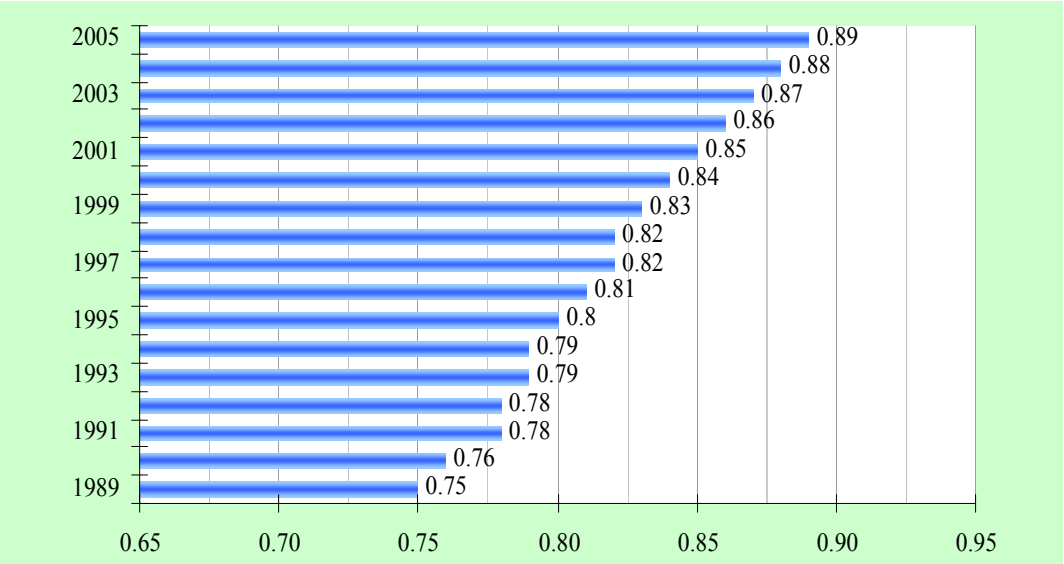


Figure 3.21 Changes HDI in Shenzhen, 1989-2005

V Human Development Index (HDI)

In the process of rapid urbanization, although the city faces serious environmental challenges that have adverse impacts on the residents' welfare, the fast-growing economy and increasing supply of social services have upgraded the urban residents' life quality. In terms of the Human Development Index (HDI)[1] proposed by UNDP, Shenzhen's HDI has

1 Human Development Index (HDI) is an integrated index that measures the average achievements of the three aspects in human development. A long and healthy life is expressed as the life expectancy when one is born. Knowledge is indicated by the literacy rate of adults and the enrollment rate of high, secondary, and primary schools. Decent life is shown by the per capita GDP calculated by Purchasing Power Parity. And then the weighted average method is applied to calculate the indexes of the three aspects. The arithmetical average value of the three indexes is the Human Development Index (HDI), which ranges from 0 to 1. The closer the HDI is to 1, the higher is the country's economic and social development level.

been rising constantly, up from 0.75 in 1989 to 0.89 in 2005. The figure is higher than that of medium-income countries (0.774) and close to that of high-income countries (0.91). (UNDP 2005) As shown by this index, Shenzhen residents enjoy good benefits as a whole, but there leaves much room for further progress as for the vulnerable people in vulnerable areas.

3.9 Environmental Changes and Urban Vulnerability

The frangibility of the city refers to the sensitivity of the urban environment, population, socio-economic systems or sub-systems to the disturbances. It is the integrated evaluation of the impacts imposed by exterior environmental changes on the artificial urban environment, socio-economic system, and human well being, etc..

The following are some signs of frangibility of Shenzhen. The rapid and high-level urbanization almost causes the city's natural ecosystem to vanish, and replaces them by dense man-made buildings such as houses, industrial parks, and infrastructure. The ecosystem of this city is fragmentized, while man-made environment is vulnerable to the changes of environmental conditions. The city is developed on the basis of its own geological conditions, which results in hidden troubles of geological disasters. The shortage in resources has hindered the city's development, causing unstable factors. What's more, under the current city administration regime, a lot of floating population interacts with the city's society, economy and environment. Urban vulnerability presents two features.

First of all, the overheated urbanization process leads to regional frangibility, and it behaves that the existence of villages-in-city in Shenzhen. According to present statistical data, there are 241 villages-in -city (as administrative villages), including 91 inside the special zone and 150 out of the special zone. In the villages-in-city that dotted Shenzhen, there are only over 200 000 aborigines but up to six to seven million floating population. 48.7% of the transient population in Shenzhen lives rent houses in the village-in-city. （SzPB 2005）

Product of Rapid Urbanization
— Village-in-City

In the process of rapid industrialization and urbanization, with the growing economy and expanding population, the development of Shenzhen extends from the city proper to the suburbs. Due to problems involving construction capitals, land acquisition, demolition and relocation, in the development process, developers keep away from the suburbs and use the agricultural lands and vacant lands that cost less for development of new city districts. As a result, the city begins to surround and mix with the suburbs, creating the village-in-city.

The village-in-city has distinct characteristics in the space environment. That is, high population density, high coverage of buildings, less open space and lower standards of supporting facilities. They become areas n;ot covered by city standards. There're dense buildings in such villages, and the space between most of the houses fail to meet the fire protection criteria, leaving with hidden troubles for safety. The municipal facilities in such villages are outdated and not covered by urban environmental management system. The water supply and drainage and electricity grids are incomplete, and the discharge of sewage water is not integrated into the

sewage treatment network, so that the sewage in the villages is discharged without order, the garbage is dumped randomly, and the sanitary conditions are so poor that they may trigger the outbreak and prevalence of infectious diseases. High-density population results in heavier load for the treatment of domestic garbage, and such villages are often one of the pollutant sources of neighboring rivers. As those villages accommodate too much informal economy and population without full employment or even unemployed, the population grows beyond the capacity of the city to provide jobs, houses and infrastructure. This phenomenon is similar to that of areas experiencing excess urbanization in Latin America. As such villages are not completely urbanized, they are signs of insufficient (or lagged) urbanization in the rapid urbanization process. (Zhikui Xie 2006)

However, the villages-in-city has trimmed the living costs in Shenzhen, meets the steady demands for cheap labor force when this city is growing and experiencing sustained development, and buffers the pressure on the society and economy as lots of floating population flood the city. The low cost for life in those villages has provided lower threshold for low-income groups and newcomers seeking for self-employment in Shenzhen, thus making the city to be more inclusive.

Second, the frangibility caused by industrial mix for low-income groups to address the environmental changes.

Although everybody is affected by some kind of environment, people's ability to adapt to and address environmental changes varies greatly. (UNEP 2002) Of the actually regulated population in this city, over 60% of population with temporary residence cards is engaged in labor-intensive and low-end sectors such as construction projects, house decoration, sectors as Sanlaiyibu, trade and catering services. Due to the constraints of some factors such as poverty and inequity, and the ability to acquire natural resources, most of the people mentioned above live in the villages-in-city. The infrastructures and public services that have been provided according to the total population of with residence cards fail to meet the demands of plenty of floating population. Under the current city management regime, the groups that are engaged in labor-intensive jobs are not guaranteed with political rights, opportunity of children's education, medical insurance and other public services. When the environmental conditions undergo drastic changes, the living situation of these groups is most vulnerable.

The two aspects of Shenzhen's frangibility actually reflect the incompatibility between the city's economic growth and the natural and social systems. These problems will constrain the city's development if not solved on a timely basis.

Gangxia Village - An Epitome of Village-in-city in Shenzhen (Source: www.sznews.com)

Chapter IV Response

Response refers to people's reaction towards the environmental changes. The analysis of the response will enable people to survey their own behaviors, which can be referential to realize sustainable development.

Shenzhen has severe environmental situation and suffering serious environmental pressure under the pressure of rapid economic development. Responding to the impacts caused by environmental pressure, Shenzhen has issued a series of laws, regulations, policies and plans; has actively carried on innovations in the following aspects, as the integrated decision-making mechanism for environment and development, the environmental governance level and capacity building, the public participation mechanism and capacity building, the commercialization of environmental science and technology industry; has increasingly enhanced the capacity building of environmental management, information service, environmental propaganda and education, scientific and technical development; so as to provide basic guarantee for the long-term development of the city's society and economy.

4.1 Administration Structure for Environmental Management

Environmental Protection Bureau of Shenzhen Municipality (EPB) is a special agency in charge of environmental protection and directly under Shenzhen Municipal Government. Apart from EPB, some other governmental agencies, in accordance with their respective functions, take part in certain environmental activities as well. These agencies at all levels guarantee the stability and harmony of this city's environment in accordance with their functions by performing as follows.

- **Environmental management and planning**

The Environmental Protection Bureau （EPB） exercises unified supervision and control of the environmental protection work, organizes, implements, leads and coordinates the city's environmental protection efforts, makes plans and implementary schemes for environmental protection and comprehensive treatment of pollutants, and supervises and inspects the implementation of various tasks in this sector.

- **Water resources and water environment**

The Water Resources Bureau is responsible for the planning and construction of projects on omprehensive treatment of the major watersheds, dredging the inner rivers，and safeguarding the city's water safety. The EPB supervises the pollutant sources and carries out total amount control of pollutants discharge.

- **Acoustic and atmospheric environment**

EPB devides the areas where the noise level is up to standard, and it receives and handles the complaints on noise pollution in the city proper. EPB also sets out the

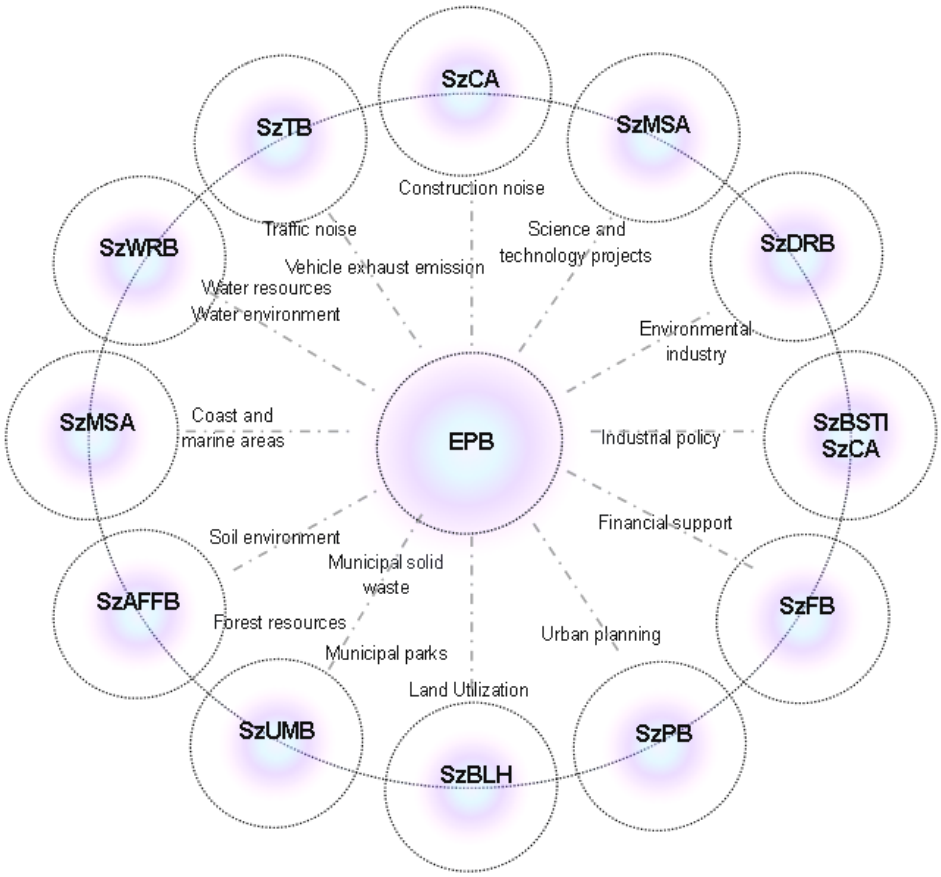


Figure 4.1 Functions and relationships of relevant organizations of urban environmental management in Shenzhen[1]

standards for vehicle exhaust emissions, and the Vehicle Emission Testing Center under this agency supervises the implementation of these standards. The Traffic Bureau (SzTB) intensifies the regulation of the vehicle maintenance agencies, develop public traffic,and optimize the public transport network.. The Construction Bureau, in cooperation with the environmental agency, enhances the noise control in construction sites, and adopts effective measures to reduce the pollution caused by dusts in the construction sites.

◆ Soil environment

The Agriculture, Forestry and Fishery Bureau (SzAFFB) makes plans for the rural environmental protection and construction projects, tightens the control of pollution caused by poultry, cattle, chemical fertilizers and pesticides, and cuts down the non-point pollution in the agricultural sector.

◆ Solid wastes

The Urban Management Bureau (SzUMB) makes overall plans for the rational layout of domestic garbage treatment facilities across the city, builds garbage landfill sites and incineration facilities that are financed by the city government, supervises the dumping of domestic garbage, silts and residue soils, urges simply-built landfill sites to build leachate treatment facilities, and enhances the control of soil-transporting vehicles so as to reduce the dust pollution.

◆ Coastal and marine environment

The Marine Affairs Bureau establishes and perfects the mechanism to prevent and control the pollution caused by ships, and sets up and develops the marine pollution emergency response system within Shenzhen jurisdiction. It supervises the pollution of marine environment caused by ships in the water area under jurisdiction and investigates the pollution accidents, and supervises the work to remove the solid floating substances in Shenzhen sea area. SzAFFB intensifies the marine protection work, builds artificial reefs, tightens the regulation of offshore and shoal cultivation areas, and mitigates the pollution of sea area caused by offshore cultivation.

◆ Ecology

EPB promotes the ecological conservation and construction in a unified way. The City Management Bureau is in charge of the building and protection of scenic spots, and municipal and suburb parks. SzAFFB enhances the protection of forest resources, continues to build ecological scenic forests, and works faster to return the orchards to forests. The Bureau of Land Resources and Housing Management (SzBLH) intensifies the regulation of quarries, exercises more control over the pollution caused by dusts in those sites, and urges the quarries with expired contracts to close down and reforest.

◆ Others

SzBTI, SzDRB, SzFB, SzPB and Sz BSTI give supports in terms of industrial policies, examination and approval of environmental protection projects, financial supports, city layouts and environmental policies respectively.

In view of the urban environmental multiple-administrative agency management，Shenzhen has made a series of attempts on organizational form and supervision and law enforcement mechanism.For example:In 2004, when it began to conduct the national pilot projects on supervising the ecological environment, the city set up a leading group for the supersion of ecological environment, which consisted of EPB, SzBLH, SzAFFB, SzWRB, SzBTI, SzMSA and the people's governments of four relevant districts. EPB unified management and supervision，and other functional departments cooperate with each other effectively. The city invents the "Shenzhen Mode" that is worth popularizing nationwide, and 107 pilot cities in the country imitate this Mode.

4.2 Policy and Planning

I Policy and Regulation

As an economically special zone, Shenzhen is entitled to exclusive law-making rights. Since 1992, the city has enacted and promulgated 38 local regulations and rules on environmental protection, including regulations on the environmental protection of the special zone, regulations on the control of noise pollution, and regulations on the management of water resources, which have been formulated with high efficiency.

Shenzhen has formed a set of local regulations and policies that meet the international management regime and are compatible with national laws, used the leverage of environmental impact assessment (EIA), treated pollutant discharge as limiting factor and controlled

the environmental pollution and ecological damages from the source, so as to vigorously promote the achievement of a resource-saving society.

On the basis of implementing the laws and regulations of the country as well as Guangdong Province in an all-round way, the city has, according to the local features and local environmental situation, formulated laws and regulations that fall into eight parts, including laws and regulations on comprehensive environmental protection, environmental management of construction projects, environmental pollution control, natural resources and ecological conservation, nuclear safety and radiation, environmental enforcement, supervision and monitoring, circular economy and cleaner production. Among others, there're some original, creative and perspective regulations, for example, the rule to set basic ecological control boundary and the Regulations on the Promotion of Circular Economy of Shenzhen Economically Special Zone, which provides references and experience for other cities. Shenzhen has made some positive achievements on environmental protection through implementing relevant laws, regulations and policies.

◆ Pollutant Discharge Permit System

Since 2004, State Environmental Protection Administration (SEPA) has carried out pilot projects on the pollutant discharge permit in Shenzhen. So the pollutant discharge permit and the collection of discharge fees is one of the major instruments to control industrial pollutant sources in this city.

The survey on the pollutant sources in Shenzhen indicates that there're nearly 20,000 pollutant-discharging enterprises all over the city, and added by the construction projects for land development, the number in need of such permits is estimated between 20,000 and 25,000. Shenzhen issues a new regulation on the control of these pollutant sources, that is, enterprises that discharge pollutants beyond the standards for three times at least shall be punished according to the upper limit of the penalty by law and be cancelled the discharge permits; and enterprises that cause heavy pollution and have no hope of being treated well shall be phased out, closed down or suspended operation. In the second quarter of 2006, Shenzhen announced 14 companies`s pollution behavior, and they were fined more than RMB 50 000 Yuan or cancelled the pollutant discharge permits.

The system for the pollutant-discharging enterprises to make public apologies and commitments in Shenzhen is unprecedented in the country. The Measures of Shenzhen Municipal Environmental Protection Bureau on Cancelling Pollutant Discharge Permits provides that the polluting enterprises, after being cancelled the pollutant discharge permits, shall apply for resuming pollutant discharge only after making pubic commitments on environmental compliance. Since this system was enforced in the end of 2005, remarkable results have been obtained. By now, 15 illegal pollutant-discharge enterprises have apologized to the public, and later inspection reveals no illegal pollutant discharge behaviors among these enterprises.

◆ Environmental Veto Power Regime and EIA Syestem

Since 1993, Shenzhen has added the lists of "Construction Projects Affecting the Environmental Protection" and of "Major Projects under Environmental Regulation" to the Instructive Catalogue for the Investment. By 2001, a total of 1,055 construction projects have been turned down due to incompliance with environmental requirements. In 2002, this number was 933. In September 2003, Shenzhen comprehensively implemented EIA and by 2006, the city has issued 11 documents to enhance the regulation of EIA for construction projects. The documents required for establishing a responsibility system, carrying out the permanent responsibility system and setting up a compensation mechanism for EIA.

◆ Withdrawal Mechanism due to Weak Environmental Protection

In the Instructive Catalogue for the Investment, the enterprises fall into three types, i.e., those enjoying incentive, disincentive and prohibitive development respectively. According to the evaluation on the industrial pollutant sources in this city in 2005, 96% of the enterprises met the standards, but few enterprises with severe pollution still had difficulty in treating pollution. In 2005, Shenzhen established a mechanism, which focused on closing down enterprises with heavy pollution, phasing out outdated technology and productivity, and reducing the total amount of pollutant discharge, so as to shrink the living space of chemical industry, electroplating, leather-making, printing and dyeing industries that cause heavy pollution in local areas.

II Planning

From 1982 to1985, Shenzhen took the lead in studying the regional environmental impact and the urban environmental planning, proposed the environmental requirements and pollution control approaches for the overall economic development process, and conducted environmental assessment on the tourism resources in Dapeng Bay and inside of the special economic zone. Since the concept of the environmental planning was first introduced, during more than two decades' practice and development process, the

Basic Ecological Control Boundary

In order to protect water sources and other ecologically sensitive areas, guarantee the basic ecological security, and prevent disorderly spreading city constructions, Shenzhen issued the statutory plan and the basic ecological control boundary in 2005, in order to stipulate the nature of land uses and guide and control the development intensity.

The statutory plan categorizes the available lands for construction within the planning scope of the three big reservoirs, and proposes to recover the vegetation of the non-available lands for construction. Since the ecological control boundary was introduced, by the end of May 2006, 105 sites have been dismantled, cleared, and recovered as green areas, covering 363 487 m^2 and taking up 93% of the total surface areas undergoing changes. This measure has effectively protected the city's environment, especially the ecological environmental in the reservoir area.

focus of the plans has shifted from the harmony of small environment in a city to the coordination of big environment in the region, from the macro and overall plan to the concrete and special plan, so as to guide the city's environment and the regional environment to take a sustainable and benign road towards development.

Generall Planning

The generall plannings decides the direction of the city's environmental protection. Along with urban development and the need of environmental protection, the city has turned from just incorporating environmental protection into its master plan, to building an ecological city as the development direction, also from the simple local plan changes to the integrated regional plan.

- **Outline of the Plan for Social and Economic Development**

In 1981, Shenzhen began to make plans for its limited land resources, formulated the *Outline of the Plan for Social and Economic Development*, and decided on the structure of "concentrated belts". In 1982 when it formulated the Outlines of the Plan for Social and Economic Development, the city government incorporated the environmental protection into the overall city plan, and explicitly stipulated that in principle, projects that may cause heavy pollution shall not be introduced, and the projects that cause light pollution and have high energy consumption shall be strictly restricted.

- **Urban Master Plan of Shenzhen （1996-2010）**

According to the *Urban Master Plan for Shenzhen* (1996-2010), Shenzhen decided to establish three development axes in the west, middle and east parts of the city. Shenzhen also made plans for the city parks and virescence, cultural facilities, and environmental protection, and set the goal to build an "eco-city". In 2006 the city finished the plan for building an eco-city.

- **Urban Environmental Protection Planning (Based on Outline of the Environmental Protection Plan for the Pearl River Delta)**

The *Outline of the Environmental Protection Plan for the Pearl River Delta*, which was adopted and implemented in 2003, is also one of the important plans to refer to while making environmental protection strategies. The Pearl River Delta has dense population and insufficient resources. Being poorly planned, the Delta suffers from a sharp conflict between the ecological environment and the economic development. Besides, due to the special geological location and the climate conditions, the pollution in this Delta has distinctive regional characteristics, so Guangdong Province issued the *Outline of the Environmental Protection Plan for the Pearl River Delta.* According to this *Outline*, Shenzhen made its own environmental protection plan, and in order to carry out this plan better, the city also formulated a number of sub-plans, so as to achieve the best results. The plan devides the ecological function zones, sets the city`s environment capacity and the environmental baseline , makes the economic layout that is compatible with the environmental capacity and resources, and guides and develops circular economy.

◆ **Plan on Building an Eco-City of Shenzhen**

In order to carry out the *Decision of the State Council on Implementing the Outlook on Scientific Development and Strengthenin Environmental Protection* and fulfill the spirits of the sixth National Conference on Environmental Protection in an all-round way, Shenzhen decides to build an eco-city and makes it to be one of the important development strategies under the Eleventh Five-Year Plan. It finishes the *Plan of Shenzhen on Building an Eco-City*, and kicks off this work in an all-round way.

Special Planning

◆ **The Special Plans are Designed to Design Specify the Macro Plans with Detailed Arrangements.**

Overall Transporation Plan of Shenzhen for and Public Transporation Plan of Shenzhen

To mitigate the traffic jams and the arising air pollution, in 2006 Shenzhen formulated the *Overall Transporation Plan of Shenzhen for and Public Transporation Plan of Shenzhen*, and proposed a development strategy to give the priority to developing public transportation, to mitigate the growth of small auto vehicles, and to create a people-oriented pedestrian traffic space. It also set out the goal to raise the proportion of the public transportation among the total passenger vehicles to more than 60% and to reduce the total vehicle emissions by 30% by 2010; and by 2030 the share of public transporation will increase to over 80%, and the total vehicle emissions will be down by 75%.

◆ **Plan for Mangrove Protection and Development of Shenzhen**

To protect the mangrove, the rare natural resources in this city, in 2006 Shenzhen compiled the *Plan for Mangrove Protection and Development of*, *Shenzhen* proposing to restore 3.35 km2 of mangrove wetlands in the next ten years, the restoration rate being 100%.

◆ **Overall Plan for Marine Areas Development and Utilization of Shenzhen (1998-2010)**

By formulating such a plan, the city defines the main function and utilization scope of the marine resources in a scientific way, clearly explains and defines the direction and degree of sea area development, and strengthens the examination and approval of marine projects and the offshore construction projects.

4.3 Projects and Measures

According to the strategic goal to build a high-grade eco-city, in the process to implement the laws, regulations and plans, Shenzhen has adopted a number of measures that have local characteristics, and by employing EIA process and applying pollutant discharge as limiting factor，the city controls the environmental pollution and ecological damages at the sources, in order to achieve an environment-friendly society.

I Comprehensive Measures

◆ **The Clean Environment, Smooth Traffic and Quiet Neighborhood Project**

In 2003, in order to solve the problems

brought about by rapid economic growth and the sharp increase in the population, such as the environmental degradation, traffic jams, and bad public security conditions, the city began to implement the Clean Environment, Smooth Traffic and Quiet Neighborhood project. The project includes several sub-projects such as city appearance cleaning, integrated treatment of water environment, air environment purification, treatment of the noise pollution, and quality safety of non-pollution agricultural products, meanwhile, it means to improve city traffic, cope with traffic jams, enhance public security management, and transform villiages-in-city, etc.

◆ Clear-up Action

In 2004, Shenzhen launched a large-scale campaign to treat and clear up the city's appearance, more than 38 million m^2 of the temporary buildings that were built disorderly and that affected the city's appearance were torn down. In order to alleviate the conflict between the land supply and demand, the city transformed the old city districts and the old villages, upgraded utilization grade of warehouse land, and centralized the current scattered lands, so as to meet the land demands of the various industries conforming with the industrial guidance.

◆ Treating Pollution and Keeping A Clean Environment

In 2005, according to the plan of Guangdong Province to treat the pollution and keep a clean environment, Shenzhen made and implemented its own plan of this kind. The project to treat pollution and keep a clean environment is the platform to treat pollution comprehensively. Therefore, a framework for environmental protection is being shaped: the city government takes the lead, the environmental agency makes overall arrangements, all relevant departments take charge according to the division of labor, and all the society takes part in environmental protection.

◆ Target-hitting Project of Industrial Pollutant Sources

In March 2002, Shenzhen began to carry out pilot projects on industrial pollutant sources in an all-round way, and they were assessed, checked and accepted in 2003. 96.9% of the industrial pollutant sources were up to standard. The city also promoted cleaner production and the certification of ISO14000 environmental management system. A total of over RMB 24.76 million Yuan was invested in treating pollution within a limited period, so that COD, and the concentration of SO_2 and soot in the industrial waste gas decreased dramatically.

II Atmosphere

◆ Blue Sky Action

In 2005, administrations including EPB, SzBLH and SzCA jointly launched the Blue Sky Action to treat soot pollution. This action focused on treating the pollution caused by vehicle exhaust emissions, fly dust, and industrial waste gas, and the pollution from the major pollution area in Nantou Peninsula. The city made use of the low-temperature surplus heat from several big thermal power plants of Nanshan District, and by pipelines or mobile tools, supplied heat for neighboring service industries and resident areas. This has not only saved the energy, but also mitigated the air pollution in this district.

III Water

◆ Pearl River Basins Dredging Action (Shenzhen section)

In 2002, according to the decision of Guangdong Provincial Party Committee and the government, Shenzhen formulated an executive plan as the *Implementation Plan for the Comprehensive Treatment of Water Environment in the Pearl River Basin (Shenzhen section)*, signed a responsibility document for the treatment of Pearl River, and organized the implementation activities. The actions included such following aspects as construction of sewage treatment plants, clear-up and rectification of poultry and cattle cultivation in the water sources, comprehensive treatment of watercourse, construction of sewage-interception engineering and vegetation restoring of the quarries. In 2004 the total investment in the treatment of water pollution amounted to about RMB 1 470 million Yuan.

◆ Establishment of Water Sources System

In order to solve the problem of the shortage in water resources, Shenzhen will do more in building water sources projects, use rainwater, flood, and seawater and recycle the reclaimed water. The city will emphasize on promoting the construction of two trunk lines of water sources (Phase II project of the Dongjiang River water sources and the water-diversion project in the north line).

The second phase project of Dongjiang River water sources began in early 2006 and will be completed and put into operation after 2009. By then there will be 370 million m^3 of water being added each year, enabling the total amount of water diversion up to 720 million m^3. The water transfer project of the north line has been started as well and it is estimated to be finished in 2009, with another 350 million m^3 of water being diverted every year. When the two projects come to a conclusion, another 720 million m^3 of water can be taken, and there will be up to 1 590 million m^3 of water being diverted out of Shenzhen. At the same time, Shenzhen will focus on planning and building the “four big jars”, as Tiegang, Gongming, Qinglinjing, and Xiajijiao in Dongjiang River, to increase the reserve capacity of water sources.

IV Solid Wastes

◆ Treatment of Kitchen Residues

In 2006, Shenzhen Environmental Protection Bureau, the Environment and Sanitation Division, and the City Management Bureau organized the surveys on the source, amount, and whereabout of kitchen residues. In July 2006, the city issued the *Measures of Shenzhen on the Management of Kitchen Residues and Waste Edible Grease (draft)*, which forbidden the illegal sales and transport of kitchen residues, further improved the kitchen residue treatment and regulation system, and introduced the whole-process regulation of such residue, i.e., the manifest management system comprising its production, collection, transportation, disposal and use.

SzUMB will conduct pilot projects on the treatment of kitchen residues in Luohu District, Futian District, and Nanshan District, and establish a system to recycle kitchen residues so as to maximize the use

Efforts to Dredge Rivers in Shenzhen

Water environmental capacity of Shenzhen is relatively small, while the total population and economic aggregates is quite large, thus the discharge of wastewater is correspondingly large. enlarged

Though the scale of sewage treatment plant and the disposal rate of sewage increased year by year, there are still much sewage discharged into rivers directly. The water quality of several river sections that flows through the urban area is worse than Grade V. In recent years, Shenzhen has taken the control of water pollution as the top priority of the environmental protection work, adopted a series of measures and actions and achieved some progress.

◆ Improving urban environmental infrastructure and supporting facilities

In recent years, Shenzhen has accelerated the construction of environmental infrastructure. At present, the number and disposal capacity of sewage treatment facilities are in the first ranks among the key cities for environmental protection, including eleven centralized sewage treatment plants, three river water purification projects, three artificial wetland systems and one constructed rapid infiltration system. As the number and disposal capacity of sewage treatment facilities increased sharply, the water environmental quality has been stabilized in recent years and is expected to be improved when the large-scale sewage treatment projects would have been implemented from now on.

◆ Comprehensively treating the pollution in Shenzhen Bay

Shenzhen River is the boundary river between Shenzhen and Hong Kong, and Shenzhen Bay where Shenzhen River, Dasha River and other rivers run into is shared by the two cities. At present, the water quality of Shenzhen Bay is polluted seriously, which bring negative effects to urban landscape and image. So the pollution problem has been widely concerned by citizens of the two cities. For this reason, Shenzhen proposes a guideline to treat the pollution as “clearing up the sources, cutting off and restricting the sewage discharge, recovering wastewater, and supplementing water by ecological methods”

“Clearing up the sources”: It means to start from the sources, and to completely separate the rainwater from sewage from the household outlet and the drainage pipe of the resident communities, to the main drainage pipes.

“Cutting off sewage”: It means to implement this project to cut off 90-95% of sewage.

“Restricting sewage discharge”: It refers to reducing the discharge amount and restricting the pollution load of the discharged pollutants.

“Recovering waste water”: It means to change the sewage into resources, and use the reclaimed water for municipal, greening and residential purposes.

“Supplementing water by ecological methods”: It refers to using the tail water to restore and rebuild the ecological environment of rivers in Shenzhen, and inhibiting the salty tides from running upstream.

Shenzhen has also planned nine sewage treatment plants, including five new being built ones as Futian, Xili, Caopu, Pudixia, and Shawan sewage treatment plants, and four existing ones as Luofang, Binhe, Nanshan, and Shekou sewage treatment plants. Besides, Nanshan sewage treatment plant will be extended.

◆ Accelerating the construction of sewage treatment plants outside the special zone and improving the supporting pipes and network of water supply and drainage

Compared with those inside the special zone, there are much fewer and smaller sewage treatment facilities and incomplete sewage pipes outside the special zone. The Guangdong Provincial government sets out higher requirements for the cross-city rivers as Longgang River and Pingshan River, which involve the problem of drinking water sources protection and are outside the special zone. (The water quality in the cross-city sections shall meet national Grade III standard for surface water). According to a series of plans made in recent years, the work to build sewage treatment plants and install supporting pipes has been fully unfolded out of the zone, and more than 17 sewage treatment plants and the supporting pipes will have been completed by 2010, so that most of the sewage discharged from each distrcts out of the zone can be treated properly.

(Source: SzPG 2005)

of them. The three enterprises selected for the pilot projects all plan to process the kitchen residues into the feedstuff additive, and process and refine the waste edible grease into fuels for self-supply or bio-diesel oils and industrial oils. In addition, the city will also make supporting policies for the enterprises engaged in collecting and treating kitchen residues, and enact more laws and regulations on treating them.

V Ecosystem

◆ Vegetation restoring of Quarries

In order to solve the problem of soil and water loss caused by the quarries, Shenzhen carries out research on the *Overall Plan of Shenzhen on the Use of Mineral Resources*, and becomes the first to make an environmental impact assessment on such plan. By the end of 2006, apart from the 12 areas which were restricted to exploit outside the special zone,, no more mining permits has been issued to the other quarries. All the quarries in Shenzhen have been almost restored vegetation.

4.4 Environmental Protection Investment and Capacity Building

During the decade of 1996-2005, the volume of investment in environmental protection has increased continuously, up from RMB 1 729 million Yuan in 1996 to RMB 11 570 million Yuan in 2005. The proportion of environmental protection investment in the total GDP has also increased from 1.86% in 1996 to 2.35% in 2005, being close to that figure in the developed countries. The city government and district-level governments make the inputs in environmental protection as one of the emphases of public expenditure, and with the economic growth, they gradually invest more in the environmental sector. During the Eleventh Five-Year Plan period, the city will invest RMB 30 000 million Yuan in the environmental protection, being equal to the total volume of the previous twenty years.

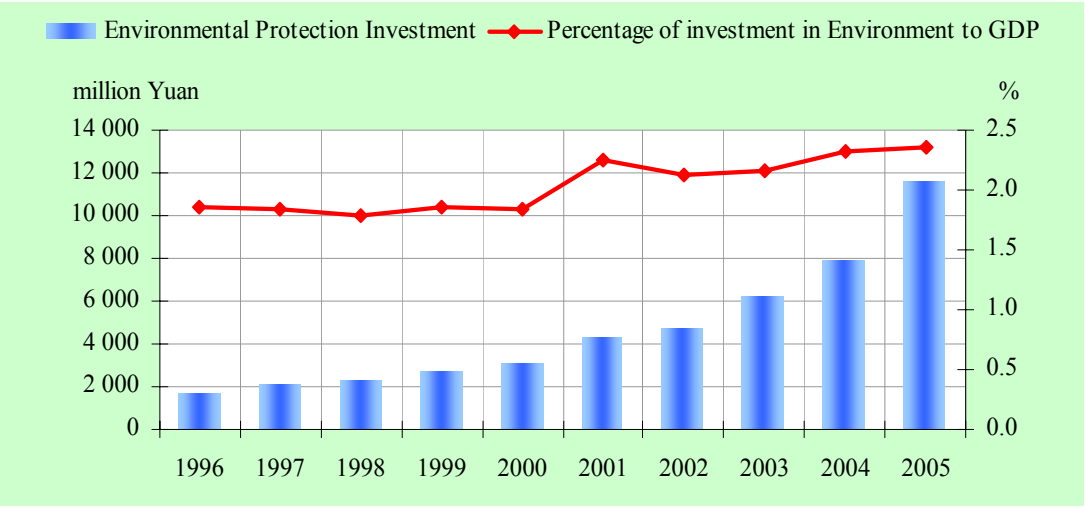


Figure 4.2 Environmental Protection Investment of Shenzhen, 1996-2005

(Source: SzSB 2006)

Meanwhile, Shenzhen enhances the capacity building in environmental protection so as to improve the environmental governance level.

I Environmental Monitoring

Shenzhen has actively explored the possibility to establish a pre-warning system for the environmental monitoring, and then initially established such a system integrating environmental quality monitoring, pollutant sources monitoring, and environmental emergency monitoring. Shenzhen has carried out environmental quality monitoring progressively, mainly about such environmental factors as ambient air, precipitation, surface water, ocean, bathing beaches, soils, tlife forms, noise and vibration, electromagnetic radiation and radioactivity. It has set up 586 sites for environmental quality monitoring, 11 substations for the auto-monitoring of air quality, an on-line control center for the monitoring data, and network of 219 monitoring sites from 200 enterprises, which preliminarily formed a modern monitoring network with two-level which covers the whole city and is operated coordinately by city and district levels. In 2000, standardized quality-control system conforming to the state standards was established in Shenzhen Environmental Protection Monitoring Center. The station has submitted 4.49 million data to the relevant government departments on several environmental factors such as air, rivers and soil, which provided scientific basis and technical supports for integrated environmental decision-making.

II Environmental Supervision

In order to reinforce environment supervision and management, Shenzhen has established an all-inclusive supervising and management system, which introduced the concept of environmental management parts to define targets of environmental supervising and management. All the targets are divided into 11 types of management parts and 43 sub-types, 16 types of management events and 80 sub-types. The management parts are coded and exactly located by GIS, According to the actual conditions of each part like distribution of responsibilities, management power, level, and efficiency, the whole city is divided into 56 grids. By an overall arrangement of the scope, items, tasks and duties of environmental management, an all-inclusive environmental management system is shaped.

Shenzhen has also reinforced the environmental supervision and enforcement, and established the principle of heavy penalty for illegal pollution behaviors. The enterprises will be punished once they discharge pollutants beyond the standards. The pollutant discharge permit system is strictly implemented. If an enterprise discharges pollutants beyond the standards for more than three times or seriously violates the environmental laws, the pollutant discharge permits shall be cancelled and the pollution behaviors should be stopped. Shenzhen created the public apology and commitment system. Enterprises that are revoked the permits shall not reapply for pollutant discharge permits before they apologize and promise to obey the law through the public media. Besides, Shenzhen established the environmental credit system. According to the enterprises' credit grade, different measures will be used as encouraging, rewarding, promoting and punishing All the environmental credit information shall be released to public timely, so that the enterprises with high grade could benefit

from this while those with low grade should be punished.

In 2006, Shenzhen investigated and punished 1934 cases of environmental illegal behaviors, with the total fine up to RMB 39.43 million Yuan. Behaviors seriously violating the laws of 64 enterprises were exposed to the public; the pollutant discharge permits of 15 such enterprises were revoked, 13 such enterprises were forced to apologize to the public and make a promise to improve their behaviors through the media; 30 heads of the illegal enterprises were detained according to the public security regulations, and five were under criminal detention; 435 polluting enterprises (or processes that causing pollution) were closed down or suspended operation. (SzSZD 2007a)

III Environmental Scientific Research

In order to enhance the environmental scientific research capacity and upgrade the research level, Shenzhen adopts a series of effective measures that encourage researchers to devote themselvesto scientific innovations, which include supporting the scientific researcher to participate in environmental scientific research and summarizing experience, carrying out environmental science academic exchanges activities termly, regarding scientific innovations as an important indicator for performance assessment, and rewarding the researchers who have made outstanding achievement in scientific research. For example, Shenzhen Hazardous Wastes Treatment Station issued the *Measures on theAdministration of the Promotion of Technical Development and Translation of the Outcomes (provisional)*, which provides a series of preferential policies on transferring registered permanent residence, arranging houses, occupational promotion, assessing professional qualifications and providing economic award, so as to encourage the technical backbones who have contributed to the research and development, technical transformations,and translation of the scientific outcomes. It has promoted the researchers to participate actively in scientific research development and innovations, so that lots of scientific research projects have been undertaken in the context of having not enough researchers.

Shenzhen has increased the investment in environmental scientific research, so as to enhance the capacity building and improve the hardware conditions of scientific research. Shenzhen appropriates RMB 30 million Yuan every year in awarding environmental protection behaviors and conducting environmental scientific research; invested RMB 20 million Yuan in building research and development base covering an area of 22 000 m^2; established an experimental base building for environmental monitoring covering an area of 10 000 m^2; established an environmental monitoring center which is modern, intellectualized, and multifunctional and meets with the international quality system. All of those have provided a scientific research platform for the environmental scientific research with a high starting point and high quality facilities.

Shenzhen has also strengthened the fostering of qualified scientists and technicians in environmental protection, actively trained innovative scientists and technicians, and rationally allocated them

so as to ensure strong scientific research and technical innovation capacity. By the end of 2005, EPB has 367 staff, 257 of whom have undergraduate diploma or higher education background, including two post-doctoral staff, 12 with doctor degree, and 76 with master degrees. 224 staff holds secondary or higher professional titles, including 98 senior engineers (five of them are professional-level senior engineers) and 126 engineers.

Besides, in the environmental scientific research and management, Shenzhen raises funds from various sources to strengthen the environmental scientific research, makes full use of the scientific research power of major institutes, carries out bilateral and multilateral technical cooperation, and focuses on translating the outcomes into practical application by depending on the institutions that apply the scientific outcomes as the scientific research subjects. For example, EPB collaborated with Shenzhen Graduate School of Peking University (SZPKU) to establish Shenzhen international environmental science and engineering research center, so as to take full advantage of the science research capacity of key institutes of higher learning that can provide services for environmental scientific research of Shenzhen.

4.5 Public Participation and Environmental Propaganda and Education

For the past decade, Shenzhen has persevered in its efforts to explore and create a model for environmental promotion and education. With the joint efforts of multi-departments, participation of all citizens, media's active scheming and the enthusiastic response of netizens, a typical Shenzhen Model that is sound and interactive has taken shape. The influence of environmental culture has been driving environmental protection cause to grow in a sustainable way.

I Joint Action of Multi-departments

Joint action of multi-departments is a fresh pattern in environmental propaganda and education. Shenzhen takes the initiative as the campaign of Building a Green Homestead in order to establish a platform for the whole civil society to be involved in environmental propaganda and education. Promoted by the whole civil society, all of the schools in Shenzhen offers environmental education courses and more 300 among them are green schools at all levels. SzWRB organizes various activities under the theme of water saving and SzBTI holds "energy conservation week" every year. Shenzhen also carries out other inspiriting activities of environmental propaganda such as setting up Green Action Day and Civil Environmental Protection Award. All the above well improves the environmental propaganda and education in Shenzhen.

Local environmental NGOs are another new force for environmental propaganda and education. including social organizations as Shenzhen Volunteer Association, Green Club and Shenzhen Bird Watching Society and so on, and campus environmental protection organizations such as Mangrove Association of Shenzhen Graduate School of Peking University. Shenzhen Volunteer Association is the first volunteer association in mainland China and has initiated quite a few coastal clean-ups and cleaning for urban environment, which was

established in Jun. 1990 and gained widespread recognition among local citizens. Such social organizations as Green Club and Youth Volunteer Association of Longgang District jointing with municipal administrations have organized several activities to build a beautiful homestead by their own hands. Shenzhen Bird Watching Society voluntarily organizes bird watching activities every spring or summer in the Mangrove Beach Park in the city center to share general knowledge of birds and ecology with citizens. Mangrove Association of Shenzhen Graduate School of Peking University organizes outdoor activities as directional cross-country and climbing, and leads the students to participate in activities organized by social organizations with their professional knowledge.

II Promoting Public Participation

Shenzhen actively explores pubic participation mechanism to encourage the citizens` participation and interaction, which aims to turn the citizens from educatees to actors as constructors and supervisors of environmental protection.

Shenzhen's pubic participation started at an early stage. In 2000, Shenzhen formulated the first public hearing regulation including 20 rules and held the first public hearing on legislation in China. Since the promulgation of *Tentative Measures on Public Participation in Environmental Impact Assessment* in Mar. 2006, Shenzhen has intensified efforts in public participation. For example, a special public hearing was hold on the Beach Hospital Project in order to solicit the citizens' opinion.

Shenzhen Bird Watching Society

Bird lovers in Shenzhen spontaneously involved themselves in bird watching and photography exchange. Then their activities gradually turned into the fixed subject of bird loving and watching. They have developed into a voluntary promotion group from few initial founders to 20-50 participants with 7 core members. Their activities have found an great echo among the bird watching amateurs in Shenzhen, Guangdong and even the state. In Mar. 2004, Shenzhen Bird Watching Society is officially established.

The Society actively involves itself in bird distribution survey. Since 2003, it has participated in the Global Synchronous Black-faced Spoonbill Census, Synchronous Waterfowl Survey in Asia and Synchronous Waterfowl Statistics in Mi Pu-Houhai Bay. By the end of Apr. 2004, 39 bird species have been added to the witness record based on the previous Shenzhen Bird List, and nearly 200 bird watching records and a number of precious pictures were submitted to record entry center for birdwatchers.

The Society selected Futian Mangrove Reserve as their activity base and organized exchanges among the bird lovers from local and other places as long-term activities.

The Society h cooperated with many institution and bird lovers, including Neilingding Island - Futian Nature Reserve of Guangdong, Futian Education Bureau of Shenzhen, Shenzhen Science and Education Association for Youth, Bird Association of Guangdong Institute of Education, WWF (Hong Kong), Hong Kong Bird Watching Society, Hongkong and Shanghai Banking Corp. and Swarovski HK Ltd., and develop a series of environmental education activities, which has made positive contributions to the biodiversity protection in Shenzhen.

The ordinary residents play an important role in the city's environmental management. For example, EPB invited one hundred citizens to be social environmental supervisors who acted as the "floating sentry", to inform against the vehicles with black smoke running on the road, which effectively helpes the treatment of vehicle exhaust pollution. During the environmental protection

enforcement actions such as Blue Sky Action, many citizens gave up their resting time, and actively took part in supervising and informing against the illegal environmental behaviors.

In order to attract more citizens to participate in environmental protection activities，EPB has taken innovative steps in carrier of environmental propaganda and education, as changing the traditional unilateral indoctrination into interactive activities, that means to lead citizens` enthusiastic will to practice. Shenzhen has defined the first Friday after World Environment Day as Green Action Day, calling on citizens to temporarily give up their cars on this day for a blue sky. About 200 000 residents voluntarily go to work on foot, by bicycles or public transit instead.

Public Participation in Beach Hospital Project

Beach Hospital is designed as a comprehensive hospital with 2000-bed, a total investment of over RMB 2 000 million Yuan and a floor area of 223 000 m^2. It is proposed to locate at No. 16 plot in Sea Filling Area of Shenzhen Bay, which is 500 m. away from the mangrove reserve. Residents in local communities called on to protect the mangrove and protest the building of hospital, by organizing opposing activities such as self-driving for publicity and collecting social signatures in an attempt to oppose the incoming government decision.

Shenzhen government changed its coping strategy under this pressure. The government sent officials to exchange ideas with local residents and published such informations as the location selecting documents and EIA report. A public hearing was held on Jun. 30, 2005 to hear public opinions.

At the hearing, representatives from health, planning and environmental departments reported the relevant informatons on the project, and individual speakers gave their opinions on the location selecting and environmental impact of the project. According to the main points of the statements participants consulted the speakers and representatives from technical institutions on unidentified issues. Both sides argued for 15 minutes on related disputes. Finally the negative side gained the upper hand with a result of 11 negative votes and 9 affirmative votes.

The hearing was held to hear opinions from all quarters on the location selecting and environmental impact of the hospital project. No decision would be made at the hearing. The municipal government will make a sound decision taking full account of public opinions according to the hearing report. The residents in local communities also noted that though the negative opinions gained the upper hand, it was hard to tell how much it could influence the decision-makers. They had to wait for the final result. Local residents will retain the authoritative institute to reassess the environmental impact of the project. The dispute on the location of Beach Hospital has not ended.

(Sources: http://www.szsh.com/NewsView.asp?ID=1871)

III Deep Cooperation with Media

Shenzhen has a deep collaboration with news media, forming an effective network of newspaper, broadcasting and TV programs. The news media has become a major education base for environmental protection. It is not only a reportor covering the environmental news but also an organizer planning environmental protection activities.

In order to publicize the idea and policy of circular economy to the citizens, local government worked with *Shenzhen Special Zone Daily (SzSZD)*, the organ of municipal party committee, to scheme the environmental protection activity as “Experience Circular Economy and Find the Beauty”. SzSZD followed up the activity and made three pages of report, which deepened the understanding of hundreds thousand readers on circular economy. *Shenzhen Evening News* has cooperated with local government for three consecutive years to give comprehensive report of Green Action Day. News reporting begins 10 days before the day and one page at least is devoted for the relevant activities , which has greatly promoted the public participation.

To curb the trend of air pollution, several administrations jointly develop the Blue Sky Action with the theme as soot pollution treatment in winter. To ensure the effect of propaganda, the three aspects of treatment as flying dust, vehicle emissions and industrial waste gas, which should be implemented at the same time according to the original plan, were divided into three gradual stages based on the rules of news reporting, after the consultation with news media. This made the Blue Sky Action became a widely known action for environmental law enforcement and achieved positive results.

IV Expanding Internet Platform

Internet, the modern technology platform, is well used as an expanding form of environmental propaganda and education to promote environmental protection. Shenzhen has upgraded the public website of environmental protection, by adding such columns as mailbox system, message system, consulting system and complaint online system, to make it more convenient for public participation. Supporting the monthly activity of environmental propaganda and education，EPB organized a weblog contest with the theme as “Circular Economy, Every One Can Make It” by internet.

Internet also becomes a platform for environmental protection department to understand public opinion and seek advice. In Nov. 2005, EPB sought comments and advice on the internet and organized a special campaign to control air pollution in response to the strong complaints of citizens on some hot issues.

Those above diversified working models have led to the blossom of environmental propaganda and education that has expanded into every level of the society, which is strongly supported by the government, widely participated by the public and effectively promoted by media. A social custom that every one cares about and participates in environmental protection has gradually formed.

4.6 Case Study: Efforts to Cope with Climate Change

Global climate change challenges urban development. Coastal cities, such as New York, London, and Shanghai, are being threatened by the rising sea level. Urban heat island effect and shortage of water supply cumber urban development. According to the meteorological material for over fifty years, the temperature is going up, the humidity is going down, the sunlight reduces, and the visibility degrades in Shenzhen. As a result, extreme weather incidents frequently occur, such as frequent high temperature days, extremely hot and dry weather, severe haze, strong thunderstorm, and intense typhoon. (SzMB b) As an economic decision-making centre, Shenzhen has the unique chance and capacity to lead to cope with climate change. In the situation that the globe gets warmer, the more risks the city faces, the more potential influence the city has. About half world population live in cities, and the energy consumption in cities account for about 75% of the total energy consumption in the world. Cities, especially city governments, play an important role in changing the carbon intensity in world economy. Shenzhen is a coastal city that develops rapidly, and keeps with international step to cope with global climate change. The city is attempting to hold circular economy as the development concept and trying the best to save energy.

Policy and Planning

In 2006, Shenzhen issued the Regulations on Promoting Circular Economy of Shenzhen Special Economic Zone, which established over ten important systems such as performance appraisal, medium and long-term planning, governmental procurement, and governmental support. This is the first local law of developing circular economy in China. Shenzhen also issued a series of guiding rules and regulations, such as the Implementation Scheme of Boosting Energy Conservation, the Rules on Comprehensive Utilization of Resources, the Management Methods of

Joint action of environmental protection in two places and four cities[1] (Source: EPB 2005)

1 Two places and four cities including Shenzhen, Hong Kong, Marco, Guangzhou, Zhuhai and Zhongshan, began a joint action of environmental protection with the theme as “All beings is in a network of life” and “Green sports makes a healthy life” on May 19, 2005. This picture shows the opening ceremony holding in Shenzhen.

Recycling and Reusing Renewable Resources, and the Implementation Opinions on Cleaner Production. The Municipal Committee of the CPC and the Municipal Government of Shenzhen officially issued the Decision on Promoting Circular Economy and the Short-term Implementation Scheme of Promoting Circular Economy of Shenzhen (2006-2008), which provided a road map for Shenzhen to develop circular economy.

Collaboration of Administrations

Under the same development objective, different governmental departments issued supportive plans as followings.

SzDRB drafted the Management Methods of Demonstration Projects of Circular Economy, proposing to establish a database of circular economy demonstration projects and including circular economy into the key fields of governmental investment.

SzBTI and SzBLH formulated the Control Standards on Industrial Land of Shenzhen, to limite land supply by improving access standard.

SzFB compiled the green product content and the green governmental procurement content.

EPB stipulated that to preferential special fund policy should be provided for anti-pollution projects that meet circular economy requirement.

SzBSTI took circular economy technologies as an important part of technical innovation and provided policy support.

Activities and Measures

Shenzhen improved the energy saving service mechanism of “Energy Management Contract” (EMC), and expedited to establish and improve the energy saving market. By March 2007, more than 60 key energy consumption units in Shenzhen have established energy saving management systems, and over 40 units carried out energy saving alteration in the mode of EMC. For instance, Shenzhen Nanhai Hotel cooperated with Shenzhen Zhongcai Energy Management Company and implemented energy alteration project in 2005, transferring the surplus heat from power plant gas to the hotel in mobile heat

Cleaner Production

Shenzhen promoted cleaner production through improving technologies. The city publicized circular economy and carried out training by taking clean energy and cleaner production demonstration projects of printing and dyeing industry as a breakthrough then expanded to other industries. In April 2005, SzBTI implemented the first phase of the plan of developing cleaner production and circular economy, and selected 15 enterprises from energy, printing and dyeing, chemical, electronic, and electroplating industries as pilot points. After half a year of cleaner production practice, the enterprises saved a large amount of energy and improved the productivity. Shenzhen will disseminate the concept of circular economy with cleaner production at the core.

supply mode and replacing heat supply with boilers. Nanhai Hotel can reduce 474 tonnes of oil consumption (equal to 862 tonnes of standard coal) and 418 tonnes of carbon dioxide, which reduces the energy consumption cost by RMB 300 000 Yuan per year. (SZPKU 2006) Shenzhen Tsingtao Asahi Beer Company carried out energy saving alteration in EMC mode, and would complete the project in 2007. Then the overall energy saving rate will reach 17%, and RMB five million Yuan would be saved per year.

Shenzhen spent RMB 5 - 8 million Yuan on supporting energy saving products and projects with interest subsidy. According to statistic, Shenzhen provided RMB 13.91 million Yuan of interest subsidy from 2001 to 2006, and encouraged RMB 530 million Yuan of social fund to invest in energy saving alteration projects and product development.

Shenzhen also carried out detailed planning and invested a lot in improving public traffic to reduce emissions from vehicles. The phase I rail project of Shenzhen has been put into use at the end of 2004, and phase II project is under construction in part and expected to be completed in June 2011. From 2011 to 2020, Shenzhen will invest RMB 107 400 million Yuan in building eight rails with a total length of 245.4 km. Those will largely improve urban traffic efficiency and reduce greenhouse gas emission from vehicles.

Shenzhen took measures of financial subsidy, forcing to reduce consumption in a given period, and encouraging energy saving pilot projects to realize the objectives of energy saving and consumption reduction. After one year of effort, the city made initial achievements. In 2006, the recovery utilization rate of renewable resources in the city reached 92%, increasing by 2% than 2005. The comprehensive utilization rate of industrial waste gas, waste water, waste residue, surplus heat, and surplus pressure reached 65%, increasing by 5% than 2005. At present, the old newspaper recovery system of Shenzhen Press Group and the comprehensive treatment project of industrial waste of Dongjiang Environmental Protection Company have been listed as the first pilot projects of circular economy of the state. The cooling water and seawater recycling utilization project of Fuhuade Power Plant and the project of industrial wastewater reusing of Seg Hitachi Company have been listed as the national demonstration projects. (SzSZD 2007 c)

Chapter V Outlook

PSIR model was used in the previous chapters to depict the changes in social and economic development as well as the environment of Shenzhen. Then analysis was made on pressures leading to the effect and on countermeasures adopted by the government. Based on the challenges Shenzhen is facing in urban development, we employ system dynamics model (SDM) model to analyze the development trend of Shenzhen's social, economic and environmental resources in the next 25 years in different scenarios. All scenarios will be elaborated in the following sections including the quantitative forecast of some sensitive indicators to measure social, economic and environmental quality.

5.1 Model Design

A simulation of system dynamics model is created in the chapter to make quantitative analysis and judgment in all scenarios. This model consists of 6 subsystems for economy, population, land, water resources and water environment, atmospheric environment as well as solid wastes. Parameters are set according to the statistics available from 1996 to 2005. For data not available on record, parameters are set through analogy by referring to data of other countries or regions. The following model is simplified to show the relationship among all the subsystems.

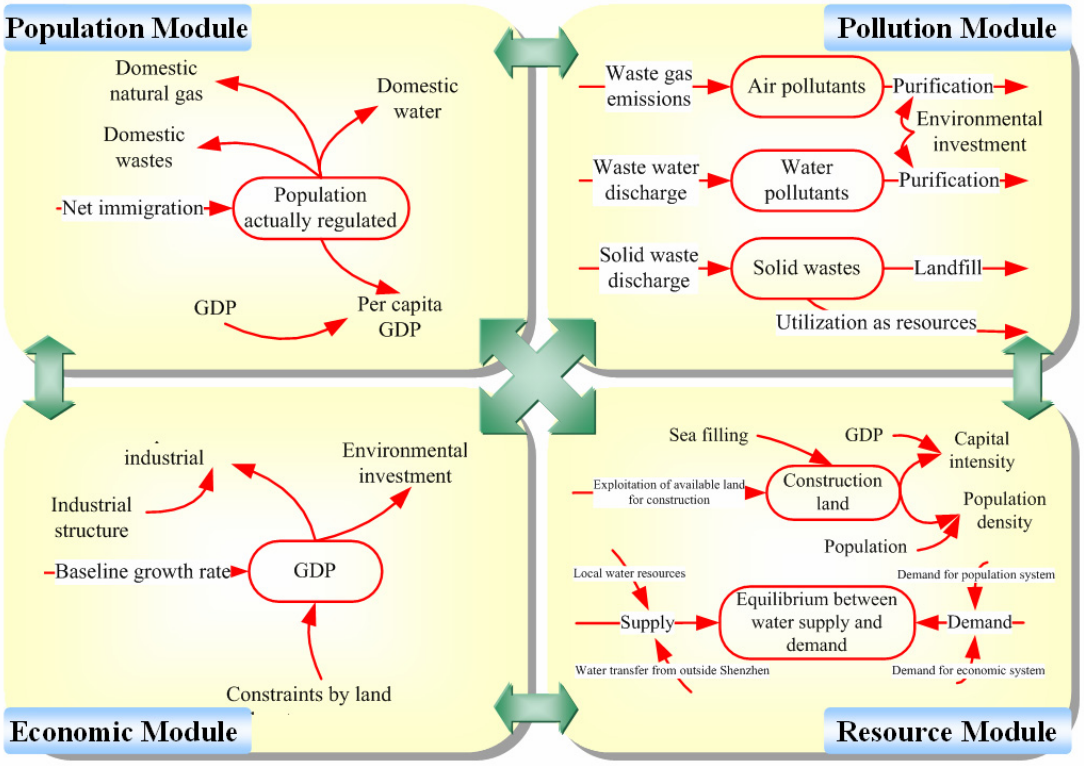


Figure 5.1 Basic structure of relationship among economy, population and environment system in Shenzhen

Based on materials and site investigation, the major control and regulatory factors of SDM include the followings.

Economic subsystem

- Basic rate for annual GDP growth
- Factors limiting GDP growth due to water and land resources
- Relationship between GDP growth and environmental input and environmental taxation
- Change of industrial structure

Population subsystem

- Relationship between population growth and GDP growth
- Restrictive factors of population growth with regard to water and land resources
- Relationship between population change and industrial structure
- Relationship between population change and reconstruction of old cities and villages
- Proportion of population with residence cards and temporary residence cards, and floating population.

Land subsystem

- Process of sea filling program
- Process of reconstruction of old city and villages
- Exploitation intensity of available land for construction

Water resources and water environment subsystem

- Changes of water demand, including per capita domestic water demand, water consumption for per RMB 10 000 Yuan industrial output, water consumption for public and other uses.
- Changes of water supply, including local water supply (including groundwater), water diverted from outside Shenzhen, reused water and desalinated seawater.
- Treatment level of urban sewage

Atmospheric environment subsystem

- Changes of industrial energy consumption structure
- Reduction rate of industrial air pollutants
- Total number of vehicles, average mileage per year and emission coefficient

Solid waste subsystem

- Generation of domestic waste per capita and recycling rate of domestic waste
- Total discharge of solid wastes for per RMB 10 000 Yuan industrial output
- Generation of construction garbage and its recycling rate

5.2 Scenario Analysis

All scenarios assumed here shall follow the following rules:

- All the scenario analysis is made by using the same model. The parameters are set according to the statistic data provided by SzSB from 1996 to 2005. For parameters having no historical record for reference, analogy with data of other countries ore regions is adopted.
- The ongoing projects are assumed to happen in the future in all scenarios. Projects that have just been planned may appear in different forms.

- All laws and regulations promulgated and enforced or to take effect are supposed to be carried out faithfully in all scenarios.
- Different government decisions, corporate and public behaviors, measures, standards as well as local policies are considered in all these scenarios followed the assumptions in rule 2 and 3.
- Each scenario is matched with a strategy. And all the scenarios are likely to happen and tend to seek advantages. That is to say, the scenarios will have the ability of self-adjustment according to the reality and it will not lead to an extermely devastating strategy.

Five scenarios are designed in this chapter to predict the development of Shenzhen in the next two decades in a quantitative or qualitative way. Tales of the first four scenarios are briefly decribed as follows.

Scenario A
Business as usual — hidden problems are not fully addressed

Shenzhen has witnessed sustained GDP growth of over 20% in the past two decades. Such a momentum is closely intertwined with Shenzhen's unique location and the development policies for special economic zones. However, the economic growth is mainly driven by investment in capital and human resources. With the expanding of population and worsening of environmental quality, the consumption of water and land resources and energy for unit GDP is far more than that of developed countries.

In Scenario A, the extensive development mode will continue. More attention is devoted to economic growth rate instead of the diminishing sustainability. This development mode will directly result in the following problems. First, the environmental pollution is severe. Quite a few rivers suffer from serious pollution and hazy days account for over 1/3 of the year. Second, economic development relies heavily on natural resources and energy. Consumption of water, energy and land for per RMB 10 000 Yuan of GDP is big but such resources in Shenzhen are exceptionally scarce. Third, the structure of three industries is not rational with the secondary industry making up over 50%. Among others, traditional manufacturing still holds a large share and lacks high technology content, which imposes heavy pressure on population. Scenario A maintains this development mode where the proportion for the secondary industry keeps going up and labor-intensive sectors further expands. In a short term, the economy will retain a fast growth pace but in a long run the resources and energy can hardly meet the demand of the influx of population and surging industrial development, and water and land resources are in tight supply. Massive sea filling projects have great impacts on coastal ecology and urban expansion has reached the extremity. Pollutant discharge is more than doubled and serious pollution is threatening urban ecology. As the impact of resource depletion and environmental destruction loom large, the economy falls into recession after experiencing fast speed development. Various contradictions emerge as a result. In a word, Scenario A presents a picture of a deteriorating society.

Facing to severe environmental pollution, unbalanced industrial structure, and economic growth excessively depended on natural resources. how should we cope with the practical problems or hidden trouble

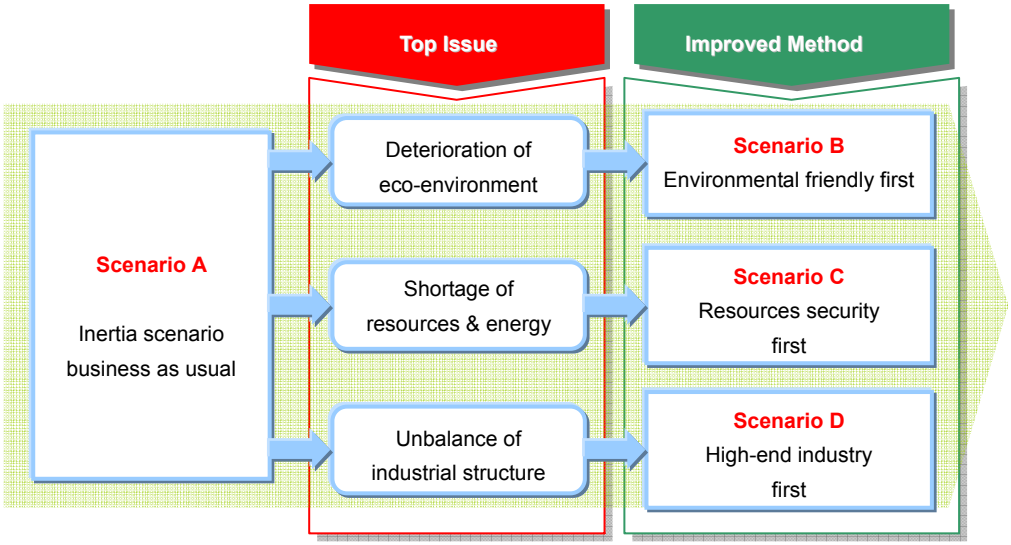


Figure 5.2 Design of three scenarios for improvement

brought about by the traditional development mode, and which should be the priority that we contribute our limited money and energy to? We have designed three sets of improving strategy, targeting the above three problems but emphasizing on different aspects. This gives rise to the next three scenarios of this chapter.

Scenario B Environment-friendly First — a harmonious and livable city

In this scenario, the protection and improvement of Shenzhen's eco-environment is the fundamental principle. The government will continue to increase investment in environmental protection, develop more reasonable laws and regulations in this regard and conscientiously implement them. Environmental access mechanism is set up so that corporate production and public behavior are restricted by high environmental standard. Pollution control technologies are introduced and promoted and a number of enterprises causing heavy pollution will be phased out. More and more measures combining pollution control projects and related policies will be adopted to strictly control the discharge of pollutants into water bodies and the atmosphere. Urban waste is disposed of in an environmentally friendly way and sea filling projects are restricted. The

development pace of land for construction purpose will face coercive control. Local government will dramatically reduce the proportion of heavy oil in the energy consumption structure disregarding the cost for promoting the development and use of new source of energy. Under this circumstance, pollution discharges reduce by large margins until the environmental problems are properly solved in the near future. Hence ecological resources will be effectively conserved and gradually rehabilitated. The eco-environment will be fundamentally improved and move towards new balance at a higher level. Nonetheless, due to big environmental investment, environmental taxation, limited supply of land resources and high environmental standard, economic development will incur considerable losses.

Scenario C
Resource Security First — a sustainable city

To tackle the problem of unsustained capacity of Shenzhen in water and land supply, this scenario features resource conservation, recycle and reuse of resources and increasing the GDP output for per unit of energy at all levels of the society. Energy consumption for per unit of GDP will be reduced and an energy security system for intensive utilization will be established. Restricted by limited water and land resources, recycle and reuse of resources will be promoted to guarantee that water resource is used in a sustainable way. The traditional water supply pattern will be replaced by multi-channel supply that caters for different requirements on water quality. Shenzhen government will tap all resources possible in the city and promote reuse of treated water, sewage and rain water in a bid to increase water resources per capita. Intensified efforts will be made to save water by increasing water saving rate of domestic water and water for public use. Interbasin cooperation will further guarantee water supply from other regions through increased ecological compensation to the upper reaches. A scientific approach to integrating water use, water supply and water management will ultimately put an end to the passive situation threatened by water scarcity. As far as land resources are concerned, Shenzhen government will highlight the need to protect land for ecological purpose within the ecological control boundary in order to protect the service functions of major ecosystems. On the other hand, land exploitation will be put under strict control. Land will be used to its best advantage, including appropriate sea filling projects and land replacement through rebuilding old cities, villages and industrial parks to improve the economic and ecological efficiency of developed construction land. The city will enhance its capacity in waste reuse so that landfill pressure can be eased by decreasing the amount of waste for ultimate disposal. While enhancing the energy efficiency, Shenzhen will carry out strategies to secure energy security and conservation to ensure sustainable use of energy. From a middle-to-long term perspective, the early investment in this regard will take effect in the future. A series of proactive measures will largely relieve resource shortage that limits economic growth and effectively address the potential resource and energy crisis.

Scenario D
High-end Industry First —a technologically innovative city

Scenario D focuses on industrial restructuring where optimal industrial structure is realized through a shift of traditional economic growth mode driven by capital and labor investment into a mode fueled by technology progresses. Policy guidance will promote balanced development and overall upgrade of the three industries, which nurtures pivotal industry and boosts the development of high-tech industry, modern financial service, modern logistics and cultural industry. High-tech corporations that consume less energy and cause less pollution will be the mainstay of industry. With conventional manufacturing gradually retreating, employment in labor-intensive sectors will plunge and the entrance of floating population will be contrained. The ertiary industry will replace the secondary industry as the dominant sector and the traditional agriculture which accounts for a fraction will give way to agricultural services. The successful transition in industrial

Table 5.1 Identification of the Four Scenarios

	Scenario	A	B	C	D
Land resource	Reconstruction level of villages-in -city	week	medium	strong	medium
	Intensity of sea filling	strong	week	medium	medium
	Development intensity of remaining land	week	week	week	week
Water resource & water environment	Per capita resource supply level	week	medium	strong	medium
	Plan of water saving	week	medium	strong	medium
	Utilization level of rainwater, seawater and treated water	week	medium	strong	medium
	Treatment level of sewage	week	strong	medium	medium
Economic subsystem	Industrial structure adjustment	week	medium	medium	strong
Atmospheric environment	Control of industrial pollution sources	week	strong	medium	medium
	Change of energy consumption structure	week	medium	medium	strong
	Utilization level of energy	week	medium	strong	medium
	Control of domestic pollution sources	strong	strong	strong	strong
	Control of traffic pollution sources	week	strong	medium	medium
Solid wastes	Reduction of pollution sources	week	medium	strong	medium
	Recovery and utilization level of wastes	week	medium	strong	medium

structure will ease much of the population pressure. The shrinking proportion of conventional industry will lead to less discharge from industrial pollution sources and less industrial energy consumption. In a middle-to-long term, eco-environment will start to be better.

Table 5.1 gives the identification of above four scenarios in terms of the control effect. Ratings range from strong, medium to weak.

System dynamics model is employed to measure the four scenarios. The estimated results and analysis on economic, social, air and water indicaters are as follows:

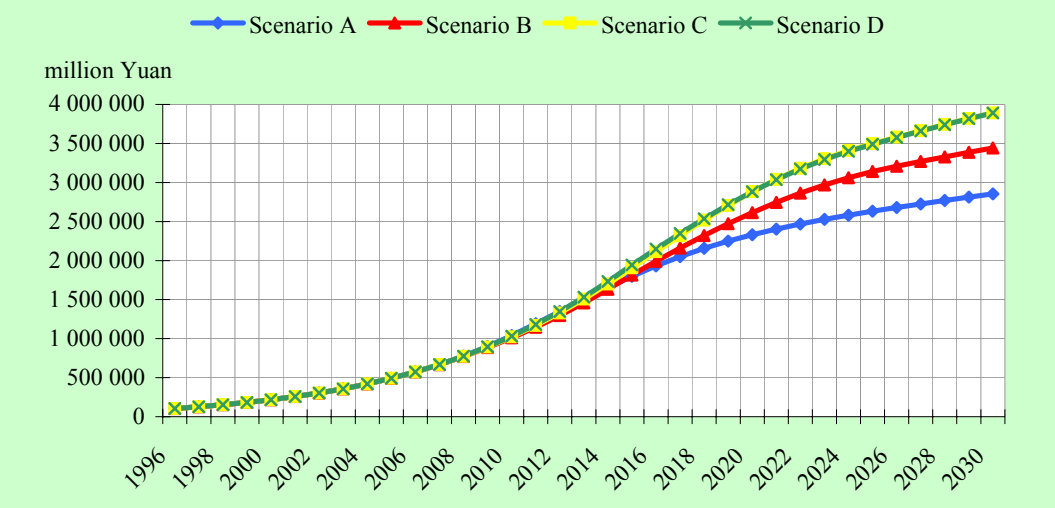


Figure 5.3 Forecast of GDP in different scenarios

As is shown from the trend of economy gross, the gross product of Shenzhen in different scenarios before 2015 does not vary much. Specifically, Scenario A, which represents traditional economic growth mode, has a higher GDP value than that of the other three scenarios before 2010. After 2010 Scenario C and D featuring efficient use of resources and industrial restructuring begin to take lead. And after 2015, the curve diverges in two directions. Scenario B, C and D, which emphasize change of development mode demonstrate protruding advantage over the traditional development in Scenario A. The reason is the overuse of resource in Scenario A where the carrying capacity of water and land resources and the environment approximates the limit, hence restraining the growth of GDP. Among Scenario B, C and D, GDP in Scenario B is lower than that in C and D because strict environmental standard and pollution reduction lead to some losses in GDP.

Analysis

In terms of economy gross, we designed Scenario B, C and D through reflection of the extensive development mode. Even though GDP growth in these scenarios in the next 5 years is lower than that in Scenario A, enhanced resource efficiency and less stressed environment and population will make a middle-to-long term GDP growth more robust than that of Scenario A. Therefore, the change of economic growth mode is necessary to guarantee sustained economic growth. As for urban actual regulated population and residential population (statistical population)[1], only Scenario D attains a desirable effect on population control. By 2030, the statistical population will reach 12 million and total urban population under management will be 15 million. In Scenario D, urban population will level off after 2020 and see slight decrease. For the other three scenarios, Scenario A's control of

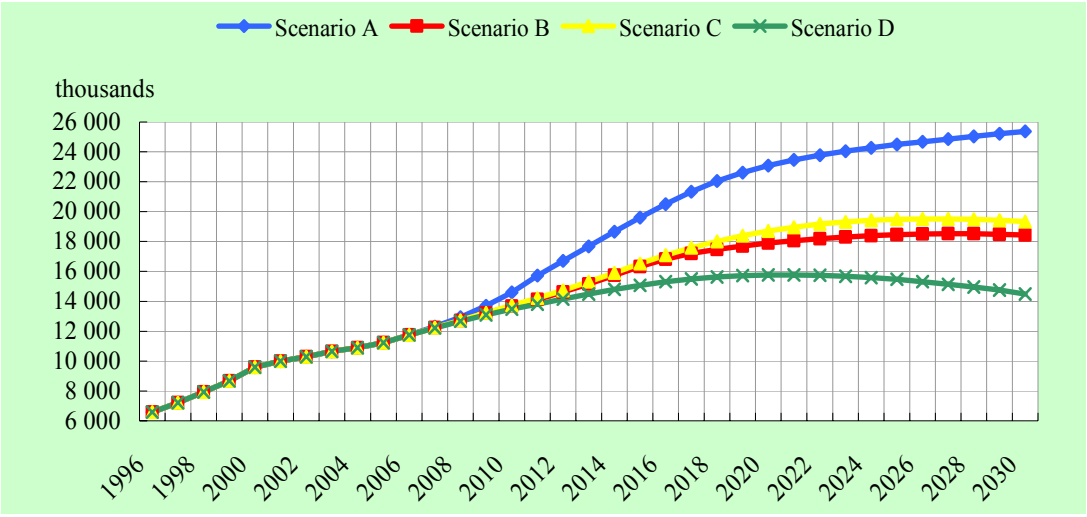


Figure 5.4 Forecast of actual regulated population in different scenarios

1 The baseline for population forecast in this report is borrowed from 2006 Shenzhen Statistics Year Book. Due to data adjustment there may be discrepancies in the forecast between the report and the released planning.

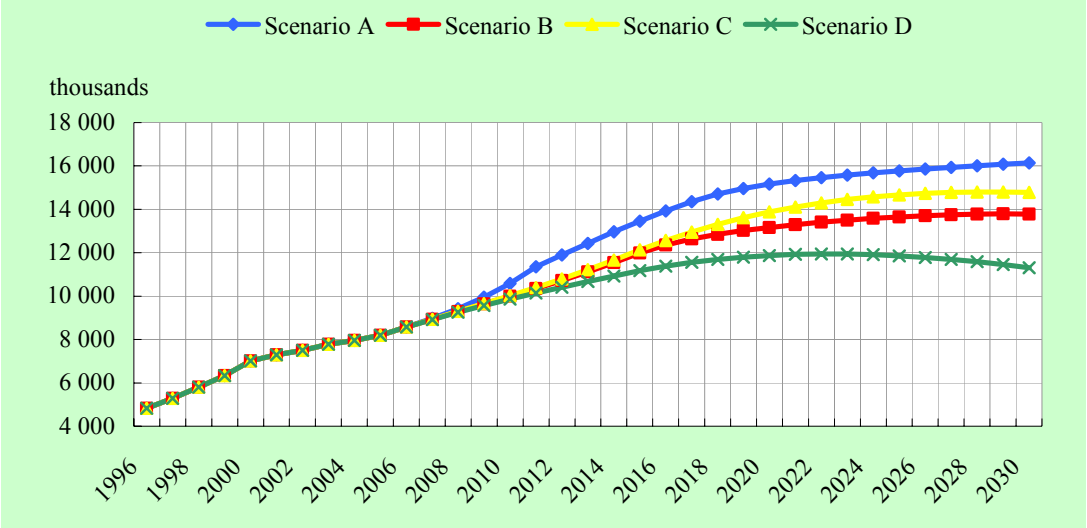


Figure 5.5 Forecast of residential population (statistical population) in different scenarios

population is the weakest where the projected statistical population will exceed 16 million by 2030 and the total urban actual regulated population grow to well over 25 million. We can see that if processing trade and manufacturing still dominate the development, it has an adverse effect on population control. Scenario B and C have close population, which lie between that of Scenario A and D.

Analysis

Calculations from the model show that it is hard to achieve the desired goal on population control if coercive and ideal measures are adopted. We should start from regulating industries that absorb many of the floating population and adjusting the industrial structure. Reducing the proportion of manufacturing might be a feasible option.

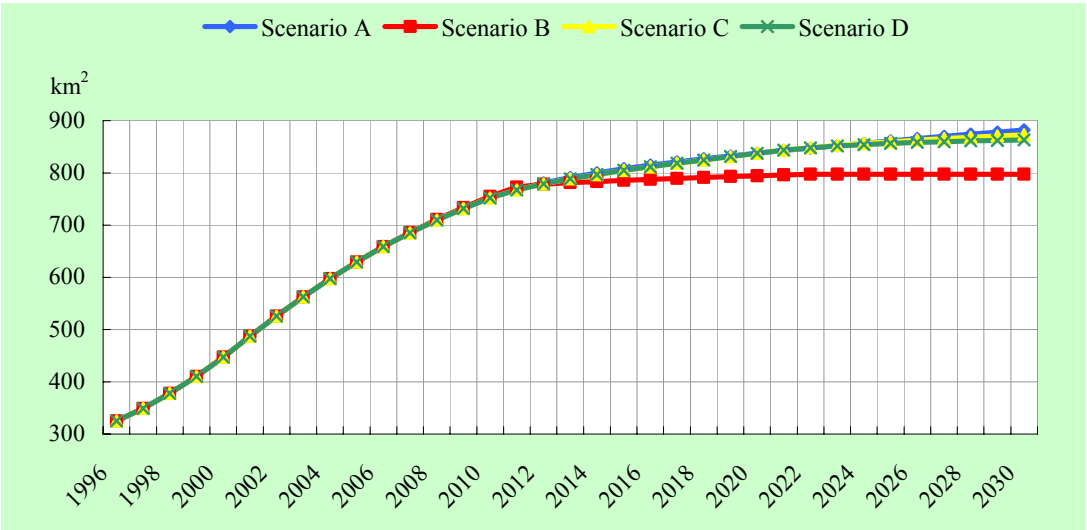


Figure 5.6 Forecast of construction land change in different scenarios

Statistical data reveal that by 2006, the land developed for construction purpose in Shenzhen had reached over 700 km^2, with little resource left for construction. As land supply is rigid, Shenzhen will soon have no available land under present development pace. Facing a shortage of land for construction in reserve, Shenzhen has launched large-scale sea-filling programs in Qianhai, Shekou, Houhai, Shenzhen Bay, Shatoujiao and Yantian Port ever since 1996. By 2005, 26.8 km^2 of land had been reclaimed from the sea. All the four scenarios take account of sea-filling at varied degrees, old towns and villages are rebuilt to expand land supply and measures to enhance land use efficiency. Estimation shows the scale of developed construction land in all the scenarios will not change much in the next 20 years as a result of restriction of land supply. The upper boundary of total area of land for construction is about 900 km^2 adding other land reclaimed from such means as sea filling. The rigid constraint of land resources has posed a big challenge to Shenzhen as how to use land resources wisely to ease the tension of land supply.

Analysis

Currently, the expansion of construction land in Shenzhen has nearly reached its limit. The tension between land demand and supply looms large. Additionally, the overall arrangement of land for construction purpose is not effectively controlled, especially in the two districts outside the special economic zone. Land use for different purposes is disproportionate, which is reflected from the big proportion of land for industrial use, lower one for residential and public purposes, and many villages-in-city still exist. To cope with the short supply of land resources, Shenzhen should use the remaining construction land properly. As is shown from the model, sea-filling remains an important means to expand construction land in the near future. Sea-filling projects should proceed according to plans but the possible impact on ecology should be assessed with caution. Moreover, there is a need to tap the potential of redeveloped land to rebuild old towns, villages and industrial parks. Land use of newly launched projects should be strictly controlled. Projects with low output for per unit of land will gradually withdraw.

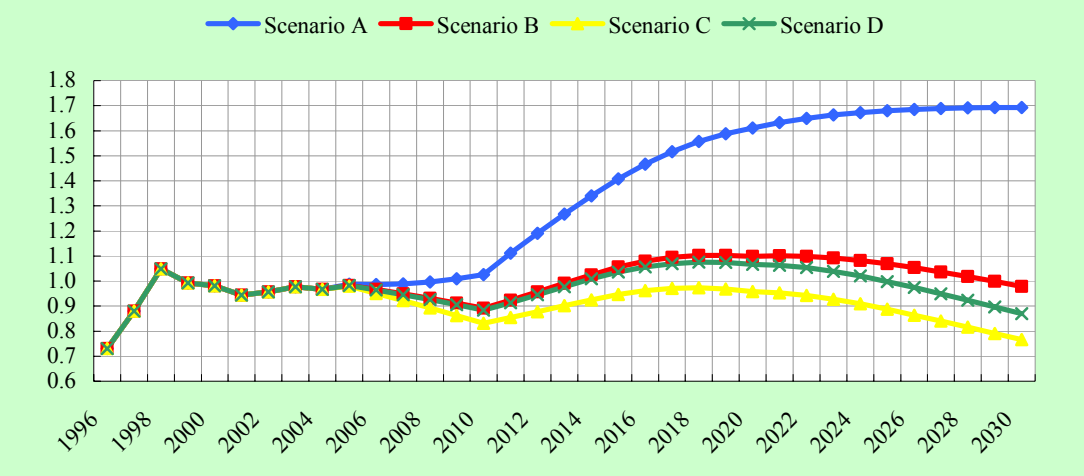


Figure 5.7 Forecast of annual water demand-supply ratio in different scenarios

In terms of water demand and supply, Scenario C is the only one that offers solution to strike a balance between demand and supply in both the near future and the long run dues to its proposition of water saving, reuse of treated water and development of new sources of water. In Scenario B and D, there will be unbalanced water demand and supply in some certain years after 2016, but the supply is slightly less than demand. In Scenario A, the problem of water shortage pops up rapidly and the ratio of water demand to supply comes to more than 1.6 in a long term. The simulative data indicate that the greatest water supply pressure will appear between 2016 and 2023.

In terms of total discharge of COD and NH_3-N, Scenario B which stresses pollution control will contribute less discharge compared to the situation in other scenarios after 2010. By 2030, Scenario A will emerge as the worst option as far as COD and NH_3-N discharge is concerned, whose discharge is twice as much as that of Scenario B and far more than that of Scenario C and D. Comparatively, Scenario D which features industrial restructuring is better than Scenario C. In regard to the discharge of water pollutants, water environment under Scenario A will deteriorate while pollution under Scenario C and D will ameliorate on the level of 2005. The quality of water environment under Scenario B will be restored with less pollutant discharge than 1996.

Table 5.2 Forecast of water supply capability in different scenarios[1]

(Unit：100 million m^3)

The forecast year	Scenario A			Scenario B			Scenario C			Scenario D		
	Supply	Demand	Gap	Supply	Demand	Gap	Supply	Demand	Gap	Supply	Demand	Gap
2010	2091	2145	54	2249	2004	—	2363	1966	—	2217	1958	—
2020	2188	3526	1338	2593	2848	255	2938	2816	—	2556	2726	170
2030	2233	3781	1548	2822	2762	—	3282	2515	—	2776	2414	—

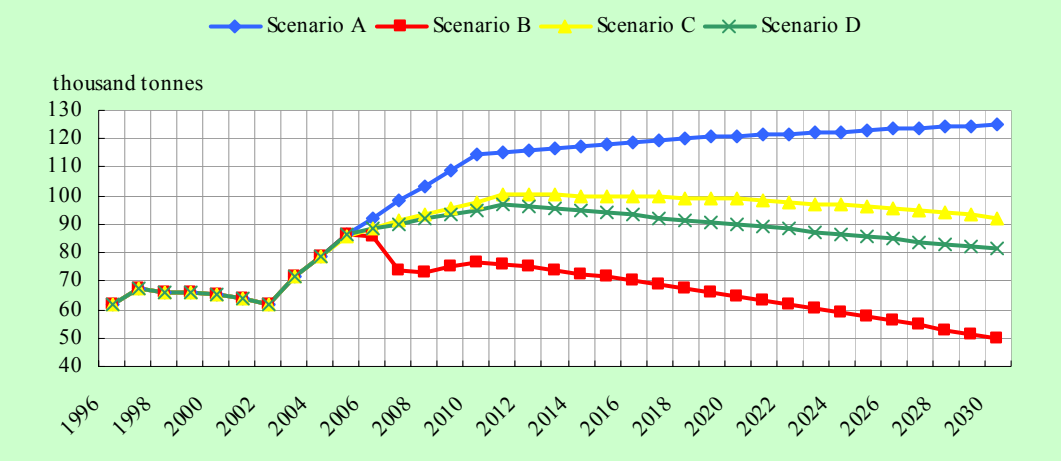


Figure 5.8 Forecast of annual COD discharge from waste water in different scenarios

1 According to the *Report of Revised Plan on Sources of Water Supply in Shenzhen*, the estimated water supply of Shenzhen by 2010 is about 2 096 million m^3 and the demand is between 1 850 -2 200 million m^3. By 2020 water demand will total 2 800 million-3 100 million m^3. This report assumes much room for potential use of treated water, so the amount of water supply is bigger than the planned one.

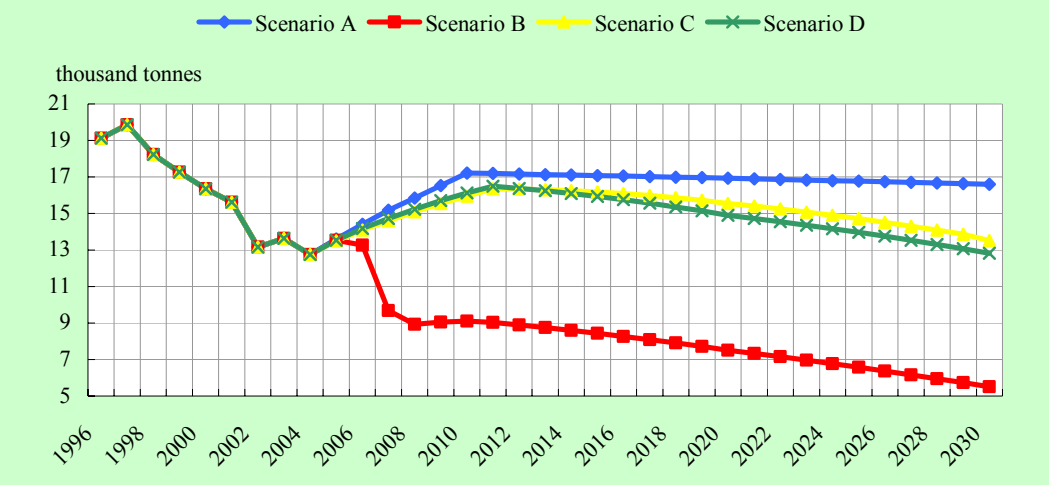


Figure 5.9 Forecast of annual ammonia-nitrogen discharge from wate water in different scenarios

Analysis

Water shortage might be the biggest challenge for Shenzhen in its future development. The pressure of water supply will gradually emerge after 2015. Particularly from 2016 to 2023, ratio of water demand to supply under all scenarios will come to the peak. Even various water resources may be utilized to ease the pressure of water supply, continuous growth of population and the economy will still push the ratio to its peak value. The ratio will not decline until 2025 when a set of policies may be fully implemented, and the pressure of water supply may be relieved. The simulative results suggest that the tight water supply can hardly be resolved in the middle-to-long term if we simply embark on saving water and reusing treated water. We must set out to utilize rain water and seawater or scale up water storage projects. As Scenario C takes account of all means possible to use various water resources, such as reuse of treated water and waste water, conservation of water for

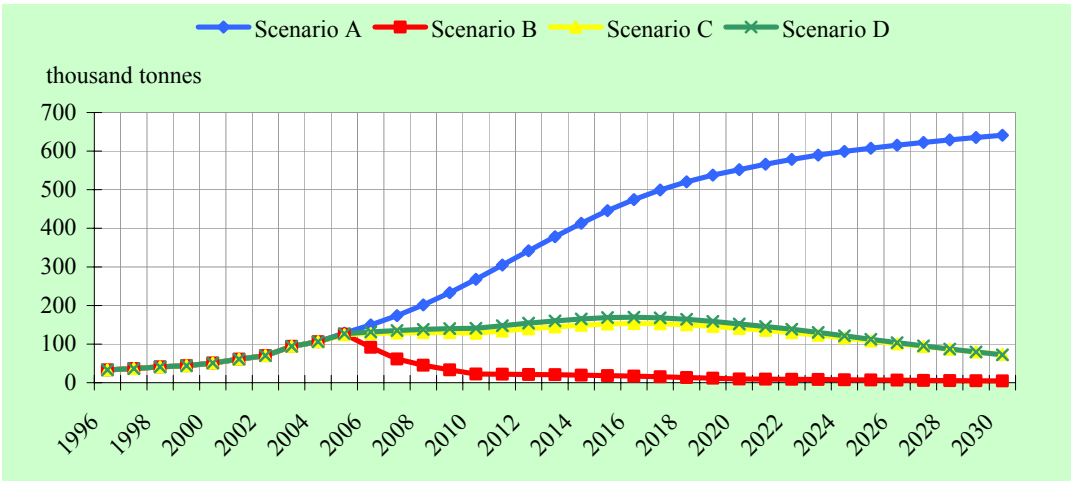


Figure 5.10 Forecast of annual SO_2 emissions in different scenarios

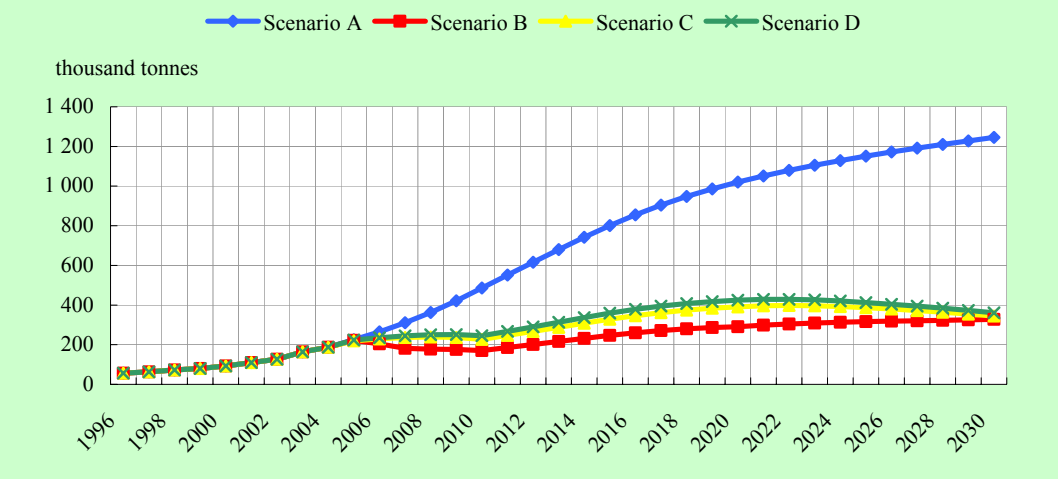


Figure 5.11 Forecast of annual NO_2 emissions in different scenarios

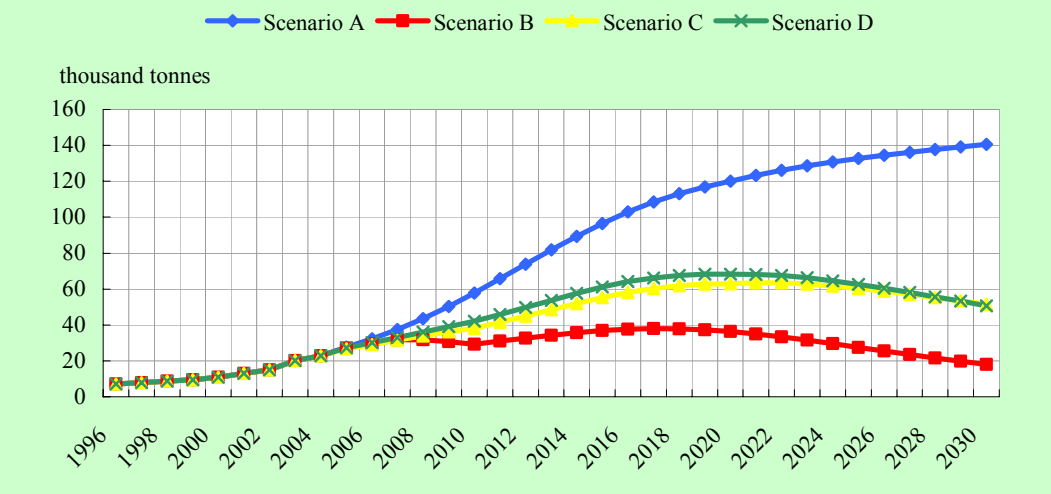


Figure 5.12 Forecast of annual soot emissions in different scenarios

domestic, industrial and public purposes and utilization of rain water and seawater, it proves to be effective to strike a balance between water demand and supply. Therefore taking innovative measures to develop water use channels is an arduous task for Shenzhen in the future.

Industrial source is the major contributor to SO_2, NO_2, and soot and dust emissions. Compared with Scenario A, the growth of emissions under the other three scenarios will gradually slow down, and then become stable and reduce since 2020. By 2030, Scenario C and D achieve almost the same effect in terms of the emissions of the above three pollutants. Scenario B will see a slash of emissions accompanied by large economic losses. Compared with Scenario B which manages to control emissions by imposing environmental tax, strict emission standard and adjusting energy consumption structure, Scenario C makes some achievements in the long run through reducing industrial energy consumption, so it is with Scenario D where the proportion of energy-intensive industries is lowered.

Scenario B, C and D will see dramatic decline of CO and HC emission which are mainly contributed by traffic sources over the five years from now to 2010. The reason is that vehicle emissions are assumed to meet Euro III standard by 2010 in all the above scenarios. The first batch of Euro III coaches was used in Mar. 2006 in Shenzhen. In Scenario A emissions will reduce after 2020 as stricter standard is imposed. Since most citizens use LPG in their daily life, domestic sources contribute much less to air pollution than industrial and traffic sources do.

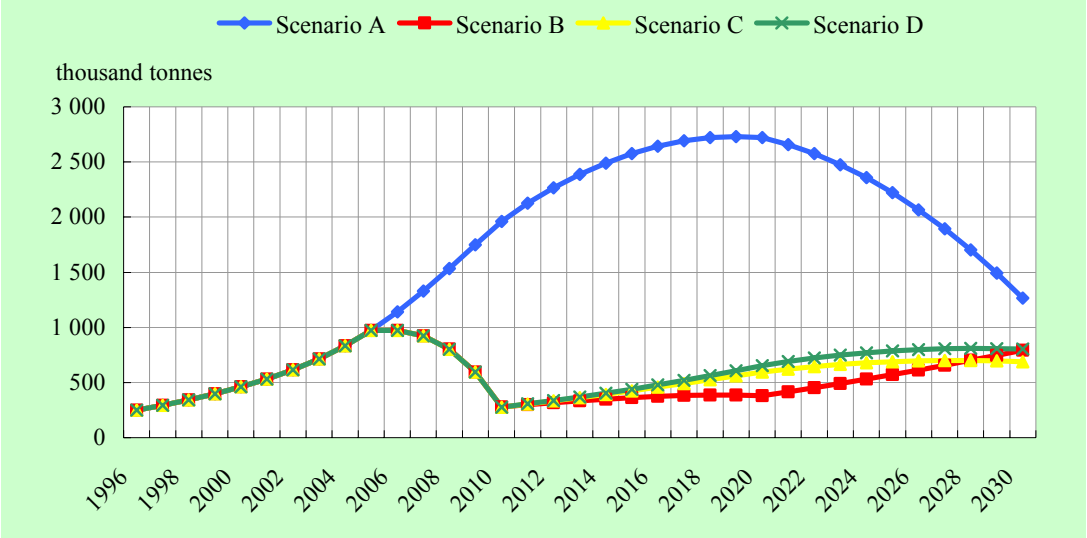


Figure 5.13 Forecast of annual CO emissions in different scenarios

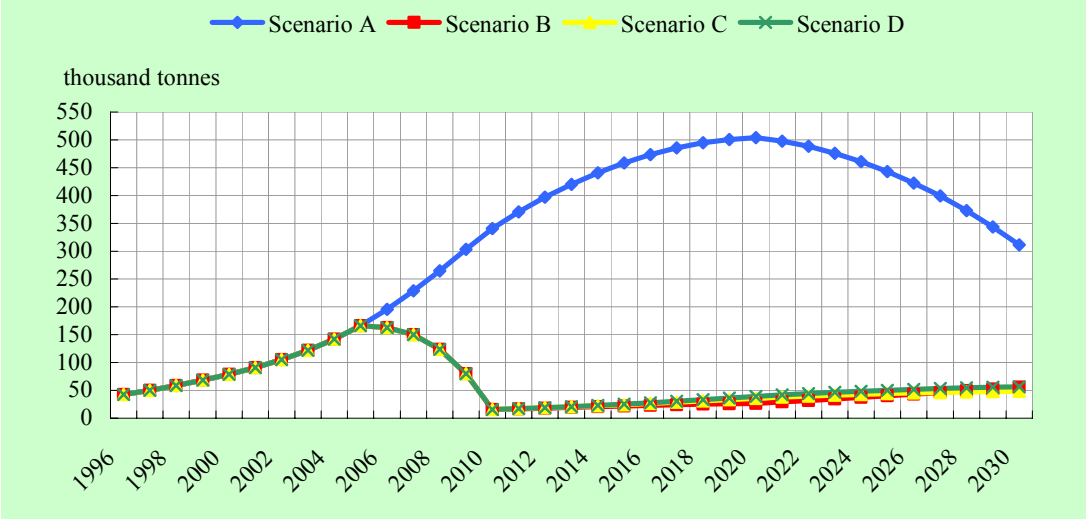


Figure 5.14 Forecast of annual hydrocarbons emissions in different scenarios

Analysis

Adjustment of industrial structure and energy consumption pattern is a sound option to control air pollution than stricter standard for emissions, for it can both effectively reduce pollutants from industrial sources and avoid large economic losses. If current ECE15-03 standard (GB147611－93) is gradually replaced by higher standard like Euro III and Euro IV, there will be a big cut in vehicle emissions. The key step rests with faithful enforcement of these standards.

In terms of the amount of solid wastes generated, the amount of waste collected in Scenario D is the least whereas Scenario A shows the biggest amount. This results from the change of population that leads to synchronous changes. If the amount of waste for ultimate landfilling is examined, Scenario C will stand out for it stresses reuse of domestic and construction waste. If Shenzhen can achieve the waste recycling rate of 45% by 2010 as proposed in the plan for circular economy, the pressure on ultimate disposal of waste will be greatly eased.

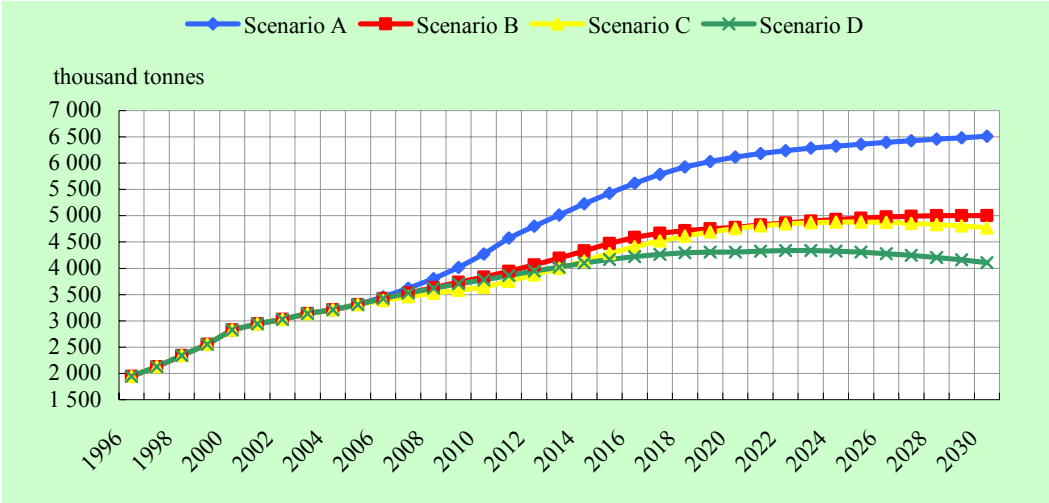


Figure 5.15 Forecast of annual amount of domestic waste in different scenarios

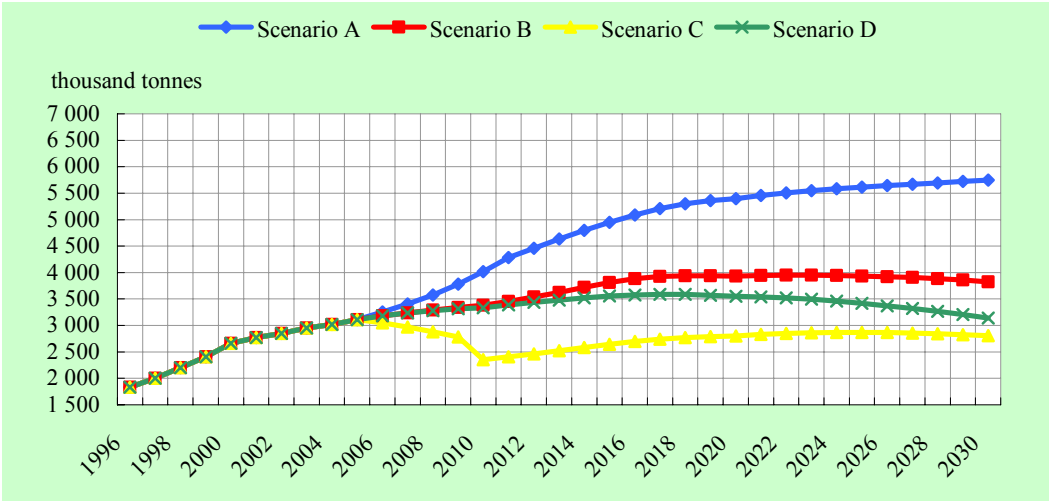


Figure 5.16 Forecast of annual amount of domestic waste for final disposal in different scenarios

Analysis

Forecast results suggest reuse of waste is the most important means to reduce the amount of waste for ultimate disposal. Currently a market has emerged in Shenzhen to reuse industrial wastes in an environmentally friendly manner. However, vicious competition and some small companies overriding the requirement of environmentally friendly disposal constitute a major hidden trouble for reuse of industrial wastes. Domestic waste is still recovered with low technology content. Although it is technically feasible to reuse construction garbage in building materials, complicated procedure of transportation, narrow profit margin and difficulty in market operation make it a hard nut to crack. Policy support may be a way out.

On the whole, Scenario B, C and D, which are designed to counter the flawed development mode in the past, display the advantage in pollution control, resource utilization and population control respectively. A preferred development mode is a combination of the three scenarios with Scenario D applied in major aspects. It is sagacious of Shenzhen government to take reforms and innovative measures that are consistent with policies like development of circular economy, encouraging independent innovation and boosting the development of high-end service industry. Compared with other scenarios, Scenario D, which focuses on adjustment of industrial structure and energy consumption structure, is particularly effective in population control. It can reduce the discharge of various pollutants in varying degrees at the time of developing the economy. So the impact on economic development is smaller than Scenario B that merely concerns about pollution control. Some measures proposed in Scenario C may further strengthen resource utilization if adopted in Scenario D. Thus the pressure on resources may be effectively eased in Shenzhen. Decision-makers should broaden their mind to explore and practise ideas that can help balance different decisions and realize optimal combination. The fifth scenario explained below is an optimal combination bearing the following characteristics.

Scenario E
Sustainability first — a pioneering city

Shenzhen will transform from pure economic growth into science-based development that is all-rounded, coordinated and sustainable. From a global perspective, Shenzhen will further cooperate with Hong Kong to jointly grow into cosmopolitan cities. Domestically, Shenzhen will consolidate its position as a high-tech industrial base and a demonstration city for independent innovation. Regionally, Shenzhen will become a regional logistic center.

Development goal

Economic development- prosperity and vitality

Shenzhen will develop multi-polar industrial structure that harmonizes with the society and environment to maintain its core competitiveness. It will keep its annual GDP growth at above 7% in the next 25 years and perform up to par with cities in the most developed countries by 2030.

Social development- equality and harmony

Efforts will be made to narrow the gap among different social communities by offering more opportunities in housing and employment, improving habitat and working environment and increasing cohesion of the city so as to bring a stronger sense of security and belongingship to citizens and build a harmonious society.

Environmental development- natural and livable

Shenzhen will stick to the concept of sustainable development. It will finally embrace harmonious development between man and nature through the campaign of building a resource efficient and environmentally friendly city.

Chapter VI Options for Action

As a pioneer of China's reform and opening up, Shenzhen has achieved fast economic growth in the past two decades. However, the conflict between the extensive growth mode and resources and environment also looms large. According to the simulative results presented in Scenario A, Chapter V, if Shenzhen preserves the current development mode, water and land resources will deviate far from the supply and demand equilibrium. Population explosion and heavy pollution will render the economy lacks of stamina. We must reflect upon past development mode from a strategic point of view to break up the four bottlenecks restraining sustained economic development, namely limitation of land and space, energy and water shortage, pressure on population expansion and strained environmental carrying capacity. Only a combination of efficiency gain and economic growth can we work our ways to sustainable development where both the economy and environment thrive.

Policy & Regulation Guarantee Strategy

Effective security system is the prerequisite for enforcement of all strategies and measures. Making full use of the legislative right of special economic zone, Shenzhen has gradually set up a sound system for policy, law and regulations to secure the smooth implementation of other strategies.

◆ Improving policies and laws on energy and environment

Policies and laws regarding energy and environment should be further improved based on current legal system in a bid to tackle the practical issues Shenzhen is facing. We should follow the principle of focusing on the most important issues to gradually perfect the system while developing the most relevant policies needed at different stages of development, so that the legal system will go hand in hand with social and economic development. A legal system that have Shenzhen characteristics, can solve Shenzhen's questions and safeguards Shenzhen's energy security and environmental protection will finally take shape.

◆ Enhancing the review of policy and regulations

The development of policies and regulations is a dynamic and circular process which includes several steps such as identification of objectives, implementation, review and assessment. In the past, more attention is given to development and implementation when drafting policies. Review and evaluation are not the major concerns. However, review and evaluation can serve as a strong guidance for readjustment and re-implementation of the legal system. So future management of policies should not only stress policy goals and implementation, but also reinforce policy review and evaluation, which will help to further modify policies and achieve expected result.

Industrial Restructuring Strategy

Scenario A indicates that the structure of certain industries cannot cater for the need of sustained economic development. Industrial restructuring is imperative if the economy is to develop in a fast and healthy manner. According to the forecast of Scenario D, a sound industrial structure will not only promote economic development in a long term, but also help ease the pressure on population, energy and environment.

◆ Identify pillar industry properly

Industrial restructuring is of great meaningful for transforming economic growth mode, promoting adjustment of industrial population and relieving environmental pressure. In view of current development of Shenzhen and the direction of the industrial development, an industrial structure taking electronic information industry as the mainstay and supported by modern service industry, high-tech industry, financial, logistic and cultural industries is more fitful for Shenzhen. Independent innovation should be instilled into the restructuring process to enable a shift of Shenzhen's image from a manufacturing base into an inventive brand.

◆ Optimize industrial distribution

Rational industrial distribution is conducive to the full play of regional advantage and achievement of scale efficiency. Meanwhile, it also promotes integrated utilization of resources and effective control of pollution. Therefore, while the industries are undergoing overall upgrade, industrial structure and layout should also be adjusted accordingly. Based on the characteristics and edges of different regions, an industrial structure should be formed to cater for the need of economic development as well as energy conservation and environmental protection.

◆ Establish exit and access mechanism

Industries should be classified according to their impact on environment. Such indicators as consumption of energy and water, land use and pollution discharge should be taken as basic factors for enterprises to access Shenzhen market in order to keep a firm control on industries in Shenzhen. An exit mechanism is to be developed at the same time. Enterprises that are encumbered with backward technology, difficulty in reform and intensive energy consumption and pollution discharge should be relocated or eliminated justifiably.

Population Regulation Strategy

A distinct characteristic of Shenzhen's population structure is the disproportionate number of population with temporary residence cards and floating population to the number of permanent population. The manufacturing dominated development mode in Scenario A will lead to increasing population expansion. Analysis of other scenarios also suggests urban population must be kept at a proper level if harmonious development is to be attained.

◆ Control of population size

Population control is a long-term process. A combination of short-term and long-term measures can be adopted for Shenzhen to control its population. A short-term goal is to maintain permanent population at 9

million by 2010. And in the long run, a steady control over population can be realized through industrial adjustment and upgrade.

- **Optimize population structure and distribution**

Adjustment of population structure and its regional distribution through industrial restructuring can be a strategy for Shenzhen to regulate its population structure. It can accelerate the development of industries driven by technology, capital investment and knowledge and control labor-intensive sectors to optimize resource allocation, hence promote population structure adjustment and optimization of population distribution.

Resource and Energy Security Strategy

The current development mode of Shenzhen relies much on resources. Among the four scenarios, only one simulative result reaches the balance of demand and supply of resources and energy. This further displays the restrictive effect of resources and energy on Shenzhen's future development. To secure the supply of resources and energy is not only an urgent task for Shenzhen at present, but also a strategic issue that allows no neglect in years to come.

- **Develop clean energy and adjust energy structure**

The direction of energy development of Shenzhen is to develop clean energy and renewable energy on the basis of guaranteed energy security. For instance, thermal power plants can be replaced by LNG clean power generation facilities and other new energy sources like solar power, wind power and nuclear power. Natural gas engineering shall be promoted to reduce the use of petroleum. The development of clean energy and renewable energy is a positive contributor to facilitating energy structure adjustment, securing energy reserve and reducing environmental pollution.

- **Improve water resource guarantee system**

As the scope for water diversion from outside Shenzhen is limited and the growing economy and population will continue to boost the demand for water, water shortage will be one of the most serious issues facing Shenzhen in the next 15 years. To cope with the potential threat to water resource, we should, on the one hand, coordinate efforts to protect water sources through trans-regional eco compensation to reduce risks of water supply from outside Shenzhen while ensuring supply in the east area and smooth operation of water diversion projects along the north line. On the other hand, more attention should be given to local efforts to tap new sources of water supply and reduce water consumption in a bid to depend less on water supply from outside Shenzhen and strengthen water resource management. Measures to relieve the pressure including expanding the capacity of reservoir, establishing waterworks, experimenting with scattered means for water storage such as making use of the top of building or underground systems to ease the pressure of centralized water storage. The use of water saving instruments shall be promoted to increase reuse of industrial water. The supporting network of sewage treatment projects should be improved to increase sewage treatment level. The residual of treated water can be used for various civil

purposes and serve to compensate eco service. Demonstration communities for reusing treated water should be established to accumulate and extend relevant experience. More efforts are needed to make use of rainwater and flood and desalinize seawater. We can also improve management by advocating water saving audit, reusing treated water, developing water quota for domestic use and reforming water price.

- **Develop circular economy**

While making vigorous efforts to develop clean energy and renewable energy, we must establish a collection and reuse system for renewable resources as well as promote energy conservation and reuse, so that reduction, reuse and recycle becomes a social practice. We will gradually form a recycling industrial system, production pattern and consumption pattern to ensure the security and full use of resources and energy.

Effective and Intensive Spatial Distribution Strategy

All the simulative results of the four scenarios in Chapter V show that Shenzhen's land reserve is severely scarce. Almost all space has been used up. To tackle the deficiency of space, we have to focus on the dual tasks of space expansion and management improvement.

- **Expand and use space efficiently**

The amount of construction land in Shenzhen has come close to the margin of eco control line. Only fractional land for construction purpose is left. There are two means to explore the useable space of Shenzhen provided that the administrative border and eco control line remain unchanged. One is to develop new space through proper sea filling projects and effective use of underground space. The other is land redevelopment, which is to say, to rebuild or change the function of current village-in-city houses for lease and old industrial parks in order to expand space and improve space efficiency.

- **Enhance land resource management**

Management of land resources carries great significance as Shenzhen is in great need of space. On the one hand, we should make rational plan on land resources and strictly control land supply. On the other hand, we should promote market mechanism to regulate land supply and form effective pricing system for land deals. Thus we can ensure the efficiency of land use.

Eco-environment Harmony Strategy

The development of Shenzhen in last decades has put much pressure on eco environment. To further promote sustainable development, we should put building eco civilization high on agenda while calling for material, political and spiritual aspects of civilization. To build Shenzhen into a livable city that is environmentally friendly and harmonious in ecology, we must take environmental management and improvement into consideration.

- **Strengthen environmental management**

We should stick to the principle of taking prevention as priority and using comprehensive treatment, frame reasonable environmental protection plans and designate environmental function

zones. We will further promote the total amount control and environmental impact assessment system to improve pollutant discharge permit system. Efforts are needed to build capacity in environmental law enforcement and management. Eco compensation mechanism should be established step by step. We should encourage the rational development of environmental industry, step up environmental promotion by raising public awareness, encouraging public participation and advocating eco civilization.

◆ Comprehensive environmental improvement

On the one hand, we should map out schemes to address key environmental problems for comprehensive control. For example, we should control water environment in such key water areas as Shenzhenhe Bay, Maozhou River, Guanlan River and promote the drive of desulphurization and denitrification. We should encourage the use of environmental friendly refrigerant and launch air environmental control program such as vehicle emission control. Efforts should be made to promote garbage classification and collection and reuse of solid wastes. On the other hand, we will build more supporting facilities for environmental infrastructure, improve urban sewage collection and treatment network, establish sewage treatment plants and increase treatment level. We will build more waste disposal sites and transfer station and build or rebuild public toilets.

◆ Enhance intercity cooperation to control regional pollution

Shenzhen is located in the city cluster of the Pearl River Delta and is adjacent to Hong Kong. Air pollution and water pollution tend to involve related region. If we only rely on a city or a couple of cities to control pollution, it is hard to improve the region's overall environmental quality. Therefore, we should strengthen regional cooperation to jointly control pollution and protect the eco environment. First, we can explore a regional coordination mechanism for environmental management, where we can identify regional environmental policy, coordinate trans-regional environmental laws, regulations and standards; second, there is a need to establish trans-regional environmental information exchange system and dispute settlement system; third, we should also establish a joint planning mechanism and emergency response cooperation system. Thus, we can improve the overall level of environmental protection in the region to meet the goal of regional pollution control and environmental protection.

The above six strategies are complementary and focus on different aspects, forming a perfect system to safeguard economy, resources and ecology. It is in line with the positioning of Shenzhen to seek efficiency and harmony and carries the urban spirit that promotes innovation, pioneering and aggressiveness. These strategies will facilitate the sustainable development of ecology, economy and the society, paving a way for Shenzhen's ultimate development strategy of being a global pioneer.

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Annexes

Annex I Standard Limited Value for Basic Items in Environmental Quality Standard for Surface Water (National standard of People's Republic of China)(GB3838－2002)

Item	Grade Ⅰ	Grade Ⅱ	Grade Ⅲ	Grade Ⅳ	Grade Ⅴ
Permanganate Index ≤	2	4	6	10	15
BOD_5 ≤	3	3	4	6	10
NH_3－N ≤	0.15	0.5	1.0	1.5	2.0
TP (calculated by phosphorus) ≤	0.02 (0.01 for Lakes and Reservoirs)	0.1 (0.025 for Lakes and Reservoirs)	0.2 (0.05 for Lakes and Reservoirs)	0.3 (0.1 for Lakes and Reservoirs)	0.4 (0.2 for Lakes and Reservoirs)

Annex II Ambient Air Quality Standard (annual average)(National standard of People's Republic of China)(GB3095－1996)

Unit: mg / m^3

Item	Grade I	Grade II	Grade III
SO_2	0.02	0.06	0.10
TSP	0.08	0.20	0.30
PM_{10}	0.04	0.10	0.15
NO_x	0.05	0.05	0.10
NO_2	0.04	0.04	0.08

Annex III Explanation and identification of the degrees (strong, medium and weak) of relevant influencing factors in the four Scenarios

Table I Influencing factors of land resources

Factors	Degrees	Current status	Description
Sea filling	Strong	26.8 km^2 of land has been reclaimed from sea.	Reclaiming 89.2 km^2 from sea filling by 2020, and continue the work to 2030 with 4 km2 being reclaimed on average every year.
	Medium		Reclaiming 89.2 km^2 from sea filling by 2020 and stop the activity afterwards.
	Weak		Reclaiming 60.25 km^2 from sea filling by 2010 and stop the activity afterwards.

Reconstruction of villages-in-city	Strong	Rebuild 20 km^2 from 2006-2010	To continue the rebuilding plan till 2030 at current speed
	Medium		To continue the rebuilding plan till 2020 at current speed
	Weak		To carry out current rebuilding plan (rebuilding 20 km^2 of areas that can be redeveloped most easily by 2010)
Development intensity of remaining land for construction	Strong	Develop 50 km^2 every year since 2003	Till all land for construction purpose is used up
	Medium		Keep 5% of land resources for construction purpose
	Weak		Keep 10% of land resources for construction purpose

Table II Influencing factors of economic subsystem

Factors	Degrees	Current status	Description
Industrial structure adjustment	Strong	The secondary industry accounted for 51.6% in 2004 and 53.2% in 2005	The proportion of the secondary industry will reach 48% by 2010, 42% by 2020 and 35% by 2030.
	Medium		The proportion of the secondary industry will reach 50% by 2010, 45% by 2020 and 40% by 2030.
	Weak		The proportion of the secondary industry will grow at current speed, reaching 55% by 2010, 58% by 2020 and 60% by 2030.

Table III Influencing factors of atmospheric environment

Factors	Degrees	Current status	Description
Control of industrial pollution sources	Strong	Currently the industrial removal rate of SO_2 is 85% and that of NO_2 and soot is respectively 80% and 90%	The SO_2 removal rate of industrial sources will reach 95% by 2010 and 98% by 2020. SO_2 reduction rate will reach 20% by 2010 and 40% by 2030 through taxation. NO_2 removal rate of industrial sources will reach 90% by 2010, 95% by 2020 and 98% by 2030. Soot removal rate of industrial sources will reach 95% by 2020 and 98% by 2030.
	Medium		The SO_2 removal rate of industrial sources will reach 90% by 2030. SO_2 reduction rate will reach 10% by 2010 and 20% by 2030 through taxation. NO_2 removal rate of industrial sources will reach 85% by 2030. Soot removal rate of industrial sources will maintain at 90%.
	Weak		The SO_2 removal rate of industrial sources will keep at current level of 85%. NO_2 removal rate of industrial sources will maintain at 80%. Soot removal rate of industrial sources will maintain at 90%.
Adjustment of energy consumption structure	Strong	The gas-oil ratio in the Pearl River Delta is 0.95：0.05	The gas-oil ratio will be 0.8: 0.2 by 2010, 0.7: 0.3 by 2020 and 0.6: 0.4 by 2030.
	Medium		The gas-oil ratio was 0.9: 0.1 in 2005, and will reach 0.8: 0.2 by 2010 and 0.75: 0.25 by 2030.
	Weak		The gas-oil ratio was 0.95: 0.05 in 2005 and will be 0.9: 0.1 by 2030.

Utilization level of energy	Strong	The energy consumption for per RMB 10 000 Yuan industrial output in the Pearl River Delta is 0.8 tonne coal equivalent.	The energy consumption for per RMB 10 000 Yuan industrial output will reach 0.6 tonne by 2010, 0.45 tonne by 2020 and 0.35 tonne by 2030.
	Medium		The energy consumption for per RMB 10 000 Yuan industrial output will reach 0.7 tonne by 2010, 0.55 tonne by 2020 and 0.45 tonne by 2030.
	Weak		The energy consumption for per RMB 10 000 Yuan industrial output will reach 0.75 tonne by 2010, 0.65 tonne by 2020 and 0.6 tonne by 2030.
Control of traffic pollution sources	Strong	Current standard applied equals to ECE15—03 (GB147611—93) HC:7.7 CO:45 NO_2:2.7	The current standard of ECE15—03 will meet Euro III by 2010 (HC:0.29, CO:5.22, NO_2:0.78) and meet Euro IV by 2020 (HC:0.16, CO:2.27, $N0_2$:0.39) (Unit: g/km)
	Medium		The current standard of ECE15—03 will meet Euro III by 2010 (HC:0.29, CO:5.22, NO_2:0.78) and meet Euro IV by 2030 (HC:0.16, CO:2.27, $N0_2$:0.39) (Unit: g/km)
	Weak		The current standard of ECE15—03 will meet Euro II or Euro I by 2030 (HC:1.7, CO:6.9, NO_2:2) (Phase II of national vehicle emission standard) (Unit: g/km)
Control of domestic pollution sources	Strong	All residents are considered using LPG.	The consumption of LPG is 248 tonnes/year per 10 000 permanent residents using past statistics on population. According to the latest statistics and *Report on Residential Energy Consumption in Five Chinese Cities* (2001), the consumption in Guangzhou is 195kg. Among waste gas generated, SO_2 accounts for 0.018%, NO_2 0.17%, CO 0.41% and soot 0.0126%.

Table IV Influencing factors of water resources and water environment

Factors	Degrees	Current situation	Description
per capita water resources supply level	Strong	The annual per capita water consumption between 1998 and 2002 ranged from 54 to 60 tonnes (as calculated by permanently resided population in 2006); the number increased somewhat since 2003 and hit the top in 2004, reaching 76 tonnes per capita.	Annual per capita water consumption will reach 73 tonnes by 2010 and come to 82.13 tonnes by 2020. The level will be maintained afterwards.
	Medium		Annual per capita water consumption will reach 73 tonnes by 2010 and come to 82.13 tonnes by 2030.
	Weak		Annual per capita water consumption will level at 57 tonnes.

Factors	Degrees	Current situation	Description
Plan of water saving	Strong	Annual water consumption per capita was 76.65 tonnes in 2005.	The water saving rate of domestic and public sources will reach 5% by 2010, 10% by 2020 and 15% by 2030. Industrial water withdrawal for per RMB 10 000 Yuan industrial output will be reduced by 25% by 2010 (4.08 tonnes) from 6.7 tonnes in 2004 (estimated to be 5.4375 tonnes according to revised data of 2006); by 30% by 2020 (2.85 tonnes) and 30% by 2030 (1.99 tonnes).
	Medium	In 2004, water consumption per capita was 102.9 tonnes. The adjusted amount was 76.78 tonnes after allowing for population adjustment.	The water saving rate of domestic and public sources will reach 5% by 2010, 10% by 2020 and remain at the level thereafter. Industrial water withdrawal for per RMB 10 000 Yuan industrial output will be reduced by 20% by 2010 (4.35 tonnes) from 6.7 tonnes in 2004 (estimated to be 5.4375 tonnes according to revised data of 2006); by 20% by 2020 (3.48 tonnes) and 20% by 2030 (2.78 tonnes).
	Weak		The water saving rate of domestic and public sources will reach 5% by 2030. Industrial water withdrawal for per RMB 10 000 Yuan industrial output will be reduced by 15% by 2010 (4.62 tonnes) from 6.7 tonnes in 2004 (estimated to be 5.4375 tonnes according to revised data of 2006); by 15% by 2020 (3.93 tonnes) and 15% by 2030 (3.34 tonnes).
Tapping more water sources (including reuse of treated water)	Strong	The pipe leak rate is 15% in Shenzhen now. Rainwater that is easy for utilization amounted to 44.74 million m^3 per year and rainwater that it is feasible to use is 428 million m^3. Recycling rate of treated water in 2005 was 0.0376%.	Water diversion from outside Shenzhen and water supply from local area will proceed according to the supply plan; Loss from pipe leakage will be reduced to 8% by 2010 and to 5% by 2020. Utilized rainwater will reach 44.74 million m^3 by 2010 and 428 million m^3 by 2030. Desalinized seawater used will reach 6.2 million m^3 by 2010 and 116.8 million m^3 by 2020 and the utilization level will be maintained. Recycling rate of treated water will reach 20% by 2010, 25% by 2020 and 30% by 2030.
	Medium		Water diversion from outside Shenzhen and water supply from local area will proceed according to the supply plan; Loss from pipe leakage will be reduced to 10% by 2010 and to 8% by 2020. Utilized rainwater will reach 44.74 million m^3 by 2010, 152 million m^3 by 2020, and 212 million m^3 by 2030. Desalinized seawater used will reach 6.2 million m^3 by 2010 and 116.8 million m^3 by 2030 and the utilization level will be maintained afterwards. Recycling rate of treated water will reach 10% by 2010, 15% by 2020 and 20% by 2030.

Factors	Degrees	Current situation	Description
	Weak		Water diversion from outside Shenzhen and water supply from local area will proceed according to the supply plan; Loss from pipe leakage will be reduced to 12% by 2010 and 10% by 2020. Utilized rainwater will reach 44.74 million m^3 by 2020 and the level maintained till 2030. Desalinized seawater used will reach 6.2 million m^3 by 2010 and the utilization level will be maintained afterwards. Recycling rate of treated water will reach 5% by 2020 and 10% by 2030.
Treatment level of sewage	Strong	Urban sewage treatment rate was 62.85% in 2004 and 60.5% in 2005. The treatment was of B of Level I.	The centralized urban sewage treatment rate will reach 90% in 2010, 95% in 2020 and 98% in 2030. The treatment level of COD and NH_3-N will reach A of Level I in 2010, advanced treatment level (A Level I *0.8) in 2020 and advanced level (A Level I *0.6) in 2030. (water temperature of NH_3-N is above 12℃)
	Medium		The centralized urban sewage treatment rate will reach 70% in2010, 80% in2020 and 85% in 2030. The treatment level of COD and NH_3-N will reach A of Level I in 2030.
	Weak		The urban sewage treatment rate will reach 60% at the level of B, Level I.

Table V Influencing factors of solid waste subsystem

Factors	Degrees	Current situation	Description
Reduction of pollution sources	Strong	No sign of reduction or lacking related data	The reduction rate of both construction waste and domestic waste will reach 10% in 2010, 15% in 2020 and 20% in 2030.
	Medium		The reduction rate of both construction waste and domestic waste will reach 5% in 2010, 10% in 2020 and maintained at 10% in 2030.
	Weak		No reduction
Recovery level of wastes	Strong	15% of The recovered waste before and after collection is respectively 15% and 5%. Recovery of construction waste has not been commercialized.	The recycling rate of domestic waste will reach 45% in 2010, 50% in 2020 and the level will be maintained till 2030. Recycling rate of construction waste will reach 5% in 2010, 15% in 2020 and 25% in 2030.
	Medium		The recycling rate of domestic waste will reach 25% in 2010, 30% in 2020 and 35% in 2030. Recycling rate of construction waste will reach 5% in 2020 and 10% in 2030.
	Weak		The recycling rate of domestic waste will reach 25% in 2020. No construction waste will be reused.

封面右一：深圳市深南大道
封面右二：深圳市市民中心
封面右三：深圳市红树林自然保护区
封面右四：深圳市夜景
封　　底：深圳市荔枝公园