Chapter Ⅱ.

Establishment of a Comprehensive Monitoring Plan

Chapter II. Establishment of a Comprehensive Monitoring Plan

1. Overview of the Present Study Results

1.1. Description of the Environment

1.1.1. Tide and Current

Tidal level changes in a regular diurnal cycle in the Pearl River Estuary. The semidiurnal component is dominant, with a substantial diurnal inequality.

Water current vectors in the estuary also vary in a diurnal cycle according to the tide. During ebb tide, currents are generally toward the south, but they are in the opposite direction during flood tide. The maximum current magnitude observed is around 2.0 m/s during ebb tide near Humen.

The tidal residual currents in the upper layer are southerly in the entire estuary. In the middle and bottom layers, however, they are northerly in the eastern part of the estuary, and southerly in the western part.

Characteristic features found in vertical distributions of salinity and temperature in the rainy season survey are as follow:

- Distribution patterns of salinity and temperature are vertical during spring tide and horizontal during neap tide.
- Distributions of temperature and salinity vary depending on the conditions of tidal level and currents, i.e.:
  - ♦ stratification in salinity and temperature occurs during flood tide or when northerly tidal currents prevail; and
  - ♦ stratification disappears or becomes weaker during ebb tide or when the southerly currents prevail.
- Stratification in both salinity and temperature is more pronounced during neap tide than during spring tide. Stratification occurs at most of the survey locations throughout the rainy season, regardless of the strength or the direction of tidal currents.

Conversely, clear stratification was not detected in the dry season survey, as a result of reduced river discharge and a narrower water temperature range.

The distribution pattern of temperature and salinity in the transient season (spring) is similar to that in the dry season. The stratification in salinity, however, is more pronounced in the transient season.

The vertical distribution of turbidity is closely related to the current strength, especially in the bottom layer. This indicates that turbidity increase follows the incremental increase in current strength in the bottom layer, as resuspension of the bottom sediment takes place.

The distribution of “compensation depth” is closely related to the turbidity distribution.

1.1.2. Water and Sediment Quality

Water quality in the Pearl River Estuary is influenced by the seasonal changes of river discharge and tidal change. In many samples analyzed in the estuary, characteristic water qualities were COD, I-N (Inorganic Nitrogen, especially NO_3-N) and PO_4-P, as indicators of organic pollution and eutrophication of the estuary.

Loads of COD and NO_3-N are mainly supplied from four river outlets namely Humen, Jiaomen, Hongqimen, and Hengmen. These loads govern the water quality distribution of the estuary, since there are clear relationships between these concentrations and salinity.

High concentrations of COD (over 2 mg/L) are spread over the whole of the estuary in the rainy season, but in dry season are restricted to the northern part, i.e., the outer area of Humen, and Shenzhen Bay. High NO_3-N concentrations (over 0.5 mg/L) have a distribution similar to COD (see Chapter IV, Figures 2.2.1 and 2.2.2).

In addition to the aforementioned four river outlets, PO_4-P loads are supplied from coastal areas by direct runoff. High PO_4-P concentrations (over 0.05mg/L) are widely spread throughout the central part of the estuary in both the seasons, especially in Shenzhen Bay. The PO_4-P levels are higher in the dry season than the rainy season throughout the estuary. It appears that most of the PO_4-P load originated from the coastal area, i.e., highly developed areas such as Shenzhen, Dongguan, and Zhuhai. (See Chapter IV, Figure 2.2.4).

Characteristics of the sediment quality are follows:

- Organic matter contents and oil contents are not very high, except in Shenzhen Bay.
- Negative redox potentials are not observed throughout the estuary, except in Shenzhen Bay.
- Heavy metal contents exceed the standard of coastal bottom sediment quality (Hg:<0.2 mg/kg, Cu:<30mg/kg, Cd: <0.5mg/kg, Zn:<80mg/kg, Pb:<25mg/kg, As:<15mg/kg) in most parts of the estuary, except for Hg.

1.1.3. Aquatic Biota

Aquatic species in the study area have adapted to, or have been regulated by, the physical and chemical environments mentioned above. The plankton and benthos surveyed in the present study had poor mobility and had been affected by the ambient environment. The major zooplankton in the estuary were copepods, which were abundant in the rainy season and decreased in the dry season. The abundance further declined in the transient season (spring), which can be explained by the proliferation of the red-tide dinoflagellate, *Noctiluca scintillans*, throughout the entire study area at this time.

Freshwater phytoplankton are distributed in the upper bay area of the estuary in the rainy season, due to the large amount of river water discharge, but are rare in the dry and transient seasons. Diatoms were the dominant phytoplankton throughout the survey periods. Cell numbers were significantly high in the transient season, lower in the dry season and lowest in the rainy season. A *Skeletonema costatum* bloom occurred in the transient season

(spring), due to optimum temperature, reduced diffusion of the plankton (due to less freshwater discharge) and less tidal exchange during the neap tide.

The abundance of phytoplankton remained in the order of 10^1–10^2 cells/ml in the rainy and dry seasons. This is much lower than those found in eutrophic waters in Japan, with 10^3 cells/ml or more.

The distribution of benthos showed a similar pattern throughout the survey periods, with a low abundance in the low salinity areas, because almost all the benthos species were marine origin. The species composition was also similar among the three survey periods. The northern and western parts of the study area showed less species diversity and less biomass, particularly in the rainy season. This may have resulted from the lack of a stable habitat for benthos, due to large variations in salinity and current velocity in the estuary.

The marine environment of the Pearl River Estuary is largely regulated through seasonal variation of river discharge and strong tidal currents, and these factors, in turn, have affected the physical, chemical and biological environment. In recent years, human activity has further complicated the estuarine environment through pollutant discharge, so that the present environment is a result of the interaction between anthropogenic and environmental factors.

1.2. Water Pollution Mechanisms

With the exception of Shenzhen Bay, the Pearl River Estuary can be generalized by its shallowness, the strong tidal influence and the large quantity of freshwater inflow, with an annual runoff exceeding 1.8×10^{11} m^3 through the four major outlets of the Pearl River system outlets, namely Humen, Jiaomen, Hongqimen, and Hengmen. The majority of the pollutant load into the estuary is attributable to the river inflow that passes through the densely populated and industrialized drainage basin, carrying more than 4×10^5 tons/year of COD_{Mn} and over 3×10^7 tons/year of sediments.

Because of the high tidal-flushing rate, the retention time of the water in the estuary is very short, on the order of few days, and, therefore, the pollutant load does not accumulate in the basin. Consequently, DO levels in the estuary remain higher than would normally be expected from the extent of the organic load. Similarly, no accumulation of organic matter is detected in the bottom sediment, as evidenced by the positive redox potentials observed throughout the basin, except Shenzhen Bay.

As a result of the huge quantity of fresh water inflow, combined with the strong tidal exchange, phytoplankton in the basin are constantly alternating from freshwater origin to marine origin. This impedes *in-situ* primary production, despite the abundance of dissolved nutrients. The exceptionally high turbidity in the basin, reaching 800 FTU in the rainy season, is also unfavorable for algal growth. Enhanced biochemical reactions, so commonly associated with typical estuary bays elsewhere, do not flourish in this estuary.

Overall, these factors indicate that the Pearl River Estuary is biologically unproductive and its water quality is primarily governed by transport phenomena. The fate of conservative pollutants, such as heavy metals, can be inferred analogously; flushed to the outer ocean without significant accumulation.

In contrast, Shenzhen Bay is an entirely different water body, exhibiting every characteristic of a semi-enclosed stagnant coastal basin with eutrophication. Currents in the bay are weak and its water quality is exemplified by the high concentration of phosphorous, nearly 20 times the values elsewhere in the estuary, and high levels of chlorophyll-a. Even though there is a moderate level of DO, a likely result of photosynthesis, the redox potential of the bottom sediment is significantly lower than those observed elsewhere in the estuary, suggesting the occurrence of DO depletion in the low-level waters.

1.3. Simulation Model Development

The physical characteristics of the Pearl River Estuary are an extremely complex interaction of two strongly opposing factors; the unusual quantity of freshwater inflow and the very strong tidal influence forcing open water within the very shallow basin. However, despite the shallowness, averaging only 5 m, and the strong currents, approaching 2 m/s on some occasions, significant density stratification does occur during the rainy season. These complex interactions in the estuary create several computational difficulties in developing a simulation model. Three outstanding complexities are the shallowness versus three-dimensionality, the strong mixing action versus gravitational stability and the large magnitude of water currents.

The successful modeling of a water body as complex as the Pearl River Estuary heavily depends on the availability of detailed high-quality data on hydro-meteorology and oceanography, as well as on pollutant and nutrient loads for calibration and verification processes. As is often the case in the real world, acquisition of such ideal data was not possible for the Pearl River Estuary, despite utmost efforts by both the JICA study team and the counterparts at SCSB-SOA.

While the river discharge data, as multi-annual monthly averages collected by the counterpart, is generally reliable, the collection of high quality spatially and temporally variable nutrient and pollutant load data was not feasible. The study team had to collate sparse data from published literature, as well as field data collected during the present study, to assess seasonally averaged point and distributed sources. Characteristically, the quality of these load data, can only be described as a 'rough estimate', since the field data are limited to the interior of the estuary. In the case of distributed source data along the coastline, estimates are based on information available on land-use, population density, and industrial output.

During the first to the third study periods in China, the study team, assisted by the counterpart, was involved in the design and construction stages of the model development for both the hydrodynamics and the water quality components. As discussed and shown in Chapter V of this report, the development of a hydrodynamics model went rather smoothly. The basic physical features of the estuary, including the formation of density stratification, current patterns and salinity distributions, are satisfactorily, if not perfectly, reproduced. Further fine-tuning of the model coefficients, as well as refinement of river-discharge data, would benefit the model performance.

The water quality component of the modeling, although fully developed, has had some operational obstacles. Among them, the aforementioned lack of load and calibration data is the most problematic. Nonetheless, the preliminary results of the model for both the conservative and the reactive constituents are in agreement with the transport-dominated nature of the water quality in the Pearl River Estuary.

2. Comprehensive Monitoring Plan

2.1. Objectives and Concepts of Monitoring

2.1.1. Objectives

The primary objective of developing a comprehensive monitoring plan is to formulate a management strategy for sustainable development and preservation of the marine environment in the Pearl River Estuary. The results of monitoring and simulation in the present study provided the baseline information for developing the monitoring plan.

2.1.2. Concepts

Monitoring of the Pearl River Estuary can be categorized into the following five sections, according to each purpose.

1) Understanding the physical, chemical and biological characteristics of the water environment: to continuously monitor the water environment of the Pearl River Estuary, targeting an entire area regularly.
2) Monitoring pollution loads: to estimate the loads from four outlets and coasts, targeting each discharge point. The survey could be minimized if data from several agencies could be shared, such as the survey results by the Pearl River Water Resource Commission (PRWRC) for the four outlets and those by Guangdong Environment Protection Bureau (GEPB) for the coastlines.
3) Monitoring the special pollution sources: to understand the cause and area of its influence targeting Shenzhen Bay and other local points with a high concentration of heavy metals. It is necessary to improve the survey plan periodically according to its purpose, such as by adjusting the survey area and sampling frequency, based on careful analyses of preceding survey results.
4) Surveying the state of eutrophication: to further improve the understanding of each pollution mechanism of the area, such as production, decomposition, elution, and settlement surveyed in the study. In particular, surveys are essential in the shallow area of the western part of the bay and Shenzhen Bay, where eutrophication processes are most prominent.
5) Assessing the environmental impacts of industrial development, such as the construction of factories.

In the Pearl River Estuary, surveys 2) to 5) are essential, while limiting survey points, time, items, and frequency according to their purposes. Survey 1) has been monitored continuously by SCSB (South China Sea Branch of State Oceanic Administration) since 1984. Based on these results and those of the present study, the JICA study team proposes that the SCSB monitoring program should proceed effectively, continuously and economically.

2.2. Monitoring Methodology

2.2.1. Characteristics of the Monitoring Area

SCSB has continued marine environmental monitoring in the Pearl River Estuary at some 11 points, as shown in Figure 2.2.1.

Based on the features of water quality, bottom sediment quality and aquatic biota as well as the proximity to common load sources, the estuary has been divided into the six sub-basins shown in Figure 2.2.2. Characteristics of each sub-basin are as follows:

(1) Upper Bay Area

The Upper Bay Area is located off the Humen and Dongguan. Water quality is influenced by the urban area of Guangzhou and Donguang. The area is among the most polluted sub-basins in the estuary. The main pollutants are COD, nitrogen, and phosphorus. The concentration varies following the mixing of river water and seawater by tidal currents. The bottom sediment is composed mainly of silt and clay.

(2) River Mouth Area

The river mouth area is located off the river mouths of Hongquimen, Hengmen, and Zhongshan. This is the area most influenced by the river discharge. Low salinity persists throughout a year, with conspicuously low values observed in the rainy season. COD, nitrogen, and SS are the main pollutants, influenced not only by the riverwater, but also by the pollutant load from the upper bay area and Zhongshan. Because of the shallow depth in the coastal area of Zhongshan, survey vessels are restricted from navigation. Therefore, this area has not been surveyed sufficiently. In the future, a monitoring scheme using small vessels should be established. The bottom sediment is mainly composed of very fine grain.

(3) Lingding Sea Area

The Lingding sea area is located in the central part of the estuary. Water quality is representative of the Pearl River Estuary.

(4) Shenzhen Bay Area

The Shenzhen Bay area reflects the pollutant load from the city of Shenzhen. This area, as well as the upper bay area, are among the most polluted areas in the estuary. The area is dominated by phosphorus, and other major pollutants: COD, nitrogen, and oil. Because the area is geographically semi-enclosed, the water quality is different from those found elsewhere in the estuary. The bottom sediment is also polluted.

(5) Western Part of Bay Mouth

The western area is located off Zhuhai, Macau, and Modaomen. The estuarine water exits from the estuary to the outer sea through this area. A comparatively low salinity water mass extends into the upper layer in the area, and this phenomenon is especially conspicuous in the rainy season. The main pollutants are COD, nitrogen, SS, and metals. In addition, relatively high chlorophyll-a values are observed. The bottom sediment is of very fine grain. Heavy metal concentrations are higher in this area than elsewhere. Zhuhai and Macau are major cities around the Pearl River Estuary. Therefore, implementation of monitoring in the coastal area is necessary to identify the influence of these major cities.

(6) Eastern Part of Bay Mouth

The eastern area is located around Dawanshan Island and to the west of Lantau Island. Water quality is representative of incoming water quality from the outer sea. High chlorophyll-a values are observed, and water masses with low DO are identified in the lower layer during the rainy season. Because the area is influenced by the outer seawater, high salinity values are observed throughout a year. The area is the least polluted area in the estuary.

2.2.2. Proposal for the Establishment of Monitoring Points

Recommendations are made based on comparisons made between SCSB monitoring points and the survey points of this study, as summarized in Table 2.2.1. In this proposal, five additional points to SCSB monitoring are proposed:

- Coast of Dongguan
- River mouth of Henmen or Hongquimen
- Coast of Zhongshan
- Coast of Zhuhai
- Centre of Shenzhen Bay

However, only the center of Shenzhen Bay requires regular monitoring, if the effects of effluent from the coastal cities are not identified as serious.

If further reduction of monitoring points is deemed necessary, the three points shown below could be considered. This recommendation is based on a cluster analysis of water quality survey results to evaluate the similarity among survey points (Chapter IV, Table 2.4.1). However, further data and cluster analyses are required before finalizing whether to eliminate the survey points.

N1103	Could be eliminated, due to the similarity with N1102. If N1103 is eliminated, N1102 should be shifted a little closer to that of N1103.
N1104	Could be eliminated, due to the similarity with N1106.
N1105	Could be eliminated, due to the similarity with N1107. However, if N1105 is eliminated, a new point in Shenzhen Bay would have to be added.

2.2.3. Analytical Methods and Parameters

(1) Water Quality

Water quality analysis includes 35 parameters of the 'Environmental Standard for Seawater in People's Republic of China' as basic parameters. In addition, four parameters on human health and eutrophication, and four basic parameters of marine observation are included. Analytical methods of these are mainly to follow 'GB17378.4-1998, The specification for marine monitoring Part 4: Seawater Analysis'. A total of 43 parameters are to be monitored.

It is important in view of efficiency that the analytical parameters are prioritized according to urgency. Water pollution in the estuary is primarily related to human health and eutrophication factors. Therefore, the priority for organic matter and nutrients should be high and that of less urgent parameters, such as heavy metals should be low. Parameters of water quality analysis are shown in Table 2.2.2.

(2) Bottom Sediment Quality

Parameters for bottom sediment quality analysis are composed of 11 items, mainly of heavy metals and organic pollution indices. Analytical methods are to follow the 'GB17378.4-1998, The specification for marine monitoring Part 5: Sediment Analysis'. Parameters and methods for the bottom sediment analysis are shown in Table 2.2.2.

(3) Aquatic Biota

The aquatic biota of interest in a pollution monitoring program are phytoplankton, zooplankton and benthos, because these organisms are low in the food chain and they are the dominant biota.

2.2.4. Monitoring Frequency

(1) Water Quality

In the Pearl River Estuary, water quality is heavily influenced by freshwater discharge from rivers and, as a result, changes largely by season. Therefore, water quality observations should be carried out seasonally. Survey times should be determined in accordance with the amount of river discharge i.e., the rainy season, the dry season, and a transient season. Each observation should take place during neap tide, when measurements are stable and expected to represent the water quality in each season. However, in the rainy season, observations should be conducted during both spring and neap tides because water quality changes dramatically with tidal cycle.

(2) Bottom Sediment Quality

Because pollution on the bottom sediment is not very serious, observations need not be frequent. Monitoring on a biennial basis should be sufficient. However in Shenzhen Bay, because the bottom sediment is slightly polluted, it is desirable to survey more frequently than the other areas.

(3) Aquatic Biota

Phytoplankton and water quality sampling should be synchronized. Sampling of zooplankton and benthos should take place thrice a year, during the rainy, dry, and transient seasons. Sampling during neap tide period is desirable.

It may be necessary to limit continuous monitoring to phytoplankton that cause red tides, because the analysis of aquatic biota requires considerable resources.

Table 2.2.1 Proposal of Monitoring Points

Sub-Area	SCSB Monitoring	This Study Monitoring	Recommendation
Upper Bay Area	N1102, N1104, N1103	P01, P02, P05, P06	Basically, SCSB points are sufficient to grasp the condition of the marine environment. As an additional point, the coast of Dongguan is recommended because some anthropogenic pollutants are discharged into this area occasionally.
River Mouth Area	-	P03, P04	SCSB points do not involve this area. If river water quality and load can be obtained easily, allocating a new point is not necessary. If it is difficult, some interior points should be substituted for the estimation of river loads.
Lingding Sea Area	N1106, N1107, N1108	P07, P08, P11, P13, P15, P16	Basically, SCSB points are sufficient to grasp the condition of the marine environment in this area. As an additional point, the coast of Zhongshan is recommended as there is no point in the ongoing program that reflects the industrial discharge into this area.
Shenzen Bay	N1105	P09, P10, P12	A new point should be allocated at the center of the bay, because there is no point in SCSB Monitoring.
Western Part of Bay Mouth	N1111, N1112	P14, P17, P19, P21, P24, P25, P26, P27	As an additional point, the coast of Zhuhai is recommended, because there is no point in the ongoing program reflecting the industrial discharge into this area.
Eastern Part of Bay Mouth	N1109, N1110	P18, P20, P22, P23	Basically, SCSB points are sufficient to grasp the condition of the marine environment.

Table 2.2.2 Proposal of Monitoring Items

	Items	SCSB Monitoring	This Study	Proposal of Monitoring Plan
Field Obsevation	Floating Matter			◎
	Color, Smell and Taste		○	◎
	Transparency	○	○	◎
	Salinity	○	○	◎
	Sea Current		○	□
	Light Quanta		○	□
	Tidal Current, Water Level	○	○	□
	Turbidity	○	○	□
Water Quality	Temperature	○	○	◎
	pH	○	○	◎
	Dissolved Oxygen (DO)	○	○	◎
	Chemical Oxygen Demand (COD)	○	○	◎
	Biochemical Oxygen Demand (BOD)	○	○	◎
	Suspended Solid (SS)	○	○	◎
	Inorganic Nitrogen (IN)	○	○	◎
	Inorganic Phosphorus (PO4-P)		○	◎
	Total Nitrogen (T-N)	○	○	◎
	Total Phosphorus (T-P)		○	◎
	Chlorophyll-a	○	○	◎
	Total Organic Carbon (TOC)	○	○	○
	Coliform		○	○
	E.coli	△		○
	Oil Contents	○	○	○
	Silicate (SiO3-Si)	○	○	○
	Pathogenic Organisms			△・×
	Cyanide (CN)			△・×
	DDT			△・×
	Parathion			△・×
	Methyl-Parathion			△・×
	Nonionic Anmonium			△
	Mercury (Hg)		○	△
	Cadmium (Cd)	○	○	△
	Lead (Pb)	○	○	△
	Chromium(VI) (Cr(VI))		○	△
	Tortal Chromium (T-Cr)	○		△
	Arsenic (As)	○	○	△
	Cupper (Cu)		○	△
	Zinc (Zn)		○	△
	Selenium (Se)			△
	Nickel (Ni)			△
	Sulfide (S)		○	△
	Volatile Phenol			△
	Chlorobenzene			△
	Benz-(a)-pyrene			△
	Anionic Surface Active Agent			△
	Radioactive Nucleons			△
	Red Tide Causative Organisms	△		×
	Eh	○		
Sediment Quality	Grain Composition	○	○	△
	Ignition Loss		○	△
	Total Nitrogen (T-N)	○	○	△
	Total Phosphorus (T-P)	○	○	△
	Oil Contents	○	○	△
	Heavy Metals (Hg,Cu,Cd,Pb,Zn,As)	○	○	△
	Eh	○	○	△
	COD	○	○	△
	Sulfide (S)	○	○	△
Aquatic Biota	Zooplankton	○	○	○
	Phytoplankton	○	○	○
	Benthos	○	○	○
	Residual Toxins in Organisms	○		×

Legend
◎: Core monitoring parameters
○: Genaral monitoring parameters
△: Low frequency monitoring parameters
□: Research parameters
×: Parameters at an accident

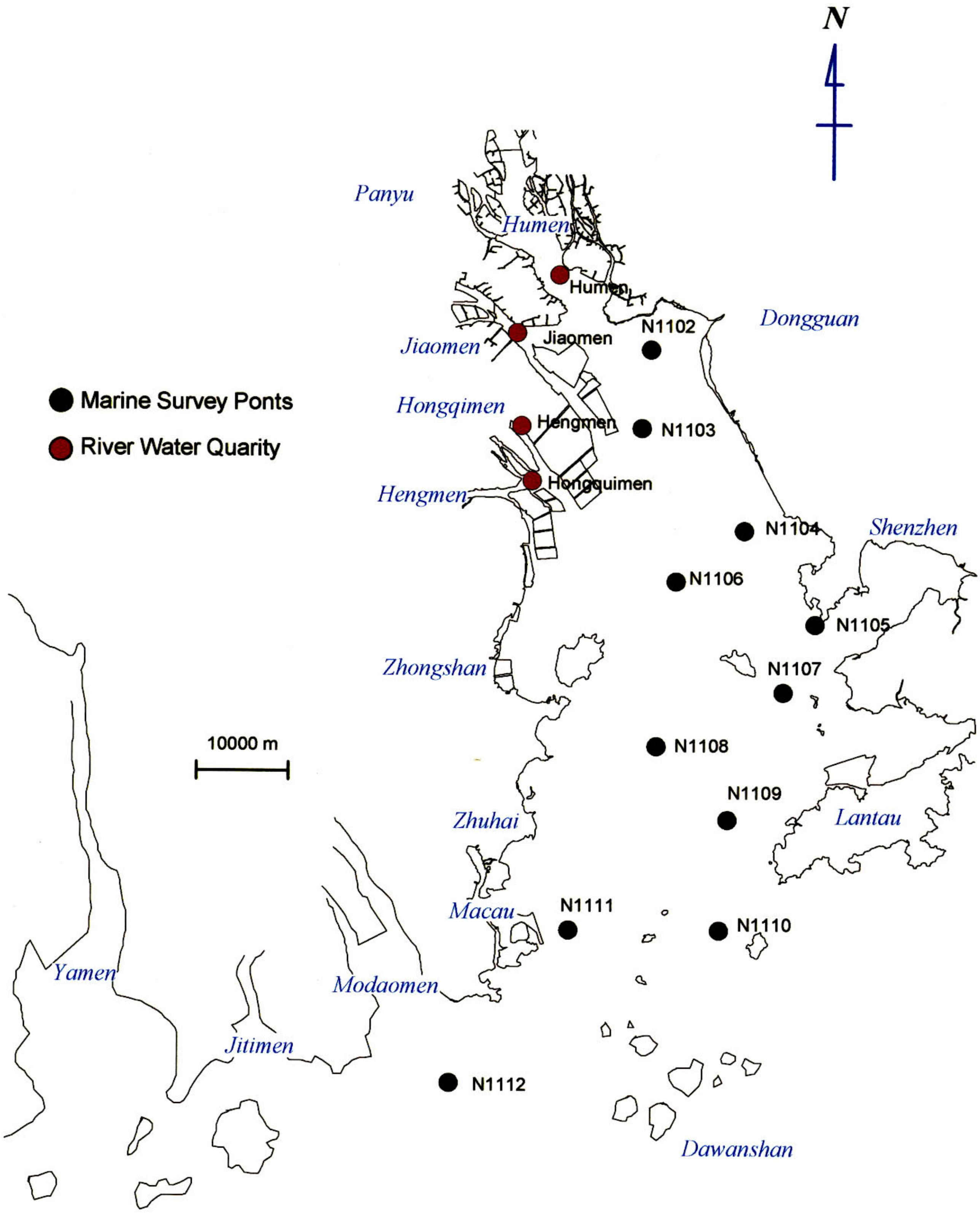


Figure 2.2.1. Monitoring Points Operated by Chinese Organizations

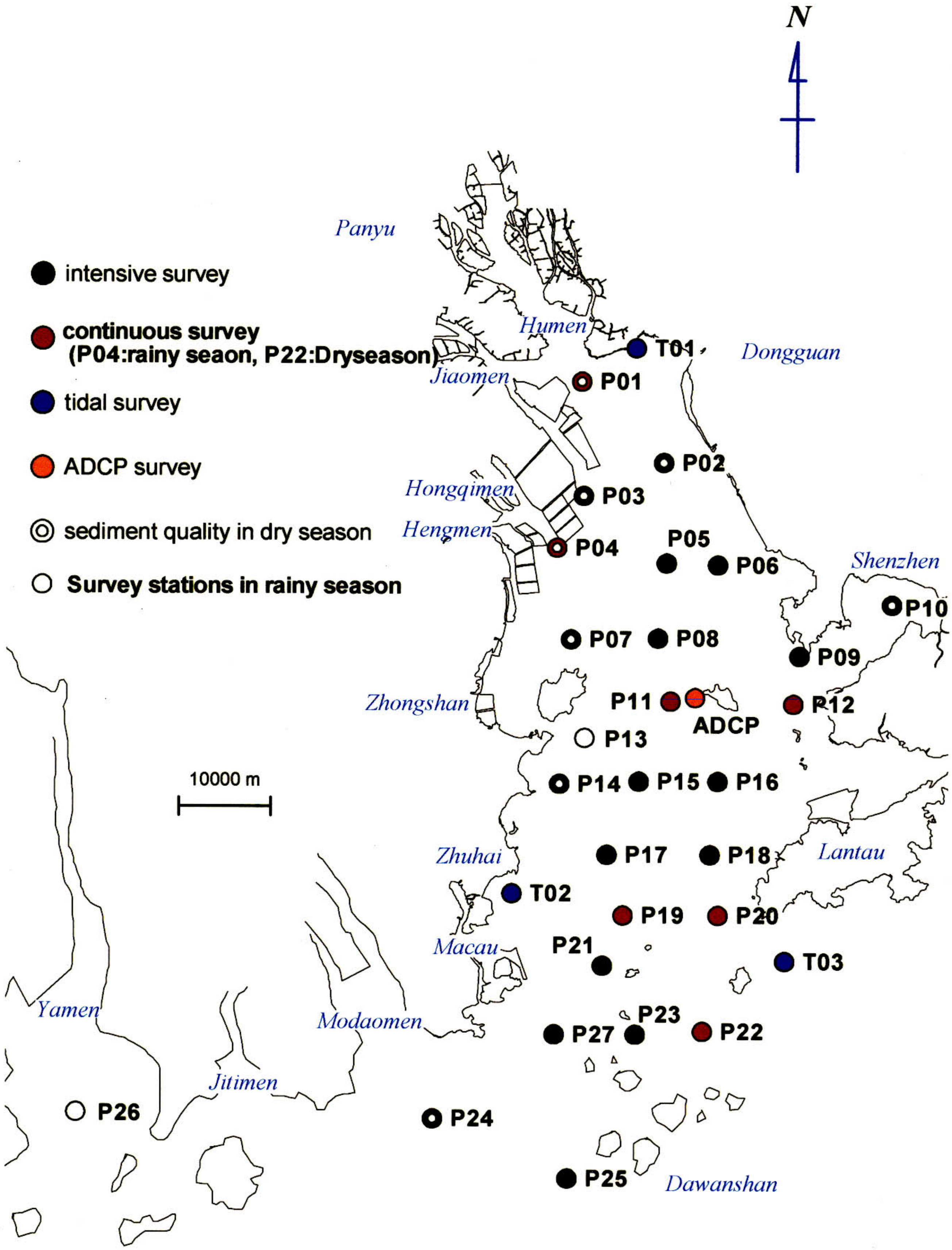


Figure 2.2.2. Survey Stations in Two Seasons

2.3. Data Analysis and Management

2.3.1. Analysis and Management of Water Quality and Bottom Sediment

(1) Certificate of metrological authorization

Chinese metrological management is mainly based on the 'Law on Metrology of the People's Republic of China', the 'Rules for the Implementation of the Law on Metrology of People's Republic of China', and the 'Acts for Metrological Authorization Management'.

As part of metrological management, the 'State Bureau of Technical Supervisory' authorizes a 'Certificate of Metrological Authorization' on laboratories.

In this certification, an inspection is conducted on the management of analysis equipment and chemical analysis methods. Every laboratory involved should obtain this license as a part of quality management.

(2) Detection limit and significant number

The determination of detection limits is necessary for chemical analysis, and is very important for quality control. Although some analytical method manuals describe detection limits beforehand, these values are only index values and should be viewed as a general guideline. Detection limits cannot be determined based only on the values in a manual.

As detection limits are dependent on the analysis equipment, reagent and methodology, they should be determined in each laboratory under its own conditions, and the limits should be defined as reliable values for those conditions only.

It is particularly important to determine lower detection limits. If the empirical values are lower than the lower detection limits, they should be declared 'under detection limit', and values should not be reported because they could provide misinformation.

Generally, the detection limit for analysis by instruments should be determined as the S/N ratio (Signal to Noise ratio) of 2 to 3.

Observation of significant digits is not practiced sufficiently at present. Generally, significant digits for chemical analysis are taken by 2 to 3 figures (only salinity values can be expressed by 4 digits because they less prone to errors due to the measurement principle). However, values with 4 or 5 digits have been reported in the ongoing program. Problems on significant numbers should be improved immediately since they are the fundamental requirement of chemical analysis.

(3) Detection and accommodation of unusual values

Statistic approaches are effective for detection of unusual values. Values which exceed 'average $\pm 2\sigma$, where σ is the standard deviation, can be considered as unusual values. Unusual values can be easily detected by data sheets in computers that are programmed for such detection. When an unusual value is detected, re-analysis and evaluation should be carried out immediately. If possible, different analytical methods should be applied to improve reliability at the same time. It is also necessary to establish a system for protecting samples from deterioration.

2.3.2. Analysis and Management of Biological Data

Analysis of aquatic biota is different from chemical analysis, in the sense that it depends on specific interpretive skills that vary among technicians. Consequently, data compiled for aquatic biota depend on the technical skill of individual who carries out the identification. Special knowledge and techniques are needed for a worker to identify the aquatic biota in a study area. In addition, analytical methods should be standardized in a specific area.

When a survey takes place several times within a year, dilution (or concentration) rates should be standardized when sub-samples are extracted from the samples. However, where a few species are observed abundantly, the cell number of these species can be counted easily by extended dilution. Without standardization in dilution process, scattering in diversity and abundance of species is likely to occur.

In a series of surveys at a specific area, the name of identified species should be standardized. The most recently published taxonomic keys and other literature on identification should be used where possible. Care must be taken to determine whether a species name has been taxonomically revised, which is not uncommon with invertebrates. While it is most important that only one name is used so that misinterpretation of the data does not occur, the person responsible for the identification and analysis should note and record the relationship between the former name and the new one. If a species is known by more than one name, and the organism has been recorded in previous studies under the former name, the former name should be used so that comparisons can be made with previous surveys at a specific site.

When more than one person analyzes a parameter of aquatic biota, information on the identification must be communicated. When the samples can be preserved, they can be kept and observed for analysis by another person. Where the samples cannot be preserved, photographs of the samples should be taken for reference in later analyses.

When a species is recognized that can not be identified, the specific forms should be described at the lowest taxonomic level possible (e.g. genus). If the unidentified species can be preserved, the organism(s) should be recorded with their sampling dates and sites for later observation. If the organism(s) is extreme small, photographs should be taken rather than preservation because it is not easy to detect the organism(s) again under microscope.

The spelling of a species name, and the calculated values per volume (or area), should be checked by a colleague. To be rigorous, it should be checked whether the identified species is distributed in existing survey and, in a case where a species is not found elsewhere in a current survey, the distribution of the species should be checked in existing literature. The biomass (individuals or cells) should be also checked to see if the ranges are comparable to that of an existing survey and, where they are not, the values should be recalculated. Samples should be kept for at least one year in case reanalysis is necessary.

2.4. Facility Development Plan

The existing monitoring facilities of the subordinate units of SCSB are described in Section 4.1 of Chapter III. Most of the equipment for their present monitoring work seems to be ready, but extra work is required because some of equipment is very old or outdated. There are plans to purchase new equipment, and the desire to replace the aged equipment with automatic and modern equipment is strong. These pieces of equipment are listed in Tables 4.1.3, 4.1.4, 4.1.6, 4.1.7, 4.1.9, 4.1.10, 4.1.12, 4.1.13, 4.1.15, 4.1.16 and 4.1.17 in the section stated above. These should be acquired as soon as possible.

In addition, the equipment in the following sections should also be acquired.

2.4.1. Analysis equipment for new hazardous substances

Dioxins are being given close attention in many countries as carcinogens, and endocrine disruptors have been given recent attention as the substances affecting the hormones of living organisms. These substances are not yet recognized as a problem in China. In the near future, however, China may become more concerned over dioxins and endocrine disruptors, and it is deemed wise to prepare for this. These substances can damage human health, even in very small quantities. For the analysis of these new substances, it is necessary to introduce the high performance analytic equipment as follows.

- Analysis equipment for dioxins
  - High performance gas chromatograph mass spectrometer
  - Chemical hazardless laboratory
- Analysis equipment for endocrine disruptors
  - High performance liquid chromatography
  - LC/MS
  - Super critical extractor

2.4.2. Data communication facility

At present, each unit of SCSB collects monitoring data individually. The units compile the data and summarize them as a monthly report. The units submit their reports to SCSB and the original reports are sent to SCSIC of SCSB. There are no daily or weekly reports, except for a special patrol report or in the case of an accident. Thus, anyone who wants to use the official monitoring data of another unit has to wait for one month. If it could be possible to collect and make accessible all the data, including the data of other units in real time, it would be effective for the analysis of each unit's own data and for research collaboration.

The concept of the establishment of a Central Data Control Station (CDCS) is described in detail in Section 2.5.4. of this chapter. The system and facility required are shown in Figure 2.4.1 and Table 2.4.1.

In the system, a host computer is installed in CDCS at the SCSB head office, and computer terminals are installed in each unit of SCSB and the sections of the SCSB head office where they are needed. These computers are connected by a network and the each unit is enabled to see real-time data at any time.

Table 2.4.1 Equipment of the Central Data Control Station

Equipment	Maker and Type	Number of items	Unit price (1,000) J¥	Unit price (1,000) RMB	Total expense (1,000) J¥	Total expense (1,000) RMB
1. Computer server	Compaq (3000 6/400 512)	2	3,000		6,000	
2. Terminal computer	Compaq (EN 6333MMX/3200)	10	320		3,200	
3. Printer	HP Laser Jet 4000	6	230		1,380	
	HP Disk Jet 1120C	1	100		100	
4. Host computer	SCOMEC (EGYS-LP-2000)	2	110		220	
	SCOMEC (EGYS-L-520)	10	30		300	
5. Software		1 set				
MS NT (10 license)	Windows NT Server 4.0	1	260		260	
MS Office 2000	Microsoft	10	120		1,200	
Visual basic	MS Visual Basic	1	110		110	
Oracle	Oracle for Windows NT Server	1	1,000		1,000	
Communication soft		5	120		600	
6. Parts		1 set				
Cable		19	15		285	
Hub (Super Stack II)	Hub 500TP 24 Ports	1	400		400	
Modem		5	5		25	
7. CRT		2		20 *		40 *
8. Copy m/c		1		6 *		6 *
9. Graphics Printer		1		30 *		30 *
10. Installation expense		1 set	500		500	
Total					15,580	76 * 180 *

Note: * are estimates in China (10,000-yuan) or converted to RMB

Currency exchange rate: J¥15 = RMB

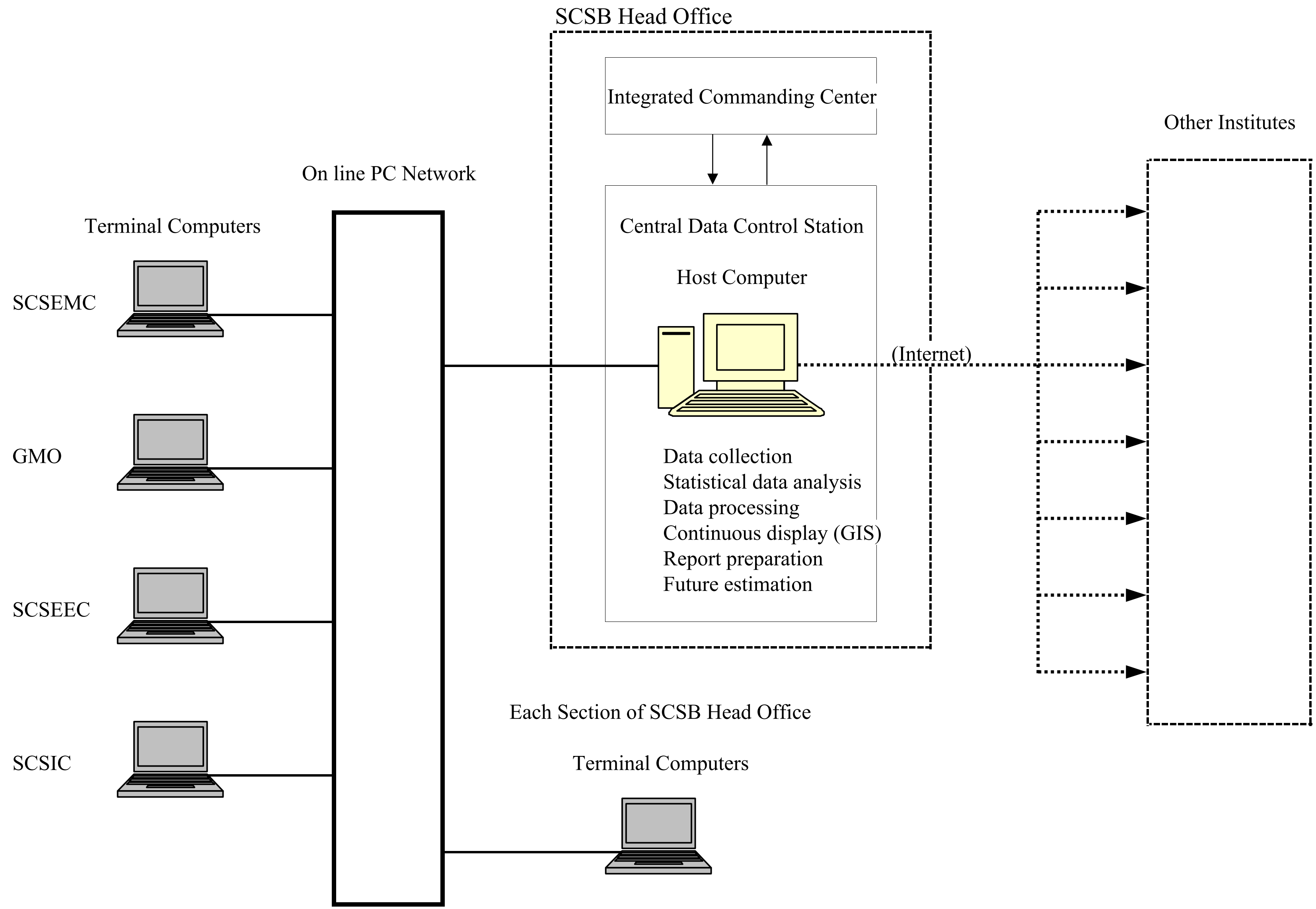


Figure 2.4.1 Plan of the Central Data Control Station for Marine Environmental Monitoring

2.5. Proposal for Organization, Regulations and Supporting System for Monitoring Operations

2.5.1. Problems and Subjects to Be Improved in the Present Organization, Regulations and Systems

The economy in Guangdong province, especially in the cities of the Pearl River Estuary drainage basin, has developed rapidly as described in Section 3 of Chapter III. At the same time, the water quality of the Pearl River Estuary has gradually deteriorated, to the extent that damage is being caused to marine resources. The government has carried out various projects to mitigate the environmental degradation, such as the following:

- review and improvement of environmental law, regulations, and standards;
- reduction of industrial water consumption volume by requiring manufacturing plants to recycle wastewater;
- construction of sewage treatment plants.

These efforts have been effective in preventing serious environmental degradation. But industries such as the fisheries sector have been affected in its production output by seawater contamination, as mentioned in Section 3.5 of Chapter III. This means that even if the government has vigorously carried out environmental protection measures, it has been lagging behind the environmental stress of economic development.

Furthermore, according to the Tenth Five-Year Plan of China and Guangdong (refer to Table 3.10.1 in Chapter III), the central government is striving for harmonized development between urban and rural areas, and that means further development of the western area of China. Guangdong will become increasingly important as the supply base of commodities to this big consumer demand area, in addition to functioning as a supply base to overseas markets. Hence, its economy will continue to develop. The Guangdong provincial government and Guangzhou city government have adopted high economic development targets (11% and 12% GDP annual growth rates) in the Tenth Five-Year Plan. In particular, the Guangzhou city government is putting emphasis on the development of core industries (heavy industry) and tertiary industry.

In such a situation, there is danger that environmental degradation will become serious. Of course, the Guangdong government intends to enhance its environmental protection project, called 'Blue Sky and Blue Water', to ensure sustainable development, and has adopted practical projects in the plan. To make detailed plans and schedules for those projects that are appropriate to issues of economic development, it is essential to have much better and more precise information about the present environmental situation and the ways that is changing. It is also important to confirm the effects of those mitigation measures. The role of monitoring, therefore, is of great importance for ascertaining the present situation and its changes, and confirmation of the effects.

The South China Sea Branch of SOA (SCSB) has ample experience in marine administration and marine environmental monitoring. It has no significant operational problems except that the facilities for monitoring and survey works are too old and out of date. If further development is desired, the following items could be listed as subjects to be improved.

- Replacement of the superannuated equipment and introduction of high-performance monitoring and analysis equipment.
- Implementation of co-monitoring works with the institutes of another organizations.
- Full, efficient sharing of data and information.

The second and the third items are difficult to solve by the efforts of SCSB of SOA alone because they are concerned with governmental administrative institutions and regulations.

2.5.2. Improvement of Organization

The organization needed for marine environmental monitoring in SCSB of SOA already exists. However, in the Pearl River Estuary, the Environmental Protection Bureau, Pearl River Water Resources Commission, Guangdong Ocean and Fishery Department and many other institutes in the transportation department, the Navy, universities, etc. are also monitoring and/or surveying the seawater quality. Each organization monitors by its own plan, and there is little communication and cooperation. Closer communication and cooperation is desired to improve efficiency and knowledge. According to one of the managers in SCSB, a joint meeting on environmental monitoring was held among the bodies concerned in past. However, the meetings were not continued because agreement on the agenda items could not be reached owing to the need for every entity present to give priority to instructions and policy from above.

The Guangdong Tenth Five-Year Plan states that the government intends to establish an environmental monitoring network and cooperative system for environmental protection. This implies that a joint meeting must be reconvened. To sustain the activities of the meeting, it is important to organize top layers of the city governments of The Pearl River Estuary in the first instance. Annex-1 shows a cooperation organization in Japan, 'Setonaikai Marine Environmental Association', which is mostly a political association lead by governments. The association is slightly different from the Guangdong Marine Association, which is more of a research association.

There are no problems regarding the internal organization of SCSB. Two recommendations, however, can be made. The first is to set up a Central Data Control Station, and the second is to carry out educational activities or to set up an informal Human Resources Development Committee. Details of these two items are provided in section 2.5.4. of this chapter.

2.5.3. Improvement of Regulation

(1) Guangdong Ordinance for Water Quality Protection in the Pearl River Estuary

The present laws, ordinances, regulations etc. regarding marine environmental monitoring in the Pearl River Estuary are more or less as written in Section 4.2. of Chapter III. As far as monitoring work is concerned, there seems to be no significant problems. At present, the environmental situation of the Pearl River

Estuary is not serious except in Shenzhen Bay. If the situation deteriorates in the future, however, monitoring will become more important, meaning that close communication and cooperation will become all the more essential. It is important to prepare for such a possible future.

To promote the establishment of good cooperative relations among the parties concerned, that are at present difficult, as mentioned above, it would be effective to issue a regulation similar to the Guangdong Ordinance for Water Quality Protection in Pearl River Delta, but for water resource conservation. Annex-2 is provided as an example from Japan, of what can be done in the form of the 'Law of Special Measure for Setonaikai (Japan Inland Sea) Environmental Protection'. This law obliges the central and provincial governments to formulate a 'Basic Plan' and 'Regional Action Plans'. The law is the basis of the Setonaikai environmental protection system, which is as shown in Figure 2.5.1. It is desirable to issue a regulation or ordinance that might be called, for example, the 'Guangdong Ordinance for Environmental Protection of Pearl River Estuary'.

SCSB of SOA cannot draft such an ordinance by itself, but SCSB can propose it to the provincial government.

(2) Internal Regulations of SCSB of SOA

The employees of SCSB and its subordinate units are faithfully following the existing laws, ordinances, regulations, rules and standards issued by the central or provincial government and SOA. It is not necessary to adopt any new, special regulations. But to ensure that the monitoring work is made more reliable, standards of working procedures can be usefully reviewed. The items to be standardized are described in following section.

2.5.4. Improvement Plan for the Monitoring Institution

The general requirements for marine environmental monitoring are shown in Table 2.5.1. Most tasks are being appropriately accomplished by the SCSB, but if further improvements are made more effective monitoring will be established.

(1) Formulation of a Monitoring Plan

As the degree, type and kind of environmental pollution change year by year in accordance with socioeconomic development, the monitoring system should be devised so as to be capable of coping with those changes.

The head office of SCSB of SOA has to make clear its policy for a marine environmental monitoring system to each subordinate unit and all of the staff charged with monitoring works. It also needs to unify the vectors of their future aim by formulating an integrated basic plan (hereafter called 'Master Plan'), and the each unit needs to formulate a practical action plan (hereafter called 'Action Plan'). The Master Plan can be revised every five years, but the Action Plan should be prepared and reviewed annually.

These plans are not evident in SCSB of SOA and its subordinate units at this time. The following are recommendations of what can be included in those plans.

1) Formulation of the Master Plan

The Master Plan should include following items.

- Summary of the present marine environmental situation and its future projections, including regional socioeconomic development.
- Monitoring items, points, frequency (times), and water quality standard (target figure).
- Administrative policy, methodology, organization, schedule, etc. for improvement of the monitoring system.

2) Formulation of the Action Plan

The preparation of the Action Plan should be based on the policy in the Master Plan. In order to realize each policy from Master Plan, the practical, hands-on targets of the Action Plan should be stated precisely and concretely. The targets should be quantified as far as possible and should include detailed contents, methodology, schedules and identification of the responsible sections or persons in charge. Managing the progress of implementation of the Action Plan is important to ensure the achievement of the objectives. This requires the establishment of a follow-up system that has reporting, assessment, an award system and other elements.

(2) Enhancement of the Marine Environmental Monitoring System

The subordinate units in SBSC are carrying out routine marine environmental monitoring in an appropriate manner. But their additional monitoring activities seem to be rather academic or businesslike. If greater attention is given to the relationship between the environment and socioeconomic development, improved monitoring will be needed. The following are the recommendations of the study team.

1) Improvement of the pollution source data inventory system

The environment is not improved by monitoring *per se*, but by the action taken to control pollution at its sources. Improvement of pollution control is the responsibility of individual enterprises and is regulated by the government organizations concerned. In practice this means the Environmental Protection Bureaus of provincial and city governments. The monitoring bodies are responsible for supporting the enterprises and government bodies so that appropriate countermeasures can be taken and that the effects of those measures can be confirmed. The monitoring bodies must have sufficient knowledge about pollution sources to make their monitoring results effective. This knowledge is also important for efficient conducting of monitoring work within the budget provided.

At present, there seems to be insufficient information on pollution sources in SCSB of SOA and its subordinate units.

It is necessary to establish a pollution source data inventory system, and it should include the following:

- kind and type of pollution discharged and wastewater treatment plants;

- quantity and quality of pollutants;
- plant layouts and wastewater discharge pipeline maps;
- future plans for environmental improvement.

These data and information should be shared by all organizations concerned. Otherwise, they will lack a common ground for discussion about environmental protection and monitoring activities.

To ensure the continuation of data collection, it is necessary to prepare a manual, including the following:

- items to be collected;
- method of data collection;
- data inventory form;
- reporting procedure.

2) Improvement of marine environmental monitoring

The present routine monitoring items, and the items prescribed in the National Standard of Seawater Quality, do not include every item required for the conservation of a healthy ecosystem. In addition to routine monitoring, special monitoring is needed in accordance with the specific type and degree of pollution. Details of additional items are shown in Table 2.5.1 of this chapter. Some of the items are listed in the National Standard. For example, benzo [a] pyren was added to the standard at the time of the most recent revision (1997), but is not currently being monitored because of a delay in preparation for analysis. Dioxin and endocrine disruptors also need to be studied, as stated in section 2.4. of this chapter.

Realistically, manpower and budgetary constraints mean that not all of the items mentioned above can be monitored. However, it is important to review the ongoing monitoring system periodically and to take action to improve monitoring efficiency. The following areas should be considered as important places for the revision of a monitoring system.

- Littoral area of Guangzhou: the chemicals and solids discharged from industrial plants, and sewage.
- Littoral area of Dongguan: same as above.
- Shenzhen Bay: the chemicals and solids discharged from industrial plants.
- Zhuhai sea area: the cause of red tides.
- Waste dumping places: organic chemicals, oil, heavy metals.

Legally, routine monitoring is required three times a year. However, for special monitoring points it would be better to increase the frequency, to, for example, once every one to two months. The interval should be decreased after the environmental condition has recovered and is stable.

As stated and listed in Section 2.4, some of the current monitoring and analysis equipment is aged or outdated and should be replaced. Items to be replaced should be prioritized according to need and budget.

An operation manual and maintenance manual is essential for the monitoring work to yield accurate data. The descriptions of manuals in Table 2.5.1 of this chapter are based on the requirement of the ISO 9000 series. SCSEMC is applying to get the certification of ISO 9002. The other units of SCSB should follow SCSEMC.

There are many organizations and institutions in the Pearl River Estuary, as mentioned in Section 2.5.2 of this chapter. It will be effective for them to cooperate with each other to save time and money, and to facilitate monitoring relevant to technological developments. The following items should be considered in connection with the establishment of cooperative relations.

- Periodic meetings with the monitoring center of the Environmental Protection Bureau, Pearl River Water Research Commission and Guangdong Ocean and Fishery Department
- Standardization of monitoring items and analytic methods, monitoring and sampling time
- Data exchange and co-utilization of data, etc.

3) Improvement of environmental information control and data disclosure

It is important for the entities concerned with marine environmental monitoring to cooperate in order to take appropriate and speedy action in daily monitoring work and in a case of a serious accident. In the case of an accident, a Commanding Center is temporarily set up in SBSC and all the data and information are reported to the Center. It would be effective for the prevention of further dispersion of contamination if all data could be reported to one room in real time, not only at times of emergency but also for daily routine work. Such a station could be called the 'Central Data Control Station'. The suggested system and facility are provided in Section 2.4 of this chapter. By this system, all the data and information can be integrated and shared. The system will also be useful for data processing and report preparation.

The system also can be used for data exchange with the institutes of other government departments and private institutes, such as universities and private enterprises. At present, most data and information are controlled internally and utilized only inside SOA, except in special cases such as when accidents occur or collaborative projects are implemented. Those data are not disclosed to other institutes concerned or to the public. Consequently, valuable data, which are expensive to collect in both time and money, are not being utilized effectively. The availability of these data to interested parties would promote collaborative research and technical development in many institutes and private enterprises. Those research activities and technical developments would be useful in the marine environmental monitoring work of SCSB in the future.

The following is the recommended procedure to implement the suggestion made above.

- Unification of data and information control
- Setting up of the 'Central Data Control Station'
- Establishment of a data processing and reporting system.
- Establishment of a data disclosure system.
- Establishment of a pollution estimation model and the development of a marine environmental GIS.

The system for the Central Data Control Station is shown in Figure 2.4.1 of this chapter.

Figure 2.5.2 presents an annotated diagram of a marine environmental information network in Japan, the Setouchi Net.

4) Enhancement of research and technological development

There are many research subjects important to the development of marine environmental monitoring. The following are some of them. To promote work on these subjects, cooperation with other institutes is necessary and, for this reason, the activities of Guangzhou Marine Association should be enhanced.

- Research and study on monitoring and analysis methods for new hazardous substances
- Research on pollutant dispersion mechanisms and validation of the numerical model of environmental pollutants dispersion
- Development of environmental impact assessment methods for human health and the ecosystem
- Research on environmental benefit transfer (BT).
- Development of industrial pollution protection technology, wastewater recycle use technology, etc.
- Development and introduction of high-tech monitoring equipment
- Research on sustainable development for functional sea-areas, etc.

5) Enhancement of human resources

It is essential to develop the human resources needed for the enhancement of marine environmental monitoring technology. At present, the improvement of the technical capabilities of the staff mostly relies on their own study. The section responsible for education and training is the business section of each unit of SCSB, but systematic education or training is not currently being done.

Table 2.5.2 gives an example of procedures and a detailed plan for human resources development. First of all, an appropriate human resources development system should be established. To establish the system and to ensure its effective, continuing functioning, it will be effective to set up an education committee. The committee may be informal and its members may be assigned together with routine jobs. However, the chairperson should be the head of the unit, and the members should be the key person in each unit.

The recommended roles of the committee are to:

- set up an education system;
- make an education plan;
- organize the education and/or training courses;
- control the progress.

The education system should include:

- organization of the teaching team;
- preparation of textbooks;
- establishment of a personal education recording system;
- formulation of an annual plan;
- establishment of a budget.

The preparation of this work is anticipated to require one year, so the earliest that this system can be commenced is 2002.

The practical education plan should consider the following:

- newcomer training;
- upgrade education;
- professional education or training, OJT, in-house seminars, forums, dispatching technical staff to academic seminars in China or elsewhere, dispatching managers and operators to training courses in China or elsewhere, invitation outside specialists, dispatching students to universities in China or elsewhere
- special skill training, PC, QC, IE, report making, foreign language (conversation), and so on.

It is also important that the Document Center makes specialized books and literature from both China and foreign countries available in each unit, to encourage the self-education of staff.

Table 2.5.1 Improvement Plan for a Marine Environmental Monitoring System (Draft) (1 / 3)

Title	Sub-title	Details	Organization in charge
1. Formulation of the plan (1) Formulation of an integrated basic plan	A. Formulation of a Master Plan for marine environmental monitoring	· Summary of present marine environmental situation · Monitoring items, points, frequency (time), standard (aimed figure), etc. · Clarification of policy, methodology, schedule, organization, etc. on monitoring system · Periodical review on the plan (every 5 years)	SCSB of SOA
(2) Formulation of a practical action plan	A. Formulation of an Action Plan for each plan	· Clarification of detailed contents, schedule, organizations in charge, etc. for each plan · Progress control of each plan (reporting and follow up system, etc)	SCSEMC, GOM SCSEEC, MINIC
2. Setting up of a marine environmental monitoring system (1) Improvement of data inventory system of pollution sources	A. Information control of pollution discharging plants	· Kinds and types of pollution discharging, and water treatment plants, quantity and concentration of pollution substances, plant layout and discharge pipe line maps, future construction plans for environmental improvement, etc. · Joint ownership and practical use of pollution source data (by PC network) , utilization (statistical analysis, estimation of future environmental conditions), etc.	SCSIC
	B. Preparation of manual for data collection and control	· Items, method of data collection, data inventory form, reporting procedure, etc. · Continuation	SCSIC
(2) Improvement of marine environmental monitoring 1) Monitoring items, points, frequency a) Monitoring of new items	A. Organic pollution substances B. Heavy metals C. Entrophication substances D. Non-metals E. Pesticides F. Radiation G. Pharmaceuticals H. New chemicals I. Aquatic organisms	· Phenol, PCB, Benzo [a] pyren, Petroleum, Dioxin, Chloroform, Naphthalene · Cu, Pb, Zn, Cd, Hg, Cr, As · T-N, T-P, PO_4-P, SiO_3-Si, POC (Particle Organic Carbon), PON (Particle Organic Nitrogen) · CN, S^{2-}, TOC · Organic Chloride, Organic phosphate, (Carbamate, Thiram, Thiobencarb, Simazine) · Radioactive substances · Antibiotics · Endocrine disruptors (Tri-butyltin Compound, Bisphenol A , Diethylhexyl phthalate) · Periphyton, fish, shell fish, marine algae, microbes	SCSEMC, ZCMC SOAO
b) Review of monitoring items, points, frequency, etc.	A. Accentuation of monitoring items and points	· Setting up of important monitoring points and items by pollution type and degree Coastal sea-area of Guangzhou; the items discharged from industrial waste water and sewage Coastal sea-area of Dongguan; -ditto- Shenzhen Bay; the items discharged from industrial waste water Zhuhai sea-area; the items causing red tides Around the waste dumping places; organic chemicals, oil, heavy metals, etc.	SCSB, SCSEMC
	B. Increase of monitoring frequency	· Study on the increase of monitoring frequency from every four months to every one or two months, in accordance with pollution degree or in case of accidents	SCSB, SCSEMC

Table 2.5.1 Improvement Plan for a Marine Environmental Monitoring System (Draft) (2 / 3)

Title	Sub-title	Details	Organization in charge
2) Enhancement of monitoring, sampling and analysis equipment	A. Formulation of the plan	・Refer to Table 1-3, -6, -9, -12, -15 ・Setting of priorities (1st to 3rd step)	SCSEMC, GOM, SCSEEC, SCSIC
3) Improvement of the operation and maintenance system for monitoring equipment (follow ISO 9000s procedure)	A. Preparation of operation manual	・Operation manual (measurement principle, specification, caution items) ・Maintenance manual (maintenance schedule, equipment list, accuracy control, traceability to the standard measure, routine check, check and maintenance record) ・Composition of automatic monitoring system, maintenance, replacement, etc. ・Decision on measuring data, treatment of abnormal data, control and use of the data	SCSEEC
	B. Preparation of sampling, measuring and analysis manual	・Sampling/pre-treatment method, analysis, chemicals/materials, equipment/apparatus, operation, detection limit, calculation of concentration, significant figure, etc. for each monitoring item ・Accuracy Control of measuring and analysis	SCSEMC, SCSEEC
4) Cooperation with other organs	A. Co-monitoring with another organs	・Holding periodical meetings with Environmental Protection Bureau, Pearl River Water Resources Commission, Guangdong Ocean and Fishery Department, etc. ・Standardization of monitoring items, monitoring and sampling time, analysis method, etc. ・Exchange of data and joint utilization of data	SCSEMC, GOM, SCSEEC, SCSIC, SCSIC
(3) Improvement of environmental information and disclosure			
1) Enhancement of environmental information control	A. Unification of data control	・Establishment of a data interchange system with other organizations and institutes ・Co-ownership of the data and information and disclosure to the public (by Internet)	SCSB, SCSIC
	B. Setting up of a central data control station	・Collection and control of monitoring and pollution sources data, continuous display, statistical analysis ・Co-ownership of data and information using PC network, efficient report making, etc. ・Decision, commanding, leading, administration and control at an abnormal accident ・Publication of environmental information and routine monitoring activities	SCSB, SCSIC
	C. Establishment of a monitoring data reporting system	・Hourly, daily, monthly and yearly reports ・Establishment of reporting route	SCSB, SCSEMC, GOM, SCSEEC, SCSIC, MINIC
	D. Preparation and publication of a white paper	・Monitoring results and the standard passing rate, present situations of pollution sources, progress of the Master Plan and the Action Plan. ・Publication of an annual report, reporting to superior and another organizations concerned, opening to the public	SCSB
2) Enhancement of estimation technology for pollution dispersion	A. Building a pollution estimation model	・Completion of simulation model, and training in technology ・Utilization of the simulation model for daily administration work	SCSB, SCSEMC, GOM
	B. Preparation of marine environmental GIS	・Real time display on a CRT of pollution materials concentration at each point	SCSB, SCSEMC, GOM

Table 2.5.1 Improvement Plan for a Marine Environmental Monitoring System (Draft) (3 / 3)

Title	Sub-title	Details	Organization in charge
(4) Enhancement of research and technnology development 1) Own research activity by SCSEMC, GMO, SCSEEC	A. Research and study on monitoring and analysis	• Development of monitoring methods for hazardous materials, (Chloroform, Pesticides, Dioxin) • Development of monitoring method using remote sensing technology (dispersion of pollution in marine areas, and analysis of land and marine development)	SCSB, SCSEMC, GOM
	B. Research on clarification of pollution phenomena and estimation of pollution dispersion	• Clarification of pollution mechanism, model building (water pollution, red tide, hazardous materials) • Validation of environmental pollution simulation model and development of its utilization	SCSB, SCSEMC
	C. Research on EIA	• Development of assessment methods for pollution materials that impact the environment, health and ecosystem	SCSEMC
2) Joint research with another institutes	A. Research and development forum	• Enhancement of the activities of Guangdong Marine Association	SCSB, Association
	B. Improvement of polluters	• Development of industrial pollution prevention technology, waste water treatment technology, waste recycle use technology • Development of industrial production efficiency improvement and unit consumption improvement technology	SCSB
	C. Development of new technology and apparatus for monitoring	• Introduction and development of high tech and IT	SCSB
	D. Sustainable development for each functional area	•	
	E. Environmental benefit transition (BT)	•	
(5) Enforcement of human resources	A. Formulation of human resources development plan	• Improvement of the senior supervisors, supervisors and operators of monitoring, measurement and analysis • Internal training, and dispatching trainees to domestic or overseas training courses, schools and seminars • Formulation of an annual plan and schedule for human resources training	SCSB
	B. Training	• Preparation of textbooks, organization of trainers, promotion of incentives for getting certificates, etc. • Establishment of a training fund, control of training record	SCSB

Table 2.5.2 Master Plan for Human Resources Development (1 / 2)

Items	Detail	Objected person (organ)	Org. in charge	Term (Frequency)	Schedule 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
I Establishment of human resources development system														
1. Setting up of education committee (informal)	SCSB, each unit Chair man: chief of each unit Members; section manager	Each unit	SCSB	0.5 Y										
	Planning and progress control			Continuous										
2. Planning of system set-up	Establishment of an education system	Each unit	Committee	0.5 Y										
3. Setting up and progress of the system		Each unit	Committee	0.5 Y										
(1) Organization of teaching team	In-house and outside specialists													
(2) Preparation of textbook	For newcomers and promoted staff training													
(3) Establishment of education recording system	Personal recording form													
(4) Formulation of an annual education plan and procedure for reporting and review	Preparation of manual													
(5) Establishment of budget														
(6) Commencement														
II Action plan for human resources development														
1. Newcomer training	every year (joint lecture) Orientation, outline of jobs and duties, law/regulation, organization, special technology, discipline, etc.	Newcomer of the year	Each unit	0.5 M										
2. Upgrade education	every year (joint lecture) Working regulation, job supervising technology, job improvement technology, personnel control technology, etc.	Staff promoted in last year	Each unit	0.5 M										
3. Professional training (1) OJT (On the Job Training)	Operation manual, principle of equipment, operation method, data control, etc.	Operator	Superior	Continuous										
(2) In house seminar	Study by voluntary applicants Theme; decided by applicants Teacher; each applicant, in-house or outside specialist	Voluntary	Committee	(Once/M) 2 Hr										

Table 2.5.2 Master Plan for Human Resources Development (2 / 2)

Items	Detail	Objected person (organ)	Org. in charge	Term (Frequency)	Schedule 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
(3) Forum	Report and discussion of job and study results	Each applicant	Committee	(Once/Y) 0.5 D										
(4) Dispatching to academic seminar	Dispatching staff to out side Seminar	Technician	Research association	As occasion										
(5) Dispatching to training course 1) Manager training course	The institute in China and over sea Advanced monitoring technology, marine administration technology, human resource development technology	Manager	Overseas training institute	(Once/3 Y) 1 M										
2) Operator training course Analysis operater	Learning of advanced technology Analysis equipment and analysis method of new hazardous substances	Person in charge	Each unit	(Once/Y) 3 M		Advanced equipment, new monitoring items				New substance analysis				General
Meteorological monitoring staff	Advanced monitoring technology			1 M										
Marine monitoring staff	Advanced monitoring technology			1 M										
Data processing and mechanism analyzer	Advanced data analysis technology			3 M										
Data and information control staff	Data control system in progressed country			1 M										
(6) Invitation of out side specialist	Technical lecture from specialist in China or from overseas	Technical staff	Each unit	As occasion										
(7) Study abroad	Overseas university or in China	Technical staff	Each unit	(Once/2 Y) 2 Y										
4. Special skills training														
(1) PC	Training to promoted staff	Promoted staff	Each unit	(once/Y), 2D										
(2) Management technology (QC, IE, etc.)	-ditto-	Promoted staff	Each unit	(once/Y), 2D										
(3) Report making	-ditto-	Promoted staff	Each unit	(once/Y), 2D										
(4) Language (conversation)	Group training (voluntary)	Voluntary	Each unit	(once/W), 2H										
	Special training (selected staff)	Selected staff	Each unit	4 M										
III Enhancement of Document Center (1) Purchase of speciality literature	China and overseas	DC	Each unit	Continuous										

Setonaikai Environmental Protection Law

- Formulation of Master Plan for Setonaikai Environmental Protection
  ↓
- Formulation of Provincial Action Plan based on Master Plan

Practical Methodology for Promotion of Master Plan

Action Based on Another Law, etc

- Restriction of water discharge
- Designation of natural park
- Designation of seawater protection area
- Consolidation of sewage system
- Construction of waste treatment facilities

- Enhancement of public consciousness

- Approval for construction of specific facilities
- Decrease of total pollution load
- Guidelines for decreasing designated substances

- Special consideration for reclamation works

- To specify the natural seashore conservation area

⇩

Realization of the Aim in Promotion of Master Plan

Protection of water quality

- Achieving water quality standard and maintenance
- Clarification of red tide inducing mechanism
- Achieving standard for hazardous substances in benthos
- Protection of seaweed beds and tidal flats required for fisheries resources
- Protection of natural coasts for marine recreation

Natural landscape management

- Landscape management of designated areas such as national
- Preservation of greeneries of islands and coasts
- Appropriate maintenance of natural coasts
- Maintenance of sea surface and coastal aesthetics
- Conservation of cultural resources as historical and scenic sites

Figure 2.5.1 Environmental Protection System of SETONAIKAI in Japan

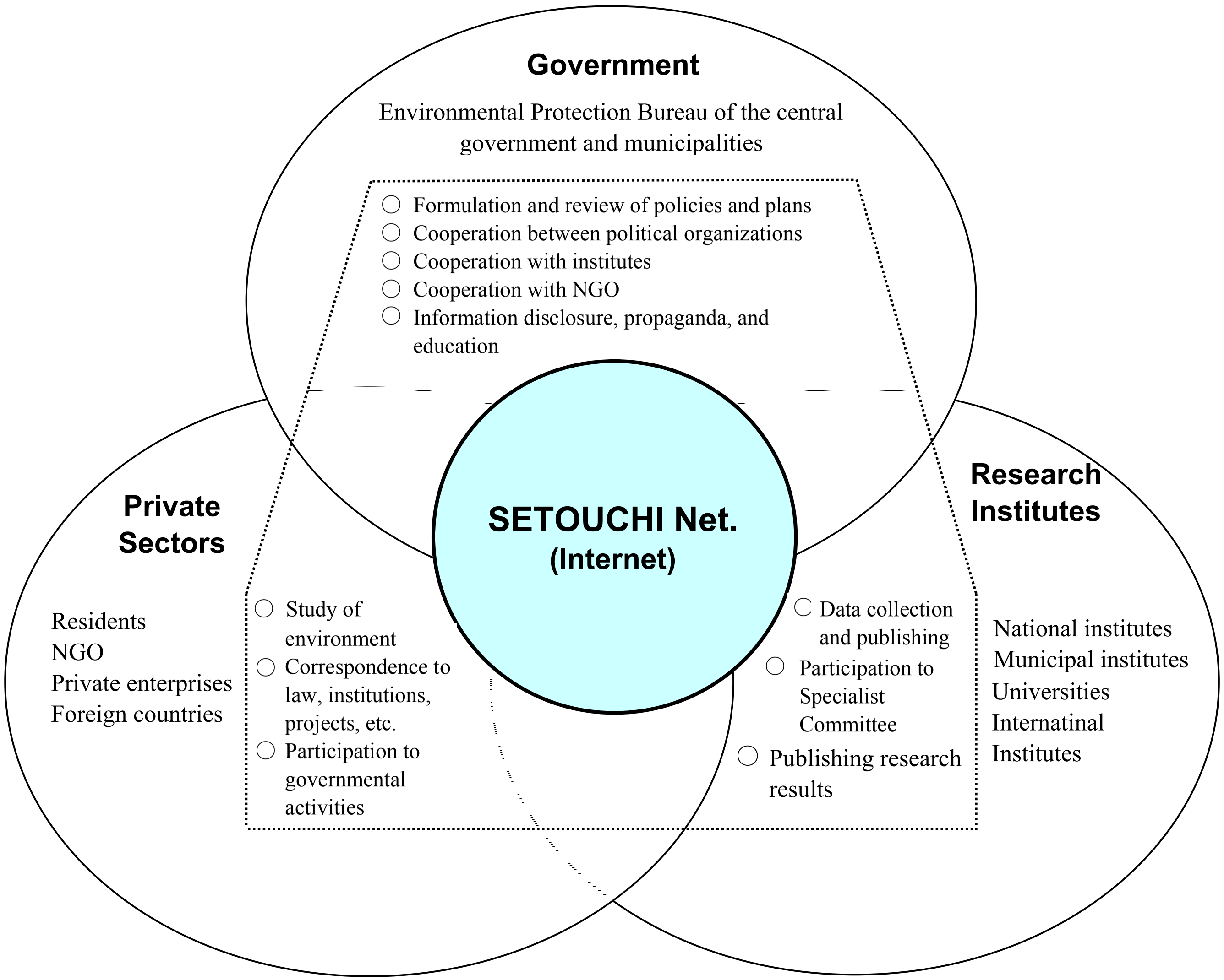


Figure 2.5.2 Network for Supporting Governent Decision Making of Environmental Protection Policy and Measure of Setonaikai in Japan

2.6. Cost Estimation

Cost estimation results are shown in Table 2.6.1. The total expense is about RMB 57 million. This is only for the improvement of the facilities for marine environmental monitoring, and does not include expenses for human resources development. The latter expense should be added to this table after formulation of the plan. As some of the costs in the table are estimated on the basis of costs in Japan, those should be re-estimated in China.

RMB 57 million for the proposed monitoring facility development plan is a large sum relative to the ordinary budget. Therefore, it is necessary to seek a long-term loan from a financial institution (in or outside China, and not necessarily from only one institution). There are several relevant schemes available.

The World Bank is most famous source of funding. It has two schemes. One is the commercial scheme of the International Bank for Reconstruction and Development (IBRD) or World Bank itself, and the other is the scheme for developing countries, called the Second World Bank, or the International Development Association (IDA). The interest rate, commission, repayment term and grace period of each are as follows. IDA is preferable and China was approved US$ 422 million in 1999.

	IBRD	IDA
Interest	floating (5.11% at Dec. 2000)	0%
Commission	0.25%	0.75%
Repayment	20 years*1)	40 years*2)
Grace period	5 years*1)	10 years*2)

Note; *1) per-capita GNP is lower than US$ 1,445
*2) per-capita GNP is lower than US$ 1,460

The Asian Development Bank has two schemes. One is Ordinary Credit (OCR) and the other is the Asian Development Fund. Financing conditions are as follows. ADF is preferable, but China is not on the list of countries than can use the ADF. OCR approved US$ 1,258 million to China in 1999.

	OCR	ADF
Interest	floating (6.24% at Jul. 1999) *1)	1% (in grace period) 1.5% (in repayment p.)
Commission	0.75%	0-0.5%
Repayment	5-30 years*2)	32 years
Grace period	2-7 years*2)	8 years

Note; *1) credit based on US$
*2) per-capita GNP is lower than US$ 925

Japan Bank for International Cooperation (JBIC) has two schemes for yen credits to environmental projects. One is the Special Interest Rate for Ordinary Environmental Projects (SIR-OEP) and the other is the Special Interest Rate for Special Environmental Projects (SIR-SEP). Financing condition is as follows. JBIC approved JPY 192,637 million of credit to China in 1999. The proposed project can be categorized as a 'nature environmental conservation project

(including environmental monitoring)', which is listed as suitable in the table of SIR-SEP.

	SIR-OEP	SIR-SEP
Interest	1.7%*1)	0.75%*1)
Commission	-	-
Repayment	25 years*1)	40 years*1)
Grace period	7 years*1)	10 years*1)

Note; *1) per-capita GNP is US$ 786-1,505

Table 2.6.1 Cost Estimation of Facilty Improvement of SCSB and its Subordinate Units

Name of the Unit	Objective	Number of items	Unit price (1,000)		Total expense (1,000)	
			JPY	RMB	JPY	RMB
1. SCSEMC	Monitoring and analysis	1 set				2,500
	Analysis of Dioxin	1 set				
	High functional gas cromato-mass spectrometer	1	60,000 *		60,000	
	Chemical hazardless lab.	1	20,000 *		20,000	
	Sub total		80,000		80,000	5,333
	Analysis of endocrine disruptors					
	High speed liquid cromato-graphy	1	8,000 *		8,000	
	LC/MS	1	28,000 *		28,000	
	Super critical extractor	1	4,790 *		4,790	
	Sub total		32,790		32,790	2,186
Total of SCSEMC						10,019
2. GMO	Meteorological observation	1 set				8,000
3. SCSEEC	Monitoring	1 set				32,600
4. SCSIC	Information collecting and service	1 set				143
5. SOAO	Monitoring					2,500
6. ZCMS	Monitoring	1 set	32,250 *		32,250	2,150
7. Head office of SCSB (CDCS)		1 set	15,580 *	76		1,115
Total						56,527

Note: * are estimates in China (10,000-yuan) or converted to RMB

Currency exchange rate: JPY 15 = RMB 1

ANNEX-1

SETONAIKAI Environmental Protection Association

1. Members

1) Governors of 13 prefectures around SETONAIKAI
Kyoto, Osaka, Hyogo, Nara, Wakayama, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime, Fukuoka, and Ooita

2) Mayors of 12 major cities around SETONAKIKAI
Kyoto, Osaka, Kobe, Hiroshima, Kitakyushu, Sakai, Himeji, Okayama, Wakayama, Ooita, Fukuyama, and Takamatsu

3) Heads of Fishery Associations of national and 11 major prefectures around SETONAIKAI
Japan, Osaka, Hyogo, Wakayama, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime, Fukuoka, and Ooita

4) Heads of National Park Associations

5) Heads of Health and Sanitary Associations of 8 prefectures and cities
Hyogo, Wakayama, Okayama, Hiroshima, Yamaguchi, Kagawa, Fukuoka-prefecture, and Kitakyushu-city

6) NGOs
Osaka EIFU Voluntary Network

2. Major Activities

1) Dissemination of Thought
2) Enhancement of Conscious
3) Support to Environmental Protection Activities
4) Survey and Research on Marine Environmental Protection

ANNEX-2

Law of Special Measure for SETONAIKAI Environmental Protection

Section 4	Project Promotion for Environmental Protection
Article 14	Construction of Swage Treatment and Waste Treatment Plant
Article 15	Fund for Assistant
Article 16	Setting Up of Plan for Clean up Project of SETONAIKAI
Article 17	Prevention of Oil Discharge by Accident
Article 18	Promotion of Technical Development
Article 19	Support for Fisher Suffered from Damage

Chapter 4	Miscellaneous Rule
Article 20	Warning or Guidance
Article 21	Measure for Progress
Article 22	Procuration of Administration Job to Regional Government
Article 23	Deliberation Committee of SETONAIKAI Environmental Protection

Chapter 5	Punishment
Article 24 ～ Article 27	

Chapter Ⅲ.

Description of the Environment

Chapter III. Description of the Environment

1. Environmental Profile

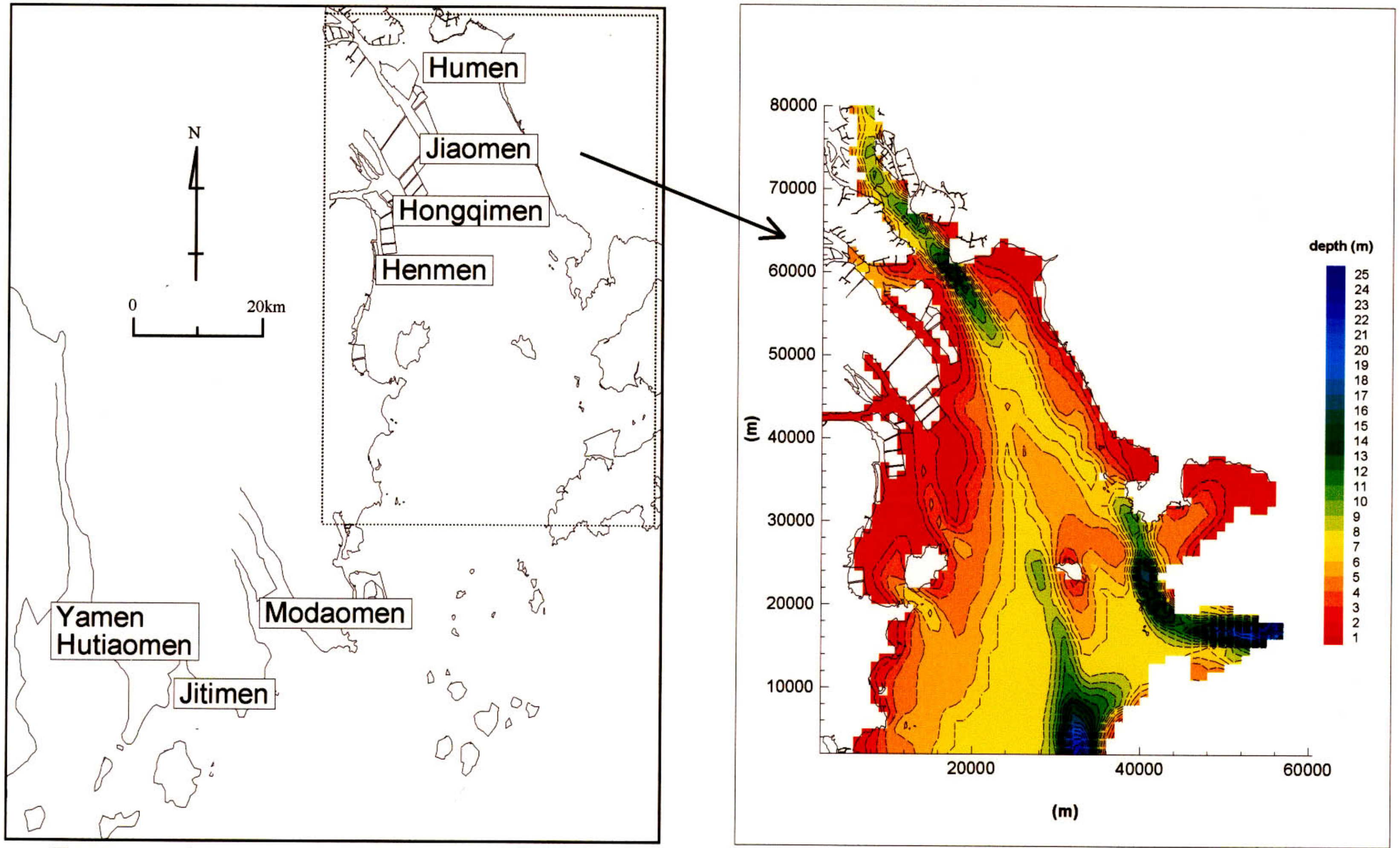
1.1 General Profile of the Pearl River Estuary

The Pearl River Delta region is broadly triangular in shape, extending down both sides of the Pearl River Estuary. The provincial capital of Guangzhou is situated at its northern apex, the Special Economic Zone (SEZ) of Shenzhen is at its south-eastern corner and the Zhuhai SEZ is at its south-west corner.

The Pearl River Delta Economic Region, with an area of 41,700 km^2 and a population of 22.4 million (in 1998), is the economic and cultural core of South China. Rapid urbanization and industrialization in this region has been reflected by a significant increase in the urban population (i.e., non-agricultural population), which in 1982 was just 9.62 million. At the end of 1998, the GDP in the region amounted to RMB 580 billion, some 74 % of Guangdong Province's total GDP (Guangdong Statistical Yearbook, 1999).

The Pearl River is the largest river system in South China. The river has a catchment area of 452,600 km^2 and an annual runoff of approximately 330 billion m^3. About 80 % of the annual runoff occurs between April and September, which is the wet season in southern China (Hills et al., 1998).

The Pearl River enters the South China Sea through eight outlets: Yamen, Huyiaomen, Jitimen, Modaomen, Hengmen, Hongqili, Jiaomen, and Humen (Figure 1.1.1). The latter four outlets are located to the east and discharged into the Pearl River Estuary, which is the area of this study.



Entire study area and eight river mouths

Simulation area and depth contour

Figure 1.1.1 Study Area

The Pearl River Estuary and eight river mouth

1.2 Topography and Geology

The Pearl River Delta lies in the middle southern region of Guangdong Province, and is formed by alluvial deposits from the Pearl River and its three tributaries; the Xijiang (West River), Dongjiang (East River) and Beijiang (North River). It stretches from Gaoyao, in the west, to Huizhou in the east, and from Quigyuan in the north, to Yamen in the south. Its main section lies between Sanshui, Shilong and Yamen.

About ten prefecture-level cities, such as Guangzhou, Shenzhen, Zhuhai, Huizhou, Dongguan, Zhongshan, Jiangmen, Foshan, Zhaoqing and Qingyuan, 30 districts, counties and county-level cities, and 100 towns are located on the Delta.

This estuarine delta plain has a total area of 11,000km^2. It is formed in an ancient bay and is dotted with hills and large rocks. The flat ground is less than 50m above sea level. The plain is crisscrossed by rivers and canals and studded with lakes and ponds.

As the branches constantly deposit great quantities of silt at their estuaries, the plain is extending in area by 50 - 170m^2 per year, forming sand-flat resources.

The Delta is an area with a prosperous economy, flourishing foreign trade and expanding foreign economic and technical cooperation. Since the reform and opening up in China, it has established the Shenzhen and Zhuhai special economic zones. The Pearl River Delta Open Economic Zone has opened up 160 harbors to the world and set up 700 various bases, such as the export-oriented industrial and agricultural product bases, bases for producing different commodities as well as the rear supply bases of the South China Sea Oil Field. At the same time, great progress has been made in township economies.

The Pearl River Estuary is composed of the Lingdingyang Estuary, which involves Shenzhen Bay, and southern part which leads to the South China Sea. It spreads from Latitude 22^o 49' 00" N to 21^o 48' 53" N, and from Longitude 114^o 37' 21"E to 113^o 06' 48" E. The size of entire area reaches 8000 km^2. Related cities are Zhuhai, Zhongshan, Doumenxian, Panyu, Dongguan, Shenzhen and Baoanxian, from the western to eastern sides, going clockwise. There are over 250 large and small islands in the estuary (Guangdong Ocean Natural Resource Survey Team, 1993, 1995).

The Pearl River flows into the Lingdingyang Estuary from four river mouths, Humen, Jiaomen, Hongqili, and Hengmen, out of eight main outlets. Four other main river outlets of the Pearl River, Modaomen, Jitimen, Yamen, and Huyiaomen, face the southern part of the Pearl River Estuary (Li et al., 1991).

The Lingdingyang Estuary spreads longitudinally about 50 km from the Pearl River mouth to the south. Its width is about 8 km laterally at Humen and about 30 km at Neilingding Island.
The width of southern part of the Pearl River Estuary becomes wider and leads to the South China Sea through Wanshan Islands. The total area of the estuary is about 2,110 km^2 (Lin et al.,1996).

Average depth of Lingdingyang Esuary is approximately 5 m, except the eastern and the western trough whose depths are over 10 m. (Han et al., 1995). The southern part of the Pearl River Estuary is deeper than the Lingdingyang Estuary, and its depth becomes deeper southward.

1.3 Meteorology

Lying in the subtropical monsoon zone, the Pearl River Delta is favored with a warm climate and adequate rainfall. It is known for having a 'long summer, short mild winter and an ever-blooming scenery'.

The climate around the Pearl River Estuary belongs to a type of subtropical oceanic monsoon climate, which is one of most pluvial and humid areas in South China.

Basic information about climate is as follows:

- Air temperature: 21.8 ± 0.5 ℃
- Humidity: 80 %
- Rainfall: 1600 - 2200 mm
- Illumination: 1900 - 2000 hours

Note: All data are annual averages (Hong Kong Environmental Protection Agency, 1995)

The annual average wind speed is 2.0 - 4.5 m/s, but wind-scales of more than 6 (over 12 m/s) often occur over the South China Sea. These fast winds are caused by heat thunderstorms and cold waves, and typhoons and tropical low pressure systems (Han et al., 1995). The dominant wind direction in the winter season is NE. In summer, SW or NE wind dominates the shore area, and ESE wind dominates the middle of the estuary.

The rainy season is from May to September (mostly summer), and about 80 % of the annual rainfall concentrates in this period.

1.4 Oceanography

1.4.1. Tides

Irregular semi-diurnal tides dominate in the Pearl River Estuary with considerable diurnal inequalities. The average time difference between consecutive high tides is 9h 09 min and 2h 57 min for low tides. The calculated duration of an ebb is 6h 13.5 min and 6h 11.5 min for a flood. The maximum tide level for an average spring tide is 310.8 cm above the datum line (Lin et al., 1996).

The average tidal range is 1.7 m at Humen and 0.85 to 0.95 m at Wanshan Islands. However, the maximum tidal range is 1.0 to 1.7 m greater than the average (Guangdong Ocean Natural Resource Survey Team, 1993).

The long term average annual tidal ranges at each of the eight river mouths vary from 0.89 m to 1.37 m. These tidal ranges are within 1.90 m to 2.70 m at the flood tide, and 2.29 m to 3.44 m at the ebb tide. The tidal range is smallest at Modaomen, and increases toward to the east (Li et al., 1991).

The maximum tidal range at the eastern side of the estuary varies from 3.4 m to 3.6 m, from 2.5 m to 3.2 m at western side of the estuary, and from 2.3 m to 2.5 m around the Wanshan Islands (Guangdong Ocean Natural Resource Survey Team, 1995).

Guangdong Province History Compilation Committee (2000) also describes the maximum tidal range. The document states that it ranges from 3.0 to 3.5 m in the eastside of the estuary, and from 2.5 to 3.0 m in the westside.

According to the tide table of the Pearl River Estuary area, in the survey period, July 31, 2000 - August 10, 2000, the tidal range during spring tide was 300 cm, and during neap tide 200 cm.

Figure 1.4.1 shows time series of estimated tide levels at three different sites around the Pearl River Estuary: Shanbanzhou, Neilingding, and Guishandao. Phase differences between each point are as expected.

1.4.2. Water Currents

The Pearl River Estuary is shallow. This means that the big difference in the water level between ebb and flood tides, and the high volume of river flow, result in currents with a very high magnitude.

Wang et al. (1992) simulated the current in the Pearl River Estuary during the dry season, using the calculated major tidal harmonic components in this estuary, M_2, K_1, and O_1. The simulation shows that the current in the estuary shows a typical go-and-return pattern longitudinally along the coast. The maximum current velocity was determined as 144 cm/s.

Lin et al. (1996) described the maximum surface current velocity in the Pearl River Estuary. They showed that at the spring tide the current velocity was 190 cm/s in the rainy season and 148 cm/s in dry season, and at the neap tide was 52 cm/s in rainy season and 67 cm/s in dry season.

Because of river flow and tide, field current velocity becomes greater than the field constant current velocity, so-called residual current, which flows longitudinally to southward.

Wang et al. (1992) simulated the maximum residual velocity in the Pearl River Estuary as 40 cm/s, Lin et al. (1996) described it as 35 cm/s and Han et al. (1992) simulated it as 30-40 cm/s.

The maximum tidal current speed at surface layer around Neilingding Islands is:

- 103.4 cm/s at flood tide in summer;
- 161.5 cm/s at ebb tide in summer;
- 79.5 cm/s at flood tide in winter;
- 80.1 cm/s at ebb tide in winter.

Tidal residual current speeds at the surface layer around the same area ranges from:

- 10.6 to 35.8 cm/s in summer;
- 29.6 to 37.1 cm/s in winter.

(Guangdong Ocean Natural Resource Survey Team, 1995)

1.4.3. Water Temperature and Salinity

Annual water temperatures in the Pearl River Estuary range from 14 to 31 ℃ at the surface layer and from 14 to 30 ℃ at the bottom layer. Temperatures are highest in summer and the lowest in winter.

Temperature ranges:

- 27.81 to 30.09 ℃ at the surface layer in summer;
- 16.77 to 18.66 ℃ at the surface layer in winter;
- 21.85 to 29.19 ℃ at the bottom layer in summer;
- 16.64 to 18.71 ℃ at the bottom layer in winter.

(Guangdong Ocean Natural Resource Survey Team, 1993)

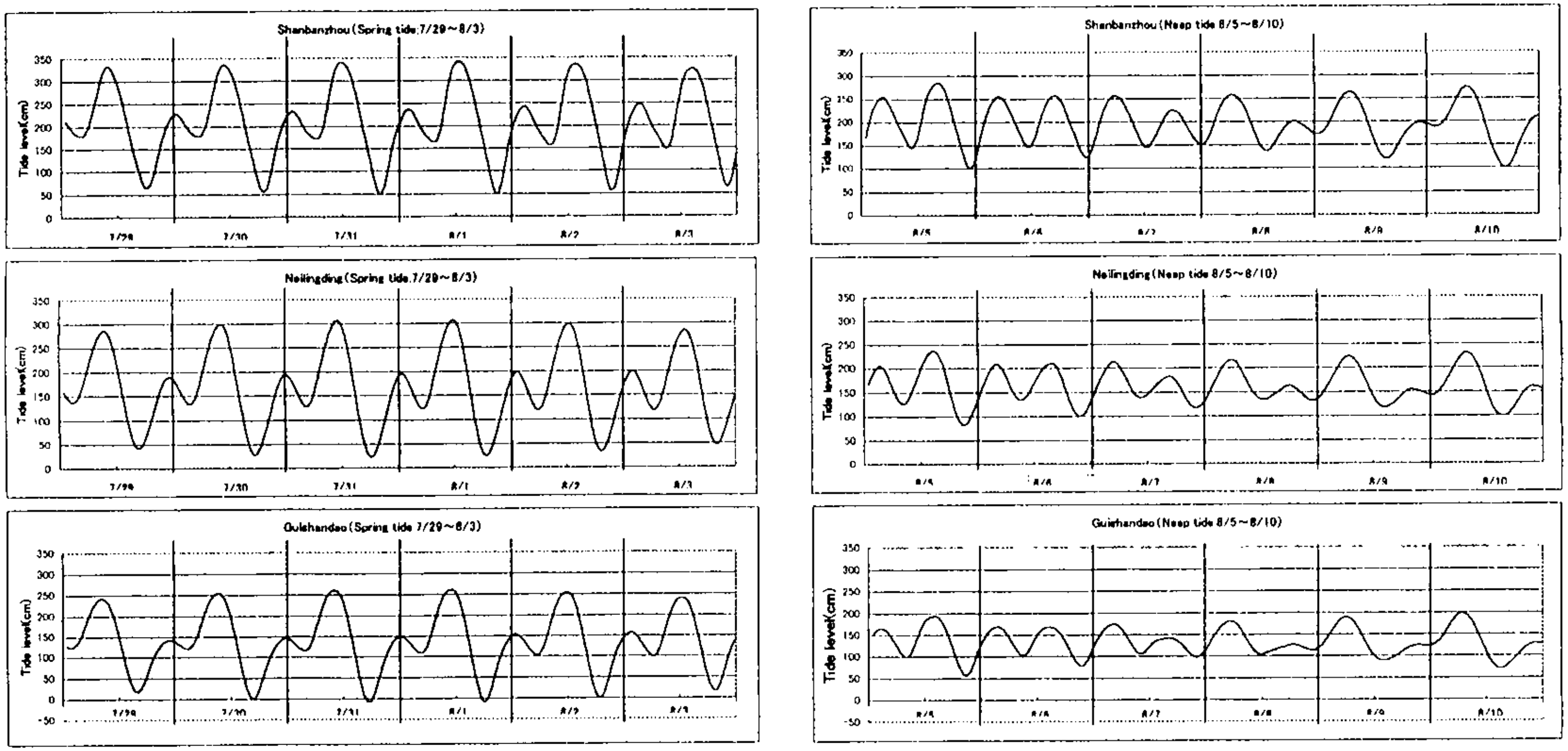
The differences in temperature between the surface and bottom layers ranges between 0 - 2 ℃ annually. The vertical temperature difference is the greatest in spring, and becomes greater to the southward longitudinally (Peng et al., 1991).

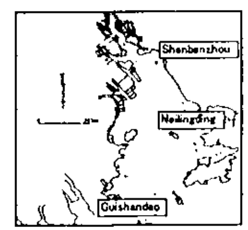
Salinity in the Pearl River Estuary ranges from 4 to 34 anually. Bottom salinity ranges from 11 to 34. The difference between surface salinity and bottom salinity ranges from 0 to 14 annually. The vertical salinity difference is greater in summer than in winter, and becomes greater to the southward longitudinally (Han et al., 1995; Peng et al., 1991).

The distribution of temperature and salinity is limited by the condition of tide and flow in the Pearl River Estuary. Upwelling also contributes to the temperature and salinity distribution.

Upwelling, which brings low-temperature, high-salinity and high-nutrient water masses from the deep sea, exists along the east coast of Guangdong province which faces the South China Sea directly. When an upwelling event occurs, temperature decreases about 4 ℃ and salinity increases about 3. The main dynamic to force an upwelling is wind (Han et al., 1995).

A northeastward surface current induced by a SW-dominant wind in summer season cause an upwelling just in front of the Pearl River Estuary (Gao et al., 1999; Guangdong Province History Compilation Committee, 2000; Figure 1.4.2).





Reference:Tide table 2000, China

Figure 1.4.1 Time Series of Estimated Tide Levels

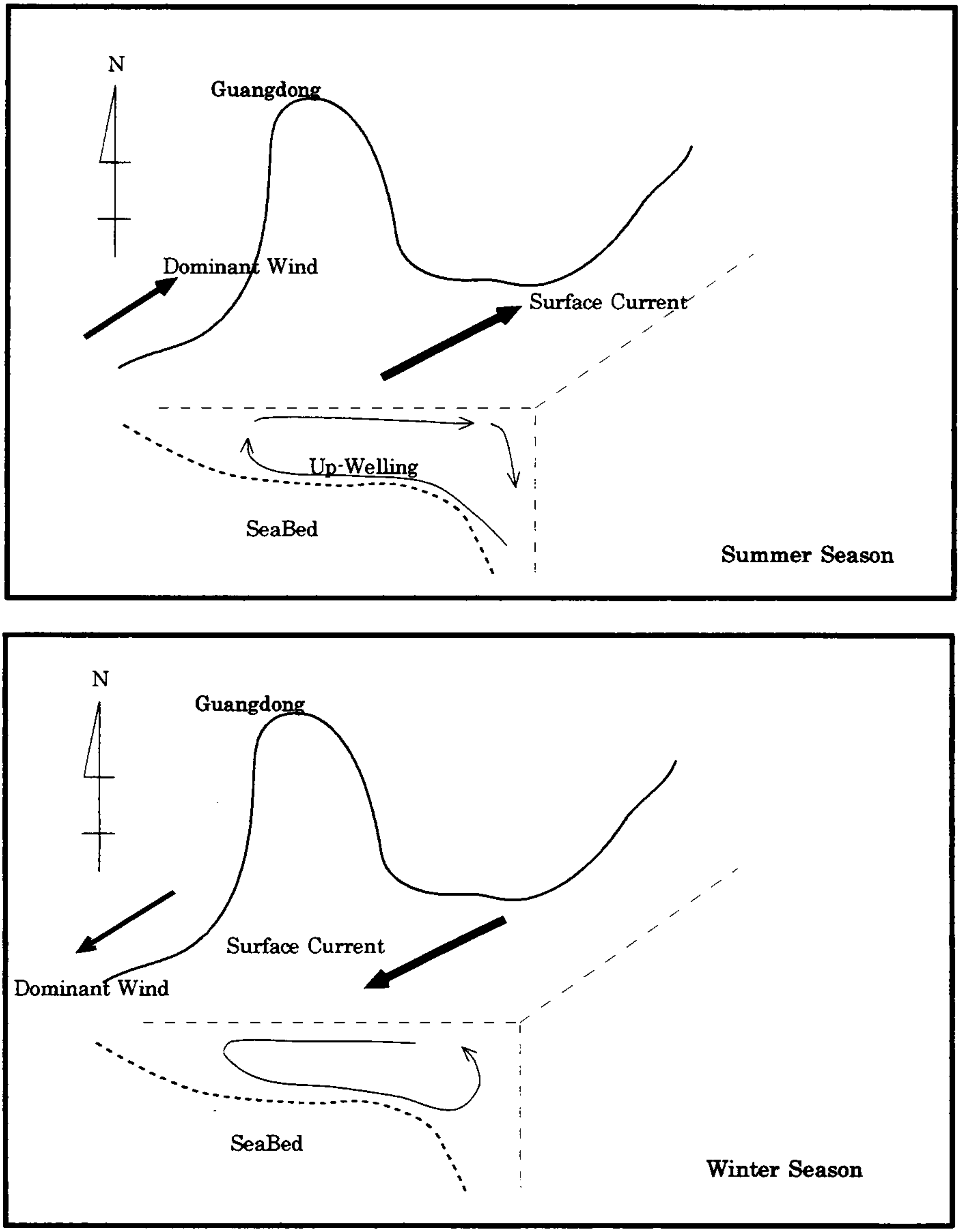


Figure 1.4.2 A Diagrammatic Representation of Upwelling in The Pearl River Estuary

1.5 River Hydrology

Two kinds of major literature about the discharge into the Pearl River Estuary are reported here. One is about measured or simulated discharge related to the northern four river mouths, and the other is related to the eight river mouths mentioned above in Section 1.1 of this chapter.

The long term average annual discharge of the eight river mouths is 3,412 x 10^8 m^3/year. The discharge value from this average for each river mouth is 24.4 % at Modaomen, 19.3 % at Jiaomen, 16.4 % at Humen, 14.0 % at Hongqimen, 12.4 % at Hengmen, 6 % at Yamen, 4.6 % at Jitimen, and 2.9 % at Hutiaomen (Li et al., 1991).

Feng (19__) measured the discharge into the Pearl River Estuary at eight river mouths in the dry season as 38,300 m^3/s, although he warned that the measurement was unlikely to be accurate.

Han et al. (1992) simulated discharge at the eight mouths of the Pearl River Estuary in the flood period in July 1989. Their simulated value was 96,490.5 x 10^4 m^3/day (11,167 m^3/s), whereas the measured value was 110,758.7 x 10^4 m^3/day (12,819 m^3/s).

Chen (1993) found that the average annual discharge from the four river mouths into the Pearl River Estuary was 5,296 m^3/s. The difference in the monthly total discharges was stated, such as 5 x 10^9 m^3 (1,929 m^3/s) in January and 29 x 10^9 m^3 (11,188 m^3/s) in July.

Ying (1995) found that the discharges from the four river mouths into the Pearl River Estuary were 345,430 x 10^4 m^3/day (39,980 m^3/s) at ebb tide, 238,950 x 10^4 m^3/day (27,656 m^3/s) at flood tide and 106,480 x 10^4 m^3/day (12,324 m^3/s) as residual discharge.
Wang et al. (1992) calculated the average annual discharge from four river mouths as 1,772 x 10^8 m^3/year (5,619 m^3/s) by extrapolation from data collected only in the dry season. Han et al. (1995) stated that average annual discharge of the four northern river mouths is 1,792.6 x 10^8 m^3/year (5,684 m^3/s), and that one of the four southern river mouths is 1,453.8 x 10^8 m^3/year (4,610 m^3/s).

Discharge of the Pearl River Estuary is highly variable. It depends on the flood condition of the Pearl River, and tide conditions, such as ebb and flood tides. The range of the discharge in the literature mentioned above is between 2,000 to 40,000 m^3/s.

Generally, discharge is greatest in the rainy season, such as in July, and lowest in the dry season, such as in January. The flood period is from April to September and runoff accounts for 80 % of the annual discharge. The dry period is from October to March and in this season runoff accounts for 20 %, i.e., the rest of the annual discharge. With regard to diurnal changes, discharge is naturally greater at ebb tide than at flood tide (Han et al., 1995).

Discharge values from four river mouths are summarized in Table 1.5.1 according to data collected by South Sea Information Center.

Table 1.5.1. Discharges from four outlets in the Pearl River Estuary
(Average values of data collected from 1997 to 1999)

(m^3/sec)

	Humen	Jiaomen	Hongqimen	Henmen	Total
Rainy Season	3,761	3,518	1,300	2,277	10,856
Transient Season	1,645	1,537	568	996	4,746
Dry Season	741	693	256	448	2,138
Annual Mean	2,049	1,916	708	1,241	5,914

Notes: Rainy Season; May, June, July and August
Transient Season; March, April, September and October
Dry Season; January, February, November and December
Source: Collected by the South Sea Information Center

1.6 Land Use

The Pearl River Delta region has experienced very rapid economic development since the late 1970s and this has had major impacts on the local environment. Extensive tracts of land have been converted from agricultural to urban and industrial uses. Between 1980 and 1990, some 12 % of arable land in the area was lost, but in some areas, especially in the zone between Hong Kong and Guangzhou, the figure reached 25 % (Hills et al., 1998).

Major new industrial centers, such as Dongguan and Foshan, have recently emerged. Much of the development in the region has been speculative, and poorly planned and coordinated. Development in the region has given rise to increasingly serious pollution problems. In particular, under-treated sewage discharges have increased significantly with the rapid growth in population in the Pearl River Delta region, and many of this sewage flushes into the Pearl River through its various tributaries.

Agricultural activity, still a significant factor in the regional economy, gives rise to pollution from fertilizers and pesticides, as well as animal wastes.
Some reports show that there has been an increase in intensive livestock production, and an increasing reliance on chemical fertilizers, pesticides and herbicides in the delta region. From 1986 to 1989, chemical fertilizer use increased by 40 % (Hills et al., 1998).

Although China possesses an extensive array of environmental legislation, and has a well-established organizational structure for environmental protection, from the national down to municipal and county levels, the problems of the delta region are recognized as being especially serious due to the scale and rapidity of the development there. Water pollution is regarded as a particularly serious problem, as water quality in the Pearl River and its tributaries is threatened by a variety of urban-industrial and agricultural sources (Hills et al., 1998).

Land use images are obtained by satellite (Landsat) image analysis, as shown in section 2.