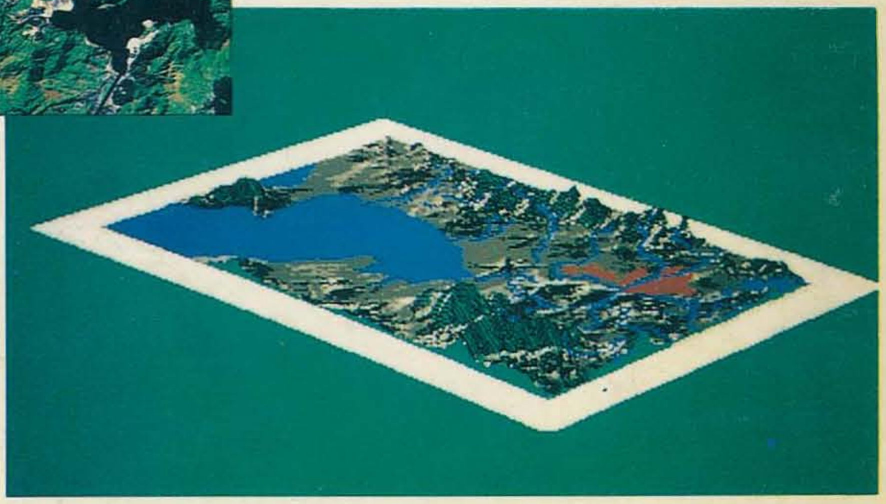
SHENZHEN RIVER REGULATION OFFICE OF MUNICIPAL GOVERNMENT

ENVIRONMENTAL IMPACT ASSESSMENT STUDY ON SHENZHEN RIVER REGULATION PROJECT

STUDY REPORT FOR STAGE I WORKS



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STUDY REPORT FOR STAGE I WORKS

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TABLE OF CONTENTS

APPENDICES

REFERENCES

PART I SUMMARY

S1 INTRODUCTION

This Section provides a summary of the key findings of the EIA on Stage 1 works of the Shenzhen River Regulation Project. The approach to the assessment, the baseline conditions, and the potential impacts of the Project are summarized, and mitigation measures and audit and monitoring requirements are recommended. The study area is considered to comprise any areas within the catchment of Deep Bay potentially affected by the Stage 1 works of the Shenzhen River Regulation Project.

S2 STUDY AREA AND THE PROJECT

S2.1 Shenzhen River

The Shenzhen River forms the border between the Shenzhen Special Economic Zone (SEZ) within the People's Republic of China (PRC) and Hong Kong.

The ecosystem of Shenzhen River, its estuary, and Deep Bay is a wetland ecosystem of international importance. Its core is the Mai Po Marshes and Neilingding-Futian National Nature Reserve, along with the adjacent Sites of Special Scientific Interest (SSSI). This area provides a habitat for numerous rare and endangered species, in particular waterfowl and migratory birds including a number of species under threat on a global scale.

Flow of Shenzhen River at flood peak is high. The river channel downstream is narrow and bending. The river embankment is low and narrow. Combined with tidal pressure, the river's safety flood-discharge capacity corresponds to a 1 in 2 year storm capacity, and results in frequent flooding.

Shenzhen River is heavily polluted due to untreated discharge of pollutants from industry, agriculture, poultry and livestock farming, and human sewage.

S2.2 The Shenzhen River Regulation Project

The Shenzhen and Hong Kong Authorities have developed the Shenzhen River Regulation Scheme. The full Project consists of a three stage scheme. Stage 1 involves relatively localized works to truncate two existing meanders of the river at Liu Pok and Lok Ma Chau. Stage 2 involves more extensive dredging works downstream of Lo Wu to increase the depth and width of the channel, and construction of flood protection works along both banks of the widened stream. Stage 3 involves dredging works upstream of Lo Wu.

The programme for the Stage 1 works is planned to take approximately 28 months. The programme includes the relocation of the border fence, construction of the haul road, excavation of the Lok Ma Chau Bend, excavation of the Liu Pok Bend, and the excavation of the Seung Ma Lei Yue Hill. Material from the Seung Ma Lei Yue Hill is expected to be used for embankment construction. Upon completion of Stage I works, the length of the section of the river trained in Stage 1 will be reduced from 6.2 km to 3.2 km.

The meander at Lok Ma Chau will be eliminated during the Stage 1 work and the realigned channel will be located at the north of the bends in the old river channel. The area was farm land before being converted to fish ponds in anticipation of designation as a disposal area of the Project. The 70 ha commercial fish pond area was created for temporary use while waiting for the Project to begin. During the Stage 1 work of the Project, these fish ponds will be filled up by spoil. In the river section between Liu Pok and Yumin Village, the new river channel following Stage 1 work will cut through the eastern portion of Seung Ma Lei Yue Hill. At Liu Pok Bend, material will be disposed of in the existing river channel.

Small suction dredger will be used for dredging. A large portion of the excavation will be carried out in isolation from the main river. The quantity of dredged material from the river channel excavation for Stage I works has been estimated at approximately 1.7 Mm^3. Approximately 10% of dredged material will be dredged from the existing channel, of which 56,000 m^3 or so will be contaminated mud.

S2.3 The Environmental Impact Assessment on the Project

Both the Shenzhen and Hong Kong governments have recognised that the Project may affect the internationally important Mai Po and Futian Nature Reserves at the mouth of the river. The Project also presents other potential environmental problems. The environmental impact assessment (EIA) is thus jointly funded by the Shenzhen and Hong Kong Authorities to ensure that these environmental concerns are addressed. The EIA of the first two stages of the Project started on Dec.16, 1993 and will be finished by the middle of March, 1995. The EIA report on the first stage of the Project is to be submitted by middle of June, 1994 to enable decision on this part of the Project. This has therefore been structured to address this issue for the EIA of Stage 1 Works. The purpose of this Stage 1 Works EIA is to provide information to assist in a decision on the acceptability of the Stage 1 works and to recommend specific requirements for environmental protection which should be included in the detailed design of Stage 1. The study area is shown in Figure S-1.

S2.4 Key Environmental Issues

Due to the localized nature of the Stage 1 works, the direct losses of wetland habitat will be limited to areas at Liu Pok and Lok Ma Chau bends. Potential impacts to terrestrial ecosystems will be limited for the most part to works on the upper portion of Seung Ma Lei Yue Hill.

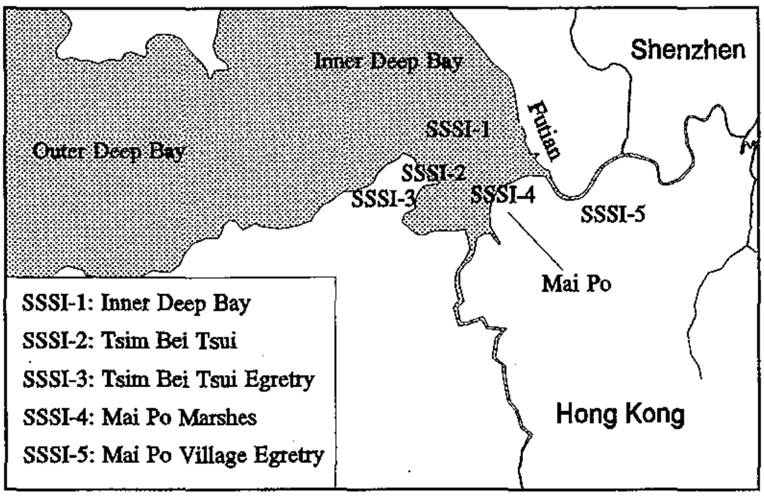

Figure 3-1 Study Area

Stage I of the Project may effect hydrodynamics, sediment flux, and release rates of nutrients and pollutants from sediments in Shenzhen River estuary area, resulting in alteration in erosion, sedimentation and water quality.

The extent and nature of the impact caused by disposed mud will be determined by the quantity of the spoil and the degree of contamination of the mud.

Dust and noise from construction and traffic may be produced during the construction period.

S3 ASSESSMENT APPROACH

To assess potential impacts, the consultants' technical approach focused on the use of existing information, supplemented by a baseline monitoring programme and special investigations. Baseline monitoring included air quality, noise, water quality, sediment and soil quality, ecology and socioeconomy. The purpose of baseline monitoring was to provide a better understanding of the existing environment. Special investigations were designed to provide specific input to some of the assessment tasks or to investigate specific issues. These included 50-hr continuous hydrographic surveys, elutriate tests, and mangrove survival studies.

Air quality baseline monitoring focused on dust. Parameters monitored include dust fall, total suspended particulates (TSP), and respirable suspended particulates (RSP). For baseline monitoring on water quality, over 20 parameters, including dissolved oxygen (DO), 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), nutrients, heavy metals, and *E. coli.*, were measured. Sediment and bank soil samples were also collected for determination of a number of parameters including heavy metals.

A 50-hr monitoring exercise was undertaken to provide hydrographic data for hydrodynamic, sediment transport, and water quality modelling. Information was also collected on pollution sources, including water quality data of main tributaries on both sides of Shenzhen River and Deep Bay.

Potential release of oxygen-consuming organics, nutrients, and metals from the suspended sediment in river and marine waters during dredging was estimated using the elutriate test.

The ecological survey aimed to build on the existing data base by providing additional information required to better understand the ecosystem and allow for impact evaluation. The surveys were directed at consideration of the ecosystem as a whole. Major elements of the ecological survey included terrestrial ecology (mainly the Seung Ma Lei Yue Hill), mangroves, mud flat and mangrove invertebrates, and birds.

Data gathered through these studies were then used for determining potential impacts on air quality, noise, water quality, sediment quality, hydrodynamics, sediment transport, ecology and socioeconomy. Where appropriate, modelling techniques were used for prediction of impacts. The Fugitive Dust Model (FDM) was used to examine potential dust impacts during construction. Noise modelling was based on various Technical Memoranda (TM) published by the Environmental Protection Department in Hong Kong on construction noise. For hydrodynamics, sediment transport and water quality modelling, a mathematical model of unsteady flow and sediment transport was used. The model regarded Shenzhen River (downstream from Sanchahe), estuary, and Deep Bay as a whole system with smooth transition between a one dimensional (1-D) model and a two dimensional (2-D) model for the estuary and Deep Bay. Details of the above models are provided in the relevant sections in this report. A flow diagram showing trophic linkages between major components of the Deep Bay ecosystem was developed.

S4 EXISTING CONDITIONS

S4.1 AIR QUALITY

Baseline TSP and RSP levels in the vicinity of the Stage 1 works area complied with both Shenzhen and Hong Kong air quality standards. Total dust fall in spring however exceeded the Shenzhen standard. Compared to the control station upstream of the study area, strong and unpleasant odour was detected from all monitoring locations along the river. The Project is not intended to reduce the odour of Shenzhen River.

S4.2 NOISE

Noise levels at Lok Ma Chau Bend and Hekou were comparatively lower than those at other stations and were within PRC and Hong Kong standards. Both day and night time noise levels at the other stations generally exceeded the applicable noise standards of both sides, especially at night. Major night time noise sources included construction work, loading and unloading operations at the piers, and land and marine based traffic.

S4.3 WATER AND SEDIMENT QUALITY

The existing water quality of middle and downstream sections of Shenzhen River was severely polluted and nitrogen and phosphorus were the principle pollutants. The river failed nearly all standards applied by both the Hong Kong and Shenzhen Authorities. Water quality deteriorated downstream as pollutant load increased due to industrial and sewage discharges. The most polluted section was near Zhuanmatou.

Water quality in Deep Bay was polluted referring to PRC, Hong Kong, or Joint Guangdong Hong Kong standards. The dominant pollutants were nitrogen and phosphorus. As the pollutants mainly washed from Shenzhen River, the most severely polluted area was in the estuary region.

Shenzhen River had not been dredged for many years, nor had pollution discharge been controlled. Therefore, there were thick deposits of sediment which were severely polluted by all kinds of pollutants including heavy metals. The concentration of most pollutants in Deep Bay was much lower than that in the river. The majority of pollutants accumulated in the bay sediments were from Shenzhen River.

Soils along the river were not polluted.

S4.4 ECOLOGY

The intertidal flats of Inner Deep Bay and surrounding wetlands comprised an area of international importance. The population of wintering and migrant waterfowl had been increasing over the past decade. The mangroves of Inner Deep Bay appeared to be in a satisfactory state.

The benthic assemblage in the Inner Deep Bay tidal flats was dominated by a few species which can tolerate high organic loadings. These species often occurred in very high densities. There appeared to be some gradient in species abundance, diversity and biomass in parallel with the pollution gradient away from the mouth of Shenzhen River. Current levels of sedimentation within the Inner Bay were not thought to adversely affect the existing benthos.

The habitats to be directly affected by the Stage 1 works include hillside, fish ponds, freshwater marsh and the river itself.

Five habitats were delineated on the Seung Ma Lei Yue Hill. The habitat of greatest extent is shrub/ grassland. Pine woodland occurred on the north and southeast slopes of the hill and broadleaf woodland habitat was riparian and confined to small areas at the base of the hill on the southeast slope and at the northern point. Open pine woodland occurred on the ridge on the north slope of the hill. Abandoned paddy habitat was located adjacent to the north slope of the hill.

The Seung Ma Lei Yue Hill supported a relatively rich fauna. The avifauna of the hill was found to be locally and regionally important. In addition to those species relatively common in Hong Kong on an annual or seasonal basis, Imperial eagles, Bonelli's eagles, and Black kites were also observed.

There has been a significant loss of fish ponds on both sides of Shenzhen River in the past 20 years due to large-scale infilling for planned developments, as well as extensive unauthorised and illegal filling for open storage. The 65 ha of fish ponds on Lok Ma Chau Bend which will be filled during the Stage 1 works were created after being designated as a disposal area while waiting for the Project to begin. The net loss of fish pond as a result of the Project, therefore, will be 19 ha on Liu Pok Bend, equivalent to about 2% of the estimated fish pond area on the Hong Kong side of Deep Bay.

The existing river banks upstream of Lok Ma Chau were generally steep with little emergent vegetation other than grasses and a small number of mangroves. The north bank of the river had been largely reclaimed and offered no habitat of conservation value. No benthic organisms were observed in bottom sediments upstream of the River mouth.

S5 POTENTIAL IMPACTS

S5.1 AIR QUALITY

Modelling results showed that under worst-case meteorological conditions during Stage 1 Works period, 24-hr average total suspended particulate (TSP) levels wold exceed PRC limits at Shenzhen sensitive receivers (Shenzhen City, Yumin Village, and Yunong Village) and Hong Kong AQO at Hong Kong sensitive receivers (Lo Wu, Liu Pok Village, Lok Ma Chau, and Ha Wan Village).

Adverse impact at the sensitive receivers caused by odour from disturbance of the river system and the discharge of dredged spoil is expected.

There will be no significant air quality impacts during the operational and maintenance period of the Stage 1 works.

S5.2 NOISE

Daytime Hong Kong construction noise standards should not be difficult to meet. Assuming that the proposed list of equipment, or a combination of equipment which produces a total sound power level of less than 123 dB(A) is used, the non-stationary limit of 75 dB(A) at Villages on Hong Kong side would not be exceeded. PRC daytime standards will be more difficult to meet, since they stipulate noise at the construction site boundary. The use of items of PME near the boundary will thus be constrained.

More stringent evening and night-time noise standards require lower night time noise levels. Concurrent use of the equipment for a single activity would generally not be possible in the evening and at night under either the PRC or Hong Kong standards unless quietened or shielded items are used.

The noise from haul road use is expected to remain within acceptable limits at all but the very nearest distances. Restrictions during the night-time may be necessary to meet PRC standards.

There will be no significant noise impacts during the operational and maintenance period.

S5.3 HYDRODYNAMICS AND SEDIMENTATION

According to the modelling results, no significant changes in hydrodynamics of the River and the Bay are expected after the Stage 1 works. The water surface curve in the longitudinal direction of the river would fall slightly after the Stage 1 works. Flow fields in both the River and the Bay would not be significantly changed. There would be a minor increase in the tidal exchange volume (and hence flushing) and flume storage owing to the Stage I works.

A slight increase in sediment flux from the Shenzhen River and a moderate change in sedimentation rate on the mudflat would be expected during the construction operation of the Stage 1 works. The maximum annual increase in sedimentation depth due to the Stage 1 works would be 1.8mm and 2.0mm for Futian and Mi Po respectively. Therefore, the mud flat at the head of the Bay would not be affected significantly by sedimentation during and after the Stage 1 works of the Project.

It was also shown by modelling that the largest increase in sedimentation would occur at high tide and high water level.

S5.4 WATER QUALITY

The effect of the increase in tidal exchange volume on water quality of the Shenzhen River would be a minor improvement due to greater flushing and dilution by the relatively cleaner water from Deep Bay.

The dredging operation in the existing river course would give rise to an unavoidable increase in the concentrations of suspended materials in the lower river, the estuary and Deep Bay receiving waters. Release of pollutants from resuspended solids would not cause a serious problem to water quality of Shenzhen River.

Estimated increase in SS content during the dredging operation of the Stage 1 works would not exceed 40mg/l (10mg/l on average), less than 20% of the total concentration of the SS content at the head of the Bay.

The elutriate tests showed that no more than 5% increase in all pollutant concentrations is expected at a SS increase of 40mg/l. Since the value of 40mg/l is a conservative estimation of a worse case, it can be concluded that no significant impact on water quality at the head of the Bay will be caused by the release of pollutants from the re-suspended solids due to the Stage 1 works.

Potential effects on water quality from the operation of Stage 1 may result from the re-settlement of re-suspended sediments after transportation in downstream reaches and changes in hydrodynamics and sedimentation. Based on the modelling predictions, only moderate changes are expected, which will not have significant impacts on hydrodynamics, sedimentation, or water quality.

S5.5 DISPOSED SPOIL

The contaminated dredged spoils (organics and heavy metals) to be disposed of during the Stage 1 works will total 56,000 m^3, constituting 3-4% of the total amount of dredged spoils. According to the dredged spoil classification standards of Hong Kong polluted spoils from Stage 1 works are class "C" materials. Based on the Hakanson method, however, the potential comprehensive ecological toxicity of the contaminated spoil is slight.

Since the dredged spoils will be disposed of in the Stage 1 working area, the issue of contaminated spoil transport will not become a problem. Because the spoils disposal area will not be used for agriculture, adequate care taken during disposal and prevention of potential for erosion by surface runoff, the disposal of contaminated spoil will not cause ecological damage.

The spoil disposal area is near Shenzhen River channel, the hydrological connection between these sediments and ground waters will not be changed by the dredging and disposal. Pond mud and underlying marine deposits have also been found to be practically impermeable. Therefore, storage sites for contaminated spoils will not cause pollution of ground waters.

S5.6 ECOLOGY

Stage 1 works will result in direct loss of habitats, including fishponds and part of the hill at Seung Ma Lei Yue. Total areas of habitats which will be directly lost are relatively small in a regional context, and are mitigated through provision of replacement habitats and revegetation.

The 65 ha of fish pond on Lok Ma Chau Bend which will be filled during the Stage 1 works was created after being designed as disposal area while waiting for the Project to begin. The net loss of fish pond as a result of the Project, therefore, is 19 ha on Liu Pok Bend, equivalent to about 2% of the estimated fish pond area on the Hong Kong side of Deep Bay. The loss of the fish ponds of 19 ha as a net result of the Stage 1 works is not of itself likely to be a significant effect on the overall ecological system although certain species will be adversely affected.

Portions of all five habitat types found on the hill will be lost due to the proposed earthworks. The loss of the shrub/grass habitat and the open pine woodland habitat would not result in significant ecological impact. Loss of an estimated 2.0 ha of pine woodland would potentially result in adverse impacts on roosting and/or nesting birds of prey. Loss of broadleaf woodland would eliminate some preferred eagle perch sites at the northern foot of the hill. Approximately

0.6 ha of the abandoned paddy adjacent to the north foot of the hill would also be lost due to excavation for the new river channel.

Changes in air quality, noise, hydrodynamics, sedimentation, and water quality, as well as human disturbance, caused by the Stage 1 works would result in indirect impacts. The dust effect of the Stage 1 works on ecology will not be significant. It is not expected that noise generated as a result of either the construction or operation of the Project will significantly impact birds.

The moderate changes in hydrodynamics, sediment flux, and sedimentation rate resulting from the Stage 1 works are considered to pose no threat to ecological resources in Shenzhen River estuary area. Changes in water quality resulting from the Stage 1 works would not affect waterfowl, benthic fauna, mangroves, or commercial species of the area.

S6 MITIGATION MEASURES

AIR QUALITY

- Fifteen measures were proposed to avoid or mitigate air quality impacts included standard works practices such as watering haul roads, washing haul trucks, and sprinkling loading areas;
- Enclosed systems for materials handling and storage were also proposed as were speed limits on haul trucks;
- Heavily contaminated spoil should be segregated and disposed to separate spoil storage sites with capping to reduce potential odour problems;
- In view of the conservatism of the model and with the implementation of the proposed mitigation measures, dust problems during construction are unlikely to be insurmountable and can possibly be mitigated to acceptable levels.

NOISE

- It is desirable to avoid concentrating large numbers of PME at one location at same time. PME and activities should be sited as far from sensitive areas as possible. Whenever possible, stored materials on site may also act as noise barriers;
- A second effective way of mitigating construction noise is to control it at source, either through use of silenced equipment or through the use of mufflers, silencers or acoustic barriers.

WATER QUALITY

- The use of a works method which isolates the main excavation works from the river channel is fundamental to the environmental performance of the Stage 1 works;
- The use of suction dredgers is thus strongly supported;
- The worse case of resuspension of sediments during dredging can be easily avoided if the construction is programmed in dry season;
- Opening the channel during a period of low river flow and low tides will greatly reduce sedimentation risks.

DISPOSAL OF SPOIL

- The contaminated spoil from the existing river course should be disposed separately in isolated locations without mixing with uncontaminated spoil;
- The contaminated spoil disposal area should be capped with uncontaminated spoil to prevent erosion of contaminated sediments.

ECOLOGY

- Potential impacts to water birds due to loss of 19 ha of fish ponds could be mitigated by retention of the old Shenzhen River channel at Lok Ma Chau Bend. The restoration plan will be included in the Environmental Monitoring and Audit Manual;
- Impacts due to loss of upland habitats on Seung Ma Lei Yue Hill can be mitigated by successful restoration of vegetation on the proposed cut slope and adjacent slopes of the Hill. Further impact mitigation can be achieved by habitat creation on materials storage areas;
- Fire control methods should be specified;
- Rock drilling and blasting should be minimized during the nesting season of birds;
- Ecological impacts from Stage 1 works can possibly be mitigated or compensated to acceptable levels.

S7 MONITORING AND AUDIT REQUIREMENTS

AIR QUALITY

- Setup of two monitoring stations consisting of a TSP dust monitor and a weather station at each of the works areas;
- Baseline information provided by this studies;
- Measurement of 24-hour average TSP level once every 6 days during construction period;

NOISE

- Set up of two stations on each side of the River at Lok Ma Chau and Liu Pok, respectively;
- Baseline information provided by this study;
- Weekly monitoring during the construction period;
- Additional monitoring during restricted hours.

WATER QUALITY

- Set up of three monitoring stations for Lok Ma Chau and three for Liu Pok (control, 500m and 2,000m downstream);
- Baseline information provided by this studies;
- Daily measurement of SS during the wet dredging within the existing river course. The frequency can be reduced to once a month if the condition remain stable;
- Measurement of COD, TP, TN, and Cu only when unexpected amount of SS is observed;
- Routine monitoring will provide information during operation and maintenance periods.

ECOLOGY

- Baseline information provide by current studies;
- Survey of birds every month between the Lok Ma Chau and Lo Wu bridge during the works period, and every 2 months thereafter for 1 years;
- Survey of mudflat after the construction;
- Survey of mangroves, benthos, and waterbirds is necessary only significant change in mudflat is observed;
- Monthly survey of old River channel at Lok Ma Chau before conservation management works commence and seasonally for a period of 3 years following completion of the works.

S8 CONCLUSION

The purpose of the Stage 1 EIA was to provide information to assist in decisions on the environmental acceptability of the Stage 1 works and to recommend on any specific environmental protection measures which should be included in the detailed design of the Stage 1 works.

The major conclusions of the study which should influence decisions on the Stage 1 works are summarised below.

The scale of the Stage 1 works would be comparatively small. Upon implementation of the proposed mitigation measures, the construction works would not create any unacceptable air, noise or other nuisance which should influence major decisions on the acceptability of the Stage 1 works.

The Stage 1 works would have minimal effect on the down stream ecological resources. Predicted changes in sedimentation and water quality would be unlikely to have any noticeable effect on ecological resources in the estuary or Inner Deep Bay.

There would be potential for release of contaminants from sediments due to the dredging works. With effective control and close monitoring programme, this increase, however, would not have any detrimental effect on the habitats in the estuary or Deep Bay.

The Stage 1 works would result in direct loss of habitat, 19ha of fish ponds at Liu Pok and parts of the Seung Ma Lei Yue Hill. Recommendations were made by the consultants on various measures which would compensate the loss of the habitats.

PART II OVERVIEW

1 *INTRODUCTION*

2 *DESCRIPTION OF THE STAGE I WORKS*

3 *ENVIRONMENT AND KEY ENVIRONMENTAL ISSUES*

1. INTRODUCTION

1.1 THE SHENZHEN RIVER

1.1.1 The Shenzhen River

The river originates near Niuweiling in the Wutong Mountains. Above Shenzhen Reservoir it is called the Shawan River. The Shawan River becomes the Shenzhen River below Shenzhen Reservoir and downstream of the confluence of the Shawan and Liantang Rivers at Sanchahe. The mouth of the river is at the eastern head of Deep Bay. The river course and Deep Bay are shown in Figure 1-1. The study area is considered to comprise any areas within the catchment of Deep Bay potentially affected by the Shenzhen River Regulation Project.

Shenzhen River flows from northeast to southwest past Mankamto and Lo Wu Port. Its major tributaries include the Shawan and Buji Rivers on Shenzhen side, and the Ping Yuen and Indus Rivers on the Hong Kong side. The drainage pattern of the river is dendritic with a fan-like catchment. The catchment area covers 312.5 km^2, of which 60% lies on the Shenzhen side and 40% lies in the New Territories of Hong Kong. The length of the river(from Sanchahe to the river mouth) is currently 16.9 km, upon completion of the training project the length of the river would be reduced to 12.5 km.

Upstream of Sanchahe, Shenzhen River is a mountain stream. The width of the River is approximately 20 m at Sanchahe, expanding gradually as it travels downstream to approximately 60 m at the Buji River confluent and approximately 230 m at the river mouth. In the area around Shenzhen City the river is contained within banks and is only some 20m wide. Downstream of Sanchahe, as Shenzhen River meanders on the flat alluvial-marine plain, the river bends increase in size and the gradient decreases. The average gradient of the river bed is only 0.05%, decreasing to 0.02% below the Yunong Village.

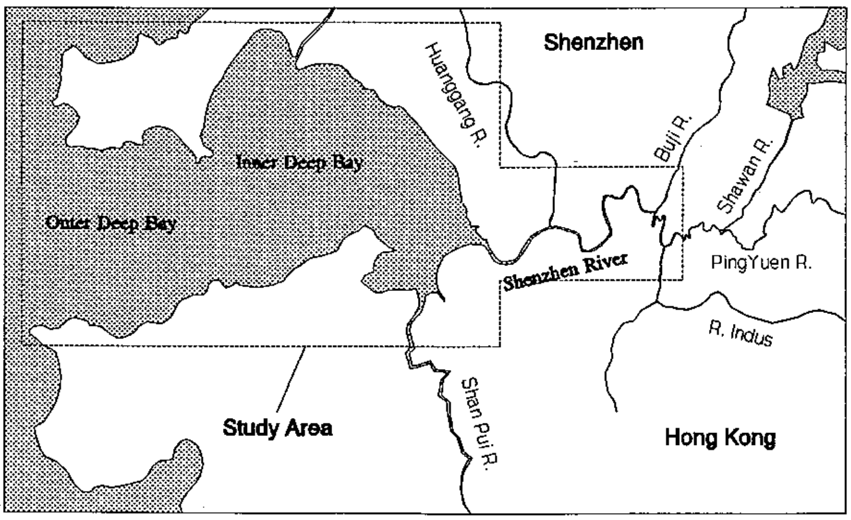

Figure 1-1 The Shenzhen River and The Deep Bay

The entire Shenzhen River is subject to tidal influence. The mud flat extends 4 km into the bay during low tide but totally disappears at high tide. The tidal regime in the area is a typical irregular diurnal tide. The shape of the tidal wave gradually changes upon entering the estuary, becoming faster during flood tide and slower during ebb tide, thus raising the tidal height and causing long retention time. During periods of low runoff at the upstream portion of the river, water retention time is 30-60 minutes longer in the vicinity of Yunong Village than at the mouth of the bay. The maximum tidal difference of the river is 10-30 cm higher than that of the bay during flood tide and 50-100 cm lower during ebb tide. The average duration of flood tide on the river is 1 hour less than that in the bay, while the duration of ebb tide is 1 hour more.

Shenzhen River drains into Deep Bay, which receives water also from the Shan Pui River and the Tai Sha River, and joins the Lingding Sea on its seaward side. The bay is also influenced by flows from the Pearl River delta which are drawn into the bay from the coastal currents. Deep Bay has an area of 115 km^2. It is half enclosed and shallow, with an average depth of 2.9 m and an average capacity of 330 Mm^3. From the southern part of the bay a deep channel extends in a east-northeast direction to the Inner Bay. The bottom of the bay slopes seaward and is deeper in the south than in the north because of the existence of the channel. This results in complicated hydrological conditions in the bay. The annual average tidal difference is 1.37 m. The tide is influenced by the irregular mixed diurnal tide of the South China Sea, flowing oscillately.

1.1.2 Flooding

The study area is influenced by the southern subtropical monsoon climate with distinct wet and dry seasons. Rainfall in the catchment area is typically 1900 mm/year. The wet season is from April to October. Rainfall during this period constitutes 90% of the annual total. Shenzhen River water is mainly sourced from storm water runoff. Since precipitation and runoff intensity are closely interrelated, there is considerable variation in runoff volume between the wet and dry seasons. Wet season runoff volume is typically 87% or more of the annual total.

The upper portion of the river is short with a steep gradient and short retention time. Flow at flood peak is high, and this section of the river is characterized by sudden rise and fall in water depth. The flood peak reaches the downtown area of Shenzhen in a matter of hours following a storm. The river channel downstream is narrow, bending and low-lying. The river embankment is low (approx 2m) and narrow (from 2m - 10m). Combined with tidal pressure, the river's safety flood-discharge capacity is low, only several hundred m^3/s. This corresponds to a 1 in 2 year storm capacity, and results in frequent flooding.

An area of about 15 km^2 on Shenzhen side of Lo Wu, at Futian and at other low-lying river bank areas is inundated 1-2 times per year on average for a duration of 1-3 days each time. Following a decade of rapid economic growth these areas are now intensively developed for commercial, industrial and residential activities and have high population density. Each flood incident now causes serious economic losses and results in severe hardship to the local population. The south side of Shenzhen River is largely used for fish culture and flooding here also causes serious economic losses and hardship.

During a typhoon on 23 October 1964, 1,300 ha on the right bank of Shenzhen River were flooded. Due to discharge from Shenzhen Reservoir following the typhoon flooding in low-lying river bank areas downstream lasted for 3-7 days. Several floods occurred during the wet season in 1993, causing economic losses of several hundred millions of HK$ and threatening the safety of residents in Shenzhen and Hong Kong. During the most severe incident flooding extended over an area of approximately 1500 ha on Shenzhen side. On the Hong Kong side some 1350 ha of the New Territories were flooded.

1.1.3 Wetland

Adjoining the mouth of the river at the head of Deep Bay is an estuarine wetland which is of international significance. The Mai Po Reserve is managed by the World Wide Fund for Nature Hong Kong under license from the Hong Kong Government. The Futian Nature Reserve is managed by the Neilingding Futian National Nature Reserve.

1.2 OBJECTIVE OF THE SHENZHEN RIVER REGULATION PROJECT

The Shenzhen and Hong Kong Authorities initiated cross border liaison meetings in 1982 to review and co-ordinate measures to prevent flooding and reduce pollution in the river catchment. As a result of these initiatives a scheme to realign and widen Shenzhen River downstream of Lo Wu was proposed in 1985. This scheme has subsequently been refined and developed to provide the current Shenzhen River Regulation Scheme, hereafter referred to as the Project. The objectives for the Project as described in the Terms of Reference (TOR) for Environmental Impact Assessment Study for Shenzhen River Regulation Project (hereafter referred to as the EIA) are to prevent flooding and reduce pollution. Flood protection is the dominant objective.

The full Project consists of a three stage scheme to realign, widen and deepen Shenzhen River. Stage 1 involves relatively localized works to truncate two existing meanders of the river close to Shenzhen City. Stage 2 involves more extensive dredging works downstream of Lo Wu to increase the depth and width of the channel, and construction of flood protection works along both banks of the widened stream. Stage 3 involves dredging works upstream of Lo Wu. The project is described in detail in Section 2 of this report. The EIA is required to address only the first 2 Stages of the Project.

1.3 OBJECTIVES OF THE STAGE ONE EIA

The primary purpose of the Project is to alleviate flooding in the lower catchment of Shenzhen River. Both the Shenzhen and Hong Kong Authorities have given priority to the implementation of flood control programmes to overcome this severe problem. The Shenzhen River Regulation Project is central to these works programmes on both sides of the border. An outline design and programme for the Project has been developed jointly by the Shenzhen River Regulation Office and the Drainage Services Department of the Hong Kong Government. Both the Shenzhen and Hong Kong governments, however, have recognised that the Project may affect the internationally important Mai Po and Futian Nature Reserves at the mouth of the river. The Project also presents other potential environmental problems. The environmental impact assessment (EIA) is thus jointly funded by the Shenzhen and Hong Kong Authorities to ensure that these environmental concerns are addressed. The EIA of the first two stages of the Project started on Dec.16, 1993 and will be finished by the middle of March, 1995. The EIA report on Stage 1 of the Project is to be submitted by middle of June, 1994 to enable decision on this part of the Project.

The international importance of the wetlands potentially affected by the Project dictates that the environmental assessment process is comprehensive and thorough. The requirement to gather data over all seasons to construct and calibrate the hydrodynamic and sediment models, and to establish an ecological baseline which is essential to the study dictate that the study cover a 12 month period. However, it is also important that the environmental assessment process does not unnecessarily delay progress of the detailed design and planning for the Project and the implementation of environmentally sound proposals for flood control. The outline programme for the Project is aimed at the earliest possible introduction of flood protection measures and community benefits. This programme requires an early start to the detailed design and contract preparation for the Stage 1 works. A delay to these activities would potentially delay the Project by many months. To facilitate this programme a decision in principle on the acceptability of the Stage 1 works is required to be taken in advance of completion of the full EIA.

The EIA has therefore been structured to address this issue through this EIA of Stage 1 Works. The purpose of this Stage 1 Works EIA is to provide information to assist in a decision on the acceptability of the Stage 1 works and to recommend specific requirements for environmental protection which should be included in the detailed design of Stage 1.

At the time of writing the assessment has been in progress for only 6 months. Consequently, this Stage 1 EIA has necessarily been based only on the information, data and analysis available through May 1994. Assessment of potential ecological effects of the Project is based on the results of baseline investigation and modelling obtained thus far, and complete results will not be available until the end of 1994.

Notwithstanding these constraints, the consultants believe that from the information and analysis gained through the first 6 months of the EIA, and given the nature of the Stage 1 works, it is possible to provide a reliable assessment of the likely impacts of Stage 1 and the acceptability of the net environmental effects at this point in the study.

The approach adopted in completing the assessment of Stage 1 has been to utilise the available information with a view to defining an environmentally acceptable option for the works which offers greatest safeguards to the environment, presents no identifiable risks to the viability of the conservation reserves, and enables the programme for the Project to be maintained. The analysis of impacts has progressed through the following stages:

1) to identify those potential key issues or impacts which might potentially be so severe as to influence key decisions on the design, programme or acceptability of the Stage 1 works. Recommendations on Stage 1 have been based on these issues.
2) to identify all potential activities that would contribute to these issues or impacts. These activities have then been analysed in terms of design, programme and construction decisions affecting Stage 1 of the Project.
3) to identify opportunities to mitigate these effects such that short and long term environmental performance can be safeguarded and the progress of Stage 1 can be maintained.

4) to adopt a conservative environmental approach aimed at providing least risk to environmental resources and accepting reasonable costs in terms of construction method or design;
5) to present clearly the risks and consequences associated with the recommended strategy and conclusions in terms of environmental performance;

There are several precedents in Hong Kong and elsewhere for adopting such a staged approach to completing an environmental assessment. These precedents have arisen where the project and the implementation programme can be shown to offer overriding community benefit, and the veracity of the environmental decisions will not be unreasonably compromised by the incomplete seasonal data or other information. The consultants believe that the Stage 1 of the Project satisfies both of these criteria. In adopting such an approach, however, it must be recognised that conclusions and recommendations are necessarily based on incomplete data and a more cautious interpretation of potential effects is essential, together with an explicit recognition of the uncertainties and risks involved in the assessment.

The specific objectives of the Stage One EIA Report are :

1) To describe the Project including:

a. the outline design for the works which has been adopted as a basis for the EIA;
b. the construction method and programme which is likely to be used and which has been adopted as a basis for the assessment;
c. any practicable alternatives to the design and construction method which might be considered to reduce environmental effects of the project;

2) To describe the environment and community likely to be affected by the project including:

a. to describe, qualitatively and quantitatively, the ecological resources affected by the project;
b. to evaluate and identify the most sensitive and critical ecological resources, particularly those affected by Stage 1;
c. to describe the community potentially affected by the Project and particularly Stage 1;

3) To assess the potential environmental effects arising from the Stage 1 works;

a. to identify and evaluate potential short term effects;
b. to identify and evaluate potential long term effects;
c. to identify key potential issues or impacts which might influence project decisions in respect of Stage 1;

4) To identify potential mitigation options in respect of Stage 1;

a. to describe potential mitigation measures which could be applied to reduce effects from Stage 1;
b. to recommend on the most effective mitigation measures;

5) *To evaluate acceptability of mitigation measures;*

a. to establish measures against which potential effects can be evaluated.
b. to evaluate the significance of net impacts arising from Stage 1.

6) *To define the risks and consequences associated with conclusions and recommendations;*

a. to define the lack of information or other uncertainties associated with the assessment;
b. to define the risks and consequences arising form the recommendations.

1.4 STRUCTURE OF THE STAGE ONE EIA REPORT

This report is presented in 3 parts.

Part I summarizes the objectives of the assessment, potential impacts of the Project, mitigation options, and the overall acceptability of the project.

Part II sets out the background for the assessment and comprises this introduction together with the description of the Project and the existing environment and community that could be affected by the Project.

Part III contains the assessment of technical issues. The technical approach and methodology are presented in Section 4. Impacts on air quality, noise, water quality and sedimentation, ecology and socioeconomics are addressed in Sections 5, 6, 8, 9, and 10, respectively. Hydrodynamics, sediment transport, and water quality modelling are discussed in Section 7.

2. DESCRIPTION OF THE STAGE I WORKS

2.1 OVERVIEW OF STAGE 1 WORKS

Implementation of the Shenzhen River Regulation Project will be divided into three stages. Stage 1 works involve realigning, widening and deepening the meandering sections of the river between Lo Wu and Liu Pok and at Lok Ma Chau. The Stage 2 works are still in the planning stage but will involve widening and deepening the river downstream of Lo Wu Bridge. Stage 3 will involve similar works upstream of the Lo Wu bridge. Figure 2-1 shows the various stages of the Project. Figures 2-2 and 2-3 show views of the major areas for Stage 1.

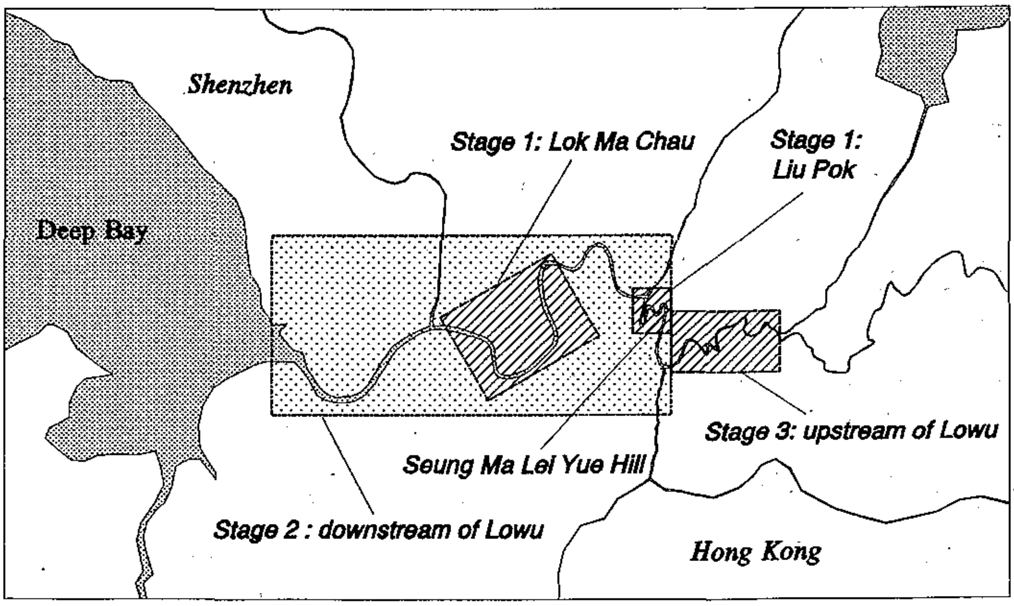

Figure 2-1 Shenzhen River Regulation Project

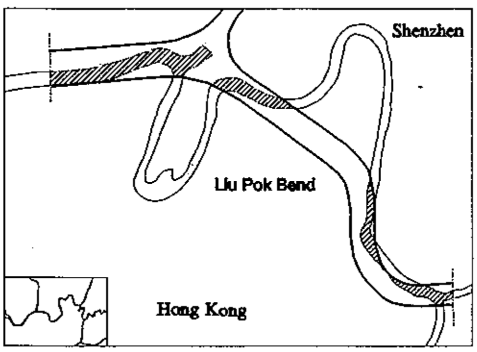

Figure 2-2 Liu Pok Bend

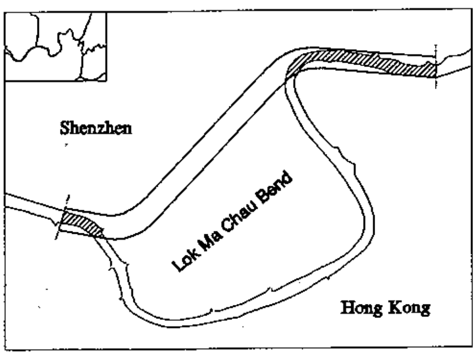

Figure 2-3 Lok Ma Chau Bend

The programme for the Stage 1 works is planned to take approximately 28 months. The progr amme includes the relocation of the border fence, construction of the haul road, excavation of the Lok Ma Chau Bend, excavation of the Liu Pok Bend, and the excavation of the Seung Ma Lei Yue Hill. Material from the Seung Ma Lei Yue Hill is expected to be used for embankment construction.

Upon completion of Stage 1 works, the length of the section of the river trained in Stage 1 will be reduced from 6.2 km to 3.2 km. Further, the channels created at Lok Ma Chau and Liu Pok Bends will be temporarily some 2 m lower than the existing channels upstream and downstream.

2.2 DESIGN

2.2.1 Hydraulic Design

An one in 50 year flood return period has been used for determining the maximum water levels. This return period has been agreed by the Joint Technical Group (JTG) and gives the flows and water levels presented in Table 2-1 and 2-2.

Table 2-1 One in fifty years flood discharge(m^3/s) estimated by JTG

Location	upstream of Lo Wu	downstream of Lo Wu	Lok Ma Chau	San Tin
Discharge	870	1,500	1,900	2,100

Table 2-2 One in fifty years flood levels estimated by JTG

Location	Lo Wu Bridge	Buji River	Shangbu Pier	Lok Ma Chau
Now	6.63(7.48)	5.86(6.71)	5.21(6.06)	3.64(4.49)
Fully trained	3.87(4.72)	3.45(4.30)	2.98(3.83)	2.94(3.79)

* Yellow River Datum, ( ) m.P.D. Hong Kong

2.2.2 Sediment Control Measures

The outline design assumes that construction of the new river channel will be by small suction dredger. This is in response to low stability of sediments along the new river course which will make it easier to work in the wet. The use of a suction dredger will also make materials handling simpler but will restrict opportunities for spoil storage to areas immediately along the river course.

It has been assumed that the construction of the new channel at Lok Ma Chau Bend and immediately downstream of Seung Ma Lei Yue Hill at Liu Pok Bend will be carried out in isolation from the main river.

The Stage 1 works provide for catchpits or stilling basins where tributaries and ditches join the main river. These measures will also assist in containing sediment.

2.2.3 Geotechnical Conditions and Constraints

The soft, silty nature of the material overlying the site, its lack of shear strength and high compressibility have been taken into account in the design of the works. The channel cross-section addresses these matters by adopting shallow side slopes for the channel and an intermediate berm which places the toe of the embankment some 5 to 15 m away from the top of the channel slope. This berm adds stability to the channel slope which otherwise might slip under the weight of the embankment and its compaction.

2.2.4 Cross Section

The channel cross section proposed in the Outline Design is presented in Figure 2-4. This is for a regular trapezoidal shape bounded by flood control bunds.

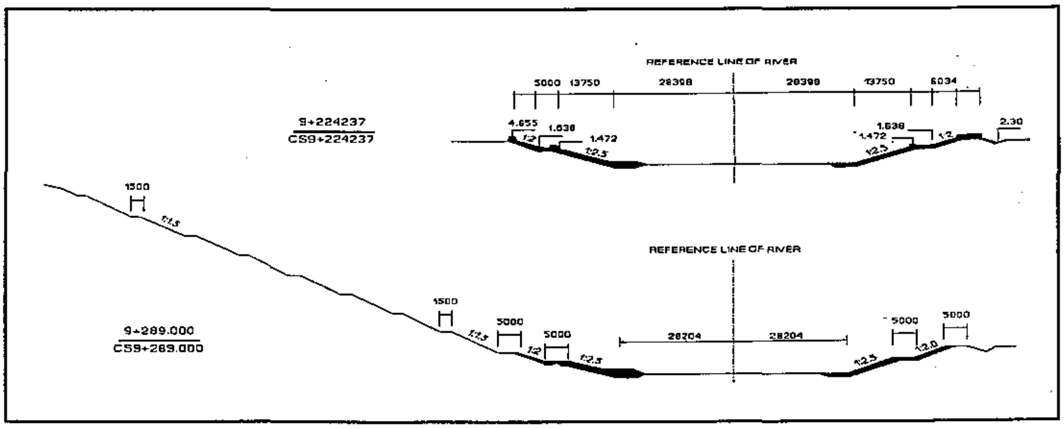

Figure 2-4 Channel cross section

As the flood water levels in the channel are dependent upon the cross-sectional area, roughness, and gradient, any significant improvement of these factors would result in the lowering of flood levels for any given tidal condition. The effect on flood levels after the completion of all the planned works would be in the order of 3 m reduction in flood heights at the Lo Wu bridge. This beneficial effect would extend into the drainage basins which discharge into the main river. Velocities are likely to be in the order of 0.6 m/s for normal flows, increasing to 2.0 m/s for flood flows. The Outline Design has assumed a roughness factor of 0.0225.

Access the berm and channel is required for maintenance. The outline design for Stage 1 works provides for an access track along the top of the berm. However, given the solid conditions forming the underlying berm foundation, access along the berm may only be suitable for pedestrians or very light vehicles as the ground is unlikely to permit the passage of heavy machinery which would disturb or break the presently proposed concrete slabs.

2.2.5 Long Section

It is assumed that because of hydraulic considerations the gradient and base level of the channel are fixed.

The Outline Design provides for the slopes leading into the depressions formed during Stage 1 works at Lok Ma Chau and Liu Pok Bends to be lined with stone.

2.2.6 Lining

The fine material forming the upper layers of the channel profile would be subject to erosion if left unprotected. The Outline Design proposes to line the channel with precast concrete slabs. The lining of the channel slopes is consistent with the need to prevent erosion following the diversion of the river from its natural course.

Rock is proposed for channel lining below water level. This will provide good protection and will be easier to place than concrete slabs or in-situ concrete in underwater conditions.

2.2.7 Embankment Design

The Outline Design proposes to use material excavated from Seung Ma Lei Yue Hill for the embankments where possible. This material is better suited for use in embankment works than dredged material as it can be readily compacted and will be excavated in a dry state. Due to the likely settlement of the embankment over the construction period, regular topping up would be required.

Embankment trials were carried out in 1986 to demonstrate the construction of embankments using dredged material. The trials indicated settlement of up to 1 m over a two-year period. This settlement is assumed to have resulted from the consolidation of the foundation and "punching in" of the fill material. This factor would support the use of non-rigid protection at the sides of the embankment.

2.2.8 Spoil Disposal and Storage

The Outline Design proposes to utilise areas along the river bank as disposal area. The enclosed area of the Lok Ma Chau Loop is designed as major storage area for Lok Ma Chau material, while at Liu Pok Bend, material is disposed of to the existing river channel. Storage areas for revetment and embankment material should be located near to the embankment.

The majority of the material to be excavated will be removed in a semi-liquid state and is likely to be piped to on-site disposal points as permanent filling material. Suitable and unsuitable material will be defined in order to separate the materials for disposal to different parts of the spoil storage site.

The majority of suitable material excavated from Seung Ma Lei Yue Hill approxi. 270,000 m^3 (total excavated yield approxi. 665,000 m^3) will be used for embankment construction for Stage I works.

2.2.9 Access

A co-ordinated site boundary has been indicated on the drawings for Stage 1 works. It is assumed that all construction activities would take place within these limits. The two areas of work at Liu Pok Bend and Lok Na Chau Bend will be connected by a haul road of at least 12 m in width to permit two way construction traffic. The Programme in the Outline Design (Technical Design Manual) gives high priority to the construction of the haul road for moving the material from Seung Ma Lei Yue Hill for embankment construction.

Access points into the site are shown at the temporary river crossing to be constructed at chainage 8+150, at Shangbu Pier and at Futian Village. Access points downstream of Lok Ma Chau have not been defined. The temporary river crossing at chainage 8+150 would enable material to be moved from Seung Ma Lei Yue Hill to the right bank and along the haul road to Lok Ma Chau Bend.

2.3 PROGRAMME

2.3.1 Overview

The programme indicates that Stage 1 works would take 28 months. Key elements of the work include:

1) Erection of temporary site fence	2 months
2) Construction of the haul road	2 months
3) Excavation of Lok Ma Chau Bend	18 months
4) Excavation of Liu Pok Bend	18 months
5) Excavation of Seung Ma Lei Yue Hill	22 months

Works within Stage 1 are divided into two sections at Lok Ma Chau Bend and Liu Pok Bend. These sections are likely to be constructed independently. The only constraint at Lok Ma Chau Bend is the requirement of material from Seung Ma Lei Yue Hill for embankment construction. The need for constructing the haul road during the early stages of the contract and relocating the border fence have been identified in the Technical Design Manual.

2.3.2 Programming Constraints

Dredging may not be possible at all times due to flow conditions, inclement weather, navigational requirements, etc. Criteria for the cessation of dredging need to be defined in the contract documents. Similarly, excavation of material from Seung Ma Lei Yue Hill and the placing and compaction of material in embankments would also be weather dependent. This has been partly addressed in the Technical Design Manual.

2.4 CONSTRUCTION METHODS

2.4.1 Dredging

The construction will proceed in the wet using small dredgers to minimise potential problems due to the instability of the areas to be excavated. At Lok Ma Chau assuming that the contractor opts to carry out the excavation without making the final cut through to the existing river, he would be able to work unhindered by boats and flows within the main river channel. Dredging operations could be contained without risk of sediment passing downstream.

The quantity of dredged material from river channel excavation for Stage 1 works has been estimated at approximately 1.7 Mm^3. The average excavation depth would be between 5.2 and 5.5 m, and the material excavated for the new channel would consist of muck, medium/fine sand or light clay. Approximately 10% of dredged material will be dredged from the existing channel and will comprise a mix of river bottom sediment (partially contaminated) and uncontaminated material from the banks. A small auger type suction dredger has been proposed. The material would be conveyed by a pipe directly to the stockpile area, which would typically lie within 700 m of the dredger, and would be piled to a height of between 2.5 to 3 m.

Excavation at Seung Ma Lei Yue Hill is expected to yield 665,000 m^3 of material, mostly composed of heavily and moderately weathered phyllitic metamorphic rock. This can be won using large bulldozers and excavators. A small amount of slightly weathered rock may require blasting prior to excavation. Part of the material would be used for embankment construction. The remainder would be stockpiled at a designated area approximately 3 to 5 km away.

2.4.2 Plant Requirement/Dredging Plant

The trial embankment construction carried out within the Lok Ma Chau Bend has demonstrated the successful use of a small auger type suction dredger which pumped spoil from the channel excavation to the embankment site. The channel section dredged was 20 m at the base, 50 m at the top with 1 in 3 sides. The base level was -4.5 m and the rate of excavation about 7,000 m^3/month.

Traditional equipment would be required to place lining material and form concrete structures where necessary. It is envisaged that properly constructed haul roads would be routed adjacent to the embankments to facilitate this work and the transportation, haulage and compaction of embankment material. Excavation at Seung Ma Lei Yue Hill would require traditional earthmoving equipment and limited blasting.

2.4.3 Embankment

In Stage 1, embankments would be constructed in two phases. Phase 1, to be completed in approximately 6 months to one year, would require 210,000 m^3 of material to achieve a height of 2.5 m. Phase 2 would require 40,000 m^3 of material (excluding additional volume required due to settling) to take the embankment up to the designed height.

Rock boulder would be used for bank revetment and dike footing. These boulders could be shipped in, or cast manually by machines on board vessels or by purpose built vessels. The floodplain terrace surface would be laid with precast concrete slabs, each measuring 600 mm x 600 mm x 300 mm and weighing 200 kg. These concrete slabs would initially be cast and stockpiled at a casting area off site and transported to the site as required. Small cranes would be required to place these slabs on site. Discharge culverts would be constructed by conventional methods using reinforced concrete cast on site.

3. ENVIRONMENT AND KEY ENVIRONMENTAL ISSUES

3.1 ENVIRONMENT

3.1.1 Location and Political Significance

Shenzhen River forms the border between Shenzhen Special Economic Zone (SEZ) within the People's Republic of China (PRC) and Hong Kong and is thus of geographical and political importance. The restricted border areas and the border fence follow the general course of the river on the both sides of the river. Access to the river is generally restricted. The original course of the river has been preserved over the past century to maintain the border. The realignment of the river therefore has very serious implications in terms of political relations between Hong Kong and the PRC, operational issues in respect of the controlled border area, and arrangements for access during construction and for use of affected land after completion of the works.

3.1.2 River Water Quality

Shenzhen River is heavily polluted due to discharge of untreated pollutants from industry, agriculture, poultry and livestock farming, and human sewage. The pollutants from Shenzhen include mainly commercial, industrial and domestic discharges while most pollutants from Hong Kong arise from livestock waste. Generally the water is so polluted as to be unsuitable for any beneficial uses except navigation.

The Hong Kong - Guangdong Environmental Protection Liaison Group (1992) reported that biochemical oxygen demand (BOD) loadings entering Deep Bay from Shenzhen River contributed over 55% (52,685 out of 95,049 kg/day) of the total from all catchments of Deep Bay in 1988. In that year BOD loading from Shenzhen side was estimated to be 19,922 kg/day (59% from commercial and 39% from domestic sources). BOD loading from the Hong Kong side was estimated to be 28,465 kg/day, with over 77% from livestock waste.

3.1.3 Wetland Ecological System

The wetland ecological system of Shenzhen River, its estuary, and Deep Bay consists of the inner portion of Deep Bay together with the adjacent intertidal mudflats, gei wais, bay waters, Mai Po and Futian mangroves and the fish ponds of the northwestern New Territories, Hong Kong. This is a wetland ecosystem of international importance and one of the most important in the South China region. Its core is the Mai Po Marshes and Neilingding-Futian National Nature Reserve, along with the adjacent Sites of Special Scientific Interest (SSSI). This area provides a habitat for numerous rare and endangered species, in particular waterfowl and migratory birds including a number of species under threat on a global scale. This system is also an important habitat for many other types of plants and animals. At least 19 new species of invertebrates have been discovered here.

Five SSSIs have been established in the Inner Deep Bay area. Two additional SSSIs have been proposed for Inner Deep Bay. The SSSIs designate areas of particular importance to local ecology, such as mangroves and intertidal zones (Figure 3-1).

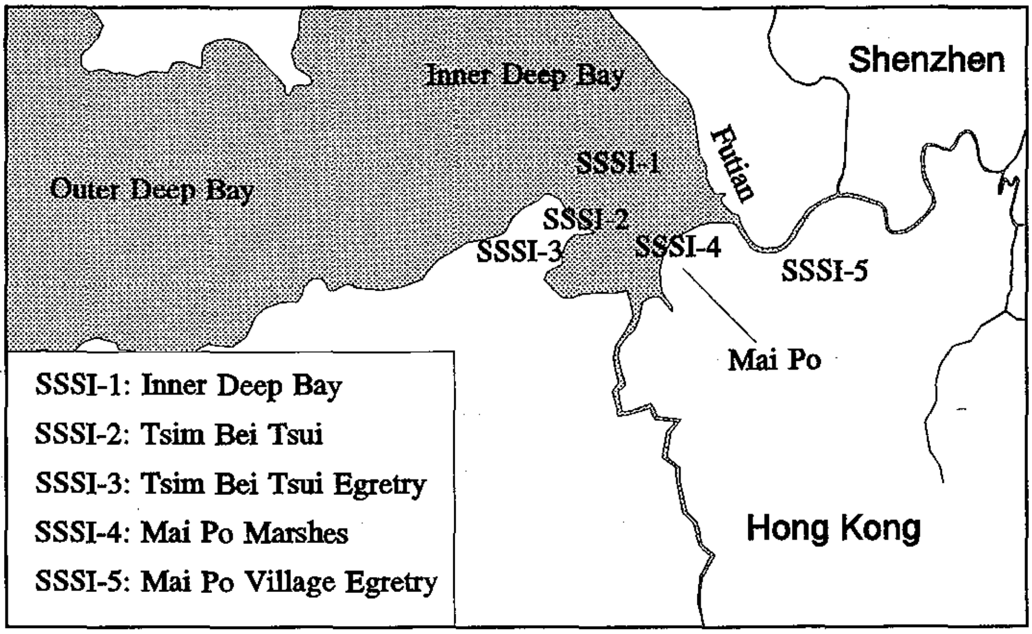

Figure 3-1 Mai Po, Futian, and SSSIs in Study Area

3.1.4 Lok Ma Chau

The meander at Lok Ma Chau will be eliminated during the Stage 1 work and the realigned channel will be located to the north of the bend of the old river channel. The area was farm land before being converted to fish ponds in anticipation of designation as a disposal area for the Project. The 70 ha commercial fish pond area was created for temporary use while waiting for the Project to begin. During the Stage 1 works of the Project, these fish ponds will be filled up by spoil.

3.1.5 Liu Pok and Seung Ma Lei Yue Hill

In the river section between Liu Pok and Yumin Village, the new river channel following Stage 1 works will cut through the eastern portion of Seung Ma Lei Yue Hill.

3.2 KEY ENVIRONMENTAL ISSUES

3.2.1 Ecological Impacts

Implementation of Stage 1 of the Shenzhen River Regulation Project may cause a number of environmental problems. First among these is impact on the ecosystem of Shenzhen River, estuary and Deep Bay. Due to the localized nature of the Stage 1 works, direct losses of wetland habitat will be limited to areas at Liu Pok and Lok Ma Chau bends.

The most important ecological impact of Stage 1 of the Project may stem from alteration in hydrodynamics and sediment flux in the Shenzhen River estuary area. An increase or decrease in sediment flow may produce potential impacts on the ecosystem of the protected areas, and may affect its viability. Other potential ecological impacts of Stage 1 works include alterations in water and sediment nutrient content and release of pollutants.

Potential impacts to terrestrial ecosystems will be limited for the most part to works on the upper portion of Seung Ma Lei Yue Hill. Excavation will remove part of the foot of the hill. A key issue is damage to the forest habitat adjacent to the heron and egret habitat on the south side of the hill and to the forest system on the north side of the hill which is a bird feeding area.

3.2.2 Impacts on Hydrological Characteristics, Siltation, and Water Quality

Due to the release and resuspension of sediments and pollutants combined therewith, dredging works during the construction phase may have an impact on water quality. Before it is possible to make any judgment on the impacts of dredging on the environment, it is necessary not only to understand the total losses directly attributable to dredging but also to consider the natural characteristics of sediment transport and the factors influencing the transport process.

During work on the Project, changes in the hydrology of Shenzhen River may have effects on water quality. The level of pollutant discharge into Deep Bay may vary due to changes in hydrologic conditions. Maintenance dredging may also affect water quality.

3.2.3 Air and Noise Impacts

Dust and noise from construction and traffic may be produced during the construction period. Based on experience in assessment of construction impacts, vehile exhaust emissiong from construction and lighter traffic will not be a serious problem. Dumping of wastes, transport of dredged silt, movement of road traffic and dredging works may all produce dust. A dust problem will arise from such sources as disturbance of mud in storage pits. Noise from motorised equipment and construction traffic may be harmful to sensitive receivers.

No noticeable air quality problems will persist following completion of the Project. However, noise impacts may result from dredging and lighter traffic during maintenance dredging. Sensitive noise receivers along Shenzhen River will be subject only to short-term (e.g. several days) and infrequent (e.g. once per year) potential impact.

3.2.4 Impacts of Spoil Disposal

The major potential Project impact outside the construction area may result from disposal of dredged mud. The extent and nature of this impact will be determined by the quantity of the spoil, the degree of contamination of the mud, method of transport of the mud, and final site of disposition.

Contaminated mud from Stage 1 works will be deposited on-site causing no transport problem. The potential environmental impact from the possible release of the disposed mud is to be assessed.

PART III TECHNICAL ASSESSMENT

4. TECHNICAL APPROACH AND METHODOLOGY

4.1 INTRODUCTION

To assess potential impacts, the consultants' technical approach focused on the use of existing information, supplemented by a baseline monitoring programme and special investigations. Baseline monitoring included air quality, noise, water quality, sediment and soil quality, ecology and socioeconomy. The purpose of baseline monitoring was to provide a better understanding of the existing environment. To fully exploit available information and to maintain continuity of methodology, a monitoring plan was developed based on that drafted by the Shenzhen Municipal Environmental Monitoring Section in 1994. Where possible, existing stations set up by the Shenzhen Municipal Environmental Monitoring Station were used. These were supplemented by additional sampling locations and parameters.

Special investigations were designed to provide specific input to some of the assessment tasks or to investigate specific issues. These included 50-hr continuous hydrographic surveys, elutriate tests, and mangrove survival studies. Data gathered through these studies were then used for determining potential impacts on air quality, noise, water quality, sediment quality, hydrodynamics, sediment transport, ecology and socioeconomy. Where appropriate, modelling techniques were used for prediction of impacts.

A database management system was developed particularly for this study to insure the reliability and efficient use of all information collected.

4.2 LITERATURE REVIEW

Literature pertinent to the Project, pollution sources, and the environment of the study area was gathered. Sources included the governments of Shenzhen and Hong Kong, academic institutions, scientific literature, private sector sources, and computer data bases. All publications gathered were reviewed, and useful data and information extracted for the assessment tasks.

4.3 ENVIRONMENTAL BASELINE MONITORING AND SPECIAL INVESTIGATIONS

4.3.1 Air and Noise

Due to difficulties in establishing common sampling procedures for Shenzhen and Hong Kong, and the fact that major potential air and noise impacts are in Shenzhen, the baseline monitoring for air quality and noise has been undertaken only on Shenzhen side.

Since the main potential impact of the project on air quality would be from dust during the construction phase, air quality baseline monitoring focused on this aspect. Parameters monitored include settleable dust fall, total suspended particulate (TSP), respirable suspended particulate (RSP), wind direction and velocity. Monitoring sites were set up at the Yumin Village(A1) and Zhuan Matou(A2), both in close proximity to the Stage 1 works areas (Figure 4-1). Monitoring was undertaken in April 1994. Dust fall was monitored for a continuous period of 30 days. TSP and RSP were measured for 5 days. Dust levels were determined using the gravimetric method.

Existing background noise levels were measured at Yumin Village(N1), Binjiangchang(N2), Zhuan Matou(N3), Lok Ma Chau(N4), Yunong Village (N5), and in the estuary(N6) in April 1994. Locations of the monitoring stations are shown on Figure 4-1. L_{10}, L_{50}, L_{90} and Leq were determined using sound level meters.

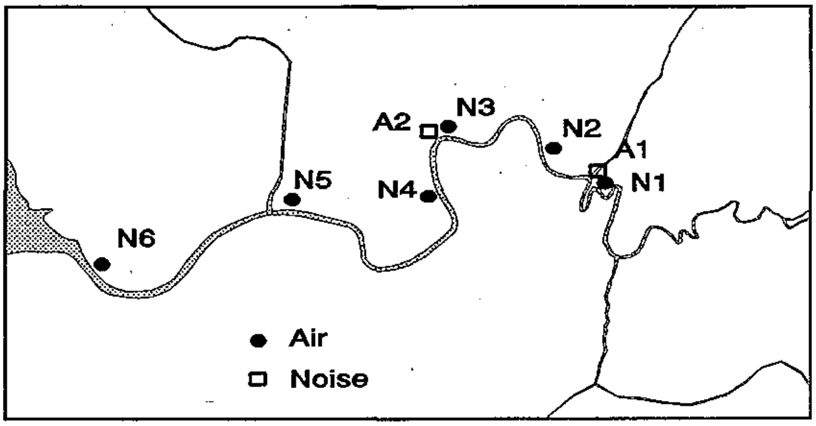

Figure 4-1 Air/noise sampling locations

4.3.2 Water Quality

Water quality was monitored on Shenzhen River twice in January and in Deep Bay once in April 1994.

For baseline monitoring on Shenzhen River, parameters measured included water temperature, pH, suspended solids (SS), dissolved oxygen (DO), five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total nitrogen (TN), total phosphorus (TP), copper (Cu), cadmium (Cd), lead (Pb), chromium (Cr), mercury (Hg), nickel(Ni), zinc(Zn), odour, color, salinity, conductivity, oil, arsenic, phenol, cyanide, and *E. coli.* Both total and dissolved metal content were determined. Organic carbon and carbohydrates were not measured because the former is correlated to COD and the later was replaced with oil.

In-situ measurements or water samples were taken at both high tide and low tide on each occasion. Sampling locations include Jindu(W0), Yumin Village (W1), Zhuan Matou (W2), Yunong Village (W3), an estuary station (W4), and a station outside of the estuary (W5).

For baseline monitoring in Deep Bay, parameters measured include water temperature, pH, colour, salinity, SS, DO, BOD_5, COD, NH_3-N, NO_3-N, NO_2-N, Cu, Cd, Pb, Cr and Hg, TN, TP, dissolved N and P, turbidity, oil, conductivity, chlorophyll-a and *E.coli.* Total and dissolved contents of all

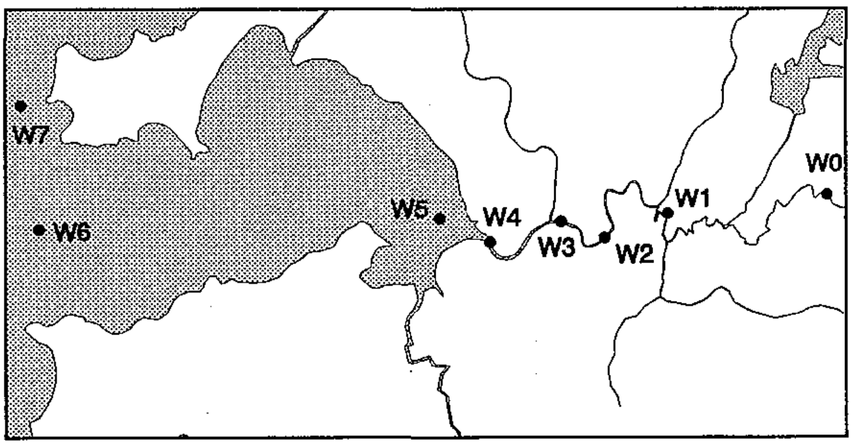

Figure 4-2 Water quality sampling locations

heavy metals were determined respectively. In-situ measurements or water samples were taken during low tide at 2 stations, Deep Bay outlet (W6) and Chiwan Harbour (W7), as shown in Figure 4-2.

4.3.3 Soil and Sediment

Soil and sediment monitoring was undertaken in May 1994. Figure 4-3 indicates the sampling locations. Soil samples were collected from Yumin Village(S1), Zhuan Matou(S2) and Yunong Village(S3). Sediment samples were collected from Yumin Village(B1), Zhuan Matou(B2), Yunong Village(B3). estuary (B4), Inner Deep Bay(B5), a gei wai(B6) and a fish pond (B7). Parameters measured included organic matter, Pb, Cd, Hg, Ni, Zn, Cr, Cu, pH, redox potential (Eh), particle size distribution (PSD), DDT, BHC, and polycyclic aromatic hydrocarbons (PAHs). Both total and available contents of heavy metals were determined.

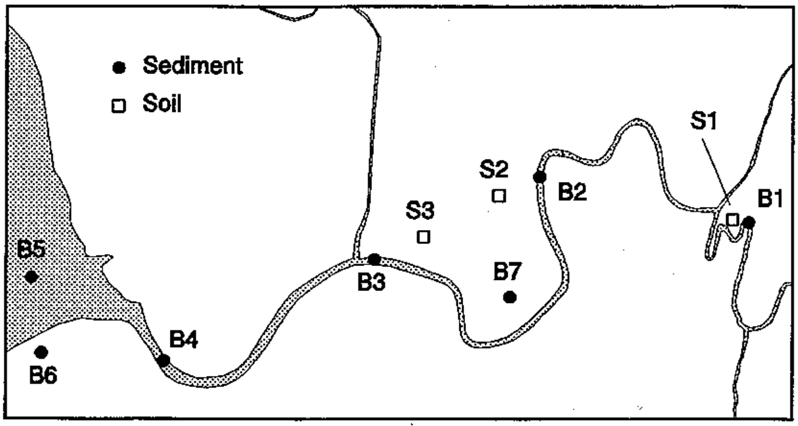

Figure 4-3 Soil/sediment sampling locations

4.3.4 Special Monitoring for Input to Hydrodynamic, Sediment Transport and Water Quality Modelling

A 50-hr monitoring exercise was undertaken in March to provide dry season hydrographic data for hydrodynamic and sediment transport modelling. Monitoring was undertaken at four cross sections of Shenzhen River(S1-S4) and six stations of Deep Bay(S5-S10). Figure 4-4 shows the locations of the cross sections and sampling stations. In-situ measurements or water samples were taken for temperature, DO, BOD_5, COD, TN, TP, chloride, Cu, Pb, *E. Coli.*, SS, flow, current speed and water level. At Deep Bay cross sections, current direction was also measured.

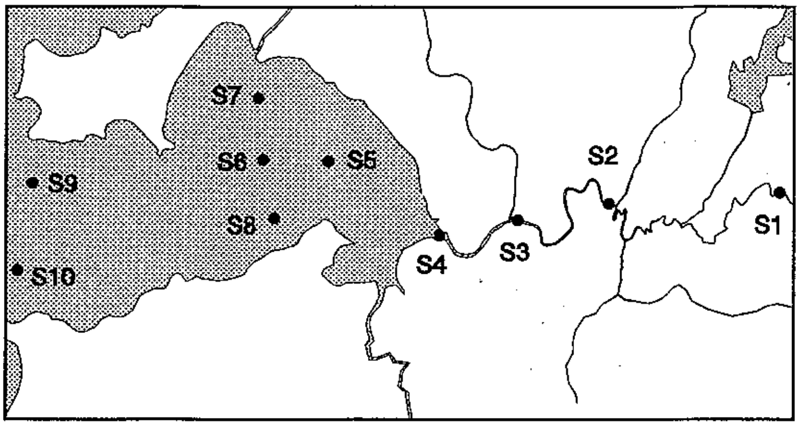

Figure 4-4 50h monitoring stations

4.3.5 Pollution Sources

Information recorded on pollution sources included water quality data of main tributaries on both sides of Shenzhen River and Deep Bay. Figure 4-5 shows the locations of the outlets and the tributaries along the river. The water quality data of tributaries in Hong Kong was provided by EPD of Hong Kong Government. On Shenzhen side, in addition to the routine monitoring data, a survey on main pollution sources was carried out to measure water temperature, COD, BOD_5, TN, TP, *E. Coli.*, Cu, Pb, SS, and flow rate.

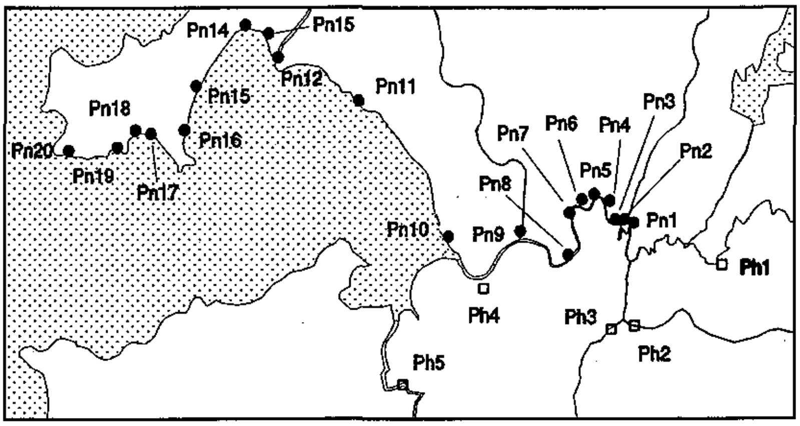

Fig. 4-5 Tributaries and outlets

4.3.6 Elutriate Test

Potential release of oxygen-consuming organics, nutrients, and metals from the suspended sediment in either river or marine waters during dredging was estimated using the elutriate test. A sample of contaminated sediment collected from Shenzhen River (Lok Ma Chau) was suspended in river water from the same location and marine water from Inner Deep Bay at sediment/water ratio of 1:100 and 1:1000, the concentrations of COD, Cu, Pb, TN, and TP in raw water were measured. After addition of sediment of a fixed amount, the water samples were mixed, shaken, and settled overnight. The same parameters in the water were then sampled.

4.4 ECOLOGICAL BASELINE MONITORING AND SPECIAL INVESTIGATIONS

4.4.1 Ecology

The ecological survey aimed to build on the existing data base by providing additional information required to better understand the ecosystem and allow for impact evaluation. The surveys are directed at consideration of the ecosystem as a whole. Major elements of the ecological survey included terrestrial ecology (mainly the Seung Ma Lei Yue Hill), mangroves, mud flat and mangrove invertebrates, and birds.

4.4.2 Terrestrial

Terrestrial ecological survey was conducted at Seung Ma Lei Yue Hill since part of the Hill will be removed by the Project. Habitat mapping and qualitative wildlife surveys were carried out to identify ecosystem components of conservation value.

4.4.3 Mangrove

One fundamental element in ecological investigations is the understanding of food web relationships and energy transfer between different trophic levels.Studies involved stable isotope analysis (for carbon and nitrogen) on organisms (including mangrove species, mangle crustaceans and algae, mud flat invertebrates and fish) and organic matter to establish the linkage between major components of Deep Bay ecosystem in terms of energy flow (the results will be provide as soon as available). Mangrove survey included analysis of aerial photographs followed by ground truthing to determine existing vegetation distribution.

4.4.4 Benthic invertebrates

Benthic invertebrates were sampled by coring to determine species distribution and abundance along two transects on Hong Kong side and one transect on Shenzhen side. Each transect consisted of three stations. Five replicate samples were collected from each station in January and March 1994. Since benthic invertebrates provide virtually the sole source of food for water birds in Deep bay, predator exclosure studies were carried out in January and March to determine the impacts of predation on benthic organisms by birds.

4.4.5 Birds

Bird studies included population assessment and feeding observations. Bird populations were assessed by conducting monthly(once every three days during spring season) bird counts at the Futian Nature Reserve and twice monthly along the Hong Kong side of Shenzhen River from Lo Wu to the river mouth. The nocturnal feeding behaviour of water birds was observed monthly from 2 observation hides located on the mud flat off Mai Po Marshes near the benthos sampling transect. This information allowed the food chain linkage to be elucidated.

4.5 MODELLING AND EVALUATION

Modelling techniques were used for impact evaluation. The Fugitive Dust Model (FDM) was used to examine potential dust impacts during construction. Noise modelling was based on various Technical Memoranda (TM) published by the Environmental Protection Department in Hong Kong on construction noise. At this stage, noise assessment was very crude due to the lack of detailed information (e.g., the number, timing, and types of plant deployed during the construction phase).

The hydrodynamics of Shenzhen River and Deep Bay was modelled by a 1-D unsteady flow model and a 2-D model respectively. A non-equilibrium sediment transport model was used for both Shenzhen River (1-D) and Deep Bay (2-D). A 1-D steady estuary model was used for water quality modelling. Both 1-D and 2-D dynamic water quality models will be used for the evaluation of combined impact of Stage 1 and 2 works. Both the flow and sediment models regarded Shenzhen River (downstream from Sanchahe), estuary, and Deep Bay as one system with the transition between a 1-D model for the river and 2-D model for Deep Bay. Details of the above models are provided in Section 7 and Appendix 7.

A flow diagram showing trophic linkages between major components of the Deep Bay ecosystem was developed. The initial intent was to expand this into an energy flow model based on biomass transfer. Upon completion of literature review, it was obvious that the biomass within each component showed considerable variation and decreased exponentially up the food chain. In other words, within the trophic hierarchy the top compartments were insensitive to changes in the bottom compartments unless such changes occurred in orders of magnitudes greater than the existing levels, which was considered unlikely to happen. In spite of this, trophic flow diagrams were provided to illustrate linkages between major components of Deep Bay ecosystem. Ecological impact evaluation was therefore focused on key pathways among the lower trophic levels rather than on changes that may occur in the higher trophic levels. The rationale was that if changes in the lower trophic pathways were within the limits of natural variation, there were unlikely to be adverse changes at the higher trophic level and impacts should thus be considered acceptable. Conversely, should changes lie outside the limits of natural variation, it would be necessary to determine the degree of change at the lower trophic level and whether such changes would be acceptable at both the lower and possibly higher trophic levels. Based on a review of trophic pathways of the Deep Bay ecosystem by a panel of experts on the study team, it was determined that sediment flux in Inner Deep Bay and its effects on the mud flat benthic invertebrates was the most important process. Ecological assessment was thus focused on this aspect.

5. AIR QUALITY

5.1 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

5.1.1 Introduction

Potential air quality impacts arising from the Project would result mainly from dust emissions. Dust will be generated from excavation, materials handling, vehicle movements over unpaved site surfaces, wind erosion of exposed site areas and possibly concrete batching. There will be vehicle movements associated with the construction but based on previous experience on similar assessments, vehicle exhaust emissions of NO_x, CO and particulate should be minor and are not considered to be a key issue.

5.1.2 Hong Kong Legislation and Standards

The Air Pollution Control Ordinance (APCO) (Cap. 311, 1983) provides authority for controlling air pollutants from a variety of stationary and mobile sources, including fugitive dust emissions from construction sites, and encompasses a number of Air Quality Objectives (AQOs). Currently AQOs stipulate concentrations for sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), and total and respirable suspended particulates (TSP/RSP) in ambient air over the Territory. The objectives for TSP and RSP are listed in Table 5-1.

Table 5-1 Hong Kong AQOs of TSP and RSP

Parameter	Maximum Average Concentration $\mu g/m^3$		
	1-Hour[1]	24-Hour[2]	Annual
TSP	500[3]	260	80
RSP		180	55

1 Not to be exceeded more than three times per year
2 Not to be exceeded more than once per year
3 In addition to the above established legislative controls, it is generally accepted that an hourly average TSP concentration of 500 $\mu g/m^3$ should not be exceeded. Such a control limit is particularly relevant to construction work and has been imposed on a number of construction projects in Hong Kong in the form of contract clauses.

The TSP AQOs are relevant to the construction works of the Project.

The APCO specifies a number of processes which require licensing and are subject to special controls. Recent amendments to the APCO gave provision to include concrete batching as a Specified Process. The licensing requirements call for the Best Practicable Means (BPM) of dust suppression measures to be employed.

5.1.3 PRC Legislation and Standards

For the purposes of this study, Air Quality Standard Category 2 (GB3095-82) control limits have been applied. The standards for TSP and RSP are given in Table 5-2.

Table 5-2 PRC Air Quality Standard Category 2

Parameter	Maximum Average Concentration ($\mu g/m^3$)	
	Instantaneous	24-Hour
TSP	1000	300
RSP	500	150

5.1.4 Reconciliation of Standards

As dust affects specific sensitive receivers the assessment has assumed the relevant standard for Hong Kong and PRC areas respectively.

5.2 EXISTING CONDITIONS

5.2.1 Existing Conditions

According to the Hong Kong-Guangdong Environmental Protection Liaison Group (1992), daily TSP levels in the urban area of Shenzhen in 1989 ranged from 50-640 $\mu g/m^3$, with an annual daily mean of 168 $\mu g/m^3$. Mean 24-hr TSP levels in Hong Kong ranged from 113 $\mu g/m^3$ in April to 235 $\mu g/m^3$ in November, mean 24-hr RSP levels were 60 and 102 $\mu g/m^3$ in April and November respectively, and total dust fall was 7.9 tonnes/km ^{2}/month in April and 6.3 tonnes/km ^{2}/month in November. Since the data from the Hong Kong side only showed averages for the monitoring periods, it could not be determined whether the individual daily averages were in compliance with the AQOs. With a maximum of 640 $\mu g/m^3$, Shenzhen SEZ data show exceedance of the daily average criteria in the urban area on occasion.

Baseline air quality monitoring was conducted at Yumin Village and Zhuanmatou in this study in April 1994, on the north bank of Shenzhen River near the Stage 1 works areas. Sampling locations and parameters are described in Section 4.3.1. A summary of the monitoring results is presented in Table 5-3.

Table 5-3 Summary of Air Quality Monitoring Data

Location	TSP ($\mu g/m^3$)		RSP($\mu g/m^3$)		Dust Fall ($t/km^2/mo$ n)
	Max 24hr avg	5day 24hr avg	Max 24hr avg	5day 24hr avg	
Yumin Village	204	180	8	5	10.13
Zhuanmatou	175	105	4	3	9.94

According to the historical data from routine air quality monitoring in Shenzhen, comparatively higher dust levels generally occur in winter and spring (Figure 5-1). In spring, TSP and RSP levels are approximately 60% and 30% higher than the annual average respectively. Upon arrival of the raining season in April/May, dust levels usually drop considerably, reaching minimum levels in June.

TSP and RSP levels at both monitoring locations complied with the PRC Category 2 standards. Total dust fall, however, exceeded the standard of 8 t/km ^{2}/month at both locations. According to the annual variation in TSP shown in Figure 5-1, the PRC Category 2 standards(1,000 and 500$\mu g/m^3$) are unlikely to be exceeded even during dry season.

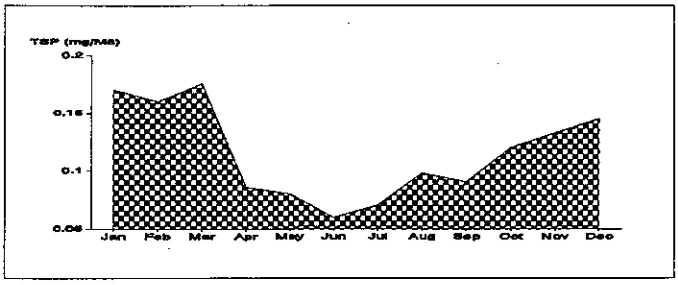

Figure 5-1 Seasonal variation in TSP of Shenzhen

TSP levels at both locations were within the Hong Kong AQO for 24 hours. The TSP collected at these monitoring stations were from either local construction or traffic. The relatively low levels of RSP indicates that the majority of the TSP were large size particles which settled within a short distance from the emission sources. The TSP levels on Hong Kong side of Shenzhen River are expected to be much lower than those observed on Shenzhen side in view of the lack of construction activities and heavy traffic.

Baseline TSP and RSP levels in the vicinity of the Stage 1 works area complied with both Shenzhen and Hong Kong air quality standards. Total dust fall in spring however exceeded the Shenzhen standard.

Besides dust, odour from the river was also investigated. Compared to the control station upstream of the study area, strong and unpleasant odour was detected from all monitoring locations (water quality monitoring stations) along the river.

5.2.2 Future Development

Dust will only be a problem during the construction phase. There are no known future developments planned in the area of the Stage 1 works during this period which will be affected by dust or are likely to influence the outcome of assessment.

5.2.3 Sensitive Receivers

Sensitive receivers of dust were identified and listed in Table 5-4.

Table 5-4 Locations of Dust Sensitive Receivers

Sensitive Received	location	City
A	Shenzhen City (100m from site boundary)	Shenzhen
B	Yumin Village	Shenzhen
C	Yunong Village	Shenzhen
1	Lo Wu	Hong Kong
2	Liu Pok Village	Hong Kong
3	Lok Ma Chau	Hong Kong
4	Ha Wan Village	Hong Kong

5.3 MODELLING

5.3.1 Model Selection

The Fugitive Dust Model(FDM) approved by USEPA and Hong Kong EPD was used to assess potential dust impacts from the construction activities. This model was used in preference to the Industrial Source Complex Short Term (ISCST) model as it is specifically designed for estimation of impacts from fugitive dust sources using wind-dependent emission and advanced gradient-transfer deposition algorithm.

The FDM model is limited by its inability to simulate accurately the effects of complex terrain. The terrain in the studied area is 'rolling' rather than mountainous, so the model was considered suitable.

5.3.2 Assumptions Used

Background Dust Level: Background 24-hour average TSP level was taken as 168μg/m_3 which was the annual daily TSP mean in the urban area of Shenzhen in 1989 according to the Hong Kong-Guangdong Environmental Protection Liaison Group (1989)(see Section 5.2.1)

Dust Emissions: The estimation of dust emissions was based on data from USEPA AP-42 and information from "Shenzhen River Regulation Project Stage 1 Technical Design Manual" and "Shenzhen River Regulation Project Stage 1 Specifications".The emission rates (g/s/m_2) of construction activities remained the same as those previously submitted except the percentage time for bull dozing overburden and grading was estimated to be a total of 50% (25% each) rather than 50% for each activity. The stock piling area for borrow area materials and embankment construction area were corrected but did not result in any change in the emission rates in the assessment. Works areas are depicted in Fig.2-2 and 2-3. At the time of the assessment, on definite concrete batching plant of location of such plant was identified. There was no indication of whether concrete batching would be on-site or ready mixed cement from off-site would be used for pre-casting of construction materials. Emissions from concrete batching activities were not incorporated in the assessment. Concrete batching in Hong Kong side will be regulated by the specified process license and thus must comply with licensing conditions on emissions and control measures.

Soil Moisture and Dust Erosion: According to Section 4.5.1 of the "Shenzhen River Regulation Project Stage 1 Technical Design Manual", natural moisture content of material from river channel excavation ranges from 53% to 64%, i.e. it is in a semi-liquid state. Therefore, river channel excavation and erosion of dredged material will result in minimal dust erosion if any.

Work Programme: According to the construction program in Section 10 of the "Shenzhen River Regulation Project Stage 1 Technical Design Manual" the worst-case dust erosion scenario will occur when the borrow area operation is in parallel with embankment construction. Dispersion modelling was undertaken based on this period of construction.

Particle size: The model used the default particle size distribution in FDM, that is, the fraction in each of 0-2.5, 2.5-5, 5-10, 10-15 and >15 micrometer diameter was 0.0262, 0.0678, 0.1704, 0.1536 and 0.5820 respectively.

Silt Content: Material silt content was taken as 29% from the specified particle size distribution of general fill material for embankment construction as stated in Section 12.24 of the "Shenzhen River Regulation Project Stage 1 Specification". Haulage road surface material silt content was taken as 8.4% from AP-42 (Table 11.2.1-1, Western surface coal mining, haul road). Material moisture content was taken as 13.5% from Section 3.2 of "Shenzhen River Regulation Project Stage 1 Technical Design Manual".

Spoil Transport: Haulage trucks with 10 m^3 capacity were assumed for transferring materials in the site. Vehicle speed of 15 km/hr and 30 km/hr were taken for traffic in the borrow area and other site areas respectively. Schedule and programme of material transport between the two work sites have not been determined. Assuming adequate wheel washing facilities at site exits and public paved roads will be used as haulage route outside the site areas (as indicated in "Shenzhen River Regulation Project Stage 1 Technical Design Manual"), dust emissions from vehicle movements between the two site areas would be limited. Assessment was done considering activities within the two site areas only.

Dust Suppression Measures: Additional assessment was undertaken to determine residual dust impacts on sensitive receivers after implementation of dust suppression measures. The following measures were taken into account:

- reduction of speed of haul trucks to 10km/hr in the borrow area and 20 km/hr in other site areas,
- reduction of grading speed of graders to 8km/hr, and
- twice daily watering of all site roads and active site area(mitigation efficiency of 50% according to AP-42).

Based on the above assumptions and work rates from the "Shenzhen River Regulation Project Stage 1 Technical Design Manual", estimated dust emissions are given in Table 5-5.

Table 5-5 Predicted Dust Emissions from Construction Activities (kg/day)

Location	Activity	Dust Emission (kg/day)	
		W/O dust suppression	W/dust suppression
Seung Ma Lei Yue Hill Borrow Area	Loading material from excavator to haul trucks	0.67	0.67
	Haul trucks on unpaved site roads	47.33	15.78
	Site erosion	49.38	24.69
Embankment Construction Area	Tipping material from haul trucks	0.53	0.53
	Bulldozing overburden	74.63	74.63
	Grading embankment material	255.12	73.86
	Haul trucks on unpaved site roads	422.53	140.84
	Site erosion	257.38	128.69
Stockpiling Area	Tipping material from haul trucks	0.15	0.15
	Site erosion	748.16	374.08

5.3.3 Simulation Modelling

One hour sequential data for wind speed and direction were obtained from the Ta Kwu Ling meteorological station. Other surface observations required to process the meteorological data were obtained from the Hong Kong Royal Observatory. Data for the year 1990 were used for the assessment.

The FDM dispersion model was used to calculate 24-hour average TSP levels during periods of maximum construction activity at varying distances from the site. The resulting concentration contour plots for without and with dust suppression measures are shown in Figures 5-2 to 5-5.

5.4 POTENTIAL IMPACT

5.4.1 Construction Period

Table 5-6 shows the maximum 24-hour average TSP concentrations at the sensitive receivers with and without adoption of dust suppression measures. With no mitigation, there may be exceedance of the 24-hour average TSP PRC limit at all the sensitive receivers in Shenzhen arising from borrow area operation and embankment construction activities (Figures 5-2 and 5-3). There may also be exceedance of the 24-hour average TSP HKAQO at all the sensitive receivers in Hong Kong and adverse impact may occur during worse-case meteorological conditions.

When dust suppression measures were taken into account, the 24-hour average TSP levels at the sensitive receivers would be reduced by 20 to 40%. As shown in Table 5-6, there may still be exceedance of the 24-hour average TSP PRC limit and HKAQO at some of the receivers in Shenzhen and Hong Kong respectively.

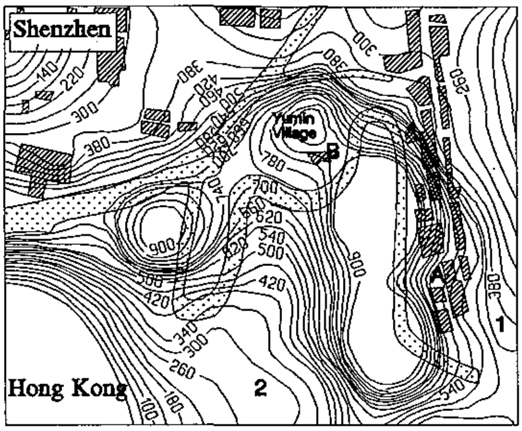

Figure 5-2 Maximum 24h average TSP conc. Liu Pok Bend, without dust suppression measures

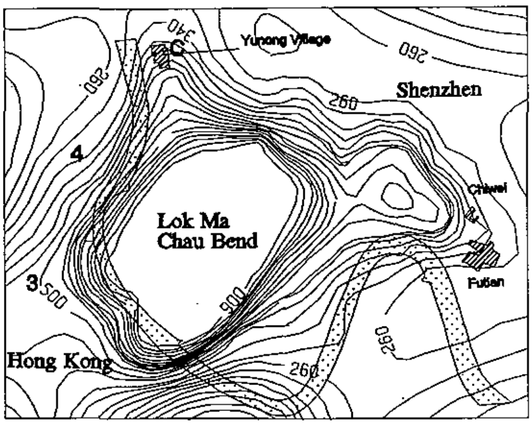

Figure 5-3 Maximum 24h average TSP conc. Lok Ma Chau Bend, without dust suppression measures

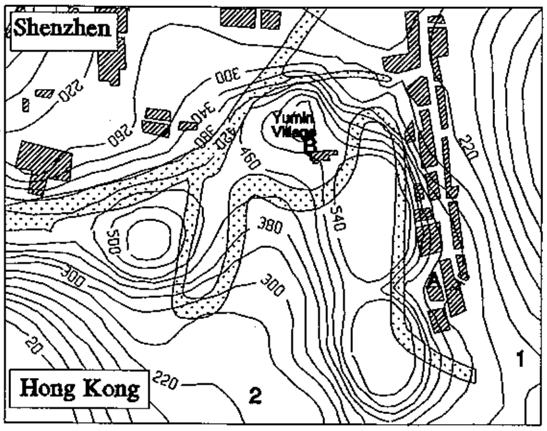

Figure 5-4 Maximum 24h average TSP conc. Liu Pok Bend, with dust suppression measures

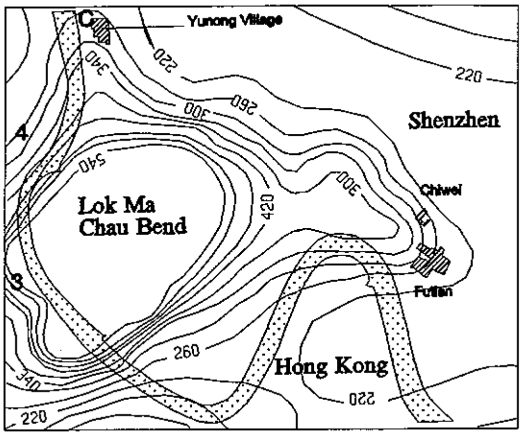

Figure 5-5 Maximum 24h average TSP conc. Lok Ma Chau Bend, with dust suppression measures

Table 5-6 Maximum 24-hour Average TSP Concentrations at Sensitive Receivers

Receiver	Location	TSP concentration ($\mu g/m^3$)	
		W/O Dust Suppression	W/Dust Suppression
A	Shenzhen City	607_1	385_1
B	Yumin Village	812_1	486_1
C	Yunong Village	337_1	251
1	Lo Wu	405_2	285_2
2	Liu Pok Village	286_2	225
3	Lok Ma Chau	496_2	332_2
4	Ha Wan Village	292_2	228

1 Exceedance of the 24-hour average TSP PRC limit
2 Exceedance of the 24-hour average TSP HKAQO

Based on 1990 meteorological conditions, modelling results indicate that, with the adoption of dust suppression measures, there were 2 exceedances of the PRC daily TSP limit at Shenzhen City (Sensitive Receiver A) and 8 exceedances at Yumin Village (Sensitive Receiver B). Similarly, the HKAQO for 24-hour average TSP were execeeded once at Lo WU (Sensitive Receiver 1) and twice at Lok Ma Chau (Sensitive Receiver 3). Such exceedances occurred when persistent winds of high speed were blowing from the north and north-west.

The high TSP level at the receivers should be viewed with the fact that the probability of high wind speed with adverse wind direction in the area was low. Besides, background level ranging from 50 to 640 $\mu g/m^3$. The probability of high background dust level coinciding with maximum dust generating activities and worst-case meteorological conditions is low.

Dust problems during construction are therefore unlikely to be insurroundable and can possibly be mitigated to acceptable levels.

Dust predictions are conservative, as they were based on maximum dust generating activity coinciding with worst-case meteorological conditions.

Besides dust, adverse impact at the sensitive receivers caused by odour from disturbance of the river system and the discharge of dredged spoil is expected.

5.4.2 Operational and Maintenance Period

There will be no significant air quality impacts during the operational and maintenance period of the Stage 1 works.

5.4.3 Risks and Uncertainties

The models used are internationally accepted and recognised as being appropriate for the situation. There are no exceptional uncertainties involved in the modelling exercise. Reliable information was available on all existing and likely future sensitive users.

Uncertainties involved in the assessment include:

1) Specifications for plant and equipment were estimated based on reasonable requirements for this type of project. At this stage of the Project planning information on actual plant to be used or specifications for plant were not available.

2) The contract conditions were not determined and may involve a mix of Hong Kong and Shenzhen requirements. The assessment assumes that the contract can include the environmental controls identified and that these can be enforced.

There is little risk that the air quality assessment is inaccurate in a significant way. The consequences of any inaccuracies are unlikely to be critical to decisions on the EIA.

5.5 MITIGATION MEASURES

Mitigation measures will be required by the contractors to minimise dust generation. Suitable contract conditions and a commitment by the contractors to adopt good operational practices will be necessary. A number of practical measures are listed below:

1) Frequently used site roads should be watered on a regular basis
2) Vehicles should use wheel wash facilities or should be hosed before leaving the site
3) Water sprinklers should be used at all material loading areas
4) Deliveries of cement (if any) should be from tankers to silos through an enclosed system

5) Open stockpiles should be avoided through the use of silos and storage bins;
6) Cement silos (if any) should be fitted with a high level alarm and all vents should be fitted with fabric filters;
7) The site should be watered and cleaned regularly, particularly during dry weather;
8) Speed controls for on-site vehicles should be applied and enforced. (Note: A maximum speed of 8 km/h is recommended by Hong Kong EPD, and may become a legislative requirement);
9) During the selection of plant, consideration should be given to the level of dust suppression measures provided;
10) If concrete is batched, it should be loaded wet to the mixer trucks;
11) Side enclosure and covering of aggregate or dusty material storage piles to reduce fugitive erosions. Where this is not practical due to frequent usage, aggregate fines should be watered as needed to suppress dust;
12) Where possible, avoid placing dusty material storage piles and locating site exit points near sensitive receivers;
13) Tarpaulin covering of all dusty vehicle loads during transport to, from and between site locations;
14) Where feasible, routing of vehicle and positioning of construction plant at maximum separation distance from sensitive receivers;
15) Provision of a fixed spray bar system to wet loads prior to dumping on site.

For typical concrete batching the use of filters on vents, regular watering, water sprays at vehicle loading points and partial or total enclosure of the truck loading area would reduce dust emission in the order of 90%. For concrete batching activities on the Hong Kong side, a license will be required and permissions and control measures must comply with licensive conditions.

Heavily contaminated spoil should be segregated and disposed to separate spoil storage sites and covered with uncontaminated spoil to reduce potential odour problems.

5.6 MONITORING AND AUDIT REQUIREMENTS

5.6.1 Monitoring Locations

Two monitoring stations consisting of a TSP dust monitor and a weather station will be required at each of the works areas. Ideally, the monitoring stations should be sited at ground level and away from obstructions or potential fresh air inlets. However, selection of monitoring locations will be constrained by practices such as the availability of power sources, access for monitoring personnel, and security.

5.6.2 Monitoring Frequency

This study should provide adequate and recent baseline TSP data for the monitoring and audit programme provide that construction commences within 6 months after completion of this study, If construction starts more than 6 months after completion of this study, baseline monitoring should be carried out to generate daily 24-hour average TSP measurements over a 14 day period prior to the start of the construction. During construction works 24-hour average TSP level should be monitored once every 6 days, starting at mid-night.

5.6.3 Action Plan

It is recommended that initial target level is set at the PRC Category 2 standard or Hong Kong AQO. Percentile and median values of monitoring data should be calculated. The trigger level should be based on the 95% ile and the action level at an intermediate value.

If monitoring data exceed the above critical levels, the actions listed in Table 5-6 should be taken by the contractor.

A detailed monitoring and audit manual will be prepared to the satisfaction and mutual agreement of Hong Kong and Shenzhen authorities.

Table 5-6 Action Plan for Exceedance of TAT Levels

Level	Actions
Trigger	1) Notify client, Identify source, Review working methods, Continue monitoring 2) Implement simple additional mitigation measures identified 3) Notify client following termination of exceedance
Action	1) Notify client, Commence additional monitoring 2) Contact client to discuss and implement remedial action 3) Notify client following termination of exceedance
Target	1) Notify client, continue additional monitoring 2) Analyse procedures to identify and implement additional mitigation measures 3) Notify client following termination of exceedance

6. NOISE

6.1 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

6.1.1 Introduction

During Stage 1 works, noise impact will result mainly from site preparation, excavation, blasting, dredging, construction of embankments, and transport of fill material.

6.1.2 Hong Kong Legislation and Standards

In Hong Kong standards set by the Noise Control Ordinance (NCO) and EPD guidelines regulate daytime construction noise (Table 6-1). Hong Kong's Deep Bay Guidelines are also relevant to regulation of noise for construction projects in Deep Bay.

NCO standards are contained in the *Technical Memorandum on Noise from Construction Work other than Percussive Piling*. The Allowable Noise Levels (ANLs) depend upon the Area Sensitivity Rating (ASR) of the Noise Sensitive Receiver (NSR). In the areas surrounding Shenzhen River construction site on the Hong Kong side, the ASR were assumed to be "A", corresponding to rural areas (including villages) and low density residential areas. Where noise from an industrial area or major road is noticeable (but not dominant), an ASR "B" rating may be assumed.

Outside the restricted evening and night-time hours, the NCO requirements do not apply. Regardless of the ASR rating, construction noise may be assessed with reference to EPD guidelines stating that the L_{eq} noise level should not exceed 75 dB(A).

Table 6-1 Hong Kong Construction Noise Level Limits, L_{eq} (dB(A))

Time Period	Acceptable Noise Level at Facade of nearest NSR	
	ASR = A	ASR = B
All days (1900 - 2300 hours) and holidays (0700 - 2300 hours)[1]	60	65
All days (2300 - 0700 hours)[1]	45	50
Non-holiday (0700 - 1900 hours)[2]	75	75

1 From the NCO *Technical Memorandum on Noise from Construction Work other than Percussive Piling.*
2 From EPD guidelines concerning daytime construction noise levels.

In Hong Kong, a construction noise permit is required for construction works using powered mechanical equipment between the hours of 7:00pm and 7:00am, or at any time on a general holiday (including Sundays).

6.1.3 PRC Legislation and Standards

PRC standards, regulations and ordinances concerning noise are set by China's Environmental

Protection Department. The noise division deals with noise control, noise monitoring, and permitting. The relevant noise standard for construction site boundary noise limits is National Standard GB12523-90 which is summarized in Table 6-2.

Table 6-2 PRC Construction Site Boundary Noise Level Limits(L_{eq},dB(A))

Construction Stage	Major Noise Sources	Noise Level Limits	
		Daytime	Night
Site Preparation	Bulldozer, excavator, transport equipment	75	55
Structural Activity	Concrete mixer, poker vibrator	70	55

6.1.4 Reconciliation of Standards

The two sets of standards are significantly different in terms of their designation of receiver location and their maximum stipulated noise levels. The following differences between noise standards in the two juristitions should be noted:

1) The PRC guideline indicates that noise is assessed at the site boundary; the Hong Kong standard applies to noise measured at the facade of the nearest exposed NSR;
2) Daytime noise levels are assessed against a specific maximum under the PRC guideline, but are assessed against a variable standard under the Hong Kong guideline.
3) The nature of construction activities (i.e., whether site formation or structural work) is significant under the PRC standard, but not under the Hong Kong standard.

Noise impacts have been assessed with reference to the respective standards for the PRC and Hong Kong according to the location of the Sensitive Receiver.

6.2 EXISTING CONDITIONS

6.2.1 Existing Conditions

Results of the baseline monitoring(Section 4.3.1) are given in Figure 6-1 and 6-2. Figure 6.1 shows various noise levels and Figure 6.2 shows daily variation in noise levels.

Noise levels at Stations N4 and N6 were comparatively lower than those at other stations and were within PRC and Hong Kong standards. Both day and night time noise levels at the other four stations (N1, N2, N3, N5) generally exceeded the applicable noise standards of both sides, especially at night. Major night time noise sources included construction work, loading and unloading operations at the piers, and land and marine based traffic. Environmental noise was especially serious at Yunong Village (Station N4). This was probably due to its close proximity to Huanggang which had considerable traffic noise. Measured night time noise was close to 70 dB(A).

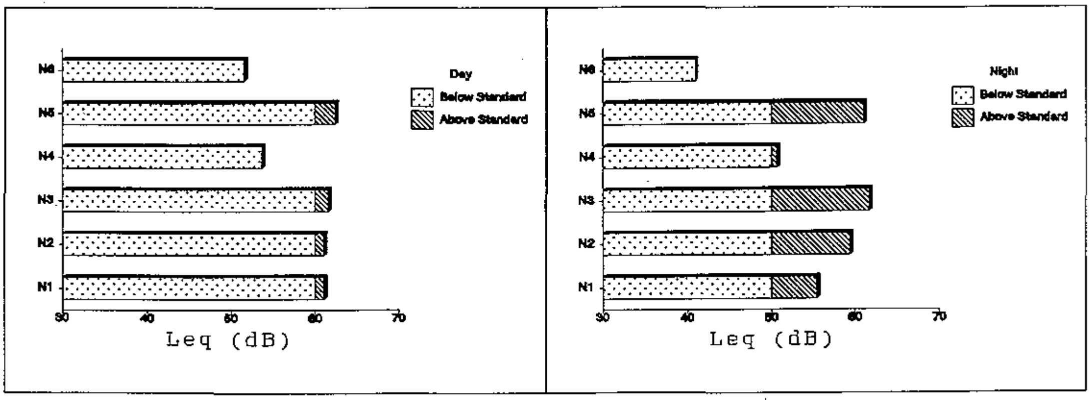

Figure 6-1 Baseline noise levels

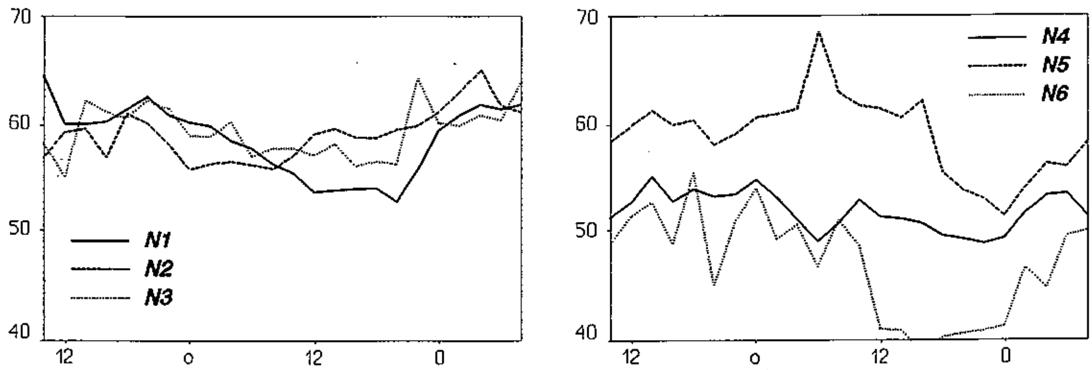

Figure 6-2 Daily variation in noise level

6.2.2 Sensitive Receiver

The construction site is closely bordered on the north by part of Shenzhen City, an industrial area, and villages. On the south, the site is bordered by wetlands and fish ponds, beyond which lie small villages.

Specific NSRs to be considered, and their approximate closest distance to the construction site boundary on Shenzhen side are:

1) Shenzhen City (20 m),
2) Yumin Village (10 m),
3) village across from Hoo Hok Wai (30 m),
4) Futian (10 m),
5) Yunong Village (170 m).

Sensitive receivers on Hong Kong side consist largely of scattered dwellings, with larger receiver concentrations at:

1) Lo Wu (140 m),
2) Liu Pok Village (400 m),
3) Lok Ma Chau (300 m),
4) Ha Wan Tsuen (220 m).

6.3 MODELLING

6.3.1 Assessment Methodology

The Hong Kong NCO's *Technical Memorandum on Noise from Construction Work other than Percussive Piling* outlines an assessment methodology for calculating construction site noise. This methodology was used for prediction of construction noise for both the PRC and Hong Kong. Assumptions of typical positions were made based on the general location of major works.

The calculation methodology contained in Section A.3.4.2 of *BS 5228: Part 1: 1984* was used to calculate noise from traffic on the haul routes. The *BS 5228* methodology provides an equivalent L_{eq} noise level on the basis of sound power levels of mobile plant, the number of vehicles per hour, average vehicle speed, and the distance of the receiver from the haul road.

6.3.2 Construction Plant and Equipment

Plant lists and construction schedules were not available at this stage of the EIA. This assessment assumed commonly-used major items of powered mechanical equipment (PME), with associated sound power levels (SWL), as indicated in Table 6-3. The list is not exhaustive but indicates the type of the equipment that will be required and typical noise levels.

It was assumed that the haul road will be utilised for 12 hours a day. Based on a daily rate of 135 trips and a peak-hour factor of 1.5, 17 vehicle trips were assumed for the one-hour assessment of haul road noise. An average vehicle speed of 30 kph was also assumed, along with a SWL of 105.2 dB(A), based on a sample of six 20t and 24t dumptrucks in *BS 5228.*

Table 6-3 Typical Construction Equipment Requirements

Construction Activity	Possible Equipment (with *Technical Memorandum* identification code)	SWL per piece (dB(A))
Site Preparation	Circular saw (CNP 201)	108
	Lorry (CNP 141)	112
	Excavator/loader (CNP 081)	112
	Bulldozer (CNP 030)	115

Excavation of Seung Ma Lei Yue Hill	Bulldozer (CNP 030)	115
	Excavator/loader (CNP 081)	112
	20-t and 24-t dumptruck (BS 5228)	105
Construction of Haul Road near western works yard	Bulldozer (CNP 030)	115
	20-t and 24-t dumptruck (BS 5228)	105
	Road roller (CNP 185)	108
River Channel Excavation	Suction dredger	109
	Excavator (CNP 081)	112
	Water pump (petrol) (CNP 282)	103
Construction of Embankments	Bulldozer (CNP 030)	115
	Excavator/loader (CNP 081)	112
	20-t and 24-t dumptruck (BS 5228)	105
	Vibratory roller (CNP 186)	108
Revetment and Slope Protection Works	Barge-mounted crane (CNP 048)	112
	20-t and 24-t dumptruck (BS 5228)	105
	Road roller (CNP 185)	108
	Vibratory compactor (CNP 050)	105
	Lorry-mounted crane (BS 5228)	116
Works Yard	Concrete batching plant (CNP 022)	108
	Concrete mixer (CNP 045)	96
	Poker vibrator (CNP 170)	113
	Fork lift trucks (BS 5228)	114
	Winch (petrol) (CNP 263)	102
	Lorry (CNP 141)	112

6.3.3 Calculation of Allowable Total Sound Power Levels

Because detailed construction schedules and equipment lists were not available, accurate predictions of construction noise impacts could not be made. Therefore, an alternative approach was taken. Given permitted noise levels, allowable total sound power levels (SWL) for sitework were determined. In determining the allowable total SWL, the PRC standards were assumed to be based on free field noise measurement. Daytime Hong Kong standards were assumed to be 75 dB(A). The practical limitations of these allowable SWL are discussed in Section 6.4.

Table 6-4 shows the maximum total SWL of combined construction equipment (exclusive of haul road traffic) that still allows PRC and Hong Kong noise daytime standards to be met.

Table 6-4 Allowable source SPL (dB(A)) for daytime construction noise

Distance(m)		5	10	20	50	75	100	150	200	250	300	500
PRC	site preparation	97	103	109	117	121	123	127	129	131	133	137
	structural	92	98	104	112	116	118	122	124	126	128	132
Hong Kong	ASR=A	94	100	106	114	118	120	124	126	128	130	134
	ASR=B	94	100	106	114	118	120	124	126	128	130	134

Table 6-5 shows the maximum total SWL of combined construction equipment (exclusive of haul road traffic) that still allows PRC and Hong Kong evening and night-time noise standards to be met.

Table 6-5 Allowable source SPL (dB(A)) for evening and night time construction noise

Distance(m)		10	30	50	100	200	300	500	700	1000	1600	2000	3000
PRC	preparation	83	93	97	103	109	113	117	120	123	127	129	133
	structural	83	93	97	103	109	113	117	120	123	127	129	133
Evening(HK)	ASR=A	85	95	99	105	111	115	119	122	125	129	131	135
	ASR=B	90	100	104	110	116	120	124	127	130	134	136	140
Night (HK)	ASR=A	70	80	84	90	96	100	104	107	110	114	116	120
	ASR=B	75	85	89	95	110	105	109	112	115	119	121	125

The predicted noise levels at various distances from the source line are given in Table 6-6.

Table 6-6 Predicted Haul Road Noise Level (dB(A))

Distance	5	10	20	30	40	50	75	100	150	200	250	300
Facade	65.7	62.7	59.7	58.0	56.7	55.7	54.0	52.7	51.0	48.7	49.8	48.0
Free-field	62.7	59.7	56.7	55.0	53.7	52.7	51.0	49.7	48.0	46.7	45.8	45.0

6.4 POTENTIAL IMPACTS

6.4.1 Site Noise: Daytime

Based on the data listed in Table 6-4, the Hong Kong daytime noise limit of 75 dB(A) would not be exceeded at an NSR facade 200 m from the notional source position if the total SWL of all operating equipment was 126 dB(A) or less. Similarly, the PRC standard for site preparation noise would not be exceeded at the site boundary 20 m away if the total SWL of all operating equipment remained below 109 dB(A). This assessment assumed no pre-existing natural or purpose-built barriers.

Hong Kong's noise restrictions are based on noise at the facades of NSRs. Most NSRs are 140 to 400 m away from the construction site boundary (6.2.2), and thus benefit from significant distance attenuation. It should be noted that individual isolated NSRs closer to the riverbank may benefit less from distance attenuation. The limits on total source SWL shown in Table 6-4 permit the concurrent use of several pieces of PME on each task. Examples of permitted equipment combinations include:

1) Embankment Construction: Assuming that 3 bulldozers, 3 excavators, 6 dumptrucks, and 3 rollers are used, the resulting total SWL is about 123 dB(A), which would not exceed a 75 dB(A) daytime noise limit at villages on the Hong Kong side of the river.
2) Revetment and Slope Protection Works: Assuming that 1 barge-mounted crane and 2 each of dumptrucks, road rollers, vibratory compactors, and lorry-mounted cranes are used, the resulting total SWL is about 121 dB(A), which also would not exceed a 75 dB(A) daytime noise limit at villages on the Hong Kong side of the river.

Though equipment requirements are unknown at this time, since the Contractor determines his own construction method and operates within programming constraints, the assessment indicates that daytime Hong Kong construction noise standard should be achievable assuming that the above list of equipment, or a combination of equipment that produces similar SWL, is used. A detailed construction noise impact assessment to confirm this finding should be undertaken by the Contractors, when he has determined his construction programme, working methods, and equipment requirements.

The PRC noise restrictions are based on noise at the construction site boundary. This criterion places significant restrictions on activity near the site boundaries. For example, concurrent use of a bulldozer, dumptruck and road roller for construction of the haul road near the western works yard would be expected to exceed the PRC Site Preparation noise standard at the site boundaries, which are close to the road. In each works yard, the concurrent operation of 1 concrete batching plant and 2 each of concrete mixers, poker vibrators, forklift trucks, winches and lorries would generate a notional source SWL of about 121 dB(A). This would result in noise exceedances at the boundaries of the works yards.

In general, the assessment has indicated that daytime Hong Kong construction noise standards should not be difficult to meet. PRC daytime standards will be more difficult to meet, since they stipulate noise at the construction site boundary. The use of items of PME near the boundary will thus be constrained.

6.4.2 Site Noise: Evening and Night-time

According to the results shown in Table 6-5, the Hong Kong night-time noise limit (ASR = A) of 45 dB(A) would not be exceeded at an NSR facade 200 m from the notional source position if the total SWL of all operating equipment was 96 dB(A) or less. Similarly, the PRC night-time standard for construction noise (55 dB(A) for either site preparation or structural activity) would not be exceeded at the site boundary 50 m away if the total SWL of all operating equipment remained below 97 dB(A). This assessment assumed no pre-existing natural or purpose-built barriers.

As expected, more stringent evening and night-time noise standards require lower night time noise levels. Concurrent use of the equipment shown in Table 6.3 for a single activity (which is not an exhaustive inventory of equipment needed for each activity) would generally not be possible at night under either the PRC or Hong Kong standards. Only the use of quietened or shielded items of PME could be expected to meet the more restrictive evening and night time standards.

6.4.3 Haul Road Noise

Unlike general site noise, the noise from the haul road use is expected to remain within acceptable limits at all but the very nearest distances (Table 6-6). Restrictions during the night-time may be necessary to meet PRC standards.

6.4.4 Operational and Maintenance Period

There will be no significant noise impacts during the operational and maintenance period.

6.4.5 Risks and Uncertainties

The models used are internationally accepted and recognised as being appropriate for the situation. There are no exceptional uncertainties involved in the modelling exercise. Reliable information is available on all existing and likely future sensitive users.

Uncertainties involved in the assessment include:

1) Specification of plant and equipment is based on reasonable requirements. At this Stage of Project planning information on actual plant to be used or specifications for plant is not available.
2) The contract conditions are not determined and may involve a mix of Hong Kong and PRC requirements. The assessment assumed that the contracts can include the environmental controls identified and that these can to be enforced.

There is little risk that the noise assessment is inaccurate in a significant way. The consequences of any inaccuracies are unlikely to be critical to decisions on the EIA.

6.5 MITIGATION MEASURES

The analysis of construction noise indicated that some degree of control is required to bring construction noise to acceptable levels. Noise control may take two forms: construction programming or the use of quietened equipment.

6.5.1 Construction Programming

When programming construction it is desirable to avoid concentrating large numbers of PME at one location. A less intensive construction programme may enable the number of operating items of PME to be reduced. Adequate planning may enable PME to be more evenly distributed around the site, rather than concentrated in a single location. Parallel operation of several sets of equipment should be avoided close to a sensitive area or the construction site boundary. PME and activities should be sited as far from sensitive areas as possible.

Stored materials on site may also act as noise barriers, if they are sufficiently dense and free from gaps. Containers/offices on the site may also be stacked and positioned so as to act as noise barriers. When removing stockpiled earth, activity should start at the side far from noise-sensitive areas, so that the earth mound acts as a noise barrier for as long as possible.

6.5.2 Quietened Equipment

A second effective way of mitigating construction noise is to control it at its source, either through the selection of silenced equipment or through the use of mufflers, silencers or acoustic barriers. The following measures are recommended:

1) Stationary and earth-moving plant such as compressors, concrete pumps, excavators, bulldozers and dumptrucks are amenable to noise reduction through exhaust silencers and isolation of vibrating engine components. Noise-generating components may be partially or fully enclosed, and vibrating panels dampened. Super-silenced compressors incorporate acoustic casing linings, mufflers, and anti-vibration mounts to isolate the engine and compressor unit from the chassis. Quieter electrically-powered pumps and hoists are readily available for use.
2) Idle equipment should be turned off or throttled down when it is not in use.
3) All PME should be adequately maintained.
4) Temporary noise barriers may be constructed at the construction site boundary, or may be located closer to the noise-generating PME if it is reasonably stationary.

6.6 MONITORING AND AUDIT REQUIREMENTS

6.6.1 Monitoring Locations

Two stations on each side (Shenzhen and Hong Kong) are necessary for monitoring noise from two sites of the Stage 1 works. Monitoring locations should be positioned as close as possible to sensitive receivers.

6.6.2 Monitoring Frequency

This study should provide adequate and recent baseline noise data for the monitoring and audit programme provided that construction commences within 6 months after completion of this study. If construction starts more than 6 months after completion of this study, baseline monitoring should be carried out at the identified monitoring locations for 12 working days prior to the commencement of site activities by the contractor. .

Daytime monitoring should be carried out at least weekly. Additional monitoring should be carried out during restricted hours whenever activities are undertaken within these hours.

6.6.3 Action Plan

No action should be taken unless measured noise level exceeds 75 dB(A) or noise complaints are received. The trigger, action, and target levels are:

1) Trigger: One noise complaint received or measured noise level > 75 dB(A);
2) Action: More than one independent noise complaint received about a similar source in one week;
3) Target: Hong Kong and PRC statutory standards(Table 6-7).

Table 6-7 Target Noise Levels (dB(A))

Time period	Hong Kong		Shenzhen	
	ASR=A	ASR=B	Preparation	Construction
Daytime (0700 - 1900 hours)	75		75	70
All days (1900 - 2300 hours) Holidays (0700-2300 hours)	60	65	75	70
All days (2300 - 0700 hours)	45	50	55	55

If the monitoring result exceed above critical levels, the actions listed in Table 6-8 should be taken by the contractor.

Table 6-8 Action Plan for Exceedance of TAT levels

Level	Actions
Trigger	1) Notify Client, Identify source, Review working methods, Continue monitoring 2) Implement simple additional mitigation measures identified 3) Notify client following termination of exceedance
Action	1) Notify client, Commence additional monitoring 2) Contact client to discuss and implement remedial action 3) Notify client following termination of exceedance
Target	1) Notify client, continue additional monitoring 2) Analyse procedures to identify and implement additional mitigation measures 3) Notify client following termination of exceedance

The target levels refer to cumulative noise from all sources. If measurements exceed the lowest target levels, it will be necessary to identify noise sources to determine the contribution from construction activity alone. This will be done using standard acoustical principles. If the construction is identified to be the source of the noise problem, the contractor should be required to immediately review working methods and plant employed, successfully mitigate the problem, measure noise level after implementation of mitigation measures, and report.

It may be that baseline noise levels in the vicinity of the works areas are in excess of regulatory limits. The actual noise level will be determined by making reference to readings taken at times when there is no construction activity. At stations with direct line of sight to the construction works areas, a control station approach should be adopted. This would allow some direct determination of the significance of the construction noise source in relation to other sources.

A detailed monitoring and audit programme will be prepared to the satisfaction and mutual agreement of Hong Kong and Shenzhen authorities.

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A detailed monitoring and audit programme will be prepared to the satisfaction and mutual agreement of Hong Kong and Shenzhen authorities.

7. HYDRODYNAMIC, SEDIMENT TRANSPORT, AND WATER QUALITY MODELLING

1 OVERVIEW

This section describes the models which have been developed and applied as part of the EIA to assess the effects of the proposed works on the water quality and sediment transport and the consequent impact on key environmentally sensitive areas.

7.1.1 Objective

The prime objective of these models is to provide a quantitative assessment of the impact of the Project works on the water quality and sediment transport processes in the areas of Futian, Mai Po and the inter-tidal mud flats at the mouth of Shenzhen River. In order to meet this objective it is necessary for the models to be able to simulate the following:

1) Hydrodynamic processes in the river and in Inner Deep Bay, including the flood alleviation characteristics of the proposed works;
2) Sediment transport, erosion and deposition
3) Water quality for a wide range of conservative and non- conservative pollutants.

7.1.2 Overview of the Models

Hydrodynamic Models

Satisfying the study objective requires the use of several models, with varying degrees of inter-dependency. At the most fundamental level, it is essential to be able to reproduce the hydrodynamic water transport under a range of conditions: spring or neap tides, wet or dry season or a range of storm events. The hydrodynamic processes in the river are primarily longitudinal, whereas the processes in the bay are both longitudinal and lateral. The choice of model has therefore been optimized through the use of a one dimensional (1D) computational representation of the river, and a two dimensional (2D) representation of the bay.

In order to ensure continuity these two models have been numerically coupled at a boundary in the lower Shenzhen River and are run as a single model. Both elements of the model (river and bay) make use of internationally respected systems of equations to describe the physical processes and employ standard computational systems.

It is recognized that the outer part of Deep Bay is subject to stratification during the wet season as a result of the complex mixing occurring in the area of the Kongsu Bank described in previous studies (Binnie and Partners 1983). In summary, the large wet season freshwater discharge from the Pearl River can periodically be observed overlaying the denser waters moving north through the Urmston Road resulting in stratification at the mouth of Deep Bay, extending into the Bay under certain conditions. However, this is an extremely complex process and its influence on sediment transport into Inner Deep Bay cannot be determined on the basis of available data. The majority of Deep Bay is extremely shallow, with good mixing characteristics and stratification is considered unlikely to occur in the areas at the head of the bay which are of specific concern in this study.

Since the impact of the density current is likely to be minimal on the overall hydrodynamics in the study area, it has been decided that the use of a vertically homogenous hydrodynamic model for the bay is appropriate. It is recognized that additional sensitivity testing of the open boundary sediment flux is required to provide an indication of the potential significance of this simplification.

Sediment Transport Model

The model used to predict sediment transport, erosion and deposition is uncoupled from the hydrodynamic model. The output files from the integrated hydrodynamic model are used as input files, together with information on sediment sources (boundary concentrations and direct inputs). This uncoupled structure is more efficient allowing the sediment transport model to be run relatively quickly and avoiding duplicate calculations, thereby increasing the number of model runs that can be preformed for sensitivity testing.

The modelling of sediment transport is recognized to be one of the most complex water quality modelling tasks and is a subject of considerable academic debate. The model used in this study incorporates the latest research on sediment transport undertaken within the PRC and is based on an empirical approach developed using extensive data sets from a range of alluvial river channels, including the Pearl River, which have similar sediment transport characteristics to Shenzhen River.

A significant problem in attempting to model sediment transport is the difficulty in establishing the sediment fluxes across the model boundaries, including direct inputs from tributaries and pollution sources. Obtaining such data would require extensive long term data acquisition programmes for both flow and suspended sediment, as well as bed load transport. Given the nature of the hydrodynamics at the western boundary of Deep Bay, this would require continuous measurements over the full water column over several years.

Similarly for the various river sources, information would be required over a full range of flow conditions including storm flows.Since such information is not available within the constraints of this study, assumptions had to be made and the study includes extensive sensitivity testing of those assumptions. Various data sources from previous studies have been identified and approval is being sought to gain access to these data for use it in the current study.

Within the model it is not possible to attempt to represent all of the various factors which influence sediment transport; such as wave action, bed load transport, gravity current, cohesive sediment behaviour or sediment consolidation. Attempting to do so would require considerable observed suspended sediment distribution. This is compatible with the empirical basis of the model and is considered appropriate for this study.

Water Quality Model

Shenzhen River is a typical tidal river with a narrow, shallow channel where pollutants are circulated in the river and subject to continuous mixing, dilution, transformation and degradation. The pollutant concentrations are uniformaly distributed vertically and transversely according to a series of measurements. Therefore, the water quality of Shenzhen River may be reasonably modeled by one-dimensional modelling.

Shenzhen River is not used to supply water for human use. Thus, for the purpose of this report it is not necessary to accurately describe the temporal variation of the water quality within a tidal cycle. However, the differences in water quality between tidal cycles must be understood as this could influence environmental effects at the head of the bay. These differences can be documented by choosing the environmental objectives in order to compare water quality during different tidal cycles or different seasons. A one-dimensional steady state model with finite divisions of reaches of the river can be used to predict the time averaged water quality in an estuary such a Shenzhen River estuary over tide cycles.

There are many mathematical water quality models that describe pollutant migration and transformation processes in tidal rivers, estuaries, and bays, including dynamic or steady state models, one-dimensional or multi-dimensional models. Selection of water quality models is primarily based on water quality characteristics of the water modelled as well as the principal concern of the modelling.

Two types of water quality model will be used for this study; a steady state model to consider longer-term effects and a dynamic model to consider the tide varying behaviour. Each model is run in a similar fashion to the sediment transport model, being uncoupled from the hydrodynamic model.

The Thomann Model has been used in the assessment. The results of studies carried out by the South China Institute of Environmental Sciences and others comparing different water quality models indicate that the Thomann Model can reliably predict water quality variation in Shenzhen River and Deep Bay. The model is considered to be satisfactory to predict accurately water quality effects in Shenzhen River and Deep Bay as a result of the Stage 1 works.

The model includes the dispersive phenomenon in opposing directions of river flow in the estuary (upstream tidal and downstream movements) and the opposing dispersive phenomenon can be well reflected when the time-averaged treatment over the tide cycles is made. However, the tidal flow also influences the net discharge into the estuary. By inputting fluid volume in the dynamic term in the model the effect of tide on estuary flow can be considered for both steady state or time-averaged treatments over tide cycles.

More than 80% of fresh water flow into Inner Deep Bay are from Shenzhen and Yuen Long Rivers. Residual flow within the bay runs along the thalweg beneath the surface water in the bay. The tidal current into the bay is dominated by oscillation flow. Therefore, the bay can be considered as an extension of the river. Consequently the river and the bay can be considered an integrated system and it may reasonably be generalized as a one-dimensional system. The one-dimensional time-averaged water quality model over tide cycles is taken as the primary mechanism to predict the environmental impact before and after the Stage 1 works in Shenzhen River and Deep Bay.

The dynamic variation of water quality, including seasonal variation in Shenzhen River and Deep Bay, can be predicted by using the 2-dimensional dynamic model when the second modelling monitoring data become available at the end of June 1994.

Except for the BOD-DO coupled model all other pollutants (for example, COD, Coliform, Cl, TN, TP, Cu, and Pb) are described with a single factor model. By use of standard, simple determination methods of decay coefficients these models have been shown to be reasonable for Shenzhen River and Deep Bay.

7.2 DESCRIPTION OF THE MODELS

7.2.1 Hydrodynamic Model

The River

The hydrodynamic flow model for the river utilises a standard approach based on a multi-segment computation using the De Saint Vernant equations with a Preissman scheme adopted for numerical computation. A detailed specification of the mathematical formulae underlying the model is given in Appendix 7.1.

The principle of the model is as follows. The river from the upper Sanchahe to the estuary mouth is divided into segments. This representation includes the tributaries of the Buji River and the Sheung Shui River as direct inputs and incorporates representation of Shenzhen Reservoir to enable its effect to be determined during storm flows.

Each segment of the model is defined in terms of the characteristic cross-section, the length and resistance to flow (friction coefficient), together with details of discharges to the river within each segment. At each time step the model computes the water depth in each segment together with the discharge from one segment to the next.

The model does not directly consider over bank flows. This means that although the model predicts that the water level in a certain segment will exceed the known bank height, the model considers the banks to be vertical at the cross-section limits so no loss of water volume will occur and the flow will continue to the next segment. This has the advantage that the anticipated water levels along the full length of the river is predicted allowing the effect of upstream flood alleviation schemes on downstream levels to be anticipated.

The model has been implemented using topographic data on longitudinal slope and cross-sections obtained from both Shenzhen and Hong Kong sides for the existing situation and for the project Stage 1 works.

The information on discharge characteristics of the river and its tributaries is from EPD and has been used for assessment of the Project under a broad range of design conditions. The data made available for the preparation of this model is considered adequate for the purpose of the study.

Deep Bay

The hydrodynamic model of Deep Bay utilises a standard approach based on the horizontal two-dimensional shallow flow equations, expressed using a finite difference scheme on the regular 100m square grid. The flow equations are solved using the alternating-direction-implicit (ADI) procedure. A detailed specification of the mathematical formulae underlying the model are given in Appendix 7.1.

The principle of the model is as follows. Deep Bay is divided into a grid of cells, each of which is regarded as vertically homogenous. The model extends from an open boundary at the western end of the bay, between Black Point and Chiwan, to the interface with the river at Shenzhen Estuary. It includes the key sensitive areas of Mai Po, Futian and the inter-tidal mud flats.

Each cell is described in the model in terms of its average depth and its roughness coefficient. The boundary cells are driven by an input file defining the elevation at each time step. At each time step the model computes the new water depth in the cell and the flux between the cell and its neighbors.

One of the most important features of the model for the current study is the handling of intertidal areas, ie. those areas which are under water for part of the tide and exposed at other times. It is important for the model to be able to accurately calculate the changing boundary and to cope with the flows into or from flooding, especially as this will have a significant impact on the predicted sediment deposition or erosion.

Detail of the bathymetry of the bay has been obtained from a number of sources, including Admiralty Charts, data supplied by Hong Kong Civil Engineering Department and other sources. Data for the open western boundary has come from the fieldwork undertaken for this study plus long term tide gauge records for Chiwan Station and a 50 hr short term record for Black Point.

The available data for this model is considered generally poor, in particular the paucity of detailed topographic information in the inter-tidal areas and the lack of coherent data for both ends of the open boundary. Action is in hand to overcome this deficiency. However, it is considered that this deficiency is of relatively less concern in regard to the Stage 1 works, which are concentrated upstream, than for assessment of Stage 2 works which will affect the major part of the river.

Interface Between River and Bay

Since the flux between the bay and the river is anticipated to be critical to the processes directly affecting the key sensitive areas, it was decided to dynamically couple the hydrodynamic models for the bay and the river. Thus the river model is configured as a subroutine within the bay model.

During the decreasing tide period the discharge at the interface may be considered as the upper inflow condition of the two dimensional model. The water level at the same location is considered as the boundary condition at the lower end of the one-dimensional model. On the other hand, during the increasing tide period the discharge at the interface is considered as the boundary condition at the lower end of the one-dimensional model and the water level here is taken as the boundary condition of the upper end of the two-dimensional model. The integration model after coupling of the one-dimensional and two-dimensional models is verified by the simultaneous monitoring data in both Shenzhen River and Deep Bay in March 1994.

7.2.2 Sediment Transport Model

The sediment transport model has been developed utilising the relationships derived from an extensive body of research work undertaken on alluvial channel rivers in China. This work utilises the principle of non-equilibrium transport of suspended sediment. The sediment carrying capacity of a body of water is expressed as a function of the speed at which the water is moving, the depth of the water and the settling velocity of the sediment.

The basic equation contains two coefficients which ideally need to be derived for the study river. Since this requires an extensive data set collected over many years, it is not possible to derive these coefficients for Shenzhen River explicitly. Thus figures obtained from comparable rivers in the region have been employed and the sensitivity of the model to these coefficients will be examined.

The sediment model equations are essentially the same in both the river model and the bay model, merely being expressed differently to cope with the 1D or 2D systems employed respectively. In each case, at each model time step, the model calculates the sediment carrying capacity for the cell or segment and compares this with the current suspended sediment concentration. If the actual suspended sediment concentration exceeds the sediment carrying capacity, deposition will occur and the bed level will increase. If the actual suspended sediment concentration is less than the sediment carrying capacity, erosion will occur and the bed level will decrease. In Appendix 7.2 a detailed description of the mathematics of the sediment transport model is presented.

In order to improve the information obtained from the model, the sediment in suspension may be considered in terms of several fractions with differing grain sizes and therefore different settling velocities. This enables the model to predict the sediment which will be deposited in the various areas of the model.

Because of its semi-empirical basis, which considers the relationship between channel stability (no erosion or deposition implies the river is stable and the flow matches the sediment carrying capacity on an annualized basis) and suspended sediment concentrations, it is not necessary to directly consider such factors as bed load transport, sediment cohesion or sediment consolidation. The variability in these factors from one area to another would result in variations of the coefficients in the empirical relationship used, which will be assessed in the comprehensive coefficient.

Wave action on the inter-tidal areas cannot be considered directly as part of this study. Since its effect is extremely complex and requires an extensive data set describing the behaviour of the sediment, it is not feasible to address this in the study. It is not anticipated that this will be one of the dominant factors controlling the maintenance of the mud flats given the relatively sheltered nature of the area.

Besides the bathymetric data of the River and Deep Bay used in the hydrodynamic models, the data required in the sediment transport model includes revised suspended solids data collected over several years by both Shenzhen and Hong Kong governments. The sediment hydrography in the mouth of Deep Bay is given based on measured data over recent years in Black Point and Chiwan. Annual monitoring results for suspended solids measured in different sections along Shenzhen River and Deep Bay have been used with some revisions to avoid analysis errors. The sediments flowing into Sanchahe from upstream as well as those into Shenzhen River from tributaries are estimated according to visual surveys and assumptions to compensate for the paucity of data. The data for sediment modelling is considered adequate for the purposes of the Stage 1 works but the results of the sedimentation model should be interpreted with caution. It provides a quantification tool for the assessment but must be applied with considerable reliance on professional judgement and knowledge of the areas involved.

7.2.3 Water Quality Model

The water quality model is a finite-reach model in which the original river is divided into a number of reaches of finite length located sequentially in the streamwise direction. For each of the finite reaches, the water body is assumed to be fully mixed or able to be described by a 0-D model, so that the entire estuary can be simulated by a 1-D model. With the finite reach-model, the modeled quantities, including the state variables and model parameters, represent the time average over tidal cycles, and the flow rate of the model is the river runoff. The phenomena of convection, dispersion and material decay which are related to the mass transport are fully considered for each of the river reaches.

Empirical formula and salt-tracer methods are adopted to estimate the dispersive coefficient in the estuary region to permit the results to be cross verified. Given the pollutant sources, the water quality in the sense of time-averaged state over tide cycles will be predicted.

The monitoring data on pollutant sources, including the discharges released from outlets of pollutants, has been provided by Shenzhen Environmental Protection Monitoring Station. Those for the modelling calibration and validation are the latest modelling monitoring results on water quality and tide flow in Shenzhen River and Deep Bay simultaneously. The prediction of pollution sources at the time of the Stage 1 works are primarily based on the universal exponential relationship correlating the rate of population or economy growth to the total amounts of contaminants. The predicted results of the pollutant sources are subsequently used as input parameters of water quality model, so that the water quality in the construction and operational period for Stage 1 works may be further predicted.

The model has been widely used for the simulation and prediction of water quality in estuary region and is described in detail in Appendix 7.3.

7.3 VERIFICATION AND PREDICTION

Verification is being undertaken as a two stage process, calibration and validation. The calibration of the model is undertaken as an iterative process employing field data, both to drive the boundary and for comparison with model predictions, the model parameters being adjusted to give a best fit between predicted and observed data. Validation involves the use of a second set of field data.

The preliminary model runs have assumed the design parameters included in the Outline Design. This reflects the early stage of modelling work and is appropriate as any changes made to the channel design will have greatest influence on Stage 2 works.

The tributaries are simply considered as the inflow sources into Shenzhen River because of the paucity of basic data. When small frequency flood appears in a tributary, the inflow is estimated according to the fullback discharge. The verification of the flood level in the main channel is based on the record of the flood trace at five locations along the river, provided by the joint survey of Shenzhen Sanfang Office and Guangdong Institute of Hydraulic and Electric Survey and Designing (May 1979). The recorded actual tide type at Tsim Bei Tsui (as the boundary condition of the lower end) on the same day is used to match the flood equivalent to that with the return period of 1-in-5 years. The data measured at Yumin Village and Wenjindo in 1983 (typical tide from April to May and November) are used for the verification of the tide level.

The tributaries flowing into Shenzhen river between Sanchahe and Shenzhen estuary include Sheung Shui River, Buji River, Futian River and Huanggang River. The combined designed flood frequency of the tributaries as that of the river consideration of the small length of Shenzhen River as well as the relatively small drainage area as the whole. The influences of Shenzhen Reservior, Sun Gang flood detention basin and Ma Xian Reservior are also taken into account based on the data and designed conditions provided by Guangdong Institute of Hydraulic and Electric Survey and Designing.

The one dimensional steady state water quality modelling in the estuary region has been calibrated. The lack of simultaneous hydrologic and water quality monitoring data makes it difficult to validate the model. Calibration and validation are being carried out separately on the basis of the first and second 25 hours data from the 50 hours successive monitoring data.

As a result of the Stage 1 works the tide level would be slightly decreased. This is due to the increased capacity in the tidal section of the river and marginally greater tidal flows. The additional flume capacity in the river will not be significant in terms of flood flows however, and storage capacity remains extremely small in comparison to flood flows.

Interpretation of the preliminary runs of the river and Deep Bay bay models suggests that the water surface curve in the longitudinal direction of the river was fall slightly after the Stage 1 works. Flow fields in both the river and bay should not change significantly. There would be a small increase in the tidal exchange volume (and hence flushing) and flume storage owing to the Stage 1 works but this should be relatively minor. The effect on water quality would be a minor improvement due to greater flushing by the relatively cleaner water from Deep Bay. In absolute terms the effect would not be significant.

Comparisons of the elevations of the embankments have been made with the predicted supreme water levels along the river before and after the Stage 1 works using different tide level of the bay matched with different designed floods (return periods of 1-in-5 year, 1-in-10 year, 1-in 20 year and 1-in-50 year).Given that the embankments are not available after the construction of Stage 1 works, the occurrence of the extreme floods during this period would still result in widespread flooding.

Although the present model does not consider the routing of overbank flows in flood areas, the existing study shows that, theoretically, the flood areas covers 13.5 km^2 in Hong Kong and 17 km^2 in Shenzhen for the 1-in-50 year return period flood. The flood storage capacity of Shenzhen River after Stage 1 works can only meet the requirements of the flood with a return period of 1 in 5 years.

Given the information now available on hydrology and sediment movements in Shenzhen River and Deep Bay it is possible to make a reasonable analysis of the likely effect of the Stage 1 works on sediment transport and deposition. The issue of primary concern is how sediment deposition rates will be affected in the ecologically important intertidal areas and mud flats.

For the Stage 1 works the primary concern is whether the release of sediment due to dredging works in the river could result in severe sedimentation, affecting benthic infauna and mangroves. Given that the Stage 1 works have minimal effect on the gradient or capacity at or near the river mouth there is considered to be no risk of erosion of the mudflats due to increased flow velocity.

The best available measure of the significance of any changes is the comparison of predicted rates of deposition with naturally occurring sediment deposition rates which cause no ill effects on the estuarine ecological system. The following analyses explores this issue based on available information.

7.3.1 Hydrodynamic Modeling

The preliminary model runs have assumed the design parameters included in the Outline Design. This reflects the early stage of modelling work and is appropriate as any changes made to the channel design will have greatest influence on Stage 2 works.

The tributaries are simply considered as the inflow sources into Shenzhen River because of the paucity of the basic data. When small frequency flood appears in a tributary, the inflow is estimated according to the fullbank discharge. The verification of the flood level in the main channel is based on the record of the flood trace at five locations along the river,provided by the joint survey of Shenzhen Sanfang Office and Guangdong Institute of Hydraulic and Electric Survey and Designing (May 1989).The recorded actual tide type at Tsim Bei Tsui(as the boundary condition of the lower end) on the same day is used to match the flood equivalent to that with the return period of 1-in-5 years. The data measured at Yumin Village and Wenjindo in 1983 (typical tide from April to May and November) are used for the verification of the tide level. The results of verification are shown in Table A7-5 and Fig.A7-7. The relative error is less than 10%.

The modelling results based on 4 designed conditions with P equals to 2%, 5%, 10%, 20% are obtained and shown in Fig.A7-13 to Fig.7-22,including the water level and discharge variation before and after the stage I works. The variations in estuary with spring, average and neap tides are also predicted (as shown in Fig.A7-23).The calculated results show that the water surface level will decrease owing to the stage I work, but the increase of tidal discharge is not significant.

The range of modelling is from the upper end of Shenzhen Estuary to the mouth of Deep Bay bordered Chi Wan and Black Point. 100x100m square grid is used and the time steps are 40 seconds. Fluctuating boundary method is used to simulate the change of intertidal areas due to the rise and fall of the tide flow.

The result of hydrodynamic calculation was verified based on the modelling monitoring data of Mar. 1-4, 1994. 4 flow velocity monitoring locations were set up in Deep Bay (Fig. 4-4). The test results of tide flow velocity is presented in Fig. A7-31. In this figure, velocity <0 represents the direction of decreasing tide. From Fig. A7-31 we can see that the calculated and measured values show good coexistence in the location S7 and S9 in the Bay, but a certain extent difference for location S8 and S10. For the latter, the reason is that S8 and S10 are near the intertidal areas, and thus the change of depth is significant, which results in the difference between measured and calculated locations. In general,the relative error is still less than 10%.

According to the modelling results, the highest tide velocity can be found in the period of high tide. The highest increase tide velocity is 0.8m/s, and the highest decrease tide velocity is 0.9m/s. During the increase and decrease tide, the highest velocity are mainly along the SW-NE direction in the southern part of Black Point and She Kou, similar to the direction of depression course. During the period of beginning the increase and decrease of the tide, the water flow around the Bay mouth. During the increase period, the water flow into the Bay from the southwestern direction, and leave the Bay from northwestern direction; During the decrease period, the water flow into the Bay from the northwestern direction, and leave the Bay from southwestern direction. The flow of water in the Inner Deep Bay is controlled by Tim Bi Tsui at a certain extent, and form a graph of flow around the Jian Bi Zui. The velocity in these areas is also high. The highest velocity is 0.65m/s, and the higher decrease tide velocity can bring the sediment from river mouth to the certain part of the Bay. During the high tide, the flow velocity in river mouth is low with little turbulence; and during the low tide, the flow is mainly along the two with significant turbulence. Compared with the inner side of the Bay, the intertidal area of Deep Bay shows low flow velocity, the highest velocity is between 0.2-0.25m/s. Besides, during the time of high-normal and low-normal tides, some reverse flow exist in the Bay because of the effects of topography. But there is no definite reverse flow along the edge of the Bay. During the period of low tide, large areas of intertidal area are exposed, and the water flow concentrated in the two deep courses in the central area of the Bay. Thus, during the period of increase tide, significant scrambling exist in intertidal areas around the Bay.

During the period of low tide, there is no definite distribution of highest velocity in the Bay, but the characters of increase and decrease tides is similar to the those of spring tide. The highest velocity can be found near Tim Bi Tsui, and it is similar to that in Black Point (about 0.5m/s). During the period of low tide, since the weaken of inertial, the structure of reverse flow in the Bay is extremely unclear, and the flow velocity in river mouth is low with little turbulence. This means that it is very difficult to bring the sediment from the Shenzhen River into the central part of the Bay by the water flow in the river mouth. Therefore, more sediment deposit in river mouth areas during low tide period.

During low tide period, the expose of intertidal is not as significant as that during the high tide period, but the tide flow structure in intertidal areas is similar to that during the high tide period. During this time, the flow velocity in Chi Wan - She Kou is low and more sediment may be deposited in this area.

The situation of average tide is between the high tide and low tide, the highest velocity of increase tide is 0.6m/s and the highest velocity of decrease tide is 0.75m/s. The velocity in the river mouth area is also high (about 0.55m/s). Besides, short term reverse flow can be found in part of the Bay during the average tide.

The flow field characters in high, low and average tide types are showed in Fig. A7-32(b), A7-32(k), Fig. A7-33(b), A7-33(k), Fig. A7-34(b), Fig. A7-34(k). Among them, Fig. A7-32(a), Fig. A7-33(a) and Fig. A7-34(a) showed the time and tide level of each flow fields.

From Fig. A7-29 we can see that the flow discharge input and output Deep Bay from Shenzhen River under flood season and average tide type have no significant difference before and after the

Project. Therefore, the hydrodynamic condition changes little before and after the Project.

7.3.2 Sediment Transport Modelling

The sediment transport modelling runs based on the sediment yield analysis given in Appendix 7.2 and subsequently verified by the channel topographic data during 1981 and 1985. The relative error is also less than 10%.

The corresponding flood frequency is P=100%. The predicted results of annual sediment erosion and deposition is listed in Table A7-11. In addition, the predicated results of sediment erosion and deposition during flood and different tides are also given in Table A7-12 and A7-13 in greater details.

According to the numerical results of the modelling given in Appendix 7.2(see Table A7-12),the deposited volume of sediment in the channel resulted from the flood with 1-in-1 year frequency is about 14263m^3 before 1986,and is 46619m^3 after 1986. The deposited volume after the stage I works is about 32647m^3. As a conservative consideration,another value of the sediment deposition,51171m^3, is suggested for comparisons in the study, which is directly obtained by the original value of 32647 plus its 0.5 time.Furthermore,the annual sediment erosion volume in the existing channel due to tide flows is 30588m^3. Although the channel is really in the aggravation condition with the annual deposited volume of 3472m^3 during the period of construction works, the channel in operation stage will approximate to the existing conditions. From Table A7-13 in Appendix 7.2,we can see the annual erosion volume of sediment is about 32976m^3 in the operation stage.

According to the 1-D sediment transport modelling for the channel, the sediment deposition volume in the channel will slightly increase during period of construction under the joint effect of flood and tides. However,the river will adjust itself and soon reaches the existing quasi-equilibrium state during the operation stage of the works.

Considering the effects of tide, season, flood and the perform of Stage I works on sediment deposition and erosion, totally 21 runs are carried out in the calculation. Run1-Run9 represent the situation of flood period, and Run10-Run21 represent the current normal situation and in and after Stage I works. In order to check the effects of input increase of sediment on Deep Bay from river catchment, Run3, Run6 and Run9 is calculated separately two cases including 1) after Stage I works,2)after stage I works with increase 50% of catchment sediment input, which can be considered as the result of sensitivity analysis. Besides, it is assumed that the work would be stopped in the flooding period, and no calculation for this stage is performed.

In Table A7-14, the volume of sediment taken from Shenzhen River to Deep Bay is listed. From the table, we can see that for one year return period, the volume of sediment taken from Shenzhen River to Deep Bay varied significantly. Before the Stage I works, the total volume of sediment taken to the Bay by a flood is 14800m^3. After the works, because of the erosion of upstream in flood period, the volume of sediment taken into Deep Bay is 29700m^3, is as much as 2 folds as those before the works. It must be pointed out that the period of "After the works" means the short period in which the Stage I works is just been finished. With time lapes, the erosion in upstream will get to a new equilibrium, and the sediment taken into the Bay would decrease because of the Amoring of the bed material, toward the situation before the works.

Besides, during the Stage I works of average season, since the intake of sediment of the dredge works, the peak content of sediment taken into the Bay exist. The volume of sediment in two days would be as high as $1000m^3$.

Generally speaking,both suspended sediment concentration and deposition thickness are larger in river estuary than in other areas, which can be clearly seen in Figs.A7-50 to A7-60. The eminent deposition occurs in the period of a flood. On the other hand, little deposition or no deposition occurs under normal conditions in the whole Deep Bay.

It worthwhile to give special illustration that the modelling results summarized in Table 7-1 provide the sediment distributions in the whole Deep Bay only for 2 days. The annual sediment deposition or erosion in different locations must be estimated according to the different compositions in terms of the tide types,flood or seasons,and the stage of works, either in the existing condition or in the construction or operation stage. As an example, the deposition thickness at Mai po during 2 days before the realignment is 0.45mm according to the results from Run no.1 which corresponds to the alternative of flood-spring tide;however, the annual deposition thickness therein is only 22.2mm for the normal case according the results from Run No.10,11,14,15,18 and 19. Thus,the total annual deposition thickness at Mai po is about 22.65mm in the existing condition. Correspondingly,the 2-day deposition thickness for the flood-spring tide composition is predicted as 1.03mm from Run no.3,and the annual deposition thickness for the normal case is predicted as 23.4mm from Run no.12,16 and 20; the annual total deposition thickness is about 24.43mm. It is Obvious that the annual additional deposition thickness at Mai Po and Futian due to the realignment is about 2mm and 1.8mm respectively. Similarly, the erosion or deposition condition at other locations in the Deep Bay may be estimated. In summary, following results are obtained from the present model:

1) Little change in sediment deposition around the wet land of Deep Bay is observed before and after the realignment works;
2) The dredging volume will increase owing to the additional sediment deposition in the channel of river estuary after the realignment;
3) The supreme sediment deposition in Deep Bay occurs during the spring tide-flood combination;
4) The sediment concentration will increase slightly in the estuary region but principally in the main channel.

7.3.3 Water Quality Modelling

The recent modelling monitoring data in March 1-3, 1991, are used for verification of the 1-D steady state water quality model.

Comparisons of the calculated results and the measured ones are listed in Table A7-22, Figure.A7-65 and Fig.A7-66. The relative errors are less than 26.7 percent. Table A7-23, Fig.7-65 and Fig.A7-66 show the simulation results of Shenzhen River and Deep Bay under the current pollution level. Taking the planning year as 2000, we can see from the results of predicated simulation (Table A7-24, Fig.A7-67 to Fig.A7-80), that the water quality is getting worse significantly. The concentration of DO in all cross sections of the river is less than 0.1 mg/l. Based on the modelling results the realignment of the river channel is beneficial to water quality in Shenzhen River, but has no significant effects for the water quality in Deep Bay.

8. WATER QUALITY AND SEDIMENT

8.1 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

8.1.1 Introduction

Assessment of potential effects on water and sediment quality was restricted to Shenzhen River downstream of Lo Wu Bridge and Deep Bay. The Stage 1 works will have no effects above Lo Wu. Possible impacts caused by dredged spoil are also addressed in this section.

8.1.2 Hong Kong Legislation and Standards

1) River Water Quality

In Hong Kong, regulations for protecting Hong Kong's watercourses are the Water Pollution Control Ordinance (Cap.358) and the Waste Disposal (Livestock Waste) Regulations 1988 under the Waste Disposal Ordinance (Cap.354). Water quality objectives for Shenzhen River are tabulated in Table 8-1.

Table 8-1 Water Quality Objectives of Rivers (Hong Kong)

Parameter	WQOs	Zone
Bacteria	1) The level of Escherichia coli should be zero per 100 ml, calculated as the running median of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days. 2) The level of E.coli should not exceed 100 per 100 ml, calculated as the running median of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days.	Yuon Long, Kam Tin (upper), Beas, Indus, Ganges, Water Gathering Ground subzones All inland waters
DO	Waste discharges shall not cause the level of dissolved oxygen to be less than 4mg/l	All inland waters
SS	Waste discharges shall not cause the annual median of suspended solids to exceed 20 milligrams per litre	All inland waters
Ammonia	The un-ionized ammoniacal nitrogen level should not be more than 0.021mg/l, calculated as the annual average(arithmetic mean)	Whole zone
Nutrients	Nutrients shall not be percent in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants	Inner and Outer Marine subzones
BOD_5	Waste discharges shall not cause BOD_5 to exceed 3m/l	All inland waters
COD	Waste discharges shall not cause COD to exceed 30mg/l	All inland waters

2) Marine Water Quality

The waters of Hong Kong are protected by the Water Pollution Control Ordinance (WPCO Chapter 358). The study area falls under Deep Bay Water Control Zone. Water quality objectives for the zone are presented in Table 8-2.

Table 8-2 Water Quality Objectives for Deep Bay Water Control Zone

Parameters	Objective
E. coli (annual geometric mean)	≤ 610/100ml (mariculture zone) ≤ 180/100ml (bathing beach)
DO (2 m from bottom)	≥ 2mg/l for 90% samples
DO (depth average)	≥ 4mg/l for 90% samples
DO (1 m below surface)	≥ 4 mg/l for 90% samples
pH	6.5 - 8.5, change ≤ 0.2
Salinity	change ≤ 10% of natural ambient level
Unionized ammonium N	annual mean ≤ 0.021 mg/l
inorg. N (depth average)	≤ 0.7 mg/l (Inner Deep Bay)
(annual mean)	≤ 0.5 mg/l (Outer Deep Bay)

3) Contaminated Sediments

A license would be required from the Fill Management Committee for disposal of marine mud. Dredged sediments can be classified into three groups according to their level of contamination by toxic metals (Table 8-3). Classification refers to Technical Circular No. (TC) No. 1-1-92.

Table 8-3 Hong Kong Classification of Sediments by Metal Content (mg/kg dry weight)

Class	Cd	Cr	Cu	Hg	Ni	Pb	Zn
A	0.0-0.9	0-49	0-54	0.0-0.7	0-34	0-64	0-140
B	1.0-1.4	50-79	55-64	0.8-0.9	35-39	65-74	150-190
C	> 1.5	> 80	> 65	> 1.0	> 40	> 75	> 200

The requirement for disposal of three categories of mud are as follows:

Class A Uncontaminated, for which no special dredging, transport, and disposal methods are required;

Class B Moderately contaminated, which requires special care during dredging and transport, and which must be disposed of in a manner which minimises the loss of pollutants either into solution or by resuspension;

Class C Seriously contaminated, which must be dredged and transported with great care, which cannot be dumped in the gazetted marine disposal ground and which must be effectively isolated from the environment upon final disposal.

8.1.3 PRC Legislation and Standards

1) River Water Quality

In PRC the pollution of inland waters is controlled by the Water Pollution Prevention and Control Act. The relevant standards for river water quality in the PRC are the National Environmental Quality Standard on Surface Water of PRC (GB3838-88). This sets 5 categories of beneficial uses for classification. Shenzhen River falls within the lowest (Category 5) with objectives designated primarily for landscape with no direct water uses. The main requirements of these standards are summarised in Table 8-4.

Table 8-4 PRC Surface Water Quality Standards(Category 5) for Surface (mg/l)

parameter	NH_3-N*	NO_2-N	NO_3-N	TN*	TP	DO	COD	BOD_5	SS*	Hg	Cd
standard	0.2	1.0	25	1.0	0.2	2	10	10	150	0.001	0.01

* the standard of NH_3-N recommended by the National Environmental Monitoring Centre for urban rivers is adopted (already adopted by Shenzhen Environmental Monitoring Station), category 3 of GB-83 Standard is used for TN (not available in GB-88), and for suspended solids 150 mg/l is used (not available in GB-88)

2) Marine Water Quality

There is a range of beneficial marine water uses within Deep Bay. Impact assessment was based on The National Environmental Quality Standard on Marine Water of PRC (category 2). The main requirements are summarised in Table 8-5.

Table 8-5 PRC Marine Water Quality Standards(category 2, mg/l)

parameter	SS*	COD	DO	E.Coli	Hg	Cd	Pb	Cr	Cu	Zn	P
standard	50	4	>4	1000/l	0.001	0.01	0.1	0.5	0.1	1.0	0.03

* Increament less than 50mg/l

3) Contaminated Sediments

There is no standard for sediment or dredged mud in PRC. The Potential Ecological Risk Index developed by Hakanson was applied for assessment of impacts due to sedimentation from any contaminated spoil disposed within the PRC in this study. The preindustrial maximum background values were adopted as the references. The ratio of the biotoxicity of elements to geochemical abundance was used for the assessment. The methodology and the calculation procedure are given in Appendix 8.1.

8.1.4 Reconciliation of Standards

1) Water Quality

Shenzhen River is the boundary between Hong Kong and PRC, and water quality standards from both administrations are relevant to the study. It is apparent that Shenzhen River is unable to comply with all water quality standards. The criterion used for impact assessment was the degree of relative improvement or degradation.

Within Deep Bay the individual water quality standards (PRC and Hong Kong standards, as well as Water Quality Standards for Deep Bay agreed by Guangdong and Hong Kong) were used in the assessment. However, ultimate measure of impact may be change in water quality parameters which would result in a detrimental effect on the most sensitive ecological resources. These are, prima Facie, the habitat at Futian and Mai Po and the oyster beds. The water quality standards agreed by Guangdong and Hong Kong are given in Table 8-6.

Table 8-6 Deep Bay Water Quality Objectives for Scenic Area(Guangdong & Hong Kong)(mg/l)

Parameter	Inorg. N	Inorg. P	COD	NH_3-N	BOD_5	DO[1]	E.Coli[2]	pH	SS[3]
Standard	0.7	0.1	5	0.05	5	>4	1000	6.5-8.5	30%

1 depth average, 90% of samples of the year
2 geometrical mean(nos/100ml)
3 increased due to anthropogenic activities should be less than 30% of the ambient level

2) Contaminated Sediment

Dredged spoil to be disposed on the Hong Kong side will be classified into 3 categories according to the HK standard and will be treated respectively. On Shenzhen side, owing to lack of standard for spoil disposal, the Hakanson method will be employed for assessment.

8.2 EXISTING CONDITIONS

8.2.1 Existing water quality of Shenzhen River

Water quality of the river was considered to be satisfactory until the 1960's. From that time economic development on both sides of the river resulted in growing discharge of industrial and organic pollutants and water quality progressively deteriorated. Water flows in Shenzhen River are dominated by direct runoff. At times of low flows the quantity of sewage frequently exceeds the natural flows. The middle and downstream reaches are tidal, which further reduce flushing. Except during flood flows, the retention time of pollutants entering the tidal sections of the river is believed to be 2-7 days, making the situation even worse.

An ongoing monitoring programme of water quality in Shenzhen River and Deep Bay was undertaken as part of the EIA (Section 4.3.2). To date data are available only from the 1994 dry season. The results are presented in Appendix 8.2. Figure 8-1 shows the variation of major pollutants along Shenzhen River.

The water quality of Shenzhen River can be assessed using following index, the definition and calculation of which is given in Appendix 8.3

1) the integrated pollution index, which is a measure of pollution by a number of pollutants,

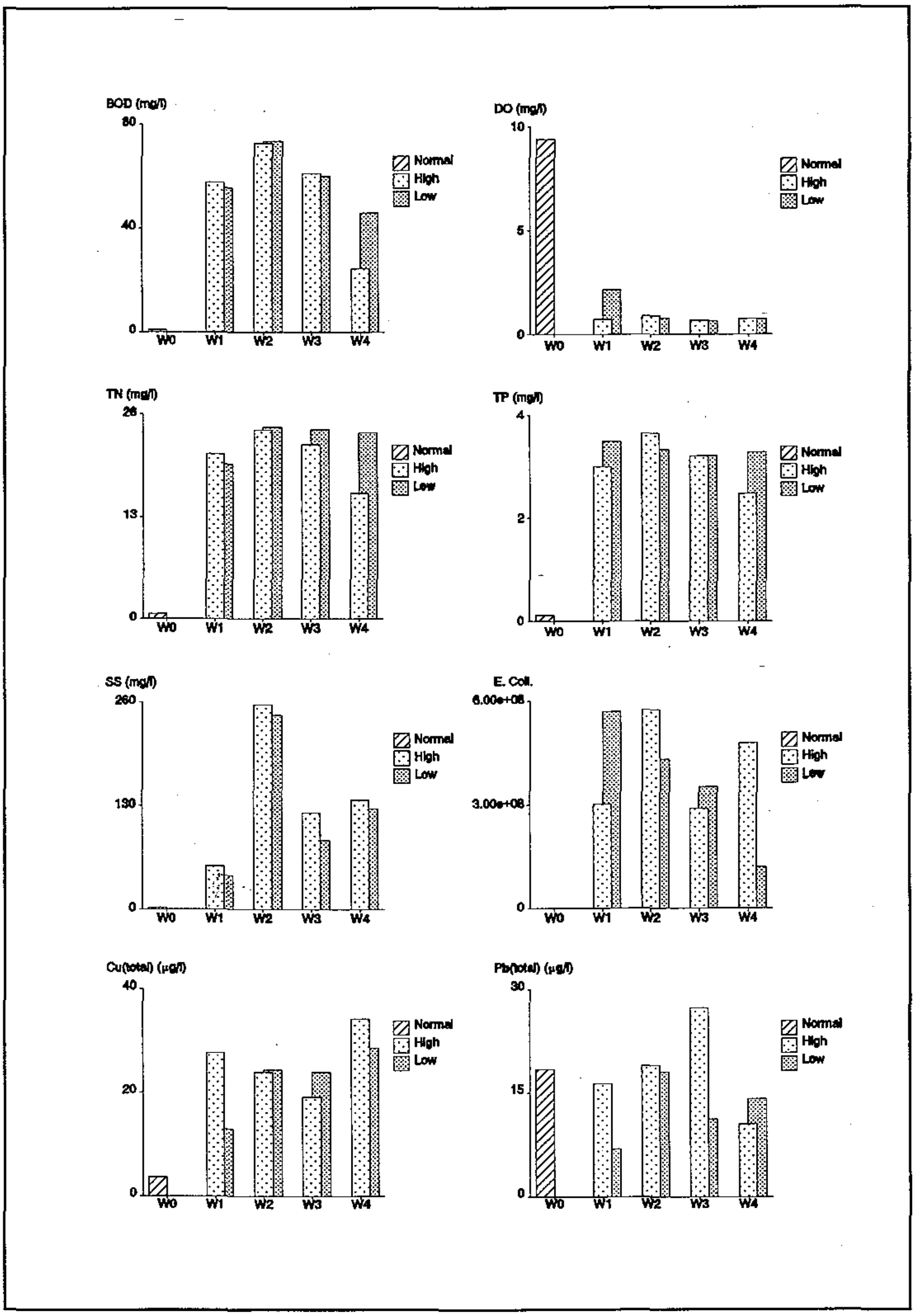


Figure 8-1 Water Quality of the Shenzhen River (at normal, high, and low water levels) in Dry Season of 1994

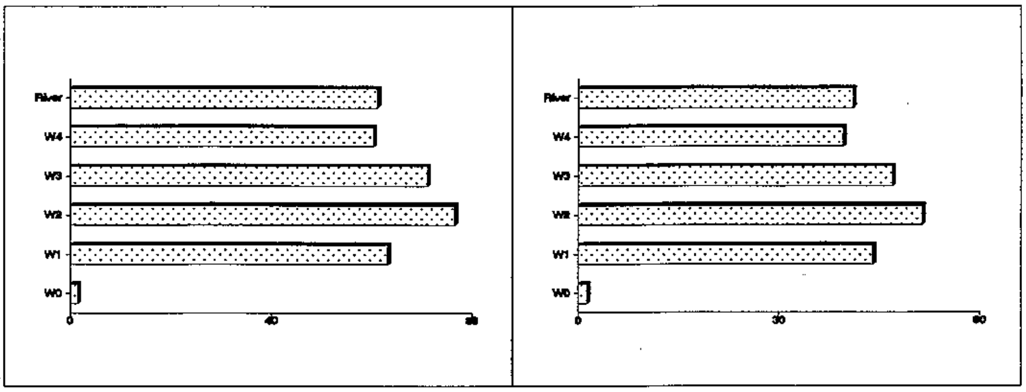


Figure 8-2 Integrated Pollution Index of Shenzhen River in Dry Season, 1994
(left: seven parameters, right: four parameters)

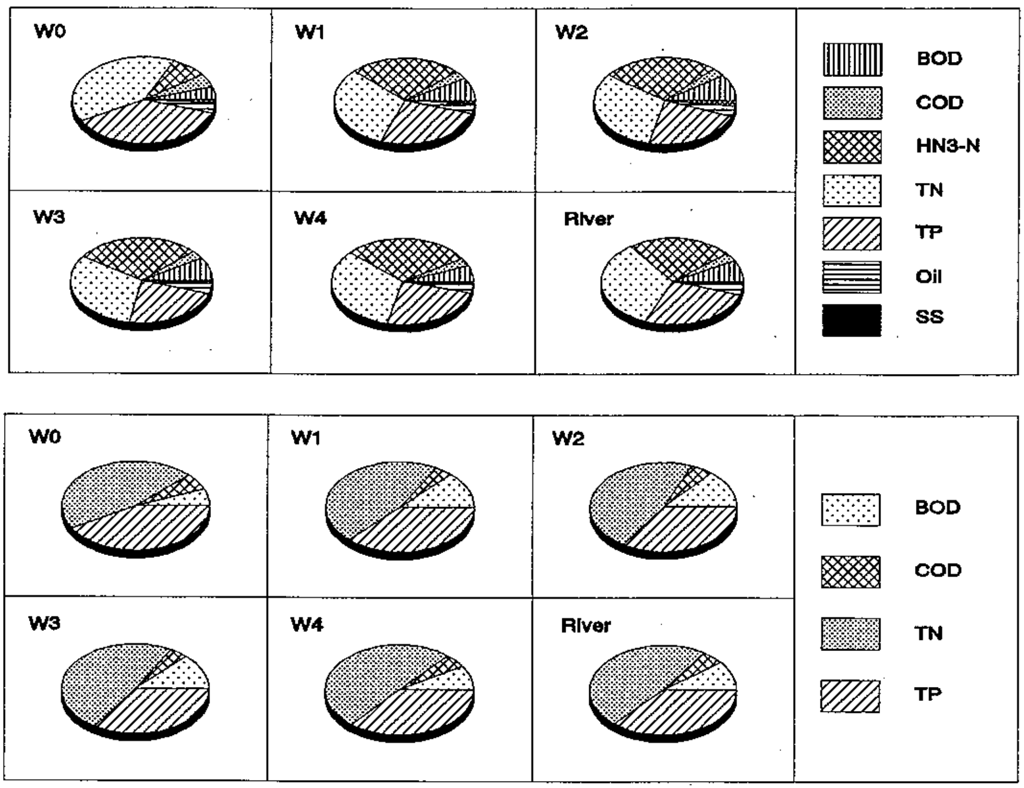


Figure 8-3 Pollution Sharing Rate of Major Pollutants in Shenzhen River

2) the pollution sharing rate, which describes the contribution of various pollutants to the total pollution loads.

The comprehensive pollution indices based on PRC standards are shown in Figure 8-2. The integrated indices were calculated using either seven (COD, BOD_5, NH_3-N, TN, TP, oil, and SS) or four (BOD_5, COD, TN, and TP) parameters, the former are used for comparison with the assessment results recently carried out by Shenzhen Environmental Monitoring Center and the later are those pollutants modelled in this study. Figure 8-3 demonstrates the pollution sharing rate of major pollutants in various sampling locations along Shenzhen River.

It can be seen from Figure 8-3 that the existing water quality of middle and downstream sections of Shenzhen river are severely polluted and nitrogen and phosphorus are the principle pollutants. The river water quality cannot comply with all standards applied by both the Hong Kong and Shenzhen Authorities. Water quality deteriorates downstream as pollutant load increases due to industrial and sewage discharges. The most polluted section is around Zhuanmatou.

8.2.2 Existing water quality of Deep Bay

The flushing time for water entering Deep Bay is on average about 15 days, which is relatively short when compared to other estuaries with similar mid-tide volumes. However, the complex circulation patterns cause the actual retention times to vary considerably. This is due to complex hydrographic conditions caused by shallowness of Deep Bay, the semi-diurnal inequalities of the tides, the seasonal variations in river runoff, the offshore currents and water regimes, and the influence of the Pearl River estuary.

The principal sources of pollution entering Deep Bay are domestic sewage, agricultural wastes derived from livestock rearing, and industrial effluents. Of these the largest source of pollution is untreated domestic sewage and livestock waste water discharged into the Bay via Shenzhen River. The water quality within Deep Bay is considered poor and is characterized by high levels of nutrients. Levels of inorganic nitrogen ranged up to a maximum of 11.3mg/l in 1991. The levels of Chlorophyll-a encountered in inner Deep Bay during 1991 showed a four fold increase on the previous year annual average value. The high BOD_5 levels (1991 annual mean was 2.7mg/l) recorded in Deep Bay are indicative of the large amounts of organic pollution in the water bodies. The levels of *E.coli* are among the highest encountered in Hong Kong's waters and are comparable with the levels encountered in Victoria Harbour.

Results of the baseline monitoring (Section 4.3.2) carried out during the dry season in 1994 are listed in Appendix 8.2. The data were used for calculation of the integrated index and sharing ratio. Parameters used for Deep Bay water quality assessment were the same as those used for Shenzhen River:

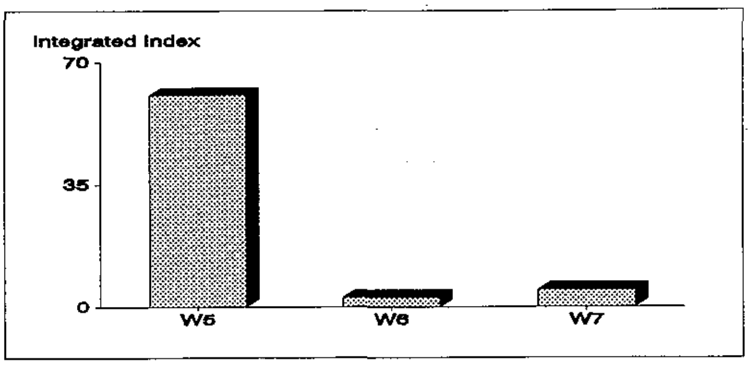


Figure 8-4 Integrated Pollution Index of Deep Bay

1) COD, BOD_5, NH_3-N, TN, TP, Oil, and SS as

used by Shenzhen Environmental Monitoring Station, and
2) BOD_5, COD, TN, and TP, those selected for model prediction.

The calculated results are shown in Figures 8-4 and 8-5.

The results of current and previous monitoring showed that water quality in Deep Bay is polluted referring to PRC, Hong Kong, or Joint Guangdong Hong Kong standards. The dominant pollutants were nitrogen and phosphorus. The most severed polluted area was in the estuary region.

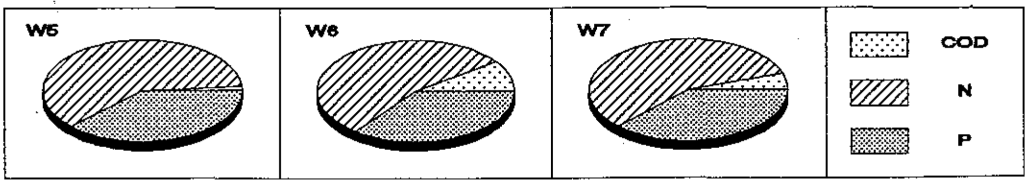


Figure 8-5 Pollution Sharing Rate of Major Pollutants in Deep Bay

8.2.3 Contamination of River Sediment and Bank Soil

The river has not been dredged for many years, nor has pollution discharge been controlled. Therefore, there are thick deposits of sediment which are heavily polluted. The bottom sediments of Deep Bay have also been polluted to some extent. The levels of selected heavy metals in sediments recently collected from Shenzhen River and Deep Bay are tabulated in Table 8-7.

Table 8-7 Monitoring results of Shenzhen River and Deep Bay sediments (1993, mg/kg,dry)

	Locations	Cr	Cu	Hg	Ni	Pb	Zn	Cd
River[1]	Zhuanmatou	106.0	207.0	0.30		102.0	523.0	0.43
	Hekou	65.0	99.0	0.13		82.0	308.0	0.24
Bay[2]	estuary	54.3	86.3	0.06	30.7	56.0	213.3	
	inner	43.3	41.3	0.06	21.0	45.3	116.7	
	outer	33.7	28.3	0.05	21.0	39.0	83.0	

According to Hong Kong's classification of sediments by heavy metal content (PRC has no such standards), it could be noted from Table 8-7 that:

1) The bottom sediments in Shenzhen River have been severely polluted by heavy metals. This is especially true in Zhuanmatou where the water is also heavily polluted;

2) Due to the geochemical nature of the estuary, the level of heavy metals in Deep Bay sediments are much lower than those in the river. The majority of heavy metals accumulated in the bay

sediments is from Shenzhen River, causing a decreasing continuum of metal contents from the estuary to outer Deep Bay.

According to results of a study on "The background values of trace elements of soils in Shenzhen"(CEPA 75-60-10-31), only paddy soils have been polluted to some extent by mercury. Other soils along the river are not polluted.

8.3 POTENTIAL IMPACTS ON WATER QUALITY AND SEDIMENT

8.3.1 Changes in Hydrodynamics

According to the hydrodynamics modelling result presented in Section 7, no significant changes in hydrodynamics of the River and the Bay are expected after the Stage 1 works. The water surface curve in the longitudinal direction of the river would fall slightly after the Stage 1 works. Flow fields in both the River and the Bay would not be significantly changed. There would be a minor increase in the tidal exchange volume (and hence flushing) and flume storage owing to the Stage 1 works.

8.3.2 Effect on Sediment Erosion and Deposition

The sedimentation transport model of both 1-D and 2-D predicted that a slight increase in sediment flux from the Shenzhen River and a moderate change in sedimentation rate on the mudflat would be expected during construction of the Stage 1 works. Calculated increases in sedimentation depth due to the Stage 1 works are 1.8mm and 2.0mm for Futian and Mai Po respectively (Section 7.3.2), which is negligible. The trend of the increase, in sediment flux from the river and in the sedimentation rate would continue after the Stage 1 works of the Project. The extra sediments would most likely deposit in deep channels within Deep Bay. The mud flat at the head of the Bay would not be affected significantly by sedimentation during and after the Stage 1 works of the Project.

It was also shown by modelling that the largest increase in sedimentation would occur at high tide and high water level.

8.3.3 Direct Effect on Water Quality

The effect of the increase in tidal exchange volume on water quality of the Shenzhen River would be a minor improvement due to greater flushing and dilution by the relatively cleaner water from Deep Bay. In absolute terms the effect of the Stage 1 works would not be significant. There would be no direct influence on water quality of the Bay.

8.3.4 Indirect Effect on Water Quality

The bottom sediments of Shenzhen River were contaminated by inorganic and organic pollutants. The dredging operation of the Stage 1 works will affect water quality through resuspension of the sediments and release of pollutants from them.

The dredging operation in the existing river course would give rise to an unavoidable increase in the concentrations of suspended materials in the lower river, the estuary and Deep Bay receiving waters. The quantity of the resuspension and the migration distance of the suspended solids downstream would depend largely on the flow rate. Generally, less suspended solids will be produced and they will travel shorter distances during the dry season.

Since the water of Shenzhen River is heavily polluted the increase in pollutant content from resuspended solids is unlikely to cause a noticeable effect. The distortion in water quality of Deep Bay due to the release of contaminants from the resuspended solids, however, will cause potential impacts.

According to the model prediction, during non-flood period, the maximum sediment contents (during high tide) will be 320mg/l and 360mg/l (90mg/l and 100mg/l on average) before and during the construction period, respectively (Section 7, Table 7-1, Run 11 and Run 12). Estimated increase in SS content during the dredging operation of the Stage 1 works would not, therefore, exceed 40mg/l (10mg/l on average), less than 20% of the total concentration of the SS content at the head of the Bay.

The results of the elutriate tests(Section 4.3.6) shown in Table 8-8 indicate that the percentages of increase in pollutant concentration in sea water after mixing with contaminated sediments at a ratio of 1,000:1(w/w) are generally less than 30%, and a maximum of 60% for Pb. Although the linear extrapolation of the results to a much lower SS content is not valid, it is apparent that no more than a 5% increase in all pollutant concentrations is expected at a SS increase of 40mg/l. Since 40mg/l is a conservative estimation, it can be concluded that no significant impact on water quality at the head of the Bay will be caused by the release of pollutant from the re-suspended solid due to the Stage 1 works.

Table 8-8 Results of the Elutriate Tests(mg/l)

	(w/w)	TN	TP	COD	Cu	Pb
River Water	no sediment	26.97	2.82	19.39	0.018	0.048
	1:100	24.50(-)	0.55(-)	20.13(3.8%)	0.014(-)	0.048(-)
	1:1000	28.48(5.6%)	1.87(-)	21.06(8.6%)	0.014(-)	0.048(-)
Sea Water	no sediment	5.98	1.41	6.36	0.014	0.0016
	1:100	8.67(47%)	0.14(-)	7.93(25%)	0.014(-)	0.0019(19%)
	1:1000	7.66(28%)	0.95(-)	4.98(-)	0.014(-)	0.0026(63%)

(-) decrease due probably to adsorption or degradation

8.3.5 Operational and Maintenance Effects

Potential effects on water quality from the Stage 1 operation may result from the re-settlement of re-suspended sediments after transportation to downstream reaches and changes in hydrodynamics and sedimentation. Based on the modelling predictions (Section 7), only moderate changes are expected, which would not have significant impacts on hydrodynamics, sedimentation, or water quality.

8.3.6 Uncertainty and Risks

All predictions based on hydrodynamic, sediment transport, and water quality models were based on conservative assumptions and were conservative themselves.

8.4 POTENTIAL IMPACTS FROM DREDGED SPOIL

According to the design, dredged material from Stage 1 Works will be disposed of in the old River channel in Liu Pok and in the fish ponds in Lok Ma Chau bend.

Most of the Stage 1 works will be completed in isolation from the existing River channel. The dredged materials from these sites will not be contaminated. Most of the dredged spoils from near or below the old River channel will be slightly contaminated. Only portions of the existing River channel measuring 70,000 m^2 will be dredged, the remaining portions will not be disturbed. The thickness of the bottom spoils in the existing River channel is conservatively taken to be 0.8 m. The polluted spoils which must be placed in the fish ponds and the old River channel will total 56,000 m^3. Contaminated spoils will constitute only 3-4% of the total amount of dredged spoils.

Compared with other dredged spoils the contaminated spoils are heavily polluted with organic matter and heavy metals (Section 8.2.3). According to the dredged spoil classification standards of Hong Kong polluted spoils from Stage 1 works are class C materials (based on concentrations of Cr, Cu, Pb and Zn). Since there is no special spoil disposal standard in Shenzhen, the Hakanson method was used in the contaminated spoil assessment. Using as an example the spoils at Zhuanmatou which are most seriously polluted, the Hakanson method (Hakanson, 1981) was used in reference to the global pre-industrial background metal concentrations to calculate an ecological toxicity index as shown in Table 8-9 below.

Table 8-9 Potential heavy metal ecological toxicity index in Zhuanmatou(data from 91-93)

metal	As	Hg	Pb	Cd	Cu	Zn	Cr	RI
minimum	6.6	22.4	5.9	7.2	9.9	1.6	0.9	57.3
maximum	11.0	102.4	7.9	29.7	26.9	4.1	2.4	144.2

From Table 8-9 it can be seen that among the heavy metals only Hg has a concentration adequately high to be potentially toxic. Other metals occurred in concentrations which are only slightly toxic. Therefore, the potential comprehensive ecological toxicity in Shenzhen River sediments is slight.

It can be seen that if the contaminated spoils can be effectively segregated from crops and natural water bodies, the pollutants in the spoils will not be transported. Since the dredged spoils will be disposed in the Stage 1 working area and the spoils disposal area will not be used for agriculture, adequate care taken during disposal and prevention of potential for erosion by surface runoff, the disposal of contaminated spoil will not cause ecological damage. Also, because the spoil will be disposed in the immediate working area, the issue of contaminated spoil transport will also not become a problem.

Since the spoil disposal area is near Shenzhen River channel, it will not change the hydrological connection between these sediments and ground waters. Therefore, storage sites for contaminated spoils will not cause pollution of ground waters.

The permeability of the fish pond mud and the underlying marine mud is expected to be low. Based on 35 boreholes drilled from fish ponds in the northwest New Territories in Hong Kong (Maunsell Geotechnical Services Ltd, 1993), the vertical profile of fish pond substrata includes on the average 2m pond mud (soft to firm sandy clay/silt), 3m marine deposit (soft to slightly sandy clay/silt with occasional shell fragments) and 15 m of underlying alluvium. Laboratory tests on cores taken from these boreholes indicated an average permeability of $1.6x10^{-9}$ m/s for pond mud and marine deposit. This is equivalent to a 1m migration in 50 years and can thus be regarded as practically impermeable.

8.5 MITIGATION MEASURES

8.5.1 Construction Methods

An important concern for water quality protection is the choice of construction method. The use of a works method which isolates the main excavation works from the river channel is fundamental to the environmental performance of the Stage 1 works. It will reduce the extent of environmental risk from the Project.

One of the key issues arising from the Stage 1 works is the resuspension of the sediment during the dredging operation. The selection of dredging equipment is identified as the key mitigation measures to protect water quality. The use of suction dredgers is thus strongly supported. The benefit offered by this type of equipment in terms of reduced sediment release in some ways compensates for the restrictions it imposes on spoil treatment and disposal.

Other dredging methods can also be considered. Grab dredgers, though among the dirtiest types of dredger in terms of the amount of sediment released to the water column during dredging, undoubtedly offer the greatest flexibility due to their ability to work in very shallow water and handle debris and rubbish with relative ease. Sediment loss could be minimized by using specialised equipment such as sealed grabs, or by adopting special methods such as reducing the grab lowering and hoisting speeds. The production rate of grab dredgers is much lower than suction dredgers and the resulting loss of production with respect to programming would be a constraint for the Project, unless several grabs or sealed grabs can be deployed simultaneously to make up for such loss.

8.5.2 Works Programme

Benefit can be gained from the timing of the works. The worse case of resuspension of sediments during dredging can be easily avoided if the construction is programmed in dry season. By reducing significantly the quantity of sediment resuspended and transported downstream, the risk of any significant effect of the works on downstream sedimentation and water quality will be reduced greatly.

Similarly the timing of the opening of the channel can be used to reduce any possible downstream effect. Opening the channel during a period of low river flow and low tides will greatly reduce sedimentation risks.

8.5.3 Disposal of Dredged Spoil

The contaminated spoil from the existing river course should be disposed separately in isolated locations without mixing with uncontaminated spoil. The contaminated spoil disposal area should be capped with uncontaminated spoil to prevent erosion of the contaminated sediments.

Contaminated spoil ideally should be placed in fish ponds near the middle of Lok Ma Chau Bend, to be surrounded by ponds filled with clean spoil, thus maximising the distance separation from river channels. Contaminated spoil should not be filled higher than 1m below the bund height and the top 1m should then be capped with clean spoil to prevent erosion of contaminated sediments.

8.6 MONITORING AND AUDIT REQUIREMENTS

8.6.1 Locations of the Monitoring Stations

Monitoring stations will be set downstream from the Stage 1 working sites. There will be three stations for Lok Ma Chau Bend and three for Liu Pok Bend, including a control upstream and two downstream (500m and 2000m from the working sites, respectively).

8.6.2 Monitoring Frequency

The parameters to be monitored include SS, COD (as oxygen consuming organic compounds), total nitrogen and phosphate (as nutrients), as well as copper. For most samples, SS is the only parameters to be measured. Measurement of the other parameters is to be carried out only when a significant increase of SS is observed. Information gathered during this study will be used as a baseline.

The monitoring program should be launched when dredging must be carried out in the existing river course. Samples should be collected daily after making final cut through to the existing river course and the frequency of the sampling can be reduced to once a month if the condition remain stable.

Routine monitoring by Shenzhen Environmental Monitoring Station will provide necessary information during operation and maintenance periods.

A detailed monitoring and audit programme will prepared to the satisfaction and mutual agreement of Hong Kong and Shenzhen authorities.

8.6.3 Action Plan

If monitoring data at 2000m downstream of Lok Ma Chau site exceed certain levels, the action listed in Table 8-10 should be taken by the contractor.

Table 8-10 Action Plan

	increase*	Actions
Trigger	> 20%	1) Notify client, review working methods 2) Implement simple additional mitigation measures 3) Notify client following termination of exceedance
Action	> 25%	1) Notify client, commence monitoring(other than SS) 2) Contact client, Continue monitoring 3) Notify client following termination of exceedance
Target	> 30%	1) Notify client, Continue monitoring 2) Analyse procedure to identify and implement mitigation measures 3) Notify client following termination of exceedance

* percentage of the ambient level

9. ECOLOGY

9.1 APPLICABLE REGULATIONS AND GUIDELINES

9.1.1 International Conventions

Hong Kong, through the United Kingdom, is a Party to two international conventions which are relevant to the Project. The PRC is only a Party to the Ramsar Convention. These are listed below and described in detail in Appendix 9.1.

1) The Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the *Ramsar Convention*); and
2) The Convention on the Conservation of Migratory Species of Wild Animals (the *Bonn Convention*).

9.1.2 Hong Kong Legislations

Hong Kong legislation relating to the protection of fauna and flora and of relevance to Deep Bay includes:

1) The Forests and Countryside Ordinance, Cap. 96;
2) The Forestry Regulations;
3) The Town Planning Ordinance, Cap. 131;
4) The Wild Animals Protection Ordinance, Cap. 170;
5) The Fisheries Protection Ordinance, Cap. 171;
6) The Fisheries Protection Regulations;
7) The Hong Kong Planning and Environmental Guidelines (non-statutory).

Relevant portions of these statutes and guidelines are described in detail in Appendix 9.2.

9.1.3 PRC Regulations

The following regulations govern habitat and wildlife protection in China. Relevant portions of the Regulations are described in Appendix 9.3

1) The Wildlife Protection Law in the PRC;
2) Wildlife Protection Implementation Regulation of the PRC;
3) Guideline for Nature Reserves for Forests and Wildlife Species of PRC;
4) The National Protection List of Important Wild Animals;

As noted in Section 9.1.1, China is a party to the Ramsar Convention. Futian National Nature Reserve harbours wildlife which qualify it as a wetland of international importance, therefore, it is subject to consideration under the Ramsar Convention.

9.2 EXISTING ECOLOGICAL RESOURCES

9.2.1 Regional Context

Current land-use, vegetation and habitats in Inner Deep Bay and Shenzhen River Catchment are shown in Figure 9-1. Deep Bay wetlands comprise areas of both natural and man-made habitats. An inventory of wetland and related habitats in the area of Deep Bay and Shenzhen River Catchment is presented in Table 9-1.

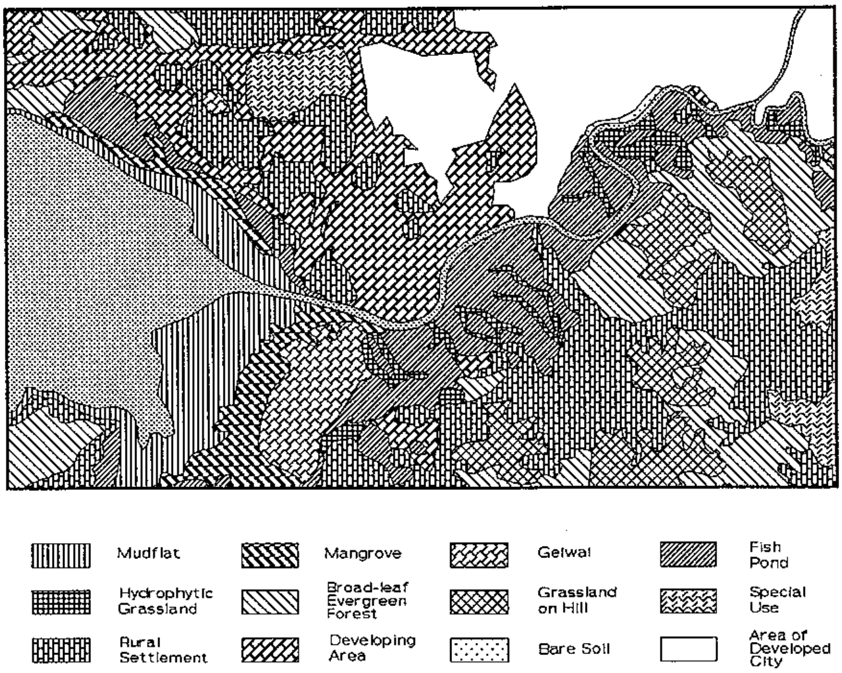


Figure 9-1 Land use, vegetation and habitats in Inner Deep Bay and Shenzhen River catchment

There have been very significant changes in the extent and mix of habitat within the local region over the past decade. The rate of development has accelerated, particularly over the past 5 years.

Consequently extensive areas of wetland on both sides of the border have been filled for industrial and residential development, open storage and other uses. The rate of change is illustrated by the loss of fish pond areas on the Hong Kong side which has declined by some 41% over the past 14 years. [From 1,597 ha in 1979 (Anon. 1988a) to <1,100 ha in 1993 (Hong Kong Agriculture and Fisheries Department)]. (Some areas formerly used for fish farms are now abandoned and are reverting to a more natural condition with the invasion of emergent macrophytes such as *Phragmites, Juncus and Scirpus.*)

These trends are important background in the decisions on the relative importance of various habitat areas.

Table 9-1 Inventory of Habitat in Deep Bay and Shenzhen River

Habitat Type	Condition[1]	Security[2]
River	bad	secure
Mudflat	poor	secure/threatened
Mangrove(Mai Po)	good	secure
Mangrove(Futian)	good	secure?
Mangrove(Shenzhen River)	poor	to be destroyed
Gei wai	good	secure
Fish ponds	good	secure/threatened
Wet grassland	good	threatened
Forest	moderate	secure/threatened
Hillside grassland	moderate	secure/threatened
Urban	n.a.	n.a.

1 subjective grading system:
Bad = physically degraded and/or heavily polluted
Poor = polluted, but not severely degraded
Moderate = affected by human abuse, but capable of rapid recovery
Good = not physically or chemically degraded in any obvious way
2 subjective grading based on known developments and plans in the catchment area

9.2.2 Status and Condition of Estuarine Mudflats

The intertidal flats of Inner Deep Bay comprise a wetland of international importance. Inner Deep Bay is polluted with organic waste, however, the population of wintering and migrant waterfowl has been increasing over the past decade.

The mangroves of Inner Deep Bay appear to be in a satisfactory state, apart from the annual infestation of *Avicennia marina* by defoliating caterpillars. Current levels of pollution and sedimentation are affecting the mangroves in Inner Deep Bay, although apparently not adversely (Chiu 1992).

The prey-base which supports the waterfowl has only recently been subject to investigation (McChesney unpublished). Initial results indicate that the benthic assemblage in the Inner Deep Bay tidal flats is dominated by a few species which can tolerate high organic loadings. These species often occur in very high densities (the density of polychaetes being among the highest recorded worldwide - Piersma et al. 1993). Similar situations with low species diversity but high populations have been found in enriched temperate estuaries in western Europe (Pearson and Rosenberg 1978).

There appears to be some gradient in species abundance, diversity and biomass in parallel with the pollution gradient away from the mouth of Shenzhen River. Species at the river mouth are more abundant but smaller than the same species away from the mouth. Species diversity also decreases towards the river mouth (McChesney 1993, 1994).

Capitellids are more abundant adjacent to river mouth locations, consistent with their known pollution indicator status (Chiu 1992, McChesney unpublished).

The present benthic invertebrate community appears to be stressed by current levels of pollution. Further increases in pollutant loads entering the Bay are likely to result in more widespread eutrophication and adverse effects on macrobenthos (McChesney 1993, 1994).

Current levels of sedimentation within the Inner Bay are not thought to adversely affect the existing benthos.

Preliminary studies (Leader 1994b) indicate that the waterfowl feed over the whole surface of the intertidal flats, although certain species may favour certain areas. Bird distribution is principally related to the distribution of available prey (Wolff 1969) and thus any impacts on benthic invertebrates could affect bird populations/distributions.

9.2.3 Ecological Resources in the Stage 1 Works Area

In the area of the Stage 1 works the wetlands are heavily man-modified. The area has been used for paddy farming, fish and duck ponds for many decades. The habitats in the area to be directly affected by the Stage 1 works include hillside, fish ponds, freshwater marsh and the river itself.

1) Lok Ma Chau

The existing river banks upstream of Lok Ma Chau are generally steep with little emergent vegetation other than grasses and a small number of mangrove, the most abundant species being *Kandelia candel* and *Aegiceras corniculatum* (Anderson 1994). The north bank of the river has been largely reclaimed and offers no habitat of conservation value.

2) The River

River water is heavily polluted and bottom sediments are contaminated with organic matter as well as toxic metals (Section 8). Previous investigations by McChesney (unpublished) revealed no benthic organisms in bottom sediments upstream of the River mouth at the Mai Po Nature Reserve.

3) Seung Ma Lei Yue Hill and Abandoned Farmland

Approximately 5 ha of the hill will be affected by Stage 1 works of the Project. The affected area are shown in Figure 9-2.

Although the area lies within the Frontier Closed Area all habitats have been altered by recent or historic human activity. There is a small village (Tak Yuet Lau) immediately adjacent to Seung Ma Lei Yue Hill on the southeast. Village activity (particularly the use of fire to control vegetation) may occasionally result in outbreak of wild fire on the Hill itself. A small fire occurred on the abandoned paddy during the survey period. The *Dicranopteris-Rhodomyrtus-Baekia* shrub community which occurred over much of the Hill is a fire dis-climax community.

A Hong Kong border control search light tower was situated on the peak of Seung Ma Lei Yue Hill. The search light was not functional at the time of field surveys, but routine foot patrols were conducted on the Hill by guards posted at Tak Yuet Lau. The disturbance area for construction of the light tower had naturally revegetated at the time of the surveys. The south boundary of the Hill was demarcated by the Frontier Closed Area border fence and service road.

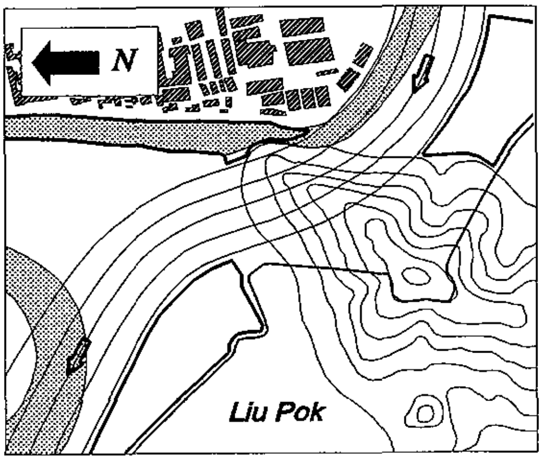


Figure 9-2 Disturbance to Seung Ma Lei Yue Hill

Approximately 0.6 ha of abandoned agricultural land at the foot of the hill will be lost due to the proposed earthworks. This farm plot was probably used for rice production, but appears to have been idle for 2-3 years. It is integral to the hill habitat because of its use by foraging birds which use Seung Ma Lei Yue Hill as a roost site.

The area is probably inundated annually during the rainy season when flood waters breach the embankments of Shenzhen River. The embankment has eroded near the abandoned paddy, so flooding may occur with greater frequency than on nearby duck/fish ponds. Therefore, the paddy is technically a wetland rather than an upland site.

Habitat Types

Five habitats were delineated on the hill site as shown in Table 9-2. and Figure 9-3.

Table 9-2 Habitats and habitat area on Seung Ma Lei Yue Hill, April 1994

Habitat type	Shrub/ grassland	Pine woodland	Broadleaf woodland	Open pine woodland	Abandoned paddy
Extent (ha)	2.5	2.0	0.3	0.4	0.6

The habitat of greatest extent is shrub/grassland. Dominant plant species in the shrub/grassland were *Dicranopteris linearis, Baekia frutescens, Rhus* spp., *Rhodomyrtus tormentosa, Melolotus indicum, Lantana camara* and *Panicum* spp. These species are indicative of frequent fire disturbance on the site. Vegetative cover was typically complete in this habitat type in spite of frequent burning. Shrub/fern cover averaged 81%, and grass cover averaged 24% (Table 9-3).

Pine woodland occurred on the north and southeast slopes of Seung Ma Lei Yue Hill. The dominant species was *Pinus massoniana*. Standing dead and fallen trees were common, reflecting natural mortality due to nematode infestation and fire damage. Tree cover was most dense in sheltered ravines where soils may be better developed and ground water more readily available. Shrub understorey was dense, and the habitat was virtually impenetrable on foot.

The relatively mesic nature of this habitat compared to the shrub/grassland may protect the shrub understorey and the tree overstorey from low-intensity wild fires. Pine woodland habitat is common in Hong Kong and Shenzhen, but is decreasing in extent due to natural tree mortality caused by nematode infestation and fire (Hong Kong Agriculture and Fisheries Department, pers. comm.).

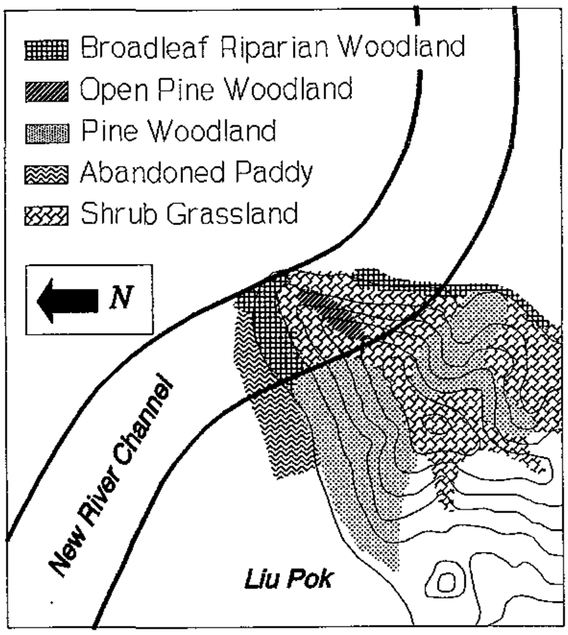


Figure 9-3 Habitats on Seung Ma Lei Yue Hill

Broadleaf woodland habitat is riparian and confined to small areas at the base of Seung Ma Lei Yue Hill on the southeast slope and at the northern point. These areas were near the shoreline of fish ponds (southeast slope) or near Shenzhen River embankment (north point). Representative dominant tree species were *Ficus microcarpa, Sapium sebiferum, Melia azedarach, Celtis sinensis, Bombax malabaricum, Litchi sinensis, Macaranga tanarius* and *Albizia* spp. The stand at the north point of the hill consists of only a few trees growing near the south bank of Shenzhen River. The stand on the south-east side comprises dense tree and shrub cover with a closed canopy. Although this site is near Tak Yuet Lau village, the woodland has not been subject to cultivation and is not a typical *fung shui* woodland.

Table 9-3 Percent coverage of vegetation types in five 2 x 3m plots on Seung Ma Lei Yue Hill during April 1994

Plot No.	1	2	3	4	5
Shrub	85	70	80	85	85
Grass	15	40	25	20	20
Bare ground	5	0	0	5	0

Open pine woodland occurs on the ridge on the north slope of the hill. It consists of scattered *P. massoniana* trees growing in shrub/grassland habitat. *P. massoniana* trees in open pine woodland were smaller than those in pine woodland habitat in breast height diameter ($t=3.02$, $p<0.01$, $n=30$). The smaller size and lower density of trees compared to the pine woodland may be attributable to the combined effects of the exposed ridge location, increased fire frequency, and limited availability of ground water.

Abandoned paddy habitat is located adjacent to the north slope of Seung Ma Lei Yue Hill. In terms of habitat, this lowland (wetland) is linked to the hill because of its value foraging habits of birds which roost or forage on the hill. Abandoned paddy habitat covers approximately 1 ha in total, 60% of which is within the proposed Project area. The paddy was overgrown by native grasses seeds, and sedges. Due to erosion of the south bank of Shenzhen River, flood waters probably frequently inundate the abandoned paddy.

Fauna

The hill supports a relatively rich fauna. Partial protection of the area from human disturbance due to its location in the Frontier Closed Area affords a degree of habitat protection and security for animals from poaching or hunting. The security of the site was particularly significant for species such as those birds whose breeding is often frustrated by human disturbance.

Fauna surveys were conducted between March and May 1994. Birds were considered to be the fauna group of greatest conservation significance. Due to the small area and concurrent year-long sampling programme for migratory birds at Mai Po it was not considered necessary to conduct full seasonal fauna inventories at Seung Ma Lei Yue Hill. Surveys were scheduled to coincide with spring migration and breeding season which are important seasons in terms of bird ecology.

The avifauna of Seung Ma Lei Yue Hill was found to be locally and regionally important due to the seasonal presence of migratory birds which are rare in Hong Kong and in Shenzhen. Birds recorded in the study area are listed in Table 9-4.

Most of the species are relatively common in Hong Kong on an annual or seasonal basis. Three species seen on the hill are not common: the Imperial eagle *Aquila heliaca*, Bonelli's eagle *Hieraaetus fasciatus*, and hobby *Falco subbuteo*.

Imperial eagles occupy Deep Bay area during winter, when their local numbers are thought to be significant in terms of the total regional population (P. Leader, pers. comm.). During late March 1994 Imperial eagles were seen soaring over Seung Ma Lei Yue Hill, as well as along Shenzhen River toward Deep Bay. The maximum number recorded in flight over the Hill was 4 birds with up to 7 seen in the area. They were also seen perching in dead pine trees (snags) on the north slope of the Hill at locations 50m and 250m west of Shenzhen River. Raptor perch sites are shown in Figure 9-4.

Bonelli's eagles may nest near Seung Ma Lei Yue Hill. Birds were recorded soaring over the hill and perching in snags on the north slope and observed carrying nesting material toward the dense stand of pine trees in a ravine on the north slope approximately 250m west of Shenzhen River. One bird was observed on 30 March carrying nesting materials while a second bird was perched in a nearby snag. No nest was located.

Table 9-4 Birds recorded on Seung Ma Lei Yue Hill from March through May 1994

Cormorant	Indian Cuckoo	Yellow-bellied Wren-warbler
Night Heron	Koel	Black-faced Laughing Thrush
Chinese Pond Heron	Greater Coucal	Great Tit
Gattle Egret	House Swift	Rufous-backed Shrike
Little Egret	White-breasted Kingfisher	Blue Magpie
Black Kite	Common Kingfisher	Treepie
Crested Serpent Eagle*	Pied kingfisher	Magpie
Marsh Harrier	Swallow	Jungle Crow
Imperial Eagle *+	Grey Wagtail	Collared Crow
Bonelli's Eagle *	White Wagtail	Grey Starling
Hobby *	Creasted Bulbul	Black-necked Starling
Peregrine *	Red-vented Bulbul	Crested Mynah
White-breasted Waterhen	Chinese Bulbul	Tree Sparrow
Rufous Turtle Dove	Magpie	Masked Bunting
Spotted Dove	Stonechat	Little Bunting

* locally rare
+ wintering population of regional significance (Southern China)

Black kites were also observed in pairs foraging over and perching on Seung Ma Lei Yue Hill from March through May 1994. Although the black kite is common in Hong Kong, the number of breeding pairs is thought to be small and possibly declining due to loss of nesting habitats through urbanization (Viney and Phillipps 1989). Therefore, any recorded nests sites are of local conservation importance.

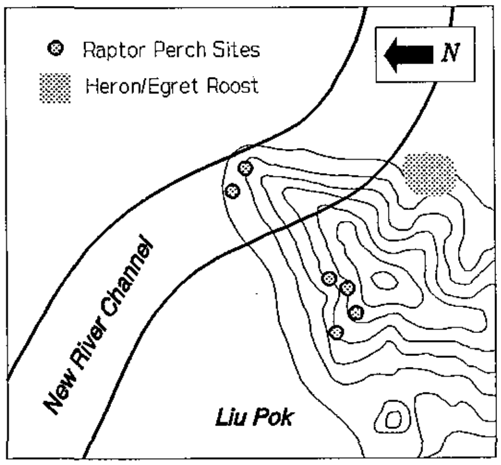


Figure 9-4 Important habitats for birds on Seung Ma Lei Yue Hill

Hobbys are regionally widespread, and in Hong Kong are passage migrants and scarce summer visitors. One bird was observed foraging over the abandoned paddy north of Seung Ma Lei Yue Hill. The hobby captured a swallow which was part of a large flock (over 100 birds) feeding on insects over the abandoned paddy. Large numbers of swallows (*Hirundo rustica*) together with fewer house swifts *(Apus affinis)* were routinely observed feeding over the abandoned paddy and the lower slopes of the Hill. These areas appeared to provide abundant forage for swallows and swifts as well as for their predator, the hobby. The area is suitable for breeding hobbys. A pair of Crested serpent eagles was observed near the Hill in June 1994. These may have been young birds, possibly fledged from a nest in Deep Bay area.

Other species for which habitats in the area were found to be important were Chinese pond herons *(Ardeola bacchus)* and night herons *(Nycticorax nycticorax)*. Pond herons and night herons shared a communal roost in broadleaf woodland and pine woodland at the eastern foot of the Hill.

Birds were seen to roost in greatest density in a wooded ravine at the southern boundary of the proposed cut slope. In addition, some trees further south were used in a band along the shoreline of the fish pond (Figure 9-4). No evidence of nesting was recorded in the roost area, but up to 50 night herons and 35 Chinese pond herons were observed using the roost site.

No evidence of mammalian use of the hill area was observed. Due to the small size and frequent nocturnal disturbance resulting from border security operations it is unlikely that use of the area by mammals is significant. No burrows, trails, droppings, or other sign of large or mid-sized mammal presence was found.

Reptile and amphibian records for Deep Bay area are listed in the Initial EIA Study Report for Stage 2 Works. No observations were made of either group on Seung Ma Lei Yue Hill.

9.3 MODELLING

There are two interrelated ecological systems within the study area. One is the estuarine system comprising Inner Deep Bay, the alluvial mud flats at the mouth of the river, and the habitat areas included within Mai Po and Futian Nature Reserves. The second is the broader ecosystem comprising the river basin and surrounding areas. This system includes the important terrestrial and wetland habitats such as fish ponds.

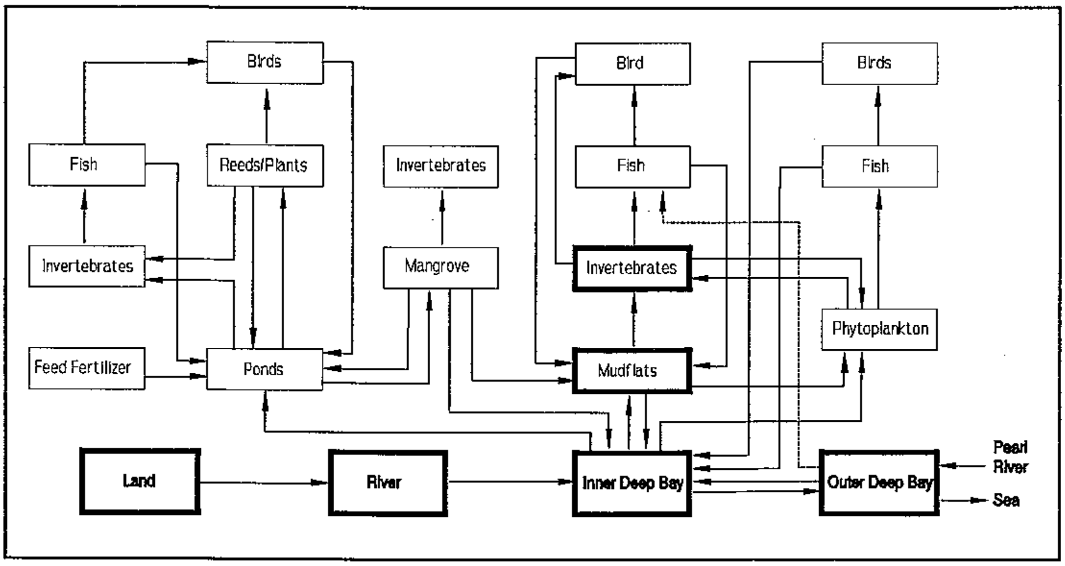


Figure 9-5 Ecological model for Shenzhen River and Deep Bay area

The two systems interact and Shenzhen River is an important physical link providing a corridor between the estuary and the upstream areas. The river is both a physical means of transport of nutrients and pollutants between the systems and a corridor for movement of wildlife, particularly water birds.

An ecological model is being developed for the EIA and is outlined in Figure 9-5. This is a conceptual model focused on trophic transfers within the estuarine system. Due to the complexity of the system, the limited amount of data available in the literature, and the limited scope of investigation able to be undertaken under the present study, it is not possible within this EIA to develop a quantitative energy flow model for wetlands within Deep Bay.

The above model was used to identify the most critical transfers and linkages within Deep Bay wetlands and to focus on investigations undertaken within the EIA. Importantly the model was used to direct and focus the analysis of the systems by the expert panel. This served to establish the relative importance of various transfers, pathways and interactions within this very complex and dynamic system.

The model identified linkages between the estuarine system and the upstream wetlands and other habitats in the surrounding areas. However, expert review concluded that these linkages are of relatively little importance compared to the energy transfers within the estuarine system itself. The assessment therefore addressed ecological effects of these two systems separately.

The major direct effect of Stage 1 concerns the direct loss of habitat as a result of the works. These effects will impact directly on the broader ecological system and must be assessed in this context. The secondary effects of the Stage 1 works will potentially affect the estuarine system downstream, either by pollutant transfer or changes in the hydrodynamic balance at the mudflats. Secondary effects must therefore be considered in the context of the estuarine model and the effect of the river in influencing this system.

9.4 POTENTIAL IMPACTS

The Stage 1 works will result in both direct and indirect impacts on flora and fauna. The most conspicuous direct impacts, which will result from the initial construction works for Stage 1, will be:

1) the loss of most/all vegetation and associated fauna along both sides of the river where works occur;
2) the loss of part of the hill at Seung Ma Lei Yue and associated vegetation and fauna. An area of 5ha of woodland and shrub/grass habitat will be lost;
3) the loss of fish ponds adjacent to the River. An area of 19ha of fish ponds will be lost on the Hong Kong side and approximately 65ha on Shenzhen side at the Lok Ma Chau Bend;
4) the removal of bottom sediments from the River;

The indirect impacts, which will result from the initial construction phase as well as the operational phase of the Stage 1 Works will result from changes in water quality, sediment dynamics, human disturbance, hydrodynamics, noise, and dust.

Since the relative contribution of dredging works during the construction phase is small (Section 7), the effect of release of sediment associated with Stage 1 Works is considered to pose no threat to ecological system in Shenzhen River estuary area.

Table 9-5 summarises the expected impacts of Stage 1 works on different components of Deep Bay flora and fauna. The importance of these impacts and their acceptability in terms of Stage

1 works are addressed below.

Table 9-5 Expected impacts of the Stage 1 Works on various components of Deep Bay flora and fauna.

	Habitat loss	Dust	Noise	Water	Sediment	Human Disturb	Hydro-dynamics
Mangroves	-	-	o	-	(-)	o	(-)
Bund vegetation	-	-	o	o	o	o	o
Invertebrates*	-	o	o	-	o	o	o
Fish	-	o	o	(-)	o	o	o
Birds	-	o	(-)	(-)	(-)	-	o
Mammals	-	o	(-)	(-)	o	-	o

- negative impact expected
o no impact expected
( ) impact likely, but degree of severity uncertain
* Chironomids

9.4.1 Habitat Loss

Stage 1 works will result in direct loss of habitats along both banks of the river, including loss of intertidal mud, mangroves, fishponds and associated bunds, freshwater marshes and part of the hill at Seung Ma Lei Yue. The areas of habitat which are expected to be lost as a result of the Stage 1 works are shown in Table 9-6. It is apparent that the total areas of habitats which will be directly lost as a result of the Project are relatively small in a regional context. The importance of specific losses is considered below.

Table 9-6 Direct habitat loss expected as a result of the Stage 1 Works

Habitat	Mudflats	Mangrove	Fish pond /bund	Wet grassland /abandoned fish pond	Shrub/tree/ hill side
Shenzhen (ha)			65[1]		
Hong Kong (ha)	2	2	19	5	5

[1] temporarily created while waiting for the Project to begin

Fish Ponds

The extent of fish pond loss around Deep Bay is cause for concern in terms of the loss of habitat for water birds. Chu (1993) reviewed the importance of fish ponds to wildlife, noting that they are of direct value in providing habitat for a considerable range of bird and mammal species. Fish ponds also support chironomid midges in surrounding areas, providing an important food source for migrant reed warblers (*Acrocephalus* spp.). A review of the importance of fish ponds to wildlife around Deep Bay is attached as Appendix 9.4.

There has been a significant loss of fish ponds in the North West New Territories in the past 20 years due to large-scale infilling for planned developments, as well as extensive unauthorised and illegal filling for open storage. The total area lost is in excess of 780 ha. Loss of fish ponds in Shenzhen has been almost complete.

The loss of wetlands, in particular fish ponds, appears already to have had an adverse impact on breeding egrets and herons. The importance of fish ponds to Black-faced Spoonbills *Platalea minor* has only recently been recognised.

The 65 ha of fish pond on Lok Ma Chau Bend which will be filled during the Stage 1 works was created while waiting for the Project to begin after being designed as a spoil disposal area. The net loss of fish pond as a result of the Project, therefore, is 19 ha on Liu Pok Bend, equivalent to about 2% of the estimated fish pond area on the Hong Kong side of Deep Bay.

The Hong Kong Agriculture and Fisheries Department has established a ranking scheme based on commercial viability and suitability of land as a basis for considering future applications for the development of fish pond areas. This system is perhaps the best safeguard against the continued erosion of this resource. All ponds within the Stage 1 works area on the Hong Kong side of the river are classified as "Grade A", meaning they are well established pond fish culture sites with good potential for further development [of aquaculture].

The loss of the fish ponds of 19 ha as a net result of the Stage 1 works is not of itself likely to be a significant effect on the overall ecological system although certain species, notably ardeids, will be adversely affected (Appendix 9.4). The loss is also of concern in the context of cumulative loss of wetland due to development, but this cannot be addressed within the context of the Project.

Mangroves

The mangroves on the southern bank which will be directly lost as a result of the Project were surveyed by Anderson (1994). These mangroves include *Kandelia candel* and *Aegiceras corniculatum*. Results of mangrove surveys on Hong Kong side are shown in Appendices 9.7 and 9.8.

Anderson's study indicated that, although specimens are reproducing along the river, recruitment of mangroves is very low, probably due to inhibition of seedling growth by high organic pollution loads and waves generated by boat traffic.

Potential Impacts of Earthworks on Seung Ma Lei Yue Hill

Portions of all five habitat types found on the hill will be lost due to the proposed earthworks. The greatest loss would occur in the shrub/grassland habitat. This habitat is common in the immediate area and throughout nearby upland areas in Shenzhen and Hong Kong. Its wide distribution and broad extent is due to man-caused disturbance and exploitation of forested habitats which preceded shrub/grasslands. Loss of an estimated 2.5 ha of shrub/grassland would not result in significant ecological impact.

Similarly, loss of the open pine woodland habitat would not result in significant ecological impact. This habitat did not support important ecological resources.

Loss of an estimated 2.0 ha of pine woodland would potentially result in adverse impacts on roosting and/or nesting birds of prey. The pine woodland on the southeast slope of the hill was not used by birds of prey to the extent of that on the north slope. Therefore, loss of a portion of the pine woodland on the southeast slope may not result in detectable impacts. The proposed disturbance boundary covers approximately 0.2 ha of pine woodland habitat in this area.

On the north slope of the hill the proposed disturbance area extends up to 50m into pine woodland habitat, which would result in loss of about 0.5 ha of potential perching or nesting sites. Based on spring 1994 surveys, the affected area did not include the preferred perch or nest sites. However, earthworks potentially involving blasting would take place within 50 m of the preferred sites. Based on the larger tree size and more frequent bird use of this woodland, impacts due to habitat loss should be avoided or mitigated to the extent possible.

Loss of broadleaf woodland would eliminate some preferred eagle roost sites at the northern foot of the hill. At the southern extent of the proposed works boundary some broadleaf woodland would be lost near the heron roost. The wooded ravine which lies at the centre of the roost area would not be directly affected by the earthworks, but indirect impacts would be possible due to encroachment of equipment and blasting operation to within 30 m of the site. More important are potential impacts due to filling of the adjacent fish pond with disposed dredged material from the River channel. This would remove a substantial area of feeding habitat (2.2 ha of fish pond and associated bunds) for egrets and herons, which should be expected to abandon the site. It would also remove feeding habitat for 3 species of kingfisher, all of which were observed feeding in the pond.

Approximately 60% (0.6 ha) of the abandoned paddy adjacent to the north foot of the hill would be lost due to excavation for the new river channel. Although approximately 0.4 ha of abandoned paddy would remain undisturbed, there is likely to be significant reduction of foraging area for swallows. This could, in turn, reduce prey availability for birds of prey such as the hobby (and possibly the peregrine falcon) which was observed feeding on swallows.

9.4.2 Air Quality

Air quality impacts of the Stage 1 works are discussed in Section 5. Air quality impacts on wildlife are unlikely to be severe. Adequate dust control measures are recommended in Section 5. The only potential impact will be the adverse effect of dust on vegetation. The dust effect of the Project works on ecology will however not be significant against the general background of other construction works in the area.

9.4.3 Noise

Noise impacts of the Stage 1 works are discussed in Section 6 of this Report. The Project will generate noise from plant activity during the construction phase. There may also be limited drilling and blasting of rock at Seung Ma Lei Yue Hill.

The major potential concern is the effect of disturbance on birds. The auditory range of birds is broadly similar to that of man (Pettingill 1985), but generally birds cannot detect low sounds as well as humans. Birds hear best within the frequency range of 1-5 kHz (Dooling 1985).

Contrary to general public opinion, birds often are remarkably tolerant to noise and often acclimate to noise quickly - hence the regular occurrence of birds on airfields (e.g. Melville 1980), for example. Noises have regularly been used in attempts to scare birds off airfields, but generally with a notable lack of success (Wright 1963, Blokpoel 1976) even when modern technology is used to generate high levels of synthetic noise (Briot 1988).

It is not expected that noise generated as a result of either the construction or operation of the Project will significantly impact birds, except possibly in the immediate vicinity of particularly noisy activities such as pile driving and rock blasting.

Potential noise impacts on mammals in the study area are considered to be slight.

9.4.4 Water Quality

Impacts of the Stage 1 works on water quality are discussed in Section 8 of this Report. Currently Shenzhen River and Deep Bay are heavily polluted, especially with nutrients and organic matter from livestock farms and sewage, as well as with inorganic pollutants including toxic metals.

The majority of the construction works for Stage 1 are unlikely to affect water quality in the river (Section 8). Water quality is expected to worsen, at least locally, during the construction phase when dredging is undertaken and the coffer dams for the new channels are broken through. The effect, however, will be short lived.

According to the model prediction, the moderate changes in hydrodynamics, sediment flux, and water quality resulting from the Stage 1 Works are considered to pose no threat to ecological resources in Shenzhen River estuary area.

During the dewatering of the contaminated spoil, runoff after rain could lead to discharge of pollutants into the river. It is considered unlikely, however, that the discharge would have any effect on wildlife or ecology as indicated by the comparatively low ecological toxicity(Sec. 8.4).

The Stage 1 works will provide greater channel capacity over 2 sections of the river. Apart from some increased local sedimentation, flows and water quality will still be dominated by the remaining sections of the river which will be unchanged. The Stage 1 works are not expected to have any effect on ecological resources due to changes in water quality or flows.

Mangroves

2 ha of mangroves will be destroyed as a result of the Stage 1 Works. A mangrove restoration plan will be proposed in the Stage 2 report. It is considered unlikely that changes in water quality resulting from the Stage 1 works will adversely affect mangroves downstream.

Benthos

Previous studies indicate that the bottom sediments of the river in the Stage 1 works area do not support any benthic fauna (McChesney unpublished). Impacts resulting from changes in water quality due to Stage 1 construction works are thus not considered to be significant within the works area.

The results of modelling and elutriate tests demonstrated that there will be no significant change in water quality during the operation of the Stage 1 works. Downstream impact on benthic fauna is not expected.

Waterfowl

Waterfowl are very seldom seen on the river in the Stage 1 Works area, and are not thought to feed on the river, apart from occasionally scavenging (Leader 1994b). Changes in water quality resulting from the Stage 1 works will not affect waterfowl.

Commercial species

Downstream effects or increased pollutant loads enter Deep Bay are considered to be an insignificant risk as a result of the Stage 1 works, it is concluded that the Stage 1 works are unlikely to have any significant effect on commercial species or operations.

Mammals

Because Stage 1 works will not cause significant deterioration of water quality no adverse impact is predicted for the Otter *Lutra lutra*.

9.4.5 Effect of Sediment Quality and Sedimentation

The Stage 1 Works will involve only limited dredging since most of the construction works will be isolated from the river course until completion. Concentrations of suspended sediments in the river will be elevated as a result of dredging works during the construction phases. The relative contribution of this sediment to the overall load in the river is small (Section 7). The effect of release of sediment associated with Stage 1 works is, therefore, considered to pose no threat to ecological resources downstream of the works.

Mangroves, Benthos, Waterfowl and Commercial Species

There is no evidence to suggest that mangroves in Deep Bay area are stressed by current levels of siltation (Anderson unpublished) and it is considered unlikely that localised increases in sediment resulting from Stage 1 Construction Works will have any impact on mangroves.

As there are no waterfowl, benthos, or commercial species in the river at the Stage 1 area there will be no direct effect on these resources.

A moderate increase or decrease in sediment input to Inner Deep Bay resulting from the Stage 1 Works (Section 7) is considered unlikely to affect the benthos. Benthic invertebrates have been shown able to survive deposits of sediments ranging from 21 through 50 cm (Maurer et al. 1981a, 1981b, 1982; Krantz 1972; Saila et al. 1972). Increased sedimentation of the Shenzhen River estuary and Deep Bay due to Stage 1 works is not predicted to exceed 0.2 cm (Section 7.3.2). Because predicted levels of sedimentation are at least an order of magnitude below those at which lethal effects have been documented by previous studies, it is improbable that adverse impacts to benthos will result from the Project.

9.4.6 Human Disturbance

Waterfowl

Human disturbance to wildlife can result in a variety of impacts, including reduced food intake rates, reduced breeding output, abandonment of breeding attempts and increased predation. Human disturbance to waterfowl is regarded as potentially the most serious impact.

Human disturbance will result from both the construction and operational phases of Stage 1 works. Human disturbance relevant to the Project includes passage of construction plant within the works area, boat traffic on the river (including dredgers), and humans moving along the banks of the River.

Other Wildlife

Human disturbance to other wildlife is not considered to be a major problem with respect to the Project.

9.4.7 Hydrodynamics

The potential effect of changes on hydrodynamics, sedimentation and water quality on ecological resources in the estuary and Deep Bay is considered in Section 8. It is concluded that there will be no significant effect as a result of the Stage 1 works.

9.4.8 Risks and Uncertainties

The risk arising from the assessment of sedimentation, hydrological, and water quality effects is considered to be acceptable. This reflects the relatively small scale of the Stage 1 works and the effects caused compared to natural variations in the systems and the conservatism of assumptions used.

9.5 MITIGATION MEASURES

The most important potential ecological impact of the Stage 1 works is the loss of habitat. The mitigation of this will necessarily involve either changes to the outline design to reduce habitat loss, and /or the creation of new habitat as compensation for that lost.

Most, if not all, attempts to mitigate for habitat loss (whether resulting directly or indirectly from the Project) will have to be undertaken on the Hong Kong side since almost all habitat sites in Shenzhen have been lost to development. Habitat management on the Hong Kong side must be undertaken in the context of the future landuse and management of the North West New Territories and guidelines of the *Territorial Development Strategy*.

The Deep Bay Buffer Zones provide an outline for future conservation management and land use planning in Deep Bay area. The Hong Kong Government Ramsar Working Group is currently looking into possible future conservation management of Deep Bay wetlands and a proposal has been submitted by WWF Hong Kong for the establishment of a Conservation Management Zone on the Hong Kong side of Deep Bay (*Proposal for a managed conservation zone in Deep Bay*, WWF Hong Kong 1993). There are also various proposals being developed by the private sector (e.g. Grant 1994).

There is however a continuing loss of wetland on the Hong Kong side of Deep Bay for residential development, open storage and other uses. Recent extensions of controls under the planning legislation will assist in addressing the trend of environmental decline but will not influence conservation needs.

Mitigation measures proposed for loss of ecological resources are listed below.

1) Potential impacts to water birds due to loss of 19 ha of fish ponds could be mitigated by retention of the old Shenzhen River channel at Lok Ma Chau Bend. Because the old River channel will be truncated by the new channel, the old channel will become a pond of approximately 80 m width by 2500 m length. This will provide 20 ha of pond surface area. In addition, the south bank of the old channel will remain, and could be managed specifically for enhancement of conservation potential. Facilities for water level control in the new "Lok Ma Chau Pond" should be designed during the detail engineering phase of the Stage 1 works. It is recognized that the existing river channel is heavily polluted, and restoration would be required to provide suitable habitat for development of a prey base for feeding water birds (herons and egrets in particular). Design and implementation of such restoration measures should be included in the works contracts for Stage 1.

2) Impacts due to loss of upland habitats on Seung Ma Lei Yue Hill can be mitigated by successful restoration of vegetation on the proposed cut slope and adjacent slopes of the Hill. Further impact mitigation can be achieved by habitat creation on materials storage areas. Approximately 14.3 ha of surface area along the south bank of the new channel will be available for re-vegetation following completion of scheduled disposal of dredged materials (2 sites) or stockpiling of unsuitable materials (1 site). Finished levels at these locations will range from 3.0 m to 4.6 m, making them more suitable for restoration of upland vegetation These areas have potential to replace total area of lost upland habitat on Seung Ma Lei Yue Hill in a ratio of 14.3 ha replaced for 5 ha lost. Plant species selected for revegetation should be native trees and shrubs indigenous to the Deep Bay area which can provide future nest sites, perches, roosts, or forage sources.

3) Potential impacts to roosting herons and to loss of pine woodland on the southeast slope of the hill could be partially avoided by minor revision of the southern disturbance boundary to preclude loss of broadleaf woodland habitat in the immediate vicinity of the roost site. This revision may be, however, geotechnically unacceptable. Based on existing geotechnical data from the Geotechnical Engineering Office (GEO) of the Hong Kong Government, the proposed slope has a marginal factor of safety and thus should not be altered. The feasibility of any proposed revision would have to be made subject to confirmation of slope stability requirements.

4) Potential impacts on perching or foraging birds of prey due to loss of pine woodland on the north slope of Seung Ma Lei Yue Hill are unavoidable without revision of the disturbance limits, which is not possible due to engineering constraints. A minor adjustment of the western

disturbance limit in an eastwardly direction would reduce habitat loss and potential disturbance. The adjustment may be, however, geotechnically unacceptable.

5) The loss of part of the hill will not result in major impacts on flora and fauna. However mitigation works should be undertaken on the disturbance area and adjacent slopes on Seung Ma Lei Yue Hill, including the planting of native trees and fire control to ensure successful establishment. Open cooking fires should be prohibited on site. Fire fighting equipment should be maintained on site to the satisfaction of the Director of Fire Services and the Director of Agriculture and Fisheries.

6) The site should be fenced on the landward side to prevent encroachment by workers who might disturb/trap wildlife in the area. Introduction of domestic dogs to the work site should be prohibited to reduce dog predation on wildlife.

7) Rock drilling and blasting should be minimized during the nesting season of birds, particularly the locally rare Bonnelli's Eagle *Hieraaetus fasciatus*, which nests early in the year (approx. December - April). Controls on noise generation should be included in the contract documents.

9.6 MONITORING AND AUDIT REQUIREMENTS

Current baseline ecological studies will provide essential information against which to measure possible future changes.

Future ecological monitoring should include:

1) survey of birds every month in the wetland area between the Lok Ma Chau and Lo Wu border crossings and the north side of the Lok Ma Chau range of hills during the works period, and every 2 months thereafter for 1 years.

2) survey of mudflat after the construciton;

3) survey of mangroves, benthos, and waterbirds if only a significant change in mudflat is observed;

9.7 PROPOSED FUTURE ENHANCEMENT OF ECOLOGICAL RESOURCES

The Project provides scope for developing proposals for enhancing conservation management. Impact mitigation proposals in Section 9.5 will address impacts of the Stage 1 works. The following options are proposed by WWF(HK) to address future potential cumulative impacts from development of the Shenzhen River floodplain following flood control. Therefore, these measures are recommended as ecological resource enhancement and cumulative impact avoidance. Options will require provision of other wetland areas which can be managed for conservation. Ideally any such wetland area would contribute to a consolidated conservation resource under secure management. It is recognized that creation of new wetlands in the Deep Bay area is impracticable as an enhancement strategy. Therefore, enhanced conservation management of existing wetlands is seen as the preferred option.

Option 1 Ma Tso Lung

Under this option the Ma Tso Lung area would be designated as a conservation management area. The new flood control bund and border security facilities would be set along the bottom of the Ma Tso Lung hills, and the present area of marshlands and ponds retained and permitted to flood periodically (as at present). This would retain wetlands for conservation and have an added advantage in providing some flood storage capacity.

Existing land uses (fish pond operation) could be permitted to continue, subject to an approved conservation management plan for the area. This would retain important feeding areas for egrets, herons, and other waterbirds. This area of wetland would be linked to that in the San Tin area by a corridor of ponds along the south bank of Shenzhen River.

The Ma Tso Lung proposal has the added advantage that it would keep the area relatively free from disturbance in the future and thus permit continuing use of the area by raptors, including the locally/regionally important wintering population of Imperial Eagles *Aquila heliaca.*

This option has appeal for broad conservation reasons as the hill side and associated wetland have been shown to be unexpectedly rich as a habitat and could be further developed as a conservation resource. The site is not directly linked to Mai Po Marshes Nature Reserve.

Option 2 Sam Po Shue

The fish pond area at Sam Po Shue, to the west of San Tin, would be designated as a conservation management area. As at Ma Tso Lung, the new flood control bund and security road could be set back from the new river channel to allow a floodplain on the south bank of the River. The area would flood periodically during storm events, as at present. Existing land uses (fish pond operation) could be permitted to continue, subject to an approved conservation management plan for the area. This area currently falls within the Hong Kong Deep Bay Buffer Zone II, and thus is already subject to land use controls.

The San Tin Option has the advantages of offering some flood storage capacity, as well as a managed wetland conservation area in close proximity to Mai Po. The present Deep Bay Buffer Zone I boundary comes to the western boundary of the proposed mitigation area, and thus a corridor to Mai Po would be created.

It is understood that consideration is being given to development of a major container storage facility at San Tin. The area lies between Deep Bay Buffer Zone II and San Tin village and is principally fish ponds which would be filled. There would be a need to ensure that the conservation management area is not adversely affected, e.g. by storm water runoff containing oil and other pollutants.

In both options there is the possibility of retaining active fish pond operations. At a time when freshwater fish are increasingly attractive as a commercial venture, this is an opportunity to combine landuse and conservation objectives.

Limited landscaping works would be required as part of the conservation management plan, and to screen the border security road. The realignment of the flood control bund and security road could result in cost savings since the length of the bund would be shortened in Options 1 and 2.

It is stressed that, given the political and landuse issues involved in the Project and the areas around the border crossings generally, any decisions on the most acceptable form of mitigation will need to take account a wide range of issues. It is considered premature to develop any of these options further in isolation of the broader issues involved.

10. SOCIOECONOMY

10.1 EXISTING CONDITIONS

10.1.1 Existing Landuse Situation on Shenzhen Side

The existing landuse situation within the scope of impacts from Stage 1 works of the Project is shown in Figure 10-1.

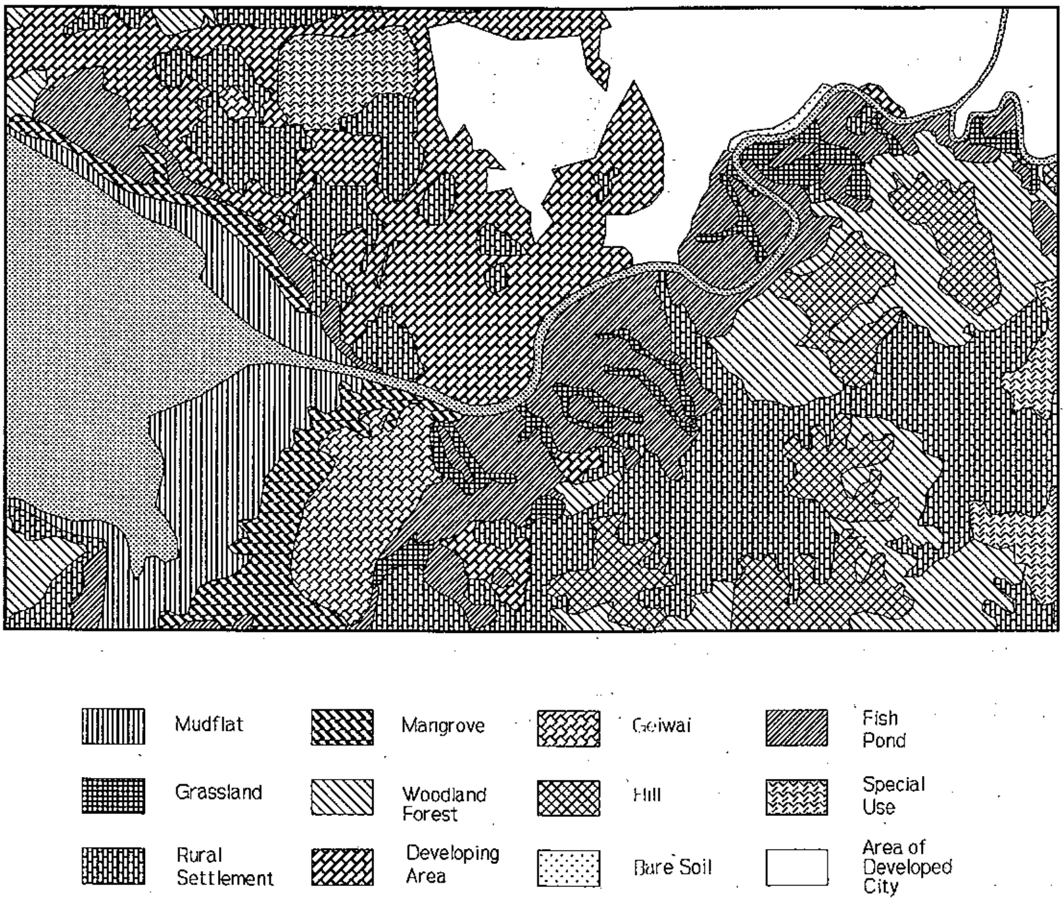


Figure 10-1 Existing land use situation

In the section of Shenzhen River at Liu Pok Bend, the new river channel would cut through the eastern portion of Seung Ma Lei Yue Hill. Most of the river channel will be on the Hong Kong side of the border, with approximately 130-150 m of the new river channel on Shenzhen side. The area to be occupied by the new channel is presently open ground (fish ponds) with an area of 5-6 ha, of which approximately 1.5 ha will be occupied directly by the new river channel. Following implementation of the Project, the remaining land may be used in accordance with Shenzhen Municipality planning schemes.

In the Lok Ma Chau section of the river, the axis of the new river channel will pass through an area of fish ponds. This section of the river channel will lie entirely on Shenzhen side of the border and will be approximately 1.5 km in length. The land to the west of the new river channel has been or will be developed for residential purposes. The area of approximately 1 km^2 between the old and the new river channels now supports approximately 70 ha of aquaculture area. This area will be used for spoil disposal during Stage 1 works of the Project.

10.1.2 Existing Landuse Situation on Hong Kong Side

The Mai Po Nature Reserve, which as part of Deep Bay ecosystem qualifies as a wetland of international significance. Two designated buffer zones are intended to control development within the vicinity of the Nature Reserve. There are a number of recognised villages within these buffer zones, with areas dedicated for expansion.

To the south of Mai Po Nature Reserve lies the substantial suburban residential development of Fairview Park. The population of the area is 15,300 persons (1991 Census), about 85% of which lives in Fairview Park with the remainder in several villages including Mai Po Tsuen, Chuk Yuen Tsuen and Sheung San Wai. Some non-indigenous villagers also occupy the area.

To the east the Nature Reserve lies the San Tin area, which comprises the main border crossing at Lok Ma Chau, seven villages, actively cultivated fish ponds, villages within the Frontier Closed Border Area, and substantial areas of open storage and lorry parking.

Land-use options for the area have recently been considered in the Mai Po Development Statement, resulting in the preparation of the Mai Po Recommended Outline Development Plan (RODP), in which substantial new Conservation Areas around the Mai Po Egretry and a Conservation Area at Tai Law Hau are designated.

10.1.3 Flooding and Flood Prevention in Shenzhen River Drainage

The channel of Shenzhen River is narrow and winding. The safety flood-discharge level of the river channel is only a few hundred m^3/sec, equivalent to a flood with a one in two-year return period. Any storm exceeding 150-200 mm of rainfall per day causes a flood. Results of three rounds of continuous hydrological monitoring on 12-25 September 1983, 11-19 January 1984 and 12-19 August 1984 along the Yunong Village section of Shenzhen river showed that each flood period lasted 1-5 days. In two major floods in 1964 and 1971, the areas affected by flooding on Shenzhen side alone were 8.7 km^2 and 5.3 km^2 respectively. It is estimated that the area theoretically affected by a flood with a one in 50 year return period would be approximately 17 km^2 on Shenzhen side and 13.5 km^2 on the Hong Kong side. Figure 10-2 showed the direct economic losses from flooding, waterlogging, and typhoons and the area of agricultural land affected in Shenzhen Municipality.

The flood area in the New Territories of Hong Kong on the left bank is approximately 1,350 ha in area. Loss on the Hong Kong side of Shenzhen River caused by flooding was HK$164 million in 1993.

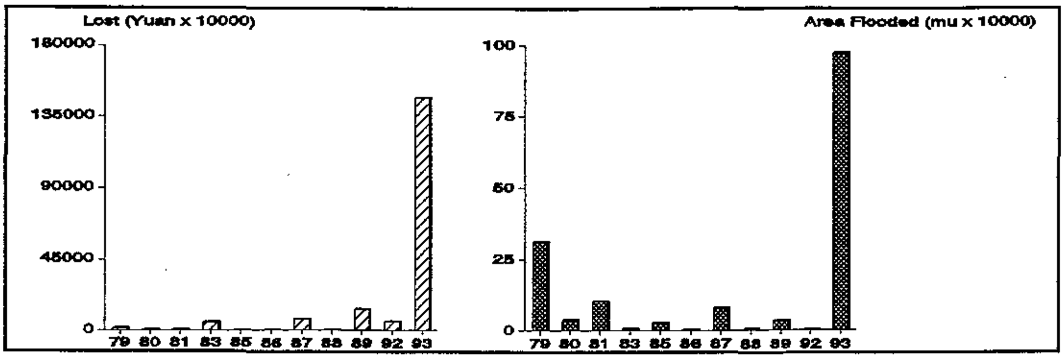


Figure 10-2 Economic losses from flooding and waterlogging

10.2 POTENTIAL IMPACTS

10.2.1 Landuse Impacts from Stage I Works

The dredging and diking activities of Stage 1 will directly occupy an area of 46.7 ha. Of this, 34.7 ha will lie on Shenzhen side of the border, mostly on the Lok Ma Chau section; 12 ha will lie on the Hong Kong side, mainly on the Liu Pok section and in the vicinity of Seung Ma Lei Yue Hill.

Impacts of Stage 1 of the Project on existing landuse will occur primarily in an area of approximately 1 km^2 in the vicinity of the Lok Ma Chau river bend. This area is currently devoted primarily to fish ponds, but was previously occupied by farmland until the area was proposed to be used as major spoil disposal area for the Stage 1 works. The fish ponds will be refilled during the Stage 1 works of the Project.

10.2.2 Flood Prevention

Following completion of Stage 1 of the Project, it is predicted that protection from a flood with a 5-year return period will be provided. Following completion of the entire project, protection against a flood with a 50-year return period will be afforded. Moreover, all areas of the Municipality will have gravity discharge into Shenzhen River, obviating the need for construction of large-scale pumping stations.

APPENDIX

A7.1 Hydrodynamic Modelling
A7.2 Sediment Transport Modelling
A7.3 Water Quality Modelling

A8.1 Hankanson's Sediment Assessment Method
A8.2 Baseline Monitoring Results for the River/Bay
A8.3 Assessment Indexes
A8.4 Heavy Metals in Sediment of Shenzhen River

A9.1 International Conventions Relevant to the Project in erms of Habitat and Wildlife Protection
A9.2 Hong Kong Statutes and Guidelines Relevant to Ecological Resource
A9.3 Relevant Statutes in the PRC
A9.4 Fish Pond around Deep Bay - Their Importance to Wildlife, Especially Waterbirds
A9.5 Baseline Survey in Futian Nature Reserve
A9.6 Terrestrial Ecology Survey for Shenzhen
A9.7 Survey of Mangroves at Mai Po Area
A9.8 Interim Report of Southern River Bank Mangrove Survey-Tam Kon Chua to Lo Wu
A9.9 Interim Report of Invertebrate Survey
A9.10 Interim Report of Wader Population Survey Results
A9.11 Interim Report on Duck and Wader Distribution in Deep Bay
A9.12 Interim Report on Shenzhen River Bird Survey

A10.1 Public Opinion Survey

APPENDIX 7. 1 HYDRODYNAMIC MODELLING

7. 1. 1 Introduction

The prime objective of the modelling is to provide a quantitative assessment of the hydrodynamic behaviours in both Shenzhen River and Deep Bay before and after the Stage 1 work. The 1—D flow model for Shenzhen River is based on the De Venant equation and Pressmann Scheme is adopted for numerical computation;the 2—D flow model for the Deep Bay is based on the horizontal two dimensional shallow flow equations.

7. 1. 2 1—D Flow Model for Shenzhen River

7. 1. 2. 1 Basic Equations

The proposed 1-D model is consitituted with the unsteady flow model. The basic equations read: Continuity equation for flow

$$\frac{\partial Z}{\partial t} + \frac{1}{B}\frac{\partial Q}{\partial x} = 0 \qquad (A7.1)$$

Momentum equation for flow

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + gA\left(\frac{\partial z}{\partial x} + \frac{Q|Q|}{k^2}\right) = 0 \qquad (A7.2)$$

Where x and t are spatial and temporal variables; z, water level; B, flow width; Q, flow discharge; A, area of cross-section; K, discharge modulus; g, gravitational acceleration.

7. 1. 2. 2 Computation Scheme

Equations (A7. 1) and (A7. 2) for th flow is discretized with the Preissmann four-point eccentric pattern as shown in Fig. A7. 1. Thus,the equations after the transformation become

$$A_{1j}\triangle Q_j + B_{1j}\triangle z_j + C_{1j}\triangle Q_{j+1} + D_{1j}\triangle z_{j+1} = E_{1j} \qquad (A7.3)$$

and

$$A_{2j}\triangle Q_j + B_{2j}\triangle z_j + C_{2j}\triangle Q_{j+1} + D_{2j}\triangle z_{j+1} = E_{2j} \qquad (A7.4)$$

respectively. Where

$$A_{1j} = -\frac{4\theta\triangle t}{\triangle x(B_j^* + B_{j+1}^*)} \qquad (A7.5)$$

$$B_{1j} = 1 - \frac{4\theta\triangle t(Q^*_{j+1} - Q^*_j)}{\triangle x\,(B^*_{j+1} + B^*_j)^2} \cdot \frac{d\,B^*_j}{d\,z^*_j} \tag{A7.6}$$

$$C_{1j} = -\frac{4\theta\triangle t}{\triangle x\,(B^*_{j+1} + B^*_j)} \tag{A7.7}$$

$$D_{1j} = 1 - \frac{4\theta\triangle t(Q^*_{j+1} - Q^*_j)}{\triangle x\,(B^*_{j+1} + B^*_j)^2} \cdot \frac{d\,B^*_{j+1}}{d\,z^*_{j+1}} \tag{A7.8}$$

$$E_{1j} = -\frac{4\triangle t(Q^*_{j+1} - Q^*_j)}{\triangle x\,(B^*_j + B^*_{j+1})} \tag{A7.9}$$

$$A_{2j} = 1 - \frac{4\theta\triangle t}{\triangle x}(\frac{Q^*_j}{A^*_j}) + 2\triangle tg\,\theta\,\frac{A^*_j\,|Q^*_j|}{(k^*_j)^2} \tag{A7.10}$$

$$B_{2j} = \frac{\theta\triangle t}{\triangle x}[\frac{2(Q^*_j)^2B^*_j}{(A^*_j)^2} - g\,(A^*_{j+1} + A^*_j) + g\,(z^*_{j+1} - z^*_j)B^*_j] + g\,\theta\triangle t\,\frac{Q^*_j\,|Q^*_j|}{(k^*_j)^2}[B^*_j - \frac{2A^*_jd\,k^*_j}{k^*_jd\,z^*_j}] \tag{A7.11}$$

$$C_{2j} = 1 + \frac{4\triangle t\theta Q^*_{j+1}}{\triangle x\,A^*_{j+1}}) + 2g\,\theta\triangle t\,\frac{A^*_{j+1}\,|Q^*_{j+1}|}{(k^*_{j+1})^2} \tag{A7.12}$$

$$D_{2j} = \frac{\theta\triangle t}{\triangle x}[-\frac{2(Q^*_{j+1})^2B^*_{j+1}}{(A^*_{j+1})^2} + g\,(A^*_{j+1} + A^*_j) + g\,(z^*_{j+1} - z^*_j)B^*_{j+1}] + g\,\theta\triangle t\,\frac{Q^*_{j+1}\,|Q^*_{j+1}|}{(k^*_{j+1})^2}[B^*_{j+1} - \frac{2A^*_{j+1}d\,k^*_{j+1}}{(k^*_{j+1}d\,z^*_{j+1}}] \tag{A7.13}$$

$$E_{2j} = \frac{\triangle t}{\triangle x}[-\frac{2(Q^*_{j+1})^2}{A^*_{j+1}} + \frac{2(Q^*_j)^2}{A^*_j} - g\,(A^*_{j+1} + A^*_j)(z^*_{j+1} - z^*_j)] - g\,\triangle t[\frac{A^*_{j+1}Q^*_{j+1}\,|Q^*_{j+1}|}{(k^*_{j+1})^2} + \frac{Q^*_j\,|Q^*_j\,|A^*_j}{(k^*_j)^2}] \tag{A7.14}$$

Then, the solutions of Eqs. (A7.3) and (A7.4), by means of Runing-After Method, are

$$\triangle Q_j = F_j\triangle z_j + G_j \tag{A7.15}$$

$$\triangle z_j = H_j\triangle Q_{j+1} + I_j\triangle z_{j+1} + J_j \tag{A7.16}$$

In which

$$H_j = \frac{-C_{1j}}{A_{1j}F_j + B_{1j}} \tag{A7.17}$$

$$I_j = \frac{-D_{1j}}{A_{1j}F_j + B_{1j}} \qquad (A7.18)$$

$$J_j = \frac{E_{1j} - A_{1j}G_j}{A_{1j}F_j + B_{1j}} \qquad (A7.19)$$

$$F_{j+1} = -\frac{aI_j + D_{2j}}{aH_j + C_{2j}} \qquad (A7.20)$$

$$G_{j+1} = \frac{E_{2j} - aJ_j - A_{2j}G_j}{aH_j + C_{2j}} \qquad (A7.21)$$

$$a = A_{2j}F_j + B_{2j} \qquad (A7.22)$$

7.1.2.3 Input Information

The total area of the catchment of Shenzhen River is 312.5 km^2. The area within PRC is 187.5 km^2, and that in Hong Kong side is 125 km^2. There was no hydrologic monitoring station within the catchment and no data were available on flow and sediment characteristics. However, hydrologic calculations for the catchment should be carried out in terms of non-discharge conditions. In order to supply the input information such as runoff from different sub-catchments of Shenzhen River for the hydrodynamic modeling, the following calculations are needed.

There are two meteorological stations with relatively long-term records for the catchment. One is at Baoan Station on Shenzhen side which maintained records from July 1952 to 1993. The second is the Emperor Meteorological Station on Hong Kong side, which maintained records from 1884 to date (excepting 1940-1946).

The designed storm frequencies in the catchment were deduced from analysis of precipitation data. In 1982 the deduction method was used for hydrologic calculation of the preliminary design of the Shenzhen Flood Control and Engineering Works (Guangdong Institute of Hydraulicand Electric Survey and Design, 1982). The peak discharge of the designed flood as well as its occurrence time were predicted. In 1984 the synthetic unit line method (Shenzhen Office of Flood Control Planning 1994) was used for the same predictions. Comparison of the results from the two different methods shows that predicted peak discharges under different flood frequencies from the latter method are often larger than those from the former method.

The designed peak discharge deduced from the two different methods for Sha Wan River, Lian Tao River, and the Shang Shui River were basically the same. However, the designed peak discharge was increased 17-27 percent using the synthetic unit line prediction method. In the upper reaches of the Buji River (Sun Gang detention basin) the 1994 cross sectional area of the channel and the flood volume over 24 hours were essentially the same as those in 1982. However, the flood volume over 6 hours increased 50 percent. This implies that the runoff convergence process is faster owing to urbanization of the catchment.

It is necessary to know the inflow process of the tributaries during one flood between San Cha River and the Shenzhen River estuary so that flood routing of Shenzhen River can be carried out. The principal tributaries of the Shenzhen River in the study reach include the ShangShui, Buji, Futian, and Huang Gang Rivers. The Buji River receives flows from Sun Gang Detention Basin, Bijia Mountain, and Caiwu Wui. The flow from Chi Wui is too small to be considered. The comparison of the peak discharge predictions from the aforementioned two methods is given in Table A7—1.

Table A7—1 Peak discharges under different design frequencies by two calculattion methods

Q (m^3/s) P / Sta.	P=2%		P=5%		P=10%		P=20%	
	1982	1994	1982	1994	1982	1994	1982	1994
Sancha River	1014	1019	819	840	657	702	550	562
Shangshui River	745	768	603	632	486	528	408	422
Buji River	661	658	536	542	432	454	342	364
Futian River	188	199	154	165	125	139		112
Huanggang River	254	259	208	214	170	180		145

Table A7—2 The designed peak discharge(P=2%) with consideration of detention (m^3/s)

Section	Sancha River	Shangshui River	Buji River	Futian River	Huanggang River
1982	869	570	359	127	165
1994	895	566	389		

When predicting peak flood discharge the influence of the management alternatives of Shenzhen Reservoir and the Sun Gang Detention Basin should be considered. Also,the flood hydrographs for the junctions of Shenzhen River with Shang Shui River, Futian River and Huang Gang River are different from those designed since the overbank flow was not discounted in the design. Thus, the real peak discharges should be smaller than those from the designed peak discharges. The peak discharges at the junctions (P=2%) after consideration of flood adjustment are given in Table A7—2. The difference between the peak discharges in 1982 and those in 1994 are very small as shown in Table A7—1, thus both can meet the requirements for flood routing.

On the basis of the 1982 data (Table A7—2) the present study gives all the flood bydrographs at different tributary junctions along the Shenzhen River under four design alternatives corresponding to frequencies of 2, 5, 10, and 20%, respectively. The calculated results are given in Figures A7—2 to A7—6, and the peak discharges are listed in Table A7—3.

Table A7—3 Peak discharges from Sancha River and its principal tributaries

Q (m³/s) P / Sta.	P=2%	P=5%	P=10%	P=20%
Sancha River	869	747	657	55
Shangshui River	570	442	360	253
Buji River	359	339	322	300
Futian River	127	103	83	66
Huanggang River	165	134	108	86

7.1.2.4 **Verification and Predication**

In 1—D sediment model, the time steps are taken as 60 seconds for flood and 600 seconds (or 900 seconds) for tide flow. Cross sections along the river are derived from the topographic map of the channel measured in 1985. Within the study reach from Sacha River section to the Shenzhen estuary, 168 cross sections are divided for the existing channel and 148 ones for the channel after realignment. The roughness along the river are from the designed values suggested by Guang Dong Institute of Hydraulic and Electric Survey and design, as shown in Table A7—4.

Table A7—4 Roughness of Shenzhen River

	Estuary—Yunong village	Yunong village—Lowu	Lowu—Sancha River
main flume	0.020	0.025	0.0275
floodplain	0.0267	0.0333	0.0367

1. Verification

The preliminary model runs have assumed the design parameters included in the OUtline Design.. This reflects the early stage of modelling work and is appropriate as any changes made to the channel design will have greatest influence on Stage 2 works.

The tributaries are simply considered as the inflow sources into Shenzhen River because of the paucity of the basic data. When small frequency flood appears in a tributary, the inflow is estimated according to the fullbank discharge. The verification of the flood level in the main channel is based on the record of the flood trace at five locations along the river, provided by the joint survey of Shenzhen Sanfang Office and Guangdong Institute of Hydraulic and Electric Survey and Designing (May 1989). The recorded actual tide type at Tsim Bei Tsui(as the boundary condition of the lower end) on the same day is used to match the flood equivelant to that with the return period of 1—in—5 years. The data measured at Yumin Village and Wenjindo in 1983 (typical tide from April to May and November) are used for the verification of the tide level. The results of verification are shown in Table A7—5 and Fig. A7—7.

Table A7—5 Calibration of the model

Location	Distance(m)	Elevation(m)	Calculated(m)
Huanggan village	3050	2.56	2.58
Shaosuo	3650	2.82	2.90
6 zhongdui	5700	3.43	3.58
Yumin village	11068	4.00	4.08
Qiaoshe	12437	4.32	4.65

2. Calculated Results

The modelling results based on 4 designed conditions with P equals to 2%, 5%, 10%, 20% are obtained and shown in Fig. A7—13 to Fig. 7—22, including the water level and discharge variation before and after the stage I works. The variations in estuary with spring, average and neap tides are also predicted (as shown in Fig. A7—23). The calculated results show that the water surface level will decrease owing to the stage I work, but the increase of tidal discharge is not significant.

7.1.3 2—D Flow Model for Deep Bay

7.1.3.1 Basic Equations

The basic equations for the 2-D depth-integrated model consists of momentum and mass conservations, namely

$$\frac{\partial Z}{\partial t}+\frac{\partial Q}{\partial x}+\frac{\partial P}{\partial y}=s \qquad (A7.23)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial uQ}{\partial x}+\frac{\partial vQ}{\partial y}+F'Q-\Omega P+gH\frac{\partial Z}{\partial x}=\nabla(K\nabla Q)+S_{mx} \qquad (A7.24)$$

$$\frac{\partial P}{\partial t}+\frac{\partial uP}{\partial x}+\frac{\partial vP}{\partial y}+F'P-\Omega Q+gH\frac{\partial Z}{\partial y}=\nabla(K\nabla P)+S_{my} \qquad (A7.25)$$

where z, water surface elevation; Q=uH; P=vH; H, the water depth; u and v, the velocity components in x and y directions, respectively; K, the momentum diffusion coefficient; Ω, the Coriolis coefficient; S, S_{mx} and S_{my}, source terms with respect to mass and momentum in x and y directions. In these equations, F' is the resistant coefficient with the consideration of local energy loss due to rapid change in bathymetry and is expressed by

$$F'=(1+\zeta_s\frac{C_h^2|\bar{n}_Q\cdot\nabla H|}{g})\frac{g\sqrt{Q^2+P^2}}{C_h^2H^2} \qquad (A7.26)$$

where $\vec{n}_Q$ is a unit vector of velocity; ∇H, water depth gradient; C_h, Chezy coefficient; ζ_s, an empirical parameter. At the land boundary, the resultant component of discharge normal to the boundary should vanish, i. e. $Q_n = 0$. The flow boundary conditions are usually water stage of discharge hydrographs. When only one boundary condition is given on the water boundary (e. g. the stage hydrograph) and when the flow directs into the zone of computation, the assumption is tacitly made that the advective terms may be neglected. This amounts to the linearization of the momentum equations at the boundary. However, the error will increase obviously when the advection terms become large. In this case, adopting discharge hydrography as the condition on the water boundary has some merits. By applying the splitting technique, the basic equations (A7. 23) to (A7. 24) may be split into three sets of component equations:

$$\frac{\partial Q}{\partial t} + u\frac{\partial Q}{\partial x} + v\frac{\partial Q}{\partial y} = 0 \qquad (A7.27)$$

$$\frac{\partial P}{\partial t} + u\frac{\partial P}{\partial x} + v\frac{\partial P}{\partial y} = 0 \qquad (A7.28)$$

For this step, only one boundary condition needs to be given when the flow is directed into the zone of computation.

$$\frac{\partial Q}{\partial t} = \nabla(K\nabla Q) \qquad (A7.29)$$

$$\frac{\partial P}{\partial t} = \nabla(K\nabla P) \qquad (A7.30)$$

The initial state for this step is given by the results of the advection step. The boundary condition are $Q_n = 0$ at the land boundary and the given hydrographs of Q and P at the water boundary. It is convenient to assume $\frac{\partial(Q,P)}{\partial n} = 0$ at the downstream boundary for this step.

$$\frac{\partial Q}{\partial t} + F'Q - \Omega P + gH\frac{\partial z}{\partial x} = S_{mx} \qquad (A7.31)$$

$$\frac{\partial P}{\partial t} + F'P + \Omega Q + gH\frac{\partial z}{\partial y} = S_{my} \qquad (A7.32)$$

$$\frac{\partial z}{\partial t} + \frac{\partial Q}{\partial x} + \frac{\partial P}{\partial y} = S \qquad (A7.33)$$

The initial conditions for this step are defined by the values of Q and P obtained in the previous steps and the previous surface elevation. On the given boundary, stages or surface slope $\frac{\partial z}{\partial n}$ computed from given discharges may be taken as boundary conditions. The land boundary conditions is again $Q_n = 0$, where n is the direction perpendicular to the boundary.

7. 1 . 3. 2 **Computation Scheme**

In order to integrate Eqs. (A7. 27) to (A7. 33) numerically, some preliminary derivations have to be done for the component equations (A7. 30) to (A7. 34) in a domain or local element as shown in Fig. A7. 24. If the coefficient K in (A7. 30) or (A7. 31) is assumed to be constant and equal to the value at the center point C, and the two derivatives $\frac{\partial Q}{\partial t}$ and $\frac{\partial P}{\partial t}$ are replaced by finite differences, then the following relations may be derived from eqs. (A7. 30) and (A7. 31)

$$(\nabla_1^2 - \sigma_l^2)\bar{\Phi} + \sigma_l^2 \bar{\Phi}_o = 0 \qquad (A7.34)$$

where

$\bar{\Phi}=(Q,P)^T$; $\nabla_1^2=\frac{\partial^2}{\partial\zeta^2}+\frac{\partial^2}{\partial\eta^2}$, local Laplace Operator; $\sigma_d^2=\triangle z^2/(K\cdot\triangle T)$, side length of a square grid; ζ and η, the local nondimensional coordinates. Subscript "o" refers to the initial status. For water surface elevation, we have

$$(\nabla_1^2 - \sigma^2)z + \sigma^2 S_p = 0 \qquad (A7.35)$$

and for Q and P:

$$Q = -\frac{\sqrt{gH_0}}{\sigma^2 C_r^2(1+F_0)}[C_r(1+F_0)\frac{\partial z}{\partial \zeta} + C_r\omega\frac{\partial z}{\partial \eta} + (1+F_0)P_x + \omega P_y] \qquad (A7.36)$$

$$P = -\frac{\sqrt{gH_0}}{\sigma^2 C_r^2(1+F_0)}[C_r(1+F_0)\frac{\partial z}{\partial \eta} + C_r\omega\frac{\partial z}{\partial \zeta} + (1+F_0)P_y - \omega P_x] \qquad (A7.37)$$

where

$$\sigma^2=[(1+F_0)^2+\omega^2]/C_r(1+F_0)$$

$$S_p=Z_0+S\triangle T+[\frac{\partial}{\partial\zeta}(\alpha_s P_y+P_x/C_r)+\frac{\partial}{\partial\eta}(P_y/C_r-\alpha_s P_x)]/\sigma^2$$

$$\alpha_s=\omega/(1+F_0)C_r$$

$$P_x \doteq (\sigma_f^x F_0\zeta+\sigma_f^y F_0\eta-1)\frac{Q_0}{\sqrt{gH_0}}+C_r(\sigma_H^x\zeta+\sigma_H^y\eta)\frac{\partial Z_0}{\partial\zeta}-S_{mx}\triangle T$$

$$P_y=(\sigma_f^x F_0\zeta+\sigma_f^y F_0\eta-1)\frac{P_0}{\sqrt{gH_0}}+C_r(\sigma_H^x\zeta+\sigma_H^y\eta)\frac{\partial Z_0}{\partial\eta}-S_{my}\triangle T$$

$$\sigma_H^x=\frac{1}{H_0}\frac{\partial H_0}{\partial\zeta},\ \sigma_H^y=\frac{1}{H_0}\frac{\partial H_0}{\partial\eta}$$

$$\sigma_f^x=(Q_0\frac{\partial Q_0}{\partial\zeta}+P_0\frac{\partial P_0}{\partial\zeta})/(Q_0^2+P_0^2)-\frac{7}{3}\sigma_H^x$$

$$\sigma_f^y=(Q_0\frac{\partial Q_0}{\partial\eta}+P_0\frac{\partial P_0}{\partial\eta})/(Q_0^2+P_0^2)-\frac{7}{3}\sigma_H^y$$

where C_r is Courant number and the subscript "o" denotes the variables of the known state. CAS for the numerical solution of eqs. (A7. 27) and (A7. 28) in addition to the equation, $(\nabla_1^2-\sigma^2)\Phi+\sigma^2 S_p=0$, further discusions are given as follows.

a) Application of the characteristic theory

Applying the theory of characteristics, one may obtain the following equations from the nonlinear hyperbolic eqs. (A7. 27) and (A7. 28), or

$$\frac{dQ}{dt}=\frac{\partial Q}{\partial t}+\frac{dx}{dt}\frac{\partial Q}{\partial x}+\frac{dy}{dt}\frac{\partial Q}{\partial y}=0 \qquad (A7.38)$$

$$\frac{dP}{dt}=\frac{\partial P}{\partial t}+\frac{dx}{dt}\frac{\partial P}{\partial x}+\frac{dy}{dt}\frac{\partial P}{\partial y}=0 \qquad (A7.39)$$

$$\frac{dx}{dt}=\frac{Q}{H} \qquad (A7.40)$$

$$\frac{dy}{dt}=\frac{P}{H} \qquad (A7.41)$$

As shown in Fig. A7—25, M(x_o, y_o) is the point of intersection of characteristics extending from a point P to the previous time plane. Discharges Q and P remain unchanged along the line PM, so that

$$Q_p=Q(x,y,t)=Q(x_0,y_0,0) \qquad (A7.42)$$

and

$$P_p=P(x,y,t)=P(x_0,y_0,0) \qquad (A7.43)$$

Now suppose ξ, η be the local nondimensional coordinates and the water depth be replaced by the bilinear interpolation of the grid values, then point M is determined by

$$\xi=\frac{\Delta T\cdot Q_0(\xi,\eta)}{\Delta X\cdot H_{s1}(\xi,\eta)} \qquad (A7.44)$$

$$\eta=\frac{\Delta T\cdot P_0(\xi,\eta)}{\Delta y\cdot H_{s2}(\xi,\eta)} \qquad (A7.45)$$

where

$H_{s1}=H_1(\xi-\xi^2/2)(1-\eta)+H_2\xi^2(1-\eta)/2+H_3\xi^2\eta/2+H_4(\xi-\xi^2/2)\eta$

$H_{s2}=H_1(1-\xi)(\eta-\eta^2/2)+H_2\xi(\eta-\eta^2/2)+H_3\xi\eta^2/2+H_4(1-\xi)\eta^2/2$

Q_o, P_o can evaluated with either bilinear interpolation or the interpolation method proposed by Holly and Preissmann. Eqs. (A7. 44) and (A7. 45) are nonlinear algebraic equations and can be solved with Newton method or Newton-Rophson method.

b)Finite analytical method

According to the finite analytical method (Chen), the common equation

$$(\nabla_1^2 - \sigma^2)\Phi + \sigma^2 S_p = 0 \qquad (A7.46)$$

can be solved analytically in the subdomain within the domain of computation if coefficient is fixed and the boundary function is assigned with the grid values of Φ_{NE}, Φ_{SE}……Φ_{NC} by parabolic interpolation. The general solution may be written:

$$\Phi = f(\Phi_N(\zeta), \Phi_S(\zeta), \Phi_E(\eta), \Phi_W(\eta), \triangle x, \triangle y, \zeta, \eta, \sigma^2, S_p) \qquad (A7.47)$$

Substituting the interpolation functions $\Phi_N(\zeta)$, $\Phi_S(\zeta)$, $\Phi_E(\eta)$, $\Phi_W(\eta)$ into the foregoing equation, yields

$$\Phi = f(\Phi_{NE}, \Phi_{SE}, \cdots\cdots \Phi_{NC}, \triangle x, \triangle y, \zeta, \eta, \sigma^2, S_p) \qquad (A7.48)$$

The actual form of Eq. (A7. 48) has been given in Zhou (1988). Let $\zeta=\eta=0$, the algebraic relationship for Φ_p with the eight surrounding grid points becomes:

$$\Phi_p = C_{EC}\Phi_{EC} + C_{WC}\Phi_{WC} + \cdots\cdots + C_{SW}\Phi_{SW} + C_{SE}\Phi_{SE} + C_P S_P \qquad (A7.49)$$

where C_{EC}, C_{SC},.... C_{NE} are known coefficients. Since the equation is symmetrical in form and $\triangle_x=\triangle_y$, the coefficients satisfy the relations of $C_{EC}=C_{SC}=C_{WC}=C_{NC}=C_0$ and $C_{NE}=C_{SE}=C_{SW}=C_{NW}=C_d$. C_o, C_d and C_p may be further evaluated by the following equations

$$C_0 = 2\sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{\lambda_{2n-1}^3 \cosh \beta_{2n-1}}$$

$$C_d = \sum_{n=1}^{\infty} (-1)^{n+1} \left(1 - \frac{2}{\lambda_{2n-1}^2}\right) \frac{1}{\lambda_{2n-1} \cosh(\beta_{2n-1})}$$

and

$$C_p = \sum_{\substack{m=1 \\ n=1}}^{\infty} \frac{4(-1)^{m+n}}{(\sigma^2 + \lambda_{2n-1}^2 + \lambda_{2m-1}^2)\lambda_{2n-1}\lambda_{2m-1}}$$

where $\lambda_m = n\pi/2$, $\beta_n = \sqrt{\lambda_n^2 + \sigma^2}$

7.1.3.3 Basic Requirements of the Model

The range of modelling is from the upper end of Shenzhen Estuary to the mouth of Deep Bay bordered Chi Wan and Black Point. 100x100m square grid is used and the time steps are 40 seconds. Fluctuating boundary method is used to simulate the change of intertidal areas due to the rise and fall of the tide flow.

The boundary condition of water level at the mouth of Deep Bay is obtained by the interpolation method using the measured tide level data in Chi Wan and Black Point. In the estuary of Shenzhen River, the flow discharge boundary condition are calculated according to the tidal flow discharge hydrograph offered by 1—D calculation model.

Since there is no overall sea—chart on Deep Bay for recent years, and the existing chart of 1: 50000 can not be used to simulate the topography of river mouth and the mud flat, additional measures are adopted as such:

a) The data of CED Model with 300m×300mm grid from Hong Kong is used.

These data hibr detailed description on the major part of Deep Bay, but can not show the micratopography change in river mouth area, even can not show the elevation of the two main channels in river mouth (the major course of Shenzhen River for sea transportation).

b) The remote sensing photograph of satellite (at 9: 00 in Dec. 21, 1992) is used for improvement treatment of the bathymetry.

This photograph is used to calculate the topography of the river mouth of Shenzhen River and mud flat around it, and the elevation of these areas are obtained. These data show the precise of 30m in plane, and the error of the predicted depth is within 10 cm. The microtopography of the river mouth area is also very clear in the graph.

The final bed elevation of the Deep Bay obtained from the two group data is shown in Fig. A7—26.

The data measured in Mar. 1 — 4, 1994 is used to verrify the hydrodynamic model. The measurement of sater level was made both in Black point and river mouth. The data for Chi Wan during this period is obtained from Ocean Observation Station. Through analysis, we can find that the characters istics of tide level in Chi Wan and Black Point are basicly the same. The phase lag of tide flow at Chi Wan is 600 seconds behind that at Black Point (Fig. A7—27).

The data of spring tide,average tide and neap tide in July 1994 are used as the typical tides. At the same time, according to the former analysis, the tide level of Black Point are believed the same as that of Chi Wan but with a 600 second advance. The typical tide types used here in are depicted in Fig. A7—28.

According to the results of 1 — D calculation, the flow discharge processes in estuary under different conditions are showed in Fig. A7—29(a),(b) and (c). From these figures, we can see the flow discharge process before and after the Stage 1 works, and the tide flow discharge of Shenzhen River has no essential change.

Considering the difference of sea bed of intertidal areas of Deep Bay and deep water area, roughness over different areas is used in the calculation. Because of the effects of shell on water flow, shallow water areas shows high roughness. The distribution of roughness is presented in

Fig. A7—30. The data of roughness are calibrated with the flow field calculation.

7.1.3.4 Verification and Predication

1. Verification

The result of hydrodynamic calculation was verified based on the modelling monitoring data of Mar. 1—4, 1994. 4 flow velocity monitoring locations were set up in Deep Bay (Fig. 4—4). The test results of tide flow velocity is presented in Fig. A7—31. In this figure, velocity <0 represents the direction of decreasing tide. From Fig. A7—31 we can see that the calculated and measured values show good coexistence in the location S7 and S9 in the Bay, but a certain extent difference for location S8 and S10. For the latter, the reason is that S8 and S10 are near the intertidal areas, and thus the change of depth is significant, which results in the difference between measured and calculated locations.

2. Calculated Results of 2—D Flow Field

From Fig. A7—29 we can see that the flow discharge input and output Deep Bay from Shenzhen River under flood season and average tide type have no significant difference before and after the Project. Therefore, the hydrodynamic condition changes little before and after the Project.

The flow field characters in high, low and average tide types are showed in Fig. A7—32(b)~A7—32(k), Fig. A7—33(b)~A7—33(k), Fig. A7—34(b)~Fig. A7—34(k). Among them, Fig. A7—32(a), Fig. A7—33(a) and Fig. A7—34(a) showed the time and tide level of each flow fields.

The highest tide velocity can be found in the period of high tide. The highest increase tide velocity is 0.8m/s, and the highest decrease tide velocity is 0.9m/s. During the increase and decrease tide, the highest velocity are mainly along the SW—NE direction in the southern part of Black Point and She Kou, similar to the direction of depression course. During the period of beginning the increase and decrease of the tide, the water flow around the Bay mouth. During the increase period, the water flow into the Bay from the southwestern direction, and leave the Bay from northwestern direction; During the decrease period, the water flow into the Bay from the northwestern direction, and leave the Bay from southwestern direction. The flow of water in the Inner Deep Bay is controlled by Tim Bi Tsui at a certain extent, and form a graph of flow around the Jian Bi Zui. The velocity in these areas is also high. The highest velocity is 0.65m/s, and the higher decrease tide velocity can bring the sediment from river mouth to the certain part of the Bay. During the high tide, the flow velocity in river mouth is low with little turbulance; and during the low tide, the flow is mainly along the two with significant turbulance. Compared with the inner side of the Bay, the intertidal area of Deep Bay shows low flow velocity, the highest velocity is between 0.2—0.25m/s. Besides, during the time of high—normal and low—normal tides, some reverse flow exist in the Bay because of the effects of topography. But there is no definite reverse flow along the edge of the Bay.

During the period of low tide, large areas of intertidal area are exposed, and the water flow concentrated in the two deep courses in the central area of the Bay. Thus, during the period of increase tide, significant scrambling exist in intertidal areas around the Bay.

During the period of low tide, there is no definite distribution of highest velocity in the Bay, but the characters of increase and decrease tides is similar to the those of spring tide. The highest velocity can be found near Tim Bi Tsui, and it is similar to that in Black Point (about 0. 5m/s). During the period of low tide, since the weaken of inertial, the structure of reverse flow in the Bay is extreamly unclear, and the flow velocity in river mouth is low with little urbulance. This means that it is very difficult to bring the sediment from the Shenzhen River into the central part of the Bay by the water flow in the river mouth. Therefore, more sediment deposit in river mouth areas during low tide period.

During low tide period, the expose of intertidal is not as significant as that during the high tide period, but the tide flow structure in intertidal areas is similar to that during the high tide period. During this time, the flow velocity in Chi Wan — She Kou is low and more sediment may be deposited in this area.

The situation of average tide is between the high tide and low tide, the highest velocity of increase tide is 0. 6m/s and the highest velocity of decrease tide is 0. 75m/s. The velocity in the river mouth area is also high (about 0. 55m/s). Besides, short term reverse flow can be found in part of the Bay during the average tide.

APPENDIX 7.2 SEDIMENT TRANSPORT MODELLING

7.2.1 Introduction

The principal purpose of the modelling is to study the sediment erosion and deposition in Shenzhen River and Deep Bay, especially in the areas of Futian, Mai Po and the inter—tital mud flats at the mouth of Shenzhen River.

The concern is primarily for the long term impact of the changes in the depositional environment resulting from the regulation works and any future maintenance dredging.

7.2.2.1 Basic Equations

The proposed 1—D sediment model is constituted with the unsteady flow model and the none-quilibrium transport model of suspended model without considering the bed load due to the paucity of primary data. The basic equations are as follows.
The proposed 1-D model is consitituted with the unsteady flow model. The basic equations read:
Continuity equation for flow

$$\frac{\partial Z}{\partial t} + \frac{1}{B}\frac{\partial Q}{\partial x} = 0 \qquad (A7.50)$$

Momentum equation for flow

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}(\frac{Q^2}{A}) + gA(\frac{\partial z}{\partial x} + \frac{Q|Q|}{k^2}) = 0 \qquad (A7.51)$$

Continuity equation for suspended sediment

$$\frac{\partial (Qs)}{\partial x} + \frac{\partial (As)}{\partial t} = -\alpha\omega B(s - s_*) \qquad (A7.52)$$

Sediment-laden capacity

$$s_* = k(\frac{u^3}{gh\omega})^m \qquad (A7.53)$$

Bed deformation equation

$$\rho' \frac{\partial z_0}{\partial t} = \alpha\omega(s - s_*) \qquad (A7.54)$$

in which s_*, sediment-laden capacity; ω, settling velocity of sediment particles; z_0, average bed elevation; ρ', dry specific gravity of sediment; α, sediment saturation recovery coefficient; k and m, coefficient and exponential index in Eq. (A7. 54).

7. 2 . 2. 2 **Computation Scheme**

The computation scheme for flow is the same as indicated in Appendix 7. 1.

Sediment continuity equation (A7. 54) and bed deformation equation (A7. 52) are written as follows in accordance with the finite—difference scheme, that is .

$$s_j^{n+1} = \frac{\triangle t \alpha_j^{n+1} \beta_j^{n+1} \omega_j^{n+1} s_{*j}^{n+1} + A_j^n s_j^n + \frac{\triangle t}{\triangle x_{j-1}} Q_{j-1}^{n+1} s_{j-1}^{n+1}}{A_j^{n+1} + \triangle t \alpha_j^{n+1} B_j^{n+1} \omega_j^{n+1} + \frac{\triangle t}{\triangle x_{j-1}} Q_j^{n+1}} \quad Q \geqslant 0 \qquad (A7.55)$$

$$s_j^{n+1} = \frac{\triangle t \alpha_j^{n+1} \beta_j^{n+1} \omega_j^{n+1} s_{*j}^{n+1} + A_j^n s_j^n - \frac{\triangle t}{\triangle x_j} Q_{j+1}^{n+1} s_{j+1}^{n+1}}{A_j^{n+1} + \triangle t \alpha_j^{n+1} B_j^{n+1} \omega_j^{n+1} - \frac{\triangle t}{\triangle x_j} Q_{j+1}^{n+1}} \quad Q > o \qquad (A7.56)$$

Correspondingly, the bed deformation equation is changed to

$$\triangle z_0 = \frac{\triangle t}{\rho'} [\alpha_j^{n+1} \omega_j^{n+1} (s_j^{n+1} - S_{*j}^{n+1})] \qquad (A7.57)$$

All the calculations in the 1-D model are based on the equations mentioned above. the scheme is shown in Fig. A7—35.

7. 2 . 2. 3 **Basic Requirements of the Model**

1. Estimation of the Sediment Volume Entering the Shenzhen River

There are few available data on sediment yield for the entire Shenzhen River catchment. In addition, dramatic recent changes in the natural geographic conditions of the catchment in Shenzhen make it even more difficult to estimate the sediment yield. The following calculation was carried out primarily based on the limited data which were specially collected for this study.

The data available for estimation of sediment yield included sediment yield records from Hong Kong and monitoring data on suspended solids (SS) in Shenzhen River. The former were drawn from BMP (Basin Management Planning, Hong Kong) reports in which sediment yield in three small basins (Basins 10, 11, and 12) were given in Table. A7—6. The latter database is from regular monitoring of SS in Shenzhen River and its tributaries since 1985. The statistical results are listed in Table A7—7 and shown in Figures A7—36 to A7—39.

Table A7—6 Sediment yield in basins of Shenzhen River

Basin	Basin10	Basin11	Basin12	Total
A(m^3/yr.)	4000	11300	3300	18600
B(m^3/yr.)	400	5650	2310	8360
B/A	10%	50%	70%	44.9%

Note: A, sediment yield in the basin; B, sediment volume entering the river.

Table A7—7 Measured results of suspended solids along the river(mg/l)

Station	Jindu	Buji estuary	Zhuanmato	estuary	Yumin village
85—86 average	9.9	26.8	87.9	95.9	
87—92 average	4.6	106.1	215.3	269.3	133.6
85—92 average	5.9	78.6	183.9	225.9	

Using available data, the sediment yield in the total catchment of Shenzhen River may be estimated if the following assumptions are made:

a)The behaviours of sediment erosion in the sub—catchment of Sherzhen River on both sides were very similar before the Shenzhen Special Economic Zone was developed, therefore, sediment erosion models on both sides of the border can be considered equivalent during that period; b) Sediment erosion patterns on Hong Kong side changed little after 1986 as compared with those before 1986. However, those on Shenzhen side changed drastically due to urbanization. Changes on Shenzhen side can be estimated based on variation of SS in Shenzhen River.

Sediment erosion modulu of the basins may be obtained directly from their sediment yields divided by the basin areas. According to assumption(a) above, the sediment erosion modulu, M, for the total catchment of Shenzhen River before 1986 is:

$$M = M_L = 149.64 m^3/yr\ km^2$$

where M_L is the sediment erosion modula on the left side of the river.

The results shown in Table A7—7 indicate that the average value of SS between 1987—92 was larger than that between 1985—86. The primary contributor to the increase in SS was the Buji River (Table A7—7). A 2.66—fold modula increase for the drainage area on Shenzhen side obtained for the period after 1986 by the ratio of SS averase values during 87—92 and 86—86 in Buji estuary. That is, the sediment erosion modula on the right side of the river, M_R, is:

$$M_R = 547.8 m^3/yr\ km^2$$

Note that ML remains the same according to assumption (b) above. The average modula of the entire catchment of Shenzhen River (M) after 1986 becomes:

$$M = 389.06\ m^3/yr\ km^2$$

This approaches 2.6 times the pre—1986 modulus, and corresponds closely with increases in SS over the same time period in Shenzhen River estuary as documented by monitoring data.

Assuming that half of the sediment volume yielded in the entire Shenzhen River catchment enters the River, then the sediment volume in the River may be given as shown in Table A7—8.

Table A7—8 The total sediment yield in the entire catchment and the sediment volume in Shenzhen River (in m^3/yr)

Period	Sediment yield	Sediment in river
before 1986	46657	23329
after 1986	121310	60655

Furthermore, the sediment distribution in different junctions between shenzhen River and its tributaries can also be given in terms of the production of sediment erosion modulas and basin areas as shown in Table A7—9

Table A7—9 Sediment distribution along Shenzhen River (m^3/yr)

Sta. / Q_s (m^3) Yr.	Sancha River	Shangshui River	Buji River	Futian River	Huanggang River	Total
before 1986	8751	5777	5631	1378	1792	23329
after 1986	24132	5777	19667	4812	6267	60655

The sediment contribution from Futian and Huang Gang Rivers is relatively small and can be neglected in the calculation. The total contributed by San Cha, Shang Shui, and Buji Rivers. The sediment distribution along Shenzhen River after the adjustment is shown in Table A7—10.

Table A7—10 Sediment distribution along Shenzhen River after adjustment (m^3/yr)

Sta. / Q_s (m^3) Yr.	Sancha River	Shangshui River	Buji River	Total
before 1986	10403	5777	7149	23329
after 1986	29881	5777	24997	60655
after 1986 +50% Q_s	44820	8666	37496	90982

Values in the bottom line of Table A7—10 represent the alternative in which the sediment volume is 1.5 times that after 1986. This treatment may be useful for sensitive analysis of the incoming sediment volume or River aggradation or degradation.

Since there is no typical flow and sediment hydrograph from measurements in Shenzhen River a simple method was used here to estimate the sediment hydrograph. Note that sediment in the River is greatest during flood periods. The total annual sediment volume entering the River may be assumed to concentrate in one flood with P=100% (see Fig. A7—40). The widely used empirical relationship between the sediment hydrograph and the flow hydrograph is expressed as $S=KQ^{\alpha}$ where S is the sediment concentration in kg/m^3; Q, discharge in m^3/sec; K, a coefficient determined by the total sediment volume; α exponent index (usually 2.5 for rivers). The treatment of α equal to 2.5 is relatively conservative. The sediment hydrograpg corresponding to this condition is tall and thin. Different sediment hydrographs at junctions as shown in Table A7—10 are shown in Figures A7—41 to A7—43.

2. Basic Requirements

Since it is difficult to get enough data to calibrate the sediment transport formula, the best way in such a case is to introduce the formula of sediment-laden capacity which is already verified in the rivers with the similar behaviours to Shenzhen River. One of the choices is to use the relations suggested for Pear Rver (Ye et al, 1986), which state

$$S_* = K_e(\frac{U^3}{gH\omega})^{0.603} \quad for\ decreasing\ tide \qquad (A7-58)$$

$$S_* = K_f S_e(\frac{U^3}{gH\omega})^{0.104} \quad for\ increasing\ tide \qquad (A7-59)$$

Where S_e is the average concentration during the decreasing tide; K_e and K_f are coefficients to be determined from the measured data. In the present study, the average case of teh different seasons are considered, thus $K_e = 0.25$ and $K_f = 0.1$ are used. In addition, saturation recovery coefficient is

$$\alpha = 2.14 - 0.28lg(\frac{U^3}{gH\omega}) \qquad (A7-60)$$

when $U^3/gH\omega \leqslant 0.1$, $\alpha=2.8$.

7.2.2.4 Calibration and Prediction of the Model

The modelling results are tested by the data of erosion or deposition in the channel during 1981 and 1985. The corresponding flood frequency is P=100%. The predicted results of annual sediment erosion and deposition is listed in Table A7—11. In addition, the predicated results of sediment erosion and deposition during flood and different tides are also given in Table A7—12 and A7—13 in greater details.

Table A7—11 Annual variation of sediment erosion or deposition (predicted)

Annual variation	Flood (P=100%)	7—11 tide	12—1 tide	2—6 tide	Total
Sediment variation (m^3)	14260	—14930	—5668	—13060	—19398

Table A7—12 Statistical results of sediment erosion or deposition during flood

P=100%flood	$W_i(m^3)$	$W_o(m^3)$	$\triangle W(m^3)$
before 1986	23329	9066	14263
after 1986	60655	14036	46619
after Realignment	60655	28008	32647
after Realignment +50%S	90982	39811	51171

Note: W_i is the sediment volume entering into Shenzhen River;
W_o is the sediment volume entering Deep Bay from the river; $\triangle W=W_i-W_o$

Table A7—13 Statistical results of erosion and deposition due to the tide flow

84.7 tide	$W_i(m^3)$	$W_o(m^3)$	$\triangle W(m^3)$
Present	3650	6199	—2549
Construction	3650+3400	6844	206
Operation	3869	6617	—2748

7.2.3 2—D Sediment Transport Model for Deep Bay

7.2.3.1 Basic Equations

This model is capable of dealing with nonunifrom sediment. The sediment may be decomposed into N_0 groups, in each group sediment is taken as uniform. The sediment concentration for the nth group. for instance, is governed by the nonequilibrium transport equation

$$\frac{\partial S_n}{\partial t}+\frac{\partial uS_n}{\partial x}+\frac{\partial vS_n}{\partial y}=\alpha_n\omega_n\frac{S_n-\Phi_n}{H}+\frac{\partial}{\partial x}K_x\frac{\partial S_n}{\partial x}+\frac{\partial}{\partial_y}K_Y\frac{\partial S_n}{\partial y} \qquad (A7.61)$$

Where K_X and K_Y are diffusion coefficients of sediment in x and y directions, respectively; Φ_n, erosion function for group n. The erosion function reflects the integrated influence of flow, bed material distribution and the upstream incomeing sediment on the nth group sediment. Φ_n is expressed as

$$\Phi_n=P_{bn}S_n^*+(1-P_{bn})Min(S_n,S_n^*) \qquad (A7.62)$$

Where S_n^* is the transport capacity for sediment in nth group; P_{bn}, fraction of group n in terms in the bed material in the top layer; ω_n, settling velocity of sediment in group n; and α_n, recovering coefficient which is evaluated by a relation of

$$\alpha_n = \frac{R_n^4(R_n + 6)}{p_0(R_n + 6)R_n^3 - 12R_n(R_n + 3)(R_n - 2\theta_n - 0.25R_n^3) + 12(6\theta_n - 3 + R_n^2 - 0.2R_n^4)(R_n + 2)} \tag{A7.63}$$

where

$$\theta_n = 1 - \frac{(1-e^{-R_n})}{R_n}, p_n = \begin{cases} 1 & S_n > \Phi_n \\ e^{-R_n} & S_n \leqslant \Phi_n \end{cases}$$

$R_n = \frac{6\omega_n}{\kappa u_*}$ herin is the Rouse number and κ, the von Karmann universal constant; and u_*, friction velocity.

The equation of bed deformation due to nonumiform sediment erosion or deposition is obtained from the theorum of the solid mass conservation

$$\frac{\partial \eta}{\partial t} = \sum_{n=1}^{N_0} \alpha_n \omega_n \frac{S_n - \Phi_n}{\gamma_{sn}} \tag{A7.64}$$

where η is the depth of bed deformation (η< 0 for erosion) and γ_{sn} is the dry unit weight. In Eq (A7. 62), S_n^* is proportional S^*, which is the transport capacity of flow corresponding to the mean size of sediment, i. e.,

$$S_n^* = P_n^* S^* \tag{A7.65}$$

where P_n^* is the percentage of concentration of group n under equilibrium condition; ω_m, mean settling velocity of the sediment, which is evaluated by

$$\omega_m = (\sum_{n=1}^{N_0} P_n^* \omega_n^{m_0})^{\frac{1}{m_0}} \tag{A7.66}$$

According to the widely used formula in China, S^* may be well predicted by

$$S^* = K_s(\frac{U^3}{gH\omega_m})^{m_0} \tag{A7.67}$$

where K_s and m_0 are empirical constants. The percentage of concentration P_n^* in Eq. (A7. 65) is expressed as

$$P_n^* = a_n P_{bn} / \sum_{n=1}^{N_0} a_n P_{bn} \qquad (n = 1,2,\cdots\cdots N_0) \tag{A7.68}$$

in which

$$a_n = (1 - A_n)\frac{1 - e^{-R_n}}{\omega_n}, A_n = \frac{\omega_n}{\frac{u_*}{\sqrt{2\pi}}e^{-\frac{\omega_n^2}{2u_*^2}} + \omega_n\psi(\frac{\omega_n}{u_*})}, \psi(x) = \int_{-\infty}^{x}\frac{1}{\sqrt{2\pi}}e^{-\frac{t^2}{2}}dt$$

In the process of nonuniform sediment transport, the bed material is unceasingly alternating itself and it has to be known before computations of every time steps. It is easy when all groups of sediment are in deposition, but it would be rather complicated if some groups of sediment are eroded from the bed. In the present study, a potential depth is used, which is proportional to the actual erosion depth during the former time step, or $\triangle_b = \beta\alpha_e$, where β ranges from 2.0 to 2.5. The bed materil distribution is then computed with

$$P_{bn} = \frac{P_{bn}^0\triangle_b + \delta_n}{\triangle_b + \delta_d - \delta_e} \qquad (A7.69)$$

in which, $\alpha_d = \sum_{\delta_n > 0}\delta_n, \delta_e = -\sum_{\delta_n < 0}\delta_n$ For most of the practical cases, lateral erosion should also be considered. A simple relation is suggested for the evaluation of the lateral erosion rate

$$\frac{d\triangle}{dt} = \frac{\Psi}{\gamma_s\gamma^2}(\tau - \tau_c)\tau \qquad (A7.70)$$

where $\triangle$ is the width being washed away; τ, the tangent shear force of the flow acting on the wall; and τ_c, the incipient shear force. In practical computations, the laterally eroded material is assumed to be stacked on the closeast grid which is under the water surface and may be washed away in the next step.

7.2.3.2 Computation Scheme

By appling the split-operator method, the basic equation for suspended sediment may be split into two sets of component equations, i.e.,

$$\frac{\partial S_n}{\partial t} + \frac{\partial uS_n}{\partial x} + \frac{\partial vS_n}{\partial y} = 0 \qquad (A7.71)$$

For this step only inflow sediment concentration is needed as boundary condition and the concentration of the previous time step is taken as initial condition.

$$\frac{\partial S_n}{\partial t} = \frac{\partial}{\partial x}K_x\frac{\partial S_n}{\partial x} + \frac{\partial}{\partial y}K_y\frac{\partial S_n}{\partial y} \qquad (A7.72)$$

The initial state for this step is given by the results of i) and the land boundary condition is $\frac{\partial S_n}{\partial n} = 0$

$$\frac{\partial S_n}{\partial t} = -a_n\omega_n\frac{S_n - \Phi_n}{H} \qquad (A7.73)$$

Characteristic coordinates scheme is adopted to decomposite eq. (A7. 71). As a result, it is transformed into

$$\frac{\partial S_n}{\partial t} + \frac{\partial u_\xi S_n}{\partial \xi} + \frac{\partial u_\eta S_n}{\partial \eta} = 0 \qquad (A7.74)$$

By droping the term $\frac{\partial u_n S_n}{\partial \eta}$, representing the mass around point P, the finite difference equation yields

$$S_n = S_n^0 + \frac{\triangle T_s}{\triangle l}(U_p S_n - U_{M\xi} S_{nM}) \qquad (A7.75)$$

The subcripts A, B, C, D, P and M denote the points shown in Fig. A7—54. In eq. (A7. 67), $\triangle l$, U_p, $U_{m\xi}$ are defined, respectively

$$\triangle l = M\bar{P}, U_p = \sqrt{u_p + V_p}, U_{M\xi} = \sqrt{u_M + V_m} cos\gamma \qquad (A7.76)$$

As for the equation (A7. 73), a simple solution is avaialble.

$$S_n = \Phi_n(1 - e^{\frac{-a_n \omega_n \triangle T_n}{H}}) + S_n^0 e^{-\frac{a_n \omega_n \triangle T_n}{H}} \qquad (A7.77)$$

7.2.3.3 Basic Requirements of the Model

The topographic data used here is the same as those described in Appendix 7. 1. The time step is taken as 80 seconds.

The time interval in 2—D model is 80 seconds. The topographic data needed in the calculation is the same to those in section 7. 1.

For suspended sediment, the boundary condition is given according to the measured average content of sediment in relevant season in the outlet of the Bay in the period of increaseing tide, and the content of suspended sediment in the period of decreaseing tide in river mouth is offered by 1—D calculation. The average time needed for one calculation is about 72 hours. The velocity, water level and sediment content for the first day are not chosen as the formal results because of the effects of initial settings. Similarly, the first two days' result of deposition and erosion of sediment also not chosen as formal results.

In the period of decreaseing tide, the content of sediment in river mouth are given by 1—D model. The content of sediment in the water entered Deep Bay from Shenzhen River is also absolutely controlled by the erosion of river catchment in the flooding period. Fig. A7—29 shows the process of sediment transport into the river mouth. The sediment content in flooding period is presented in Fig. A7—55(a), and the process of flow discharge entering the river mouth is presented in Fig. A7—55(b). The sediment content in the outlet of the Bay would be decided based on three circumstances:

a) Flood period. It is assumed that the content of sediment came from Pearl River is high, the content of sediment in the outlet of the Bay is affected by Ling Ding Sea, and is chosen as 0.1kg/m3.

b) Wet season. According to the data offered by Binnie (Fig. A7—56), the average content in the outlet of the Bay is between 0.045—0.075kg/m3. Thus, 0.06kg/m3 is taken as the boundary condition of the calculation.

c) Dry season. According to Fig. A7—56, the content of sediment is selected as 0.03kg/m3.

The see bed of Deep Bay is very complicated. Sand and shell can be found in it, and the distribution is also complicated. In our calculation, as a kind of approximate, the grain size distribution curve (Fig. A7—57) offered by Binnie is used. Because of the difficulties of suspended and transport of sand, only the sediment with grain size less than 0.063mm is chosen in the calculation, for which the average deposit velocity is low (about 2×10^{-6}m/s). On the other hand, the extreme fine part of sediment may exert flocuration when the velocity is low, and the velocity of deposition may be increase significantly (may be add to 6×10^{-5}m/s). Therefore, as a average situation, $\omega=6.2\times10^{-5}$m/s is selected as the deposition speed of suspended sediment. The sediment is taken as evenly distributed because of the lack of suspended sediment grain size distribution data.

The sediment carrying ability coefficient k and m is taken as the same to Han Qiwei Model in this study, and a series of tests are taken for different situation (m=0.92, k=0.247). Considering the suspended sediment only take a small part in river bed sediment in Deep Bay, and the body of shell and flocuration would affect the coefficient of sediment carrying ability, the coefficient k is express as:

$$k' = p_b k$$

Where P_b is the percentage of suspended sediment in bed material. After the alignment, the content of suspended sediment obtained from the calculation is compared with SS data from environmental monitoring as well as those in Fig. A7—56. The results showed that it is within the range of the existing data.

7.2.3.4 Verification and Prediction

Considering the effects of tide, season, flood and the perform of Stage I works on sediment deposition and erosion, totally 21 runs are carried out in the calculation. Run1—Run9 represent the situation of flood period, and Run10—Run21 represent the current normal situation and in and after Stage I works. In order to check the effects of input increase of sediment on Deep Bay from river catchment, Run3, Run6 and Run9 is calculated separetly two cases including 1)after Stage I works, 2)after stage I works with increase 50% of catchment sediment input, which can be considered as the result of sensitivity analysis. Besides, it is assumed that the work would be stopped in the flooding period, and no calculation for this stage is performed.

In Table A7—14, the volume of sediment taken from Shenzhen River to Deep Bay is listed. From the table, we can see that for one year return period, the volume of sediment taken from Shenzhen River to Deep Bay varied significantly. Before the Stage 1 works, the total volume of sediment taken to the Bay by a flood is 14800m^3. After the works, because of the erosion of upstream in flood period, the volume of sediment taken into Deep Bay is 29700m^3, is as much as 2 folds as those before the works. It must be pointed out that the period of "After the works" means the short period in which the Stage I works is just been finished. With time lapes, the erosion in upstream will get to a new equilibrium, and the sediment taken into the Bay would decrease because of the Amoring of the bed material, toward the situation before the works. Besides, during the Stage 1 works of average season, since the intake of sediment of the dredge works, the peak content of sediment taken into the Bay exist. The volume of sediment in two days would be as high as 1000m^3.

Table A7—14 Sediment entering Deep Bay during 2 days

		High tide		average tide		low tide	
		combin ations	sediment (m^3)	combin ations	sediment (m^3)	combin ations	sediment (m^3)
F	berore works	Run1	14846(0.1)	Run4	14846(0.1)	Run7	14846(0.1)
	after works	Run2	29700(0.1)	Run5	29700(0.1)	Run8	29700(0.1)
	after works +50%S	Run3	42300(0.1)	Run6	42300(0.1)	Run8	42300(0.1)
A	before works (Wet season)	Run10	916(0.06)	Run14	511(0.06)	Run18	320(0.06)
	before works (Dry season)	Run11	842(0.03)	Run15	500(0.03)	Run19	305(0.03)
	Druing works	Run12	969(0.06)	Run16	540(0.06)	Run20	351(0.06)
	after works	Run13	1012(0.06)	Run17	569(0.06)	Run21	351(0.06)

Note: the values in the parentheses are concentration (in kg/m^3) in the mouth of Deep Bay.
F stands for Flood Period, A for avaerage period.
The data in the () represent the contents of sediment in the outlet of the Bay (kg/m^3)

Table A7—15 Distribution of Sediment concentration and deposition thickness in Deep Bay(during 2 days)

	Estuary			Futian			Maipo			Middle Bay			Tim Bi Tsui			Mouth of the Bay		
	△η	Cmax	Cmean	△η	Cmax	Cmean	△η	Cmax	Cmean	△η	Cmax	Cmean	△η	Cmax	Cmean	△η	Cmax	Cmean
Run1	2. 8	3. 2	0. 40	0. 55	0. 24	0. 05	0. 45	0. 10	0. 03	0. 28	0. 7	0. 08	0. 14	0. 12	0. 04	0. 5	0. 1	0. 1
Run2	5. 7	5. 0	0. 80	0. 72	0. 26	0. 09	0. 49	0. 17	0. 04	0. 50	0. 9	0. 11	0. 18	0. 14	0. 08	0. 5	0. 1	0. 1
Run3	6. 8	7. 2	1. 3	1. 1	0. 60	0. 12	1. 03	0. 20	0. 06	0. 69	1. 4	0. 18	0. 22	0. 20	0. 09	0. 5	0. 1	0. 1
Run4	2. 9	3. 3	0. 45	0. 53	0. 23	0. 05	0. 4	0..15	0. 03	0. 2	0. 5	0. 05	0. 14	0. 12	0. 04	0. 62	0. 1	0. 1
Run5	5. 9	5. 2	0. 9	0. 70	0. 30	0. 11	0. 48	0. 16	0. 03	0. 44	0. 8	0. 06	0. 16	0. 16	0. 04	0. 62	0. 1	0. 1
Run6	7. 0	7. 2	1. 6	0. 96	0. 55	0. 12	0. 9	0. 19	0. 06	0. 54	1. 3	0. 1	0. 21	1. 75	0. 08	0. 62	0. 1	0. 1
Run7	3. 0	3. 3	0. 5	0. 5	0. 2	0. 04	0. 40	0. 11	0. 03	0. 08	0. 15	0. 03	0. 10	0. 11	0. 03	0. 75	0. 1	0. 1
Run8	6. 0	5. 2	1. 0	0. 6	0. 28	0. 10	0. 40	0. 12	0. 03	0. 1	0:20	0. 03	0. 10	0. 14	0. 035	0. 75	0. 1	0. 1
Run9	7. 4	7. 2	1. 9	0. 98	0. 50	0. 12	0. 45	0. 14	0. 03	0. 10	0. 21	0. 03	0. 13	0. 16	0. 035	0. 75	0. 1	0. 1
Run10	0. 55	0. 32	0. 1	0. 15	0. 18	0. 04	0. 30	0. 18	0. 035	—0. 06 ~0. 09	0. 08	0. 05	—0. 3	0. 13	0. 045	—0. 05 ~0. 20	0. 065	0. 06
Run11	0. 55	0. 32	0. 09	0. 15	0. 18	0. 04	0. 30	0. 8	0. 035	—0. 07 ~0. 05	0. 075	0. 04	0. 3	0. 13	0. 04	—0. 28	0. 045	0. 035
Run12	0. 60	0. 36	0. 1	0. 16	0. 19	0. 04	0. 32	0. 19	0. 35	—0. 06 ~0. 09	0. 08	0. 06	—0. 3	0. 13	0. 045	—0. 05 ~0. 20	0. 065	0. 06
Run13	0. 00	0. 37	0. 1	0. 16	0. 18	0. 04	0. 32	0. 18	0. 035	—0. 07 ~0. 05	0. 075	0. 04	—0. 3	0. 13	0. 04	—0. 28	0. 045	0. 035
Run14	0. 51	0. 25	0. 075	0. 06	0. 1	0. 035	0. 07	0. 09	0. 03	—0. 07	0. 07	0. 03	—0. 08	0. 08	0. 03	0	0. 065	0. 06
Run15	0. 50	0. 20	0. 08	0. 06	0. 1	0. 035	0. 07	0. 09	0. 03	—0. 06	0. 06	0. 03	—0. 08	0. 08	0. 03	—0. 07	0. 035	0. 03
Run16	0. 52	0. 27	0. 08	0. 06	0. 1	0. 035	0. 07	0. 09	0. 03	—0. 07	0. 07	0. 03	—0. 08	0. 08	0. 03	0	0. 065	0. 06
Run17	0. 51	0. 26	0. 075	0. 06	0. 1	0. 035	0. 07	0. 09	0. 03	—0. 07	007	0. 03	—0. 08	0. 08	0. 03	0	0. 065	0. 06
Run18	0. 30	016	0. 06	0	0. 04	0. 02	0	0. 035	0. 01	0	0. 045	0. 02	—0. 05	0. 05	0. 02	0. 2	0. 065	0. 06
Run19	0. 3	0. 15	0. 06	0	0. 04	0. 02	0	0. 035	0. 01	0	0. 045	0. 02	—0. 05	0. 05	0. 02	0	0. 04	0. 03
Run20	0. 31	0. 17	0. 065	0	0. 04	0. 02	0	0. 035	0. 01	0	0. 045	0. 02	—0. 05	0. 05	0. 02	0. 2	0. 065	0. 06
Run21	0. 30	0. 16	0. 06	0	0. 04	0. 02	0	0. 035	0. 01	0	0. 045	0. 02	—0. 05	0. 05	0. 02	0. 2	0. 065	0. 06

In the table A7—15, $\triangle\eta$ is the thickness of erosion or depositon in mm, as $\triangle\eta < 0$, erosion occurs; C_{max} is the maximum concentration in kg/m^3; Cmean, the mean sediment concentratio in kg/m^3. Details are given in Table A7—15, from which we can see not only the deposition thickness at different locations, but also the maximum and average sediment concentrations after 2 days's flood under idfferent runs. Each run in the table represents one alternative which reflects the runoff, tide type and the stage of works. The predicted results in greater details are shown in Fig. A7—50 to A7—63, from which the distributions of sediment erosion and deposition thickness, average concentration and the maximum concentration can be found. As results, more analyses can be made for different requirements based on the given figures.

APPENDIX 7.3 1—D STEADY STATE WATER QUALITY MODEL

7.3.1 Introduction

The principal purpose of the present model is to study the time—averaged water quality of the Shenzhen River and Estuary over tidal cycles before and after the Stage I works.

For the assessment of the environmental impact of Shenzhen River training works, a 1-D estuary water quality model with BOD_5-DO coupling is applied to simulate and estimate the time-averaged water quality of Shenzhen River over tidal cycles. Then, single-component water quality models are used for the modeling and prediction of other contaminants such as TN, TP and heavy metals. In each of these 1-D models, finite-reach method is adopted to divide the 1-D estuary into reaches of finite length, so that for each reach the mass conservation principle can be applied to derive the water quality model acounting the hydrodynamic behavior of the river flow. This type of models has been widely applied to the planning and assessment of water quality and environmental impact. Descretization of Shenzhen River estuary region by using number of volumes of finite length are reqired in order to apply the 1- D steady state estuary finite- reach model of finite- reaches. An additional restrict condition for the model application is the assumption of water in each reach being well-mixed. According to the topographical, hydrological and geological data as well as the needs for the assessment of environmental impact of the training works of Shenzhen River, totally 10 reaches as shown in Fig. A7.64 are adopted to discretize the estuary region, with reach No. 1 to No. 6 for Shenzhen River and No. 8 to No. 10 for Deep Bay. In the Fig. A7.64, the length of each reach and the locations of each tributary and the sewage-releasing works are shown. Shorter reaches are used for the middle part of Shenzhen River with the consideration of the facts that a greater concentration gradient is easily to occur in this region and that the inflows of tributaries including Shangshui Tributary and Buji Tributary often carry a great amount of contaminants into the region considered. Only 4 reaches are used for the part of Deep Bay due to several reasons. The first reason is that the concentration gradient is relatively small in the bay region; the second important reason is that flow recirculation causing currents in the transverse direction should be avoided with a simple 1-D model, so that the main stream of each reach could be kept as mornal to its upstream and downstream control-faces as possible. In addition, the water depth should not vary too much between two neighboring reaches.

7.3.2 Basic Equations

7.3.2.1 1-D Analytical Solution

If C represents the time-average concentration of contaminant over tidal cycles, then the 1-D estuary water quality model may be written as

$$D_x \frac{\partial^2 C}{\partial x^2} - \frac{\partial(u_x \cdot C)}{\partial x} + r + s = 0 \qquad (A7.78)$$

where r, decay rate of the contaminant; s, input rate of the contaminant into the system under consideration; D_z, streamwise dispersion coefficient; u_z, flow velocity(m/s); c, concentration of the contaminant(mg/l); x, distance from the starting cross-section.

For the case of no time-variation in cross-sectional area and fresh water runoff, O'Connor obtained, by assuming s=0 and r=-KC, the analytical solution of the 1-D model, as follows

$$\frac{C}{C_0} = exp(j_1 \cdot x) \tag{A7.79}$$

for x<0 (upstream of the releasing location) and

$$\frac{C}{C_0} = exp(j_2 \cdot x) \tag{A7.80}$$

for x>0 (downstream of the releasing location)
In (A7.79) and (A7.80),

$$j_1 = \frac{u_z}{2D_z}(1 + \sqrt{1 + \frac{4KD_z}{u_z^2}}) \tag{A7.81}$$

$$j_2 = \frac{u_z}{2D_z}(1- \sqrt{1 + \frac{4KD_z}{u_z^2}}) \tag{A7.82}$$

C_0, the contaminant concentration at x= 0, may calculated by the following formula

$$C_0 = W/(Q \sqrt{1 + \frac{4KD_z}{u_z^2}}) \tag{A7.83}$$

where W, amount of contaminant discharge per unit time; Q, time-averaged fresh water runoff. The streamwise dispersion coefficient may be estimated by the following empirical formula

$$D_z = 63nu_m R^{5/6} \tag{A7.84}$$

where n, Manning's roughness coefficient; u_M, velocity of the primary tide; R, hydaulic radius of the estuary cross-section.

The dispersion coefficent of the estuary is obtained by measuring, at a downstream location, the time variation of the concentration of the tracer that is released instantly into the river flow. For the case of salt-water intrusion, salt of the sea water may be used as the tracer. In this situation, the mass variation of the salt follows the conservation principle, and if r=0 and s=0 could be assumed, then the analytical solution of (A7.78) becomes

$$ln\frac{C}{C_0} = \frac{u_z}{D_z} \cdot x \tag{A7.85}$$

where x is the distance measured towards the upstream, and $x<0$. Hence, the dispersion coefficient

$$D_x = xu_x/(lnC - lnC_0) \qquad (A7.86)$$

In the present study, two methods are adopted to estimate D_x, by using empirical formula and by using salt-tracer for estimation, so that the results can be verified by each other.

7.3.2.2 BOD-DO Coupled Model

For the 1-D steady state problem, the governing equation for oxygen deficit (D) may be written as

$$D_x \frac{\partial^2 D}{\partial x^2} - u_x \frac{\partial D}{\partial x} - Ka \cdot D + Kd \cdot L = 0 \qquad (A7.87)$$

If the boundry condition $D=0$ at $x=\pm\infty$ could be assumed, the solution of above equation can be obtained as

$$D = \frac{Kd \cdot W}{(Ka\text{-}Kd)Q}(A_1 - B_1) \qquad (A7.88)$$

for $x<0$ (upstream of the discharge point) and

$$D = \frac{Kd \cdot W}{(Ka\text{-}Kd)Q}(A_2 - B_2) \qquad (A7.89)$$

for $x>0$ (downstream of the discharge point)
where

$$A_1 = exp[\frac{u_x}{2D_x}(1 + j_3) \cdot x]/j_3 \qquad (A7.90)$$

$$A_2 = exp[\frac{u_x}{2D_x}(1 + j_4) \cdot x]/j_4 \qquad (A7.91)$$

$$B_1 = exp[\frac{u_x}{2D_x}(1 - j_3) \cdot x]/j_3 \qquad (A7.92)$$

$$B_2 = exp[\frac{u_x}{2D_x}(1 - j_4) \cdot x]/j_4 \qquad (A7.93)$$

$$j_3 = \sqrt{1 + \frac{4Kd \cdot D_x}{u_x^2}} \qquad j_4 = \sqrt{1 + \frac{4Ka \cdot D_x}{u_x^2}}$$

7.3.3 Computational Scheme

With the finite-reach model, a number of reaches of finite length being sequentially located in the stramwise direction are used in the replacement of the original continuous reach. For each of the finite reaches, water body is assumed being fully-mixed or being able to be described by a 0-D model, so that the entire estuary can be simulated by a 1-D model. With the finite reach-model, the modeled quantities, including the state variables and model parameters, represent the time average over tidal cycles, and the flow rate of the model is the net river runoff.

7.3.3.1 BOD Model

For any of the river reaches, the mass transport is related to three phenomena of convection, dispersion and material decay.

The amount of transport of the i-th reach due to convection is

$$Q_{i-1}L_{j-1} - Q_iL_j$$

where, net inflow and outflow of the i-th reach, respectively; L_{i-1}, L_i, BOD concentration of inflow and outflow of the ith reach, repectively; The contribution of dispersion effect to the mass variation of the i-th reach is

$$D_{j-1,i}A_{i-1,i}\frac{L_{i-1}-L_i}{\triangle x_{j-1,j}} - D_{j,i+1}A_{i,i+1}\frac{L_j-L_{j+1}}{\triangle x_{j,i+1}}$$

$$\triangle x_{ij} = \frac{1}{2}(\triangle x_i + \triangle x_j)$$

where D_{ij}, dispersion coefficient between the i-th and j-th reaches; A_{ij}, area of the interface between the i-th and j-th reaches; Δx_{ij}, distance between the centers of the i-th and j-th reaches. The BOD_5 dacay rate of the i-th reach is

$$V_i \cdot Kd_i \cdot L_i$$

where V_i, volume of the i-th reach; K_{di}, decay coefficient of BOD_5.
Hence, the mass balance for each reach may be written as

$$V_j\frac{dL_j}{dt} = Q_{i-1}\cdot L_{i-1} - Q_iL_j + D_{i-1,j}\cdot A_{j-1,i}\cdot\frac{L_{j-1,j}-L_j}{\triangle x_{j-1,i}} - D_{j,i+1}\cdot A_{j,i+1}\frac{L_i-L_{j+1}}{\triangle x_{j,i+1}} - V_iKd_j\cdot L_j + W_i^L \quad (A7.94)$$

If $D_{ij}=D_{ij}\cdot A_{ij}/\Delta x_{ij}$ is used, then eq. (A7.94) may be rewritten as

$$V_i\frac{dL_j}{dt} = Q_{j-1}\cdot L_{i-1} - Q_i\cdot L_j + D'_{j-1,j}(L_{i-1}-L_j)$$

$$-D_{i,j+1}(L_i - L_{i+1}) - V_i Kd_i \cdot L_i + W_i^L \quad (A7.95)$$

In eqs. (A7. 94) and (A7. 95), W_j^L, inflow rate of BOD to the i-th reOach from outside.

If D_j stands for the the oxygen deficit of the i-th reach, then the related mass-balance equation becomes

$$V_i \frac{dD_i}{dt} = Q_{i-1} \cdot D_{j-1} - Q_i D_j + D'_{i-1,j}(D_{j-1} - D_j) - D'_{j,j+1}(D_j - D_{j+1}) + V_j Kd_j \cdot L_j - V_j K_{ai} D_i + W_j^D \quad (A7.96)$$

where K_{ai}, oxygen-recover coefficient; W_{iD}, input of oxygen deficit from outside.
The time-averaged state over tidal cycles may be considered as a steady state, that is, $dL_i/dt=0$. The BOD_5 distribution of the estuary may be calculated by applying eq. (A7. 95) and rewritting it in matrix form

$$G\vec{L} = \vec{W}^L \quad (A7.97)$$

where $\vec{L}$, a vector of n-components representing the BOD_5 values of all the reaches; $\vec{W}_L$, a vector of n-components representing the values of BOD_5 input to the reaches.

In eq. (A7. 97), the elements g_{ij} of n-dimensional matrix G at the i-th row and j-th colum are calculated by the following,

for $j=i$, $g_{ij}=Q_i+D'_{j-1,j}+D'_{i,j+1}+V_i Kd_j$
for $j=i-1$. $g_{ij}=-Q_{j-1}-D'_{j-1,j}$
for $j=i+1$, $g_{ij}=-D'_{j,j+1}$
and for the other elements, $g_{ij}=0$

If W_{iL}, the pollution source, are known, then it is not difficult to calculate the distribution of BOD_5 in the estuary region with

$$\vec{L} = G^{-1} \cdot \vec{W^L} \quad (A7.98)$$

7. 3 . 3. 2 **DO Model**

For the oxygen deficit, a similar equation in matrix form may written as

$$H\vec{D} = F\vec{L} + \vec{W^D} \quad (A7.99)$$

where $\vec{D}$, a vector of n-components representing the oxygen deficit of all the reaches; $\vec{W}_D$, a vector of n-components representing the values of oxygen deficit input to the reaches.

Both H and F are matrices of n-dimensions, and their elements may be obtained by using eqn. (A7. 97) ,

for $j=i, h_{ij}=Q_i+D'_{i-1,i}+D'_{i,j+1}+V_jK_{ai}$

for $j=i-1$, $h_{ij}=-Q_{i-1}-D'_{j-1,i}$
for $j=i+1$, $h_{ij}=-D'_{j,j+1}$

and for the other elements, $h_{ij}=0$; for $j=i$, $f_{ij}=V_iKd_i$, and the other elements of matrix F, $f_{ij}=0$.

The distribution of oxygen deficit in the estuary region may be obtained by sustituting (A7. 98) into (A7. 99) and finding the inverse of H,

$$\vec{D}=H^{-1}\cdot F\cdot G^{-1}\cdot\vec{W^L}+H^{-1}\cdot\vec{W^D} \qquad (A7.100)$$

Eqs. (A7. 98) to (A7. 100) are the set of governing equations of the steady-state BOD-DO coupling model for the time average over tidal cycles, which has a wide application to the simulation and prediction of water quality in the estuary region. The matrix G^{-1} of this model is called as BOD response matrix of a 1-D estuary, $H^{-1}\cdot F\cdot G^{-1}$ called as oxygen-deficit response matrix to BOD_5 of an estuary, and H^{-1} called as oxygen-deficit response matrix to oxygen-deficit input of an estuary.

7. 3 . 3. 3 **Upstream and Downstream Boundary Conditions**

The boundary conditions of the upstream and downstream estuary boundaries may calculated as the follows.

For the 1-st reach at the upstream end,

$$\begin{aligned}Q_1L_1+D'_{0,1}L_1+D'_{1,2}L_1-D'_{1,2}L_2+V_1Kd_1\cdot L_1\\=W_1^L+Q_0\cdot L_0-D'_{0,1}L_0\end{aligned} \qquad (A7.101)$$

and

$$\begin{aligned}Q_1D_1+D'_{0,1}D_1+D'_{1,2}D_1-D'_{1,2}D_2\text{-}V_1Kd_1\cdot L_1+V_1\cdot K_{a1}\cdot D_1\\=W_1^D+Q_0\cdot D_0-D'_{0,1}D_0\end{aligned} \qquad (A7.102)$$

hold. When the values of inflow rate Q_0, BOD_5 concentration L_0, oxygen deficit D'_0 and dispersion coefficient D'_0 are prescribed at the upstream end, source terms may be used to acount for the contributions of all the terms at the right-hand side of the above two equations, that is,

$$W_1^L:=W_1^L+Q_0L_0-D'_{0,1}\cdot L_0 \qquad (A7.103)$$

and

$$W_{1:}^{p} = W_{1}^{p} + Q_0 D_0 - D'_{0,1} \cdot D_0 \qquad (A7.104)$$

are the source terms for the upsteam 1-st reach.

For the last reach at the downstream end,

$$Q_{n-1}L_{n-1} - Q_n L_n + D'_{n-1,n}(L_{n-1} - L_n) - D'_{n,n+1}(L_n - L_{n+1}) - V_n K_{dn} L_n + W_n^L = 0 \qquad (A7.105)$$

and

$$Q_{n-1}D_{n-1} - Q_n D_n + D'_{n-1,n}(D_{n-1} - D_n) - D'_{n,n+1}(D_n - D_{n+1}) + V_n K_{dn} L_n - V_n K_{dn} D_n + W_n^L = 0 \qquad (A7.106)$$

hold.

It should be noticed that, two unknowns L_{n+1} and D_{n+1} need to be found for the last downstream reach. To solve this problem, two methods available may be applied.

i) In the outlet part of the estuary region, the water quality should be quite stable since the water body is close to the sea. In this case, L_{n+1} and D_{n+1} can be taken as given constants that could be acounted in the source term $W_{nL}W_{nL}$.

ii) If the last reach downstream is far away enough from the contaminant source, then the concentration gradient is approximately zero, or $L_{n+1}=L_n$ and $D_{n+1}=D_n$.

The determination of boundary conditions for the single-component models is the same as the BOD_5 model, its detailed description is dropped out here.

7.3.4 Basic Requirements

7.3.4.1 Input Information

The average water level over a tide cycle is calculated according to the measured water level hydrograph at each cross section in March, 1994.

$$H = \sum H(t_i)\triangle t_i / \sum \triangle t_i \qquad (A7.107)$$

in which:
$H(t_i)$—water level (m) at ti
$\triangle t_i$—time in terval
H—average water level (m)

Based on the relationship between average waterlevels and river widths over cross—section, the average river width over a tide cycle is derived by interpolation.

The width in the realignment reach of the river is derived based on design document, while other parts of the river channel are derived as before.

The average water depth connected with average width before the river channel realignment is derived based on the data of all cross sections in the river channel. The average water depth over a tide cycle of the realignment part after the realignment is determined by the design documents.

The cross section intervals are derived based on the map. The average flow discharge over tide cycle is designated based on the hydrograph of tide flow

$$Q = \sum Q(t_i)\triangle t_i / \sum \triangle t_i \qquad (A7-108)$$

in which
Q—average flow discharge over tide cycle
$Q(t_i)$—tide flow discharge at t_i
$\triangle t_i$—time interval

Table A7—18 shows the results of pollution sources monitoring in Shenzhen side offered by the Lead Consultant. In order to meet the need of the model, we generalized all pollutant outlet locations and the locations of tributaries into relevant cross sections (Table A7—17). In order to estimate the parameters, the concentrations of pollutants from each cross section are calculated according to the average value from the continuous monitoring:

$$C = 1/n \sum_{i=1}^{n} C_{ij} \qquad (A7-109)$$

in which
C_i—average concentration for i cross section
C_{ij}—j times monitoring concentrations for i cross section

Table A7—18 and A7—19 show data statistical results before and after the river channel realignment. The pollution sources in Hong Kong side offered by Lead Consultant (including Shang Shui River and Yuan Lang River) is also considered.

Table A7—16 Water Pollutant Sources in Shenzhen River and Deep Bay

Location	NO.	Q (m^3/s)	COD_{Mn} (mg/l)	BOD_5 (mg/l)	T—N (mg/l)	T—P (mg/l)	Col. (mil./l)	Cu (mg/l)	Pb (mg/l)	SS (mg/l)
Buji estuary	1	3.30	9.51	50.5	15.58	2.45	12.80	0.04	0.03	67.3
Ludan village I	2	0.07	26.47	190.0	29.76	5.27	21.00	0.01	0.03	214.6
Ludan village II	3	0.28	25.18	134.0	24.88	5.22	1160.0	0.13	0.03	106.0
Bin jiang	4	0.03	719.19	736.0	141.50	40.00	570.00	0.02	0.21	7748.0
Xia bu muao I	5	0.13	32.00	184.0	31.53	5.31	320.00	0.01	0.03	70.0
Xia bu muao II	6	0.10	29.35	124.0	21.25	3.44	401.00	0.01	0.03	96.7
Zhuan Ma To	7	0.11	15.59	75.4	30.48	4.73	64.80	0.01	0.03	42.9
Futian River	8	2.44	19.65	69.0	33.51	3.98	78.00	0.05	0.03	185.9
Huang Gang River	9	1.12	68.83	139.0	19.25	5.07	160.00	0.05	0.15	796.0
Xin Zhou River	10	0.86	45.53	142.0	38.79	4.63	287.00	0.14	0.03	72.0
Jinxou Zhonghua	11	0.18	56.88	204.0	30.44	4.96	4.00	0.02	0.03	156.0
Da Shahe	12	0.53	17.99	16.1	8.00	0.60	7.00	0.01	0.05	54.2
Ma Queling	13	0.05	36.98	55.8	18.02	2.36	520.00	0.56	0.03	38.0
Shenzhen Univ.	14	0.03	26.73	112.0	11.85	2.24	52.80	0.02	0.09	70.0
Bali Mei	15	0.02	31.82	59.0	26.29	2.49	2.00	13.00	0.08	69.2
Guang Jin	16	0.05	23.34	45.0	20.40	2.43	28.80	0.01	0.03	113.3
She Kou I	17	0.08	35.87	133.0	27.30	3.64	3.00	4.29	0.06	205.3
See world	18	0.30	14.12	11.4	15.14	0.84	13.10	0.27	0.08	85.3
Nanhai Hotol	19	0.26	24.81	16.0	5.91	0.64	7.00	0.06	0.32	33.8
Shekou II	20	0.10	15.96	10.0	3.00	0.96	9.00	0.05	0.33	19.5

Table A7—17 General view of the Pollutants outlets

Section No.	No. of pollutant outlet
Yumin village	1#
Buji estuary	2# 3# 4#
Futian	5# 6# 7# 8#
Yunong village	9#
Shenzhen estuary	10#
Yaying shan	11#
Shenzhen Univ.	12# 13# 14#
Shekou	14# 15# 16# 17# 18# 19#
Chiwan	20#

Table A7—18 Input data(before the realignment)

Location	NO.	L (m)	B (m)	H (m)	QL (m^3/s)	CODMn (mg/l)	BOD5 (mg/l)	TN (mg/l)	TP (mg/l)	Col.	Cu (mg/l)	Pb (mg/l)	SS (mg/l)	Q (m^3/s)	DO (mg/l)
Sancha River														0.74	
	1	394.5	22.98	8.79											
Luohu bridge					0.05	9.9	41.8	26.6	6.09	1.0×10^{6}	0.006	0.008	83		1.74
	2	828	36.31	1.24											
Yumin village					3.3	29.51	60.6	27.58	3.454	1.3×10^{7}	0.03	0.03	134.6	3.73	1.0
	3	1983	37.92	1.39											
Buji estuary					0.38	80.32	191.04	34.96	4.99	9.8×10^{6}	0.099	0.044	615.2		1.2
	4	2950	51.52	1.59											
Futian					2.78	20.42	76.61	24.08	4.05	1.0×10^{6}	0.045	0.03	178.8		8.9
	5	3298	61.27	1.85											
Yunong village					1.12	68.83	139	19.25	5.07	1.6×10^{6}	0.05	0.15	796	7.65	2.8
	6	3217	77.16	1.65											
Shenzhen estcary					1.025	45.53	150	30.0	4.16	2.9×10^{6}	6.14	0.03	94	16.17	2.45
	7	2952	2144	1.51											
Yayingshan					0.18	56.88	204	30.44	4.96	4.8×10^{6}	0.02	0.03	145		0.0
	8	6800	5900	1.70											
Shenzhen Univ.					8.61	19.98	24.87	8.01	8.82	5.1×10^{6}	0.06	0.05	53.65		0.0
	9	3875	6868	2.24											
Shekoushan					0.71	21.63	30.49	13.01	1.24	8.2×10^{7}	1.01	0.16	81.48		0.0
	10	5400	5450	3.89											
Chiwan					0.108	15.96	9.98	3.0	0.96	9.8×10^{6}	0.05	0.33	19.5		0.0

Note: L, length; B, width; H, dept; QL, input Volume

Table A7—19 Input data (After the realignment)

Location	No.	L (m)	B (m)	H (m)	QL (m^3/s)	CODMn (mg/l)	BOD5 (mg/l)	TN (mg/l)	TP (mg/l)	Col.	Cu (mg/l)	Pb (mg/l)	SS (mg/l)	Q (m^3/s)	DO (mg/l)
Sancha River														0.74	
	1	394.5	22.98	8.79											
Luohu bridge					0.05	9.9	41.8	26.6	6.09	1.0×10^{6}	0.006	0.008	83		1.74
	2	200	38.34	1.24											
Yumin village					3.3	29.51	60.6	27.58	3.454	1.3×10^{7}	0.03	0.03	234.6	3.73	1.0
	3	1038	43.96	4											
Buji estuary					0.38	80.32	191.04	34.96	4.99	9.8×10^{6}	0.099	0.044	615.2		1.2
	4	2953	51.52	1.59											
Futian					2.78	20.42	76.61	24.08	4.05	1.0×10^{6}	0.045	0.03	178.82		8.9
	5	1120	61.75	4											
Yunong village					1.12	68.83	139	19.25	5.07	1.6×10^{6}	0.05	0.15	796.0	7.65	2.0
	6	3219	77.16	1.65											
Shenzhen estcary					1.025	45.53	150	30.0	4.16	2.9×10^{6}	6.14	0.03	94.0	16.17	2.45
	7	2975	2144	1.52											
Yayingshan					0.18	56.88	204	30.44	4.96	4.8×10^{6}	0.02	0.03	145		0
	8	6800	5900	1.70											
Shenzhen Univ.					8.61	19.98	24.87	8.01	8.82	5.1×10^{6}	0.06	0.05	53.65		
	9	3875	6800	2.24											
Shekoushan					0.71	21.63	30.49	13.01	1.24	8.2×10^{7}	1.01	0.16	81.48		0
	10	5400	5450	3.89											
Chiwan					0.1	15.96	9.98	3.0	0.96	9.8×10^{6}	0.05	0.33	19.5		0

7.3.4.2 Parameter Estimation

Dispersive coefficient is estimated by Salinity Method

$$D_{xi} = X_i U_{xi} / (lnC_i - LnC_0)$$

in which:

D_{xi}—Dispersion coefficient in ith cross section (m^2/s)

X_i—The distance between tide mouse and i cross section (m)

U_{xi}—Average velocity in ith cross section (m/s)

C_i—Salinity in ith cross section (mg/l) from the modelling monitoring

C_0—Salinity in Bay Mouth (mg/l) from the modelling monitoring

Comprehensive Search Method is used in parameter estimation. The target function is selected as:

$$J_i(D_{xi}, K_{d_i}, K_{s_i}) = \sum_{j=1}^{i} [\lambda(L_{ij} - L'_{ij})^2 + (1-\lambda)(D_{ij} - D'_{ij})^2] \qquad (A7.110)$$

in which:

L_{ij}—Measured BOD_5

L'_{ij}—calculated BOD_5

D_{ij}—Measured DO

D'_{ij}—Calculated DO

λ—The weights of BOD_5 and DO

Table A7—20 Estimation of dispeersive coefficient

Section	Distance(m)	Velocity(m/s)	Sanility(mg/l)	$D_x(m^2/s)$
Sancha River	−24547.5	0.215	0.0044	888.7
Yumin village	−23325.0	0.145	0.0077	617.8
Yunong village	−15194.0	0.09	0.1474	563.3
Shenzhen estuary	−11975.0	0.087	0.5765	979.2
Chivan	0	/	1.67	/

Table A7—21 Estimation of parameter

Section NO.	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
Kd(1/d)	0.139	0.081	0.049	0.054	0.056	0.060	0.030	0.025	0.021	0.020
Ka(1/d)	2.56	1.723	0.821	0.324	0.471	0.097	0.090	0.090	1.009	1.01
$Dx(m^2/s)$	186	65.0	300	210	400	487	58	60	64	70

Table A7—22 Verificattion of the calculated results

parameter	Index	Section No.	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
estimated	BOD_5 (mg/l)	A	48.00	47.40	45.36	40.99	34.28	20.92	7.39	1.28	0.57	0.30
		B	/	63.95	/	/	46.79	26.81	1.57	0.89	/	
		E(%)	/	25.9	/	/	26.7	22.0	/	18.5	36	/
	DO (mg/l)	A	0.12	0.185	0.06	0.08	0.602	1.55	5.05	8.81	9.40	9.60
		B	/	0.19	/	/	0.72	1.17	/	7.95	8.24	/
		E(%)	/	2.6	/	/	16.4	−21.5	/	−10.8	−14.1	/
measured	BOD_5 (mg/l)	A	64.59	63.67	65.56	65.14	62.21	51.69	27.84	15.38	11.50	9.61
		B	/	25.9	/	/	46.79	26.81	/	1.57	0.89	/
		E(%)										
	DO (mg/l)	A	6.58	7.42	6.53	6.45	6.06	5.67	5.81	9.14	9.73	9.95
		B	/	0.19	/	/	0.72	1.17	/	7.95	8.24	/
		E(%)										

Note: A, calculated; B, measured; E, error.

Table A7—23 Decay coefficients for different pollutants(1/d)

No.	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
COD(mg/l)	0.04	0.04	0.06	0.06	0.06	0.05	0.04	0.04	0.04	0.04
TN(mg/l)	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02
TP(mg/l)	0.014	0.0174	0.0082	0.0082	0.008	0.0082	0.03	0.05	0.07	0.075
Col.	544.2	553.6	986.6	996.8	1288.4	2968.4	52238.3	62387.6	62379.8	62376.5
Cu(mg/l)	0.4	0.4	0.3	0.2	0.2	0.12	0.16	0.16	0.16	0.16
Pb(mg/l)	0.68	0.70	0.58	0.56	0.54	0.3	0.1	0.01	0.01	0.01

Table A7—24 Prediction of water quality in 2000 (after Realignment)

Index	section No.	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
COD (mg/l)	before	42.3	42.7	42.0	38.6	35.3	25.4	14.4	5.56	3.78	2.87
	after	35.6	35.7	34.7	32.9	29.0	25.5	14.5	5.58	3.79	2.88
TN (mg/l)	before	37.23	37.5	36.09	33.3	28.4	21.2	13.1	5.43	3.82	2.88
	after	31.1	31.1	29.9	28.4	23.7	21.3	13.1	5.43	3.28	2.88
TP (mg/l)	before	5.14	5.17	5.09	4.86	4.20	2.97	1.68	0.53	0.30	0.20
	after	4.34	4.34	4.22	4.07	3.40	2.98	1.68	0.53	0.30	0.20
Col.	before	$2.3x10^5$	$3.0x10^5$	$5.4x10^5$	$7.8x10^6$	$1.0x10^5$	$3.7x10^4$	10.9	12.6	3.01	$1.6x10^{-3}$
	after	$5.0x10^5$	$7.5x10^5$	$4.6x10^5$	$4.9x10^6$	$1.1x10^5$	$3.7x10^4$	10.9	12.6	3.01	$1.6x10^{-3}$
Cu (mg/l)	before	0.055	0.053	0.052	0.047	0.037	0.022	0.009	0.004	0.005	0.003
	after	0.044	0.042	0.040	0.038	0.028	0.023	0.009	0.004	0.005	0.003
Pb (mg/l)	before	0.037	0.037	0.036	0.036	0.035	0.024	0.014	0.011	0.011	0.0097
	after	0.033	0.033	0.032	0.031	0.030	0.025	0.014	0.010	0.011	0.0099

Table A7—25 Calculated results of pollutants before and after realignment

Index	section No.	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
COD (MG/L)	A	25.73	25.70	25.10	22.82	26.82	14.99	8.57	3.43	2.45	1.99
	B		27.30			23.84	16.25		2.46	2.33	
	C	21.42	21.34	20.65	19.45	17.12	15.09	8.62	3.45	2.46	2.00
TN (mg/l)	A	22.89	22.71	22.77	19.92	16.95	12.68	7.88	3.42	2.53	2.02
	B		23.78			21.78	15.00		1.99	2.26	
	C	18.90	18.76	17.95	16.98	14.18	12.70	7.88	3.42	2.53	2.02
TP (mg/l)	A	3.13	3.11	3.04	2.88	2.48	1.75	0.99	0.32	0.19	0.13
	B		3.20	3.31	2.51		0.251		0.25	0.18	
	C	2.61	2.59	2.51	2.41	2.01	1.78	0.99	0.32	0.19	0.13
Col.	A	$1.34x10^5$	$1.72x10^5$	$3.08x10^5$	$4.46x10^6$	$5.93x10^4$	$2.19x10^4$	6.22	7.19	1.72	9.24
	B		$1.86x10^5$			$6.12x10^4$	$2.30x10^4$		5.47	2.18	
	C	$2.86x10^5$	$4.32x10^5$	$2.65x10^5$	$2.82x10^6$	$6.42x10^4$	$2.11x10^4$	6.22	7.19	1.72	9.26
Cu (mg/l)	A	0.0382	0.0357	0.0388	0.0299	0.0235	0.014	$5.7x10^3$	$2.4x10^3$	$3.2x10^3$	$1.7x10^3$
	B		0.0335			0.0245	0.0125		0.0029	0.0031	
	C	0.0293	0.0279	0.0262	0.024	0.0178	0.0143	$5.9x10^3$	$2.5x10^3$	$3.2x10^3$	$1.7x10^3$
Pb (mg/l)	A	0.0217	0.022	0.0213	0.0209	0.0207	0.0143	$8.6x10^3$	$7.7x10^3$	$7.6x10^3$	$7.3x10^3$
	B		0.021			0.0174	0.0104		$5.9x10^3$	$7.3x10^3$	
	C	0.0195	0.020	0.0189	0.0184	0.0174	0.015	$8.9x10^3$	$7.9x10^3$	$7.7x10^3$	$7.4x10^3$

note: A represents for the calculated results (before realignment)

B represents for the measured results (before realignment)

C represents for the calculated results (after realignment)

After the search, the target function will arrive at

$$J_i((D_{si}*, K_{di}*, K_{si}*) = min \sum_{j=1}^{i} [\lambda(L_{ij} - L'_{ij})^2 + (1-\lambda)(D_{ij} - D'_{ij})^2] \quad (A7-111)$$

in which, Dxi * , Kdi * , Kai * are the results of estimation (Table7—6).

7. 4. 3 Verification and Prediction

Comparisons of the calculated results and the measured ones are listed in Table A7—22, Figure. A7—65 and Fig. A7—66. The relative errors are less than 26. 7 percent.

Table A7—23, Fig. 7—65 and Fig. A7—66 show the simulation results of Shenzhen River and Deep Bay under the current pollution level. From these table and figures, we can see that the realignment of the river channel is beneficial to water quality in Shenzhen River, but has no significant effects for the water quality in Deep Bay.

The planning year is taken as 2000. According to the pollution sources predication results, the pollutants in each pollutant outlet increase by 75%. From the results of predicated simulation (TableA7—24, Fig. A7—67 to Fig. A7—80), we can see that the water quality is getting worse significantly. The concentration of DO in all cross sections of the river is less than 0. 1 mg/l. Measures of pollution sources control and management must be taken to prevent these.

According to the experimental results by Hong Kong Public Works Lab in 1975,the particles with grain size less than 2μm is below 10% in the sample except clay which contains about 30% small particles. Since the grain size of resuspended particle should be less than 0. 45μm. the percentage of resuspended particle in the sample should be less than 5%. Thus the total amount of resuspended particle derived from the whole operational stage is 1750 tons. Since the dredge work will last about 0. 6 year, the velocity of resuspended particle is about 93g/s. Note that the average river flow discharge is approximately $10m^3/s$, The concentration of resuspended particles is 9. 3mg/l. It can be estimated that the net suspended sediment entering the Deep Bay caused by the dredging work is 9. 3mg/l, it takes only 5% of suspended sediment concentration in Deep Bay normally during operatonal period.

The serious pollution of Shenzhen River will result in the sediment Pollution. According to the data of bed variation during 1981—85, the lower reaches of Shenzhen River is eroded. For the upper reaches, deposition occurs and the major part of the deposited sediment are coarse materials and thus there is no significant increase of pollutant in flow due to the sediment release.

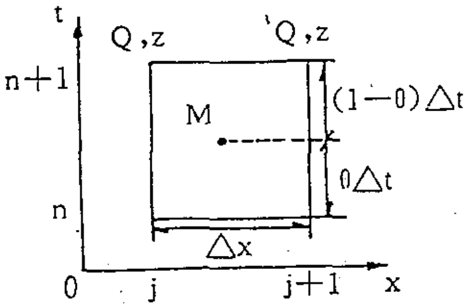


FIG. A7—1' Pressmann Scheme

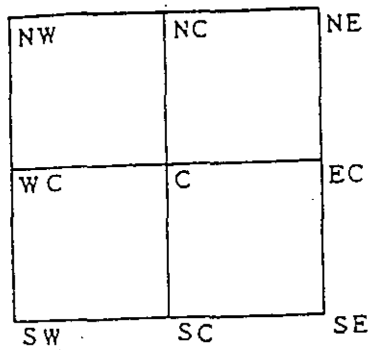


FIG. A7—24 Sketch of the computation scheme

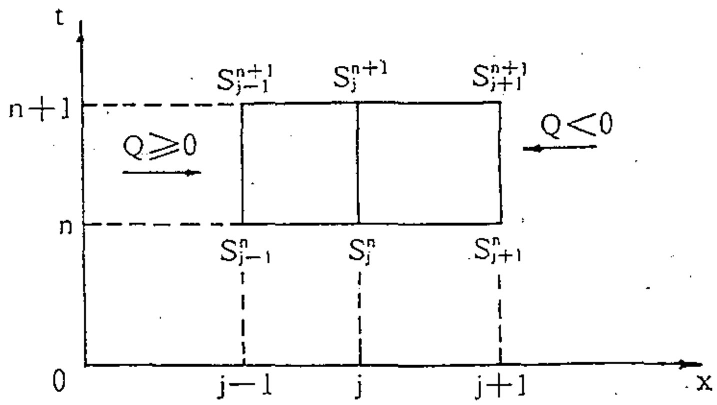


FIG. A7—35 Fi nite-difference scheme for sediment transport

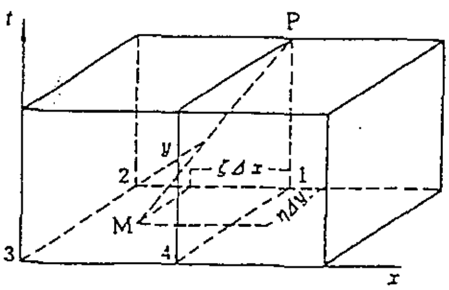


FIG. A7—25 Notation of the spatial Characteristics

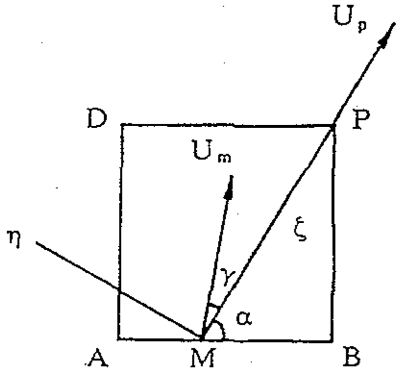


FIG. A7—54 Sketch of ten characteristic coordinate system

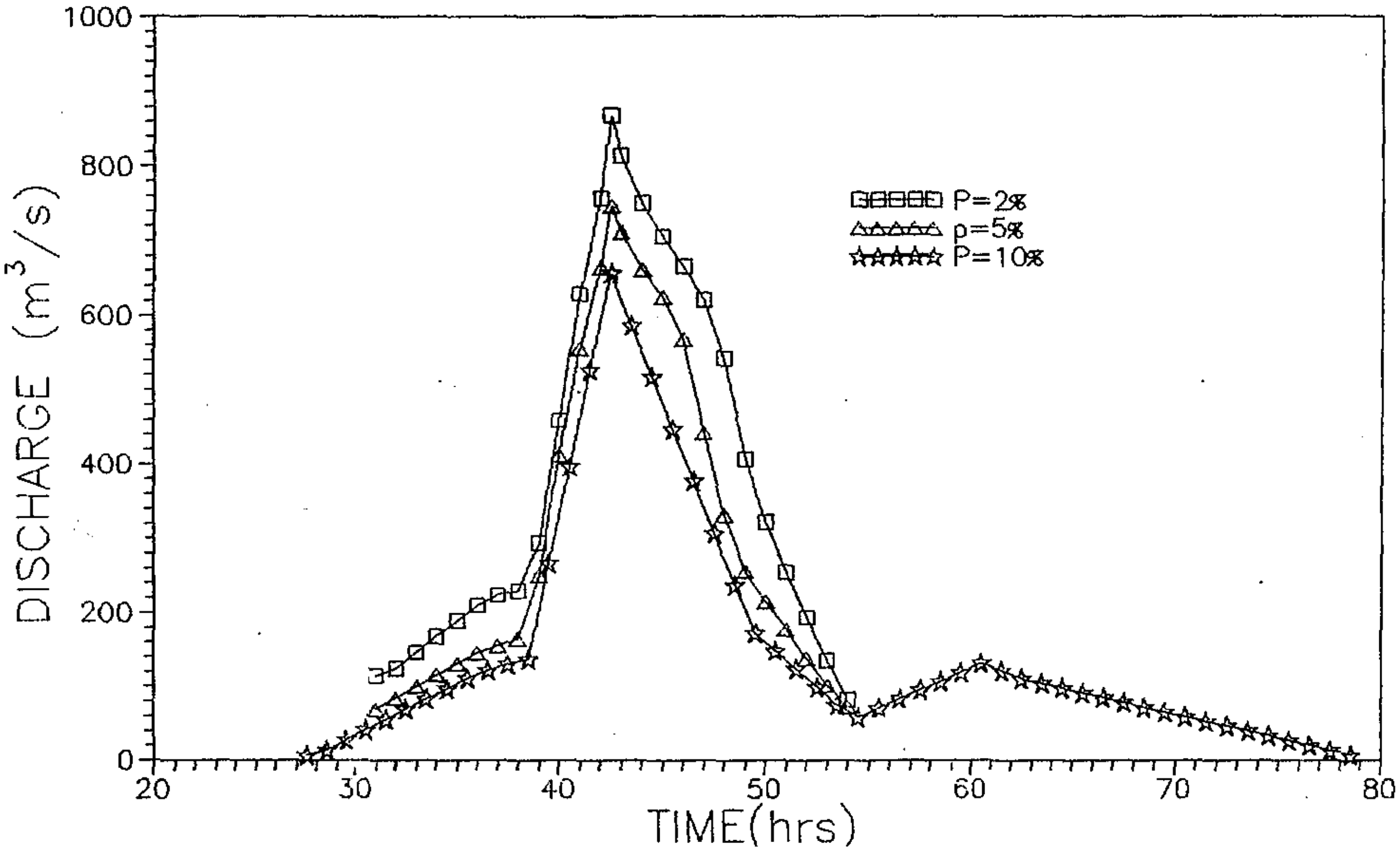


FIG. A7—2 Designed flood discharges in Sacha River

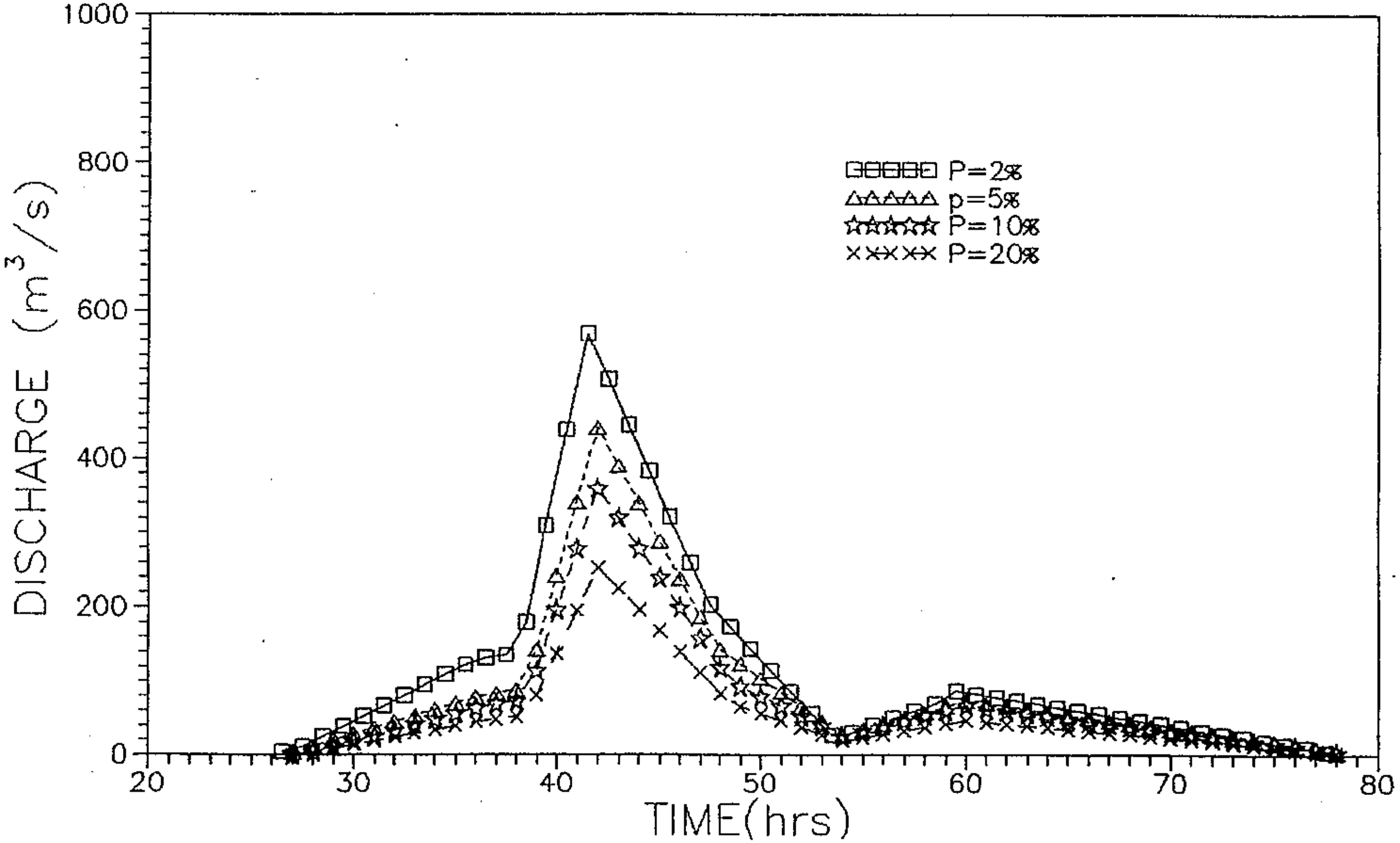


FIG. A7—3 Designed flood discharges in Shang Shui River

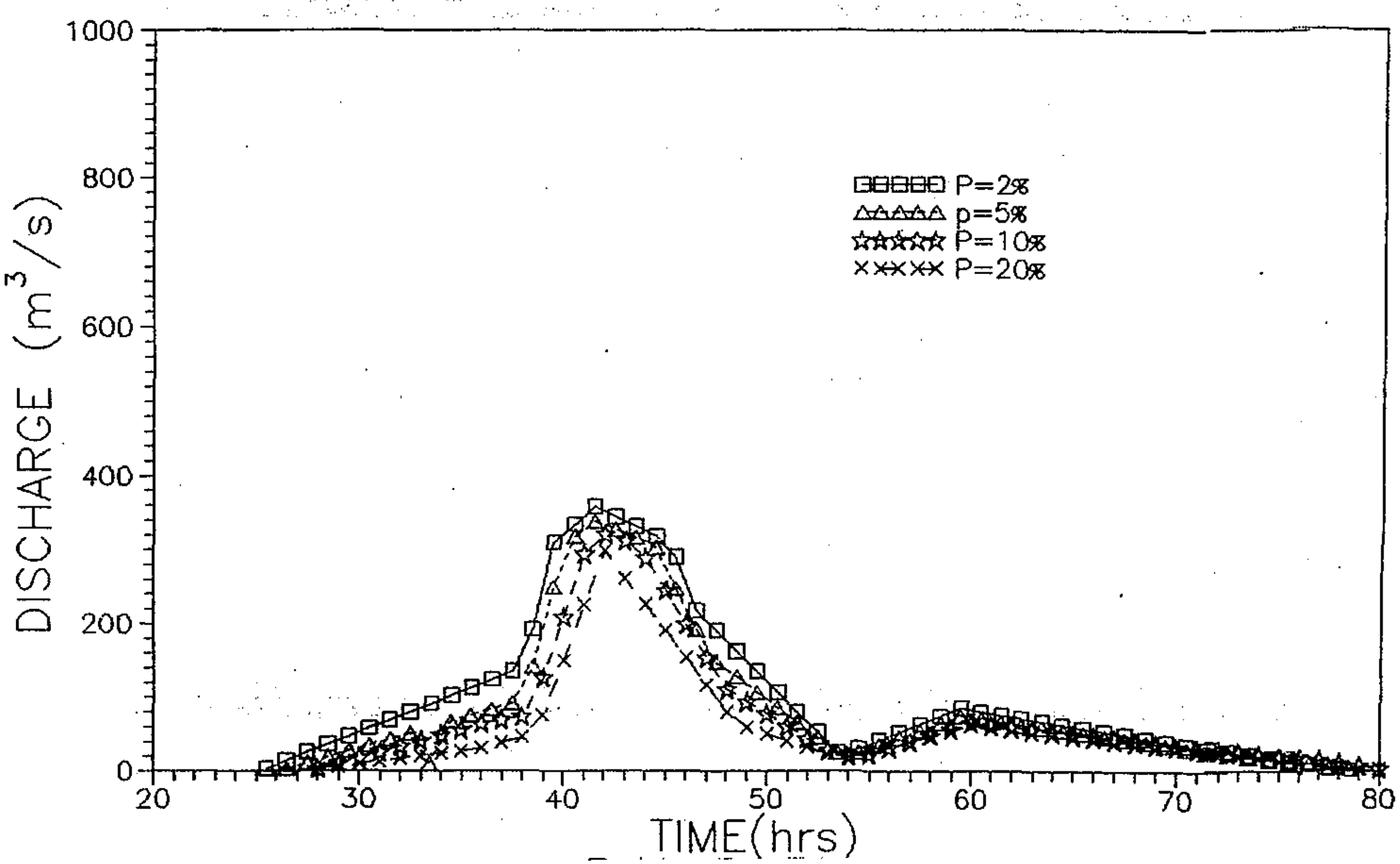


FIG. A7—4 Designed flood discharges in Buji River

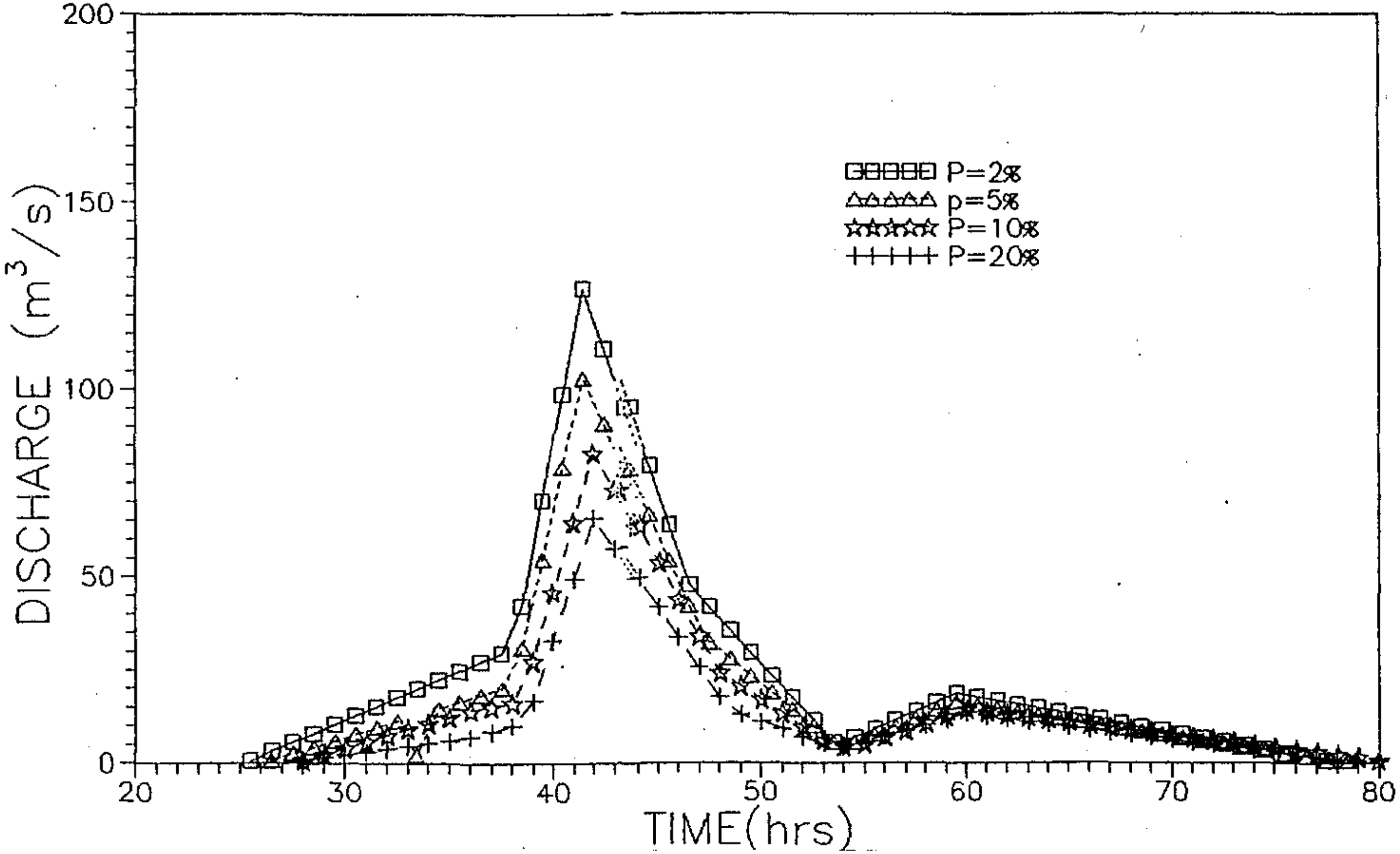


FIG. A7—5 Designed flood discharges in Futian River

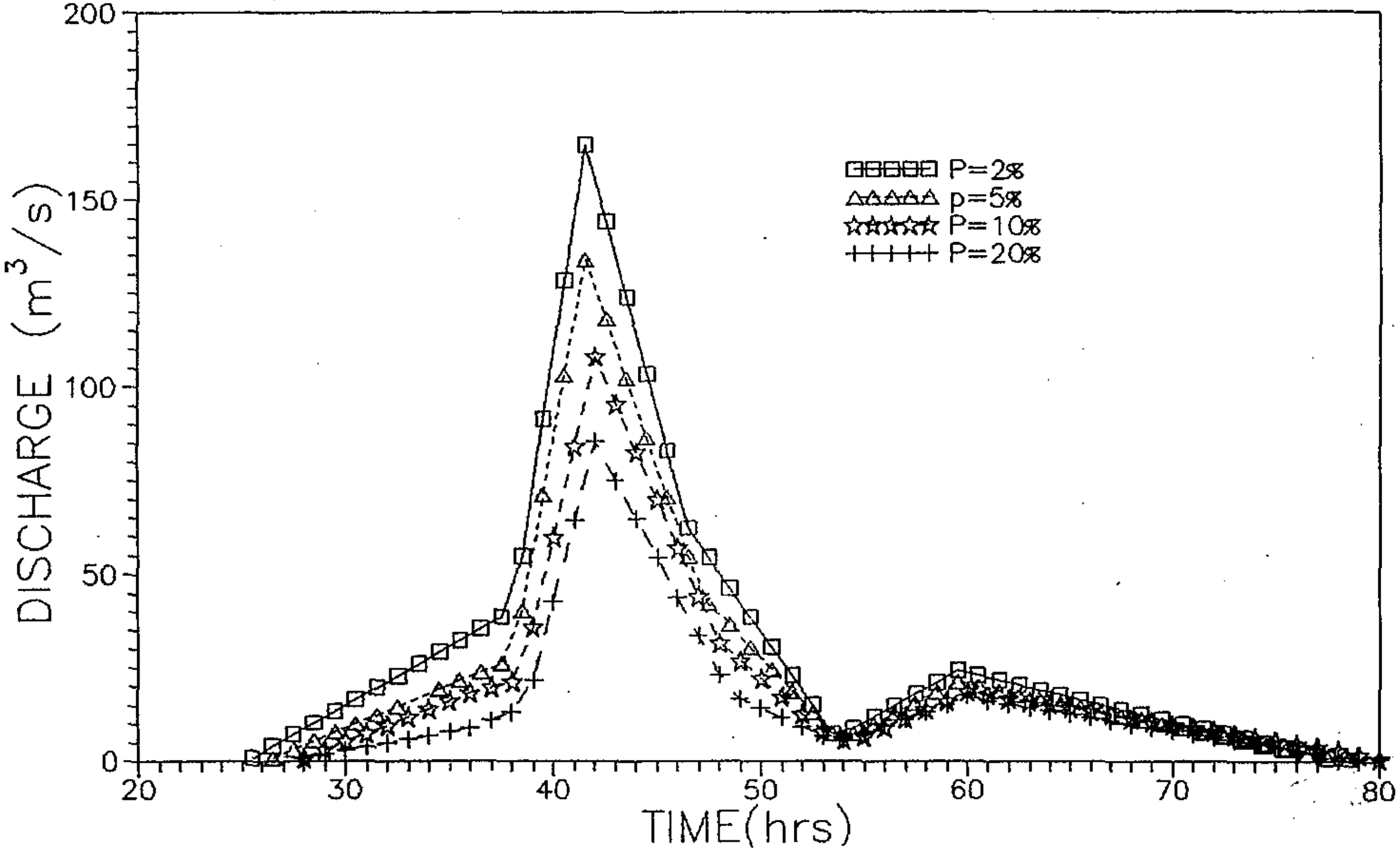


FIG. A7—6 Designed flood discharges in Huang Gang River

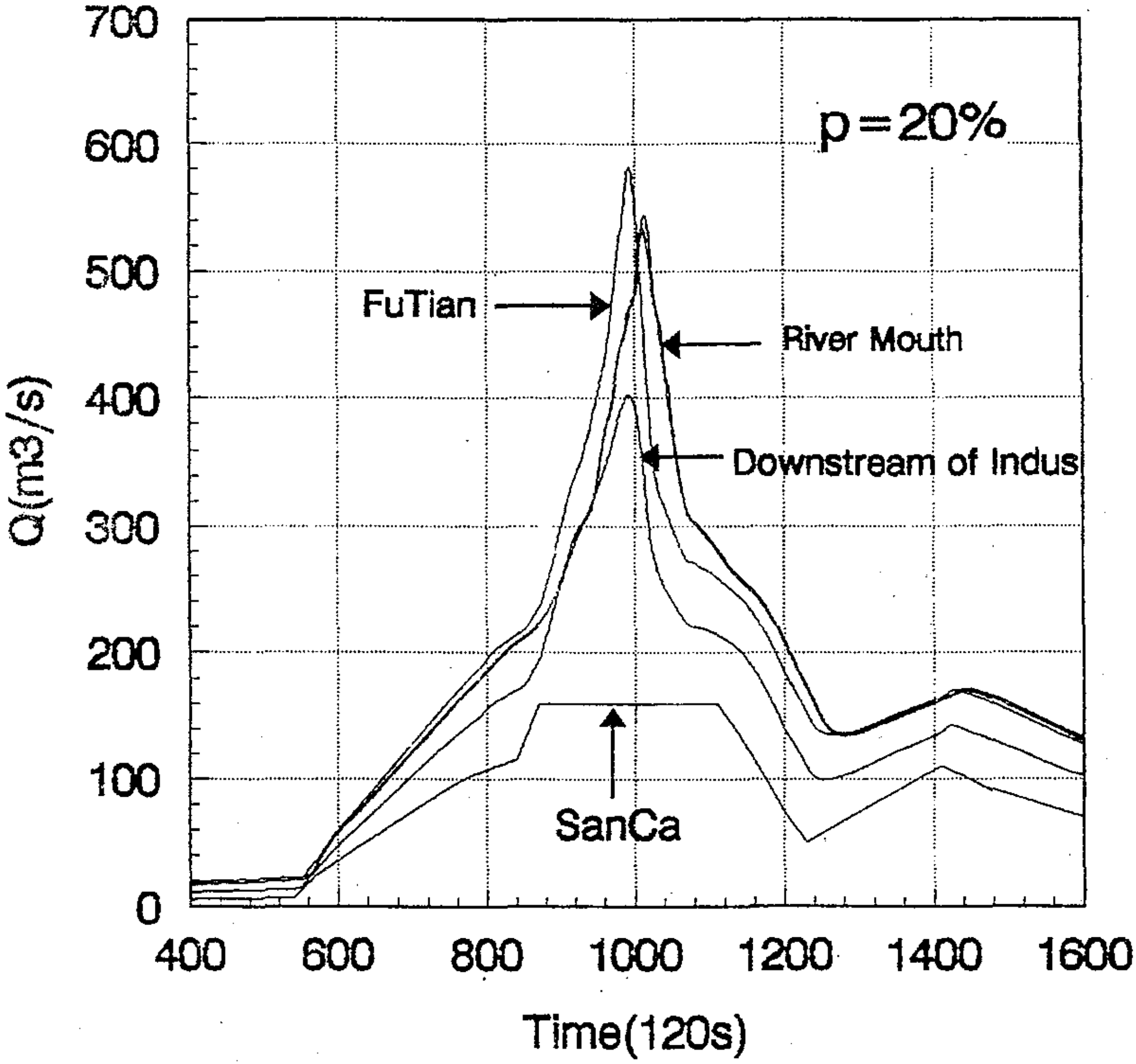


FIG. A7—7 Calibration of the model

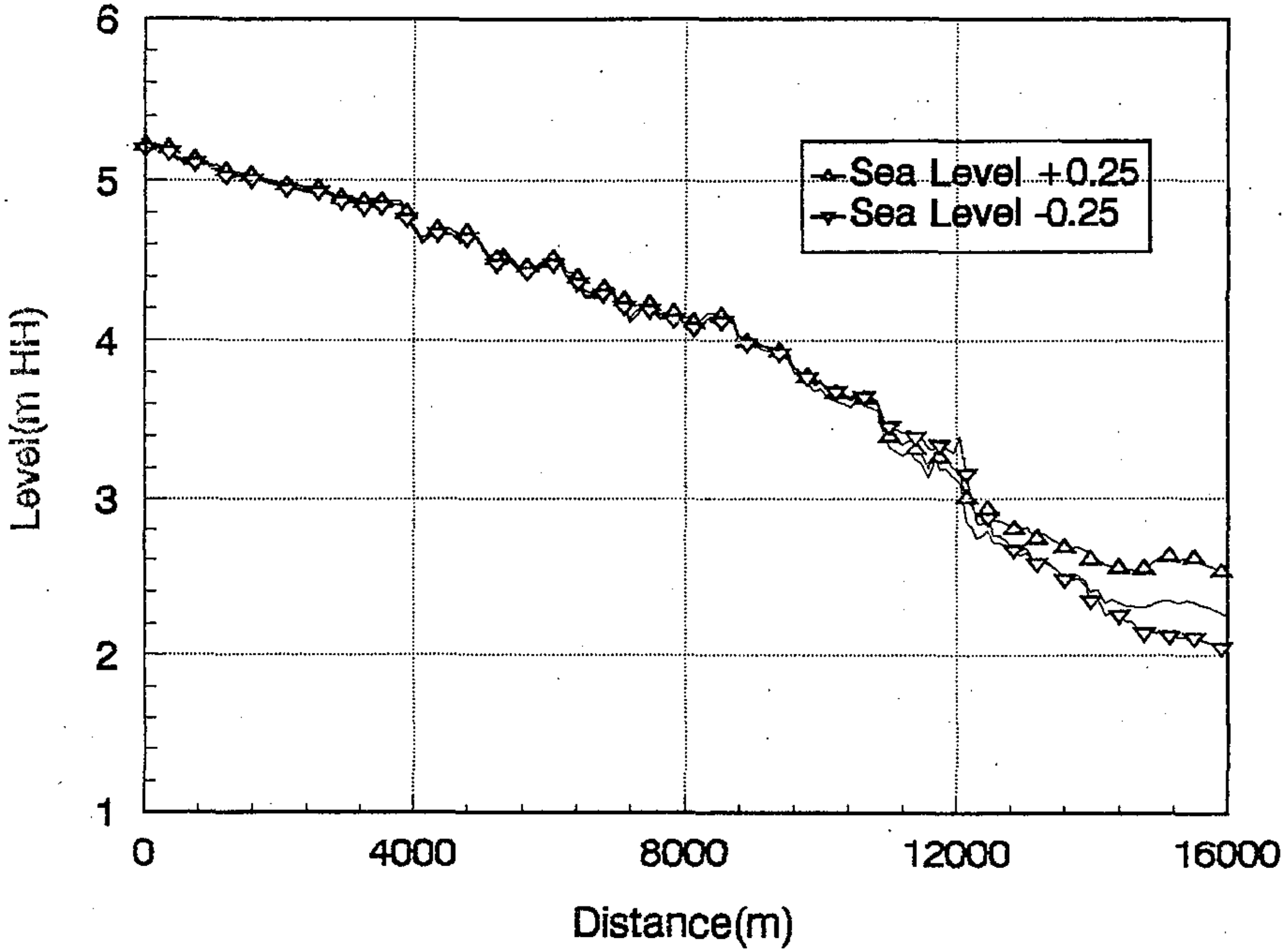


FIG. A7—8 Effect of sea level variation on water level in Shenzhen River

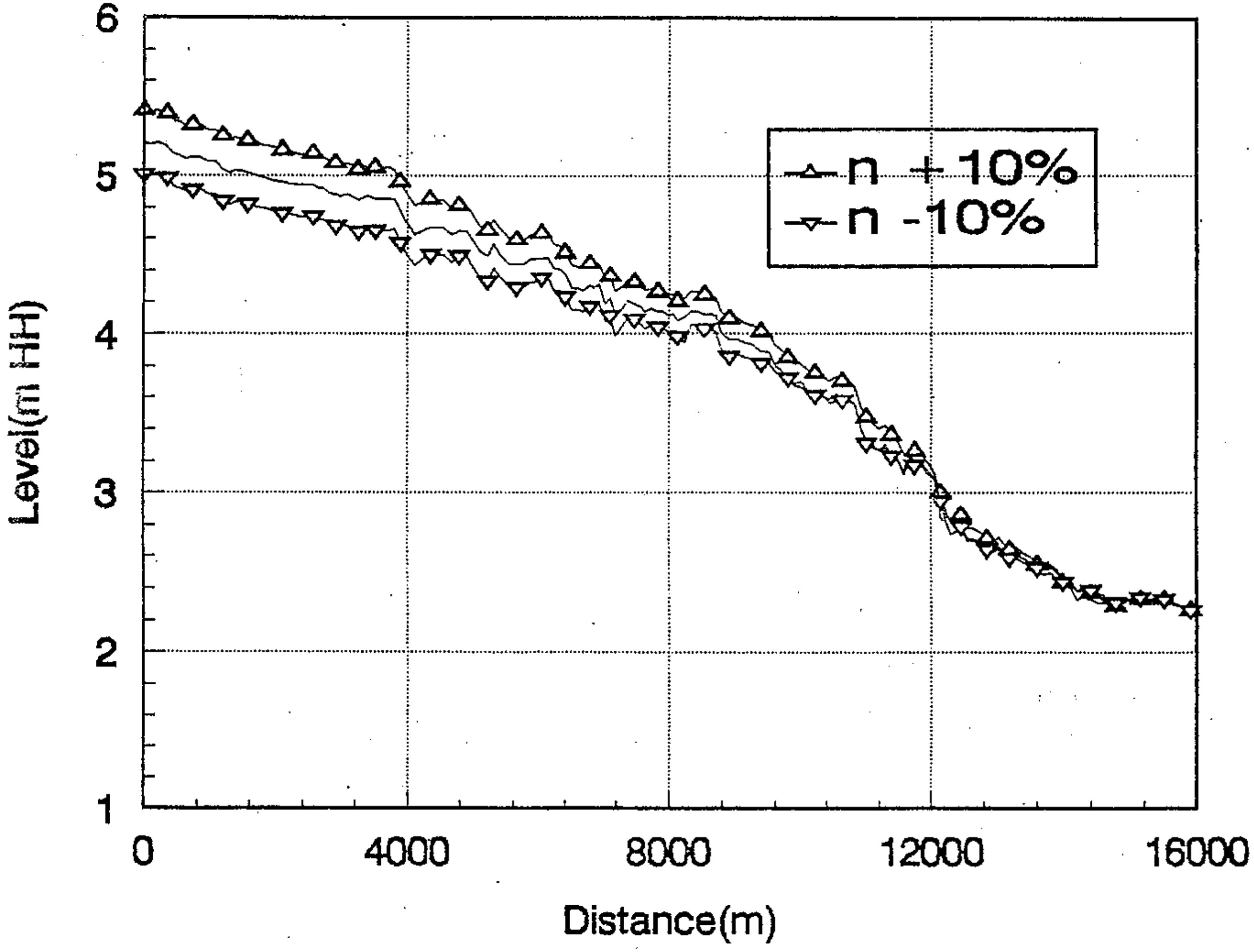


FIG. A7—9 Roughness effect on water level in Shenzhen River

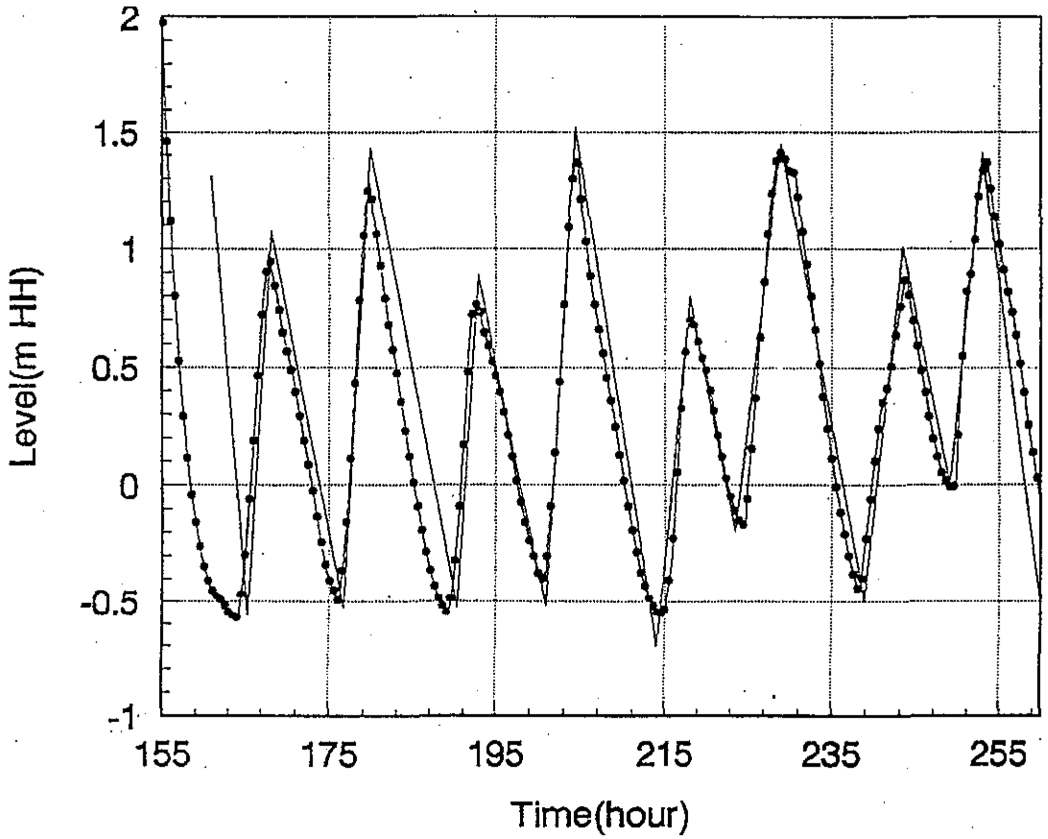


FIG. A7—10 Calibration Of Tide Model (April 1983 WengJingDu)

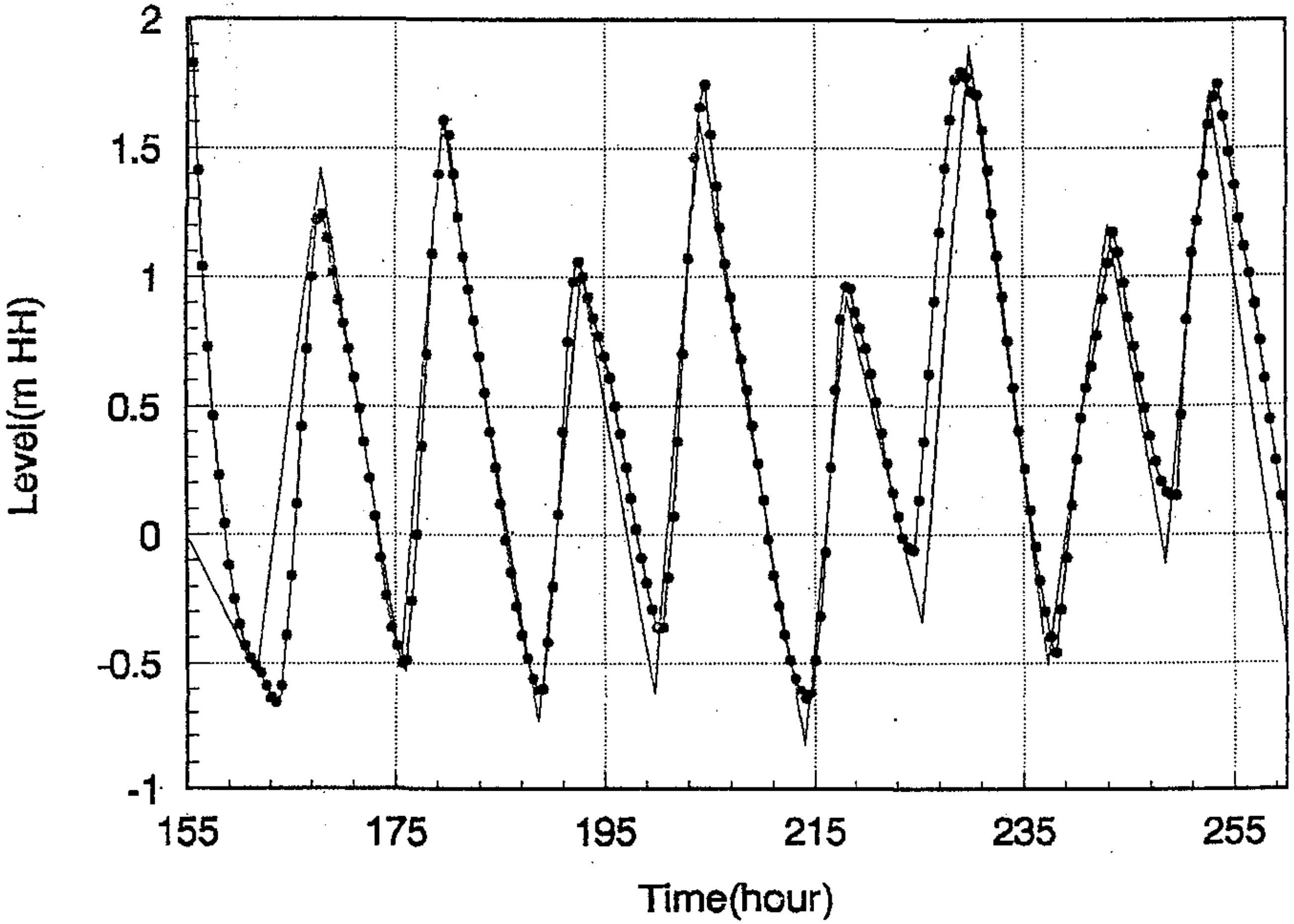


FIG. A7—11 Calibration Of Tide Model (April 1983 YuNongCun)

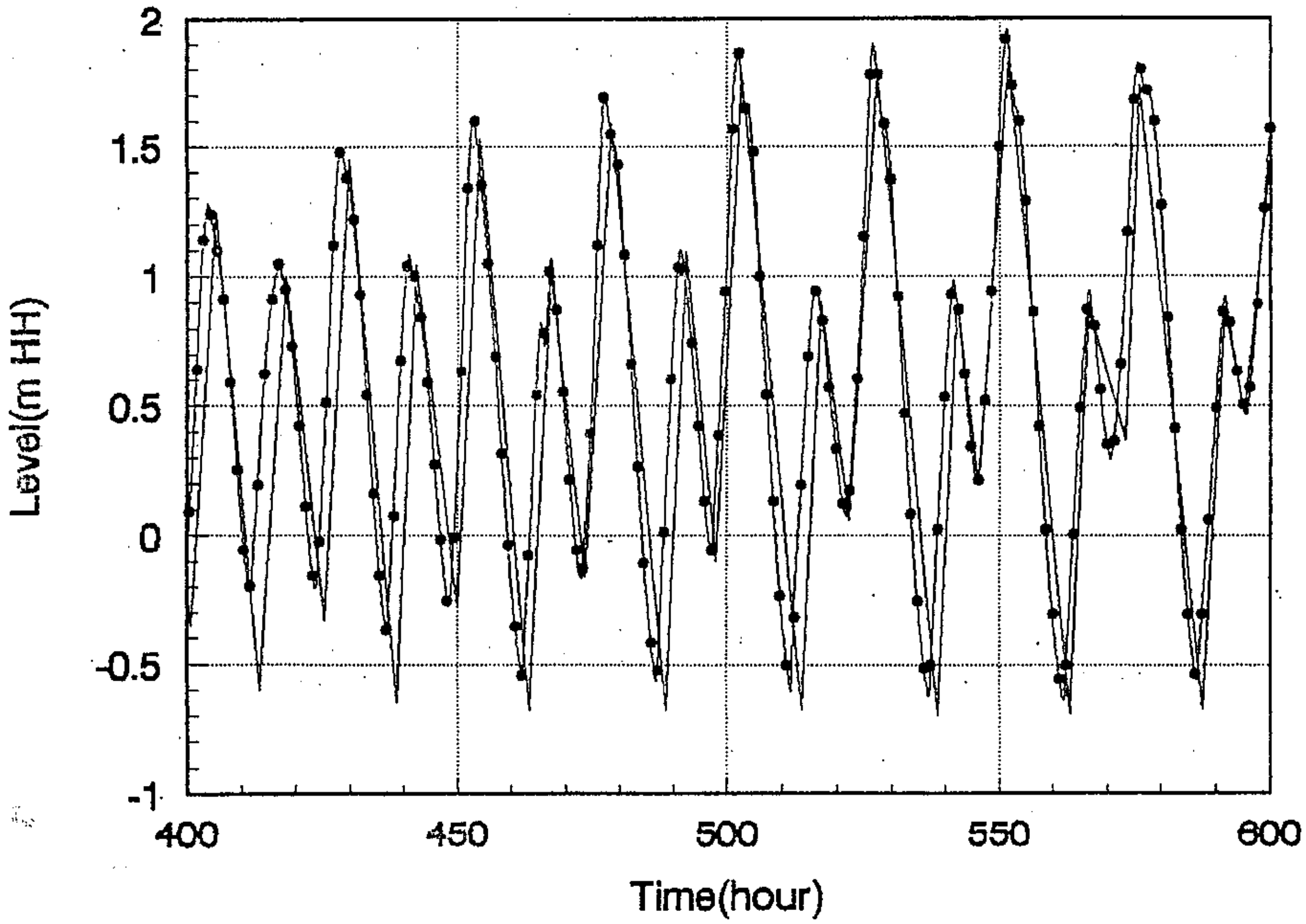


FIG. A7—12 Calibration Of Tide Model (November 1983 YuNongCun)

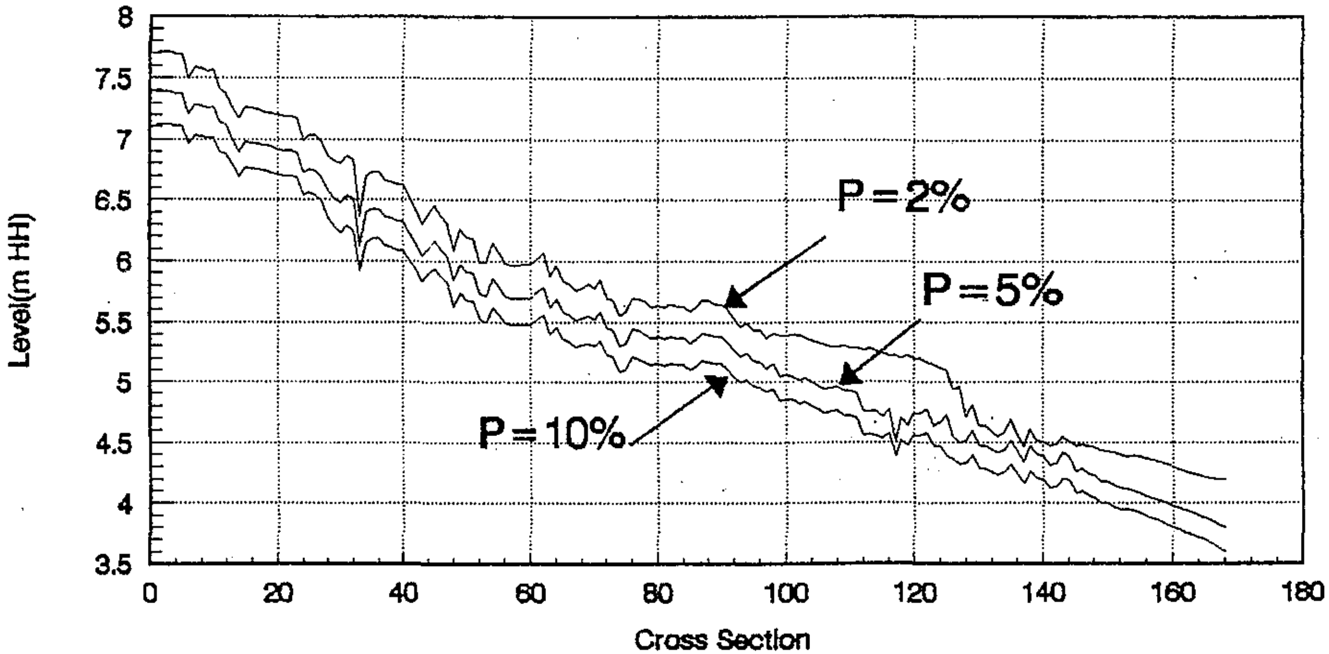


FIG. A7—13 Typical water surface lines in Shenzhen River with different frequencies

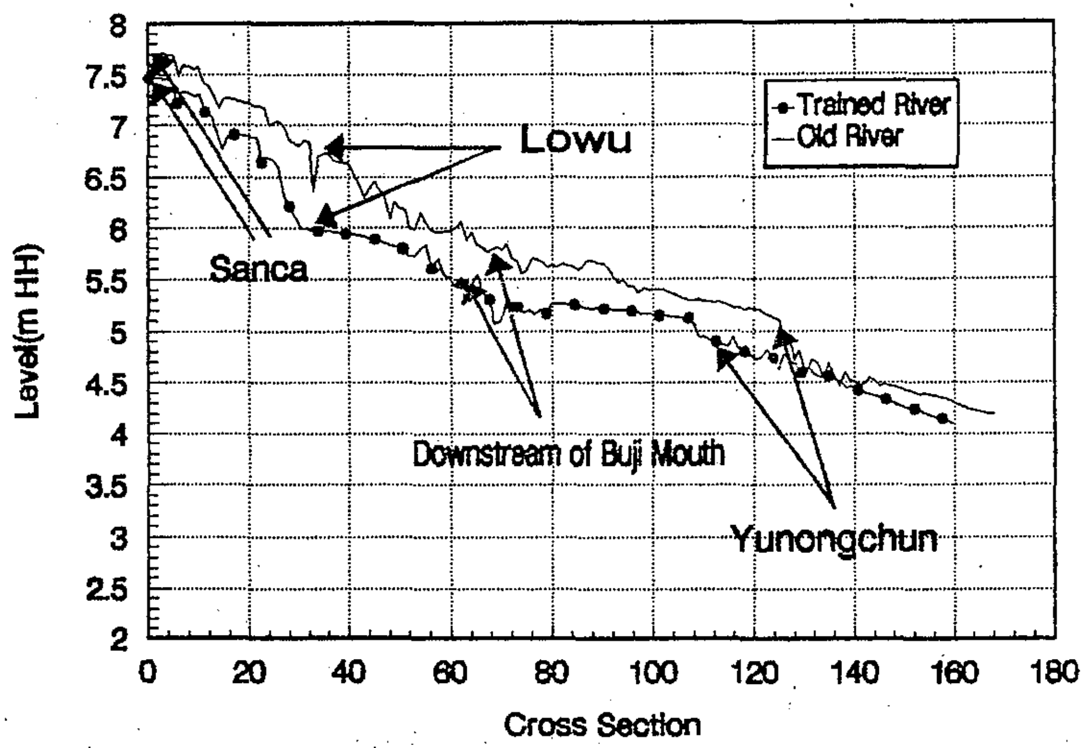


FIG. A7—14 Comparison of the water levels before and after the realignment (P=2%)

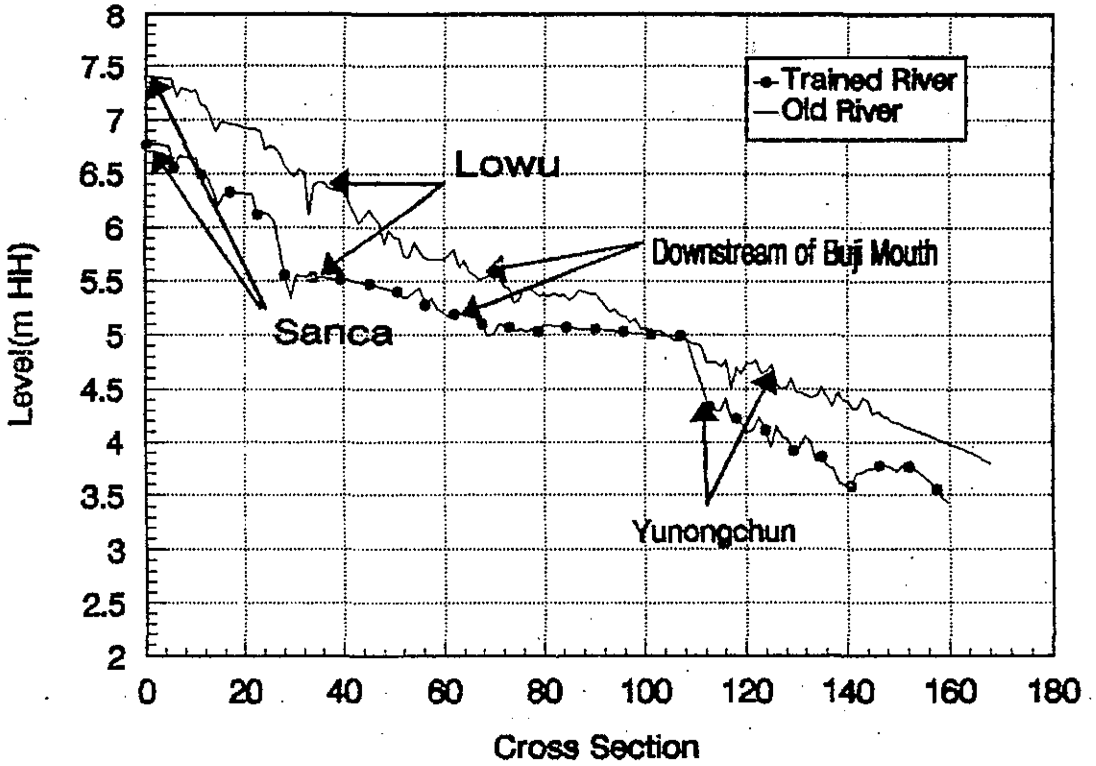


FIG. A7—15 Comparison of the water levels before and after the realignment (P=5%)

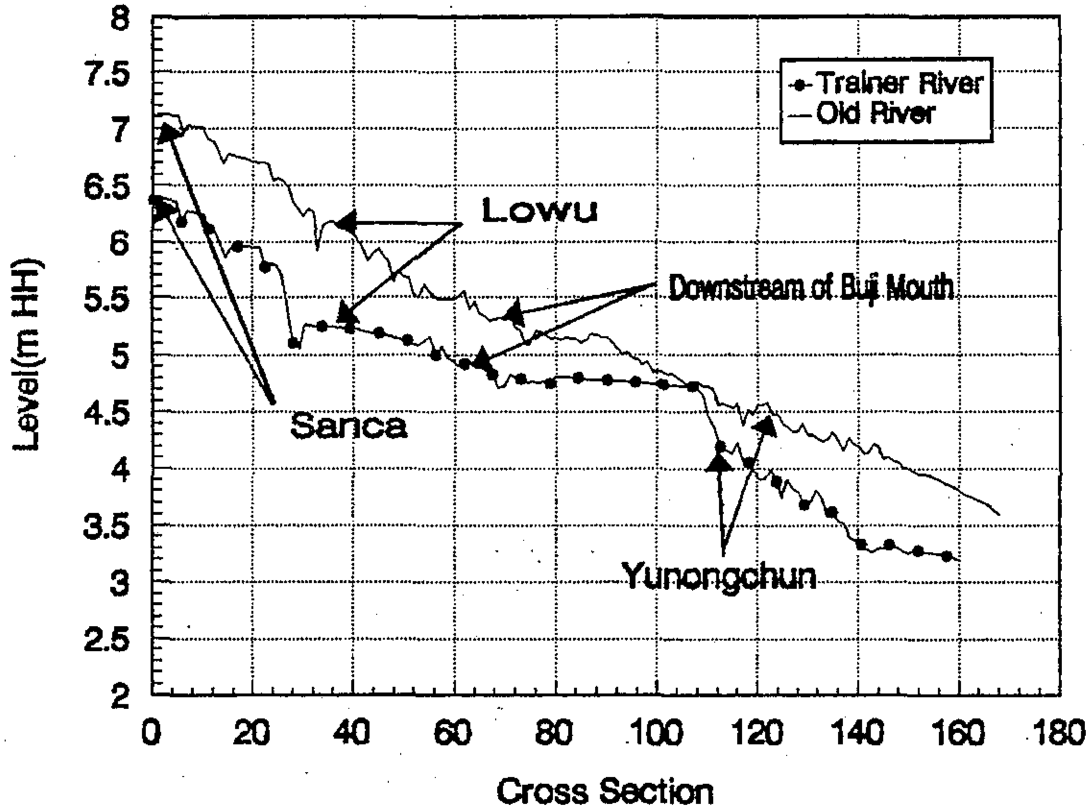


FIG. A7—16 **Comparison of the water levels before and after the realignment(P=10%)**

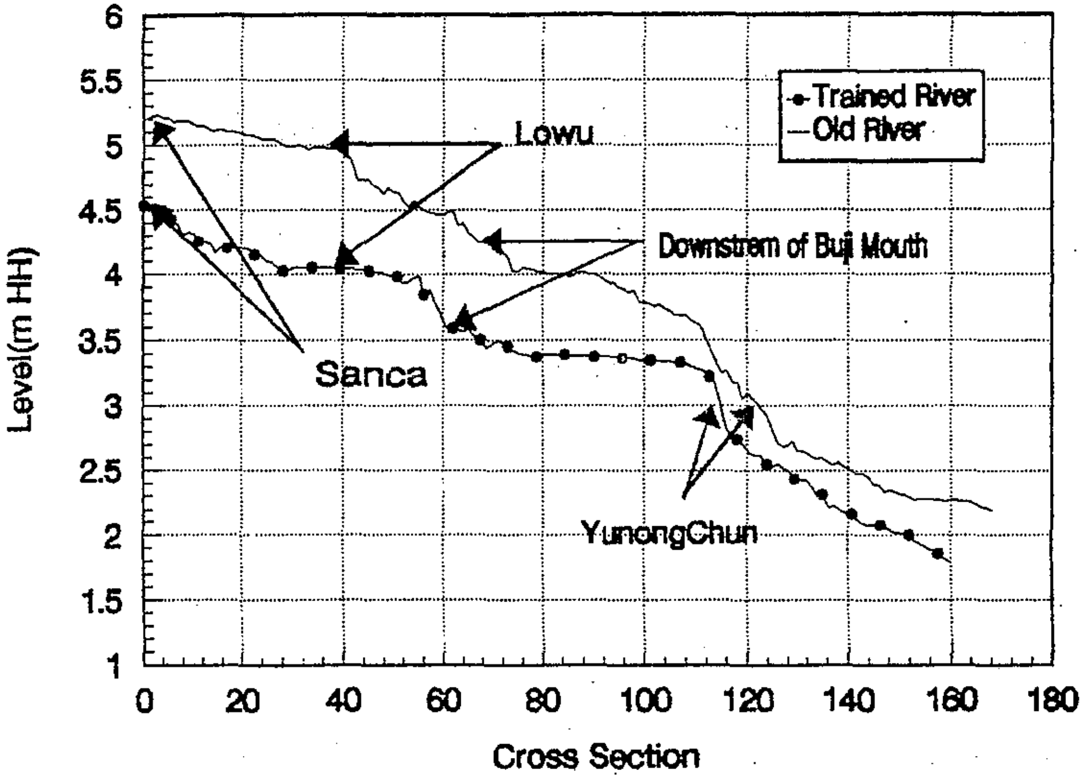


FIG. A7—17 Comparison of the water levels before and after the realignment (P=20%)

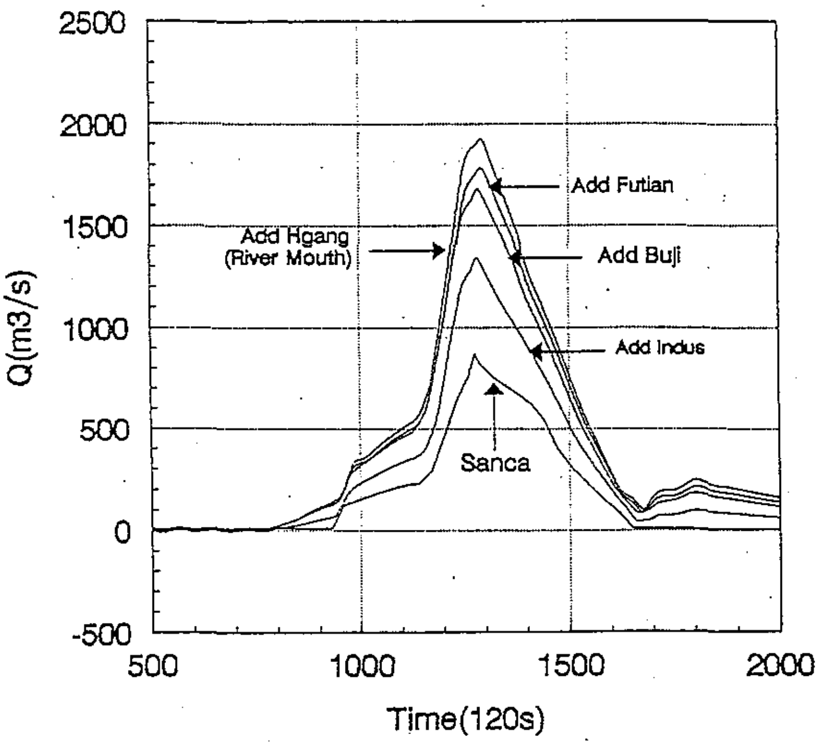


FIG. A7—18 Process Of Flood Advent (p=2%)

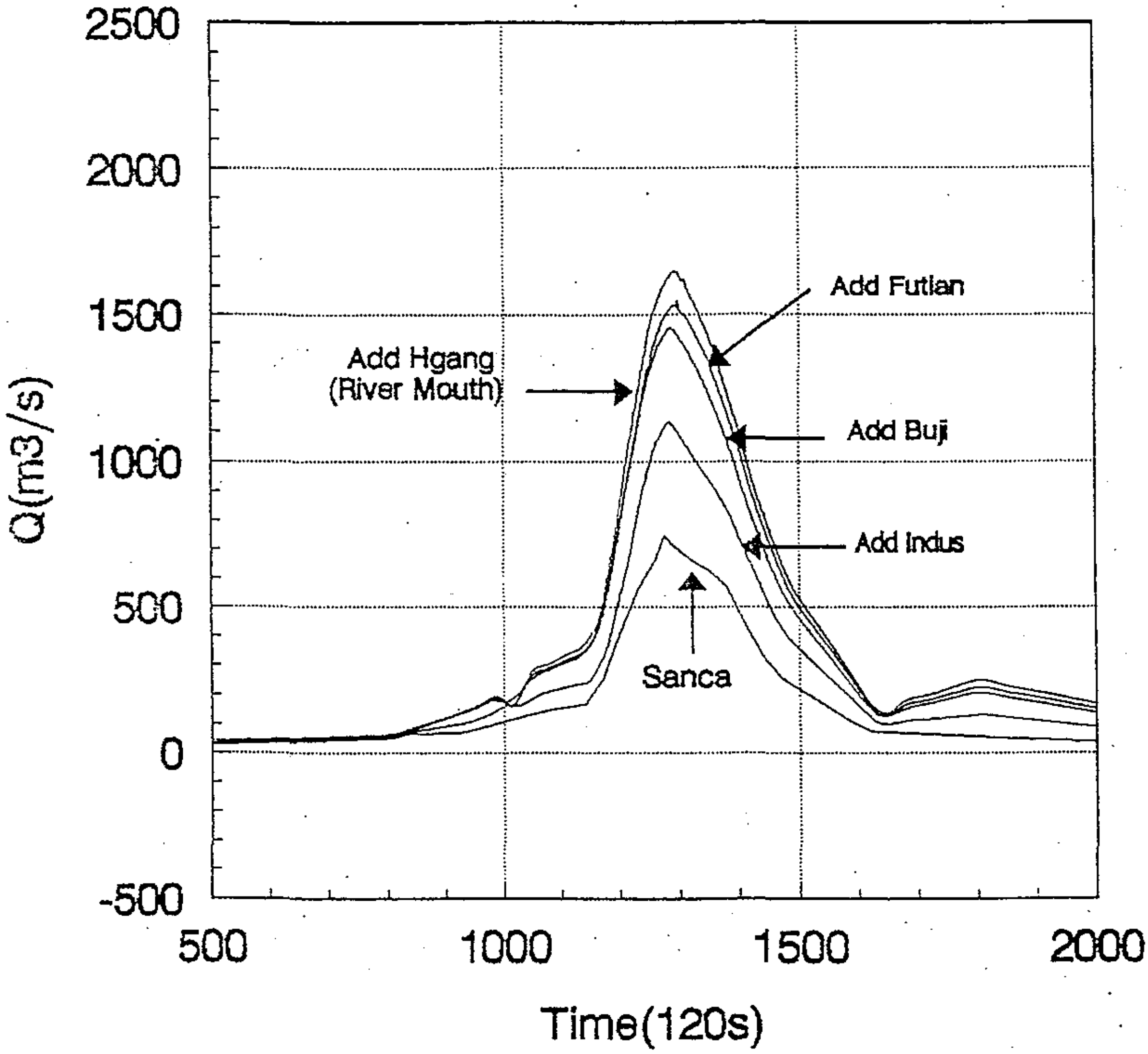


FIG. A7—19 Process Of Flood Advent (p=5%)

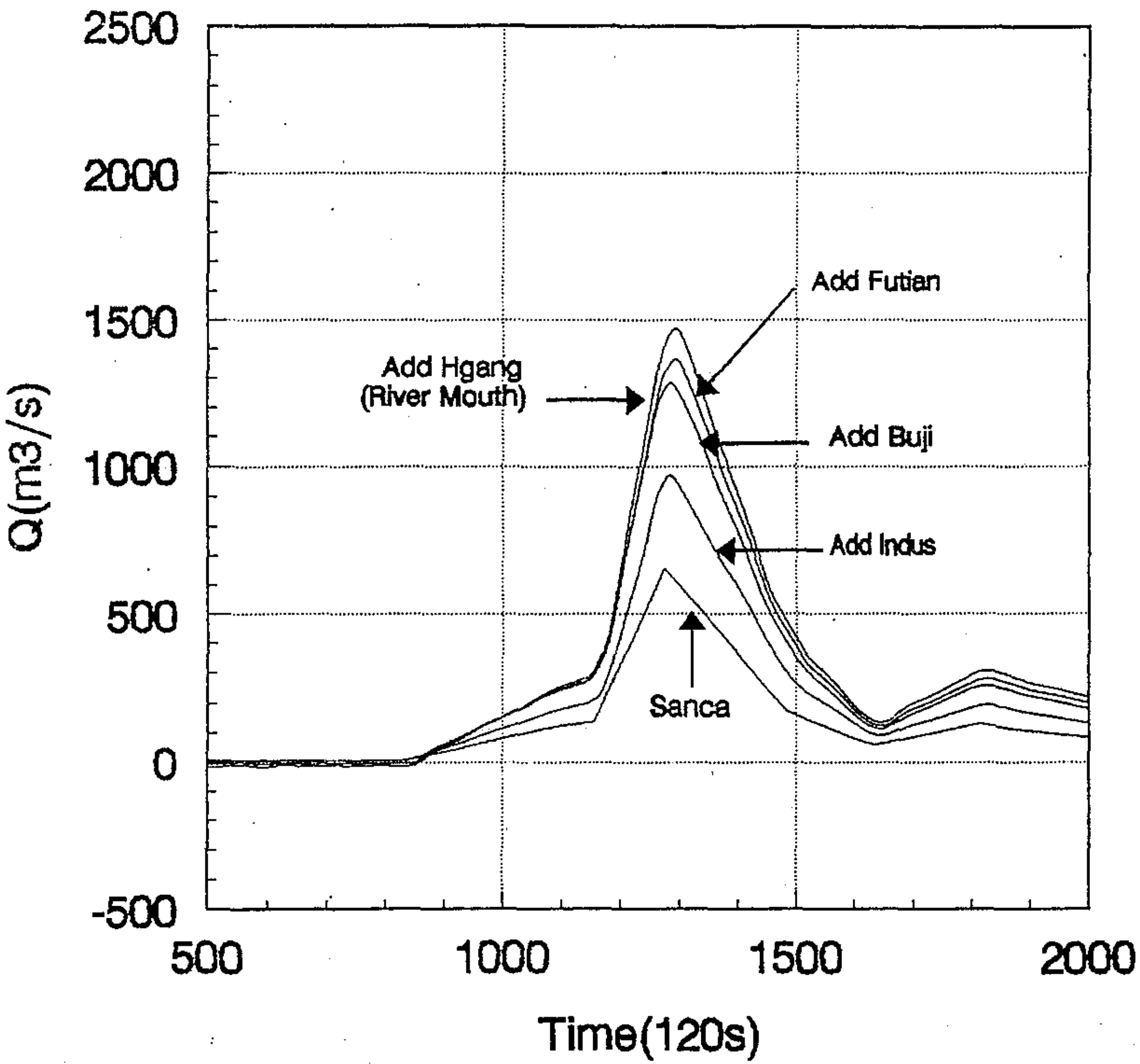


FIG. A7—20 Process Of Flood Advent (p=10%)

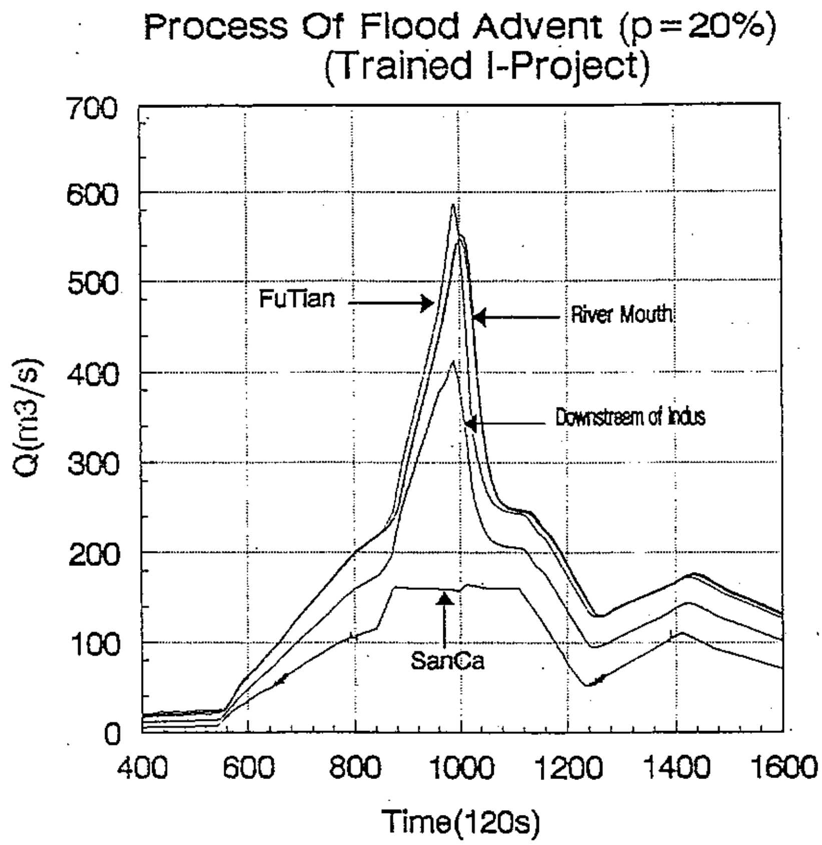


图 A7—21 裁弯后不同频率沿程各站流量过程(P=20%)

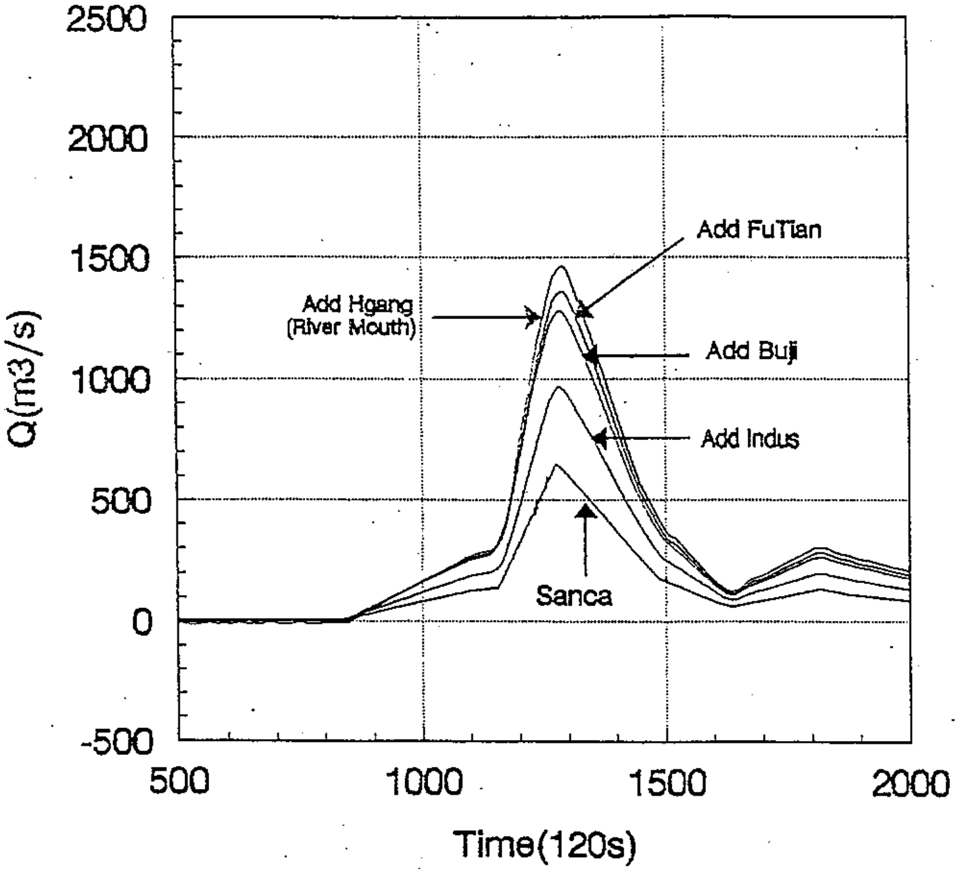


FIG. A7—22 Process OF Flood Advent (p=10%)

(After Realignment)

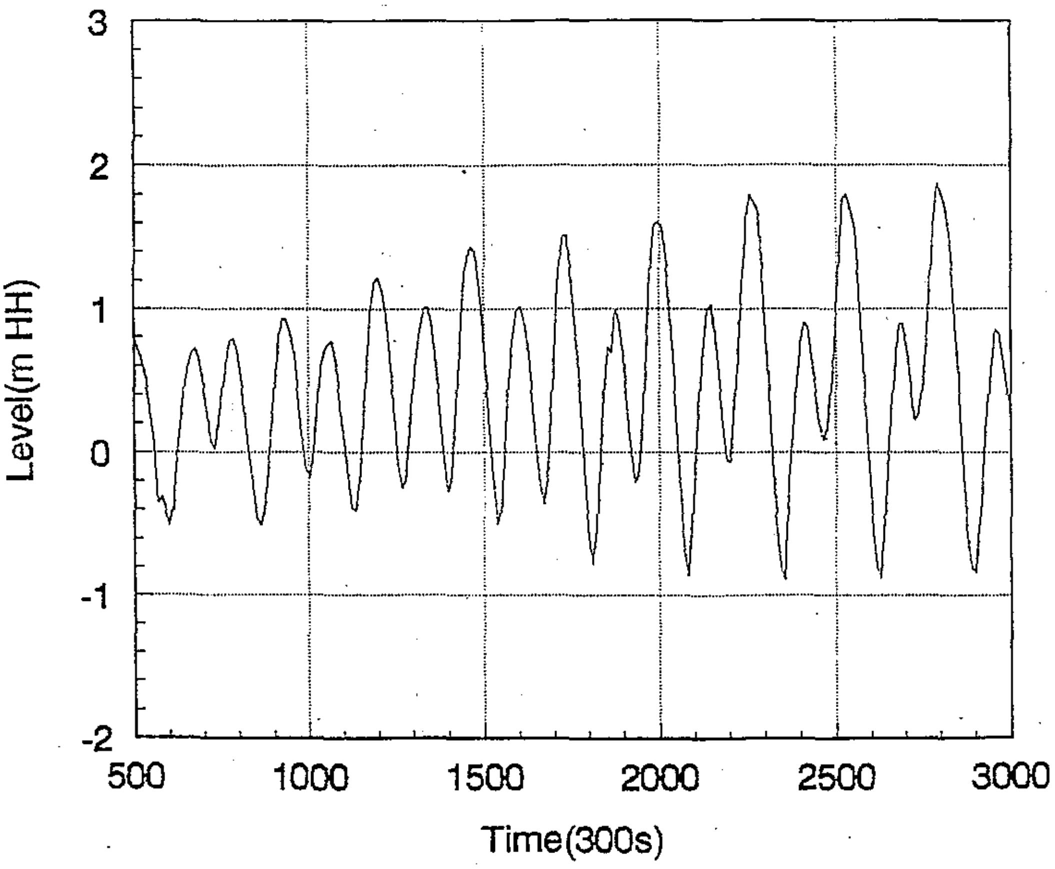


FIG. A7—23a) Process Of Water Level At River Mouth

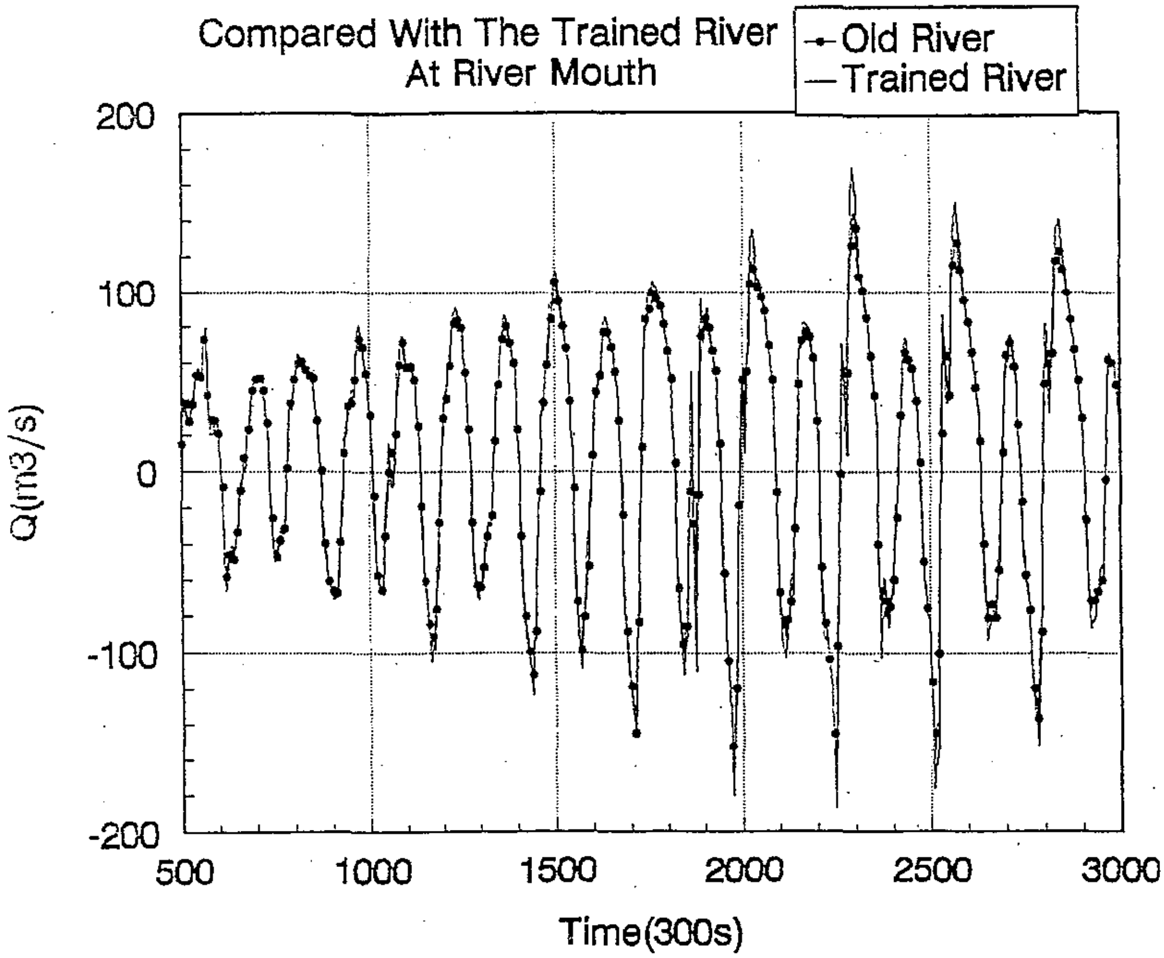


FIG. A7—23b) Comparison of discharge processes before and after realignment

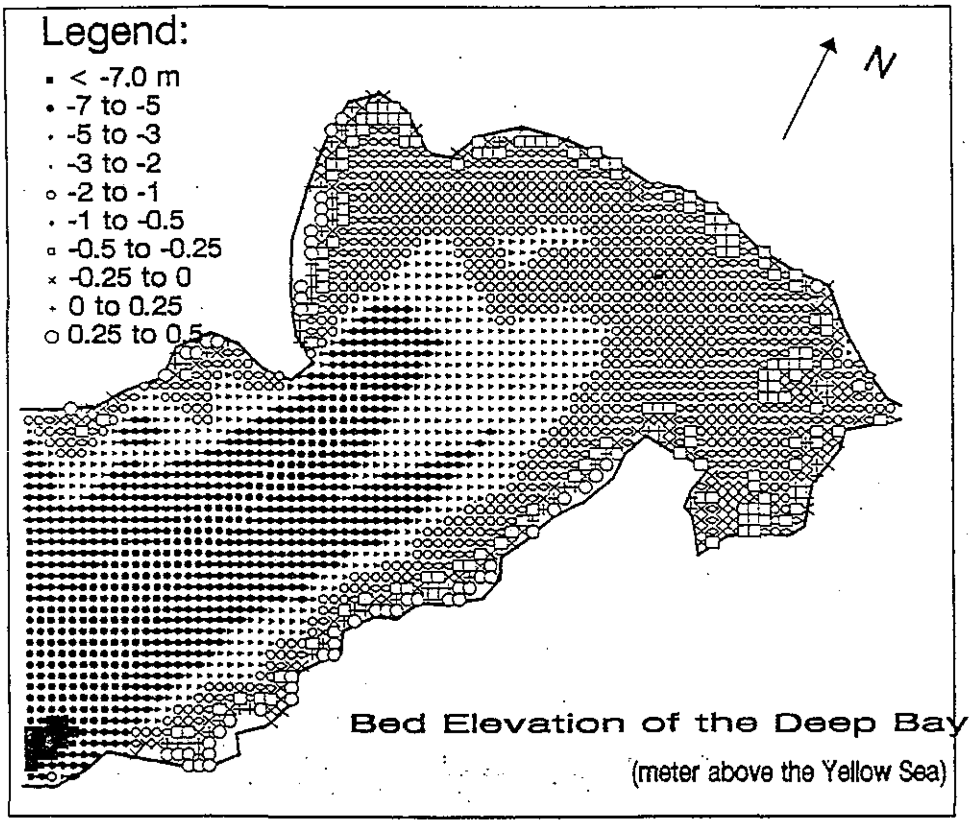

Legend:
< -7.0 m
-7 to -5
-5 to -3
-3 to -2
-2 to -1
-1 to -0.5
-0.5 to -0.25
-0.25 to 0
0 to 0.25
0.25 to 0.5
N
Bed Elevation of the Deep Bay
(meter above the Yellow Sea)

FIG. A7—26

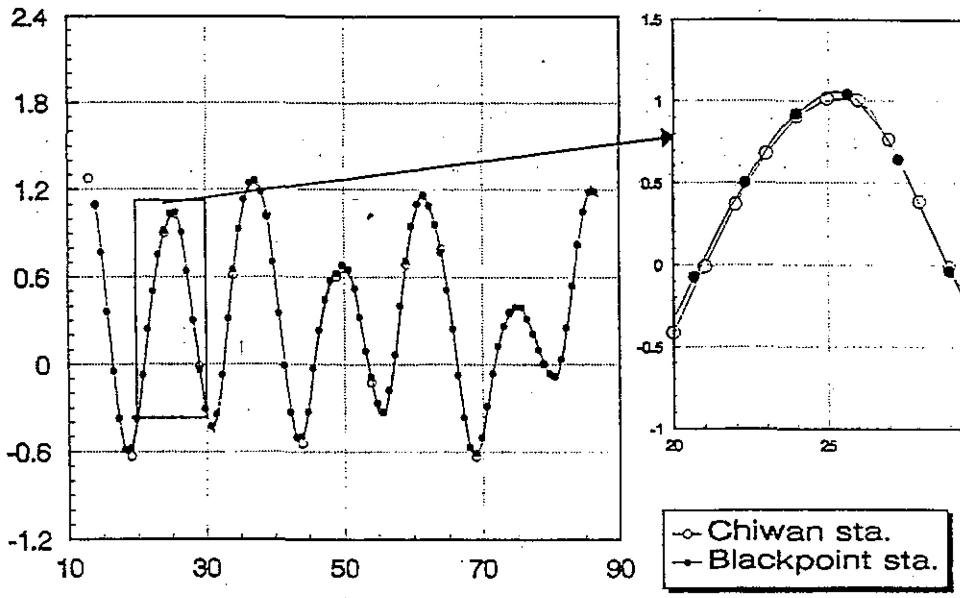


FIG. A7—27 Comparison of the water level variations of Chiwan and Blackpoint

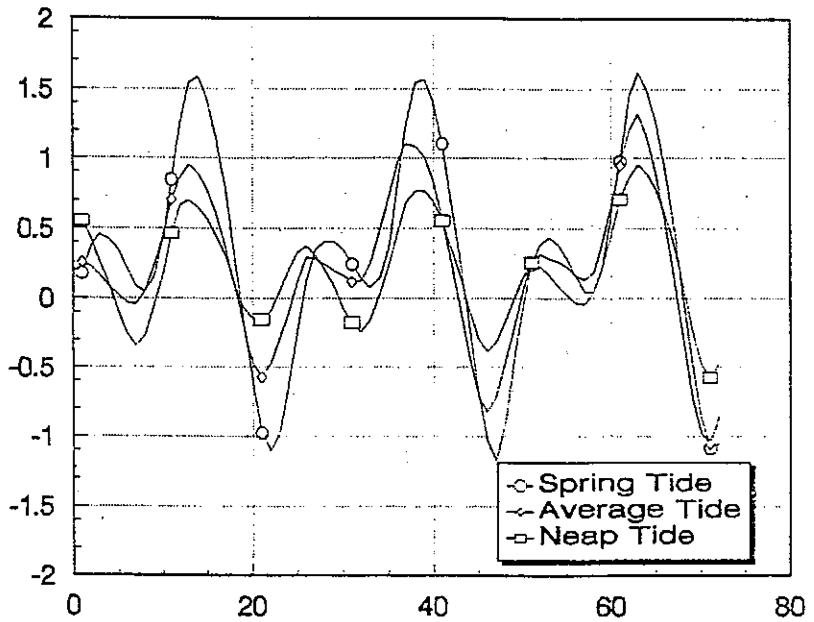


FIG. A7—28 Typical tides used in the calculation

It Also Applied for Blackpoint with 600 Sec. Time Shift

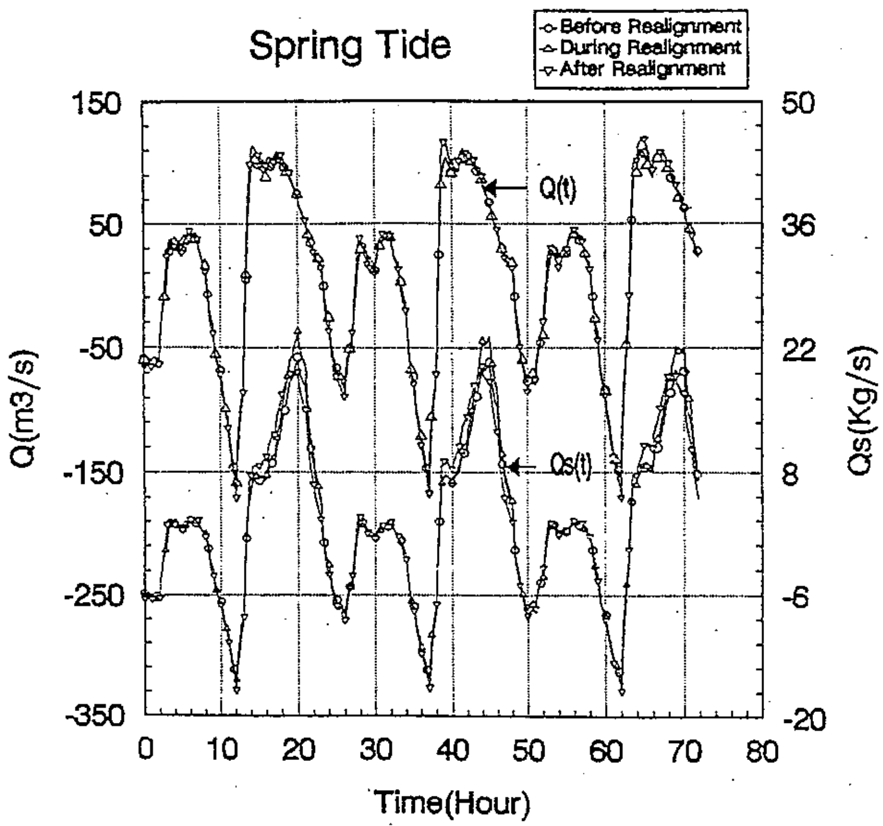


FIG. A7—29a) Comparison of before and after the realignment (Spring Tide)

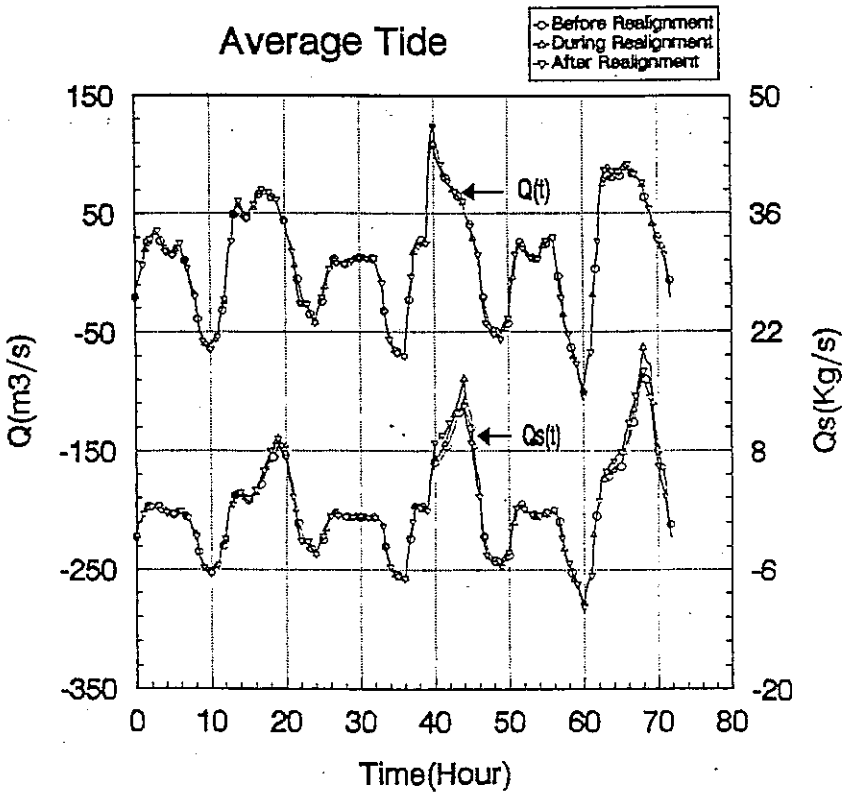


FIG. A7—29b) Comparison of before and after the realignment (Average Tide)

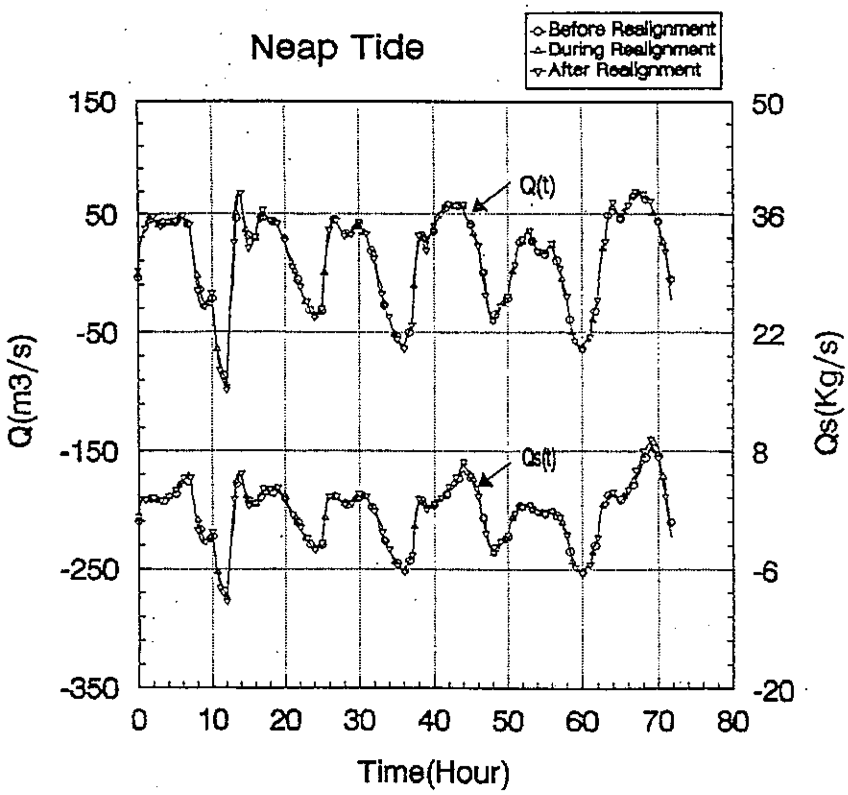


FIG. A7—29c) Comparison of before and after the realignment (Neap Tide)

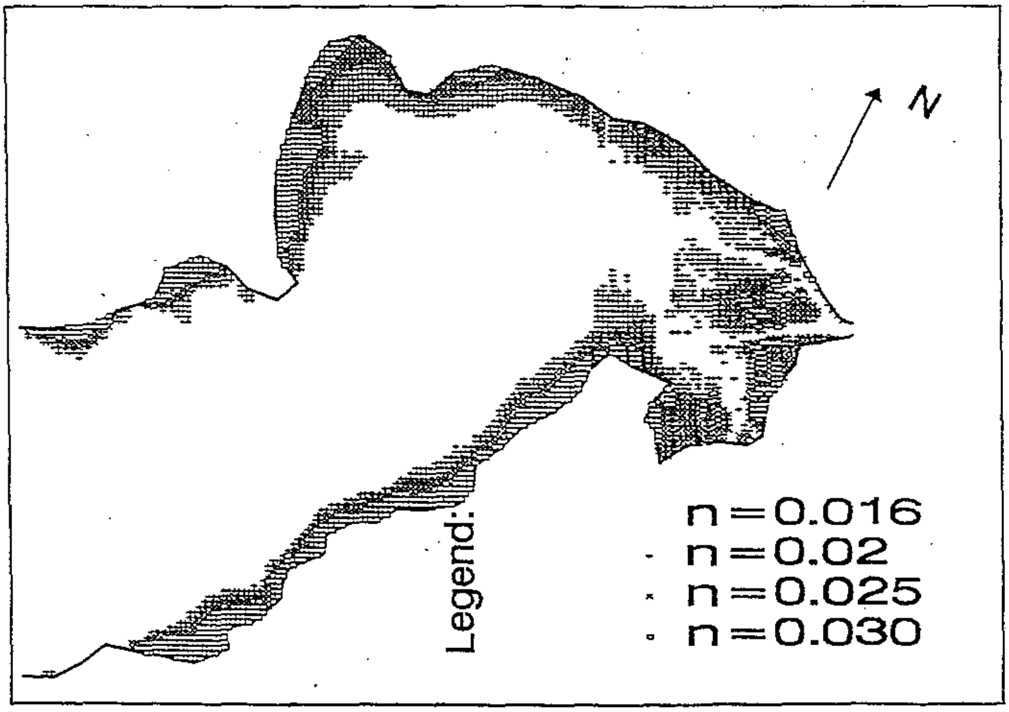


FIG. A7—30 Roughness distribution in Deep Bay

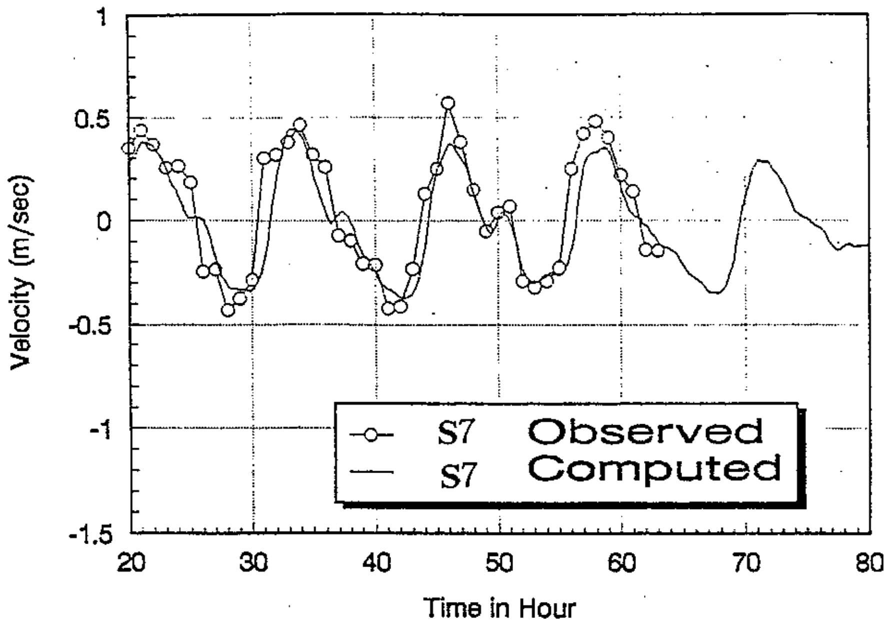


FIG. A7—31a) Verification of teh model (S7)

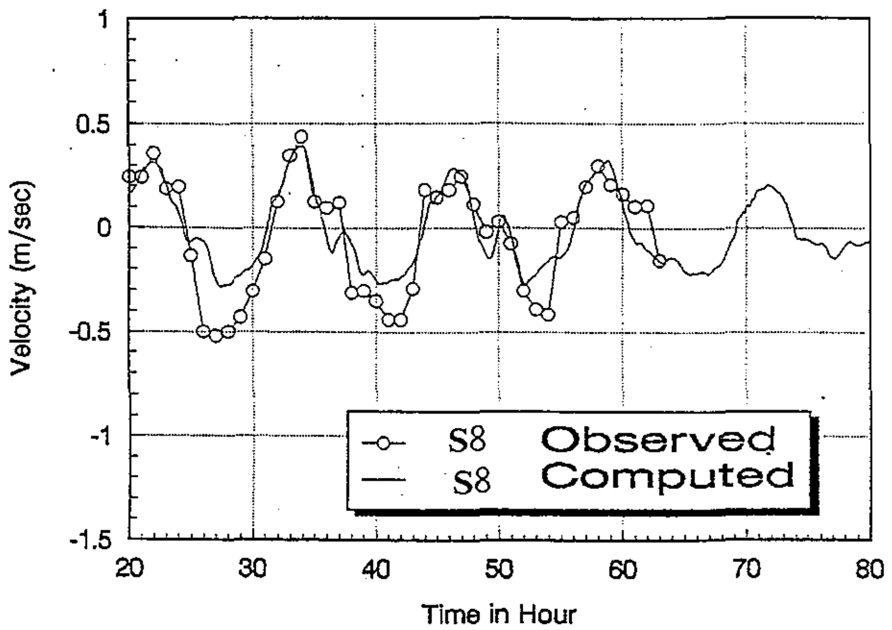


FIG. A7—31b) Verification of teh model (S8)

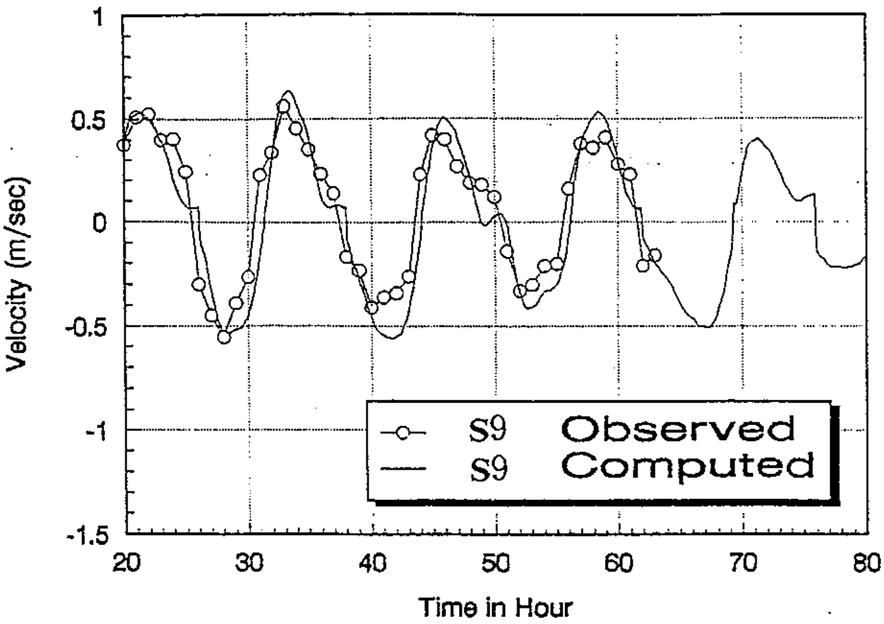


FIG. A7—31c) Verification of teh model (S9)

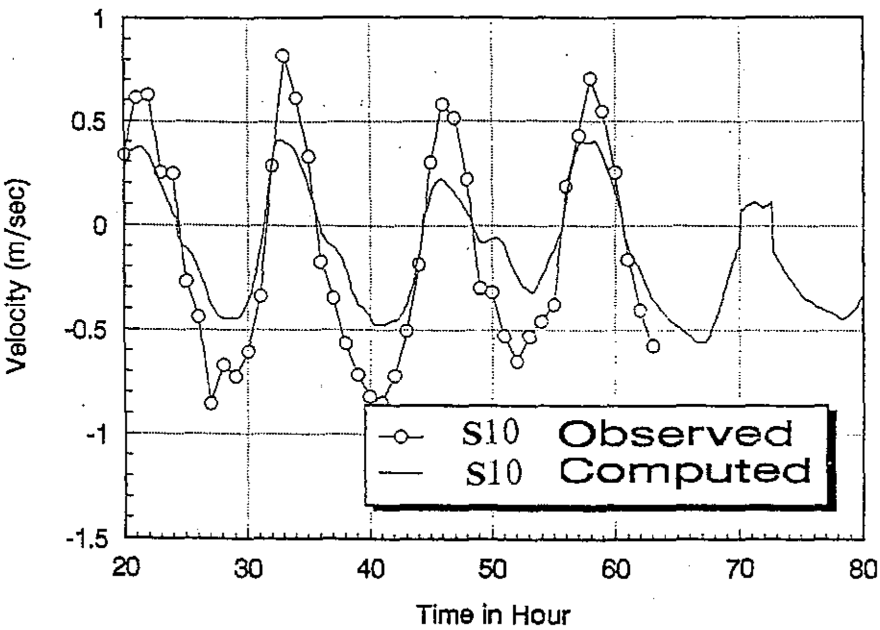


FIG. A7—31d) Verification of teh model (S10)

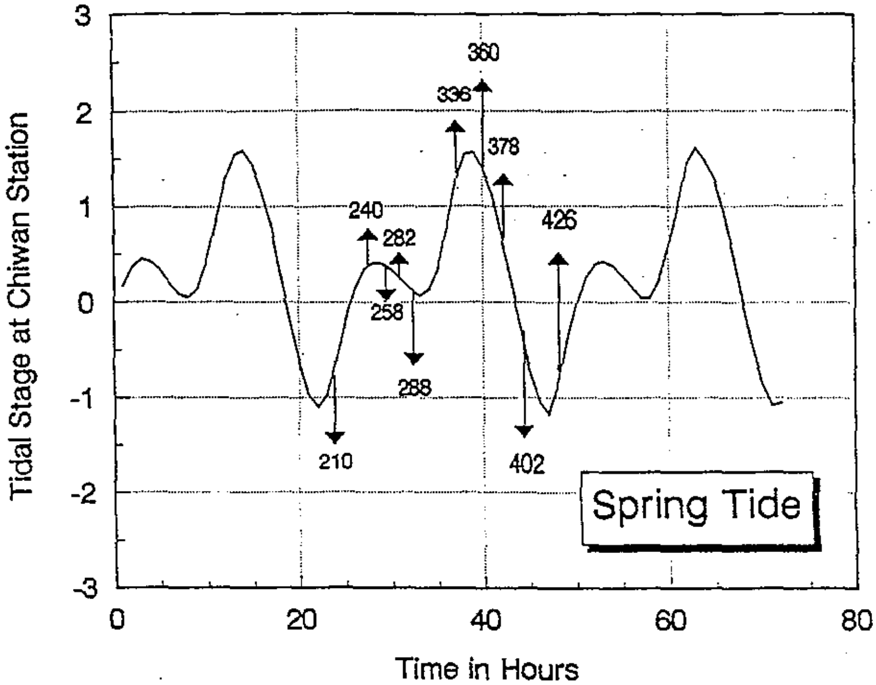


FIG. A7—32a) Typical tide level process and time sequence (Spring Tide)

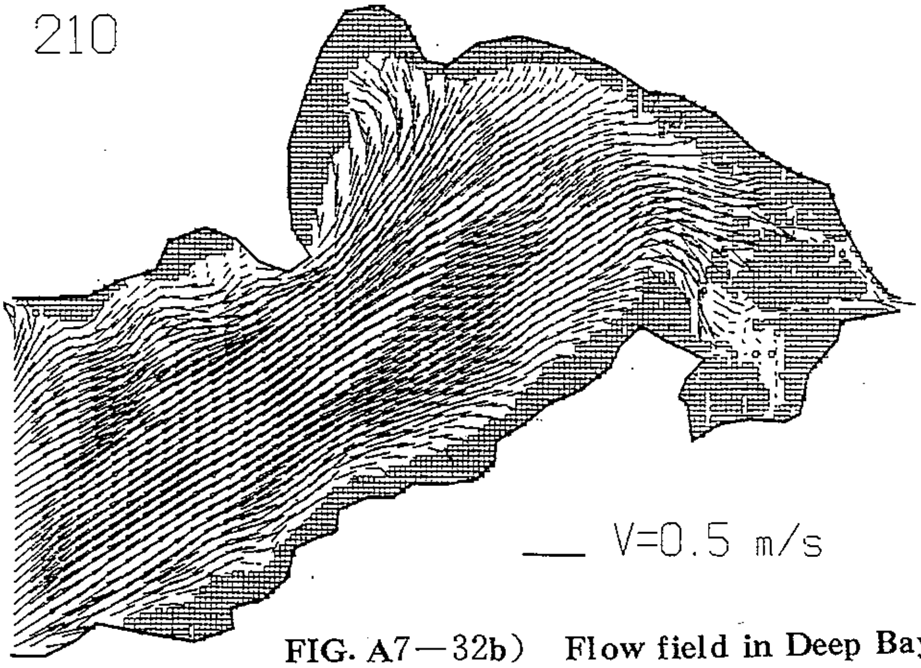


FIG. A7—32b) Flow field in Deep Bay (Spring Tide)

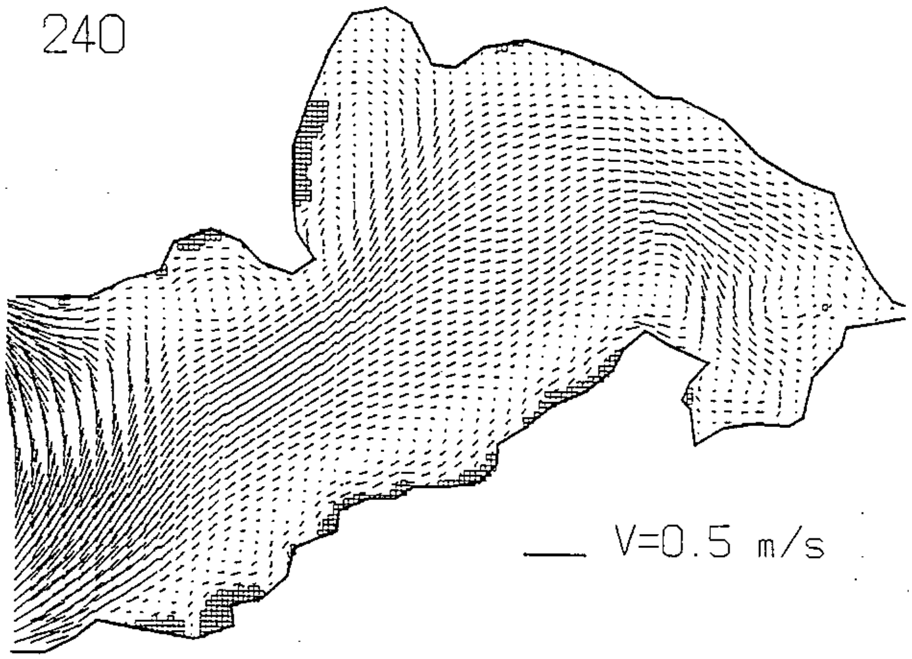


FIG. A7—32c) Flow field in Deep Bay (Spring Tide)

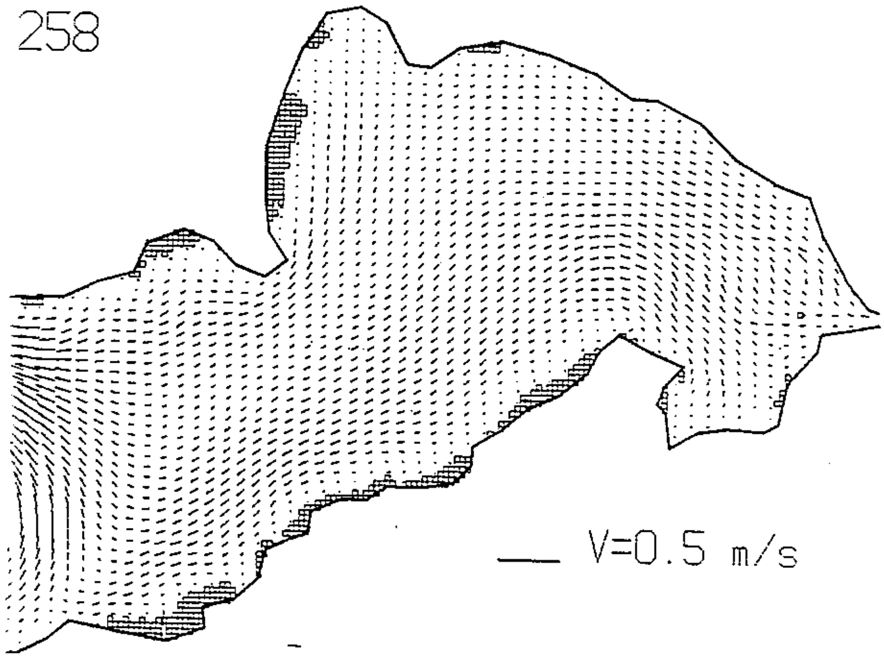


FIG. A7—32d) Flow field in Deep Bay (Spring Tide)

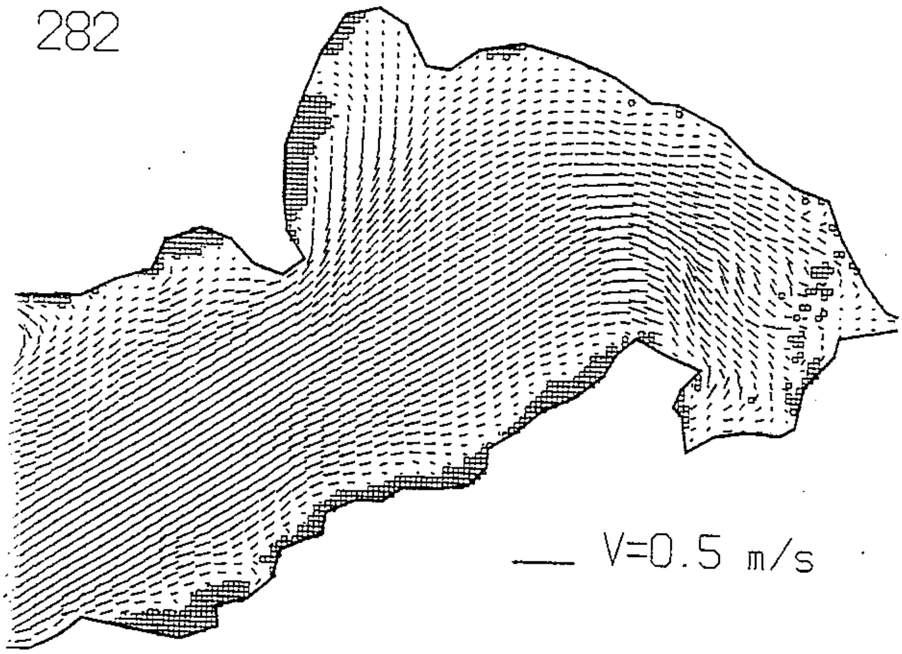


FIG. A7—32e) Flow field in Deep Bay (Spring Tide)

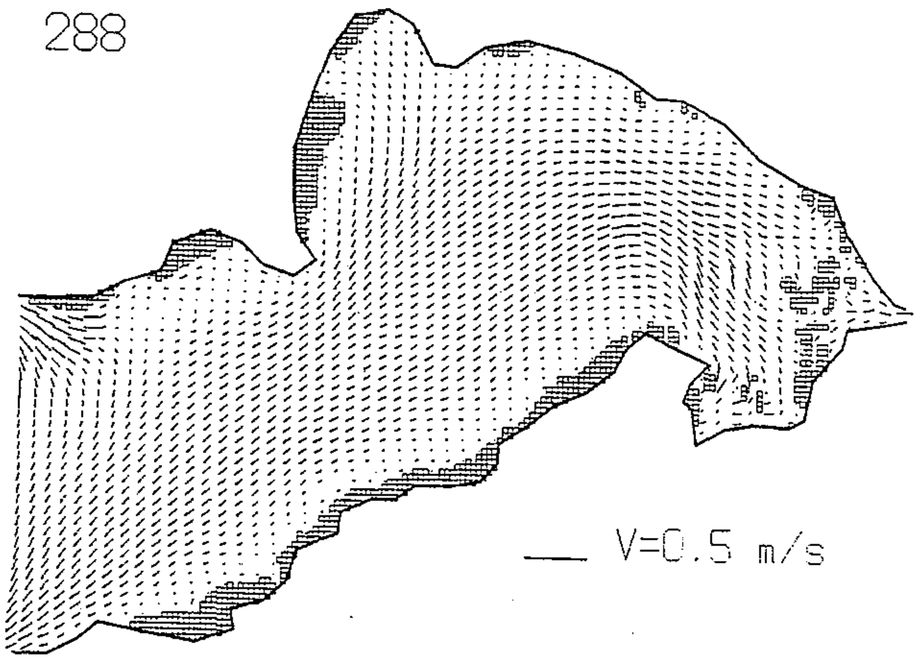


FIG. A7—32f) **Flow field in Deep Bay (Spring Tide)**

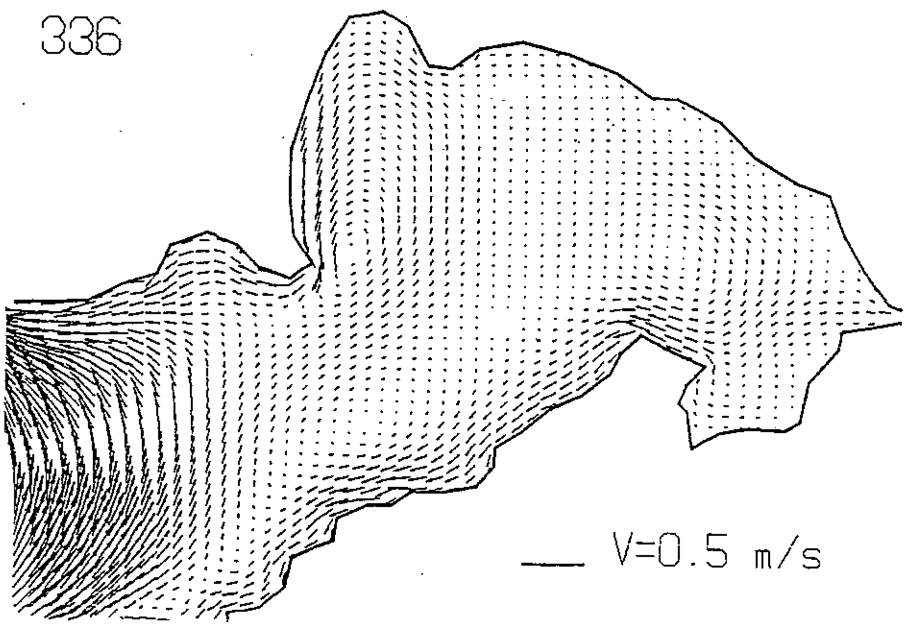


FIG. A7—32g) **Flow field in Deep Bay (Spring Tide)**

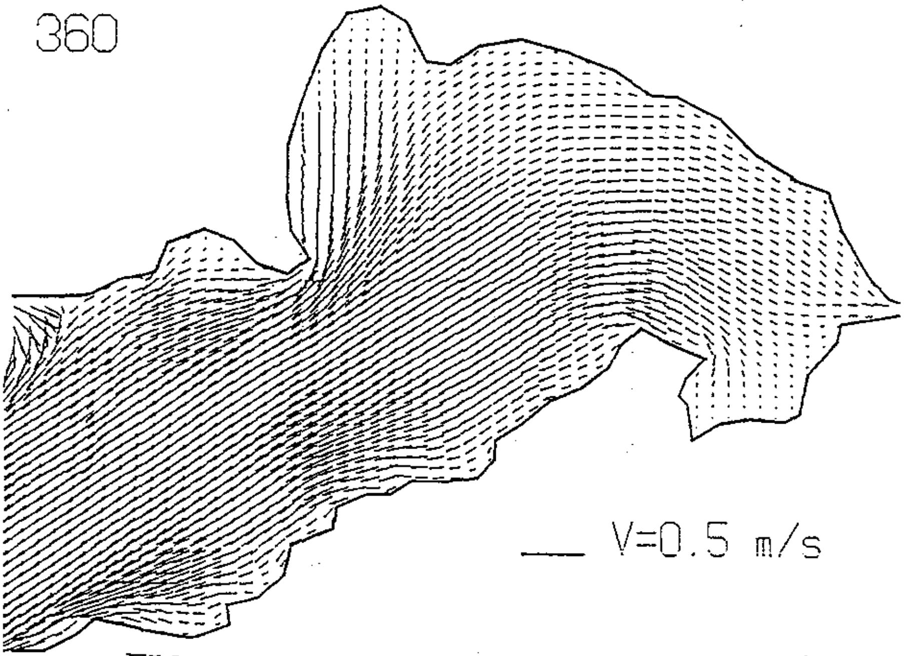


FIG. A7—32h) Flow field in Deep Bay (Spring Tide)

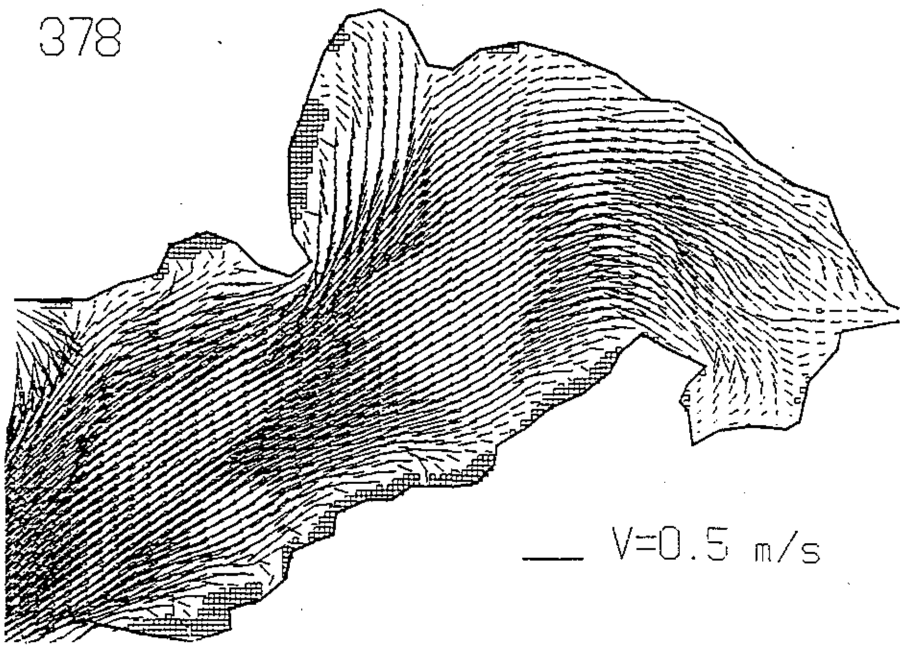


FIG. A7—32i) Flow field in Deep Bay (Spring Tide)

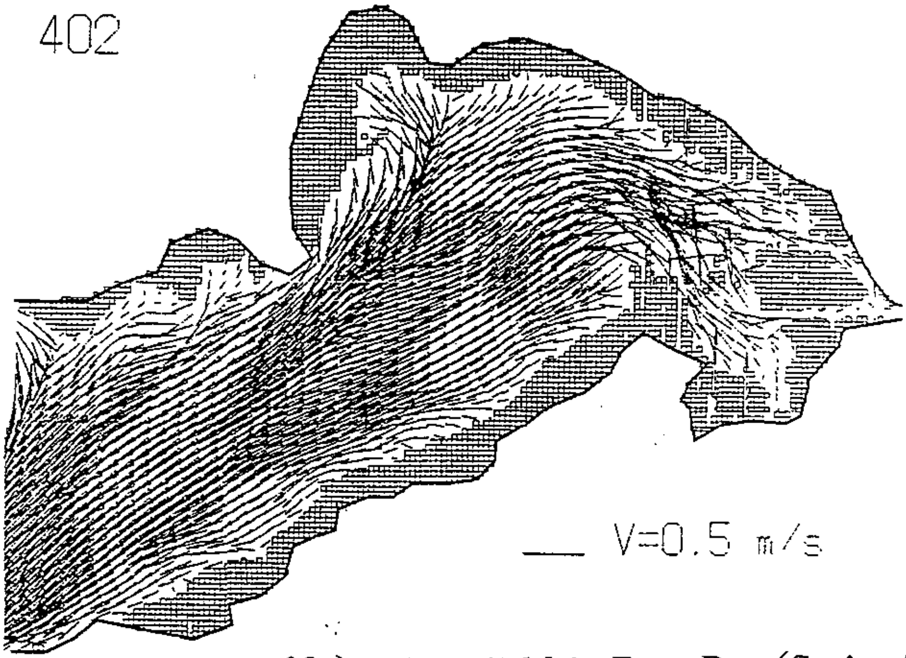


FIG. A7—32j) Flow field in Deep Bay (Spring Tide)

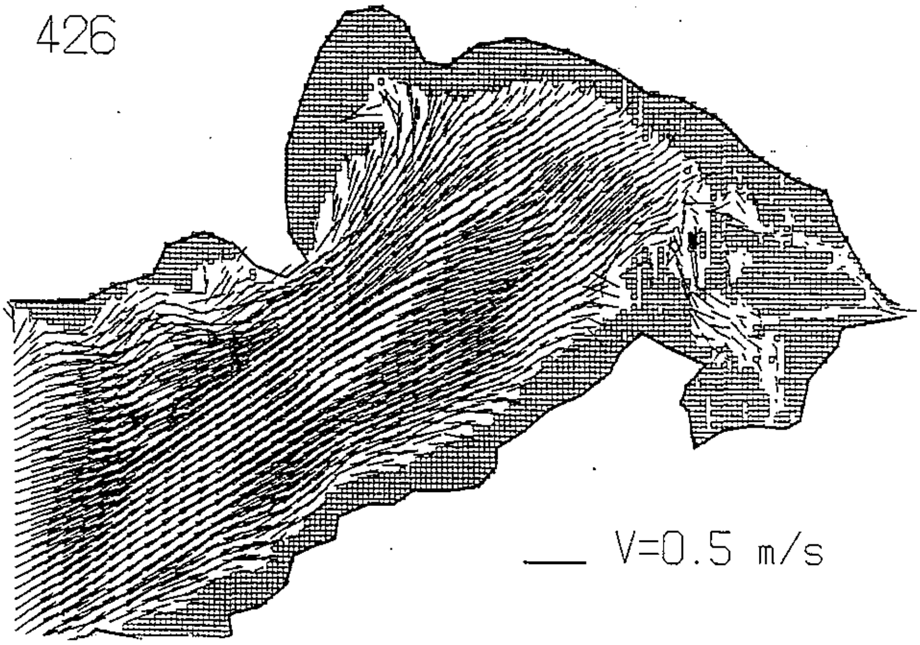


FIG. A7—32k) Flow field in Deep Bay (Spring Tide)

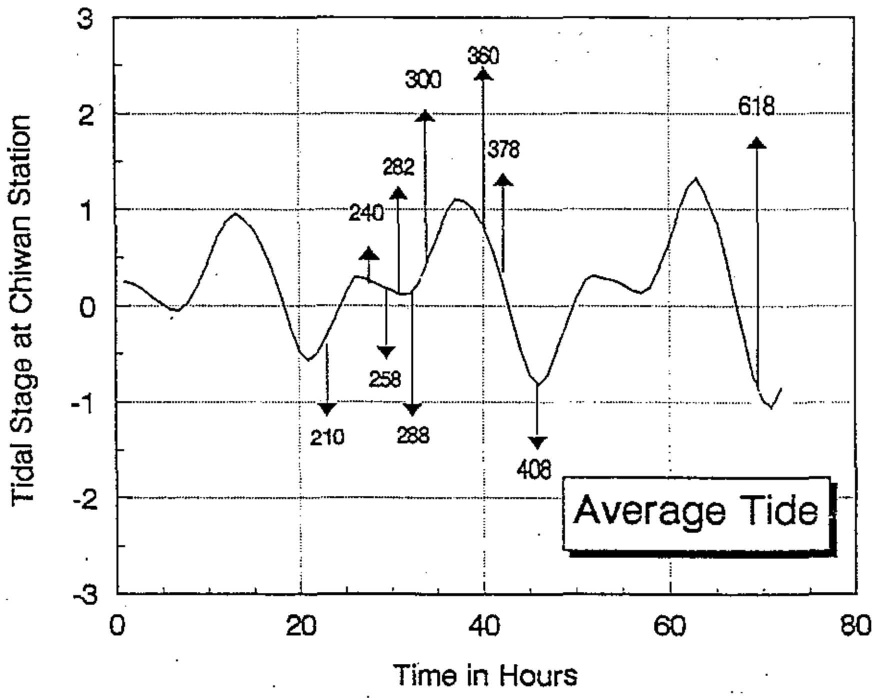


FIG. A7—33a) Typical tide level process and time sequence (Average Tide)

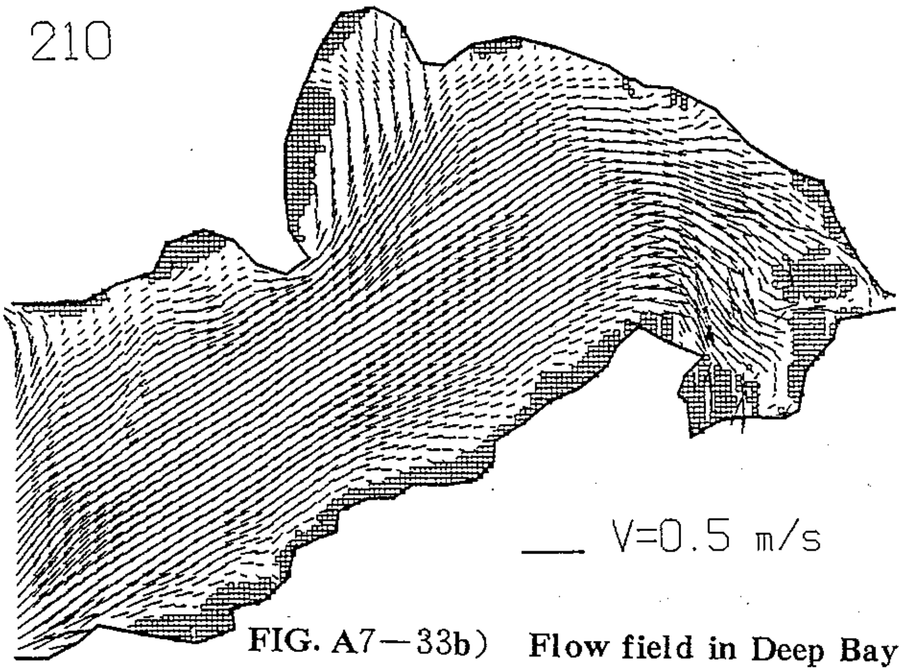


FIG. A7—33b) Flow field in Deep Bay (Average Tide)

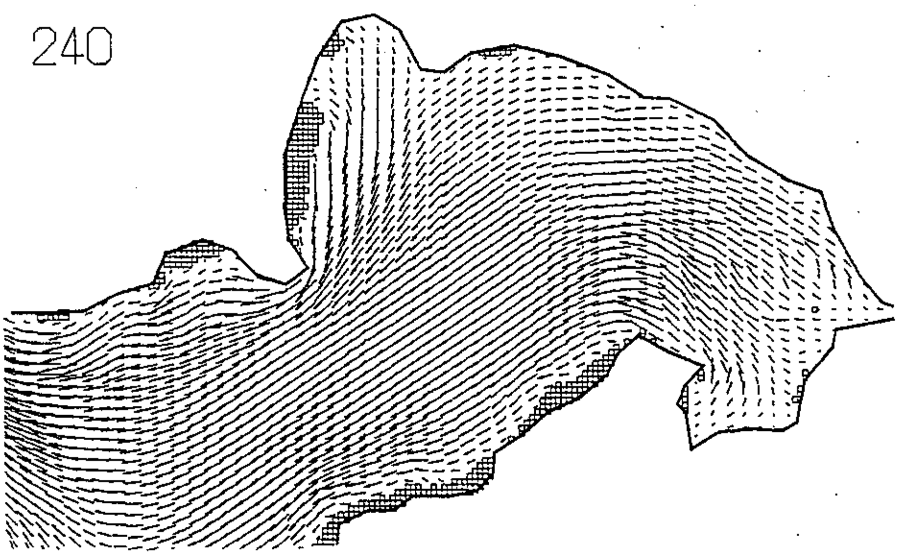


FIG. A7—33c) Flow field in Deep Bay (Average Tide)

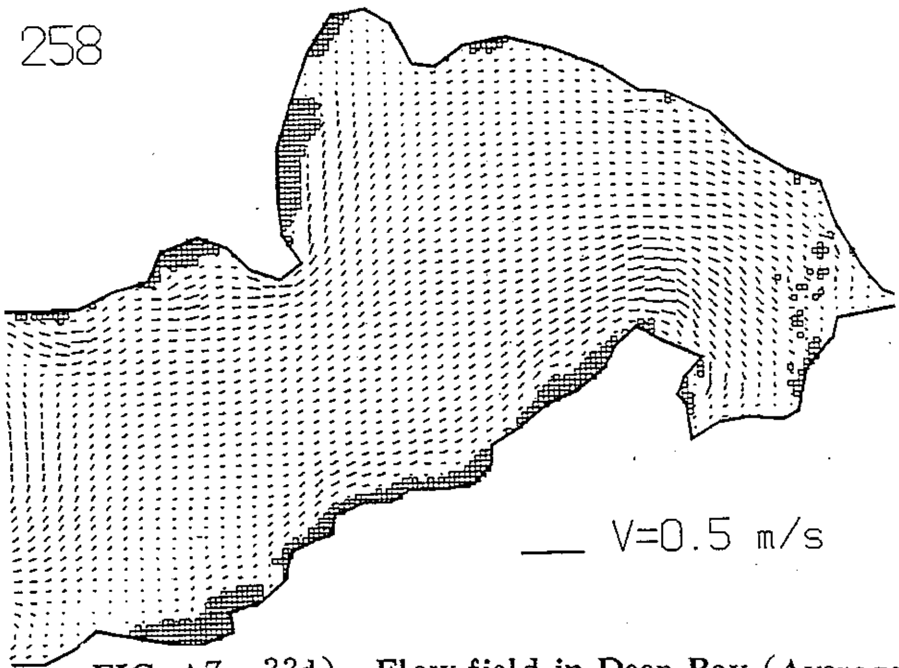


FIG. A7—33d) Flow field in Deep Bay (Average Tide)

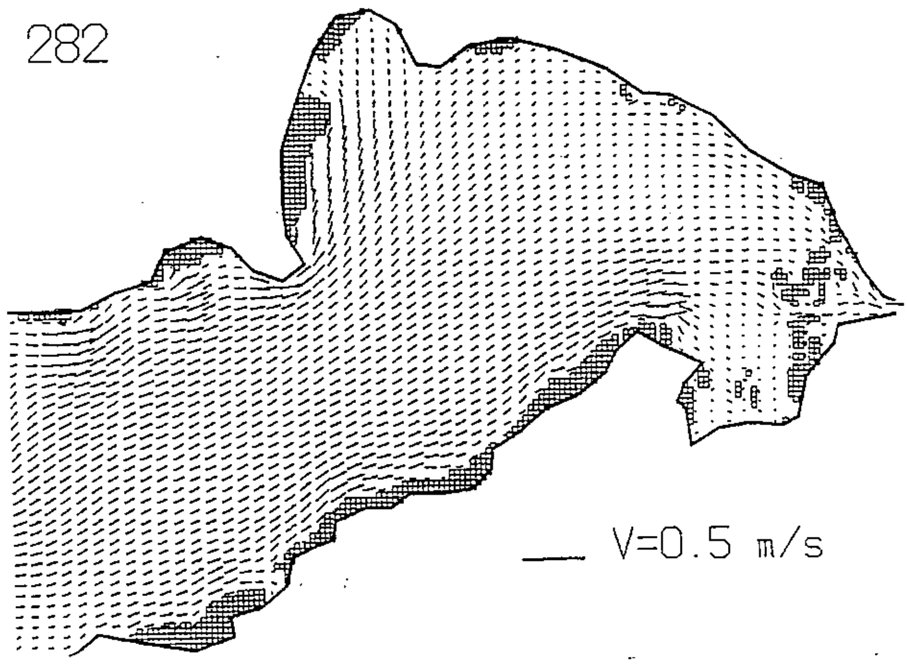


FIG. A7—33e) Flow field in Deep Bay (Average Tide)

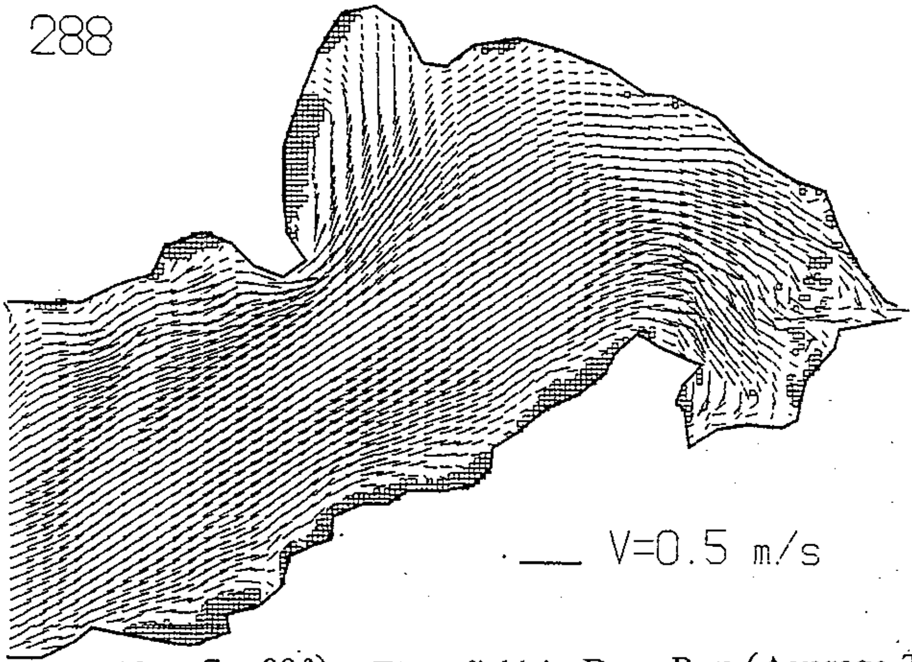


FIG. A7—33f) Flow field in Deep Bay (Average Tide)

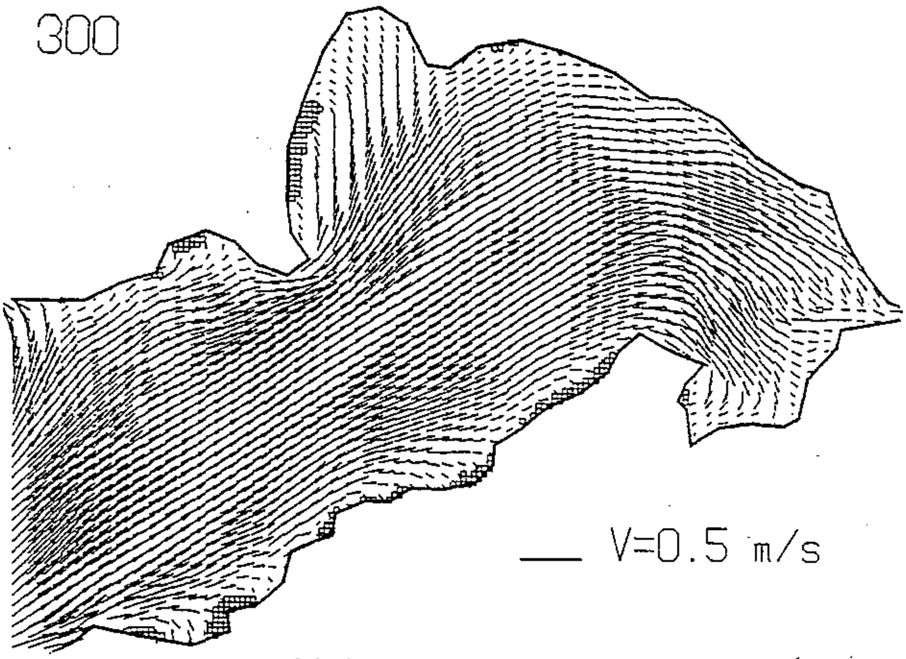


FIG. A7—33g) Flow field in Deep Bay (Average Tide)

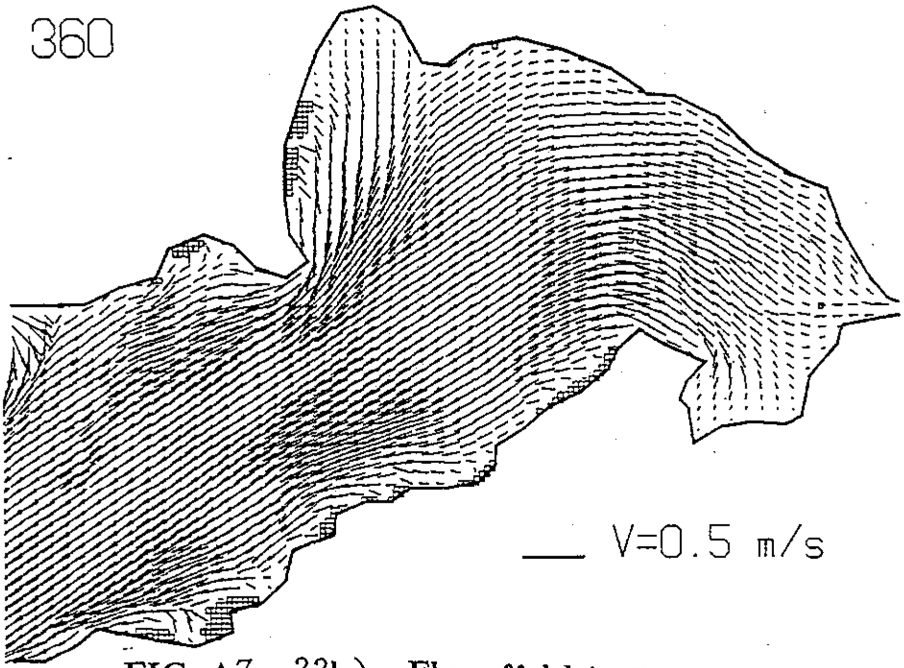


FIG. A7—33h) Flow field in Deep Bay (Average Tide)

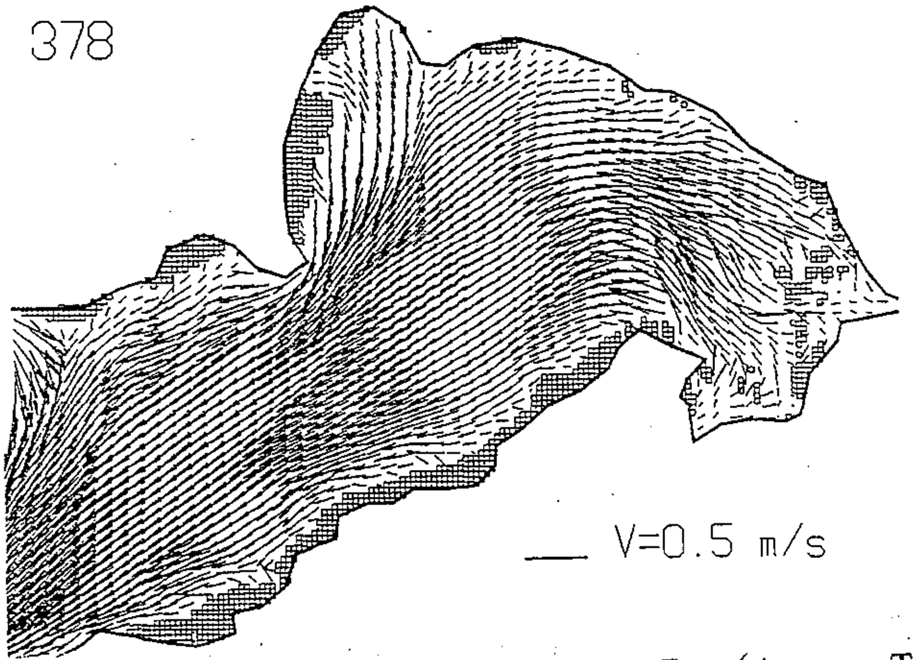


FIG. A7—33i) Flow field in Deep Bay (Average Tide)

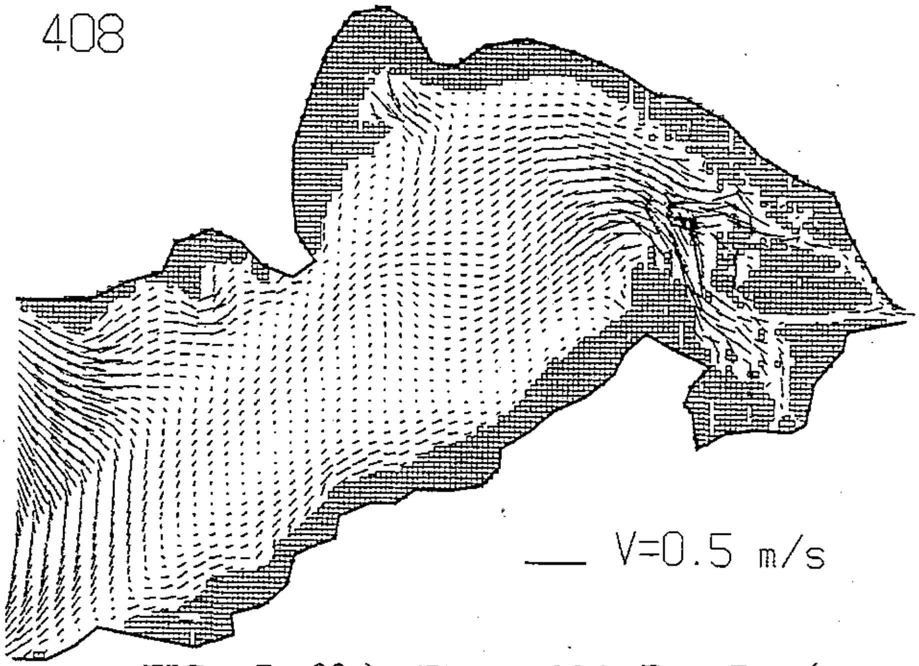


FIG. A7—33j) Flow field in Deep Bay (Average Tide)

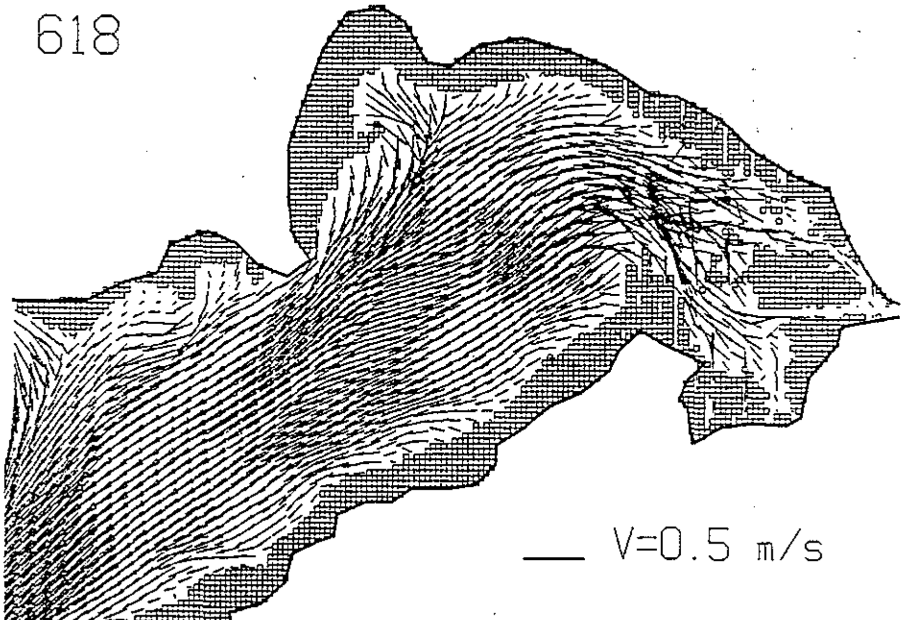


FIG. A7—33k) Flow field in Deep Bay (Average Tide)

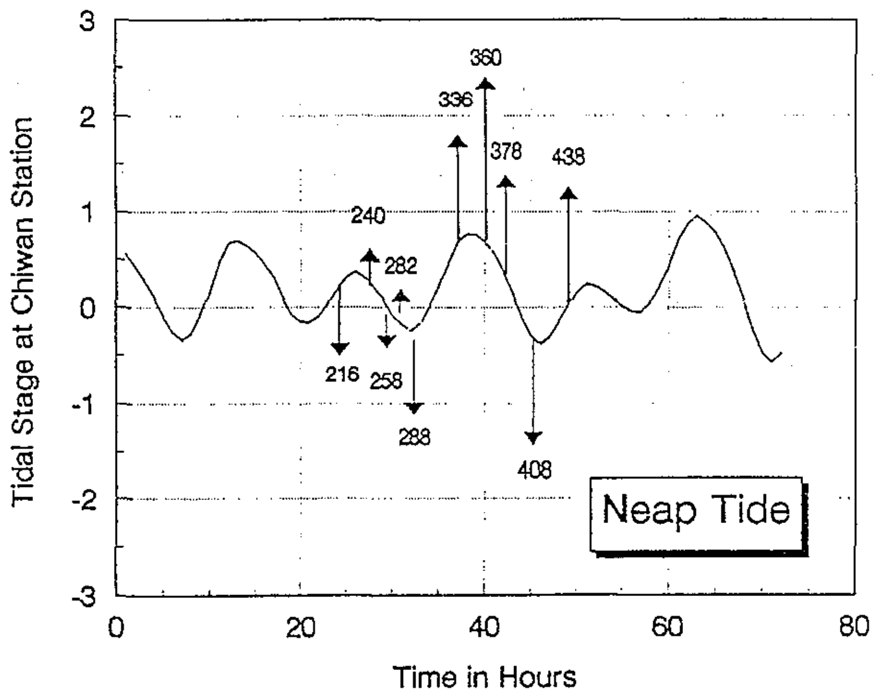


FIG. A7—34a) Typical tide level process and time sequence (Neap Tide)

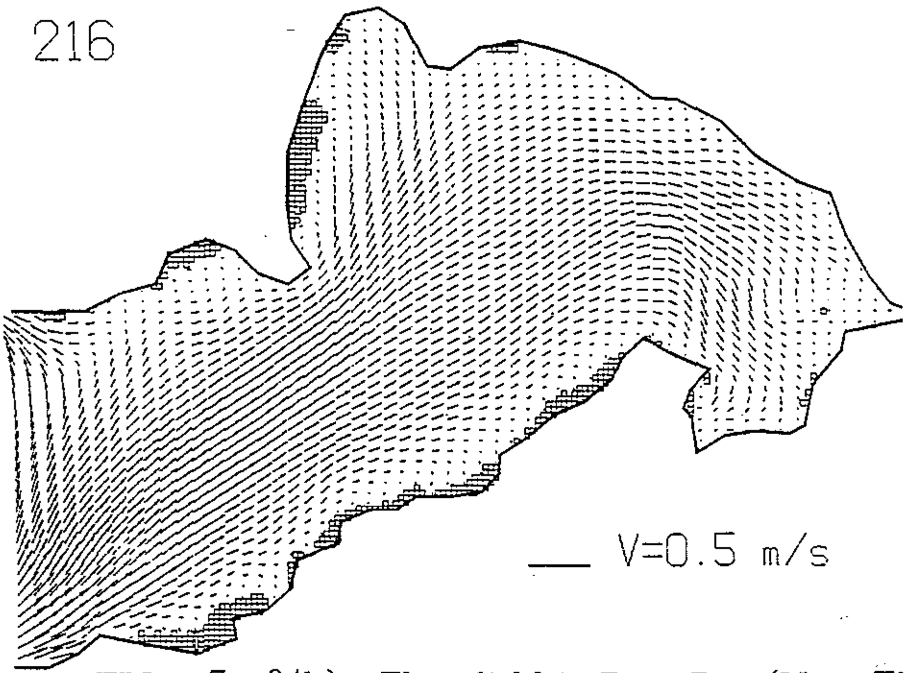


FIG. A7—34b) Flow field in Deep Bay (Neap Tide)

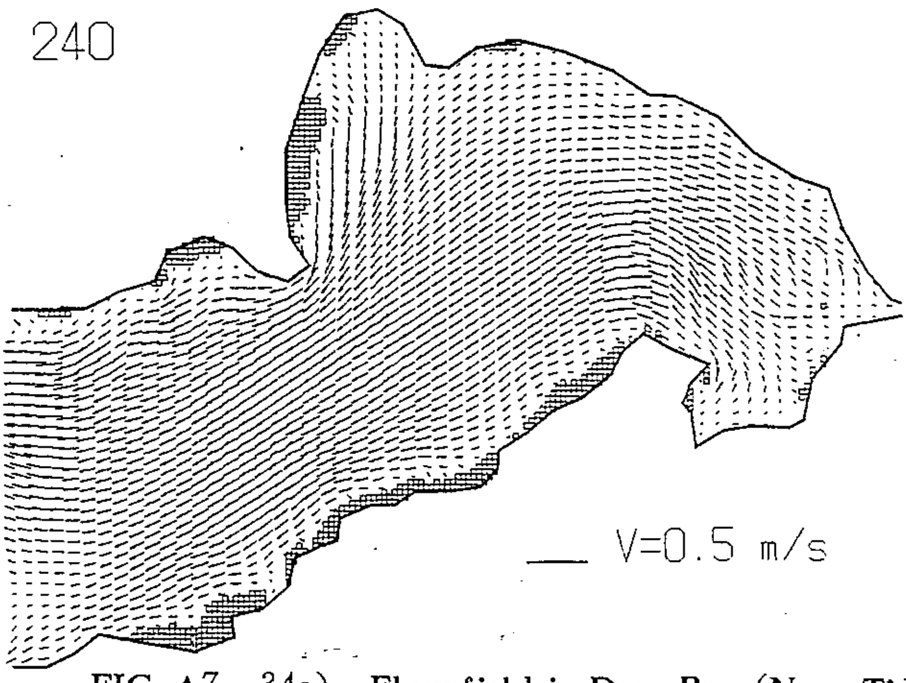


FIG. A7—34c) Flow field in Deep Bay (Neap Tide)

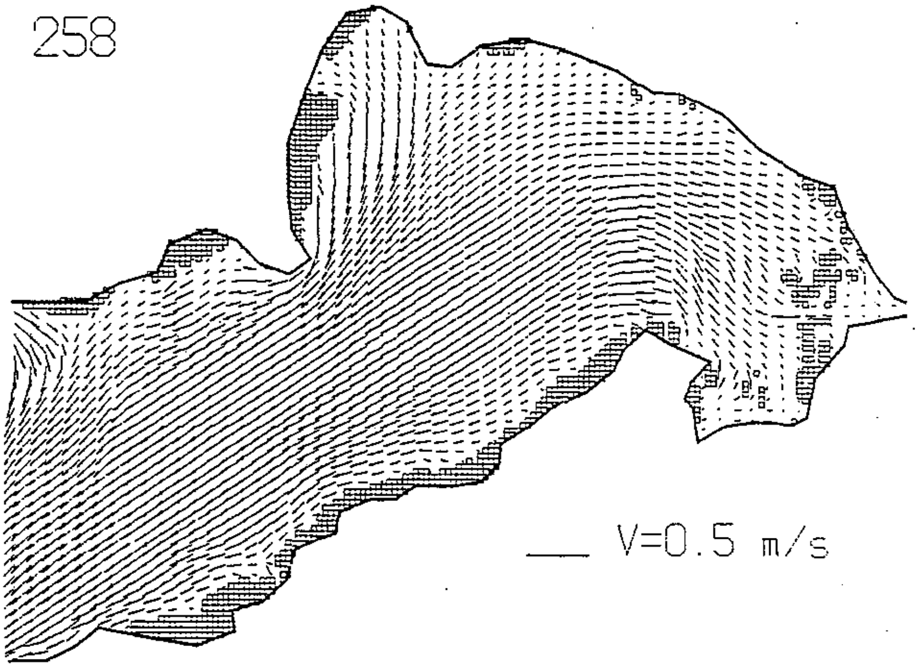


FIG. A7—34d) Flow field in Deep Bay (Neap Tide)

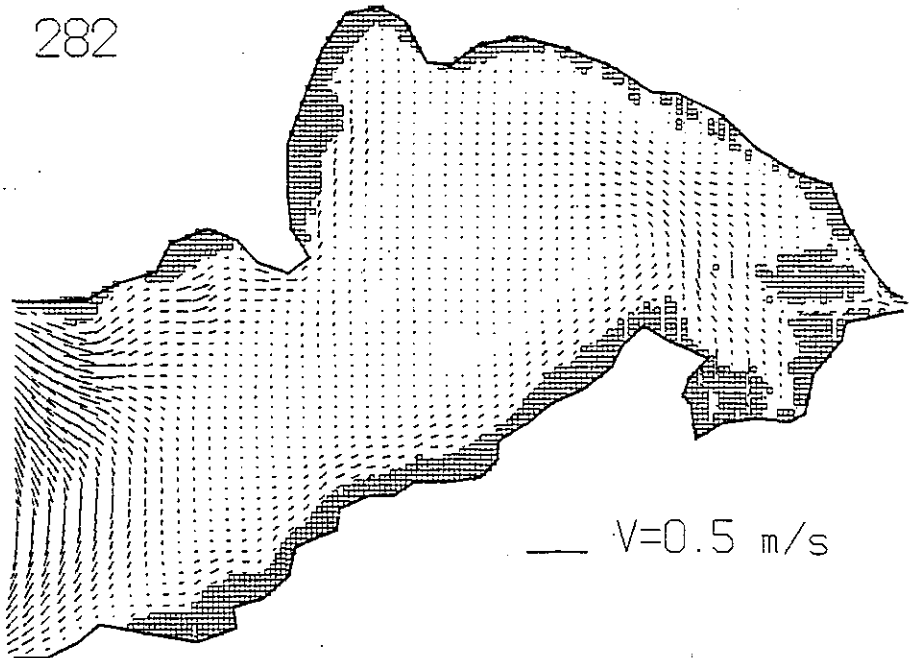


FIG. A7—34e) Flow field in Deep Bay (Neap Tide)

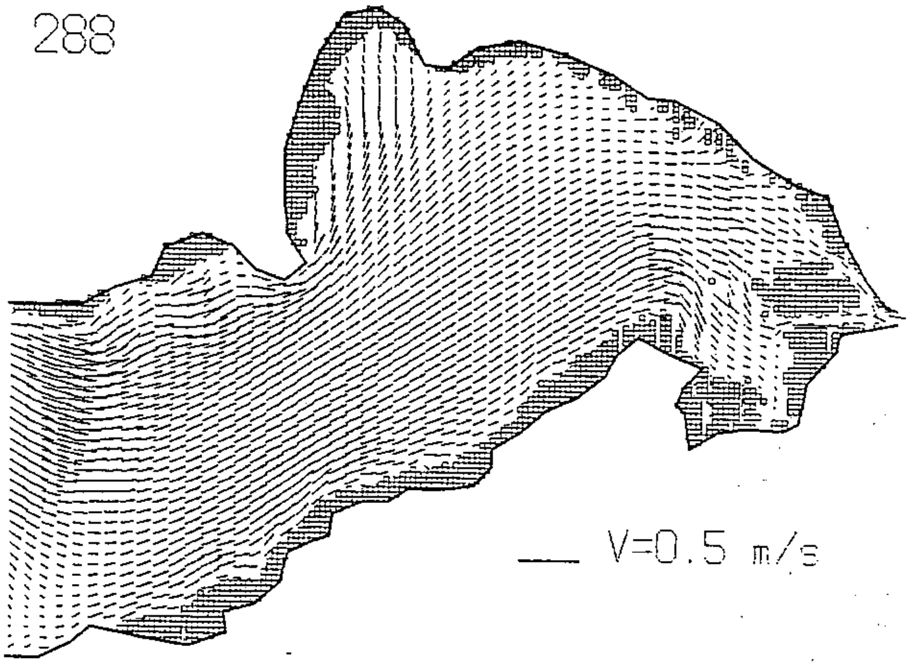


FIG. A7—34f) Flow field in Deep Bay (Neap Tide)

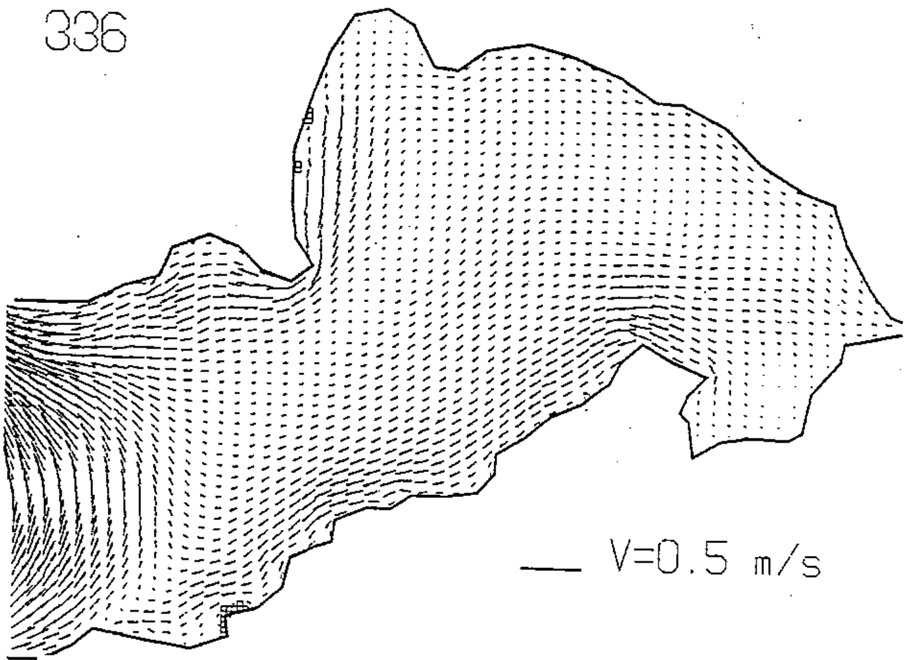


FIG. A7—34g) Flow field in Deep Bay (Neap Tide)

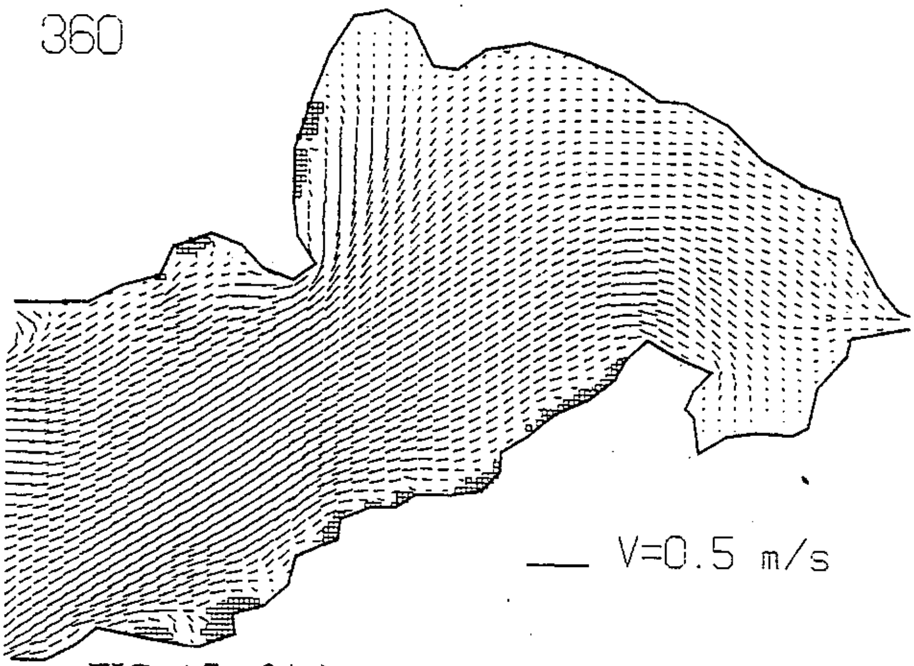


FIG. A7—34h) Flow field in Deep Bay (Neap Tide)

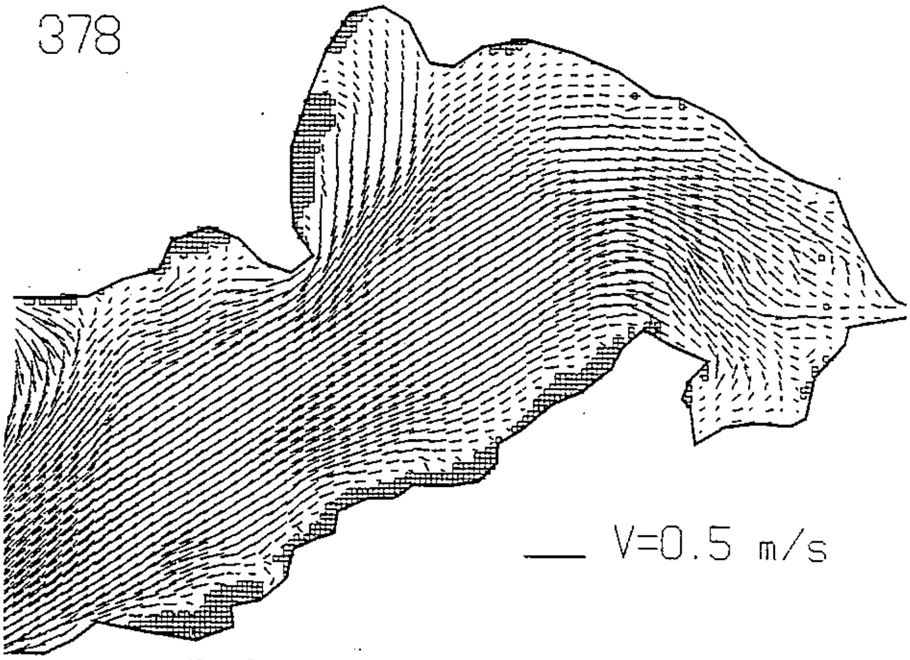


FIG. A7—34i) Flow field in Deep Bay (Neap Tide)

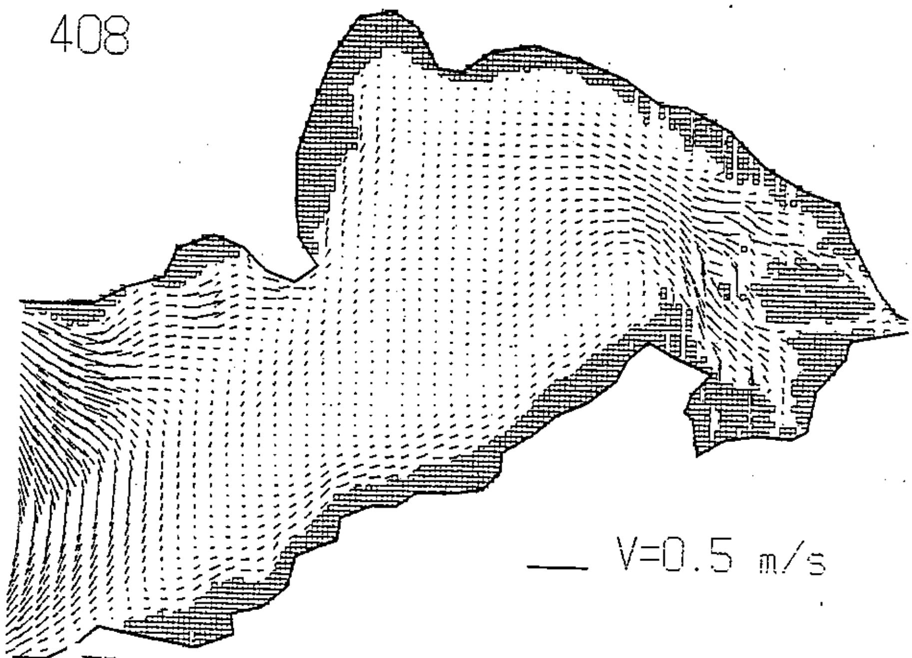


FIG. A7—34j) Flow field in Deep Bay (Neap Tide)

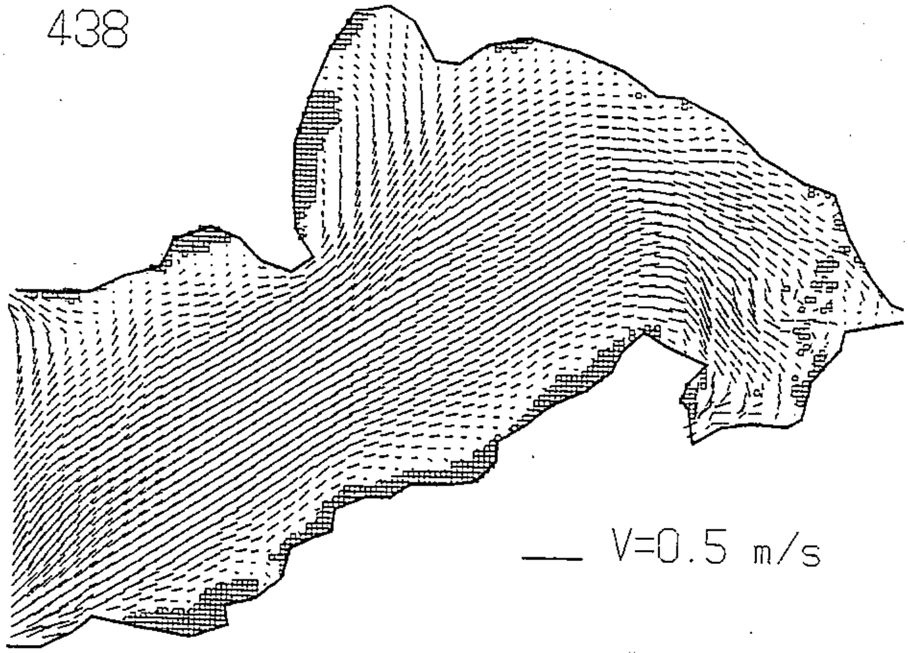


FIG. A7—34k) Flow field in Deep Bay (Neap Tide)

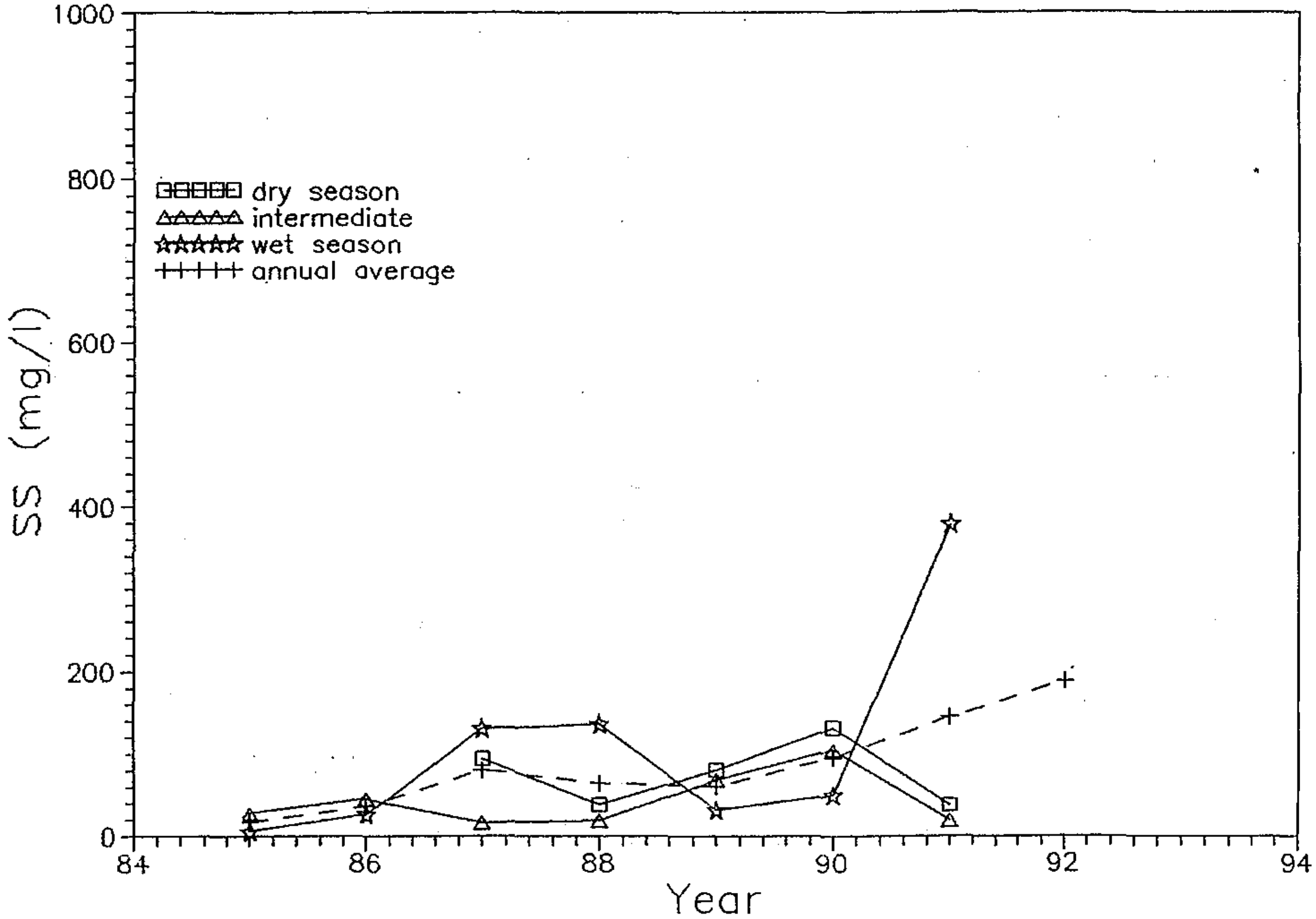


FIG. A7—36 Varation of SS in Buji estuary

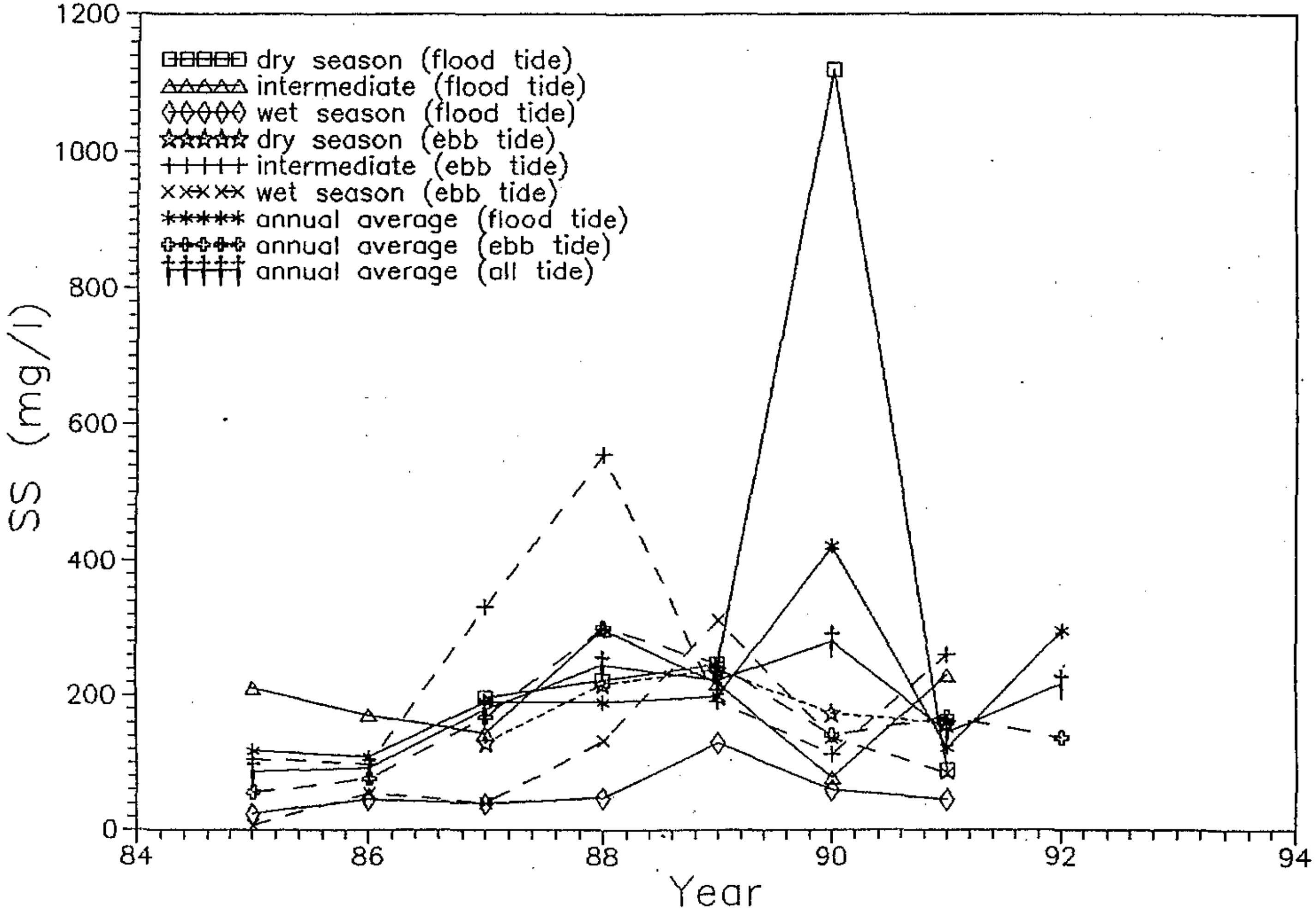


FIG. A7—37 Varation of SS in Zhuan Matou

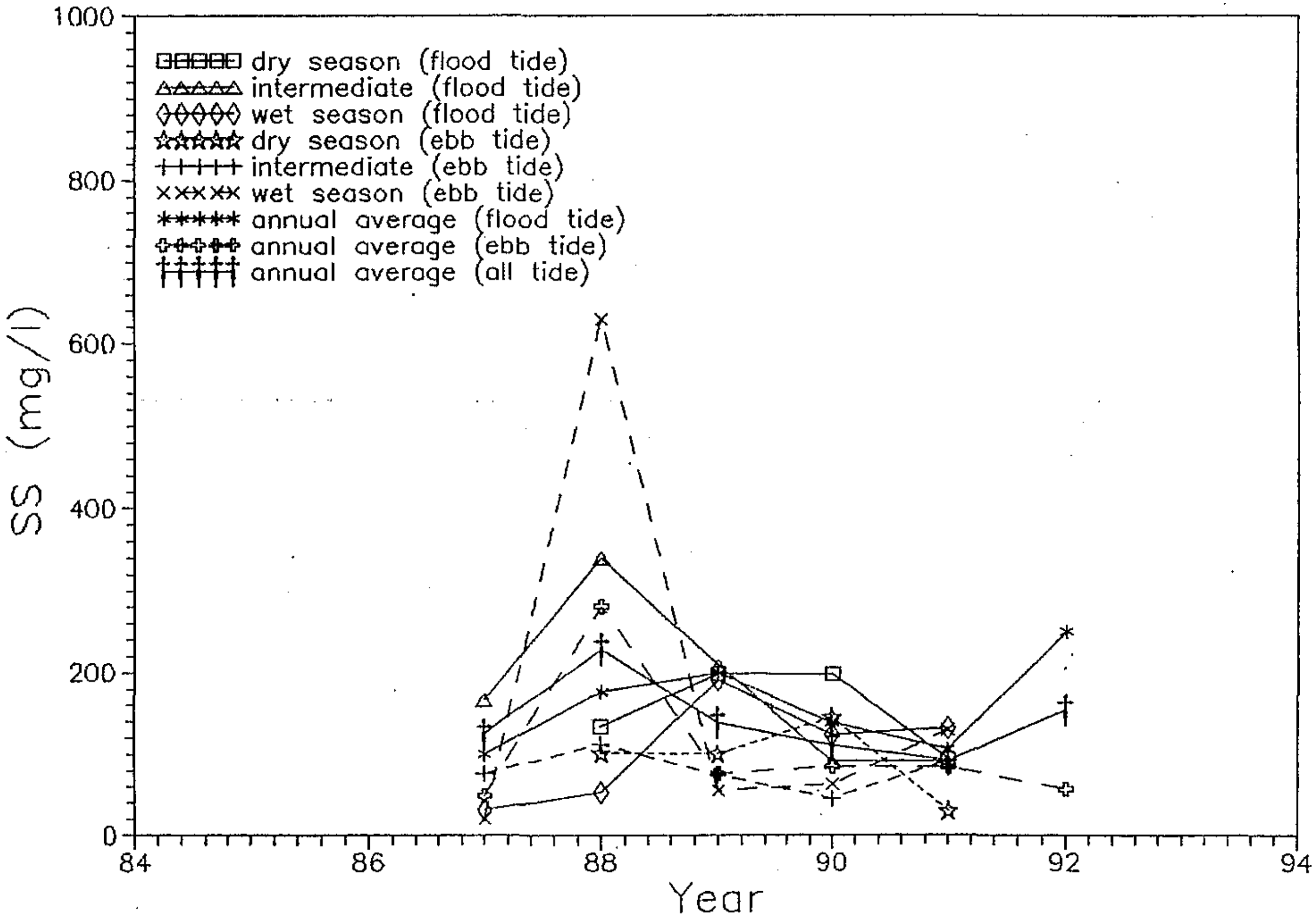


FIG. A7—38 Varation of SS in Yumin Village

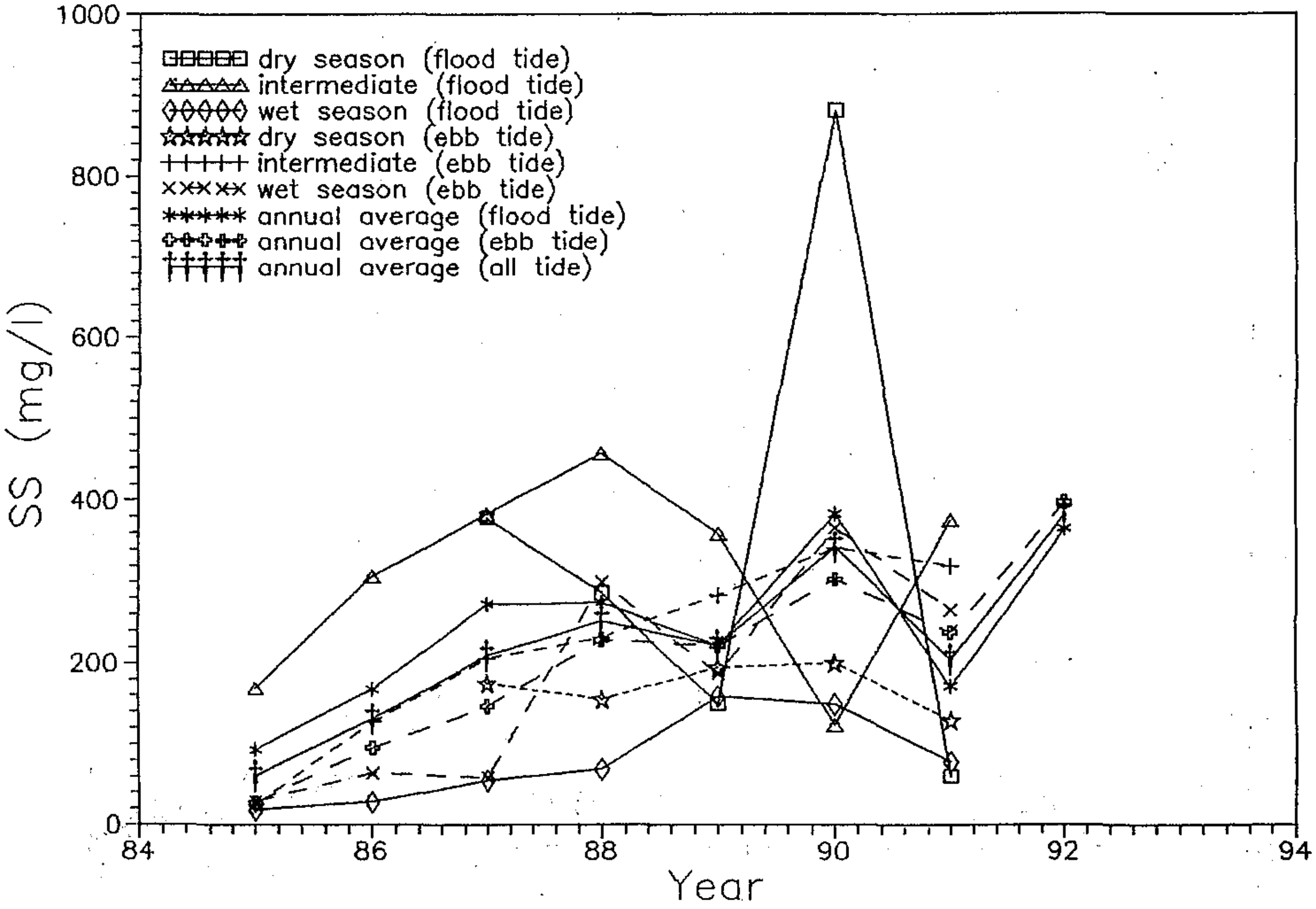


FIG. A7—39 Varation of SS in Shenzhen estuary

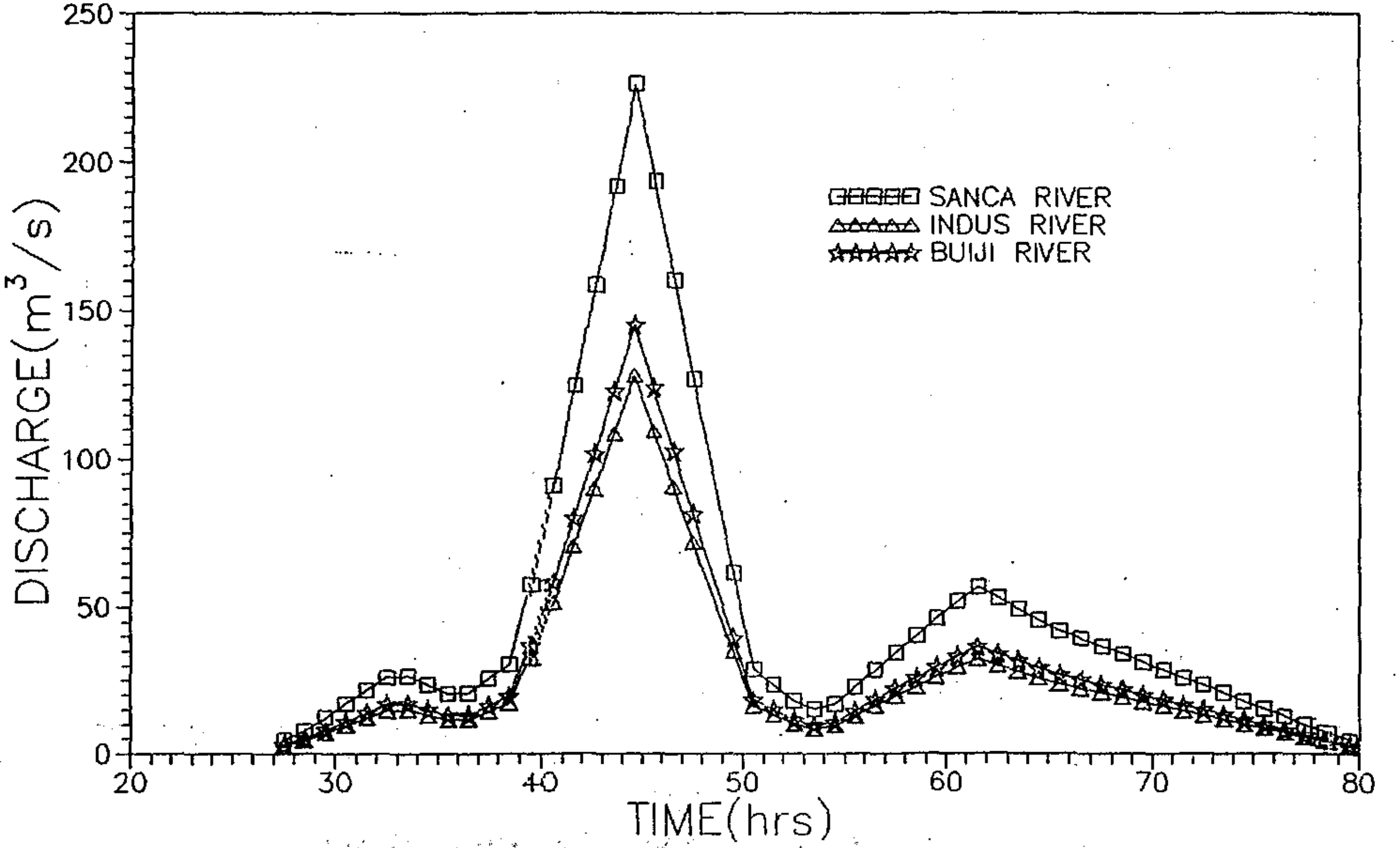


FIG. A7—40 Typical flood hydrographs at different sections along the Shenzhen River (P=100%)

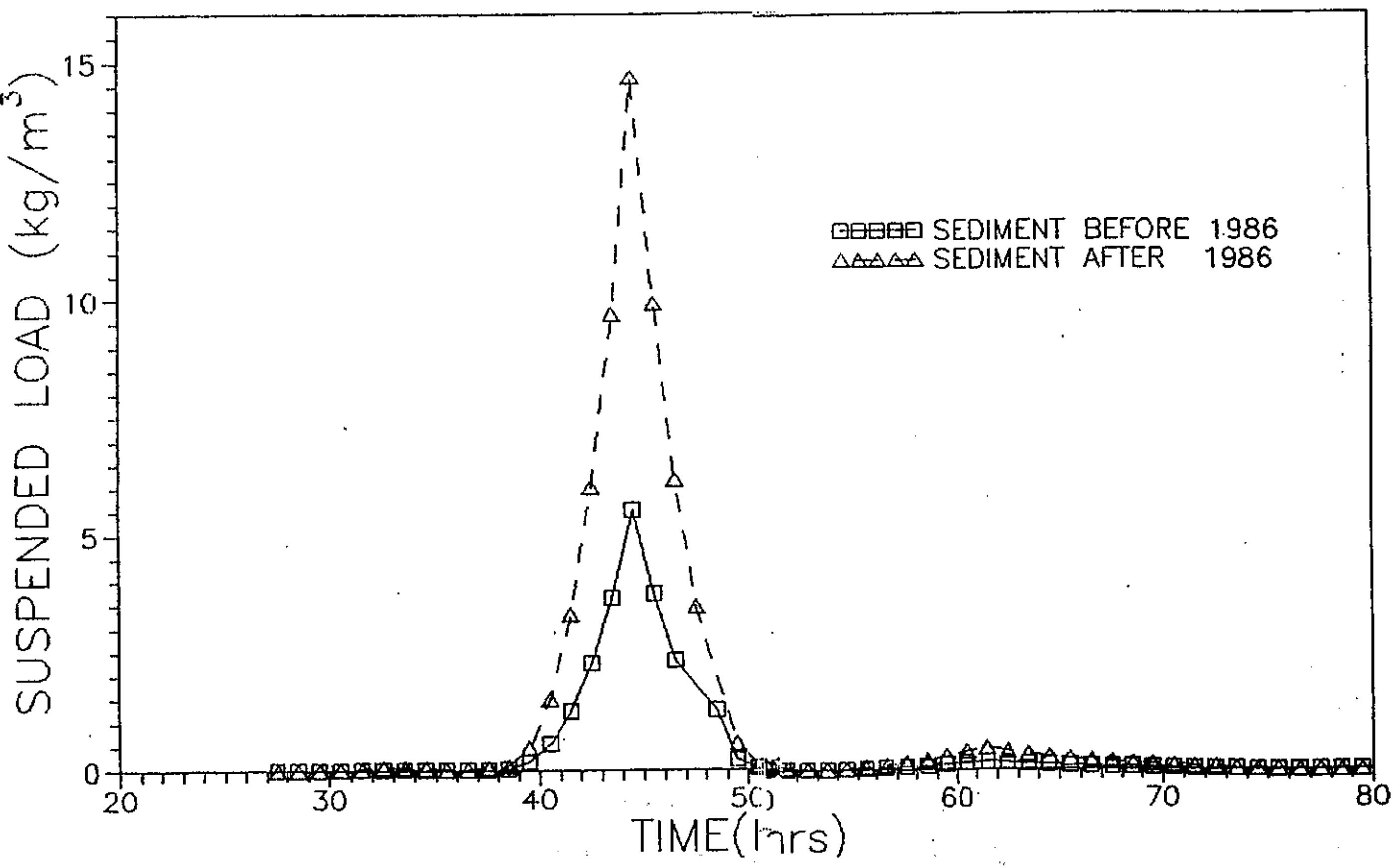


FIG. A7—41 Sediment hydrograph at Sacha River

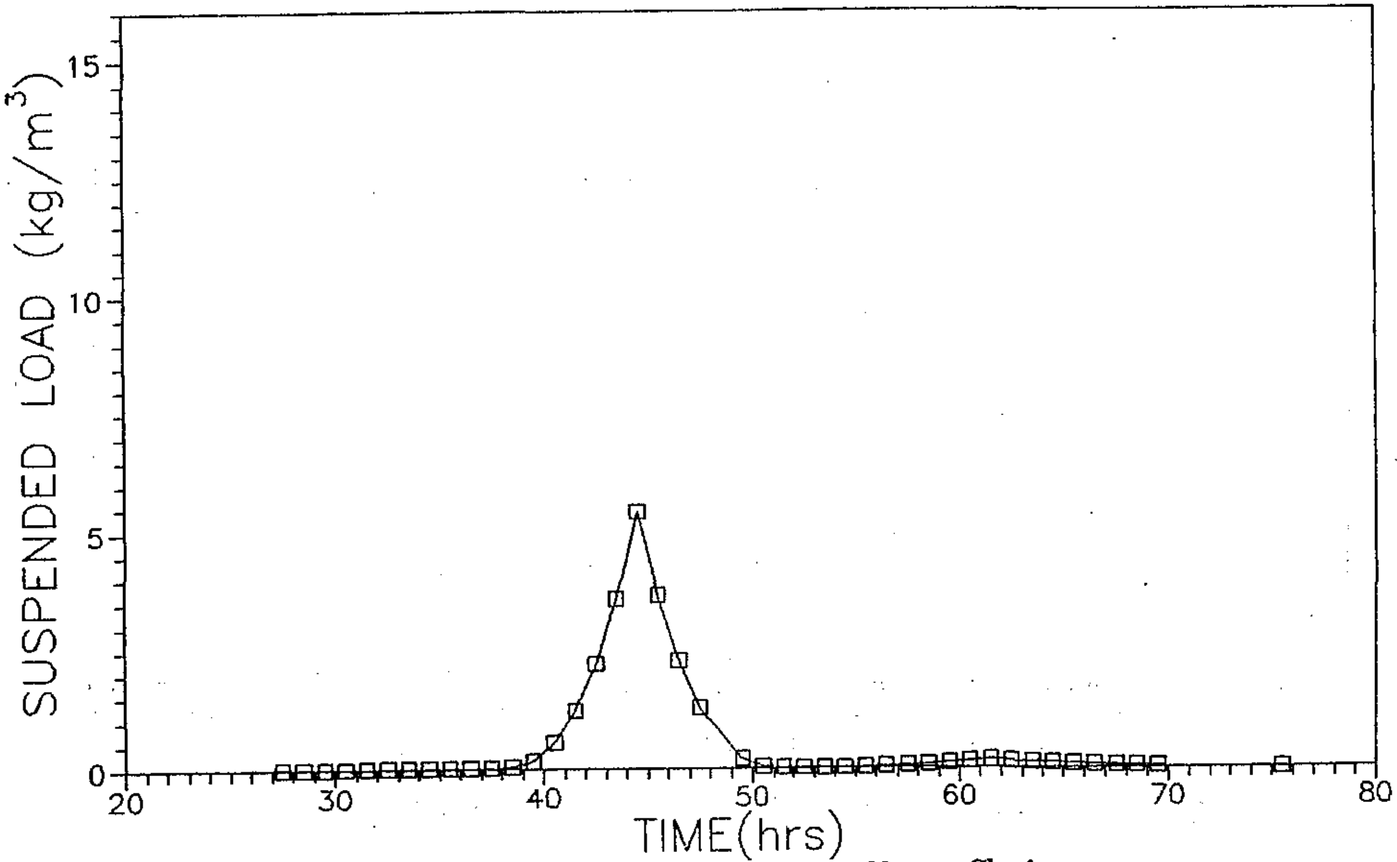


FIG. A7—42 Sediment hydrograph at Shang Shui

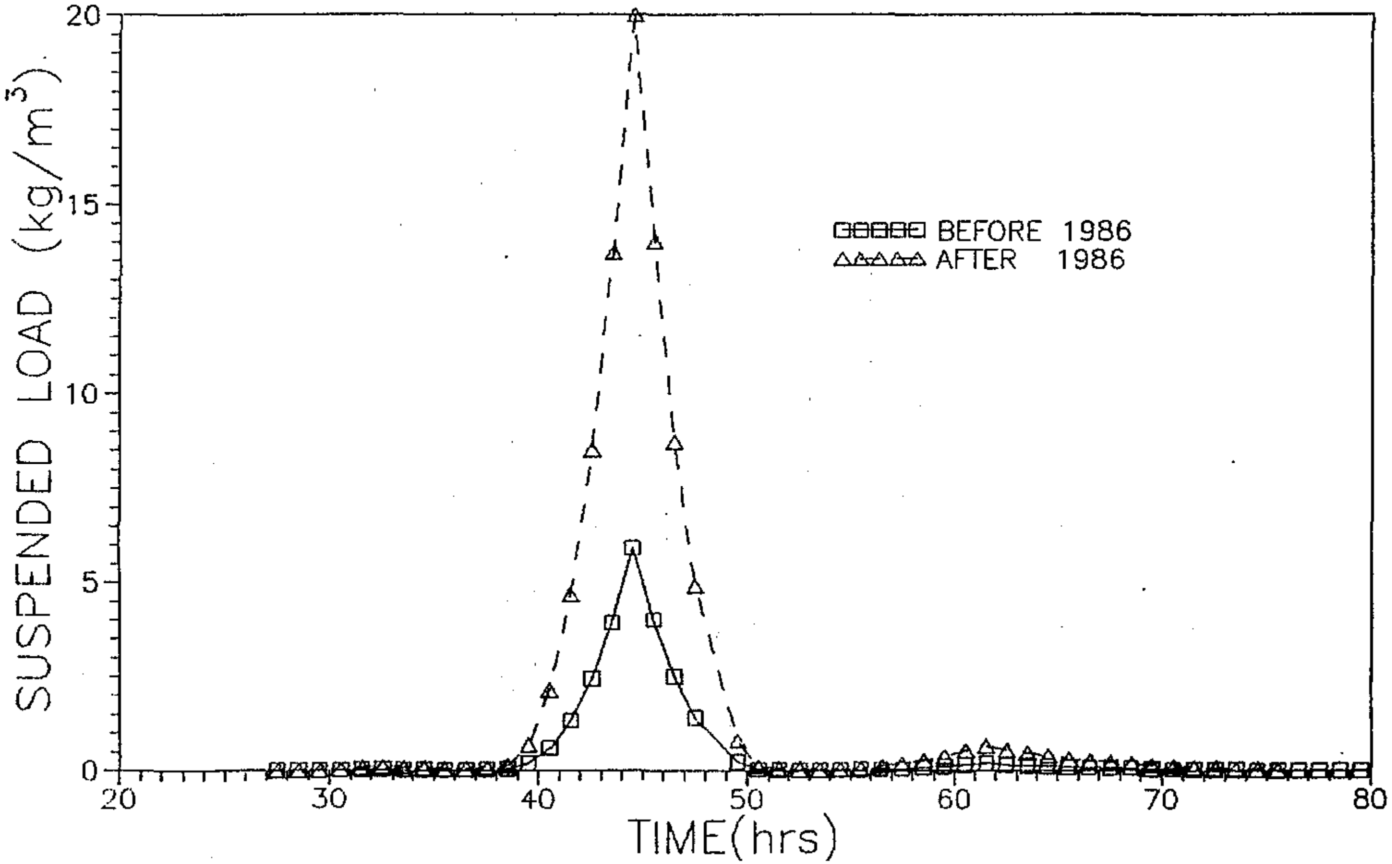


FIG. A7—43 Sediment hydrograph at Buji

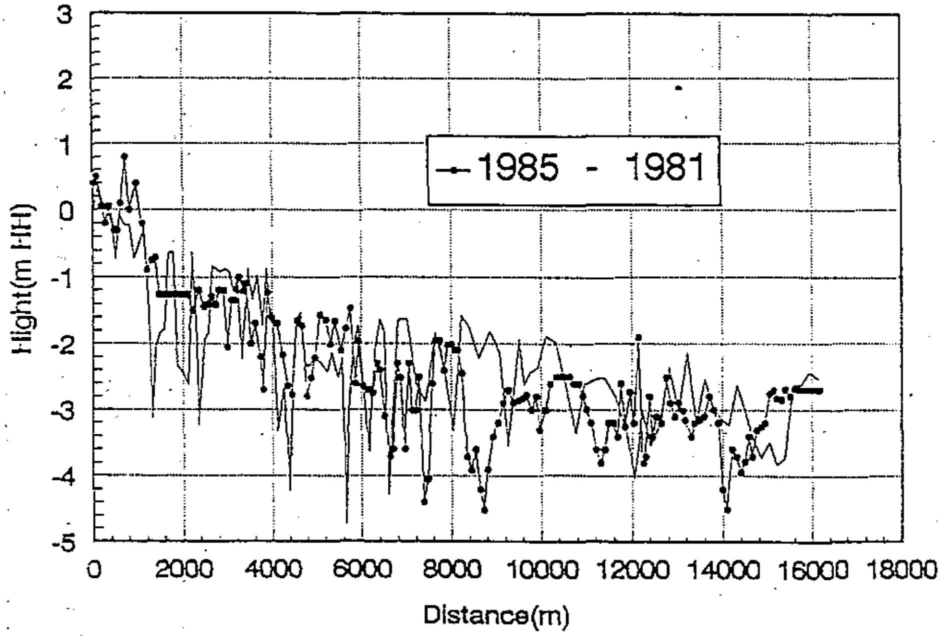


FIG. A7—44 Bed variation of Shenzhen River prior to 1986

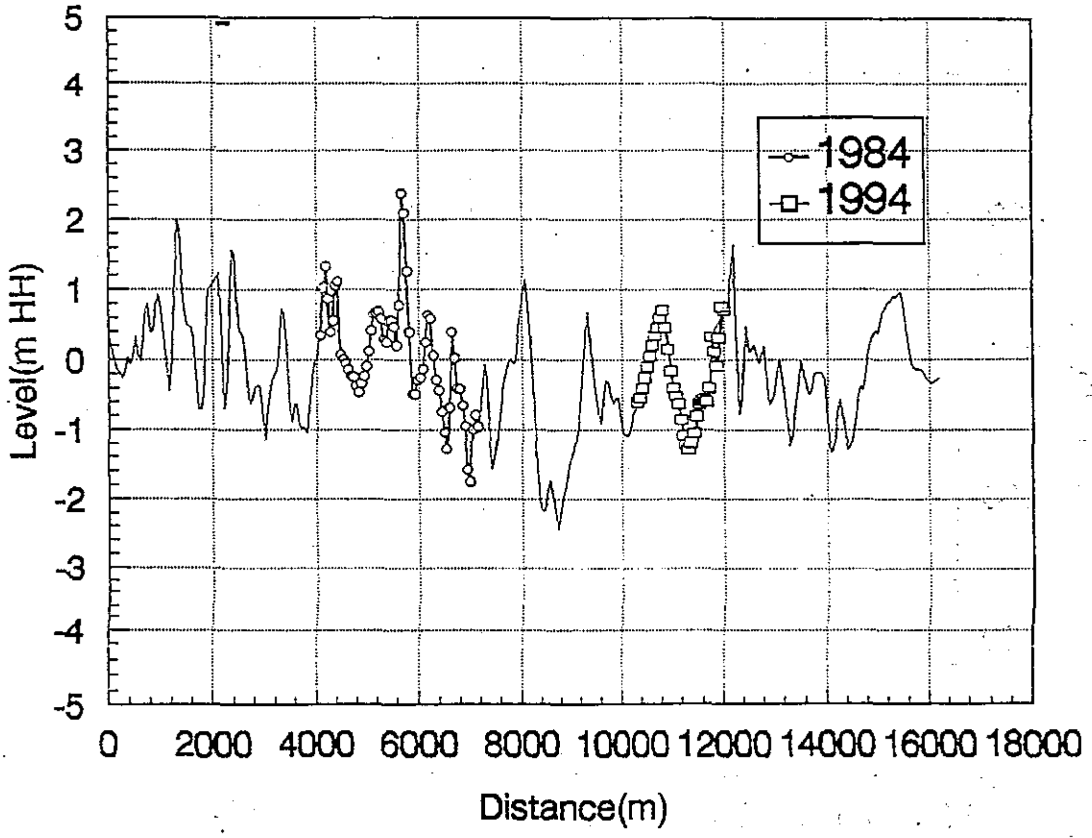


FIG. A7—45 The variation of bed elevation(1981-85)

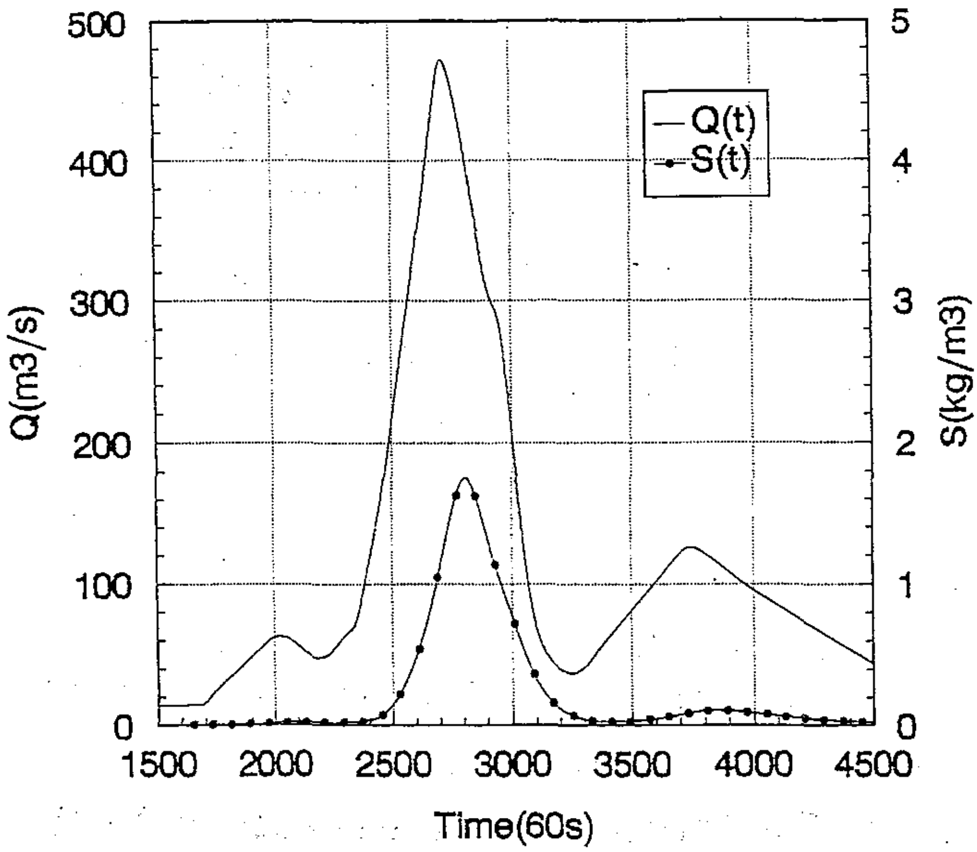


FIG. A7—46 Q(t) And S(t) At River Mouth (p=100%)

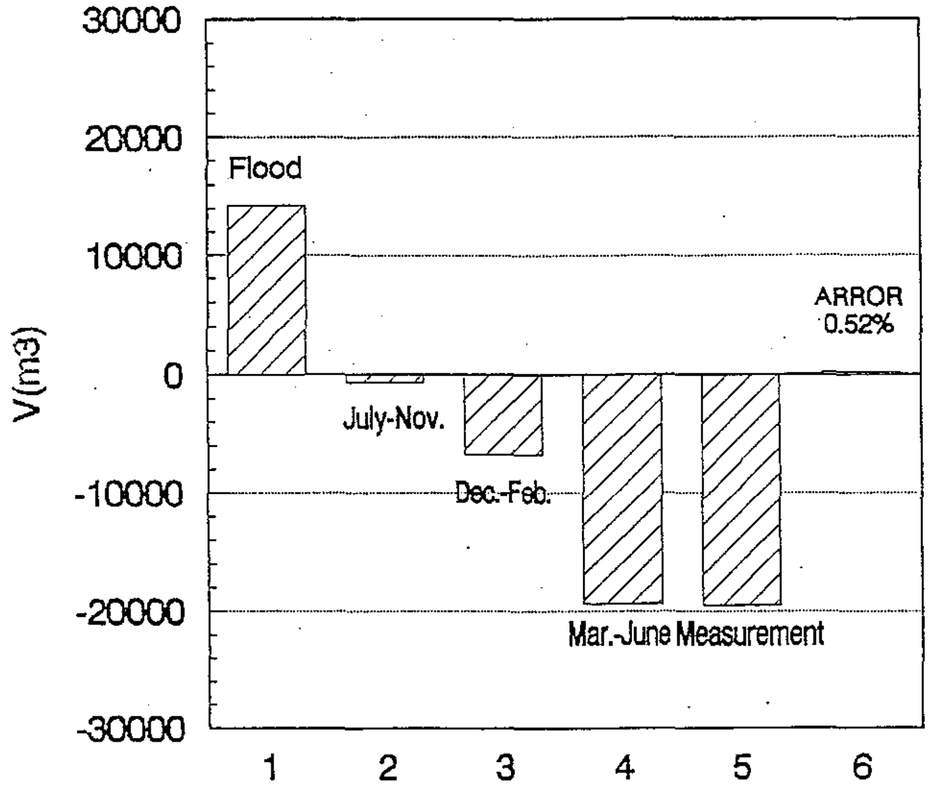


FIG. A7—47 Calibration Of The Sediment Model (Flood p=100% Tide July-June)

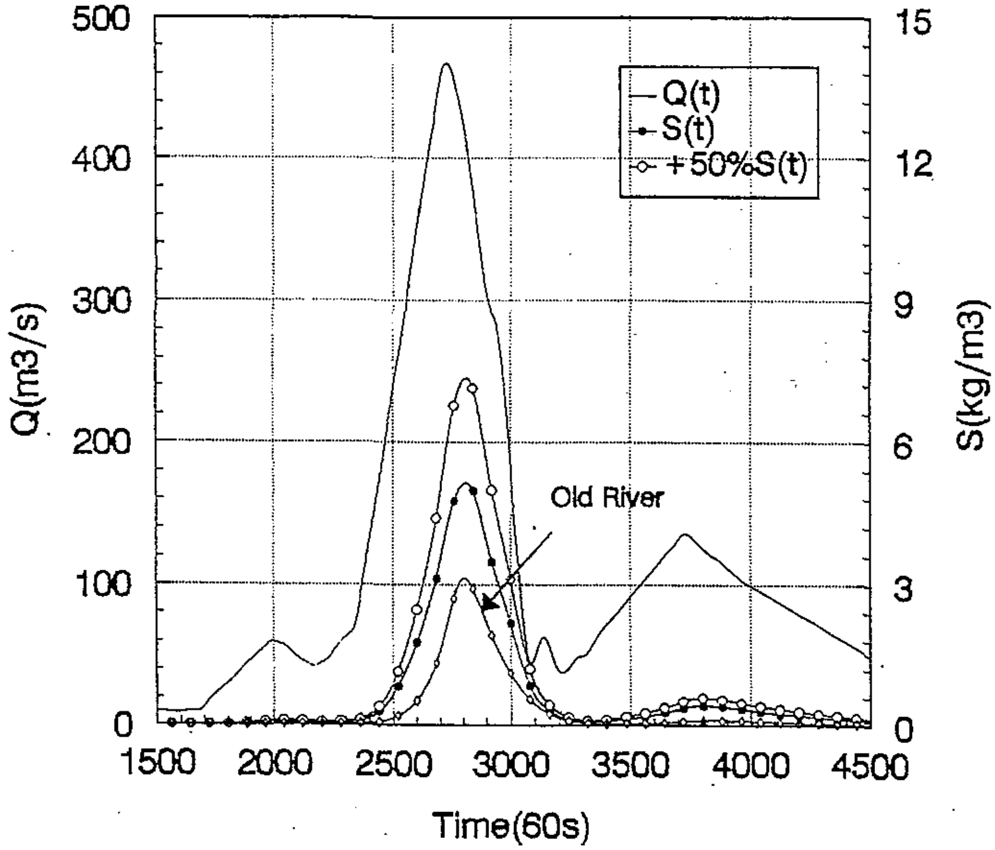


FIG. A7—48 Q(t) And S(t) At River Mouth (p=100%)
(Trained River)

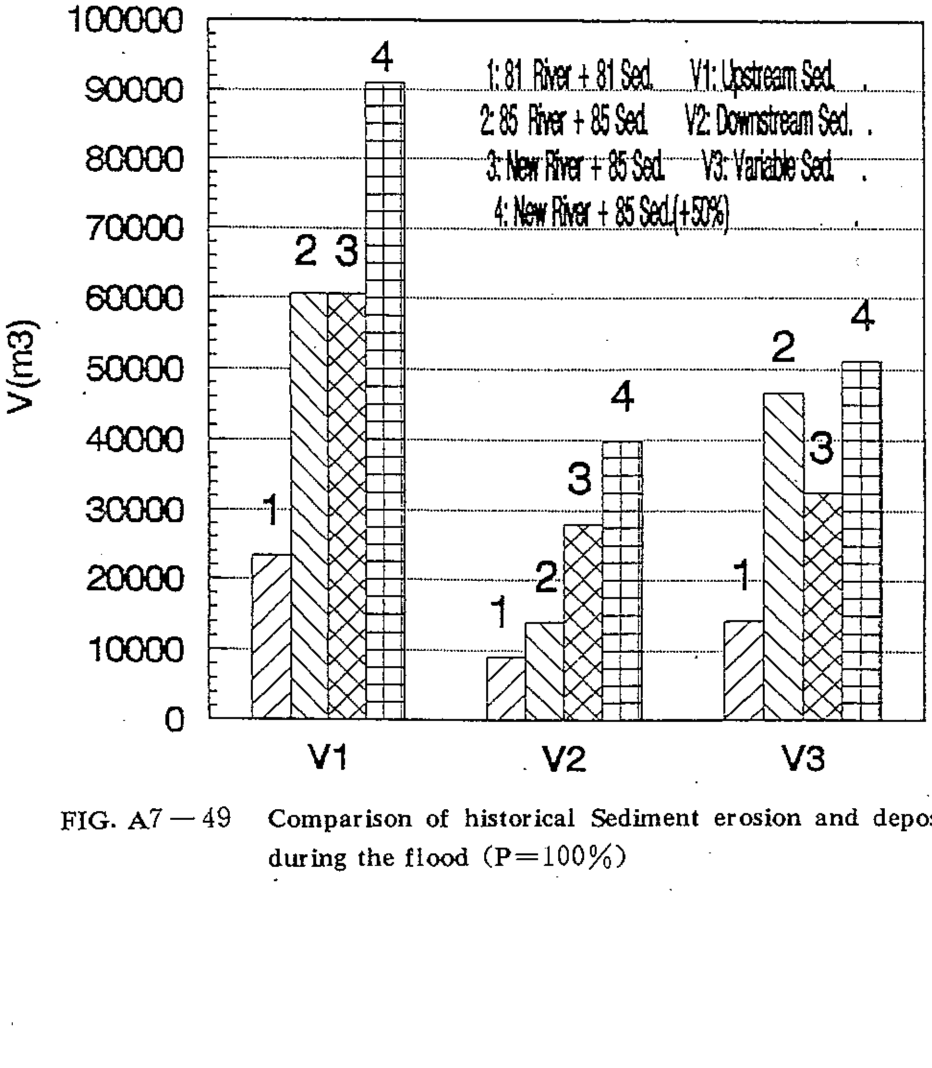


FIG. A7 — 49 Comparison of historical Sediment erosion and deposition during the flood (P=100%)

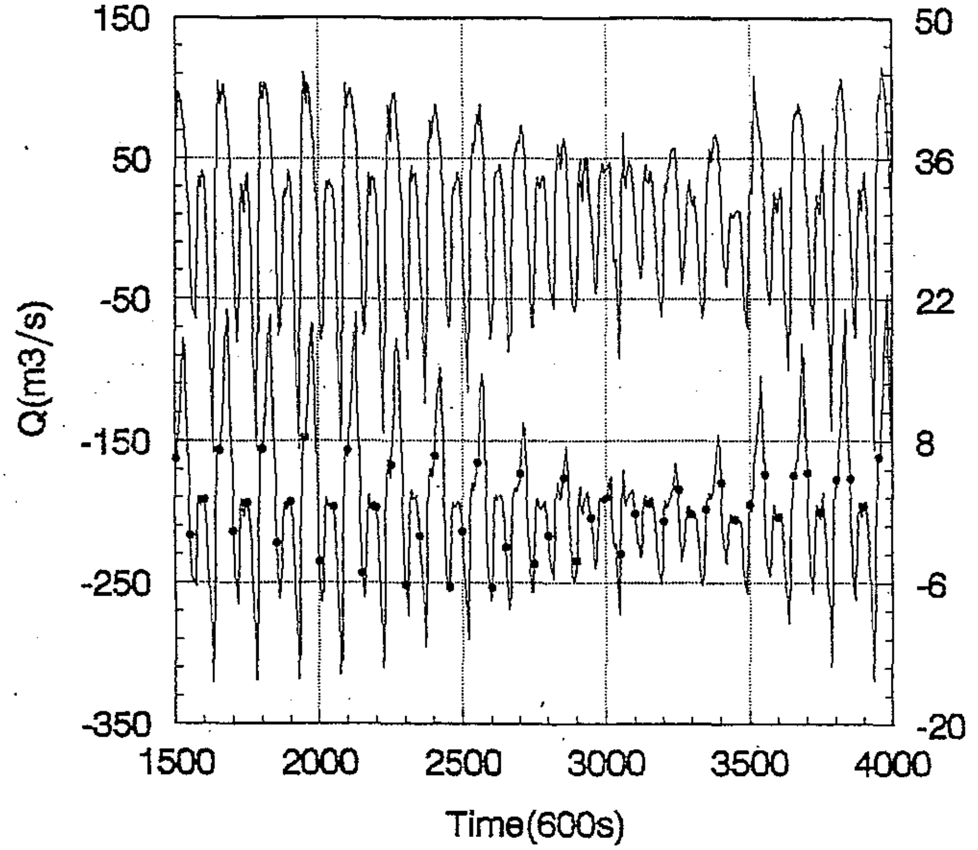


FIG. A7—50 Q(t) And Qs(t) At River Mouth (Old River)

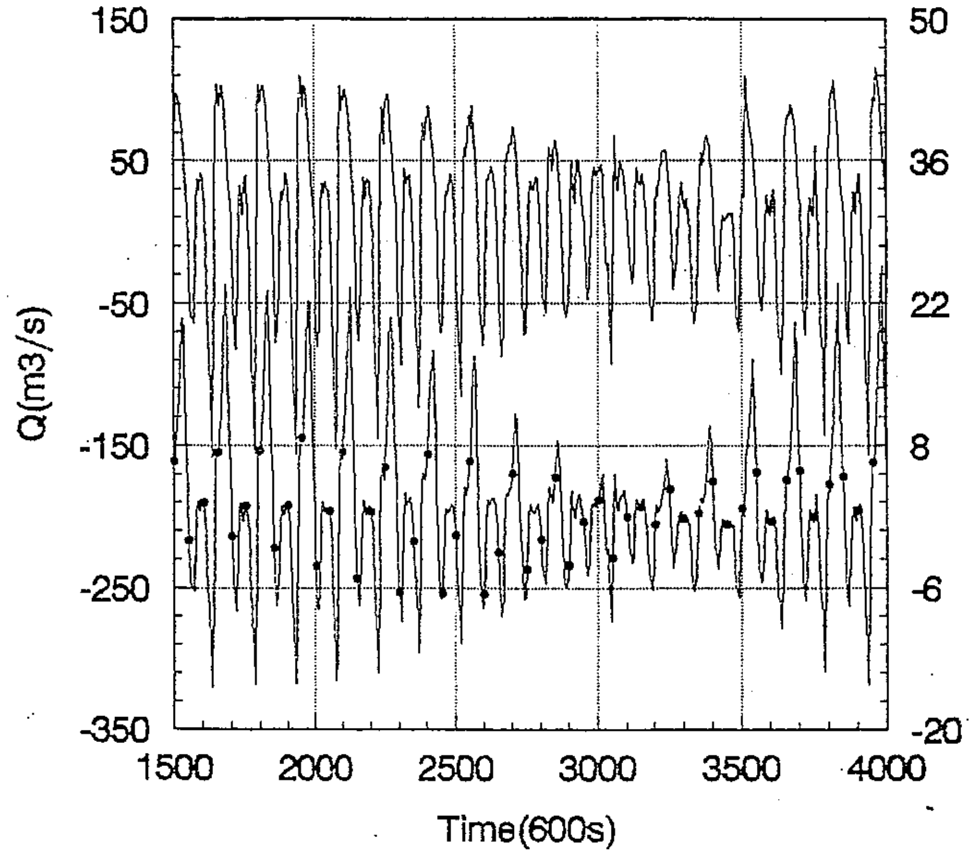


FIG. A7—51 Q(t) And Qs(t) At River Mouth
(In Operation Period)

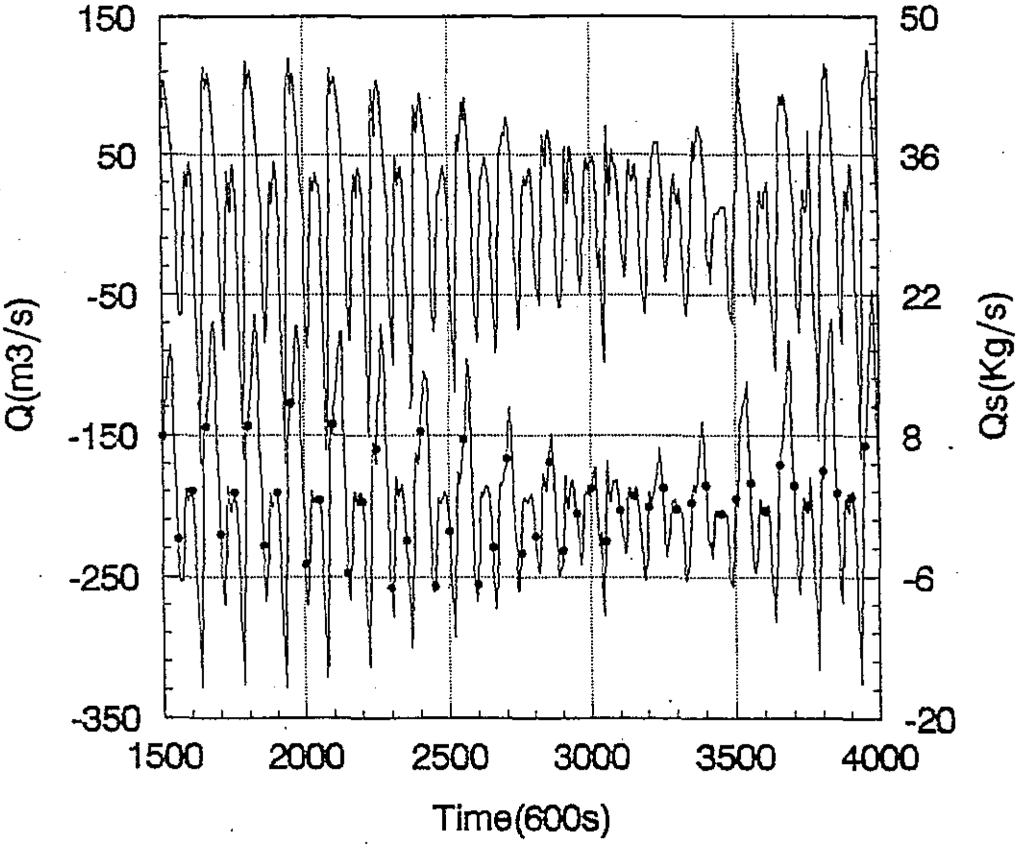


FIG. A7—52 Q(t) And Qs(t) At River Mouth (New River)

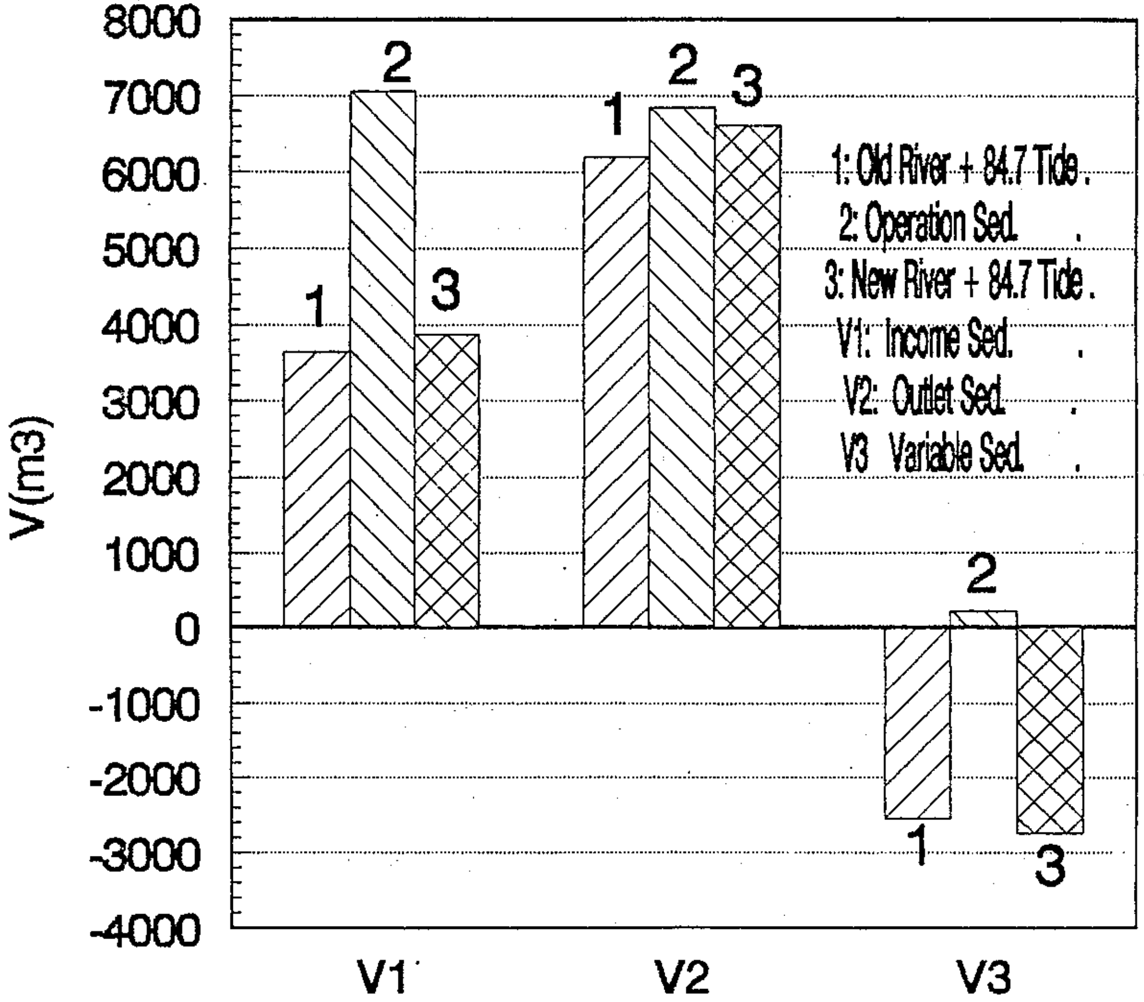


FIG. A7—53 **Comparison of sediment erosion and deposition during different stages**

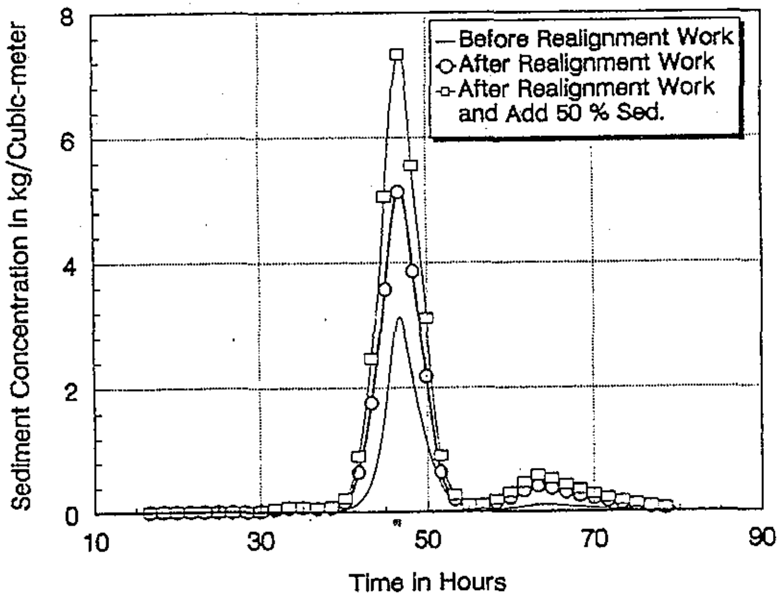
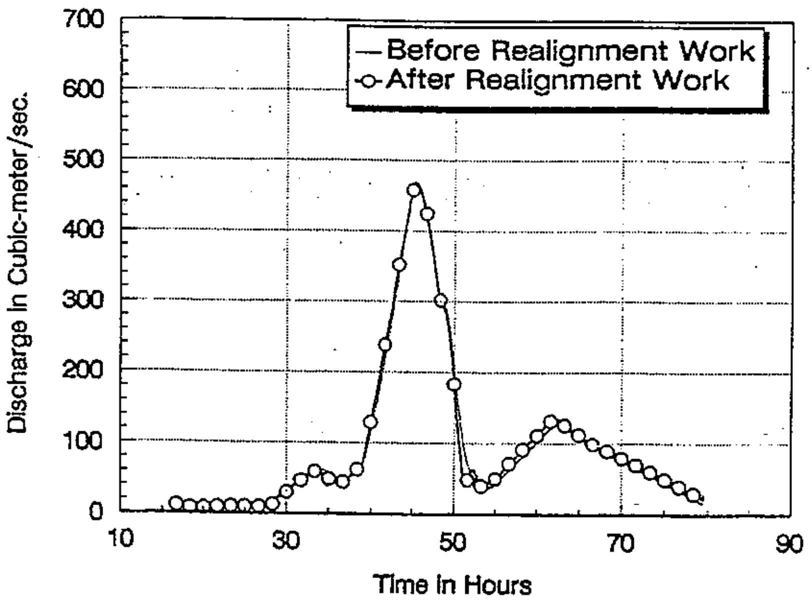


FIG. A7—55a) Typical sediment hydrograph at Shenzhen estuary during the flood with P=100%



A7—55b) Typical hydrograph of flood entering the Deep Bay

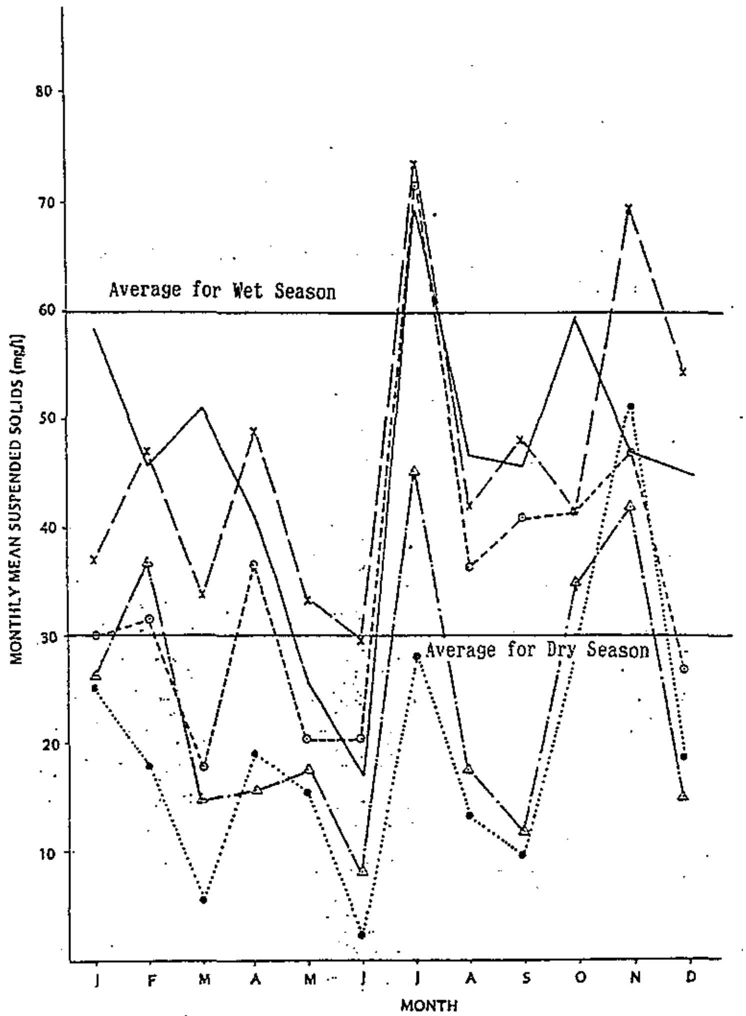


FIG. A7 — 56 Variation of sediment concentration in different seasons around Blackpint (from Binnie & Partners)

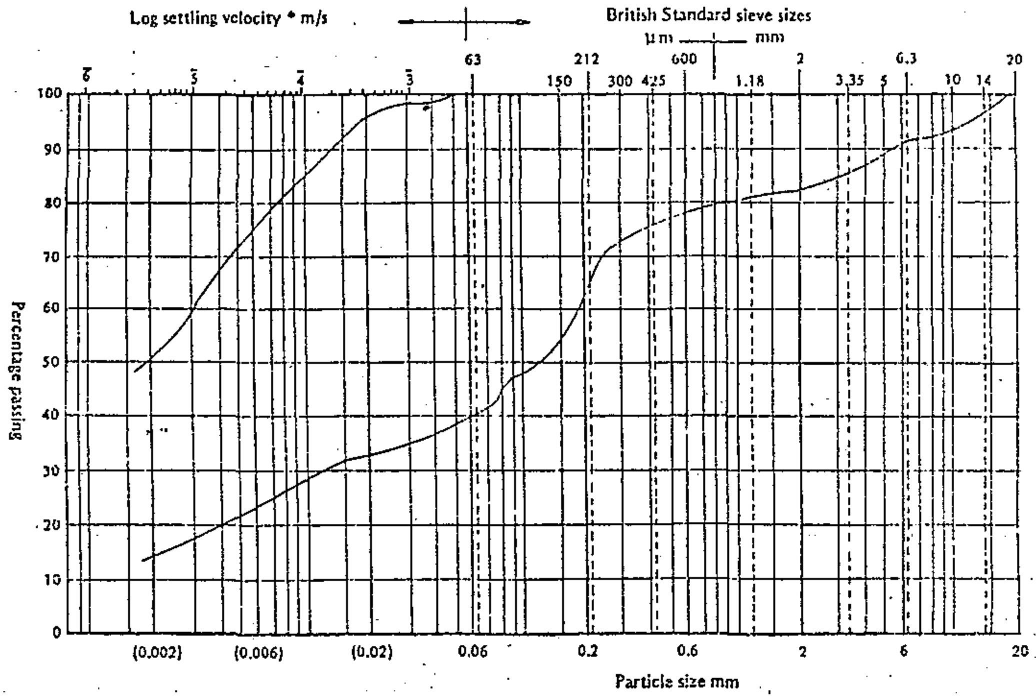


FIG. A7—57 Size distribution of bed materials in Deep Bay (from Binnie & Partners)

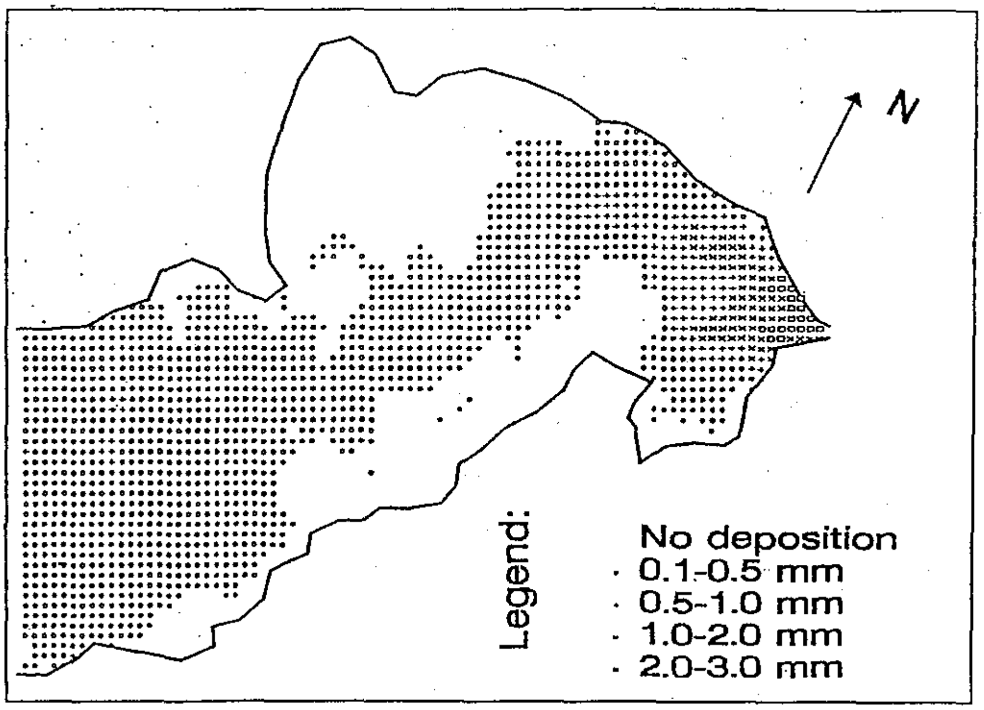


FIG. A7—58a) Sediment erosion and deposition in Deep Bay during 2 days (Run 1)

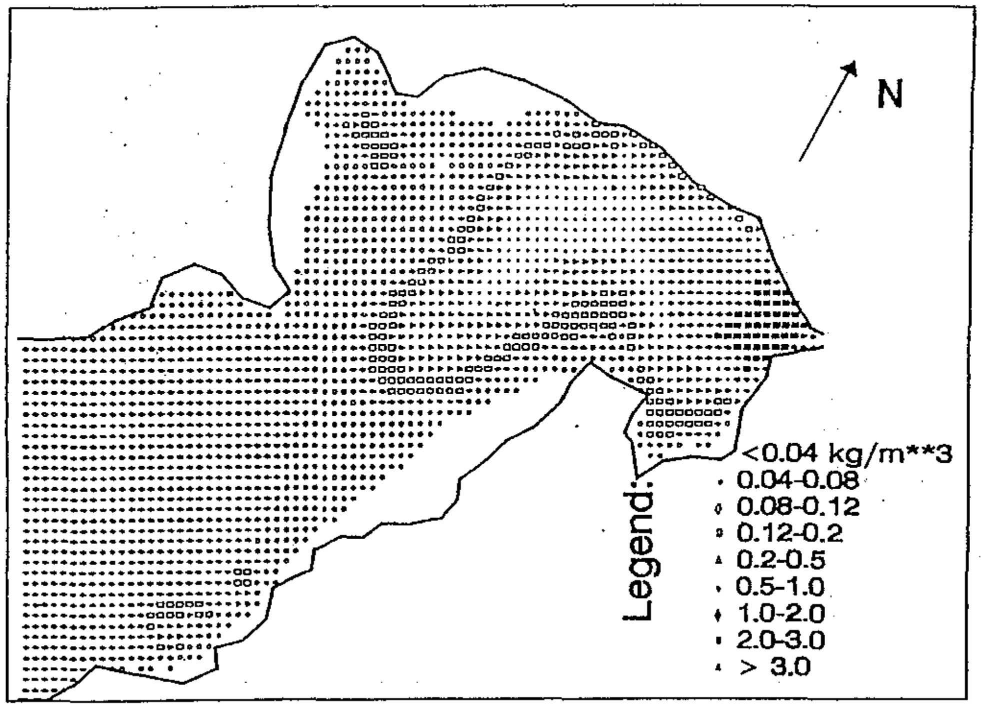


FIG. A7—58b) Maximum concentration distribution in Deep Bay during 2 days (Run 1)

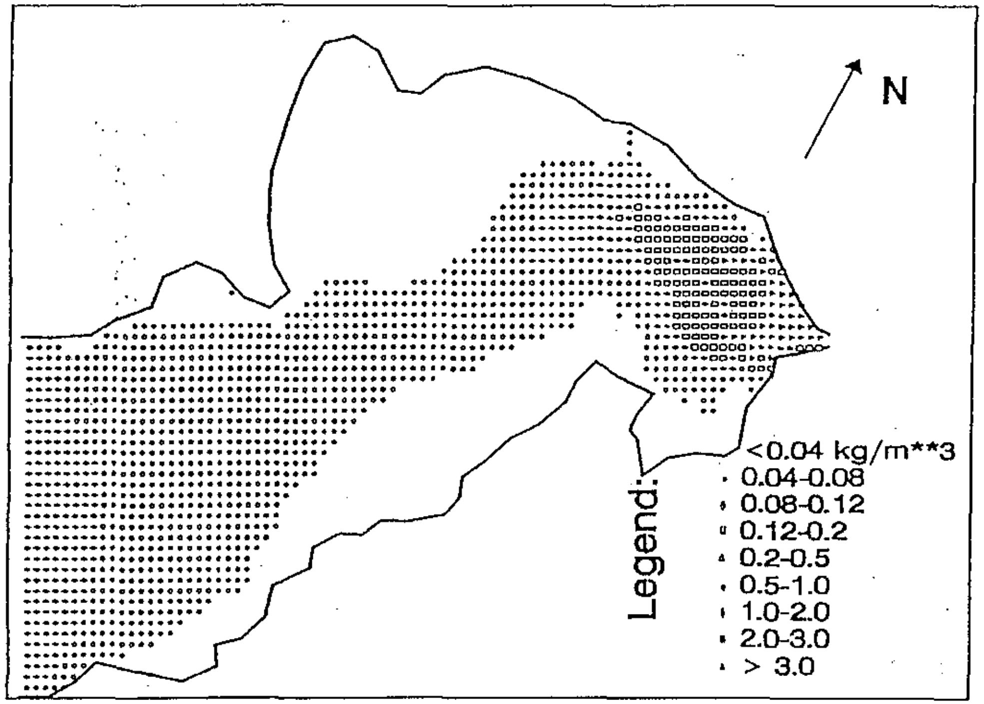


FIG. A7—58c) Average concentration distribution in Deep Bay during 2 days (Run 1)

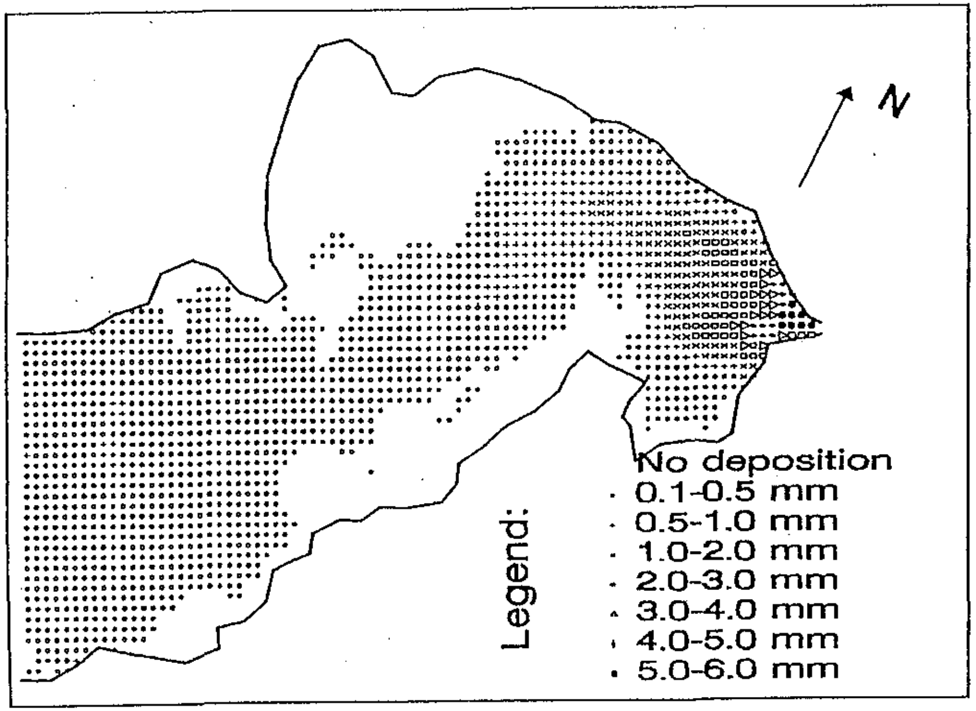


FIG. A7—58d) Sediment erosion and deposition in Deep Bay during 2 days (Run 2)

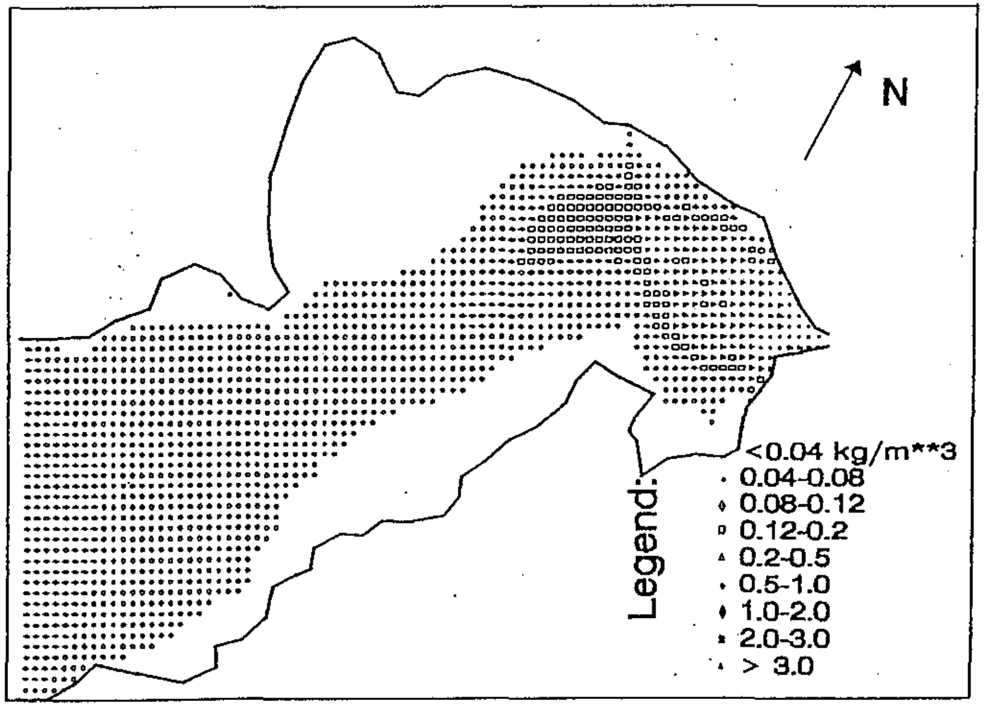


FIG. A7—58e) Maximum concentration distribution in Deep Bay during 2 days (Run 3)

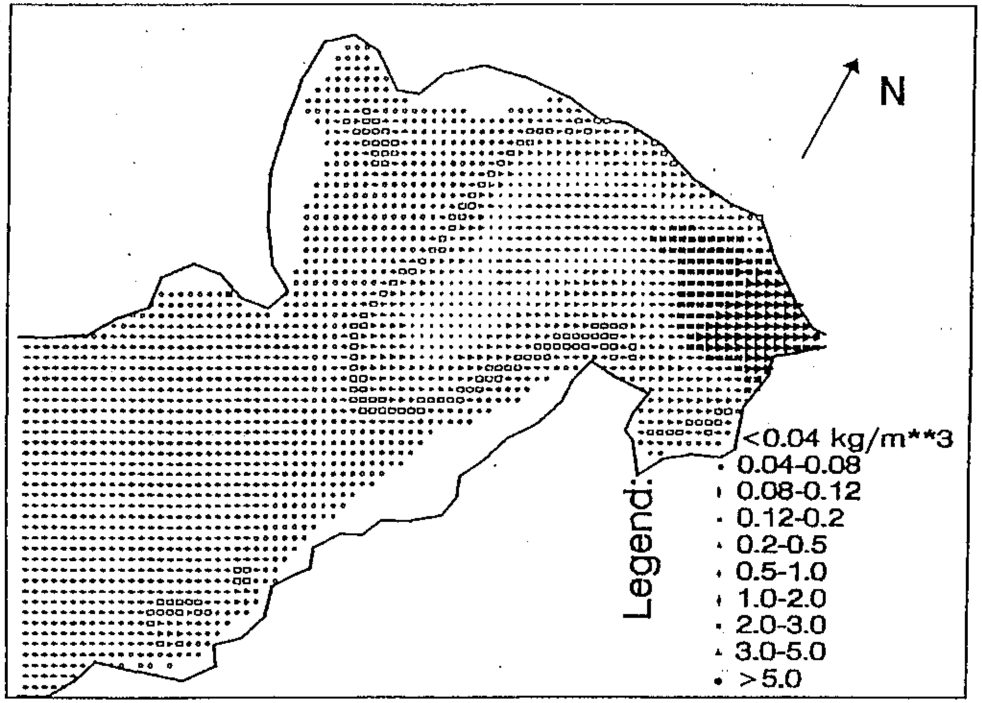


FIG. A7—58f) Average concentration distribution in Deep Bay during 2 days (Run 3)

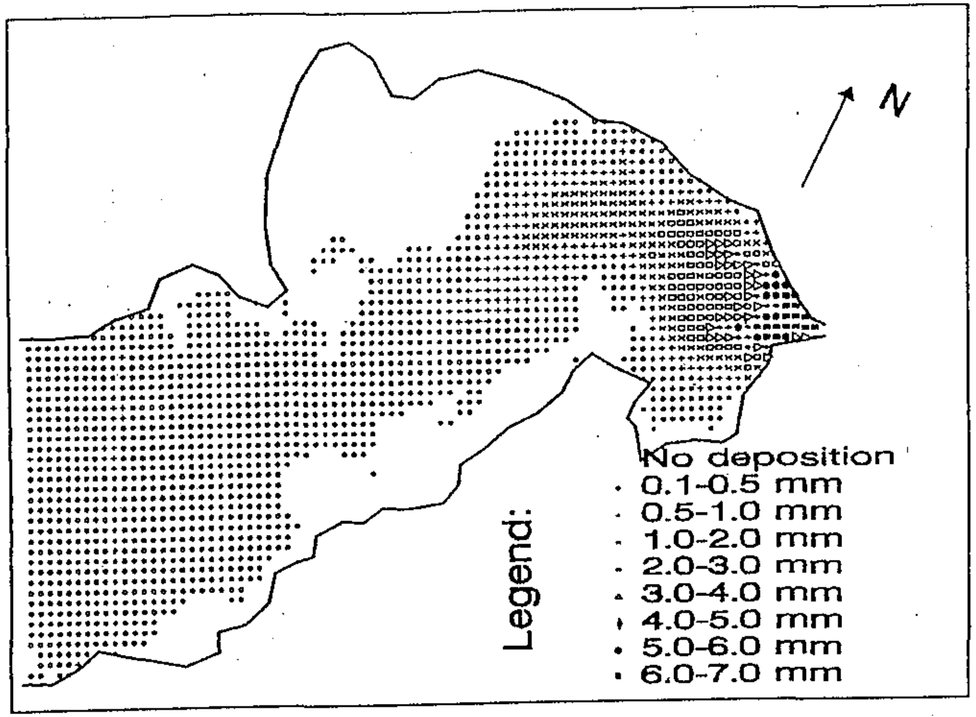


FIG. A7—58g) Sediment erosion and deposition in Deep Bay during 2 days (Run 3)

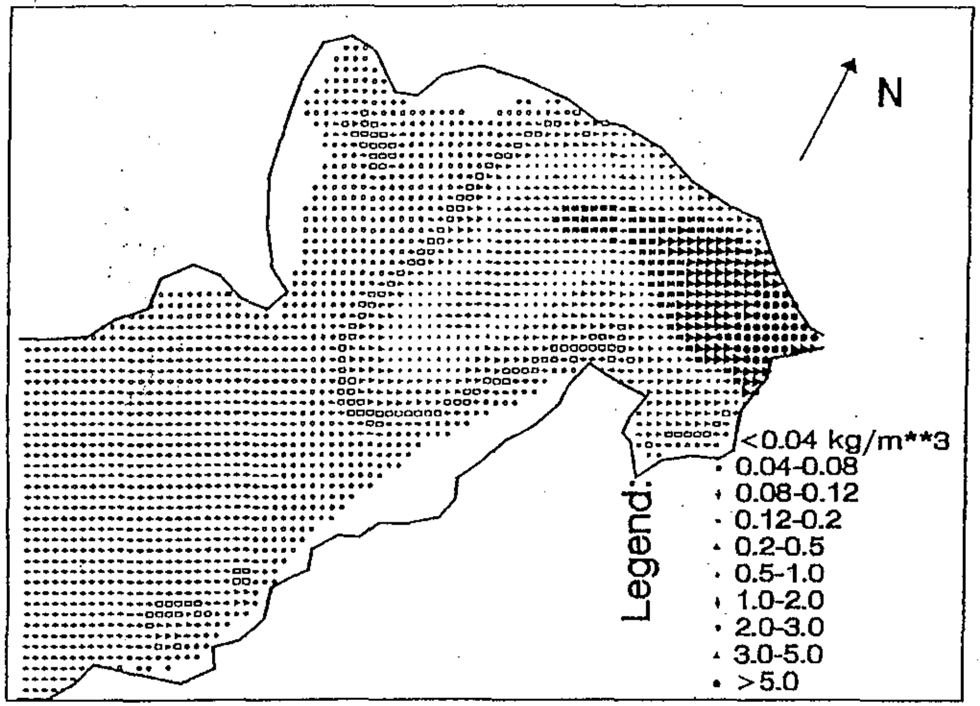


FIG. A7—58h) Maximum concentration distribution in Deep Bay during 2 days (Run 3)

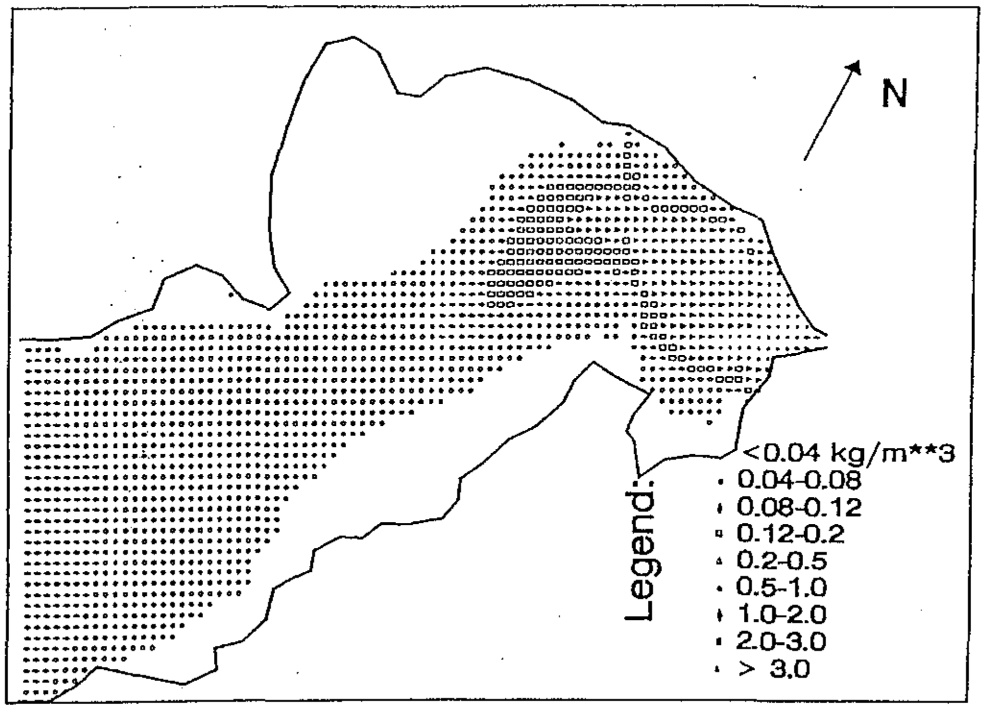


FIG. A7—58i) Average concentration distribution in Deep Bay during 2 days (Run 3)

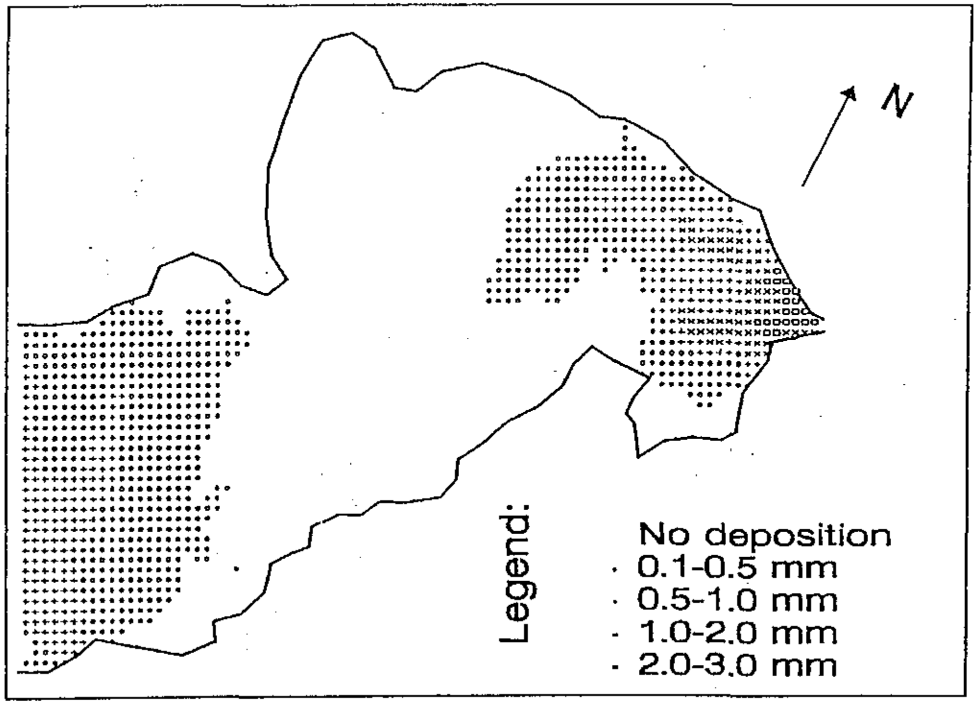


FIG. A7—59a) Sediment erosion and deposition in Deep Bay during 2 days (Run 4)

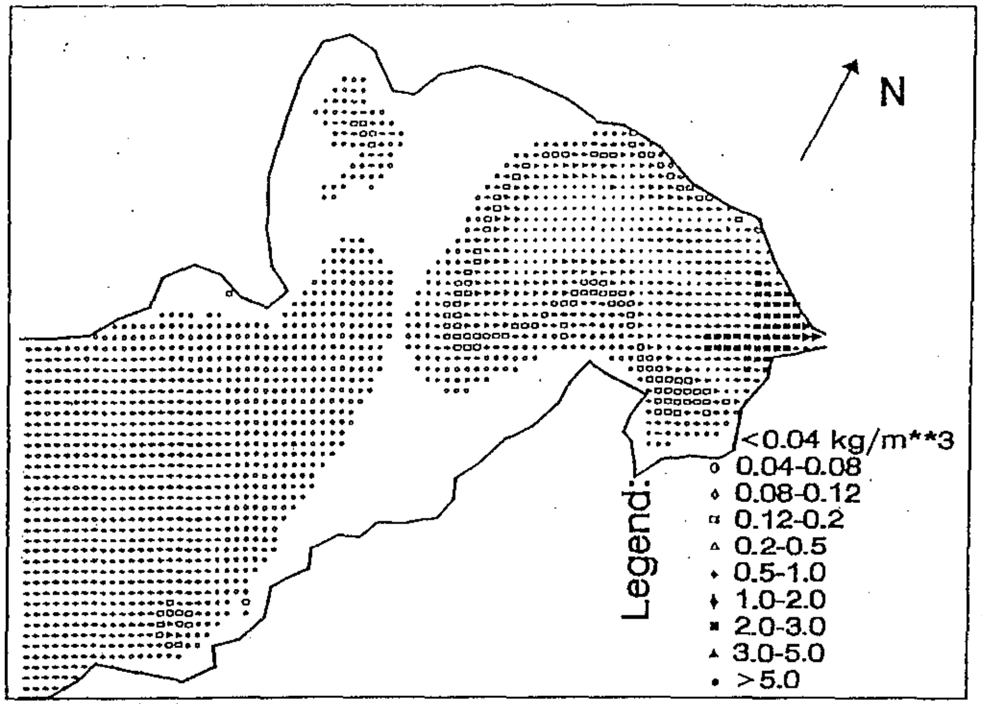


FIG. A7—59b) **Maximum concentration distribution in Deep Bay during 2 days (Run 4)**

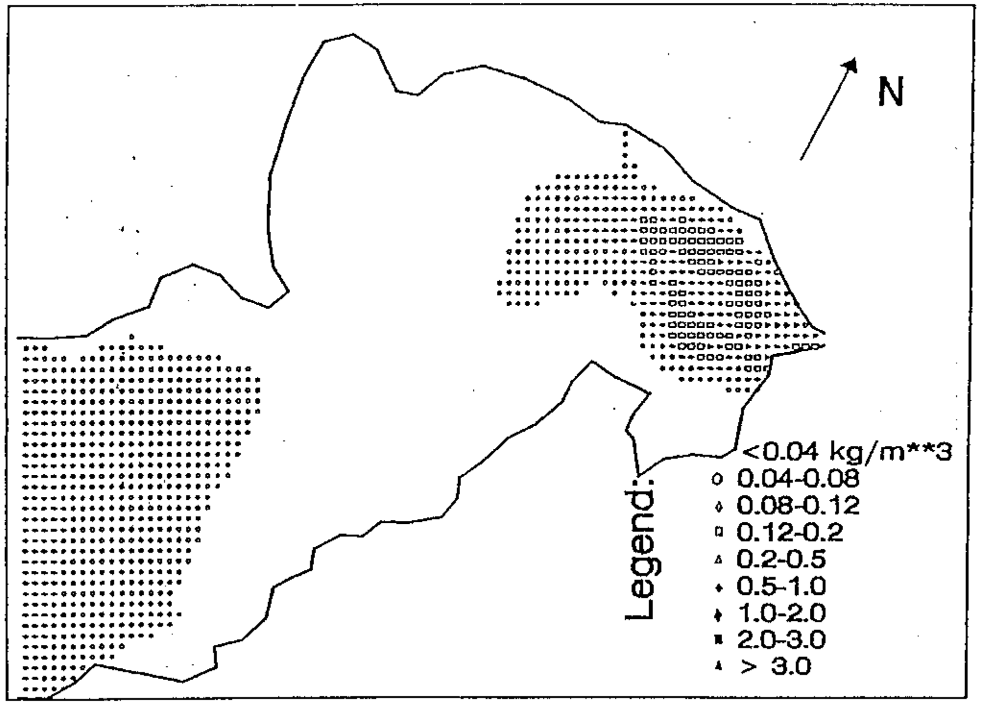


FIG. A7—59c) Average concentration distribution in Deep Bay during 2 days (Run 4)

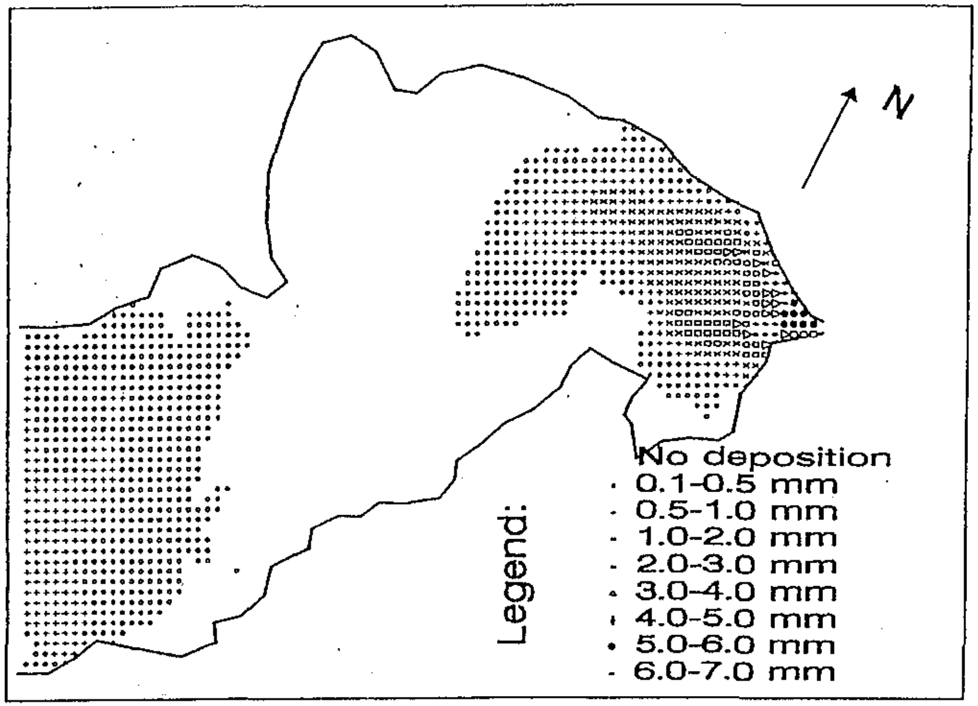


FIG. A7—59d) Sediment erosion and deposition in Deep Bay during 2 days (Run 5)

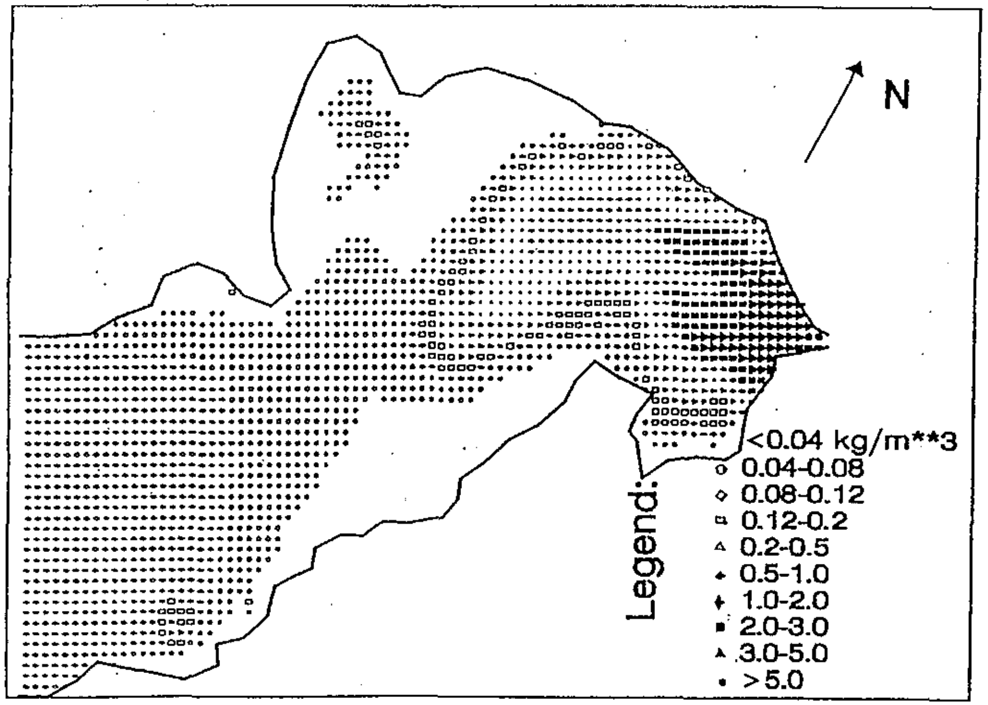


FIG. A7—59e) Maximum concentration distribution in Deep Bay during 2 days (Run 5)

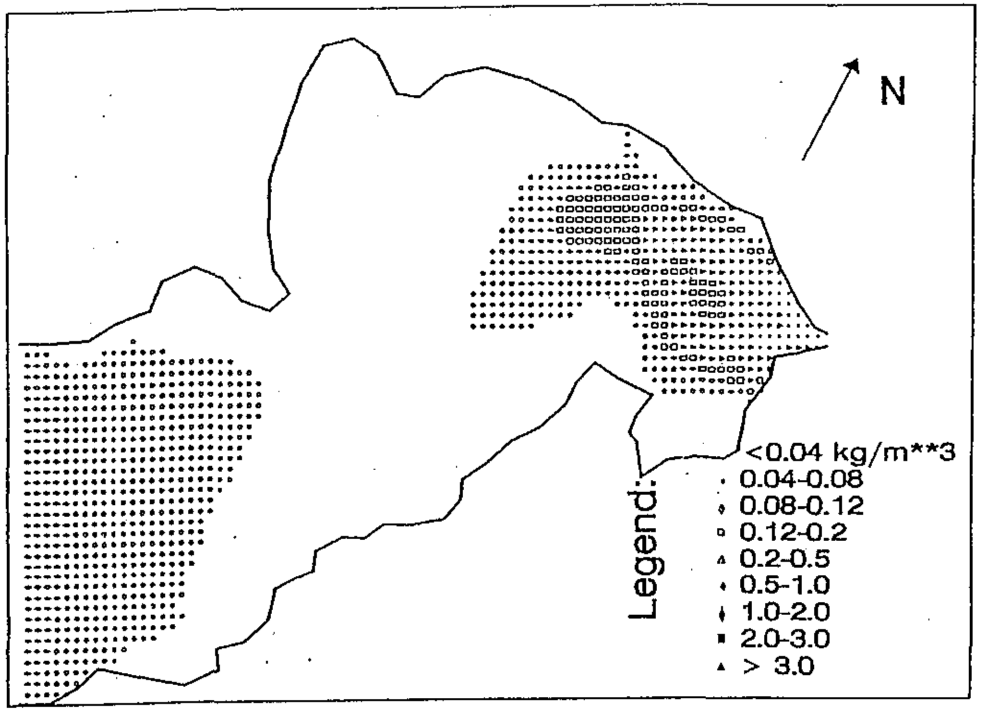


FIG. A7—59f) Average concentration distribution in Deep Bay during 2 days (Run 5)

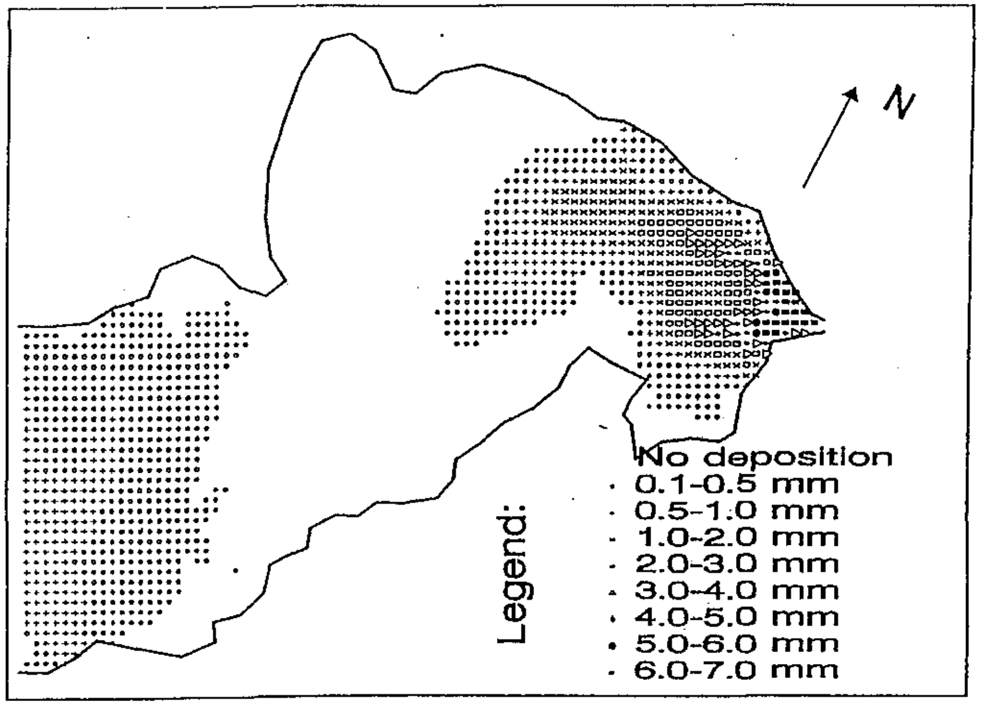


FIG. A7—59g) Sediment erosion and deposition in Deep Bay during 2 days (Run 6)

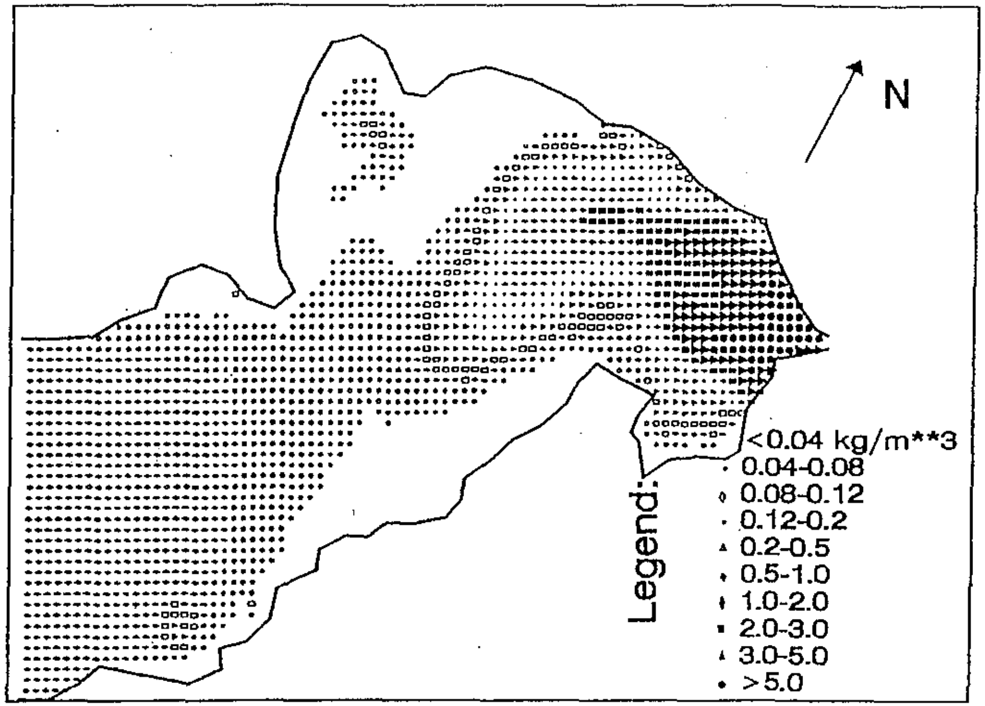


FIG. A7—59h) Maximum concentration distribution in Deep Bay during 2 days (Run 6)

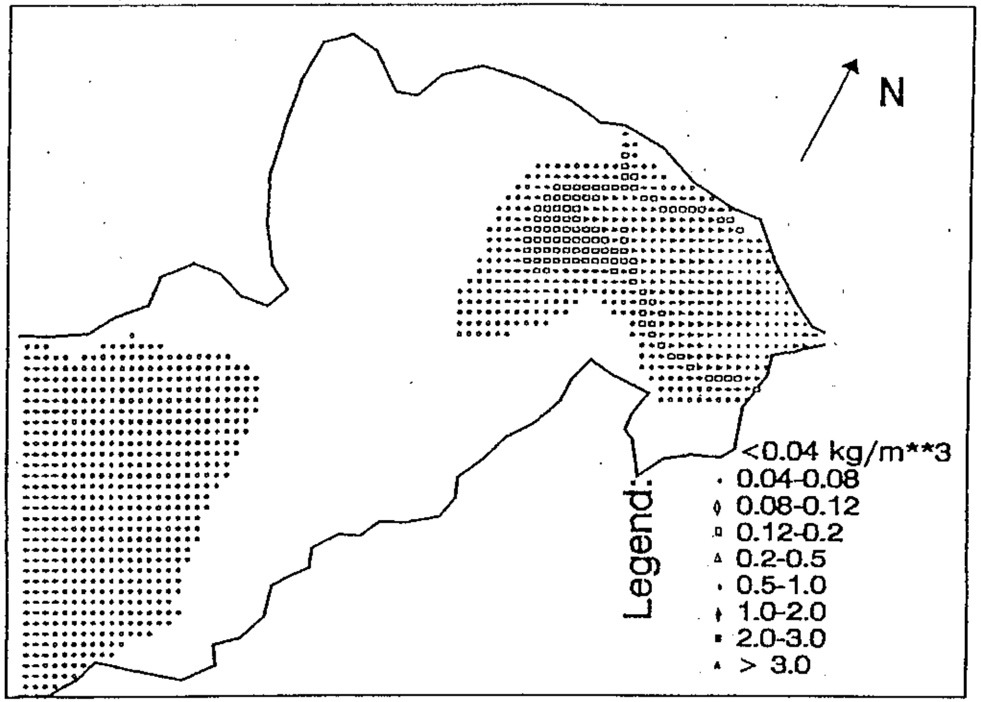


FIG. A7—59i) Average concentration distribution in Deep Bay during 2 days (Run 6)

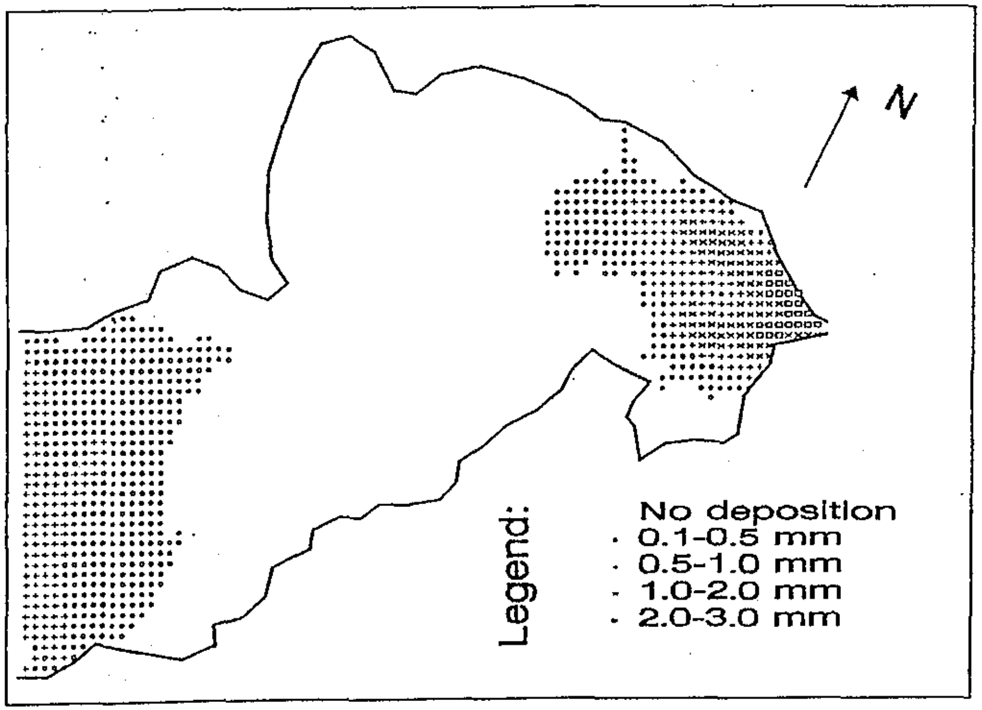


FIG. A7—60a) Sediment erosion and deposition in Deep Bay during 2 days (Run 7)

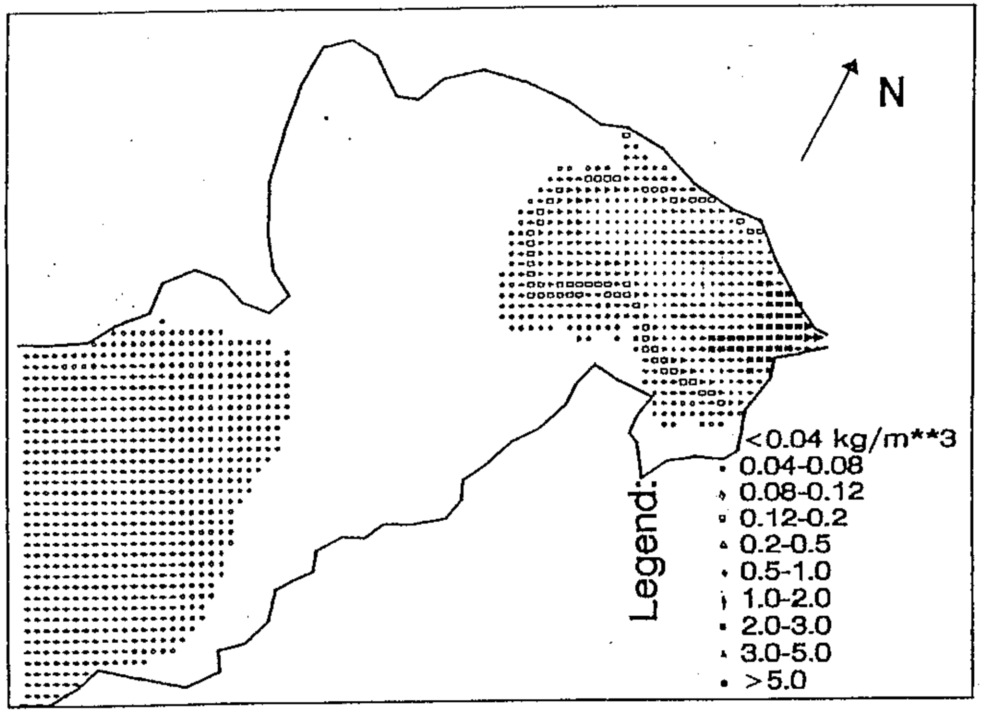


FIG. A7—60b) Maximum concentration distribution in Deep Bay during 2 days (Run 7)

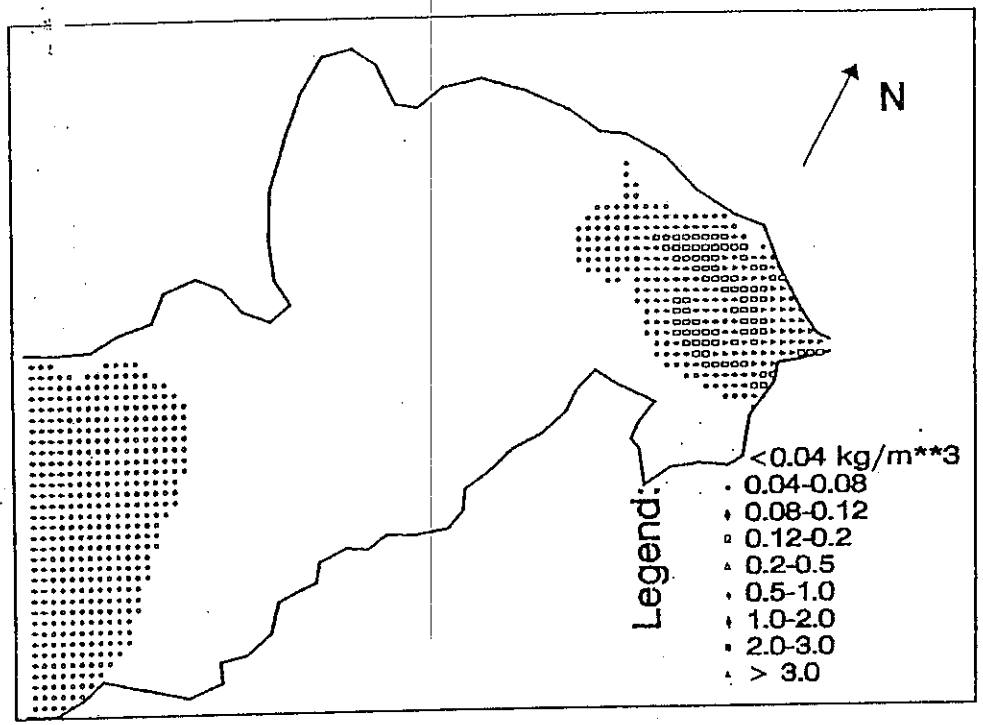


FIG. A7—60c) Average concentration distribution in Deep Bay during 2 days (Run 7)

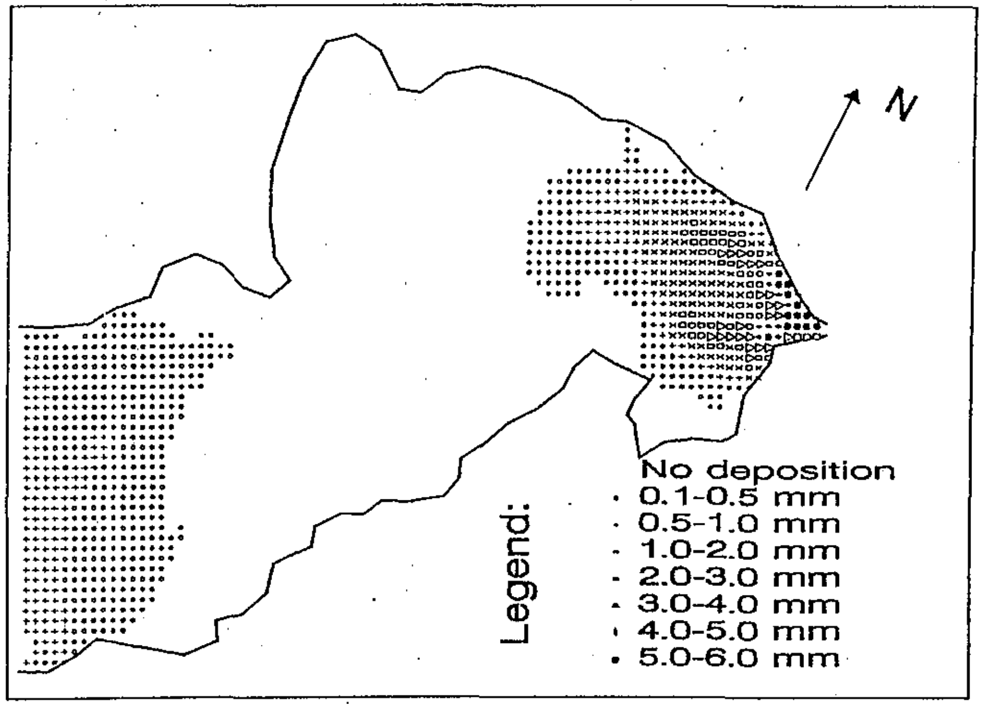


FIG. A7—60d) Sediment erosion and deposition in Deep Bay during 2 days (Run 8)

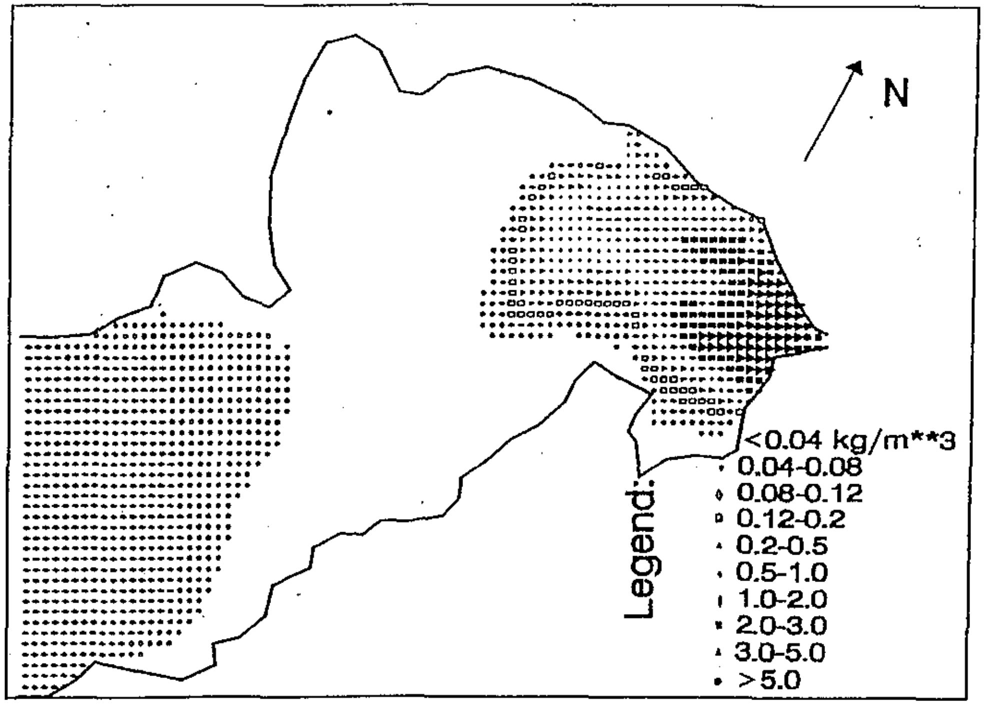


FIG. A7—60e) Maximum concentration distribution in Deep Bay during 2 days (Run 8)

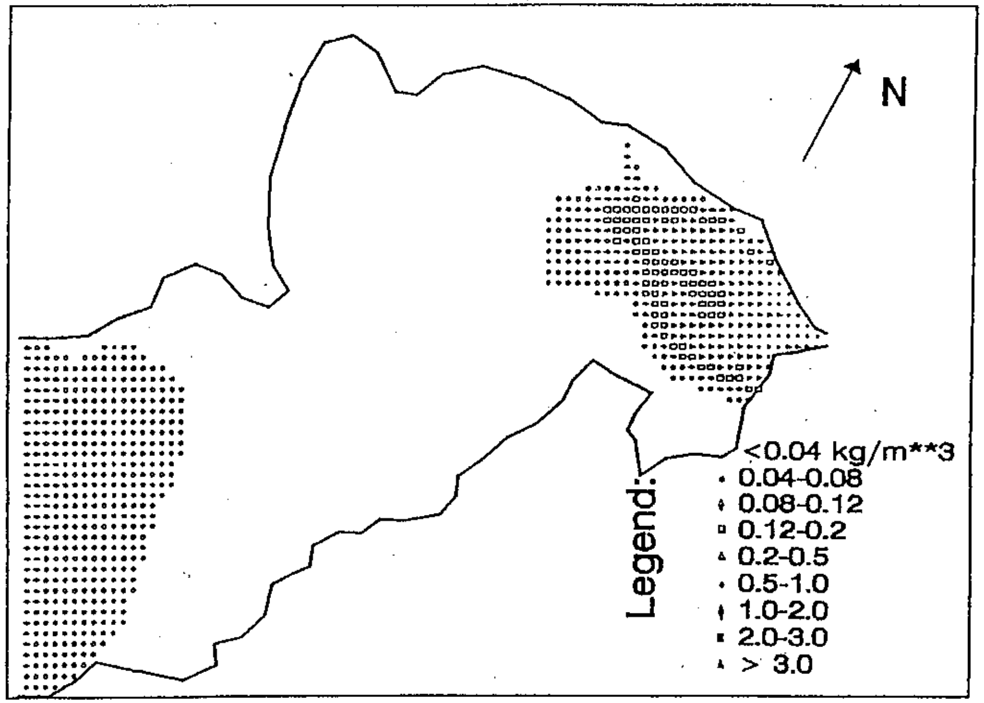


FIG. A7—60f) Average concentration distribution in Deep Bay during 2 days (Run 8)

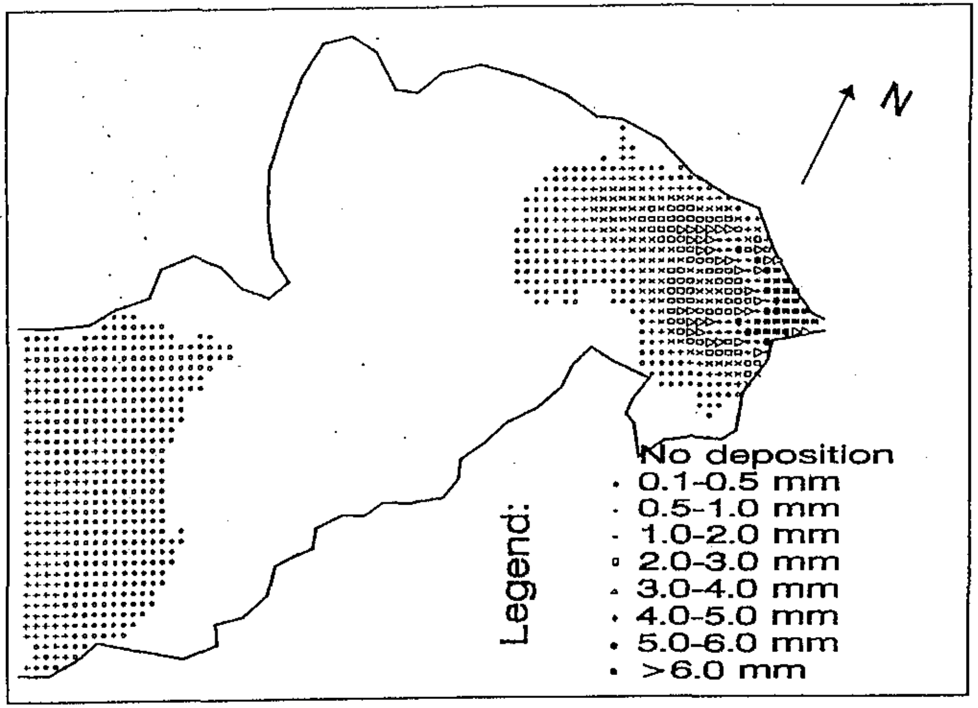


FIG. A7—60g) Sediment erosion and deposition in Deep Bay during 2 days (Run 9)

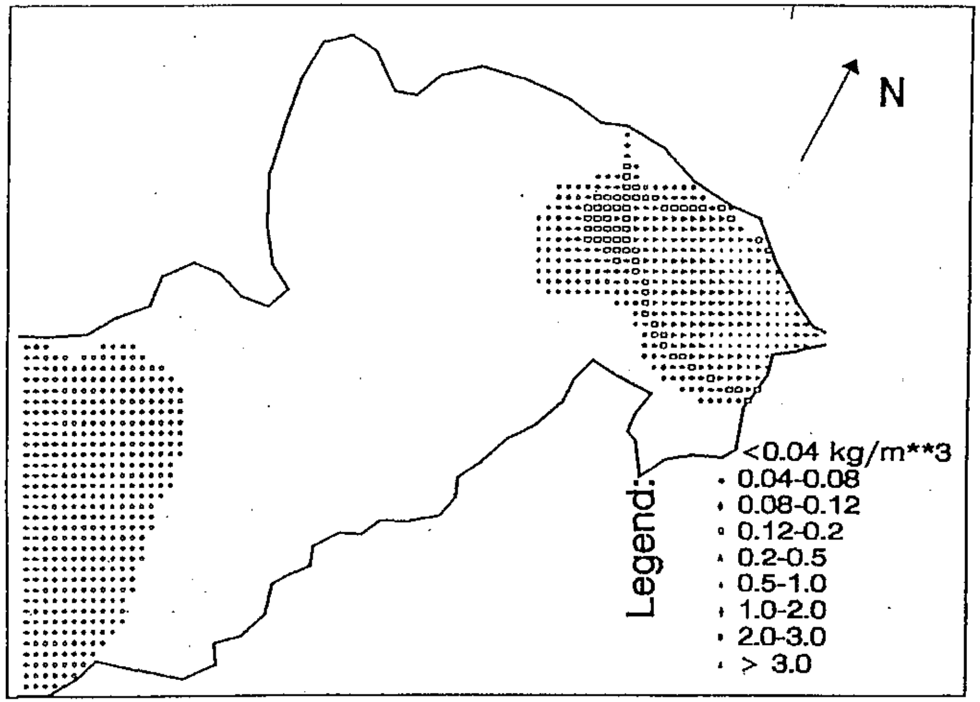


FIG. A7—60h) Maximum concentration distribution in Deep Bay during 2 days (Run 9)

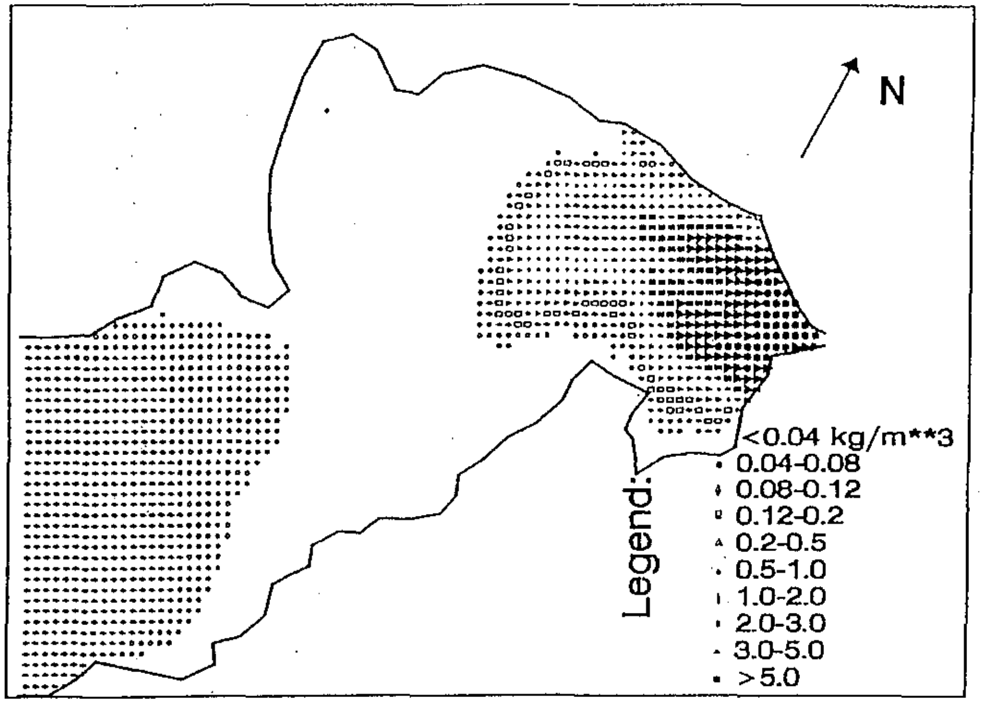


FIG. A7—60i) Average concentration distribution in Deep Bay during 2 days (Run 9)

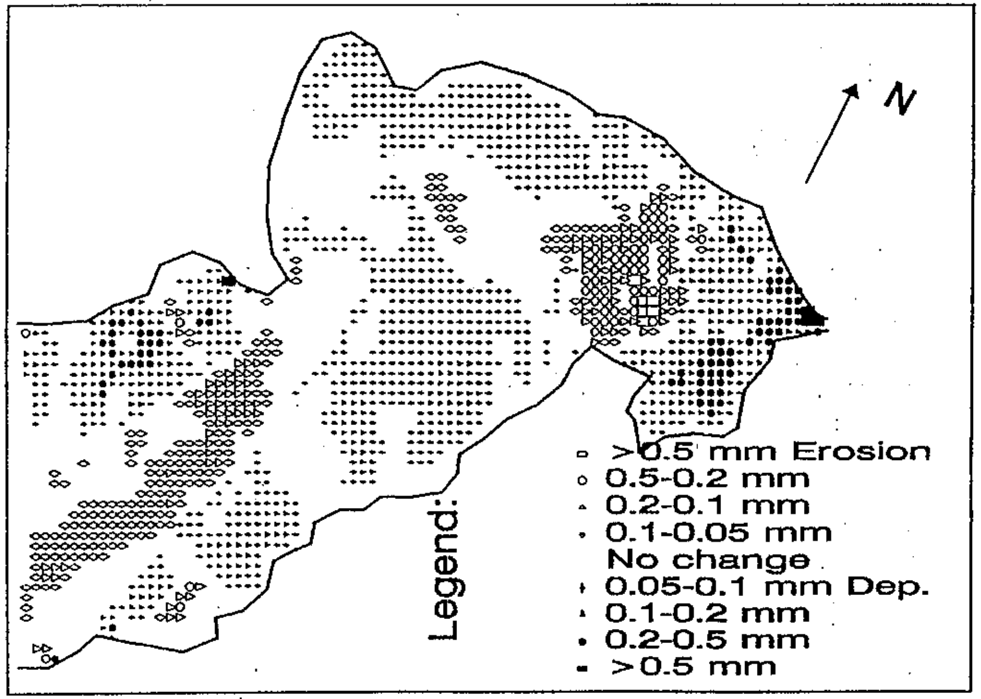


FIG. A7—61a) Sediment erosion and deposition in Deep Bay during 2 days (Run 10)

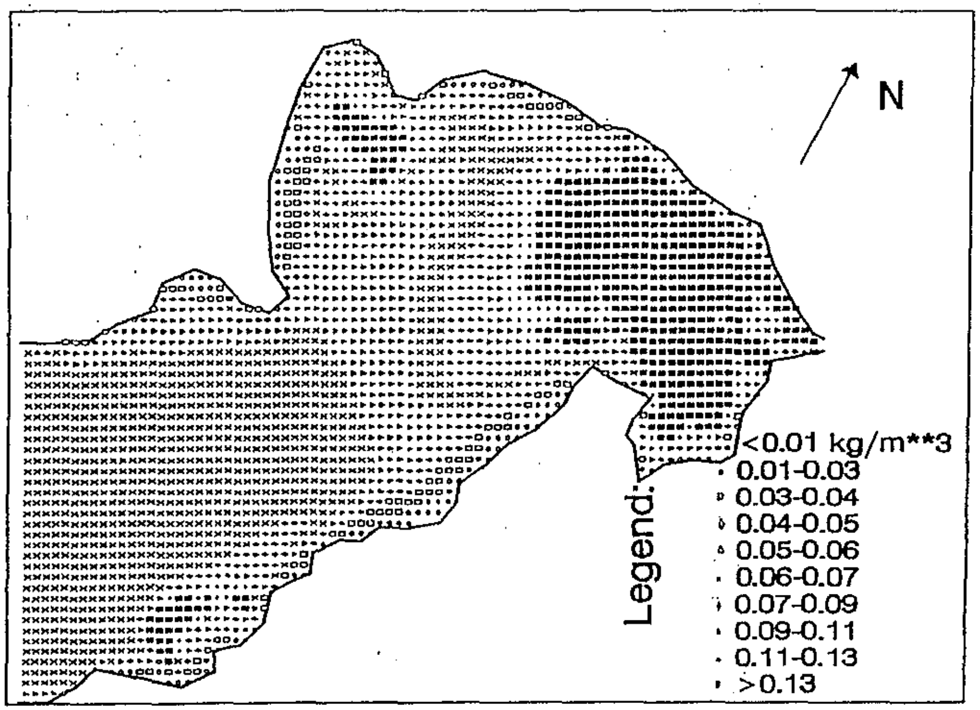


FIG. A7—61b) Maximum concentration distribution in Deep Bay during 2 days (Run 10)

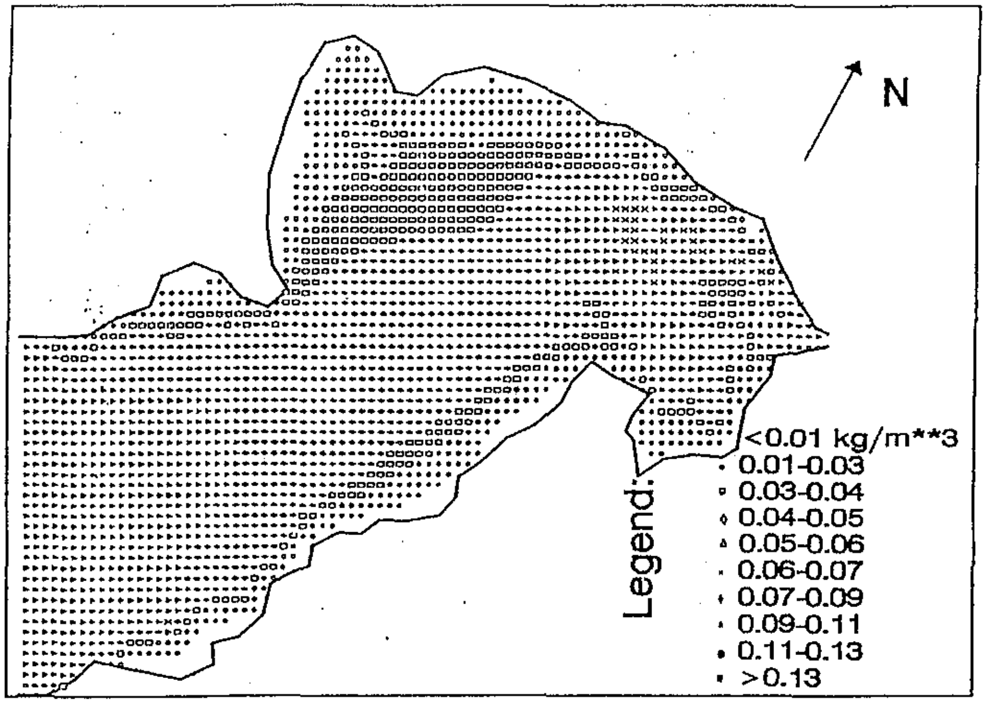


FIG. A7—61c) **Average concentration distribution in Deep Bay during 2 days (Run 10)**

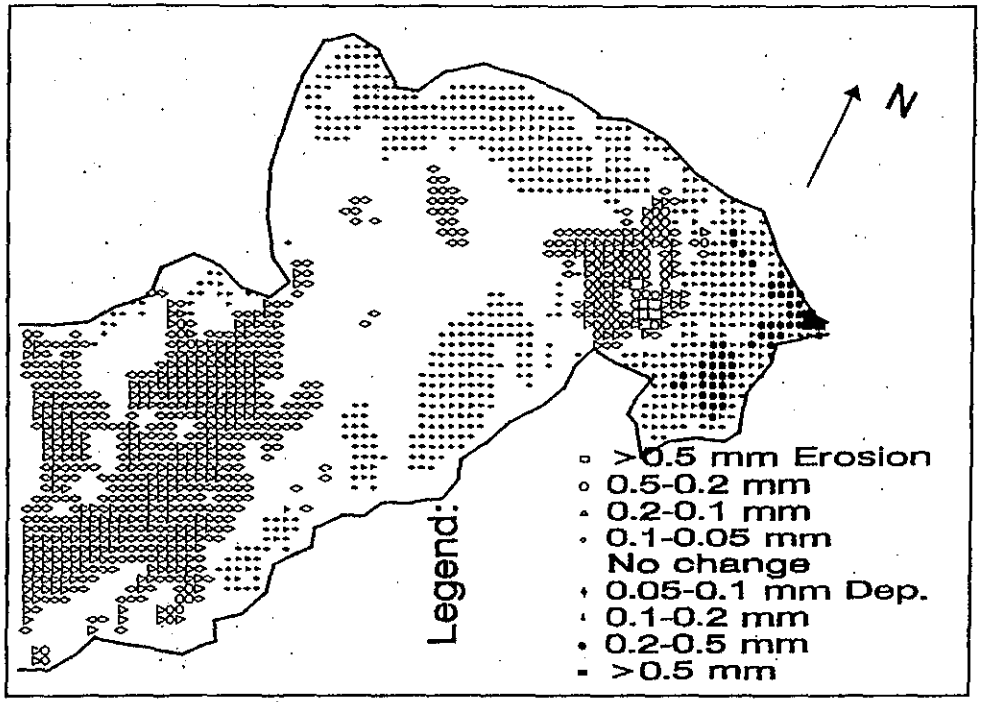


FIG. A7—61d) **Sediment erosion and deposition in Deep Bay during 2 days (Run 11)**

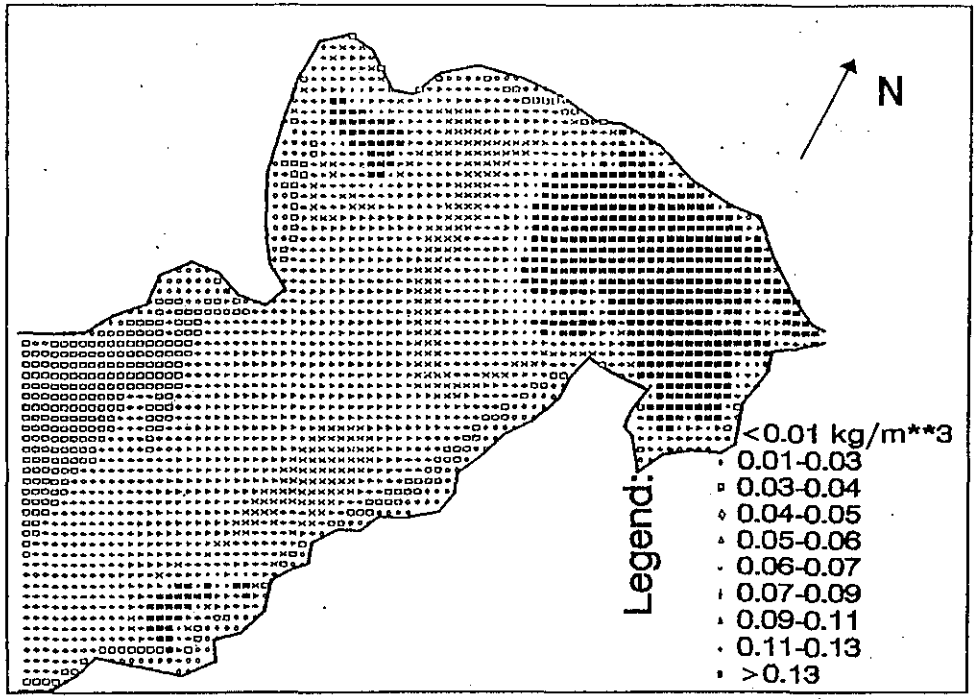


FIG. A7—6(e) Maximum concentration distribution in Deep Bay during 2 days (Run 11)

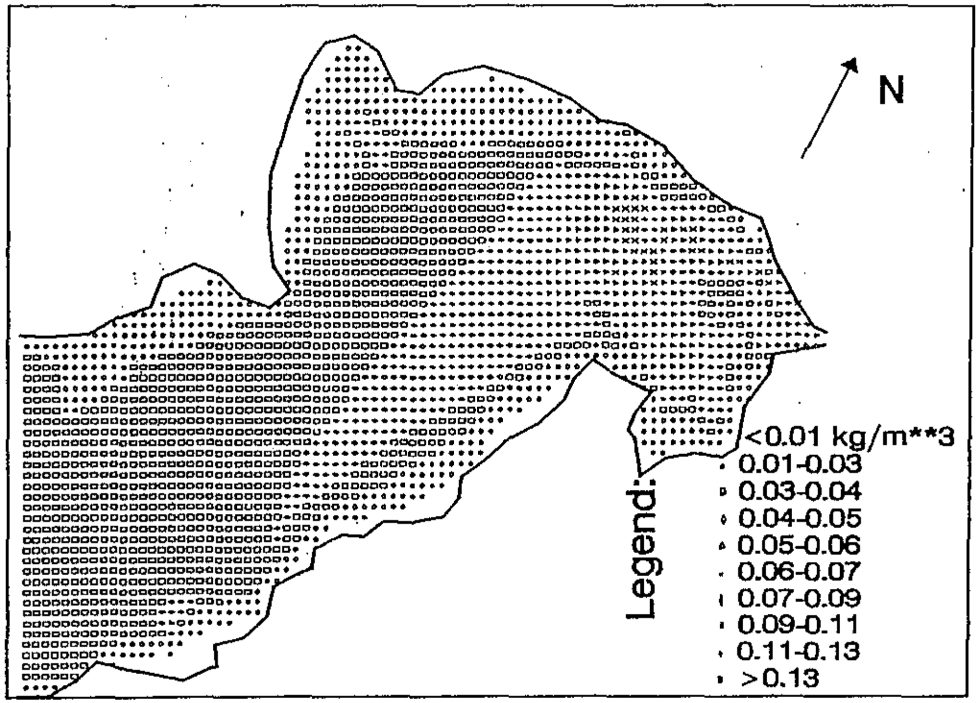


FIG. A7—61f) Average concentration distribution in Deep Bay during 2 days (Run 11)

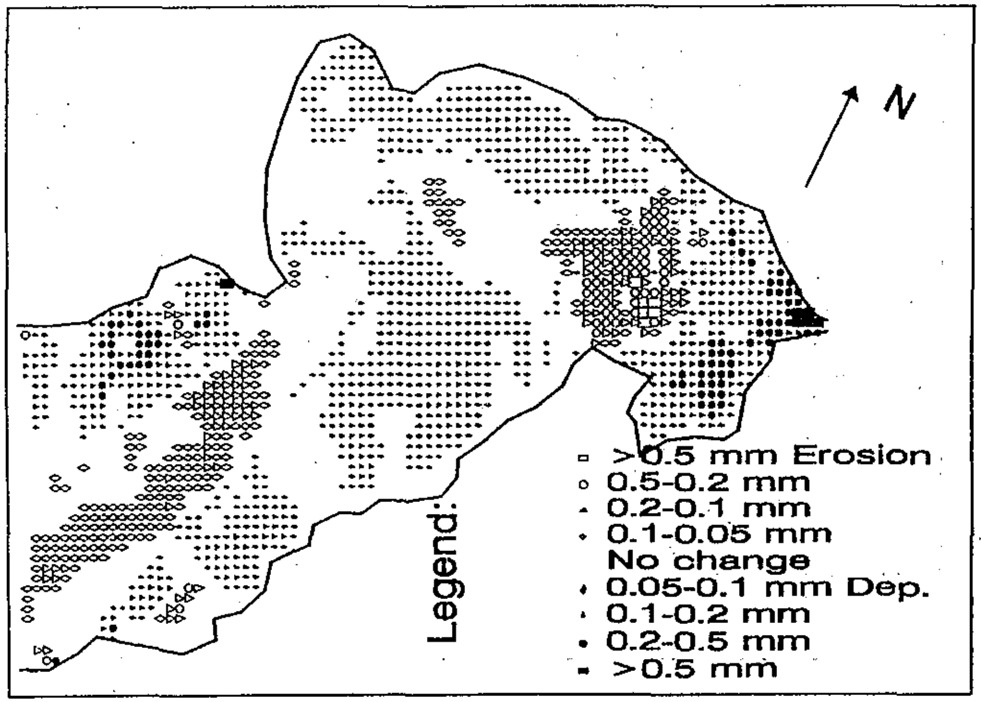


FIG. A7—61g) Sediment erosion and deposition in Deep Bay during 2 days (Run 12)

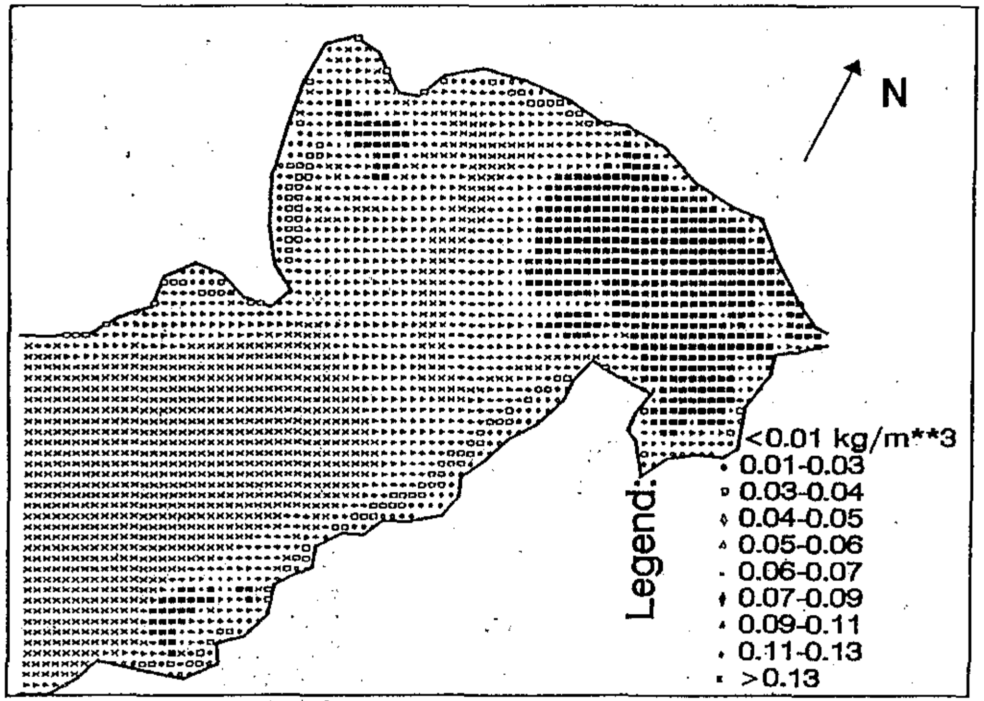


FIG. A7—61h) Maximum concentration distribution in Deep Bay during 2 days (Run 12)

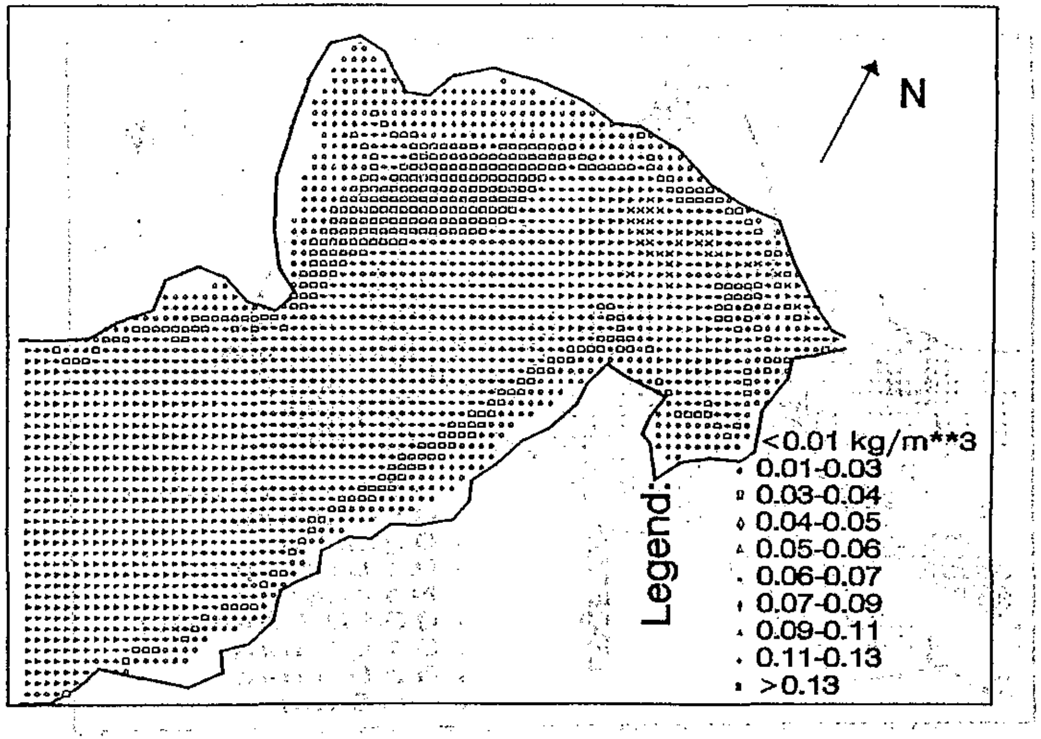


FIG. A7—61i) Average concentration distribution in Deep Bay during 2 days (Run 12)

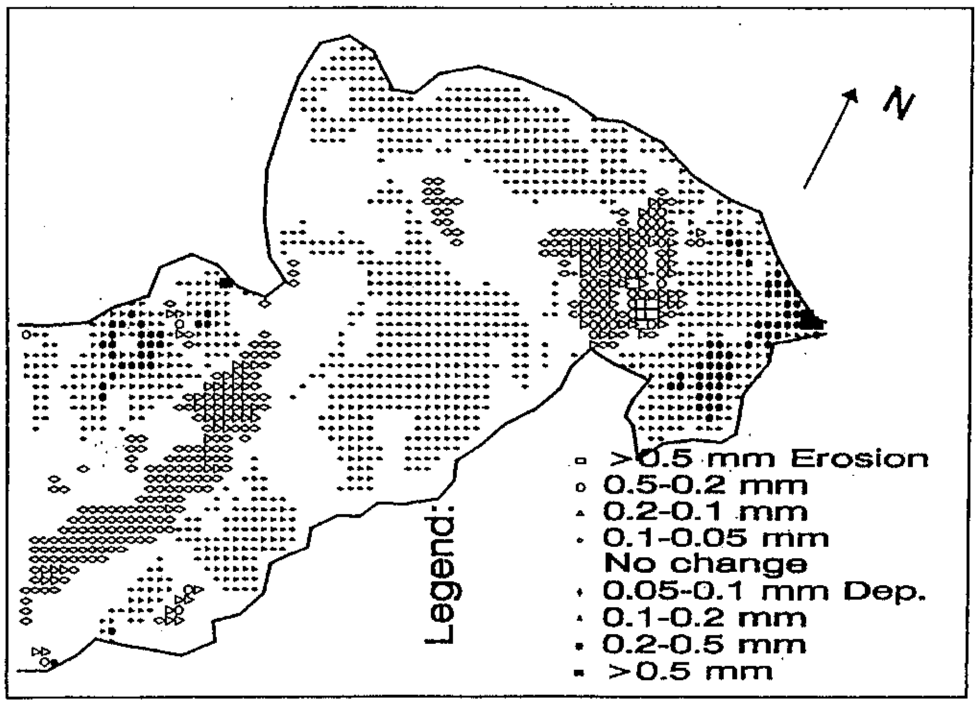


FIG. A7—61j) Sediment erosion and deposition in Deep Bay during 2 days (Run 13)

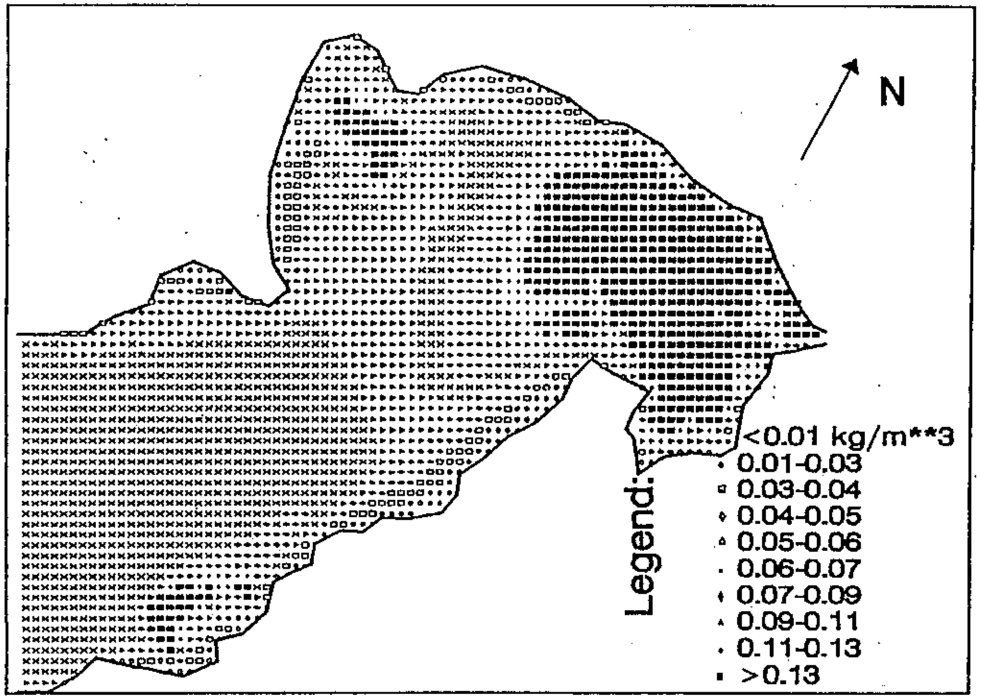


FIG. A7—61k) Maximum concentration distribution in Deep Bay during 2 days (Run 14)

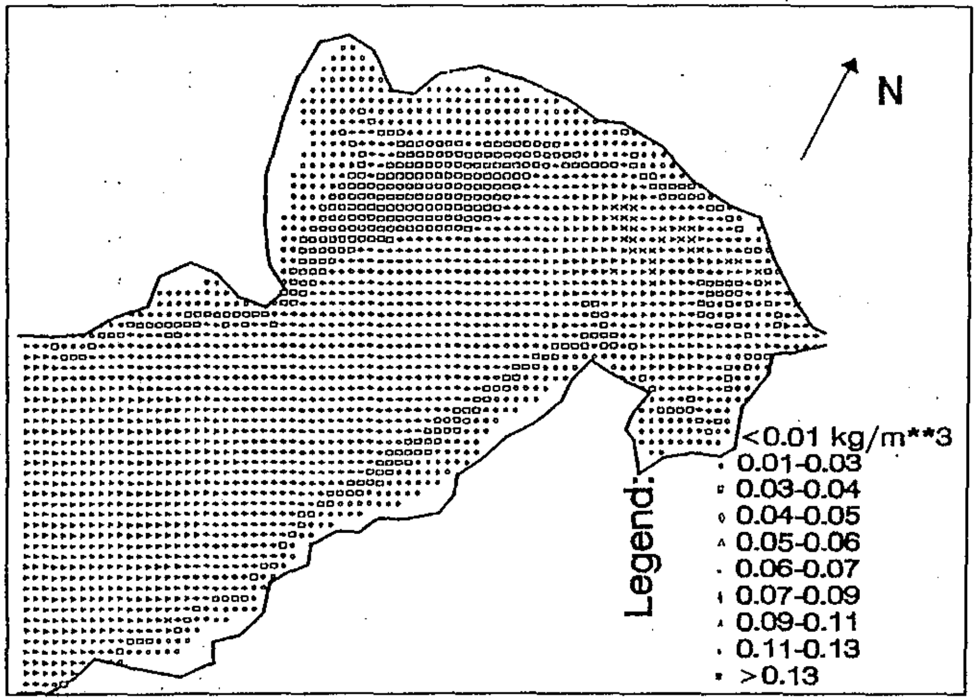


FIG. A7—611) Average concentration distribution in Deep Bay during 2 days (Run 13)

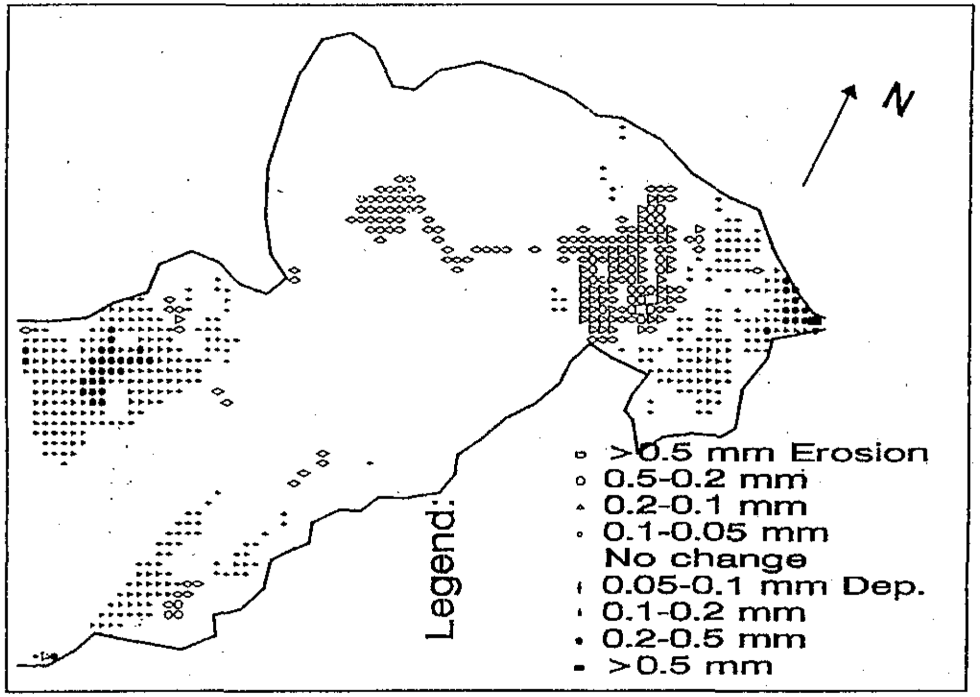


FIG. A7—62a) Sediment erosion and deposition in Deep Bay during 2 days (Run 14)

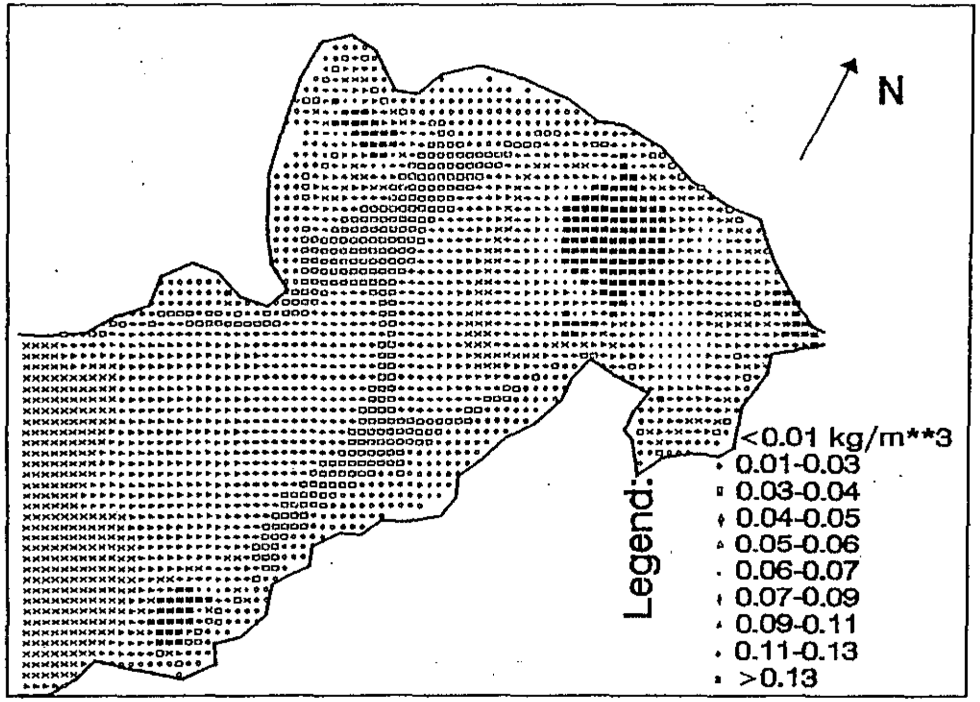


FIG. A7—62b) Maximum concentration distribution in Deep Bay during 2 days (Run 14)

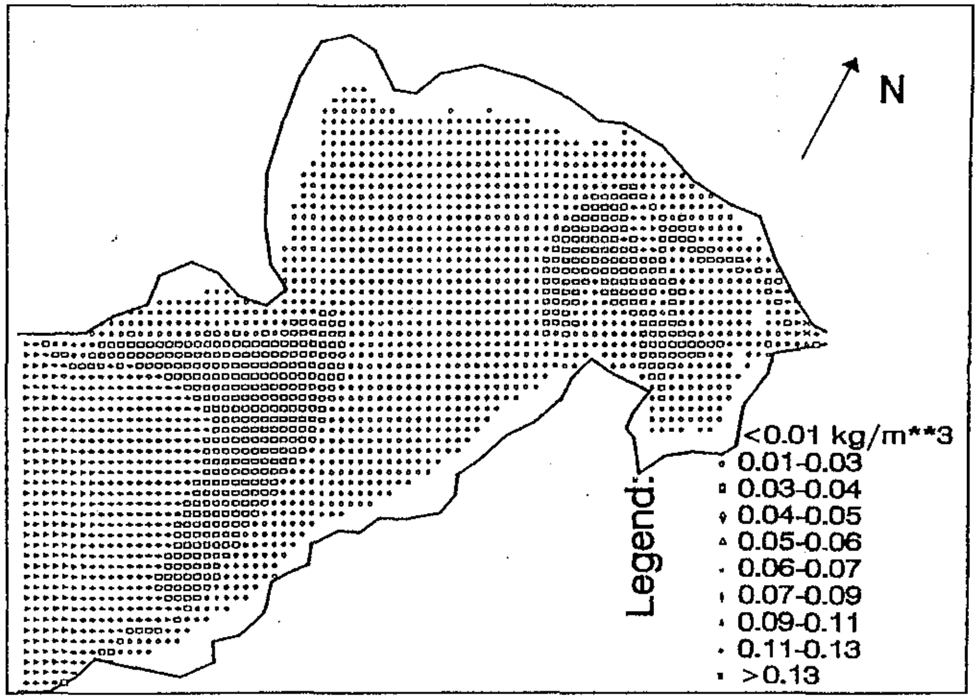


FIG. A7—62c) Average concentration distribution in Deep Bay during 2 days (Run 14)

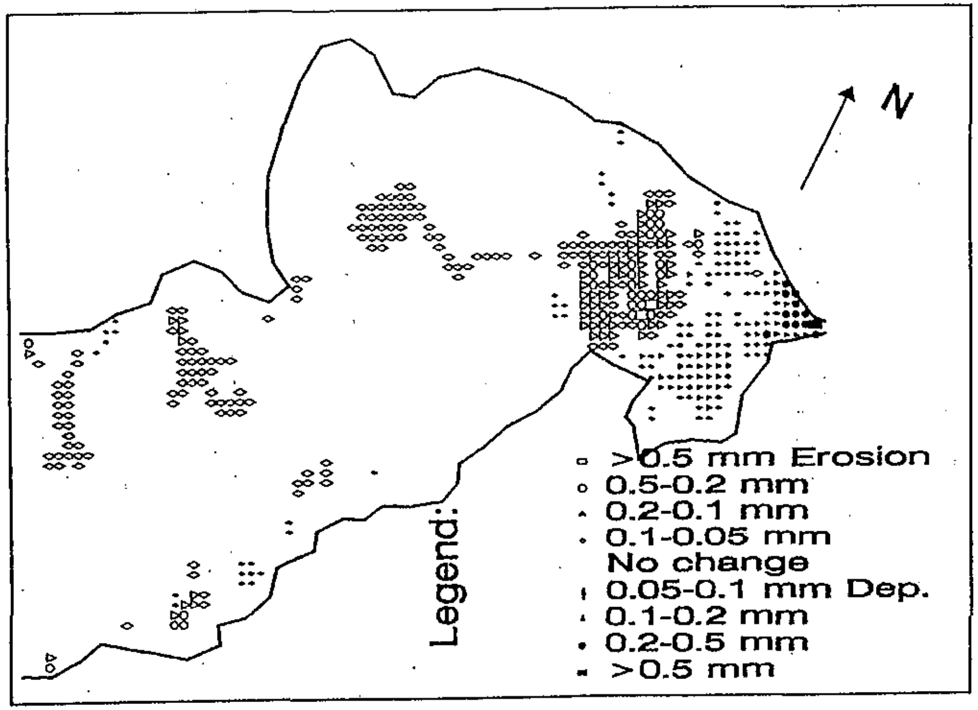


FIG. A7—62d) Sediment erosion and deposition in Deep Bay during 2 days (Run 15)

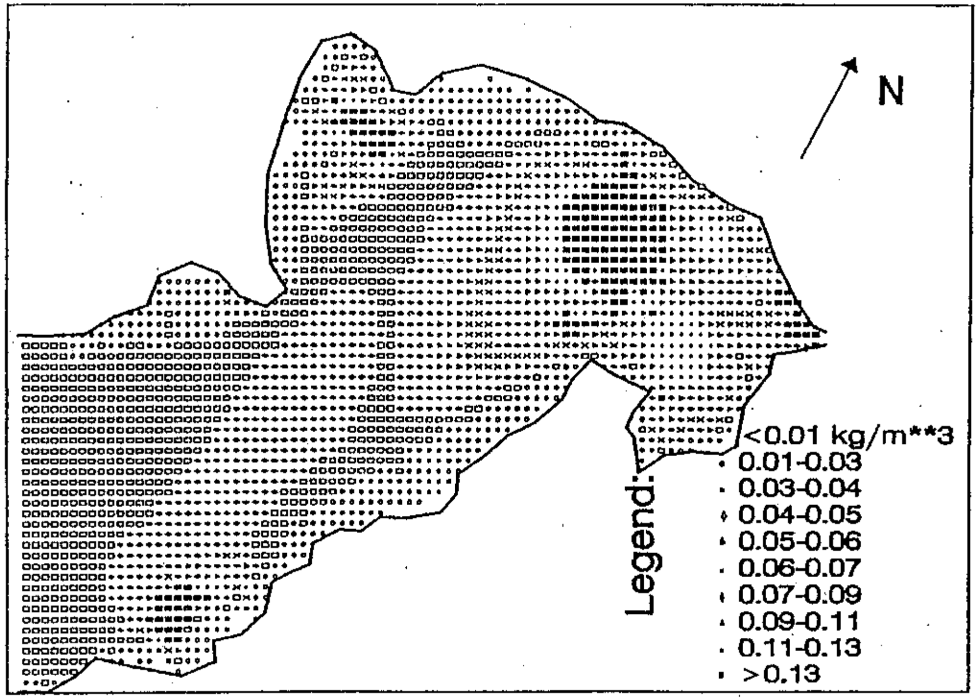


FIG. A7－62e) Maximum concentration distribution in Deep Bay during 2 days (Run 15)

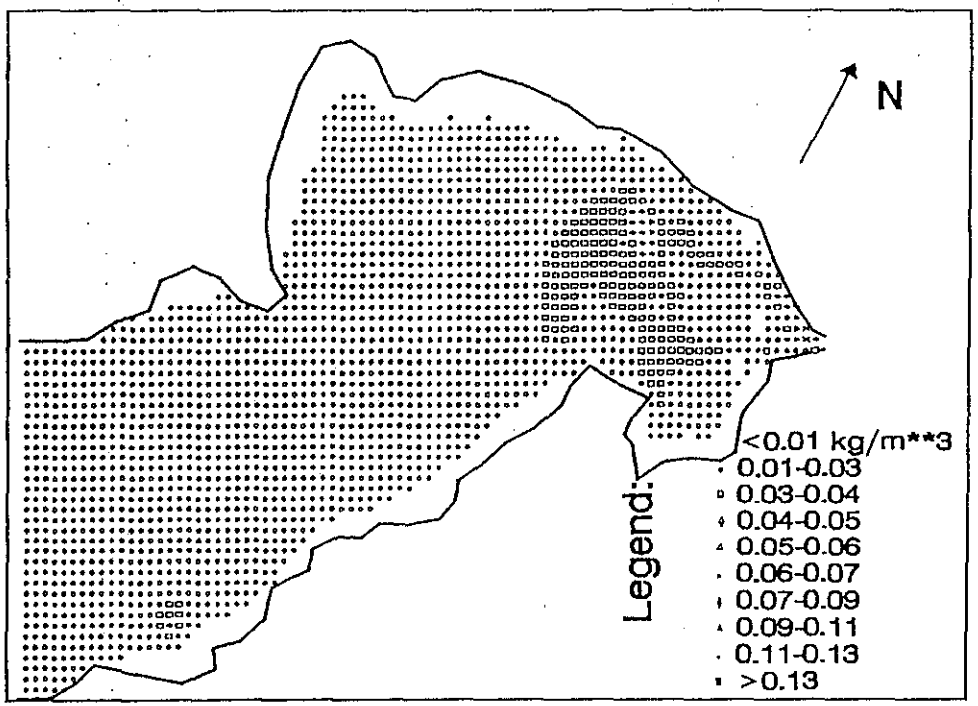


FIG. A7—62f) Average concentration distribution in Deep Bay during 2 days (Run 15)

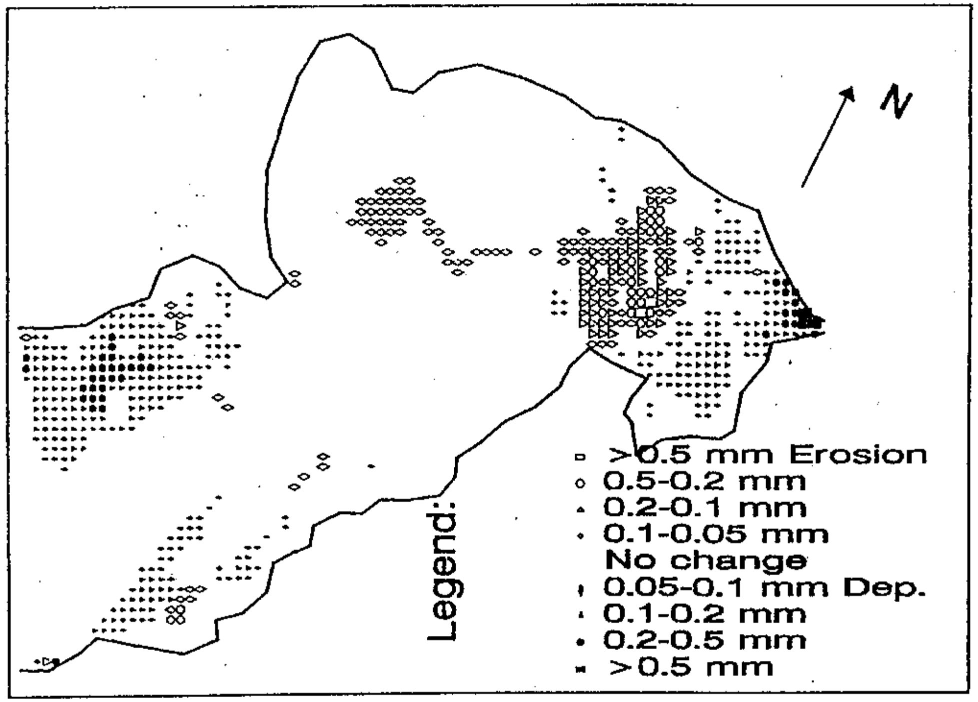


FIG. A7—62g) Sediment erosion and deposition in Deep Bay during 2 days (Run 16)

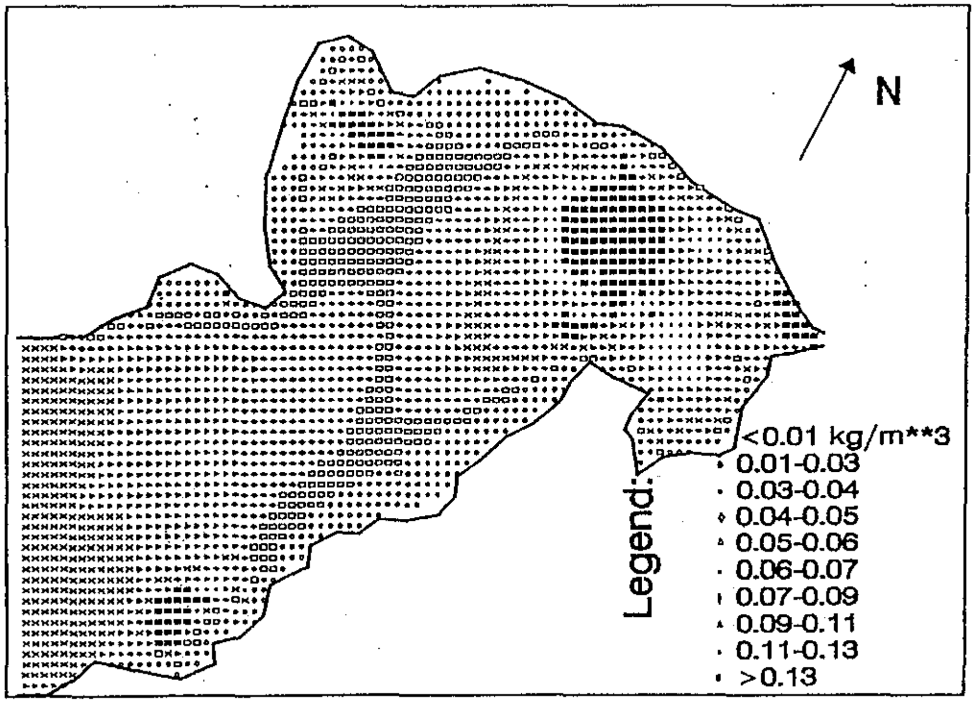


FIG. A7—62h) Maximum concentration distribution in Deep Bay during 2 days (Run 16)

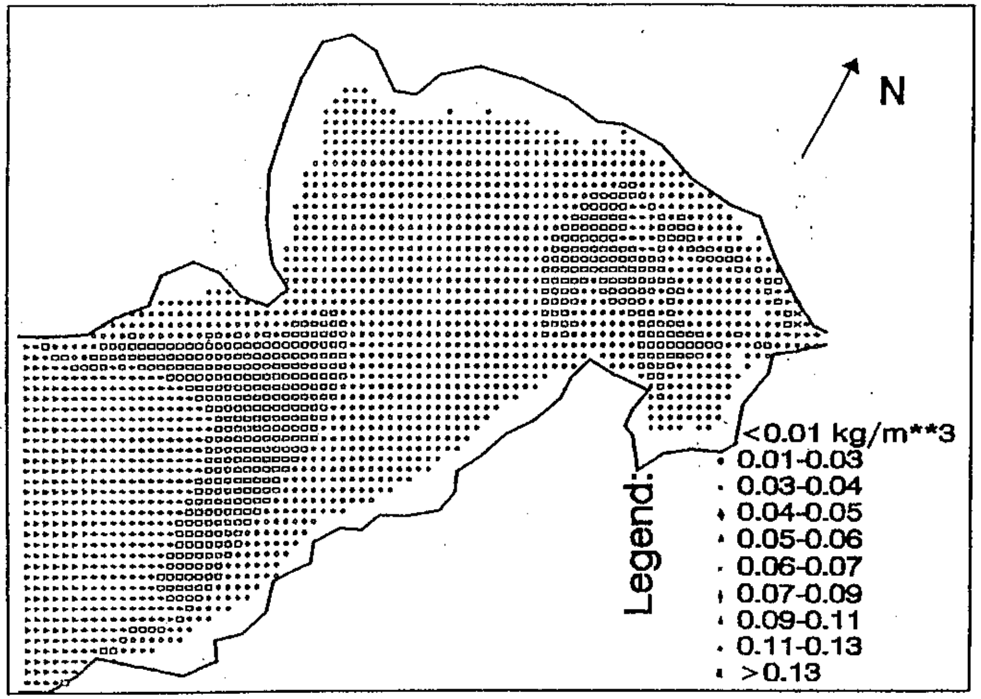


FIG. A7—62i) Average concentration distribution in Deep Bay during 2 days (Run 16)

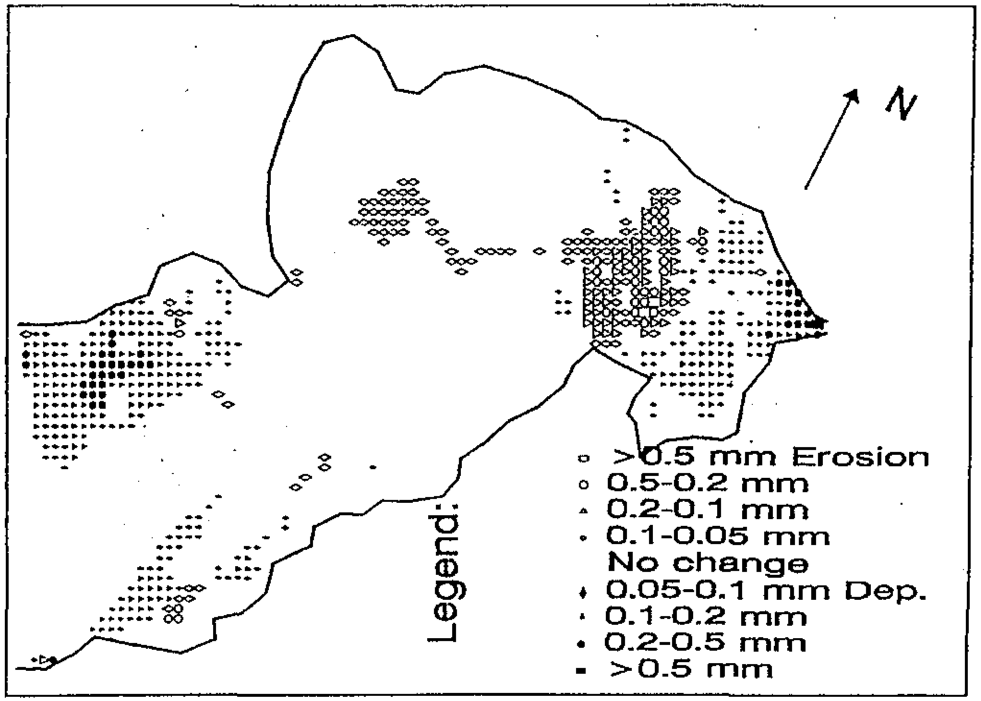


FIG. A7—62j) Sediment erosion and deposition in Deep Bay during 2 days (Run 17)

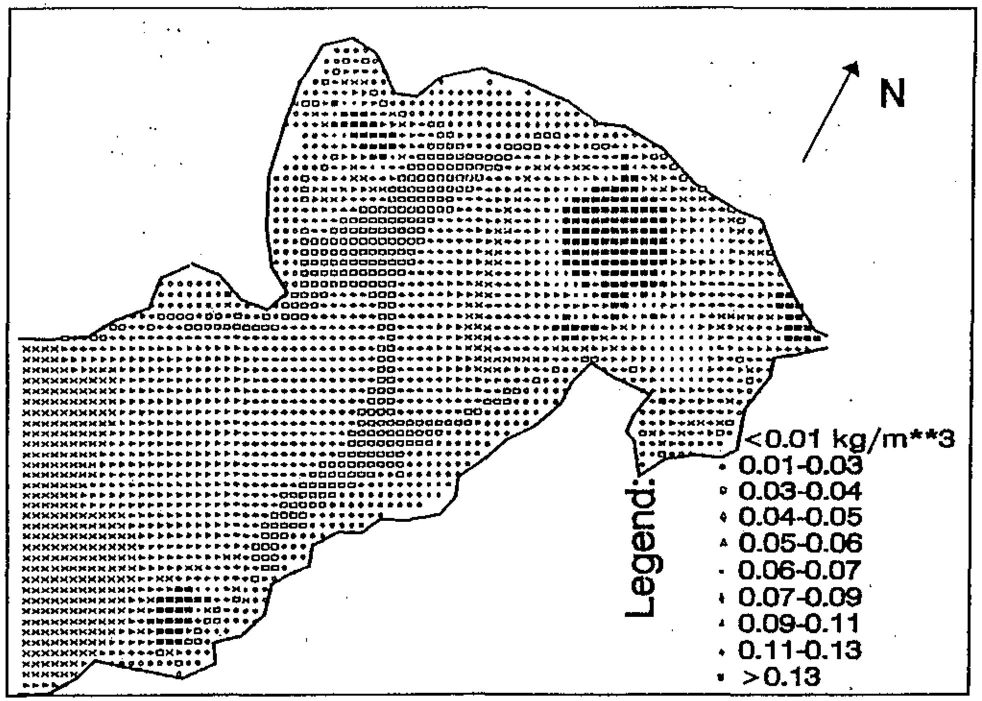


FIG. A7—62k) Maximum concentration distribution in Deep Bay during 2 days (Run 17)

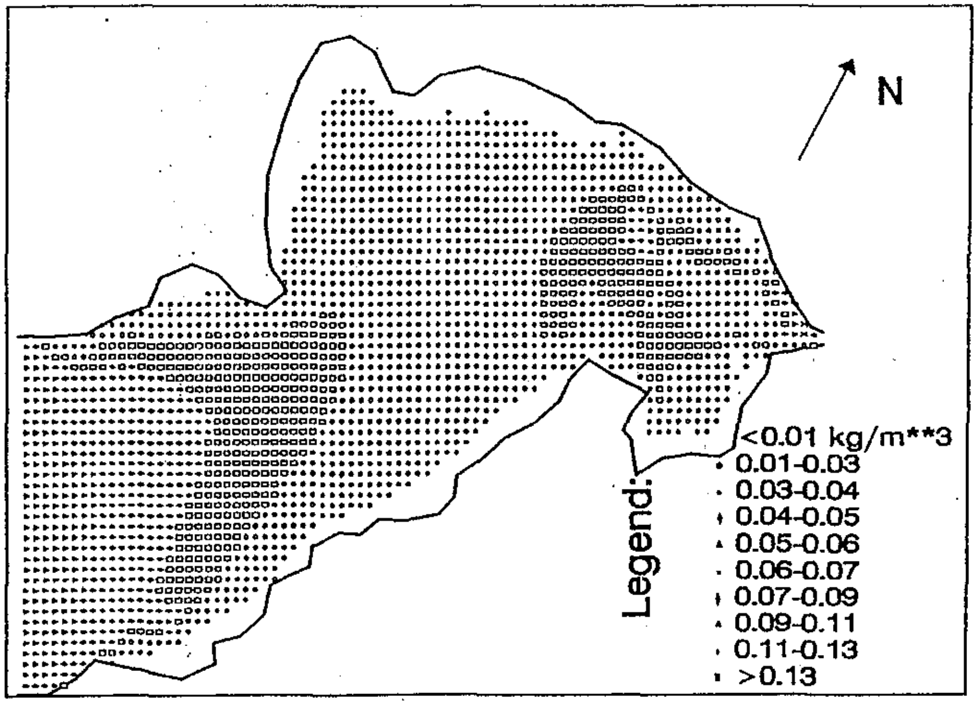


FIG. A7—621) Average concentration distribution in Deep Bay during 2 days (Run 17)

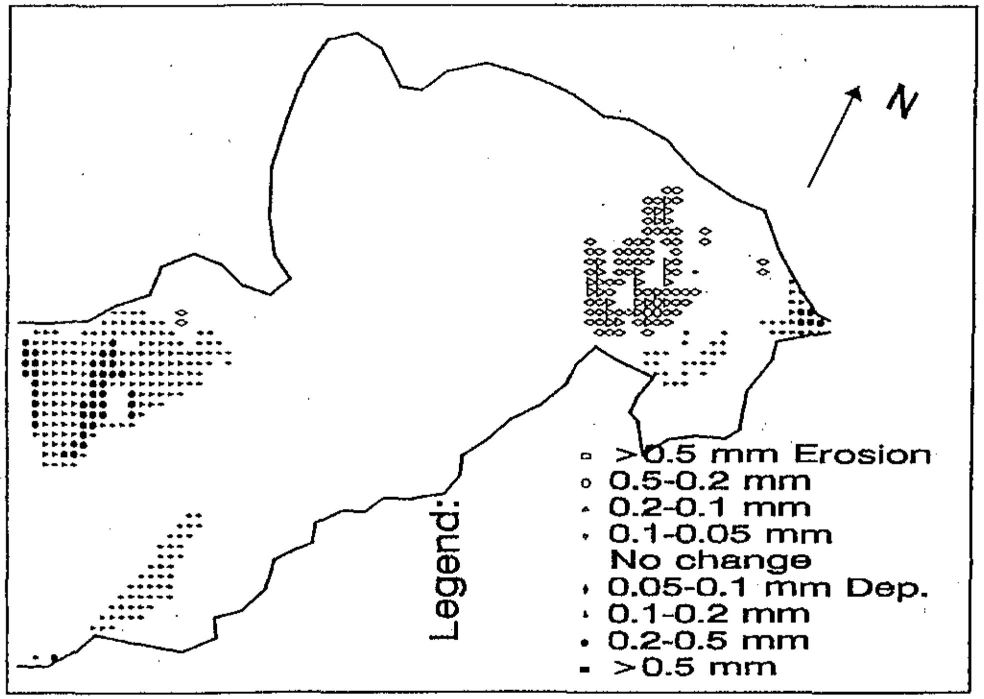


FIG. A7—63a) Sediment erosion and deposition in Deep Bay during 2 days (Run 18)

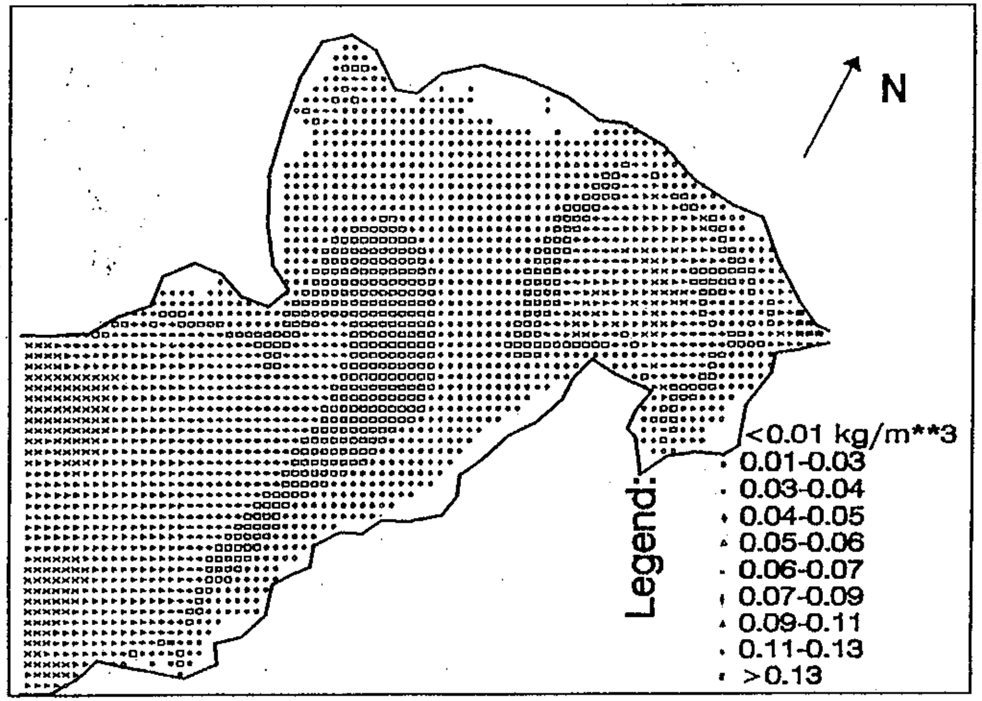


FIG. A7—63b) Maximum concentration distribution in Deep Bay during 2 days (Run 18)

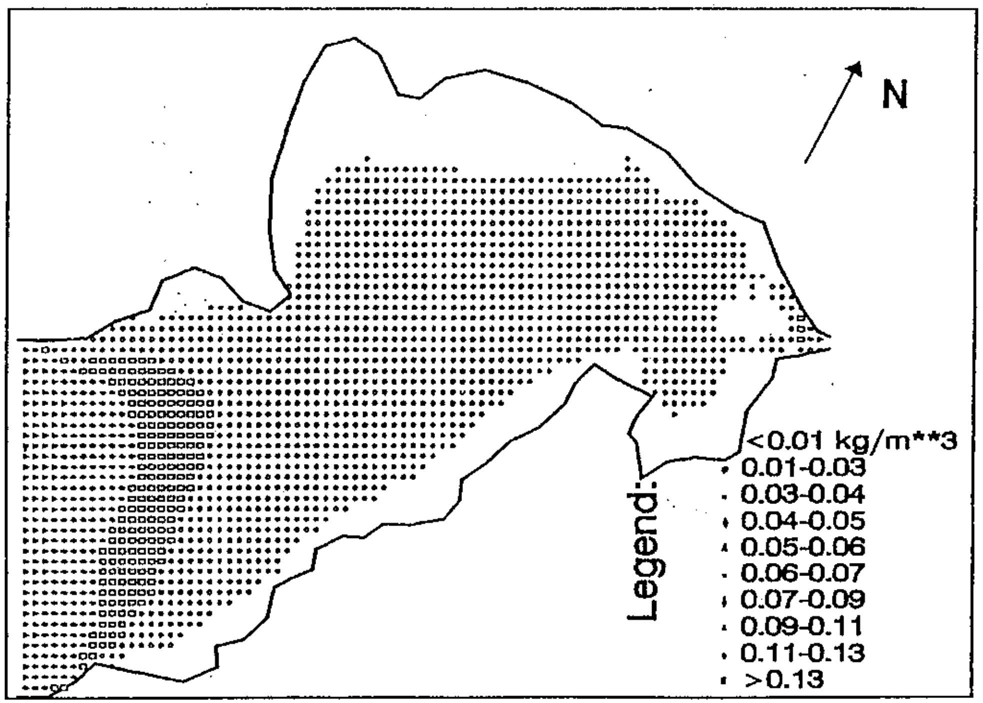


FIG. A7—63c) Average concentration distribution in Deep Bay during 2 days (Run 18)

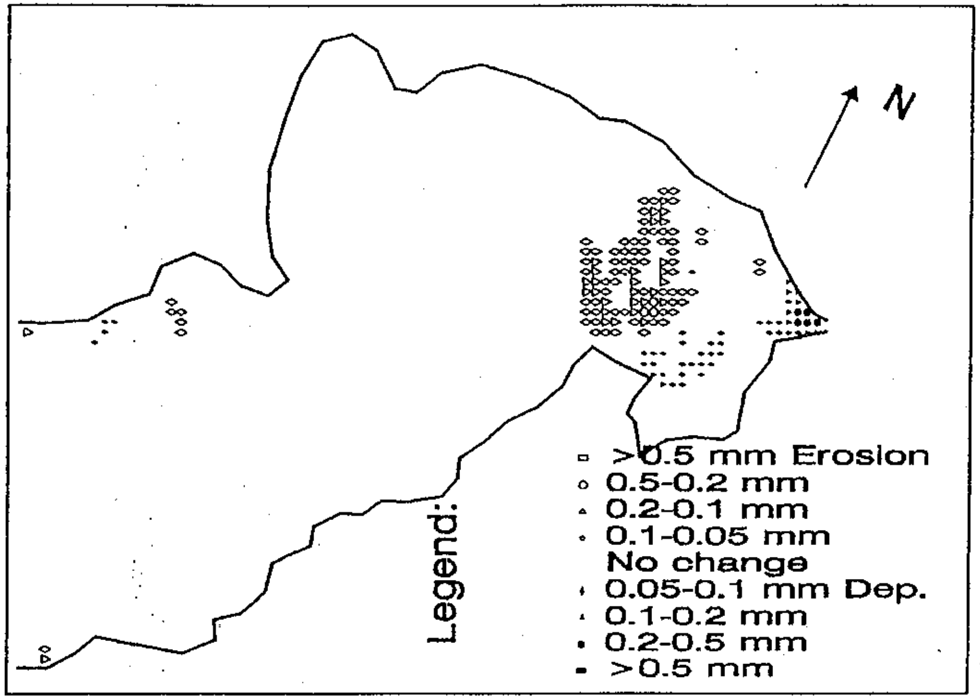


FIG. A7—63d) Sediment erosion and deposition in Deep Bay during 2 days (Run 19)

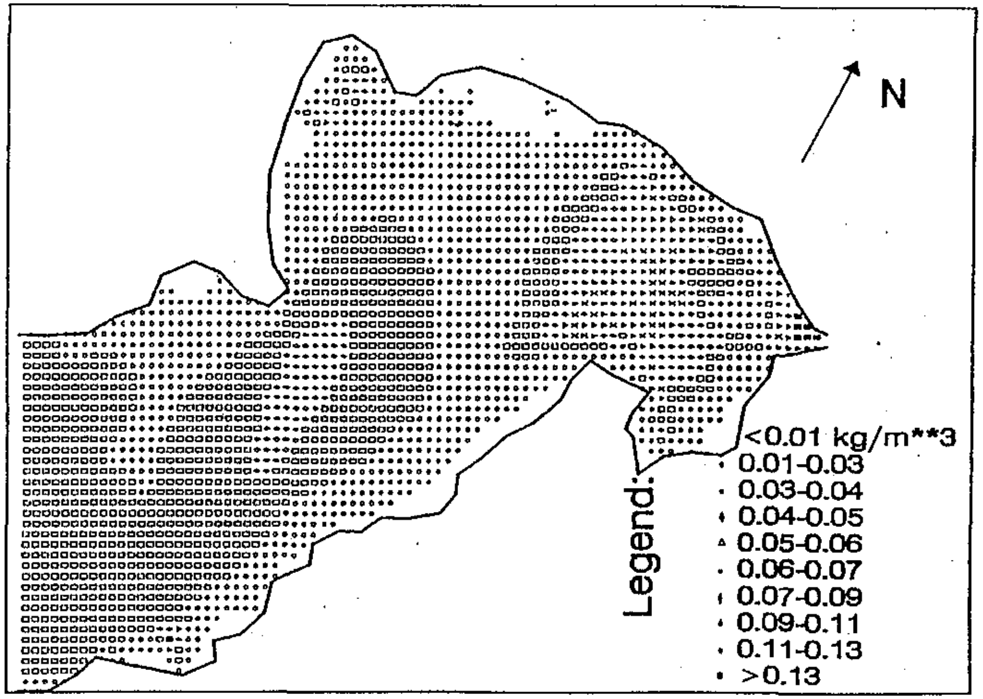


FIG. A7—63e) Maximum concentration distribution in Deep Bay during 2 days (Run 19)

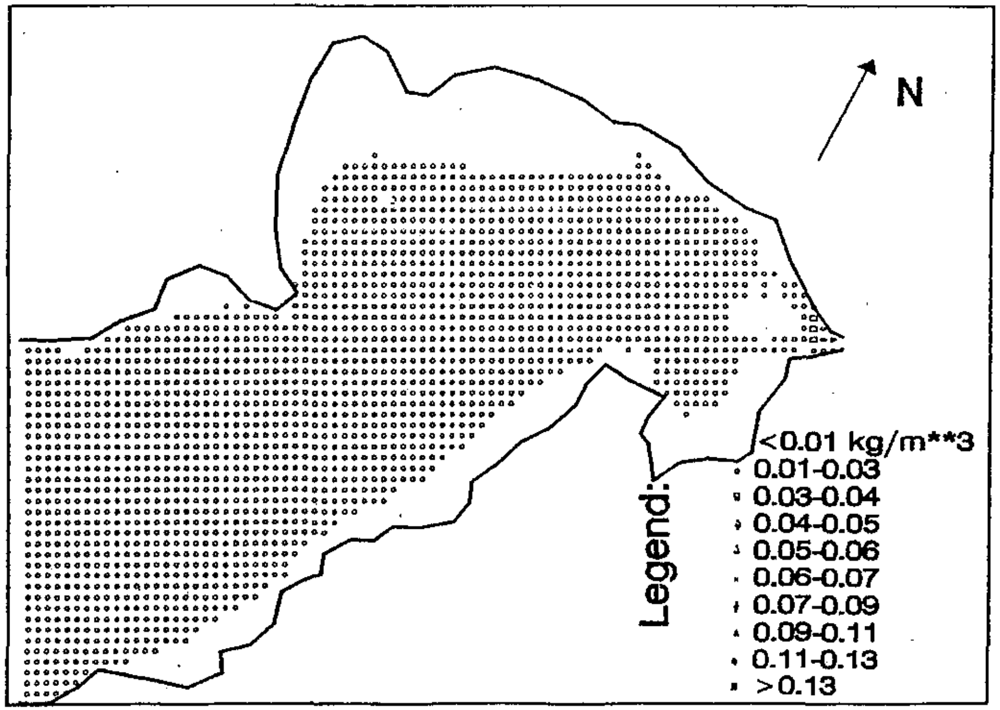


FIG. A7—63f) Average concentration distribution in Deep Bay during 2 days (Run 19)

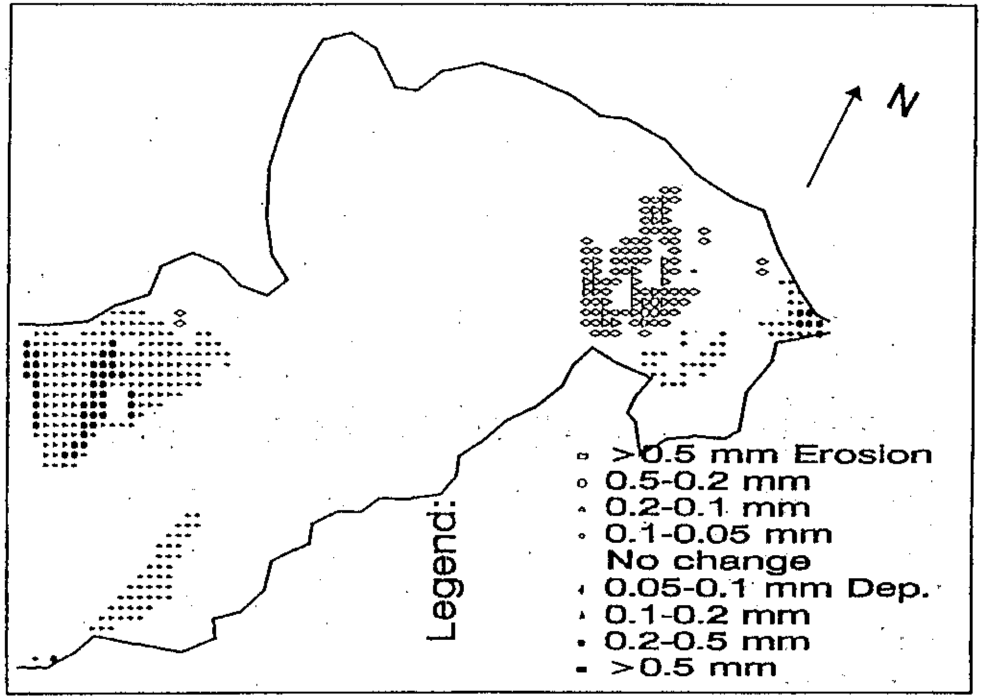


FIG. A7—63g) Sediment erosion and deposition in Deep Bay during 2 days (Run 20)

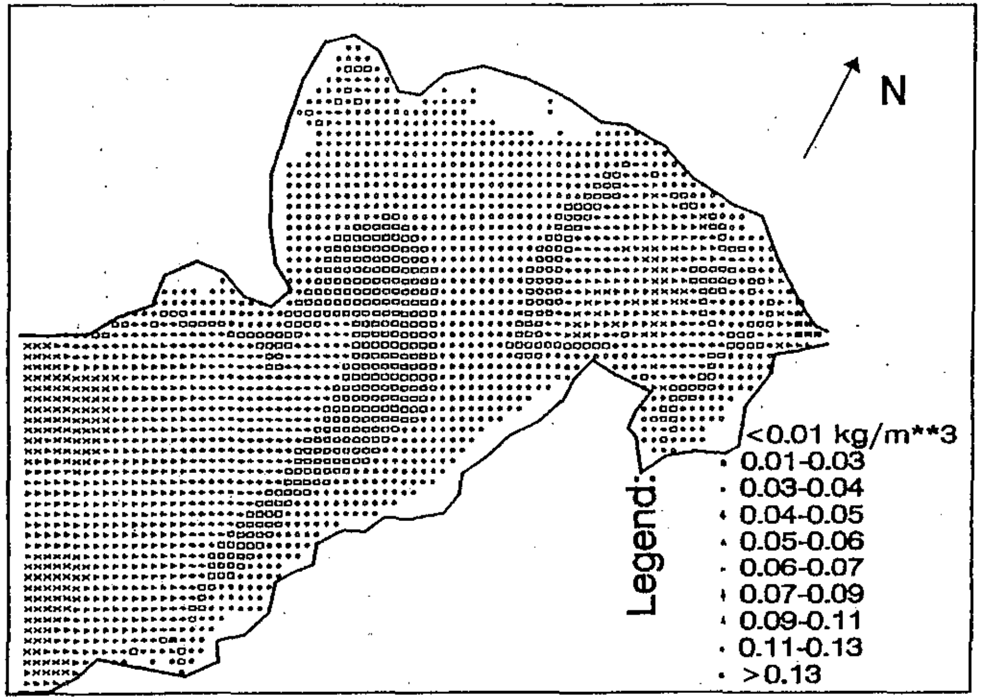


FIG. A7—63h) Maximum concentration distribution in Deep Bay during 2 days (Run 20)

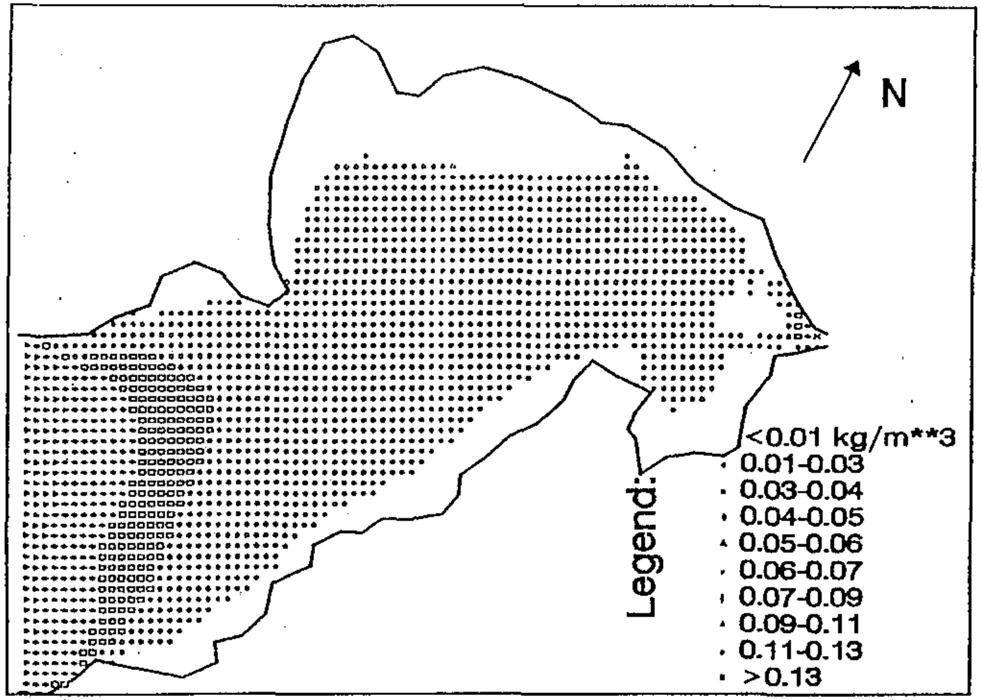


FIG. A7—63i) Average concentration distribution in Deep Bay during 2 days (Run 20)

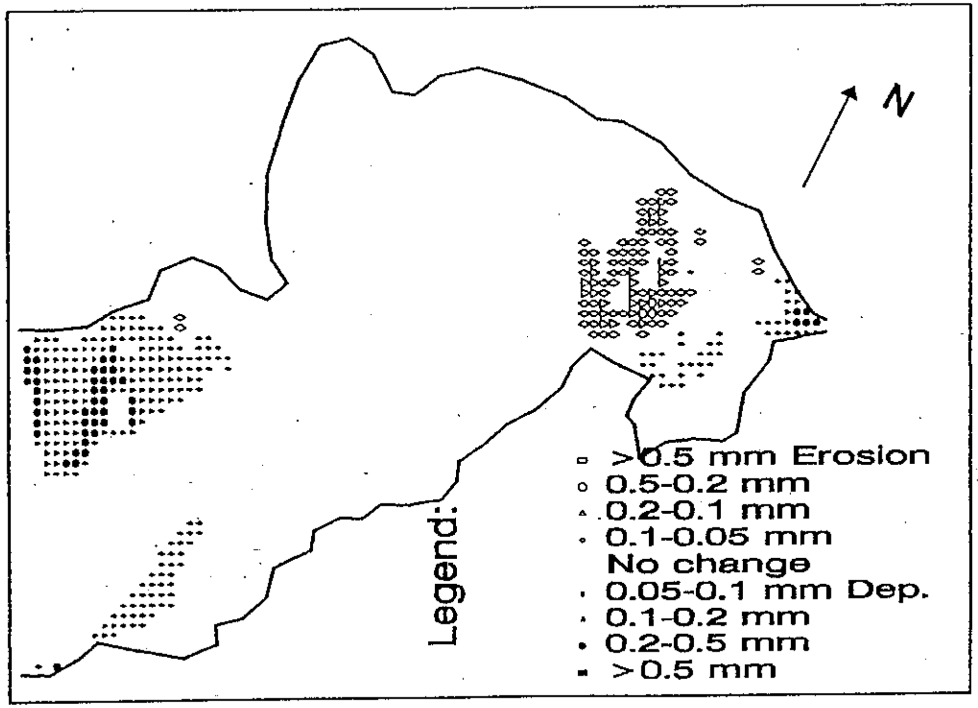


FIG. A7—63j) Sediment erosion and deposition in Deep Bay during 2 days (Run 21)

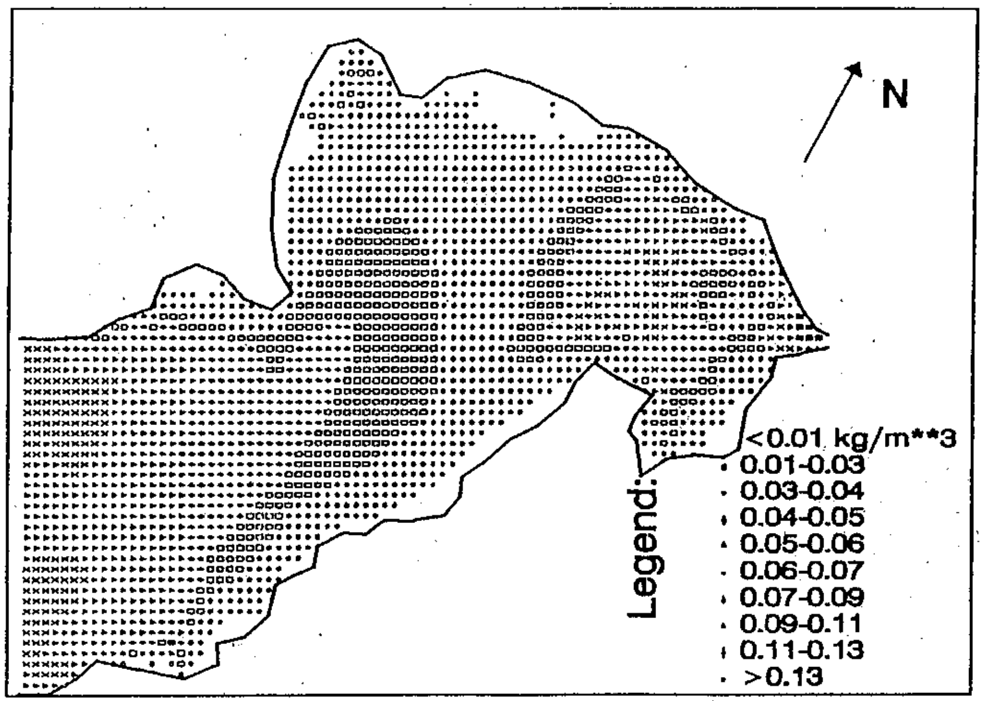


FIG. A7—63k) Maximum concentration distribution in Deep Bay during 2 days (Run 21)

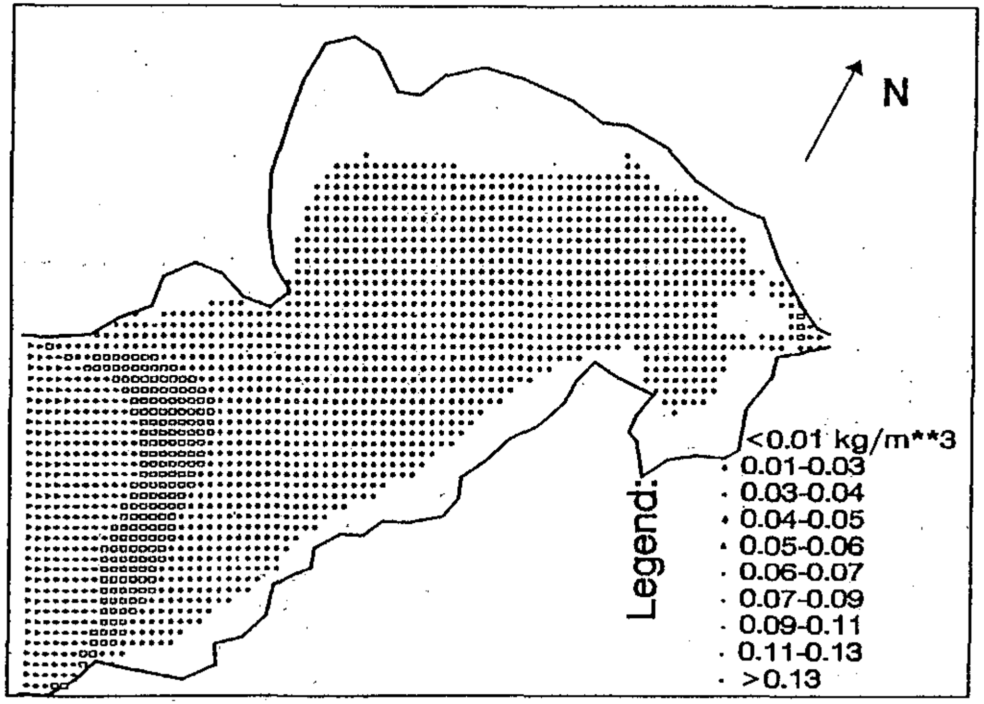


FIG. A7—631) Average concentration distribution in Deep Bay during 2 days (Run 21)

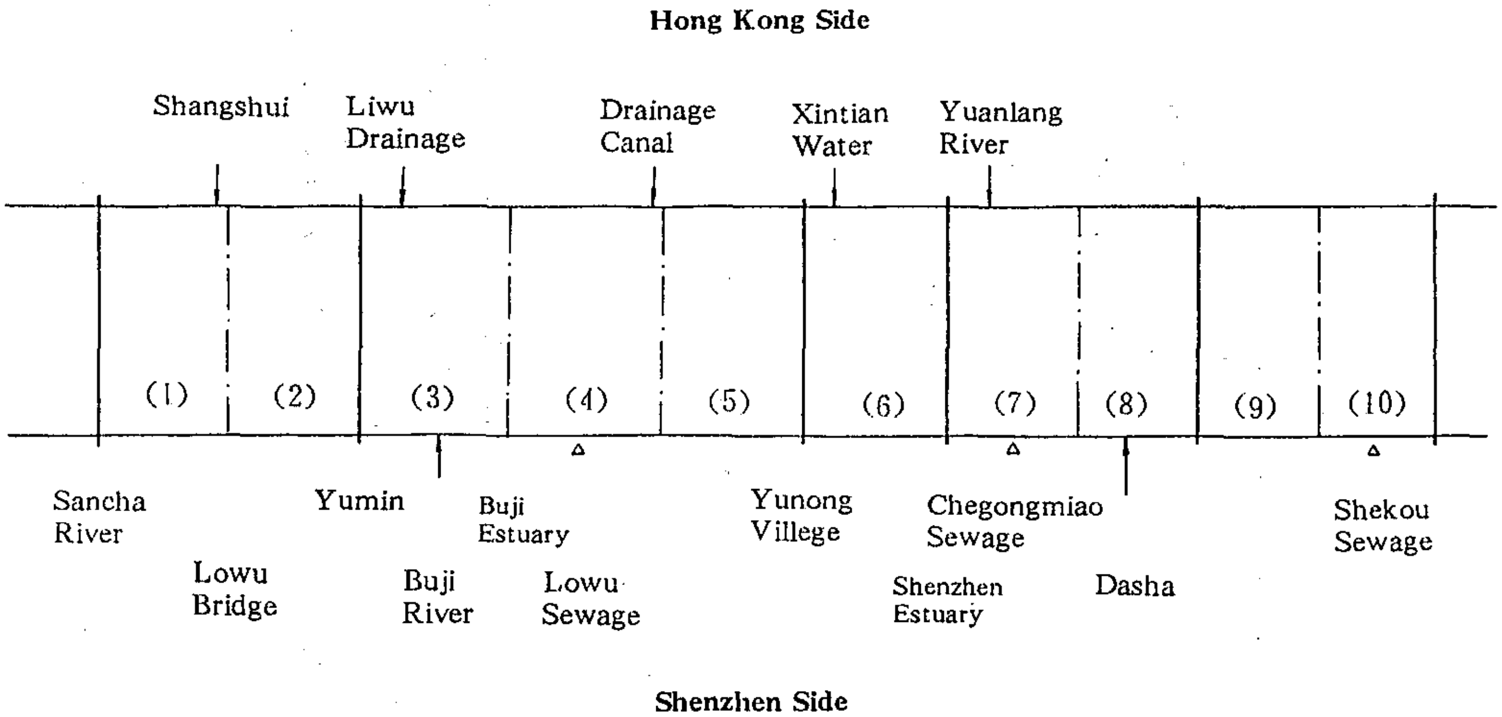


FIG. A7 — 64 General View of Drainage Area ofr Shenzhen River and Deep Bay

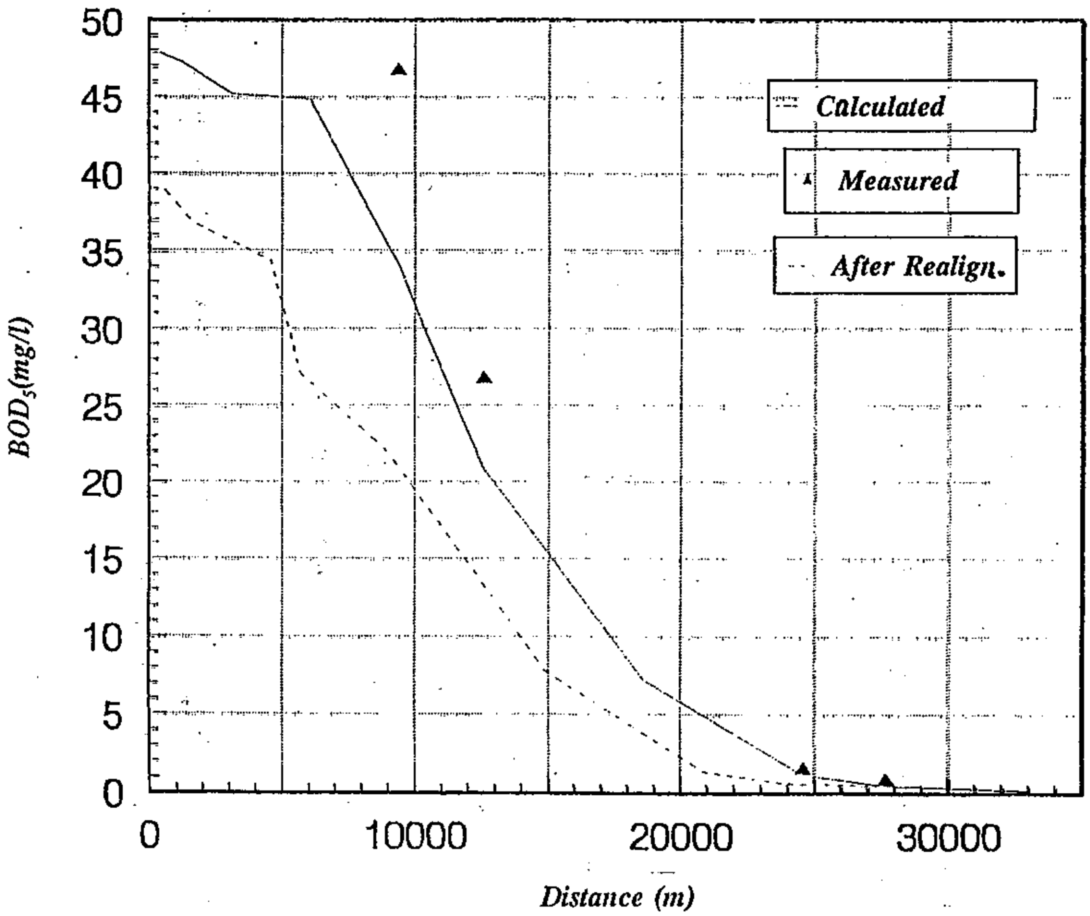


Fig. A7-65 BOD_5 Variation Along Shenzhen River

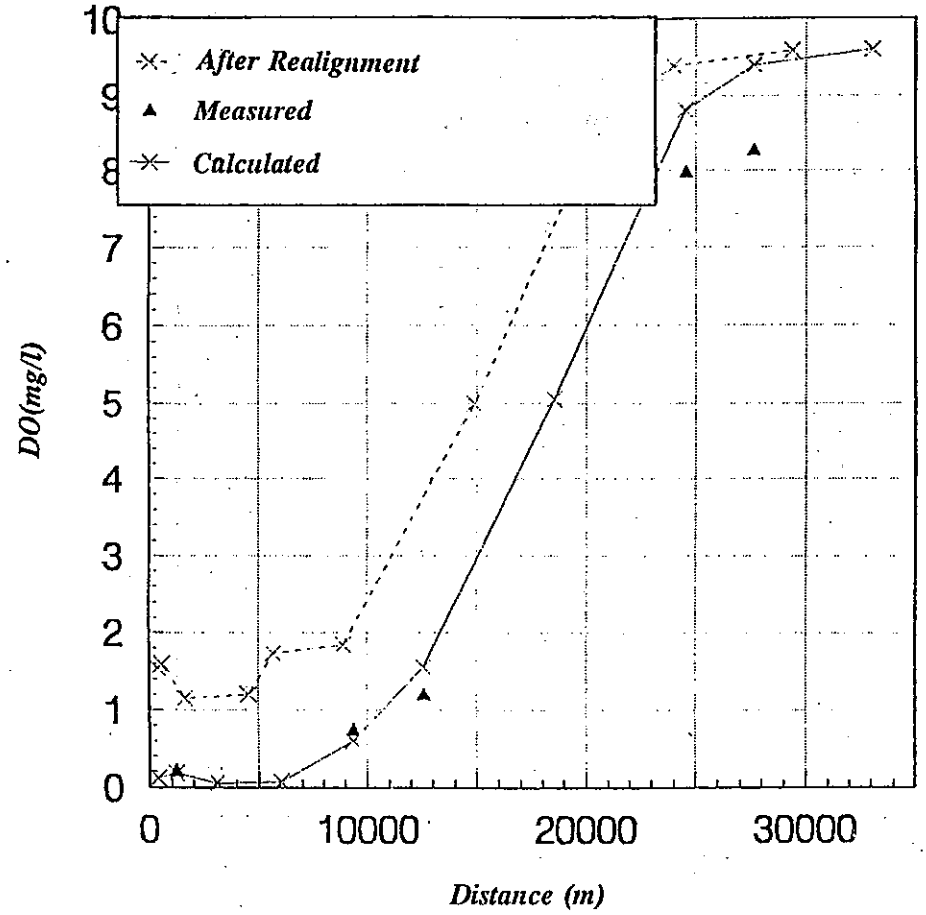


Fig. A7-66 DO Variation Along Shenzhen River

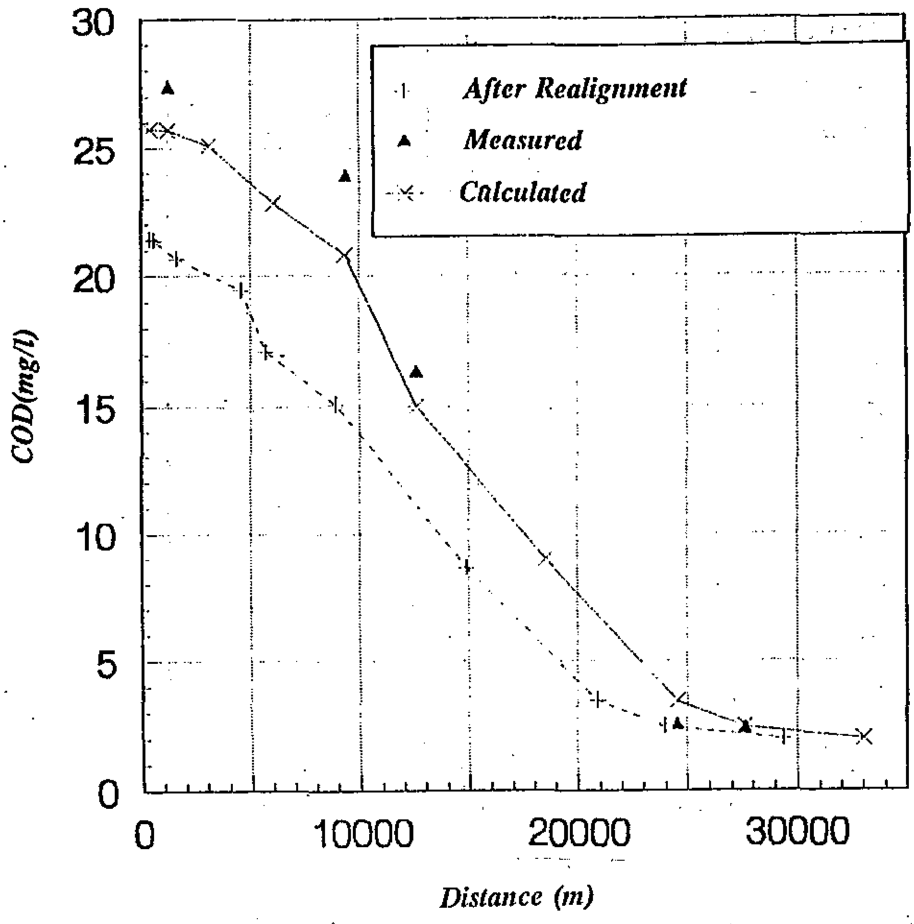


Fig. A7-67 COD Variation Along Shenzhen River

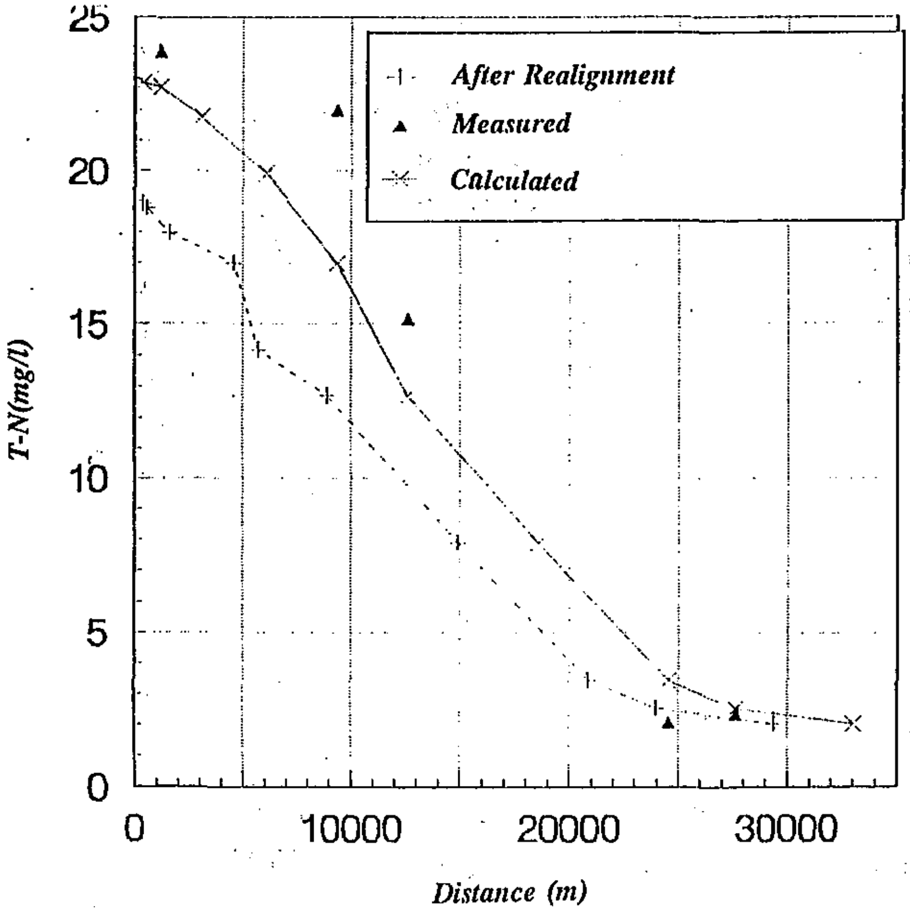


Fig. A7-68 T-N Variation Along Shenzhen River

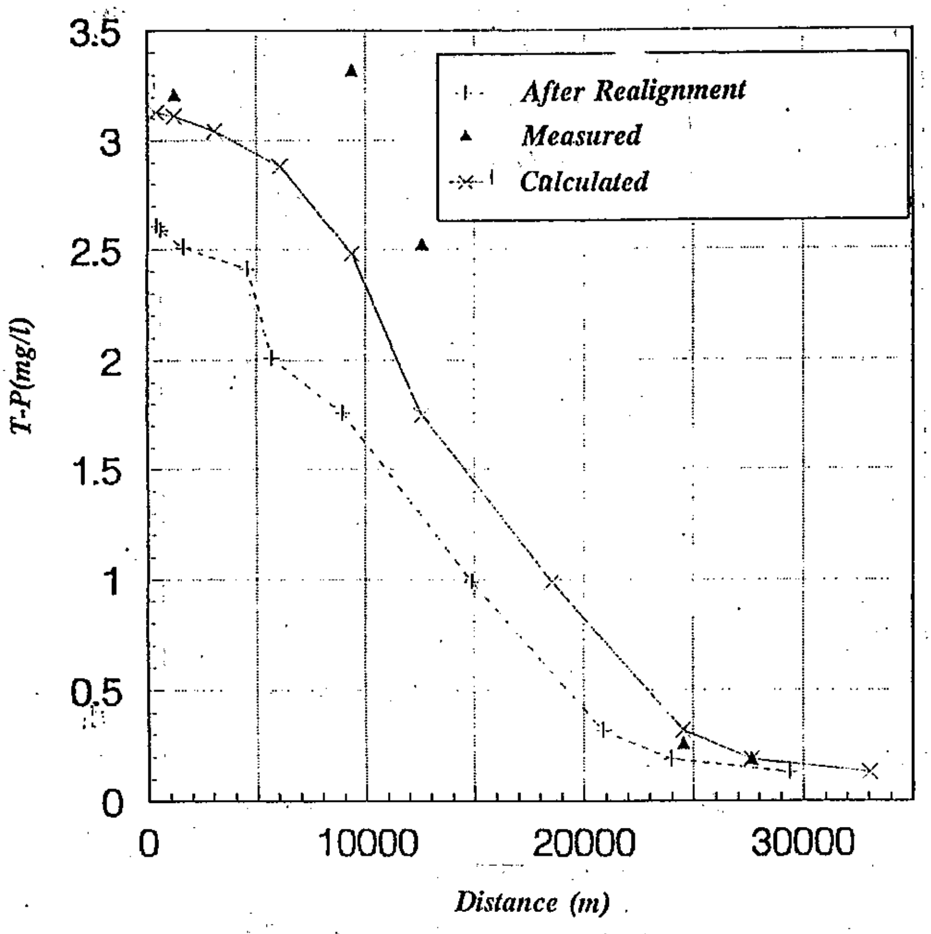


Fig. A7-69 T-P Variation Along Shenzhen River

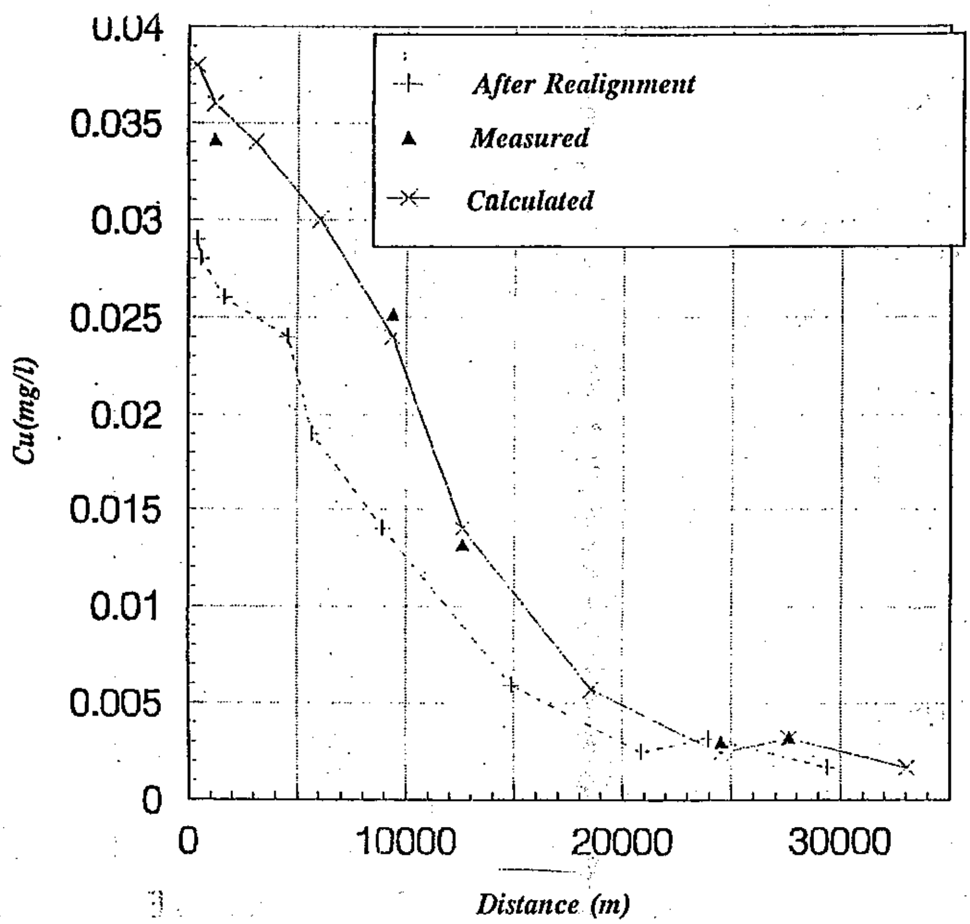


Fig. A7-70 Cu Variation Along Shenzhen River

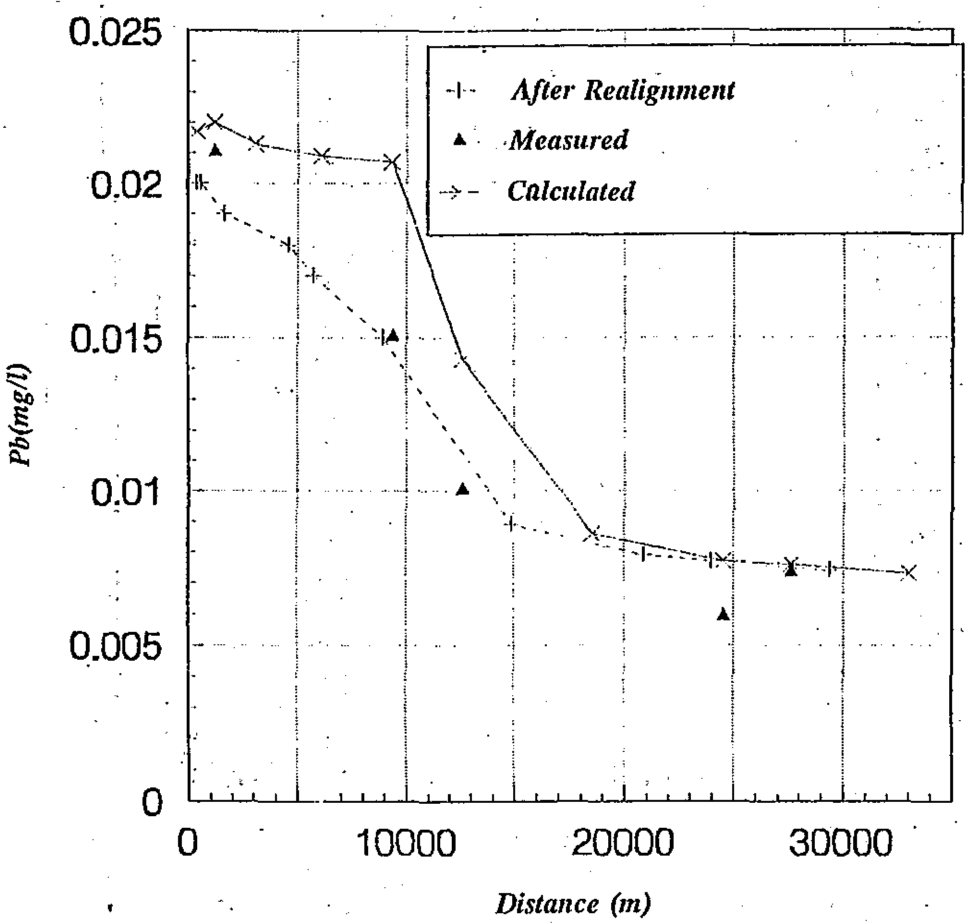


Fig. A7-71 Pb Variation Along Shenzhen River

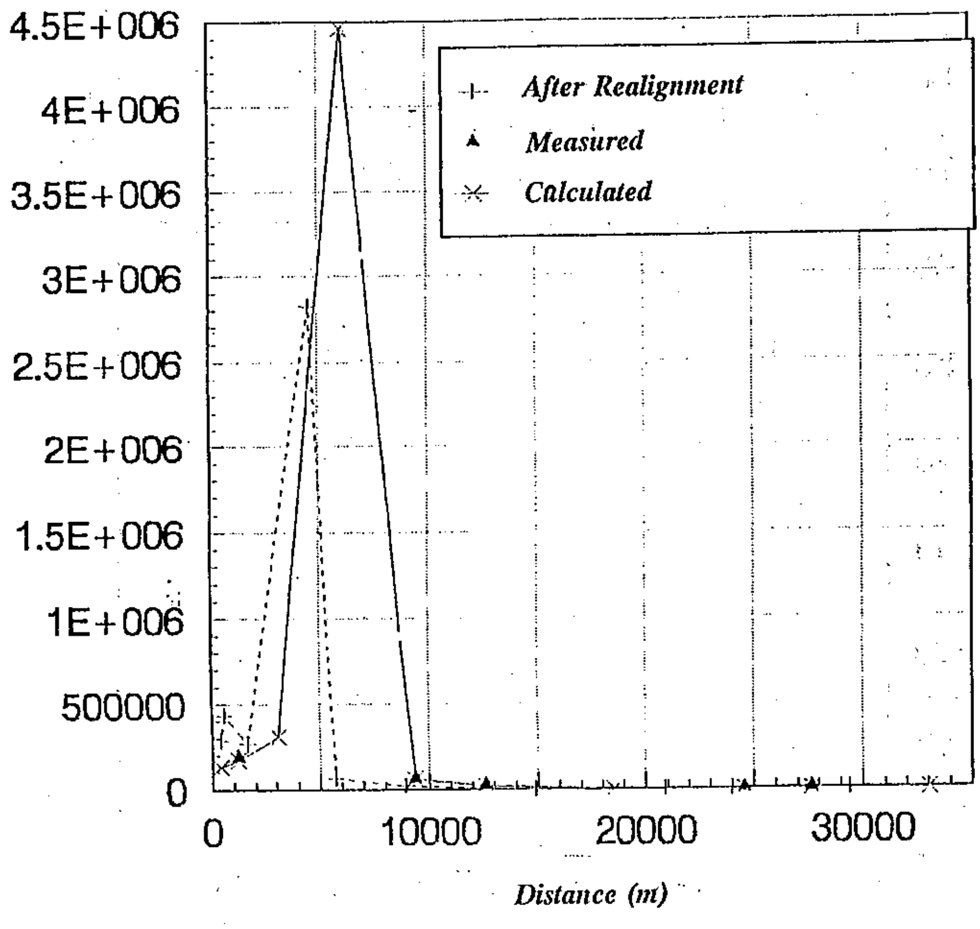


Fig. A7-72 E.Coli Variation Along Shenzhen River

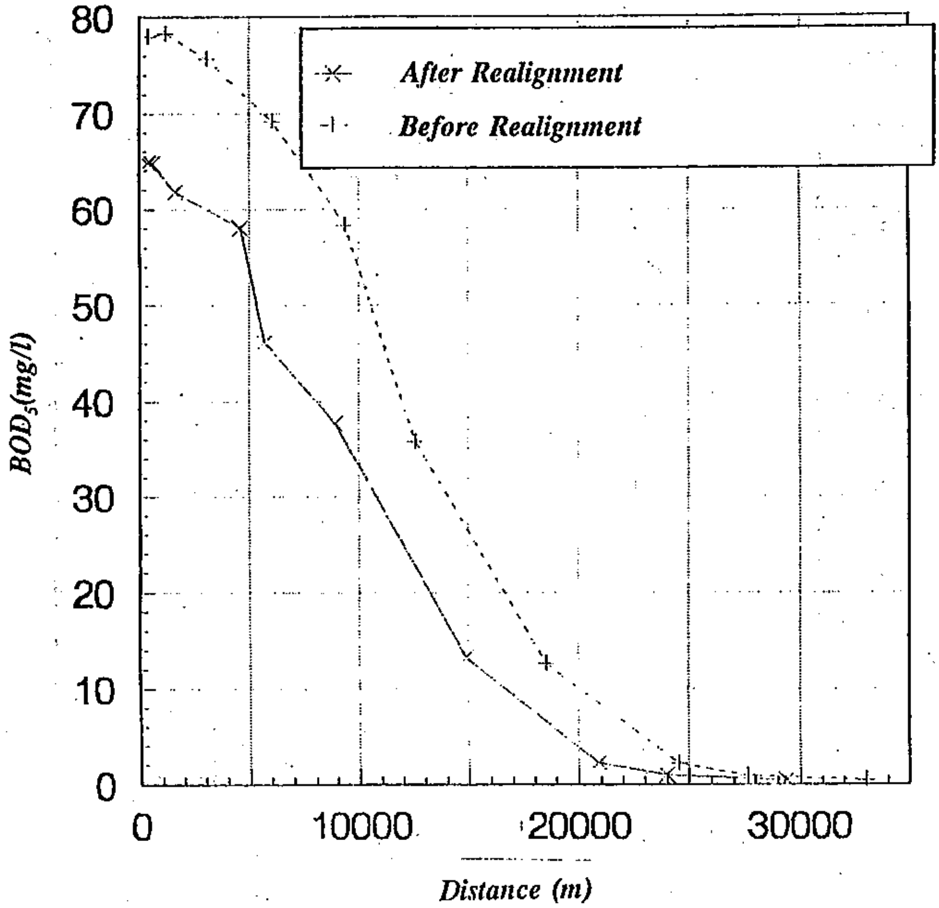


Fig. A7-73 BOD_5 Variation Along Shenzhen River in the Year 2000

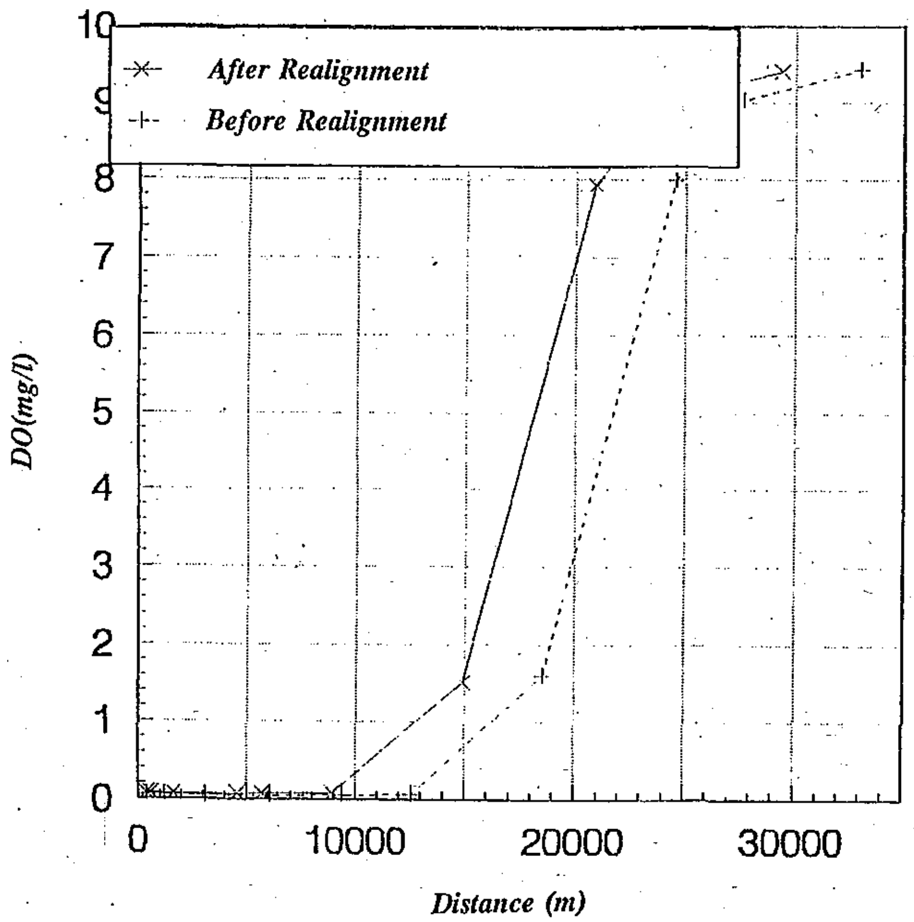


Fig. A7-74 DO Variation Along Shenzhen River in the Year 2000

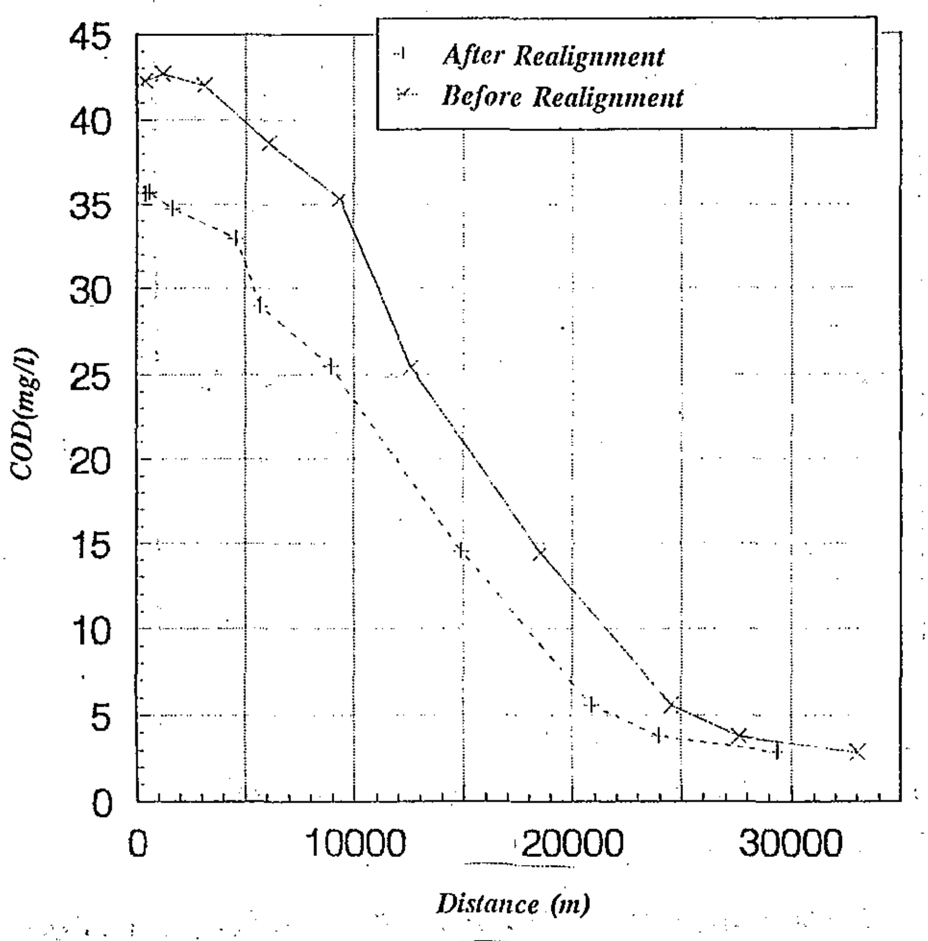


Fig. A7-75 COD Variation Along Shenzhen River in the Year 2000

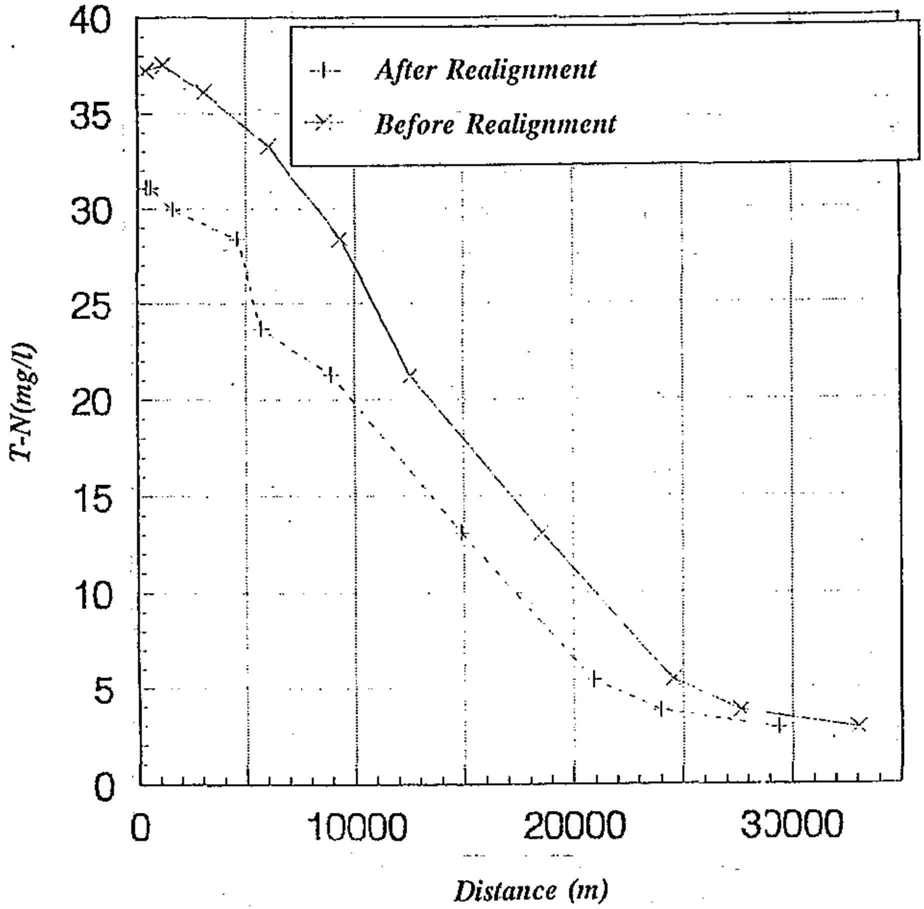


Fig. A7-76 T-N Variation Along Shenzhen River in the Year 2000

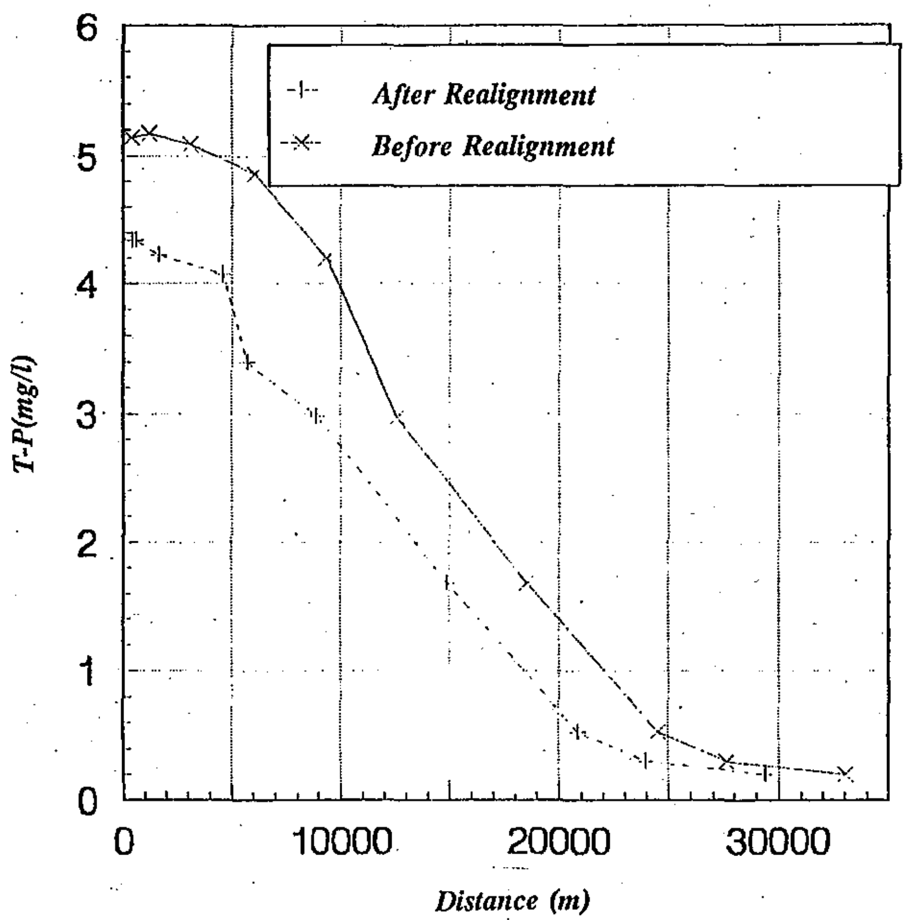


Fig. A7-77 T-P Variation Along Shenzhen River in the Year 2000

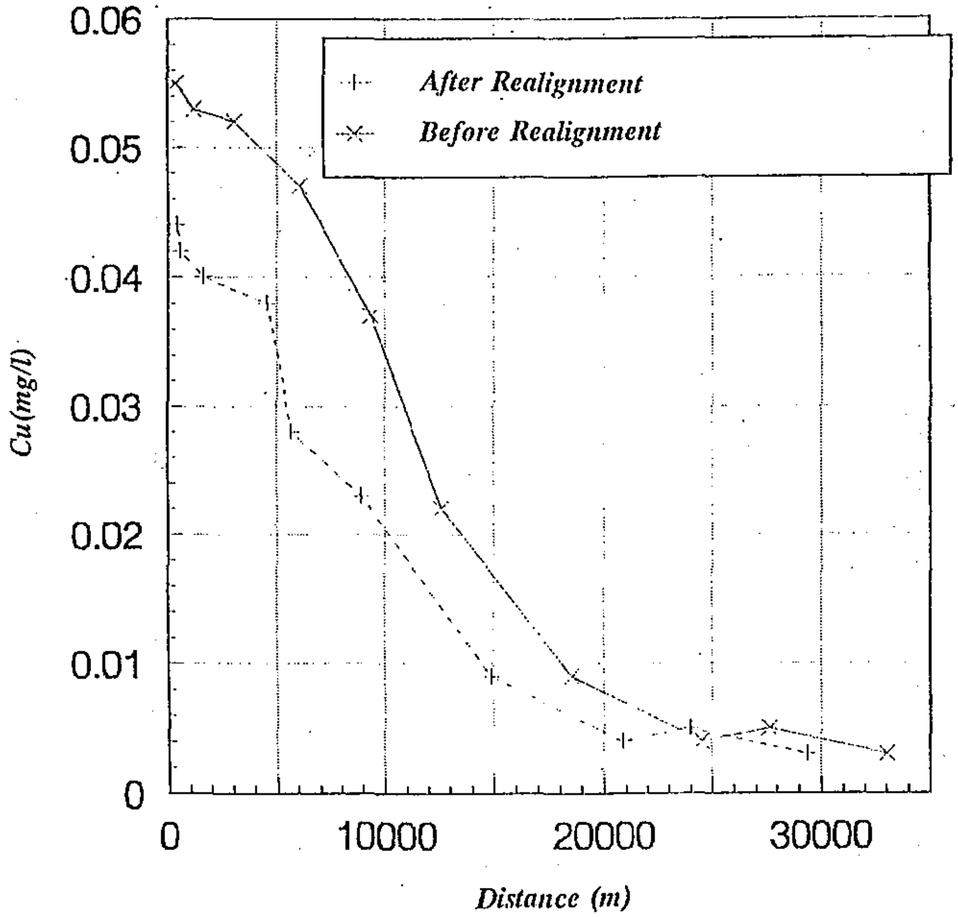


Fig. A7-78 Cu Variation Along Shenzhen River in the Year 2000

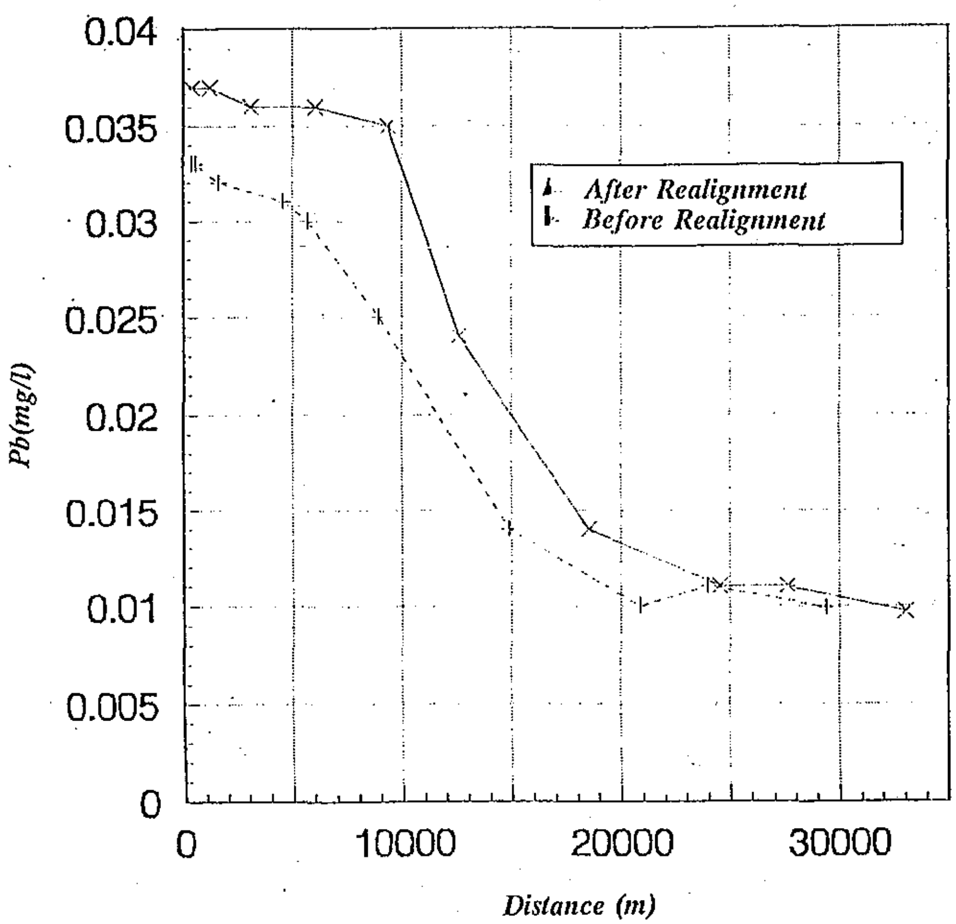


Fig. A7-79 Pb Variation Along Shenzhen River in the Year 2000

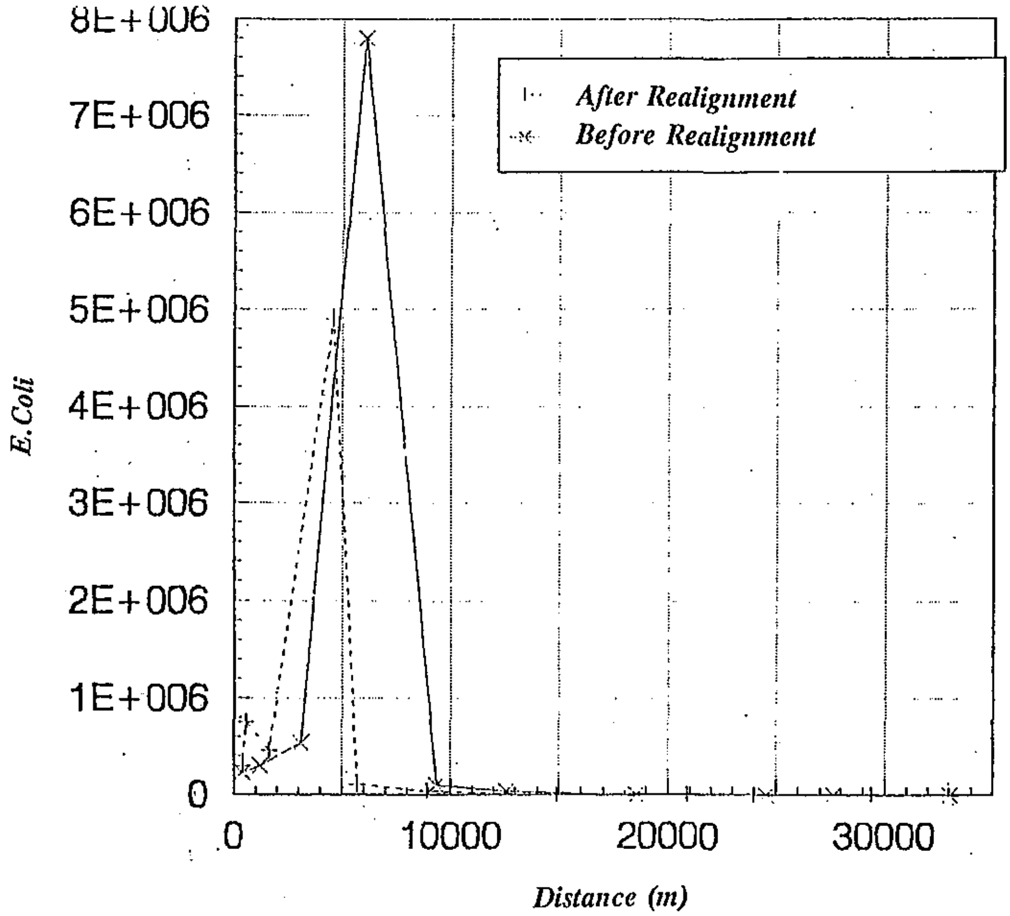


Fig. A7-80 E.Coli Variation Along Shenzhen River in the Year 2000

APPENDIX 8.1 HAKANSON'S SEDIMENT ASSESSMENT METHOD

The method refers to Sweden scientist Hakanson's Potential Ecological Hazards Assessment (Hankanson, 1982). According to the potential ecological index assessment method, Firstly, to select the possible pollution factors which may cause serious ecological hazard, and them follow the Pollutants' Average Global Sedimentation value (or the background value the soil in that local area) and Toxicity value, then work out the Ecological Hazard Value E for that pollutant, and carry out ten single factor pollution assessment.

Reference values and toxicity respondent coefficients used in the calculation are presented as follows.

Element	Cu	Cd	Pb	Zn	Cr	As	Hg
Max. Background Value(mg/kg) Before Industrial Revolution	50	1.0	70	175	90	15	0.25
Toxicity Value	5	30	5	1	2	10	40

The Relationship between E and Pollution Degree is shown in following table

Ecological Hazard Value	Ecological Hazard Degree
<40	Mild Ecological Hazard Medium
40-80	Ecological Hazard
80-150	Serious Ecological Hazard
150-320	Very Serious Ecological Hazard
>320	Extreme Serious Ecological Hazard

Base on the calculated ecological hazard value for the single factor, and them calculated Integrated Pollution Index RI of a sediment which contains different pollutants. And carry out River/ Bay sediments integrated assessment. The following table show the relationship of RI and pollution degree

Integrated Ecological Pollution Index	Degree of Ecological Hazard
<150	Mild Ecological Hazard
150-300	Medium Ecological Hazard
300-600	Serious Ecological Hazard
>600	Very Serious Ecological Hazard

APPENDIX 8.2 BASELINE MONITORING RESULTS FOR THE RIVER/BAY

1994 Shenzhen River mid/down stream dry season water quality monitoring result are given in following tables (mg/l).

	T(°C)	pH	DO	BOD_5	COD	NH_3-N	NO_2-N	NO_3-N	TN
Mean	18.4	7.3	0.91	58.4	20.0	18.8	0.0	0.02	21.9
Minimum	16.2	7.1	0.56	21.2	12.7	13.9	0.0	0.01	14.3
Maximum	20.7	7.9	3.41	75.6	26.4	21.9	0.009	0.05	25.1
W0	16.5	7.2	9.4	0.83	0.81	0.18	0.01	0.36	0.64

	TP	Total Cu	Total Zn	Total Ni	Total Cd	Total Pb	Total Cr	Total Hg
Mean	3.2	24.4	249	23.1	0.08	16.4	28.1	0.19
Minimum	1.9	8.9	89.0	0.0	0.02	3.4	23.0	0.06
Maximum	4.0	49.1	108.7	120	0.36	48.6	40.0	0.44
W0	0.12	3.70	261	0.0	1.3	18.4	16.5	0.11

	Exch. Cu	Exch. Zn	Exch. Ni	Exch. Cd	Exch. Pb	Cr^{6+}
Mean	18.7	-	25.0	0.04	1.88	1.56
Minimum	8.0	-	0.0	0.02	0.0	0.5
Maximum	40.0	-	120.0	0.12	4.8	3.0
W0	2.95	-	0.0	1.19	4.85	0.0

	Exch. Hg	Conductivity(μm/cm)	Soluble P	Oil	As	Volatile Phenol
Mean	0.12	5122	1.79	2.77	1.7	0.04
Minimum	0.04	757	1.03	0.83	0.5	0.03
Maximum	0.26	31000	2.92	3.80	3.10	0.0
W0	0.0	191	0.0	1.02	0.7	0.02

	Salinity (Cl-)	E.coli (no./l)	SS	Cl^-
Mean	1072	390000000	133.3	0.0
Minimum	51.2	100000000	28.0	0.0
Maximum	7520	800000000	409	0.003
W0	30.7	110135500	27.8	0.0

1994 Deep Bay dry season water quality monitoring result are tabulated in following table (mg/l)

	T(°C)	pH	DO	BOD_5	COD	NH_3-N	NO_2-N	NO_3-N	TN
Mean	18.3	7.8	4.16	3.12	2.14	3.68	0.057	0.13	5.28
W7	19.1	8.1	8.35	0.81	0.98	0.4	0.043	0.14	2.98

	TP	Total Cu	Total Zn	Total Ni	Total Cd	Total Pb	Total Hg
Mean	0.439	0.0021	0.0035	0.005	0.0001	0.0006	0.00002
W7	0.089	0.0028	0.0004	0.0038	0.0001	0.0008	-

	Diss Cu	Diss Ni	Diss Cd	Diss Pb	Turbidity(°)
Mean	0.0014	0.0047	0.0001	0.0006	21.4
W7	0.002	0.0036	0.0001	0.0008	9.3

	Conductivity(μs/cm)	Diss. P	Oil	chlo-a	SS
Mean	38400	0.356	0.13	1.28	21.3
W7	44300	0.057	0.04	2.28	6.2

	Salinity(%)	Cl^-	E. Coli. (nos/ml)	Bacteria (nos/ml)
Mean	24.9	15000	3500000	32300
W7	29.0	18000	3000	96

APPENDIX 8.3 ASSESSMENT INDEXES

INTEGRATED POLLUTION INDEX (P_j)

$$P_j=\sum_{i=1}^{n} P_{ji}, \qquad P_{ij}=\frac{C_{ij}}{C_{io}}$$

P_j : integrated pollution index on section j
P_{ij} : pollution index of the ith pollutant on section j
C_{ij} : annual mean of the ith pollutant on section j
C_{io} : standard value for the ith pollutant
n : number of pollutants involved

POLLUTION SHARING RATE (K_i)

$$K_i(\%)=\frac{100P_{ij}}{P_j}$$

P_{ij}, P_j, n : same as above

APPENDIX 8.4 HEAVY METALS IN SEDIMENT OF SHENZHEN RIVER

		As	Hg	Pb	Cd	Cu	Zn	Cr
1991	Zhuanmatou	9.9	0.64	85.1	0.26	178	366	61.9
	Hekou	9.9	0.19	83.8	0.31	138	286	71.2
1992	Zhuanmatou	13.1	0.44	110	0.83	269	566	63.6
	Hekou	14.1	0.19	109	0.99	102	721	38.4
1993	Zhuanmatou	16.5	0.3	102	0.43	207	523	106
	Hekou	13.1	0.14	82	0.24	99	308	65

APPENDIX 9.1 INTERNATIONAL CONVENTIONS RELEVANT TO THE PROJECT IN TERMS OF HABITAT AND WILDLIFE PROTECTION

1 THE RAMSAR CONVENTION

Article 1 of the Convention defines wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.' Thus all wetland habitats in the Deep Bay area, including man-made fish ponds and *gei wais*, and the mangroves, inter-tidal flats and open water areas of Deep Bay are 'wetlands' under the Ramsar definition.

The Ramsar Convention requires contracting Parties to designate at least one wetland within its territory for inclusion in a 'List of Wetlands of International Importance'. Currently the Hong Kong administration is considering designation of the Mai Po/Inner Deep Bay area and the Ministry of Forestry of the Peoples Republic of Chin is considering the designation of Futian National Nature Reserve. The criteria for selection of wetlands for inclusion in the List were last revised at the Fourth Conference of the Parties in 1990.

The Deep Bay wetlands qualify for designation under the Ramsar Convention on the following criteria:
Criterion 1(d): *'it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region'.*

Deep Bay supports the sixth largest protected area of mangrove in China. The Mai Po mangrove is one of the least damaged and the area contains one of the largest areas of reed bed in southern China
Criterion 2(a): *'it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one of these species'.*

Deep Bay supports ~1% or more of the world population of 5 species of bird, and ~1% or more of the flyway population of an additional 7 species. Details of these species are provided below.

- Deep Bay Supports 1 % or more of the world population of the following species.

Dalmatian Pelican	*Pelecanus crispus*	~1lack-faced
Spoonbill	*Platalea minor*	24%
Asiatic Dowitcher	*Limnodromus semipalmatus*	~1%
Spotted Greenshank	*Tringa guttifer*	10%
Saunders'Gull	*Larus saundersi*	5%

- Deep Bay supports 1% or more of the flyway population of:

Lesser Sandplover	*Charadrius mongolus*
Greater Sandplover	*Charadrius leschenaultii*
Grey Plover	*Pluvialis squatarola*
Curlew Sandpiper	*Calidris ferruginea*
Broad-billed Sandpiper	*Limicola falcinellus*
Black-tailed Godwit	*Limosa limosa*
Greenshank	*Tringa nebularia*

(East Asia/Australasia flyway population estimates after Watkins 1993).

Deep Bay also supports the largest number of Cormorants *Phalacrocorax carbo* recorded wintering in China.
Criterion 2(d): *'it is of special value for one or more endemic plant or animal species or communities'.*

Deep Bay is the 'type locality' for at least 19 species of invertebrate new to science (Lee 1993).

The Ramsar Convention also establishes principles for inter-government co-operation on the conservation of wetlands. These principles include:

Article 3 : 'The Contracting Parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory'.

Article 4: Each Contracting Party shall promote the conservation of wetlands and waterfowl by establishing nature reserves on wetlands, whether they are included in the List or not, and provide adequately for their wardening.

Article 5: The Contracting Parties shall consult with each other about implementing obligations arising from the Convention especially in the case of a wetland extending over the Territories of more than one Contracting Party or where a waterway is shared by Contracting Parties. They shall at the same time endeavour to coordinate and support present and future policies and regulations concerning the conservation of wetlands and their flora and fauna.

At the Fifth Meeting of the Parties to the Ramsar Convention, Kushiro, 1993, a resolution was passed calling on 'the contracting Parties to implement in a more systematic and effective manner, and at international, national and local levels, the guidelines on wise use adopted by the Fourth Conference of the Contracting Parties'. An Appendix to the resolution gives 'additional guidance for the implementation of the wise use concept'. Inter alia, this notes that 'the cumulative effects of separate projects should also be taken into consideration' [when conducting an EIA]. The potential loss of wetlands resulting from the Shenzhen River Regulation Project thus cannot be viewed in isolation, and wetland loss must be considered in the context of overall wetland loss around Deep Bay.

The provisions and requirements of the Ramsar Convention have played a significant role in determining the requirements for the present EIA study. The requirements of the Convention provide an important context for assessment of the acceptability of the project, or stages of the Project, on ecological grounds. In practice, tree felling permit and with conditions is given through the Lands Authority as a consolidated approval.

2 THE BONN CONVENTION

The purpose of the Bonn Convention is to protect migratory species. This is achieved through two objectives:
The first is to provide strict protection for species listed in Appendix I of the Convention. This consists of migratory species in danger of extinction throughout all or a significant portion of their range. The Bonn Convention imposes strict conservation obligations on Parties that are "Range States".

The second is to encourage "Range States" to conclude agreements for the conservation and management of Appendix II species. Migratory species are eligible for Appendix II if they have an unfavourable conservation status and require international agreements for their conservation, or they have a conservation status which would significantly benefit from international cooperation. At the present time there are no such agreements which are relevant to Hong Kong or the PRC.

Five species which occur in the Deep Bay area are currently listed in Appendix I of the Bonn Convention. These are detailed below.

Dalmation Pelican	*Pelecanus crispus*	Chinese Egret	*Egretta eulophotes*
Oriental White Stork	*Ciconia boyciana*	Relict Gull	*Larus relictus*
Saunders' Gull	*Larus saundersi*		

Article II.4 of the Bonn Convention imposes the following obligations on Parties that are Range States of a migratory species listed in Appendix I:

1) to conserve and, where feasible and appropriate, restore those habitats of the species which are of importance in removing the species from danger of extinction;
2) to prevent, remove, compensate for or minimize, as appropriate, the adverse effects of activities or obstacles that seriously impede or prevent migration of the species;

In the case of those migratory waterfowl species which use the Deep Bay wetlands as a feeding area, a significant reduction in feeding opportunities could impede the ability of the birds to migrate, and thus be in contravention of the intent of Article II.4.b of the Bonn Convention.

In addition to species covered by the Ramsar and Bonn Conventions, the International Union for Nature and Natural Resources (IUCN) prepares lists of globally threatened species. 14 species which occur in Deep Bay are included in the latest (1994) IUCN list (Groombridge 1993) and are shown below.

Chinese White Dolphin	Sousa chinensis	Dalmatian Pelican	Pelecanus crispus
Chinese Egret	Egretta eulophotes	Oriental White Stork	Ciconia boyciana
Black-faced Spoonbill	Platalea minor	Mandarin Duck	Aix galericulata
Baikal Teal	Anas formosa	Baer's Pochard	Aythya baeri
Imperial Eagle	Aquila haliaca	Spoonbilled Sandpiper	Eurynorhynchus pygmaeus
Asian Dowitcher	Limnodromus semipalmatus	Spotted Greenshank	Tringa guttifer
Relict Gull	Larus relictus	Saunders Gull	Larus saundersi

APPENDIX 9.2 HONG KONG STATUTES AND GUIDELINES RELEVANT TO ECOLOGICAL RESOURCE PROTECTION

1 THE FORESTS AND COUNTRYSIDE ORDINANCE, Cap. 96

This Ordinance provides for the protection of forests (any area of Crown land covered with selfgrown trees) and plantations (any area of Crown land which has been planted with trees or shrubs or sown with the seeds of trees or shrubs). It thus covers all mangroves within the Hong Kong part of the project area, as well as the vegetation on parts of the hills at Seung Ma Lei Yue.

The Ordinance contains provisions to prevent damage or destruction of forest or plantation through fire, removal, or collection of seeds and fruit. Relevant details of the Ordinance are shown below.

Section 21 states: 'Any person who, without lawful authority or excuse, in any forest or plantation

1) cuts grass, removes turf or earth, rakes pine needles;
2) plucks or damages any bud, blossom or leaf of any tree, shrub or plant;
3) [not relevant]
4) fells, cuts, burns or otherwise destroys any trees or growing plants; shall be guilty of an offense'.

All engineering works within the Hong Kong part of the Project Area which involve the removal of mangroves or other vegetation in 'forests' and 'plantations', within the meaning of this Ordinance, must be conducted in accordance with a special permit issued in writing by the Director of Agriculture and Fisheries under Section 23 of the Ordinance.

Regulation 2 of the Forestry Regulations provide for the protection of certain local wild plant species. All orchids are listed under the Regulations and one orchid species (*Zeuxine strateumatica*) has been recorded at Mai Po.

2 THE TOWN PLANNING ORDINANCE, Cap. 131

The Town Planning Ordinance was amended in 1991 to include the majority of the Territory of Hong Kong. The Ordinance does not have specific conservation requirements but Plans prepared under Section 3(1)(b) may include areas designated as Sites of Special Scientific Interest (SSSI).
The amended Ordinance provides for SSSI as a statutory landuse, with activities within such sites being restricted to those listed in the 'notes' attached to the Plan. However, at present not all SSSIs which received administrative designation have been incorporated into Development Permission Area Plans or Outline Zoning Plans. The status of SSSI's within the Deep Bay area is indicated in Table A9-1.1.

Table A9-1.1 SSSIs within the Inner Deep Bay Area

Location	Date of Designation	DPA
Mai Po Marshes/Lut Chau	15 Sept 1976	DPA/YL-MP/1
Tsim Bei Tsui	10 Jan 1985	DPA/YL-LFS/1
Tsim Bei Tsui Egretry	5 Jan 1989	DPA/YL-LFS/1
Mai Po Village Egretry	16 Feb 1979	DPA/YL-MP/1
Inner Deep Bay	18 March 1986	DPA/YL-LFS/1
Lok Ma Chau Egretry	Proposed	

3 THE WILD ANIMALS PROTECTION ORDINANCE, Cap. 170

This Ordinance provides for the protection of species listed in the Second Schedule. Species recorded in the Deep Bay area which are fully protected in Hong Kong are listed in Table A9-1.2.

Section 5 of the Ordinance protects the nests and eggs of protected species (all birds and selected reptiles). Any civil engineering works which will 'remove, injure, destroy or wilfully disturb' any nest or egg of a protected wild animal can only be undertaken in accordance with a written permit issued under Section 15 by the Director of Agriculture and

Fisheries. The Stage 1 works will fall into this category.

Table A9-1.2 Protected Species Recorded in Deep Bay

Bats	*Chiroptera spp.*
Chinese Pangolin	*Manis pentadactyla*
Chinese White Dolphin	*Sousa chinensis*
Crab-eating Mongoose	*Herpestes urva*
Javan Mongoose	*Herpestes javanicus*
Small Indian Civet	*Viverricula indica*
Otter	*Lutra lutra*
Leopard Cat	*Felis bengalensis*
all birds	*Aves*
terrapins	*Testudines*
Burmese Python	*Python molurus*

Section 13 of the Ordinance provides for the control of access to areas specified in the Sixth Schedule. The Mai Po Marshes are currently listed and access is restricted.

4 FISHERIES PROTECTION ORDINANCE, Cap.171

This Ordinance is intended to promote the conservation of fish and other forms of aquatic life within the waters of Hong Kong and to regulate fishing practices and to prevent activities detrimental to the fishing industry.

The Ordinance provides for Regulations to prohibit the use of explosives and fish poisons, such substances being listed in the Schedule. The Fisheries Protection Regulations enable enforcement of these prohibitions.

Provision may also be made for other conservation activities, such as the control mesh size, the protection of spawning areas and the conservation of oysters and oyster beds, however no such regulations exist at present. The current legislation provides no controlling mechanism for such activities and cannot be applied to the Project.

5 HONG KONG PLANNING AND ENVIRONMENTAL GUIDELINES

The Environmental Guidelines for Planning in Hong Kong

These, provide guidance for including environmental considerations in the planning of both public and private developments. They apply to the planning of both permanent or temporary uses which will have potential to cause significant changes to the biophysical environment or which are sensitive to environmental impacts'.

Section 5.3.14 is relevant to the Project. It states: 'Nature Reserves and Sites of Special Scientific Interest (SSSI). These areas should be adequately protected from the effects of pollution and from the diversion of natural flows'.

The Deep Bay Guidelines for dredging, reclamation and drainage works

These guidelines were developed as part of the Deep Bay Environmental Management Review conducted by the Hong Kong Government in 1991. The guidelines have no statutory authority but are applied as guidelines to address various issues affecting Deep Bay including:

- site selection
- appropriate methods of working
- environmental site investigation needs
- environmental constraints, criteria and monitoring requirements
- design procedures, including assessment of impacts and selection of mitigation measures
- specific conditions of contract and performance specifications to be applied to Deep Bay projects

Some of the Deep Bay Guidelines have been superseded, in particular those relating to 'contaminated sediments' and standards for water quality (Mott MacDonald 1992). Those sections of the guidelines which are of particular relevance to the Project with respect to flora and fauna include:

Special Measures Zone (SMZ): The guidelines recommend that 'Normally, no works will be permitted within the SMZ. In those cases where works are unavoidable the works should be designed to minimise land-take and be programmed so as not to occur during the migratory-bird over-wintering period (November to March). In addition, works should preferably not take place outside normal working hours (0700 hours to 1900 hours on the same day).' The wording for the Special Conditions of Contract are given in Section 5.2.1. of the Guidelines.

Dumping in Deep Bay: The guidelines recommend that 'All Works should be designed on the general assumption that no surplus material (i.e. surplus to the requirements of the permanent works) from dredging can be dumped in Deep Bay'.

Special Conditions of Contract and Particular Specifications: A number of special Conditions of Contract have been developed for previous projects which are directly relevant to the Project. These include the following:

'The Contractor shall expect as provided in the contract to cause the least possible interference with existing environment and amenities, whether natural or man-made. The employer is committed to protecting the environment in Deep Bay. The areas of particular environment sensitivity are shown on the Drawings and include:

- Mai Po Marshes SSSI and Nature Reserve;
- Inner Deep Bay SSSI, the Buffer Zone and Special Measures Zone
- Futian Nature Reserve

The Contractor shall endeavour to carry out the Works in such a manner as to minimise adverse impacts on the environment in these areas whether they be inside or outside the Site.'

'Where instructed by the Engineer, temporary protection as shown on the drawings shall be installed around trees (including mangroves) to be preserved prior to the commencement of other work in the vicinity. The temporary protection shall be removed when instructed by the Engineer.'

Other recommended contract conditions and specifications relating to dredging methods, measures to reduce pollution etc. are discussed under the relevant sections elsewhere in this Report. These conditions may be appropriate for inclusion in the contract for the Project.

APPENDIX 9.3 RELEVANT STATUTES IN THE PRC

1 WILDLIFE PROTECTION LAWS IN THE PRC

According to Chapter 2 Provision 12 an environmental impact assessment should be submitted by the developer for construction projects which potentially result in adverse impacts on wildlife habitat protected by national or local regulations. In the approval process the Environmental Protection Department should consult the wildlife protection agencies at the same administrative level.

2 PRC WILDLIFE PROTECTION IMPLEMENTATION REGULATION

According to Chapter 2 Provision 10 preventive measures should be taken by relevant institutions and individuals to preclude potential risk of adverse impacts on wildlife protected by national or local regulations.

3 PRC GUIDELINE FOR NATURE RESERVES FOR FORESTS AND WILDLIFE SPECIES

According to Provision 11 the natural environment and natural resources in nature reserves should be managed solely by the administrative organization of nature reserves. Without permission of the Ministry of Forestry or the provincial, autonomous regional, or municipality administrative department of forests no institution or individual is allowed to enter the nature conservation area to establish institutions or construct facilities.

4 THE NATIONAL PROTECTION LIST OF IMPORTANT WILD ANIMALS

The following birds which often appear in Shenzhen River catchment and Deep Bay are listed among species protected in PRC. There are 2 classes of protection status, First Class and Second Class. Five bird species observed in the Deep Bay area are classified as First Class protection species. Eight species of birds are listed as Second Class species.

First Class Protected Species
Chinese merganser *Mergus squamatus*
Golden Eagle *Aquila chrysaetos*
Imperial Eagle *Aquila heliaca*
White-tailed sea eagle *Haliaeetus albicilla*
Relict gull *Larus relictus*

Second Class Protected Species
Slavonian Grebe *Podiceps auratus*
Black-necked grebe *Podiceps grisegena*
Swinhoe's Egret *Egretta eulophotes*
Reef egret *Egretta sacra*
Painted stork *Ibis leucocephalus*
Black-faced spoonbill *Platalea minor*
White-fronted goose *Anser albifrons*
Nordmann's greenshank *Tringa guttifer*

APPENDIX 9.4 FISH POND AROUND DEEP BAY - THEIR IMPORTANCE TO WILDLIFE, ESPECIALLY WATERBIRDS

1 INTRODUCTION

Deep Bay, with its intertidal flats, Mangroves, gei wais and fish ponds is a wetland of international importance for biodiversity conservation. This has been recognised by both the Chinese Government, which has established the Fu Tian National Nature Reserve in Shenzhen, and the Hong Kong Government, which has protected the Mai Po Marshes Nature Reserve, as well as designating two Deep Bay Buffer Zones to control land use and development in the surrounding area. The Chinese Government is considering the designation of the Fu Tian Nature Reserve as a 'wetland of international importance' under the Ramsar Convention, and the Hong Kong, Government is similarly considering the listing of Mai po and adjacent wetlands.

The Deep Bay area has come under increasing pressure from development in the past 20 years,with the establishment of the Shenzhen Special Economic Zone on the Chinese side of the Bay , and the increasing urbanization and development of light industry and open storage on the Hong kong side. The development on both sides of the Shenzhen River has been at the expenses of wetlands,notably fish ponds,which have been filled to provide new land'.

The is a common belief that fish ponds are not of value to wildlife.This belief is false,and is based largely on a lack of knowledge of wildlife utilization of this habitat.Our knowledge is still scanty but increasing study in recent years has highlighted the importance of fish ponds,especially for certain species of wildlife. Today, there are an increasing number of projects being proposed which will result in the destruction of fish pond habitat for residential/industrial/recreational development. Recently, drainage/flood control schemes have been proposed which also will result in fish pond loss.

Both the Shenzhen and Hong Kong Governments have requested an assessment of the value of fish ponds for wildlife so that potential development impacts may be determined,particularly with a view to establishing whether it is appropriate to undertake mitigation works to compensate for loss of fish pond wetlands. The present paper summarises our current knowledge of fish pond faunas,and attempts to answer certain questions regarding potential habitat loss,especially with respect to the Shenzhen River Regulation Project. Among the questions asked are:

1) Will a reduction on habitat result in loss of wildlife?
2) Can mitigation measures reduce loss of wildlife?

Further questions which have been asked relate specifically to the questions of impacts of fish pond loss on wildlife,and the value of mitigation measures. The current state of knowledge does not permit detailed quantitative assessments at this time,and recommendations are made for further studies to promote a more quantitative assessment of the impacts of wetland loss(in particular fish ponds) in future.

2 RAMSAR CONVENTION

Both Hong Kong,through the United Kingdom,and the People's Republic of China are Parties to the Convention on Wetlands of International. Importance Especially as Waterfowl Habitat (the Ramsar Convention).

Article 3.1 of the Convention stipulates that 'the Contracting Parties shall formulate and implement their planning so as to promote...as far as possible the wise use of wetlands in their territories'. At the Fifth Meeting of the Conference of the Parties, Kushiro, 1993, a resolution was passed calling on 'the Contracting Parties to implement in a more systematic and effective manner,and at international,national and local levels,the guidelines on wise use adopted by the Fourth Conference of the Contracting Parties'.

An Appendix to the Resolution gives 'additional guidance for the implementation of the wise use concept'.Inter alia,this notes that 'The cumulative effects of separate projects should also be taken into consideration' [when conducting an EIA]. The meed for cumulative impact assessments in the Deep Bay area has been recognized for a number of years,and was addressed in the .Deep Bay Integrated Environmental Management Study. (ERL(Asia)Ltd. 1988). Anon.(1993a)also notes that 'a particular concern in the Mai Po area is the cumulative effect of development'.

It is thus clear that the loss of wetlands resulting from the Shenzhen River Regulation Project (or any other project)cannot be viewed in isolation.Wetland loss must be considered in the context of current,and planned,overall wetland loss around Deep Bay.

3 FISH PONDS

Fish ponds in the Deep Bay area currently comprise some 1000ha of wetlands on the Hong Kong side of the Bay.Agriculture and Fisheries Department(undated)statistics which show an area of 1330 ha of Grade 'A' fish ponds around Deep Bay do not take into account recent,and on-going,losses resulting from works associated with the Yuen Long/Kam Tin main drainage project,as well as some loss due to illegal in filling.20-30 Years ago most of these ponds were paddi fields.Both paddi fields and fish ponds are recognized as 'wetlands' under the definition in the Ramsar Convention.Although usually referred to as 'freshwater' fish ponds,many are slightly brackish(2-10 p.p.t).

Fish ponds are usually managed for a variety of fish species,such as carps(Cyprinide)and mullets (*Mugil* spp.).A number of other fish may also be present in the ponds ,notably *Oreochromis mozambicus*, which has virtually no economic value and is generally regarded as a pest,and the small *Gambusia affinis* .The ponds also support high populations of chironomid midges,especially shortly after flooding in spring,and populations of the freshwater shrimp *Macrobrachium nipponense*.Other freshwater fauna are generally scarce in ponds under active management for fish production,this probably being due largely to high fish populations and high nutrient input.

There is little emergent vegetation in actively managed fish ponds ,but the bands may be well vegetated with a limited number of species of grasses and herbs.These provide habitat for a variety of wildlife(Chu 1993). Ponds are usually drained down once each winter to facilitate harvesting of fish. The ponds remain drained down for several weeks/months during which time maintenance works may be conducted, e.g. excavation of channels, bulldozing of bottom sediments, although this usually only occurs once in every 2-3 years.Drying out of surface muds is thought to 'cleanse' the pond,and the disturbance of bottom sediments promotes the release of nutrients on reflooding.

Due to the acid sulphate soil conditions of the Deep Bay area lime is usually applied to the ponds at the time of flooding in the spring. The autumn drawdown of ponds usually starts in October,and reflooding usually is completed in April/May .Thus drained down ponds can usually be found for a period of some 7 months,although individual ponds are not usually left dry for so long.

Fish ponds provide habitat for a variety of wildlife,as summarized by Chu(1993).As far as current knowledge allows us to determine,the greatest importance of these ponds is as feeding grounds for a variety of waterfowl,notably egrets,herons and spoonbills.This is not to say ,however,that they are unimportant for other species(see below). Waterfowl species of principal concern with respect to fish ponds are :

Night Heron	*Nycticorax nycticorax*	R/M*	Chinese Pond Heron	*Ardeola bacchus*	R/M
Cattle Egret	*Bubulcus ibis*	R/M	Little Egret	*Egretta garzitta*	R/M
Great Egret	*Egretta alba*	R/M	Grey Heron	*Ardea cinerea*	R/M
Oriental White Stork	*Ciconia boyciana*	W	Black-faced Spoonbill	*Platalea minor*	W

* R=resident M=migrant W=winter visitor

Deep Bay supports some 24% of the WORLD population of Black-faced Spoonbill,which is recognized as an internationally endangered species (estimated world population c.350-Kennerley 1990,Rose and Scott 1994).Preliminary observations (P.J.Leader unpublished) indicate that this species feeds intensively in fish ponds around Deep Bay in winter, however detailed studies have yet to be made.

Numbers of Oriental white stork,which peaked at c.120 in 1990/91,dropped to 4 in 1993/94.The reason(s) for this are unknown.This is a globally endangered species(estimated world population 2,5000-Rose and Scott 1994). Preliminary studies indicate that this species feeds extensively in fish ponds around Deep Bay in winter (S.Chan unpublished).

4 EGRETS AND HERONS (ARDEIDS)

Egrets and herons are present in Hong Kong throughout the year,but there is some movent of birds through the Territory (e.g Chalmers 1986,Melville 1980).It is thought likely that the majority of the Hong kong birds are resident (with the possible exception of the Cattle Egret where winter numbers are usually lower than those in summer),but no marking studies have been conducted to confirm this. Ardeids breeding in northern China,Japan etc.are likely to pass through the Deep Bay area on passage,and /or winter in the area , as there is a regular winter exodus from northern areas (e.g. McClure 1974).

Hong Kong's breeding populations of egrets are considered to be of regional importance as there are few known breeding colonies in Guang dong (GAO Yu Ren in litt.to L.Young).Wintering numbers also are significant.

4.1 Wintering Ardeids

Data for numbers of wintering Ardeids is taken from the results of mid-January waterfowl counts conducted by the Hong Kong Bird Watching Society (HKBWS) - these data may not be further reproduced without permission from the HKBWS.These counts are part of a programme to assess mid-winter waterfowl populations,coordinated by the International Waterfowl and Wetlands Research Bureau (IWRB) and the Asian Wetland Bureau (AWB).

The numbers of Ardeids recorded from the Deep Bay area (excluding Fu Tian)in the mid-January waterfowl counts between 1981 and 1994 is shown in Figure 1. There is an indication of a peak in numbers around 1988-1993,with a reduction in 1994,however,there is a considerable degree of 'noise' in the data and it is too early to say whether the wintering numbers are really falling .It should be noted that the 1993/94 winter was unusually mild and this may have affected the number of birds present in Deep Bay. The fact that wintering populations of Ardeids in Deep Bay are of regional significance is indicated in Table 1.

TABLE 1 Numbers of Ardeids counted in Hong Kong and China* during mid-January 1993**

Species	Hong kong	China	Hong Kong % Total
Grey Heron	1155	2133	35.1
Great Egret	446	562	44.2
Little Egret	1837	1661	52.5
Cattle Egret	113	0	100
Chinese Pond Heron	332	425	43.8
Night Heron	204	1632	11.1

* China count data include records from Fu Tian National Nature Reserve, Shenzhen.The Hong Kong count is for Deep Bay, excluding Futian.
** after Mundkur and Taylor (1993).

The count data from China are clearly incomplete but ,bearing in mind that data come from many of the major wetlands throughout the country,the importance of Deep Bay as a wintering area is self-evident. It should also be borne in mind that in winter egrets and herons are absent from the northern and western areas of China in winter,being largely restricted to the far south of the country (Chang 1987).

From Figure 2 it can be seen that the proportion of all Ardeids recorded during mid-January counts observed in fish pond areas varies considerably from year to year,but averages about 10%. When the distribution of different species recorded during mid-January counts is reviewed (Figure 3),it appears that some species (Cattle Egret,Chinese Pond Heron,Little Egret)favour fish ponds more than other species (Great Egret,Grey Heron,Night Heron). It should be noted that not all fish ponds in the Deep Bay area are covered by observers during the mid-January counts.The counts currently cover an estimated 25% of the total area of fish ponds on the Hong Kong side of Deep Bay.As a result the figures UNDERESTIMATE the numbers of birds at fish ponds.It should be further noted that since both Grey Herons and Night Herons feed largely at night, those birds recorded during the counts are roosting, and their distributions may not reflect their feeding distributions since they are known to feed in fish ponds.

A detailed study by Young (1994)included an assessment of seasonal use of different feeding habitats around Deep Bay by Chinese Pond Herons,Little Egrets and Great Egrets.The results(Figure 4),are in general agreement with the mid-January count data,but there is a suggestion that the importance of fish ponds to species such as Chinese Pond Heron and Little Egret may be underestimated in the HKBWS data.

4.2 Breeding Ardeids

Two main factors are of crucial importance for the maintenance of breeding populations of colonially breeding Ardeids: i). protected nest sites, and ii). adequate feeding areas (Hafner et al. 1987). In Hong Kong Ardeids traditionally breed in close association with man, in fung shui woods and village bamboo groves, as well as in hillside woodlands. Egrets are regarded as 'lucky' and thus, traditionally, are not disturbed whilst nesting. In recent years, however, there have been problems at some sites due to the illegal taking of young, and disturbance resulting from construction works. Some egret sites have been used for a long time, whereas others are of more recent origin. The reason(s) for abandonment of sites and the establishment of new colonies are currently unknown, but may relate to direct human disturbance and habitat loss nearby (see below).

The distribution of egretries on the Hong Kong side of Deep Bay shows a remarkably even spacing. This is consistent with studies elsewhere, in which it has been found that in areas of suitable feeding habitat colonies usually are regularly distributed (e.g.Fasola and Barbieri 1978, Gibbs *et al.* 1987, Gibbs 1991).

Wong (1991) and Young (1994 and unpublished) have found that most breeding Ardeids in Hong Kong feed within 3km of the breeding colony. When potential feeding ranges of 3km are considered for the 7 Deep Bay breeding colonies it is found that effectively ALL fish pond habitat on the Hong Kong side of the Bay is included (Figure 5). Hafner *et al.* (1987) found that the area of favoured feeding habitat within foraging distance form the breeding side had a positive effect upon the size of heron colonies, and that the diversity of feeding habitats affected species composition.

Figure 6 'indicates that [in the Camargue] there is a threshold area for freshwater feeding habitat below which no heron colonies exist. This is a consequence of the colonial breeding habit of the species concerned. The minimum area observed was 420ha; but this amount supported only exceptionally small breeding populations, e.g. one of 27 Little Egret nests and one of 6 Night Heron nests (Hafner *et al.* 1987). Comparative data are currently unavailable for Hong Kong, but there is no reason to suppose that the same general principles which relate available feeding area and colony size, will be different, especially for the two species in common at the two sites (Little Egret and Night Heron).

Feeding behaviour of the Chinese Pond Heron has been studied in detail by Young (1994), who recorded clear seasonal patterns in the use of fish ponds and tidal mud flats by Chinese Pond Herons at Mai Po, with periods of increased use coincident with greater prey availability. Thus, numbers of Chinese Pond Herons feeding on the mud flats in April, Coincident with high mud skipper densities, large body size and high calorific value. April also is the start of the mudskipper breeding season (Chan 1989) and males may be easier to catch during territorial defense and display activities. From June to January the profitability of the mud flat as a feeding habitat decreased. The number of Chinese Pond Herons feeding around fish ponds increased from March to August when their main prey items were *Macrobrachium nipponense* and *Gambusia affinis*. In winter the adult and larval stages of necrophagous flies (Calliphoridae) are an important component of the diet around fish ponds (Young 1994, Melville 1987).

Young (1994) notes that Fish ponds are a predictable summer feeding habitat from which breeding Chinese Pond Herons can more easily collect food for nestlings. With large areas of fish ponds close to the breeding colony at Mai Po,breeding Chinese Pond Herons there will be expected to have a higher reproductive output than those at sites without ponds (Hafner et al.1987)'. Young (1994)found that in summer,once young Chinese Pond Herons are able feed independently ,they do so more frequently around fish ponds than in other habitats.This is considered to relate to food availability for these relatively inexperienced birds.Loss of fish ponds would be expected to lead to increased juvenile mortality.

There is only very limited information on the feeding behavior of other Ardeids in Hong Kong (Young unpublished,Britton 1993,Melville 1987,1990). The breeding biology of the Chinese Pond Heron has been studied by Young (1994), who found some evidence that colony placement affected breeding success,although various factors confounded interpretation of the data.Similar relationships, however,have been found elsewhere.

Hafner et al.(1987)noted that the marked variation in breeding success between Little Egret colonies in the Camargue,was attributable to differences in the availability of different types of wetland habitat within foraging range of the nest sites... Thus, while the analyses reported [previously]indicate the particular importance of a limited number of habitats,the data presented here show that other habitats can provide conditions which allow the birds to achieve high breeding success in some years. This conclusion underlines the importance of a range of wetland types in the conservation of these birds'.

TABLE 2. Estimated number of nests in egretries on the Hong Long side of Deep Bay-1994

Species	1	2	3	4	5	6
Great Egret			8	13		
Little Egret	14		110	171		3
Cattle Egret	4		13	+	6	
Chinese Pond Heron	71	3	+			62
Night Heron	2		+	253		

+ =present but no nest seen
1=Mai Po Village 2=Lok Ma Chau 3=Mong Tseng 4=Mai Po gei wai #21 5=Ka Po Tsuen 6=Ho Sheung Heung

5 Other Birds

Fish ponds are also used by a variety of other waterfowl,as noted by Chu (1993). These include shorebirds,which principally use drained ponds as high tide roosting sites although a few species are attracted to feed at such ponds , notably Green Sand-piper *Tringa ochrous*, Little Ringed plover *Charadrius dubius* and stints *Calidris* spp. Ponds with emergent vegetation may attract Little Grebes *Tachybaptus ruficollis* to breed.In winter the Deep Bay area supports the largest known population of Cormorants *Phalacrocorax carbo* in China (Mundkur and Taylor 1993),but most feeding is done in Deep Bay, rather than fish ponds. Swarms of adult Chironomid midges over fish ponds may attract large numbers of birds to feed,in particular Barn Swallow *Hirundo rustica*, swifts *Apus* and *Hirunadpus*, martins *Delichon* and *Riparia*, and Oriental Pratincoles *Pratincola maldivaru*. Chironomids also appear to provide an important food source in spring for Great Reed Warblers migrating through Hong Kong to Japan (G. Reels unpublished, D.S. Melville unpublished). There is no information available to permit any assessment of the likely impacts of pond loss on these birds.

6 Other Fish Pond Fauna

Chu (1993) has summarized the available information on the fauna recorded in and around fish ponds in Hong Kong. Among the mammals recorded, at least two are of local conservation importance: Other *Lutra lutra* (WWF unpublished) and Javan Mongoose *Herpextes javanicus* (Chan *et al.* 1992) . Both are locally rare, the other having recently returned to Hong Kong after having become locally extinct, the mongoose having first been recorded in 1990. Very little work has been conducted on the invertebrates found in fish ponds, although a study is currently being conducted (G. Walthew, pers. comm.). Young (1994 and unpublished) has conducted some work on *Macrobrachium nipponense*, and Anon. (1993b) surveyed free-swimming invertebrates in fish ponds at Pak Hok Chau (Table 3).

TABLE 3.List of aquatic (free-swimming) taxa caught in ponds and channels at Pak Hok Chau*

Taxon	1992/93				
	Jan.	Apr.	Jul.	Sep.	Nov.
ODONATA					
Coenagrionidae	x		x	x	
DIPTERA					
Psychodidae	x		x		
Chironomidae	x	x	x	x	x
Orthocladiinae			x	x	
Culicidae	x	x	x		
Notonectidae	x	x			
HEMIPTERA					
Blostomatidae unident				x	
Hemiptera sp.				x	
GASTROPODA					
Radix sp.	x		x	x	x
Pomacea canaliculata	x		x	x	x
Gyraulus sp.			x	x	
Melanoides tuberculata				x	x
ARACHNIDA					
Pirata sp.			x		
DECAPODA					
Macrobrachium sp.			x		x
Palaemon sp.			x	x	x
OLIGOCHAETA	x				

* after Anon. 1993b.

The results of core samples of benthic invertebrates taken from ponds at Pak Hok Chau are giver in Figure 7. Anon.

(1993b) noted that, although the fish ponds at Pak Hok Chau did not support a notably species-rich assemblage of free-swimming or benthic invertebrates, they did provide a ready source of food for birds throughout the year.

The insect fauna associated with fish ponds at Pak Hok Chau was also assessed by Anon (1993b). The results indicate a flush of flying insects in spring, with a smaller peak in autumn (Table 4a and 4b).

TABLE 4a.The number of individual insects caught in malaise traps at Pak Hok Chau*

Trap	Jan.	Apr.	Jul.	Sep.
1	-	566	241	308
2	27	2853	7	8
3	-	14425	-	166
4	-	939	-	108

TABLE 4b.The total number of morphospecies captured in malaise traps at Pak Hok Chau*

Trap	Jan.	Apr.	Jul.	Sep.
1	-	566	241	308
2	9	?	?	4
3	-	?	-	43
4	-	?	-	28

* after Anon. (1993b)

7 Possible Effects of Fish Pond Loss

If a habitat is destroyed then, inevitably, some individuals and/or populations will be destroyed at the same time. The severity of population loss will depend on factors such as the scale of destruction, and the degree of mobility exhibited by the organisms. Thus, local populations of aquatic macrophytes, diatoms and freshwater snails may suffer severely if a fish pond is destroyed, e.g. by infilling, but birds may suffer less as they can move from the site.

An ability to flee a site which is being destroyed should not, however, be taken as an indication that the individual will continue to flourish. If population densities in alternative areas are a already at 'carrying capacity' (*sensu* Goss-Custard 1985), then that individual will die, or,if it survives,it will be at the expense of another individual.

Most studies of the effects of wetland loss on waterfowl have concentrated on shorebirds (e.g. Sutherland and Goss-Custard 1991). Some studies have recorded substantial declines in certain species resulting from habitat loss. For example, Lambeck (1991) recorded a loss of half of the former population of Oystercatchers *Haematopus ostralegus* in the Dutch delta area following substantial habitat loss resulting from the construction of a tidal barrage.

Sutherland and Goss-Custard (1991) developed a framework for considering the effect of habitat loss on bird populations:

habitat change → increased local density → increased depletion of food → redistribution

loss of some individuals → feed back from density dependent birth rate

new equilibrium population size

As habitat is lost birds have to 'fit' into a smaller area, thus the density of a species in a given habitat will increase. An in crease in density is likely to result in an increased rate of depletion of food stocks. In the case of at least some waders interference in feeding behavior at high densities reduces food intake-information on interference effects for Ardeids in the Deep Bay area is generally lacking. When fish ponds are first drained down there are frequently high densities of birds present, but the super-abundance of food may compensate for any interference effects. If, however, birds are feeding in other situations interference may reduce food intake. Thus Young (unpublished) has recorded aggressive encounters between Chinese Pond Herons at feeding sites in both gei wais and filled fish ponds.

As the total number of birds increases, an increasing proportion can be expected to occur in the poorer quality sites because of either increased depletion of food stocks or interference. This redistribution of birds into poorer quality sites may take place within one estuary system, e.g. Deep Bay, or may occur on a larger scale with birds moving to another, but less favored/poorer site, e.g. elsewhere in southern China.

If food abundance/availability is viewed as a gradient, then birds which have a high competitive ability are expected to occur on the richest parts of the gradient (Sutherland and Parker 1985) (Figure 8). Studies indicate that, broadly speaking, this happens, at least in some shorebirds (Sutherland and Goss-Custard 1991).

The intake rates of the poorer competitors is likely to reduced in two ways by habitat loss. They will suffer from interference and a reduction in available food, and also by having to move into poorer quality habitats. Both of these processes may result in an increased risk of mortality, either directly through starvation, or indirectly if hungry birds are more at risk of being taken by predators-Ardeids have been recorded being preyed upon by a number of raptors at Mai Po, including Bonnelli's Eagle *Hieraeetus fasciatus* (WWF HK' unpublished).

Density-dependent factors,which may take effect either during the breeding season or the non-breeding season, will then feed-back to the population and the loss of poor competitors may result in a new, lower, equilibrium population size.

Evidently, if one is to develop any form of quantitative model to investigate potential population changes which may result from habitat loss a considerable degree of knowledge of the species is required. As noted above, such a detailed understanding of the biology of Deep Bay Ardeids is lacking at present.

It is clear, however, from the work of Hafner et al. (1987) that a 'threshold' can be expected, below which further loss of wetland feeding habitat will result in a precipitous decline in the breeding population. The relationship between habitat area and bird numbers is not a simple arithmetic one, where both parameters increase or decrease in a straight-line. The relationship is expected to be complex (Figure 9).

It is thus essential that the impacts of cumulative habitat loss are assessed. Any attempt to limit impact assessment to one area of fish ponds will be effectively meaningless.

To obtain the necessary information for a full understanding of the dynamics of Ardeid populations and their food resources in the Deep Bay area would take many years of full-time research which are beyond the scope of any current studies. As desirable as such studies are when considering the present large-scale loss of fish ponds on both sides of the Shenzhen River, it is unrealistic to expect that present development projects will wait pending the outcome of long term research.

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Fig. 1 Herons and Egrets in the Deep Bay Area 1981—1994

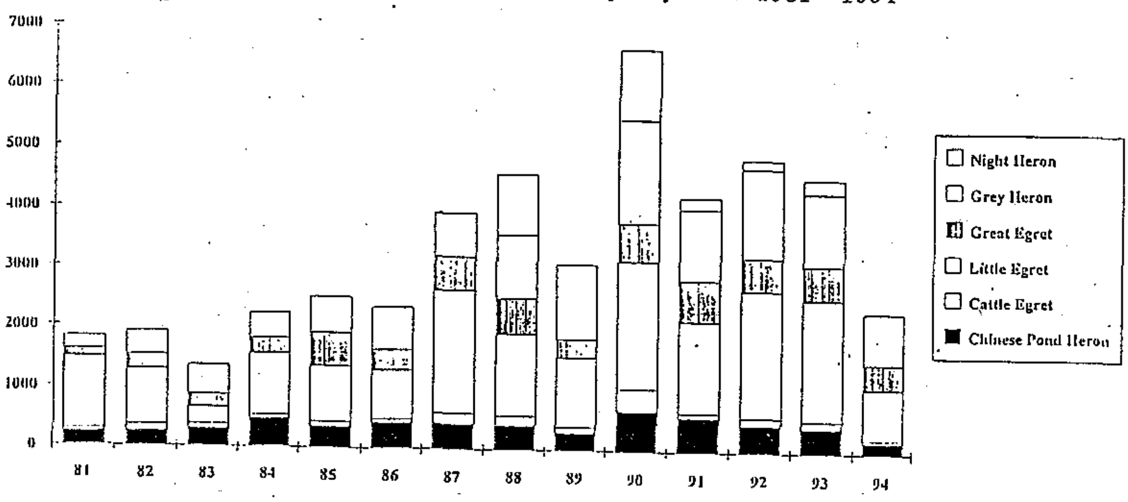
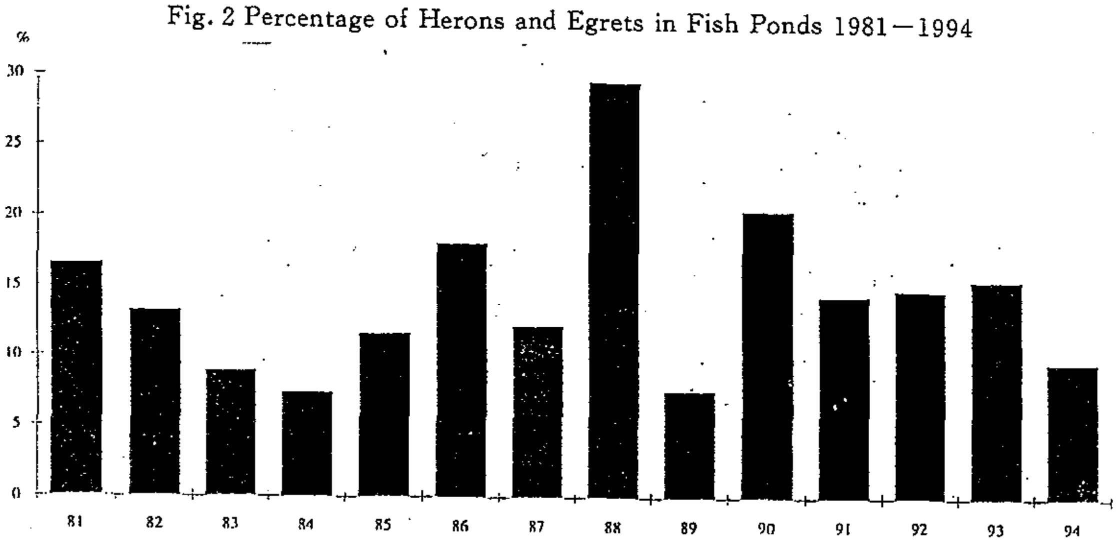


Fig. 2 Percentage of Herons and Egrets in Fish Ponds 1981—1994



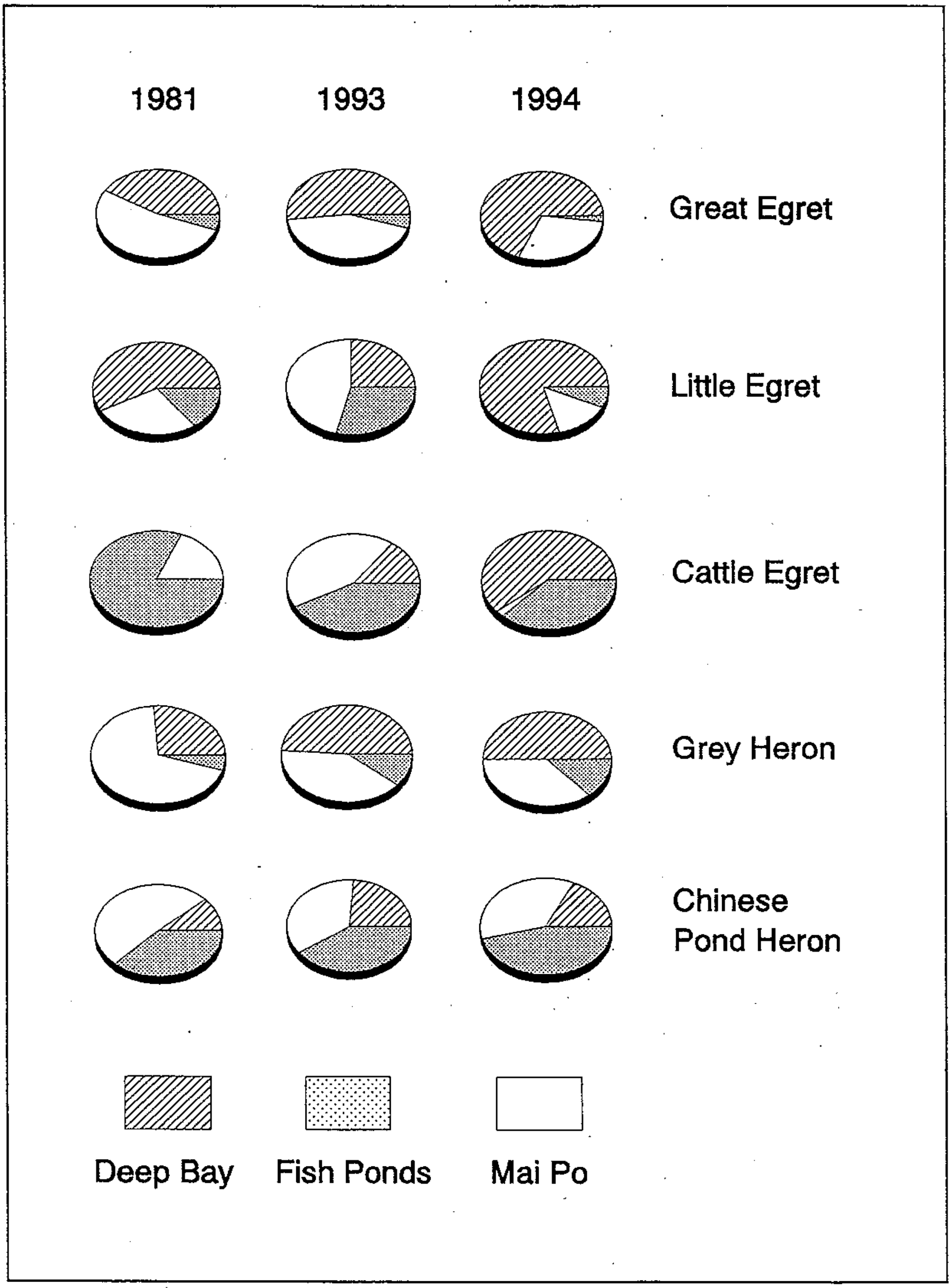


Fig. 3 Five Species of Egrets and Herons in Hong Kong in Jan.

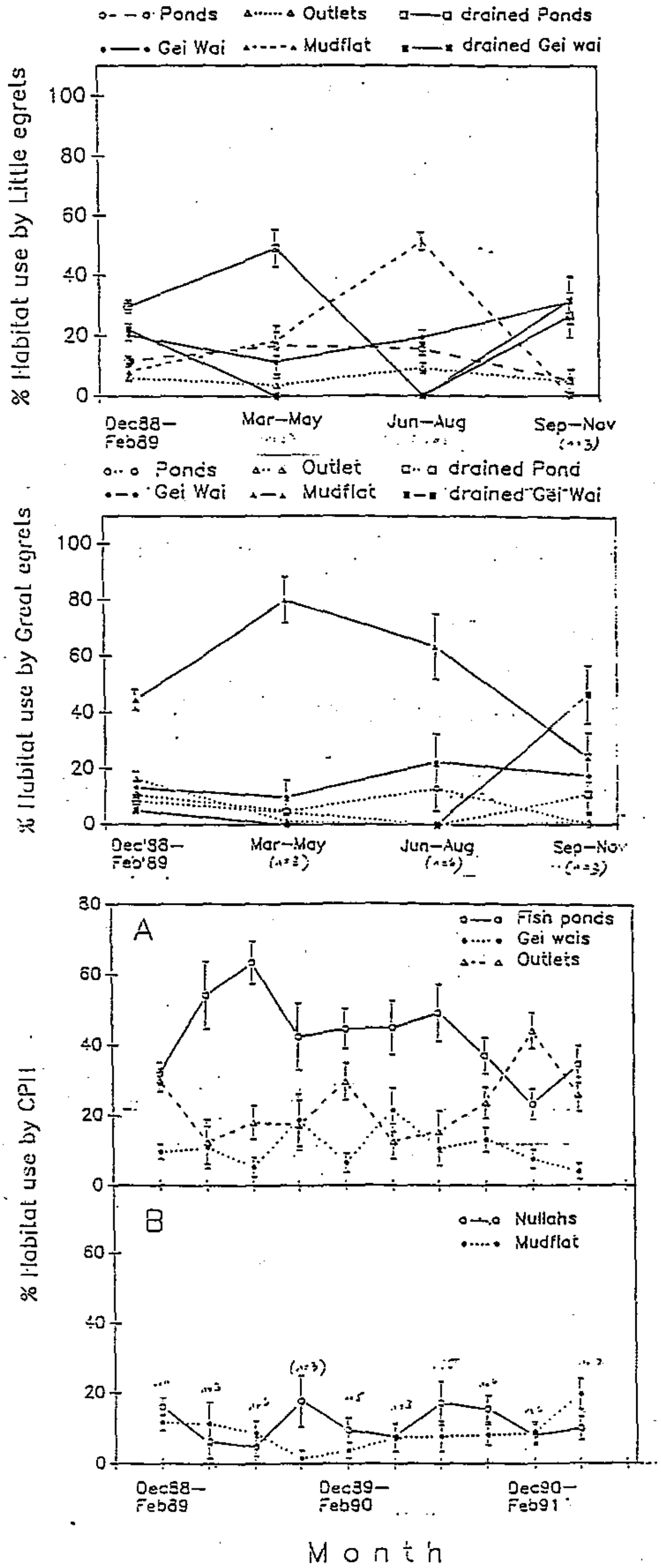


Fig. 4 Percentage Habitat Use by Some Egrets/Herons

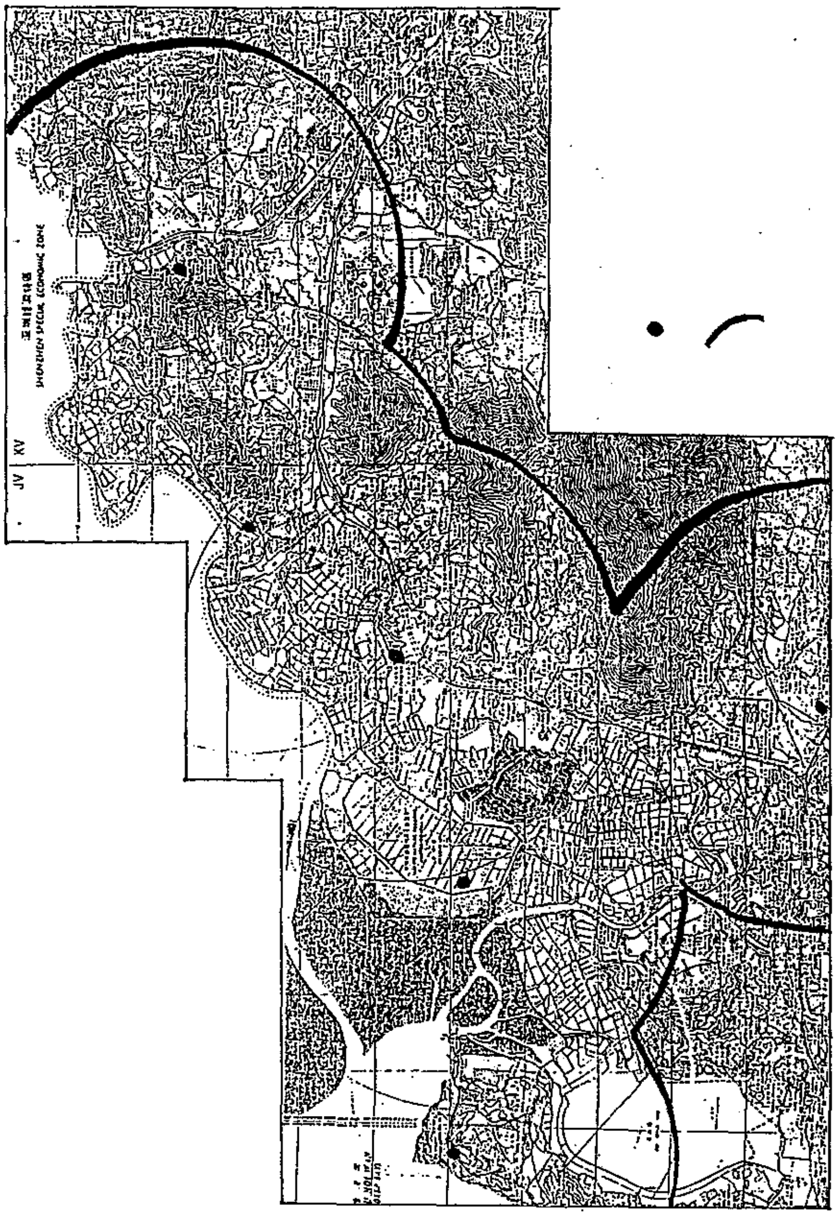
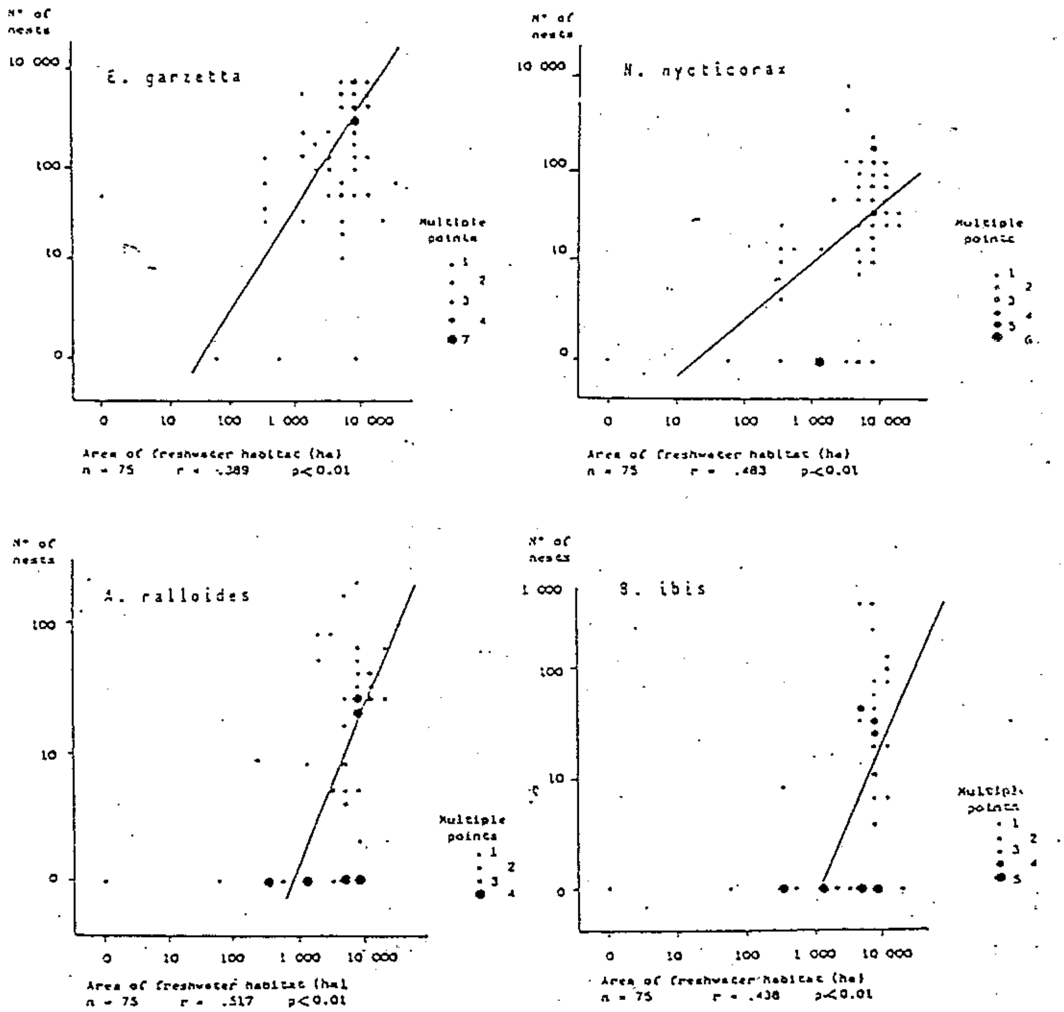


Fig. 5 Distribution of Egretries on Hong Kong Side of Deep Bay—1994



Colony size of four species of Ardeidae expressed as a function of the area of freshwater habitat within 10 km. For colonies observed over several years, each breeding season has been taken into account.

After Hafner et al. (1987)

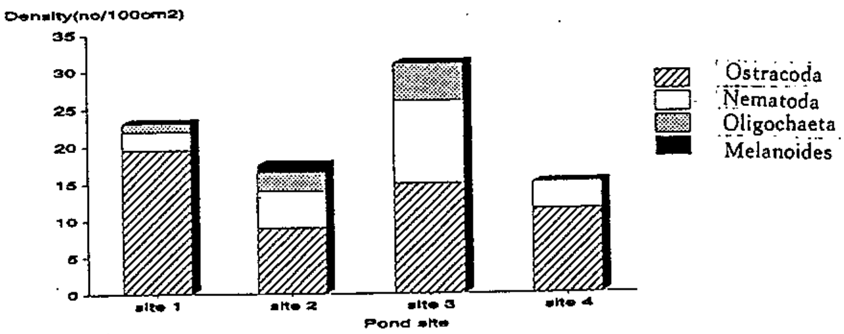


Fig7 Benthic Invertebrate Density From Pond Core Samples, Pak Hok Chau
; After Anon(1993b)

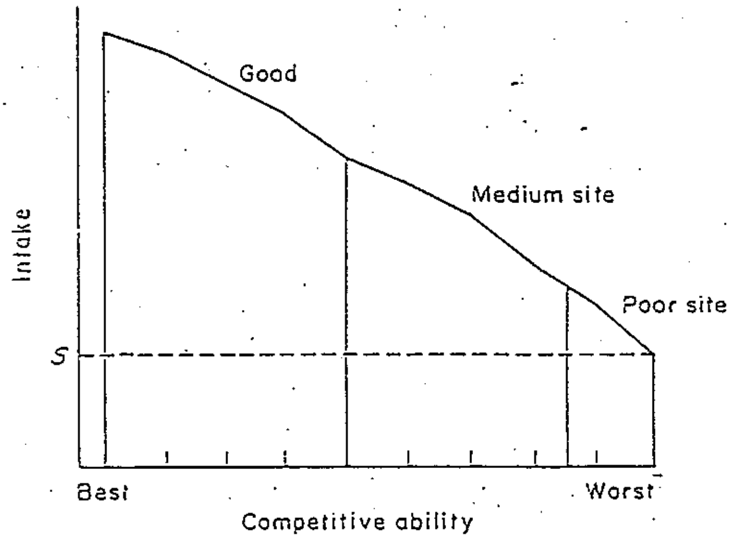


Fig. 8 Dispersion Expected for Individuals Experincing Interference

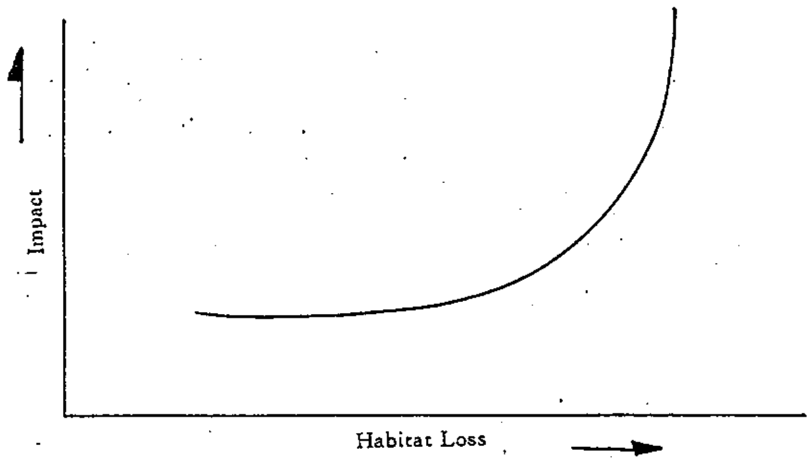


Fig. 9 The Impact of Habitat loss

APPENDIX 9.5 BASELINE SURVEY IN FUTIAN NATURE RESERVE

1 MANGROVE SURVEY

Preliminary analysis of mangroves in Futien Nature Reserve shows that the mangroves there can be divided into six community types:

1) *Kandelia candel*
2) *Avicennia marina*
3) *Aegicerus corniculatum*
4) *Bruguiera gymnorrhiza*
5) *Kandelia candel - Aegiceras corniculatum*
6) *Aegicerus corniculatum - Kandelia candel*

Sampling transects were established in each of the above six community types. The primary mangrove in the Futien area totalled 42.5 ha in area. In addition, gei wai bunds had a total of 18.5 ha of mangrove. Newly planted *Kandelia candel* areas totalled 5.4 ha. In total the mangrove coverage was 66.7 ha.

The dominant species of mangrove in Futien Nature Reserve were *K. candel*, *Bruguiera gymnorrhiza (L.) Savigny*, *Aegiceras corniculatum (L.) Blanco*, *Avicennia marina (Forsk.) Vierh.*, and *Acanthus ilicifolius Linn.*The secondary mangrove species were *Acrostichum aureum (Linn.)* and *Thespesia populnea (L.)*. The dominant creeper species was *Derris trifoliata*. Four transects were sited based on methods outlined in the Inception Report for this Project.

1.1 Transect 1

The width of the mangrove belt at the site of the first transect measured 120m. Table 1 shows results of sampling in six quadrats each measuring 5m by 5m along transect 1 at the bird watching station at Che Gong Miao, Futien Nature Reserve.

Table 1 shows that Transect 1 was dominated by *K. candel* and *A. marina*. The four landward quadrats were dominated by *K. candel*, and the 2 seaward quadrats by *A. marina* as shown in Figure 1. This transect demonstrated succession from seaward colonization by *A. marina* to landward dominance by *K. candel*. Table 1 also shows that seedlings were observed in the *K. candel* dominated areas but not in the *A. marina* sites. Because *K. candel* was producing seedlings (but *A. marina* was not), succession on Transect 1 may lead to increase in coverage of *K. candel* and decline in coverage of *A. marina*.

Table 1 Results of transect sampling in six quadrats measuring 5m by 5m along transect 1 at the bird watching station at Che Gong Miao, Futien Nature Reserve during Spring 1994.

Spp.	No.	Occ.	DBH	Rel.Ab.	Freq.	Dom.	Sign.	Rank
K.c.	114(27)	4(3)	23261	73.0	39.9	46.7	159.6	1
A.c.	9(0)	2(0)	1212	5.8	19.9	2.4	28.1	3
B.g.	9(5)	1(1)	495	5.8	10.2	1.0	16.0	4
A.m.	24(0)	3(0)	24847	15.4	30.0	49.9	94.3	2
D.t.	32	2						
A.i.	116	4						

( ) Brackets indicate seedling stem counts

1.2 Transect 2

Transect 2 was located in a mangrove belt of 100m width. Sampling was conducted in 5 quadrats of 5 x 5m dimension. Results of sampling are shown in Table 2. Transect 2 was located near the First Watch Tower.

Table 2. Results of transect sampling in five quadrats measuring 5m by 5m along Transect 2 near the First Watch Tower, Futien Nature Reserve during Spring 1994.

Spp.	No.	Occ.	DBH	Rel.Ab.	Freq.	Dom.	Sign.	Rank
K.c.	105(62)	5(5)	22507	49.1	31.3	52.2	132.6	1
A.c.	78(20)	5(3)	8642	36.4	31.3	20.0	86.5	2
B.g.	6(2)	2(1)	1036	2.8	12.5	2.4	17.7	4
A.m.	25(0)	4(0)	10946	11.7	25.0	25.4	62.1	3
A.i.	7	4						
D.t.	15	2						

( ) Brackets indicate seedling stem counts

K. candel and *A. corniculatum* dominated the mangrove community on Transect 2 as shown in Table 2. *A. marina* was dominant only in the most seaward quadrat of Transect 2 (Figure 1). The *A. marina* community sampled in Transect 2 is similar to and is likely a part of that in Transect 1. Both *K. candel* and *A. corniculatum* seedlings were recorded on Transect 2. *A. marina* seedlings were not recorded. Therefore, *A. marina* may gradually decline in abundance in this mangrove.

1.3 Transect 3

Transect 3 was 285 m in length and was located near the Second Observation Tower. Fourteen 5 x 5m quadrats were sampled.

Table 3 Results of transect sampling in fourteen quadrats measuring 5m by 5m along Transect 3 near the Second Observation Tower, Futien Nature Reserve during Spring 1994.

Spp.	No.	Occ.	DBH	Rel.A.	Freq.	Dom.	Sign.	R.
K.c.	580(446)	14(11)	54981	60.1	50.0	63.8	173.9	1
A.c.	349(176)	9(9)	16613	36.1	32.0	19.3	67.4	2
B.g.	35(0)	4(0)	14216	3.6	14.5	16.5	34.6	3
A.m.	2(0)	1(0)	339	0.2	3.5	0.4	4.1	4
A.i.	611	6						
D.t.	70	7						

( ) Brackets indicate seedling stem counts

Table 3 shows dominance of *K. candel* on Transect 3 and co-dominance by *A. marina*. The graphic representation of Transect 3 in Figure 1 shows three discrete mangrove communities along the Transect from inland seaward. The first community was dominated by *A. corniculatum* with *K. candel* as a sub-dominant species. The second community was dominated by *K. candel* with *A. corniculatum* as a sub-dominant. The third community was dominated by *K. candel*. *A. marina* occurred in small and scattered patches along Transect 3. *K. candel* seedlings were abundant, with 446 individuals recorded in 11 quadrats, for a density of 162 seedlings per 100 m^2. *A. corniculatum* seedlings numbered 176 in six quadrats for a density of more than 8 per 100 m^2. Therefore, these two species are continuing to develop while *B. gymnorrhiza* and *A. marina* are declining due to poor reproduction.

1.4 Transect 4

Transect 4 measured 160 m in length and was located 300 m west of Sha Zui River mouth. Eight quadrats measuring 5 by 5m were sampled. Results are shown in Table 4. Table 4 shows that Transect 4 was dominated by *A. corniculatum* with *K. candel* as sub-dominant and some *A. marina*. *B. gymnorrhiza* occurred only as a single seedling.

Quadrats in the most landward 50 m of Transect 4 were dominated by *A. corniculatum* and *K. candel*. The remainder were dominated only by *A. corniculatum*. *K. candel* and *A. corniculatum* seedlings were recorded at densities of 25 per

100 m^2 and 21 per $100m^2$, respectively, along Transect 4. These two species will likely continue to develop, but *A. marina* seedlings did not occur, therefore *A. marina* may decline in abundance.

Table 4 Results of transect sampling in eight quadrats measuring 5m by 5m along Transect 4 160 m west of Sha Zui River mouth, Futien Nature Reserve during Spring 1994.

Spp.	No.	Occ.	DBH	Rel.Ab.	Freq.	Dom.	Sign.	Rank
A.c.	279(57)	8(5)	60919	67.5	44.4	64.2	176.1	1
K.c.	139(42)	8(2)	30199	31.6	44.4	21.8	107.8	2
A.m.	3(0)	1(0)	3818	0.7	5.6	4.0	10.3	3
B.g.	1(0)	1(1)	0	0.2	5.6	0.0	5.8	4

( ) Brackets indicate seedling stem counts

The leaf area index of *K. candel* was determined to be LAI=2, that for *A. marina* was 2.1, and that for *A. corniculatum* was 6.9. The former two leaf area indices are comparable with other nearby sites, but the latter is somewhat higher.

2 BENTHOS SURVEY

Benthos surveys were carried out in February and April 1994 on the Shenzhen side of the River.

2.1 Species Representation

During February 1994 quantitative sampling recorded 11 species of benthic invertebrates. The primary species were *Neriedae polychaete: Dendronereis pinnaticirris, Neanthes glandicinta, Sabellidae polychaete: Potamilla acuminata, Crustacea: Upogebia major*. In April 1994 quantitative sampling covered 8 species of benthiic invertebrates. Numerically dominant species were the same as those listed above for February 1994 surveys. In total 13 species of benthos were collected during the two surveys.

2.2 Benthos Density

At the landward perimeter of the mangrove community *Upogebia major* was the most common species. Density of *U. major* was lower at the seaward perimeter of the mangrove. During April the density of *U. major* was greater than that recorded during February. The distribution of *U. major* and *Neanthes glandicinta* were similar. Both occurred with greater density near the mangrove and with lesser density near the riverside. The distribution of *Vendronereis pinnaticirris* and *U. major* were opposite. *V. pinnaticirris* occurred with greater density near the riverside and with lower density near the mangrove.

Table 5 *Upogebia major* distribution on the Shenzhen side of Shenzhen River during February 1994 (expressed as individuals per m^2).

Month	Mangrove Fringe	Mangrove core area	Riverside	Average
February	2752	280	25	1019
April	4688	3975	76	2913

Table 6 *V. pinnaticirris* and *N. glandicinta* distribution on the Shenzhen side of Shenzhen River during February 1994 (expressed as individuals per m^2).

Species	Month	Mangrove edge	Magrove core	Riverside
V.pinnaticirris	Feb.	25	1197	1656
V.pinnaticirris	April	0	178	2701
N.glandicinta	Feb.	1223	127	200
N.glandicinta	April	713	357	306

Organic matter content was higher in the mangroves (Site A3) and lower between the mangrove and the riverside (Site

A2) and at the riverside (Site A1). The distribution of benthos was directly related to the distribution of organic matter. *N. glandicinta* and *U. major* were tolerant of high organic matter content. The Shenzhen side of the River was dominated by burrowing and tunnelling benthos. All four of the above listed species are of these categories. Sediment grain size was small in this area and laboratory analysis categorized the sediments as silty clays. *V. pinnaticiris* and *N. glandicinta* are preferred food items of shore birds. It would be preferable to do further analysis of bird food habits.

Table 7 Sediment analysis on the Shenzhen side of Shenzhen River.

Sample site	Sediment type	Mean grain size(Feb.)	TOC Percentages (April)
A1(riverside)	heavy clay TY	8.81	2.5%
A2(between A1&A3)	sandy clay SY	6.38	2.3%
A3(mangrove core)	silty clay TY	7.75	3.1%

Table 8 Benthos density in February and April 1994 on the north bank of Shenzhen River.

Month	Unit	A1	A2	A3	Mean
Feb.	Ind./m^2	3153	3233	4305	3683.7
Feb.	g/m^2	344.4	272.4	89.4	235.4
April	Ind./m^2	5783	4714	6470	5656
April	g/m^2	702.4	72.3	161.3	312.0

A comparison of the density and total biomass of benthos between February and April indicates that both parameters are greater during April than February.

3 BIRD STUDY

Based on methods outlined in the Inception Report for this project, bird counting in Futian Nature Reserve of Deep Bay was undertaken on January 15, February 13, March 14, and April 19(table 9). Table 9 shows that the largest number appeared on january which was 10543 birds, and dominant species were wintering birds such as Black-Headed Gull *Larus ridibundus* and Pintail *Anas crecca*, the assemble roosting bird species were only less than 10%. Dominant species are also wintering birds in February, the number of Black-Headed Gull and Pintail were 35% and 15.7% of the total birds respectively. Cormorant *Phalacrocorax carbo* increased significantly during this period, its percentage was 31.7%, that is great than ducks. To compare with January, 1500 birds was lost in Black-Headed Gull and Pintail populations in February.

The total in March is 3012 birds, and only 1300 was Black-Headed Gull which was 2000 less than February, but this population is still about 43.2% of all the birds in this area. There were only a few of Pintail, but the ducks populations were about 33.5% of the whole bird populations during March. There were 744 birds be recorded in April, only a few wintering bird individuals appeared and the main species were assemble roosting birds like Night Heron *Nycticorax nycticorax*, Little Egret *Egretta garzetta*, Chinese Pond-heron *Ardeola bacchus*, and Cattle Egret *Bubulcus ibis* which occupayed more than 50% of all the bird populations. Heron and egret species and populations were stable from January to April, but gulls and ducks decreased significantly from February to March. Waders and plovers increased gradually following the decreasing of gulls and ducks in April.

Detail investigation information indicated that many species of the bird populations in Futian were wintering birds and had more individuals before Qingming festival. After April 5, Black-Headed Gull gradually declined, however, Great Crested Grebe *Podiceps cristatus*, Cormorant *Phalacrocorax carbo*, Grey Heron *Ardea cinerea*, Black-Faced Spoonbill *Platalea minor*, Wigeon *Anas penelope*, Teal *Anas crecca*, Pintail, Tufted Duck *Aythya fuligula*, Shoveler *Anas clypeata*, Coot *Fulica atra*, Spotted Redshank *Tringa erythropus*, Black-headed Gull, Herring Gull *Larus argetatus*, and Black-Tailed Gull *Larus crassirostris*migrated out of this area before April 15. Some waders and plovers such as Kentish plover *Charadrius alexandrinus*, Greater Sand-Plover *Charadrius leschenaultii*, Long Toed Stint *Calidris subminuta*, Wood Sandpiper *Tringa ochropus* arrived at Futian on about March 24, and others arrived on about April 5. The major plover species were Redshank *Tringa totanus* and Curlew Sandpiper *Calidris ferruginea*. Populations of Night Heron, Chinese-Pond Heron, Little Heron, Great Heron *Egretta alba*, Little Grebe *Tachyhaptus rufficollis*, and Crimson-Legged Crake *Amaurornis akool* were very stable, number of individuals of the first three species were about 180.

Table 9 Bird observation result in Futian Nature reserve of Deep Bay

bird name	Jan.	Feb.	Mar.	Apr.
Great Crested Grebe *Podiceps cristatus*	24	43	58	
Little Grebe *Tachyhaptus rutficollis*	5	1	7	1
Grey Heron *Ardea cinerea*	29	19	34	
Night Heron *Nycticorax nycticorax*	15		146	151
Little Egret *Egretta garzetta*	436	53	115	132
Lesser Egret *Egretta intermidia*			1	
Great heron *Egretta alba*	104	13	29	24
Little Green Heron *Butorides striatus*	1			
Chinese Pond-Heron *Ardeola bacchus*	279	62	89	68
Black-faced Spoonbill *Platalea minor*	5	21	13	
Cattle egret *Bubulcus ibis*				39
Cormorant *Phalacrocorax carbo*	13	3150	13	
Ruddy Shelduck *Tadorna ferruginea*	205	2		
Wigeon *Anas penelope*	289	53	120	
Mallard *Anas platyhynchos*	23	1		
Teal *Anas crecca*			157	
Pintail *Anas accuta*	3515	1563	79	
Shoveler *Anas clypeata*	158	1011	220	
Goosander *Mergus merganser*	1			
Falcated Teal *Anas falcata*		11		
Tufted Duck *Aythya fuligula*			114	
Coot *Fulica atra*	57	22	37	
Moorhen *Gallinula chloropus*	1	1		4
Crimson-Legged Crake *Amaurornis akool*	31	7	5	6
Little Ringed Plover *Charadrius dubius*	109	55	16	8
Kentish Plover *Charadrius alexandrinus*				5
Greater Sand-Plover *Charadrius leschenaultii*				7
Fantail Snipe *Gallinago gallinago*	5		1	2
Curlew *Numenius arguata*	58	2		
Redshank *Tringa totanus*	73	287	90	61
Spotted Redshank *Tringa erythropus*	1			
Greenshank *Tringa nebularia*	156	45	34	10
Termmink's Stint *Calidris temminckii*	5		2	15
Common Sandpiper *Actitis hypoleucos*			2	8
Wood Sandpiper *Tringa glareola*				1
Green Sandpiper *Tringa ochropus*				2
Marsh Sandpiper *Tringa stagnatilis*				9
Curlew Sandpiper *Calidris ferruginea*				4
Broad-billed Sandpiper *Limicola falcinellus*				1
Long Toed Stint *Calidris subminuta*				25
Black-Headed Gull *Larus ridibundus*	4901	3480	1300	2
Herring Gull *Larus argentatus*	23			
Black-Tailed Gull *Larus crassirostris*		1		

4 MANGROVE SURVEY

Three treatment plots were arranged in the estuary, middle reaches, and upstream of Shenzhen River. Two hundred droppers of *Kandelia candel* were planted in each plot, and three experimental conditions, (1) open, no protection; (2) baffled, direct wave wash prevented; and (3) partially baffled, were undertaken in the experiment. The results were listed in Table 10.

Table 10 shows that baffle might have some impact on the survival and growth of mangrove seedling. The impact of baffle on survival rate of the seedlings in estuary was not significant, but they could benefit the mangrove a lot in the upstream plot. After being treated for 30 days, survival rate was only 92.5% under open condition in upstream plot, and it was 98% under baffled condition in the same plot. This result indicates that the baffle could give protection to the survival and growth of mangrove seedlings.

The baffle could not get notable result in estuary plot because the seedlings subjected to strong wave and wind impact. It was very different in upstream plot, as the river channel is very narrow, wake wash from navigation which would harmfully impact the mangrove seedlings could be prevented by the baffle. We can result from field observation that baffled condition is beneficial to mangrove seedling growth, for all the baffled seedlings were well developed, but the open seedlings were often in bad condition.

Table 10. Survival Experiment Result of *Kandelia candel* seedlings

Plot	Time	Open		Par. Baffled		Baffled	
		Survi.	%	Survi.	%	Survi.	%
Estuary	Apri.10	200	100	200	100	200	100
	Apri.20	180	90	186	93	184	92
	Apri.30	178	89	182	91	180	90
M.Reaches	Apri.10	200	100	200	100	200	100
	Apri.20	190	95	198	99	200	100
	Apri.30	176	88	182	91	182	91
Upstream	Apri.30	185	93	192	96	200	100

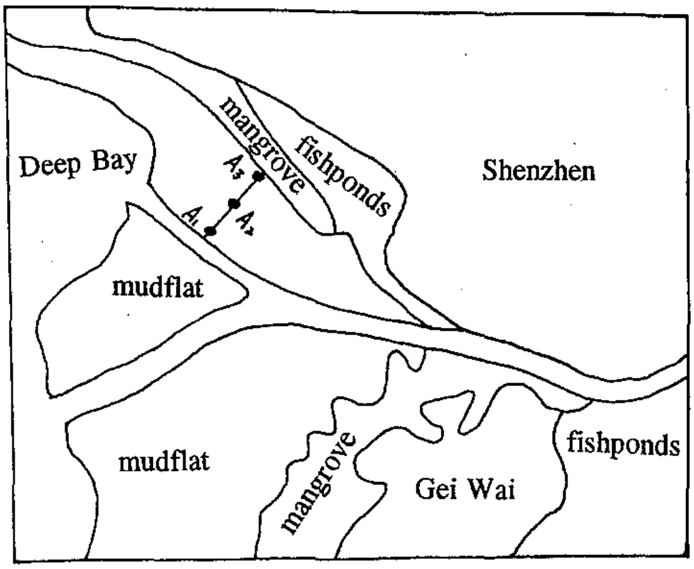


Fig. 2 Benthos Survey Stations in Futian Natural Reserve

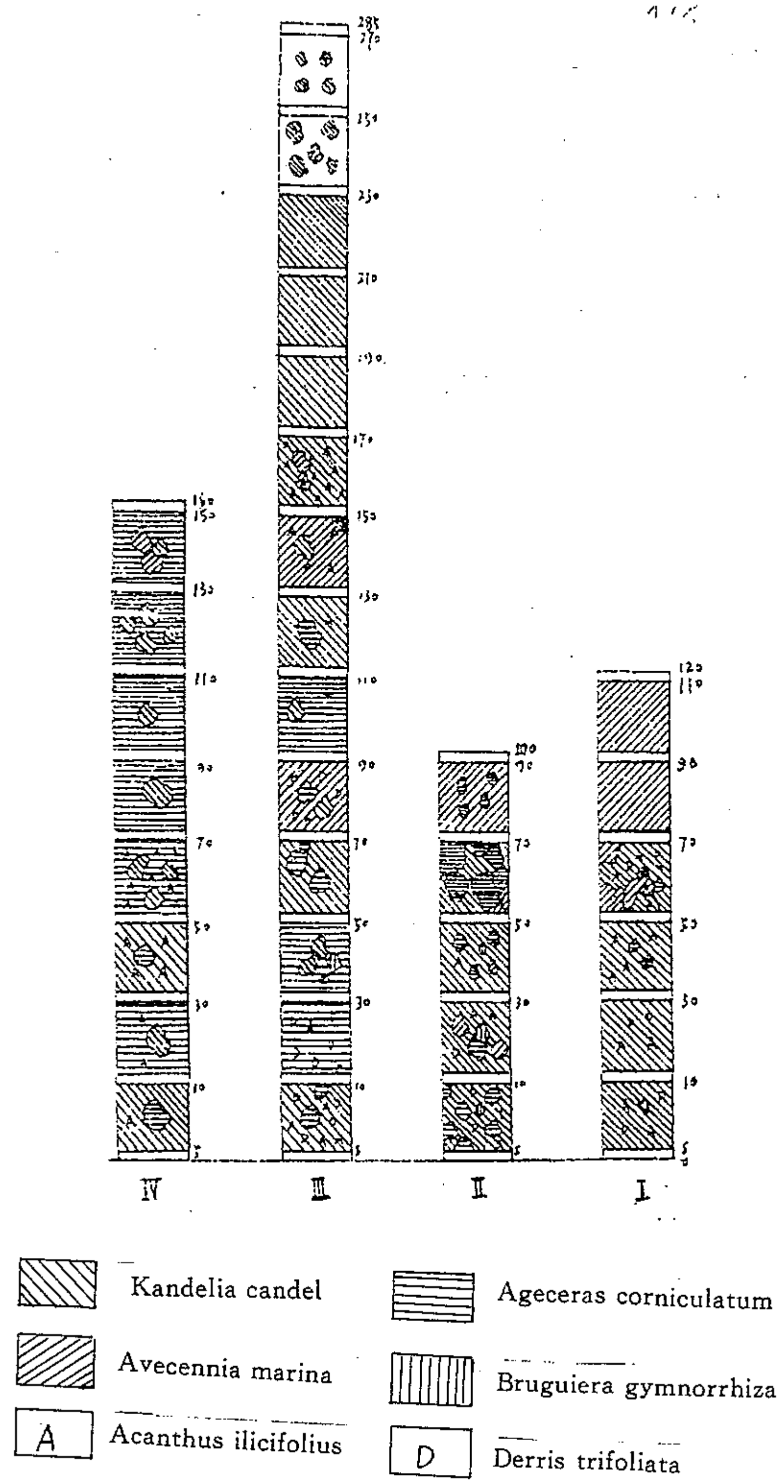


Fig. 1 Four Transections of Mangrove Survey in Futian Nature Reserve

APPENDIX 9.6 TERRESTRIAL ECOLOGY SURVEY FOR SHENZHEN

1 STUDY AREA

Based on the Inception Report for this Project the terrestrial ecological survey and impact assessment focused on identification of habitat types according to the predominant plant species. Particular attention was given to determining presence of rare or endangered species. Based on these the potential impacts of the proposed Project were identified and assessed and relevant mitigation measures were determined. The study covered areas within 1 km of the north bank of Shenzhen River.

According to the Project design Stage 1 works will realign the River course to eliminate 2 meanders, one at Liu Pok and the other at Lok Ma Chau. The realigned channel will be located at the north of the bends in the old river channel. Because the area within the truncated meander at Liu Pok is small, the abandoned oxbow will not be used as a spoil disposal site. Impacts on terrestrial ecology will be largely confined to the disturbance area on Shuangma Liyu Hill on the Hong Kong side of Shenzhen River. Therefore, on the Shenzhen side of the River terrestrial impacts will be confined largely to the Lok Ma Chau section of the Project.

The Lok Ma Chau meander is currently the largest partially natural habitat on the Shenzhen side of the River. The disturbance area within Lok Ma Chau bend will cover some 100 ha, of which 80 ha are currently used for commercial fish ponds or lie within the Futian River channel. In addition, the remaining 20 ha near Huanggang Port are used as a stone, gravel, and sand quarry. During the Stage 1 works 20 ha of land will be used for the new channel alignment which truncates the Lok Ma Chau meander. Within the Loc Ma Chau bend 50 ha of fish ponds are designated for use as a spoil disposal site. Following completion of Stage 1 works the former fish pond area is to be totally filled with spoil from the dredging operation.

2 HABITAT TYPE

Based on field surveys and a 5 December 1992 image (satellite photo) of the study area habitat mapping was carried out along Shenzhen River (Figure 9-1). To enhance comparability of habitat data on both sides of Shenzhen River, habitat surveys were conducted simultaneously. Field surveys were conducted on the Shenzhen side to ground-truth habitat boundaries mapped from imagery.

Three habitats were identified within the Lok Ma Chau meander (Figure 9-1). These were wetland, fish pond, and river channel. Within the meander southwest of Yu Ming Chuen approximately 20 mu of wetland habitat were recorded. The north side of Shenzhen River has been intensively developed for the communities of Lowu and Futian. Outside these two communities, other sections of the north bank have been developed or are under construction. Therefore, most of the area on the north bank has been controlled by human activities and will be gradually developed into a contiguous, built-up, urban area. This process will continue irrespective of implementation of the Shenzhen River training project. Therefore, within 1 km of the north bank of the River more than 90% of the land surface area will be used for urban construction. Fish ponds and wetlands which retain some form of natural landscape comprise 8% of the land area within 1 km of the north bank of Shenzhen River.

Due to the influence of intensive human activity within 1 km of the north bank of the River there is no remaining large area of native habitat. According to field surveys the existing habitats can be segregated into two categories. The first are man-made vegetation communities in urban areas or settlements. These are dominated species used in revegetation such as *Ficus microcarpa, F. altissima, Magnolia grandiflora, Cassia surattensis, Bauhinia variegata, Rhododendron spp.*, etc. Second are wetland vegetation communities along the riverside dominated by grasses, such as *Phragmites communis, Cyperus malacensis, Paspalum distichum, Phylidrum lanugi, Eriocaulan sexangulare, Zoysia sinica*, and others. Man-made habitats are widely distributed in the Shenzhen city urban area and in the villages to the west. Wetland habitats are mainly distributed in the small meanders southwest of Yu Min Chun and the area along Futian River within Lok Ma Chao meander.

3 POTENTIAL IMPACTS

According to the basic requirements for nature reserves in China, the principle concern of the stage I of the project is protection of biodiversity and the integrity of the system in Lok Ma Chau meander.

The target group of biodiversity conservation measures should be rare and endangered species and natural vegetation communities. Such vegetation communities are only distributed in small meanders and riparian sites of limited extent.

However, there are no species listed on the National Register of Rare and Endangered species which were recorded on the study area. Therefore, the existing wetland vegetation community is not significant for biodiversity conservation.

Integrity of habitat and relatively high levels of biodiversity are fundamental considerations in protection of ecosystems. The estuary area of Shenzhen River more or less meets these criteria. However, the inland portion of the north bank of the River is part of another ecosystem. Only the Shenzhen River channel, the Lok Ma Chau meander and the small meander southwest of Yu Ming Chuen are functionally connected to the estuary. The ecological connection between these areas is primarily related to birds. Because the upstream components of this ecosystem are small and disturbance due to human activities is intense many bird species have already abandoned these areas. Therefore, any additional disturbance to these areas due to the proposed Project is not likely to pose a significant threat to the ecological role of the estuary.

In summary, vegetation communities on the north bank of the River are not valuable for nature conservation. The proposed works related to this Project will not cause significant impacts to the vegetation of the study area.

Based on the nature of the dredging operations, potential impacts on terrestrial ecology may be visible in two aspects. The first source of impact will be dust generated from construction. The second is mechanical destruction of terrestrial communities during the new channel construction and dredging of the old channel. The primary terrestrial community which is subject to impact is the wetland community along Shenzhen River. Potential impacts are limited principally to the construction phase of the works. During operation and maintenance phases potential impacts on vegetation communities will be limited except during the maintenance period when sediments dredged from the channel may be disposed of on the embankment itself.

Mechanical destruction of vegetation communities will not be assessed in this study. According to the study design there are 2 natural vegetation communities on the proposed disturbance area for Stage 1 works. One is wetland habitat in Yu Ming Chuen meander. A part of this habitat will be lost due to dredging of the new river channel. The remainder will not be undisturbed. The north part of the Lok Ma Chau meander will also be used for construction of the new channel. Approximately 100 ha of land in the meander is designated for use as the new channel site and disposal site for dredged material. During Stage 1 works it is predicted that the existing fish ponds and the old Futian River channel will be filled. Then the wetland habitat which the wetland community relies upon will no loner exist in this area. Therefore, the Stage 1 works will result in loss of most of the habitat in Lok Ma Chau meander.

Potential impacts of dust generated during construction will be mainly on man-made vegetation communities in the built-up areas from Shenzhen city eastward to Huanggang Port. From the proposed construction disturbance sites to nearby residential areas is generally 100 m. Man-made vegetation communities (trees lining streets and hedgerows) are further away (500 m) from the potential sources of construction dust, and are screened from dust sources by residential sites. Measures taken to mitigate or eliminate fugitive dust impacts on residential areas will ensure that there is no dust impact on man-made vegetation communities.

4 MITIGATION MEASURES

Based on the above discussion, habitats on the north bank of the River have no particular conservation significance. Therefore, there is little requirement for consideration of design or operations measures which could reduce or mitigate impacts. A more appropriate strategy is to concentrate on restoration of habitats following completion of the construction works.

Potential impacts of Stage 1 works will result from channel dredging for meander truncation and spoil disposal in Lok Ma Chau meander. The main impact will be wetland habitat loss. Dust resulting from construction operations will not be significant for the man-made vegetation communities. Mitigation measures for dust control should be considered together with those for protection of air quality in residential areas.

The following two mitigation measures are proposed:

1) Retention of the 3.7 km length of river channel which is to be isolated from the River system by meander truncation. This measure will provide an additional degree of flood control and will preserve valuable wetland habitat. Also, it will encourage ntural, rapid development of new wetland habitat along the new channel.

2 Following completion of Stage 1 works revegetation at least 15% of the entire Luo Ma Zhou bend should be considered. This will not only increase the biodiversity of the area, but will also beautify the landscape.

APPENDIX 9.7 SURVEY OF MANGROVES AT MAI PO AREA

Survey of Mangroves at Mai Po Using Aerial Photographs and Ground Truthing

1 INTRODUCTION

The proposed Shenzhen River Regulation Project will widen the Shenzhen River at its mouth into Deep Bay, and will results in direct loss of mangrove and fish pond habitat at the northern end of the Mai Po Marshes Nature Reserve. By using aerial photographs of the proposed region,and ground truthing at several sites,the aim of this survey was to determine the historical development of the mangrove habitat (mangal) affected,its present area,structure and biomass,and possible consequences of its removal. The survey results may also be used as baseline data against which post-impact assessments and monitoring programmes may be made.This report is a preliminary report of the findings of the survey,and is intended to examine,briefly, patterns of mangal development and structure. Detailed statistical analyses will be undertaken as more information (results from an additional two transects) becomes available.

2 METHOD

2.1 Photographic Survey

The proposed Shenzhen River Regulation Project will result in the destruction of fishpond habitat and mudflat mangal as shown in Figure 1. To assess the present extent of mangal,and assess development of the mangal with respect to previous impacts (fishpond construction), aerial photographs taken between 1945 and 1993 were obtained;unfortunately the region was not regularly or consistently photographed it was necessary to use photographs taken at varying altitudes,from 2000'to 29200'. The area of mangal in Mangal A was measured from tracings of each photograph,using landmarks of known dimensions (the width of particular gei wais at certain points) for scaling. For early photographs, no distinction was made between 'fringe' mangrove,where small, sparse trees are found with mudflat visible between them, and that with full canopy cover,the limits of the mangal were defined simply as where mangrove plants were clearly visible on the photograph. Mangrove inside fishpond was not measured. These results were compared with data from studies of mangal elsewhere at Mai Po (Anderson, unpublished data) and studies of land use change in the region (Leung, 1986). Aerial photography has also been successfully used for determination of mangal structure,particularly zonation patterns and canopy species cover (Chapman 1984). Cuttent, low-altitude photographs were examined for these, in conjunction with ground truthing results.

2.2 Ground truthing

Ground truthing was undertaken in April 1994 using a rapid survey technique along three transects in the Mangal A(T1,T2,T3;Figure 1.). A further transect was established in Mangal B (T4;Figure 1.). (Data from another transect (Y1;Young, unpublished data) is currently undergoing analysis,and permission is being sought to use data from transect D1;Duke,unpublished data).

For each transect (T1,T2,T3;and T4),a line was laid out following a compass bearing perpendicular to the landward bund. Every 20m along the transect, a $5m^2$ quadrat was laid out to the north of the transect line (such that, along the transect, 15m separate quadrats). All emergent flora in the quadrats was examined and the following data recorded *in situ*:

a. Species
b. Height (Ht)
c. Diameter at Breast Height (dbh), taken at 1.3m above ground level, for trees dbh>2cm.

Trees which branched below breast height were treated as several stems, and the parameters of each branch recorded. Small (<1.3m in height) or shrubby plants (e.g. *Acanthus ilicifolius* and *Aegiceras corniculatum*), were noted if abundant, but not measured. Transects continued to the seaward limit of the mangal except in Transects 2 and 4 ,where mud consistency did not permit further penetration.

These measurements constitute several parameters of forest structure which allow comparisons between stands and between mangals, and form baseline data against which impacts may be measured. These are:

Species distribution along the transect
Vertical structure of the forest
Numerical species composition along the transect (% of total stems measured in quadrat)

Aboveground biomass

This was determined using a model of tree growth which relates biomass to Ht and dbh for which species specific allometric are available (Anderson unpublished data; Lee 1992).

Tree density

Basal diameter

This os the area covered by a tree stem and is a good measure of stand development (Cintron and novelli 1984). It is given by the equation

Basal area (g) = (?pi?/4).(dbh^2)

Basal diameter (BA) is the summed g values for all trees in the stand.

Mean stand diameter

This is the diameter of the stem of mean basal area, mdbh =v[(BA/n)/(?pi?/4)]

where mdbh is the mean stand diameter at breast height, BA is basal diameter, and n is tree density.

3 RESULT

3.1 Photographic survey

The present area of Mangal A,and a record of its development since 1945,are shown in Figure 2. The mangal generally enlarged in the period (12 ha to 36 ha), but suffered some reduction in the years between 1954 and 1960,and again between 1975 and 1984. The reductions are partly attributable to fish pond construction as pond 1 was reclaimed before 1954 and pond 2 was reclaimed before 1973.Other factors may be involved, however, as indicated in Figure 2 , which tracks the areas of Mangals A and B through the last 50 years. Of note is the simultaneous decrease in area covered by both Mangals A and B (which is not under threat from conversion to fishpond) in the 1980's.The cause of this decrease is not apparent in the photographs. Figure 2 also indicates the overall declining trend in 'swamp and marsh' in the Deep Bay area (Leung 1986).

Aerial photographs may also show features of mangal structure,such as zonation pattern and canopy cover. In this case,the photographs showed the development of the mangal with clarity. In 1945 Mangal A appears as a thin fringe of vegetation in which no canopy is visible. In 1954, the mangal area is wider and darker, with some forest canopy apparent, and in subsequent years a full canopy appears. In low altitude photographs, some canopy color variation is shown, but this does not form a consistent zonation pattern down the shore. Photographs of Mangal B,however, clearly indicate the presence of a zonation pattern with dark bands at the landward end and homogeneous light bands towards of a zonation pattern, dark coloration delimits the pioneering seedlings on the mudflat.

3.2 Ground Truthing

Preliminary analysis of transect data give some indication of the differences in forest structure which cause differences in appearance of Mangal A and B on aerial photographs. It should be noted that Transects T2 and T4 were stopped before the seaward limit was reached (approximately 20 and 50m before the seaward limit of the main stand, respectively). T3 was stopped some way into a wide fringe of small mangroves on the seaward edge of the mangal ,in which more than 30 Redshank (*Tringa totanus*)were foraging.

Species distribution and vertical forest structure

Species distribution and vertical forest structure were recorded for each quadrat as presence and maximum height attained. Transects T1, T2 and T3 do not exhibit a clear zonation pattern, nor a distinct vertical structure,as a mixture of species and heights are recorded throughout. This is in marked contrast to T4,which exhibits a clear high to low shore zonation (monospecific stands of *Kandelia candel* at the high shore being replaced over a small distance by *Avicennia marina*) and a homogeneous vertical structure with a strong canopy formation and little understorey growth.. Of interest are the grass (T1; *Eleocharis* c.f. *ascicularis*) occurring on the banks of the river (Melville 1994) and the individual of *Bruguiera gymnorrhiza* in T4,which occurred in a small stand with two others and was producing propagules.

Numerical species composition

Shown in Figures 3a, b, c and d, numerical species composition reinforces the above differences between Mangal A and Mangal B, with strong zonation in dominant species found only in T4.

Tree density

Tree density(trees.ha^{-1}) varies between 800 and 16800 in the sites surveyed , but follows no consistent pattern between quadrats on the same transect, or between transects (Figure 4). Variability is high (although it is of note that T4 shows the least, following a steep decline at the landward end of the mangal). Transect T3 intersects the x axis at two points, corresponding to two quadrats which consisted of *Acanthus ilicifolius*.

Mean stand diameter

These are displayed for all transects in Figure 5. Transrct T4 frequently shows a higher diameter than transects T1,T2 and T3.

Basal diameter

Aa displayed in Figure 6, basal diameters are highly variable between quadrats.

Summary

Biomass data and a summary of data presented graphically is given in Table 1.

Table 1 Results of the transects carried out at three sites in Mangal A(T1, T2 and T3) and one site in Mangal B(T4). Tree density=stems.ha^{-1}; %speciescomposition=numerical composotion based on abundances in quandrats; Kc=Kandelia candel; Ac=Ageciras corniculatum; Am=Avicennia marina; biomass is represented as kg dry allometric equations(Anderson unpublished data; Lee 1992) and is represented as kg dry mass.quadrat^{-1}; BA=basal area, in cm^2.quadrat^{-1}; mdbh=mean stand dimeter at breast height, in cm.

Transect 1		% Species Composition			Biomass(kg.ha^{-1}) x100			Stand Structure	
m	t.den.	Kc	Ac	Am	Kc	Ac	Am	Ba	mdbh
5	4400	90	10	0	728	136	0	639	8.6
25	6400	31	56	13	312	20	264	706	7.5
45	4800	25	17	58	64	436	512	358	6.2
65	15600	0	0	100	0	109	0	582	4.4
Transet 2									
5	4400	55	45	0	252	48	0	303	5.9
25	4800	17	33	50	16	20	0	209	4.7
45	4400	0	27	73	0	12	1104	583	8.2
65	2400	17	83	0	8	20	0	48	3.2
85	2800	0	86	14	0	20	216	106	4.4
105	4800	0	100	0	0	40	0	92	3.1
125	6000	0	73	27	0	68	420	324	5.2
145	9600	13	79	8	52	68	132	412	4.6
165	3200	0	38	62	0	12	216	170	5.2
185	2400	0	100	0	0	20	0	130	5.3
205	7200	0	100	0	0	6	0	222	3.9
Transect 3									
25	7200	22	78	0	20	72	0	179	3.6
45	8000	15	85	0	44	96	0	247	3.9
85	7200	0	100	0	0	92	0	212	3.9
105	12400	0	90	10	0	140	64	387	4

125	8400	43	38	19	84	36	128	389	4.8
145	6400	44	38	18	32	20	0	117	3
Transect 4									
5	16800	93	7	0	408	32	0	647	4.5
25	3600	100	0	0	316	0	0	331	6.8
45	2000	100	0	0	308	0	0	341	9.3
65	4800	100	0	0	1220	0	0	727	8.8
85	2800	0	0	100	0	0	752	367	8.2
105	4800	0	0	100	0	0	652	376	6.3
125	3200	0	0	100	0	0	772	399	8
145	2400	0	0	100	0	0	592	269	7.6
165	3600	11	0	89	12	0	460	244	5.9
185	800	0	0	100	0	0	28	70	6.7
205	3200	0	50	50	0	12	128	153	5.2

4 DISCUSSION

The mangal lying on the mudflat at Deep Bay (Mangals A and B), has developed since the 1940's, when the gei wais were reclaimed from existing mangrove, effectively pushing the coastline further out into Deep Bay . Leung (1986)notes that the rapid decline in areas of 'swamp and marsh' in the Deep Bay area is caused by reclamation for brackish water paddy and gei wais. In fact, the extent of the original mangrove is still visible in aerial photographs taken in the 1940's , despite gei wai construction.Photographs in later years suggest that the original mangrove declines rapidly inside the gei wais , perhaps under the influence of changed hydrological conditions and felling.Outside the seaward gei wai bund,rapid colonization of the mudflat occurs, forming the present mangal.

Aerial photographs give useful information monitoring the development of the mangal. Area measurements of Mangal A(this study) and Mangal B (Anderson, unpublished data) track the colonization of the mudflat, with the most reliable area estimates from low altitude photographs (5000' or lower).No information is available on the error involved in using high altitude photographs, and in either series, no account os taken of scale distortions across the photograph, beyond the rejection of oblique shots.The method nevertheless does detect changes in mangal area through time, albeit those of a notable proportion.Minor changes are unlikely to be detected.

Aerial photographs also yield useful data in the structure of the mangrove forest. Whereas in Mangal B a distinct zonation pattern is seen, none exists in Mangrove A,which has a heterogeneous texture in the photographs. Many factors are thought to influence mangrove forest zonation patterns (e.g. physiology, topography, propagule structure, competition, seedling predation.Smith 1992),however the history of development impact in Mangal A (in the form of fishpond construction)suggest that this mangal is younger than Mangal A. Preliminary analysis of transect data also support this. By making comparisons with an old stand (on T4; further comparison following inclusion of data from transects y1 and D1), differences in species zonation patterns, vertical structure, species composition and possibly other parameters of forest structure are observed. Generally, Mangal A has the characteristics of a young stand (high stem density, low mean stand diameter).

This information provides baseline data for future reference,but may also be used in impact assessment of Shenzhen River Regulation Project.Following mangrove removal at the present mouth of the River into Deep May, and construction of bunds and new River banks, mangrove colonization of the mudflat adjacent to the River is likely, particularly at the upstream end of this section of works, and providing hydrography, water quality and sediment characteristics are not altered as a result of the works. The extent to which mangrove colonization may occur may not be predicted at this time, but may result in significant reductions in the area of mudflat at the River mouth.This is an area where significant numbers of waders have been seen, (Leader,pers. comm. and during this study as described above). Habitat loss (mudflat) caused by the inadvertent creation of more of another habitat (mangal) by the Project is an issue that must be addressed.

Loss of all or part of Mangal A, has, however, several more immediate concerns. Firstly, the implementation of water quality control ordinances restricting discharge of livestock waste and main trunk sewer systems, will reduce the loads of organic waste (from the Hong Kong side) entering Deep May . Should water flow rates in the Shenzhen River also result in fewer organics entering the Bay (data to be provided by this study but not yet available), the organic detritus produced by the mangroves in Deep May will assume a greater importance in maintaining adjacent benthic and pelagic habitats. Secondly, fauna associated with Mangal A will also be lost with habitat removed. Benthic fauna in Mangal A is more abundant than other sites (McChesney 1994),which may be a response to high organic loads in Mangal A,but may be a reflection of the different mangrove species composition and structure in the area (for example, the high abundance of *Aegiceras cornictlatum*, which is a sparse understorey species in Mangal B).

Mangrove area removal is often mitigated by replanting programmes. In this case, history suggests that the mangrove will recolonize fairly rapidly, although it may take several decades before it attains that structure of a mature mangal. Replanting in another area as a compensation measure will probably remove mudflat area in addition to that will be recolonized, and for this reason must be examined carefully. An optimal solution may be to design an appropriate river profile in this section of the River, in which mangrove replanting can occur (thus conserving habitat and compensating for organic matter loss) without sacrificing mudflat habitat.

Long term post impact monitoring programmes in Mangal A, using aerial photography and permanent transect with marked trees, would be advised, to monitor changes in mangal structure and extent, and to detect with those changes caused by the River Regulation Project which may not be predicted.

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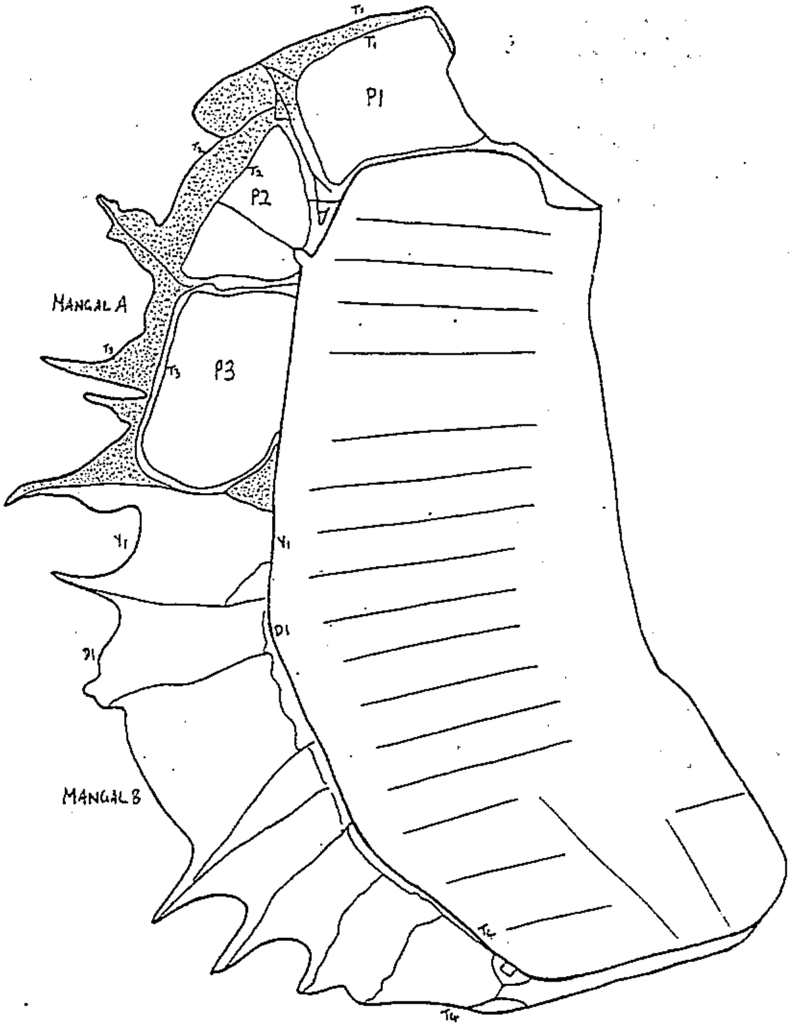
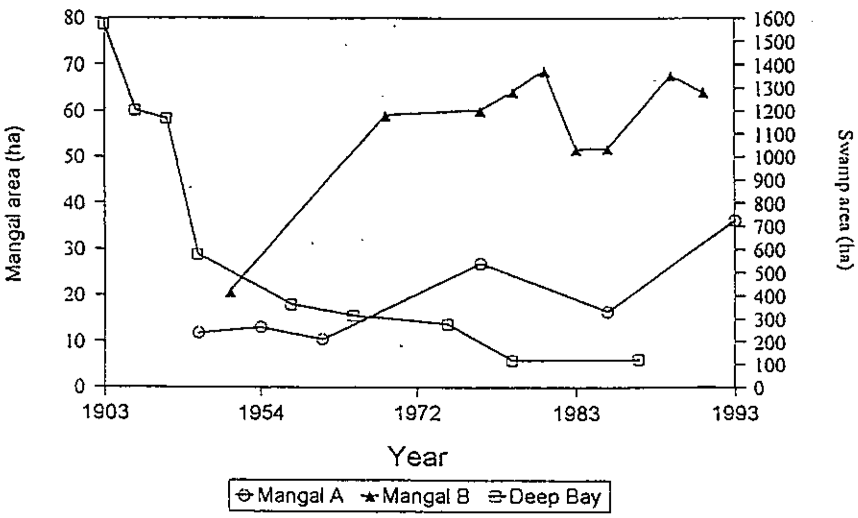
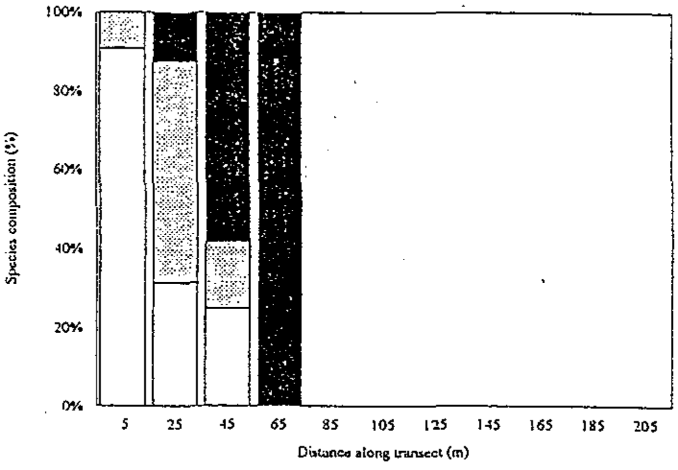


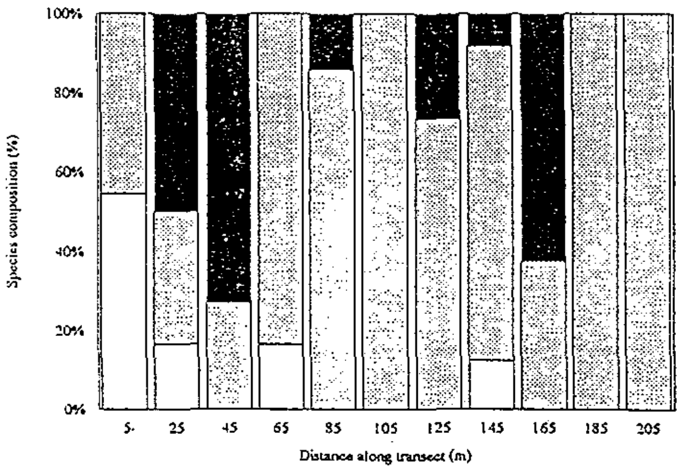
Fig. 1 Mangrove Survey Stations in Mai Po

Fig. 2 Mangrove Changing in Mai po Nature Reserve





Transection (a)



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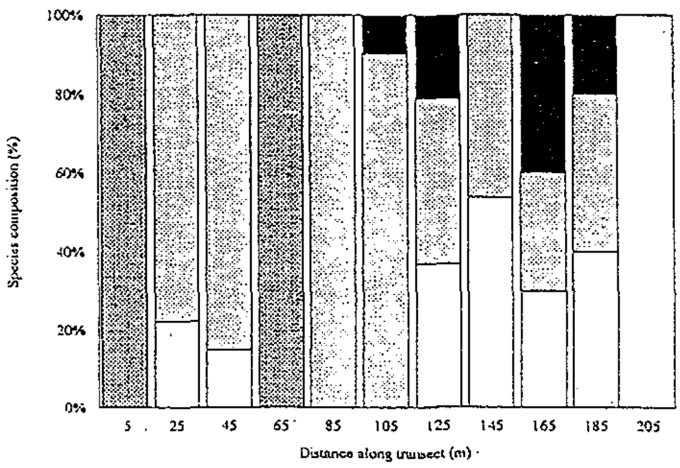
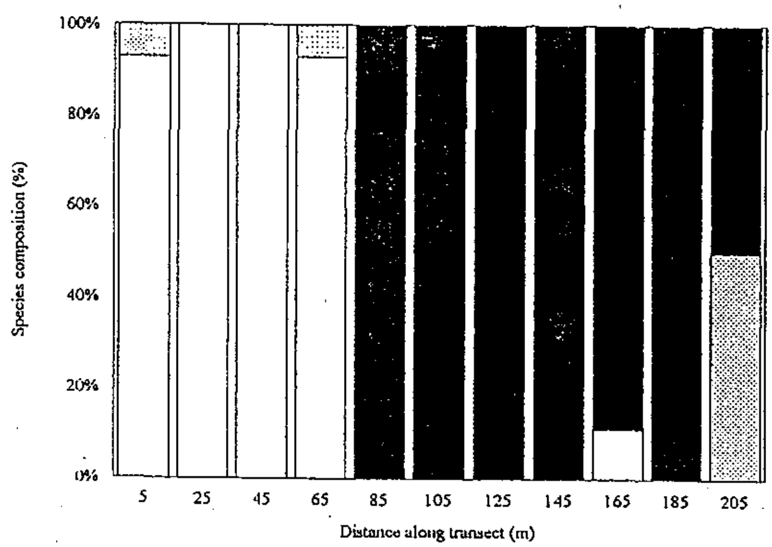


Transection (c)



Transection (d)

Fig. 3 Mangrove Survey Results on Four Transections in Mai Po

Fig. 4 Tree Density on the Four Transection

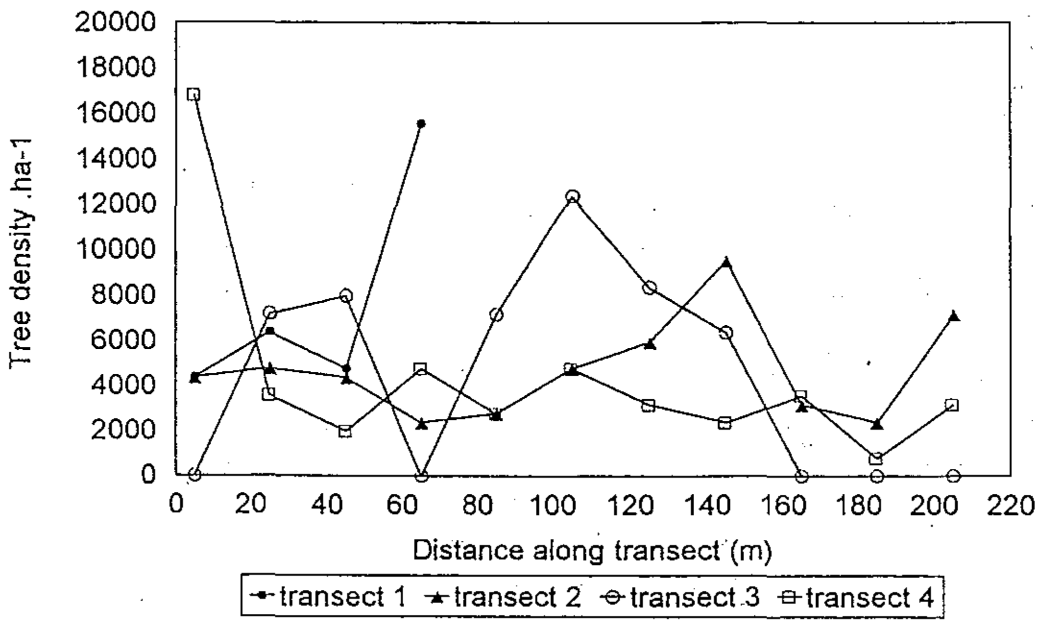


Fig. 5 Mean Stand Diameter of Mangrove on the Four Transection

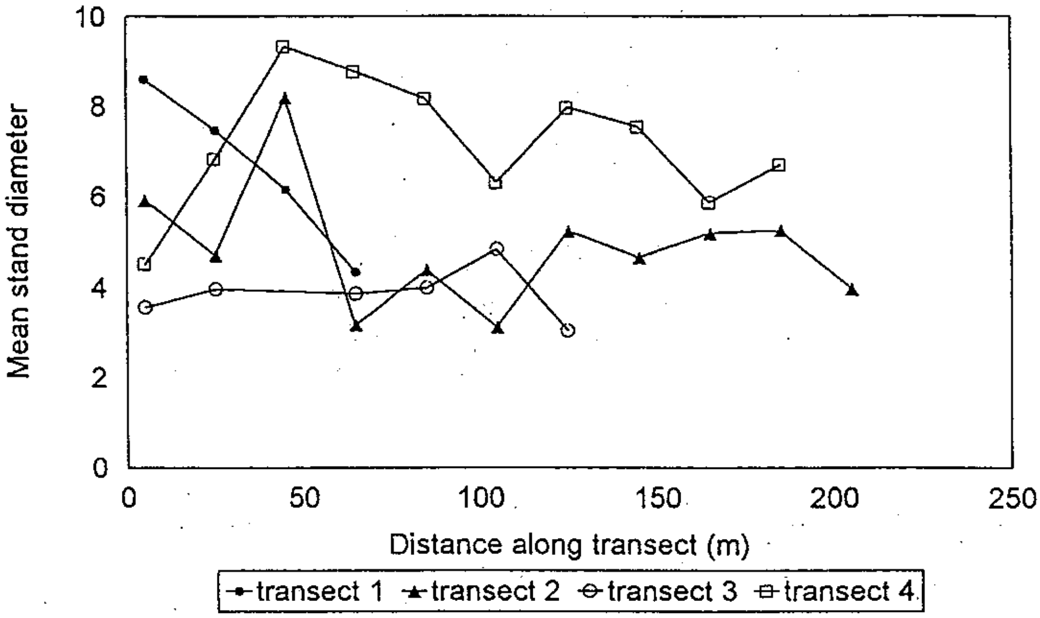
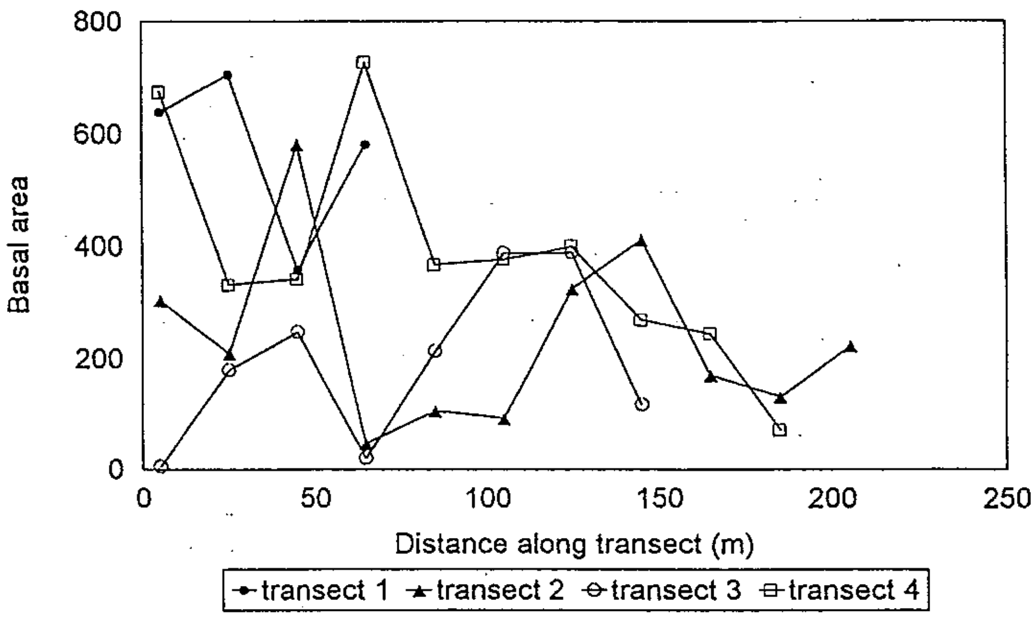


Fig. 6 Basal area of Mangrove on the Four Transection



APPENDIX 9.8 INTERIM REPORT OF SOUTHERN RIVER BANK MANGOVE SURVEY-TAM KON CHAU TO LO WU

1 INTRODUCTION

The proposed Shenzhen River Training project will change the profile and course of the Shenzhen river in its lower reaches. The lower reaches of the Shenzhen River are under considerable tidal influence, resulting in an upstream intrusion of mangrove vegetation along the river banks. The aim of this survey was to determine the exact distribution of mangroves on the southern bank of the Shenzhen River from Tam kon Chau to Lo Wu, with the purpose of assessing the species and habitat area which may be lost during the project,and,in conjunction with a similar study carried out on the northern bank,to provide baseline data which may guide possible replanting/riverbank rehabilitation programmes following construction.

2 METHOD

The southern bank of the Shenzhen River was surveyed,by bicycle and on foot, between Tam Kon Chau and the LoWu Bridge. A rapid survey technique was employed to gain basic data on the distribution of the mangroves in this habitat. For this purpose, 'mangrove vegetation' is defined as containing one or more of the species found commonly or rarely in other mangrove habitats (termed 'mangals') in Hong Kong (Morton and Morton 1982). Other species,which may include those often found in areas surrounding the mangal or other coastal habitats, are noted but not included in the survey. The protocol of data collection depended on the structure of each tree found:

Individual trees

For mangrove trees of the species *Kandelia candel* and *Bruguiera gymnorrhiza* for which it was possible to identify single trunks, and for the shrubby species *Aegiceras cornivulatum* and *Avicennnia marina* for which it was possible to identify single root bases, the location of the tree was noted and checked, where necessary, with compass transits from local landmarks. For the mangrove *Acanthus ilicifolius*, the reed *Phragmites communis*, and the mangrove fern *Acrostichum aureum*, individuals were innumerable or indiscernible. Discreet monospecific stands of these species which covered areas $<2m^2$ were treated as individuals and noted as above. The height of the tree, or, where several individuals co-occurred, the maximum height of the group of trees,was visually estimated to the nearest metre. The mature of the river bank at the location of each mangrove was noted into three categories, 'concreted', where concrete slabs, bricks or boulders formed much of the river bank,'natural', where the river bank was predominantly a soil substrate, and'mixed', where some concrete was in evidence but did not dominate the bank substrate. Any additional features of the trees or location were also recorded.

Stands

Where multiple species stands occurred and it was not possible to discern individuals,the approximate species composition wa recorded as a visual estimate of the % of total stand area made up by each species. The location of the stand was noted by the nearest border fence section number, and the maximum height of the stand, maximum width(in the direction river bank to river bed) and length of the stand (along the river course)were estimated. River bank structure was recorded as above. All drainage channels,streams and sluice gate areas receiving water from the Shenzhen River were similarly surveyed for mangrove species within a 'riparian belt' of 300 m from the river banks. (In some cases, for example, the creek flowing out to the river through Tam Kon Chau, mangroves occur further away from the river than this, however as these are unlikely to be directly affected by engineering works associated with the proposed River Regulation Project, these were not included in the survey). Results were recorded on Maps 2-SE-A and 2-NE-D, scale 1:5000 (Series HP5C, partially revised 1/94, Survey and Mapping Office, Lands Department, Hong Kong Government), with annotations noted separately.

3 RESULT

Results of the vegetation survey are shown in Maps A, B, and C(taken from Map 2-SE-A)and Maps D, E and F (taken from Map 2-NE-D).

As shown in Maps A, B and C, the southern river bank of the Shenzhen river between Tam Chau and the Lok Ma Chau border crossing is predominantly mangrove-lined. The stands in this part of the river are well established; with trees often reaching over 2 m in height. The dominant species are *Aegiceras corniculatum* and *Kandelia candel*, which are both common species in the Deep Bay mangals. Whilst most of the stands appear healthy, there are some suggestions of disturbance, for example by burning(Map C). Further upstream, between Lok Ma Chau and Lo Wu (maps D, E and F), the mangrove contribution to riparian vegetation assemblages declines markedly, with sparse occurrences of smaller, less vigorous plants, the only significant stand being the large stand of *Aegiceras corniculatum* adjacent to Hoo Hok Wai(HHW; Map E). The upstream limit of true mangrove species was found to be Ta Sha Lok(TSL; Map F), where two individuals of *Aegiceras corniculatum* are located in a small creek between fish ponds. The reed *Phragmites communis* is the dominant species of the marshy areas in between fish ponds in the Hoo Hok Wai and Ta Sha Lok areas, as indicated on Maps E and F.

In creeks and drainage channels adjacent to the Shenzhen River, mangroves generally occur in sparse stands, with a mixture of other species, including various grasses (Graminae, unidentified species), and the shrubs *Lantana camara* and *Clerodendron inerme*, These species are also found at the top of the river bank in the stands near the Lok Ma Chau Border Crossing(stand numbers 53,59 and 60).

Of particular note in the mangrove stands along the southern river bank is the occurrence of an individual of *Bruguiera gymnorrhiza* (Map A), a rare mangrove in Hong Kong, and the noticeably few individuals of *Avicennia marina*. This species dominates the mangal at Mai Po(making up over 50% of the mangal area; Anderson, unpublished data). Also of note are the extensive populations of the climber *Derris trifoliata* over many of the mangrove trees along the river.

River bank structure, as noted here, is determined by the proximity of the Border Road, such that from Tam kon Chau to Lok Ma Chau, much of the river bank slopes contain concrete, bricks or bouiders,. with a fringe or ledge of natural substrate which is colonized by mangrove species. At two locations, the bank is composed entirely of artificial substrate and forms a vertical'wall' which excludes mangrove species (Map A). Where the Border Road departs the river bank,at the Lok Ma Chau Border Crossing, the banks become more natural and are generally more steeply-sided and grassy.

4 DISCUSSION

The size and structure of the mangrove stands and the presence of a rare species(*Bruguiera gymnorrhiza*) suggest that between Tam Kon Chau and Lok Ma Chau, the present stands may be remnants of a larger stand which was destroyed during construction of the Border Road. Derailed estimation of mangrove'health' was not undertaken here, but in crude terms,despite deteriorating water quality and increasing river traffic in the river, the mangroves lining the southern river bank show little sign of degradation. The stand are dominated by species common in the Deep Bay mangals,with the exception of *Avicennia marina*, which is virtually precluded from river bank habitats, It is probably a poor colonist, as propagile production is limited(Anderson and Lee, in press), but, with aerial pneumatophores to facilitate oxygen transport to the roots, may be more sensitive to poor water quality, particularly in terms of sediment load, than *Kandelia candel* or *Aegiceras corniculatum*. Also, there is a marked absence of young seedlings of all species in the river bank stands. A similar pattern (lack of *Avicennia marina* and young seedlings in stands dominated by *Kandelia candel* and *Aegiceras corniculatum*)was documented in the Kam Tin River, Yuen Long, before drainage improvement works(Lee 1992)and was thought to be attributed to water quality parameters exceeding stress limits for establishing seedlings. Additionally, in the Shenzhen River,physical disruption of propagule lodgement may be caused by wash from river traffic, which was not a factor present in the Kam Tin River.

Upstream from the Lok Ma Chau Border Crossing,mangrove species are fewer, perhaps precluded from colonization by poor water quality, or steeply sided river banks, as suggested from the stand at Hoo Hok Wai(HHW), which occurs on the inner bend of a meander where deposition of fluvial sediment would be expected. The reed, *Phragmites communis*, *Juncus sp*. and *Cyperus sp*. are present in large beds surrounding fish ponds or in abandoned fish ponds, and in areas where the substrate has been disturbed. The proposed Shenzhen River regulation Project will result in the destruction of most of the existing mangrove stands surveyed here. The approximate area of mangrove lost may be calculated from the data obtained in this survey. Replanting the mangrove area lost,preserving the present mangrove species composition, would be an appropriate mitigation measure. A similar programme has been undertaken successfully with 2 year mangrove seedlings in the Yuen Long Creek(Drainage Services Department, 1993). Appropriate designs in the River profile must be employed to acheive an appropriate substrate.

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APPENDIX 9.9 INTERIM REPORT OF INVERTEBRATE SURVEY

1 INTRODUCTION

Migrating and resident waterbirds (e. g. egrets, herons, spoonbills, shorebirds, ducks, gulls, and terns) utilize the benthic animals living in the mudflats of Deep Bay as food resources. The benthic invertebrate animals in the mudflats and mangroves comprise annelid worms, snails and bivalves, as well as crabs. Amphipod and isopod crustaceans, common on some other soft shores, and present in the invertebrate assemblage of the tidal gei wais on the adjacent WWF-HK Mai Po Marshes Nature Reserve, are very rarely present on the mudflats. Vertebrate mudskippers provides food for some birds as well. The objectives of the invertebrate program of the Shenzhen River Regulation Project Environmental Impact Assessment are 1) to describe the distribution and abundance of these prey animals, 2) to describe how the prey resources vary with time; 3) to assess the effect of bird predation on benthic resources.

Previous work on the benthic invertebrates in Deep Bay includes identification and taxonomy work (e. g. Erseus, 1984), habitat description(e. g. Melville and Morton, 1983). Anderson (1989) study the behavior of *Uca arcuata*, and Choi (1991) studied the reproductive biology of fiddler crabs. The only previous work describing distribution, abundance, and productivity of the benthic invertebrate assemblage in Deep Bay is McChesney (unpublished).

2 METHODS

The invertebrate program comprises four tasks: 1) mudflats and mangrove benthic invertebrate monitoring, 2) predator exclusion manipulation, 3) sediment size determination, and 4) crab density. Figure 1 shows the locations of the monitoring stations for the benthic invertebrate program. Benthos both on the mudflat and in the mangrove is being monitored. Mudflat monitoring stations are located along two transects. The transect locations and site names are shown on Figure 1. The western most transect lies along the same transect sampled during earlier work (McChesney,unpublished). The transect is referred to as the "red buoy" transect and the stations along it are RBO, RB3, and 450. The other mudflat transect trends more nearly north-south, and consists of the stations ET1,ET2,and ET4. Two other stations close to these transects, labelled CH1 and ET3,are sites located on the intertidal channel levees. Site CH1 was occasionally sampled during earlier work (McChesney,unpublished);site ET3 has only been sampled in January 1994. Three other transects have been established to monitor benthos in the mangrove, each transect with one site in the *Avicennia* forest, and one site in the *Kandelia* forest (see Figure 1).

2.1 MUDFLAT AND MANGROVE BENTHIC MONITORING

The purpose of benthic monitoring is to determine the distribution and abundance of the prey species for birds. This determination will be made four times during the EIA study to assess the changes in the benthos with time . Combined with the information on changes of the benthos with time from earlier work (McChesney, unpublished), the effect of seasons on the invertebrate assemblage may be determined.

Each sampling location on the mudfalt and mangrove benthic transects has been monitored in January 1994 and March 1994; further monitoring samples will be collected in May and August determine the mean abundance and biomass of invertebrates at that station. Core samples are collected with a 10 cm diameter PVC pipe to a depth of 20 cm, and samples are transported in sealed, reusable zip-lock storage bags.

The core samples are returned to the lab within three to six hours after collection where they are stored in refrigerators. Cores are sieved through a 900 micron screen, with the exception of the January 1994 samples, the material passing through the lmm mesh was resieved through the 900 micron screen to find out what material was being lost. Most of the small oligochaetes and Capitellidae polychaetes had passed through the 1mm screen. Because these animals are generally accepted as indicators of organic pollution (Green *et al* . 1992),and because the 900 micron mesh size had been used during earlier work on these mudflats (McChesney,unpublished), samples collected subsequent to January 1994 have been sieved through the 900 micron mesh. The 1mm screen, however, catches 98. 5-83. 8%(n=3) of the biomass in mudflat samples, making the biomass figures from January 1994 comparable with biomass data from subsequent months. A 1 mm mesh size is used as a standard in most shorebird feeding studies since most smaller organisms are unavailable as prey for the birds. Invertebrates retained in the sieve are killed in hexamine-neutralized 5% formalin and are left to fix for about 48 hours. The invertebrates are then stored in 70% ethanol. The mangrove benthos monitoring samples are handled slightly differently: the core sample is fixed prior to sieving in hexamine-neutralized 5% formalin to which rose bengal is added as a stain. This turns the invertebrate animals bright pink and aids in finding invertebrate among the abundant rootlets and leaf litter in the mangrove samples. Invertebrates from the sieve are stored directly in alcohol. Samples are sorted to morphospecies. Individuals are counted for each morphospecies.

Biomass is determined for each motphospecies in each sample sa far sa is practical. Small, similarly-sized specimens of micromolluscs are lumped together, as are small annelids, to obtain a sufficient mass to measure. Molluscs and crabs, having exoskeleton composed at least partially of calcium carbonate, are digested first in 10% hydrochloric acid overnight. Annelids and decalcified mollusc and crabs are placed in pre-weighed drying boats. Samples are dried at 80 degrees Celcius for about 48 hours to allow constant dry weight to be achieved, and then re-weighed. The difference between these two measurements is the dry weight of the invertebrate. Each sample is sealed in a labelled vial and sent to the Beijing University laboratory for ash-free dry weight (AFDW) determination.

2.2 PREDATOR EXCLUSION

The purpose of predator exclusion manipulations is to assess the impact of birds from foraging on patches of mud, and the benthic invertebrate assemblage is compared between the cages and uncaged patches of mud. The difference in invertebrate abundance and biomass is inferred to result from consumption by bird predators. Predator exclusion sampling is complete for February and April 1994, and is scheduled for June and September,1994.

The cages are designed to exclude only birds: square cages 5m on a side are constructed using bamboo sticks and string. Two strings run between the sticks. The sticks are 1m apart; one string runs about 20 mm above the mud surface, and the other about 120 mm above the mud surface. Crabs are able to move in and out of the cages, and fish are able to swim in and out during high tide.

Eight separate cages as treatment replicates are placed on two areas of the mudflat: the upper and lower mudflat. As cages are erected, cores of mud are collected to evaluate the benthic assemblage present at the start of the manipulation. After two weeks, three replicate cores are collected from the surrounding mudflat (experimental control) to estimate invertebrate abundance and biomass affected by predation. The cores collected for predator exclusion manipulation are sieved and preserved as described for the mudflat monitoring samples above . Similarly, biomass for specimens collected in the predator exclusion manipulations is determined as described above.

2.3 SEDIMENT SIZE DETERMINATION

Cores of sediment are collected with the objective of determining the distribution of sediment grain size and total organic content in mudflat and mangrove sediments. Two replicate cores are collected at each monitoring station when benthic monitoring samples are collected (January, March,May, and August) (see Figure 1 for locations). Samples are dried ar 80 degrees Celcius until constant weight is achieved-about a week. Samples are then sent to Beijing University for sediment size determination.

The dried sediment size samples resemble lumps of rock: very hard and completely solid. One criticism of this method is that the dried sediments must be ground to disaggregate the solid. Does the resulting size distribution reveal the distribution of particle size in the sediment, or how well the lab grinder can grind the sediment ? Some sediment samples have been wet-sieved during previous work (McChesney, unpublished) from some of the sites, so the results from this EIA study can be compared, and perhaps calibrated.

2.4 CRAB DENSITY

Crabs are not usually collected in the benthic core samples because they are too highly mobile and easily avoid being caught in the corer. Bird feeding observations (Young, 1994; Leader, 1994; Melville, unpublished; McChesney, unpublished;Geoff Carey,pers . comm.) reveal that several bird species feeding on mudflat benthos catch crabs: Saunder's Gull *Larus saundersi*, Curlew *Numenius arquata*, Eastern Curlew *N. madagascariensis*, Whimbrel *N. phaeopus*, Terek Sandpiper *Xenus cinereus*, and Chinese Pond Heron *Ardeola bacchus* for example. Determining the abundance and biomass of the mudflat crabs is an important part of describing the food resources available to birds in Deep Bay.

Permanent quadrats have been placed close to the three bird watching hides (see Figure 1). Burrow density is counted within these quadrats from the hide . when crabs are active on the mud surface, their abundance is also counted within the permanent quadrats from the hides.

The quadrats may encourage crabs if the quadrats have a protective effect against crab predators. Crab burrow densities are compared between the permanent quadrats and haphazardly thrown quadrats to see if densities are affected by the permanent quadrats themselves. Samples of crabs are being collected. Carapace width and length, propodus length and width, and dactylus length will be measured, and ash-free dry weight determined.

3 RESULTS

3.1 Species Present and Their Distribution

Table 1 provides an alphabetical listing of morphospecies codes and the taxonomic level to which each morphospecies has been identified.

To determine any effect of preservation on biomass, a set of samples was collected and weighed fresh. A subset was dried, and ash-free dry weight determined without preservation, while another three subsets were fixed in hexamine-neutralized 5% formalin. These three subsets were then preserved in 70% ethanol for one month, two, two months, and five months, respectively. The AFDW/fresh weight ratio did not change between the unpreserved samples and the samples preserved for any length of time, leading to the conclusion that this preservation method does not affect AFDW (McChesney,unpublished). Leuven *et al.* (1985) also found that samples held in formalin did not vary in biomass as much as samples held in ethanol or Bouin. Figures 2 and 3 show the difference between the mudflat and mangrove assemblages. Note that the symbols are keyed differently in the two figures. Comparing the figures, the total biomass collected is lower in the mangrove than on the mudflat.

Mudflat benthos biomass is dominated by the Neriedae polychaete coded "dpin" (*Dendroneris pinnaticirrus*). Combined with the other Nereidae polychaete coded "ngla"(*Neanthes glandicinta*) and the Sabellidae polychaete coded "plep" (*Potamilla leptochaetal*), these three large polychaetes comprise more than 80% of the biomass on the mudflat. The tiny bivalve *Psuedopythina maipoensis* is the most abundant animal in mudflat samples. Each individual is less than 2mm long, but occur in densities up to about 90,000 per square metre, and comprise as much as 17% of the biomass. This bivalve is commensal with the polychaetes, living within the worm's burrow (Morton and Scott, 1989).

The channel levee sites were sampled in January 1994. Figure 3 illustrates that the biomass is very low on the channel levee (sites CH1 and ET3). A high proportion of the biomass collected on the channel levees is comprised of small *Ilyoplax spp.* crabs with carapace widths generally less than 10 mm . Because these crabs are very small with respect to the core sampler's volume,it is possible to catch them in the core samples.

Mangrove benthic biomass is dominated by the Iravidiidae gastropod coded "ibom" (*Iravadia bombayana*). The mangrove substrate is visibly burrowed by the fiddler crab *Uca sp.* and by *Chiromanthes bidens*, *C. maipoensis*, and *Parasesarma affinis* (Kwok,pers. comm.). Again,these crabs are too large and too mobile to be reliably caught in core samples, but probably comprise a large addition to the total biomass of bethos in the mangrove.

3.2 PREDATION PRESSURE

Bird exclosure work in February 1994 was successful in detecting a difference in the abundance of the bivalves coded "scon" (*Sinonovacula constricta*) and "tcfi" (*Theora cf. iridescens*) combined.

Samples of the bivalve *S. constricta* ("scon") collected were about 20 mm in length . Samples of *T. cf. iridescens* were just under 10 mm. Both these items are presumed to excellent bird food, similar in size to the *Macoma sp.* harvested by Red Knot *Calidris canutus* on the North Sea coasts (e. g. Dekinga and Piersma, 1993). Because these items require on handling as the birds swallow them whole, as opposed to crabs whose chaelae must be removed, or worms whose length needs to be extracted from the mud prior to consumption, bivalves are difficult to recognize as prey items during feeding observations, and thus may be overlooked. Dissection of the guts of shorebirds found dead at Mai Po Marshes Nature Reserve confirms the presence of shell hinges in large numbers, indicating that bivalves are consumed (McChesney, unpublished).

4 DISCUSSION-COMPARISON WITH OTHER MUDFLATS

Piersma *et al.* (1993) present a comparison of total biomass and taxonomic composition for 19 intertidal soft sediment shores around the world. The mudflats of Deep Bay have by far the highest proportion of polychaete worms of any Bay polychaetes, and this family of worms does well on organically enriched waters elsewhere.

5 POLLUTION GRADIENT

Deep Bay is heavily polluted with organic waste from livestock farm as well as human sewage (Anon, 1988; annual EPD water quality reports). Chiu (1992) describes the differences in mangrove benthic fauna along a transect between Yuen Long Creek and a point near the LA-LK mangrove stations in this study (see Figure 1 for location). Chiu (1992) found that polychaetes, oligochaetes,and gastropods are statistically significantly more abundant adjacent to the polluted Yuen Creek than the relatively less polluted site. This is consistent with biostimulstion as described by Pearson and Rosenberg (1978), where increased organic food leads to an increase in consumers. Chiu (1992) also found that amphipod crustaceans were absent from the more polluted site, and interpreted that as evidence that amphipods may be a toxicant-sensitive group,as suggested by Reish and Barnard (1979).

However, in a study of heavy metals in Deep May polychaetes, Tsang (1993) found that the abundance of mudflat Nereidae *Dendronereispinnaticirrus* (coded "dpin") polychaetes decreased towards Yuen Long Creek. Average body size increased in the same direction.

Increased organic pollution loading favors the presence of opportunistic species, and they tend to be small (Pearson and Rosenberg, 1978). There is a trend of increasing small-sized Capitellidae worm abundance on the mudflat towards the Shenzhen River channel (stations 450 to ET4 to ET2 to ET1) where organic pollution loadings from the Shenzhen River are most concentrated. Capitellidae worms are accepted as pollution indicator species (Green *et al.* 1992). The two channel levee stations,however, contain variable Capitellidae abundance and do not fit to the pollution gradient model. The high Capitellidae abundance in channel levee sample CH1 could be owing to the access of polluted water from the Shenzhen river up the intertidal channel, but this fails to explain the lower abundance of Capitellidar at the ET3 station,itself also a channel levee.

The survey result illustrates that the avaerage body size of the polychaete *Dendronereis pinnaticirrus* (coded "dpin") in the mudflat, which comprises more than 80% of the biomass, decreases towards the Shenzhen River mouth . The increaed organics available there stimulate the mudflat and support many more individuals. Perhaps competitive exclusion explains the observation that the individuals are stunted . Alternatively,the assemblage close to the river mouth may represent a younger cohort.

6 CARRYING CAPACITY OF THE MUDFLAT

Predator exclusion manipulations are fraught with difficulties, and results often appear counter-intuitive and are difficult to interpret. A recent paper by Kalejta (1993) provides an introduction into the problems and successes of predator exclusion manipulations. Some of the practical problems in predator exclusion manipulations include: 1) other predators (e. g. crabs, fish at high tide) exploit the protection that the cage affords them and increase in abundance within the cage, and their increased density depletes the invertebrates within the cage,reducing the difference between numbers of prey inside and outside the cages; 2) invertebrate prey species move out of the cages and may get eaten, tending to reduce the difference in invertebrate abundance inside and outside the cages; 3) birds enter the cages and reduce the number of prey within the cages; 4) juveniles are either attracted to or kept away from the cage area, thus altering the abundance of animals inside and outside the cages.

Attempts are made in the present exclusion manipulations to reduce these problems. Cages are re-sampled after only two weeks to reduce the amount of other, confouding predators taking refuge in the cages and masking the predation effect of birds. Still, burrow densities appear elevated inside the cages after tow weeks to dimensions are 5 metres on a side to tend to reduce the numbers of invertebrate prey emmigrating, and cages are sampled close to the center. Watching bird behavior around the cages indicates that birds are deterred from the cages: foraging individuals will turn around and walk the other way when they encounter a cage. Nevertheless, Black-headed Gulls *Larus ribibundus* occasionally have been seen fluttering down in flight to take prey from inside the cages, egret footprints have been recorded from inside two cages, and wader-sized bird droppings have been seen inside some cages. Still, the overall predation pressure is much greater outside the cages than within, and the experimental design is statistically powerful enough to detect an effect. The problem with birds preying within cages only means that the birds are actually eating more than we can measure. Biomass comparisons within and outside cages abundance within versus outside cages. The biomass analysis is incomplete.

If the difference between cage and control areas in the February exclusion work is presumed to be owing to predation, it appears that birds consume as many bivalves as they can find. Survey result shows no bivalves whatsoever outside the cages in the control areas while samples from inside the cages contained at least one of these bivalves in 6 of the 8 cages. Comparing the total prey consumed by birds with the total amount of food produced by the prey species is another way to evaluate the carrying capacity of the mudflat. Contained at estimates are being refined and are not presented here. The biomass produced by the 9 species comprising between 75% and 95% of the standing crop biomass in every month of previous data collection has been calculated separately (McChesney, unpublished) using the methods of Crisp (1971). The production amounts to 42. 6 g AFDW per square metre per year. This productivity figure will increase with the AFDM data for crabs generated during the EIA project. Mudskipper productivity data (Chan, 1989) and crab productivity data is not included in the existing calculation.

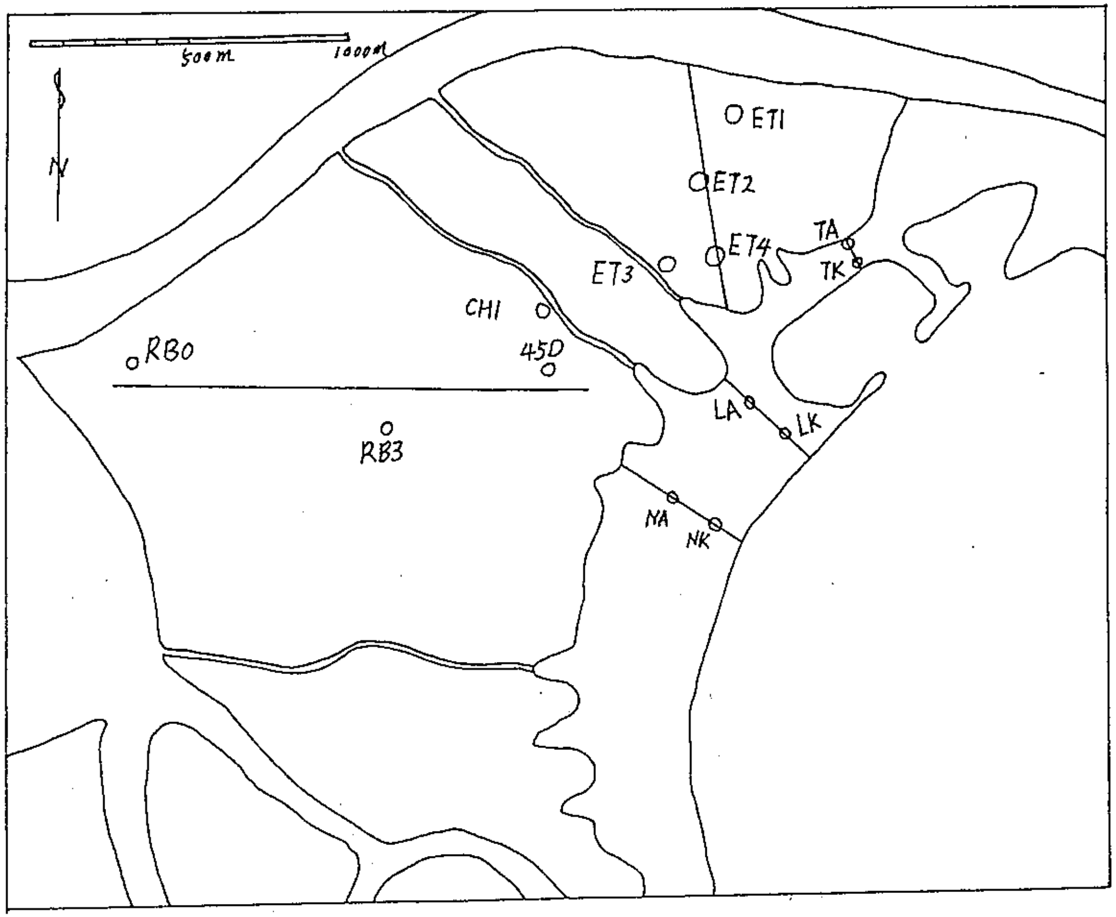

Fig. 1 Survey Station Locations of Invertebrete Study in Mai Po

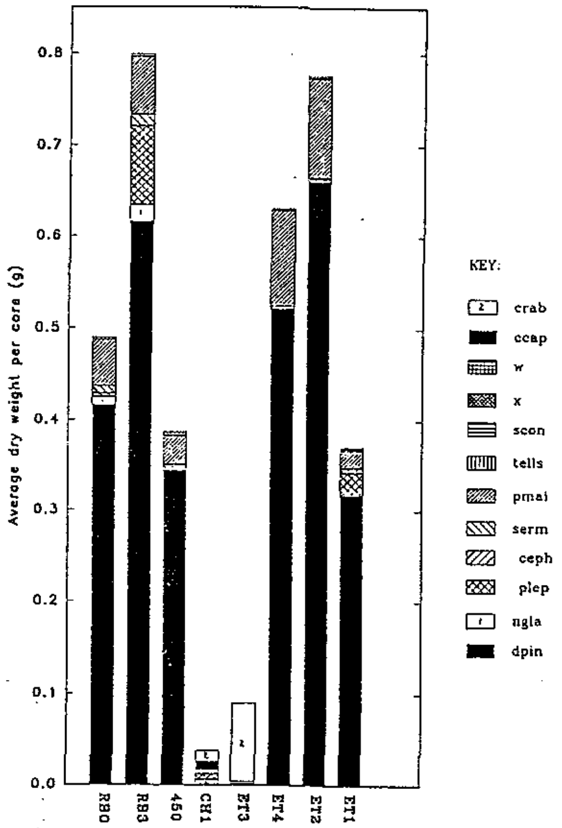

Fig. 2 Distribution of Biomass Across mudflat

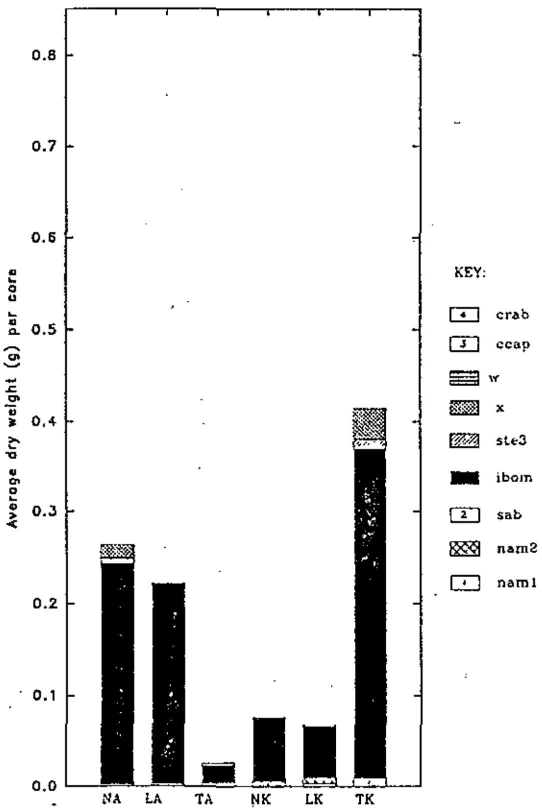

Fig. 3 Distribution of Biomass Across Mangrove

APPENDIX 9.10 INTERIM REPORT OF WADER POLULATION SURVEY RESULTS

1 INTRODUCTION

The Shenzhen River Regulation Project may result in changes to the mudflats of Inner Deep Bay, together with the benthic invertebrates which inhabit them. This in turn may affect the ' carrying capacity ' of Deep Bay for shorebirds. In order Deep Bay in spring. Counts have been conducted at minimum frequency of once every three days from 15 March 1994 . This report covers the period to 30 April 1994.

2 METHODS

Spring 1994 was unusual in that until about 23 April, few of the waders in Deep Bay were roosting on the Mai Po Nature Reserve at high tide. After which date large numbers were to be found roosting on the Reserve at high tide. In recent years the majority of waders at Mai Po roosted at high tide, on the specially managed area known as 'the Scrape '. As a result of birds not roosting on the Scrape at high tide much of the counting had to be undertaken from the Boardwalk Hide, on either a rising or falling tide, usually the latter . The effects of this on the completeness of the counts is unclear, although a coordinated count on 8 April from the Boardwalk Hide and the two Mudflat Hides indicates that some species may have been under counted by up to 30% . A more detailed account of numbers will prepared following completion of the spring fieldwork.

3 RESULTS

A total of 37 species have been recorded on the counts up to the end of April (table 1). Count data for the sixteen most numerous species are reproduced in Figures 1 (1-16). Maximum counts of the 9 commonest waders during spring migration 1990-1994 are provided for comparison in Table 1.

1) Avocet *Recurvirostra avosetta*:
The high numbers present until late March represent the remnants of the wintering flock which had peaked at a record 926 on 25 February. Most birds had departed by about 8 April, and there was no evidence of passage.

2) Kentish Plover *Charadrius alexandrinus*:
A similar situation to Avocet with the high numbers early on referring to the last of the wintering population and with little or no passage.

3) Greater Sandplover *Charadrius leschenaulti*:
There was a very slow increase in numbers until the first peak in late March, followed by the main arrival 8 to 14 April, with apparently a large departure prior to 17 April. This was followed by a smaller influx in the third week of the month.

Table 1. List of wader species recorded on the spring wader counts 15 March to 31 April

Avocet	*Recurvirostra avosetta*	Oriental Plover	*Glareola maldivarum*
Kentish Plover	*Charadrius alexandrinus*	Lesser Sand Plover	*Charadrius mongolus*
Greater Sand Plover	*Charadrius leschenaultii*	Pacific Golden Plover	*Pluvialis fulva*
Grey Plover	*Pluvialis suatarola*	Great Knot	*Calidris tenuirostris*
Red Knot	*Calidris canutus*	Sanderling	*Calidris alba*
Red-necked Stint	*Calidris ruficollis*	Little Stint	*Calidris minuta*
Long-toed Stint	*Calidris subminuta*	Sharp-tailed Sandpiper	*Calidris acumita*
Curlew Sandpiper	*Calidris ferruginea*	Dunlin	*Calidris alpina*
Spoon-billed Sandpiper	*Eurynorhynchus pygmaeus*	Broad-billed Sandpiper	*Limnicola falcinellus*
Ruff	*Philomachus pugnax*	Common Snipe	*Gallinago gallinago*
Asiatic Dowitcher	*Limnodromus semipalmatus*	Black-tailed Godwil	*Limosa limosa*
Bar-tailed Godwit	*Limosa lapponica*	Whimbrel	*Numenius phaeopus*
Eurasian Curlew	*Numenius arquata*	Eastern Curlew	*Numenius mafagascariensis*
Spotted Redshank	*Tringa erythropus*	Common Redshank	*Tringa totanus*
Marsh Sandpiper	*Tringa stagnatilis*	Greenshank	*Tringa nebularia*
Nordmann Greenshank	*Tringa guttifer*	Wood Sandpiper	*Tringa giareola*
Terek Sandpiper	*Xenus cinereus*	Common Sandpiper	*Actitis hypoleucos*
Grey-tailed Tattler	*Heteroscelus brevipes*	Turnstone	*Arenaria interpres*

Red-necked Phalarope *Phalaropus lobatus*

Table 2. Comparison of maximum counts of waders during spring migration (1990-1994)

Species	1990	1991	1992	1993*	1994
Greater Sandplover	600	100	2000		630
Great Knot	300	305	150		463
Red-necked Stint	1000	500	484		1000
Curlew Sandpiper	6000	2500	4000		5640
Black-tailed Godwit	1800	1200	1500		2000
Spotted Redshank	975	1000	1440		1688
Common Redshank	950	360	1845		3470
Marsh Sandpiper	2500	850	1700		1063
Greenshank	800	130	1470		800

* data currently awaited from Hong Kong Birdwatching Society

4) Lesser Sandplover *Charadrius fulva*
Very small numbers present in March with the main arrival coming in late April, although a lesser peak occurred around 10 April.

5) Pacific Golden Plover *Pluvialis fulva*
The March totals may refer to the wintering population, but with no records in the first week of April all subsequent numbers are considered to refer to migrants.

6) Great Knot *Calidris tenuirostris*
The marked influx on 27 March coincided with a period of very strong easterly winds. The count of 463 on that date is the highest ever in Hong Kong . The clear decrease in numbers coupled with no subsequent arrivals of note indicates that the majority of the birds stayed for 10 days or less. This species apparently usually migrates non-stop from North-west Australia to the Shanghai area non-stop (Barter and Wang 1990). The arrival of large numbers associated with easterly winds suggests that the birds may have suffered from a lack of tail winds (c. f. Melville 1980, McChesney, Tulp et al in prep.) to carry them to the Yangtze estuary and thus used Deep Bay to 'refuel'. The fact that the birds apparently remained in Deep Bay for less than ten days suggests that they may have only fed sufficiently to fly to the Yangtze estuary. Piersma and van de Sant (1992)found that the verdee area in France played a vital role as a resting/refuelling site for Bar-tailed godwits migrating from the Banc d'Argain, to the Wadden Sea in years when tail-wind assistance was reduced by unusual conditions, so that the birds were unable to complete the journey in one stage. It os possible that Deep Bay in addition to supporting large numbers of regular passage migrants, may also play an important role in providing a 'short-stop' for those species which usually overfly the area at times of adverse weather conditions.

7) Red-necked Stint *Calidris ruficollis*
The large numbers on 14 April apparently indicates a major arrival around that time. However this may be one of the species whose true status is obscured due to counts being conducted from the Boardwalk hide. This species often forages actively on the high tide roost site and as such may arrive on the newly exposed mud later than other species, thus making counting more difficult.

8) Curlew Sandpiper *Calidris ferruginea*
Numerically the most abundant wader . Apparently three major arrivals occurred, on or about 8, 14 and 23 April. On 8 April coordinated counts from the Boardwalk hide the two Mudflat Hides were undertaken . The count for this species from the Boardwalk Hide (ie the usual counting station) was 3300. Observations from the Mudflat Hides however showed that at least 4500 were present on the inter-tidal mudflats. The difference highlights the shortfall in some of the counts in spring 1994 . The arrival of new birds on or about 14 April was confirmed by a wader ringing catch on 11 April when most birds were light with little or no fat.

9) Black-tailed Godwit *Limosa limosa*
A gradual increase up to 8 April after which the picture is completely obscured by birds changing roosting sites and while

there were apparently large numbers still present in Deep Bay, these were not visible from the Boardwalk Hide.

10) Eurasian Curlew *Numensis arquata*
The large numbers present in March,refer to the last of the wintering population. There is evidence of small numbers of migrants in April.

11) Spotted Redshank *Tringa erythropus*
A similar situation to Black-tailed Godwit,with the pattern becoming obscured in early April due to a sudden change in behavior of the birds, with large numbers apparently still present in Deep bay on days when none were recorded from the Mai Po Nature Reserve.

12) Common Redshank *Tringa totanus*
Prior to this spring the highest number recorded in Hong Kong was 1800. This spring there were three counts of over 2000 with a peak count of 3474 on 29 April. The almost complete lack of birds on 20 and 22 April is probably due not to a massive departure but more likely a result of problems similar to those experienced with Black-tailed Godwit and Spotted Redshank.

13) marsh Sandpiper *Tringa stagnatalis*
Large numbers present in March, with an apparent large departure in early April and a second passage in mid-April.

14) Greenshank *Tringa nebularia*
Two clear passage periods,one in the third week of March and a larger one a month later. There is no evidence to suggest that the low numbers present between the two peaks is due to birds roosting elsewhere and not being visible from the Boardwalk Hide.

15) Turnstone *Arenaria interpres*
The 268 present on 22 April is the highest recorded in Hong Kong.

16) Terek Sandpiper *Xenus cinereus*
Two separate passage periods with a large arrival occurring in late April.

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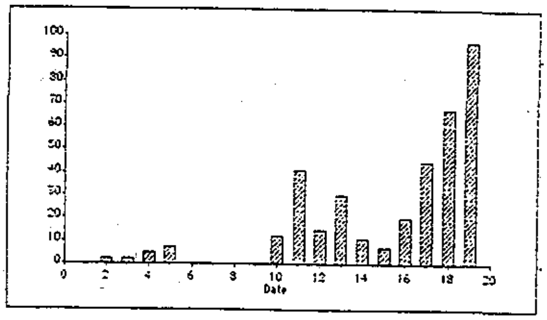
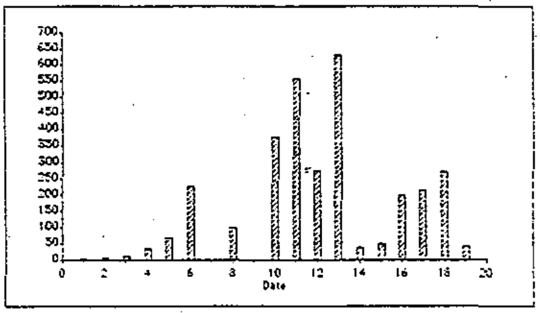
Piersma, T. and van de Sant, S. 1992 Patterns and predictability of potential wind assistance for waders and geese migrating from west Africa and Wadden Sea to Siberia. Ornis Svecica 2:55-66.

Melville, D. 1980 Bird migration through Hong Kong observed by radar and its implications for birdstrike control. Agriculture and Fisheries Department, Hong Kong (duplication).

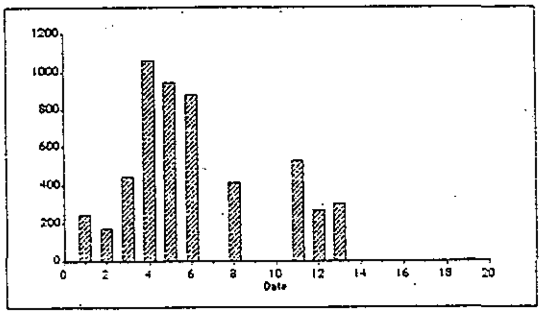
Fig. 1 Bird Survey Results of Mai Po



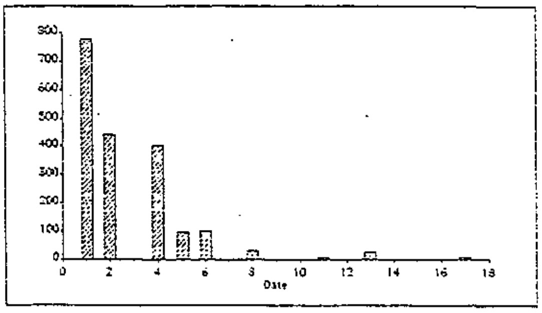
(1)Lesser Sand Plover



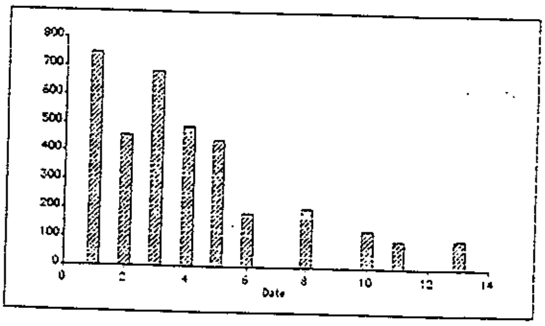
(2)Greater Sand Plover



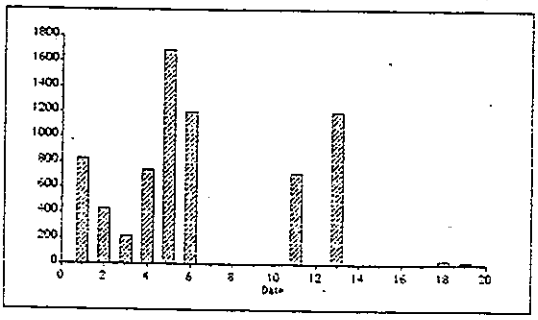
(3)Marsh Sand Plover



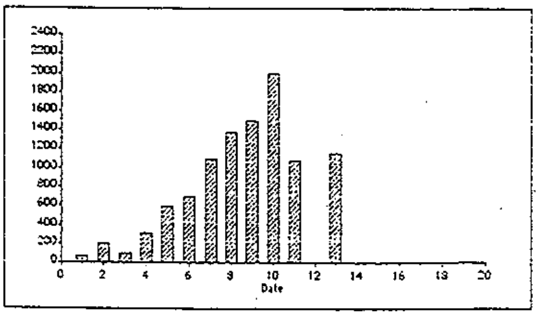
(4)Kentish Plover



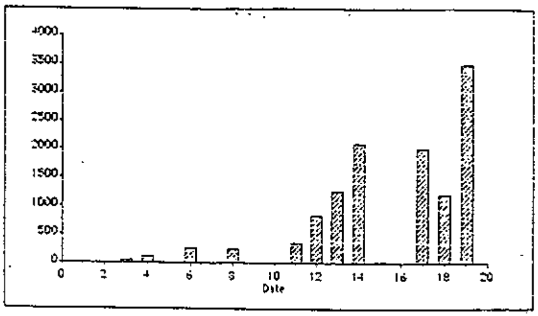
(5)Avocet



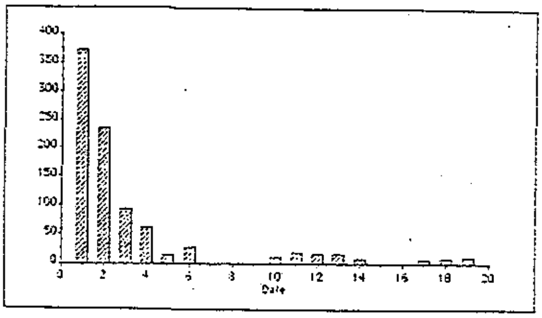
(6)Spotted Redshank



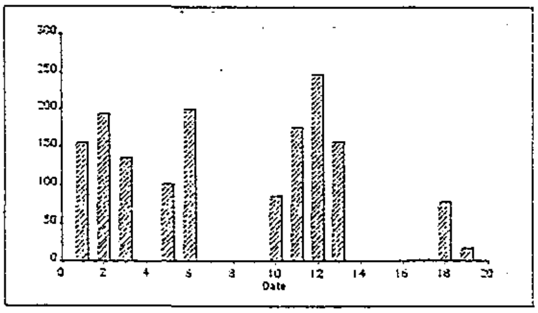
(7)Redshank



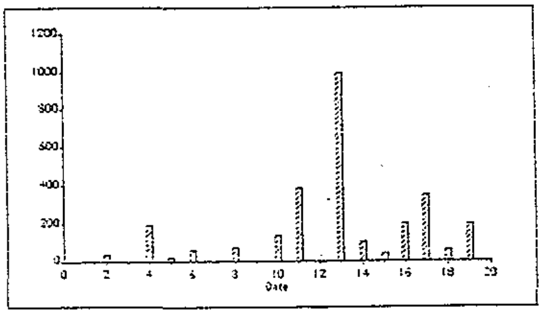
(8)Black—tailed Godwit



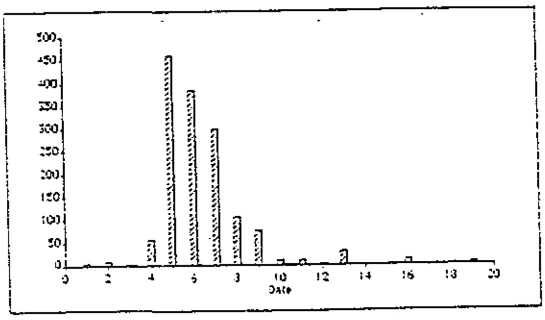
(9)Eurasian Curlew



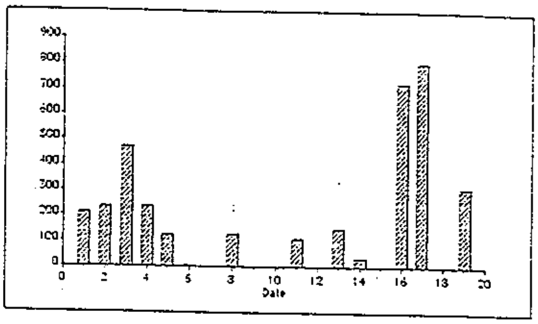
(10)Pacific Golden Plover



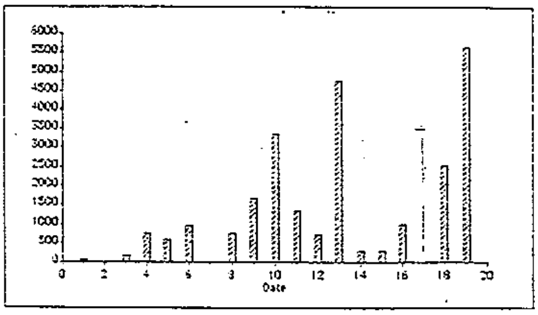
(11)Great Knot



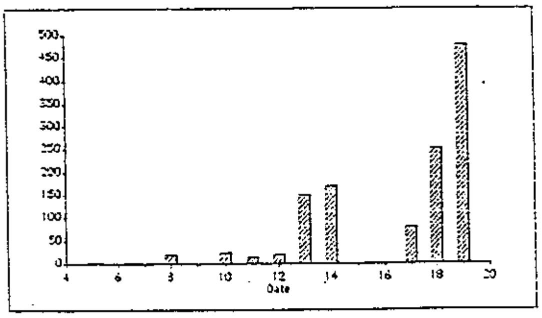
(12)Red—necked Stint



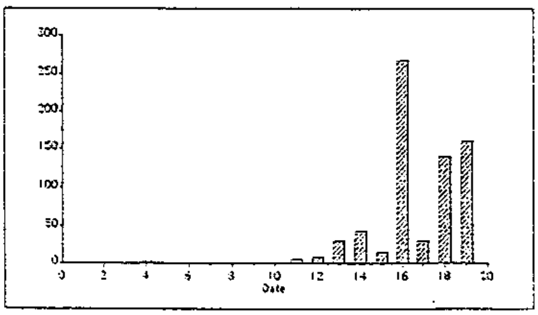
(13)Curlew Sandpiper



(14)Greenshank



(15)Turnstone



(16)Terek Sandpiper

APPENDIX 9.11 INTERIM REPORT ON DUCK AND WADER DISTRIBUTION IN DEEP BAY

1 INTRODUCTION

The proposed Shenzhen River Regulation Project may result in changes to the mudflats of Inner Deep Bay, together with the benthic invertebrates which inhabit them. Deep Bay is an important refuge for wintering waterfowl and migratory shorebirds. The aims of this survey are to establish the distribution of feeding waterfowl and shorebirds on the mudflats on the Hong Kong side of Deep Bay.

2 DUCK DISTRIBUTION

2.1 Methods

Observations were conducted from two hides on the mudflats on the Hong Kong side of Deep Bay. The observer arrived by boat at high tide and departed at the next high tide. Night time observations proved to be extremely difficult due to the limitations of the night-time viewing device,although it would appear that very few duck are in Deep Bay at night. Daytime tides were selected to give as much observation time as possible . The position of all duck in Deep Bay was mapped at least once per hour. Species composition, number,and activity were all recorded.

2.2 Results

There was a very marked concentration, at all times, along the tide line with the duck moving up and down the mudflats with the tide. At low tide the duck stopped foraging and stood/walked on the exposed mud either roosting or preening. They resumed feeding once the tide turned and followed the tide up the mudflat,finally reaching the mangrove edge where they continued to forage.

There was a notable concentration at the southern end of Inner Deep Bay, however as the tide was falling or rising the distribution away from this concentration was fairly even. Disturbance was minimal with birds being disturbed on one occasion by a Black Kite *Milvus migrans*.

3 Wader Distribution

3.1 Methods

The methods used for mapping duck distribution were the same as those used for mapping duck distribution,but with additional observations from the Boardwalk Hide. Night-time observations were also problematic. However waders are vocal at night and limited night-time observations coupled with the intensity of wader calls at night indicates considerable night-time activity.

3.2 Results

There was a very distinct difference in distribution between the wintering birds and the migrants. See figures XX to XX. The bulk of the wintering population consists of a flock of about 6,000 Dunlin *Calidris alpina* and Kentish Plover *Charadrius alexandrinus*. Large numbers of both were often to be found foraging,irrespective of tide height (except at high tide),200-500m out from the mangrove edge in front of the Boardwalk Hide.

The spring migrants on the other hand were found to forage more actively along the tideline often moving rapidly with a swiftly rising or falling tide. At low tide,the mudflat in front of Mai Po (Oysterbed #5) was often almost deserted, with the birds having flown further out into Deep Bay.

Disturbance was far greater than was observed for duck. The main source of disturbance came from avian predators such as Peregrine Falcon *Falco peregeinus* and Black Kite *Milvus migrans*. On one occasion widespread disturbance was caused by a barge playing loud music.

4 DISCUSSION

While initial results indicate certain preferred areas for both waders and duck, the fact that duck and spring waders forage over a wide area as the tide is moving indicates that the whole of the mudflat is important as a foraging area for these species.

APPENCIX 9.12 INTERIM REPORT ON SHENZHEN RIVER BIRD SURVEY

1 INTRODUCTION

The Shenzhen River Regulation Project will result in the destruction of both banks of the River together with areas of land adjacent to the River. The Hong Kong side of the river between Lo Wu and the river mouth is being surveyed to determine bird populations and their habitat requirements in the area.

2 METHODS

The area along the Hong Kong side of the Shenzhen River between Lo Wu and the river mouth is mapped and counted twice per month. The area is covered on foot and on bicycle. The area has been divided into 1 km squares (Figure 1), and all wetland birds and raptors (table 2) in each square are recorded. Care is taken not to duplicate individuals,especially where raptors are concerned. Birds passing overhead and not considered to be actively 'using' the area are not recorded. A list of all species recorded in the area appears on table 1.

Table 1 List of Waterfowl and Raptors Mapped And Counted Along Shenzhen River

Little Grebe	*Tachybaptus ruficollis*	Cormorant	*Phalacrocorax carbo*
Night Heron	*Nycticorax nycticorax*	Chinese Pond Heron	*Ardeola bacchus*
Cattle Egret	*Bubulcus ibis*	Little Egret	*Egertta garzetta*
Intermediate Egret	*Egertta intermedia*	Great Egret	*Egertta alba*
Grey Heron	*Ardea cinerea*	European Spoonbill	*Platalea leucorodia*
Black-faced Spoonbill	*Platalea minor*	Wigeon	*Anas penelope*
Teal	*Anas cercca*	Crested Honey Buzzard	*Pernis ptilorhynchus*
Black Kite	*Milvus migrans*	Serpent Eagle	*Spilornis cheela*
Crested Goshawk	*Accipiter trivirgatus*	Buzzard	*Buteo buteo*
Spotted Eagle	*Aquila clanga*	Imperial Eagle	*Aquila heliaca*
Kestral	*Falco tinnunculus*	Peregrine	*Falco peregrinus*
Whitebreast Waterhen	*Amaurornis phoenicurus*	Coot	*Fulica atra*
Painted Snipe	*Rostratula benghalensis*	Black-winged Stilt	*Himantopus*
Little Ringed Plover	*Charadrius dubius*	Temminck's Stint	*Calidris temminckii*
Common Snipe	*Gallinago*	Green Sandpiper	*Tringa ochropus*
Wood Sandpiper	*Tringa glareola*	Common Sandpiper	*Actitis hypoleucus*
Black-headed Gull	*Larus ridubundus*		

Table 2. Waterfowl at Ma Tso Lung Compared to Deep Bay-January Waterfowl Counts 1990 - 1994

Year	Ma Tso Lung	Deep Bay	%
1990	6850	37891	18. 1
1991	3504	48784	7. 1
1992	3007	46911	6. 4
1992*			
1994*			

* Data currently awaited from Hong Kong Birdwatching Society

3 HABITAT

The section of the Shenzhen River between Lo Wu and the river mouth is highly polluted with organic material. The river is tidal and mud banks are exposed at low tide. The habitat bordering the river is predominantly fish and duck ponds with fish ponds predominating between Mai Po and Lok Ma Chau,and duck ponds between Lok Ma Chau and Lo Wu. In the area north of Ma Tso Lung, there are large areas of *Phragmutes* reedbeds and wet grassland,eg at Liu Pok. Some ponds have been abandoned, and are becoming overgrown. The area north of Ma Tso Lung due to its greater diversity of habitat types, attracts a greater variety of bird species.

4 RESULTS

The distribution and counts of the species recorded are shown in table 3.

Table 3 Distribution and Counts of the Bird Species Recorded Along Shenzhen River*

Site	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
A2	CPH(2) LG(1)	LG(1) CPH(4)	CPH(2)			
B2	CPH(2) C(62) LE(320) GE(121)	LE(450)	CPH(1) CE(5) LE(490) IN(1) GE(3) GH(1) CS(1)	CPH(3)LE(8) ES(1) BFS(20) LRP(2)	CPH(4) LRP(1)	
C2	LE(1) GE(1)			CPH(2) LE(4)		
C3	CPH(1) LG(1) C(1)	LG(1) CPH(3)	CS(2)	LE(4) GS(1)		CPH(1) CE(41) LE(3) GE(3)
C4					CPH(2) CE(12) GE(1) LE(1)	
D3	GH(1) LG(1) C(3) T(8)	LG(4) CPH(5)	CPH(3) LE(3) GE(3) BK(1)	C(7) CPH(4) GE(4) BK(10) IE(1) LRP(4)		
E3			NH(8)	LG(2) CPH(10) GS(1)	CPH(4) GH(1)	CPH(3) WBW(2)
E4	CPH(2) LG(2) T(16) LE(1)	LG(2) CPH(7)	C(30) LE(10) GE(3) GH(5)	LG(2) C(14) LE(15) LRP(3)		CE(1)
F3			WBW(1) PS(1)	CPH(5)		
F4	P(1) CHB(1) P(1)	LG(4)	IE(1) WBW(2) LRP(6)	WS(60)	BK(1) P(1) WBW(1) GS(1)	CPH(3) CE(1) BK(3) CS(2)
F5	CPH(5) GH(14) C(60) T(2) LE(1) BHG(230)		LE(12) GE(4) GH(11) T(190) K(1) TS(6) WS(46) BHG(10) W(16) S(13)	LG(2) CE(2) GH(34) T(35) LRP(5) TS(4) CS(5)		CPH(5) NH(11) CE(33) LE(4) GH(4) BWS(1) CS(3)
G5	GH(24) LG(2) T(50) IE(2) BHG(60)	GH(45) T(70) BK(20) BHG(150)	CPH(5) E(1) CG(1) IE(5) BHG(250)	C(37) GE(3) GH(76)		BSK(1)
H5			IE(1)			

* LG: Little Grebe C: Cormorant CPH: Chinese Pond Heron LE: Little Egret
GE: Great Egret GH: Grey Heron Teal CHB: Crested Honey Buzzard BK: Black Kite
SE:Serpen Eagle B: Buzzard IE: Imperial Eagle K: Kestral
P: Pevegrine CO: Coot LRP: Little Ringed Plover BG: Black-headed Gull
NH: Night Heron CE: Cattle Egret IN: Intermediate Egret CG: Crested Goshant
WBW: White-brested Waterhen PS: Painted Snipe TS: Temminck's Stint
CS: Common Sandpiper WS: Wood Sandpiper W: Wigeon
S: Shoveller ES: European Spoonbill BFS: Black-faced Spoonbill
GS: Green Sandpiper BSK: Black-shouldered kite BWS: Black-winged Stint

5 DISCUSSION

The river itself and its bank are apparently hardly used by the birds in the area. Only small numbers of Black-headed

Gulls *Larus ridibundus* and Chinese Pond Herons *Ardeola bacchus* were observed searching for food in the river near Lo Wu,otherwise no habitat utilization of the river was recorded. Both species were probably scavenging since the River is effectively 'dead' in the upper reaches (McChesney,unpublished).

The fish and duck ponds hold low densities od herons and egrets. Recent studies (Britton 1992,Wong 1991, Young 1994) have shown that fish ponds are an important feeding habitat for Little Egrets and Chinese Pond Herons in the northern New Territories, and loss of such habitat has been severe in recent years, further losses could adversely affect the breeding populations of herons and egrets.

Recent studies indicate that freshly drained ponds are the most important habitat type for feeding Black-faced Spoonbills *Platelea minor* (Leader unpublished). 24% of the world population of Black-faced Spoonbills currently winters in Deep Bay . The ponds in the Deep Bay area are drained at random throughout the winter. When freshly drained these ponds attract feeding groups of up to about 30 individuals. Given the dependence of Black-faced Spoonbills on freshly drained ponds, the loss of even a small area of ponds could have a major impact on the wintering population of Black-faced Spoonbills in Hong Kong. Egrets and herons also feed in high densities on freshly drained ponds.

Small numbers of duck,mainly Teal Anas crecca were recorded on the abandoned ponds near Ma Tso Lung,these are small when compared to the overall numbers in Deep Bay,however the Ma Tso Lung area does hold a significant percentage of the waterfowl recorded on the annual January mid-winter waterfowl count (see Table 2)with up to 18% of the Deep Bay total present in the area. The area is therefore considered to be of importance for its wintering waterfowl as well as Imperial Eagles Aquila heliaca(see below).

The duck ponds in particular, appear to attract the large numbers of Imperial Eagles that were present in the area in February and March. Up to seven were present, representing the entire wintering population in Hong Kong. It is noteworthy that no Imperial Eagles were recorded from China during the January 1992 mid-winter waterfowl count (Perennou and Mundkhur 1992) despite the fact that other raptors were recorded on these counts. It is therefore highly likely that the numbers of Imperial Eagles in the Ma Tso Lung area of regional importance. The birds may be feeding on sick or dead domestic ducks.

The reedbeds are used by large numbers of migratory warblers eg. Great Reed Warbler **Acrocephalus orientalis**. Studies at Mai Po have shown the reedbeds there to be a very important stop-over site for migrant warblers (WWF HK,unpublished data). It should be noted that the reedbeds around Deep May are considered to be the largest remaining in the Guangdong area (Gao Yu Ren in litt. to L Young).

Very little habitat usage by waterfowl of the wet grasslands and abandoned ponds was recorded. However it is considered that these areas are potentially the most significant for breeding birds in the area. Indeed the area as a whole may be of more importance for its breeding rather than its wintering birds. Suitable habitat exists for species such as Watercock *Gallicrex cinerea*, Pheasant-tailed Jacana *Hydrophasianus chirurgus*, and Painted Snipe *Rostratula benghalensis*, species either very rare or locally extinct as breeding birds in Hong Kong. The breeding birds will be surveyed during the summer fieldwork.

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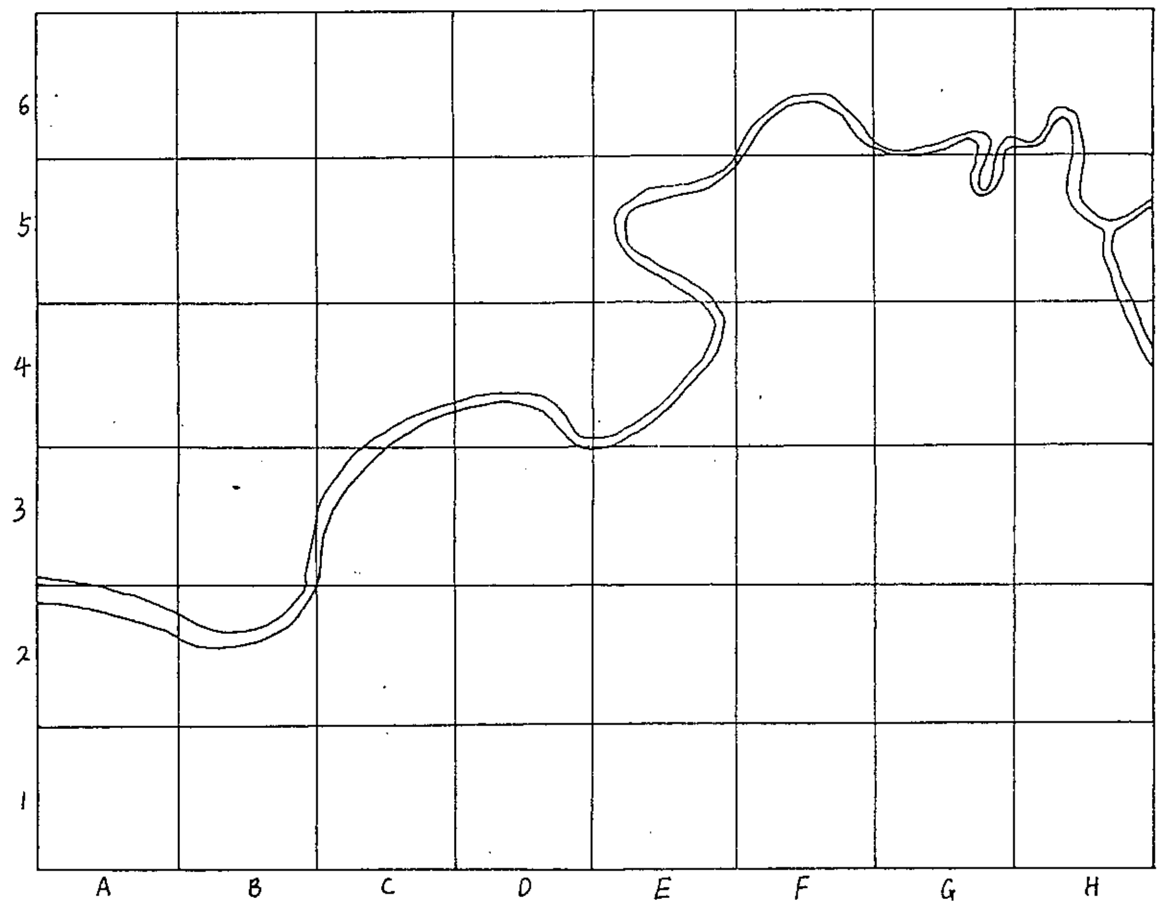

Fig. 1 Bird Counting Area of Shenzhen River

APPENDIX 10.1 PUBLIC OPINION SURVEY

In order to gain an understanding of the opinions of residents along Shenzhen River toward Shenzhen River Regulation Project, a [semi-sealed] questionnaire was designed and used in a public-opinion survey conducted in riverside areas on the Chinese side of Shenzhen River.

1. METHODOLOGY

The survey consisted of three parts:

1) *Basic Information*
In addition to basic information on sex, age, income, profession and education, a survey was also made of the residential environment (e.g., nearest distance to Shenzhen River, length of time resident in Shenzhen Municipality)

2) *Behavioral Information*

This portion of the survey contained information on the socio-economic behavior of the individuals surveyed. This included such information as increased expenditure caused by impacts from Shenzhen River and desire to pay to move away from riverside areas.

3) *Attitudinal Information*

This covered past, present and future opinions, interest, resentment and evaluations of Shenzhen River by the individuals surveyed: for example, degree of satisfaction with the existing living environment.

As the contents of the questionnaire were regionally sensitive, the survey employed a small-area sampling method, selecting households residing close to Shenzhen River as respondents and taking the Lo Wu and Futian Districts as the main survey area. The format for completing the questionnaire was primarily completion by the individual surveyed, and included distribution of questionnaires from and collection at a central point (such as the "Sanfang" Office in Futian District and the Lo Wu Middle School), individual distribution and collection of questionnaires (e.g., distribution to individuals encountered in small residential areas), and questionnaires sent by post (some questionnaires which could not be completed at the time of distribution were received by post).

A total of 900 questionnaires were distributed for this survey and 567 completed forms were returned, for a return rate of 63%. 215 of those returned were valid questionnaires, for a validity rate of 37.9%.

2 ANALYSIS OF QUESTIONNAIRE

From the 215 valid questionnaires received, the basic composition of the individuals surveyed is shown in Table 1 below.

Table 1 Composition of Individuals Surveyed

Qualification	Male	Female	Civil Servant	Worker	Student	Sole Proprietor	Others
University Level	33	23	56				
High school level	82	77	10	9	131	6	3
Total	115	100	66	9	131	6	3
Percentage %	53.5	46.5	30.7	4.2	60.9	2.8	1.4

Increasing the flood-discharge capacity of Shenzhen River is the primary goal of Shenzhen River Regulation Project. The results in Table 2 show that residents in the riverside areas of Shenzhen

River who are directly or indirectly affected by flooding constitute a majority of the total, while impacts among residents living within 300 m of the river are particularly marked.

Table 2 Residents Affected by Flooding of Shenzhen River in the Past Five Years

Distance	Staying period		Direct	Indirect	Direct & indirect	No effect	% of no effect
	< 10 years	> 10 years					
Within 300m	96	13	40	45	13	11	10.0
Excess 300m	71	35	18	39	11	38	35.8

It was determined during the course of the study that the foul smell of Shenzhen River is a major issue affecting residents in the vicinity. Reactions expressed in the questionnaires were relatively strong, and once again were more so among residents living within 300 m of Shenzhen River (Table 3).

Table 3 Impact of Foul Smell of Shenzhen River on Residents in the Area

Distance	No effect	Effect on			% of effect
		Headache	Sick	Efficiencies decreased	
Within 300m	0	24	74	24	100
Excess 300m	6	15	52	10	94.3

Based on survey results, reactions to the issue of noise disturbance impacts from navigation on Shenzhen River were relatively small. In the responses regarding the most unsatisfactory environmental factors of residential surroundings, most individuals surveyed selected air pollution and noise pollution (Table 4). This may reflect to some degree the overall pollution situation of Shenzhen Municipality at present.

Table 4 Environmental Factors With Which Residents Were Most Dissatisfied

Distance	Air Pollution		Noise Pollution		Water Pollution		Green lands decreased	
		%		%		%		%
Within 300m	57	36.8	60	38.7	19	12.3	19	12.3
Excess 300m	48	32.9	55	37.7	20	13.7	23	15.7

3 IMPACT OF THE FOUL SMELL OF SHENZHEN RIVER

It was learned from the results of the questionnaire survey that the foul smell of Shenzhen River is the environmental problem which evoked the strongest reaction among residents of the area. Its effect on environmental comfort and the losses caused by it were analysed, with the results shown in Table 5. The methods used in calculating the concentration opinions is as follows:

First the raw data obtained through the survey is non-dimensionized according to the following formula to find non-dimension data X:

$$X = C/N \times 100$$

In the above formula, C and N represent number of the sample agreeing with the opinion and total survey sample number, respectively. Peak value frequency and opinion concentration are calculated based on the non-dimension data. They represent the frequency number of the most favorite choice among selected factors concentration of opinion, respectively.

Table 5 Analysis of Impact of Foul Smell of Shenzhen River on Environmental Comfort

		Headache	Sick	Efficiencies decreased	Greenlot decreased		
Within 300m	0	14.0	43.3	14.0	28.7	Sick	0.68
Excess 300m	5.7	14.2	49.1	8.4	21.7	Sick	0.88

It can be seen from the above table that nausea is the main impact of the foul smell. In addition, residents living over 300 m away from the river had a higher [concentration] of opinion than those living within 300 m, demonstrating that expression of the impacts of the foul smell of Shenzhen River on residents living nearer the river is even more complex.

The discomfort caused to riverside residents by the foul smell of the Shenzhen River has no direct market price. However, an awareness of people's willingness to pay for improvement of the smell may be obtained through surveys of those affected. The degree of people's reactions to the comfort of their living environment is related to such factors as education, state of health and social status. People with higher living standards are more willing to live in a relatively ideal environment; this fact increases the disparity between housing prices in clean areas and those in polluted areas. Consequently, residents' willingness to pay can be estimated from their desire to move to residential areas free from foul smell impacts. Owing to the restricted sample size of this survey, reference was made to the formula relating the willingness of urban residents in Guangzhou to pay for improved air quality and annual household income to describe the relation between residents' income level and willingness to pay. Formula for calculating the willingness to pay is showed below:

$$Y = 4.23 + 0.00125X$$

In the above formula, Y represents willingness to pay per household per month, while X represents annual household income.

Among the 215 individuals surveyed, 118 had annual incomes of less than 20,000 yuan, while 75 had incomes of between 20,000 and 50,000 yuan and 22 had incomes above 50,000 yuan. Weighted average annual income was 26,600 yuan. The willingness of riverside residents to pay was calculated using a regressive equation to be 37.48 yuan/month per household. Responses that indicated a willingness to move away from the area affected by the foul smell of Shenzhen River constituted 61.0% of the total (Table 10.6).

Given that the main areas affected by the foul smell of Shenzhen River are Lo Wu and Futian Districts, which two districts had a registered population in 1992 of 398,800 (with a non-permanent population of 532,700) and an average household size of 3.8 people for approximately 104,900 households, approximately 1/3 of these households (approximately 35,000 households) are along Shenzhen River. Therefore the willingness of residents along Shenzhen River to pay for improvement of the foul smell of Shenzhen River is:

37.48 x 12 x 3.5 x 61.0% = 9,602,400 yuan

Table 10.6 desire to Move in Order to Avoid Foul Smell of Shenzhen River

Household income per year (10,000/yr)				Willing to move out		
	<10%	>10%	N/A	NO	YES	
					Rent pay more (YES)	Rent pay more (NO)
Below $20K	56	57	2	46	58	14
20K - 50K	39	35	1	30	42	3
Over 50K	12	10	0	8	10	4
%				39.0	51.2	9.8
					61.0	

It can be seen that losses suffered by residents along Shenzhen River due to impacts from the foul smell of the river are approximately 10 million yuan. It should be noted that, due to a number of unavoidable factors, this estimate should only be used for reference on the order of magnitude.

4 PUBLIC OPINION EVALUATION

Regulation of Shenzhen River has been brewing for 10 years. The people of Shenzhen Municipality earnestly wish this project to commence as soon as possible. In response to the question over whether the project will improve the quality of life of people in Shenzhen and Hong Kong, 198 people or 92.1% felt that it would cause some or considerable improvement. It is clear that the residents along Shenzhen River have high hopes for the project. Public evaluation may be roughly categorised as follows:

1) The public welcomes the project and has high hopes for it.

2) There is a high degree of public concern over the project. A total of 106 questionnaire responses made suggestions on the implementation of the project. Sixteen of these were constructive suggestions and 90 were ordinary suggestions.

3) The public reaction to the foul smell of Shenzhen River is stronger than the public reaction to flooding. This is due to the fact that flooding generally occurs once in several years, and impacts of floods are reduced or eliminated within several months afterwards, while the impact of the foul smell is constant. Moreover, the impacts of flooding on residents is typically small, while its impact on industry, commerce, transportation and communications is great.

4) Construction during the latter stages of the project is also an issue of public concern. Analysis of the survey shows that some members of the public even proposed that, should funds for the project be insufficient, construction could be carried on through contributions from residents of the Municipality or by means of other loans. This demonstrates the degree of public concern over this issue.

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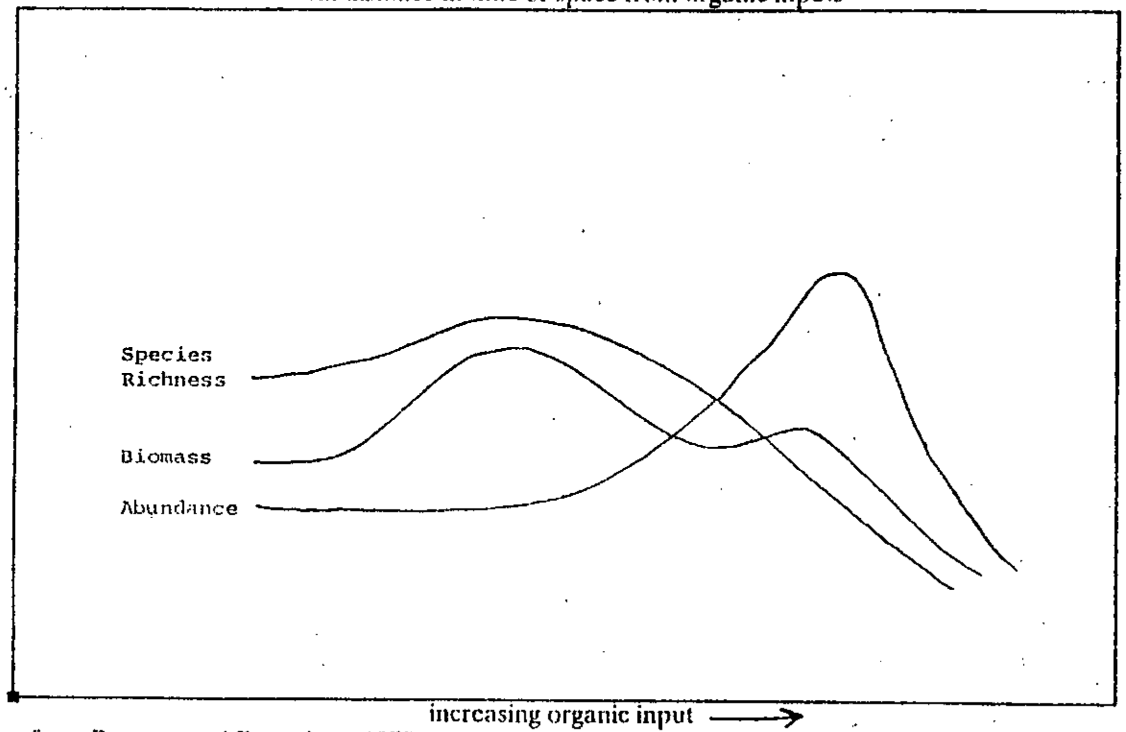
General Species Richness – Abundance – Biomass Curves
with distance in time or space from organic inputs



from Pearson and Rosenberg 1978.

From Pearson and Rosenberg (1978). General curves with distance in time or space from organic inputs. Increasing organic input towards right-hand side, to match the organic pollution gradient from left to right in the abundance and biomass figures (Figures 2, 3, 4, 5, 6, and 8).

Figure A10.9.19 General Species Richness - Abundance - Biomass Curves

A10.10 BENTHOS STUDY ON SHENZHEN SIDE

A10.10.1 Intertidal Mudflats

Deep Bay receives water from the Shenzhen River and the Shan Pui River and joins the Lingding Sea on its seaward side. The Bay is also influenced by flows from the Pearl River delta which are drawn into the Bay by coastal currents. Deep Bay has an area of 115 km^2. It is half enclosed and shallow, with an average depth of 2.9 m and an average capacity of 330 Mm^3 of sea water. From the southern part of the Bay a deep channel extends in an northeastly direction to Inner Deep Bay. The bottom of the Bay slopes seaward and is deeper in the south than in the north because of the existence of the channel. This may produce the results of complicated hydrological conditions in the Bay. The annual average tidal difference is 1.37m. The tide is influenced by the irregular mixed diurnal tide of the South China Sea, flowing oscillately.

Water temperature descends to 10-15°C from November to February because the Bay is impacted by the dry cold northeast monsoon, but salinity is still maintained at a higher level (26-32ppt). In summer, the Bay is affected by warm and rainy southeast monsoon and water temperature goes up to 28-32°C. Seasonal changes of cold are stronger in the shallow area. A lot of rain accompanies the southeast monsoon and Deep Bay receives a large amount of fresh water from rivers, so the salinity goes down to 5-15ppt. In July, the monsoon is the strongest and the salinity is the lowest, and the Bay almost reaches a fresh water state.

Intertidal mudflats on the Shenzhen side of the Bay are 1000-1600 m in width. The benthic sampling sites are shown in Figure A10.10.1..

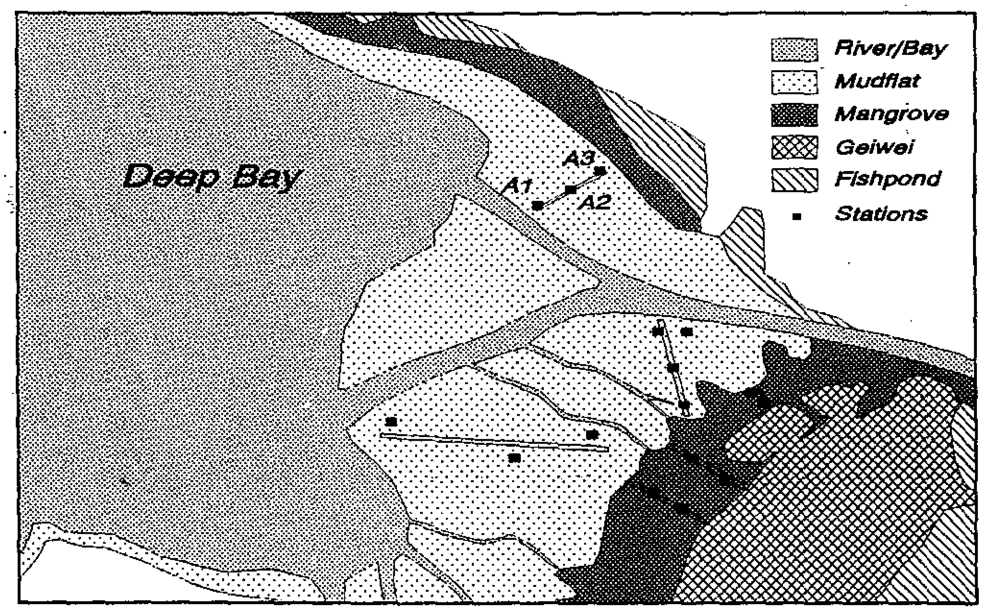


Fig. A10.10.1 Benthos sampling locations

A10.10.2 Resource and Community Structure of Benthos

Twenty species of benthos were sampled on intertidal mudflats on the Shenzhen side of the Bay during four occasions of sampling from February 1994 to September 1994(Table A10.10.1). Among them, 8 species of polychaetes, 7 species of crustacea, 8 species of molluscs, 1 species of worm and 1 species of fish. Echinodermata were not found during the investigation. Results of the investigation showed that the organic carbon content of intertidal mudflats on the Shenzhen side of the Bay was high, an average (TOC) of 2.23% (Table A10.10.2). It was higher in the mangrove, about 7%. Because of this, the benthic assemblage on intertidal mudflats in Deep Bay was dominated by a few species which can tolerate high organic loadings. These species often occurred in very high density, such as *Dendronereis pinnaticirrus*, *Neanthes glandicincta*, *Potamilla acuminata* and *Upogebia major*.

Table A10.10.1 A list of benthos species on intertidal mudflats on Shenzhen side

Species	A1	A2	A3
Dendronereis pinnaticirrus	+	+	+
Neanthes glandicincta	+	+	+
Potamilla acuminata	+	+	+
Sigambra hanaokai	+	+	+
Nephtys oligobranchia	+	+	+
Micronephtys sphaerocirrata	+	+	+
Mediomastus californiensis	+	+	+
Ceratonereis burmensis		+	
Notoplana		+	
Sinonovacula constricta		+	
Theora cf. iridescens	+	+	
Assiminea dohrniana	+		
Upogebia major	+		
Corophium sp.	+		
Caprella sp.	+		
Laomedia astasina	+	+	+
Callianssa sp.	+	+	+
Camptandrium sexdentatum	+		
Macrophthalmus convexus			+
Periophthalmus contonesis			+

Table A10.10.2 Total organic carbon on intertidal mudflats on Shenzhen side

Site	Feb	April	June	Sept	Average
A1	2.60	2.50	1.90	2.20	2.30
A2	2.00	2.30	1.70	1.50	1.88
A3	3.20	3.10	1.30	2.40	2.48

Molluscs and crustacea of economic value are seldom found on intertidal mudflats on the Shenzhen side of Deep Bay, apart from *Crassostrea gigas* and *Saccostrea cucullata* which are cultured. *Sinonovacula constricta* can be found on the middle mudflats. Its average density is low, only 6.4ind./m^2. *Theora cf. iridescens*, which is high in density and was preyed upon by birds, is seldom found on the Shenzhen side. Although the economic species were poor in intertidal mudflats on the Shenzhen side of Deep Bay, *Dendronereis pinnaticirrus*, *Neanthes glandicincta*, and *Upogebia major* play an important role in increasing oxygen on mudflats.

Biomass and abundance on intertidal mudflats on the Shenzhen side of Deep Bay increased from the mangroves seaward margin to the river channel, but they were different in every season. The benthic biomass at site two (A2), lying in the middle of the mudflats in April and June, was lower than at other sites (Table A10.10.3, Figure A10.10.2). This may have been related to the fact that Deep Bay receives a large amount of fresh water in rainy season. *Dendronereis plnnaticirrus* and *Potamilla scuminata* were more common at site A1 than at sites A2 and A3, but *Neanthes glandicincta* and *Upogebia major* were represented by more individuals at site A2 and A3 than at site A1 (Table A10.10.4, Figure A10.10.3).

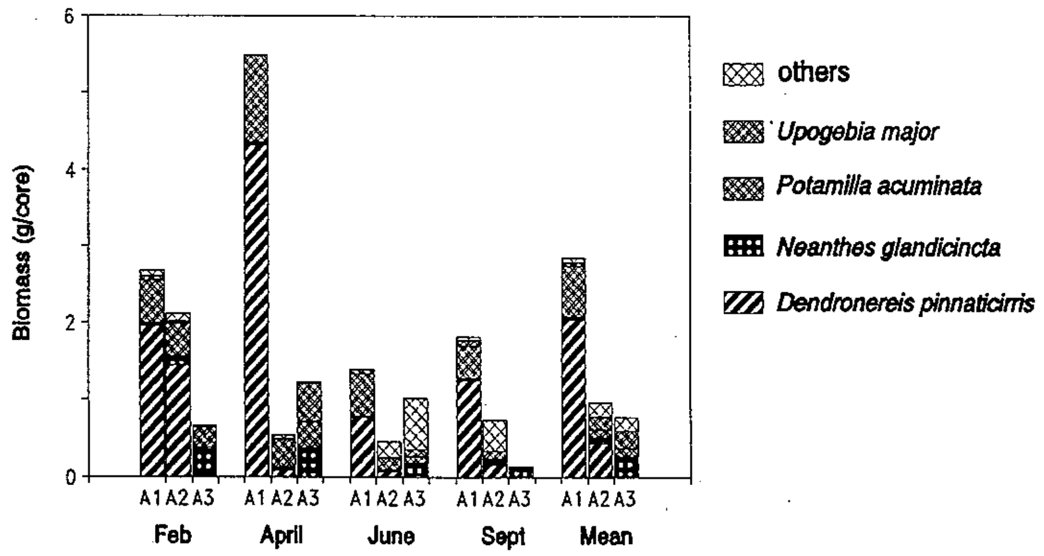


Figure A10.10.2 Benthos biomass on Shenzhen side

Table A10.10.3 Benthos biomass(g/core) on intertidal mudflats on Shenzhen side

Site	Species	Feb	April	June	Sept	Average
A1	Total biomass	2.70	5.51	1.43	1.84	2.87
	Dendronereis pinnaticirrus	1.96	4.31	0.77	1.26	2.05
	Neanthes glandicincta	0.05	0.00	0.03	0.03	0.04
	Potamilla acuminata	0.56	1.13	0.56	0.43	0.67
	Upogebia major	0.05	0.01	0.05	0.08	0.05
A2	Total biomass	2.14	0.57	0.48	0.76	0.99
	Dendronereis pinnaticirrus	1.46	0.08	0.07	0.16	0.44
	Neanthes glandicincta	0.12	0.04	0.03	0.07	0.07
	Potamilla acuminata	0.43	0.00	0.01	0.02	0.12
	Upogebia major	0.03	0.39	0.16	0.10	0.17
A3	Total biomass	0.70	1.27	1.04	0.18	0.80
	Dendronereis pinnaticirrus	0.01	0.00	0.02	0.01	0.01
	Neanthes glandicincta	0.36	0.37	0.17	0.14	0.26
	Potamilla acuminata	0.03	0.36	0.08	0.01	0.12
	Upogebia major	0.28	0.51	0.10	0.01	0.23

Table A10.10.4 Benthos abundance(n/cm^2) on intertidal mudflats on Shenzhen side

Site	Species	Feb	April	June	Sept	Average
A1	Total density	27.60	45.50	20.00	66.80	40.00
	Dendronereis pinnaticirrus	13.40	21.20	2.80	26.20	15.90
	Neanthes glandicincta	2.20	2.40	0.30	0.40	1.30
	Potamilla acuminata	11.20	19.60	7.20	25.00	15.80
	Upogebia major	0.20	0.60	8.20	8.80	4.50
A2	Total density	25.40	37.00	36.00	45.80	36.10
	Dendronereis pinnaticirrus	9.40	1.40	1.00	3.20	3.80
	Neanthes glandicincta	1.00	2.80	0.80	2.20	1.70
	Potamilla acuminata	12.00	0.00	0.70	3.00	3.90
	Upogebia major	2.20	31.20	31.20	27.20	23.00
A3	Total density	33.80	50.80	46.50	5.20	34.10
	Dendronereis pinnaticirrus	0.20	0.00	0.20	0.20	0.20
	Neanthes glandicincta	9.60	5.60	4.20	2.60	5.50
	Potamilla acuminata	1.60	8.00	3.50	1.20	3.60
	Upogebia major	21.60	36.80	37.30	0.80	24.10

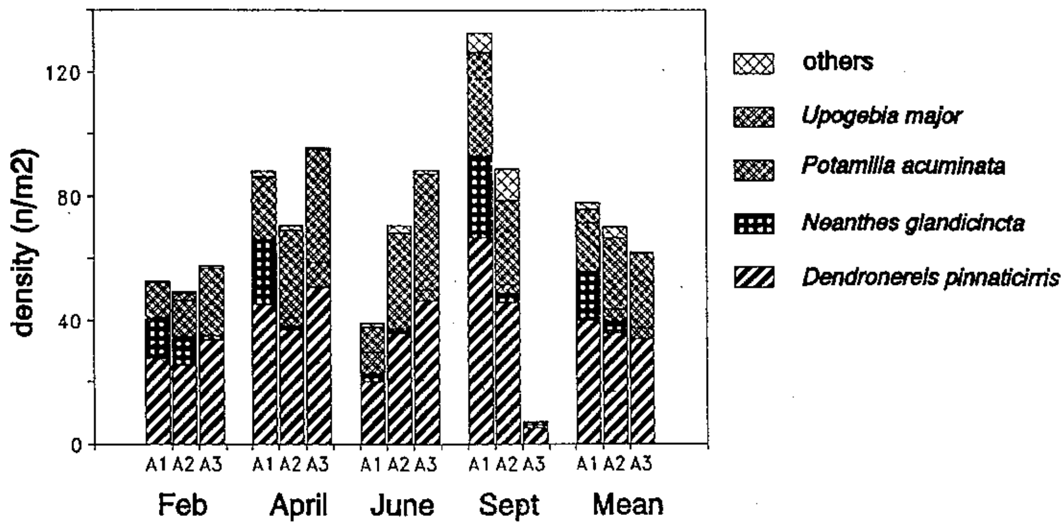


Figure A10.10.3 Benthos abundance

Tang (1992) found that the abundance of *Dendronereis pinnaticirrus* decreased towards the Yuen Long Creek in a study of heavy metal effects on Deep Bay polychaetaes. Average body size increased in the same direction. In our opinion, this change may relate to the estuary habitat, decrease in salinity, unsuitable environment, and slow growth or shortened life cycle.

The benthic communities are relatively stable on intertidal mudflats on the Shenzhen side of Deep Bay. The dominant species of benthos were the same during the four samplings because the sediments were also relatively stable. The clay content at site A1 was about 65%, silt about 31% and sand about 3.5% during the four samples (Table 10.10.5, Figure A10.10.4). The sediments at sites A2 and A3 were also relatively stable.

Table A10.10.5 Sediment components of the benthos survey sites (%)

Month	Site	Gravel	Sand	silt	Clay
Feb	A1	0.00	3.56	31.37	65.07
	A2	3.97	33.46	19.04	44.63
	A3	0.00	16.22	28.22	55.56
April	A1	0.00	3.72	32.13	64.15
	A2	0.00	13.00	30.68	56.32
	A3	0.00	11.06	31.12	57.82
June	A1	0.00	3.00	35.50	64.50
	A2	0.00	19.20	24.80	56.00
	A3	0.00	22.50	30.00	47.50
Sept	A1	0.00	3.00	30.50	47.50
	A2	3.00	22.50	24.00	50.50
	A3	0.00	15.50	31.00	53.50

A10.10.3 Effects of the Project on the Benthic Community

There are no systematic data from previous benthic studies on intertidal mudflats on the Shenzhen side of Deep Bay, so it is impossible to determine whether the benthic community has changed. The study results showed that the benthic community consisted of a few species which can tolerate high organic loadings. Monitored and evaluated by using the ABC method suggested by Warwick, the abundance curves of benthos at sites A2 and A3 on the biomass curves (Figure A10.10.5), indicating that these areas were in a polluted state.

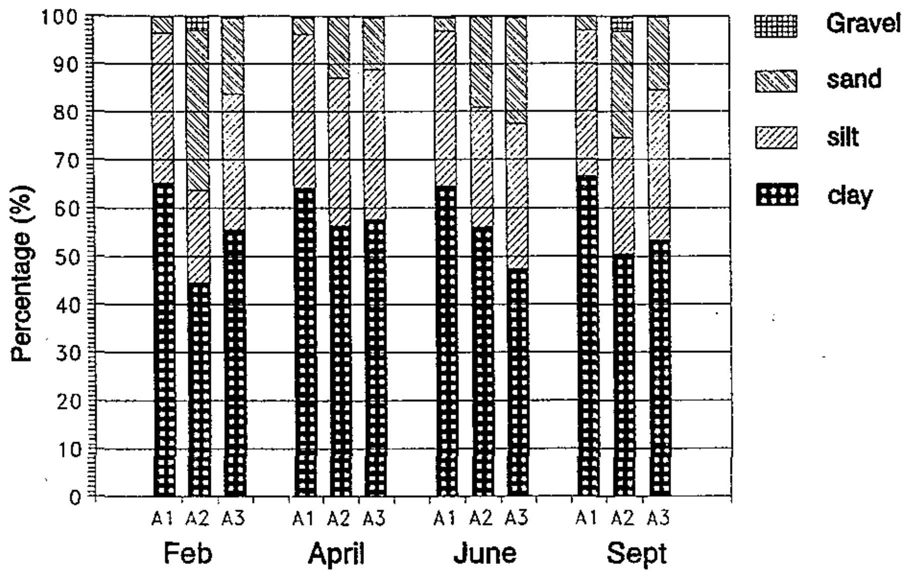


Figure A10.10.4 Sediment components

According to the modelling results at low water level, the maximum annual increase in sedimentation depth due to Stage 1 work will be 1.8 mm and 2.0 mm on mudflats of Futian and Mai Po respectively.

Whether polluted organic substances will become more serious should be a subject for further attention. It remains unknown how high organic loadings the dominant benthic species can endure. In addition, the benthic community will be affected by other pollution as well as organic pollution. Suspended pollutants will be taken to the lower reaches of the Shenzhen River estuary and Deep Bay. These substances came to the mangrove area and intertidal mudflats in Deep Bay by tide action and will stay there due to the obstruction of the mangroves and deposition. This process will pollute the mangroves and intertidal mudflats. We should not only pay attention to mud-sand sediments but also consider organic suspended substances during the construction period of the Shenzhen River regulation project.

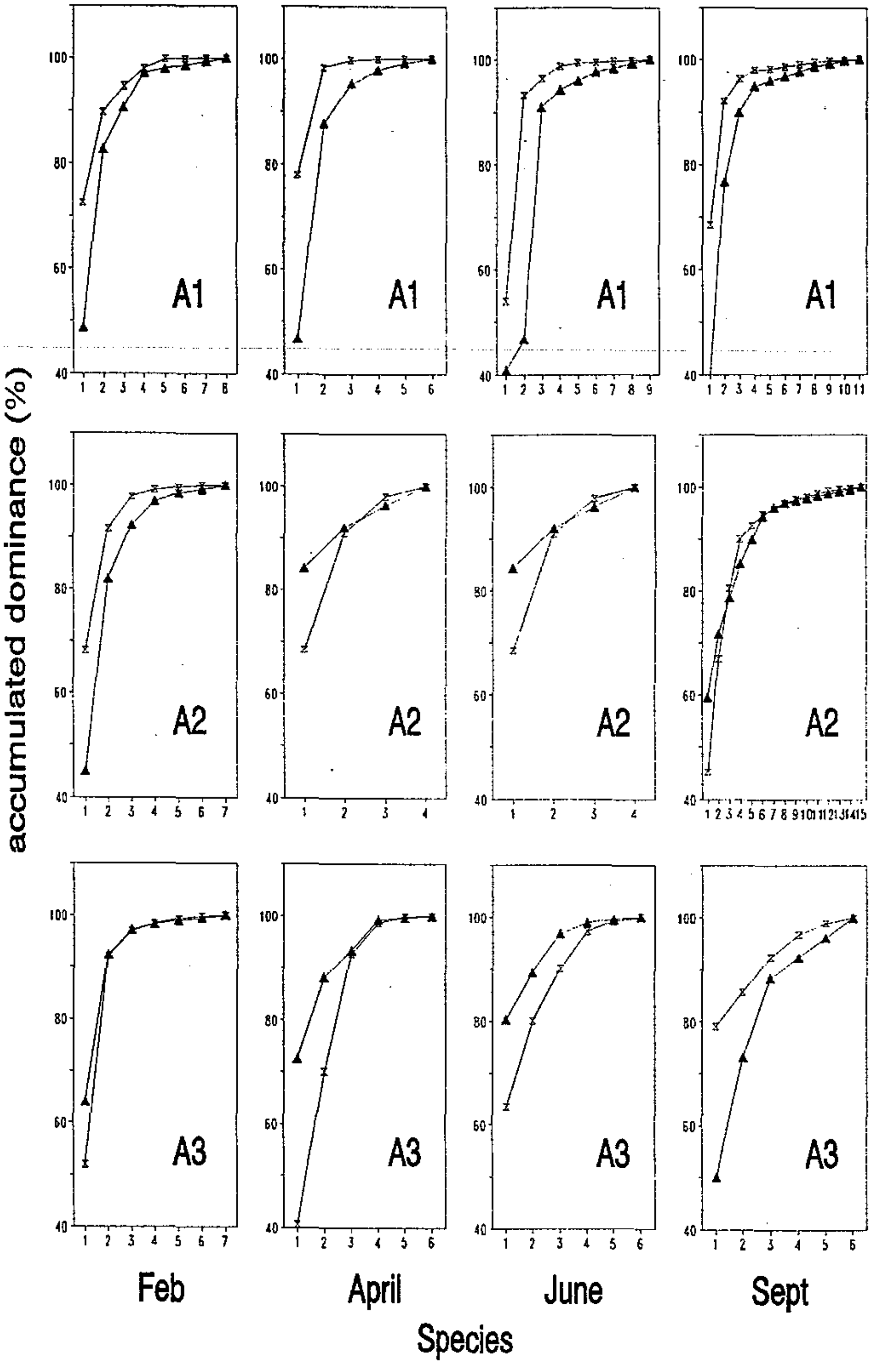


Figure A10.10.5 Biomass and abundance curves of benthos

A10.10.4 Recommendations

A10.10.4.1 Investigation proposal

To monitor and evaluate the effects on benthos and water quality on intertidal mudflats in Deep Bay during the construction phase of the Shenzhen River regulation project, benthic investigation is proposed to take place four times per year(low water level period and high water level period). Besides the vertical section of Deep Bay channel, benthic investigation should be carried out along the banks of the Shenzhen River and in the subtidal zone, to allow a full understanding of the pollution state and distribution patterns of benthos.

A10.10.4.2 Measurement of heavy metals and other pollutants

There are many polluting factors such as organic pollution, mud-sand sediments and migration, and heavy metal pollution. To find out the accumulation and translation process of benthos on pollutants and the effect on humans and birds through the food chain, measurement of the heavy metal content and changes in enzyme structure in the body of benthic dominant species is proposed, provide a scientific basis for environmental protection.

A10.11 WATERFOWL OBSERVATIONS ON THE FUTIAN SIDE OF DEEP BAY

A10.11.1 Introduction

The socioeconomic development of both Shenzhen and Hong Kong sides of Shenzhen River has caused extensive habitat destruction in the area. The Shenzhen River Regulation Project will also cause certain impacts to the wetland ecosystem of the estuary. The mangroves and surrounding areas of wetland form bird habitats of major significance for the South China coastal region. The minimisation of impact of the Project on the estuarine wetland habitats to conserve this important bird habitat is unquestionably a major component of the environmental impact assessment for the Project.

Waterfowl observations on the Futian side of Deep Bay were carried out to provide the basis for a thorough understanding of waterfowl in the Deep Bay area through observation of the populations, numbers, patterns of variation and spatial distribution of waterfowl in the Futian National Nature Reserve and surrounding areas. The purpose of this effort was to facilitate analysis and assessment of the impact of the Shenzhen River Regulation Project on waterfowl populations in the Deep Bay area and to propose corresponding conservation strategies and ecological mitigation measures.

This assessment summarises the results of observations made on the Futian side of Deep Bay from January through October 1994.

A10.11.2 Methods

Two methods, line transect counts and fixed-point counts, were employed for waterfowl observations on the Futian side of Deep Bay. Line transects were employed in the *gei wais* and fishponds on the northern edge of the Futian mangrove. Fixed-point counts were also carried out to obtain counts of waterfowl over the mangrove and southern shore and bay areas. Line transects were approximately 10 km in length. Five raised observation posts were set up from west to east along the roadside. For January, February, June and July 1994, a count was made on the 15th of each month; in March-May, observations were made every three days; and in August-September, observations were made once a week.

A10.11.3 Results

Between January and October 1994, 77 species of waterfowl representing 9 orders and 14 families were recorded on the Futian side of Deep Bay. Four of these species are listed as endangered protected species by the PRC (Oriental White Stork, Black Stork, Imperial Eagle, and Relict Gull). Waterfowl species breeding in Deep Bay represented 25% of the number of species, while 75% were winter visitors or transient species. The results of waterfowl observations on the Futian side of Deep Bay are shown in Table A10.11.1.

Table A10.11.1 Results of waterfowl surveys in Futian Nature Reserve

Month	date	Herons and egrets	Ducks	Plovers and sandpipers	Gulls and terns	Total
January	15	869	4191	407	49211	10543
February	13	168	2641	419	3481	9942
March	14	427	1010	145	1300	3027
	17	567	414		4035	5082
	21	284	326	1103	951	3059
	24	338	213	1549	3850	6845
	27	747	82	1863	4500	6723
	30	410	30	925	2251	3498
April	2	578	31	1007	2439	4017
	5	473	0	945	348	1606
	8	523	3	808	0	1132
	11	504	0	1319	3	1389
	14	414	0	457	2	744
	17	622	0	1394	0	1771
	20	602	0	1831	0	2056
	23	457	2	566	0	966
	26	2287	2	155	0	447
	29	341	2	90	1	445
May	2	599	2	40	1	656
	5	349	2	34	1	396
	8	347	0	87	0	446
	11	344	1	31	1	387
	14	376	2	20	1	408
	17	254	0	106	1	374
	20	250	0	23	0	278
	23	235	0	6	0	245
	26	496	0	1	0	505
	29	429	0	0	0	442
	31	583	1	2	1	594
June	15	593	0	2	0	601
July	15	534	0	44	0	583
August	1	487	0	55	0	558
	8	717	0	97	0	828
	15	568	0	122	0	686
	17	702	0	113	1	828
	24	630	0	138	0	780
September	1	555	0	117	0	683
	8	480	0	263	0	754
	15	528	0	46	0	588
	21	430	0	127	0	566
	28	552	0	423	0	975
October	5	379	0	169	0	566
	14	410	23	399	0	845
	20	373	14	238	0	645
	27	483	702	489	0	1536

Breeding waterfowl on the Futian side were mainly Ardeids. Results of observations over the course of many years on the Futian side show that a mixed population of Ardeids comprising over 2,000 Little Egrets (*Egretta garzetta*), Night Herons (*Nycticorax nycticorax*), Cattle Egrets (*Bubulcus ibis*), Great Egrets (*Egretta alba*), and Chinese Pond Herons (*Ardeola bacchus*) nest each year in an area centred on the Shazui mangrove. The location of the nesting site changes every year but always remains in the Shazui mangrove area. The reason for this is that this mangrove is wide. More important, it is located between Lok Ma Chau, Mai Po and Che Gong Miao, close to favoured foraging areas. Ardeids breed in April-May, in July the young begin to disperse outside the nesting site. During April-June, the frequency of the parents' feeding activities showed high environmental sensitivity, and an adverse environment will directly affect the survival rate of young.

As the Futian mangroves and few remaining northern *gei wais* and fishponds are long and narrow in form, the disturbance caused to birds by human activities is severe. Apart from some Ardeids and a few waders, most waterfowl came to Futian to feed on the bay and mudflats only during the daytime. Numbers of waterfowl coming to feed on the Futian side during the day at times far exceeded those on the Hong Kong side. In January-February 1994, the largest number of Pintail (*Anas acuta*) seen on the Futian side was 4,100, and of Shoveler (*Anas clypeata*) nearly 2,000. 300-400 Wigeon (*Anas penelone*) were often seen. A very large group of Black-headed Gulls (*Larus ridibundus*), over 8,000 individuals, was observed on the Futian side on 22 February. The numbers of Great Crested Grebes (*Podiceps cristatus*) on the Futian side were also far greater than those at Mai Po in Hong Kong. Each species of waterfowl had its own preferred foraging areas. For example, the Pintail fed on the bay at Shangsha and Xiasha, while Wigeon and Shoveler frequently appeared around the Fengtang estuary and Guanniao birdwatching pavilion. The Black-headed Gull was often found around the Shenzhen River estuary and the Inner Bay shipping channel. This indicated that the types, distribution and abundance of food varied between different parts of the bay and mudflats on the Futian side were fairly different from the Mai Po area. Changes in these conditions may cause serious impacts to feeding waterfowl.

A10.11.4 Discussion

A10.11.4.1 Analysis of Reliability of Results of Observation

The number of birds observed was probably lower than the actual number of birds. The mudflats, Inner Deep Bay *gei wais*, and fishponds on the Futian side were areas of frequent human activity. Disturbance to waterfowl on the Futian side caused difficulties in bird surveying. However, due to the high frequency of observation, results of the waterfowl observation as a whole may be taken as a basic reflection of waterfowl species composition, numbers and dynamics on the Futian side of Deep Bay.

A10.11.4.2 Analysis of Dynamics of Waterfowl Numbers on the Futian Side

The results of mid-month counts are shown in Figure A10.11.1. In order to make a closer approximation of the situation across the entire year, the observations already made for November 1994 have been included in this figure. Figure A10.11.1 shows that January was the high point for waterfowl numbers; February-April was a period of decreasing numbers (departure of migratory birds); May-September was the low point, and October-November was a period of increasing numbers (arrival), April was the peak time for wader migration.

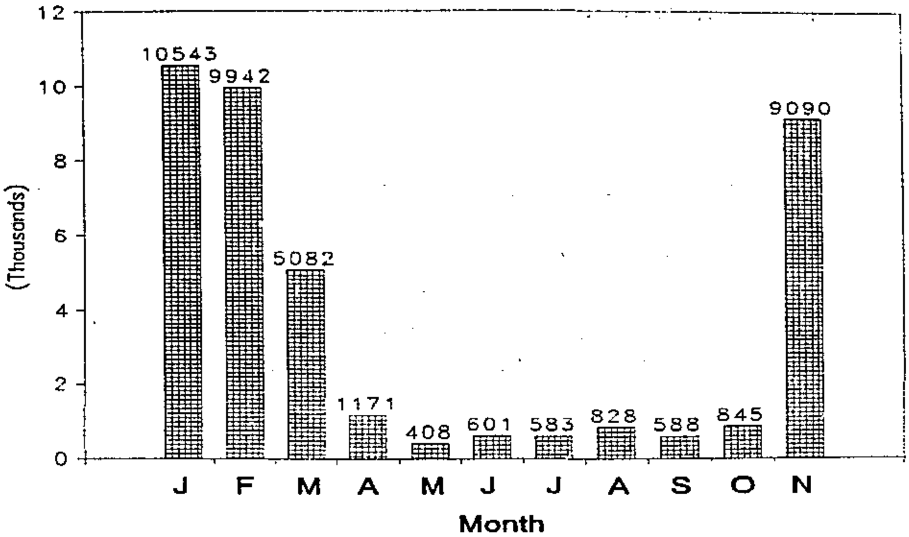


Fig. A10.11.1 Total waterfowl numbers at Futian

Using the above mentioned methods, January-November numbers were tabulated for the following four types of waterfowl; Ardeids, ducks, waders and gull and terns (Figure A10.11.2). The purpose was to analyse the variation in numbers of these four groups of waterfowl on the Futian side. Figure A10.11.2 shows that Ardeid numbers are relatively stable throughout the year, reflecting the fact that these are mostly resident birds. Numbers of waders show a slightly more marked variation throughout the year, with a relative large change in March, April, August, September and October in both numbers of species and of individuals. This reflects the fact that those members of this group which occur at Futian follow a north-south migration route. For ducks, gull and terns, a rapid drop in numbers occurred during February-March, ending with total disappearance in April; numbers increased rapidly after October. During the peak winter period, ducks, gulls and terns represented over 80% of the total numbers of water birds on the Futian side of Deep Bay.

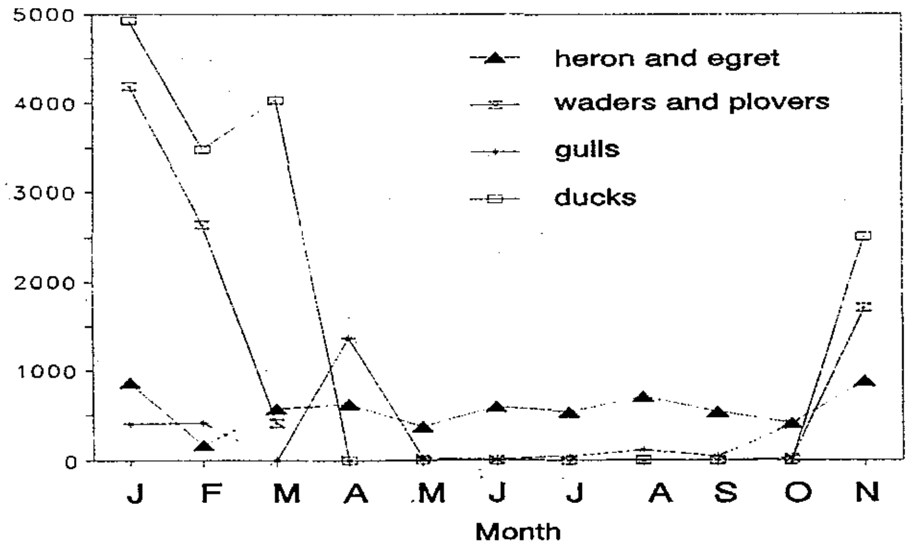


Fig. A10.11.2 Dynamics of numbers of 4 water bird groups at Futian

A10.11.5 Evaluation and Recommendations

A10.11.5.1 Assessment of Impacts

The Futian mangroves and the wetlands of Deep Bay are an important feeding area for wintering waterfowl as well as a breeding site for Ardeids. An assessment of the impacts of the Shenzhen River Regulation Project should focus on these two facts. Changes will occur in the flow rate and water quality of the Shenzhen River following completion of the Regulation Project. These changes may have impacts on the benthos of the Shenzhen River estuary, which will in turn affect the waterfowl occurring in this area. The mudflats and bay distant from the estuary will be subject to less impact: thus, except for the estuary area, the numbers and distribution of waterfowl in the broad bay and mudflat areas of the Futian side are not expected to show marked changes.

Following completion of the Shenzhen River Regulation Project, due to partial destruction of Ardeid feeding areas and habitat to the east of the estuary, an increase in the area and intensity of feeding to the west of the estuary will be necessary for these species. The Ardeids nesting site may shift toward the narrow western portion of the Futian mangrove. If corresponding compensation is not carried out in the feeding area within the 4 km area to be restored, numbers of breeding Ardeids and the area of the nesting site will decrease as a result, and the death rate of young may increase.

A10.11.5.2 Ecological Mitigation Measures

The *gei wais* to the east of the estuary which have not been occupied should be preserved so far as possible, to serve as an Ardeid feeding area following restoration. The remaining few hundred ha of *gei wais* and fishponds at the western end of the Futian mangrove should, so far as possible, not to be diverted to other uses. A way should be found to restore a portion of the wetland within the 4 km area surrounding the nesting site (i.e. the Futian mangrove area) as compensation for the Ardeid feeding habitat occupied, damaged and destroyed as a result of the Shenzhen River Regulation Project.

A10.12 BIRD SURVEY ON HONG KONG SIDE

A10.12.1 Overview

Inner Deep Bay and the adjacent wetland habitats comprise a wetland of international importance for conservation. The area is perhaps best known for the birds it supports. Many endangered and threatened species migrate through or winter in the area. In winter, up to 24% of the world population of a single species, the Black-faced Spoonbill *Platalea minor*, is to be found there. Mai Po Nature Reserve, internationally renowned for the spring wader migration, is the easiest place to see some of the rarest shorebirds in the world. As such it attracts visitors from across the globe.

Ringing of shorebirds and field observations of leg-flagged shorebirds are beginning to reveal the important role of Deep Bay within the East Asia/Australasia flyway. With the loss of similar habitat elsewhere in the region, the importance of Deep Bay is undisputed.

This survey focused on those groups of birds for which the area is considered most important.

Section Two deals with the distribution of duck and waders in Inner Deep Bay. For most of the time it was found that their feeding activities were closely related to the movements of the tide, and as a result, they fed for short portions of the day.

Section Three looks at the use of ponds along the Shenzhen River by waterfowl. This area will be subject to disturbance as a result of the project.

In Section Four, two of the rarest species in world terms that occur in winter in Deep Bay are discussed. The two species, Saunders' Gull *Larus saundersi* and Black-faced Spoonbill may both be adversely affected by the project, mainly due to the potential loss of preferred feeding areas.

Section Five details surveys of waterfowl undertaken during the year. It provides details on populations and seasonal variations throughout the survey.

Using a theoretical model, the consumption of benthos by birds in Inner Deep Bay was estimated. This is dealt with in Section Six.

A10.12.2 Duck and Wader Distribution in Deep Bay (Hong Kong Side)

A10.12.2.1 Introduction

Deep Bay is an important refuge for over 60,000 wintering waterfowl, and over 12,000 migratory shorebirds have been counted at Mai Po in a single day in spring. These birds arrive from breeding grounds as far away as Arctic Siberia and wintering grounds as distant as Australia.

Annual mid-winter waterfowl counts and spring shorebird counts undertaken by members of the Hong Kong Bird Watching Society have shown Deep Bay to be of international importance for these birds. Prior to this survey there was no information on the use of the intertidal areas of Deep Bay by duck and shorebirds.

Night feeding by waders and duck was first interpreted as a strategy used to top-up insufficient daytime energy intake. Night feeding seemed to be more intense in winter and least intense or even absent in early autumn and spring (Goss-Custard 1969). Recent authors have concluded that nocturnal feeding is widespread, and even a preferred option in certain species. As this often gives rise to birds using different habitats by day and by night, this could mean that some habitats, although little used by duck and shorebirds by day, may be important by night (McNeil *et al.* 1992).

The aims of the duck and wader distribution survey were:

a to assess the distribution and abundance of waterfowl and shorebirds on the mudflats on the Hong Kong side of Deep Bay
b to assess the importance of night-time feeding to shorebirds and waterfowl in Deep Bay
c to assess the seasonal differences in shorebird distribution in Deep Bay

A10.12.2.2 Methods

Observations were conducted from two 5m high scaffolding hides on the mudflats on the Hong Kong side of Deep Bay (Figure A10.12.1). The observer arrived and departed by boat at high tide. Length of stay varied from 12 to 27 hours.

Throughout the duration of the visit, the species, number, location, and behaviour of all the duck or shorebirds in the Bay were recorded on an hourly basis. Tide height, direction of tide movement and the causes (if known) of any disturbance were also recorded.

Observations were conducted once per month during February-March 1994 and October-December 1994 for duck, and once per month during February-December 1994 for shorebirds.

Night-time observations

Night-time observations proved to be very difficult due to the limitations of the available night-time viewing device, an experience encountered by other workers undertaking similar work elsewhere.

A 5 x image intensifier was used at night in the initial stages of the survey. The low magnification and lack of a sharp image rendered the image intensifier less useful than conventional optical aids. Subsequently night-time observations were conducted using 10x40 Zeiss binoculars and a 30 x 77 Kowa TSN4 telescope.

On one occasion thorough night-time observations could be undertaken through the coincidence of a full-moon and clear skies as the tide rose and fell. On other occasions only very limited data were obtained, usually within a distance of 100-200 m from the hide.

Accurately judging the position of the tideline at night proved to be difficult. Detecting the difference between light reflecting off wet mud and calm water was often impossible. Often it was only as the tide rose or fell immediately past the hide that its position could accurately be judged. At other times, the height was estimated on the basis of tide tables and the movements of tides of similar height during daylight.

Daytime observations

Day-time observations encountered no real problems other than the hide shaking during strong winds.

Numbered markers were placed on the mudflat, between the Boardwalk Hide and the Southerly Mudflat Hide (Figure A10.12.1), at 100 m intervals. Tide position was easily recorded against these markers.

All day-time observations were conducted using 10x40 Zeiss binoculars and a 30x77 Kowa TSN4 telescope.

Each hour all duck and waders were counted and their distribution plotted by eye using a 1x1 km gridded map of Deep Bay. Activity scans were used to record the behaviour of the birds. The activities of all waders and duck were divided into two categories:

1) feeding; and
2) preening or resting.

Scan sampling is considered to be a more appropriate method than focal-bird sampling for broad analysis of large groups of waterfowl (Gaston and Nasci 1989).

A10.12.2.3 Result of duck observations

There is virtually no information available concerning the diets of duck and waders in Hong Kong, and collection of such data was outside the scope of the present survey. As a result, information regarding feeding distribution and behaviour cannot be directly linked to the distribution of known prey items. There is, however, sufficient information from elsewhere (eg Cramp and Simmons 1977,1982), which together with local anecdotal evidence (P.J. Leader, S. McChesney, D.S. Melville unpublished), allows some interpretation of the data obtained in this study.

The most common duck species in Deep Bay in winter are Shelduck *Tadorna tadorna*, Wigeon *Anas penelope*, Teal *A. crecca*, Pintail *A. acuta*, and Shoveler *A. clypeata*.

Day-time distribution of duck

Not all duck present in the Deep Bay area feed in Inner Deep Bay during the day. A comparison of the totals of the five most common duck species recorded on the survey dates against those recorded during the monthly waterfowl has been carried out during the study (Table A10.12.1).

Table A10.12.1 Comparison of duck numbers recorded during feeding observations and on monthly counts

	F	C	F	C	F	C
	22 Feb	13 Feb	8 March	13 March	27 Oct	16 Oct
Shelduck	800	900	544	545	0	0
Wigeon	0	684	430	1629	0	0
Tea;	0	2014	900	1498	*	*
Pintail	5952	2873	210	425	0	22
Shoveler	2970	6274	880	2639	1900	31
Teal/Garganey	0	0	0	0	1400	391

F birds recorded during feeding distribution observations
C total birds recorded on monthly counts of the whole Deep Bay area
* included under Teal/Garganey

Day-time duck distribution on the survey dates was consistent.

Figures A10.12.2 to A10.12.4 show the distribution, at hourly intervals, of duck in Deep Bay on each of the survey dates. The limitations of Figures A10.12.2 to A10.12.4 are that they provide only an hourly 'snapshot' of the distribution of the duck within the observation period, and do not illustrate the movement with the tide.

On each of these dates, distribution was closely related to the tide. Most of the birds were on or near the tide line, resulting in a roughly linear distribution, up to 100 m broad, across the mudflat. Marked concentrations were recorded close to the mouth of the Shenzhen River mouth and near the mouth of the Yuen Long Creek, particularly in October 1994. The duck were recorded moving up and down the mudflat with the tide. If the tide was sufficiently high to cover the mudflat the birds present in the southerly area of the Bay would move and join those in the northern area of the Bay, presumably due to the southern area becoming submerged earlier. Large numbers of duck, particularly Pintail, were also noted on two occasions flying in from the direction of Futian N.N.R., where large numbers of this species have been recorded during the monthly waterfowl counts.

From Figures A10.12.2 to A10.12.4 it is evident that a very large proportion of the mudflat in front of Mai Po is being utilized by the duck foraging in Deep Bay over a tidal cycle.

Night-time distribution of duck

At night few duck were seen or heard either calling or flying past the hides. Small numbers of duck were disturbed on the boat journey out to the hide at night at high tide; all were in the mangrove channels or close to the mangrove edge.

Large numbers of duck were found foraging on the Mai Po Nature Reserve at night during January, February, November and December 1994. From these limited observations, it would appear that few duck remain in Deep Bay at night, and most move into adjacent areas after dark.

Foraging behaviour

The duck present in Deep Bay foraged only at certain times, this being consistent on each of the survey days. The timing of foraging, like distribution, appeared to be directly influenced by the tide. Foraging on a large scale (more than 50% of the duck present) was only recorded when the tide was rising or falling.

A typical tide cycle could be described thus:

As the tide fell the duck moved out across the mudflat into the Bay with the majority foraging along the tide line in a broad band up to 100 m wide. This tended to be narrowest near the centre of the mudflat and wider near both the Shenzhen River mouth and the Yuen Long Creek. At low tide, when the tide had stopped moving, most of the duck discontinued foraging and spent the low tide period either preening or roosting. At low tide birds roosted on the exposed mud and on the water. When the tide turned, intense foraging recommenced on a large scale and the duck moved back up the mudflat with the rising tide finally reaching the mangrove edge. At this point the duck became difficult to observe but some certainly continued to forage there. The duck fed by swimming with the incoming tide, dabbling at the surface and upending. Only Shelduck were recorded foraging on the exposed mud above the tideline.

The relationship between tide movement and foraging activity is shown in Figures A10.12.5 to A10.12.7.

A10.12.2.4 Discussion on duck

Foraging behaviour

The fact that most of the duck foraged only when the tide was moving, and rested at other times, suggests that when the tide was moving their prey was most available.

Shelduck in the Mersey Estuary, England, were found to feed extensively on receding tides at night, with 100% of the birds present in some areas feeding. Numbers feeding were found to fall around low tide and remained low throughout the advancing tide (Clark *et al.* 1989). This was attributed to the greater availability on a receding tide of the gastropod *Hydrobia ulvae*, the most important prey species of the Shelduck on many estuaries (Olney 1965). In contrast, Bryant and Lang (1975) found peak Shelduck feeding on the rising tide. Both studies, however, related peak feeding to increased prey availability.

Shelduck in Deep Bay were concentrated near the Yuen Long Creek, and were observed foraging in relation to both the rising and falling tides.

The two areas of concentration, near the Shenzhen River and the Yuen Long Creek, are an indication that certain preferred food items are more available there. The surface dwelling gastropod *Sermyla tornatella* is more abundant close to the Shenzhen River (Appendix 10.9). In January 1992 during exclosure work *S.tornatella* was found to be more abundant inside the cages than outside, suggesting consumption by birds (McChesney unpublished). It is also more available on a moving tide, due to an increase in its activity.

Night-time distribution

Differences in day and night distribution of duck in winter are not unusual. For example, Clark *et al.* (1989), reported considerable differences in the day and night distribution of certain species of duck in the Mersey Estuary. There, larger numbers of Teal were found feeding at night in an area not used at all by that species during the day.

Shorter daylight hours and harsher conditions in winter in temperate regions affect feeding behaviour, and thus distribution, of waterfowl.

Given the mild winters and small seasonal variation in daylight hours in Hong Kong, these are not considered to be important factors governing either night-time feeding or the difference between day and night-time distribution. However, mud temperature affects prey availability, as colder temperatures drive prey deeper into the mud and further away from birds.

Recent studies have suggested that night time feeding of waterfowl may actually be the preferred method of obtaining energy rather than being a way of topping up energy requirements not met during the day (Robert and McNeil 1989, McNeil *et al.* 1992).

Waterfowl wintering on estuaries in temperate latitudes often experience difficulties in obtaining sufficient energy from day-time feeding alone. In such circumstances it is necessary for them to feed at night. The decrease in daylight hours during the winter and the poorer environmental conditions at this time are the main causes for waterfowl not achieving their daily energy requirements during day time.

Given that the intertidal flats in Inner Deep Bay may be nearing carrying capacity for waterfowl (Appendix 10.9 and 10.12.6), night time feeding away from the intertidal area may be the main reason that Deep Bay can support such large numbers of duck in winter.

McNeil *et al.* (1992) discussed the role of night feeding in wildfowl. They pointed out that for those species which normally forage at low tide on intertidal habitats, tides limit access to food, and therefore the day-time and night-time feeding cycle seems to be primarily controlled by the tide. Certain species of duck, e.g. Gadwall *A. strepera*, Pintail, Teal and Canvasback *Aythya valisineria,* normally forage more at night than during the day, and increase their daytime feeding seasonally, at times of the year when their daily energy requirements are greater, e.g. when moulting, accumulating fat, responding to low temperatures or wintering in temperate regions.

Waterfowl are subject to disturbance in Deep Bay. It is clear that certain areas are avoided, particularly by duck, during daylight hours. The risk of predation during the day is likely to be greater on a relatively enclosed fish pond than on a large mudflat where any approaching predator can more easily be detected. McNeil *et al.* (1992) pointed to diurnal predation as a factor affecting day and night feeding. For example, night feeding of Teal in the Camargue occurred because Marsh Harriers *Circus aeruginosus* and Herring Gulls *Larus argentatus* (both of these species regularly occur in Hong Kong in winter) prevented day-time foraging (Tamisier 1970). Similar conclusions were drawn for Pintail and Teal in California (Euliss and Harris 1987).

Human disturbance may also play a part in the difference in day and night distribution of duck. However, certain areas favoured by duck at night on the Mai Po Nature Reserve do not suffer from human disturbance. In such areas avian predators are a more likely source of disturbance.

Owen *et al.* (1986) considered night feeding to be a response to disturbance of diurnal feeding areas during the day and possibly related to a decreased risk of predation at night.

McNeil *et al.* (1992) also discussed the role of day time disturbance in night feeding. They concluded that the diurnal gregarious habit and nocturnal feeding of duck and geese were probably the result of hunting, agricultural activities, disturbance by people, commercial navigation and small boats, aircraft, and other human activities (see McNeil *et al.* 1992 for references).

Owen and Williams (1976) found that Wigeon *A. penelope* fed by day and by night in undisturbed areas but fed only at night in disturbed areas. Where there was no day-time disturbance, 80-90% of the day was spent foraging (Owen and Thomas 1979). Day-time disturbance has also been shown to cause Snow Geese *Anser caerulescens* to switch to foraging at night (Giroux and Bedard 1988). McNeil *et al.* (1992) concluded that the regular use of separate diurnal resting places and nocturnal feeding areas is characteristic of many wintering (temperate or tropical) dabbling duck.

An additional factor may be that at night the duck are feeding on different prey items. This requires further work.

Differences in day and night height of tides in winter may also play a role. During winter, daylight tides rarely covered the mudflat; at night the opposite was true. High tides mean that the mudflat is covered for long periods of time. Given that during the day duck foraged in the Bay only on rising or falling tides, a very high tide would have resulted in long periods when the duck could not forage.

A10.12.2.5 Result of wader observations

Day-time distribution and abundance

The day-time distribution of waders on each of the survey dates showed marked seasonal differences:

a. Winter (February, March, October, November, December)

Most of the wintering wader population consisted of a flock of about 6,000 Dunlin *Calidris alpina* and Kentish Plover *Charadrius alexandrinus*, in approximately equal numbers.

Large numbers of both species were recorded foraging on the mudflat. No large concentrations were recorded along the edge of a moving tide. Marked concentrations were noted on the survey dates, and on other occasions, on the mudflat 200-500m out from the mangrove edge in front of the Boardwalk Hide. At other times the birds were widely distributed with no obvious relationship to the tide height other than its effect on the area of exposed mud (Figures A10.12.8-A10.12.10, A10.12.17).

b. Spring (April, May)

The wader population in spring consisted almost entirely of migrants, with Curlew Sandpiper *Calidris ferruginea* the most abundant species with nearly 6,000 present in April.

In spring, distribution was closely related to the tide. The birds followed the rising or falling tide across the mudflat, as did duck in winter. In marked contrast to the duck, however, at low tide the shorebirds did not commence preening or roosting but left the mudflat in front of Mai Po. At low tide the mudflat was often deserted, and birds returned only when the tide turned some hours later.

It was not possible to detect exactly where the waders went after leaving the mudflats in front of Mai Po but they were generally observed moving further out into the Bay. The rapid response to tide as it turned may indicate that they were either roosting or possibly foraging nearby. If they were foraging elsewhere, the speed with which they returned indicates that Inner Deep Bay is a preferred foraging area. It is possible that the birds moved to the extensive mudflats in the western part of the Bay near Shekou where the lower tidal flat is not truncated by river channels.

c. Summer (June, July)

The number of shorebirds recorded during the summer was too low to reveal any obvious patterns.

Figures A10.12.8 to A10.12.17 show the distribution per hour of the shorebirds in Deep bay on each of the survey dates. The limitations of Figures A10.12.8 to A10.12.18 are that they provide only an hourly snapshot of the distribution of the shorebirds within the observation period, and do not show the movement with the tide. However, Figures A10.12.8 to A10.12.17 clearly illustrate that a very large proportion of the mudflat in front of Mai Po was utilised by shorebirds in spring and autumn, and that a far smaller area was used in winter.

d. Autumn (August, September)

In autumn, Redshank *Tringa totanus* was the most numerous wader in Deep Bay.

Although the species composition in autumn was different from that in spring, the distribution of birds on the mudflats in the two seasons was very similar. As in spring, distribution was closely related to the movement of the tide. The waders were again observed foraging along both the rising and falling tide and leaving the mudflat in front of Mai Po at low tide.

Night-time distribution

Night-time observations, as noted above, were problematic. On one occasion, during a full moon, wader distribution was seen to be similar to that during the day. Interestingly, more foraging waders were present at night. On other occasions during spring and autumn when there was no moon, waders were heard calling, and this was related to movements of the tide. Although such information could not be quantified, when coupled with the limited night-time observations, it suggested considerable night-time activity. Waders certainly forage at night in Deep Bay and available information indicates that this behaviour could be quite extensive, at least at certain times during migration.

Foraging behaviour

The relationship between foraging activity and tide movement is shown in Figures A10.12.18 to A10.12.22.

The foraging behaviour of waders on each of the survey dates showed marked seasonal differences:

a. Winter (February, March, October, November, December)

Large numbers of waders were recorded foraging on the mudflat. No large concentrations of foraging birds were recorded along the edge of a moving tide. Marked concentrations of foraging waders were noted on the survey dates, and on other occasions, on the mudflat 200-500m out from the mangrove edge in front of the Boardwalk Hide.

During October the results were less clear-cut. However, if the behaviour of the Dunlin and Kentish Plover are looked at separately from the large *Tringa* spp., then a clear pattern emerges. Foraging behaviour in relation to tide movement in October were very different for Dunlin and Kentish Plover (Figure A10.12.23) than for large *Tringa* spp. (Figure A10.12.24). The large *Tringa* spp. foraged in response to the moving tide, while the Dunlin and Kentish Plovers behaved as described above.

b. Spring (April, May)

In spring foraging behaviour was closely related to the tide. The birds followed the rising or falling tide across the mudflat, foraging in a broad band across the intertidal flats, in a pattern similar to that observed for duck in winter. In marked contrast to the duck, however, at low tide the shorebirds did not commence preening or roosting but left the mudflat in front of Mai Po. At low tide the mudflat was often deserted, with the birds returning only when the tide turned some hours later. When they did return, they commenced foraging immediately.

c. Autumn (August, September)

Although the species composition in autumn was different from that in spring, the foraging behaviour of birds on the mudflats in the two seasons was very similar. As in spring, the birds foraged in close association with a falling or rising tide. The waders were again observed leaving the mudflat in front of Mai Po at low tide.

d. Summer (June, July)

The number of shorebirds recorded during the summer was too low to reveal any obvious patterns.

A10.12.2.6 Discussion on waders

The distribution and foraging behaviour of migrant waders and wintering waders were very different.

The factors which influence the foraging behaviour of shorebirds are many and complex.

That many of the migrant shorebirds in Deep Bay forage along the tide edge as it both rises and falls suggests that at that stage of the tide cycle, certain prey items may be more abundant or more available. An increase in prey abundance or availability, and thus also in the shorebirds which prey on them, has been shown to be tidally related elsewhere. For example, Boates (see Goss-Custard 1984 for reference) studied Semi-palmated Sandpipers *Calidris pusilla* eating *Corophium* in the Bay of Fundy. On the receding tide, the birds gathered on the tide edge and followed it out closely. He found their intake rate to be high as feeding success was almost 100%, and they were catching particularly large sized adult *Corophium*. This was due to the fact that on the receding tide, larger sized adult *Corophium*, especially males, move on the surface looking for mates. This lasted for only a short period and within half an hour of the tide passing, only 5% of the initial number of *Corophium* were present. Given the strong similarities in behaviour of the birds following the tide in Deep Bay, it seems likely that foraging behaviour is also due to an increase in availability of prey.

Clark *et al.* (1989) reported similar behaviour in Dunlin during both the day and at night. The proportion of birds feeding on the receding tide was high and at night very few birds were recorded after low tide. This was attributed to the Dunlin's ability to capture the more exposed invertebrates on the receding tide and not, or not being able, to feed on intertidal areas which have been uncovered for some time.

Evans (1979) noted that on soft shores many wader species feed while following the tide edge as it retreats and subsequently returns, in order to stay in those areas where prey activity is greatest and/or prey are closest to the surface. Because the tide-edge moves fastest around the mid-tide period, Reise (1986) considered that invertebrates were less at risk of capture in the mid-tidal zones, and at greater risk towards the high and low water marks where the tide advances and retreats more slowly. Evans (1979), however, thought this to be a considerable oversimplification, as different shorebird species differ in the extent to which they use particular intertidal zones. Below mid-tide level, certain birds that defend feeding territories, e.g. Curlew *Numenius arquata* and Grey Plover *Pluvialis squatarola*, are left behind as the tide retreats. Many plovers, whether or not territorial, stay to feed, well spaced out at mid- or even higher shore levels, in order to avoid interference from other birds with their visual method of foraging (Pienkowski 1981). Furthermore, when daily energy requirements can be more easily satisfied, e.g. in late autumn, many birds will spend more time at the high tide roost, or cease feeding for a time at low tide, or both. In Deep Bay during the spring migration, shorebirds left the high tide roost sites at the Mai Po Nature Reserve prior to the mud being exposed and often spent periods of up to one hour flying, waiting for the tide to fall. In autumn this behaviour was rarely seen. Birds remained at the high tide roost sites for some time after the tide had dropped.

Birds that spend more time at the high tide roost site often concentrate their foraging in the mid-tidal period and zones, which is often where the densities of prey are highest. During winter in temperate regions, when daily metabolic demands increase but foraging becomes more difficult, shorebirds on soft shores feed for longer in each daytime tidal cycle and eliminate any low-tide pause in foraging.

In general, large species of shorebirds forage for lower proportions of each tide cycle than small species (Evans 1981). This is partly due to their requirements for larger prey items in order to feed profitably: these larger prey tend to occur at lower tidal levels. Thus larger shorebirds tend to leave the high tide roost later and return earlier. Such behaviour has been noted in Curlew and Greenshank *Tringa nebularia* in Deep Bay. Evans (1981) noted that predation by shorebirds is not always least severe at mid-tidal levels, as Reise (1986) assumed, though this is more true on the larger expanses of intertidal flats he studied.

Most studies have shown that where an obvious choice is available, waders select the energetically more profitable kind species or size class of prey (Goss-Custard 1985). However, evidence that waders usually select the most profitable option does not necessarily imply that they are also foraging at the maximum possible rate. Adult Turnstone *Arenaria interpres*, for example, increase their intake rates when fattening up for migration, while the non-migratory juveniles do not (Metcalfe and Furness 1984). Migrant shorebirds in Deep Bay may therefore be expected to forage more intensely than those present in winter.

Evans (1979) also summarised the seasonal changes in the daily food requirements of shorebirds. Birds require food for the maintenance of body temperature, synthesis and storage of new materials (such as fat and feathers), to cover the costs of foraging, and other activities such as flying to roost sites or evading predators. In preparation for migration, fat is stored for fuel. The amount of fat deposited is usually higher in spring than in autumn. The distances flown non-stop are usually greater in spring. Fat reserves are also accumulated in late autumn by waders that have reached the end of their migrations. These are maintained during the winter in case difficulties are experienced in obtaining adequate daily food intakes. The amounts of fat stored varies between species but are less than those accumulated prior to migration (Davidson 1981). The preparation for migration in spring and autumn and the periods of moult are the seasons of highest daily food intake and therefore also of greatest daily predation on the intertidal fauna.

Body weight data from waders trapped for ringing at Mai Po has shown that large weight gains are achieved by certain species in Deep Bay in autumn. Weight gains between captures are shown in Figures A10.12.25-A10.12.28. Few data are available for spring weight increases, but Young and Melville (1993) noted that waders depart Hong Kong at lower weights than in the autumn, in contrast to the usual situation elsewhere.

Much of the work on daily energy requirements of shorebirds in winter has been carried out in temperate regions. Goss-Custard (1984) gave the following reasons for feeding conditions deteriorating during autumn and winter:

1. Energy demands rise as temperature falls and wind-chill increases.

2. At the same time foraging becomes more difficult as the density of prey declines a) through depletion by waders and other predators, b) through a decline in the energy value of individual prey, and c) through a decline in the proportion of the prey that is both detectable and accessible (i.e. available) as the invertebrates i) burrow deeper in the substrate, ii) become less active and visible at low temperatures or in high winds.
3. As day length decreases, an increasing proportion of the low water period in each 24 hours occurs in darkness, when, according to most field studies (but see Dugan 1981), many waders feed at <50% the daytime rate.

In response to these seasonal changes in feeding conditions waders may forage for longer during low tide, and at high tide many may also feed on terrestrial invertebrates in fields.

Given the relative mildness of winters in southern China, Reason 1 above is unlikely to influence feeding conditions in Deep Bay. In fact, higher temperatures in spring and especially autumn are more likely to adversely affect feeding conditions. The higher temperatures are likely to dry out the top surface of the mud more quickly, causing the invertebrates to burrow deeper.

Several authors have pointed out the possible importance of substrate wetness in influencing prey behaviour and thus their availability to waders. Goss-Custard (1969) found that *Corophium* do not appear at the surface in dry areas of sand or mud, and that this may be why Redshank avoid such areas. The numbers of *Nereis* (Dugan 1981) and lugworms *Arenicola* (Smith 1975) visible at the surface declines steadily after the tide has passed, in line with the drying out of the substrate.

Furthermore, other environmental factors that affect feeding rates elsewhere are less prevalent in Hong Kong during the winter. These include rainfall, which reduces the number of polychaetes appearing at the mud surface (causing birds to feed more slowly e.g. plovers, Pienkowski 1980) and strong winds which also decrease feeding rates. Both Bar-tailed Godwits *Limosa lapponica* (Smith 1975) and plovers (Pienkowski 1981) feed more slowly in strong wind. Wind is usually only likely to affect feeding behaviour in Hong Kong in winter.

Seasonal variations in day length in Hong Kong are less extreme than in temperate regions and therefore are unlikely to affect feeding behaviour. Furthermore, recent studies have shown night time feeding to be more widespread than previously considered, even in the tropics (Robert and McNeil 1988).

That widespread night-time feeding could only be observed during a full moon may indicate that this is <u>only</u> when night time feeding occurs. McNeil *et al.* (1992) discussed the influence of the lunar cycle on night feeding. They stated that some predominantly sight feeders may take advantage of moonlight to feed. Northern Lapwings *Vanellus vanellus* and Eurasian Curlew normally forage by day and roost by night, except for a few days around the full moon when the pattern is reversed. However the actual intensity of the moon was not considered to be the main reason for this change in behaviour, as they were found to forage as much on overcast nights during the full moon period as on clear nights. It is probable that increases in night feeding of some species may be due more to a lunar periodicity in the activity of their prey (see McNeil *et al.* 1992 for references).

Recent studies in Venezuela and Mauritania have shown that some neotropical residents and holarctic winter migrants do feed at night in tropical environments (McNeil and Robert 1988, Zwarts and Blomert 1990). There are, however, interesting regional variations. Nocturnal foraging in Curlew Sandpiper, for example, occurs in Australia (Dann 1981), only rarely in

Mauritania (Zwarts and Blomert 1990) and not at all in South Africa (Puttick

Similarly, Kentish Plovers forage at night in Portugal (Batty 1991) but not i
(Zwarts and Blomert 1990).

In northern Europe, nocturnal feeding may be most intense during the winter and
or absent in early autumn and spring (Goss-Custard 1969; Puttick 1984). Batty (
that in southern Portugal, night feeding predominated during the migration pe
much less common from November to March.

We still do not know if night-time feeding b shorebirds occurs in winter in Deep
the results noted above, it may well be that due to the lower daily energy requ
species wintering in Deep Bay, night feeding does not occur.

Climate is also an influence on this pattern, as at hotter times of the year the ava
food away from the tideline is much reduced.

A10.12.2.7 Disturbance

Disturbance was far greater for waders than for duck. The main source of disturba
from avian predators such as Peregrine Falcon *Falco peregrinus* and Black Kit
migrans, and boats playing music. Boats that did not play music did not cause distur
On 3 occasions widespread disturbance was caused by barges playing loud music
sources of disturbance were illegal mudskipper collectors and fisherpersons.

A10.12.2.8 Summary

The results show that duck and waders foraging on the mudflats in Inner Deep Bay do
three different ways:

1. Ducks forage extensively on both the rising and falling tide during the day, but at n
   appear to leave the area for alternative feeding grounds.
2. Migrant shorebirds forage extensively on the rising and falling tides, both at night
   during the day.
3. Wintering Dunlin and Kentish Plover forage on the intertidal mudflats but not alo
   moving tideline.

The findings suggest that ducks and migrant shorebirds are therefore restricted in the times
they can feed. As such they are also more susceptible to adverse impact of disturbance
if feeding over a longer time period. It is considered that the benthos upon which they
foraging is more readily available as the tideline moves across the mudflat. If they are un
to utilise this food source due to disturbance at the critical stage of the tide cycle then they
unlikely to be able to compensate at other times of the tide cycle, unless an alternative
source is utilised.

Disturbance, which not only reduces intake rates but increases energy expenditure due to fli
would be particularly deleterious in spring and autumn when migrant birds need to accumu
fat and protein reserves before migration.

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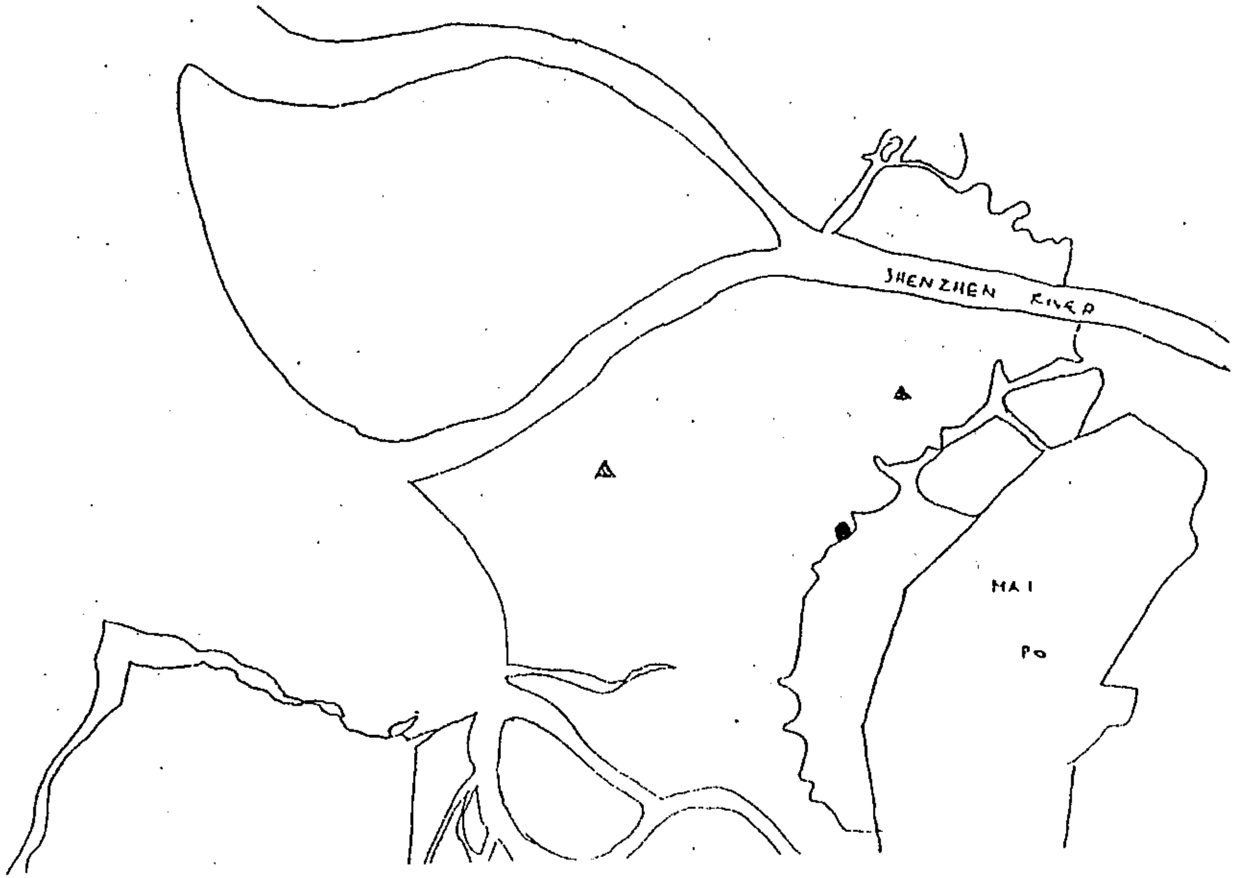


Figure A10.12.1 Bird observation stations at Mai Po (▲ Mudflat Hide, ● Boardwalk Hide)

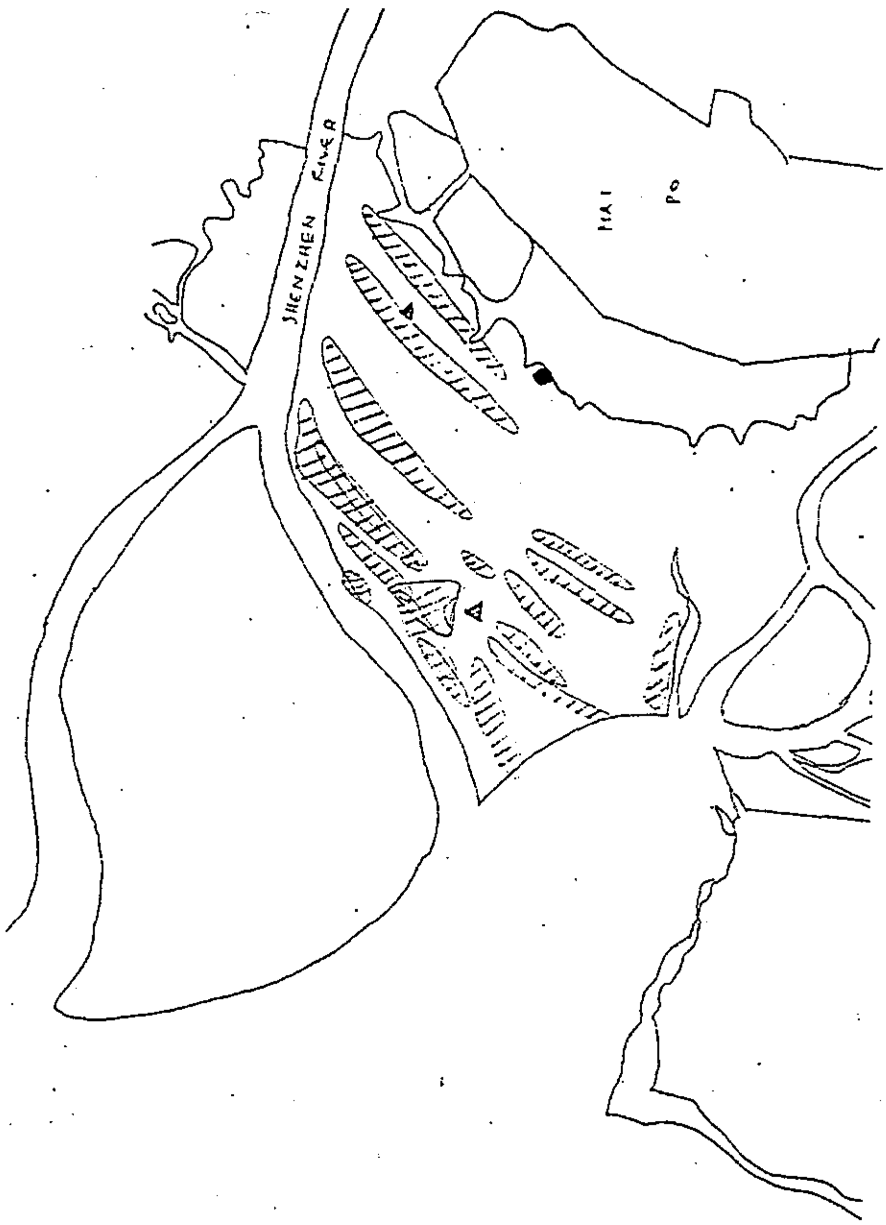


Figure A10.12.2 Duck distribution 22 February (0700-1645) (▲ Mudflat Hide, ● Boardwalk Hide)

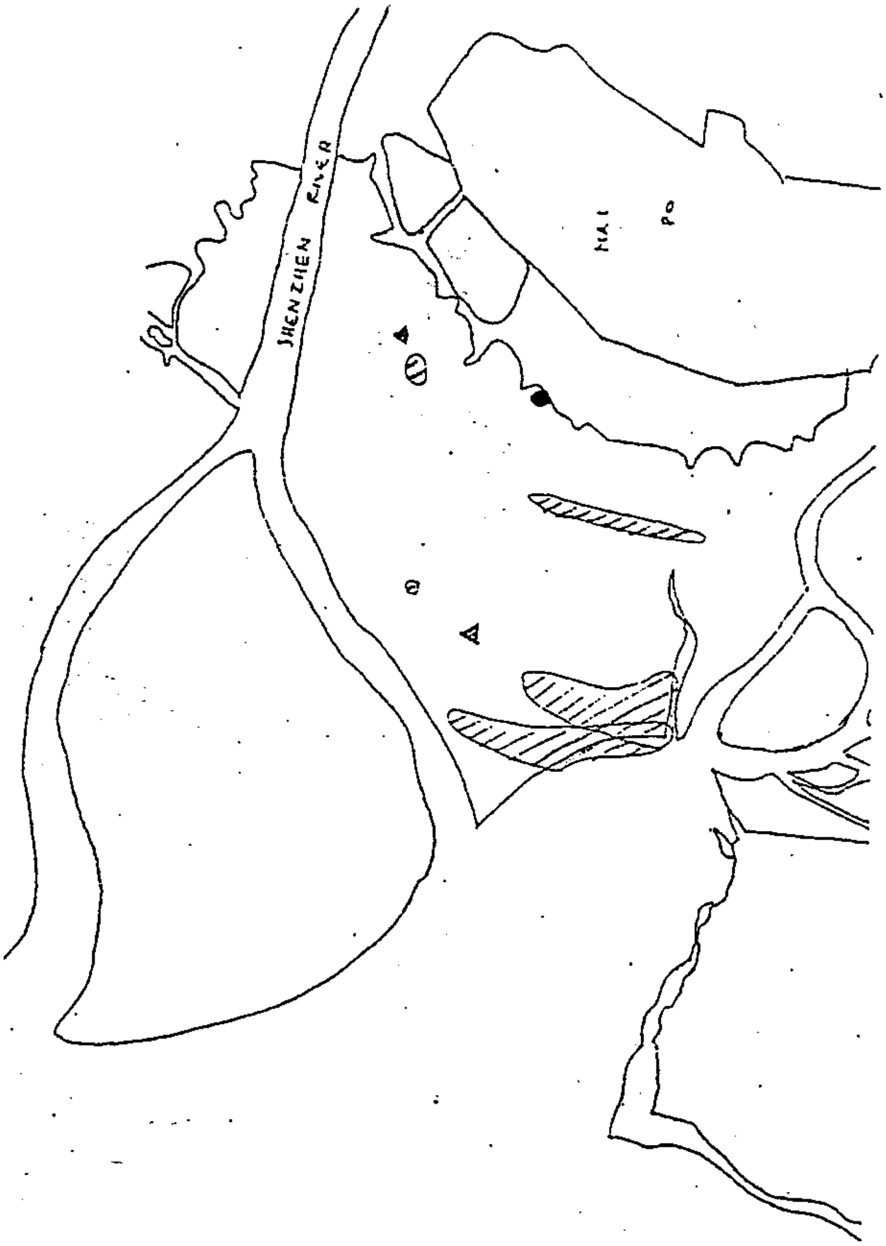


Figure A10.12.3 Duck distribution 8 March (0600-1600) (▲ Mudflat Hide, ● Boardwalk Hide)

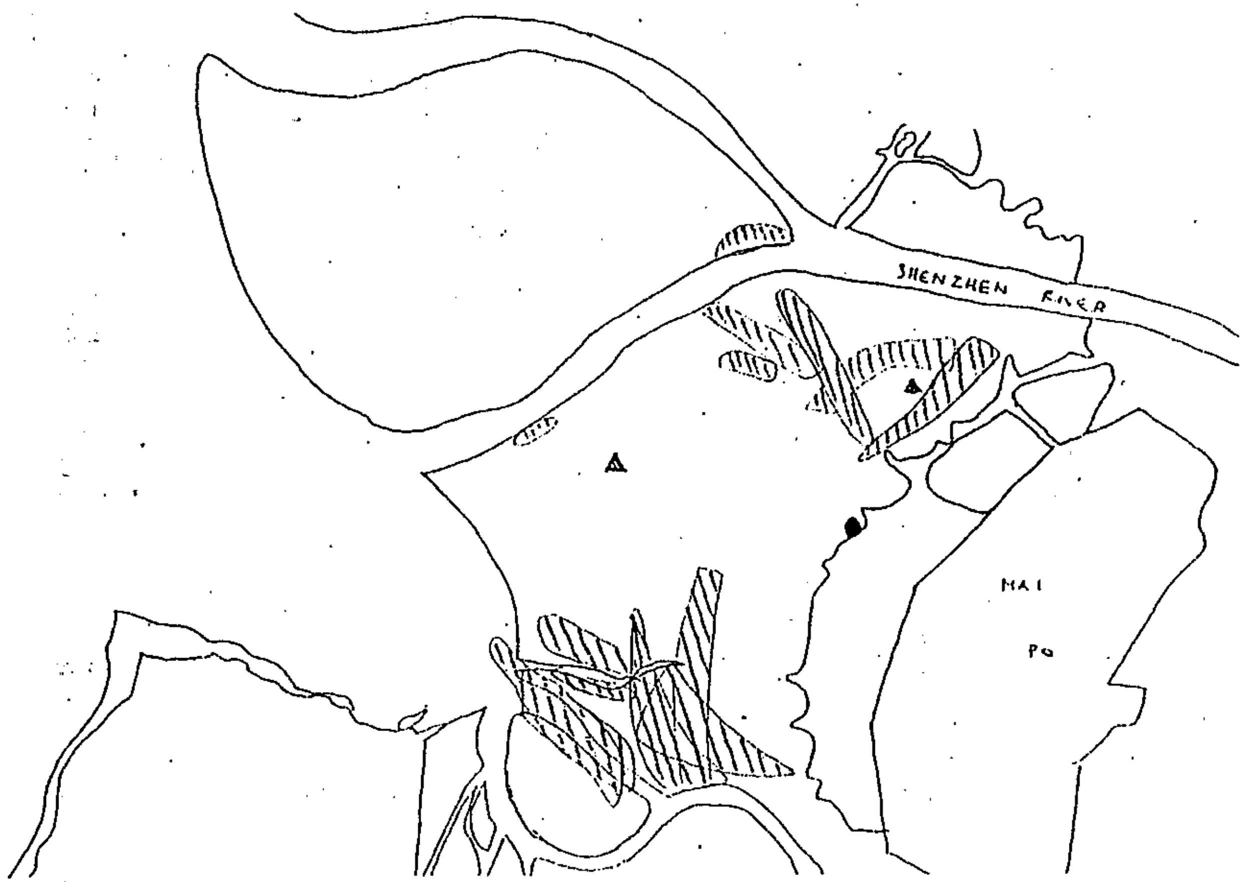


Figure A10.12.4 Duck distribution 27 October (0630 - 1700) (▲ Mudflat Hide, ● Boardwalk Hide)

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

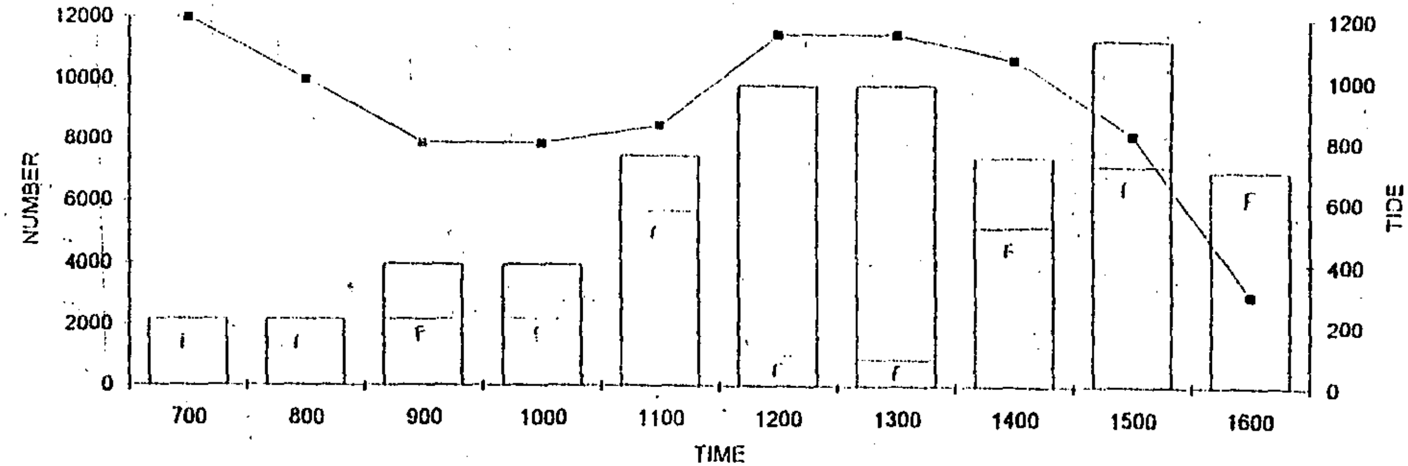


Figure A10.12.5 Duck distribution, 22 February 1994

F: Number of birds foraging

Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

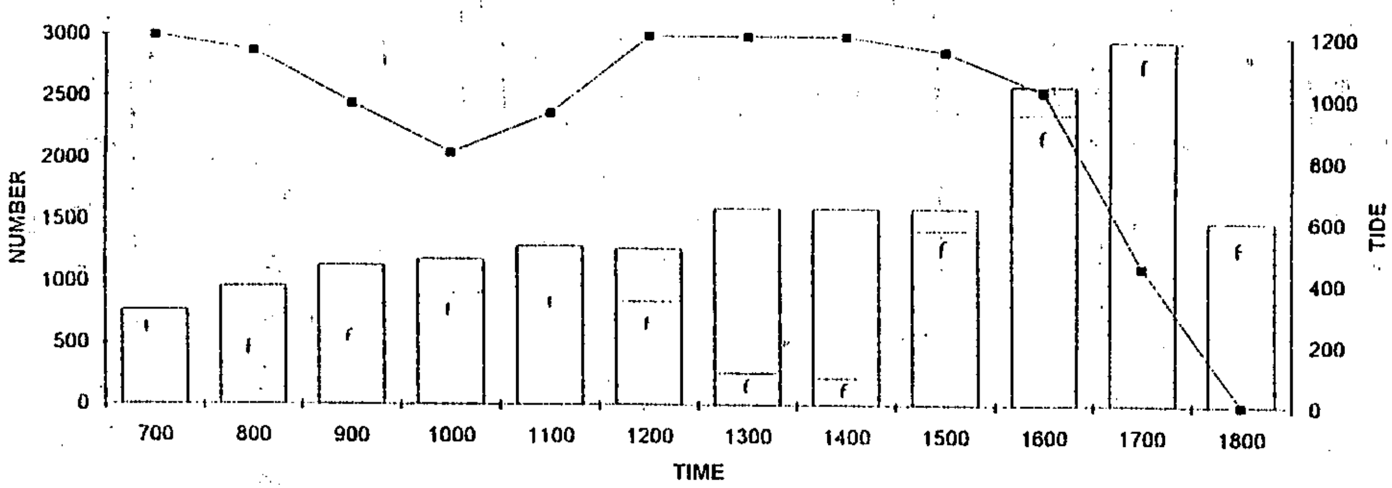


Figure A10.12.6 Duck distribution, 8 March 1994

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

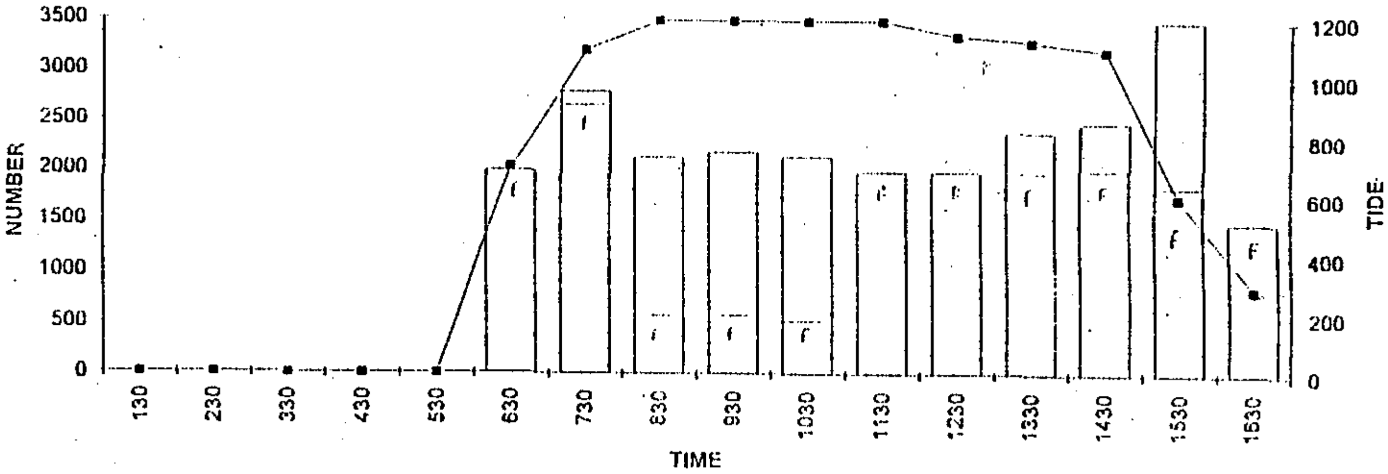


Figure A10.12.7 Duck distribution, 27 October 1994

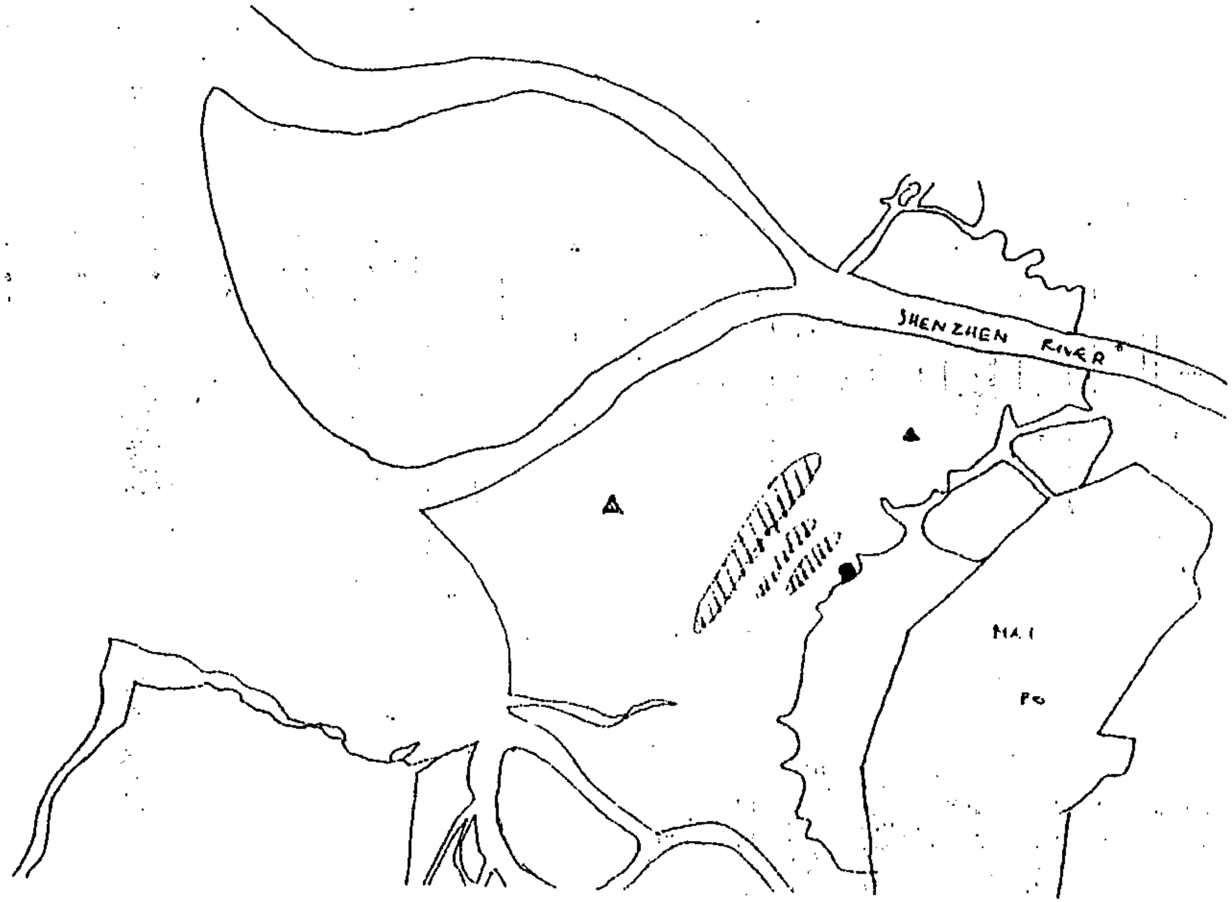


Figure A10.12.8 Wader distribution, 27 January(0600-1300) (▲ Mudflat Hide, ● Boardwalk Hide)

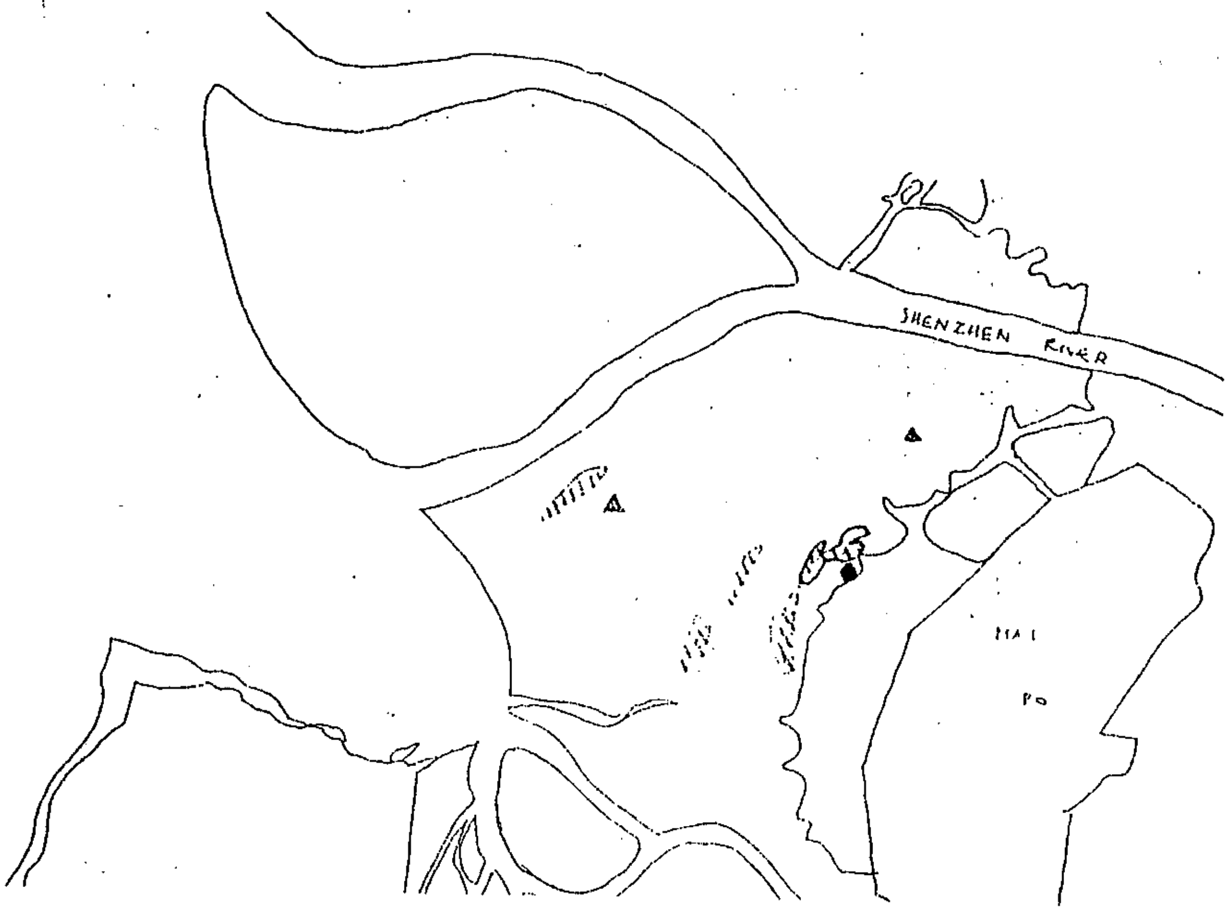


Figure A10.12.9 Wader distribution, 6 March (0700-1515) (▲ Mudflat Hide, ● Boardwalk Hide)

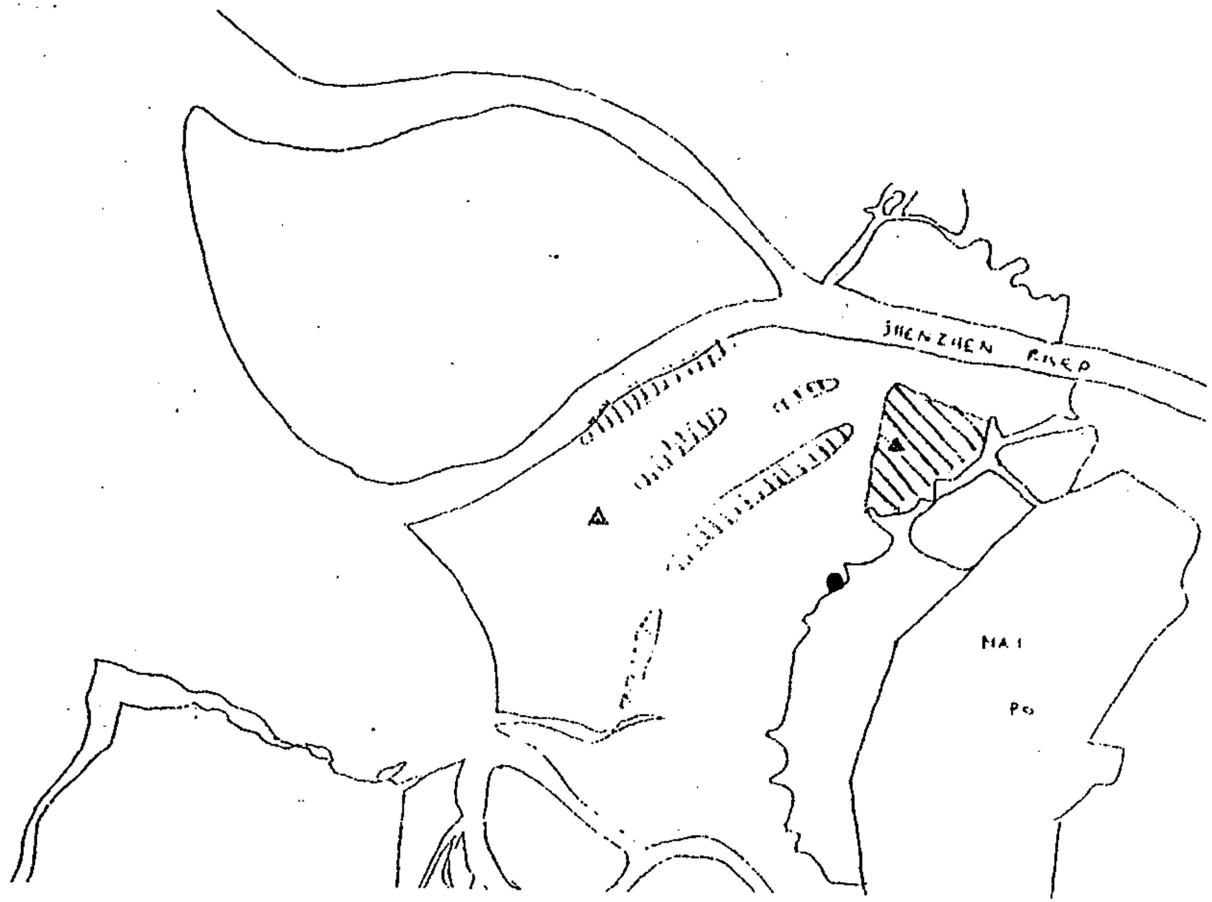


Figure A10.12.10 Wader distribution, 29 March (0100-1000) (▲ Mudflat Hide, ● Boardwalk Hide)

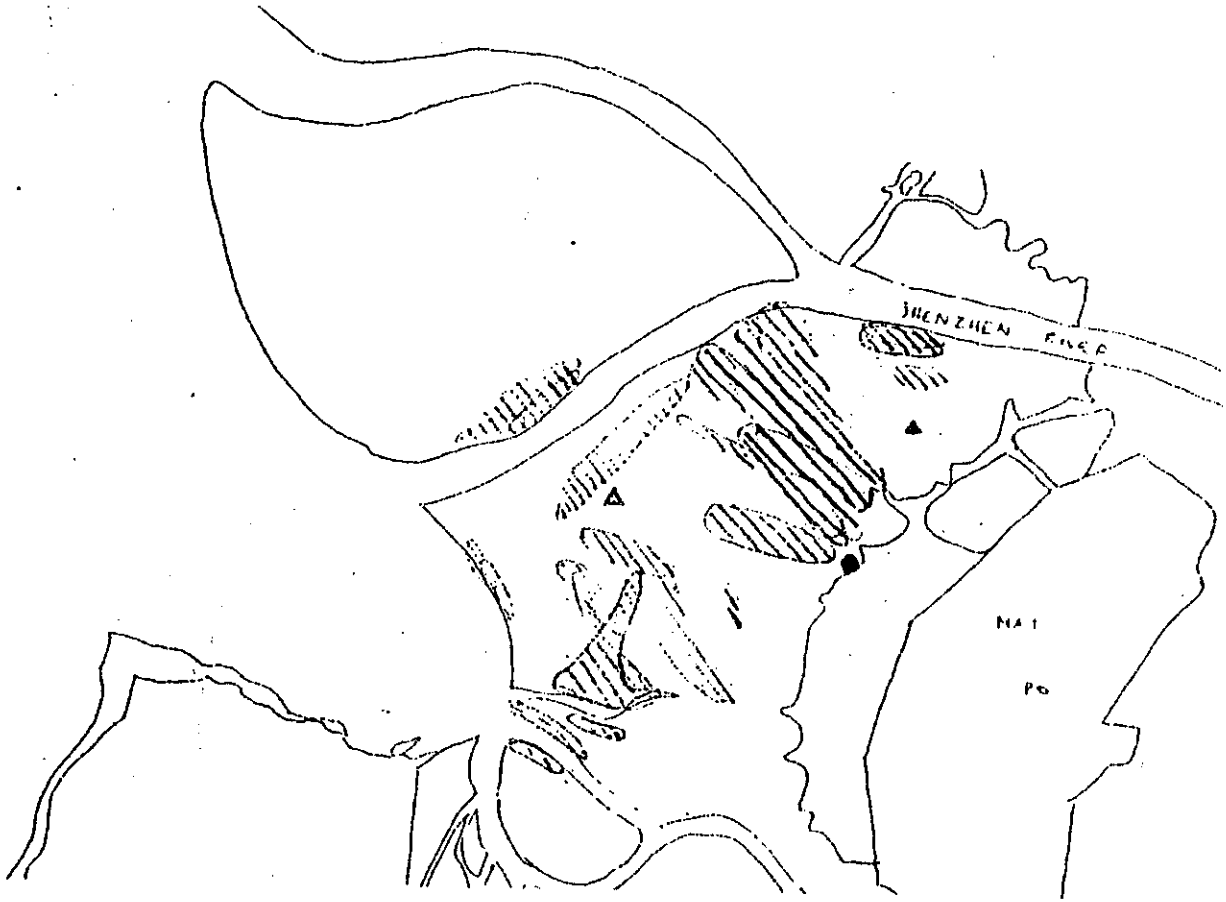


Figure A10.12.11 Wader distribution, 12-13 April (1300 on 12th - 0930 on 13th) (▲ Mudflat Hide, ● Boardwalk Hide)

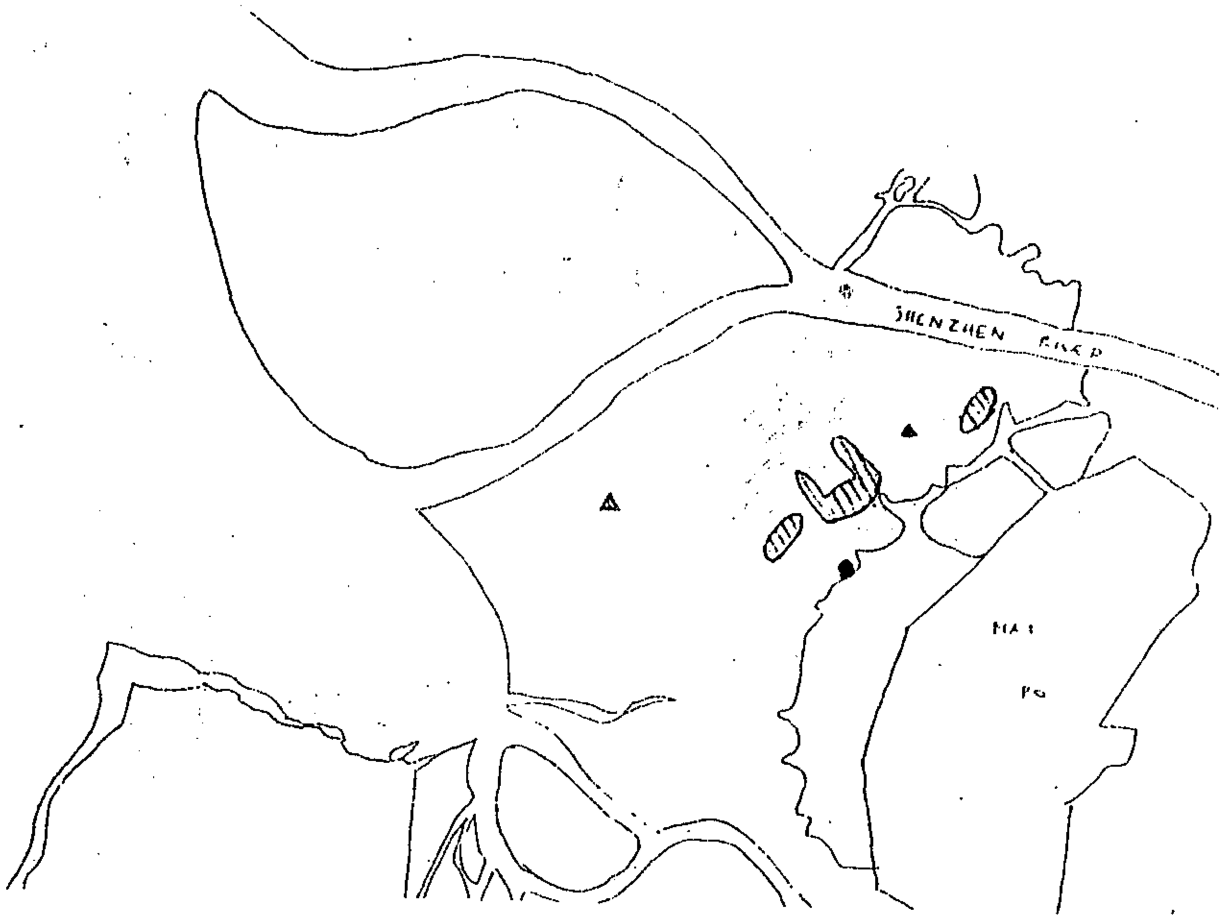


Figure A10.12.12 Wader distribution, 29-30 May (1300 on 29th - 1145 on 30th) (▲ Mudflat Hide, ● Boardwalk Hide)

Figure A10.12.13 Wader distribution 25-26 June (1200 on 25th - 0930 on 26th) (▲ Mudflat Hide, ● Boardwalk Hide)

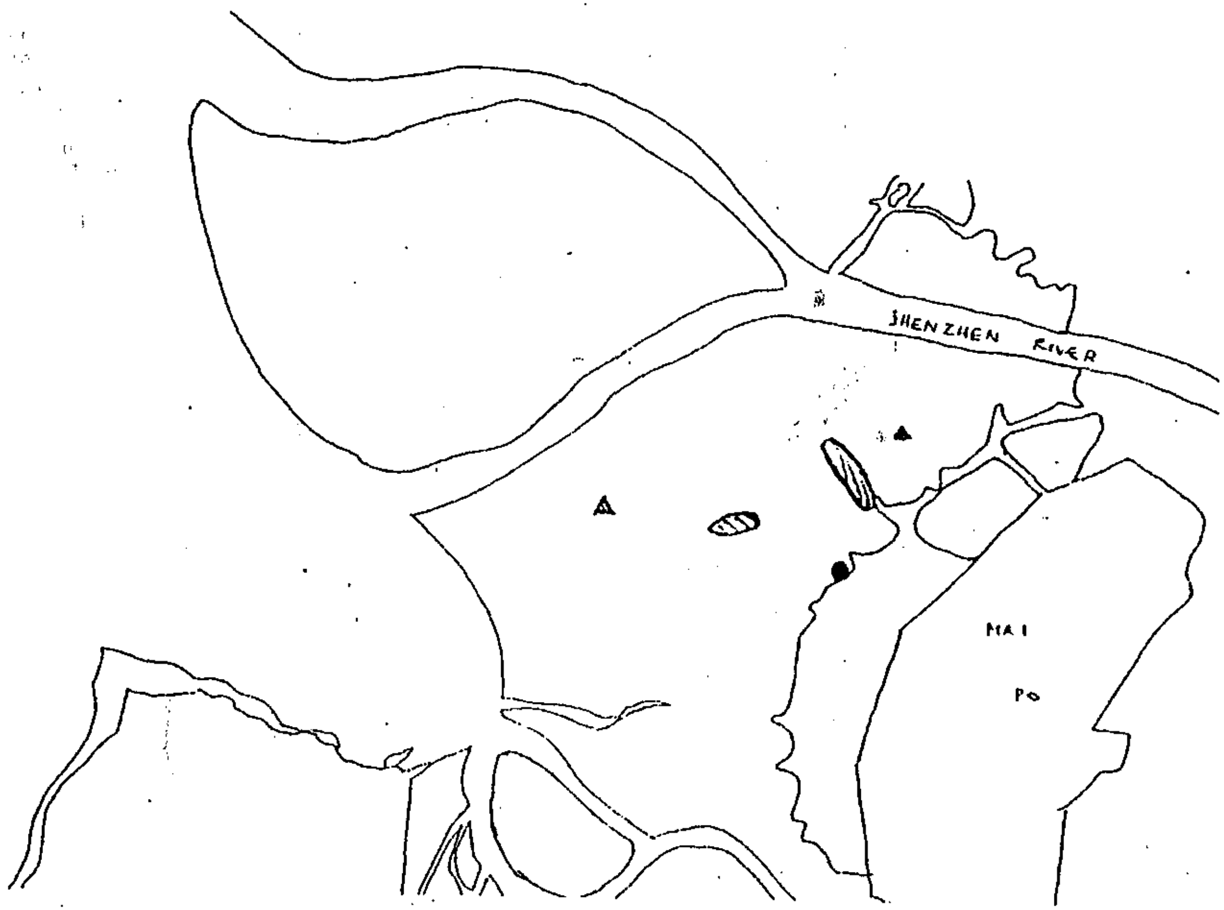


Figure A10.12.14 Wader distribution, 14-15 July (1300 on 14th - 1100 on 15th) (▲ Mudflat Hide, ● Boardwalk Hide)

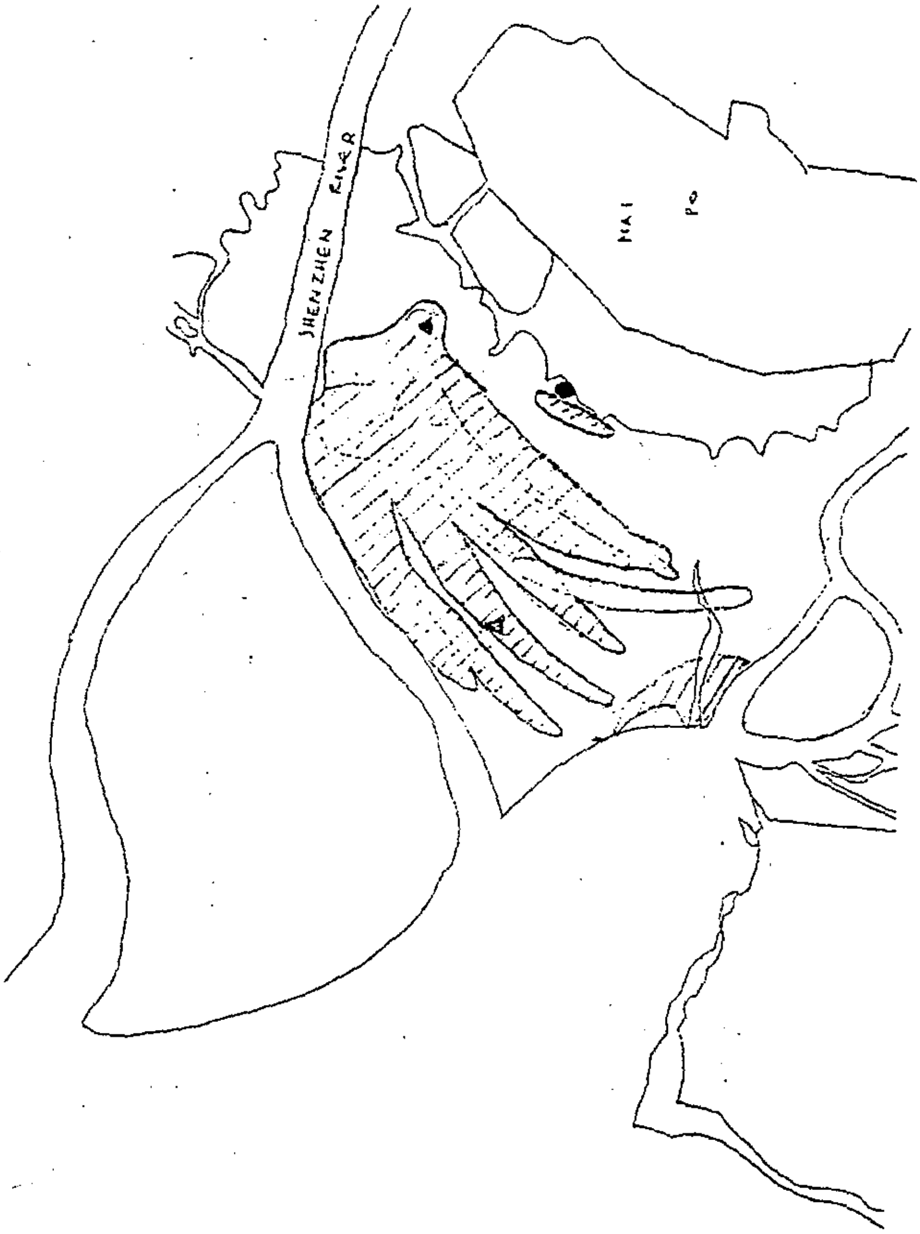
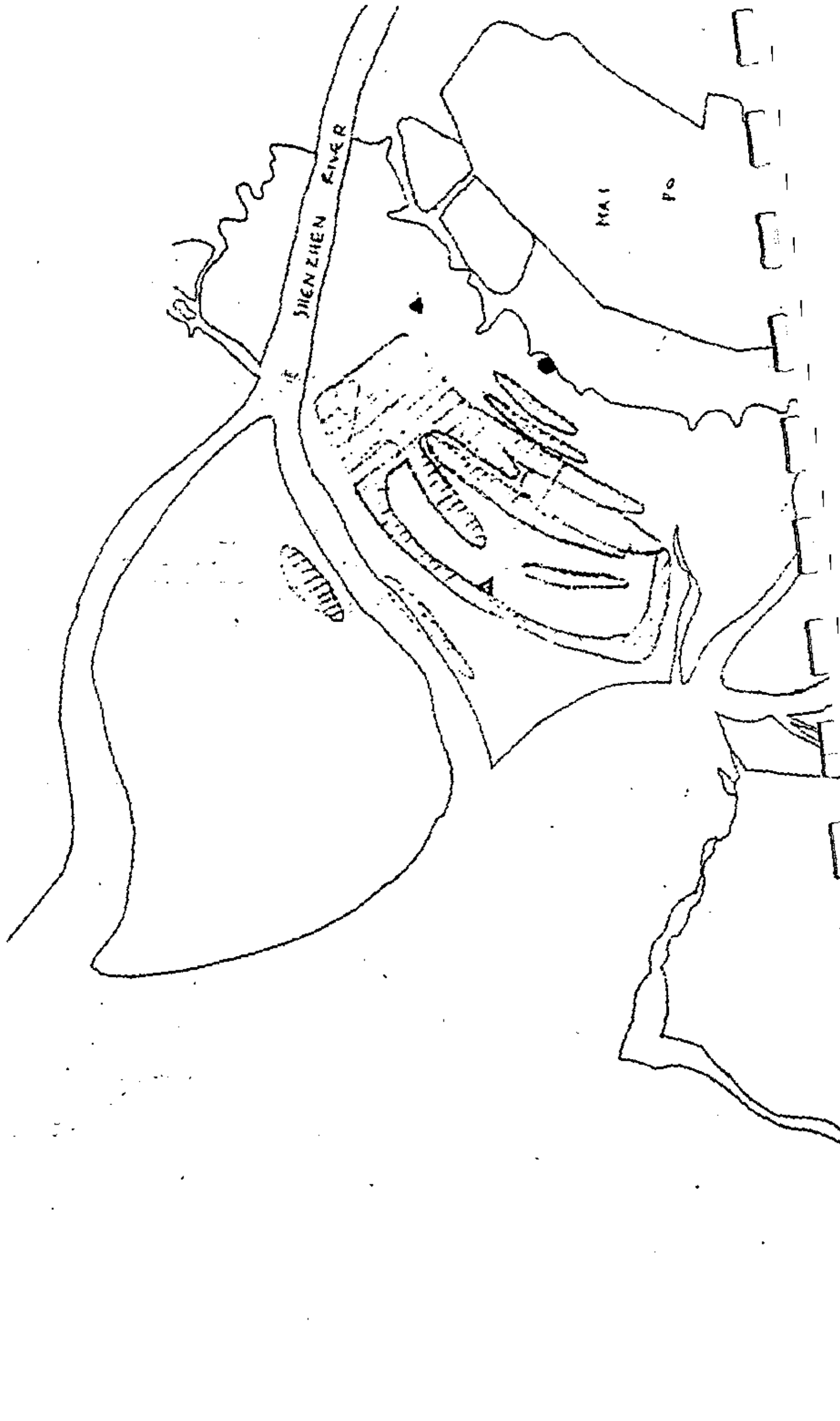


Figure A10.12.15 Wader distribution, 24-25 August (1240 on 24th -) (▲ Mudflat Hide, ● Boardwalk Hide)


SHENZHEN RIVER
MAI PO

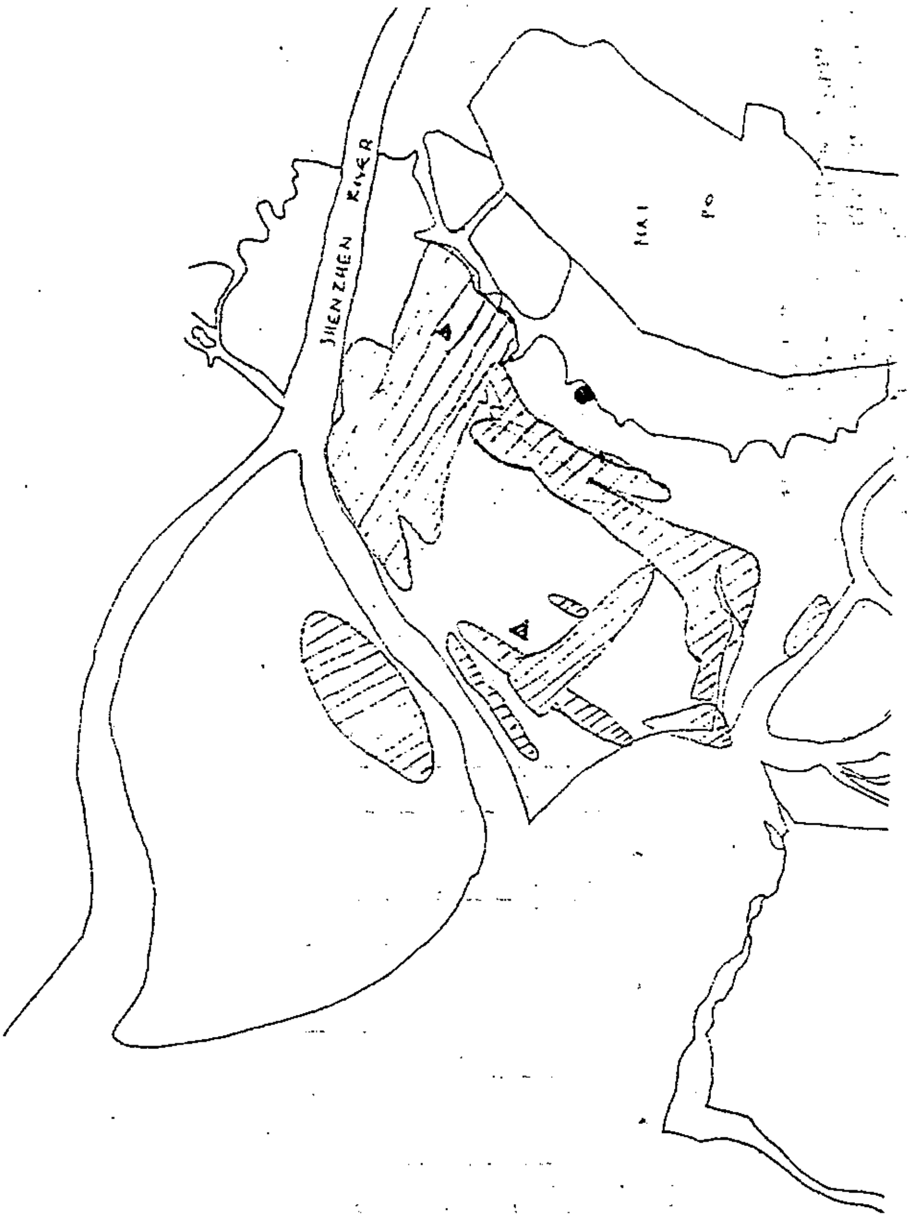


Figure A10.12.17 Wader distribution, 27 October (0300-1630) (▲ Mudflat Hide, ● Boardwalk Hide)

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

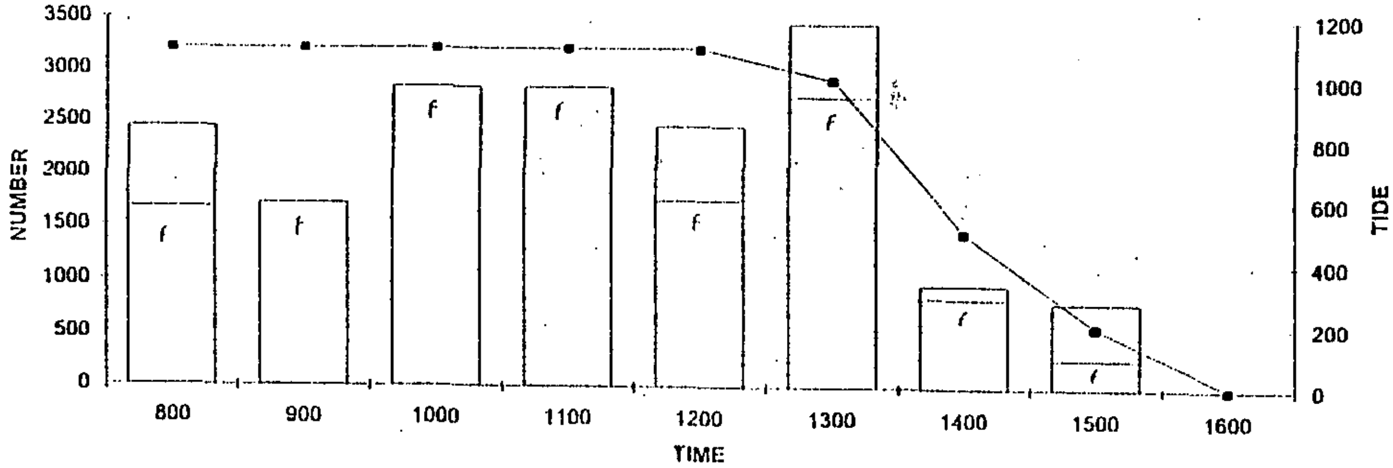


Figure A10.12.18 Wader distribution, 6 March 1994

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

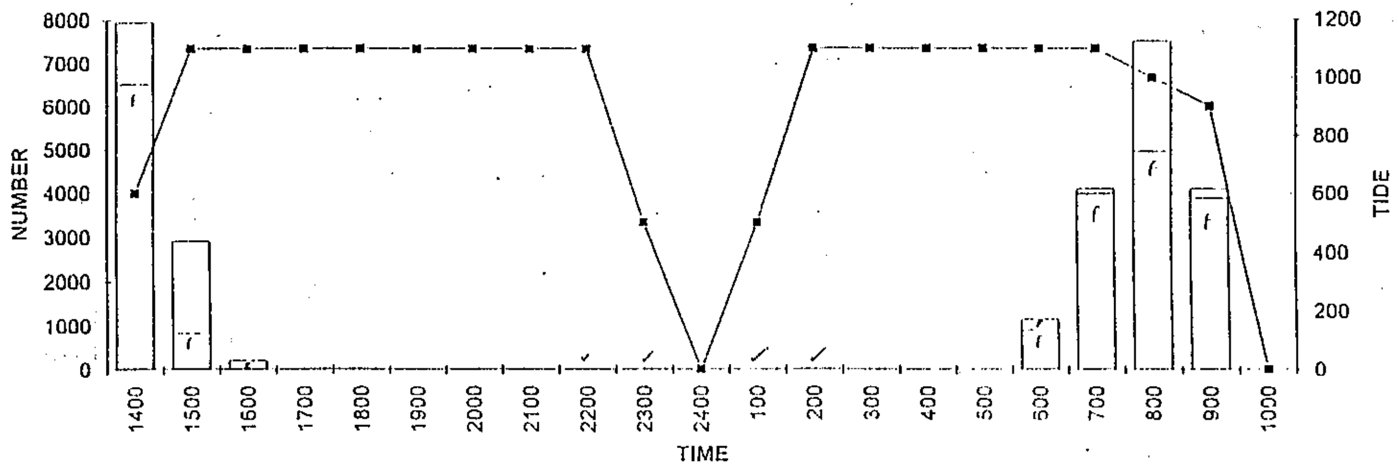


Figure A10.12.19 Wader distribution, 12 April 1994

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

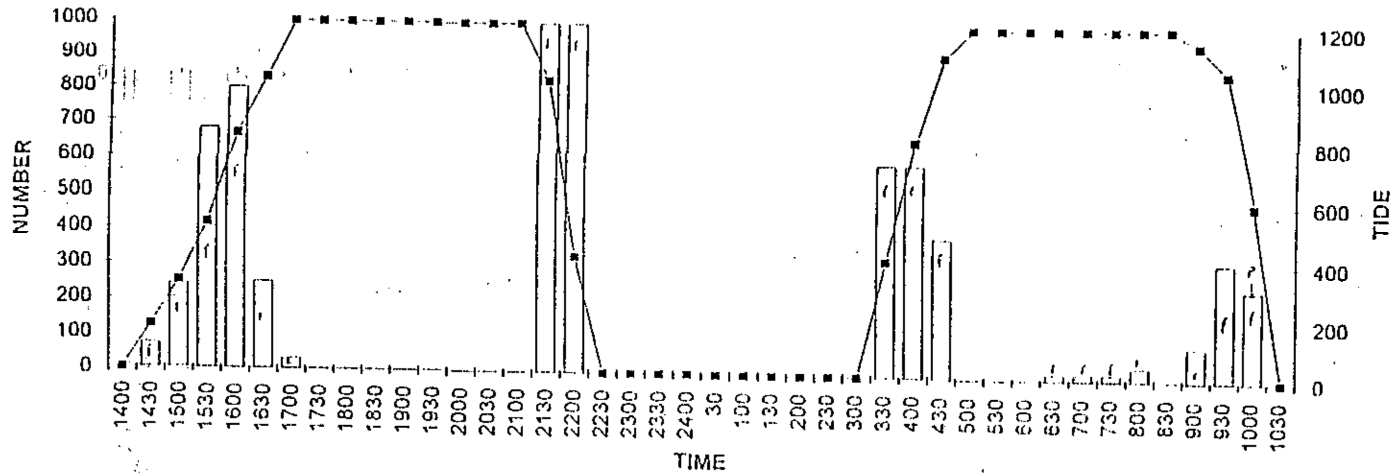


Figure A10.12.20 Wader distribution, 24 August 1994

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

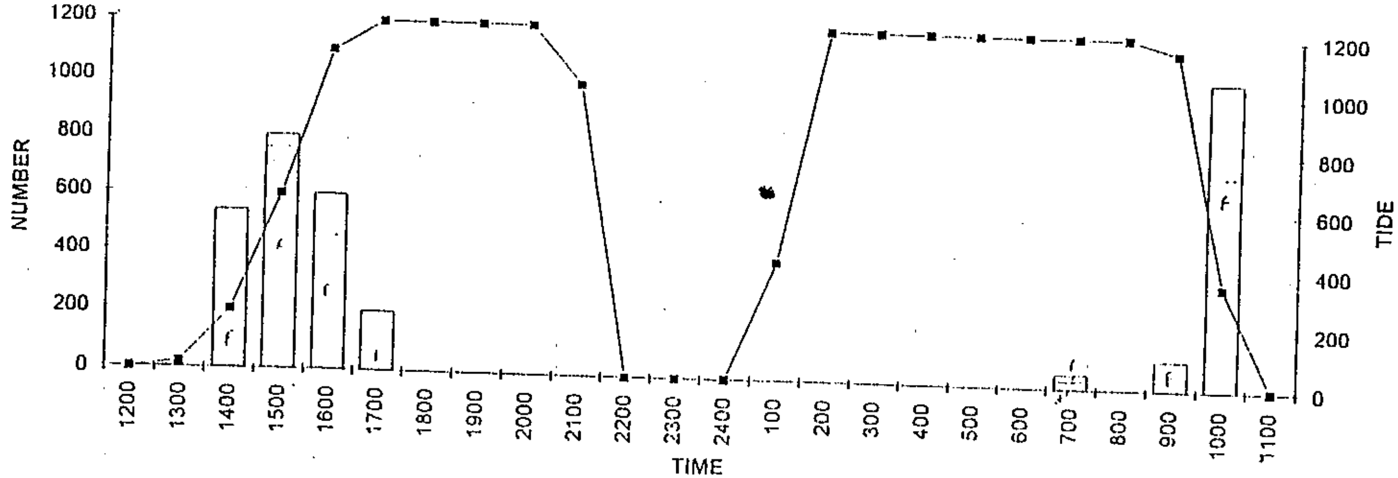


Figure A10.12.21 Wader distribution 22 September 1994

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

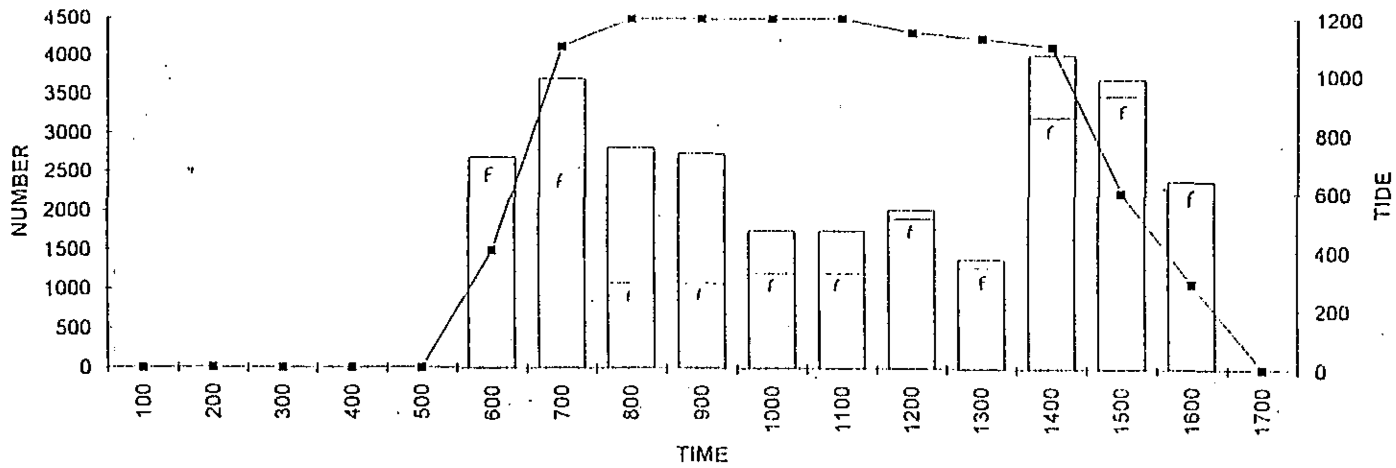


Figure A10.12.22 Wader distribution 27 October 1994

F: Number of birds foraging

Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

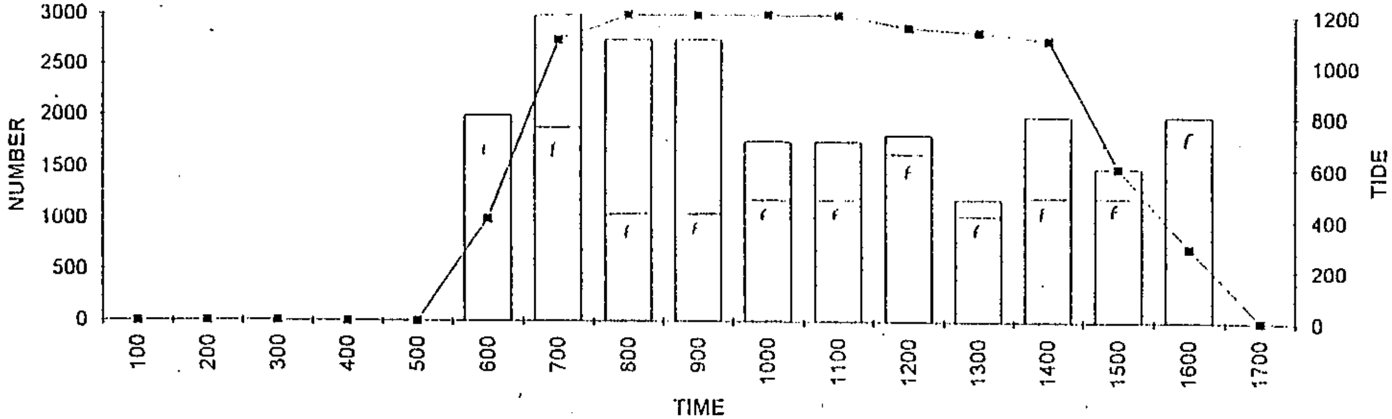


Figure A10.12.23 Dunlin and kentish plover distribution, 27 October 1994

F: Number of birds foraging
Tide: numbers refer to distance (in m) of tide line from the Boardwalk Hide. 1200m low tide, 0m high tide

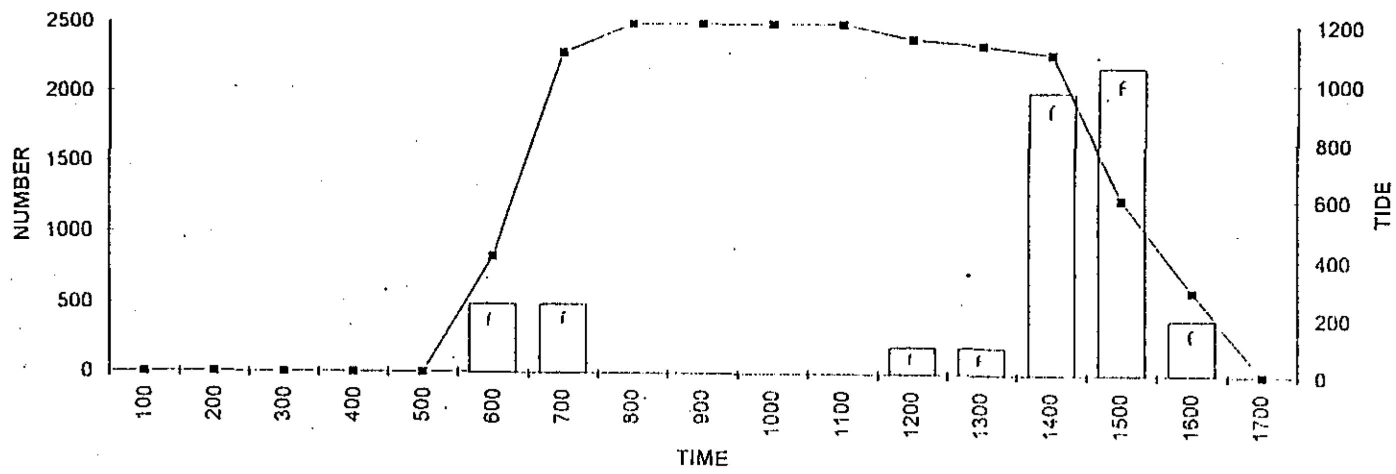


Figure A10.12.24 Tringa distribution, 27 October 1994

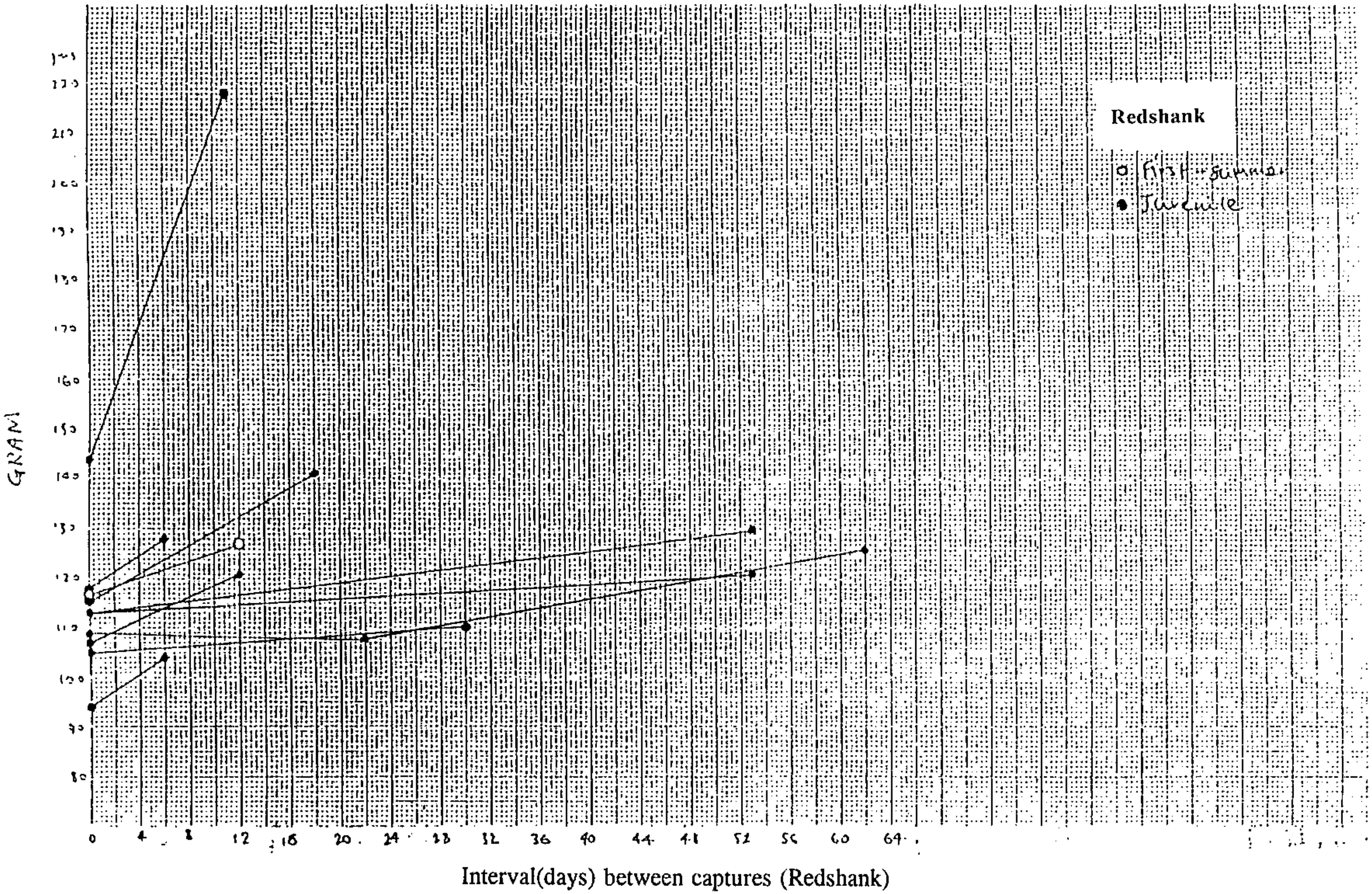


Figure A10.12.25 Weight gains of Redshank in Deep Bay

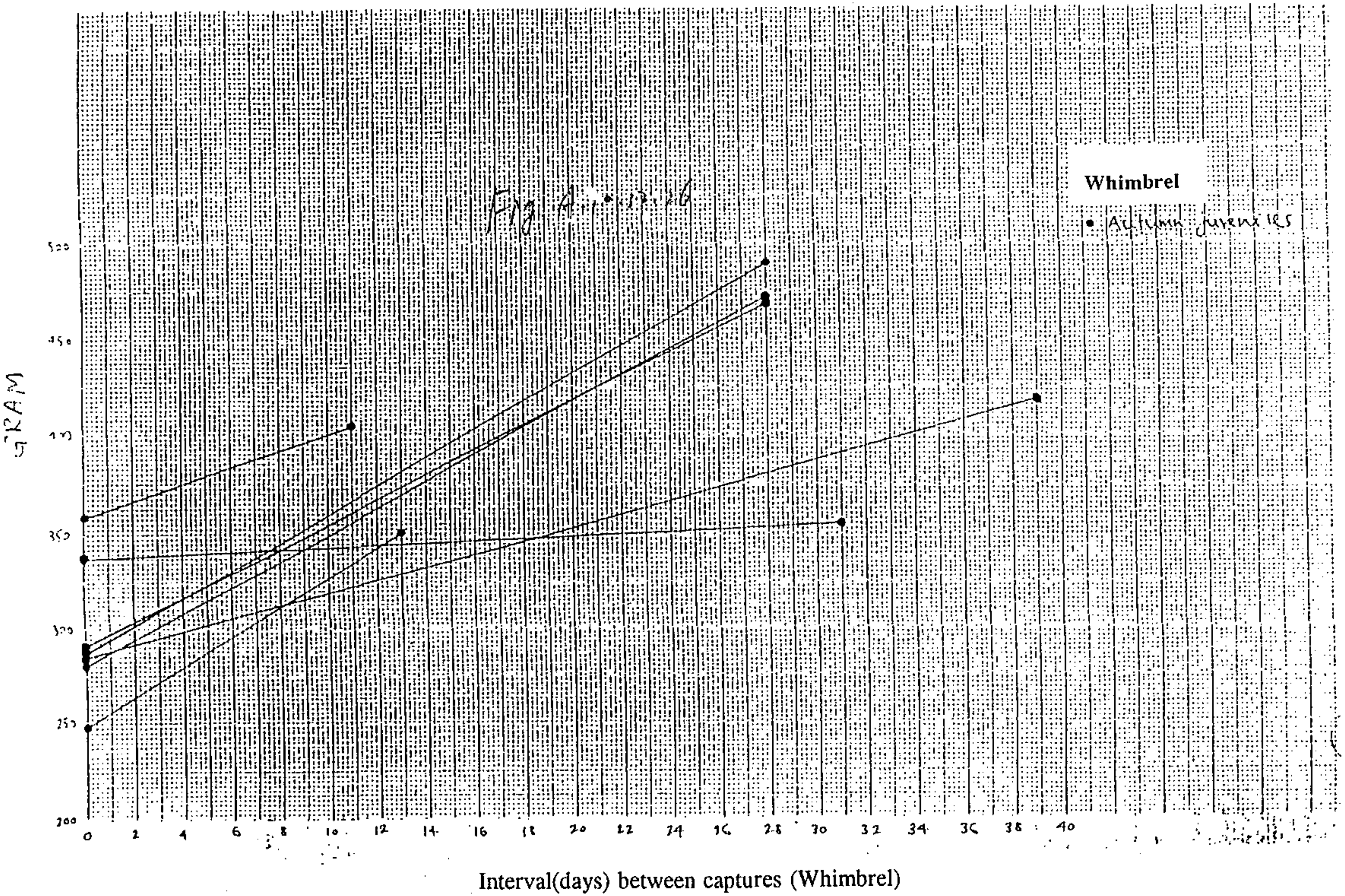
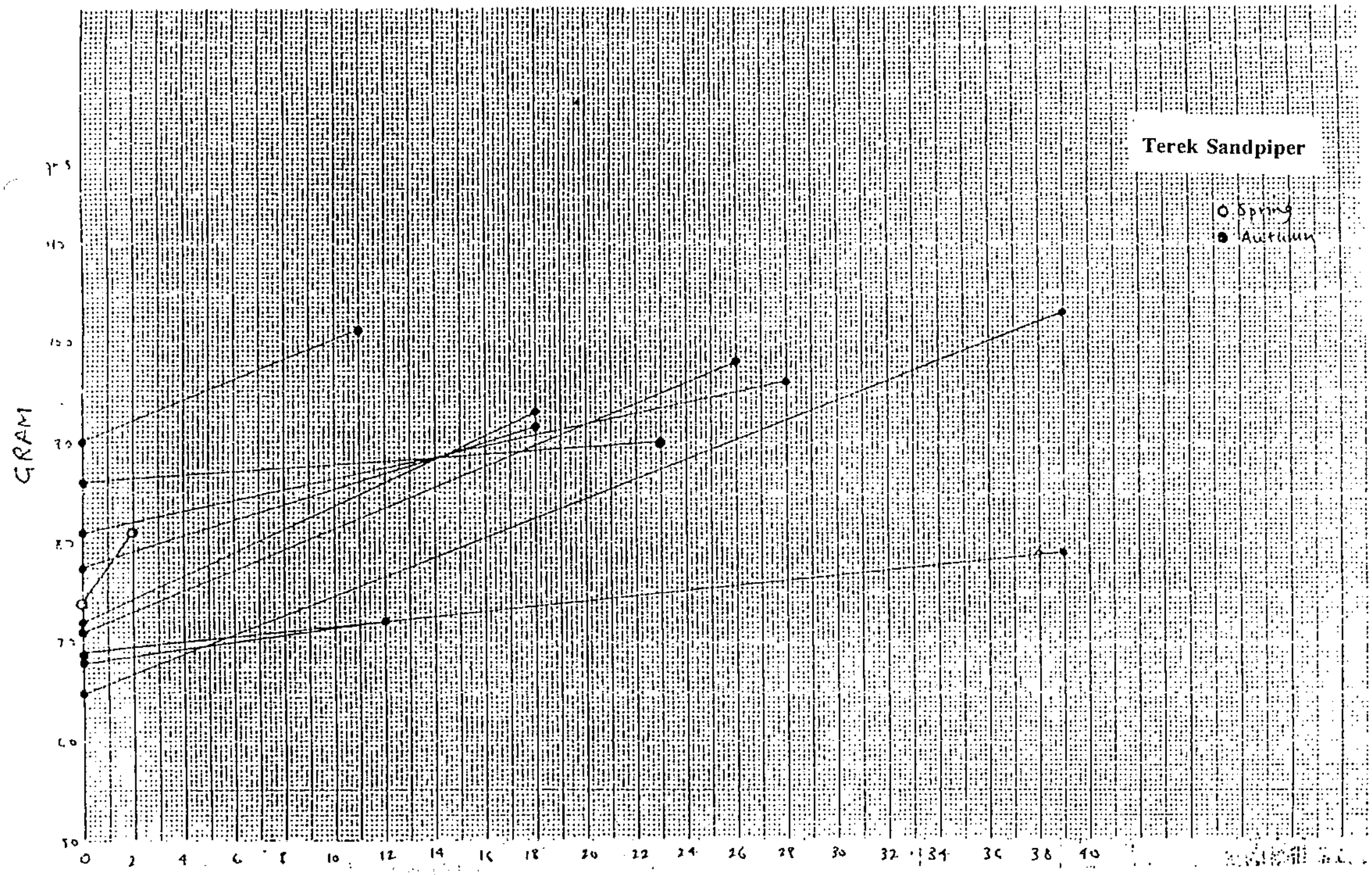


Figure A10.12.26 Weight gains of Whimbrel in Deep Bay



Interval(days) between captures (Terek Sandpiper)

Figure A10.12.27 Weight gains of Terek Sandpiper in Deep Bay

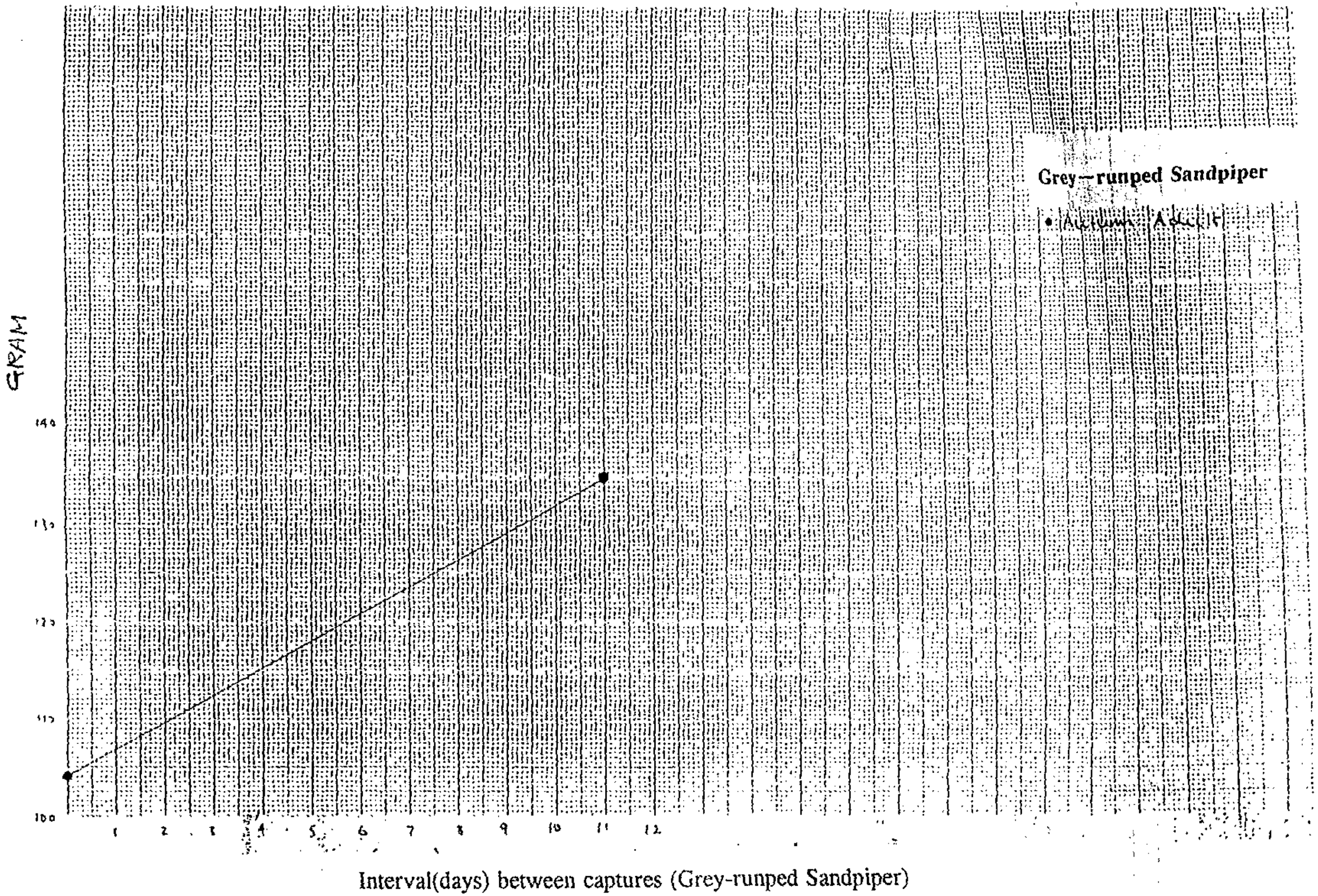


Figure A10.12.28 Weight gains of Grey-rumped Sandpiper in Deep

A10.12.3 UTILISATION OF POND HABITATS ALONG THE SHENZHEN RIVER BY BIRDS

A10.12.3.1 Introduction

The Shenzhen River Regulation Project would result in the destruction of both banks of the River together with areas of land adjacent to the River. The Hong Kong side of the river between Lo Wu and the river mouth was surveyed to determine numbers of bird present and their distribution.

A10.12.3.2 Methods

Birds along the Hong Kong side of the Shenzhen River between Lo Wu and the river mouth were mapped and counted twice per month. The area was covered on foot and on bicycle. The same route was used on each visit. The area was divided into 1 x 1 km squares (Figure A10.12.29), and all wetland birds and raptors in each square were recorded. Care was taken not to double count individuals, and birds passing overhead and not considered to be actively using the area were not recorded. Birds and raptors are listed as follows:

Waterfowl

Little Grebe	*Tachybaptus ruficollis*
Cormorant	*Phalacrocorax carbo*
Yellow Bittern	*Ixobrychus sinensis*
Night Heron	*Nycticorax nycticorax*
Little Green Heron	*Butorides striatus*
Chinese Pond Heron	*Ardeola bacchus*
Cattle Egret	*Bubulcus ibis*
Little Egret	*Egretta garzetta*
Intermediate Egret	*Egretta intermedia*
Great Egret	*Egretta alba*
Grey Heron	*Ardea cinerea*
Purple Heron	*Ardea purpurea*
European Spoonbill	*Platalea leucorodia*
Black-faced Spoonbill	*Platalea minor*
Wigeon	*Anas penelope*
Teal	*Anas crecca*
Garganey	*Anas querquedula*
White-breasted Waterhen	*Amaurornis phoenicurus*
Moorhen	*Gallinula cinerea*
Coot	*Fulica atra*
Painted Snipe	*Rostratula benghalensis*
Black-winged Stilt	*Himantopus himantopus*
Little Ringed Plover	*Charadrius dubius*
Temminck's Stint	*Calidris temminckii*
Common Snipe	*Gallinago gallinago*
Green Sandpiper	*Tringa ochropus*
Wood Sandpiper	*Tringa glareola*
Common Sandpiper	*Actitis hypoleucus*
Redshank	*Tringa totanus*
Black-headed Gull	*Larus ridibundus*

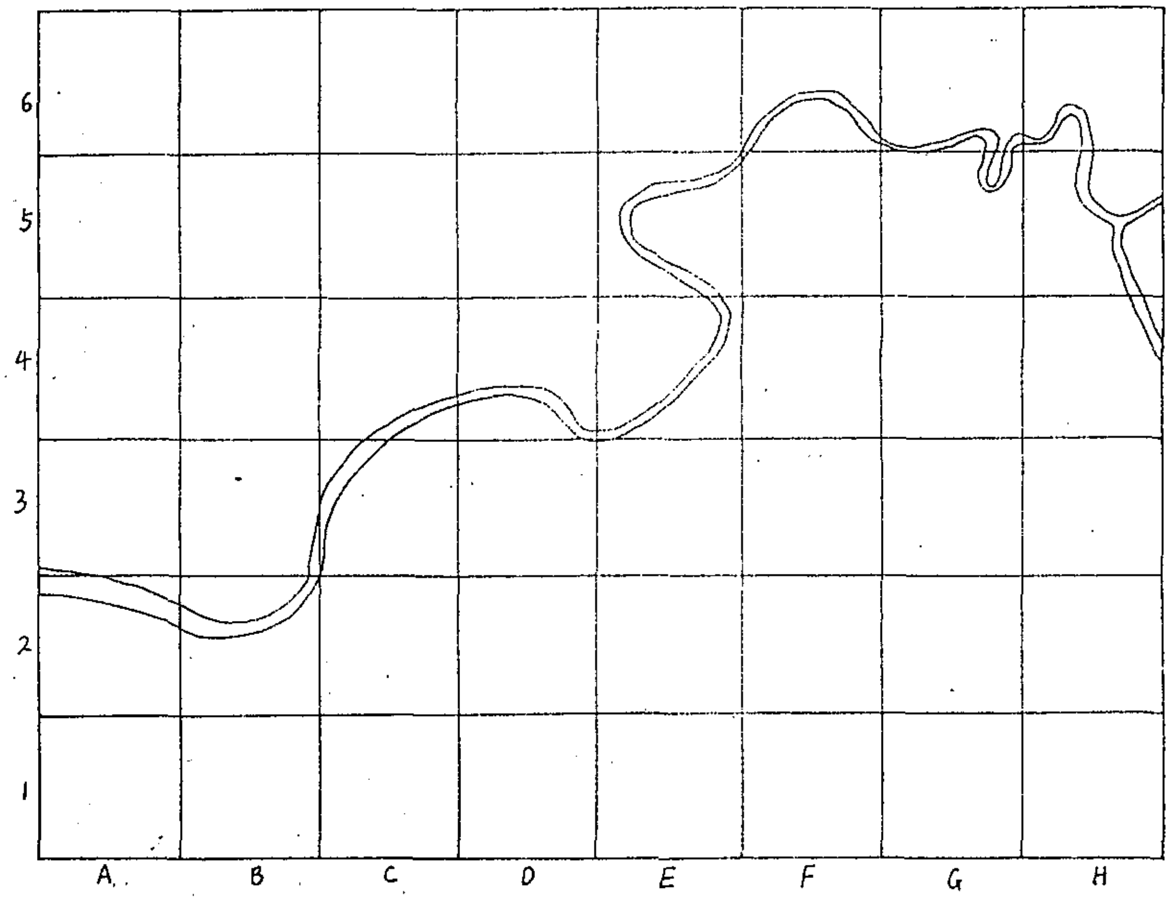


Figure A10.12.29 1 x 1 km squares

Raptors

Crested Honey Buzzard	*Pernis ptilorhynchus*
Black-shouldered Kite	*Elanus caeruleus*
Black Kite	*Milvus migrans*
Serpent Eagle	*Spilornis cheela*
Besra	*Accipiter virgatus*
Crested Goshawk	*Accipiter trivirgatus*
Buzzard	*Buteo buteo*
Spotted Eagle	*Aquila clanga*
Imperial Eagle	*Aquila heliaca*
Bonelli's Eagle	*Hieraaetus fasciatus*
Kestrel	*Falco tinnunculus*
Peregrine	*Falco peregrinus*

A10.12.3.3 Habitat

The section of the Shenzhen River between Lo Wu and the river mouth is heavily polluted, particularly with organic effluent. The river is tidally influenced and mud banks are exposed at low tide. The habitat bordering the river is mostly fish and duck ponds with fish ponds predominating between Mai Po and Lok Ma Chau, and duck ponds between Lok Ma Chau and Lo Wu. In the area north of Ma Tso Lung, there are large areas of *Phragmites* reedbeds and wet grassland, for example at Liu Pok. Some ponds have been abandoned and are becoming overgrown.

A10.12.3.4 Results

Details of distribution of waterfowl and raptors are given in Table A10.12.2. A list of all other species recorded in the area is given below.

Red Turtle Dove	*Streptopelia tranquebarica*
Rufous Turtle Dove	*Streptopelia orientalis*
Spotted Dove	*Streptopelia chinensis*
Large Hawk Cuckoo	*Hierococcyx fugax*
Plaintive Cuckoo	*Cacomantis merulinus*
Indian Cuckoo	*Cuculus micropterus*
Koel	*Eudynamis scolopacea*
Greater Coucal	*Centropus sinensis*
Lesser Coucal	*Centropus bengalensis*
Barred Owlet	*Glaucidium cuculoides*
Pacific Swift	*Apus pacificus*
House Swift	*Apus affinus*
White-breasted Kingfisher	*Halcyon smyrnensis*
Black-capped Kingfisher	*Halcyon pileata*
Common Kingfisher	*Alcedo atthis*
Pied Kingfisher	*Ceryle rudis*
Wryneck	*Jynx torquilla*
Sand Martin	*Riparia riparia*
Swallow	*Hirundo rustica*
Asian House Martin	*Hirundo dasypus*
Richard's Pipit	*Anthus novaeseelandiae*
Olive-backed Pipit	*Anthus hodgsoni*

Red-throated Pipit	*Anthus cervinus*
Yellow Wagtail	*Motacilla flava*
Grey Wagtail	*Motacilla cinerea*
White Wagtail	*Motacilla alba*
Crested Bulbul	*Pycnonotus jocosus*
Chinese Bulbul	*Pycnonotus sinensis*
Red-vented Bulbul	*Pycnonotus aurigaster*
Rubythroat	*Luscinia calliope*
Daurian Redstart	*Phoenicurus auroreus*
Blackbird	*Turdus merula*
Magpie Robin	*Copsychus saularis*
Stonechat	*Saxicola torquata*
Grey-backed Thrush	*Turdus hortulorum*
Chinese Bush Warbler	*Cettia diphone*
Fantail Warbler	*Cisticola juncidis*
Plain Prinia	*Prinia inornata*
Yellow-bellied Prinia	*Prinia flaviventris*
Lanceolated Warbler	*Locustella lanceolata*
Pallas's Grasshopper Warbler	*Locustella certhiola*
Black-browed Reed Warbler	*Acrocephalus bistrigiceps*
Great Reed Warbler	*Acrocephalus orientalis*
Long-tailed Tailorbird	*Orthotomus sutorius*
Arctic Warbler	*Phylloscopus borealis*
Pallas's Warbler	*Phylloscopus proregulus*
Yellow-browed Warbler	*Phylloscopus inornatus*
Dusky Warbler	*Phylloscopus fuscatus*
Brown Flycatcher	*Muscicapa latirostris*
Black-faced Laughing Thrush	*Garrulax perspicillatus*
Great Tit	*Parus major*
Penduline Tit	*Remiz pendulinus*
Japanese White-eye	*Zosterops japonica*
Black-naped Oriole	*Oriolus chinensis*
Rufous-backed Shrike	*Lanius schach*
Black Drongo	*Dicrurus macrocercus*
Hair-crested Drongo	*Dicrurus hottentotus*
Blue Magpie	*Urocissa erythorhyncha*
Magpie	*Pica pica*
Jungle Crow	*Corvus macrorhynchus*
Collared Crow	*Corvus torquatus*
Silky Starling	*Sturnus sericeus*
Daurian Starling	*Sturnus sturninus*
Chinese Starling	*Sturnus sinensis*
Grey Starling	*Sturnus cineraceus*
Black-necked Starling	*Sturnus nigricollis*
Crested Mynah	*Acridotheres cristatellus*
Tree Sparrow	*Passer montanus*
Spotted Munia	*Lonchura punctulata*
Black-tailed Hawfinch	*Coccothraustes migratorius*
Black-faced Bunting	*Emberiza spodocephala*
Little Bunting	*Emberiza pusilla*
Yellow-breasted Bunting	*Emberiza aureola*

4-Mar-94 SPECIES	A2	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe																			0
Cormorant										30									30
Yellow Bittern																			0
Night Heron									3										3
Little Green Heron																			0
Chinese Pond Heron	2	3					3								5				13
Cattle Egret		5																	5
Little Egret		490					3			10			12						515
Intermediate Egret		1																	1
Great Egret		3					3			3			4						13
Grey Heron		2								17	12		11						42
White Spoonbill																			0
Black-faced Spoonbill																			0
Wigeon													16						16
Teal													190						190
Pintail																			0
Shoveller													13						13
Crested Honey Buzzard																			0
Black-shouldered Kite																			0
Black Kite							1												1
Serpent Eagle																			0
Crested Goshawk															1				1
Buzzard												1							1
Spotted Eagle																			0
Imperial Eagle							1					2			4		1		8
Bonelli's Eagle																			0
Kestrel													1						1
Peregrine																			0
White-breasted Waterhen									1			2							3
Moorhen									1										1
Coot																			0
Painted Snipe									1										1
Black-winged Stilt																			0
Little Ringed Plover												6							6
Temminck's Stint													6						6
Common Snipe																			0
Green Sandpiper		1			2														3
Wood Sandpiper													46						46
Common Sandpiper		1			1														2
Black-headed Gull													10		250				260
TOTAL	2	506	0	0	3	0	11	0	11	60	12	11	309	0	260	0	1	0	1186

Table A10.12.2(1) Distribution of waterfowl and raptors

SPECIES (21-Mar-94)	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe								2	2			2						6
Cormorant						7			14					37				58
Yellow Bittern																		0
Night Heron																		0
Little Green Heron																		0
Chinese Pond Heron	3		4			4		10			5							26
Cattle Egret												2						2
Little Egret	3		4	4					15									26
Intermediate Egret																		0
Great Egret																		0
Grey Heron												34		76				110
White Spoonbill	1																	1
Black-faced Spoonbill	20																	20
Garganey											3							3
Wigeon																		0
Teal												35						35
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite						10												10
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle						1												1
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen																		0
Moorhen												5						5
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover	2					4			3			5						14
Temminck's Stint												4						4
Common Snipe												5						5
Green Sandpiper				1				1										2
Wood Sandpiper									60									60
Common Sandpiper	1		2			3						3						9
Black-headed Gull											19			350				369
																		0
TOTAL	30	0	10	5	0	29	0	13	94	0	27	95	0	463	0	0	0	766

Table A10.12.2(2) Distribution of waterfowl and raptors

20-Apr-94																		
SPECIES	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe																		0
Cormorant																		0
Yellow Bittern																		0
Night Heron																		0
Little Green Heron																		0
Chinese Pond Heron	4				2			4										10
Cattle Egret					12													12
Little Egret					1													1
Intermediate Egret																		0
Great Egret					1													1
Grey Heron								1										1
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite											1							1
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine											1							1
White-breasted Waterhen											2							2
Moorhen											3							3
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover	1																	1
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper											1							1
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
																		0
TOTAL	5	0	0	0	16	0	0	5	0	0	8	0	0	0	0	0	0	34

Table A10.12.2(3) Distribution of waterfowl and raptors

SPECIES 30-Apr-94	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe																		0
Cormorant																		0
Yellow Bittern																		0
Night Heron												11						11
Little Green Heron																		0
Chinese Pond Heron				2				1			3	5						11
Cattle Egret			17	24					1		1	33						76
Little Egret								2				4						6
Intermediate Egret																		0
Great Egret				3														3
Grey Heron												4						4
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite														1				1
Black Kite											3							3
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen											2	1						3
Moorhen												12						12
Coot																		0
Painted Snipe																		0
Black-winged Stilt												1						1
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper											2	3						5
Black-headed Gull																		0
																		0
TOTAL	0	0	17	29	0	0	0	3	1	0	11	74	0	1	0	0	0	136

Table A10.12.2(4) Distribution of waterfowl and raptors

7-May-94																		
SPECIES	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe				2														2
Cormorant																		0
Yellow Bittern																		0
Night Heron	1							9						5				15
Little Green Heron																		0
Chinese Pond Heron	5				4		2			5				7				23
Cattle Egret	1			45								2						48
Little Egret	1			1	2	1	2	1				11		2				21
Intermediate Egret																		0
Great Egret							1					5						6
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen				1														1
Moorhen												4						4
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper				2														2
Black-headed Gull																		0
																		0
TOTAL	8	0	0	51	6	1	5	10	0	5	0	22	0	14	0	0	0	122

Table A10.12.2(5) Distribution of waterfowl and raptors

31-May-94																		
SPECIES	B2	B3	C2	C3	C4	D4	D3	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe						2												2
Cormorant																		0
Yellow Bittern						1												1
Night Heron	1			2				15						5				23
Chinese Pond Heron	4			6		1		4	3			2						20
Cattle Egret				14				4				2				3		23
Little Egret	18			10														28
Intermediate Egret																		0
Great Egret																		0
Grey Heron				1														1
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk								1										1
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen									1					1				2
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
TOTAL	23	0	0	33	0	4	0	24	4	0	0	4	0	6	0	3	0	101

Table A10.12.2(6) Distribution of waterfowl and raptors

18-Jun-94

SPECIES	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe																		0
Cormorant																		0
Yellow Bittern																		0
Night Heron				2							6							8
Little Green Heron																		0
Chinese Pond Heron	6		4	12	2		1	3						6				34
Cattle Egret																		0
Little Egret	6		2	6	4									2				20
Intermediate Egret																		0
Great Egret			2	4					1					28				35
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle									2									2
Kestral																		0
Peregrine																		0
White-breasted Waterhen					1													1
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
																		0
TOTAL	12	0	8	24	7	0	1	3	3	0	6	0	0	36	0	0	0	100

Table A10.12.2(7) Distribution of waterfowl and raptors

SPECIES (29-Jun-94)	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe																		0
Cormorant												1						[illegible]
Yellow Bittern																		0
Night Heron	2			2		1			1			7						13
Chinese Pond Heron	3			5		5			6			10				3		32
Cattle Egret				56		1			3			21		11				92
Little Egret	4			11		3			10			11				4		43
Intermediate Egret																		0
Great Egret									7			3						10
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle.																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestrel																		0
Peregrine																		0
White-breasted Waterhen																		0
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper						1												1
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
TOTAL	9	0	0	74	0	11	0	0	27	0	0	53	0	11	0	7	0	192

Table A10.12.2(8) Distribution of waterfowl and raptors

15-Jul-94	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
SPECIES																		
Little Grebe					2						2							4
Cormorant																		0
Yellow Bittern																		0
Night Heron																		0
Little Green Heron																		0
Chinese Pond Heron	2		4		6			1				3	4	1				21
Cattle Egret					12													12
Little Egret	3		5			8				2	3	2	1					24
Intermediate Egret																		0
Great Egret			1								2							3
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen	1					1			1		2	3						8
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper.																		0
Black-headed Gull																		0
																		0
TOTAL	6	0	10	0	20	9	0	1	1	2	9	8	5	1	0	0	0	72

Table A10.12.2(9) Distribution of waterfowl and raptors

SPECIES (30-Jul-94)	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe																		0
Cormorant																		0
Yellow Bittern																		0
Night Heron																		0
Chinese Pond Heron	8			9					9									26
Cattle Egret					22													22
Little Egret	22			33	10				13									78
Intermediate Egret																		0
Great Egret																		0
Grey Heron	3			8					2									13
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen																		0
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
TOTAL	33	0	0	50	32	0	0	0	24	0	0	0	0	0	0	0	0	139

Table A10.12.2(10) Distribution of waterfowl and raptors

22-Aug-94 SPECIES	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
Little Grebe																		0
Cormorant																		0
Yellow Bittern																		0
Night Heron	4			1			1				1			6				13
Chinese Pond Heron	4			12	2		10		50		17			23				118
Cattle Egret	2				1				9		7			7				26
Little Egret	6			5	1		3		33		28			22				98
Intermediate Egret																		0
Great Egret				1					12					1				14
Grey Heron														1				1
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Besra														1				
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen	1								1		2			2				6
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe	1			1										1				3
Green Sandpiper																		0
Wood Sandpiper									10									10
Common Sandpiper																		0
Black-headed Gull																		0
TOTAL	18	0	0	20	4	0	14	0	115	0	55	0	0	64	0	0	0	289

Table A10.12.2(11) Distribution of waterfowl and raptors

30-Aug-94	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
SPECIES																		
Little Grebe						2												2
Cormorant																		0
Yellow Bittern																		0
Night Heron																		0
Chinese Pond Heron	11			14	4		13	20			5			21				88
Cattle Egret	2			1										12				15
Little Egret	8			4	5		9	15			11			19				71
Intermediate Egret																		0
Great Egret														1				1
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite	1																	1
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen					1													1
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Redshank														2				
Green Sandpiper																		0
Wood Sandpiper							4											4
Common Sandpiper				1										1				2
Black-headed Gull																		0
TOTAL	22	0	0	20	10	2	26	35	0	0	16	0	0	56	0	0	0	185

Table A10.12.2(12) Distribution of waterfowl and raptors

SPECIES	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
9-Sep-94																		
Little Grebe														1				1
Cormorant																		0
Yellow Bittern						3												3
Night Heron						6		2						4			3	15
Little Green Heron						1												1
Chinese Pond Heron	2			14	10			7			2			14			4	53
Cattle Egret				3	11			1						5				20
Little Egret	1			13	8				9		2			21			6	60
Intermediate Egret																		0
Great Egret																		0
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen				1	2									2				5
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
	3	0	0	31	31	10	0	10	9	0	4	0	0	47	0	0	13	158

Table A10.12.2(13) Distribution of waterfowl and raptors

19-Sep-94	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTAL
SPECIES																		
Little Grebe														1				1
Cormorant																		0
Yellow Bittern						3												3
Night Heron						6		2						4			3	15
Little Green Heron						1												1
Chinese Pond Heron	2			13	10			7			2			14		2	4	54
Cattle Egret				3	11			1						5				20
Little Egret	1			11	8				9		2			21			6	58
Intermediate Egret																		0
Great Egret					3		1		2		1							7
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen				1	2									2				5
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
																		0
TOTAL	3	0	0	28	34	10	1	10	11	0	5	0	0	47	0	2	13	164

Table A10.12.2(14) Distribution of waterfowl and raptors

SPECIES (5-Oct-94)	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTA
Little Grebe						4		2				2						8
Cormorant																		0
Yellow Bittern																		0
Night Heron	1			3		2		14	2			8	2					32
Little Green Heron																		0
Chinese Pond Heron	7			7		11		25				6		2				58
Cattle Egret																		0
Little Egret	10			2		7		21	1			9	3					53
Intermediate Egret																		0
Great Egret	2			2				7				3		3				17
Grey Heron																		0
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle																		0
Kestral																		0
Peregrine																		0
White-breasted Waterhen	5			1		3		3				3		1				16
Moorhen																		0
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
																		0
TOTAL	25	0	0	15	0	27	0	72	3	0	0	31	5	6	0	0	0	184

Table A10.12.2(15) Distribution of waterfowl and raptors

14-Oct-94

SPECIES	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTA
Little Grebe																		0
Cormorant																		0
Yellow Bittern																		0
Night Heron								5	12					6				23
Little Green Heron																		0
Chinese Pond Heron	10							10	21					42				83
Cattle Egret	7																	7
Little Egret	14							40	12					13				79
Intermediate Egret																		0
Great Egret								5	6					4				15
Purple Heron														2				2
Grey Heron	2							10	12		6	27		21				78
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal																		0
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite																		0
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																		0
Bonelli's Eagle									2									2
Kestral																		0
Peregrine																		0
White-breasted Waterhen	1																	1
Moorhen																		0
Coot																		0
Painted Snipe								1										1
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper																		0
Common Sandpiper																		0
Black-headed Gull																		0
																		0
TOTAL	34	0	0	0	0	0	0	71	65	0	6	27	0	88	0	0	0	291

Table A10.12.2(16) Distribution of waterfowl and raptors

SPECIES (10-Nov-94)	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTA
Little Grebe	1							1						1				3
Cormorant	1			1			1	2			6			2				13
Yellow Bittern																		0
Night Heron											1			40				41
Little Green Heron																		0
Chinese Pond Heron	1			3	2		4	4			2				6		2	24
Cattle Egret																		0
Little Egret	156			6	4		12		3		6			4				191
Intermediate Egret																		0
Great Egret	27			3				1	1		1			3			1	37
Grey Heron	17				4		1	1	1		4	75		64			6	173
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal												80		19				99
Pintail																		0
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite	1			2	2		2	5	9		3			16			6	46
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle																1	2	3
Bonelli's Eagle																		0
Kestral												1						1
Peregrine																		0
White-breasted Waterhen	1				1						2							4
Moorhen											30			5				35
Coot	53														3			56
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover												22		1				23
Temminck's Stint												2						2
Common Snipe																		0
Green Sandpiper																		0
Wood Sandpiper												36						36
Common Sandpiper	1						1				1	3						6
Black-headed Gull		2																2
																		0
TOTAL	259	2	0	15	13	0	21	14	14	0	56	219	0	155	9	1	17	795

Table A10.12.2(17) Distribution of waterfowl and raptors

SPECIES (24-Nov-80)	B2	B3	C2	C3	C4	D3	D4	E3	E4	E5	F4	F5	F6	G5	G6	H5	H6	TOTA
Little Grebe																		0
Cormorant				10			12				104			28				154
Yellow Bittern																		0
Night Heron																		0
Little Green Heron																		0
Chinese Pond Heron	3			80			4							53				140
Cattle Egret																		0
Little Egret	6			12	6		4							1				29
Intermediate Egret																		0
Great Egret	4			32	2	5	6											49
Grey Heron	6			22										89				117
Oriental Stork	1																	1
White Spoonbill																		0
Black-faced Spoonbill																		0
Wigeon																		0
Teal														45				45
Pintail											8							8
Shoveller																		0
Crested Honey Buzzard																		0
Black-shouldered Kite																		0
Black Kite	6			6		2	2				4			2				22
Serpent Eagle																		0
Crested Goshawk																		0
Spotted Eagle																		0
Imperial Eagle							3				5							8
Bonelli's Eagle																		0
Kestral														1				1
Peregrine																		0
White-breasted Waterhen	1										2			9				12
Moorhen														13				13
Coot																		0
Painted Snipe																		0
Black-winged Stilt																		0
Little Ringed Plover																		0
Temminck's Stint																		0
Common Snipe																		0
Green Sandpiper														2				2
Wood Sandpiper																		0
Common Sandpiper	1				2						1			4				8
Black-headed Gull														25				25
																		0
TOTAL	28	0	0	162	10	7	31	0	0	0	124	0	0	272	0	0	0	635

Table A10.12.2(18) Distribution of waterfowl and raptors

A10.12.3.5 Discussion

The river and its banks were seldom used by the birds in the area. During the survey, small numbers of Black-headed Gulls *Larus ridibundus* and Chinese Pond Herons *Ardeola bacchus* were observed searching for food in the river near Lo Wu, otherwise no habitat utilisation of the river was recorded. Both species were probably scavenging since the River is effectively devoid of fauna upriver of the Mai Po Nature Reserve (McChesney, unpublished). Herons and egrets were recorded on the river banks between Mai Po and Lok Ma Chau. None was ever observed foraging, and it appears that all were using the banks as a roost site. There was one record of a White-breasted Waterhen *Amaurornis phoenicurus* scavenging in the river near Lok Ma Chau.

The fish and duck ponds in the area supported low densities of herons and egrets. This also applies to the fish ponds on the north side of the bank at Lok Ma Chau (Peking University 1994). Recent studies (Britton 1992, Wong 1991, Young 1994) have shown that fish ponds are an important feeding habitat for Little Egrets and Chinese Pond Herons in the northern New Territories.

There has been a dramatic reduction in the area of fish ponds around Deep Bay in recent years. Further losses of such habitat could adversely affect both the breeding and wintering populations of herons and egrets (Appendix 10-13).

Recent studies indicate that freshly drained ponds are the most important feeding habitat for Black-faced Spoonbills *Platelea minor* (Appendix 10-13). 23% of the world population of Black-faced Spoonbills currently winters in Deep Bay. The ponds in the Deep Bay area are drained at random throughout the winter. When freshly drained these ponds attract feeding groups of up to about 30 Black-faced Spoonbills. Given the dependence of Black-faced Spoonbills on freshly drained ponds, the loss of even a small area of ponds is expected to have a significant impact on the wintering population of Black-faced Spoonbills in Hong Kong. Egrets and herons also feed in very high densities on freshly drained ponds with up to 900 Little Egrets *Egretta garzetta* present on a single pond (G. Chan pers. comm.).

Small numbers of duck, mainly Teal *Anas crecca* were recorded on the abandoned ponds near Ma Tso Lung. The Ma Tso Lung area held a significant percentage of the waterfowl recorded on the annual January mid-winter waterfowl count with up to 18% of the Deep Bay total present in the area for the period 1990-94 (Table A10.12.3). The area is therefore considered to be of importance for its wintering waterfowl.

Table A10.12.3 Waterfowl at Ma Tso Lung compared to Deep Bay (January waterfowl counts, 1990-94)

Year	1990	1991	1992	1993	1994
Ma Tso Lung	6,850	3,504	3,007	2,119	1,054
Deep Bay	37,891	48,784	46,911	49,153	57,492
%	18.1	7.1	6.4	4.3	1.8

The area north of Ma Tso Lung attracts a greater variety of bird species, probably due to its greater diversity of habitat types. The duck ponds in particular appear to attract the large numbers of Imperial Eagles *Aquila heliaca* that were present in the area in winter. Up to thirteen were present, representing the entire wintering population in Hong Kong. Notably, no Imperial Eagles were recorded from China during the January 1992 mid-winter waterfowl count (Perennou and Mundkhur 1992), despite the fact that all raptors are recorded on these counts. The numbers of Imperial Eagles in the Ma Tso Lung area are thus considered to be of regional importance. The birds may be feeding on sick or dead domestic ducks.

The reedbeds are used by large numbers of migratory warblers, for example Great Reed Warbler *Acrocephalus orientalis*. Studies at Mai Po show the reedbeds to be an important stopover site for migrant warblers (WWF HK, unpublished data). The reedbeds around Deep Bay are considered to be the largest remaining in the Guangdong area (Gao Yu Ren in litt. to L. Young).

Few waterfowl were recorded in the wet grasslands and abandoned ponds. This may be due to the lack of open water, making these areas unattractive to egrets and duck. The area as a whole may also be of importance for its breeding rather than its wintering birds. Suitable habitat exists for species such as Watercock *Gallicrex cinerea*, Pheasant-tailed Jacana *Hydrophasianus chirurgus*, and Painted Snipe *Rostratula benghalensis*, species which are either very rare or locally extinct as breeding birds in Hong Kong. Painted Snipe were recorded at Lok Ma Chau during autumn.

Disturbance as a result of the Project would likely affect most of the area adjacent to the river bank. Increased human activity in the area, blasting and earth works are all potential sources of disturbance. The effects of such disturbance are difficult to predict. However, birds in the Liu Pok area (which will suffer heavy disturbance) are already very wary of human activity and are easily disturbed.

Habitat loss through river widening and infilling of ponds is likely to result in a reduction in the numbers of waterbirds in the area. Both the Shenzhen and Hong Kong Governments have agreed to compensate for the loss of fish pond habitat on the south bank resulting from the Stage 1 works. Compensation will be through the creation of new wetland habitat at a ratio of 1:1 (habitat lost: habitat created). A new wetland area will created by management of the oxbow lake at the Lok Ma Chau Bend to restore it to an area which will support wildlife.

The increase in disturbance may also affect the Imperial Eagle population in the area. Whether these birds can relocate elsewhere is uncertain, but is likely to depend on disturbance levels.

References

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A10.12.4 Habitat Utilization by Saunders' Gulls and Black-faced Spoonbills

A10.12.4.1 Introduction

Deep Bay is the regular wintering site for Saunders' Gull *Larus saundersi* and Black-faced Spoonbill *Platelea minor*. Both species are highly endangered. In an attempt to gain a better understanding of the two species habitat requirements, detailed feeding observations were undertaken.

A10.12.4.2 Saunders' Gull

Saunders' Gull is probably the most endangered gull in the world. Its world population has recently been estimated at 2,000 (Hsu and Melville 1994). Saunders' Gull is a regular winter visitor to Deep Bay, maximum annual count data for the period 1980-1994 are shown in Figure A10.12.30. It feeds entirely where its local winter population apparently has been decreasing (Figure A10.12.30). It feeds entirely on mudflats, to such an extent that while regularly seen from the Boardwalk Hide (Figure A10.12.1) it is only exceptionally seen in the Mai Po Reserve, and has never been seen to feed there. It is therefore at possible risk from the effects the Shenzhen River Project may have on the Inner Deep Bay Mudflats.

Methods

Regular count data were collated during the year. As far as possible adults and first-year birds were counted separately.

Focal bird observations were carried out throughout the winter period (February-March, November-December). Observations were conducted from the Boardwalk Hide at Mai Po (Figure A10.12.1). Ten minute time budgets were recorded onto tape and subsequently transcribed. All birds were aged as either first-winter or adult. Time spent in flight and perched on the mudflats were separated. The number of pecks and steps were recorded. All prey items were identified if possible and their size estimated in relation to the bill length of the bird (av. 268 mm. n=15, D.S. Melville unpublished). Not all birds could be followed for ten minutes; often they would be lost from view either because they disappeared behind the mangrove or because they joined a larger flock of gulls.

Results

Count data for Saunders' Gulls for the period November 1993 to May 1994 are presented in Figure A10.12.31. This shows a marked passage during February. The age ratio varied during the winter (Figure A10.12.32). The known wintering area of Saunders' Gull extends as far south as northern Vietnam; it is therefore not surprising that passage occurs in Deep Bay. Peak counts per annum from 1980 to 1994 show a gradual increase in numbers over time up to 1991 but a decline since then. The reasons for this are unclear.

Figures in Table A10.12.4 show prey items for adult and first-winter Saunders' Gulls. All identified prey items were either benthic invertebrates or mudskippers.

The differences in prey items selected by adults versus first-winter birds are shown in Figure A10.12.33. This shows the apparent preference of adults for mudskippers and of first-winters for nemerteans and crabs. For both, polychaetes were the preferred prey item (94% of all identified prey items for adults and 67% for first-winters).

The Saunders' Gulls in Deep Bay showed a preference for the area of mudflat in front of Mai Po. This was the case throughout the course of the survey and before it (P.J. Leader unpublished). Very few were recorded near Tsim Bei Tsui. The reasons for this are unknown.

Discussion

As the Saunders' Gulls in Deep Bay appear to forage entirely on benthic invertebrates and mudskippers, they may be adversely affected by any changes in the availability of these prey items as a result of the river training project. Any rapid encroachment of mangrove on the mudflats may reduce the area available for them to forage. Although they presently forage over a relatively large area, they already exhibit a preference for certain areas of the intertidal flats. Any reduction of this preferred area may adversely affect the numbers of Saunders' Gulls in Deep Bay.

SAUNDERS.FOD

AGE	FLIGHT	MUD	TIME	PECK	STEPS	POLY							MUDSKIPPER		CRAB		
						1	1	2	2	2.5	3	4	2	3	1	1.5	2
1st	337	263	600	31	56												
1st W	188	112	300	39	50												
1st	36	564	600	92	220												
1st W	164	136	300	36	41												
1st W	351	249	600	29	9				1								
1st W	353	247	600	41	44			1	1								
1stW	179	121	300	17	19			1	2								
1stW	157	443	600	33	57						1						
1stW	90	92	182	13	0		2									1	
1stW	228	54	282	3	0												
1stW	285	36	321	8	5		2										
1stW	82	518	600	10	12												
1stW	274	74	348	12	0		4								2		
Total	2724	2909	5633	364	513	0	8	2	4	0	1	0	0	0	2	1	0

AGE	FLIGHT	MUD	TIME	PECK	STEPS	POLY							MUDSKIPPER		CRAB		
						1	1	2	2	2.5	3	4	2	3	1	1.5	2
Ad	229	71	300	30	14				3								
Ad	502	98	600	37	25												
Ad	430	170	600	41	23				1								
Ad	63	537	600	3	32												
Ad	436	164	600	43	14				1								
Ad	58	242	300	1	6												
Ad	268	32	300	16	3		1	1									
Ad	378	157	535	45	3	2	4	9	7	1							
Ad	445	155	600	35	16								1	1			
Ad	221	379	600	58	46												
Ad	397	203	600	39	13		5	1	2		1		1				
Ad	422	178	600	50	13		1		2								
Total	3849	2386	6235	398	208	2	11	11	16	1	1	0	2	1	0	0	0

Table A10.12.4(1) Prey items for adult and first-winter Saunders' Gulls

NEMERTEAN (X BODY)			UNID'D	TOT PREY		prey/time
1	1.5	2				
				0		0
			1	1		0.003333
				0		0
				0		0
			3	4		0.006667
		1		3		0.005
				3		0.01
1				2		0.003333
	1			4		0.021978
	1			1		0.003546
				2		0.006231
				0		0
				6		0.017241
				0		
1	2	1	4	26		0.004616
NEMERTEAN (X BODY)			UNID'D	TOT PREY		prey/time
1	1.5	2				
				3		0.01
			3	3		0.005
			5	6		0.01
						0
			10	11		0.018333
						0
				2		0.006667
			3	26		0.048598
			3	5		0.008333
						0
			4	14		0.023333
			7	10		0.016667
0	0	0	35	80		0.012831

Table A10.12.4(2) Prey items for adult and first-winter Saunders' Gulls

A10.12.4.3 Black-faced Spoonbill

The count of 78 Black-faced Spoonbills at Mai Po in December 1994 (G. Carey and R. Lewthwaite pers.comm) is the highest ever count in Hong Kong. This represents 23% of the WORLD population (Dahmer and Felley 1994). Mai Po is thus the second most important wintering site in the world. Black-faced Spoonbill numbers in the Deep Bay area are gradually increasing over time. The reasons for the increase are unknown, but may be related to habitat loss elsewhere in the region.

Methods

The main aim of the survey was to assess where the spoonbills fed and attempt to find out what they feed on.

Black-faced Spoonbills in Deep Bay usually roosted on a favoured bund in the Mai Po Reserve. Observations centred around the roost site and started before dawn. An attempt was made to follow birds as they left the roost to feed. If no birds were present at the roost site at dawn, the Mai Po area was searched until spoonbills were found. When foraging spoonbills were found, individuals were followed and their prey intake rates per minute were recorded for as long as possible.

Results

The spoonbills proved to be highly unpredictable during the course of the survey. They were not so faithful to the roost site in the Reserve as in previous winters. This often made finding the spoonbills difficult.

Two specific habitat types, fish ponds and *gei-wais*, were the preferred feeding areas for the spoonbills. All fish ponds where the spoonbills were found feeding were in the process of being drained. Spoonbills were found in fish ponds which were not being drained. Most of the birds found feeding were in the Mai Po area. However, birds are often recorded at the Futian N.N.R., thus the birds are clearly ranging over a large proportion of the Bay.

Discussion

That the spoonbills were most often found foraging in drained fish ponds is of concern. The disappearance of fish ponds in the Deep Bay area in recent years has been dramatic (Appendix 10.13). Habitat loss continues through infilling for storage and development. Losses will also include 21 ha in Hong Kong and 65 ha in Shenzhen as a result of the Stage 1 Works of the Project. Any loss of fish ponds in the Deep Bay area will reduce the area available for spoonbills to feed.

Further habitat loss is expected to impact the wintering population of Black-faced Spoonbills, which is currently 23% of the world population.

References

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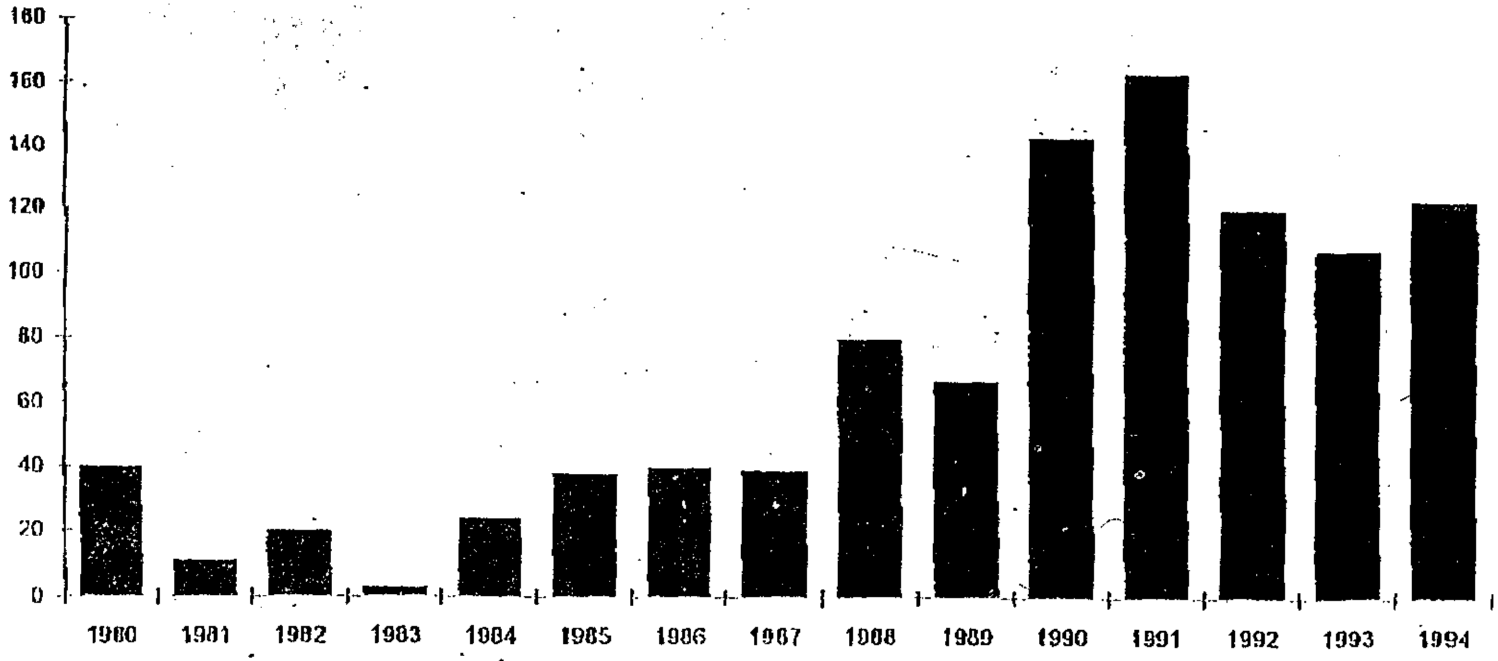

Figure A10.12.30 Saunders' Gull in Deep Bay 1980-1994

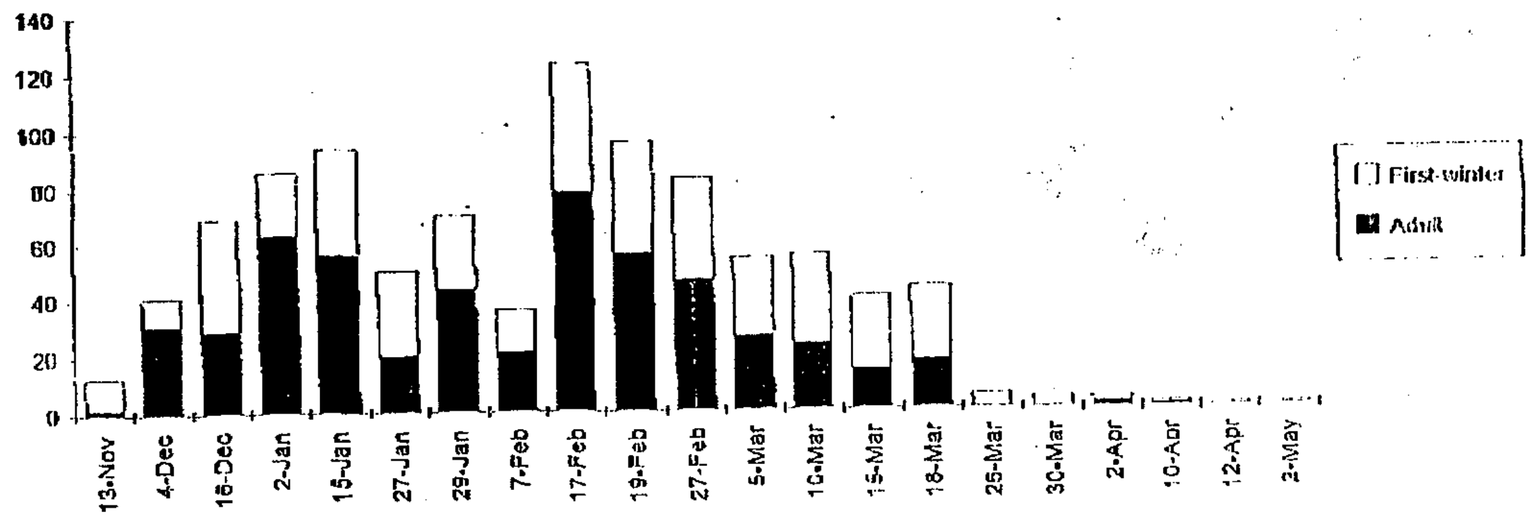

Figure A10.12.31 Saunders' Gull in Deep Bay Winter 93/94

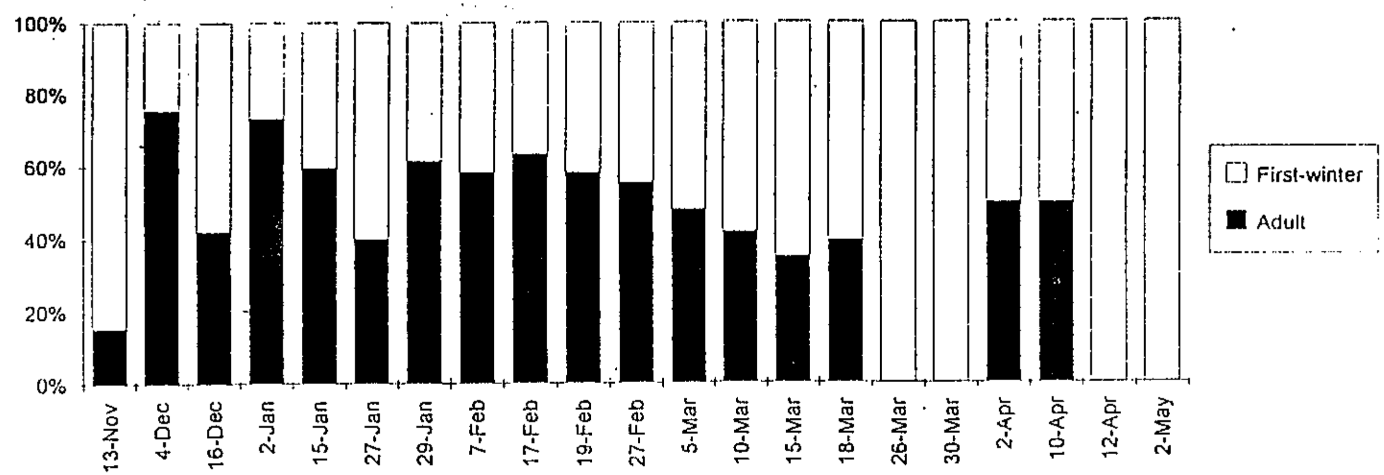

Figure A10.12.32 Saunders' Gull in Deep Bay Winter 93/94

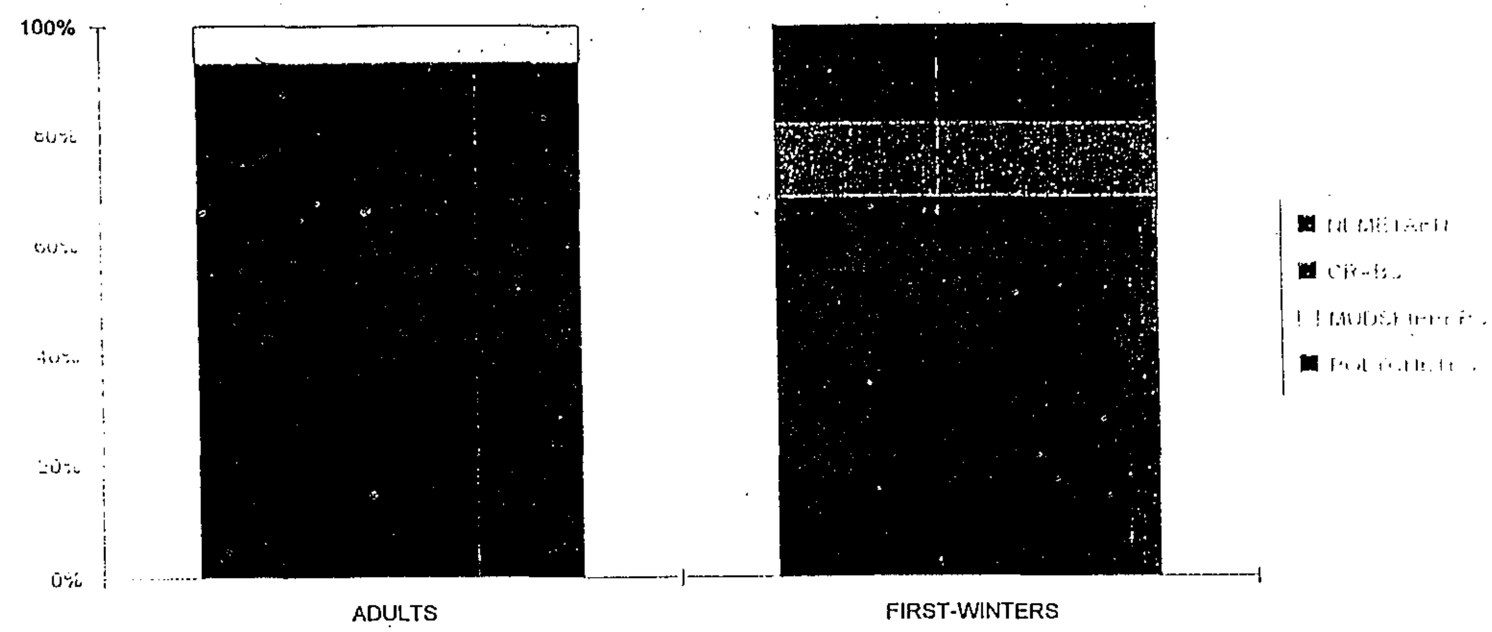

Figure A10.12.33 Prey of Saunders' Gulls

A10.12.5 Waterfowl Population Survey

A10.12.5.1 Introduction

The Shenzhen River Regulation Project may result in changes to the mudflats of Inner Deep Bay, together with the benthic invertebrates which inhabit them. This in turn may affect the carrying capacity of Deep Bay for waterfowl.

Regular counts were undertaken throughout 1994 in order to provide information on species and numbers of waterfowl using Deep Bay, and to provide a baseline against which the effects of the project can be judged.

In spring waders were counted once every three days from 15 March 1994 to 31 May 1994. In autumn waders were counted once per week from 15 August to 15 November. Monthly counts of all waterfowl were undertaken throughout the year.

A10.12.5.2 Methods

Spring 1994 was unusual in that until about 23 April few of the waders in Deep Bay were roosting in the Mai Po Nature Reserve at high tide. Subsequently large numbers were found roosting on the Reserve at high tide. In recent years the majority of waders at Mai Po roosted at high tide, on the specially managed area known as 'the Scrape'. As a result of birds not roosting on the Scrape at high tide, much of the counting had to be undertaken from the Boardwalk Hide (see Figure A10.12.1) on either a rising or falling tide, usually the latter.

Autumn counts were conducted using the same methods as were used for the spring counts. The gradual decrease in the height of day-time tides during the survey resulted in increased dependence on the Boardwalk Hide for counting.

Monthly waterfowl counts were undertaken with members of the Hong Kong Bird Watching Society.

A10.12.5.3 Spring wader counts

A total of 40 species was recorded on the counts. Total waders present on each count are shown in Figure A10.12.35. Count data for the more numerous species are reproduced in Figures A10.12.34 to A10.12.60.

The effect on the count data of birds not roosting on the Scrape at high tide is unclear, although a coordinated count on 8 April from the Boardwalk Hide and the two Mudflat Hides indicated that some species may have been under-counted by up to 30%.

1. Avocet *Recurvirostra avosetta*
   The high numbers present until late March represent the remnants of the wintering flock which had peaked at a record 926 on 25 February. Most birds had departed by about 8 April, and there was no evidence of passage.

2. Oriental Pratincole *Glareola maldivarum*
   Up to six were recorded on four dates.

3. Little Ringed Plover *Charadrius dubius*
   Present in small numbers throughout.

4. Kentish Plover *Charadrius alexandrinus*
A similar pattern to Avocet with the high numbers early on referring to the last of the wintering population, 780 on 15 March was the highest count. Very few were recorded after the beginning of April.

5. Lesser Sand Plover *Charadrius mongolus*
Very small numbers present in March with the main arrival coming in late April, although a lesser peak occurred around 10 April. The highest count was 100 on 20 April. Very few recorded after the end of April.

6. Greater Sand Plover *Charadrius leschenaulti*
There was a very slow increase in numbers until the first peak in late March, followed by the main arrival during 8 to 14 April. This was followed by a smaller influx in the third week of the month. Peak count was 630 on 14 April.

7. Oriental Plover *Charadrius veredus*
One on 6 May.

8. Pacific Golden Plover *Pluvialis fulva*
The March totals may refer to the wintering population, but with no records in the first week of April all subsequent numbers are considered to refer to migrants. If this is the case most of the spring migrants passed through in a very short period in the first half of the month, with a second smaller passage in late April, which were presumably first-summer birds. The highest count was 246 on 11 April.

9. Grey Plover *Pluvialis squatareola*
The birds in March are the remnants of the winter population, after which small numbers passed through in April and May. The highest count was 220 on 18 March.

10. Great Knot *Calidris tenuirostris*
The marked influx on 27 March coincided with a period of very strong easterly winds. The count of 463 on that date is the highest ever in Hong Kong. The clear decrease in numbers coupled with no subsequent arrivals of note indicates that the majority of the birds stayed for 10 days or less.

This species apparently usually migrates non-stop from North-west Australia to the Shanghai area (Barter and Wang 1990). Three leg-flagged birds were present in the flock, birds which had been leg-flagged on their Australian wintering grounds. The arrival of large numbers associated with easterly winds suggests that the birds may have suffered from a lack of tail winds (c.f. Melville 1980, Tulp *et al.* 1995) to carry them to the Yangtze estuary and thus used Deep Bay to refuel. The fact that the birds apparently remained in Deep Bay for less than ten days suggests that they may have only fed sufficiently to fly to the Yangtze estuary.

Piersma and van de Sant (1992) found that the Vondee area in France played a vital role as a resting/refuelling site for Bar-tailed Godwits migrating from the Banc d'Arguin to the Wadden Sea in years when tail-wind assistance was reduced by unusual conditions, so that the birds were unable to complete the journey in one stage. It is possible that Deep Bay, in addition to supporting large numbers of regular passage migrants, may also play an important role in providing a 'short-stop' for those species which usually overfly the area at times of adverse weather conditions. This may help explain marked seasonal variation in the numbers of certain shorebirds in Deep Bay.

11. Red Knot *Calidris canutus*
Maximum count was 16 on 29 April.

12. Sanderling *Calidris alba*
Recorded on 4 dates with a maximum of 8 present.

13. Red-necked Stint *Calidris ruficollis*
The count of 1,000 on 14 April indicates a major arrival around that time. Two other arrivals were detected during the spring, in late April and early May.

This may be one of the species whose true status is obscured due to counts being conducted from the Boardwalk hide. This species often forages actively on the high tide roost site and as such may arrive on the newly exposed mud later than other species, thus making counting more difficult.

14. Little Stint *Calidris minuta*
One on 8 April.

15. Long-toed Stint *Calidris subminuta*
Present on four dates with a maximum of nine.

16. Sharp-tailed Sandpiper *Calidris acumita*
Most birds passed through in late April and early May. The count of 147 on 29 April is the highest ever in Hong Kong.

17. Curlew Sandpiper *Calidris ferruginea*
Numerically the most abundant wader. Apparently three major arrivals occurred, on or about 8, 14 and 23 April. The highest count of the spring, 5,640 on 29 April, is close to the record of 6,000.

On 8 April coordinated counts from the Boardwalk hide and the two Mudflat Hides were undertaken. The count for this species from the Boardwalk Hide (i.e. the usual counting station) was 3,300. Observations from the Mudflat Hides, however, showed that at least 4,500 were present on the inter-tidal mudflats. For consistency this has been ignored in Figure A10.12.46. The difference highlights the shortfall in some of the counts in spring 1994. The arrival of new birds on or about 14 April was confirmed by a wader ringing catch on 11 April when most birds were light with little or no fat.

18. Dunlin *Calidris alpina*
The last of the wintering birds were present until 18 March, after which very few were noted. Peak count 500 on 15 March.

19. Spoon-billed Sandpiper *Eurynorhynchus pygmaeus*
Singles recorded on four dates.

20. Broad-billed Sandpiper *Limnicola falcinellus*
Maximum count 41 on 20 April.

21. Ruff *Philomachus pugnax*
One in late March.

22. Common Snipe *Gallinago gallinago*

Recorded on three dates with a maximum of 15 on 21 March.

23. Asiatic Dowitcher *Limnodromus semipalmatus*
A poor year for this species, with the highest count being only 37 on 14 Apr

24. Black-tailed Godwit *Limosa limosa*
A gradual increase up to 8 April after which the picture is completely obscured changing roosting sites, while there were apparently large numbers still present Bay, these were not visible from the Boardwalk Hide. The peak count was 2,00 April.

25. Bar-tailed Godwit *Limosa lapponica*
Most occurred during mid April. Highest count was 68 on 17 April.

26. Whimbrel *Numenius phaeopus*
Peak numbers were noted in late April, the highest count being 50 on 29 April.

27. Eurasian Curlew *Numenius arquata*
The large numbers present in March, with up to 373 present on 15 March, refer to last of the wintering population. Recorded in small numbers on most dates during Ap and May.

28. Eastern Curlew *Numenius madagascariensis*
Present on six dates with up to 5 present.

29. Spotted Redshank *Tringa erythropus*
A similar situation to Black-tailed Godwit, with the pattern becoming obscured in early April due to a sudden change in behaviour of the birds, with large numbers apparently still present in Deep Bay on days when none were recorded from the Mai Po Nature Reserve. The maximum count was 1,688 on 27 March, the highest ever in Hong Kong.

On 5 and 8 April all the tringas were too distant for specific identification. See Figure A10.12.61 showing data for all Tringas.

30. Common Redshank *Tringa totanus*
Prior to this spring the highest number recorded in Hong Kong was 1,800. This spring there were three counts of over 2,000 with a peak count of 3,474 on 29 April. Most birds had passed through by early May.

On 5 and 8 April all the tringas were too distant for specific identification. See Figure A10.12.61 showing data for all Tringas.

The almost complete lack of birds on 20 April is probably due not to a massive departure but more likely a result of problems similar to those experienced with Black-tailed Godwit and Spotted Redshank.

31. Marsh Sandpiper *Tringa stagnatalis*
Large numbers present in March, with an apparent large departure in early April and a second passage in mid-April, after which almost none were seen. The highest count was 1,063 on 24 March.

On 5 and 8 April all the tringas were too distant for specific identification. See Figure

A10.12.61 showing data for all Tringas.

32. Greenshank *Tringa nebularia*
Three clear passage periods, one in the third week of March, a larger one a month later, and another in May. There is no evidence to suggest that the low numbers present between the two peaks is due to birds roosting elsewhere and not being visible from the Boardwalk Hide. The peak count was 2,018 on 23 April.

On 5 and 8 April all the tringas were too distant for specific identification. See Figure A10.12.61 showing data for all Tringas.

33. Nordmann's Greenshank *Tringa guttifer*
Two main passage periods. All adults occurred prior to 29 April and all birds recorded after 2 May were first-years. Maximum count was 11 on 11 April. A poor year for this species.

34. Green Sandpiper *Tringa ochropus*
One or two present on most dates in March and early April.

35. Wood Sandpiper *Tringa glareola*
Present on five dates; the highest count was 40 on 17 April.

36. Terek Sandpiper *Xenus cinereus*
Three passage periods with a large arrival occurring in late April. The count of 477 on 29 April is the highest ever in Hong Kong.

37. Common Sandpiper *Actitis hypoleucos*
One or two present on most dates.

38. Grey-tailed Sandpiper *Heteroscelus brevipes*
The main arrival came after 9 May. The 442 recorded on 17 May is the highest ever in Hong Kong.

39. Turnstone *Arenaria interpres*
Most passed through during April. The 268 present on 20 April is the highest ever in Hong Kong.

40. Red-necked Phalarope *Phalaropus lobatus*
Maximum count 93 on 20 April.

A10.12.5.4 Autumn wader counts

During autumn migration 40 species were recorded with a daily maximum of 6,032 birds. The total number of waders recorded on each count is shown in Figure A10.12.62. Count data for individual species are presented in Figures A10.12.63 to A10.12.84.

1. Black-winged Stilt *Himantopus himantopus*
Recorded from 23 August. The highest count of 301 on 2 November is close to the record of 329. The data suggests two peaks occurred, one in October, and a larger one in late October and early November. This pattern accords well with Chalmers (1986).

2. Avocet *Recurvirostra avosetta*

Recorded from 14 October, and despite the apparent drop in numbers in mid-November, which was likely due to the low tide on that date, it is considered that there was no passage and that all birds belong to the winter population.

3. Oriental Pratincole *Glareola maldivarum*
The only record was an exceptional 270 on 5 October.

4. Little Ringed Plover *Charadrius dubius*
Recorded on most dates with a maximum of six.

5. Ringed Plover *Charadrius hiaticula*
One in 21 October.

6. Kentish Plover *Charadrius alexandrinus*
Recorded from 5 October after which there was a gradual increase in numbers as the wintering population arrived.

7. Lesser Sand Plover *Charadrius mongolus*
Small numbers of migrants during october followed by a maximum of 69 in November as the small winter population arrived.

8. Greater Sand Plover *Charadrius leschenaultii*
Passage was well under way when counts started, the highest count being 82 on the first count. Very few were recorded after mid-September.

9. Grey-headed Lapwing *Vanellus cinereus*
One on 14 October.

10. Northern Lapwing *Vanellus vanellus*
Two on 15 November.

11. Pacific Golden Plover *Pluvialis fulva*
Three possible peaks occurred, although interpretation is difficult due to the unpredictable nature of this species at high tide. However, a gradual increase in numbers during the autumn is apparent, and the peak in October fits well with Chalmers (1986).

12. Grey Plover *Pluvialis squatarola*
Low numbers were present on most counts until late October, when an increase in numbers reflects the arrival of wintering birds.

13. Great Knot *Calidris tenuirostris*
Maximum count was 33 no 15 September.

14. Red Knot *Calidris canutus*
Present on six dates with up to eight noted.

15. Red-necked Stint *Calidris ruficollis*
Recorded on six dates with up to eight noted.

16. Long-toed Stint *Calidris subminuta*
Present on five dates with up to seven noted.

17. Sharp-tailed Sandpiper *Calidris acumita*
Two singles, one of which on 15 November was exceptionally late.

18. Curlew Sandpiper *Calidris ferruginea*
Another species for which autumn migration was well under way by the time counting started. The highest count by far was 356 on the very first count.

19. Dunlin *Calidris alpina*
Present from 15 September, 33 on 21 September being a very high count for that month. From mid-October when the first wintering birds arrived, there was a gradual increase in numbers, with a peak count of 1,905 on 9 November.

20. Broad-billed Sandpiper *Limnicola falcinellus*
Up to 24 were recorded.

21. Ruff *Philomachus pugnax*
One on 28 October.

22. Common Snipe *Gallinago gallinago*
Present from 21 September. Maximum count was 29 on 28 September.

23. Pintail Snipe *Gallinago stenura*
Present from 8 September to 5 October; maximum count was 30 on 28 September.

24. Swinhoe's Snipe *Gallinago megala*
Recorded from 23 August to 8 September; maximum of two present.

25. Asiatic Dowitcher *Limnodromus semipalmatus*
Recorded in small numbers until 21 October with the highest count being 9 on 23 August.

26. Black-tailed Godwit *Limosa limosa*
Overall a gradual increase throughout except for the last two counts when none was recorded. Peak count of 200 on 27 October.

27. Bar-tailed Godwit *Limosa lapponica*
Recorded between 23 August and 5 October with a maximum of 21 on 21 September.

28. Whimbrel *Numenius phaeopus*
Recorded up to 5 October with 156 on 8 September being the highest count.

29. Eurasian Curlew *Numenius arquata*
A gradual increase was apparent throughout other than the last two counts. Maximum was 107 on 2 November.

30. Eastern Curlew *Numenius madagascariensis*
Present on 3 dates, maximum of two.

31. Spotted Redshank *Tringa erythropus*
Recorded in very small numbers until 2 November when 811 were present, after which date lower numbers were noted.

32. Common Redshank *Tringa totanus*

The most common wader in autumn. Passage was under way when counting started, the highest count of 2,471 was the first count. This count was almost double the next highest.

33. Marsh Sandpiper *Tringa stagnatilis*
Small numbers present until 8 September when there was an obvious arrival. The highest count was 602 on 2 November.

34. Greenshank *Tringa nebularia*
Recorded in good numbers throughout, although passage was under way when counts commenced. The highest count of the autumn was 774 on 8 September.

35. Wood Sandpiper *Tringa glareola*
Recorded on most dates with 36 on 19 August being the highest count.

36. Terek Sandpiper *Xenus cinereus*
The highest count was 169 on 23 August.

37. Common Sandpiper *Actitis hypoleucos*
Recorded on most dates with up to 11 noted.

38. Grey-tailed Sandpiper *Heteroscelus brevipes*
Recorded until 21 September. Highest count 30 on 23 August.

39. Turnstone *Arenaria interpres*
One in August.

40. Red-necked Phalarope *Phalaropus lobatus*
One present in September.

A10.12.5.5 Monthly waterfowl counts

Total waterfowl per month are shown in Figure A10.12.85.

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BLACK-FACED SPOONBILLS IN DEEP BAY 1980-1994

Figure A10.12.34

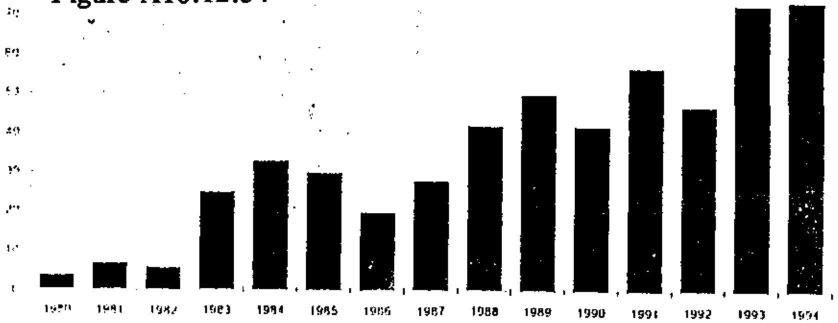


Figure A10.12.35 ALL WADERS IN DEEP BAY SPRING 1994

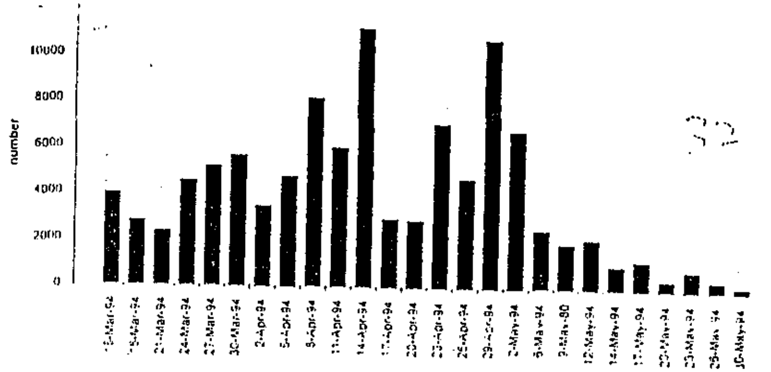


Figure A10.12.36 AVOCET

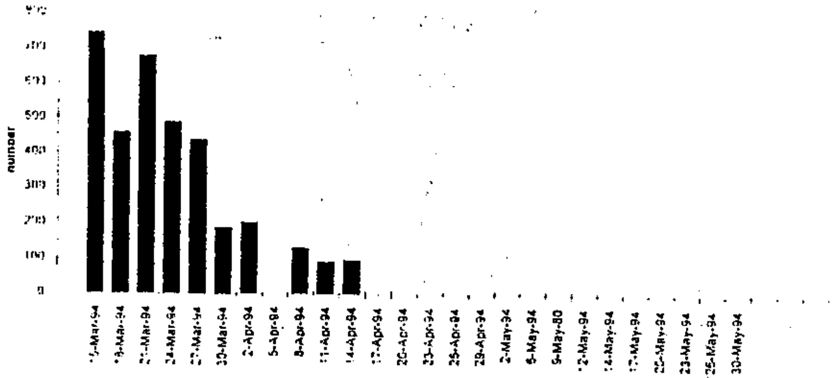


Figure A10.12.37 KENTISH PLOVER

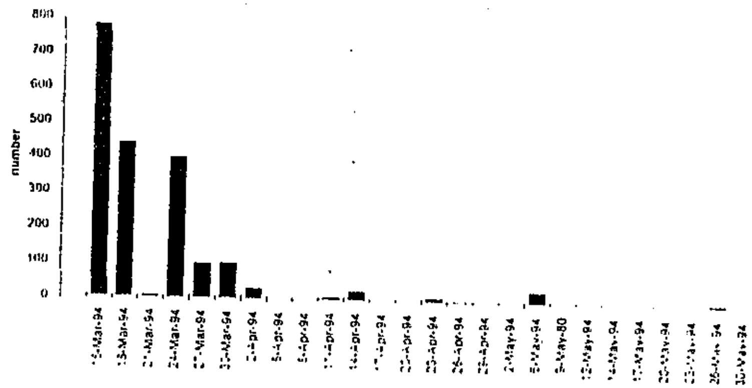


Figure A10.12.38 LESSER SAND PLOVER

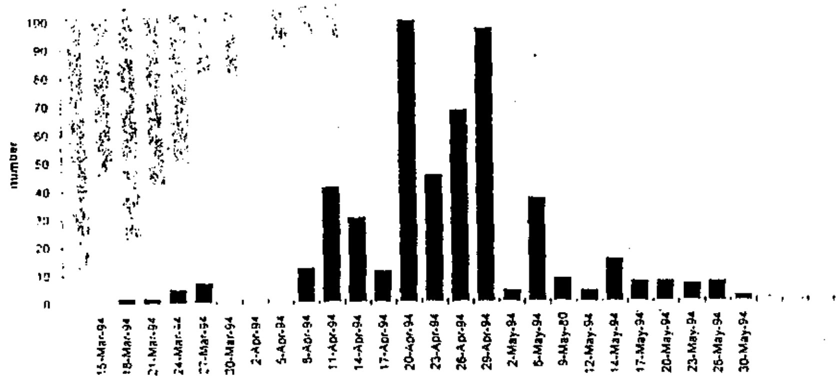


Figure A10.12.39 GREATER SAND PLOVER

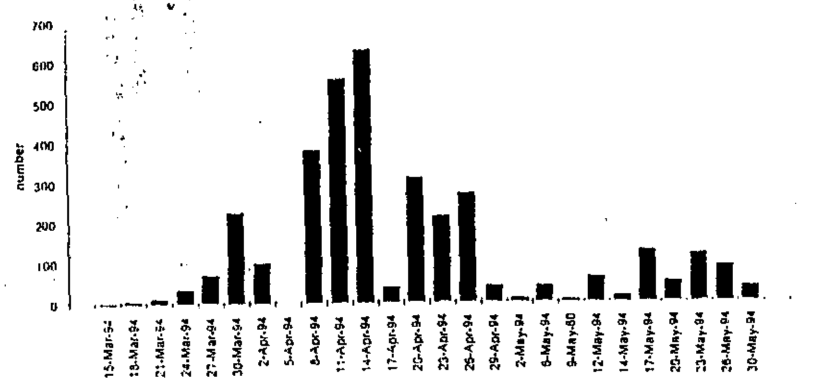


Figure A10.12.40 PACIFIC GOLDEN PLOVER

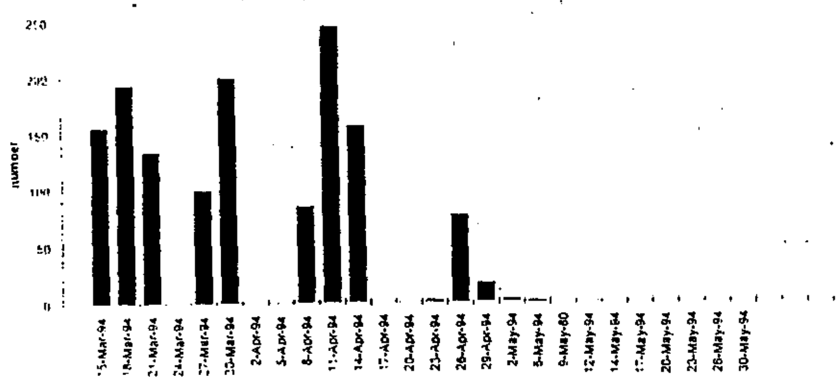


Figure A10.12.41 GREY PLOVER

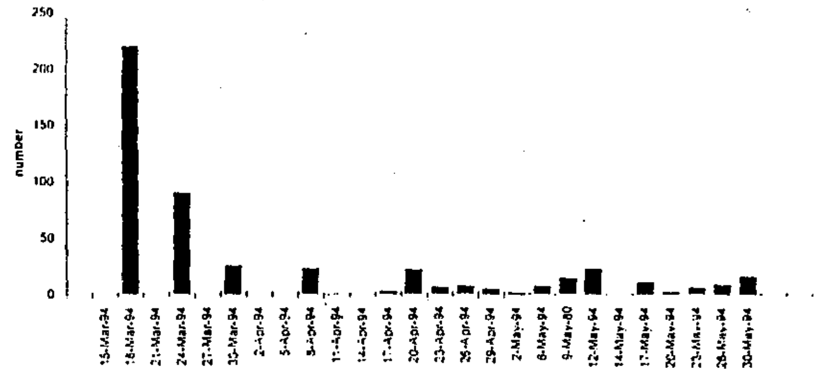


Figure A10.12.42 GREAT KNOT

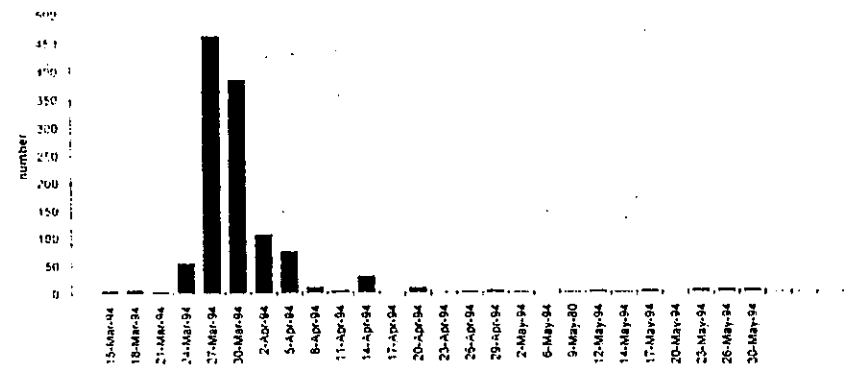


Figure A10.12.43 RED KNOT

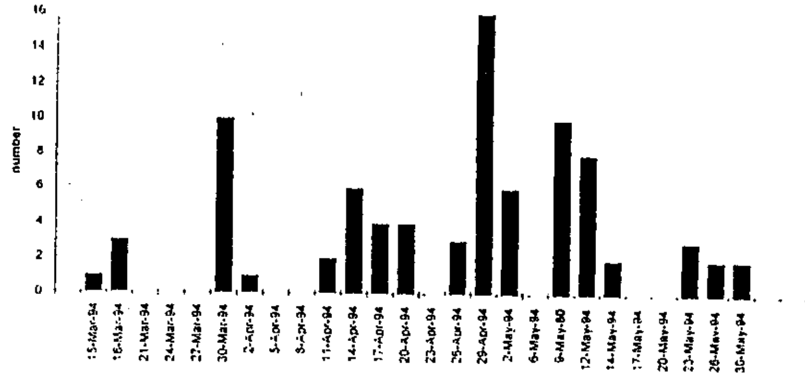


Figure A10.12.44 RED-NECKED STINT

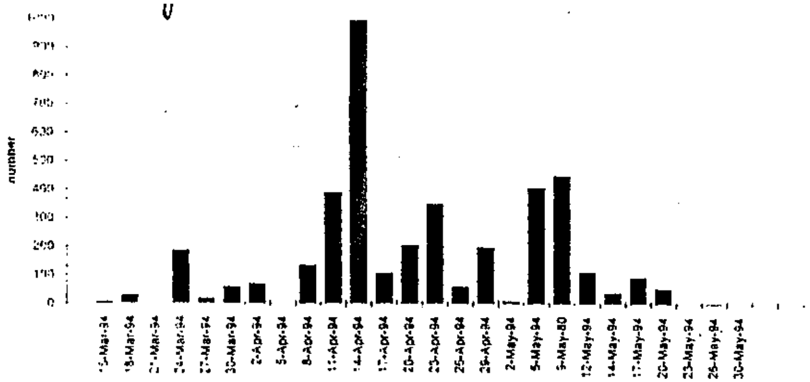


Figure A10.12.45 SHARP-TAILED SANDPIPER

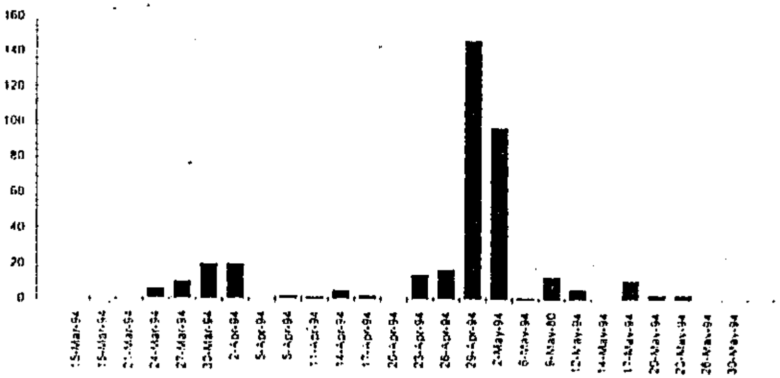


Figure A10.12.46 CURLEW SANDPIPER

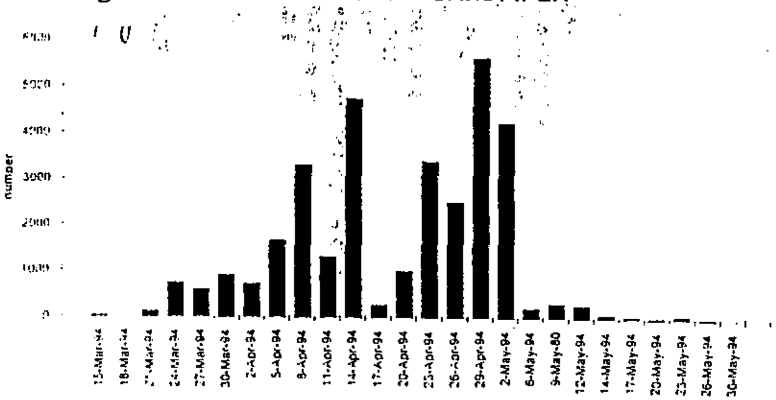


Figure A10.12.47 BROAD-BILLED SANDPIPER

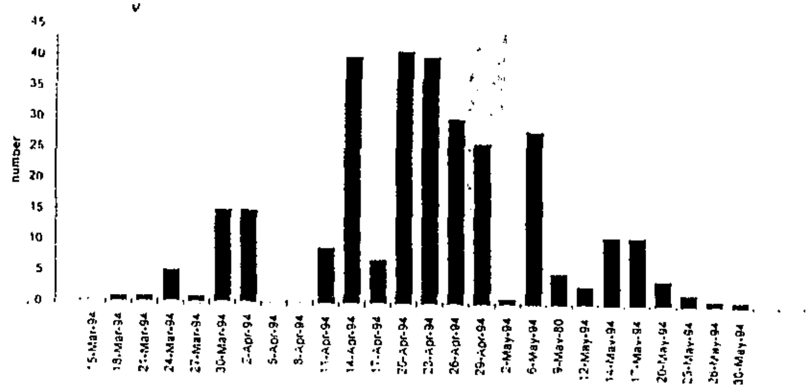


Figure A10.12.48 ASIATIC DOWITCHER

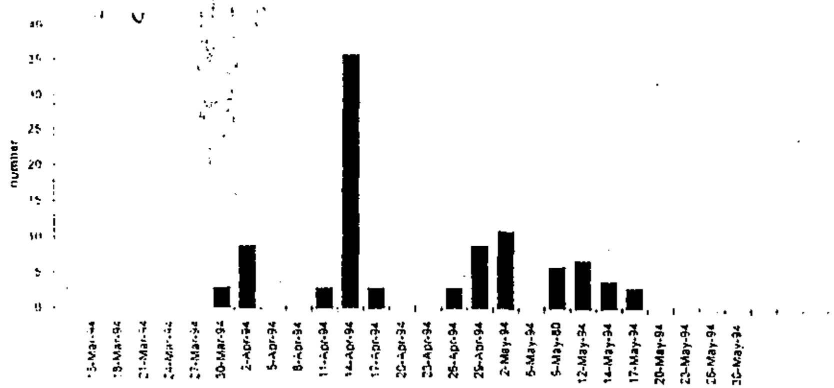


Figure A10.12.49 BLACK-TAILED GODWIT

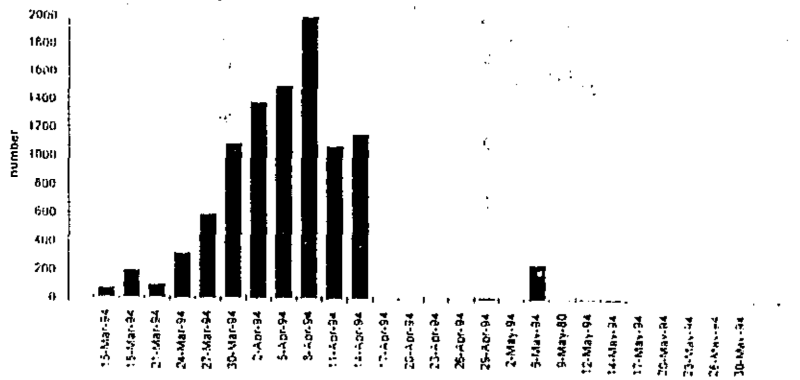


Figure A10.12.50 BAR-TAILED GODWIT

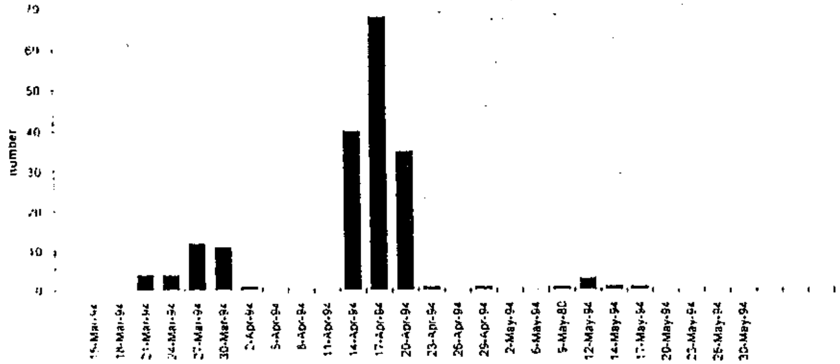


Figure A10.12.51 WHIMBREL

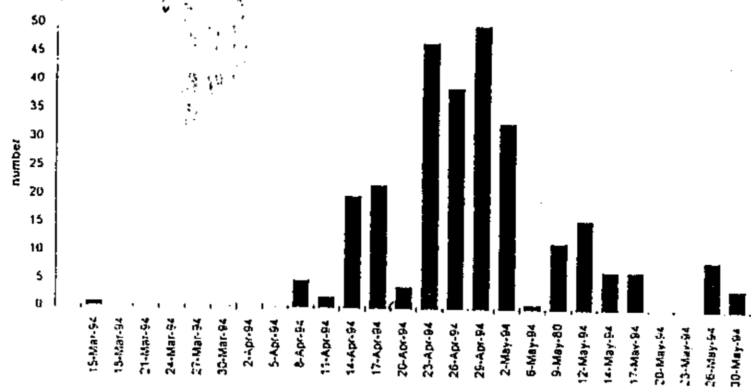


Figure A10.12.52 EURASIAN CURLEW

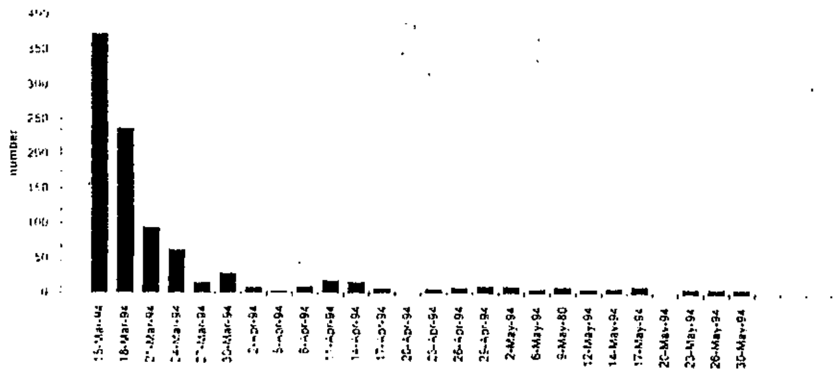


Figure A10.12.53 SPOTTED REDSHANK

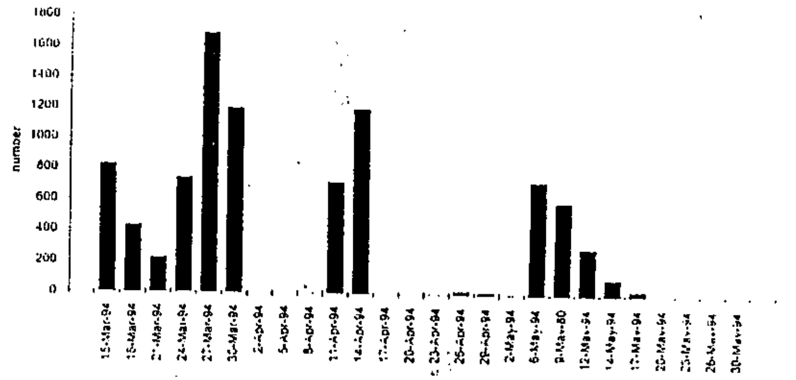


Figure A10.12.54 GREENSHANK

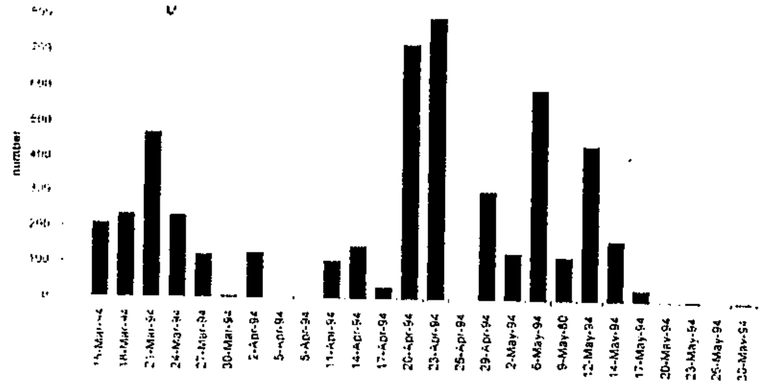


Figure A10.12.55 NORDMANN'S GREENSHANK

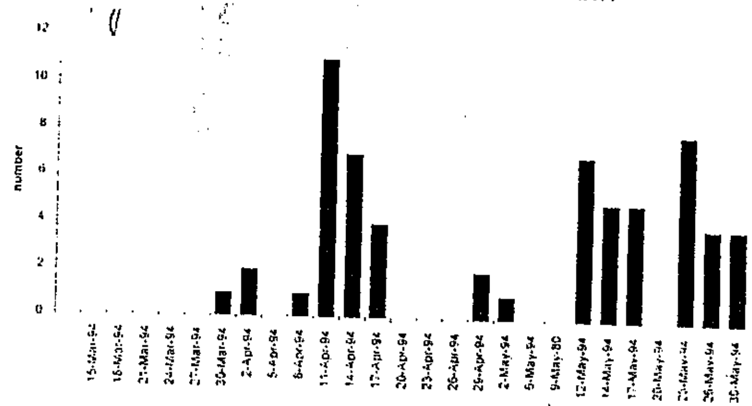


Figure A10.12.56 COMMON REDSHANK

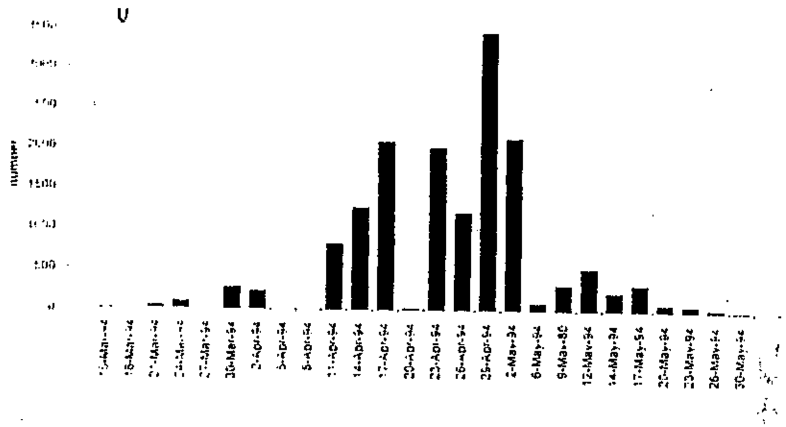


Figure A10.12.57 MARSH SANDPIPER

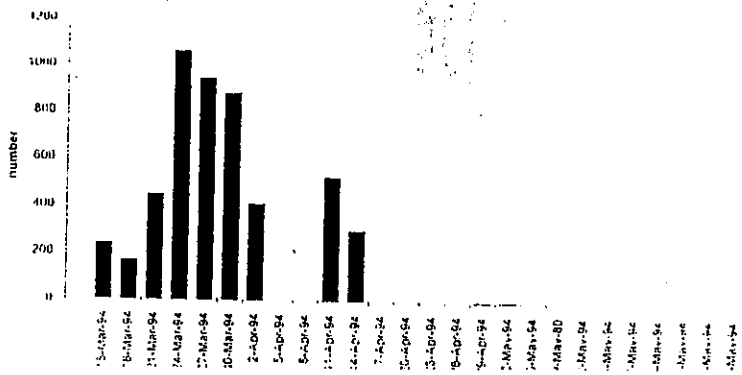


Figure A10.12.58 TEREK SANDPIPER

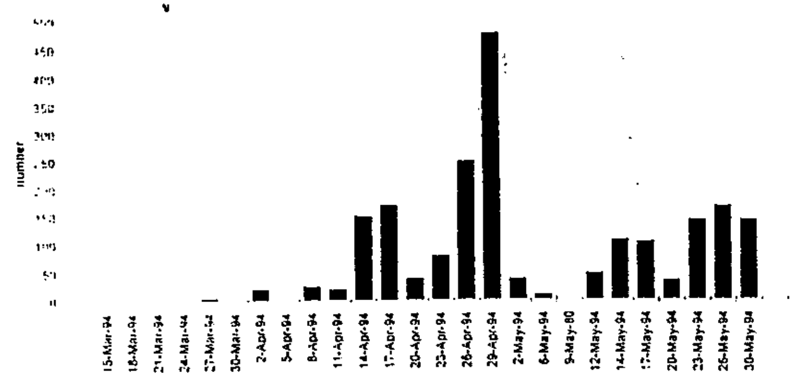


Figure A10.12.59 GREY-TAILED TATTLER

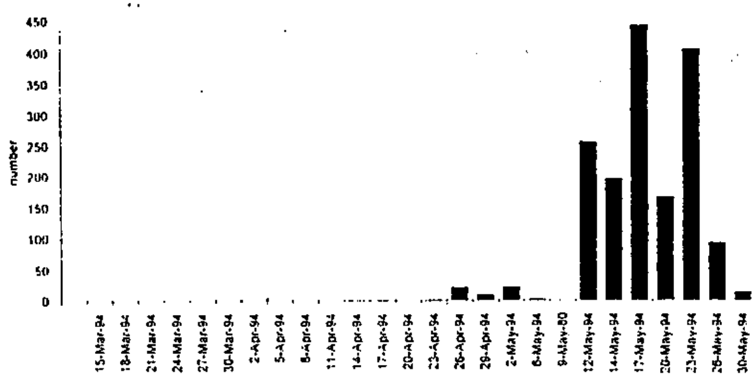


Figure A10.12.60 TURNSTONE

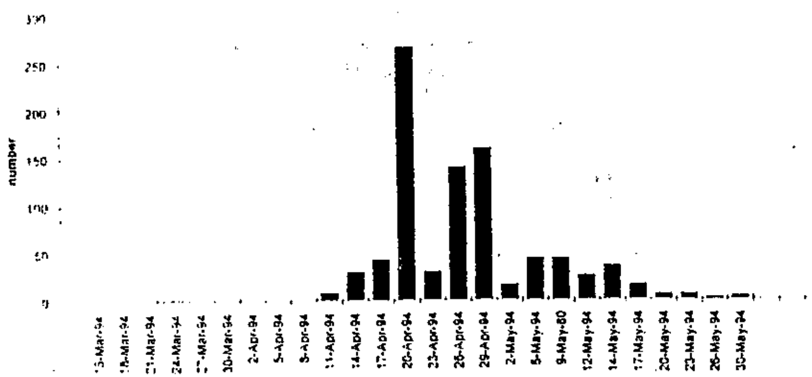


Figure A10.12.61 ALL TRINGAS

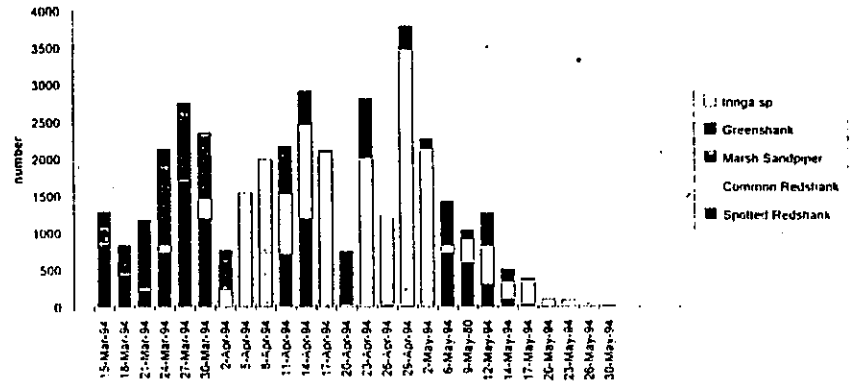


Figure A10.12.62 ALL WADERS IN DEEP BAY IN AUTUMN 1994

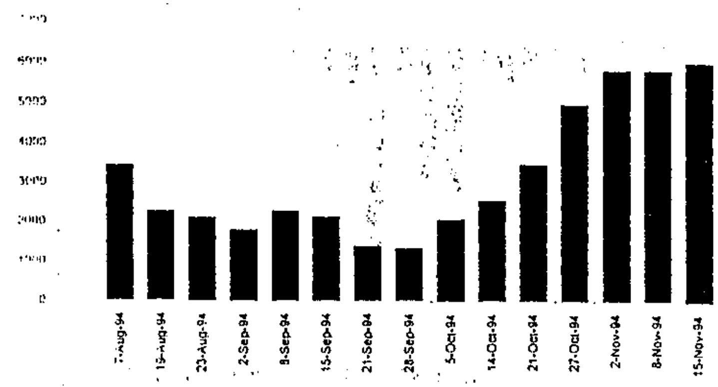
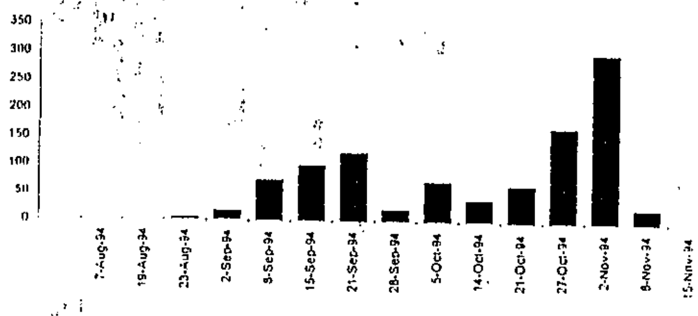


Figure A10.12.63 BLACK-WINGED STILT



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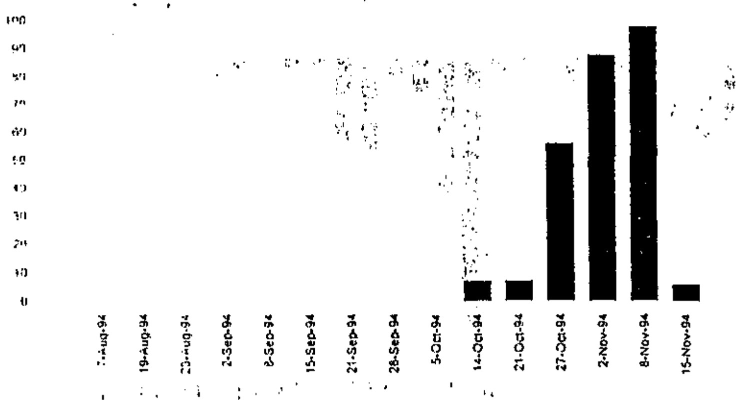
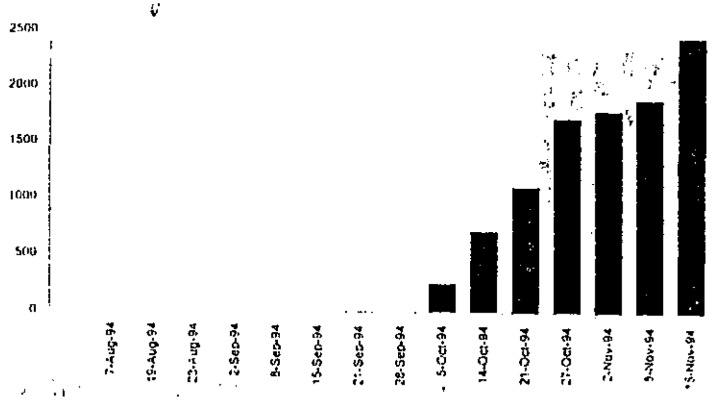


Figure A10.12.65 KENTISH PLOVER



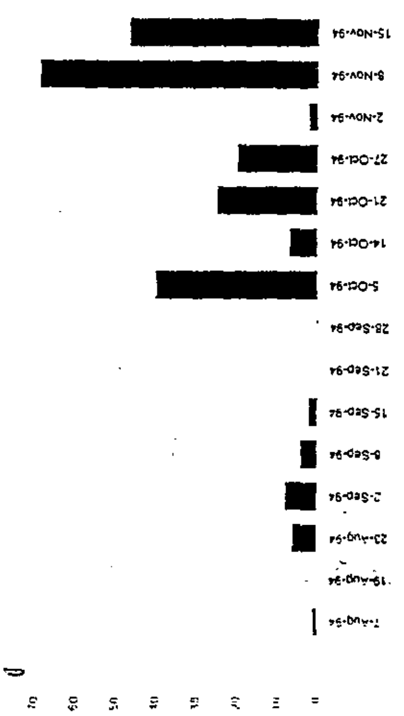


Figure A10.12.66 LESSER SAND PLOVER

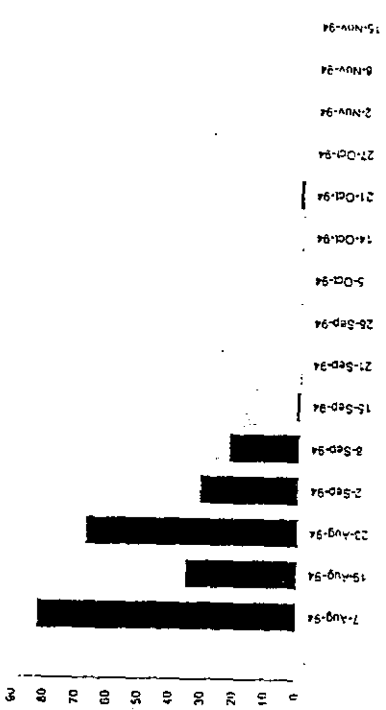


Figure A10.12.67 GREATER SAND PLOVER

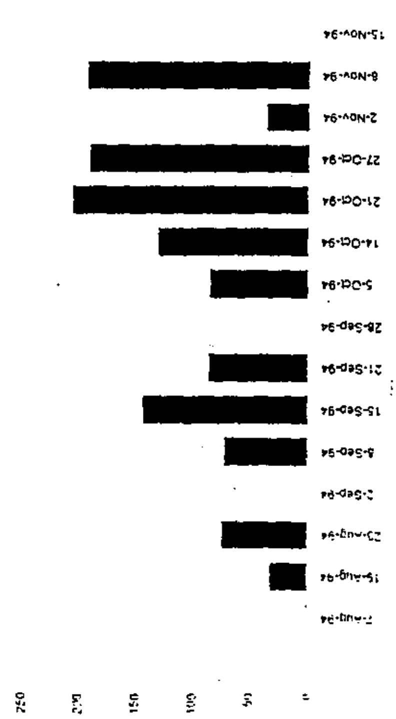


Figure A10.12.68 PACIFIC GOLDEN PLOVER

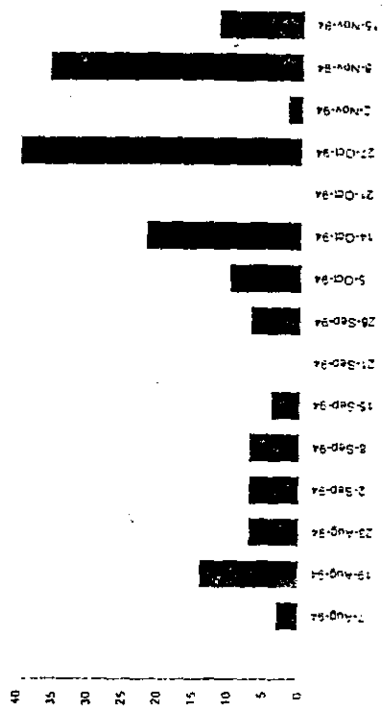


Figure A10.12.69 GREY PLOVER

Figure A10.12.70 GREAT KNOT

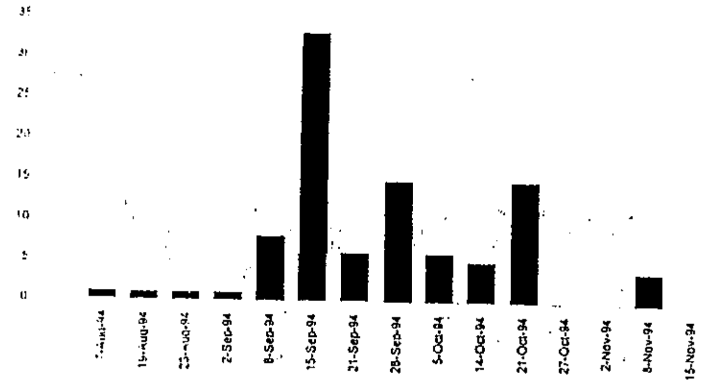


Figure A10.12.71 DUNLIN

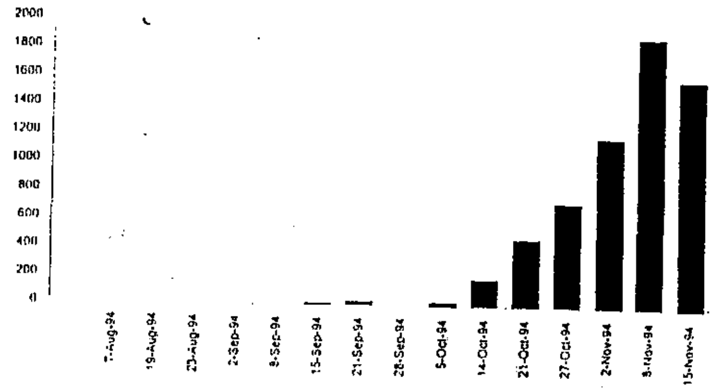


Figure A10.12.72 CURLEW SANDPIPER

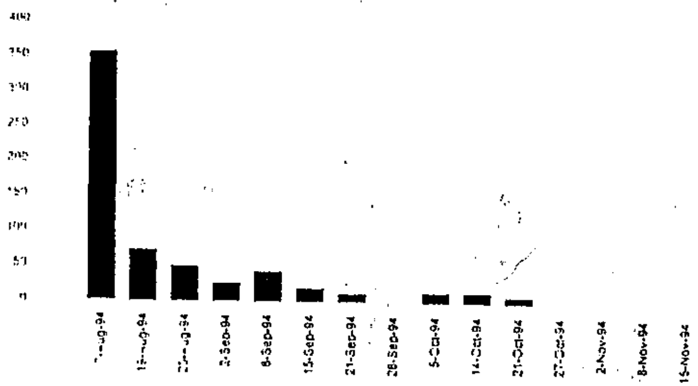


Figure A10.12.73 BROAD-BILLED SANDPIPER

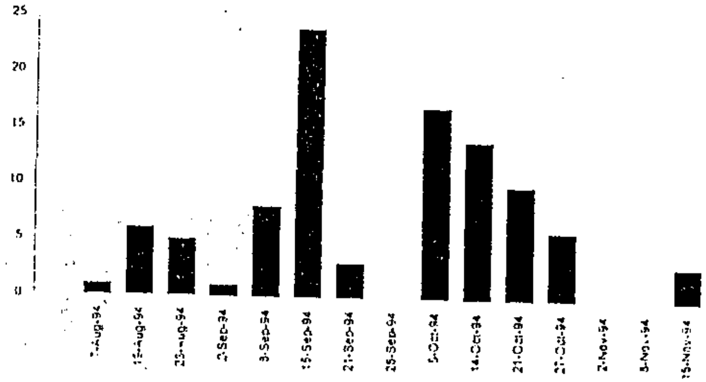


Figure A10.12.74 ASIATIC DOWITCHER

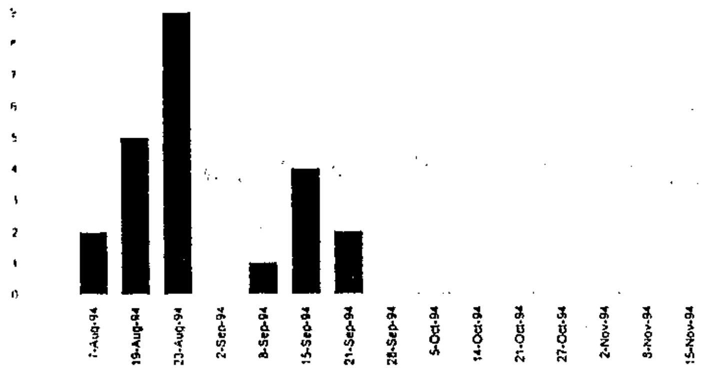


Figure A10.12.75 BLACK-TAILED GODWIT

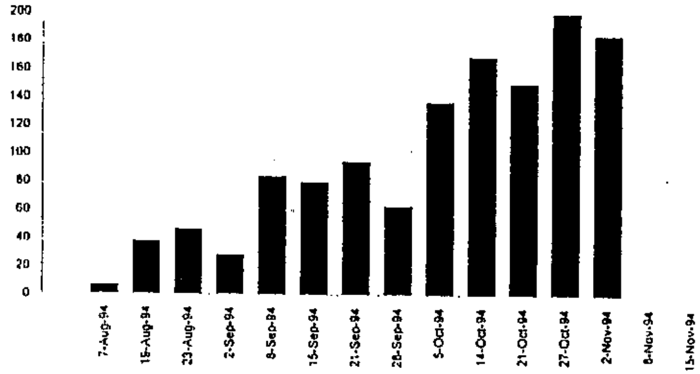


Figure A10.12.76 BAR-TAILED GODWIT

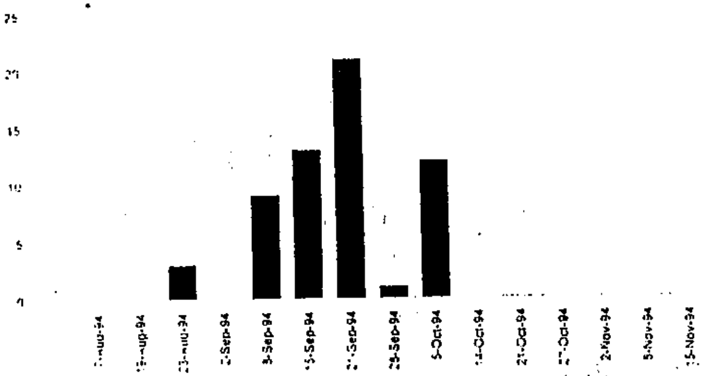


Figure A10.12.77 WHIMBREL

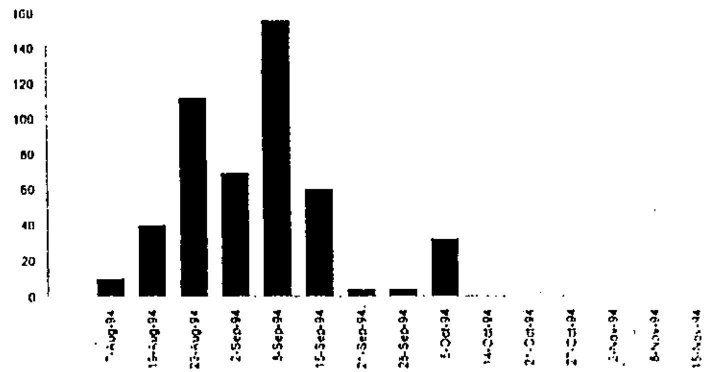


Figure A10.12.78 EURASIAN CURLEW

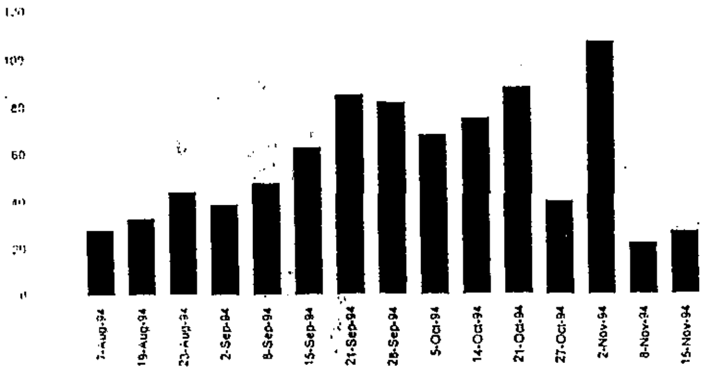


Figure A10.12.79 SPOTTED REDSHANK

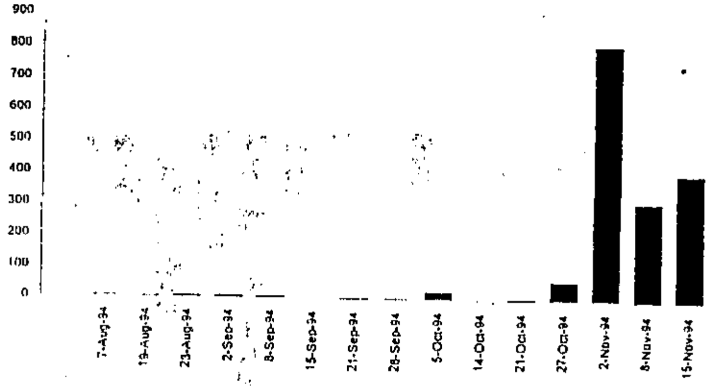


Figure A10.12.80 COMMON REDSHANK

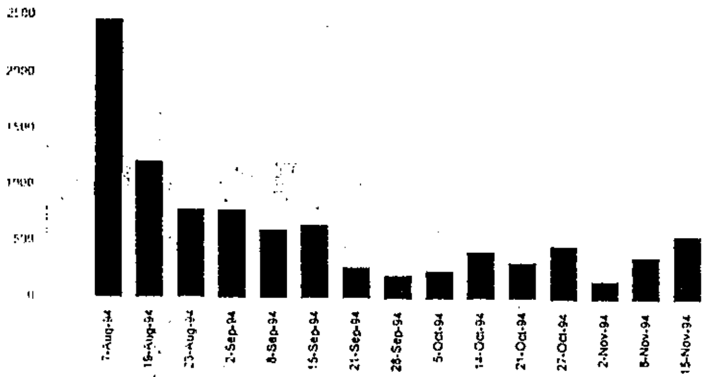


Figure A10.12.81 MARSH SANDPIPER

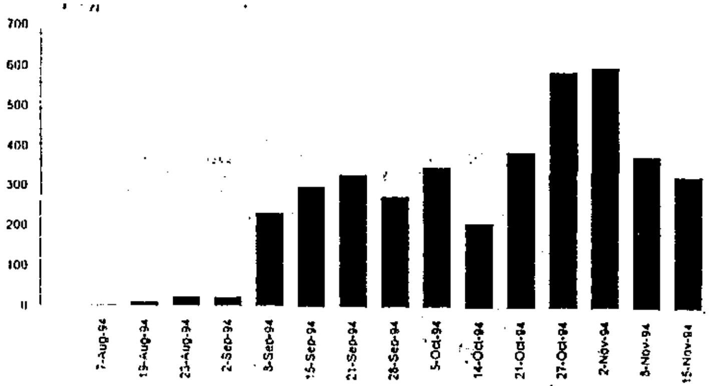


Figure A10.12.82 GREENSHANK

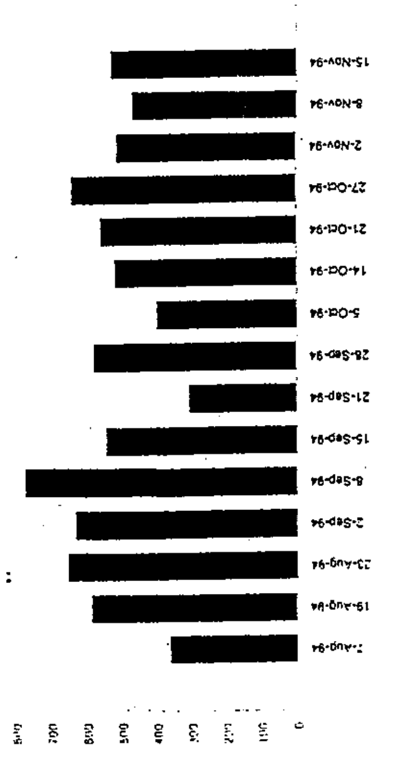


Figure A10.12.83 TEREK SANDPIPER

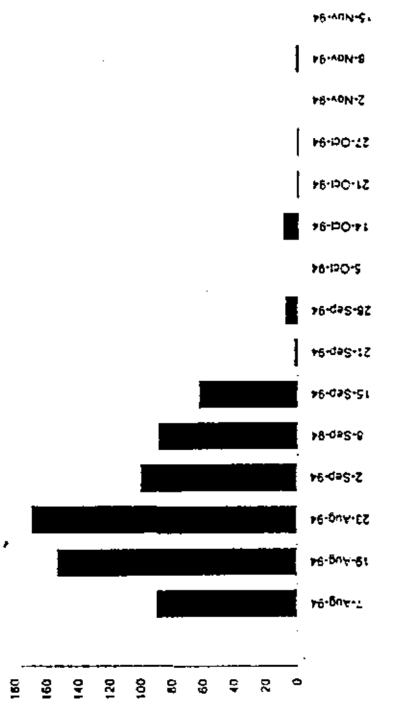


Figure A10.12.84 GREY-TAILED SANDPIPER

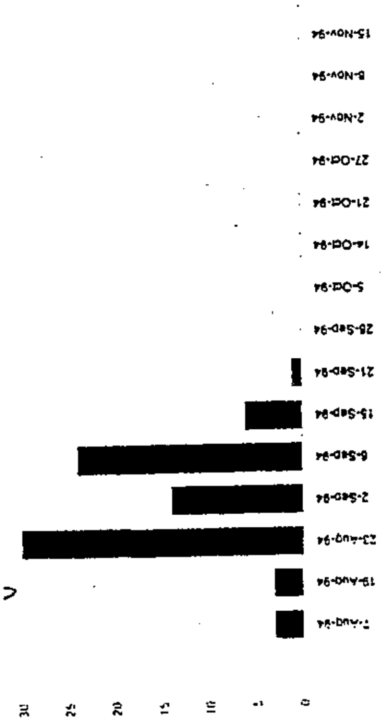
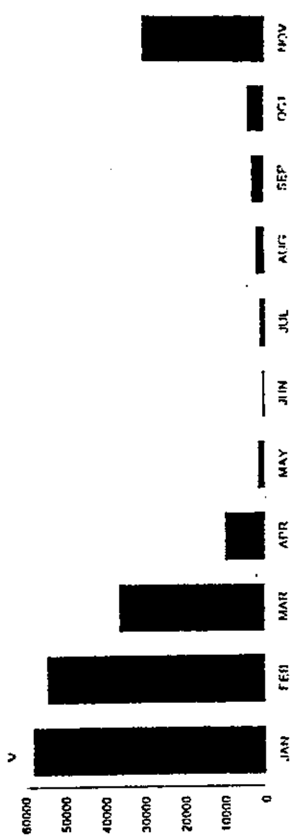


Figure A10.12.85 TOTAL WATERFOWL IN DEEP BAY 1994



A10.12.6 Preliminary Estimates of Energy Requirements of Waterbirds and Consum Benthos in Deep Bay

A10.12.6.1 Introduction

Preliminary assessments of benthic consumption by ducks, waders and gulls indicate that Bay may be close to carrying capacity for these birds. Thus any factor which re availability of prey (e.g. habitat loss or change in water quality) may result in a decr the number of birds in the area. The fact that Deep Bay supports internationally impo numbers of 16 waterbird species highlights the need to ensure that the design implementation of the Shenzhen River Regulation Project and other projects (e.g. Long/Kam Tin Main Drainage, deepening of channels through Inner Deep Bay) are do such a way as to ensure minimal impact on the intertidal flats and their benthic infauna.

The Shenzhen River Regulation Project is expected to result in various environmental imp downstream which may negatively impact waterfowl in Deep Bay.

Deep Bay supports a varying number of waterbirds throughout the year, inclu internationally important numbers for several species. Under the current inclusion criteria f wetlands of international importance in the 'List of Wetlands of International Importance' un the Ramsar Convention on Wetlands of International Importance Especially as Waterf Habitat, any site which holds 1% or more of a flyway population of any waterfowl specie qualifies for listing. Currently Deep Bay supports internationally significant numbers of waterbird species.

Even for those species for which the total numbers do not reach the 1% flyway populatio threshold level for international importance, Deep Bay cannot be ignored, especially due t its importance for long-distance migrant shorebirds.

Deep Bay is used primarily by waterfowl as a wintering site and as a staging point during migration. Numbers of waterfowl are at a minimum in summer.

Deep Bay is attractive to waterfowl due to the fact that it provides suitable feeding conditions, together with suitable roosting and breeding sites.

The great majority of waterfowl which occur in the Deep Bay area feed in the Bay, especially on the intertidal flats where an assemblage of invertebrates (notably polychaetes, molluscs and crabs) and mudskippers provide rich feeding conditions.

The Shenzhen River Regulation Project may affect the intertidal flats of Deep Bay due to changes in patterns (both temporal and spatial) of erosion and deposition, direct loss of habitat, reduced availability of prey species, increased discharge of pollutants, etc. These impacts, which may reduce the intertidal feeding area of Deep Bay and/or prey populations and prey availability, are assessed as part of the Environmental Impact Assessment Study on the Shenzhen River Regulation Project (Section 10).

Reduction in feeding area and/or available prey populations could reduce prey intake rates due to decreased total prey populations, interference in feeding due to crowding by congeners, etc., and may cause a reduction in the 'carrying capacity' of Deep Bay (Goss-Custard 1985, Sutherland and Goss-Custard 1991).

In order to provide baseline data for assessing the current relationship between consumption by waterfowl and the productivity of their food supply in the Bay, this section estimates current annual energy requirements of waterfowl using Deep Bay. The only previous attempt to assess the energy requirements of birds at Mai Po considered a limited number of species feeding in gei wais (Cheung 1979).

This report considers only those bird species which feed principally on benthic organisms in Deep Bay. Birds using benthic production as well as other food resources (e.g. rails) are not included. Therefore this estimate of consumption probably underestimates the real total consumption. Furthermore, no account has been taken of benthic consumption by fish and other organisms.

A10.12.6.2 Methods

Monthly mean species totals from count data for 1994 (this study, and Hong Kong Bird Watching Society unpublished) were used to determine energy requirements and consumption.

The total monthly energy consumption per species was calculated using the equation (after Meire *et al.* 1993):

$$C = (30 \times N \times 3 \times BMR \times (1/Q)/F)/1000$$

in which:

C = total monthly consumption by species (kg Ash-free Dry Mass AFDM)
N = number of birds present each day
BMR = Basal Metabolic Rate (kJ day^{-1})
Q = assimilation efficiency of the food
F = energy content of the food in kJ g^{-1}

Basal Metabolic Rate, the energy consumption of birds resting at thermoneutrality, was estimated using the equation (Kersten and Piersma 1987):

$$BMR = 5.06 \times 0.729LW$$

LW = the lean (fat-free) weight of the species in g.

Lean weights were taken as the lower values from a range of weights given by Dunning (1992), and unpublished records (D.S. Melville and WWF Hong Kong).

The Basal Metabolic Rate from the above equation was converted to kJ. day-1.

Total daily energy expenditure (DEE) was assumed to amount to three times BMR (Kersten and Piersma 1987, Castro *et al.* 1992).

For benthic invertebrates a digestibility of Q = 0.85 was used (Kersten and Piersma 1987, Zwarts and Blomert 1990).

It should be noted that this method gives only a very crude estimation of total energy consumption - see discussion below.

A10.12.6.3 Results

The estimated monthly consumption (kg AFDM) by ducks, waders and gulls is shown in Figure A10.12.86.

This initial assessment indicates that total energy requirements for those waterfowl which are thought to primarily consume benthic invertebrates totals 256,588 kg AFDM per year.

A10.12.6.4 Discussion

The results of this exercise have to be considered in the light of several difficulties with the model.

The assumption is that all birds feed exclusively on benthos in Deep Bay. However, it is known, for example, that some ducks also feed in gei wais and fish ponds, and gulls may also feed on items other than benthos (e.g. fish). Thus, consumption may be overestimated. There are, however, a number of species (e.g. rails) which also feed on benthos but which are not included.

No adjustments have been made for variations in daily energy expenditure within the annual cycle due to physiological processes such as deposition of energy reserves for migration (spring and autumn), and increased requirements for new feather growth during moult (spring and late summer/autumn). These can result in considerably elevated energy requirements (e.g. Drent and Piersma 1990, Piersma 1994).

The formula for estimating DEE is based on work conducted in temperate areas of Europe and North America, and thus may be rather high for 'tropical' Deep Bay. It should be noted that Klaassen *et al.* (1990) found that shorebirds wintering in tropical west Africa had lower maintenance metabolic rates than congeners wintering in Europe. Similarly, Treca (1993) determined that daily food requirements for ducks and shorebirds wintering in Senegal closely fitted estimates derived from Kendeigh's (1970) formula, and were significantly less than those in the western Palearctic.

Although Hong Kong lies within the tropics, it experiences a sub-tropical climate with an exceptionally cool winter for such a latitude - 22°20'N (Dudgeon and Corlett 1994). Thus Klaassen *et al.*'s (1990) work on energy requirements conducted in Mauritania (c. 20°N) may be less relevant to Hong Kong than the similarity in latitude might suggest.

It is not possible to calibrate the model for local conditions without extensive experimentation (cf. Piersma 1994, Wiersma and Piersma 1994), which was beyond the scope of the present study.

While the figures generated in this exercise cannot be taken as precise estimates of energy requirements by waterfowl in Deep Bay they do none the less provide a basis for inter-specific and seasonal comparisons, and a preliminary review of estimated consumption for comparison with estimated productivity (McChesney unpublished).

Table A10.12.5 compares estimated total monthly consumption in the period December 1993 to November 1994, with estimated production in 1992/93 (more recent productivity data are unavailable, but there have not been massive changes in benthos or waterbirds over this period, and thus the comparison is considered to be valid within the constraints of the present study). Over the course of the year it appears that waterfowl may be removing 41.5% of total production, with monthly figures ranging from 1.5 to 134.8% (i.e. with a total reduction in standing crop biomass). The annual total figure lies at the upper end of the range of values found at a number of temperate estuaries (Table A10.12.6).

Table A10.12.5 Estimated total consumption (kg AFDM) of benthic production by waterbirds* in Deep Bay

Month	Est. consumption	Est. production**	(% total prod)
January	74,089	74,500	99.4
February	59,314	44,000	134.8
March	32,381	67,000	48.3
April	6,190	32,000	19.3
May	1,660	52,000	3.2
June	615	41,000	1.5
July	626	22,000	2.8
August	1,602	38,000	4.2
September	2,575	68,000	3.8
October	8,240	not determined	
November	25,754	87,000	29.6
December	43,542	73,000	59.6
TOTAL	256,588	598,500	41.5***

* ducks, waders, gulls
** after McChesney unpublished
*** mean for all months except October

The fact that only 41.5% of the benthic production in Deep Bay appears to be being harvested by waterfowl does not imply that there remains 58.5% available to waterfowl and thus that carrying capacity has not been reached. As noted in Appendix A10.9, predator exclusion experiments in spring indicate a high degree of predation of available biomass (particularly of bivalve molluscs).

Table A10.12.6 Summaries of benthic invertebrate production estimates, consumption by shorebirds and consumption efficiencies, for five estuaries (after Baird, 1985)

Locality	energy equivalent (kJ.m^{-2}.yr^{-1}) of consumption efficiency: Consumption by birds	Invertebrate production	Invertebrates to birds (%)
Dutch Wadden Sea (intertidal zone)	103.6	619.2	17
Grevelingen estuary	71.5	1201.4	6
Ythan estuary	873.6	2448.1	36
Tees estuary	367.0	851.0	44
Langebaan Lagoon	141.6	705.0	20
Mai Po, Deep Bay			41.5

At any one time not all benthic organisms are in a situation where predators are able to harvest them, since they may be buried too deep (Piersma 1986). Thus in Deep Bay in winter *Dendronereis* is usually at a depth of more than 120cm, which is beyond the probing depth of all waders at Mai Po except curlews (*Numenius arquata/madagascariensis*). Furthermore, as noted by Zwarts and Wanink (1991), the accessible prey (shallow burrowing) may have relatively poor body condition compared with animals of the same size at a greater depth in the substrate. If this is the situation in Deep Bay, then a given energy intake by available near the surface, than if all animals were of similar body condition irrespective of depth. Such a situation would result in an increased depletion of available prey.

The relationships between benthos production and predation are complex, as indicated in Figure A10.12.87, Piersma (1987) provides a useful discussion of this complex model for further elucidating such relationships, but the model requires a far more detailed knowledge of both predators and prey than is currently available for Deep Bay.

The results of the present study, albeit crude, suggest that current levels of predation on benthos are near a maximum and thus that carrying capacity of Deep Bay may have been nearly reached. Support for this is further provided by mid-winter duck counts which show a stabilisation of numbers over the past 5 years, following a substantial increase over the previous 10 years (Section 10, Figure 10.5). In this context, it is noteworthy that Wolff (1991) has suggested that the 'surplus' supply of benthos (i.e. difference between production and predation) may be notably smaller in the tropics than in temperate areas (Figure A10.12.88).

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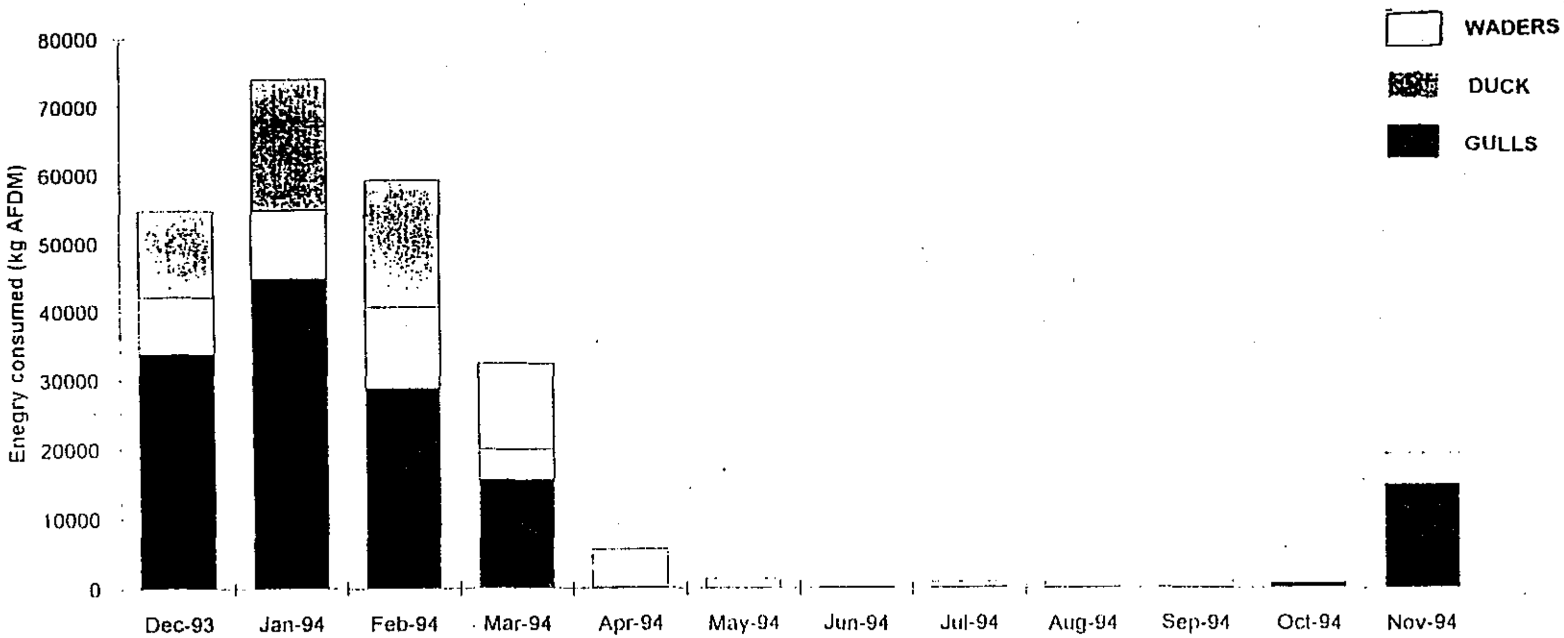


Figure A10.12.86 Estimated monthly consumption of benthos (kg/ash-free dry mass)

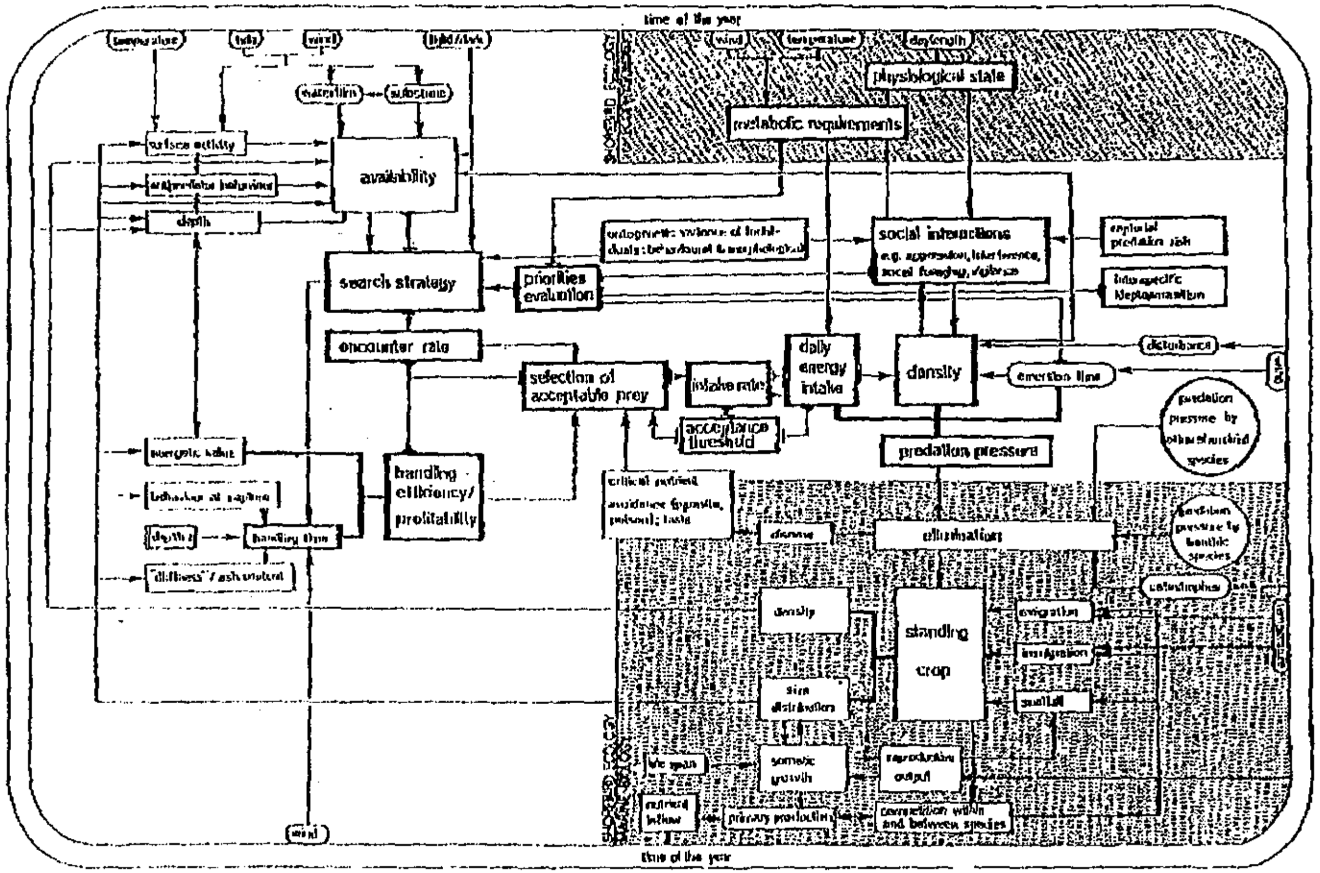


Figure A10.12.87 Heuristic model to describe the direct causal interactions between a shorebird species and one of its benthic prey (after Piersma 1987)

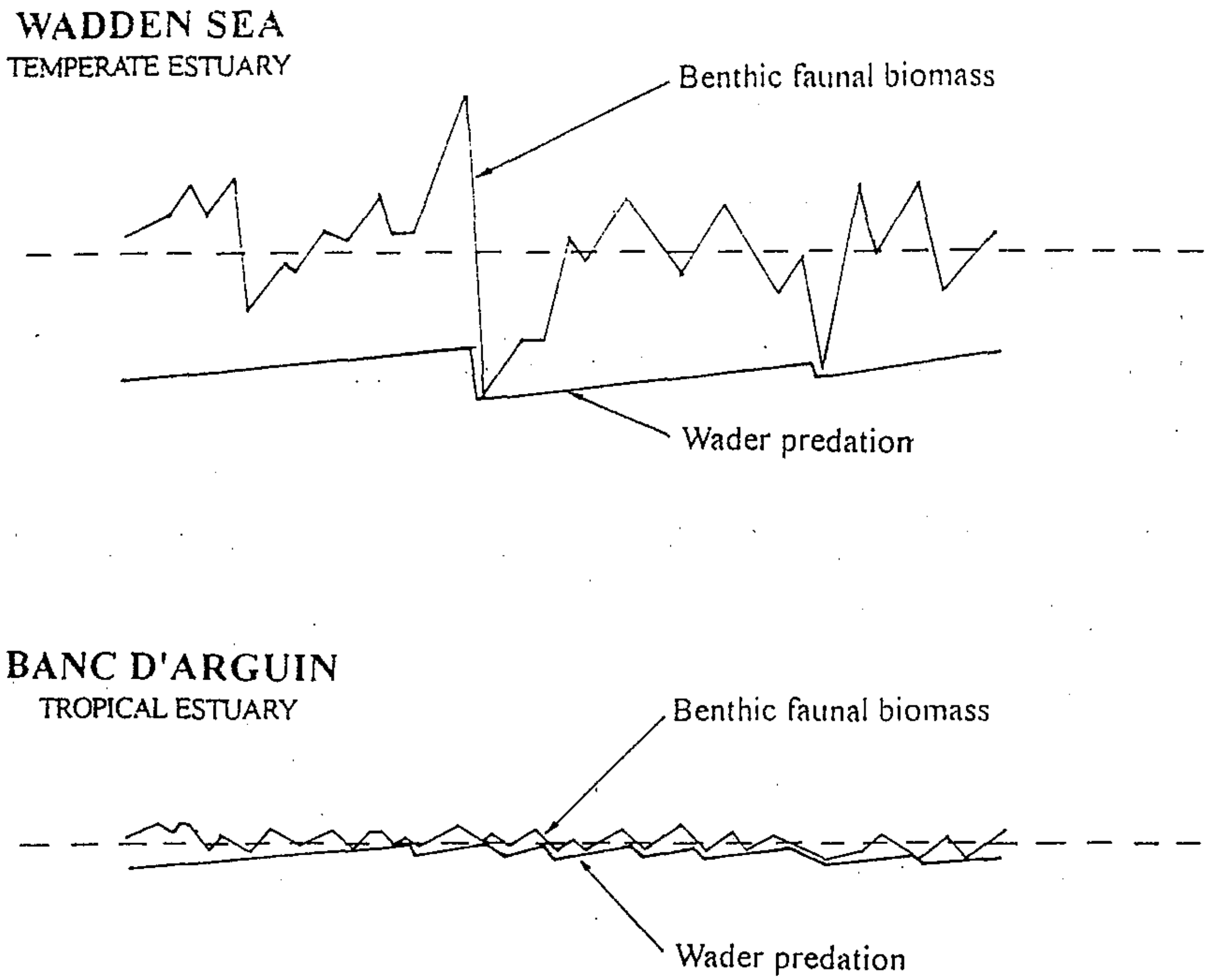


Figure A10.12.88 Hypothetical examples of relationship between tidal flat fauna and wader predation

A10.13 THE IMPORTANCE OF FISH PONDS AROUND DEEP BAY TO WILDLIFE, TOGETHER WITH A REVIEW OF POTENTIAL IMPACTS OF WETLAND LOSS AND MITIGATION MEASURES

A10.13.1 Introduction

Deep Bay, with its intertidal mudflats, mangroves, *gei wais* and fish ponds, is a wetland of international importance for biodiversity conservation. This has been recognised by both the Chinese Government, which has established the Futian National Nature Reserve in Shenzhen, and the Hong Kong Government, which has protected the Mai Po Marshes Nature Reserve, as well as designating two Deep Bay Buffer Zones to control land use and development in the surrounding area. The Chinese Government is considering the designation of the Futian National Nature Reserve as a 'wetland of international importance' under the Ramsar Convention, and the Hong Kong Government is similarly considering the listing of Mai Po and adjacent wetlands.

The Deep Bay area has come under increasing pressure from development in the past 20 years, with the establishment of the Shenzhen Special Economic Zone on the Chinese side of the Bay, and the increasing urbanisation and development of light industry and open storage on the Hong Kong side.

The development on both sides of the Shenzhen River has been at the expense of wetlands, notably fish ponds, which have been filled to provide new land.

There is a common belief that fish ponds are not of value to wildlife. This belief is false, and is based largely on a lack of knowledge of wildlife utilisation of this habitat. Our knowledge is still scanty but increasing study in recent years has highlighted the importance of fish ponds, especially for certain species of wildlife.

Today, there are an increasing number of projects being proposed which will result in the destruction of fish pond habitat for residential/industrial/recreational development. Recently, drainage/flood control schemes have been proposed which also will result in fish pond loss.

Both the Shenzhen and Hong Kong Governments have requested an assessment of the value of fish ponds for wildlife so that potential development impacts may be determined, particularly with a view to establishing whether it is appropriate to undertake mitigation works to compensate for loss of fish pond wetlands.

The present paper summarises our current knowledge of fish pond faunas, and attempts to answer certain questions regarding potential habitat loss, especially with respect to the Shenzhen River Regulation Project. Among the questions asked are:

- Will a reduction in habitat result in loss of wildlife?
- Can mitigation measures reduce loss of wildlife?

Further questions which have been asked relate specifically to the quantification of a). impacts of fish pond loss on wildlife, and b). the value of mitigation measures. The current state of knowledge of the Deep Bay area does not permit detailed quantitative assessments at this time but, based on relevant studies of the same species elsewhere, breeding bird populations are positively related to area of feeding habitat, thus a reduction in habitat is expected to result in a reduction in bird numbers.

A10.13.2 Ramsar Convention

Both Hong Kong, through the United Kingdom, and the People's Republic of China are Parties to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention).

Article 3.1 of the Convention stipulates that **'the Contracting Parties shall formulate and implement their planning so as to promote...as far as possible the wise use of wetlands in their territory'**.

At the Fifth Meeting of the Conference of the Parties , Kushiro, 1993, a resolution was passed calling on 'the Contracting Parties to implement in a more systematic and effective manner, and at international, national and local levels, the guidelines on wise use adopted by the Fourth Conference of the Contracting Parties'.

An Appendix to the Kushiro Resolution gives 'additional guidance for the implementation of the wise use concept'. Inter alia, this notes that 'The **cumulative** effects of separate projects should also be taken into consideration' [when conducting an EIA].

The need for cumulative impact assessments in the Deep Bay area has been recognised for a number of years, and was addressed in the Deep Bay Integrated Environmental Management Study (ERL (Asia) Ltd. 1988). Anon. (1993a) also notes that 'a particular concern in the Mai Po area is the **cumulative** effect of development'.

It is thus clear that **the loss of wetlands resulting from the Shenzhen River Regulation Project** (or any other project) **cannot be viewed in isolation. Wetland loss** <u>must</u> **be considered in the context of current, planned and potential, overall wetland loss around Deep Bay.**

A10.13.3 Fish Ponds

Fish ponds in the Deep Bay area currently comprise some 1350ha of wetlands on the Hong Kong side of the Bay, and 440ha in the Shenzhen Special Economic Zone. Agriculture and Fisheries Department (undated) statistics which show an area of 1330 ha of Grade 'A' fish ponds around Deep Bay do not take into account recent, and on-going, losses resulting from works associated with the Yuen Long/Kam Tin main drainage project, as well as some loss due to illegal infilling. 20-30 years ago most of these ponds, on both sides of the Bay, were paddi fields. Both paddi fields and fish ponds are recognised as 'wetlands' under the definition in the Ramsar Convention. Although usually referred to as 'freshwater' fish ponds, many are slightly brackish (2-10 p.p.t.).

Fish ponds are usually managed for a variety of fish species, such as carps (Cyprinidae) and mullets (*Mugil* spp.). A number of other fish may also be present in the ponds, notably *Oreochromis mossambicus*, which has virtually no economic value and is generally regarded as a pest, and the small *Gambusia affinis*. The ponds also support high populations of chironomid midges, especially shortly after flooding in spring, and populations of the freshwater shrimp *Macrobrachium nipponense*. Other freshwater fauna are generally scarce in ponds under active management for fish production, this probably being due largely to high fish populations and high nutrient input.

There is little emergent vegetation in actively managed fish ponds, but the banks may be well vegetated with a limited number of species of grasses and herbs. These provide habitat for a variety of wildlife (Chu 1993).

Ponds are usually drained down once each winter to facilitate harvesting of fish. The ponds remain drained down for several weeks/months during which time maintenance works may be conducted, e.g. excavation of channels and bulldozing of bottom sediments, although this usually only occurs once in every 2-3 years. Drying out of surface muds is thought to 'cleanse' the pond, and the disturbance of bottom sediments promotes the release of nutrients on reflooding.

Due to the acid sulphate soil conditions of the Deep Bay area lime is usually applied to the ponds at the time of flooding in the spring.

The autumn drawdown of ponds usually starts in October, and reflooding usually is completed in April/May. Thus drained down ponds can usually be found for a period of some 7 months, although individual ponds are not usually left dry for so long.

A10.13.4 Waterfowl

Fish ponds provide habitat for a variety of wildlife, as summarised by Chu (1993). As far as current knowledge allows us to determine, the greatest importance of these ponds is as feeding grounds for a variety of waterfowl, notably egrets, herons and spoonbills. This is not to say, however, that they are unimportant for other species (see below).

Waterfowl species of principal concern with respect to fish ponds are:

Cormorant	*Phalacrocorax carbo*	W
Night Heron	*Nycticorax nycticorax*	R/M
Chinese Pond Heron	*Ardeola bacchus*	R/M
Cattle Egret	*Bubulcus ibis*	R/M
Little Egret	*Egretta garzetta*	R/M
Great Egret	*Egretta alba*	R/M
Grey Heron	*Ardea cinerea*	R/M
Oriental White Stork	*Ciconia boyciana*	W
Black-faced Spoonbill	*Platalea minor*	W

R = resident M = migrant W = winter visitor

Cormorant

Deep Bay supports the largest known winter concentration of Cormorants in East Asia (Perennou *et al.* 1994), and thus is of regional conservation value for this species. The species feeds mainly in Deep Bay (Hong Kong Bird Watching Society records, WWF HK unpublished), but a certain number feed in fish ponds. The Agriculture and Fisheries Department is currently undertaking a study of Cormorant predation on pond fish and possible measures to reduce damage to commercial stocks.

Black-faced Spoonbill

Deep Bay supports some 24% of the WORLD population of the Black-faced Spoonbill, and thus is of international importance for the conservation of this critically endangered species (estimated world population c.350 - Kennerley 1990, Rose and Scott 1994, Dahmer and Feolley 1994). IUCN currently categorise this species as 'Endangered' - the most severely threatened category, where 'survival is unlikely if the causal factors continue to operate' (Groombridge

1993). Preliminary observations (P.J. Leader unpublished) indicate that this species feeds extensively in drained fish ponds around Deep Bay in winter, particularly on *Macrobrachium nipponense*; however, detailed studies have yet to be made. In Taiwan, Black-faced Spoonbills also feed extensively in fish ponds (E. Poorter and T. Dahmer pers. comm.).

Oriental white stork

Numbers of Oriental White Stork, which peaked at 121 in 1990/91 (Chan 1991), dropped to 4 in 1993/94. The reason(s) for this are unknown. This is a globally endangered species (Groombridge 1993), with an estimated world population of 2,500 (Rose and Scott 1994). Preliminary studies indicate that this species feeds extensively in fish ponds around Deep Bay in winter (S. Chan unpublished).

Egrets and herons (Ardeids)

Egrets and herons are present in Hong Kong throughout the year, but there is some movement of birds through the Territory (e.g. Chalmers 1986, Melville 1980). It is thought likely that the majority of the Hong Kong birds are resident (with the possible exception of the Cattle Egret where winter numbers are usually lower than those in summer), but no marking studies have been conducted to confirm this. Ardeids breeding in northern China, Japan, etc. are likely to pass through the Deep Bay area on passage and/or winter in the area, as there is a regular winter exodus from northern areas (e.g. McClure 1974).

Hong Kong's breeding populations of egrets are considered to be of regional importance as there are few known breeding colonies in Guangdong (Gao Yu Ren pers. comm.). Wintering numbers also are significant (Perrenou *et al.* 1994).

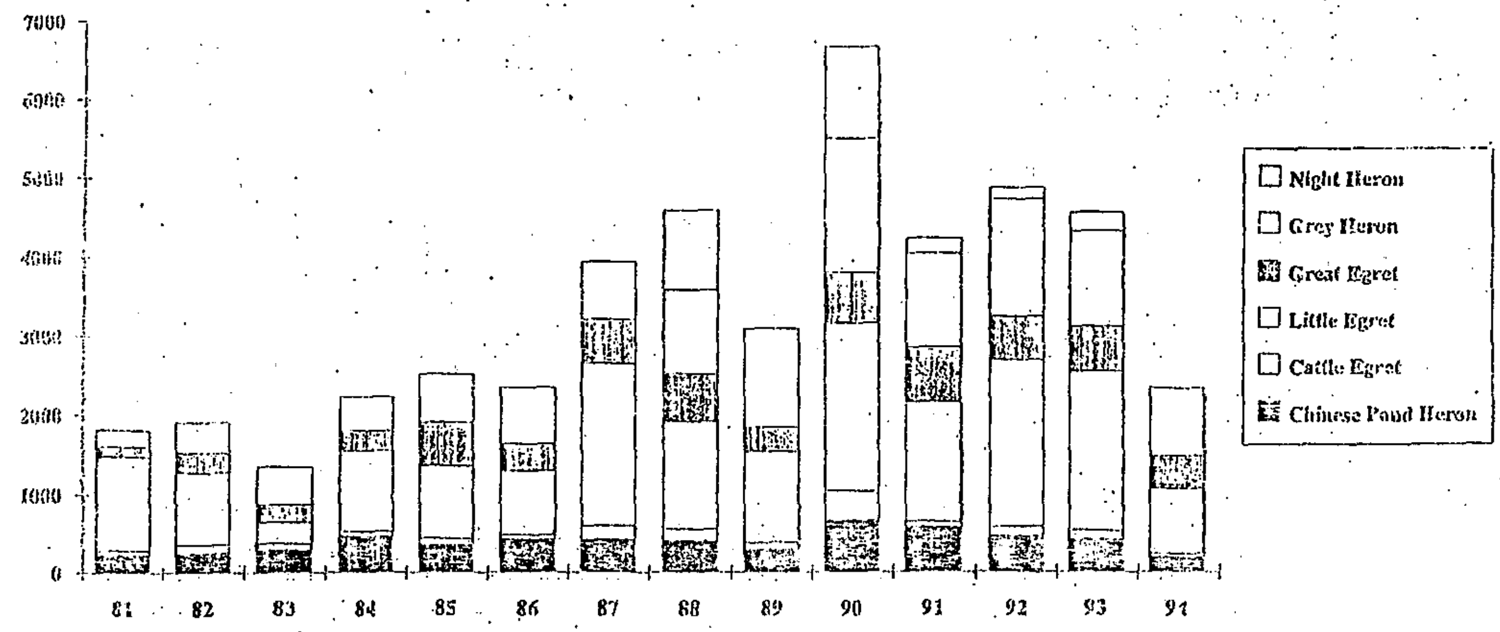
Wintering ardeids

Data for numbers of wintering Ardeids is taken from the results of mid-January waterfowl counts conducted by the Hong Kong Bird Watching Society (HKBWS). These counts are part of a programme to assess mid-winter waterfowl populations, coordinated by the International Waterfowl and Wetlands Research Bureau (IWRB) and the Asian Wetland Bureau (AWB). The numbers of Ardeids recorded from the Deep Bay area (excluding Futian) in the mid-January waterfowl counts between 1981 and 1994 are shown in Figure A10.13.1. There is an indication of a peak in numbers around 1988-1993, with a reduction in 1994; however, there is a considerable degree of 'noise' in the data and it is too early to determine whether the wintering numbers are really falling. It should be noted that the 1993/94 winter was unusually mild and this may have affected the number of birds present in Deep Bay.

The fact that wintering populations of Ardeids in Deep Bay are of regional significance is indicated in Table A10.13.1.

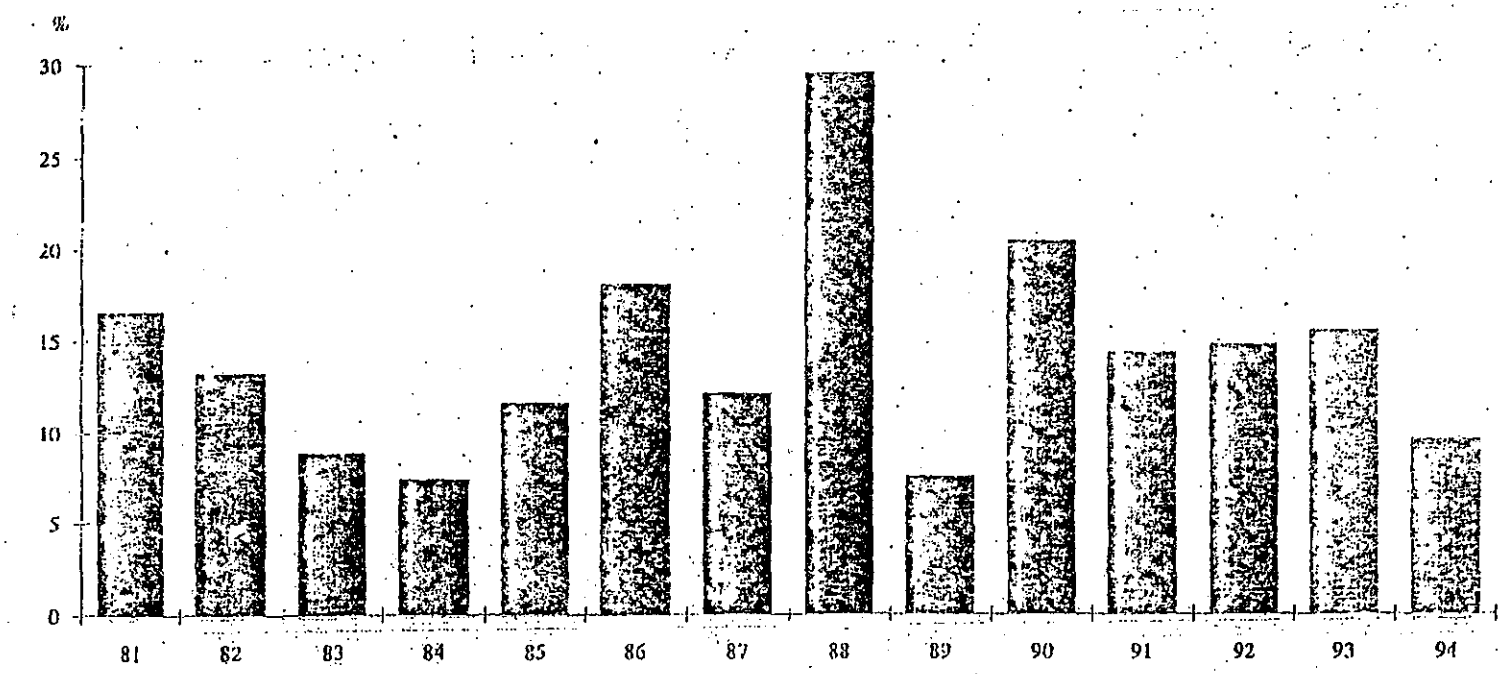
The count data from China are clearly incomplete but, bearing in mind that data come from many of the major wetlands throughout the country, the importance of Deep Bay as a wintering area is self-evident. It should also be borne in mind that in winter egrets and herons are absent from the northern and western areas of China, being largely restricted to the far south of the country (Cheng 1987, Perrenou *et al.* 1994).

From Fig. A10.13.2 it can be seen that the proportion of all Ardeids recorded during mid-January observed in fish pond areas varies considerably from year to year, but averages about 10%.



Hong Kong Bird Watching Society data

Figure A10.13.1 Herons and Egrets in the Deep Bay Area 1981-1994



Hong Kong Bird Watching Society data

Figure A10.13.2 Percentage of Herons and Egrets in Fish Ponds 1981-1994

Table A10.13.1 Numbers of Ardeids counted in H.K. and China* during mid January 1993**

Species	Hong Kong	China	Hong Kong % Total
Grey Heron	1155	2133	35.1
Great Egret	446	562	44.2
Little Egret	1837	1661	52.5
Cattle Egret	113	0	100
Chinese Pond Heron	332	425	43.8
Night Heron	204	1632	11.1

* China data include records from Futian National Nature Reserve, Shenzhen.The H.K. count is for Deep Bay, excluding Futian.
** after Mundkur and Taylor (1993)

When the distribution of different species recorded during mid-January counts is reviewed (Figure A10.13.3), it appears that some species (Cattle Egret, Chinese Pond Heron, Little Egret) favour fish ponds more than other species (Great Egret, Grey Heron, Night Heron).

It should be noted that not all fish ponds in the Deep Bay area are covered by observers during the mid-January counts. As a result, the figures may underestimate the numbers of birds there. It should be further noted that since both Grey Herons and Night Herons feed largely at night, those birds recorded during the counts are roosting, and their distributions may not reflect their feeding distributions since they are known to feed in fish ponds.

A detailed study by Young (1994) included an assessment of seasonal use of different feeding habitats around Deep Bay by Chinese Pond Herons, Little Egrets and Great Egrets. The results (Figure A10.13.4), are in general agreement with the mid-January count data, but there is a suggestion that the importance of fish ponds to species such as Chinese Pond Heron and Little Egret may be underestimated in the HKBWS data.

Breeding Ardeids

Two main factors are of crucial importance for the maintenance of breeding populations of colonially breeding Ardeids: i). protected nest sites, and ii). adequate feeding areas (Hafner *et al.* 1987). In Hong Kong Ardeids traditionally breed in close association with man, in *fung shui* woods and village bamboo groves, as well as in hillside woodlands. Egrets are regarded as 'lucky' and thus, traditionally, are not disturbed whilst nesting. In recent years, however, there have been problems at some sites due to the illegal taking of young, and disturbance resulting from construction works. Some egret sites have been used for a long time, whereas others are of more recent origin. The reason(s) for abandonment of sites and the establishment of new colonies are currently unknown, but may relate to direct human disturbance and habitat loss nearby (see below).

Wong (1991) and Young (1994 and unpublished) have found that most breeding Ardeids in Hong Kong feed within 3km of the breeding colony. When potential feeding ranges of 3km are considered for the 7 Deep Bay breeding colonies it is found that effectively ALL fish pond habitat on the Hong Kong side of the Bay is included (Figure A10.13.5).

In addition, the distribution of egretries on the Hong Kong side of Deep Bay shows a remarkably even spacing. This is consistent with studies elsewhere, in which it has been found that in areas of suitable feeding habitat colonies usually are regularly distributed (e.g. Fasola and Barbieri 1978, Gibbs *et al.* 1987, Gibbs 1991).

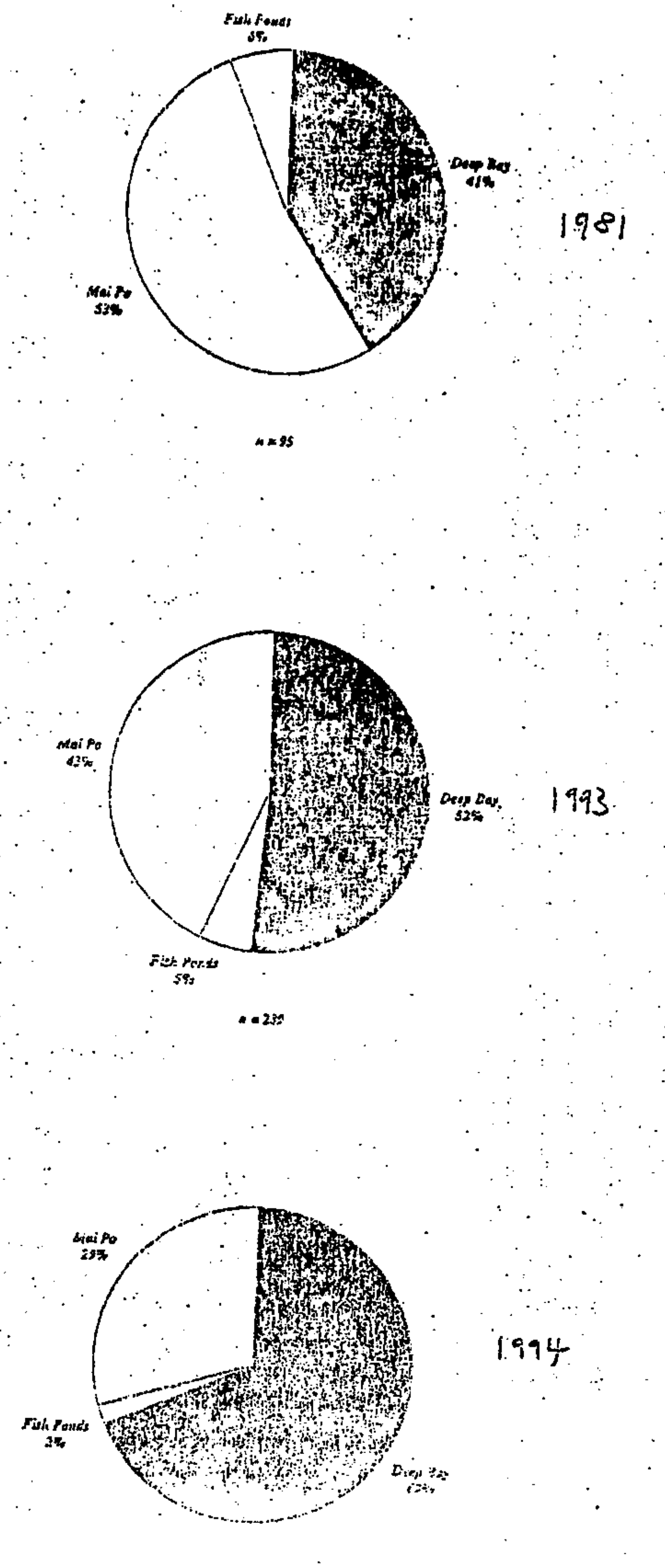
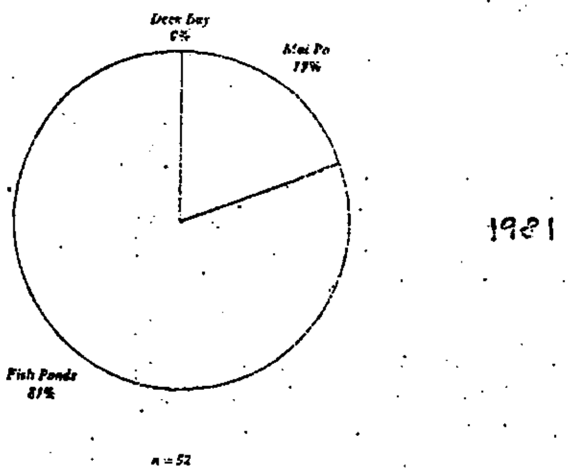
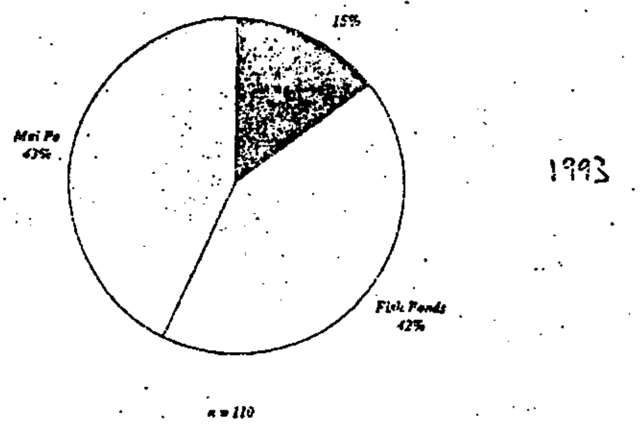
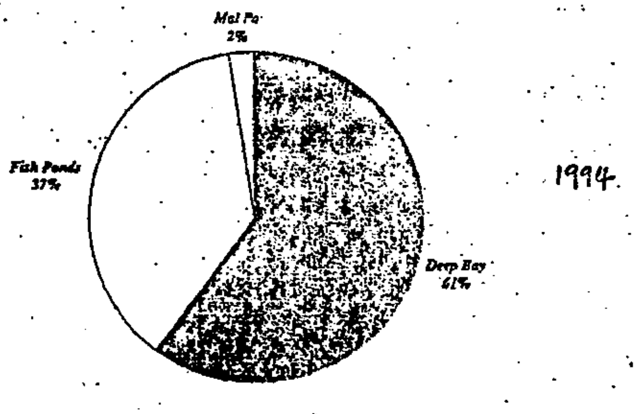


Figure A10.13.3(a) Great Egret in Hong Kong in January







n= 113

Figure A10.13.3(b) Cattle Egret in Hong Kong in January

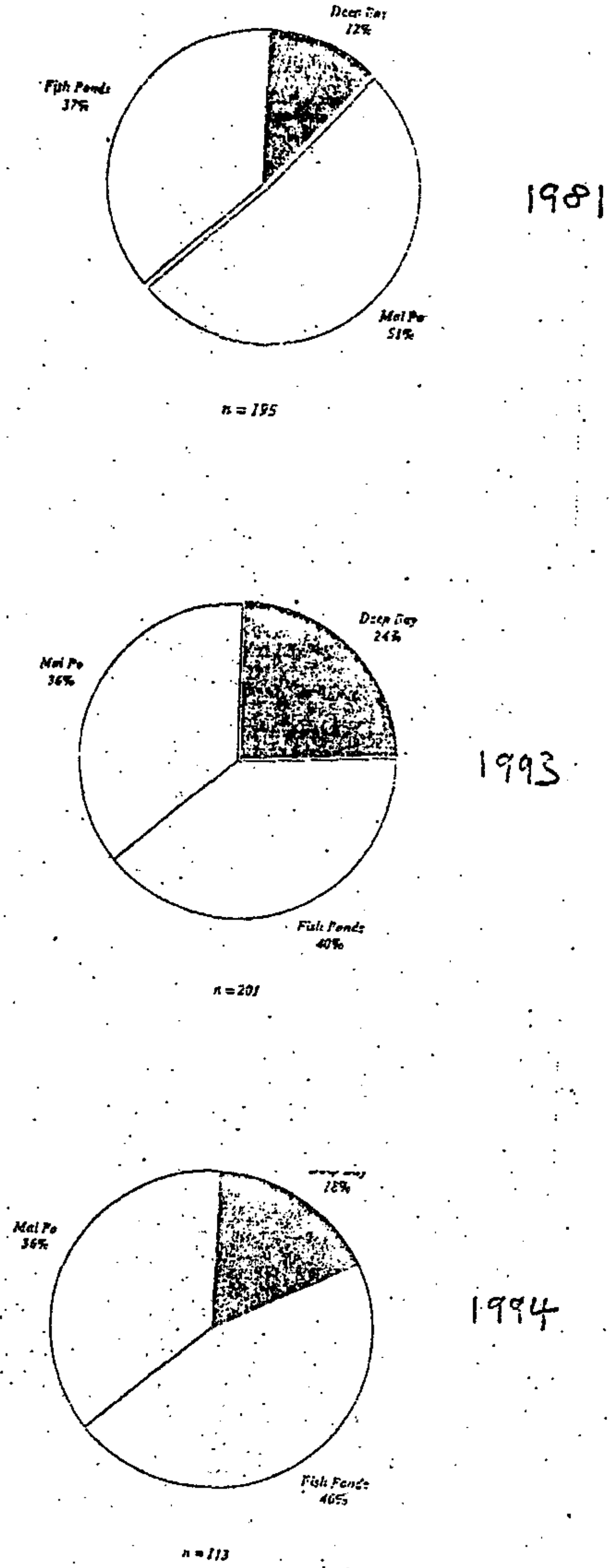


Figure A10.13.3(c) Chinese Pond Heron in Hong Kong in January

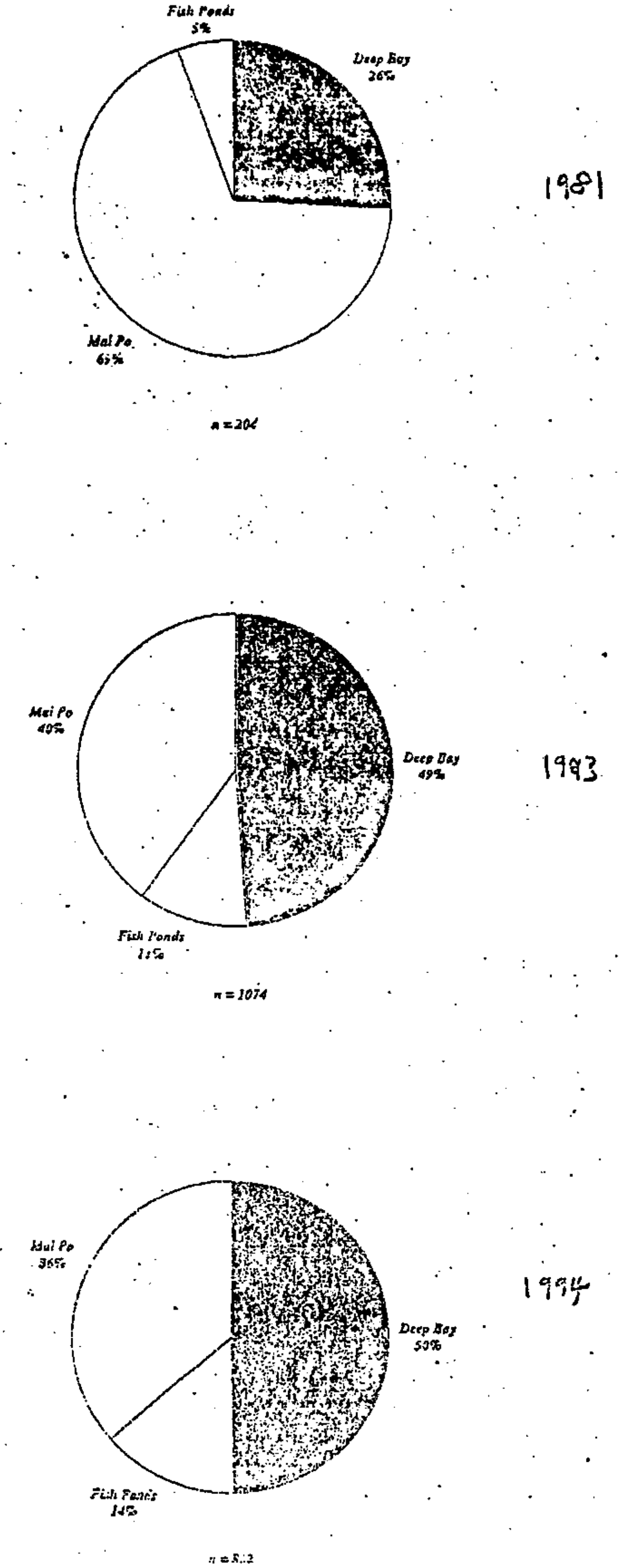


Figure A10.13.3(d) Grey Heron in Hong Kong in January

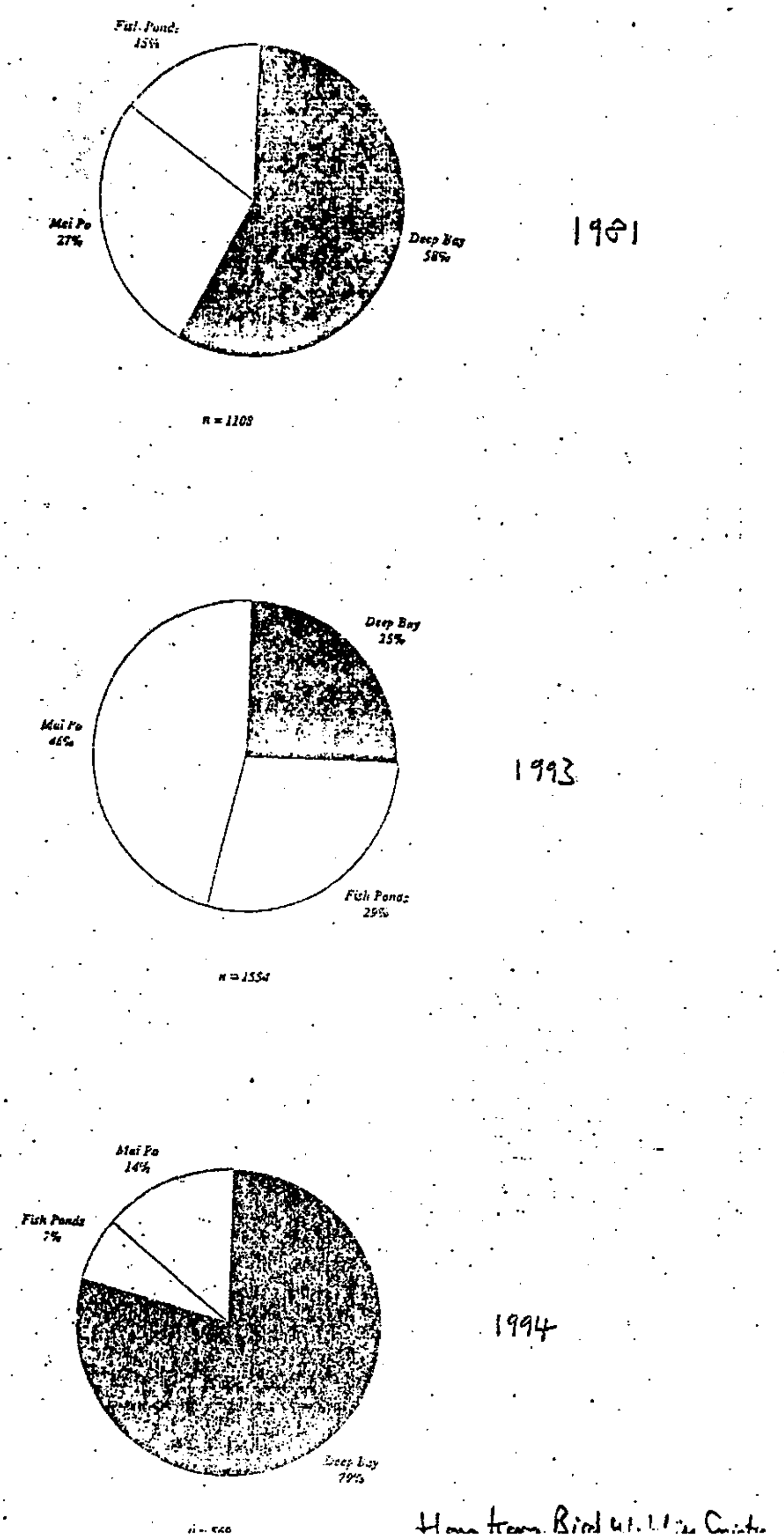


Figure A10.13.3(e) Little Egret in Hong Kong in January

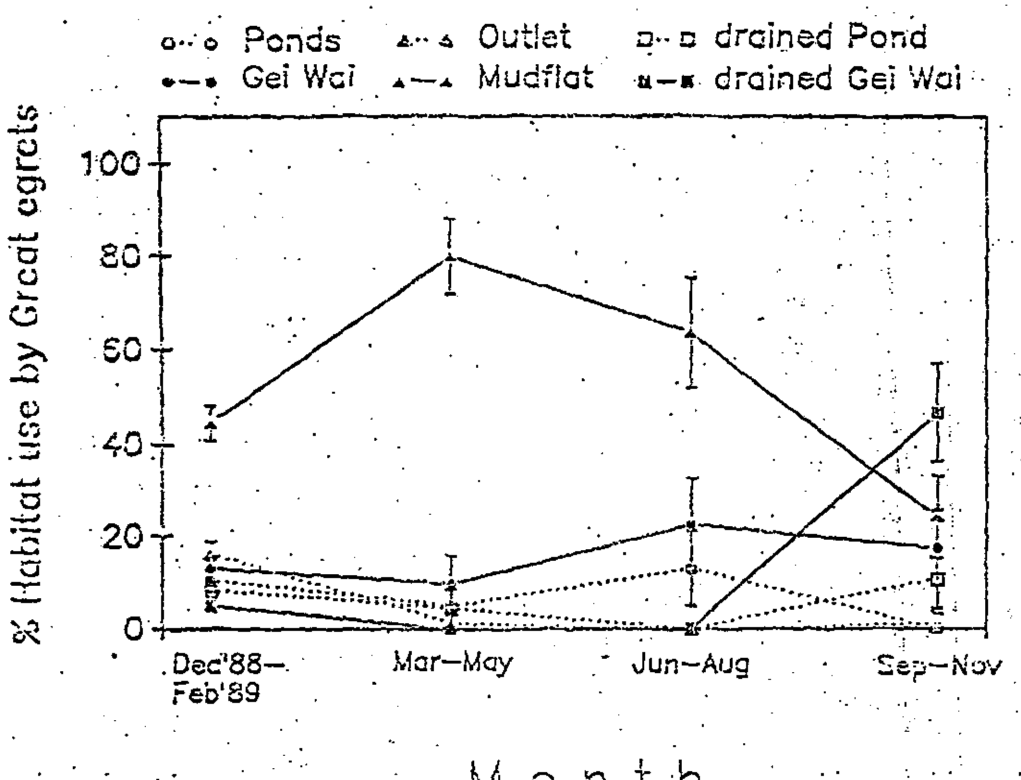


Figure A10.13.4(a) Seasonal use of low tide feeding habitats at Mai Po by Great Egrets (Dec 1988 to Nov 1989) (mean ± SEM). Use of nullahs is not shown because their percentage use was <5% in all seasons. (After Young, 1994)

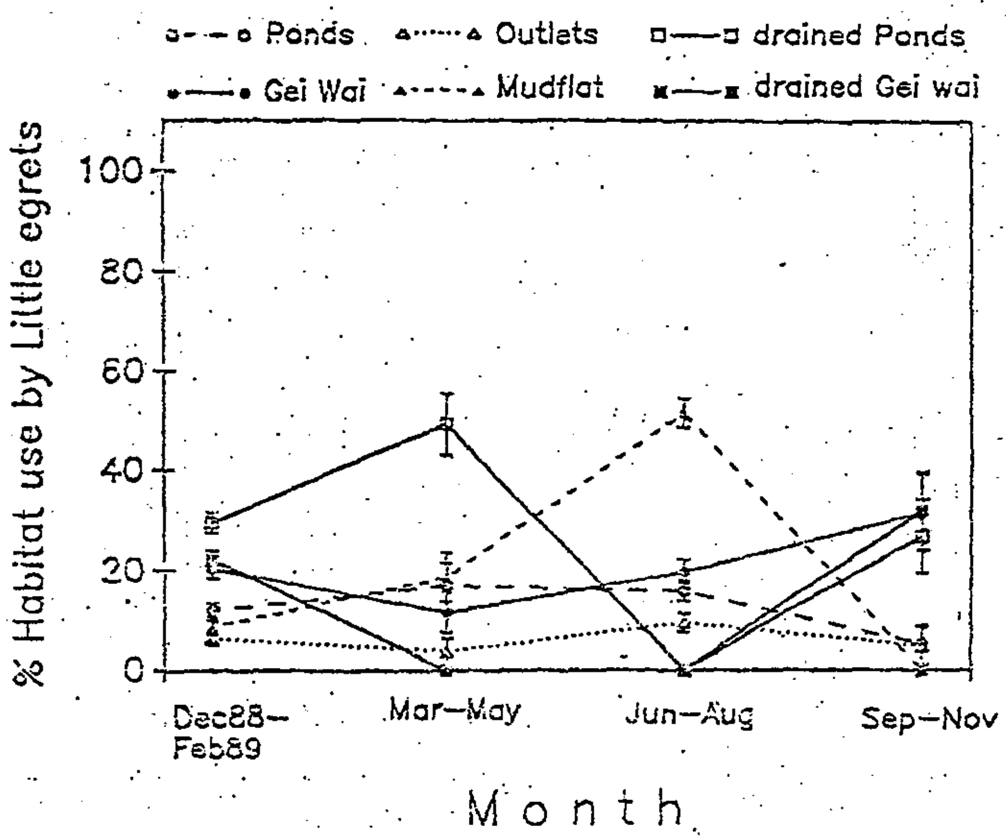


Figure A10.13.4(b) Seasonal use of low tide feeding habitats at Mai Po by Little Egrets (Dec 1988 to Nov 1989) (mean ± SEM). Use of nullahs is not shown because their percentage use was <5% in all seasons. (Dec 88 - Feb 89, n = 11; Mar - May, n = 3; Jan - Aug, n = 6; Sep - Nov, n = 3) (After Young, 1994)

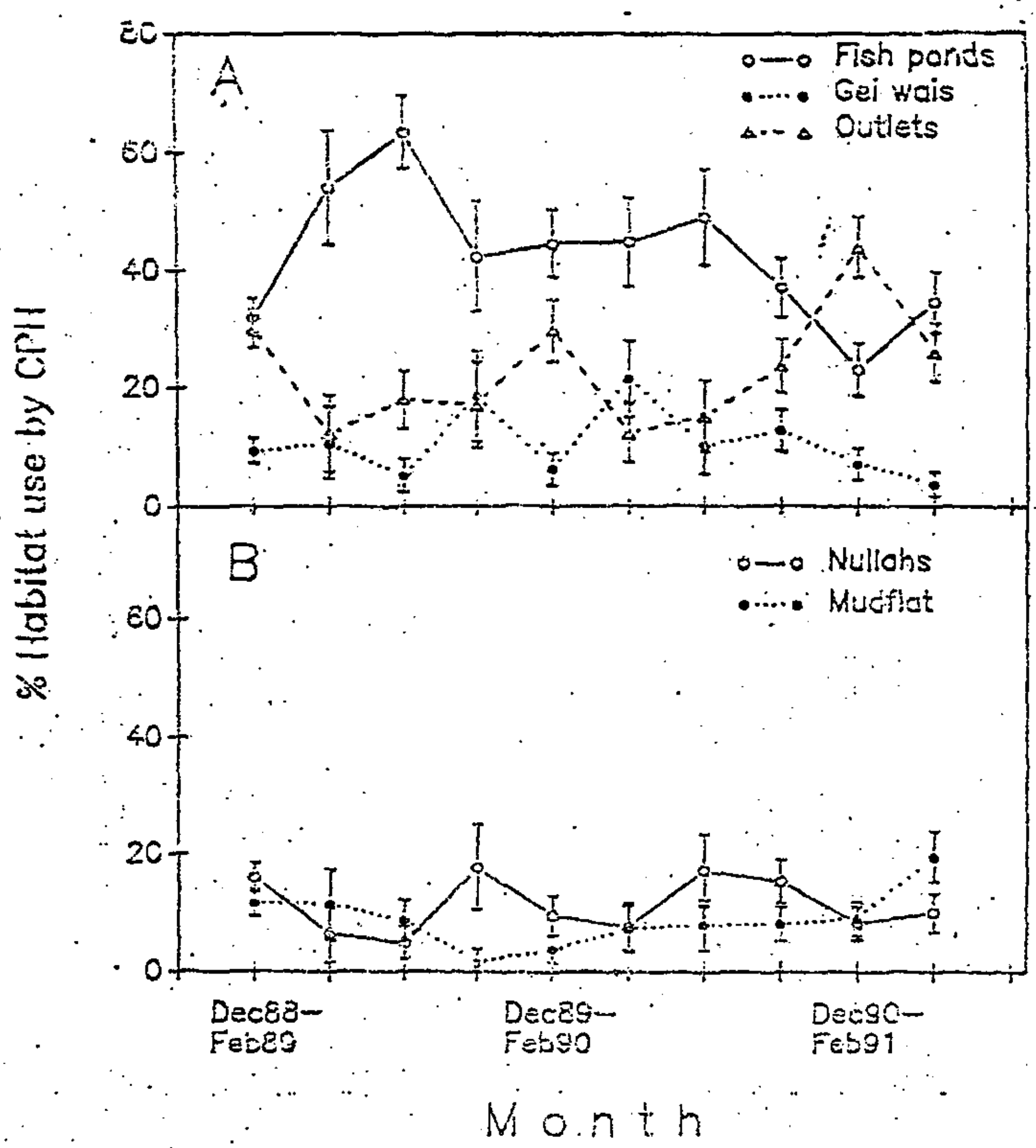


Figure A10.13.4(c) Seasonal use of low tide feeding habitats at Mai Po by Chinese Pond Herons (Dec 1988 to Feb 1991) (mean ± SEM). (Dec 88 - Feb 89, n = 11; Mar - May, n = 3; Jan - Aug, n = 6; Sep - Nov, n = 3; Dec 89-90, n = 5; Mar - May, n = 3; Jun - Aug, n = 5; Sep - Nov, n = 6; Dec 90 - Feb 91, n = 6; Mar - May, n = 2) (After Young, 1994)

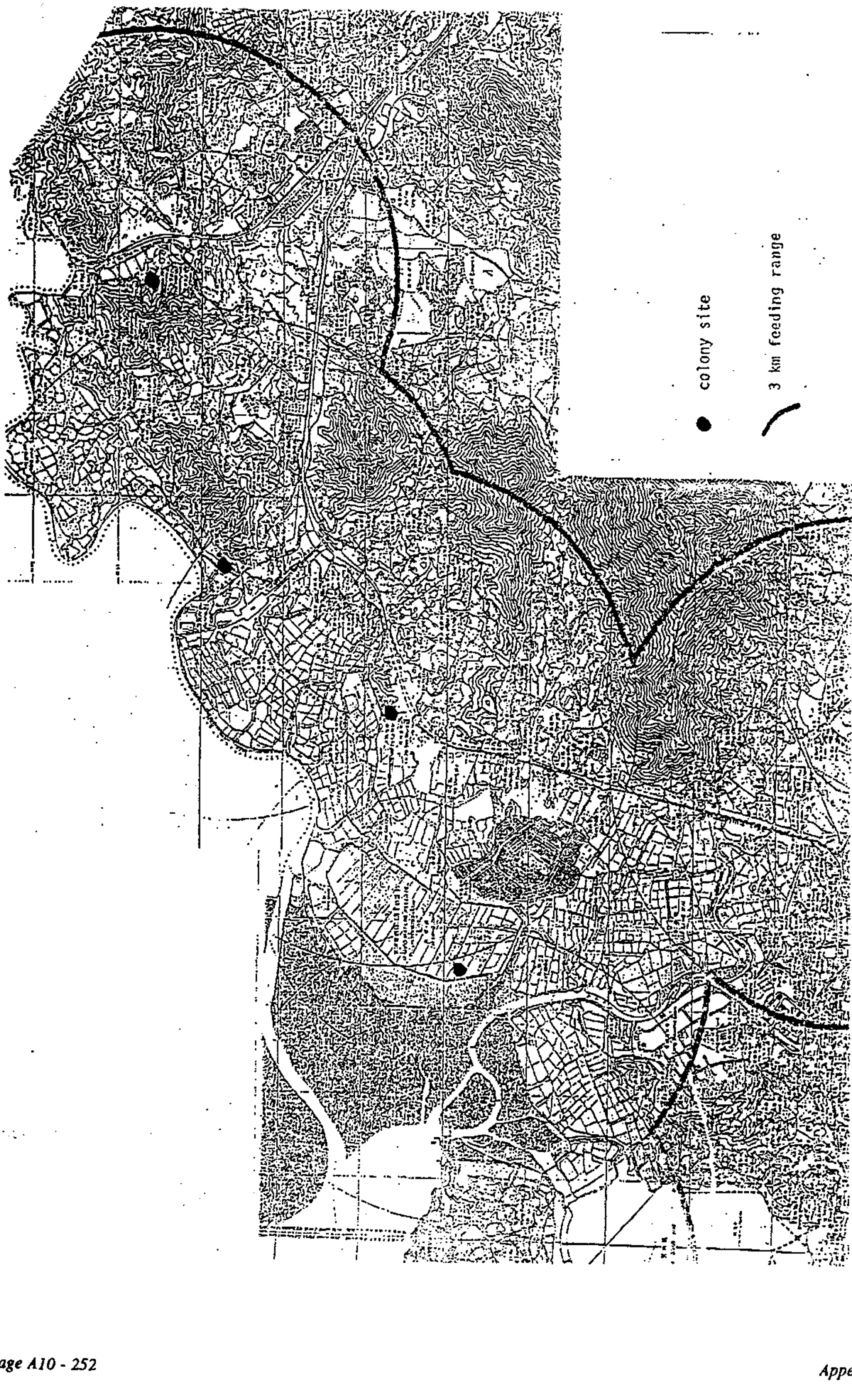


Figure A10.13.5 Distribution of Egretries on Hong Kong Side of Deep Bay, 1994

Hafner *et al.* (1987) found that the area of favoured feeding habitat within foraging distance from the breeding site had a positive effect upon the size of heron colonies, and that the diversity of feeding habitats affected species composition.

Figure A10.13.6 indicates that [in the Camargue] there is a threshold area for freshwater feeding habitat below which no heron colonies exist. This is a consequence of the colonial breeding habit of the species concerned. The minimum area observed was 420ha, but this amount supported only exceptionally small breeding populations, e.g. one of 27 Little Egret nests and one of 6 Night Heron nests (Hafner *et al.* 1987).

Comparative data are currently unavailable for Hong Kong, but there is no reason to suppose that the same general principles which relate available feeding area and colony size will be different, especially for the three species in common at the two sites (Little Egret, Cattle Egret and Night Heron).

Feeding behaviour of the Chinese Pond Heron has been studied in detail by Young (1994), who recorded clear seasonal patterns in the use of fish ponds and tidal mudflats by Chinese Pond Herons at Mai Po, with periods of increased use coinciding with greater prey availability. Thus, numbers of Chinese Pond Herons feeding on the mudflats peaked in April, coinciding with high mudskipper densities, large body size and high calorific value. April also is the start of the mudskipper breeding season (Chan 1989) and males may be easier to catch during territorial defense and display activities. From June to January the profitability of the mudflat as a feeding habitat decreased. The number of Chinese Pond Herons feeding around fish ponds increased from March to August when their main prey items were *Macrobrachium nipponense* and *Gambusia affinis*. In winter the adult and larval stages of necrophagous flies (Calliphoridae) are an important component of the diet around fish ponds (Young 1994, Melville 1987).

Young (1994) notes that 'Fish ponds are a predictable summer feeding habitat from which breeding Chinese Pond Herons can more easily collect food for nestlings. With large areas of fish ponds close to the breeding colony at Mai Po, breeding Chinese Pond Herons there will be expected to have a higher reproductive output than those at sites without ponds (Hafner *et al.* 1987).

Young (1994) found that in summer, once young Chinese Pond Herons are able feed independently, they do so more frequently around fish ponds than in other habitats. This is considered to relate to food availability for these relatively inexperienced birds. Loss of fish ponds would be expected to lead to increased juvenile mortality.

There is only very limited information on the feeding behaviour of other Ardeids in Hong Kong (Young unpublished, Britton 1993, Melville 1987, 1990, Young *et al.* 1989).

The breeding biology of the Chinese Pond Heron has been studied by Young (1994), who found some evidence that colony placement affected breeding success, although various factors confounded interpretation of the data. Similar relationships have been found elsewhere.

Thus, Hafner *et al.* (1987) noted that the marked variation in breeding success between Little Egret colonies in the Camargue was 'attributable to differences in the availability of different types of wetland habitat within foraging range of the nest sites...Thus, while the analyses reported [previously] indicate the particular importance of a limited number of habitats, the data presented here show that other habitats can provide conditions which allow the birds to achieve high breeding success in some years. This conclusion underlines the importance of a range of wetland types in the conservation of these birds'.

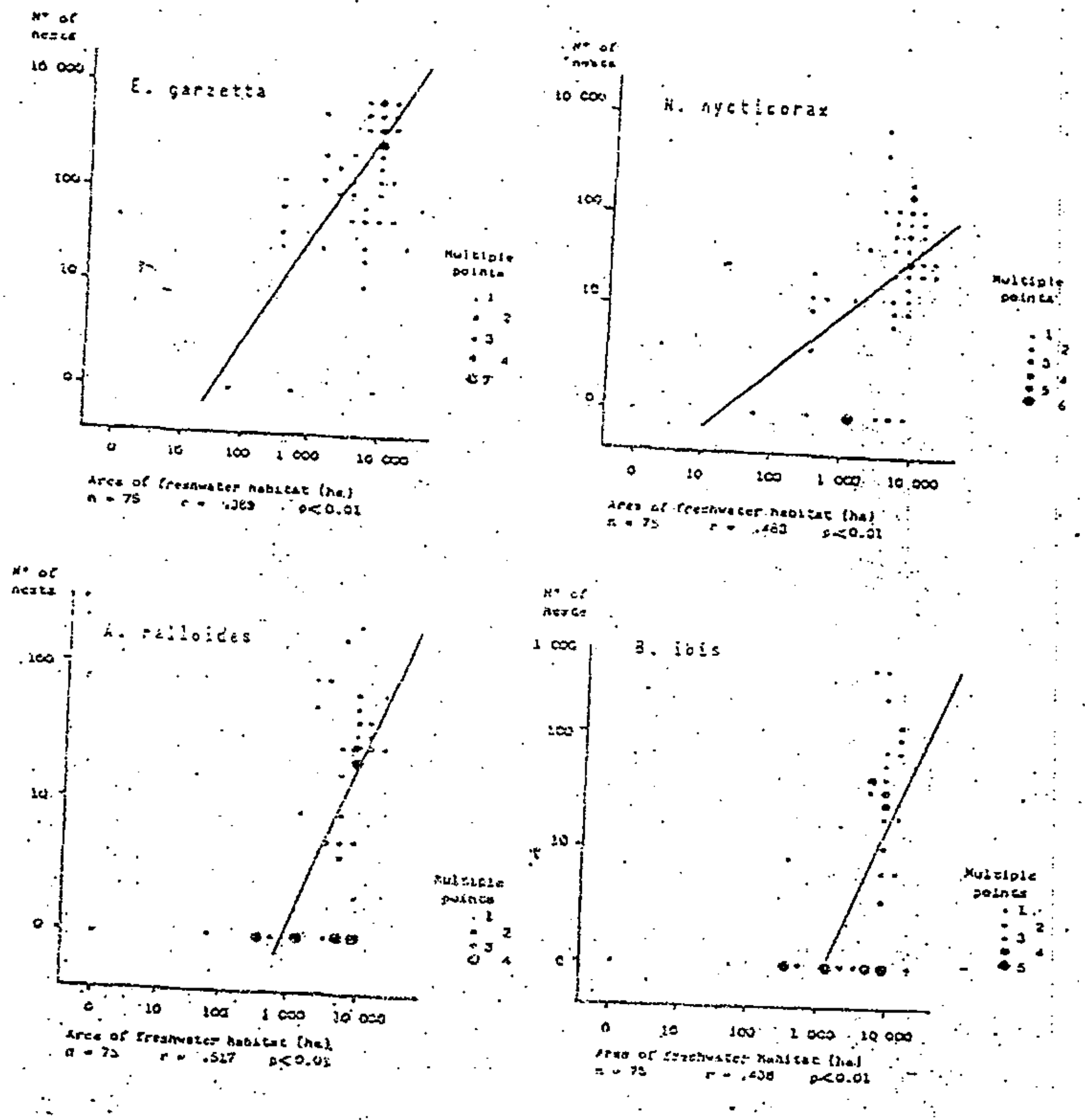


Figure A10.13.6 Colony size of four species of Ardeidae expressed as a function of the area of freshwater habitat within 10 km. For colonies observed over several years, each breeding season has been taken into account (After Hafner *et al*)

Table A10.13.2 Estimated number of nests in egretries on the H.K. side of Deep Bay-1994*

Species	1	2	3	4	5	6
Great Egret			8	13		
Little Egret	14		110	171		3
Cattle Egret	4		13	+	6	
Chinese Pond Heron	71	3	+			62
Night Heron	2		+	253		

+ = present but no nest seen
1 = Mai Po Village 2 = Lok Ma Chau 3 = Mong Tseng 4 = Mai Po gei wai 5 = Ka Po Tsuen 6 = Ho Sheung Heung
* L.Young and P.J.Leader, unpublished data

Other birds

Fish ponds are also used by a variety of other waterfowl, as noted by Chu (1993). These include shorebirds, which principally use drained ponds as high tide roosting sites although a few species are attracted to feed at such ponds, notably Green Sandpiper *Tringa ochropus*, Little Ringed Plover *Charadrius dubius* and stints *Calidris* spp. Ponds with emergent vegetation may attract Little Grebes *Tachybaptus ruficollis* to breed.

Swarms of adult Chironomid midges over fish ponds attract large numbers of birds to feed, in particular Barn Swallow *Hirundo rustica*, swifts *Apus* and *Hirundapus*, martins *Delichon* and *Riparia*, and Oriental Pratincoles *Pratincola maldivarum*. Chironomids also provide an important food source in spring for Great Reed Warblers migrating through Hong Kong to Japan (G. Reels unpublished, D.S. Melville unpublished).

There is no information available to permit any quantitative assessment of the likely impacts of pond loss on these birds at present.

A10.13.5 Other Fish Pond Fauna

Chu (1993) has summarised the available information on the fauna recorded in and around fish ponds in Hong Kong. Among the mammals recorded, at least two are of local conservation importance: Otter *Lutra lutra* (WWF unpublished) and Javan Mongoose *Herpestes javanicus* (Chan et al. 1992). Both are locally rare, the Otter having recently returned to Hong Kong after having become locally extinct, and the mongoose having first been recorded in 1990. Other mammals recorded include Leopard Cat *Felis bengalensis* and Small Indian Civet *Viverricula indica*.

Very little work has yet been conducted on the invertebrates found in fish ponds, although a study is currently being conducted (G. Walthew, pers. comm.). Young (1994 and unpublished) has conducted some work on *Macrobrachium nipponense*, and Anon. (1993b) surveyed free-swimming invertebrates in fish ponds at Pak Hok Chau (Table A10.13.3).

The results of core samples of benthic invertebrates taken from ponds at Pak Hok Chau are given in Figure A10.13.7. Anon. (1993b) noted that, although the fish ponds at Pak Hok Chau did not support a notably species-rich assemblage of free-swimming or benthic invertebrates, they did provide a ready source of food for birds throughout the year.

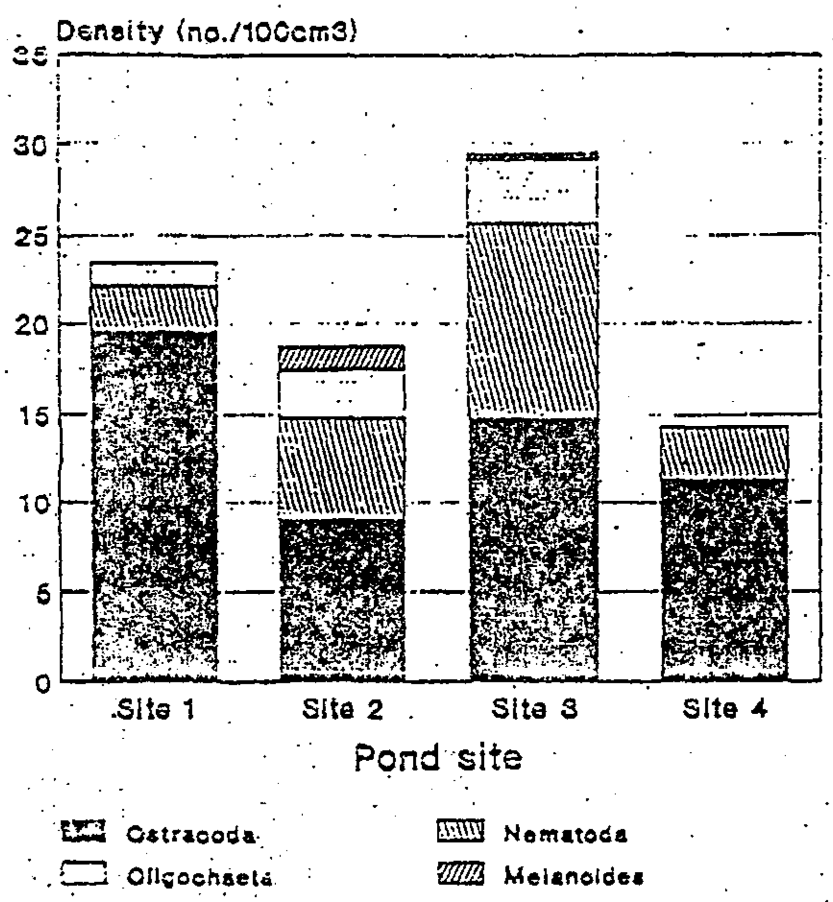


Figure A10.13.7 Benthic invertebrate density from pond core samples (Pak Hok Chau, November, 1992) (After Anon, 1993b)

Table A10.13.3 List of aquatic(free-swimming) taxa caught in ponds and channels at Pak Hok Chau (1992/93)*

	Jan.	Apr.	Jul.	Sep.	Nov.
ODONATA					
Coenagrionidae	x		x	x	
DIPTERA					
Psychodidae	x		x		
Chironomidae	x	x	x	x	x
Orthocladiinae			x	x	
Culicidae	x	x	x		
Notonectidae	x	x			
HEMIPTERA					
Blostomatidae unident				x	
Hemiptera sp.				x	
GASTROPODA					
Radix sp.	x		x	x	x
Pomacea canaliculata	x		x	x	x
Gyraulus sp.			x	x	
Melanoides tuberculata				x	x
ARACHNIDA					
Pirata sp.			x		
DECAPODA					
Macrobrachium sp.			x		x
Palaemon sp.			x	x	x
OLIGOCHAETA	x				

* after Anon. 1993b

The insect fauna associated with fish ponds at Pak Hok Chau was also assessed by Anon (1993b). The results indicate a flush of flying insects in spring, with a smaller peak in autumn (Table A10.13.4 and A10.13.5).

Table A10.13.4 The number of individual insects caught in malaise traps at Pak Hok Chau*

Trap	Jan.	Apr.	Jul.	Sep.
1	-	566	241	308
2	27	2853	7	8
3	-	14425	-	166
4	-	939	-	108

* after Anon, 1993b

Table A10.13.5 The total number of insect morphospecies captured in malaise traps at Pak Hok Chau*

Trap	Jan.	Apr.	Jul.	Sep.
1	-	566	241	308
2	9	?	?	4
3	-	?	-	43
4	-	?	-	28

* after Anon. (1993b)

A10.13.6 Possible Effects of Fish Pond Loss on Waterfowl

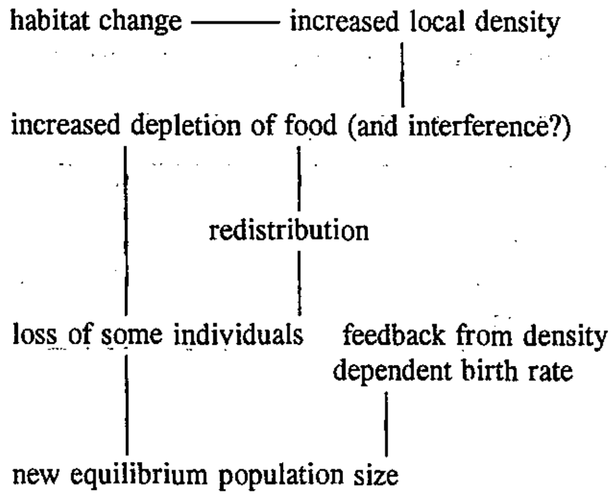
If a habitat is destroyed then, inevitably, some individuals and/or populations will be destroyed at the same time. The severity of population loss will depend on factors such as the scale of destruction and the degree of mobility exhibited by the organisms. Thus, local populations of aquatic macrophytes, diatoms and freshwater snails may suffer severely if a fish pond is destroyed, e.g. by infilling, but birds may suffer less as they can move from the site.

An ability to flee a site which is being destroyed should not, however, be taken as an indication that the individual will continue to flourish. If population densities in alternative areas are already at 'carrying capacity' (*sensu* Goss-Custard 1985), then that individual will die, or, if it survives, it will be at the expense of another individual.

Most studies of the effects of wetland loss on waterfowl have concentrated on shorebirds (e.g. Sutherland and Goss-Custard 1991). Some studies have recorded substantial declines in certain species resulting from habitat loss. For example, Lambeck (1991) recorded a loss of half of the former population of Oystercatchers *Haematopus ostralegus* in the Dutch delta area following substantial habitat loss resulting from the construction of a tidal barrage.

Sutherland and Goss-Custard (1991) developed a framework for considering the effect of habitat loss on bird populations (Table A10.13.6).

Table A10.13.6 Prediction of effects of habitat loss on water birds*



* after Sutherland and Goss-Custard (1991)

As habitat is lost birds have to 'fit' into a smaller area, thus the density of a species in a given habitat will increase. An increase in density is likely to result in an increased rate of depletion of food stocks. In the case of at least some waders interference in feeding behaviour at high densities reduces food intake. Information on interference effects for Ardeids in the Deep Bay area is generally lacking. When fish ponds are first drained down there are frequently high densities of birds present, but the super-abundance of food may compensate for any interference effects. If, however, birds are feeding in other situations interference may reduce food intake. Thus Young (1994) has recorded aggressive encounters between Chinese Pond Herons at feeding sites in both gei wais and filled fish ponds. With increasing fish pond loss the displaced birds will move to the remaining habitats where their density will increase, leading to increased competition.

As the total number of birds increases, an increasing proportion can be expected to occur in the poorer quality sites because of either increased depletion of food stocks or interference. This redistribution of birds into poorer quality sites may take place within one estuary system, e.g. Deep Bay, or may occur on a larger scale with birds moving to another, but less favoured/poorer site, e.g. elsewhere in southern China.

If food abundance/availability is viewed as a gradient, then birds which have a high competitive ability are expected to occur on the richest parts of the gradient (Sutherland and Parker 1985) (Figure A10.13.8). Studies indicate that, broadly speaking, this happens, at least in some shorebirds (Sutherland and Goss-Custard 1991).

The intake rates of the poorer competitors is likely to be reduced in two ways by habitat loss. They will suffer from interference and a reduction in available food, and also by having to move into poorer quality habitats. Both of these processes may result in an increased risk of mortality, either directly through starvation, or indirectly if hungry birds are more at risk of being taken by predators. Ardeids have been recorded being preyed upon by a number of raptors at Mai Po, including Bonnelli's Eagle *Hieraeetus fasciatus* (WWF HK unpublished).

Density-dependent factors, which may take effect either during the breeding season or the non-breeding season, will then feedback to the population and the loss of poor competitors may result in a new, lower, equilibrium population size.

Evidently, if one is to develop any form of quantitative model to investigate potential population changes which may result from habitat loss, a considerable degree of knowledge of the species is required. As noted above, such a detailed understanding of the biology of Deep Bay Ardeids is lacking at present. The Hong Kong Planning Department, however, is funding a study of the ecological value of fish ponds, with particular attention to the carrying capacity of this habitat for wildlife. The results will be available in mid-1996, and will permit a much greater understanding of the dynamics of wildlife use of fish ponds.

It is clear, however, from the work of Hafner *et al.* (1987) that a 'threshold' can be expected, below which further loss of wetland feeding habitat will result in a precipitous decline in the breeding population. The relationship between habitat area and bird numbers is not a simple arithmetic one, where both parameters increase or decrease in a straight line. The relationship is expected to be complex (Figure A10.13.9). At the present time, limited observations of the use of fishponds by Ardeids during winter drawdown suggest that the Deep Bay area may have reached carrying capacity for these birds (WWF HK unpublished).

It is thus essential that the impacts of cumulative habitat loss are assessed. Any attempt to limit impact assessment to one area of fish ponds will be effectively meaningless.

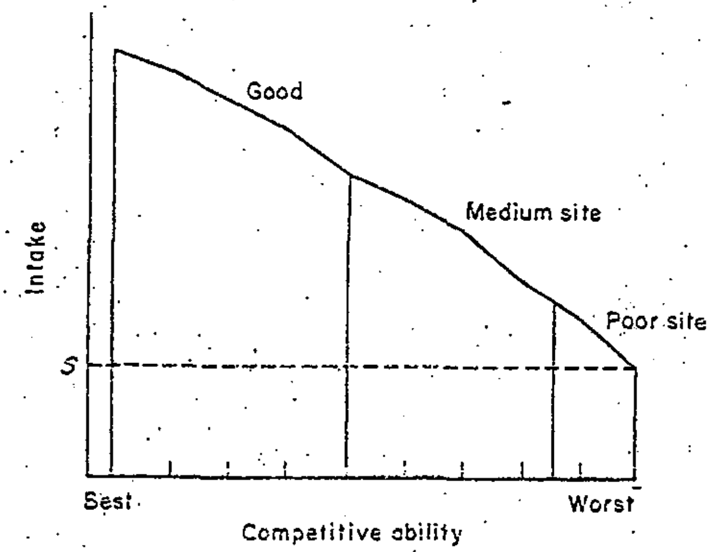


Figure A10.13.8 Dispersion expected for individuals experiencing different i- When feeding. Each individual goes where its intake is h simulation assumes three different habitats (good, medium an which the foraging efficiencies are 6, 4 and 2 respectively. C ability runs from 1 to 10 with equal numbers of each. T interference m is 0.1. S is the amount of food necessary for surv Sutherland and Parker, 1985)

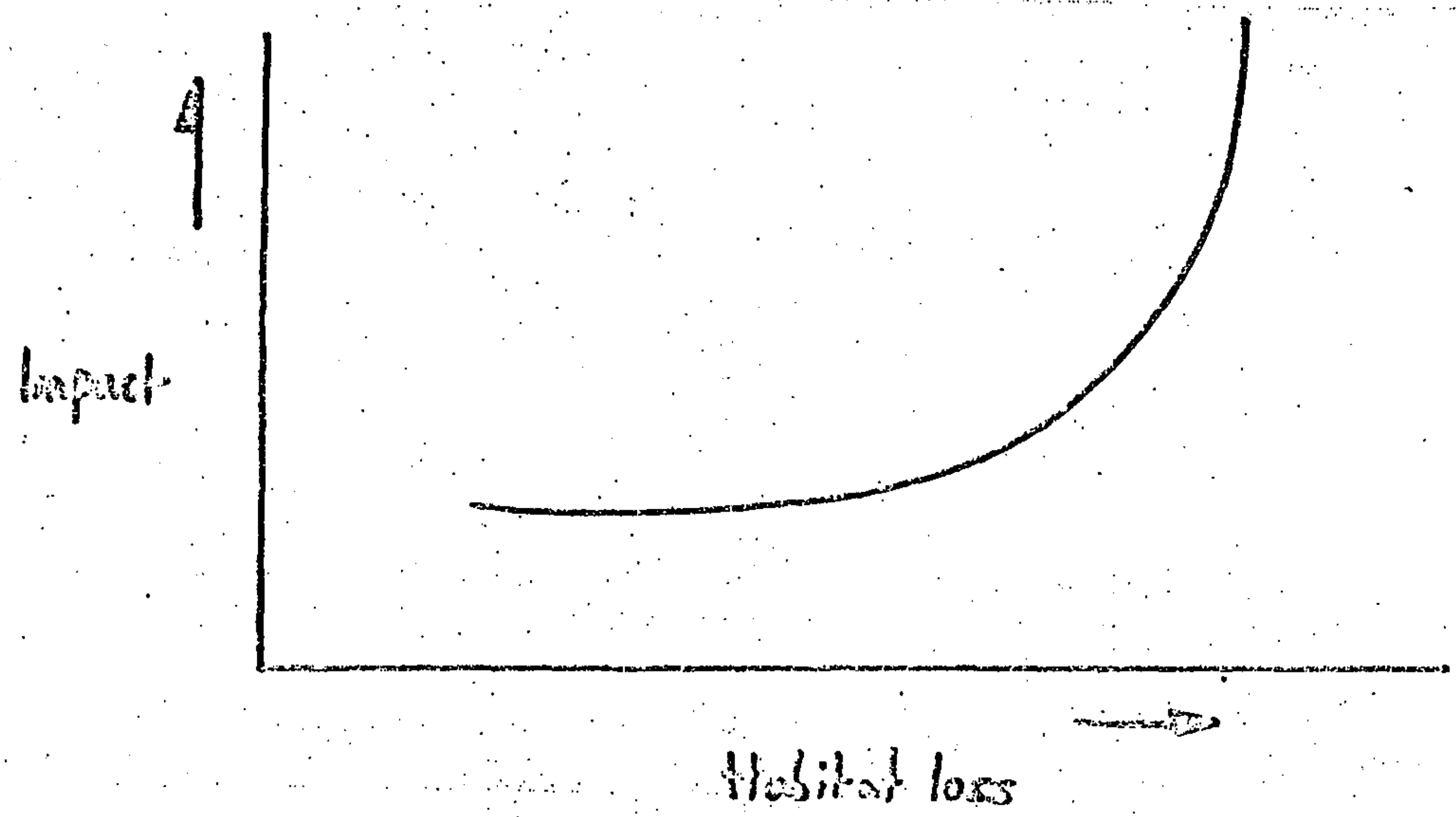


Figure A10.13.9 Schematic representation of relationship between habitt loss and impact on ardeids

A10.13.7 Future Fish Pond Loss in the Deep Bay Area

There has been a dramatic loss of fish ponds in the Deep Bay area during the past decade (Figure A10.13.10). Of the area remaining in Shenzhen, 16% is expected to be lost as a result of the Shenzhen River Regulation Project. Future fish pond loss in Hong Kong could account for up to c.29% of the remaining area, based on current development proposals by both Government and the private sector. If the Ma Tso Lung area is protected from flooding as a result of the Shenzhen River Regulation Project, a further c.210ha of wetland is expected to be lost to infilling and development in due course, resulting in a cumulative total loss of c.42% of Hong Kong's fish pond wetlands. All of those likely to be lost to development are currently classified by the Hong Kong Agriculture and Fisheries Department as 'Grade A' fish ponds, 'well established pond fish culture with good potential for further development'.

It is evident that a substantial reduction in fish pond area can be expected in the Deep Bay region in future. Based on the above review, it is evident that the potential loss of some 41% of the fish ponds on both sides of Deep Bay can be expected to have severe impacts on waterfowl and other wildlife, which use this habitat for feeding and breeding.

A10.13.8 Mitigation

Concern over the loss of wetlands worldwide has prompted moves to off-set losses through various 'mitigation' measures. These include attempts to create new wetlands to compensate for those lost, and the management of existing wetlands to enhance their value to wildlife and their 'carrying capacity'.

A resolution adopted by the Conference of the Contracting Parties to the Ramsar Convention in 1990 recommended that 'all parties examine the possibility of establishing appropriate wetland restoration projects; [and that] the Agency or Agencies responsible for wetlands in each Contracting Party should have wetland restoration in their mission'.

Some countries have incorporated requirements for compensation into national legislation. In the USA, for example, under the Clean Water Act developers may be required to undertake mitigation actions as a condition of the development permit for activities within a wetland. Thompson and Williams-Dawe (1988) note that, in the USA, 'demonstrating the unavoidability of adverse impacts is a threshold requirement before the Environmental Protection Agency will consider compensation proposals [redesign to avoid impacts being preferred]...it does not obligate acceptance of whatever mitigation plan is proposed. Indeed, once consideration of mitigation is shown to be appropriate, the specific plan must pass muster on several accounts relating to engineering, biology and economics. The mitigation must be adequate, appropriate and have a reasonable likelihood of success before EPA will support permit issuance' [for wetland destruction].

The ratio of area impacted to area managed (created/restored) may vary (e.g. Grenell 1988), but frequently a minimum of 1:1 is recommended (Figure A10.13.11). Kosian *et al.* (1992) note that in the USA, the recommended ratio of area managed to area lost may be 1.5:1 for wetland restoration, between 1.5:1 and 2:1 for wetland creation, and between 2:1 and 3:1 for wetland enhancement. Ratios may be adjusted for various reasons. For example, a lower ratio may be acceptable in cases where there is a proven ability to create a wetland type, whereas in cases where there is doubt about the likelihood of success, a higher ratio would be required.

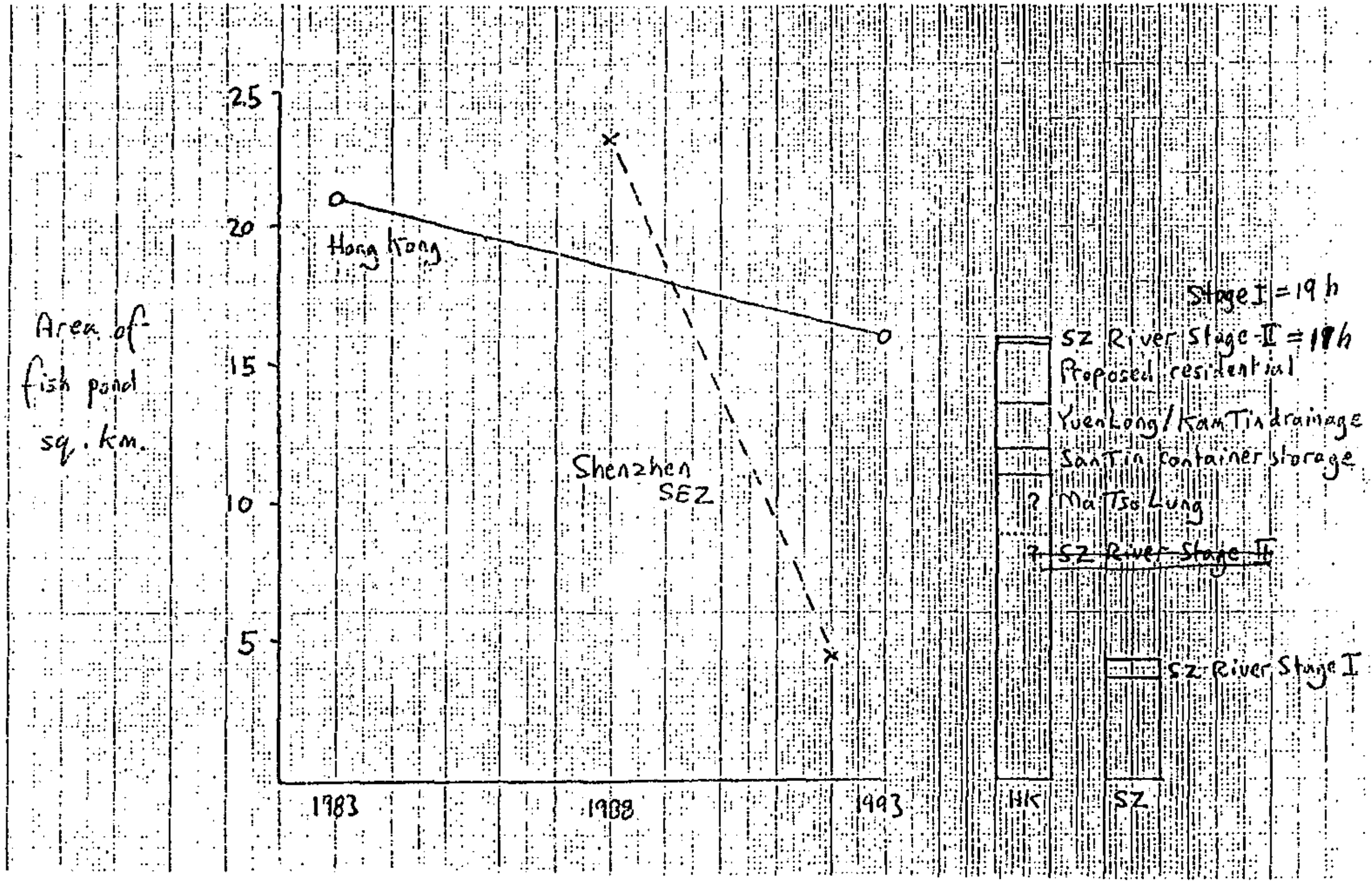


Figure A10.13.10 Reduction in area of fish pond around Deep Bay

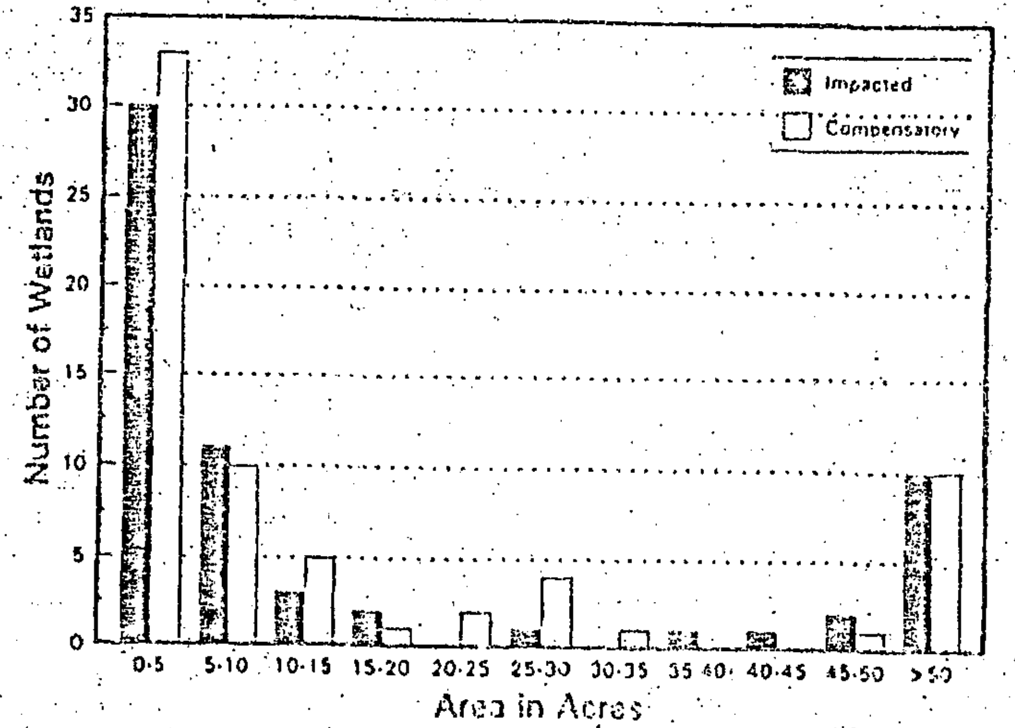


Figure A10.13.11 Comparison of the sizes of impacted and compensatory freshwater wetlands involved in Section 404 permits requiring compensatory mitigation in Texas in the period 1982 to 1986 (After Sifneos *et al.* 1992)

Currently the Hong Kong Government has no formal guidelines or policy regarding habitat management/creation to compensate for habitats lost as a result of development projects. It should be noted, however, that the Hong Kong Government adopted a 3:1 ratio (3 ha planted for 1 lost) when planning to compensate for woodland destroyed as a result of the development of Chek Lap Kok and north Lantau, and a similar ratio for woodland lost due to the Country Park Section of Route 3.

Wetland mitigation in the USA remains a somewhat controversial topic (Roberts 1993) since some projects have been unsuccessful. Although uncertainties remain, especially where new wetlands are to be created, many failures have resulted from agreed management programmes not being implemented.

In the Deep Bay area there is no option for the creation of new wetlands due to unavailability of sites; thus wetland mitigation must focus on the enhancement management of existing wetlands.

Wetland management is a relatively old 'science' and there is very considerable knowledge and literature (e.g. Anon. 1972, Becker and Sills 1988, Smith *et al.* 1989, Payne 1992), including local experience at the WWF Hong Kong Mai Po Marshes Nature Reserve. Local experience at Mai Po permits the confident prediction that management of wetlands in the Deep Bay area to enhance their value to wildlife can be achieved. Thus it will be possible to compensate for future wetland loss to some extent.

Further detailed studies are required before it will be possible to quantify the predicted results of wetland management with respect to different wildlife species. This topic is likely to be further addressed by the Hong Kong Planning Department's fish pond study.

A10.13.9 Potential for Mitigation of the Impact of Cumulative Loss of Fish Ponds in Hong Kong

It is anticipated that the Project will have a significant impact on future land use in the Ma Tso Lung Lok Ma Chau/San Tin area. Large areas of wetland will no longer be subject to regular flooding and thus will become suitable for development. There already are plans for significant infrastructure development projects in the San Tin/Lok Ma Chau area (e.g. container back-up, railway) which are likely to result in the loss of c.80 ha of fishponds. Other development proposals are expected in future.

In accordance with Article 3(1) of the Ramsar Convention, Hong Kong has an obligation to 'formulate and implement [its] planning so as to promote....as far as possible the wise use of wetlands in [the Territory]'.

Because of the far-reaching implications of the Shenzhen River Regulation Project for wetlands in the Ma Tso Lung/Lok Ma Chau San Tin area, there is a need to consider cumulative impacts of the project. The Project does offer opportunities for wetland conservation and 'wise use' policies to be implemented in Hong Kong through redesign of the alignment of the proposed embankment. Three options are shown in Figure A10.13.12, and are discussed below.

Option 1

The Ma Tso Lung area be designated as a conservation management area. The new flood control bund and border security facilities would be set along the base of the Ma Tso Lung hills, and the present area of marshland and ponds retained and permitted to flood periodically (as at present). This would retain wetlands for conservation, as well as providing some flood storage capacity. Existing land uses (fish culture) could be permitted subject to an approved conservation management plan for the area. This area of wetland would be linked to that in the San Tin area by a corridor along the south bank of the River at Lok Ma Chau, adjacent to the Stage 1 conservation management area.

The Ma Tso Lung proposal has the added advantage that it would keep the area relatively free of disturbance in future and thus permit continuing use of the area by raptors, including the regionally important wintering population of Imperial Eagles *Aquila heliaca.*

Option 2

The fish pond area at Sam Po Shue, to the west of San Tin, be designated as a conservation management area. As at Ma Tso Lung, the new flood control bund and security could be set back from the new River channel to allow a flood plain on the south bank - the present Frontier Closed Area boundary would provide an appropriate alignment in view of the fact that development is not permitted within the FCA. The area would flood periodically during storm events, as at present. Existing land uses (fish culture) could be permitted to continue subject to an approved conservation management plan. This area currently falls within the Hong Kong Deep Bay Buffer Zone II and thus already is subject to land use controls.

The San Tin option has the advantages of offering some flood storage capacity, as well as a managed wetland conservation area in close proximity to the Mai Po Nature Reserve. The present Deep Bay Buffer Zone 1 boundary comes to the western boundary of the proposed mitigation area, and thus a corridor to the Mai Po Nature Reserve would be created.

Option 3

This is a combination of Options 1 and 2.

In all three options there is the possibility of retaining active fish culture operations. At a time when freshwater fish are of growing economic importance, this could be an important consideration, not only for the land directly involved, but also by indicating the Hong Kong Government's clear intention to support fish farming, which could lead to a reduction in the current level of land speculation in the area.

The position of the border security road and fence requires review by the security authorities. It would be possible to maintain the road adjacent to the River, as at present, whilst constructing the flood control embankment inland of the River. A second road could be placed along the inland embankment, together with a second fence for added security. There would be a need for vehicle access over the embankment if fish pond operation is to continue in the Sam Po Shue area.

Limited landscaping works would be required, as part of the conservation management plan, to screen the border security road.

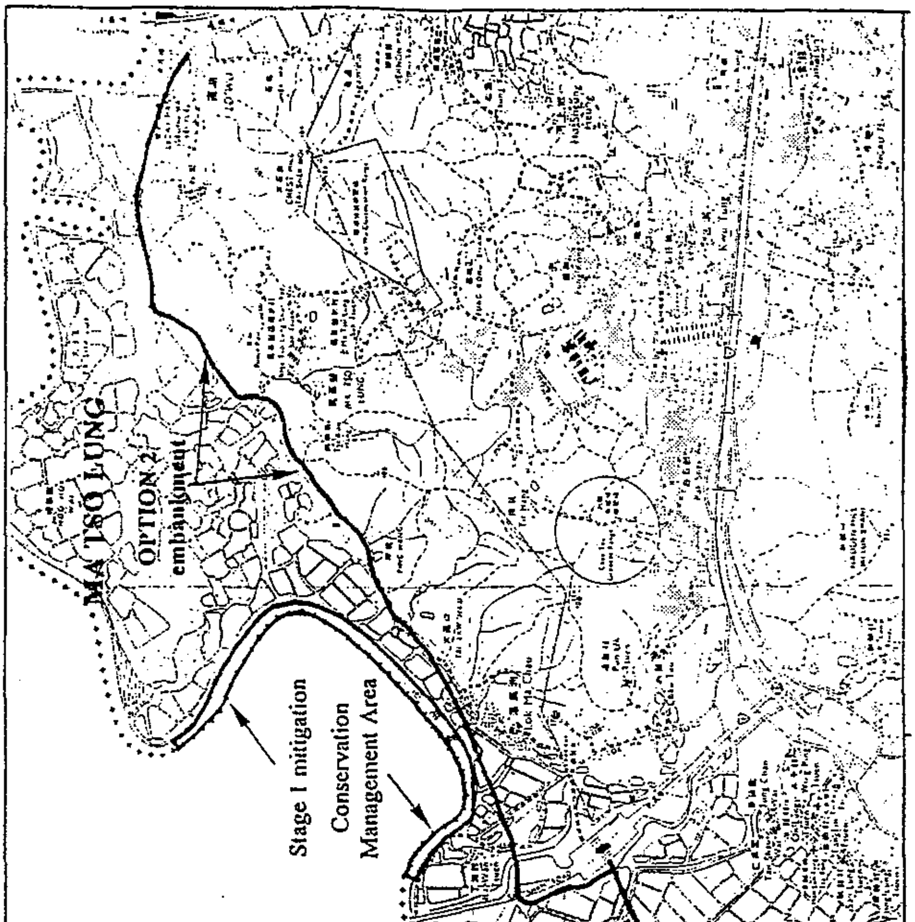


Figure A10.13.12 Proposed New Embankment Alignments for mitigation of the impact of cumulative wetland loss

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APPENDIX 11 PUBLIC OPINION SURVEY

A11.1 PUBLIC OPINION SURVEY ON SHENZHEN SIDE

In order to gain an understanding of the opinions of residents along Shenzhen River toward Shenzhen River Regulation Project, a semi-sealed questionnaire was designed and distributed on Shenzhen side of Shenzhen River.

A11.1.1 Methodology

The survey consisted of three parts:

1) *Basic Information* In addition to basic information on sex, age, income, profession and education, a survey was also made of the residential environment (e.g., nearest distance to Shenzhen River, length of time resident in Shenzhen Municipality)

2) *Behavioral Information* This portion of the survey contained information on the socio-economic behavior of the individuals surveyed. This included such information as increased expenditure caused by impacts from Shenzhen River and desire to pay for moving away from riverside areas.

3) *Attitudinal Information* This covered past, present and future opinions, interest, resentment and evaluations of Shenzhen River by the individuals surveyed: for example, degree of satisfaction with the existing living environment.

As the contents of the questionnaire were regionally sensitive, the survey employed a small-area sampling method, selecting households residing close to Shenzhen River as respondents and taking the Lo Wu and Futian Districts as the main survey area. The format for completing the questionnaire was primarily completion by the individual surveyed, and included distribution of questionnaires from and collection at a central point (such as the "Sanfang" Office in Futian District and the Lo Wu Middle School), individual distribution and collection of questionnaires (e.g., distribution to individuals encountered in small residential areas), and questionnaires sent by post (some questionnaires which could not be completed at the time of distribution were received by post).

A total of 900 questionnaires were distributed for this survey and 567 completed forms were returned, for a return rate of 63%. 215 of those returned were valid questionnaires, for a validity rate of 37.9%.

A11.1.2 Analysis of Qestionnaire

From the 215 valid questionnaires received, the basic composition of the individuals surveyed is shown in Table A11.1.

Increasing the flood-discharge capacity of Shenzhen River is the primary goal of Shenzhen River Regulation Project. The results in Table A11.2 show that residents in the riverside areas of Shenzhen River who are directly or indirectly affected by flooding constitute a majority of the total, while impacts among residents living within 300 m of the river are particularly marked.

Table A11.1 Composition of Individuals surveyed

Qualification	Male	Female	Civil Servant	Worker	Student	Sole Proprietor	Others
University Level	33	23	56				
High school level	82	77	10	9	131	6	3
Total	115	100	66	9	131	6	3
Percentage %	53.5	46.5	30.7	4.2	60.9	2.8	1.4

Table A11.2 Residents affected by flooding of Shenzhen River in the past five years

Distance	Staying period < 10 years	> 10 years	Direct	Indirect	Direct & indirect	No effect	% of no effect
Within 300m	96	13	40	45	13	11	10.0
Excess 300m	71	35	18	39	11	38	35.8

It was determined during the course of the study that the foul smell of Shenzhen River is a major issue affecting residents in the vicinity. Reactions expressed in the questionnaires were relatively strong, and once again were more so among residents living within 300 m of Shenzhen River (Table A11.3).

Table A11.3 Impact of foul smell of Shenzhen River on residents in the area

Distance	No effect	Effect on				% of effect
		Headache	Sick	Working Efficiencies decreased	Study Efficiencies decreased	
Within 300m	0	24	74	24	49	100
Excess 300m	6	15	52	10	23	94.3

Based on survey results, reactions to the issue of noise disturbance impacts from navigation on Shenzhen River were relatively small. In the responses regarding the most unsatisfactory environmental factors of residential surroundings, most individuals surveyed selected air pollution and noise pollution (Table A11.4). This may reflect to some degree the overall pollution situation of Shenzhen Municipality at present.

Table A11.4 Environmental factors with which residents were most dissatisfied

Distance	Air Pollution		Noise Pollution		Water Pollution		Greenlot decreased	
Within 300m	57	(36.8%)	60	(38.7%)	19	(12.3%)	19	(12.3%)
Excess 300m	48	(32.9%)	55	(37.7%)	20	(13.7%)	23	(15.7%)

A11.1.3 Impact of the Foul Smell of Shenzhen River

It was learned from the results of the questionnaire survey that the foul smell of Shenzhen River is the environmental problem which evoked the strongest reaction among residents of the area. Its effect on environmental comfort and the losses caused by it were analysed, with the results shown in Table A11.5. The methods used in calculating the concentration opinions is as follows:

First the raw data obtained through the survey is non-dimensionized according to the following formula to find non-dimension data X:

$$X = C/N \times 100$$

In the above formula, C and N represent number of the sample agreeing with the opinion and total survey sample number, respectively. Peak value frequency and opinion concentration are calculated based on the non-dimension data. They represent the frequency number of the most favorite choice among selected factors concentration of opinion, respectively.

Table A11.5 Analysis of impact of foul smell of Shenzhen River on environmental comfort

	No impact	Headache	Sick	Working Efficiency decreased	Study Efficiency Decreased	Greenlot decreased	Sick(%)
Within 300m	0	14.0	43.3	14.0	28.7	28.7	0.68
Excess 300m	5.7	14.2	49.1	8.4	21.7	21.7	0.88

It can be seen from the above table that nausea is the main impact of the foul smell. In addition, residents living over 300 m away from the river had a higher [concentration] of opinion than those living within 300 m, demonstrating that expression of the impacts of the foul smell of Shenzhen River on residents living nearer the river is even more complex.

The discomfort caused to riverside residents by the foul smell of the Shenzhen River has no direct market price. However, an awareness of people's willingness to pay for improvement of the smell may be obtained through surveys of those affected. The degree of people's reactions to the comfort of their living environment is related to such factors as education, state of health and social status. People with higher living standards are more willing to live in a relatively ideal environment; this fact increases the disparity between housing prices in clean areas and those in polluted areas. Consequently, residents' willingness to pay can be estimated from their desire to move to residential areas free from foul smell impacts. Owing to the restricted sample size of this survey, reference was made to the formula relating the willingness of urban residents in Guangzhou to pay for improved air quality and annual household income to describe the relation between residents' income level and willingness to pay. Formula for calculating the willingness to pay is showed below:

$$Y = 4.23 + 0.00125X$$

In the above formula, Y represents willingness to pay per household per month, while X represents annual household income.

Among the 215 individuals surveyed, 118 had annual incomes of less than 20,000 yuan, while 75 had incomes of between 20,000 and 50,000 yuan and 22 had incomes above 50,000 yuan. Weighted average annual income was 26,600 yuan. The willingness of riverside residents to pay was calculated using a regressive equation to be 37.48 yuan/month per household. Responses that indicated a willingness to move away from the area affected by the foul smell of Shenzhen River constituted 61.0% of the total (Table A11.6).

Given that the main areas affected by the foul smell of Shenzhen River are Lo Wu and Futian Districts, which two districts had a registered population in 1992 of 398,800 (with a non-permanent population of 532,700) and an average household size of 3.8 people for approximately 104,900 households, approximately 1/3 of these households (approximately 35,000 households) are along Shenzhen River. Therefore the willingness of residents along Shenzhen River to pay for improvement of the foul smell of Shenzhen River is:

37.48 x 12 x 3.5 x 61.0% = 9,602,400 yuan

Table A11.6 Desire to move in order to avoid foul smell of Shenzhen River

Household income per year (10,000/yr)				Willing to move out		
	<10%	>10%	N/A	NO	YES	
					Rent pay more (YES)	Rent pay more (NO)
Below $20K	56	57	2	46	58	14
20K - 50K	39	35	1	30	42	3
Over 50K	12	10	0	8	10	4
					51.2	9.8
%				39.0	61.0	

It can be seen that losses suffered by residents along Shenzhen River due to impacts from the foul smell of the river are approximately 10 million yuan. It should be noted that, due to a number of unavoidable factors, this estimate should only be used for reference on the order of magnitude.

A11.1.4 Public Option Evaluation

Regulation of Shenzhen River has been brewing for 10 years. The people of Shenzhen Municipality earnestly wish this project to commence as soon as possible. In response to the question over whether the project will improve the quality of life of people in Shenzhen and Hong Kong, 198 people or 92.1% felt that it would cause some or considerable improvement. It is clear that the residents along Shenzhen River have high hopes for the project. Public evaluation may be roughly categorised as follows:

1) The public welcomes the project and has high hopes for it.

2) There is a high degree of public concern over the project. A total of 106 questionnaire responses made suggestions on the implementation of the project. Sixteen of these were constructive suggestions and 90 were ordinary suggestions.

3) The public reaction to the foul smell of Shenzhen River is stronger than the public reaction to flooding. This is due to the fact that flooding generally occurs once in several years, and impacts of floods are reduced or eliminated within several months afterwards, while the impact of the foul smell is constant. Moreover, the impacts of flooding on residents is typically small, while its impact on industry, commerce, transportation and communications is great.

4) Construction during the latter stages of the project is also an issue of public concern. Analysis of the survey shows that some members of the public even proposed that, should funds for the project be insufficient, construction could be carried on through contributions from residents of the Municipality or by means of other loans. This demonstrates the degree of public concern over this issue.