JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
STATE OCEANIC ADMINISTRATION (SOA)
PEOPLE'S REPUBLIC OF CHINA

THE STUDY ON IMPROVEMENT OF MARINE ENVIRONMENTAL MONITORING SYSTEM FOR THE PEARL RIVER ESTUARY IN THE PEOPLE'S REPUBLIC OF CHINA

FINAL REPORT

SUPPORTING REPORT

September 2001

METOCEAN ENVIRONMENT INC.
UNICO INTERNATIONAL CORPORATION

SSS
CR (3)
01-135

Report Structure

The Supporting Report consists of the detailed information of Monitoring in the Study (Chapter I) and Simulation Model Development (Chapter II), assisting the Main Report. The major argument and conclusions of these two contents are in the Main Report.

The "Monitoring in the Study" of this report describes the objectives, methodology, and results of the Monitoring conducted in the Study in details, which were not mentioned in the Main Report.

The "Simulation Model Development" of this report describes how the pollutant load which is the vital input data for the Model was obtained, and how the Hydrodynamics-Water Quality Simulation Model was developed specifically for the Pearl River Estuary in detail.

Table of Contents

Chapter I. Monitoring in the Study

Chapter II. Simulation Model Development

List of Tables

Chapter II. Simulation Model Development

Table 2.5.11 Examples of Sediment Oxygen Demand in Tokyo Bay

List of Figures

Chapter I. Monitoring in the Study

(2) Turbidity

(3) Light Quanta

3.3 Bottom Sediment Quality

3.4 Aquatic Biota

Chapter II. Simulation Model Development

Chapter I. Monitoring in the Study

Chapter I. Monitoring in the Study

1. Objective of the Monitoring in the Study

The monitoring in the study was conducted for 1) rainy season, 2) dry season, and 3) transient season (complementary). The objectives were to:

- build the basic system for monitoring in the future,
- obtain information pertinent to the environmental issues in the Pearl River Estuary,
- gather necessary information to establish parameters for simulation model development, and
- introduce Japanese monitoring technologies to the Chinese side.

2. Methodology of the Monitoring in the Study

The main area of the survey was Lingding Sea (the upper bay area of the Pearl River Estuary), inside the line connecting Macau to Lantau Island. The survey points are shown in Figure 2.1.1.

The outline of three monitoring surveys is shown in Table 2.1.1 and Table 2.1.2. The detailed survey periods are shown in Table 2.1.3 for the rainy season, Table 2.3.4 for the dry season, and Table 2.1.5 for the transient season. The survey items are shown in Table 2.1.6 for the rainy season, Table 2.1.7 for the dry season, and Table 2.1.8 for the transient season.

2.1. Physical Survey (Water Level and Current)

Water levels and tidal currents were continuously monitored by self-contained recording instruments. The methodologies applied for the survey are described below:

2.1.1. Locations

Water levels were monitored at T01, T02 and T03, and tidal currents were observed at six points: P01, P11, P12, P19, P20 and P22 as indicated in Figure 2.1.1. Additionally, in the dry and transient season survey, continuous vertical current profiles were measured at P11 (ADCP) also seen in Figure 2.1.1(2) and (3).

2.1.2. Method and Instruments for Sea Level Recording

The water level monitoring used three AANDERAA INSTRUMENTS WLR-7 attached at the sea bottom of the respective locations for continuous recording for 30 days with an interval of 10 minutes.

2.1.3. Method and Instruments for Tidal Current Survey

Six recording current meters, AANDERAA INSTRUMENTS RCM-9, were used for this survey. The instruments were positioned in three layers in a manner illustrated in Figure 2.1.2. The upper layer corresponds to one meter below the sea surface, the middle layer at 1/2 depth, and the bottom layer at one meter above the sea bottom. Tidal currents were recorded for 24 hours at each location with a 10 minute-interval.

2.1.4. Method and Instruments for Multi-layer Current Survey

An Acoustic Doppler Current Profiler (ADCP), NORTEK-1500kHz, was also attached at the sea bottom of P11 for continuous recording with an interval of 10 minutes for 30 days during the dry season and 24 hours during the transient season. The method used to anchor the instrument is illustrated in Figure 2.1.3.

Table 2.1.1 Outline of Surveys in Three Seasons

	Rainy Season (First monitoring)	Dry Season (Second monitoring)	Intermediate Season (Third Monitoring)
Continuous survey	P01, P04, P11, P12, P19, P20	P01, P11, P12, P19, P20, P22	-
Intensive survey	20 points	19 points (P13, P26 canceled P27 added)	25 points
Water Level	3 points	3 points	-
Water Current	6 points	6 points	-
ADCP	-	1 point	1 point
Water Quality Metals	26 points 3 layers	25 points 2 layers	25 points 2 layers
Bottom Sediment Quality	26 points	P01, P02, P03, P04, P07, P10, P14, P24	-
Aquatic Biota Coliforms	26 points 3 layers	25 points 2 layers	25 points 2 layers

Schedule for Aquatic Environmental Surveys in Pearl River Estuary

Parameter	Item	Season [1] and Tide	Rainy Season (Jul-00: 25, 31; Aug-00: 5, 10, 15, 20, 25, 31)	Dry Season (Nov-00: 25, 31; Dec-00: 5, 10, 15, 20, 25, 31)	Intermediate Season (Mar-01: 5, 10, 15, 20)
Water Level [2]		–	7/31 – 8/30	12/1 – 12/31	
Water Current	Observation on board [3]	Spring tide	7/31–8/3	12/11– 12/14	
		Neap tide	8/7–8/10	12/5–12/8	
	Multilayer Observation by ADCP [4]	–		12/3 – 12/28	3/4-3/7
Water Quality	Intensive Survey [5]	Spring tide	7/31–8/3	12/11– 12/14	
		Neap tide	8/7–8/10	12/5–12/8	3/4-3/7
	Continuous Survey [6]	Spring tide	7/31–8/3	12/11– 12/14	
		Neap tide	8/7–8/10	12/5–12/8	
Aquatic Biota [7]	Zooplankton	Spring tide	7/31–8/3	12/11– 12/14	
		Neap tide			3/4-3/7
	Phytoplankton	Spring tide	7/31–8/3	12/11– 12/14	
		Neap tide			3/4-3/7
	Chlorophyll-a	Spring tide	7/31–8/3	12/11– 12/14	
		Neap tide	8/7–8/10	12/5–12/8	3/4-3/7
	Benthos	–	7/31–8/3, 8/7–8/10		3/4-3/7
	Coliform	–	7/31–8/3	12/11– 12/14	3/4-3/7
Bottom Sediment Quality [8]	Organic Matter and Heavy Metal	–	7/31–8/3, 8/7–8/10	12/4 – 12/10	

1) Rainy season is from June to August in Pearl River Estuary with the highest monthly rainfall in June. Dry season is from December to February with the smallest monthly rainfall in December. March is the intermediate period between two seasons (Rainfall records in Guanzhou City (1997), Han W. et al.(1995)).

2) Water levels were observed at 3 stations, i.e. Humen, Zhuhai, and Guishan in order to develop a hydrodynamics model in the Estuary. Tide gauge (WLR-7) was installed at each observation site and continuous tidal data is obtained for a month in both rainy and dry seasons.

3) Water current observation on board is conducted in connection with continuous water quality survey. These two surveys (on water current and water quality) are conducted during spring and neap tide in both rainy and dry seasons, due to the close relationship of tidal characteristics and changes in water quality. 6 Main survey points are set up among the Estuary mouth. The exact locations in rainy and dry seasons don't necessarily match because of the seasonal change in water depth. Survey boats are moored at points in order to continuously observe folloiwng parameters by ADCP (Acoustic Doppler Current Profilers, RCM-9): water temperature, salinity, current direction and velocity, and turbidity.

4) Multilayer observation of tides is conducted by installing ADCP onto a buoy at a center survey point (inner Bay area). Following data are sampled from approximately 17 layers with a depth interval of 0.5m: water temperature, salinity, current direction and velocity. Total days for the continuous observation are 25 days in dry season and 4 days in intermediate period, respectively.

5) Intensive survey is conducted in order to characterize chemical distribution pattern in Pearl River Estuary, which is highly dependent on seasonal (rainy and dry season) and tidal conditions. Intermediate season is recognized as a transition period between vertical-mixing and stratification period, and this serves to supplement two seasons. The survey is only conducted during neap tide when stratification is becoming significant. Total survey points are 26 in rainy season and 25 in dry and intermediate seasons, respectively.

6) Continuous survey is conducted in order to record time series of water quality change in the Estuary mouth. Survey boats are moored at points and water quality is measured for continuous 24 hours. Total points are 6 among the Estuary mouth and the survey period is during both spring and neap tides in both rainy and dry seasons.

7) Zooplankton, phytoplankton, and coliform are collected during spring tide in both rainy and dry seasons as representative samples, because freshwater (river water) and sea water are frequently mixed at that time (during spring tide). In intermediate season the same biological groups are collected during neap tide as representative samples, when stratification is becoming significant. Chlorophyll-a survey is conducted in connection with water quality survey.

8) Sediment quality survey is conducted both in rainy and dry seasons. From the result of rainy season (26 points surveyed) it is concluded that contamination level is not very high: thus the number of survey points decreased in main 8 points in dry season.

Table 2.1.3 Survey Period in the Rainy Season

	Survey points	Sping Tide	Neap Tide
Water Level	T01,T02,T04	Jul. 30, 2000 - Aug. 30,2000	
Water Current Continuous Survey	P01	Aug. 2 20:00 - Aug. 3 20:00,2000	Aug. 9 20:00 - Aug. 10 20:00,200
	P04	Aug. 2 20:00 - Aug. 3 20:00,2000	Aug. 9 20:00 - Aug. 10 20:00,200
	P11	Jul. 31 10:00 - Aug. 1 10:00,2000	Aug. 7 10:00 - Aug. 8 10:00,2000
	P12	Jul. 31 10:00 - Aug. 1 10:00,2000	Aug. 7 10:00 - Aug. 8 10:00,2000
	P19	Aug. 1 15:00 - Aug. 2 15:00,2000	Aug. 8 14:00 - Aug. 9 14:00,2000
	P20	Aug. 1 15:00 - Aug. 2 15:00,2000	Aug. 8 14:00 - Aug. 9 14:00,2000
Intensive Survey	20points	Jul. 31 - Aug. 1, Aug. 4, 2000	Aug. 6 - Aug. 9, 2000

Table 2.1.4 Survey Period in the Dry Season

	Survey points	Sping Tide	Neap Tide
Water Level	T01,T02,T03	Dec. 1 10:00, 2000 - Dec. 31 10:00, 2000	
Muti-Layer Currents	P11	Dec. 3 16:30, 2000 - Dec. 28 12:50, 2000	
Water Current Continuous Survey	P01	Dec. 13 20:00 - Dec. 14 21:00,2000	Dec. 7 20:00 - Dec. 8 21:00,2000
	P11	Dec. 13 20:00 - Dec. 14 21:00,2000	Dec. 7 20:00 - Dec. 8 21:00,2000
	P12	Dec. 12 15:00 - Dec. 13 16:00,2000	Dec. 6 15:00 - Dec. 7 16:00,2000
	P19	Dec. 12 15:00 - Dec. 13 16:00,2000	Dec. 6 15:00 - Dec. 7 16:00,2000
	P20	Dec. 11 10:00 - Dec. 12 11:00,2000	Dec. 5 10:00 - Dec. 6 11:00,2000
	P22	Dec. 11 10:00 - Dec. 12 11:00,2000	Dec. 5 10:00 - Dec. 6 11:00,2000
Intensive Survey	20points	Dec. 9 - Dec. 10, 2000	Dec. 4 , 2000

Table 2.1.5 Survey Period in the Intermediate Season

	Survey points	Neap Tide
Muti-Layer Currents	P20	Mar. 4, 2001 - Mar. 6, 2001
Intensive Survey	25points	Mar. 4 , 2001 - Mar. 6, 2001

Table 2.1.6 Survey Items in the Rainy Season

	Current	Experimental Detamina	CTD / Quantum	Water sampling	Bottom sediment /Benthos	Phyto plankton	Zoo plankton	Chlorophyll -a	Coli form	Frequency	Longitude	Latitude	Estimated depth (m)	Continuous survey	Intensive survey
Spring tide	O	·	O	O	·	O	O	O	O						
Neap tide	O	O	O	O	O	·	·	O	·						
P01	O	O	O	O	O	O	O	O	O	Every 1 hour for 24 hours	113°40′ 00″	22°43′ 59″	17.5	O	
P02			O	O	O	O	O	O	O	1 time	113°44′ 33″	22°38′ 30″	6.8		O
P03			O	O	O	O	O	O	O	1 time	113°39′ 29″	22°36′ 42″	3.0		O
P04	O		O	O	O	O	O	O	O	Every 1 hour for 24 hours	113°37′ 48″	22°33′ 30″	5.5	O	
P05			O	O	O	O	O	O	O	1 time	113°43′ 59″	22°32′ 30″	8.5		O
P06			O	O	O	O	O	O	O	1 time	113°47′ 59″	22°32′ 30″	5.6		O
P07			O	O	O	O	O	O	O	1 time	113°38′ 42″	22°28′ 07″	4.9		O
P08			O	O	O	O	O	O	O	1 time	113°44′ 12″	22°28′ 11″	5.0		O
P09			O	O	O	O	O	O	O	1 time	113°52′ 59″	22°27′ 00″	11.0		O
P10			O	O	O	O	O	O	O	1 time	113°58′ 48″	22°30′ 25″	3.5		O
P11	O		O	O	O	O	O	O	O	Every 1 hour for 24 hours	113°45′ 00″	22°24′ 29″	6.5	O	
P12	O	O	O	O	O	O	O	O	O	Every 1 hour for 24 hours	113°52′ 36″	22°24′ 29″	9.0	O	
P13			O	O	O	O	O	O	O	1 time	113°38′ 56″	22°22′ 41″	2.2		O
P14			O	O	O	O	O	O	O	1 time	113°37′ 59″	22°19′ 47″	3.4		O
P15			O	O	O	O	O	O	O	1 time	113°43′ 00″	22°19′ 47″	5.5		O
P16			O	O	O	O	O	O	O	1 time	113°47′ 59″	22°19′ 47″	11.1		O
P17			O	O	O	O	O	O	O	1 time	113°40′ 59″	22°15′ 29″	4.6		O
P18			O	O	O	O	O	O	O	1 time	113°47′ 30″	22°15′ 29″	11.5		O
P19	O		O	O	O	O	O	O	O	Every 1 hour for 24 hours	113°42′ 00″	22°11′ 56″	5.5	O	
P20	O	O	O	O	O	O	O	O	O	Every 1 hour for 24 hours	113°48′ 00″	22°11′ 56″	18.0	O	
P21			O	O	O	O	O	O	O	1 time	113°40′ 42″	22°08′ 59″	6.1		O
P22			O	O	O	O	O	O	O	1 time	113°46′ 59″	22°08′ 59″	11.0		O
P23			O	O	O	O	O	O	O	1 time	113°42′ 47″	22°04′ 57″	10.2		O
P24			O	O	O	O	O	O	O	1 time	113°30′ 00″	22°00′ 00″	8.0		O
P25			O	O	O	O	O	O	O	1 time	113°38′ 30″	21°56′ 30″	18.2		O
P26			O	O	O	O	O	O	O	1 time	113°04′ 59″	21°53′ 59″	5.5		O
Layer	U,M,B	M	S to B	U,M,B	·	U,M,B	B to S	·	U,M,B						
T1	Water Level continuous measurring										22°45′ 04″	113°42′ 29″			
T2											22°13′ 39″	113°34′ 40″			
T3											22°09′ 15″	113°52′ 12″			

"Weather/Sea conditons" involves measurments of "water color", "depth" and "transparency".

Each letter in layer row shows;

- U :1m below surface
- M :1/2 of the depth
- B :1m up to bottom
- S to B :from surface to 1m above bottom, every 1m
- B to S :from 1m above bottom to surface continuously

Table 2.1.7 Survey Items in the Dry Season

Point No.	Current	Weather /Sea condition	CTD Quantum	Water sampling	Bottom sediment	Benthos	Phyto plankton	Zoo plankton	Coli form	Frequency	Latitude(N)	Longitude(E)	Depth(m)	Continuous survey	Intensive survey
Spring tide	○	○	○	○	○	-	○	○	○						
Neap tide	○	○	○	○	○	○	-	-	-						
P01	○	○	○	○	○	○	○	○	○	Every 1 hour for 24 hours	22°43′ 59″	113°40′ 00″	17.5	○	
P02		○	○	○	○	○	○	○	○	1 time	22°38′ 30″	113°44′ 33″	6.8		○
P03		○	○	○	○	○	○	○	○	1 time	22°36′ 42″	113°39′ 29″	3.0		○
P04		○	○	○	○	○	○	○	○	1 time	22°33′ 30″	113°37′ 48″	5.5		○
P05		○	○	○		○	○	○	○	1 time	22°32′ 30″	113°43′ 59″	8.5		○
P06		○	○	○		○	○	○	○	1 time	22°32′ 30″	113°47′ 59″	5.6		○
P07		○	○	○	○	○	○	○	○	1 time	22°28′ 07″	113°38′ 42″	4.9		○
P08		○	○	○		○	○	○	○	1 time	22°28′ 11″	113°44′ 12″	5.0		○
P09		○	○	○		○	○	○	○	1 time	22°27′ 00″	113°52′ 59″	11.0		○
P10		○	○	○	○	○	○	○	○	1 time	22°30′ 25″	113°58′ 48″	3.5		○
P11	○	○	○	○		○	○	○	○	Every 1 hour for 24 hours	22°24′ 29″	113°45′ 00″	6.5	○	
P12	○	○	○	○		○	○	○	○	Every 1 hour for 24 hours	22°24′ 29″	113°52′ 36″	9.0	○	
P14		○	○	○	○	○	○	○	○	1 time	22°19′ 47″	113°37′ 59″	3.4		○
P15		○	○	○		○	○	○	○	1 time	22°19′ 47″	113°43′ 00″	5.5		○
P16		○	○	○		○	○	○	○	1 time	22°19′ 47″	113°47′ 59″	11.1		○
P17		○	○	○		○	○	○	○	1 time	22°15′ 29″	113°40′ 59″	4.6		○
P18		○	○	○		○	○	○	○	1 time	22°15′ 29″	113°47′ 30″	11.5		○
P19	○	○	○	○		○	○	○	○	Every 1 hour for 24 hours	22°11′ 56″	113°42′ 00″	5.5	○	
P20	○	○	○	○		○	○	○	○	Every 1 hour for 24 hours	22°11′ 56″	113°48′ 00″	18.0	○	
P21		○	○	○		○	○	○	○	1 time	22°08′ 59″	113°40′ 42″	6.1		○
P22	○	○	○	○		○	○	○	○	Every 1 hour for 24 hours	22°08′ 59″	113°46′ 59″	11.0	○	
P23		○	○	○		○	○	○	○	1 time	22°04′ 57″	113°42′ 47″	10.2		○
P24		○	○	○	○	○	○	○	○	1 time	22°00′ 00″	113°30′ 00″	8.0		○
P25		○	○	○		○	○	○	○	1 time	21°56′ 30″	113°38′ 30″	18.2		○
P27		○	○	○		○	○	○	○	1 time	22°04′ 57″	113°37′ 40″	6.2		○
Layer	U,M,B	-	S to B	U,M,B	-	-	U,M,B	B to S	U,B						
T1	Water Level continuous measurring										22°45′ 04″	113°42′ 29″			
T2											22°13′ 39″	113°34′ 40″			
T3											22°09′ 15″	113°52′ 12″			
ADCP	Multi-layer current measuring										21°24′ 42″	113°46′ 33″			

"Weather/Sea conditons" involves measurments of "water color", "depth" and "transparency".

Each letter in layer row shows;

U :1m below surface

M :1/2 of the depth

B :1m up to bottom

S to B :from surface to 1m above bottom, every 1m

B to S :from 1m above bottom to surface continuoucely

Table 2.1.8 Survey Items in the Intermediate Season

Point No.	Weather /Sea condition	CTD Quantum	Water sampling	Benthos	Phyto plankton	Zoo plankton	Coli form	Frequency	Latitude(N)	Longitude(E)	Depth(m)
Spring tide	○	○	○	-	○	○	○				
P01	○	○	○	○	○	○	○	1 time	22°43′ 59″	113°40′ 00″	17.5
P02	○	○	○	○	○	○	○	1 time	22°38′ 30″	113°44′ 33″	6.8
P03	○	○	○	○	○	○	○	1 time	22°36′ 42″	113°39′ 29″	3.0
P04	○	○	○	○	○	○	○	1 time	22°33′ 30″	113°37′ 48″	5.5
P05	○	○	○	○	○	○	○	1 time	22°32′ 30″	113°43′ 59″	8.5
P06	○	○	○	○	○	○	○	1 time	22°32′ 30″	113°47′ 59″	5.6
P07	○	○	○	○	○	○	○	1 time	22°28′ 07″	113°38′ 42″	4.9
P08	○	○	○	○	○	○	○	1 time	22°28′ 11″	113°44′ 12″	5.0
P09	○	○	○	○	○	○	○	1 time	22°27′ 00″	113°52′ 59″	11.0
P10	○	○	○	○	○	○	○	1 time	22°30′ 25″	113°58′ 48″	3.5
P11	○	○	○	○	○	○	○	1 time	22°24′ 29″	113°45′ 00″	6.5
P12	○	○	○	○	○	○	○	1 time	22°24′ 29″	113°52′ 36″	9.0
P14	○	○	○	○	○	○	○	1 time	22°19′ 47″	113°37′ 59″	3.4
P15	○	○	○	○	○	○	○	1 time	22°19′ 47″	113°43′ 00″	5.5
P16	○	○	○	○	○	○	○	1 time	22°19′ 47″	113°47′ 59″	11.1
P17	○	○	○	○	○	○	○	1 time	22°15′ 29″	113°40′ 59″	4.6
P18	○	○	○	○	○	○	○	1 time	22°15′ 29″	113°47′ 30″	11.5
P19	○	○	○	○	○	○	○	1 time	22°11′ 56″	113°42′ 00″	5.5
P20	○	○	○	○	○	○	○	1 time	22°11′ 56″	113°48′ 00″	18.0
P21	○	○	○	○	○	○	○	1 time	22°08′ 59″	113°40′ 42″	6.1
P22	○	○	○	○	○	○	○	1 time	22°08′ 59″	113°46′ 59″	11.0
P23	○	○	○	○	○	○	○	1 time	22°04′ 57″	113°42′ 47″	10.2
P24	○	○	○	○	○	○	○	1 time	22°00′ 00″	113°30′ 00″	8.0
P25	○	○	○	○	○	○	○	1 time	21°56′ 30″	113°38′ 30″	18.2
P27	○	○	○	○	○	○	○	1 time	22°04′ 57″	113°37′ 40″	6.2
Layer	-	S to B	U,M,B	-	U,M,B	B to S	U,B				
ADCP	Multi-layer current measuring								21°24′ 42″	113°46′ 33″	

"Weather/Sea conditons" involves measurments of "water color", "depth" and "transparency".

Each letter in layer row shows;

- U :1m below surface
- M :1/2 of the depth
- B :1m up to bottem
- S to B :from surface to 1m above bottom, every 1m
- B to S :from 1m above bottom to surface continuoucely

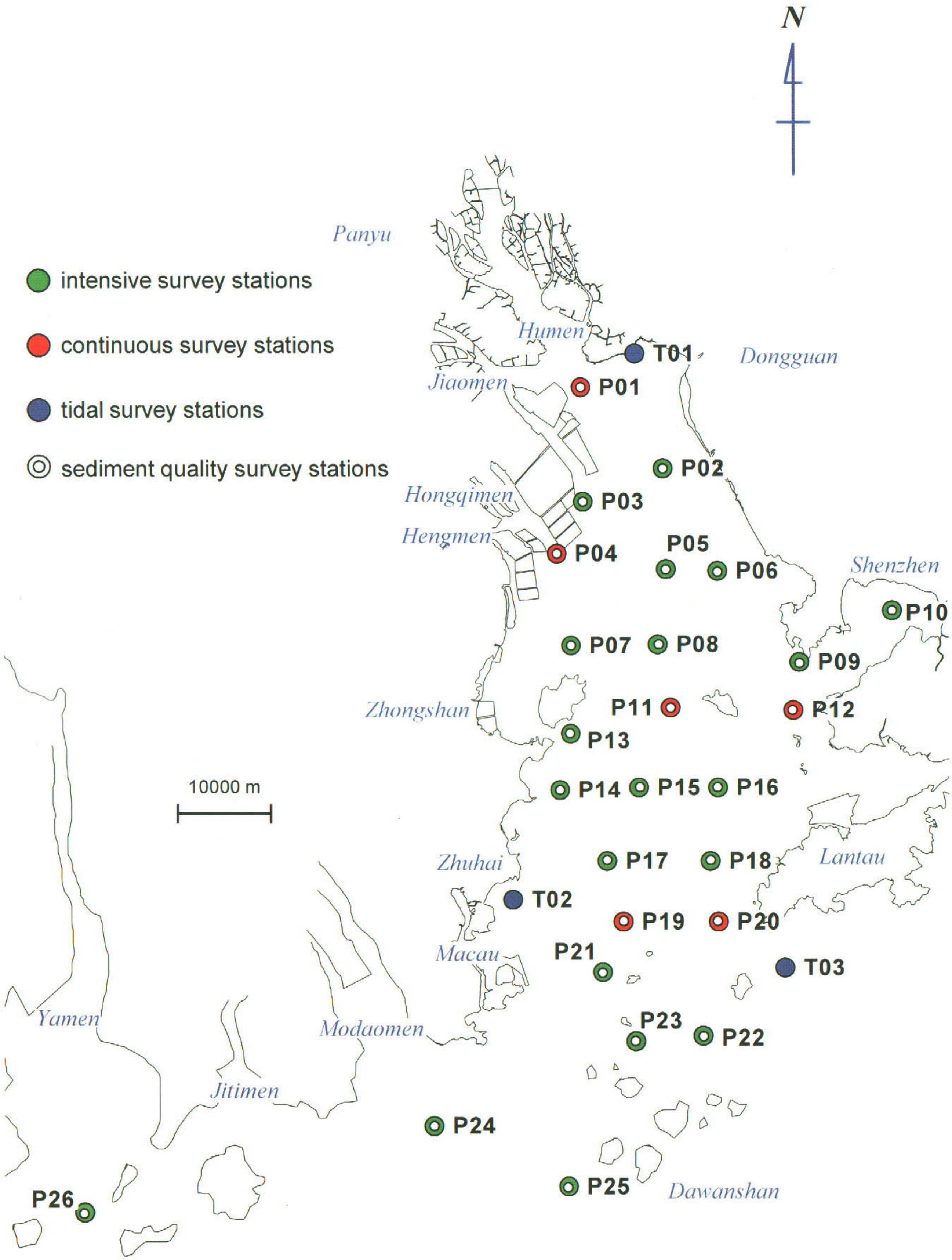

Figure 2.1.1(1) Location of Survay Stations (Rainy Season)

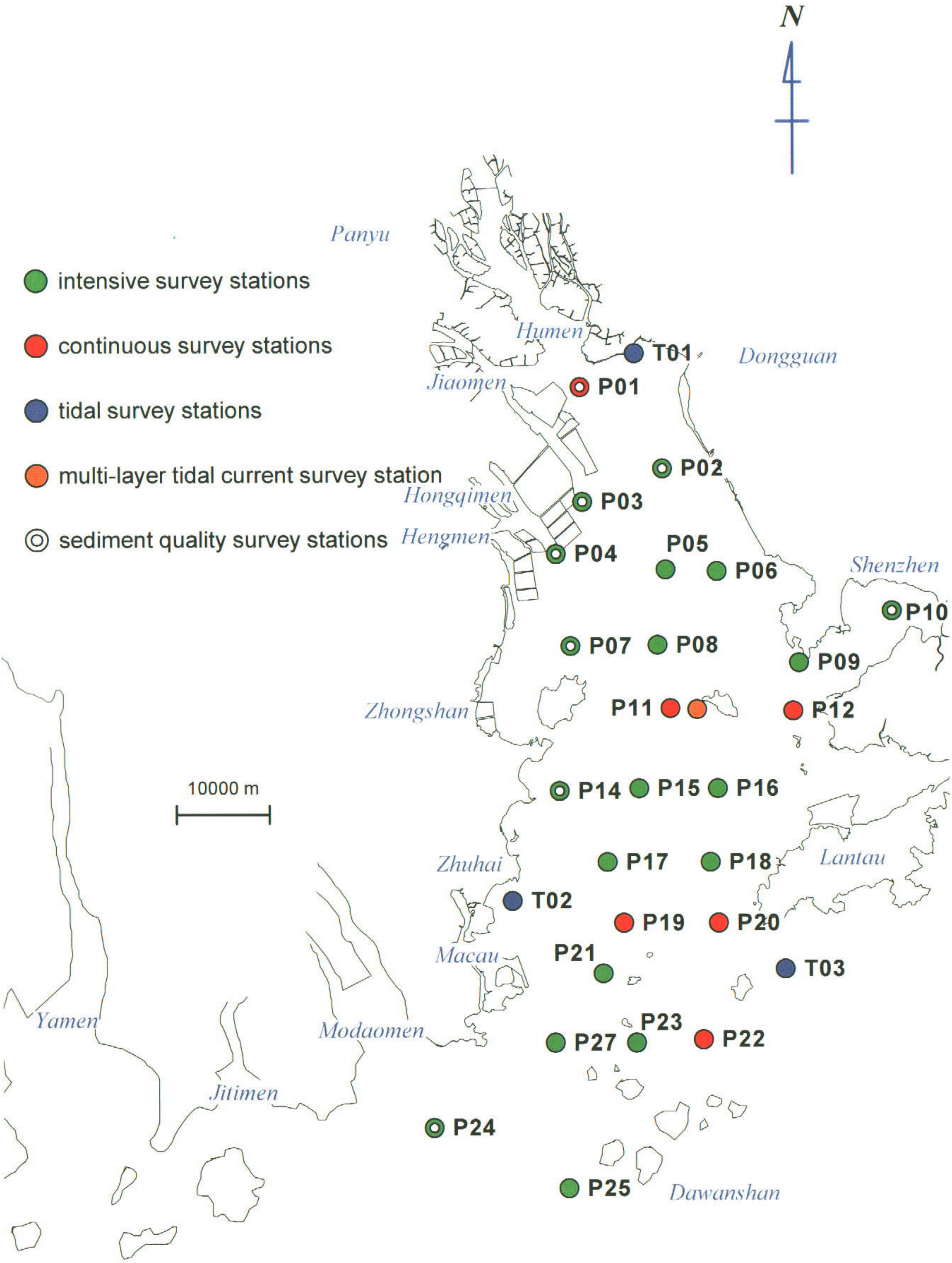

Figure 2.1.1(2) Location of Survey Stations (Dry Season)

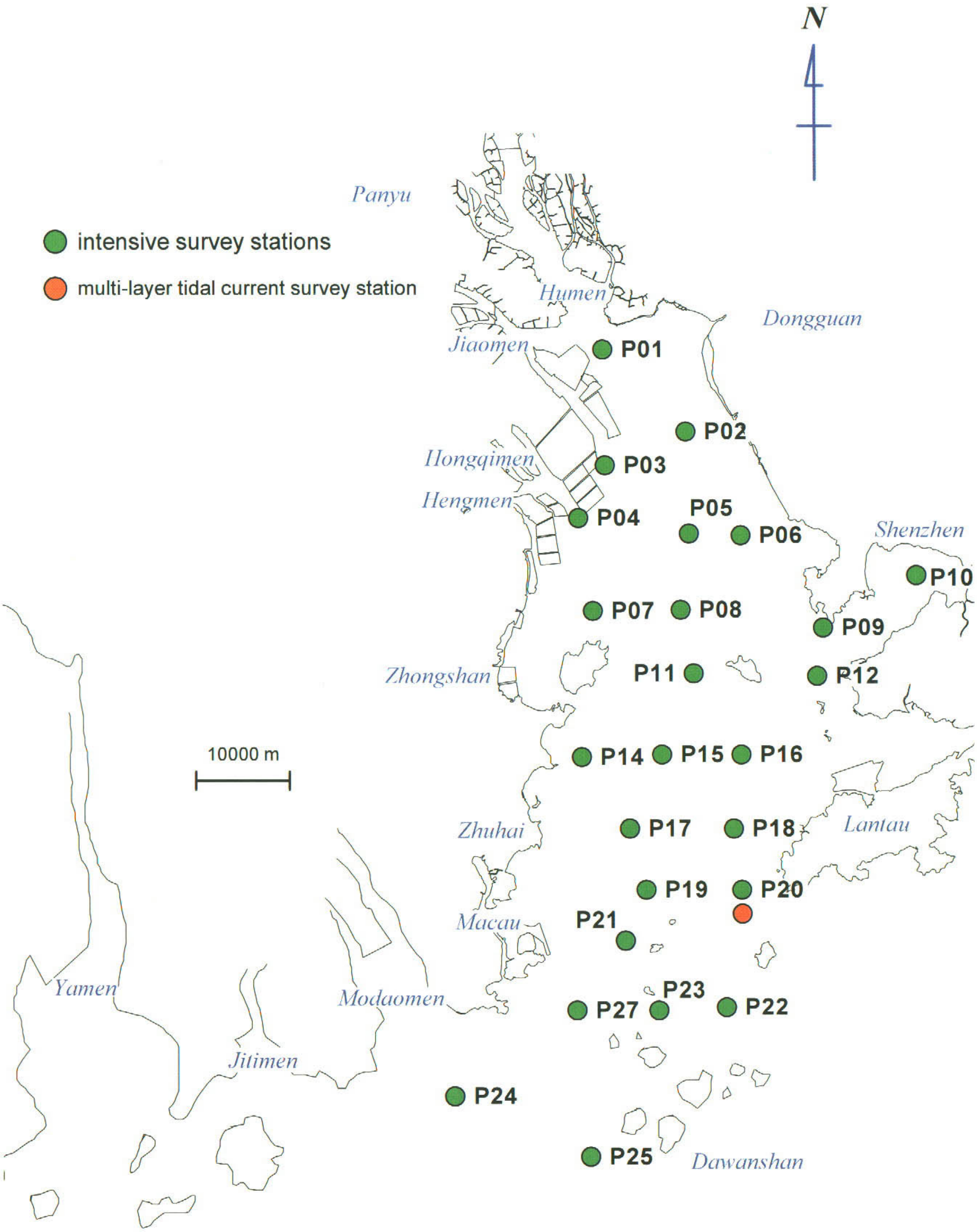

Figure 2.1.1(3) Location of Survey Stations (Transient Season)

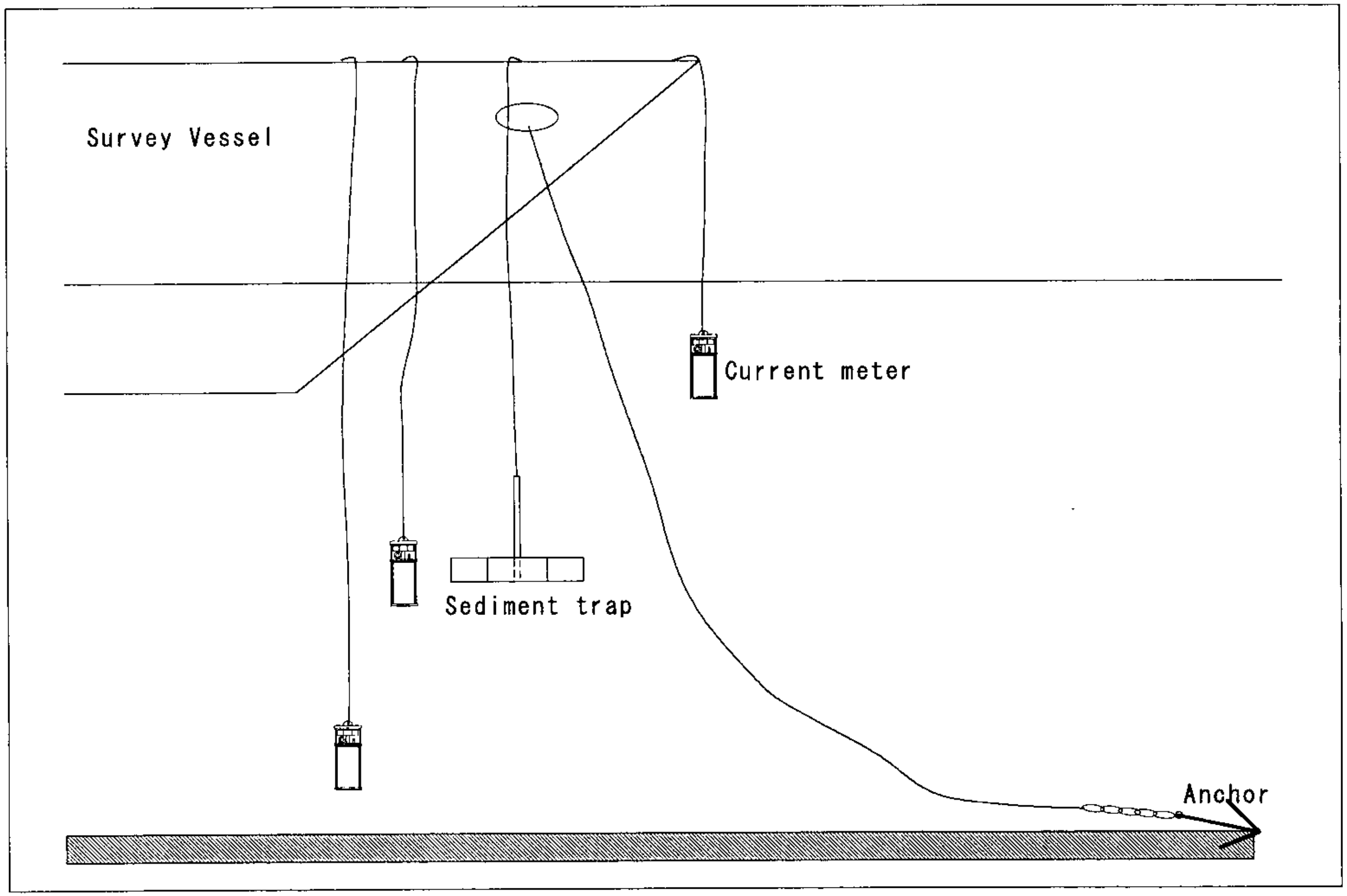

Figure 2.1.2 Overview of Installation of a Current Meter and a Sediment Trap

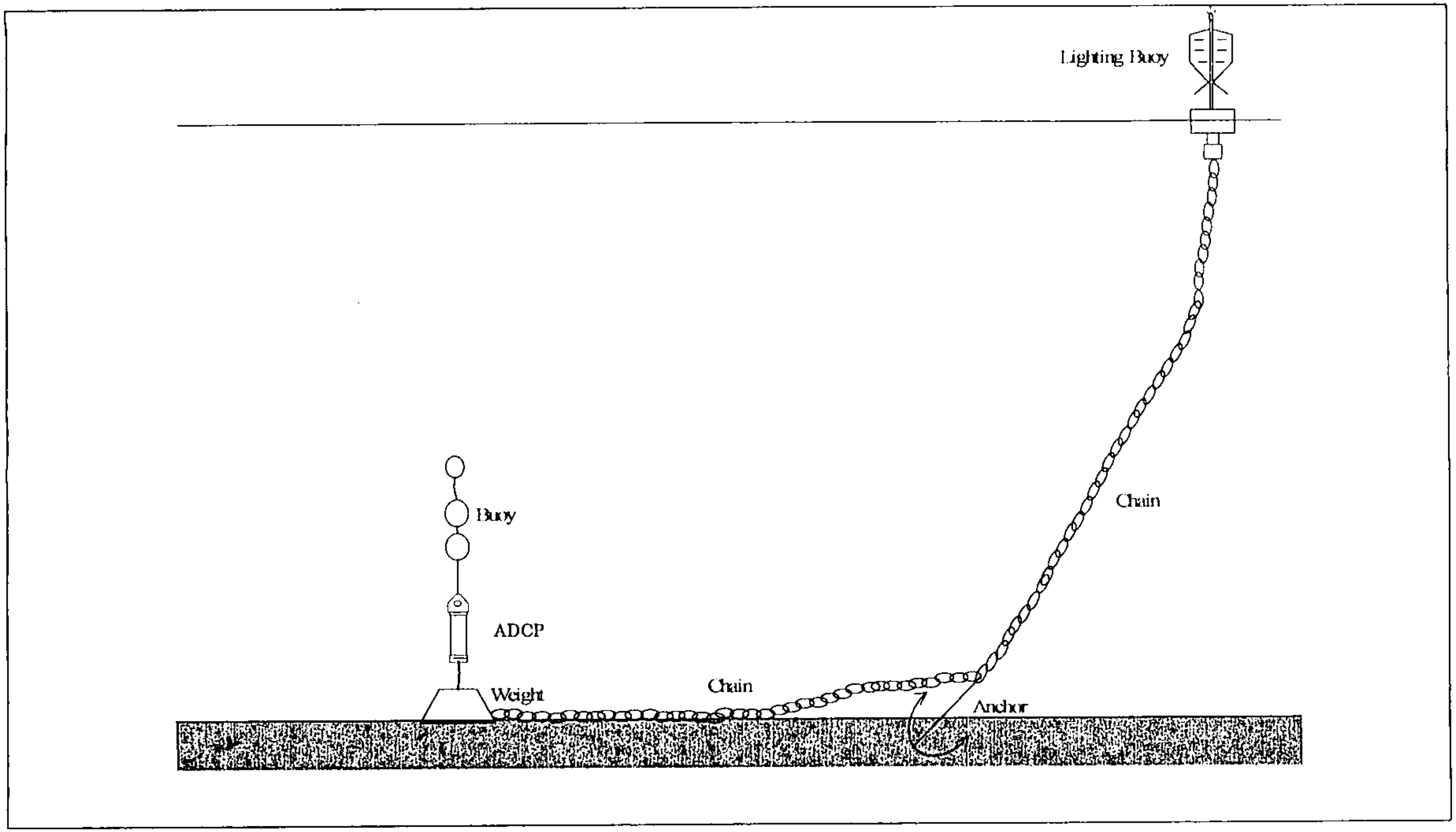

Figure 2.1.3 Overview of an ADCP Installation

2.2. Chemical Survey (Water Quality)

The water quality survey took place to assess the current state of aquatic environment in the rainy, dry, and transient season as well as to provide verification data for simulation model development.

2.2.1. Area and Points

The survey area and locations were the same as in the physical survey shown in Figure 2.1.1.

2.2.2.Intensive Survey and Continuous Survey

The water quality survey involved two programs: a continuous survey at 6 points to collect time-series information, and an intensive survey at 19 points to determine spatial distribution.

For the intensive survey, water quality samples were collected twice, once during neap tide and twice during spring tide, at each location

For the continuous survey, samples were collected at variable intervals depending on water quality items during a 24-hour period. The sampling layers were the same as those in the tidal current survey (see section 2.1.3), with exceptions of oil sample collection which targeted the upper layer only and metal sample collection which targeted the upper and bottom layers only.

2.2.3. Instruments for Sample Collections

Three floating-type oil samplers, QCC9-1, and nine water samplers, GO-FLO1080, were used for water sample collection. Three CTD, FSI-MCTD/TU, and light quantum meters, LI-COR, were also used for vertical profiling of temperature, salinity, turbidity, and underwater light quanta.

2.2.4. Water Quality Items, Methods of Analysis, and Sampling Frequency

The water quality items and methods of analysis are shown in Table 2.2.1(1).

The frequency of sampling and analysis in the continuous survey varied depending on the object of analysis as follows:

- Temperature, Salinity, Turbidity, Light quantum: all samples at every hour;
- Oils: upper layer samples at every 6 hours;
- Metals: three-layer samples at high- and low-tide; and
- Others: all samples at every 3 hours.

2.2.5. Meteorology and Sea State

During the sample collection program, meteorology and sea state were also observed. Items of measurement and equipment used are listed in Table 2.2.1(2).

Table 2.2.1(1) Analysis Items, Methods of Analysis, and Number of Samples

<Water Quality>

Items	Methods of Analysis	Detected Limit	Unit
Salinity	FSI-MCTD/Tu	-	-
Turbidity	FSI-MCTD/Tu	-	FTU
DO	海洋監測規範・第４部・海水分析・32	0.32	Mg/L
PH	海洋監測規範・第４部・海水分析・27	0.1	-
BOD	海洋監測規範・第４部・海水分析・34	0.5	Mg/L
COD_{Mn}	海洋監測規範・第４部・海水分析・33	0.1	Mg/L
TOC	海洋監測規範・第４部・海水分析・35	0.18	Mg/L
T-N	Based on NO_3-N method after pre-treatment	14	Mg/L
NH_4-N	海洋監測規範・第４部・海水分析・37	5	Mg/L
NO_2-N	海洋監測規範・第４部・海水分析・38	0.5	Mg/L
NO_3-N	海洋監測規範・第４部・海水分析・39	6	Mg/L
T-P	Based on PO_4-P method after pre-treatment	3	Mg/L
PO_4-P	海洋監測規範・第４部・海水分析・40	1	Mg/L
SiO_2-Si	海洋監測規範・第４部・海水分析・18	1	Mg/L
Oil contents	海洋監測規範・第４部・海水分析・14	9.2	Mg/L
SS	海洋監測規範・第４部・海水分析・28	1.5	Mg/L
Pb	海洋監測規範・第４部・海水分析・8	0.19	Mg/L
Cd	海洋監測規範・第４部・海水分析・9	0.014	Mg/L
Hg	海洋監測規範・第４部・海水分析・6	0.008	Mg/L
Cu	海洋監測規範・第４部・海水分析・7	1.4	Mg/L
Zn	海洋監測規範・第４部・海水分析・10	1	Mg/L
As	海洋監測規範・第４部・海水分析・12	1.3	Mg/L

<Aquatic Biota>

Items	Methods of Analysis
Chlorophyll-a	海洋監測規範・第７部・近海汚染生態調査和生監測・8
E-coli.	海洋監測規範・第７部・近海汚染生態調査和生監測・9
Phyto-plankton	海洋監測規範・第７部・近海汚染生態調査和生監測・5
Zoo-plankton	海洋監測規範・第７部・近海汚染生態調査和生監測・5
Benthos	海洋監測規範・第７部・近海汚染生態調査和生監測・6

Table 2.2.1(2) Analysis Items, Methods of Analysis, and Number of Samples

<Bottom Sediment Quality>

Items	Methods of Analysis
Pre-treatment	海洋監測規範・第5部・沈積物分析・5
Grain size	JIS A 1204 (Japanese Method)
COD	底質調査方法・20 (Japanese Method)
S	海洋監測規範・第5部・沈積物分析・18
T-N	底質調査方法・13 (Japanese Method)
T-P	底質調査方法・14 (Japanese Method)
Oil contents	海洋監測規範・第5部・沈積物分析・14
Ignition Loss	底質調査方法・3 (Japanese Method)
ORP	海洋監測規範・第5部・沈積物分析・21
Pb	海洋監測規範・第5部・沈積物分析・8
Cd	海洋監測規範・第5部・沈積物分析・9
Hg	海洋監測規範・第5部・沈積物分析・6
Cu	海洋監測規範・第5部・沈積物分析・7
Zn	海洋監測規範・第5部・沈積物分析・10
As	第二次全国海洋汚染基線調査技術規定

<Meteorology and Sea state>

Items	Methods / Instruments
Air temperature	Mercury thermometer
Water temperature	CTD (FSI-MCTD/Tu)
Wind direction and Speed	Air speedometer
Air pressure	Barometer
Light Quantum	Li-Cir Li-1000, Li192-SA and Li-190SA
Transparency	Secci Disc
Water color	Color card and Standard color liquid

2.3. Bottom Sediment Quality

Bottom sediment quality survey took place at 26 points in the rainy season and 8 points in the dry season as shown in Figure 2.1.1(1) to (2). Sediment samples were collected once at each point during neap tide. The items and the methods of sediment quality analysis are summarized in Table 2.2.1(2). The analysis of heavy metals took place only in the rainy season.

2.4. Low-Level Aquatic Biota

The low-level aquatic biota, including zoo- and phyto-plankton, benthos, coliform, and chloropyll-a, were surveyed to determine the *standing crop* of the region. The area and locations of this survey coincided with the water quality survey. The items and the methods of analysis are shown in Table 2.2.1(1).

2.4.1. Zooplankton

The zoo-plankton survey took place during the daytime in spring tide. The samples were intended to represent the entire water column at each location, collected by pulling up a plankton-net from the sea bottom to the surface.

2.4.2. Phytoplankton

The phyto-plankton survey took place simultaneously with the zoo-plankton survey. The sampling layers of this survey were the same as those in the water quality survey.

2.4.3. Benthos

The benthos samples were collected from the bottom sediment by the same method applied to the bottom sediment sampling, and were preprocessed by filtering on the shipboard.

2.4.4. Coliform

The coliform samples were collected during spring tide of the water quality survey from the upper and the bottom layers, omitting the middle layers.

2.4.5. Chlorophyll-a

The sampling method for chlorophyll-a analysis closely resembled that for the water quality survey.

2.5. Experimental Determination of Model Parameters

In an estuary where seawater was constantly mixed with freshwater, silt and clay particles were carried by river, suspended from the sea-bottom, and transported by tidal currents and turbulence. Where conditions permit, these particles accumulate and deposit in some areas, forming tidal flats and the bottom mud layers.

Such areas are rich in nutrients and are characterized by abundance and diversity of marine biota, the nursery grounds of complex estuarine ecosystem, involving biochemical chain reactions. An estuary also undergoes multitude of physical processes such as tidal mixing, dilution, advection, dispersion, settling, re-suspension, and stratification. The Pearl River Estuary is a typical example of such environment.

In these combined physio-biochemical process, the nutrients contained in water encounter various reactions, for instance, advection, dispersion, settling, and sedimentation of suspended particles, uptaking in the food chain of marine biota, decompositions by bacteria, primary productions by phytoplankton, mineralization, and elution of nutrients in inorganic forms from bottom sediment, etc. These reactions take place in very close and complex relationship to each other. In such a state, a material circulatory system may be formed with the nutrients, often referred to as the biochemical nutrients cycle. Thus, to construct a water quality simulation model of the Pearl River Estuary, each reaction process involved in a cycle needs to be formulated and quantified.

In this survey, four key-parameters that represent the nutrients cycle were experimentally investigated as described bellow:

2.5.1. Settling Rate

Numerous and various types of suspended particles are present in estuarine waters, such as zooplankton, phytoplankton, bacteria, detritus, and soil particles (silt and clay). In the transport process in the horizontal direction, the particles are carried entirely by currents and turbulent diffusion. As for the vertical direction, the process is influenced by vertical current, diffusion, specific gravity, and interfacial potential. In addition, because the interfacial potential of particles is neutralized, coagulation process takes place, thus the settling process is promoted in estuaries where freshwater mixes with seawater. The suspended particles settle slowly and pile up on the bottom sediment. Particulate organic carbon, nitrogen, phosphorus etc, present in the seawater, transfer to the bottom sediment in this process. This portion of nutrient cycle is considered as the key factor in development of a water quality simulation model. Since the settling rate of suspended particles is strictly a site-specific parameter, experimental determination is necessary. In the present experimental survey, settling particles were collected using sediment traps at three locations for 24 hours each. The experimental and analytical procedures are shown in Figure 2.5.1. The sampling method is summarized in Table 2.5.1.

2.5.2. Decomposition Rate

Various organic matters are present in seawater, particularly in abundance in estuaries compared to open seas. The organic matters are roughly divided into two types: particulate form represented by zooplankton, phytoplankton, bacteria, and detritus found in abundance in eutrophic waters, and dissolved form typically including many types of carboxylic acids, amino acids, and esters commonly found in abundance in river mouth, carrying domestic and industrial wastewater. Both the particulate and the dissolved forms of organic mater constantly undergo decomposition process by the bacteria in the seawater. The organic matter in seawater decreases while going through such a biological reaction. In this process, nitrogen and phosphorus contained in the organic matters are mineralized at the same time. Mineralized nitrogen and phosphorus are recycled for uptake in the primary production by phytoplankton.

In the present experiment, the processes in which organic matter was decomposed and nutrients were mineralized were investigated. The experimental and analytical procedures are shown in Figure 2.5.2. The sampling method is summarized in Table 2.5.2.

2.5.3. Primary Production (AGP: Algae Growth Potential Test)

In estuaries, organic matter and nutrients are typically supplied by river inflow. When concentrations of nutrients and intensity of solar radiation are sufficient, the photosynthesis by phytoplankton takes place, increasing the quantity of particulate organic matters. Because particulate organic matters support the base of the marine food chain, it is called primary production. In general, photosynthesis in estuary is very active compared with open seas because nutrients are abundant.

There are several kinds of methods to study the primary production such as dissolved oxygen method, isotope carbon method, AGP, etc. In the experiment, the primary production in the Pearl River Estuary was measured by AGP. AGP is a type of biological assay, based on the law that the growth of algae is controlled by the most restricted component among the factors involved, i.e., water temperature, light intensity, nutrients (N, P), etc. Growth of algae is limited if there is even a single factor unsuitable for growth. In a usual sea water, nitrogen or phosphorus is often the limitation factor. The quantity and speed of algae's cell-proliferation obtained by AGP are considered to be a governing parameter of the primary production.

The procedures of AGP analysis applied in the present survey are shown in Figure 2.5.3. The sampling method is summarized in Table 2.5.3.

2.5.4. Elution Rate

The bottom sediment in estuary contains a significant quantity of organic matters. A variety of benthos and bacteria inhabit in abundance in the bottom sediment, rich in organic matter. In the estuarine bottom sediment, the physiological activity by marine biota was very high. Benthos plays as the organic matter such as foods and excretes, and bacteria decompose the organic matter for their own growth. As a result of these biological processes, mineralized nitrogen and phosphorus, a part of organic matter, are released from the bottom sediment to the overlying water. In addition, it was a chemical characteristic that DO level was generally low in the estuarine bottom sediment. The oxidation-reduction potential of such sediment was very low. In such a state, ferric phosphorus compound was released chemically from the bottom sediment. These phenomena are the processes by which the nutrients are transferred from the bottom sediment to the lower water, called elution.

As the elution is also a governing site-specific factor in the nutrients cycle of local waters, an experimental determination is necessary. The procedure of experiment applied in the survey is shown in Figure 2.5.4. The sampling method is summarized in Table 2.5.4.

Table 2.5.1 Summary of Sampling for Subsidence Experiment

Items	Contens		
Survey points	PO1	P12	P20
Experiment beginning time	PM8:00 9-Aug.	AM9:15 7-Aug.	PM2:00 8-Aug.
Experiment end time	PM8:00 10-Aug.	AM9:15 8-Aug.	PM2:00 9-Aug.
Collection time (hr.)	12.0	12.0	12.0
Depth of survey point (m)	26.5	12.0	18.0
Setting depth of sediment trap (m)	13.3	6.0	9.0
Number of collection container	5	6	6
Collection area (m^2)	0.0318	0.0382	0.0382
Analysis items	SS,Organic compound,T-N,T-P,Chlorophyll−a		

Table 2.5.2 Summary of Sampling for Decomposition Experiment

Items	Contens		
Survey points	PO1	P12	P20
Sampling time	AM8:00 10-Aug	PM4:30 7-Aug.	AM8:00 9-Aug.
Sampling depth (m)	0.0		
Condition of water temperatur (℃)	28		
Fluid condition	Always stir by magnet bar		
Monitoring turm (day)	0, 1, 2, 3, 5.		
Analysis items	COD(Japanese),T-N,NH_4-N,NO_2-N,NO_3-N, T-P,PO_4-P		

Table 2.5.3 Summary of Sampling for Primary Production

Items	Contens		
Survey points	PO1	P12	P20
Sampling time	AM8:00 10-Aug	PM4:30 7-Aug.	AM8:00 9-Aug.
Sampling depth (m)	0.0		
Preprocess of sea water	Filteration by grass filter(whatma GF/C)		
Algae	*Skeletonema costatum.*		
Water temperatur of cultur (℃)	28.0		
Illuminance(lux.)	4000 and 500		
Light and shade cycle	Light and shade for 12 hours.		
Monitoring method of algae growth	Cells count.		
Turm	To the maximum proliferation.		
Analysis items	COD(Japanese),T-N,NH4-N,NO2-N,NO3-N, T-P,PO4-P,Chlorophyll－a		

Table 2.5.4 Summary of Sampling for Elution Experiment

Items	Contens		
Survey points	PO1	P12	P20
Sampling time of sea bottom sedimen	AM8:00 10-Aug	PM3:00 7-Aug.	AM8:00 9-Aug.
Sampling time of bottom layer water	AM8:00 10-Aug	PM4:30 7-Aug.	AM8:00 9-Aug.
Core size (Length ×Diameter)	1000mm×100mm		
Experiment emperatur (℃)	28.0		
Density condition of DO (mg/L)	<1		
Fluid condition	Always stir by magnet bar		
Monitoring turm (day)	0, 1, 2, 3, 5.		
Analysis items	COD(Japanese),T-N,NH_4-N,NO_2-N,NO_3-N, T-P,PO_4-P		

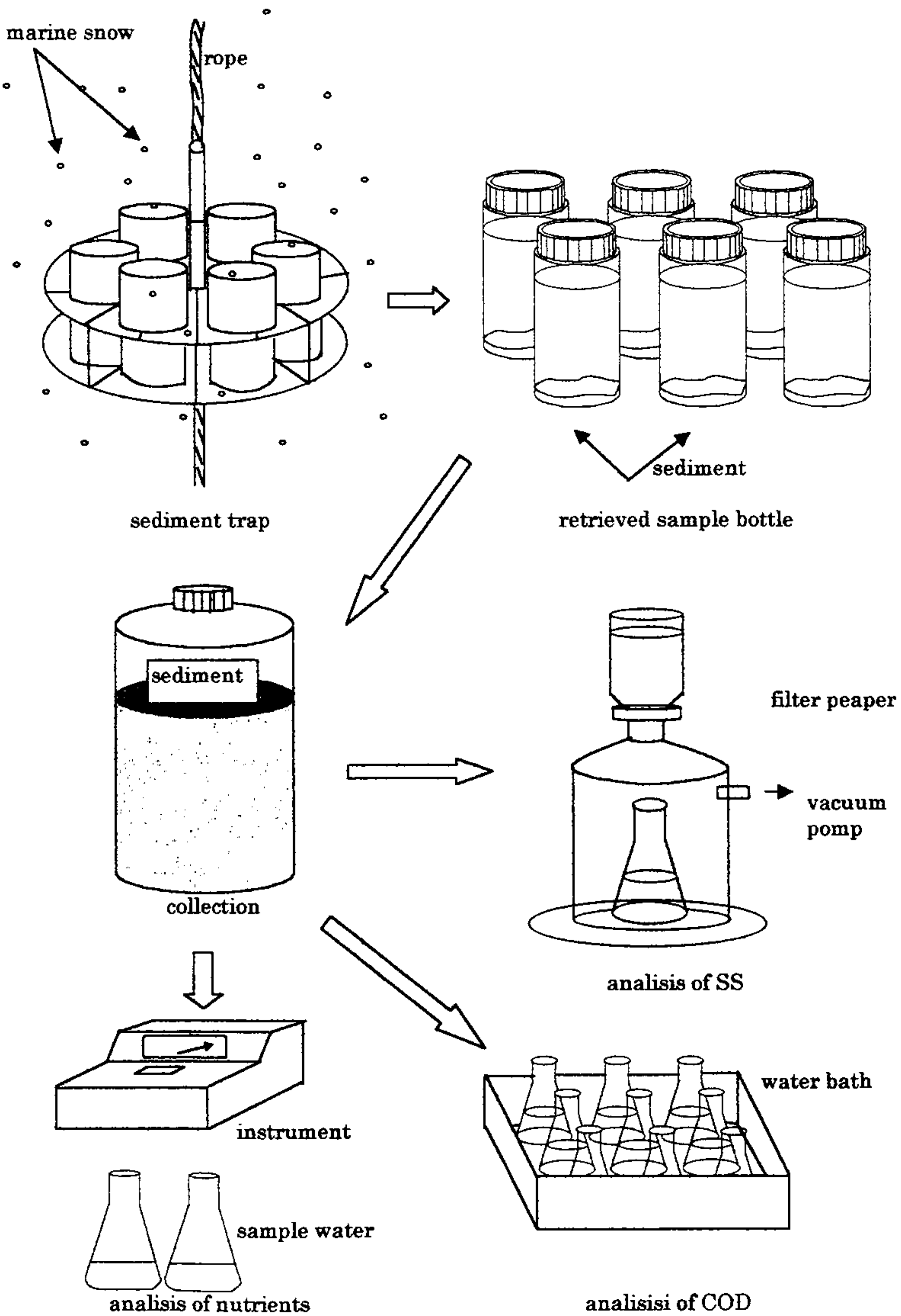

Figure 2.5.1 Overview of Subsidence Experiment

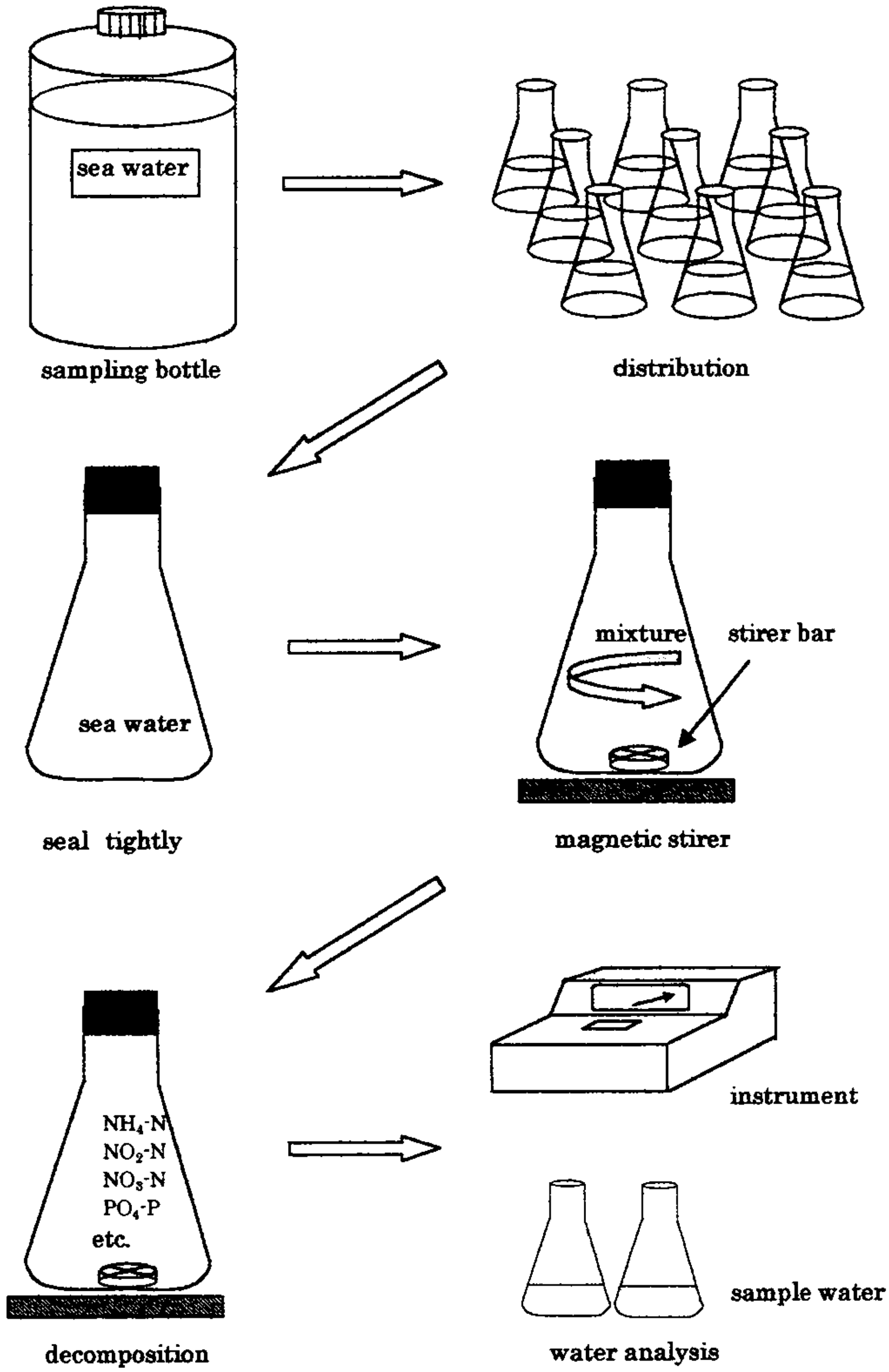

Figure 2.5.2 Overview of Decomposition Experiment

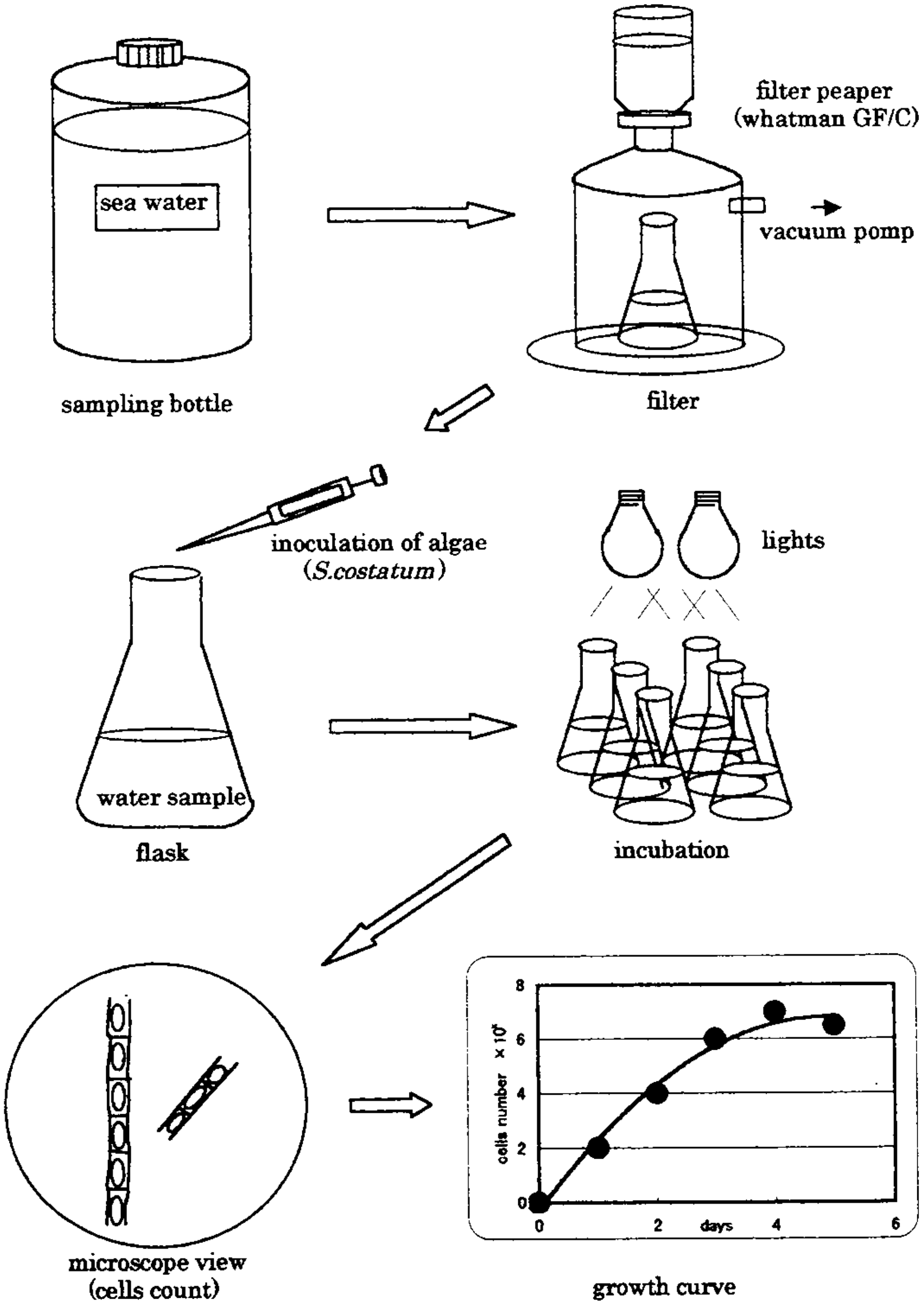

Figure 2.5.3 Overview of Experiment for Measuring Primary Production

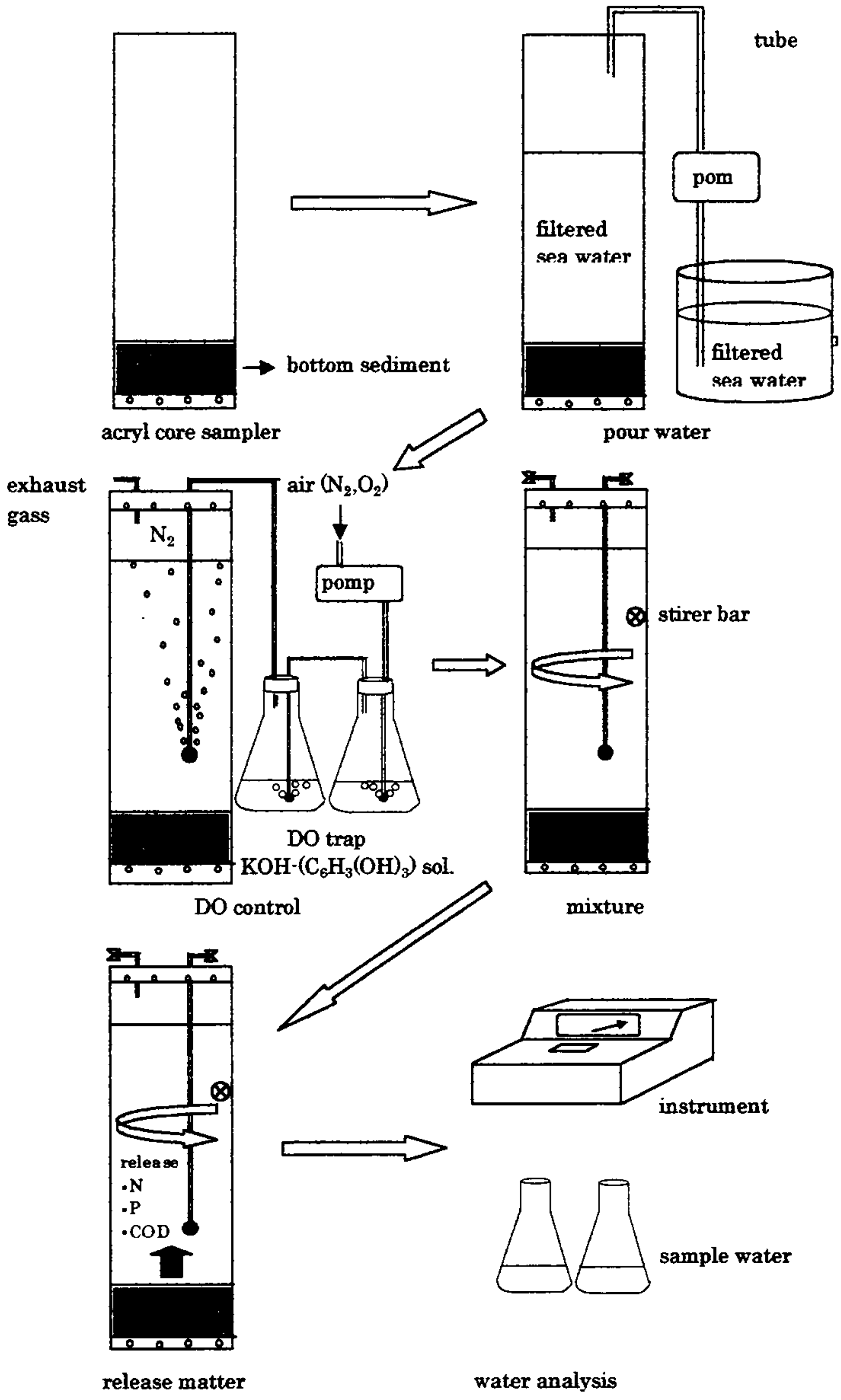

Figure 2.5.4 Overview of Elution Experiment