The Hongkong Electric Company Limited

ENVIRONMENTAL IMPACT ASSESSMENT

OF

UNITS L7 AND L8 LAMMA POWER STATION

Final Initial Assessment Report

May 1992

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Kennedy& Donkin International
In Association with

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SUMMARY

SUMMARY

This report is an initial assessment of the environmental impacts arising from the provision of two additional coal fired generating units (L7 and L8) each of 350MW rating, at Lamma Power Station. The Initial Assessment Report (IAR) has been prepared on behalf of the Hongkong Electric Company Limited (HEC) by a consultants team comprising: Kennedy & Donkin International; Kennedy & Donkin Generation & Industrial; Ashdown Environmental Limited; Binnie Consultants Limited; BMT; Environmental Management Consultants Limited and RMJM HK.

The report outlines the background to the Environmental Impact Assessment (EIA), explains the need for the additional generating capacity and assesses the impacts associated with the proposed extension on all key sectors of the environment. Where impacts have been judged to be significant, the report addresses the requirement for mitigation measures to minimise or eliminate such impacts. It also considers the requirements for more detailed environmental studies to resolve particular key issues.

The methodologies used in the EIA were documented and agreed with Government in the Inception Report. This report therefore represents the implementation of these methodologies and the conclusion of Phase 2 of the EIA.

This IAR considers possible environmental impacts arising in several definable areas. These are: construction and decommissioning; air quality; water quality; solid waste disposal; visual impacts; marine and terrestrial ecology; noise; socio-economics; planning and maritime transport. Requirements for additional environmental monitoring and for auditing are also considered.

The power station extension would comprise 2 x 350MW coal fired units. The two units would be developed to the east of the existing plant buildings and wholly within the confines of the existing power station site. The design of the plant would be essentially similar to Unit L6, currently under construction. As with L6, a flue gas desulphurisation (FGD) system would be included in the design in accordance with the requirements of EPD. The exact nature of the FGD system for the two new coal-fired units has not yet been determined, but for the purposes of this EIA, a limestone-gypsum process has been assumed, similar to that of the L6 FGD system.

The extension would require provision of a third chimney on the Lamma site, to house the two flues from the new units. In addition, a new cooling water intake and discharge would be required. Apart from these structures, no further major additions would be needed. The existing coal storage and handling system is sufficient to cater for the additional capacity and the infrastructure for the material handling equipment of the FGD process is being provided during the development of L6. Furthermore, the existing pulverised fuel ash (PFA) storage/reject silos and furnace bottom ash (FBA) settlement basins would be used for processing/buffer storage of PFA and FBA respectively produced from L7 and L8. Moreover, the existing transmission system is sufficient for power export purposes from the additional units. The Lamma site is therefore suitable, in size and infrastructure terms to accommodate the extension.

The preparation of this IAR has been undertaken after extensive consultation with various Government Departments to ensure that all reasonable concerns were addressed. In addition to a number of officials in EPD, consultations were also held with officials from Agriculture and Fisheries Department; Marine Department; Royal Observatory and Buildings and Lands Department. The extensive assistance and information supplied by these various officials has proved invaluable in the preparation of this report and is gratefully acknowledged.

Impacts predicted for various sectors of the environment are described in detail in the body of this report, a summary of individual issues is given below:

Construction and Decommissioning

Construction of the whole extension would take place over a period of approximately 70 months. Site formation is already complete as part of the original development and so the major impacts normally associated with site formation will not arise. The key issues likely to arise during the construction phase are those related to noise and dust impacts. Predictions of noise impacts indicate that there should be no difficulty in complying with the requirements of relevant Technical Memoranda, although some restriction of night-time working may have to be considered. This restriction would be dependent upon any Construction Noise Permit which would be required, prior to any night-time working being permitted.

Experience of dust control during construction activity on the Lamma site is now extensive and no particular environmental concerns are likely to arise in this regard. There will, however, need to be adequate dust control measures provided on site during the works and the need for specific dust control conditions in Contractors contracts has been identified. Regular auditing of the dust control measures will also be required by HEC staff to ensure compliance.

If the recommended mitigation measures are incorporated, it is unlikely that any significant environmental impact will arise from construction of the additional units.

No significant impacts are expected to arise from decommissioning of the proposed units, although adequate precautions for final disposal of any asbestos based items, which may remain in use at the time of decommissioning, will need to be taken.

Air Quality

The air quality impacts of the proposed extension have been assessed by both numerical and physical modelling techniques.

Numerical modelling of the key pollutants sulphur dioxide, oxides of nitrogen and particulates, using a complex terrain model (RTDM), indicated that maximum predicted ground level concentrations remained within the relevant Air Quality Objective in all cases.

Highest ground level air quality impacts were predicted by the modelling to occur at the Peak area of Hong Kong Island and at Mt Stenhouse on Lamma.

The numerical model tests were used to define the scope of a detailed physical model test programme, which was subsequently undertaken in BMT's wind tunnel test facility in Teddington, UK. The coverage of the physical model test was such that all areas predicted to be significantly affected by emissions from Lamma Power Station were included.

Physical modelling indicated that concentrations of nitrogen dioxide and particulates fell well below the relevant AQO in all areas. Furthermore, for all receptors on Hong Kong Island, sulphur dioxide concentrations are predicted by the model to remain below the AQO.

Some marginal exceedence of the specified 1 hour AQO limit of $800\mu g.m^{-3}$ SO_2 was predicted for Lamma Island at a few, uninhabited hill-top locations; such exceedences only occurring under high wind speed conditions (i.e. $>11ms^{-1}$). Moreover, the frequency of such wind speeds, coincident with S/SW winds, is extremely rare, probably amounting to no more than 0.1% of the time over the six month period April to September. It is most unlikely, therefore, that exceedence of the AQO would arise in practice any where within the study area.

The increases in SO_2 emissions from the proposed new units L7 and L8 would be modest compared with the overall emissions from the existing power station, due to the provision of FGD control on the new units. The limited air quality impacts that are predicted to arise are therefore primarily the result of existing emissions from Lamma, rather than from the proposed new units. Numerical modelling suggests that retrofitting of Unit L5 with FGD could generally increase the margin between the predicted maximum SO_2 concentrations and the AQO from around 20% to 40%. However, the environmental benefits of such retrofitting would require to be carefully balanced against the significant economic penalty.

Water Quality

The proposed increase in the capacity of the Lamma Power Station will inevitably increase the amount of waste heat released into the sea around Lamma Island.

A variety of model tests have been carried out to determine both near and far field effects under different tidal regimes. These tests were caried out using conservative assumptions of continuous cooling water flow at maximum design level and maximum temperature of discharge throughout the 24 hour period. In practice, rather lower heat discharges would occur due to the diurnal power station load factor. As a consequence, the area of water affected by the thermal discharge is likely to be lower than model predictions indicate.

The thermal discharge from the existing 1800MW installation is predicted by computer modelling to cause water temperature rises in excess of +2°C at certain states of some tides. The modelling suggests that the maximum temperature contours extend further from the outfall on the north side than on the south side. Increasing the power station capacity to 2500MW will increase the area enclosed by the +2°C envelope, particularly during the summer when water temperatures are highest and the water column is stratified. The extent of the zone affected by temperature increases of +2°C will depend upon tidal conditions and season. A detailed field survey to assess the performance of the model used for the assessment was undertaken. This showed that the overall performance of the hydrodynamic model was good, although there was a tendency for the model to over-predict maximum temperature rises in the near field. Field measurements suggest that the +2°C contour arising from the existing power station thermal discharge is contained within the current consent limit of 1.5km. However, the measurements suggest that, under some tidal conditions, the margin may be small. Additional thermal discharges from the proposed new units could, therefore, increase the risk of the +2°C contour exceeding 1.5km, albeit for short periods under specific tidal conditions. The actual extent of the +2°C contour under such conditions cannot be determined with certainty at this stage although conservative estimates indicate that it may exceed 1.5km under certain conditions. More precise predictions will require detailed investigation. In any event, however, the position of the +2°C contour relative to the outfall has no environmental significance.

The other discharges from the power station due to sewerage wastes will rise in line with the increase in the workforce. These discharges are relatively small and will have little environmental impact. The existing treatment facilities have sufficient spare capacity to cater for up to eight units although some expansion of the sewer network will be required.

The introduction of an FGD plant may release additional nitrate into the trade effluent caused by the removal of NO_x gases from the chimney emissions. The quantity of nitrate released would be dependant upon the number of FGD units fitted. Under a "worst case" scenario of up to 5 FGD units, the release of nitrate in the FGD waste stream is predicted to result in inorganic nitrogen concentrations in the vicinity of the power station exceeding the WQO of 0.1 mg/l. To mitigate this, it may be necessary to incorporate appropriate treatment of the FGD waste stream to remove nitrates to an acceptable level. A detailed assessment of this requirement will be needed as a key issue.

Solid Waste

A gypsum waste management strategy was initially developed and this identified the following disposal options:

- industrial use in cement and wallboard production
- as a fill material to restore part of Lamma Quarry
- marine disposal in either stabilised or unstabilised form
- as a fill material in specific areas of the ash lagoon

Industrial use in Hong Kong is the preferred disposal option, because it has economic benefits for the Territory and, in the case of cement manufacture, minimal environmental effects. For the same reasons, industrial use outside Hong Kong is an attractive option.

Restoration of Lamma Quarry is the recommended contingency disposal option for gypsum which cannot be used for industry. It has the advantages of being environmentally beneficial, flexible and not capital intensive. Most of the infrastructure and monitoring procedures necessary for gypsum disposal will be provided for the disposal of PFA. Gypsum disposal in either the sea or in specific areas of the ash lagoon is expected to be environmentally acceptable. However, these options may not generally have the environmental benefits associated with quarry restoration, in which case they would be less attractive.

The environmental effects associated with each disposal option can only be accurately determined by testing gypsum produced at Lamma Power Station. Similarly, the suitability of gypsum for use in industrial processes can only be determined by testing the actual material. It is impossible to predict the properties of FGD gypsum, since they are dependent on raw material properties, as well as FGD system design and mode of operation. However from the information available, the gypsum which will be produced can be disposed in an environmentally acceptable manner.

The additional units would also result in additional quantities of PFA and FBA. The disposal strategy for these wastes has already been agreed with Government and an ash management plan covering production from Units L1 to L8 has been prepared. The problem of disposal of these wastes has therefore already been solved.

Visual Impacts

The zone of visual influence of the proposed additional 215m chimney is judged to be no greater than that of the two existing chimneys. The extension of the existing power station will need to be carried out with due regard for the existing architectural vocabulary. It is considered that addition of Units L7 and L8 would provide a fitting piece to complete the Lamma Power Station development and complete the transformation of the existing landscape.

Marine Ecology

The impact of the additional thermal discharge on marine ecology is likely to be of minor significance. Those species which cannot physically move away from the heated area and are of low thermal tolerance could become scarce on the western shores of Lamma, and be replaced by relatively fewer, thermally tolerant species. This, however, will be of only local significance.

There are considerable difficulties in assessing the marine ecological impacts of trace metal discharges arising from power station operations. This is due to the lack of data on metal concentrations in Hong Kong seawater, and the lack of detailed studies on the rates of uptake of metals by marine biota. However, from a review of possible impacts arising from probable actual metal discharges it would seem unlikely that the additional units would have any significant additional impact. Modelling of effluent discharges suggests that metal inputs to the marine environment would not cause metal concentrations to exceed internationally accepted criteria providing any effluent from the FGD process was routed to the c.w. outfall. This is therefore the preferred environmental option.

Modelling of nitrate releases from the FGD effluent stream indicated that some local increase in sea water nitrate levels could result if this effluent stream were untreated. The significance of this is believed to be limited in the context of the general marine water quality of the Southern Water Control Zone, but the matter will require more detailed investigation as a Key Issue.

Terrestrial Ecology

Construction of the additional generating capacity will have no adverse impacts on the terrestrial ecology of Lamma, or neighbouring islands. In ecological terms, there are sound reasons for providing the necessary additional plant on Lamma, rather than seeking an alternative location where an existing, undisturbed ecological habitat would necessarily have to be destroyed. Development of the additional capacity on Lamma is therefore seen as a positive benefit in conservation terms and one which needs to be weighed carefully against any perceived disbenefits.

Noise

The EPD criteria for development of new installations is that the Corrected Noise Level (CNL) from the new installation must not exceed either the appropriate Acceptable Noise Level (ANL) minus 5dB(A) or the prevailing L_{A90} background noise level, whichever is the lower.

The predicted noise levels from the two additional generating units are less than the criteria noise level at all Noise Sensitive Receivers (NSR's) to the north of the power station, but are slightly in excess at the NSR's to the east of the site. The assessment shows that some minor mitigation measures will need to be undertaken in order to meet the EPD criteria. The cumulative effect of the proposed new units and the existing power station has also been assessed. Predicted noise levels are lower than the Acceptable Noise Levels at all NSR's and the overall noise impact is therefore judged to be acceptable.

Socio Economic Impacts

A key issue in assessing the socio economic impacts of the extension is community perception. "Creeping Industrialisation" is always seen as contentious in rural areas. There is currently very little economic or physical interaction between the power station and the community. On the other hand, the profile of HEC on Lamma is high. Positive efforts have been made by HEC to maintain close liaison with the community and to maintain a "good neighbour" approach. Inevitably, however, some complaints about the power station operation have occurred in the past, although at a low frequency. These have all been responded to by HEC and remedial measures taken where possible.

The nature of Lamma as a dormitory community means that people's sensitivity to tranquillity and amenity is high. It will therefore be essential to reassure the community that all practicable steps will be taken during construction of the extension to avoid nuisance. Furthermore, the positive economic benefits of the extension in terms of employment opportunity and local spending will need to be stressed and maximised.

Some negative impacts on amenity and tourism are predicted. The concern focuses on Hung Shing Ye beach, where additional visual intrusion and noise during the construction phase will arise. These negative impacts however, need to be balanced against positive economic benefits which could amount to some $30,000+ annually per local unskilled worker. Further positive initiatives linked to local catering supplies could also be examined as a means of maximising benefits to the local economy of Lamma.

Maritime Transport

The proposed extension of the power station will necessitate an increase in the transport of bulk materials (coal, limestone, etc) to the site. The impact of the additional shipping movements arising from this has been assessed. The time taken to unload an average shipment of coal is about three to four days and in the worst month and year scenario it is estimated that there would be about 9 shipments per month. The duration of coal bulk carriers transiting the channel/berthing/unberthing/swinging in the turning area, is unlikely to exceed about 20 hours per month, which is an increase of 8 hours per month over the 1994 baseline case. All movements will be in daylight hours and no additional marine hazards are envisaged.

Movements of smaller vessels (e.g. tugs, barges, etc) between the East Heavy Unloading Area jetty and other berths elsewhere will be more frequent. In the worst scenario, 75 shipments a month are estimated. Whilst these movements are significant, it is not considered that there will be any consequential increase in marine hazards. Furthermore, in terms of total movements in Victoria Harbour, the additional traffic represents only a very small proportion.

Environmental Monitoring and Auditing

HEC already operate a comprehensive environmental monitoring programme covering air and water quality. An addition to the air quality monitoring network was made in August 1990, when a new air monitoring station was established at the Peak. It is believed that the air quality monitoring network is now sufficiently extensive to assess the air quality impacts of the Lamma Power Station, both in its current configuration and with the proposed extension. A limited additional air monitoring study is, however, recommended to assess possible dust impacts on crops grown on Lamma. This study would be in response to local concern over dust fallout affecting agricultural products, which was expressed by some residents during the public consultion exercise. The results should be used to assess if any further dust controls are needed on the power station site.

The HEC self-monitoring program for liquid effluents provides a good basis for monitoring the discharges from Lamma power station. This program should continue and include any additional pollutants that are anticipated to be released with the FGD effluent. The database for temperature rises in the coastal waters off Lamma is rather limited and there are therefore uncertainties in assessing the current extent of the +2°C contour, or that arising from the extended power station. Additional thermal monitoring is recommended to assess the adequacy of the existing 1.5km mixing zone.

There are specific monitoring requirements specified in the Air Pollution Control Licence. Similar requirements are envisaged for the additional units. This monitoring, together with ambient air and water quality monitoring should form the basis of a reporting and auditing strategy for compliance and environmental management purposes. As environmental auditing has not yet been formally introduced into Hong Kong, the details of a formal auditing procedure will need to be considered in collaboration with EPD. This should be considered as a key issue in Phase 3 of the study.

Conclusions

To meet the continuing load growth, HEC's forecast shows that two more coal fired units are required to be added to their generation system between 1994 and 1997. The preferred rating for each of these units is 350MW. Environmentally, there are no major unacceptable impacts predicted to arise from the provision of the additional generating capacity at Lamma and the extension at Lamma would present fewer problems than the development of a new power station at a different location. There would also be a significant saving in project costs - in excess of HK$ 3.5 Billion - by extending Lamma Power Station.

On the basis of this initial environmental assessment, there would seem to be no significant environmental consideration which would disqualify the Lamma site as being suitable for the additional generating capacity.

INTRODUCTION

1.0 INTRODUCTION

1.01 The development of Lamma Power Station has taken place progressively in stages since 1978. The Stage 1 development, comprising three 250MW units and auxiliaries, including oil and coal handling and storage plants, was successfully completed in 1983.

1.02 The development of the second stage is now nearing completion and comprises the installation of three 350MW coal fired units. The first of these was successfully synchronised in November 1986, the second in November 1987, and the final (L6) unit will enter service in 1992. Power generated from the Stage 2 units is taken via four 275kV underground/submarine circuits to Hong Kong Island.

1.03 The present power station site has sufficient capacity to cater for additional generating units. This study is an initial assessment of the possible environmental impacts arising from provision of such additional capacity.

The Need for Additional Generation

1.04 To meet the continuing load growth, HEC's forecast shows that two more coal-fired generating units would have to be added to the HEC generation system after the commissioning of Unit L6 in 1992 and before year 2000. The forecast was based on a moderate load growth of 5.4% per annum over the next 10 years as against the actual load growth of 8.4% over the last 10 years.

1.05 Studies carried out by HEC show that the present Lamma Power Station site has sufficient area to accommodate two additional 350MW or 500MW coal fired units after the commissioning of L6. However, HEC have decided that the additional capacity to be accommodated on the Lamma site is 2 x 350MW. This study has therefore focused on the provision of such additional capacity.

1.06 Environmentally, the extension at Lamma would present fewer problems than the development of a new power station at a different location. Moreover there are other advantages in extending Lamma Power Station rather than building a new power station to meet the future demand. These advantages are summarised below:

1. **Coal Storage and Ash Disposal**

   After completion of the stacker/reclaimer installation at the existing coal yard, the coal storage and handling facility will be sufficient for 8 coal fired units.

   Furthermore, the already developed long term ash disposal strategy which caters for 8 coal fired units (i.e. the existing 6 units plus up to 2 x 500MW of additional capacity) has been accepted by Government. Thus, the problem of ash disposal has, in principle, been solved.

2. **Transmission of Power from Two Additional Units**

The present 8 circuits of 275kV transmission underground and submarine outlets from Lamma Power Station have already sufficient capacity to transmit the additional power from Lamma Power Station.

3. **Infrastructure and Costs**

A new power station would, in addition to preliminary civil works, require common facilities, such as coal handling jetty, coal and oil storage yards, coal and ash handling systems, new transmission capacity and additional resources for the management, operation and maintenance of the generating units. At Lamma, all these common facilities already exist.

There would thus be a significant saving in project costs in extending Lamma Power Station, and HEC have estimated this to be in excess of HK$3.5 billion at current costs (including transmission equipment).

Scope of the Study

1.07 Before Lamma Power Station was built, a site search was carried out and the Lamma site was identified as being environmentally suitable for the development of a power station.

1.08 The objective of this current study is therefore to assess the effects on the environment of the proposed extension to the existing power station, by two units, L7 and L8, each to be rated at 350MW.

1.09 The Terms of Reference (TOR) of the EIA for units L7 and L8 are wide ranging and cover a number of areas.

- To describe the proposed installation and requirements for development;
- To identify the elements of the community likely to be affected;
- To establish the environmental acceptability of the site;
- To identify security and reliability implications;
- To recommend whether or not an alternative site is required;
- To minimise pollution, environmental disturbance and nuisance arising from the total development at Lamma Power Station;

- To identify, predict and evaluate the net environmental and marine impacts, cumulative effects from construction, operation and decommissioning of the development;

- To identify and specify mitigation measures in the detailed design;

- To design and specify environmental audit requirements;

- To identify and assess the economic and tariff implications of the development and any pollution control measures.

1.10 Whilst the TOR covers the issue of alternative locations for the power station extension, HEC wish at this stage to concentrate on the extension of Lamma Power Station because of the advantages described earlier, subject to the environmental impact being acceptable. The EIA study has therefore been conducted on this basis and has not covered the selection of alternative locations.

1.11 One of the key environmental issues to be examined is the air quality impacts of the extension. Consent has already been given to HEC to construct and operate Unit L6, a 350MW addition to the current generating capacity. This consent was granted subject to a requirement by EPD to provide a flue gas desulphurisation (FGD) system, to remove 90% of sulphur dioxide from the flue gas before discharge to atmosphere. The study is not therefore concerned with environmental acceptability of L6 individually, although the cumulative emissions from the power station (including L6) have, however, been considered, together with the additional contribution from units L7 and L8.

1.12 As consent for unit L6 has already been given, the EIA has taken the following plant configuration as a baseline condition:

- Units L1 - L6 Total 1800MW

- 6 x 125MW and 1 x 55MW gas turbines

1.13 In addition to the existing and proposed plant configuration, agreement has recently been reached with Government on the establishment of a PFA lagoon, to be constructed adjacent to the south eastern boundary of the Lamma Power Station. For the purposes of establishing baseline conditions, therefore, the study has adopted the premise that the ash lagoon is an existing feature of the power station environment. Completion of the lagoon is expected in 1993.

1.14 As noted above the requirement to incorporate FGD on unit L6 has already been determined and agreed between HEC and EPD. The present study has not therefore addressed the environmental implications of incorporating FGD to unit L6 or of the provision of the infrastructure to operate the FGD system. The quantities of materials required to operate the FGD system and the waste disposal implications have, however, been addressed as part of the evaluation of cumulative impacts.

1.15 With regard to the requirement for air pollution control technology on units L7 and L8, it is accepted that FGD control will be a requirement. The current study has taken as its basis that a limestone-gypsum FGD process will be applied to units L7 and L8. Notwithstanding this, however, a parallel study is being conducted by HEC to evaluate the relative environmental, technical and economic merits of alternative FGD methodologies.

Basis of Studies

1.16 As noted, the unit configuration that has been considered in the EIA is two units, each of 350MW capacity. Although this represents a departure from the original basis of the studies, as documented in the Inception Report (IR), it has now been decided by HEC that the maximum desirable additional generating capacity to be installed at Lamma is 700MW (i.e 2 x 350MW units).

1.17 In addition to plant capacity, there are a range of fuel sources which are used by the power station, each with its own particular physical and chemical properties and resultant emission quantities. Finally, there are a number of different operating regimes that could be considered for the EIA, depending upon whether an average, typical or "worst case" condition was to be evaluated.

1.18 It would clearly be unrealistic to study all possible permutations, neither would it be justified on technical grounds. The normal procedure in cases such as this is to take a "worst case" condition as a basis for study and evaluate the environmental impacts under this condition. At the same time, it is important to take as a basis realistic conditions, rather than theoretical operating regimes which would never be achieved in practice. This study has therefore utilized the predicted "worst case" load factor for the peak year of 2000, when the peak output of the Lamma Power Station is estimated to be of the order of 3072MW. With a 350MW option for the additional units, a new power station will become HEC's base load station in 2001 and the output from Lamma will drop steadily from 2001 onwards. For consideration of the baseline case, this has been taken as the operating regime at l994, when unit L6 as well as all gas turbines and coal fired units will be in full operation.

1.19 With regard to atmospheric emission quantities and gas flow conditions, the study has taken as a basis realistic values, typical of normal operation. These emission quantities have been taken as applying under Maximum Continuous Rating (MCR) conditions. Adjustments to these emission quantities have been made for non-MCR operation.

1.20 For coal type, the study has assumed coal with a maximum sulphur content of 1% (air dried) and 19.0% ash as "upper limits". For the purposes of this IAR, oil for emergency or start up use has been assumed to have a sulphur level of 3.5%, as a worst case scenario.

1.21 The basis for the evaluation of impacts from liquid effluent discharge has been that all existing discharges will continue and that additional effluents will be added to current discharges in accordance with typical operating experience. Any effluent discharges from the PFA lagoon, to be constructed, have also been taken as an "existing discharge", as consent for this development has already been given. The EIA has therefore addressed the additional and cumulative impacts of the proposed extension units. It has also been assumed that any liquid effluent streams arising from the FGD system may need to be treated on site prior to discharge.

1.22 For the purposes of assessing the impacts of the thermal discharge, worst case conditions of typical maximum c.w. flow and temperature have been assumed. The impacts of additional metal discharges in liquid effluents on water quality have been assessed by assuming such discharges occur in accordance with realistic operating experience limits. For the FGD waste stream, however, metal discharges have been assumed to be in accordance with current EPD proposed licence conditions. This is, in practice, likely to be a pessimistic basis for assessment, but is considered suitably conservative in the absence of actual site operational experience.

1.23 For visual and noise impact assessments, the condition as at I994 with Unit L6 fully operational and the ash lagoon constructed has been taken as the baseline case.

Government Review

1.24 The draft IAR was submitted to Government for review in December 1990. Comments on the draft received from Government and the Study Management Group have been addressed in this final report where appropriate. Responses to all comments made on the draft IAR have been prepared and, for completeness, a schedule of all comments and responses is included in Annex 1 at the end of this report.

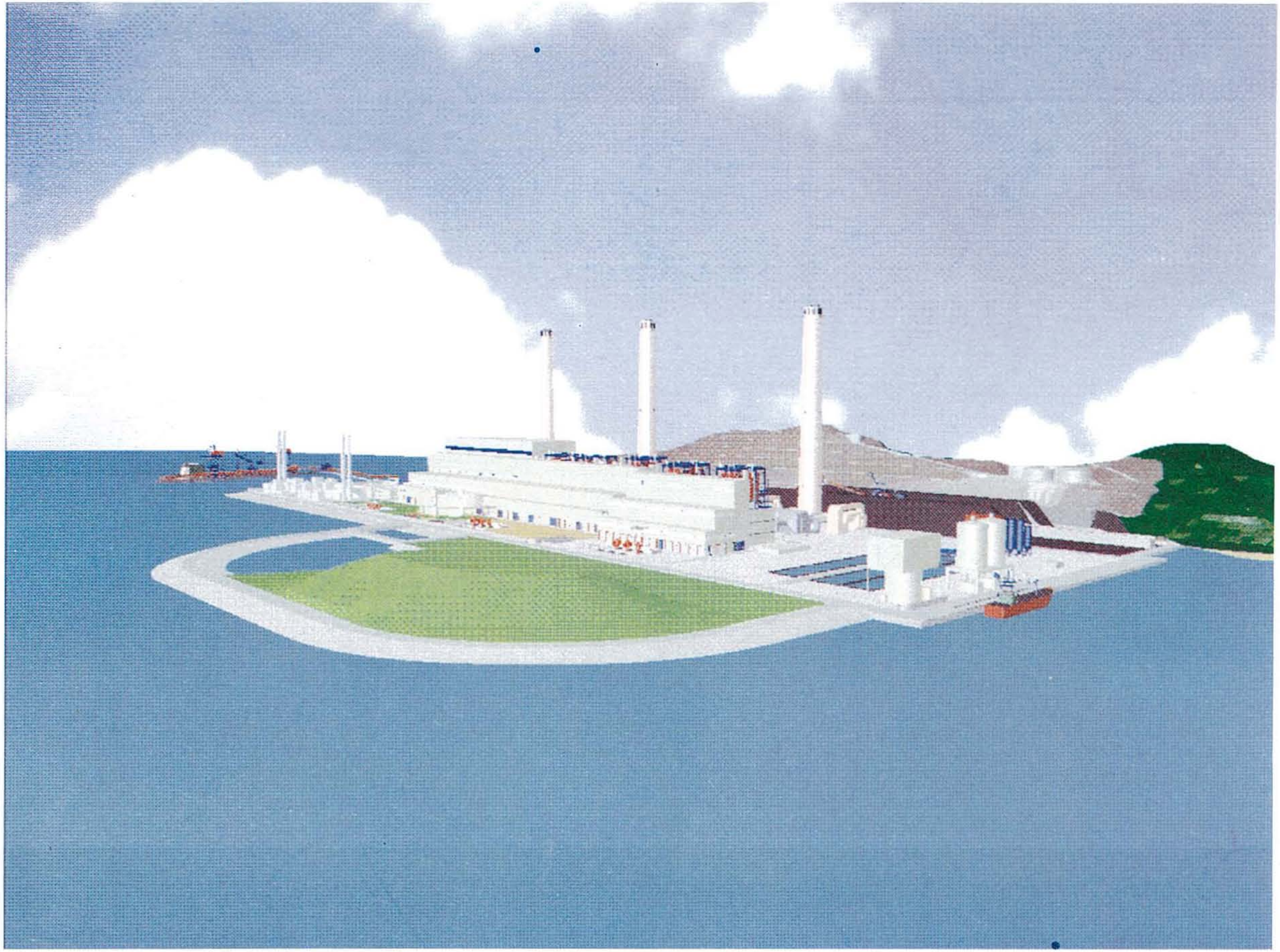


FIG. 1.1 3-DIMENSIONAL VIEW OF OVERALL STATION COMPLEX (350 MW)

DESCRIPTION OF PROJECT

2.0 DESCRIPTION OF PROJECT

The Existing Power Station

2.01 There are currently five coal fired power generating units at Lamma, designated L1 to L5, with a sixth unit, L6, under construction, which will enter service in 1992 (see Figure 2.1). Unit L1 became operational in 1982.

2.02 The total capacity of units L1 to L6 is 1800MW and the primary fuel for power generation is coal; oil being used during start-up and shutdown of a unit and, when necessary, for safe operation of the boiler at low loads, in combination with coal firing.

2.03 In addition, there are seven gas turbine generating units, six rated at 125MW each and one rated at 55MW, which burn diesel fuel and are primarily used for meeting peak demands and emergencies of the HEC system.

2.04 The power station is also equipped with a 2.2MW black start gas turbine, the main purpose of which is to provide electric power for the emergency start up of the 6 x 125MW gas turbines.

2.05 The electrical power output from Lamma is transmitted via 275 kV high voltage cables, which run underground across Lamma Island to the submarine cable landing point on the eastern shore of Lamma Island. Submarine cables have been laid across the East Lamma Channel to transmit the electrical power to the Hong Kong Island transmission and distribution system.

2.06 In accordance with the licence granted to HEC, unit L6 (350MW) is planned to be fitted with a flue gas desulphurisation (FGD) process to remove 90% of the sulphur dioxide from the flue gases before being discharged into the atmosphere through the tall chimney - 215m above principal datum.

2.07 The wet limestone - gypsum FGD process selected by HEC and agreed with EPD for L6 is due to be fully operational in 1993. In this process, combustion gases from the boiler, after passing through the electrostatic precipitator, come into contact with a slurry, made by mixing finely ground limestone with fresh water, in an absorber tower.

2.08 The limestone reacts with the sulphur dioxide in the flue gas to form gypsum ($CaSO_4 . 2H_2O$) as a usable by-product, while the "scrubbed" gas is discharged through a gas reheater and then to atmosphere via the chimney. Details of this system are described more fully in Chapter 7 of this report.

2.09 Limestone for the FGD process will be delivered to the power station by sea in small vessels (2000 DWT) and stored in silos at the east jetty. Gypsum produced by the process will be temporarily stored in the same area.

Additional Units

2.10 The need for additional generation has been discussed in Chapter 1. The proposed extension for the development of Lamma is two units, each rated at 350MW.

2.11 These 2 x 350MW extension units would be technically and practically similar to unit L6. In accordance with the HEC load forecast, L7 will need to be in service by March 1995 and L8 two years later.

2.12 For technical and operational reasons it would be advantageous to fit both units L7 and L8 with FGD identical to L6, provided the proposed solid waste (gypsum) disposal scheme is acceptable environmentally to EPD.

2.13 However, a separate study is being done by HEC at the request of EPD to evaluate and compare different FGD technologies to determine the suitability, or otherwise, of the limestone - gypsum process for units L7 and L8.

Site Layout, Main Plant & Civil Works

2.14 A site plan, showing the existing station as it is likely to appear in 1997 with the two extension units L7 and L8 is shown in Figure 2.2. Major items of mechanical and electrical plant which make up the project are shown in Figure 2.3 which is indicative of the current stage of design and will be refined as detailed design work progresses.

2.15 The main items of marine construction work for L7 and L8 will be the No.3 Cooling Water (c.w.) Intake and the c.w. outfall, the designs for which are at the conceptual stage only.

2.16 The inlet culverts for the c.w. Intake will be incorporated in the ash lagoon bund on the south side during construction of the ash lagoon, and the intake screens and pump chambers are likely to be located inland.

2.17 The c.w. outfall for the extension units will be similar to the existing outfall, but located to the north of it, as shown on the site plan. This arrangement will maximise dispersion of the thermal plume and minimise recirculation of the thermal discharge back into the c.w. intake.

Jetties

2.18 Coal unloading and handling for units L7 and L8 will take place at the existing West jetty, by means of grab and bucket elevator coal unloaders and a conveyor belt system which carries the coal to either the coal storage yard or direct to the boiler bunkers. Oil and heavy goods will be delivered to the heavy unloading berth, at the western side of the station, whilst the existing passenger jetty would be used for any additional personnel.

2.19 At the East jetty, the facilities to be provided for the unloading and handling of limestone and gypsum for unit L6 have catered for the extension units, if these are fitted with the same FGD process as L6.

2.20 The East jetty will continue to be used by small vessels (1500 - 2000DWT) for the transport of ash from the power station for delivery to commercial users.

Electrical Power Transmission

2.21 Transmission of electrical power output from the proposed 2 x 350MW extension will be effected by the existing 275kV underground and submarine circuits linking Lamma Power Station to Hong Kong Island. Thus the existing electrical power transmission system will remain unchanged.

Liquid Effluents and Solid Wastes

Statutory Requirements

2.22 The Consent to Discharge currently held by HEC for liquid wastes embraces cooling water discharge, miscellaneous trade effluents and sewage and applies to Units L1 to L6. It is assumed that similar consents would also apply to the proposed extension Units L7 & L8.

2.23 Licence No. L-7-002, effective from 6th March 1990 until 5th March 1992 pursuant to the Air Pollution Control Ordinance, is in respect of the steam turbine generator Units L1 to L6, and gas turbine generator GT1. An additional licence, L-7-001, has been issued for the gas turbine units GT2 to GT7 and the Black Start Gas Turbine. Licence L-7-002 refers to flue gas desulphurisation (FGD) for Unit L6 while a letter from the Environmental Protection Department dated 10th November 1989 advises the following requirements for FGD waste water:-

(1) The FGD waste water needs to be treated by a separate treatment system to standards required under the Water Pollution Control Ordinance (W.P.C.O.) licensing conditions.

(2) The proposed pollutant concentration limits are those given in Table 2.1 which, for comparison purposes, also shows the WHO recommendations [1] for potable water and a typical seawater analysis [2]. Typical concentration ranges for potable water at Lamma Power Station are shown in Table 2.2.

(3) FGD wastes are considered as industrial waste.

2.24 For this IAR, it has been assumed that the FGD plant for Units L7 & L8 will be of the limestone-gypsum type as for Unit L6. It is recognised that the type of desulphurisation plant for Units L7 and L8 has not yet been specifically identified or justified. This will be done by HEC in a separate report.

TABLE 2.1: FGD WASTE WATER QUALITY DISCHARGEABLE TO SEA

Parameter	Proposed Upper Limit (mg/l)	W.H.O. Potable Water [1] (mg/l)	Seawater [1] (ppm)
pH Range	6 to 9	6.5 to 8.5	-
Temperature °C	43	-	-
Suspended Solids	30	-	40
C.O.D.	80	-	-
Grease & oil	20	-	-
Mercury	0.1	0.001	0.00003
Cadmium	0.1	0.005	0.0001
Arsenic	2.0	0.05	0.003
Chromium	2.0	0.05	0.00005
Copper	2.0	1.0	0.003
Lead	2.0	0.05	0.00003
Nickel	2.0	-	0.002
Silver	2.0	-	-
Zinc	2.0	5.0	0.01
Barium	5.0	No Limit nec	0.03
Boron	5.0	No Limit nec	4.6
Manganese	5.0	0.1	0.002
Tin	5.0	-	-
Total non-ferrous metals	5.0	-	-
Iron	10.0	0.3	0.1
Cyanide	0.1	0.1	-
Sulphate	-	400	2700
Aluminium	-	0.2	0.01
Nitrate (as N)	-	10.0	0.05
Chloride	-	250	19350
Sodium	-	200	10760
Antimony	-	No Limit nec	0.0005
Calcium	-	No Limit nec	-
Carbonate	-	No Limit nec	-
Bicarbonate	-	No Limit nec	-

TABLE 2.2 : COMPOSITION RANGE FOR POTABLE WATER FROM LAMMA POWER STATION

Parameter	Range ppm
pH	7.0 to 9.3
T.D.S.	-
Calcium as Ca	2.1 to 7.6
Magnesium as Mg	0.3 to 0.8
Chlorides as Cl	2.4 to 5.3
Sulphates as SO_4	4.1 to 10.6
Iron as Fe	-
Cadmium as Cd	-
Lead as Pb	-
Arsenic as As	-
Copper as Cu	-
Zinc as Zn	-
Aluminium as Al	-
Manganese as Mn	-
Total Hardness as $CaCO_3$	6.8 to 20.6

Power Generation - Liquid Effluents

2.25 Water is an essential input without which no power generation would be possible. Primary inputs are fresh water and seawater which, after use, become the primary effluents. The liquid effluent schematic diagram shown in Figure 2.4 gives the flows and uses of all liquids from their input to their final point of discharge.

2.26 Neither fresh water nor seawater are completely suitable for use in the plant without prior treatment. An exception is the use of fresh water for potable, fire fighting and domestic applications. Another use of freshwater will be for limestone slurry production for the FGD plants.

2.27 While the use for domestic applications will increase pro-rata to the number of additional personnel required to operate the plant extension, the treatment and quality of the effluent will be the same as that presently discharged.

Freshwater Uses

2.28 The process uses of fresh water are indicated in Figure 2.4 and again, while the quantities used will increase in each area, the effluent quality for L7 & L8 will be similar to that applicable to the installed units, except for a short period during testing and commissioning of the new plant.

2.29 The major use of fresh water will be as feed to the demineralization plant which in turn produces demineralized water for boiler feed and for equipment cooling. During testing and commissioning of the proposed new units, the quantity of demineralized water used for testing, cleaning and flushing purposes will be very high by comparison with the normal operating uses. In spite of the chemical additions made to the water used during commissioning ie. hydrochloric acid, caustic soda and hydrazine, the contamination problem will arise mainly from the iron oxides removed during the cleaning processes. Effluent from the commissioning uses will pass into the existing neutralization basins, where both pH adjustment and dilution will occur before discharge. The effluent may also be held in the system by planned recirculation until such time as a composition suitable for discharge is attained.

2.30 Once the new units L7 & L8 are commissioned, the use of demineralized water will reduce significantly and be confined to make up of evaporation losses and possibly, occasionally to replace water blown down to reduce chemical concentration effects.

2.31 Additions to the boiler feed water will be limited to hydrazine for oxygen scavenging and ammonia for alkalinity control. Phosphate will be added at the Boiler Circulation Pumps inlet for alkalinity control. In the case of hydrazine, the added chemical will be "used up" by reaction with oxygen, while the phosphate ion level in the boiler water will seldom rise above 4 ppm.

2.32 Following a planned or fault condition shut down, it may be necessary on re-starting, to blow down boiler water for a period until the silica level reduces to an acceptable level for normal operation. The blown down water will thus contain phosphate at about the 4 ppm level and will flow into the cooling water outlet culvert, where it will be diluted to an acceptable level for discharge to the sea.

Seawater Uses

2.33 The primary use of seawater is as a coolant for the main turbine condensers, and oil and water heat exchangers. Seawater is also used for furnace bottom ash cooling and conveyance, as a slurry, to the ash settlement basins. To ensure satisfactory behaviour of the plant, it is necessary to disinfect the incoming seawater and this is achieved by the addition of sodium hypochlorite produced on site by the electrolysis of seawater. The addition is adjusted such that it removes the risk of fouling by marine life. Oxidation and reaction in passing through the system produces a low residual free chlorine level in the discharge from the plant. The residual can therefore be controlled to within the consent limit at all times.

2.34 The existing Units L1 to L3 condensers are tubed with aluminium brass. To protect the tubes during normal operation, it is essential that the bores are covered uniformly with an iron enriched, natural oxide film. Iron enrichment is obtained by the addition of ferrous sulphate heptahydrate ($FeSO_4.7H_2O$) to the inlet cooling water. Dosing is on a routine basis at a frequency of once (1 ppm Fe for l hour) for every 120 running hours. This frequency of dosing is reviewed from time to time depending upon the condition of the condenser tubes.

2.35 The proposed new Units L7 and L8 are likely to be tubed with titanium, as are Units L4, L5 and L6 and, while chlorination will still be necessary, no ferrous sulphate injection will be required.

2.36 Seawater used for furnace bottom ash cooling and conveyance will leach out trace elements from the ash. The present system is such that the levels of contamination are well within the consent levels and there is no reason to believe that this will not also be the case for the proposed new units.

Solid Wastes

2.37 Figure 2.5 shows the schematic diagram for solid and associated wastes for the existing installation at Lamma and the proposed extension L7 and L8.

2.38 The principal solid wastes include fly ash, furnace bottom ash, gypsum and sludge from the oil/water separators and the FGD waste water treatment system. While the volume of these will obviously increase pro-rata with proposed increase in generation capacity, disposal methods will remain the same as the existing installation. A long term ash management strategy has been developed which caters for all the ash produced from the existing and proposed future units. This strategy has been endorsed by Government and calls for an active marketing policy to ensure that as much as possible of the PFA produced goes to industrial users or to landfill formation. Other elements of the strategy include the use of PFA as fill to restore the Lamma Quarry site and the formation of an ash lagoon adjacent to the power station. The disposal of ash can be accomodated without significant adverse environmental impacts.

2.39 Gypsum disposal options are considered in detail in Chapter 7 of this IAR, but the precise nature of the solids produced cannot be stated with certainty until the detailed design of the FGD system has been completed, the sourcing of limestone is known, the requirements for waste water treatment are finalised and the related consent limits are discussed and agreed with EPD.

Conclusions

2.40 The preferred option of 2 x 350MW units L7 & L8, can be accommodated at the existing power station site at Lamma with minimal changes to the existing infrastructure.

2.41 There is no doubt that while flow volumes will increase pro-rata to the increase in generating capacity, the liquid effluent quality for units L1 to L8 will remain within the existing consent limits.

2.42 Liquid effluent from any FGD waste stream will be treated on site in accordance with Government EPD requirements. The form of the treatment system and the licence conditions to be applied will need to be discussed between HEC and EPD. In this regard, it is noted that EPD have strong reservations concerning any 'dilution' technique and this will therefore need to be taken account of in the design of any waste water treatment facility.

REFERENCES

1. WHO Recommendations Volume 1. (ISBN 92 4 15 4 168 7 - reprinted 1985)

2. Cremer & Warner Report to HEC May 1979. "Assessment of Marine Discharges". (Report Ref. H5001.56, Table 7.5)

The Hongkong Electric Company Limited

PROJECT

EIA LAMMA POWER STATION

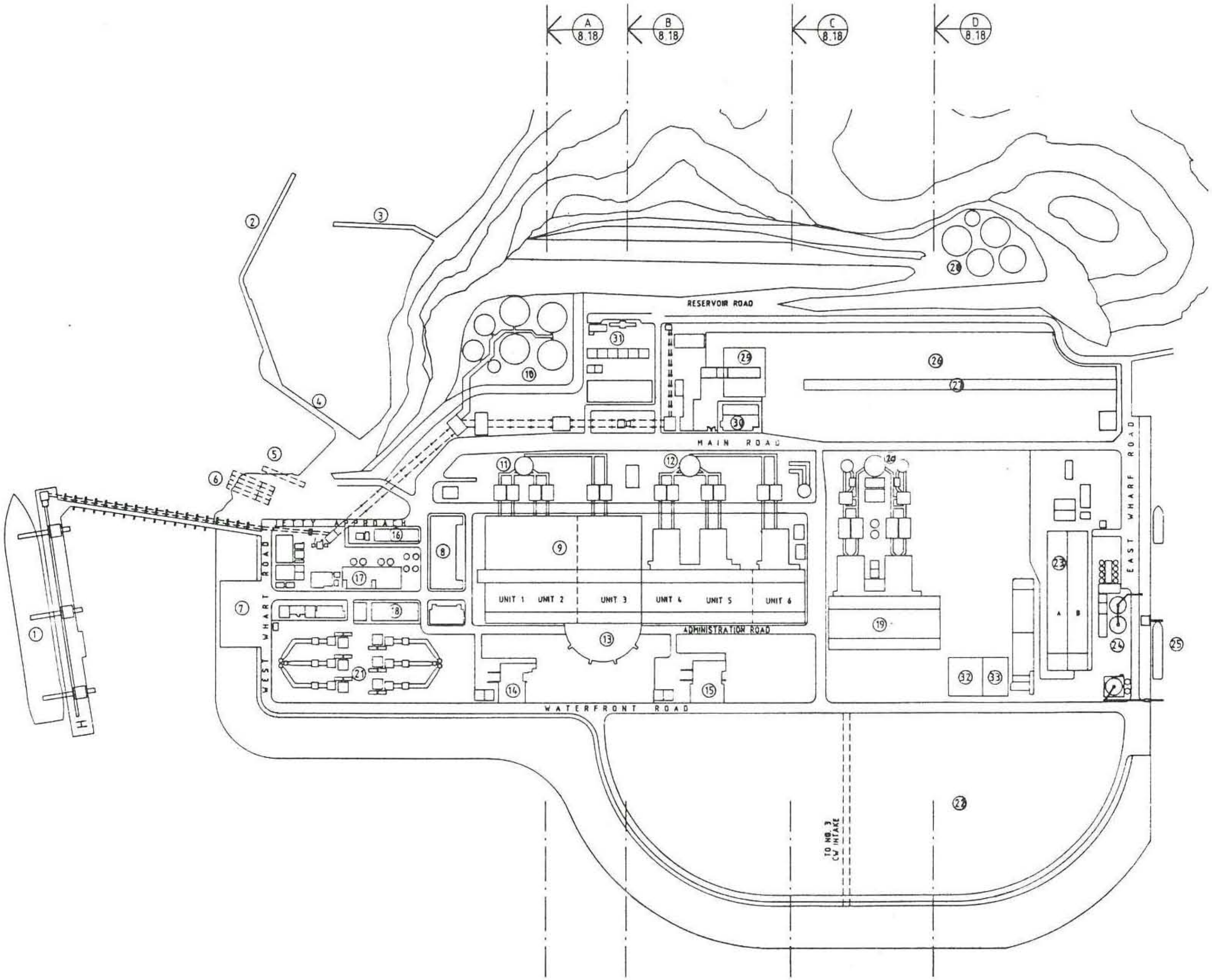
TITLE

THE EXISTING POWER STATION

FIGURE 2.1

KEY

1. COAL SHIP
2. BREAKWATER B
3. BREAKWATER C
4. PASSENGER JETTY
5. FUTURE C.W. OUTFALL
6. C.W. OUTFALL
7. WEST HEAVY UNLOADING AREA
8. WORKSHOP & OFFICE
9. STAGE I STATION BUILDING
10. OIL TANK FARM
11. NO. 1 CHIMNEY
12. NO. 2 CHIMNEY
13. ADMINISTRATION BLDG. & CONTROL RM.
14. NO. 1 C.W. INTAKE
15. NO. 2 C.W. INTAKE
16. D.G. STORE
17. DEMINERALIZATION PLANT
18. AMENITY BUILDING
19. 350MW STATION MAIN PLANT
20. NO 3 CHIMNEY
21. NO. 2-7 GAS TURBINE
22. ASH LAGOON
23. ASH SETTLEMENT BASIN
24. GYPSUM & LIMESTONE HANDLING PLANT
25. EAST JETTY
26. COAL YARD NO. 2
27. STACKER RECLAIMER SUPPORTING STRUCTURE
28. RESERVOIR
29. COAL YARD COVERED STORE
30. FUEL & ASH CONTROL ROOM
31. NO. 1 GAS TURBINE
32. DEMINERISATION PLANT
33. EFFLUENT TREATMENT PLANT



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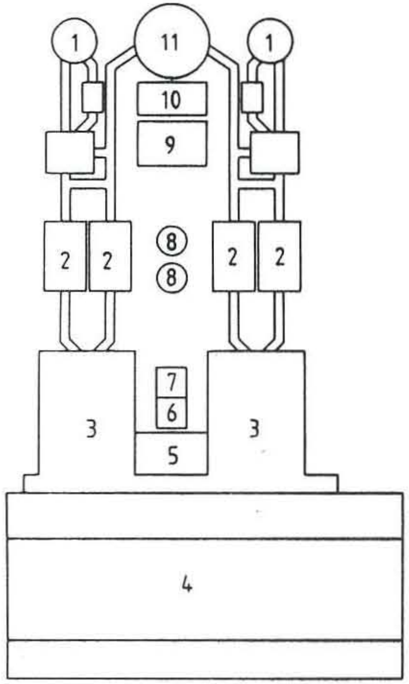
PROJECT:
EIA LAMMA POWER STATION

TITLE:
350 MW SITE PLAN

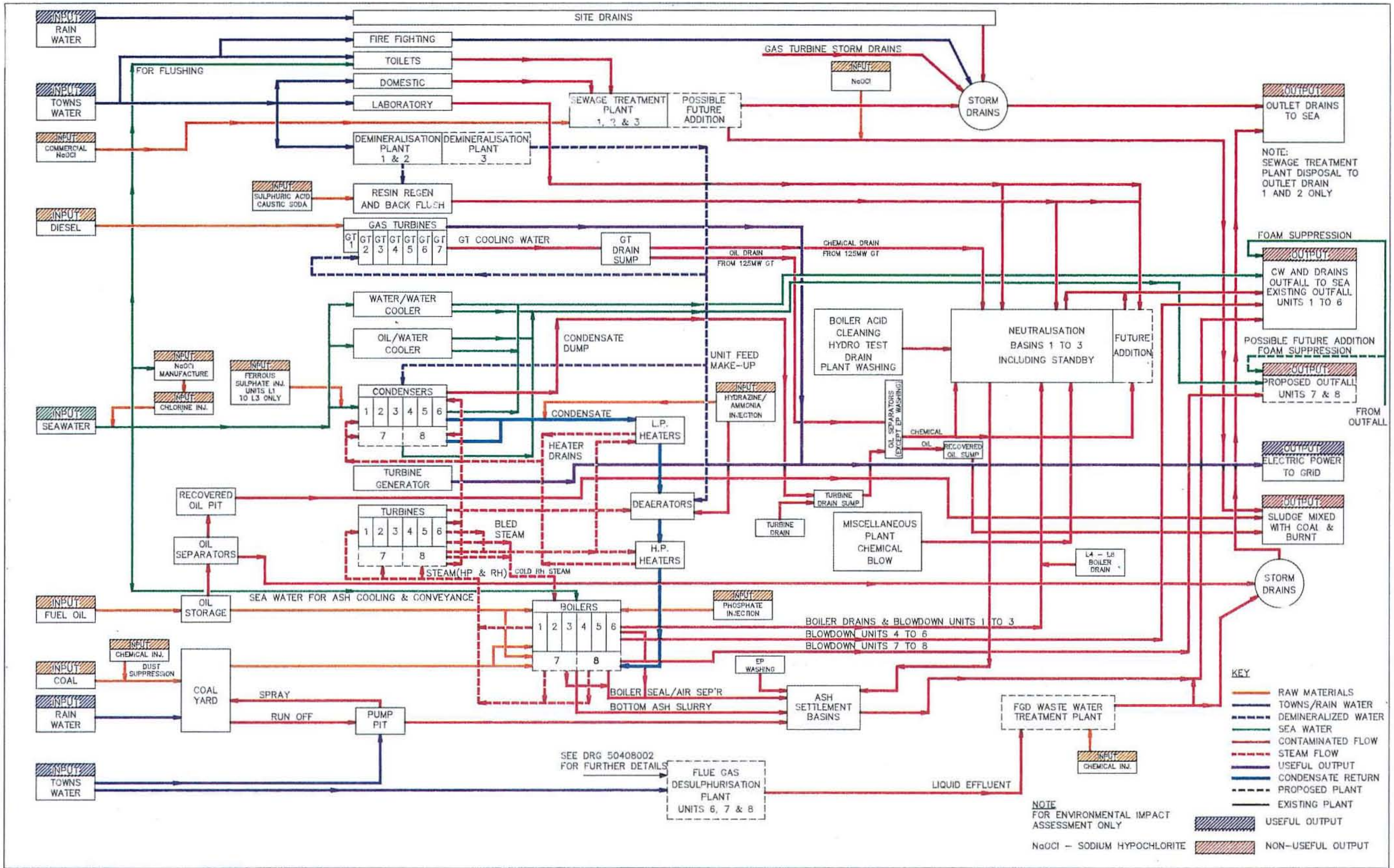
FIGURE: 2.2



KEY

1. F.G.D. ABSORBER TOWER
2. ELECTROSTATIC PRECIPITATOR
3. BOILER UNIT
4. STATION BUILDING UNIT 7 & 8
5. CENTRAL CONTROL BUILDING
6. MAIN A/C PLANT ROOM
7. PFA CONVEYING A/C ROOM
8. PFA TRANSFER BIN
9. FGD SWITCH GEAR ROOM & ELECTROSTATIC PRECIPITATOR CONTROL ROOM
10. LIGHT OIL TANK
11. NO.3 CHIMNEY

	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: 350MW STATION MAIN PLANT FIGURE: 2.3



DRG No. 50408001

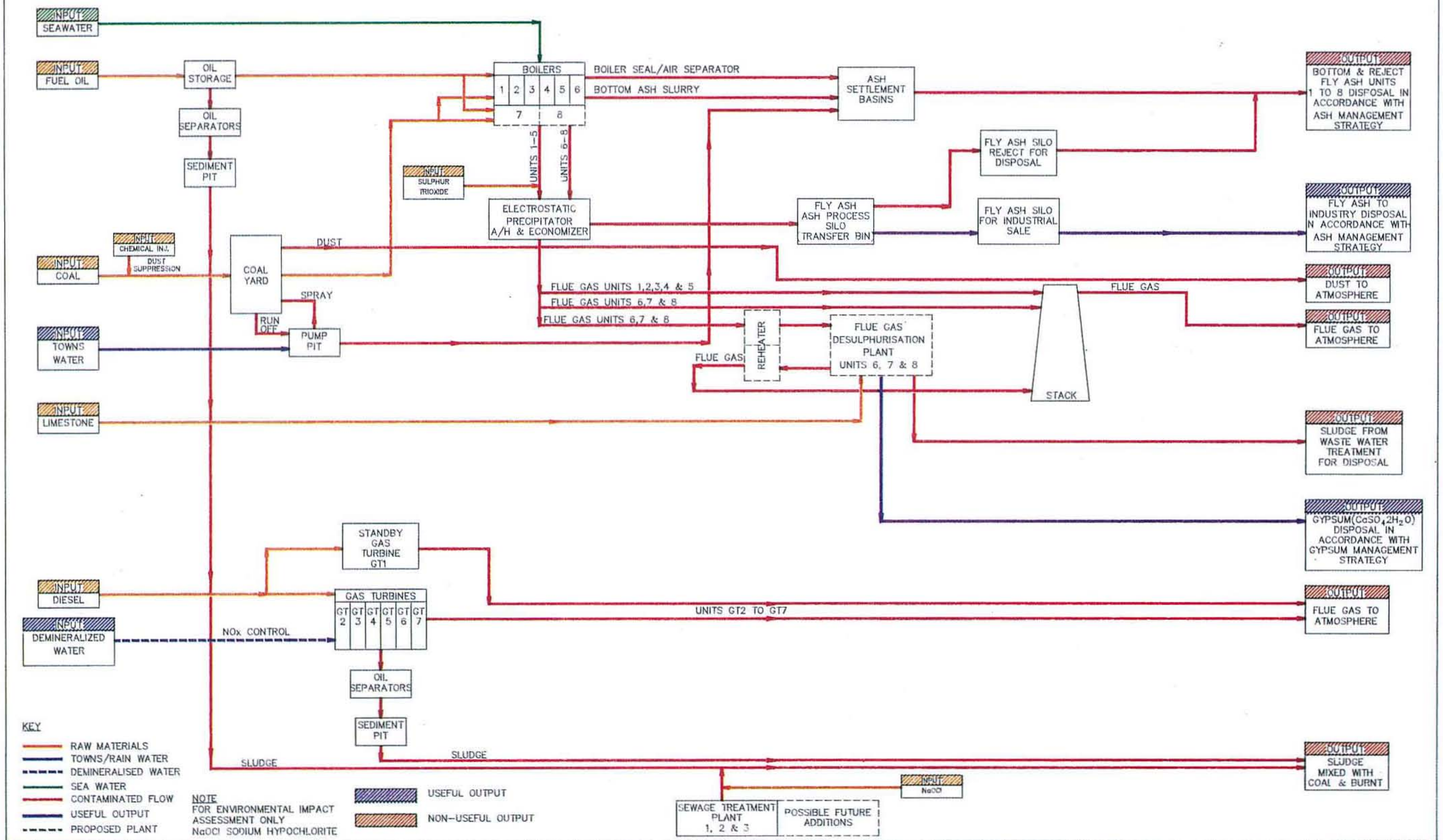
ISSUE DATE 31st DEC 1990 | FILE REF. GIL/IND/50408006

The Hongkong Electric Company Limited

PROJECT
EIA STUDY
LAMMA POWER STATION

TITLE
SCHEMATIC DIAGRAM OF ENVIRONMENTAL LIQUID EFFLUENTS

FIGURE 2.4



DRG No. 50408002

ISSUE DATE 17th MAY 1991 | FILE REF. GIL/IND/50408005

The Hongkong Electric Company Limited

PROJECT
EIA STUDY
LAMMA POWER STATION

TITLE
SCHEMATIC DIAGRAM OF ENVIRONMENTAL SOLID WASTES

FIGURE 2.5

EXISTING ENVIRONMENT

3.0 EXISTING ENVIRONMENT

3.01 LAMMA ISLAND or Pok Liu Chau, is 13.5 square kilometres (5 square miles) in area and is the third largest island in the Territory after Lantau (142 square kilometres) and Hong Kong Island (77 square kilometres).

3.02 Lamma is very mountainous, with an irregular coastline and is nearly divided in two at Lo So Shing, in the centre. It is often described as the last unspoiled outpost of Hong Kong. It has a population officially estimated of around 3,000 and no motor traffic, apart from that serving the power station and small motorised carts, used primarily for local movements of goods, agricultural produce etc. Most of the inhabitants are concentrated in the northern half which is less rugged and has more cultivated land. The main population centre is at Yung Shue Wan.

3.03 The greater part of Lamma is covered with grass and scrub land or woodland. Agricultural land is divided almost equally into actively used and unused. The actively cultivated land is limited to pockets in the northern half of North Lamma, around Pak Kok village and surrounding the village agglomeration of Yung Shue Wan. In addition, there are three small patches on South Lamma, associated with coast fringe settlement. Most of the unused agricultural land is on South Lamma.

3.04 Vegetable farming is the main form of cultivation, comprising 24 out of the 52 hectares of cultivated land recorded in the Farm Survey of 1987.

3.05 The island consists of undulating hills falling steeply to an irregular coastline punctuated by small bays and inlets with most of the settlements and associated agriculture contained in the valley floors and sides. South Lamma is dominated by Mount Stenhouse which rises to 353m, with two lower hills, Luk Chau Shan and Ling Kok Shan, rising to 128m and 250m respectively to the north and south sides of Sok Kwu Wan. North Lamma consists of low cultivated land to the west, with hills to the east.

3.06 The main rock type on Lamma is granite with volcanic rocks occurring in the northeast of the island. Some other minor sites include Tai Wan To and Hung Shing Ye.

3.07 Lamma Power Station is an industrial complex located on the Po Lo Tsui headland. The station comprises the main building housing the turbo-generators, two chimneys rising to 215m P.D. each; coal handling and storage facilities and several auxiliary structures, including water and oil storage tanks, transformers, ash storage silos, etc. Development of the power station site has been ongoing since 1978 and now comprises five coal fired generating units (L1-L5), a sixth unit (L6) currently under construction, plus seven gas turbines.

3.08 To the east of the power station site there is a gazetted beach - Hung Shing Ye - which attracts a large number of weekend visitors. There is also another beach - Tai Wan To - which abuts the eastern boundary of the site. Tai Wan To is not gazetted but nonetheless attracts a number of visitors.

3.09 Figure 3.1 shows the present land use characteristics of Lamma Island, in the context of the power station development.

Ecology

3.10 In 1980 most of South Lamma was declared a Site of Special Scientific Interest (SSSI) to conserve the habitat and nesting grounds of various unusual bird species. The southern part of this SSSI has been identified as the breeding ground of large birds of prey including the white-bellied sea eagle haliaetus leucogaster and Bonelli eagle although they have not been sited in recent years. The eagle owl Bubo and the black-eared kite Milvius migrans have also been observed within the SSSI. All these birds are endangered species.

3.11 North Lamma is noted for its mixed habitats including small pockets of woodland and cultivated land but the area is not a special bird's habitat. It is notable that Lamma is the location of the first record of Swinhoe's Storm Petrel and the second of the Ancient Auk (off Lo So Shing) although they can be found elsewhere as well now. Offshore, the East and West Lamma Channels are notable bird habitats as they are regularly used by migrant terns. The West Lamma Channel is regarded as a winter site for a major gull roost, estimated in 1977 to hold over 10,000 black-headed gulls.

3.12 Most of the hills on Lamma Island are steeply sloping and exposed, supporting only grass and occasional areas of scrubland. Poor soil, exposure and frequent hill fires are the main reasons for the lack of significant woodland cover. Scrub land forms a transitional stage between grassland and woodland, and is characterised by scattered trees and shrubs, such as Litsea sp., Melastoma sp., and Rhodmyrtus sp. with a dense undergrowth including Dicranopteris sp. and Lygodium sp. Scrubland develops initially on north and west facing slopes in sheltered hollows and streamsides.

3.13 Throughout Tai Wan Tsuen, Lo So Shing and north facing Mo Tat Wan, there is generally a dense cover of broadleaf woodland with some areas of agricultural land. This vegetation type is characterised by evergreen and semi-deciduous broadleaf hardwood trees and shrubs. High soil moisture, sheltered hollows and a thick surface cover of leaf litter, are the main reasons for the development of dense broadleaf woodland.

3.14 Within the broadleaf woodland area, mature and developing woodland has been identified. Developing woodland is a transitional stage between scrubland and mature woodland. Also included in this category is newly planted woodland such as the planting carried out as part of the reinstatement of electricity cable routes across Lamma Island.

3.15 Lamma has no unusual fauna. There is a species of freshwater frog in the streams around Sok Kwu Wan which was once thought rare but has since been found elsewhere in Hong Kong. There are some freshwater terrapins in the streams and on rare occasions, marine turtles can be observed on Lamma beaches. In the more rural areas, there is a typical snake population with cobras and ratsnakes being common.

Climate

3.16 Lamma Island lies in Hong Kong harbour which is on the eastern side of the mouth of the Pearl River estuary. The climate is dominated by two monsoon seasons; the winter monsoon which brings mainly northeasterly winds which are generally cool and dry while the summer monsoon brings warm wet southeasterly winds. The transition between monsoons brings unstable weather. About 80% of the 1.6m of annual rainfall on Lamma falls in the summer monsoon and heavy rainstorms are generally associated with typhoons of which an average of 8 per year affect Hong Kong. The summer air temperature averages about 28°C but may reach a maximum of about 36°C. Winter temperatures average about 15°C.

Existing Noise Environment

3.17 The noise climate of Lamma Island is consistent with its rural setting with only two sources of industrial noise occurring - the power station and the quarry at Sok Kwu Wan.

3.18 Background noise levels have been measured by HEC at two sites close to the boundary of the Lamma Power Station since 1980. A review of these measurements show that average background (L_{A90}) levels have declined over the past decade and are now typically in the range of 42-47dB(A). This decline is attributed principally to the cessation of the main construction activities for the power station, which would have had a dominant effect on measured noise levels during the early years of the power station development.

3.19 There are a variety of transient noises associated with the power station including coal unloading, mobile plant movement, construction activities, shipping, etc. These transient sources do not significantly influence the L_{A90} level but could be noticeable in close proximity to the site.

3.20 The large number of visitors to Lamma at weekends probably makes a significant contribution to the general noise level at certain locations although no measurements exist to quantify this noise source.

Air Quality

3.21 There have been no systematic studies of air quality on Lamma Island, but HEC have carried out a large number of measurements of suspended particulate and dustfall within the confines of the power station site. These measurements have been taken in order to assess the contribution that various parts of the power station operation have on particulate levels within the Lamma site, and to assess the efficacy of environmental control measures.

3.22 Particulate levels on Hong Kong Island and Kowloon are generally high, as revealed by results of EPD monitoring work in recent years. Annual particulate levels throughout Hong Kong varied from $95\mu g.m^{-3}$ to $146\mu g.m^{-3}$ during 1988 [1] with the annual AQO of $80\mu g.m^{-3}$ being exceeded at all monitoring stations. The fraction of respirable particulate measured at EPD monitoring sites is consistently high and makes up some 60-70% of the total suspended particulate in the urban area. Annual averages of respirable particulate have also been found to exceed the AQO at all monitoring sites. General construction site activities, motor vehicles and industrial operations are the main sources of these high particulate levels.

Water Quality

3.23 The development of the power station introduced various changes to the water environment off the Po Lo Tsui headland. The principal change has arisen from the requirement to abstract cooling water for the condensers, which is then discharged not greater than 10°C higher, off the north west sea wall of the site. The thermal discharge undergoes dispersion in the surrounding water body, depending upon the prevailing hydrographic condition. The extent to which the thermal plume is detectable in the marine environment is therefore very dependent upon the hydrographic regime at any given time.

3.24 A variety of ad-hoc surveys of the distribution of the thermal effluent have been conducted by HEC since 1983. These surveys indicate that the thermal discharge had dissipated within 1km of the site.

3.25 Monitoring of maximum surface water temperatures in Hong Kong waters by EPD during 1988, shows that the coastal waters of Lamma have a temperature regime varying from 29°-30°C at the north of the Island, to >30°C in the south. Maximum bottom water temperatures remained <28°C at all monitoring stations near Lamma Island.

3.26 Dissolved oxygen levels in the coastal waters of Lamma were within the range of 75%-100%, in common with most of the waters of the Southern Water Control Zone.

3.27 Most of the marine waters of Hong Kong have high nutrient loadings. EPD surveys in the West Lamma Channel and South Lantau during 1988 showed high inorganic nitrogen content, exceeding the water quality objective. An increase in the level of Chlorophyll-a and in the frequency of red tides was also recorded.

3.28 The analysis of trends from the EPD surveys suggests the marine waters in the vicinity of Lamma are becoming increasingly eutrophic as a result of nutrient loading, leading to an overall deterioration in water quality in this area [2]. There is no evidence, however, that this deterioration is due to operation of Lamma Power Station. Similar eutrophication has also been observed in other parts of Hong Kong, e.g. Tolo Harbour.

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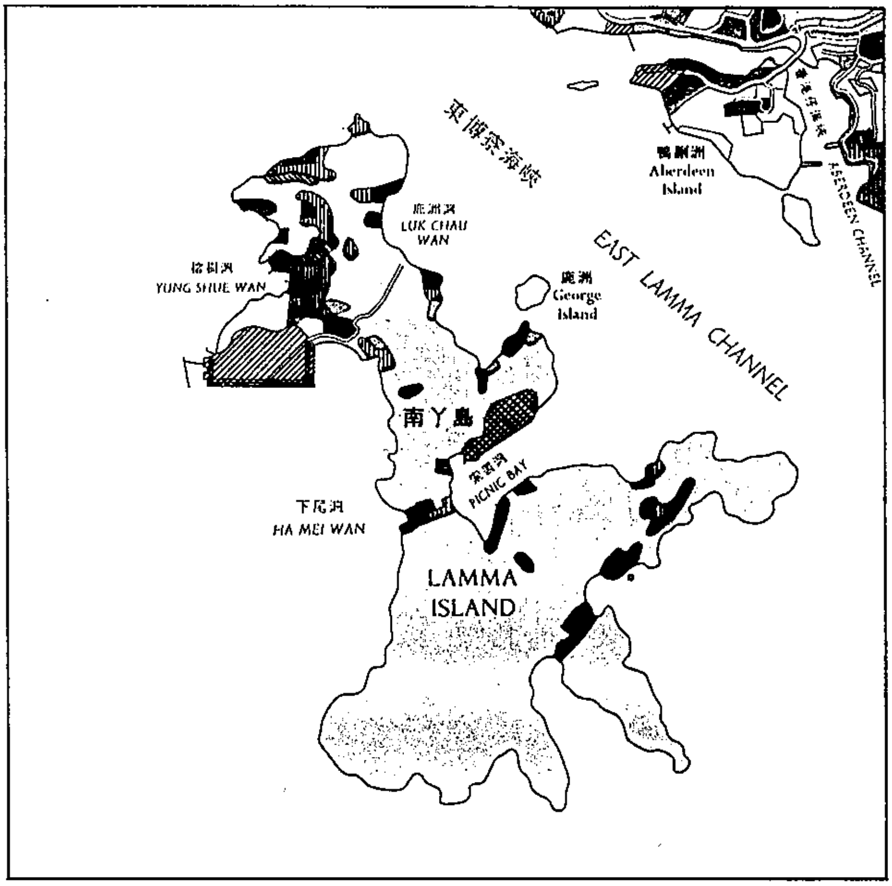
1. Hong Kong Government Environmental Protection Department (1989). "Environment Hong Kong".

2. Hong Kong Government Environmental Protection Department (1988). "Marine Water Quality in Hong Kong".



Scale 1:75.000

LEGEND

Power Station	Cultivated
Quarry	Agricultural (unused)
Industrial	Village housing

Grass, Scrub, Wood, Swamp

The Hongkong Electric Company Limited	
PROJECT EIA LAMMA POWER STATION	TITLE PRESENT LAND UTILIZATION LAMMA ISLAND FIGURE 3.1

CONSTRUCTION AND DECOMMISSIONING

4.0 **CONSTRUCTION AND DECOMMISSIONING**

(a) Construction

4.01 The construction of the additional units would require a number of activities over a period of approximately 70 months. The activities fall into two main categories - foundation works and superstructure works - and an outline programme for the 2 x 350MW units is shown in Figure 4.1

4.02 Prior to the start of the construction, Coal Yard number 1 would be removed so that there is access to the site. It is planned that this would take place over a period of seven months, prior to the commencement of the main unit works.

Foundation Works

4.03 The foundation works would comprise essentially of piling. Driven steel pipe piles using conventional hydraulic piling hammers would be used, with work restricted to between 07.00 and 19.00 hours. The main piling activity is expected to occur over a period of 10 months, with a second phase being required for the c.w. intake/outfall construction.

Superstructure Works

4.04 The superstructure works for the main plant and FGD system would include: pile caps and ground beams, steelwork erection, floor construction and cladding.

4.05 Construction of a third chimney would be required to contain the flues from Units L7 and L8. This would primarily involve a concreting operation. Additional concreting work would be required for the c.w. culvert construction and pump pit.

Marine Construction Work

4.06 The main items of marine construction work specifically for L7 and L8 would be the No 3 c.w. intake and the c.w. outfall extensions for L7 and L8. At present, the designs for these are at the conceptual stage.

4.07 The inlet culverts for No. 3 intake would be incorporated in the ash lagoon bund on the south side during construction of the ash lagoon. The No 3 intake screen and pump chambers are likely to be located inland. This structure is likely to be of insitu reinforced concrete founded on piles, and constructed within a sheet pile cofferdam.

4.08 The c.w. outfall extension would be formed within a temporary earth bund with a rock armoured revetment on the seaward side: the form of the bund would be up to the Contractor, but an earth bund, as used for the present outfall construction is most probable since rock is near the surface and sheet piling inappropriate.

4.09 The outfall culverts would be insitu or precast reinforced concrete founded on a prepared bed on the rock sea bed. These would be covered with fill, filter layer and armour rock, as is the existing outfall. The only piles are likely to be for the spraying walkways on each side of the outfall (these are 1500mm diameter piles for the existing outfall). There may be some blasting of rock required for excavating from the outfall culverts.

4.10 The main environmental issues that need to be addressed with regard to the proposed construction activities are impacts arising from noise and dust. Issues arising from the transport of materials to the site are considered in Chapter 13 whilst the socio economics aspects of the construction are addressed in Chapter 12.

Construction Noise Control

4.11 The method of noise control and assessment in Hong Kong is through the Noise Control Ordinance administered by the Environmental Protection Department. The legislation groups construction activities into two categories: general construction work and percussive piling. Each of these categories is controlled by means of a system of Construction Noise Permits (CNP's).

General Construction Activity

4.12 In August 1989, legislation was enforced prohibiting the carrying out of general construction work using powered mechanical equipment between 7.00pm and 7.00am or at any time on a general holiday (including Sunday) unless a valid Construction Noise Permit is in force. An application for a permit must be made to the Noise Control Authority, in the prescribed form and accompanied by the prescribed fee. In order to grant an application, the Authority will assess the impact of the noise generated by the equipment at any Noise Sensitive Receiver (NSR) in the vicinity, in accordance with the assessment procedure contained in the Technical Memorandum on Noise from Construction Work other than Percussive Piling [1]. A NSR is defined as any domestic premises, hotel, hostel, temporary housing accommodation, hospital, medical clinic, educational institution, place of worship, library, court of law or performing arts centre. A Construction Noise Permit with appropriate conditions, will be issued if the Authority is satisfied that the noise which will be generated will be within the applicable Acceptable Noise Level (ANL). The ANL is calculated from the above mentioned Technical Memorandum but includes a Basic Noise Level (BNL), which is dependent upon the Area Sensitivity Rating (ASR) and time of day. This is then corrected for construction duration and number of permits in operation in the area.

Percussive Piling

4.13 Percussive Piling is prohibited between the hours of 7.00pm and 7.00am and on holidays unless specifically exempted by an order made by the Governor in Council. In addition to this, legislation was enforced in November 1989 prohibiting percussive piling during the daytime, except in accordance with a Construction Noise Permit. In considering such applications, the Authority will assess the impact of the noise generated by the activity at any NSR in accordance with the assessment procedure contained in the Technical Memorandum on Noise from Percussive Piling [2]. The method of assessment given in this document allows the determination of the permitted hours of operation for percussive piling. The Construction Noise Permit, when issued, may contain permitted hours of operation and other conditions where necessary.

Technical Memoranda - Methods of Assessment

Noise from Construction Work other than Percussive Piling

4.14 For the assessment of allowable noise limits for night-time and evening work, the following general procedures need to be followed:-

1. **Location of the Most Affected Noise Sensitive Receiver (NSR)**

   The NSR that will be most affected by noise from the construction works shall be identified. The definition given of an NSR is that detailed in Paragraph 4.12.

2. **Determination of the Area Sensitivity Rating (ASR)**

   This is a function of the type of area within which the NSR is located and can be determined from Table 4.1:

TABLE 4.1 : AREA SENSITIVITY RATINGS (ASR'S)

Degree to which NSR is affected by IF/ Type of Area Containing NSR	Not Affected	Indirectly Affected	Directly Affected
(i) Rural area, including country parks or village type developments	A	B	B
(ii) Low density residential area consisting of low-rise or isolated high-rise developments	A	B	C
(iii) Urban areas	B	C	C
(iv) Area other than those above	B	B	C

This table includes categories for area type and whether they are affected by other Influencing Factors (IF's). These are defined as industrial areas which consist of significant numbers of factories, areas next to major roads or areas within the boundary of HK International Airport.

3. **Determination of the Basic Noise Level (BNL)**

This level is determined using the ASR categorisation from Table 4.1 and by reference to Table 4.2.

TABLE 4.2 - BASIC NOISE LEVELS (BNL'S)

ASR/Time Period	A	B	C
All days during the evening (19.00 to 23.00 hours), and general holidays (including Sundays) during the daytime and evening (07.00 to 23.00 hours)	60	65	70
All days during the night-time (23.00 to 07.00 hours)	45	50	55

This table allows differentiation of allowable levels for the evening 19.00 to 23.00 hours and night-time, defined as 23.00 to 07.00 hours.

4. **Correction for Duration of the Construction Noise Permit (CNP)**

This correction is made if the CNP applied for is for a period of less than 14 days and basically allows a 3dB(A) addition to the BNL.

5. **Correction for Multiple Site Situations**

This allows a correction if multiple CNP's are operative and are affecting a NSR. The BNL is appropriately corrected by the Authority having regard to standard acoustical principles and practices.

6. **Determination of the Acceptable Noise Level**

The corrections applied in 4 and 5 to the BNL give the ANL for the NSR.

7. An assessment of site plant and activity is thus undertaken with reference to the activity areas and sound power levels of typical plant. This gives the Predicted Noise Level (PNL). These levels are corrected to the NSR's by distance, barriers and acoustic reflections. These corrections when applied to the PNL give the Corrected Noise Level (CNL) at the NSR's.

8. A Construction Noise Permit (CNP) is usually issued if the CNL at the NSR is equal to or less than the ANL. If the CNL is greater than the ANL then the CNP will not be issued unless a specific case under Section 3 of the Technical Memorandum can be shown.

4.15 Having assessed the elements of the CNL, it is considered that, as far as reasonably practicable this index can be directly related to the L_{Aeq} and, as such, this has been assumed in the calculation methodology. This assumption has also been made by the British Standards Committee for the revision of BS4142 where the CNL has been replaced by the L_{Aeq} index. The use of this index is also advocated in ISO 1996 [3].

Methodology

4.16 The methodology used in the assessment to predict the CNL at each NSR is based upon the calculation procedure detailed in British Standard 5228 Pt 1 1984 [4] and Ciria Report No. 64 [5]. This methodology has been incorporated into a computer programme which uses a grid reference, height A.O.D., plant type and months of operation input.

4.17 The calculation procedure uses the L_{Aeq} index and assumes a 12 hour working day which for the purposes of this report is assumed to be 07:00 -19:00 hrs.

4.18 The calculation procedure and methodology to produce the CNL at each NSR is as follows:

<u>L_{Aeq} Noise Index</u>

4.19 The L_{Aeq} noise level is the steady noise level that would provide, over the same time period, the same sound energy as the intermittent noise. The L_{Aeq} over the time period T is defined by the equation:

$$L_{Aeq} = 10 \times \log_{10} \frac{1}{T} \int_{t=0}^{t=T} \left[\frac{P_A(t)}{P_o}\right]^2 dt$$

where: L_{Aeq} = the equivalent continuous sound level in dB(A) over a time period T

$P_A(t)$ = the instantaneous A-weighted sound pressure level varying with time, t

Po = reference sound pressure level

4.20 The usual unit of L_{Aeq} assessment is the hourly or 12 hourly L_{Aeq} level, i.e. the logarithmically averaged noise level over 12 hours. If the noise only lasts for T hours, i.e., the work stops for a break, the new L_{Aeq} becomes:

12 hour L_{Aeq} = L_{Aeq} (for the activity) + 10 $\log_{10}$ (T/12)

If the noise only lasts for half the time, then the new

12 hour L_{Aeq} = L_{Aeq} (for the activity) + 10 $\log_{10}$ 0.5

= L_{Aeq} (for the activity) - 3dB(A)

For a number of sources (Q) the L_{Aeq} = L_{Aeq} (for a single source) + 10 $\log_{10}$ Q.

Construction Noise Calculations

4.21 To determine the noise levels generated from a construction site, consideration must be given to the type of plant and working periods most likely to be used in a particular area. There are primarily two distinct types of construction equipment namely, static plant and moving plant.

Point or Moving Point Plant

4.22 Noise levels can be measured by activity. For example, if a backacter is being used, the activity L_{Aeq} noise level is that level measured at 10m from where it is being used. This automatically takes into account the variation of work rate or loading during a normal operation. Activity L_{Aeq} noise levels for various types of construction plant are given in the Technical Memoranda, CIRIA Report No. 64 and BS 5228: Part 1. This type of plant can be either static in one location or moving along a restricted fixed path along which noise levels are averaged.

4.23 If the activity L_{Aeq} is not known then noise measurements need to be taken. Due to the variation in the type, condition and age of the construction plant a number of measurements should be taken to determine a level that is representative. The levels and the type of plant used in this assessment are shown in Table 4.3.

4.24 The attenuation of noise from static plant can be readily calculated using the inverse square law, i.e.

L_{Aeqd} = Activity L_{Aeq} - 20 $\log_{10}$ (d′/10)

where L_{Aeqd} = L_{Aeq} at distance d′

d′ = slant distance

4.25 In addition to the distance attenuation, there will also be attenuation due to barriers or grassland (soft ground). For a point source, the attenuation due to a barrier is different from that for a line source (i.e. road traffic noise). The grassland attenuation for line sources is given in "Calculation of Road Traffic Noise" (HMSO, 1988) [6]. There is no information on grassland attenuation for point sources. In this assessment, it has therefore been assumed that grassland attenuation is the same for both types of source, i.e

$$5.2 \log_{10} \left[\frac{3h}{(d' + 3.5)} \right]$$

where h = mean propagation height
d′ = minimum slant distance between source and receiver

However, although this soft ground option is available, for this assessment only hard ground has been used. This not only gives a worst case assessment, but is also more applicable to the terrain in the vicinity of the site.

4.26 The method of calculating the construction noise for the point or moving point source was to estimate, for any one month, the sources operating on the site. The L_{Aeq} for each source was then determined and adjusted for:

1) duration of operation, e.g. for 8 hours of working subtract $10 \log_{10} (8/12) = 1.8dB(A)$

2) distance attenuation to the point of interest, $20 \log_{10} (d'/10)$

3) grassland or barrier attenuation

Moving Plant

4.27 In an urban area where construction is near housing, noise from a vehicle visiting the site or other moving vehicles will be difficult to evaluate using the point source equation. The L_{Aeq} equation can be modified to provide information on the L_{Aeq} noise level of sources moving along the formation of the road. The modified equation is:

$$L_{Aeq} = SPL - 33 + 10 \times \log_{10} \left[\frac{Q}{Vd'}\right]$$

Q = flow in vehicles/hour for hourly L_{Aeq} or flow in vehicles per day divided by 12 for daily L_{Aeq}

v = speed in km/hour

d′ = slant distance from centre-line of road

SPL = Sound Power Level

4.28 If only a small part of the road can be seen, a further correction of $10 \log_{10} (\Theta/180)$ is made to the noise level, where Θ = the angle of view of the segment of the road.

4.29 The major use for this formulation lies in calculating the L_{Aeq} levels from haul routes and cut and fill operations. This equation has in it a correction for distance attenuation. In addition to this attenuation, there will also be the attenuations for grassland and barriers described earlier.

4.30 If a roller vibrator, say, is compacting an area, or some other slow moving equipment is being used, then the noise can be calculated by taking its mean speed and the distance over which it travels, then assessing the number of times it passes backwards and forwards during the day and substituting this flow and speed into the formulae.

Other Corrections

4.31 With a large construction project the noise will change from hour to hour, day to day and month to month. The hourly variation can be taken into account by using the 12 hour L_{Aeq} level. By estimating the monthly noise levels, the monthly variation can also be evaluated. A difficulty occurs when there is a large variation in noise from day to day.

Method of Calculating L_{Aeq}'s

4.32 The computer program, LEQ, has been used for calculating the construction noise for both point and moving plant, incorporating the methods described in BS5228 and CIRIA Report No. 64.

4.33 The input for the program is in three main parts. Firstly, noise from point plant, which requires inputs for the location of the source, the activity L_{Aeq} and the assumed months of operation. This input data is listed in Table 4.3 and 4.4. Secondly noise from moving plant, which requires information on the sound power level, speed, flow, height of source and the assumed months of operation. The final part is the data relating to the location of the receiver, which includes distance from the construction site and information on the intervening topography.

4.34 Depending on the input data, the program gives either the L_{Aeq} noise levels month by month for the assumed duration of the work or the maximum noise levels expected for any one time period (for example daytime 07.00-19.00 hours, evening 19.00-23.00 hours or night-time 23.00-07.00 hours).

Method of Assessing Maximum Noise Levels from Percussive Piling

4.35 The Technical Memorandum on Noise from Percussive Piling gives a methodology for calculating noise from this plant, but only up to a distance of 300m. Beyond this distance, attenuation shall be calculated "having regard to standard acoustical principles and practices". The noise from piling has therefore been assessed in two ways. Firstly, to produce an L_{Aeq} level as given in Tables 4.7 and 4.9 and secondly to produce a maximum noise level. The method to calculate the maximum noise levels was to take the impulsive sound power level of a piling rig. This figure was then corrected to a 10m sound pressure level which was then corrected to the NSR position by using the formula:

SPL at NSR = SPL at 10m - 20 log (d′/10)

where d′ is distance to the NSR

This figure was then corrected for the number of operational rigs and a reflective facade.

TABLE 4.3 : PLANT USED IN THE ASSESSMENT WITH ASSOCIATED NOISE LEVELS

Moving Plant	Sound Power Level dB(A)	Height of Source (m)	Speed (kph)	Quantity
Concrete Trucks	109	1.5	15	6
Cement Carrier	109	1.5	25	2
Derrick Truck	108	2.0	25	4
Dump Trucks	117	2.0	30	8
Vibratory Roller	108	2.0	15	2
Water Truck	108	1.5	30	2

TABLE 4.3 (CONT'D) : PLANT USED IN THE ASSESSMENT WITH ASSOCIATED NOISE LEVELS

Static Plant	Sound Power Level dB(A)	L_{Aeq} @ 10m dB(A)	Height of Source (m)	Quantity
Piler	132	104	7.0	10
Concrete Batching Plant	108	80	5.0	2
Concrete Pump	109	81	1.8	1
225t Crane	112	84	3.0	1
100t Crane	112	84	3.0	1
40t Crane	112	84	3.0	2
25t Crane	111	83	2.0	1
35t Crane	110	82	3.0	1
Loader	113	85	1.5	3
Back Hoe	113	85	1.5	6
Ground Breaker	122	94	2.0	1
Generator	108	80	1.0	3
Air Compressor	109	81	1.5	10
Water Pump	103	75	1.0	8
Percussion Drill	103	75	1.5	5
Grouting Pump	108	80	1.0	6
Derrick Barge	104	76	2.0	1
Dredger	118	90	3.0	1
TugBoat	110	82	2.0	1
Bulldozer	115	87	2.0	1

Assumptions

Construction Programme

4.36 The timing and duration of the construction programme was supplied by HEC and is shown in Figure 4.1. This details the start and end months of the various proposed works.

Construction Plant

4.37 The type, quantities and months of operation of all the proposed plant to be used on site have been estimated from data supplied by HEC. The noise levels for the plant have not been supplied and have therefore been obtained from information included in the Technical Memoranda, BS5228 and CIRIA Report No. 64.

Noise Propagation

4.38 The propagation of noise from source to receiver has been assessed as being over hard ground. This gives both a worst case assessment and is considered to be slightly more suited to undulating ground, which results in high level (altitude) noise paths, which would normally exclude any ground attenuation.

NSR's

4.39 15 NSR's have been coded in for the area to the north and east of the power station. The noise levels calculated at these sites are facade levels for the first floor. This again gives a worst case assessment and is applicable for evening/night-time operation. The assumed ANL's for the 15 sites for Noise from Construction Work other than Percussive Piling are shown on Table 4.4. The locations of the NSR's referred to are shown on Figure 4.2.

TABLE 4.4 : ANL'S FROM WORK OTHER THAN PERCUSSIVE PILING

BNL = ANL (No Corrections Under Steps 4 or 5 of Technical Memorandum)

Site No.	IF Classification	ASR	Evening 19.00-23.00	Night-Time 23.00-07.00
1	NA	A	60	45
2	NA	A	60	45
3	NA	A	60	45
4	NA	A	60	45
5	NA	A	60	45
6	NA	A	60	45
7	NA	A	60	45
8	NA	A	60	45
9	NA	A	60	45
10	NA	A	60	45
11	NA	A	60	45
12	NA	A	60	45
13	NA	A	60	45
14	NA	A	60	45
15	NA	A	60	45

ANL = Acceptable Noise Limit
BNL = Basic Noise Level
ASR = Area Sensitivity Rating
IF = Influencing Factor
ID = Indirectly Affected
D = Directly Affected
NA = Not Affected

4.40 The ANL's for noise from percussive piling from these sites have been extracted from the Technical Memorandum and are detailed in Table 4.5. An ANL of 85dB(A) has been assumed for all 15 sites. This assumes NSR's with windows or other openings, but without central air conditioning. A further 10dB(A) would need to be subtracted from these levels if it is known that they are hospitals, medical clinics, educational institutions, courts of law or other "sensitive" NSR's. However, this does not apply to the current assessment. Permitted hours of operation for different levels of exceedence are shown in Table 4.6.

TABLE 4.5 : ACCEPTABLE NOISE LEVELS (ANL'S) FROM PERCUSSIVE PILING

NSR Window Type or Means of Ventilation	ANL (dB(A))
(i) NSR (or part of NSR) with no windows or other openings	100
(ii) NSR with central air conditioning system	90
(iii) NSR with windows or other openings but without central air conditioning system	85

Note : 10dB(A) shall be subtracted from the ANL's shown above for NSR's which are hospitals, medical clinics, educational institutions, courts of law or other NSR's which are considered by the Authority to be particularly sensitive to noise.

TABLE 4.6 : PERMITTED HOURS OF OPERATION

Amount By Which CNL Exceeds ANL	Permitted Hours of Operation on Any Day not being a General Holiday
More than 10dB(A)	08.00 to 09.00 AND 12.30 to 13.30 AND 17.00 to 18.00
Between 1dB(A) and 10dB(A)	08.00 to 09.30 AND 12.00 to 14.00 AND 16.30 to 18.00
No Exceedence	7.00 to 19.00

General Assumptions

4.41 Any assessment of this type is limited by the base data provided, and it is the accuracy of this data which obviously governs the accuracy of the final noise level assessed for each site. Due to the inherent variability of construction works, day to day, week to week, the calculated noise levels can never be more than indicative of the extent of noise impact. The noise levels calculated therefore provide an indicator of the times and construction activity which may give rise to complaint or may exceed the limiting criteria. Any assessment of this type and at this stage in the project should therefore be viewed with caution as, at best, it can only provide an indication of impact.

Discussion

4.42 To assess the impact from the proposed construction activities three scenarios have been examined which would correspond as closely as possible to daytime, classed as 07.00-19.00 hours, evening, classed as 19.00-23.00 hours and night-time, classed as 23.00-07.00 hours. The legislation governing times or periods of operation is described in section 4.13-4.14. However, there is basically no restriction on daytime activity except for piling, which from the above assessment, should be limited to a maximum noise level below 85dB(A), and which is only allowed between the hours of 07:00 and 19:00 hours. The evening and night-time periods are governed by Acceptable Noise Levels as defined in the Technical Memorandum on Noise from Construction Work other than Percussive Piling. From examination of the Technical Memorandum, the ANL's have been assessed to be 65dB(A) during the evening and 50dB(A) at night. However, EPD have specified that, for the purposes of this IAR, the ANL's for the power station should be 60dB(A) for the evening and 45dB(A) at night. This has therefore been used for the assessment.

4.43 The three scenarios that have been run are therefore daytime activity including piling, evening/night-time activity excluding piling and piling alone. The results are shown respectively as Tables 4.7, 4.8 and 4.9. The tables give average monthly L_{Aeq} figures over the working period day/night and commence at month 1. The first month is in fact equal to seven months and provides an assessment of the noise impact of moving Coal Yard No. 1. The main unit L7 and L8 construction activities commence from month 1 and end in month 36.

Daytime Working

4.44 Table 4.7 shows the variation in noise levels during typical daytime operation which includes piling. It can be seen from this table and from Table 4.9, which shows the contribution of piling alone, that the piling operation does not exceed even the lowest assessed ANL at the nearest NSR. Maximum assessed L_{Aeq} levels are 76dB(A) at site 7 for some 5 months. It is clear from this assessment that noise levels at nearly all the NSR sites (excluding 7 and 8) are relatively low due to the shielding effects of the mountain at the rear of the site.

4.45 The assessment undertaken (including piling) has been calculated using the methodology explained and produces an L_{Aeq} level as shown in Tables 4.7 and 4.9. The Technical Memorandum on Noise From Percussive Piling requires the assessment of the maximum levels to the NSR's. This requires a different method of calculation as given in Paragraph 4.35 of the methodology section.

4.46 It is considered that sites 7 and 8 are in the area most likely to be affected by high noise levels from piling activity. Piling noise has therefore been assessed at these sites as these are the worst affected case areas and are likely to exhibit the highest impact. It is probable that 10 piling rigs will be on site at any one time of which at least 2 are likely to be down for repair. This means 8 operational although it is unlikely that more than 4 rigs will be striking at any one time. With these assumptions, and using the method outlined in Paragraph 4.35, the maximum predicted noise level at NSR No. 7 is unlikely to exceed 80dB(A). A level of 79dB(A) is unlikely to be exceeded at NSR No. 8. Levels at all other sites will be significantly lower due to the barrier attenuation.

4.47 When the CNL's of 80dB(A) at site 7 and 79dB(A) at site 8 are compared with the ANL of 85dB(A) assessed for these sites, it is clear that no exceedence occurs. Therefore, from Table 4.6 and assuming an ANL of 85dB(A), the permitted hours of operation would be 07.00 to 19.00.

Evening Working

4.48 Table 4.8 shows the effect of all the other plant activity except piling which may be expected to be carried on overnight, subject to the ANL in the CNP. This table indicates that this level of full activity is acceptable at all NSR's to the North of the power station during the evening period 19.00-23.00 hours when an ANL of 60dB(A) has been assumed. However, the table also indicates that levels up to 63dB(A) would occur during this period at the two NSR's to the East of the power station, some 3dB(A) above the maximum allowable. It should be possible to reduce these levels by localised screening of plant, and this could be examined further when more details of the construction programme are known.

Night-Time Working

4.49 Although the assessment shows that levels generated during the evening period are acceptable with an ANL of 60dB(A), the effects of night-time working are more prohibitive. This is due to the ANL over this period which is 15dB(A) lower than for the evening period, i.e. at a level of 45dB(A). With calculated levels of 63dB(A) an exceedence of 18dB(A) is indicated above the night-time ANL. This level of exceedence would probably generate complaints and indeed it is unlikely that a CNP would be issued.

TABLE 4.7 : CALCULATED NOISE LEVELS FOR CONSTRUCTION PROGRAMME, DAYTIME ACTIVITY INCLUDING PILING (dB(A))

AVERAGE MONTHLY LEVELS - SUMMARY TABLE OF RESULTS

	Site No. (See Figure 4.2)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coal Yard Movement	39	36	34	40	36	43	56	56	47	32	36	32	30	30	29
Operational Months															
1	47	46	45	44	46	44	68	67	62	43	45	43	42	41	43
2	47	46	45	44	46	44	68	68	62	43	45	43	42	41	43
3	47	46	45	44	46	44	68	68	62	43	45	43	42	41	43
4	47	46	45	44	46	44	68	68	62	43	45	43	42	41	43
5	57	54	60	53	54	52	76	75	67	51	51	52	50	49	50
6	57	54	60	53	54	52	76	75	67	51	51	52	50	49	50
7	57	54	60	53	54	52	76	75	67	51	51	52	50	49	50
8	57	54	60	53	54	52	76	75	67	51	51	52	50	49	50
9	57	55	60	53	55	52	76	75	67	51	51	52	50	49	50
10	56	54	60	52	55	52	75	75	66	51	50	51	50	49	49
11	56	54	60	52	55	52	75	75	66	51	50	51	50	49	50
12	56	54	60	53	55	52	75	75	66	51	51	51	50	49	50
13	56	54	60	52	54	52	75	75	66	51	50	51	50	49	50
14	51	49	48	48	60	48	72	71	69	56	59	46	45	54	44
15	51	49	48	48	60	48	72	71	69	56	59	46	52	54	50
16	51	49	48	48	60	48	72	71	69	56	59	46	52	54	50
17	44	42	42	41	46	40	63	63	55	43	46	39	51	41	50
18	44	42	42	41	46	41	63	63	55	43	46	40	56	41	55
19	44	42	42	41	46	40	63	63	55	43	46	39	56	41	55
20	44	42	42	41	45	40	63	63	54	42	45	39	56	40	55
21	44	42	42	40	45	40	63	63	54	42	45	39	55	40	54
22	43	41	41	40	45	39	63	62	54	42	45	38	49	39	48
23	43	41	41	40	45	39	63	62	54	42	45	38	49	39	47
24	41	39	40	38	44	38	61	61	54	41	44	37	50	39	49
25	41	39	40	38	43	37	61	60	52	40	44	36	49	37	49
26	40	38	39	37	43	37	60	60	52	40	43	36	46	37	45
27	40	38	39	37	43	37	60	60	52	40	43	36	47	37	46
28	40	38	39	37	43	37	60	60	52	40	43	35	47	37	46
29	40	38	39	37	43	37	60	59	52	40	43	35	47	37	46
30	40	37	38	36	42	36	59	59	52	39	43	35	42	36	41
31	39	37	38	36	42	36	59	58	52	39	43	34	35	36	34
32	39	37	38	36	41	35	59	58	52	39	43	34	32	36	32
33	39	37	38	36	41	35	59	58	52	39	43	34	32	36	32
34	39	37	38	36	41	35	59	58	52	39	43	34	32	36	32
35	31	29	28	29	40	31	53	53	51	37	42	26	25	34	24
36	31	29	28	29	40	31	53	53	51	37	42	26	25	34	24

TABLE 4.8 : CALCULATED NOISE LEVELS FOR EVENING/NIGHTTIME ACTIVITY EXCLUDING PILING (dB(A))

AVERAGE MONTHLY LEVELS - SUMMARY TABLE OF RESULTS

	Site No. (See Figure 4.2)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coal Yard Movement	39	36	34	40	36	43	56	56	47	32	36	32	30	30	29
Operational Months															
1	36	33	36	32	34	32	55	55	47	34	40	30	29	29	28
2	36	34	36	32	34	32	56	55	47	34	40	31	29	29	29
3	36	34	36	32	34	32	56	55	47	34	40	31	29	29	29
4	36	34	36	32	34	32	56	55	47	34	40	31	29	29	29
5	41	39	40	38	39	37	61	60	49	37	41	36	34	34	34
6	41	39	40	38	39	37	61	60	49	38	41	36	35	34	34
7	41	39	40	38	39	37	61	60	49	38	41	36	35	34	34
8	41	39	40	38	39	37	61	60	49	38	41	36	35	34	34
9	44	42	42	40	49	39	62	62	49	39	42	39	39	36	38
10	44	42	42	40	49	40	62	62	49	40	42	39	39	37	38
11	44	42	42	41	49	40	62	62	49	40	42	39	39	37	38
12	45	43	43	41	49	40	62	63	49	40	43	40	40	38	39
13	44	42	42	40	45	40	62	62	49	40	42	39	39	37	38
14	44	42	42	41	47	40	63	63	55	43	46	40	41	41	40
15	45	43	43	41	47	41	63	63	55	43	46	40	51	41	49
16	44	42	42	41	46	40	63	63	55	43	46	39	51	41	49
17	44	42	42	41	46	40	63	63	55	43	46	39	51	41	50
18	44	42	42	41	46	41	63	63	55	43	46	40	56	41	55
19	44	42	42	41	46	40	63	63	55	43	46	39	56	41	55
20	44	42	42	41	45	40	63	63	54	42	45	39	56	40	55
21	44	42	42	40	45	40	63	63	54	42	45	39	55	40	54
22	43	41	41	40	45	39	63	62	54	42	45	38	49	39	48
23	43	41	41	40	45	39	63	62	54	42	45	38	49	39	47
24	41	39	40	38	44	38	61	61	54	41	44	37	50	39	49
25	41	39	40	38	43	37	61	60	52	40	44	36	49	37	49
26	40	38	39	37	43	37	60	60	52	40	43	36	46	37	45
27	40	38	39	37	43	37	60	60	52	40	43	36	47	37	46
28	40	38	39	37	43	37	60	60	52	40	43	35	47	37	46
29	40	38	39	37	43	37	60	59	52	40	43	35	47	37	46
30	40	37	38	36	42	36	59	59	52	39	43	35	42	36	41
31	39	37	38	36	42	36	59	58	52	39	43	34	35	36	34
32	39	37	38	36	41	35	59	58	52	39	43	34	32	36	32
33	39	37	38	36	41	35	59	58	52	39	43	34	32	36	32
34	39	37	38	36	41	35	59	58	52	39	43	34	32	36	32
35	31	29	28	29	40	31	53	53	51	37	42	26	25	34	24
36	31	29	28	29	40	31	53	53	51	37	42	26	25	34	24

TABLE 4.9 : CALCULATED NOISE LEVELS FOR PILING ACTIVITY ONLY (dB(A))

AVERAGE MONTHLY - SUMMARY TABLE OF RESULTS

Operational Months	Site No. (See Figure 4.2) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	47	45	44	44	46	44	68	67	62	43	43	43	42	41	43
2	47	45	44	44	46	44	68	67	62	43	43	43	42	41	43
3	47	45	44	44	46	44	68	67	62	43	43	43	42	41	43
4	47	45	44	44	46	44	68	67	62	43	43	43	42	41	43
5	56	54	60	53	54	52	76	75	67	51	51	52	50	49	50
6	56	54	60	53	54	52	76	75	67	51	51	52	50	49	50
7	56	54	60	53	54	52	76	75	67	51	51	52	50	49	50
8	56	54	60	53	54	52	76	75	67	51	51	52	50	49	50
9	56	54	60	53	54	52	76	75	67	51	51	52	50	49	50
10	56	54	60	52	53	51	75	74	65	50	50	51	49	48	49
11	56	54	60	52	53	51	75	74	65	50	50	51	49	48	49
12	56	54	60	52	53	51	75	74	65	50	50	51	49	48	49
13	56	54	60	52	53	51	75	74	65	50	50	51	49	48	49
14	49	48	46	47	60	48	71	71	69	56	59	45	43	54	42
15	49	48	46	47	60	48	71	71	69	56	59	45	43	54	42
16	49	48	46	47	60	48	71	71	69	56	59	45	43	54	42
17	49	48	46	47	60	48	71	71	69	56	59	45	43	54	42

4.50 The assessment has shown that there may be a problem with night-time working at sites to the east of the power station where no barrier attenuation occurs due to the topography. However, as most of this exceedence is due to heavy plant such as back hoes, bulldozers and loaders, noise levels could be maintained at a level lower than the ANL if this plant was restricted to working only daytime and evening hours. This exceedence is also due to a high level of activity in the second year of the project when most of the construction activities are occurring at the same time.

Dust Control

4.51 As the site for the proposed development of Units L7 and L8 is already formed, one of the major potential sources of dust - site formation - will not arise. The principal remaining sources of dust that need to be considered are:

1. Movement of vehicles over unsurfaced temporary roadways;
2. Concrete mixing/batching operations;
3. Piling;
4. Materials handling;
5. Stockpiling of sands, gravel, etc;
6. Relocation of the Coal Yard No. 1

4.52 Because of the long term nature of the development programme that has taken place at the power station site, there is extensive experience of the measures needed to control dust from these construction activities. Observations of the current construction activities associated with Unit L6 have confirmed that dust nuisance is not a significant factor. This is confirmed by a review of dust concentration and deposition data (cf Chapter 5) which show no significant increase following the commencement of construction activities associated with Unit L6.

4.53 Nonetheless, it is important that the procedures to be used during construction are thoroughly reviewed at the appropriate time and the necessary precautions included in Contractors contracts where necessary.

4.54 One of the main potential sources of dust from construction activity is the movement of construction vehicles over unsurfaced roadways. The emissions of dust from this source are dependent upon various factors, such as the nature of the surface of the roadway (particularly the silt fraction); the speed of vehicles and the moisture content. The moisture content is particularly important and is most amenable to effective control.

4.55 The particle size of dust released from construction activity is variable, depending upon the nature of activities occurring at any one time, and the stockpiling of materials etc.

4.56 From an evaluation of the particle size fraction of dust in Hong Kong, some 60-70% is considered to be respirable, (i.e. <10μm) with the rest being larger [10]. The size of dust particles, and their aerodynamic properties affect their ability to travel from their point of origin and their rate of settling.

Dust Definitions

4.57 "Dust" is a generic term used to describe a wide range of particulate materials which result from the disintegration of solids. The size of the particles is generally in the range 1-100μm (1μm = 1 micrometre = 10^{-6} metre). The particles size is important because it determines the settling velocity of the dust, i.e. the speed at which particles fall to ground level, and hence the length of time for which the particle remains airborne. Typical settling velocities for various particle sizes with a density of 1g cm^{-3} are given below [8].

Particle Diameter (μm)	Settling Velocity ($msec^{-1}$)
0.1	1.2×10^{-6}
1.0	1.2×10^{-4}
10	1.2×10^{-2}
100	1.2

4.58 In order to assess potential for a dust problem to be caused during any activity, there is a need to consider both the likely particle size of material encountered and the effects of wind dispersion. A range of particles sizes for materials is given below for purposes of comparison:

Substance	Diameter (μm)
Clay Particles	<2
Silt Particles	2-20
Fine Sand	20-200
Coarse Sand	200-2000

4.59 Studies of wind action on a range of particle sizes show that the pick-up velocity (i.e. the air speed at which materials become airborne) ranges from $3ms^{-1}$ to $7ms^{-1}$ for dry particles between 10μm-105μm depending on their mass. However, wind may raise dust, but not always keep particles airborne. Higher velocities are needed to mobilise damp or wet particles. Once airborne, dust particles will disperse in a similar manner to gaseous pollutants, forming a plume that increases in size with distance from the point of emission. Therefore, if the dust is emitted at or just above ground level, the highest ground level dust concentrations will be found near the emission source and concentrations will decrease further from the point of emission.

4.60 The environmental effects of particles depends on their deposition rate and their concentration. Deposition rate is expressed in terms of mass per unit area per unit time, e.g. $mg.m^{-2}.d^{-1}$. Concentration is expressed in terms of mass per unit volume, e.g. $\mu g.m^{-3}$.

4.61 Deposition of dust onto building surfaces or fabric can cause soiling and be a source of nuisance, depending on the quantity of dust fall and its nature. Levels of dust deposition vary widely from place to place and are influenced by a large variety of sources.

4.62 High concentrations of airborne dust can be of concern from a health protection perspective, particularly if they occur in combination with other pollutants such as sulphur dioxide. Various criteria have been established internationally to protect the general public from exposure to excessive airborne dust levels.

4.63 High dust concentrations can also be a problem if they affect sensitive operations such as those requiring 'clean' conditions. In such situations, external air may require filtering to ensure it is of sufficient quality for the process.

4.64 Various mathematical models are available to estimate possible dust concentration from construction activities. However, these models require a number of assumptions to be made concerning such matters as the number of vehicle movements over unsurfaced roadways, stockpile heights, materials handling procedures, etc. At this stage, it is not possible to accurately predict such factors and it is therefore not considered that quantitative modelling would be useful in assessing possible impacts. The analysis has therefore been confined to a qualitative evaluation.

4.65 As noted in Paragraph 4.51, movement of vehicles over temporary roadways represents the single largest construction dust emission source. This will therefore require to be controlled by application of water sprays. Such control techniques are already in use at the Lamma Power Station site and have been found to be very effective. However, the frequency of water spraying does require to be regulated, in accordance with climatic conditions. In the summer months, the high ambient temperatures can result in surface drying within a very short period of water spray application and, depending upon the area of the site in question, water spraying may be needed on a semi continuous basis. During the winter, the lower rainfall means that natural damping down of surfaces needs to be frequently supplemented.

4.66 In view of the climatic variations, spraying of roadway surfaces needs to be effectively managed and this is best ensured by appropriate conditions applying to Contractors contracts.

4.67 Relocation of the coal stockyard will require special consideration as this could potentially cause dust emission. Depending upon the prevailing climatic conditions, it will probably be necessary to damp down surfaces prior to use of mobile plant. It should be noted that the coal yards are fitted with water spray systems for dust control purposes and their use should provide adequate mitigation during removal of Coal Yard No. 1. However, movement of coal during high wind conditions will need to be avoided.

4.68 Other mitigation measures which will be required for dust suppression during coal pile relocation include the minimisation of drop heights of coal to as low as practical, and the use of only vehicles with vertically directed exhausts.

4.69 With regard to stockpiling of aggregate, etc, the siting of such stockpiles will need to be based upon operational, as well as environmental requirements. However, as a general measure, it is recommended that any stockpiles are screened on at least 3 sides to prevent fugitive dust. In addition, water sprays should be provided and used as necessary. Appropriate controls will be needed during materials handling.

4.70 Concrete batching also requires careful control. For dry mix batching, the process should be carried out in enclosed conditions, with exhaust air passing through a suitable filter before discharge to atmosphere. Cement silos should also be fitted with filters.

4.71 Finally, pile driving in dry conditions could be a minor source of dust. The need for any mitigation measures, such as water spraying, will need to be considered at the time of construction work and should be covered by appropriate dust control clauses in Contractors Contracts.

(b) Decommissioning

4.72 Decommissioning of the proposed L7 and L8 extension will not take place for at least 20 years. It is likely that development of Hong Kong generally, and possibly Lamma itself will create major differences to the existing land uses. As a consequence, it is not considered that a detailed evaluation of possible environmental impact, with current land use as a basis, would be realistic. However, it is possible to consider possible impacts in a general manner.

4.73 One of the key factors that is likely to require consideration at the decommissioning phase, is the presence of asbestos and its eventual disposal.

4.74 The only asbestos products currently installed at Lamma Power Station are compressed asbestos gaskets and packing. These have been used as there is not, as yet, any suitable alternative materials. The ultimate goal is to replace all asbestos with alternative materials in due course. Realistically, however, it is unlikely that asbestos could be eliminated completely from the power station and provision will need to be made for disposal after decommissioning.

4.75 HEC estimate that the total quantity of material containing asbestos requiring removal at decommissioning would be of the order of 1 tonne per coal fired generating unit and less than 1 tonne for all the gas turbine plants. These are upper estimates of the total material contaminated with asbestos and the actual asbestos quantities would therefore be very much less.

4.76 Removal and disposal of any asbestos waste would need to be carried out in accordance with the Environmental Protection Departments Code of Practice [9], or such other regulation that may be in force at the time. In addition, effective supervision of stripping and disposal operations by HEC will be needed to ensure compliance with relevant codes.

4.77 From a review of current EPD requirements, and international practice, the following precautions will be required to be taken.

4.78 The EPD Code of Practice identifies three different types of waste viz Types 1, 2 and 3. Type 1 waste includes material likely to release asbestos fibres. Within this category are listed such products as asbestos reinforced jointings, packings and gaskets.

4.79 Type 2 waste comprises any waste containing loose asbestos fibres, for example asbestos lagging, cement, floor sweeping, etc. Type 3 waste is all blue (crocidolite) and brown (amosite) asbestos.

4.80 Because of the different degrees of hazard associated with the different categories of waste, different methods of disposal are prescribed in the Code of Practice. Type 1 waste does not require to be packaged before disposal although it does require to be separately transported to the disposal site. Type 2 and 3 waste require to be packaged in double thickness bags, or other approved container and properly identified.

4.81 In accordance with the Code, HEC adopt the above precautions as standard practice. All waste asbestos is packaged into steel drums and stored until sufficient quantities have accumulated for dumping. Drums are then transported to a controlled dump site, following approval from the Waste Management Planning Division of EPD.

4.82 In addition to the specific precautions envisaged for asbestos removal/disposal, it will be necessary to review any particular environmental controls with respect to noise and dust suppression which may be required by virtue of the surrounding land use at the time.

Summary and Conclusions

4.83 Construction of the proposed L7 and L8 extension will occur over a period of approximately 70 months. During this period a variety of activities will take place including piling; excavating and concreting. To minimise nuisance to neighbouring areas, certain mitigation measures will be required.

4.84 Calculations of noise from construction activity have been undertaken for the duration of the major activities. These indicate likely levels for the daytime and evening/night-time periods. Comparisons of these calculated levels with the ANL indicate that exceedence may occur over the evening and night-time periods due to the lower ANL's. These exceedences can be prevented by restricting the use of large mobile plant at night and possibly by localised screening of plant during the evening. Comparison of the worst case CNL's and maximum levels from piling with the ANL at the most affected NSR's, indicates that there should not be any requirement to limit daytime piling activity.

4.85 There are a variety of potential dust sources associated with construction activity. In the case of the proposed extension the two principal areas of concern have been identified as the movement of construction traffic over unsurfaced roadways and the relocation of the Coal Yard No. 1.

4.86 To prevent any possibility of dust nuisance arising, appropriate mitigation measures will be required on the site. These include the application of water sprays to stockpiles in dry weather and the use of water sprays to unsurfaced roads at regular intervals. These measures should prove effective in minimising dust impacts, but will require contractual conditions, and periodic auditing to ensure compliance. It is therefore recommended that such contractual conditions and supervision procedures are developed in accordance with EPD requirements.

REFERENCES

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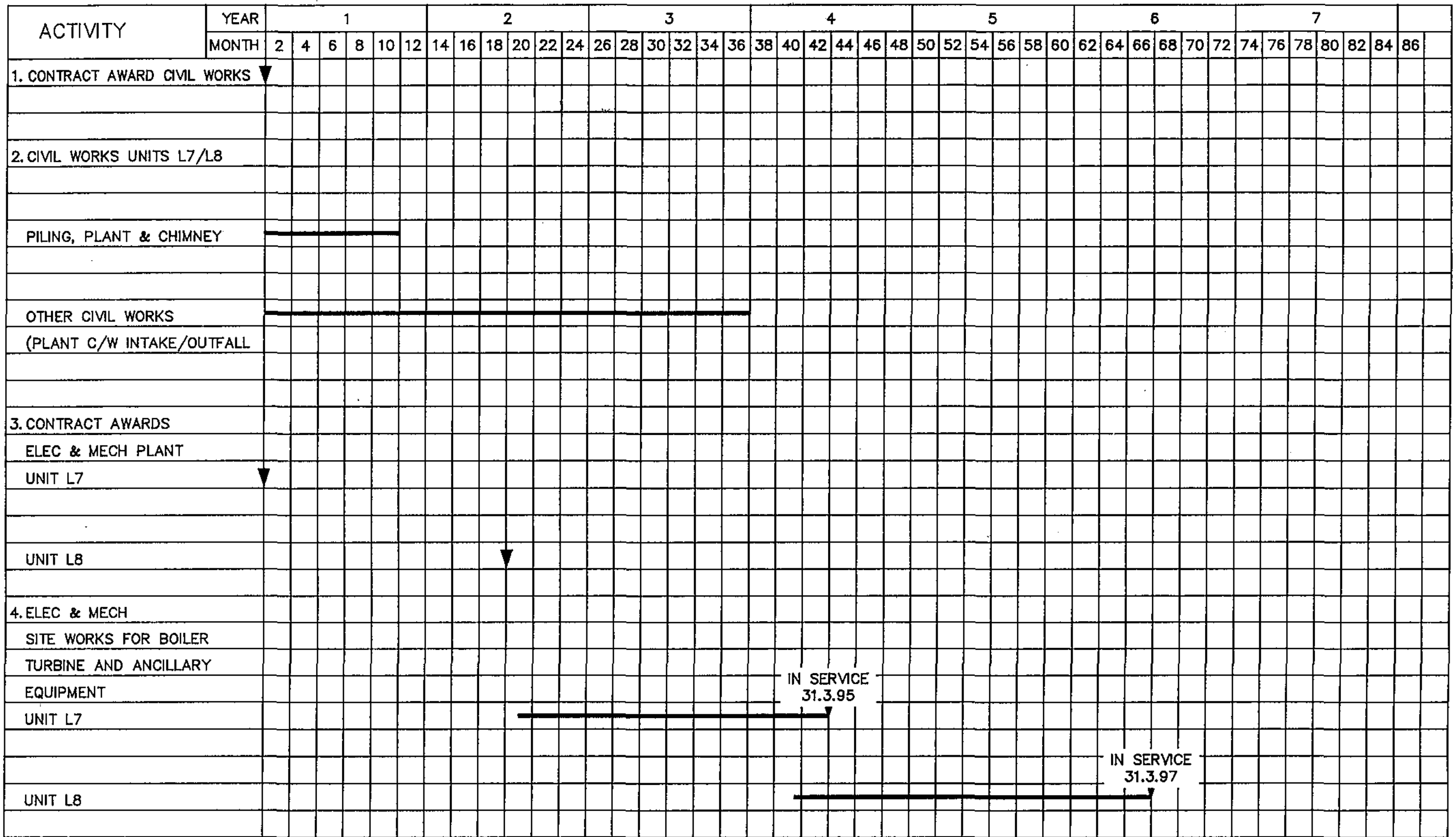

The Hongkong Electric Company Limited

PROJECT:

EIA LAMMA
POWER STATION

TITLE:
OUTLINE CIVIL WORKS & PLANT ERECTION PROGRAMME FOR UNITS 7 & 8 – 350MW

FIGURE: 4.1

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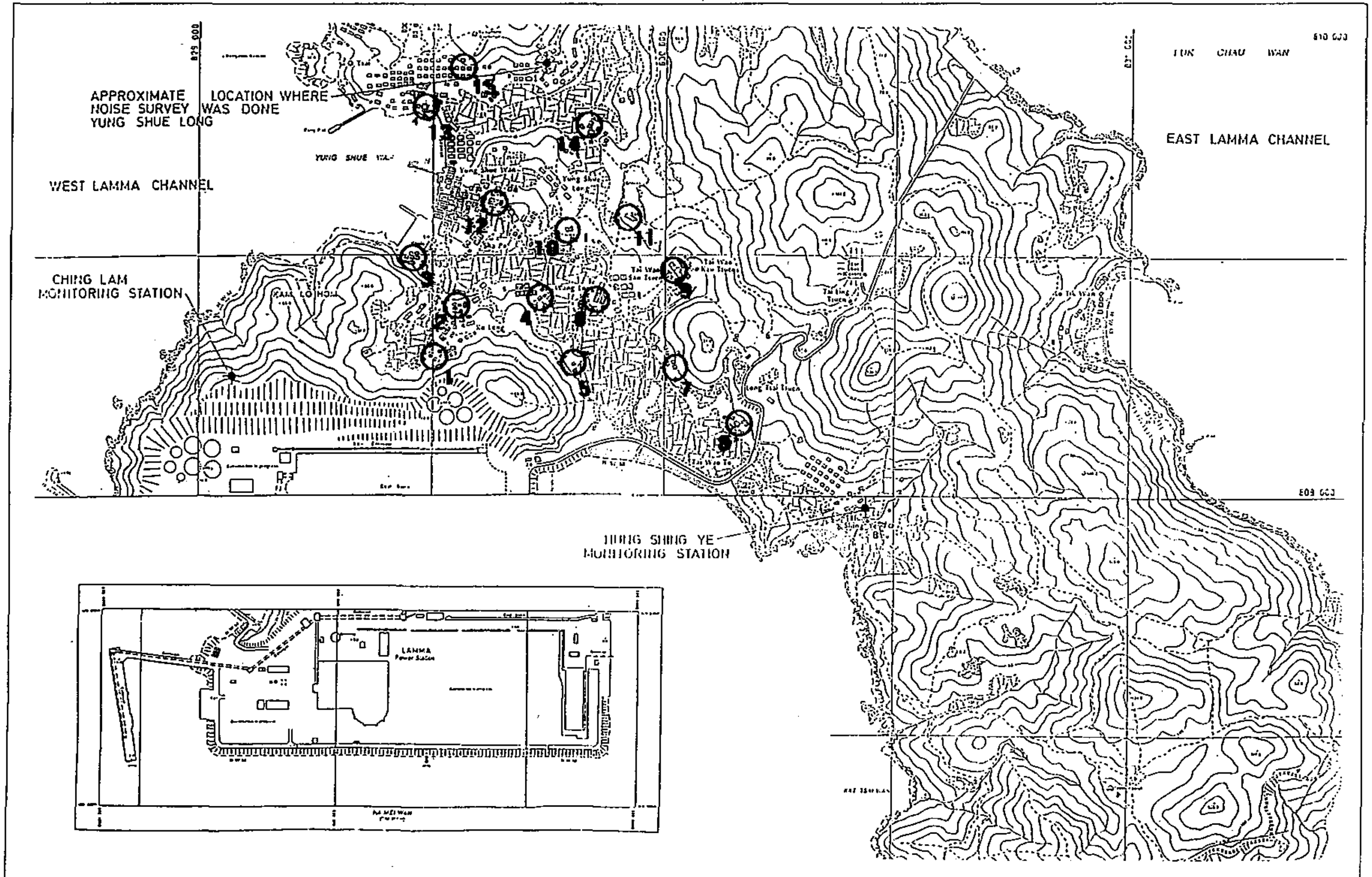

	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: NOISE CALCULATION SITES
			FIGURE: 4.2

ATMOSPHERIC IMPACTS

5.0 ATMOSPHERIC IMPACTS

5.01 The combustion of fossil fuel for electricity generation results in the production of a number of gaseous and particulate pollutants. The main pollutants are sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2) and particulates. The relative concentrations of these pollutants in flue gases is dependent upon the particular fuel being burned, the burn rate and the type of combustion plant. The quantities of the various pollutants emitted to atmosphere depends upon the presence or absence of pollution control devices, and their efficiency.

5.02 Since 1980, the progressive introduction of generating capacity at Lamma Power Station has resulted in a shift of load from HEC's Ap Lei Chau Power Station to Lamma. As the fuel burned at Ap Lei Chau was heavy fuel oil, with a sulphur content of 3.5%, the transfer of load to Lamma, which uses coal with a maximum sulphur content of 1%, has resulted in a proportional drop in sulphur emissions from Ap Lei Chau. It is to be anticipated that these load changes would have been associated with beneficial effects on air quality, particularly on Hong Kong Island.

Air Quality Criteria

5.03 Hong Kong has been divided into 10 different air control zones designated as follows:

(a) Junk Bay Air Control Zone;
(b) Lantau Air Control Zone;
(c) Fanling Sha Tau Kok Air Control Zone;
(d) Port Shelter Air Control Zone;
(e) South Hong Kong Island Lamma Air Control Zone;
(f) Tolo Air Control Zone;
(g) Tuen Mun Air Control Zone;
(h) Yuen Long Air Control Zone;
(i) Harbour Air Control Zone;
(j) Tsuen Wan - Kwai Chung Air Control Zone.

5.04 Air Quality Objectives (AQO) were promulgated for these zones under Section 7 of the Air Pollution Control Ordinance (Chapter 311), in December 1989. The AQO's are as follows:

Pollutant	Concentration in micrograms per cubic metre (i) Averaging Time				
	1 hour (ii)	8 hours (iii)	24 hours (iii)	3 months (iv)	1 year (iv)
Sulphur Dioxide	800		350		80
Total Suspended Particulates			260		80
Respirable Suspended Particulates (v)			180		55
Nitrogen Dioxide	300		150		80
Carbon Monoxide	30000	10000			
Photochemical Oxidants (as ozone) (vi)	240				
Lead				1.5	

(i) Measured 298°K (25°C) and 101.325 kPa (one atmosphere).
(ii) Not to be exceeded more than three times per year.
(iii) Not to be exceeded more than once per year.
(iv) Arithmetic means.
(v) Respirable suspended particulates means suspended particles in air with a nominal aerodynamic diameter of 10 micrometres and smaller.
(vi) Photochemical oxidants are determined by measurement of ozone only.

Baseline Air Quality Conditions

5.05 HEC have installed several air quality monitoring stations on Hong Kong Island which continuously monitor ambient concentrations of SO_2, particulates and NO_x. These stations have been progressively commissioned since 1980, as a condition of the site licence for the development of Lamma Power Station. A new monitoring station (Victoria Road) was established in 1988, to replace the Wah Fu station, which ceased operation in September 1988. An additional air quality monitoring station was installed at the Peak in August, 1990. Figure 5.1 shows the location of all monitoring stations in the HEC network.

5.06 The Environmental Protection Department operate a network of air quality monitoring stations on Hong Kong Island and Kowloon. These stations continuously monitor ambient levels of SO_2, NO_x, particulates and rainfall acidity. They have been progressively installed since 1982.

5.07 The air quality monitoring database is therefore comprehensive and enables a realistic appraisal of current baseline conditions to be made.

5.08 Sulphur dioxide concentrations measured at the HEC monitoring stations since 1980 are summarised in Figure 5.2. These results demonstrate a general reduction in SO_2 concentrations since 1980 at all monitoring sites. These reductions are consistent with the view that the transfer of load from ALC Power Station using high sulphur fuel oil to Lamma Power Station using low sulphur coal has resulted in generally improved air quality as recorded at the monitoring sites.

5.09 The results of SO_2 monitoring carried out by EPD during 1988 are shown in Figure 5.3. These results show a range of annual average concentrations from 53 to $126\mu g.m^{-3}$ at Kwun Tong, Tsim Sha Tsui and Kwai Chung, and from 9 to $35\mu g.m^{-3}$ at the other sites in the network. Short term exceedences of the AQO were noted at Kwun Tong, but not at any other monitoring station. Similarly, no exceedences of the AQO have been found at the HEC monitoring sites since measurements began in 1980.

5.10 A summary of oxides of nitrogen monitored in the HEC network is given in Figure 5.4.

5.11 Unlike SO_2, the database for NO_x is more limited and it is therefore difficult to evaluate trends. NO_2 forms the greater proportion of NO_x at all sites, although the ratio $NO:NO_2$ is variable spatially and temporally. The data shows a range of NO_2 concentration from $24\mu g.m^{-3}$ to $70\mu g.m^{-3}$ over the monitoring period, with some indication of relatively higher concentrations in the winter period. All concentrations measured to date are within the AQO.

5.12 NO concentrations in the EPD network during 1988 ranged from 7 to $64\mu g.m^{-3}$, whilst NO_2 concentrations varied from $21\mu g.m^{-3}$ to $93\mu g.m^{-3}$. Exceedences of the annual, 24 hour and 1 hour AQO's were observed at the Kwun Tong site, and of the 1 hour and 24 hour AQO at the central/western site. A seasonal pattern of higher NO_2 levels during winter months was also found in the EPD data. This was attributed to the existence of stable conditions and inversions which predominate at this time of year [1].

5.13 The long term average suspended particulate data at the HEC sites is summarised in Figure 5.5. Unlike the gaseous pollutants, there is no discernable trend in these data, which generally show pronounced spatial and temporal variation. Over the duration of the monitoring period, annual average TSP levels varied from $43\mu g.m^{-3}$ to $76\mu g.m^{-3}$.

5.14 Annual average TSP levels at the EPD monitoring sites during 1988 showed a range of from $95\mu g.m^{-3}$ to $146\mu g.m^{-3}$. The annual AQO of $80\mu g.m^{-3}$ was exceeded at all monitoring sites. A maximum concentration of $392\mu g.m^{-3}$ (24 hour) was recorded at Causeway Bay.

5.15 In a review of their air quality data [1], EPD attribute the high levels of TSP to motor vehicles and construction activity.

5.16 From a review of air quality data collected by both HEC and EPD, it is clear that the pollutant of most concern with regard to exceedence of the relevant AQO is TSP, with virtually the whole Territory showing unacceptably high levels. For SO_2, most monitoring sites show concentrations within the AQO's, although local areas such as Kwai Chung and Kwun Tong show comparatively high levels. NO_2 concentrations at certain sites on Kowloon and in the central/western area of Hong Kong Island are also high.

5.17 No direct measurements of air quality on Lamma Island have been made, except for specific particulate measurements within the power station boundary. However, it is to be expected that air quality on the Island is generally good with low levels of the principal gaseous pollutants SO_2 and NO_x. From an assessment of monitoring data, typical average concentrations in the urban area are judged to be within the range : 5-50μg.m^{-3} for SO_2; 20-100μg.m^{-3} for NO_2; and 40-150μg.m^{-3} for TSP. These concentrations may therefore be taken as representative of current background concentrations on Hong Kong Island and Kowloon. For the southern part of Hong Kong Island, data from the HEC network is probably more pertinent. These data show a rather narrower range of concentrations from 3-16μg.m^{-3} for SO2 and 47-72 μg.m^{-3} for TSP (1987-1990). NO_2 concentrations averaged over the years 1989-1990 show a range from 27-41μg.m^{-3}.

Meteorology

5.18 Hong Kong's climate is dominated by the two monsoons, the warm rain-bearing south-easterly in summer, and the cool dry north-easterly in winter. The cool season generally lasts from October until mid March. The hot season typically begins in April and continues until September.

5.19 Summer is the wet season, bringing about 80% of the 222cm average annual rainfall. Much of this arrives with the typhoons which are prevalent in summer with gale force winds, lashing rain and mountainous seas. Air temperatures average 28°C in July, but may reach a maximum of 36°C.

5.20 Winter is often cold and dry and the temperatures on mountain peaks may fall to zero, with resultant frosts. A usual winter minimum is 15°C in February.

5.21 Because of the uneven terrain, winds in Hong Kong vary widely with location. Moreover, differences arise between the prevailing wind speed and direction at various locations, at different times of the day and at different hours of the day [2]. A summary of the principal meteorological parameters measured in Hong Kong is given in Table 5.1. These data show the prevailing wind pattern is easterly for most months of the year, changing to south westerly in July. Average wind speeds are highest in the winter and range from 2.8m.s^{-1} to 4.1m.s^{-1} over the year. Wind speeds at exposed sites of the Territory tend to be higher than the corresponding recorded speeds at the Royal Observatory [3].

TABLE 5.1 : SUMMARY OF PRINCIPAL METEOROLOGICAL VARIABLES

MONTH	ATMOSPHERIC PRESSURE				AIR TEMPERATURE						DEW POINT	WET BULB TEMPERATURE
	Absolute Maximum	Mean	Absolute Minimum	Mean Diurnal Range	Absolute Maximum	Mean Daily Maximum	Mean	Mean Daily Minimum	Absolute Minimum	Mean Diurnal Range		
	mbar	mbar	mbar	mbar	°C	°C	°C	°C	°C	°C	°C	°C
January	1035.4	1020.1	1003.1	4.1	26.9	18.7	15.6	13.2	0.0	5.5	9.8	12.8
February	32.7	18.6	998.3	4.1	27.8	18.8	15.9	13.7	2.4	5.1	11.7	13.7
March	31.6	16.2	1001.9	4.1	30.1	21.3	18.5	16.3	6.2	5.0	15.0	16.5
April	28.4	13.1	999.9	3.8	33.4	25.0	22.1	20.0	9.9	5.0	18.9	20.1
May	20.2	09.1	981.1	3.3	35.5	28.9	25.9	23.9	15.4	5.0	22.7	23.7
June	14.4	06.2	973.8	3.0	35.6	30.4	27.7	25.6	19.2	4.8	24.5	25.4
July	14.8	05.4	975.8	3.2	35.7	31.6	28.6	26.3	22.2	5.3	25.0	26.0
August	16.3	05.2	961.6	3.5	36.1	31.2	28.2	25.9	21.6	5.3	24.8	25.8
September	18.2	08.5	953.2	3.6	35.2	30.5	27.5	25.2	18.4	5.3	23.2	24.6
October	24.5	14.0	977.3	3.6	34.3	27.9	25.0	22.7	13.5	5.2	19.3	21.4
November	33.2	17.6	974.9	3.8	31.8	24.4	21.3	18.9	6.5	5.5	14.9	17.7
December	33.5	19.8	1004.6	4.0	28.7	20.8	17.7	15.2	4.3	5.6	11.4	14.4
Year	1035.4	1012.8	953.2	3.7	36.1	25.8	22.8	20.6	0.0	5.2	18.4	20.2
Date on which the Extreme Value was Recorded	6 January 1903		1 September 1962		19 August 1900				18 January 1893			
Observed at	Royal Observatory											

MONTH	RELATIVE HUMIDITY				AMOUNT OF CLOUD	RAINFALL						BRIGHT SUNSHINE		WIND		
	Mean	Mean at 0200 H.K.T.	Mean at 1400 H.K.T.	Absolute Minimum		Total	Duration	No. of Days with Measurable Rain	Hourly Maximum	Daily Maximum	Monthly Maximum	Duration	Percentage of Possible	Prevailing Direction *	Mean Speed *	Maximum Gust *
	%	%	%	%	%	mm	h		mm	mm	mm	h	%	degrees	knots	knots
January	71	76	62	10	59	26.9	45	6	21.8	99.6	214.1	153.5	45	070	12.8	55
February	78	82	70	13	71	41.9	66	8	24.6	86.1	210.2	108.7	34	070	12.4	59
March	82	87	74	16	76	54.8	85	9	39.9	96.1	291.7	101.4	27	070	11.6	55
April	83	88	75	22	76	139.4	78	11	92.4	190.2	435.9	120.2	32	080	10.4	52
May	83	88	76	23	73	298.1	91	15	86.4	520.6	1240.5	162.6	40	090	10.3	76
June	84	88	77	29	75	431.8	90	21	108.2	382.6	962.9	159.2	39	090	11.2	10[illegible]
July	81	86	74	43	66	316.8	65	18	100.7	534.0	763.9	230.9	56	230	10.2	86
August	83	87	76	41	66	413.4	77	18	82.1	288.1	871.4	206.0	52	090	9.9	113
September	79	84	71	26	62	320.4	71	15	84.0	325.5	844.2	188.5	51	090	11.5	124
October	72	77	64	21	52	121.2	43	8	71.6	292.2	718.4	209.9	58	090	14.0	99
November	69	75	59	17	52	34.7	33	5	44.2	149.2	223.9	191.5	58	080	14.4	94
December	69	75	60	14	52	25.3	34	5	51.7	177.3	206.9	179.3	54	080	13.3	59
Year	78	83	70	10	65	2224.7	777	140	108.2	534.0	1240.5	2011.6	45	080	11.8	124
Date on which the Extreme Value was Recorded				16 January 1959					12 June 1966	19 July 1926	May 1889					5 September 1964
Observed at	Royal Observatory											King's # Park		Waglan Island		

Observations in years 1947 - 1960 were taken at the Royal Observatory

* 1953 - 1981

5.22 In order for emissions from Lamma Power Station to affect the populated areas of Hong Kong Island, winds must blow from the west/south west sector (i.e. between approximately 210-270°). The Kowloon Peninsula would be affected by emissions from the station with winds blowing from between approximately 180°-260° and the Islands of Lantau and Cheung Chau would be affected when winds blow from approximately 50°-135°.

5.23 In considering the most appropriate meteorological data for dispersion modelling purposes, discussions were held with scientific staff of the Royal Observatory. These discussions led to the conclusion that the most appropriate meteorological station from which to obtain the necessary input data was Cheung Chau. Cheung Chau lies some 8km west of Lamma and is the nearest R.O. site to Lamma. The meteorological observations at Cheung Chau have been made since 1970 at an anemometer height of 92.1m.

5.24 Annual surface wind frequency data for Cheung Chau are shown in Figure 5.6. For comparison, the wind rose for data collected at the power station site is also shown. The prevailing wind direction is east/northeast for the majority of the year. For the remainder of the year, wind direction is variable, although there is a preponderance of west/south westerly winds during the summer months. In the critical sectors of interest for this study, the frequency distributions at the two stations are broadly similar and therefore the Cheung Chau data can be regarded as representative of conditions affecting the Lamma site.

5.25 The annual frequency of winds in the 60° sector between 210° and 270° is about 13%. The long term average wind speed at Cheung Chau for this sector ranges from 0.5-8 ms^{-1}.

5.26 Much of the land in Hong Kong and the New Territories is above 200m, with individual peaks above 600m. Therefore air flow in the boundary layer is significantly affected at the 300 and 600m levels, and also probably at 900m. This is confirmed by radiosonde data collected by the Royal Observatory from releases at Kings Park, which show an increase in wind speeds at 900 and 1100m, compared with surface observations [4]. Radiosonde data also demonstrate that, because of horizontal temperature gradients, there is an increase in the frequency of W/SW winds with altitude.

5.27 The frequency of stable conditions over Hong Kong is between about 10-20% whilst unstable conditions occur for between 30-40% of the time. The frequency of stable conditions associated with W/SW winds is, however, extremely rare [5].

5.28 The frequency of inversions with bases below 3000m is shown in Table 5.2 which is based on radiosonde releases during the ten year period 1961-1970.

TABLE 5.2 : NUMBER OF INVERSIONS OBSERVED IN GIVEN HEIGHT RANGES FOR THE TEN YEAR PERIOD 1961-1970

Height m	January to April	May	June	July	August	September to December
66 - 119	26	0	0	0	0	3
120 - 179	5	0	0	0	1	2
180 - 239	5	1	0	0	0	1
240 - 299	14	1	0	0	0	1
300 - 359	39	1	0	0	0	5
360 - 419	43	4	1	0	0	10
420 - 479	59	4	0	0	0	14
480 - 539	61	1	0	0	2	13
540 - 600	35	6	1	1	2	17
600 - 1500	497	66	16	11	13	329
1500 - 3000	475	56	25	17	22	441

5.29 For the period concern (ie the summer period, between June - August, when wind directions are such that emissions from Lamma Power Station could affect the populated areas of Hong Kong Island), inversions below 600m were only observed for about 1% of occasions. The frequency of inversions below 1500m is about 5% and between 1500 m and 3000 m, about 7%. These data clearly demonstrate that inversions predominate in the winter period between September to April, with low level inversions (ie below 600 m), being principally confined to the period January to April.

5.30 For the purposes of assessing the air quality of the proposed extension to Lamma Power Station, the effects of limited dispersion and plume trapping by inversion, can therefore be largely ignored.

5.31 The final factor to be considered in the context of meteorology is rainfall. The rainfall distribution pattern over Hong Kong is illustrated in Figure 5.7. From this figure it can be seen that the rainfall distribution over Lamma averages 1600mm per annum.

5.32 The frequency distribution of monthly rainfall is shown in Figure 5.8. This shows that peak rainfall occurs during the summer monsoon season, June to September.

5.33 The period of the year when prevailing wind patterns are such that the populated parts of the territory could be affected by emissions from Lamma Power Station, therefore coincides with the maximum annual rainfall. This will have a reducing effect on air pollution levels as both gaseous and particulate pollutants will be subject to washout at these times.

Dispersion Modelling

5.34 There are essentially two tools available for estimating air pollution impacts from stationary combustion sources, - numerical and physical modelling. For flat terrain conditions, numerical modelling is generally regarded as adequate for the purposes of assessing air quality impacts, as typical simulation models have been shown to be reasonable predictors of actual conditions. In complex terrain conditions, however, standard gaussion diffusion models are not regarded as sufficiently robust to accurately simulate conditions, and a more complex approach is required.

5.35 For complex terrain conditions, USEPA Guidelines have not provided approval designation for any numerical model, although the model RTDM is authorized as a "third level screening model" [6].

5.36 Because of the complexity of the terrain conditions in Hong Kong, it is clear that the numerical simulation approach alone is unlikely to provide a sufficiently accurate analysis of possible impacts. It is therefore necessary to use physical modelling techniques.

5.37 Extensive discussions on the methodology of assessing the air quality impacts of units L7 and L8 have been held with EPD. These discussions essentially resolved that the best approach was to conduct a numerical modelling study in the first instance, followed by a physical model study. The output from the numerical model would be used to define the scope of the wind tunnel testing programme, which would subsequently be implemented. It is on this basis, therefore, that the initial atmospheric impacts study has been carried out.

5.38 Emissions of chimney pollutants from the power station vary according to the electrical power generated and the fuel burned. The following paragraphs outline the method used for determining the pollutants from the boilers, in particular during periods of high unit electrical demand.

5.39 To assess the change in air pollutants from the power station, two typical periods of time have been chosen for analysis in the years l994 and 2000. Data calculated for these periods has been used for input into the computer model for assessment of air quality impact.

5.40 Emission rates have been estimated for three principal pollutants; sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulates (dust). The quantity of each pollutant has been calculated on an hourly basis for the following load schedules:

1. Baseline case. Existing units L1 to L6 inclusive. Electrical load based on 1994 July Peak day load schedule. (Table 5.3)

2. Preferred option. Existing units L1 to L6 plus two additional new 350 MW units L7 and L8. Electrical load based on 2000 July Peak day load schedule. (Table 5.4)

5.41 It should be noted that the emission rates refer to existing plant and new planned facilities. The implementation of current air emission standards and installation of Flue Gas Desulphurisation (FGD) has been taken into account where applicable to meet possible future legislation. The estimation of air emissions also assumes that the present licence for the conduct of a specified process issued under the Air Pollution Control Regulations for existing plant at Lamma Power Station will be adhered to.

5.42 The limiting effect of installing FGD plant can be seen on Figure 5.9. During the night period SO_2 emissions are actually reduced from the present levels, whilst in daytime there is a very small change. Despite the considerable increase in electrical load demand (and coal burned) between year 1994 and 2000, the calculations indicate no appreciable change in SO_2 levels over a typical 24 hour period. The reduction in emissions for each MW generated can be seen in Figure 5.10.

TABLE 5.3 : 1994 JULY PEAK DAY LOADING (FORECAST), BASE CASE

Hour	System Load (MW)	L6 380	L5 380	L4 380	L1 280	L2 280	L3 270	GTI 55	GT2-7 125
		Loading Schedule (MW)							
Peak 11.30	2055	365	365	365	270	270	270	--	75 x 2
1	942	314	314	314	--	--	--	--	--
2	872	291	291	291	--	--	--	--	--
3	832	277	277	277	--	--	--	--	--
4	805	268	268	268	--	--	--	--	--
5	788	263	263	263	--	--	--	--	--
6	812	271	271	271	--	--	--	--	--
7	982	269	269	269	177	--	--	--	--
8	1380	314	314	314	219	219	--	--	--
9	1764	350	350	350	251	251	213	--	--
10	1934	365	365	365	270	270	270	--	29 x 1
11	2008	365	365	365	270	270	270	--	52 x 2
12	2027	365	365	365	270	270	270	--	61 x 2
13	1965	365	365	365	270	270	270	--	30 x 2
14	1987	365	365	365	270	270	270	--	41 x 2
15	2002	365	365	365	270	270	270	--	49 x 2
16	1985	365	365	365	270	270	270	--	40 x 2
17	1956	365	365	365	270	270	270	--	26 x 2
18	1833	361	361	361	261	261	223	--	6 x 1
19	1714	341	341	341	243	243	205	--	--
20	1589	320	320	320	223	223	184	--	--
21	1506	341	341	341	242	242	--	--	--
22	1412	321	321	321	225	225	--	--	--
23	1282	294	294	294	200	200	--	--	--
24	1085	295	295	295	201	--	--	--	--

Notes:
1 Assumes no outage or test run
2 Source : HEC

TABLE 5.4 : **2000 JULY PEAK DAY LOADING (FORECAST +10%), 350MW OPTION**

Hour	System Load (MW)	L8 380	L7 380	L6 380	L5 380	L4 380	L1 280	L2 280	L3 270	GTI 55	GT2-7 125
					Loading Schedule (MW)						
Peak 11.30	3072	365	365	365	365	365	270	270	270	--	87 x 5
1	1408	282	282	282	282	282	--	--	--	--	--
2	1303	326	326	326	326	--	--	--	--	--	--
3	1244	311	311	311	311	--	--	--	--	--	--
4	1204	301	301	301	301	--	--	--	--	--	--
5	1177	294	294	294	294	--	--	--	--	--	--
6	1213	303	303	303	303	--	--	--	--	--	--
7	1468	294	294	294	294	294	--	--	--	--	--
8	2062	322	322	322	322	322	226	226	--	--	--
9	2637	365	365	365	365	365	270	270	266	--	6 x 1
10	2891	365	365	365	365	365	270	270	270	--	85 x 3
11	3001	365	365	365	365	365	270	270	270	--	92 x 4
12	3030	365	365	365	365	365	270	270	270	--	99 x 4
13	2937	365	365	365	365	365	270	270	270	--	76 x 4
14	2971	365	365	365	365	365	270	270	270	--	84 x 4
15	2992	365	365	365	365	365	270	270	270	--	89 x 4
16	2968	365	365	365	365	365	270	270	270	--	83 x 4
17	2925	365	365	365	365	365	270	270	270	--	73 x 4
18	2740	365	365	365	365	365	270	270	270	--	53 x 2
19	2562	362	362	362	362	362	262	262	224	--	6 x 1
20	2375	338	338	338	338	338	240	240	202	--	--
21	2252	323	323	323	323	323	226	226	187	--	--
22	2110	329	329	329	329	329	232	232	--	--	--
23	1917	336	336	336	336	336	238	--	--	--	--
24	1622	324	324	324	324	324	--	--	--	--	--

Notes: I. Assuming no outage or test run
2. Source : HEC

Unit Loading Forecast

5.43 Highest unit load factors occur just prior to taking over new generating plant. At Lamma power station, this occurs in summer 1994 before Unit L7 is due to start commercial operation, and July 2000, which would coincide with the operation of a new power station.

5.44 These dates have been selected for analysis because they represent "worst case" conditions from a pollutant emission point of view. After the introduction of Unit L7, planned for March 1995, a reduction in SO_2 will be achieved by the introduction of Flue Gas Desulphurisation (FGD). Similarly, in the year 2001 new generating plant will result in reduced unit load factors as the older plant at Lamma drops down the merit rating.

5.45 It should be noted that the daily load forecasts shown in Table 5.4 and unit outputs have been adjusted to allow for a 10% increase in output power over HEC's forecast load demand, with consequential higher emissions. This provides a suitable "safety margin" for predictive purposes.

Estimating Airborne Emissions

5.46 Estimations of sulphur dioxide, nitrogen dioxide and particulates have been based on realistic operating experience of maximum emissions. These emission levels are equal or slightly lower than the EPD consent limits depending on the type of pollutants.

5.47 The EPD emission consent limits and realistic limits are shown in Table 5.5 together with the emission rates used in the assessment. These rates refer to maximum unit load conditions and the procedure for calculating emissions at lower unit loads has assumed a direct relationship with the electrical load.

TABLE 5.5 : EPD CONSENT LIMIT EMISSION RATES OF AIR POLLUTANT NOT TO BE EXCEEDED AND REALISTIC LIMITS (Kg/h)

	L1	L2	L3	L4	L5	L6	L7[1]	L8[1]
Consent Limits			Steam Boilers (without FGD)					
Sulphur Dioxide (Kg/h)	1900	1900	1930	2540	2540	2540	2540	2540
Nitrogen Oxide (Kg/h)	960	960	960	1250	1250	880	880	880
Particulates (Kg/h)	125	125	125	160	160	115	115	115
			Steam Boilers (with FGD)					
Sulphur Dioxide (Kg/h)						250	250[1]	250[1]
Realistic Limits			Steam Boilers (without FGD)					
Sulphur Dioxide (Kg/h)	1900	1900	1930	2540	2540	2540	2540	2540
Nitrogen Oxide (Kg/h)	850	850	850	1190	1190	800	800	800
Particulates (Kg/h)	125	125	125	160	160	115	115	115
			Steam Boilers (with FGD)					
Sulphur Dioxide (Kg/h)						250	250	250

Notes:
1. EPD consent limits for proposed 350MW units L7 and L8 are as clarified at 6th June 1990 meeting.
2. Details of consent limits for L1 to L6 are taken from Licence No. L-7-002 dated 6th March 1990 (Schedule A).

5.48 The method assumes no significant change to the ratio of air pollutant against load when using coal listed in the permitted approval range. It also assumes that estimated boiler emissions are maximum values. The part-load assumption will not affect the assessment for the worst case scenario which has taken full load data. As the air pollutants are generated from combustion of fuel which is approximately proportional to load output, the assumption of no significant change to the range of air pollutant against load is considered sufficient for environmental assessment purposes.

5.49 Total emissions for each boiler have been calculated against the unit schedule loads using the method described above for determining pollutants at the various loads. In practice however, the loading schedules at 1994 and 2000 are very close to MCR conditions and so the degree of adjustment (reduction) calculated is limited.

Sulphur Dioxide Emissions

5.50 Details of the coal analysis previously submitted to EPD by HEC from approved fuel suppliers are shown in Table 5.6.

5.51 Coals in Table 5.6 are generally classified; bituminous, high/medium volatile, low sulphur. Examination of the list of coal indicates the analysis from Rietspruit should be ranked as "worst coal" for calorific value and ash content.

5.52 Combustion calculations carried out on the Rietspruit coal indicates the EPD consent limits for SO_2 emissions can be achieved. Further check calculations for typical coal based on Rietspruit but with the sulphur content increased to 1.0% (air dried) also confirms the products of combustion meet the EPD consent limits.

Particulate Emissions (Dust)

5.53 Particulate emissions from low sulphur coal are difficult to estimate. The problem is related to the high resistivity in fly ash that results from such coal. High resistivity ash reduces the flow of electrical current across the flue gas stream and affects the electrostatic precipitator dust removal efficiency.

5.54 Sulphur trioxide (SO_3) conditioning of the boiler flue gas is the conventional method for reducing particulate emissions where such problems occur. Such equipment has been fitted to Units L1 - L5 at Lamma Power Station.

5.55 When designing electrostatic precipitator equipment, data relating to coal analysis is specified to obtain technical guarantees of performance. Test measurements of the dust burden taken by HEC support the view that the emission consent limits can be achieved by SO_3 gas conditioning.

5.56 It is therefore concluded that, using the current EPD emission limits at full boiler load is an acceptable basis for dust emission calculations. At lower loads, when the coal burn is reduced, it is assumed that the ash burden leaving the chimney is reduced proportionately.

Nitrogen Oxides

5.57 Nitrogen oxides (NO_x) are present in flue gas emissions from the combustion process in the form of nitric oxide (NO) and nitrogen dioxide (NO_2). Part of the NO will be oxidised to NO_2 in atmosphere. EPD consent limits refer to the total quantity of NO and NO_2.

NO_x is formed in two ways:-

1. Thermal NO_x

   Thermal NO_x results from nitrogen in the air supply to the boiler combining with oxygen at high combustion temperatures.

   The process is sensitive to high temperature (>l530°C) and other factors such as excess air to fuel ratio, burner combustion and boiler design particularly in the combustion zones.

TABLE 5.6 : HONGKONG ELECTRIC CO LTD APPROVED COAL SUPPLIES

COAL ANALYSIS YEAR OF TEST : 1982 - 1989

TYPE OF COAL	T.M.,% (AR)	R.M.,% (AD)	ASH,% (AR)	V.M.,% (AR)	F.C.,% (AR)	GROSS C.V. KCAL/KG (AR)	C,% (AR)	H,% (AR)	N,% (AR)	TTL S.,% (AR)	PYR. S.,% (AR)	SUL S.,% (AR)	CL,% (AR)	O,% (AR)
CERREJON	12.0	6.3	8.8	32.6	46.6	6485	64.5	4.19	1.1	0.7	-	-	-	8.7
DRAYTON	8.8	3.1	12.0	32.1	47.1	6415	62.7	4.30	0.2	0.8	0.12	0.04	0.039	11.2
ERMELO	7.1	3.3	12.5	28.4	52.0	6390	65.2	3.85	0.7	0.9	0.43	0.02	0.003	9.8
GOEDEHOOP	8.4	3.2	13.2	25.1	53.3	6285	65.5	3.73	1.4	0.7	0.20	0.30	-	7.1
KOORNFONTEIN	7.4	3.0	12.7	26.6	53.3	6350	65.6	3.74	1.6	0.6	0.26	0.02	0.006	8.4
NEWLANDS	7.3	2.6	13.6	24.6	54.5	6455	65.9	3.88	1.4	0.5	0.36	0.17	0.070	7.4
OPTIMUM	8.2	3.8	9.9	30.3	51.6	6530	63.0	3.95	1.5	0.6	0.30	0.02	0.010	12.9
PINGSHUO	9.7	4.3	12.1	29.4	48.8	6145	64.3	3.73	1.4	0.7	-	-	0.020	8.1
RICHMOND, USA	6.4	2.0	11.0	30.7	51.9	6880	66.8	4.73	1.2	0.8	0.20	0.02	0.020	9.1
RIETSPRUIT	7.8	3.6	14.4	24.2	53.6	6080	64.4	3.67	1.2	0.6	0.20	0.01	0.027	7.9
S. BLACKWATER	10.2	1.2	9.1	24.1	56.6	6725	67.7	4.02	1.0	0.9	0.45	0.05	-	7.1
TATUNG	11.2	5.3	7.7	26.6	54.5	6445	67.0	4.00	0.8	0.6	0.38	0.02	0.025	8.7
TAVISTOCK	7.3	2.4	11.9	25.1	55.7	6380	65.6	4.16	0.9	0.7	0.20	0.01	0.030	9.4
TDM	11.3	2.3	11.2	24.9	52.6	6475	63.2	5.06	0.8	0.4	0.17	0.04	0.050	8.0
TWEEFONTEIN	7.0	2.9	12.7	24.6	55.7	6325	66.6	3.76	1.5	0.8	-	-	-	7.6
VAN DYKS DRIFT	7.0	2.4	13.1	24.4	55.5	6425	67.1	3.85	1.5	0.6	-	-	-	6.9

AR : AS RECEIVED BASIS
AD : AIR DRIED BASIS

T.M. : TOTAL MOISTURE
R.M. : RESIDUAL MOISTURE
V.M. : VOLATILE MATTER
F.C. : FIXED CARBON

C : CARBON
H : HYDROGEN
N : NITROGEN
TTL.S. : TOTAL SULPHUR

PYR.S. : PYRITIC SULPHUR
SUL.S. : SULPHATIC SULPHUR
CL : CHLORINE
O : OXYGEN

REMARKS: R.M.,%(AD), ASH,%(AR), V.M.,%(AR), F.C.,%(AR), GROSS C.V. KCAL/KG(AR), TTL.S.,%(AR) ARE AVERAGES OF THE CONTRACTUAL SAMPLES OF ALL THE SHIPMENTS FOR THE SAME PERIOD

2. Fuel NO_x

Fuel bound nitrogen in coal is converted to NO_x during combustion. Specified coals used by HEC contain between 0.2% to 1.6% of nitrogen but only a proportion of this will result in NO_x. The percentage conversion may be typically 50% but will depend upon excess air, diffusion of fuel in the air, burner flame temperature and the volatility of the nitrogen in coal.

5.58 The exact amounts of nitrogen oxides cannot be precisely calculated for Lamma Power Station and the problem is further complicated when operating at part load.

5.59 Furthermore, the highest fuel bound nitrogen content in coal does not correspond with the highest sulphur coal. For the purposes of this study, maximum realistic NO_x emission rates measured by HEC have been used.

5.60 The method for estimating NO_x at part load is identical to the methods for SO_2 and particulates. At lower loads it is assumed that NO_x will reduce proportionately (pro rata). The combustion temperature will also be reduced at part load, leading to further reductions in NO_x. However, for the purposes of a conservative assessment, no account has been taken of this reduction. For NO_x from the gas turbine units, a linear relationship has been assumed, based on the licence NO_x and gas flow limits for the two load points stipulated in the licence. The variation of % O_2 with load was ignored for emission calculation purposes again leading to a conservative estimate.

Boiler Efflux Gas Velocity

5.61 The boiler efflux gas velocity from the top of each individual stack is based on realistic operating data provided by HEC.

Boiler Efflux Gas Temperatures

5.62 Boiler exit gas temperatures are based on measured exit gas temperatures given by HEC for various unit loads. Where FGD plant is fitted, it is assumed that the gas temperature is reduced to a nominal 80°C to take account of the wet limestone process. HEC have provided test data giving actual gas exit temperatures for all units under different load conditions. These data were used for modelling emissions under non MCR conditions.

Numerical Modelling Study

5.63 As documented in the Inception Report and agreed with EPD, this study has utilised the USEPA UNAMAP system for numerical modelling.

5.64 As a first level screening process, the model ISCST (Industrial Source Complex Short Term) was used to estimate short term concentrations of SO_2, NO_x and particulates at all sensitive receptor locations within 17km of the power station site. A companion model, ISCLT (Industrial Source Complex Long Term) was used to estimate long term average concentrations of the same pollutants.

5.65 ISCST has the following features:-

Plume rise calculated by the method of Briggs:
Urban or rural dispersion coefficients;
Limited Complex Terrain algorithms

5.66 The dispersion coefficients chosen for this study were McElroy Pooler (Urban Mode 3), as these were considered to be the most appropriate. Rural coefficients were not used as the meteorological data from Lamma Island suggests the wind turbulence is similar to the conditions under which the McElroy Pooler coefficients were determined.

For each case studied, a stack file containing all the emission characteristics of each chimney was created.

For each source the following input data were used:

Emission Rate g/s
Emission Velocity m/s
Emission Temperature °K
Stack Height m
Stack Diameter m

Where the source represented a combined flue, the diameter was calculated as the diameter of a circle with the same area as the total area of the combined flues.

The source file was incorporated into a data file containing various program run options (eg, dispersion mode), receptor information, terrain height and source scaling factors.

ISCST requires a meteorological data file to be created . Surface meteorological observations at Cheung Chau were supplied by the Royal Observatory for 1988, the latest year for which the requisite data are available. These data were then reformatted to be compatible with model input requirements. The data utilized were:-

Hourly wind speed and direction
Hourly Dry Bulb temperature
Hourly Cloud Cover
Hourly Cloud Ceiling Height
Daily AM and PM mixing heights

This information was input to the Rammet preprocessor programme, together with longitude, latitude and time zone data. Rammet calculates sunrise and sunset times and then calculates the atmospheric stability class from solar insolation data and wind speed. All the information was then written to a further meteorological data file for subsequent processing.

The model was run for the whole of 1988 and the following results were produced as output:

Annual Average Concentration at each receptor
Annual Maximum 1 hour average at each receptor
Annual Maximum 24-hour average at each receptor

For each of the Maximum concentrations, the day and hour of occurrence was also computed. The results were then placed in a contour generating package to create isopleths of the pollutant concentrations.

5.67 ISCST was run for the following cases:

(i) 1994 (July) Base Case, Units L1-L6 (L6 fitted with FGD);

(ii) 2000 (July) Units L1-L8, 350MW Option (L6, L7 and L8 fitted with FGD);

The construction of the source files for ISCST modelling was such that the effects of individual unit emissions could be identified, thus facilitating analysis of where mitigation measures would be most beneficial.

ISCLT

5.68 ISCLT is designed to calculate annual average concentrations using long term averaged meteorological data. It has many of the features of ISCST, using the same plume rise and dispersion coefficients.

5.69 A source file was first prepared, containing average emission characteristics for each source.

5.70 A meteorological data file was then prepared containing, for each atmospheric stability class, the frequency of a particular wind speed category arranged by wind direction. For this analysis, six wind speed categories and sixteen wind directions were used. For the initial study, stability class, as calculated by the Pasquill-Gifford method, was used for modelling. However, following detailed analysis of the occurrence of various stability classes and discussion with the Royal Observatory, it was concluded that the Pasquill-Gifford method produced an unrealistic assessment of stability, particularly in the case of the stability classes E and F. It was subsequently agreed with EPD that the occurance of even slightly stable conditions during the summer period, when prevailing winds could carry the power station plume across to Hong Kong Island, was not a realistic basis for model testing. Subsequent numerical modelling work therefore concentrated on neutral (stability Class D) conditions.

5.71 The source file and the meteorological data file were then incorporated into the data file containing the program control information, receptor information and terrain information.

5.72 The program was then run to produce a data file containing the annual average concentration for each receptor. For the local study, a polar receptor of 17km range was used. For the transfrontier study a polar grid of 100km was used.

5.73 As already noted, the major limitation of ISCST for this study is in its handling of complex terrain. The model makes no adjustment to the plume's path, but simply raises the mixing height by the same height as the terrain. This means that, in elevated terrain, the model will generally over predict concentrations as the plume centreline generally rises as the terrain rises. Thus ISCST assumes that the plume centreline is closer to the ground than would occur in practice.

5.74 Because of this limitation, further numerical modelling was carried out using other models from the UNAMAP suite.

COMPLEX1

5.75 COMPLEX1 is similar to ISCST in features although rather more limited and its terrain handling features are very simplistic. It raises the height of the plume centreline over elevated terrain by a user defined factor. This factor depends on the stability class. For all but stable conditions a plume has sufficient energy to pass over elevated terrain. Under stable conditions it can pass over the hill, round the hill or impact onto the hillside. The plume energy must be determined to decide which path the plume takes, COMPLEX1 does not do this.

5.76 This model was evaluated but it was considered that the combination of a poor choice of dispersion coefficients and the simplistic complex terrain handling features made this model unsuitable for the assessment.

RTDM (Rough Terrain Dispersion Model)

5.77 RTDM has the following complex terrain handling abilities:

5.78 It increases the plume centreline height when it passes over elevated terrain. The amount of this increase is determined by the plume energy (quantified by Froude number : a dimensionless number representing plume energy similar in concept to the Reynolds Number) and by user selected parameters. Generally, the plume height will be increased in unstable and neutral conditions, in stable conditions the height may not be changed.

5.79 If the plume impacts on the terrain, ground level concentration are not allowed to increase with distance (thus avoiding a conflict with the second law of thermodynamics). This situation could occur for instance when the plume impacts on a steep hill. Downwind of the initial point of impact the ground level could increase in height up into the plume centreline. In the normal Gaussian model, this point would then have a greater concentration than points upwind. This would not happen in practice as the plume would spread laterally, RTDM makes corrections to avoid this occurring.

5.80 Apart from these features, RTDM works in a similar manner to ISCST to calculate concentrations. The model has only rural dispersion coefficients built in explicitly. However, the user has the option of using any dispersion coefficient as long as it can take the form $\sigma = AX^B+C$ where X is the distance downwind. The McElroy Pooler coefficients can be fitted to this equation with excellent correlation (r-squared > 0.99) and thus have been used for the assessment.

5.81 RTDM does not use scaling factors to provide hourly emission estimates, instead the user supplies a file containing hourly values for mass emission rate, emission velocity and emission temperature for each hour and each day of the year. It is therefore considerably more refined in this respect than ISCST. The same method was used to define stacks as used in the ISCST runs, i.e. a separate source was defined for each combination of boiler operations.

5.82 RTDM calculates the hourly average concentration for each set of data in the emission file and meteorological data file. From these values yearly maximum and average concentrations can be determined.

5.83 As also noted, meteorological input to the RTDM model includes information on stability class, derived from solar insolation data and wind speed. As it is evident that the Pasquill-Gifford method of calculation significantly over estimates the incidence of stable atmospheric conditions in Hong Kong, and highest air pollution levels tend to occur under stable conditions, this therefore means that any numerical simulation using calculated stability class will tend to over predict air pollution levels. RTDM model runs were therefore carried out using stability Class D to produce a more realistic assessment of actual impact.

5.84 As already noted, the source emission characteristics used for all modelling described above, were derived from realistic emission limits, adjusted for individual unit loading. The emission data used for these runs are summarised below:

Unit	L1-L3	L4-L5	L6-L8
Maximum Flow Rate (x10^6Nm^3/h)	0.9	1.26	1.20
Minimum Efflux Velocity at MCR (m/s)	16	18	15
Minimum Exit Temperature (°C)	125	116	80

Short Term (Emergency) Conditions

5.85 In addition to the assessment of air quality impacts under normal operation, abnormal operations were also examined. For the purposes of this assessment, emergency conditions have been taken as a switch from normal low sulphur coal, to oil burning with a sulphur content of 3.5%. It has also been assumed that all FGD plant was unavailable. The assessment was carried out using ISCST, with meteorological data fixed at Stability Class D, as used by HMIP in the assessment of UK Power Stations.

5.86 The probability of such events occurring in practice is, of course, extremely low. However, this combination of circumstances has been selected as representative of worst case.

Model Calibration

5.87 The ability of any numerical model to accurately predict pollutant concentrations can only be assessed by performance testing. Detailed performance testing is outside the scope of the Initial Assessment Study, but it was considered useful to conduct some initial performance evaluation using modelled data in conjunction with air quality monitoring results from the HEC network.

5.88 For the initial evaluation, the highest 20 concentrations of SO_2 for receptors at Aberdeen, Queen Mary Hospital, Wah Fu and Ap Lei Chau were estimated by RTDM, together with the day and hour of their occurrence.

5.89 These results were then used in a correlation analysis with measured SO_2 concentrations at the same receptors during 1988.

5.90 It is recognised that this approach is simplistic in that it does not take account of the specific wind pattern occurring at the time of the measured concentrations, or of the lag in emissions from the power station reaching a particular receptor. However, implicit in the prediction methodology is that highest concentrations arise as a consequence of power station emissions. Hence wind patterns which could carry emissions from Lamma towards Hong Kong Island are explicitly catered for in this underlying assumption.

5.91 Following the establishment of the HEC air quality monitoring station on the Peak, the opportunity was taken to examine observed and predicted SO_2 concentrations at this site in more detail. For this study, model runs were undertaken using actual emission data supplied by HEC for particular periods of the day when the wind direction recorded at Lamma power station, and Cheung Chau, was such that the plume from the power station could have affected the Peak. Individual model runs were then carried out for each hour of relevant air monitoring data.

5.92 The results of model calibration test are summarised in Appendix 5A. The results generally show a weak correlation between observed and predicted data, with predicted values being typically higher than observed values. Correlations between observed and predicted results using wind speed and direction data from Lamma were generally better than with meteorological data from Cheung Chau. It is clear that any assessment based upon the output from numerical modelling alone is likely to be unrealistically pessimistic and the results should therefore be treated with caution.

Results of Dispersion Modelling

ISCST/LT

5.93 Contour plots of ISCST predicted maximum 1 hourly SO_2 concentrations, for the various cases examined are shown in Figures 5.11 to 5.12. These plots have been produced using the Pasquill-Gifford stability class calculation and, as such, are based predominantly on "stable" meteorological conditions. They therefore represent a very pessimistic "worst case" condition, which, in practice, would be most unlikely to arise.

5.94 In the base case condition (Figure 5.11) the model predicts relatively high concentrations of sulphur dioxide over large areas of Hong Kong Island, with maximum concentrations in excess of $2000\mu g.m^{-3}$ at The Peak area.

5.95 Relatively high concentrations are also predicted for South Lamma (Mt Stenhouse).

5.96 With the addition of Units L7 and L8 the predicted concentrations do not differ appreciably from those in the 1994 base case (Figure 5.12). This is to be anticipated from a consideration of the changes in SO_2 emission quantities that would arise with the additional 2 x 350MW. As FGD is assumed to be fitted to Units L7 and L8, the additional mass emission of SO_2 would be no more than the equivalent of adding 70MW of plant (assuming 90% sulphur removal efficiency in the FGD process). The limited increase in mass emission of sulphur, would be reflected in a limited additional impact on existing SO_2 concentrations.

5.97 The predicted long term average SO_2 concentrations are shown in Figures 5.13 to 5.14.

5.98 For the 1994 base case, predicted concentrations are greatest to the west of the power station with a maximum of around $26\mu g.m^{-3}$. Predicted concentrations are well within the annual AQO of $80\mu g.m^{-3}$, even with allowance for the addition of background levels.

5.99 The effect of addition of 2 x 350MW units is shown in Figure 5.14. The model predicts a small increase over the baseline condition, with maximum annual average levels of $32\mu g.m^{-3}$. Again, predicted maxima are well within the annual AQO.

Oxides of Nitrogen

5.100 Figures 5.15 to 5.18 show the ISCST predicted contours for NO_x.

5.101 As with SO_2, the 1 hour maximum concentrations are predicted to be highest over Hong Kong Island.

5.102 With the addition of 2 x 350MW units, there would be a modest increase in ground level NO_x concentration compared to the 1994 base case situation (Figures 5.15 to 5.16).

5.103 Long term average NO_x concentrations are predicted to be low, with a maximum predicted concentration of around $16\mu g.m^{-3}$, about 2km west of Lamma. Addition of 2 x 350MW makes no significant difference to the predicted long term average ground level concentrations and in all cases the concentrations are well within the annual AQO of $80\mu g.m^{-3}$.

Particulate

5.104 ISCST predicted particulate concentrations are shown in Figures 5.19 to 5.22.

5.105 Predicted concentrations in the 1994 base case condition show a maximum 24 hour average of around $200\mu g.m^{-3}$ at Victoria Peak, with levels typically between 40-$100\mu g.m^{-3}$ elsewhere on Hong Kong Island. With the exception of The Peak, predicted concentrations are generally less than 50% of the AQO. Addition of 2 x 350MW would make only a small difference to maximum TSP levels.

5.106 Long term average TSP levels are predicted to be extremely low in both the base case and with addition of Units L7 and L8 (Figures 5.21-5.22). The maximum predicted long term average TSP is less than 5$\mu g.m^{-3}$ or less than 6% of the AQO.

5.107 The modelled TSP concentrations can also be used to provide an estimate of the impact of respirable particulate (RSP). A typical value for the respirable fraction of particulate in Hong Kong is 60% [10]. However, manufacturer's data for the size of particles at the E.P. outlet suggests about 79% is respirable (i.e. < 11μm). Taking this latter figure and scaling the ISCST predicted maxima accordingly, the maximum 24h predicted RSP concentration becomes 221$\mu g.m^{-3}$.

5.108 As noted above, the pollutant concentrations predicted by ISCST are likely to be an overestimate, both because of the model's treatment of complex terrain and the use of "stable" atmospheric conditions for meteorological inputs. However, from the foregoing assessment of ISCST/LT predictions, it is evident that the area of the Territory most likely to be of concern with regard to emissions from Lamma Power Station is Hong Kong Island, and specifically Victoria Peak. Furthermore, modelling suggests that the existing power station operations are responsible for the majority of the predicted ground level air quality impacts, with the proposed additional generating capacity making little or no significant difference to the base case predictions. This is consistent with the small overall increase in emission quantities that would arise with the additional units.

RTDM

5.109 The results of modelling SO_2 concentrations using RTDM are given in Tables 5.7 to 5.9. These tables show the predicted 5 highest 1 hour concentrations at 8 key receptors.

5.110 Table 5.7 gives the results of the base case situation at 1994. As with ISCST, the model predicts that ground level SO_2 concentrations would be highest on Hong Kong Island but concentrations would be considerably lower than those predicted by ISCST. The results show that the 1 hour AQO of 800$\mu g.m^{-3}$ would not be exceeded at any of the 8 receptors studied.

5.111 With the addition of 2 x 350MW units (Table 5.8), predicted concentrations show a small increase at most sites, ranging from 3-77$\mu g.m^{-3}$.

5.112 These results therefore confirm the findings of ISCST that the provision of the additional generating capacity at Lamma would not significantly affect ground level SO_2 concentrations, or the probability of exceedence of the AQO. It is the existing generating capacity at Lamma that is the major contributor to predicted SO_2 concentrations on Hong Kong Island and South Lamma.

5.113 The conclusion from the modelled SO_2 results is that neither the operation of the existing nor the extended power station are likely to result in SO_2 concentrations at ground level in excess of the AQO. In the areas predicted to experience the highest concentrations of SO_2, there is a margin of around 20% between the predicted maximum SO_2 concentration and the AQO. The acceptability of such a margin is a matter of judgement and one that needs careful consideration. In this context, EPD have advised that, for the extension to be acceptable in air quality terms, an "adequate" margin needs to be maintained between predicted concentrations and the AQO, in order to allow for other possible pollution sources within the air shed. Whilst it is considered that a 20% margin is adequate for air quality management purposes, it was felt it would be useful to examine the options for improving the margin, should this eventually be considered desirable.

5.114 As the modelling study indicates that it is SO_2 emissions from the existing Units L1 to L5 which are the greatest contributors to predicted ground level concentrations, it is on these units that attention should be focused if additional air emission controls are considered necessary.

5.115 If it is considered necessary to reduce the existing emissions of SO_2 from the site to allow for a greater margin, retrofitting of sulphur removal technology needs to be considered. With the base case condition (L1 to L6), only unit L6 will have FGD. If FGD were to be applied to unit L5, this could reduce SO_2 emission from the unit by up to 90%. In sulphur emission terms therefore, the output from unit L5 would reduce from 350MW to 35MW. This represents a 20% reduction in SO_2 emissions compared to the present day. In practice, however, if further FGD control is confirmed to be necessary, it may not necessarily be required to have 90% removal efficiency. For the purposes of predictive modelling, however, 90% removal efficiency has been assumed.

TABLE 5.7 : BASE CASE 1994 JULY : FGD ON L6, HIGHEST 5 SO_2 CONCENTRATIONS ($\mu g.m^{-3}$)

Receptor	1	2	3	4	5
1. High West	537	533	532	528	488
2. Mt Kellett	629	559	557	557	549
3. Victoria Peak	564	502	496	481	478
4. Mt Gough	507	491	485	454	440
5. Reservoir	518	428	411	383	281
6. Aberdeen	440	439	439	415	393
7. Pok Fu Lam	505	398	372	370	345
8. Mt Stenhouse	561	506	499	488	424

Number of Hours of Exceedence of AQO : $800\mu g.m^{-3}$

Receptor	1	2	3	4	5	6	7	8
No. Hours	0	0	0	0	0	0	0	0

TABLE 5.8 : JULY 2000 : FGD ON L6-L8 350MW, HIGHEST 5 SO_2 CONCENTRATIONS ($\mu g.m^{-3}$)

Receptor	1	2	3	4	5
1. High West	614	584	550	533	529
2. Mt Kellett	637	635	575	572	572
3. Victoria Peak	567	565	532	521	497
4. Mt Gough	519	512	506	500	470
5. Reservoir	569	523	491	425	409
6. Aberdeen	460	454	447	430	425
7. Pok Fu Lam	567	510	426	412	388
8. Mt Stenhouse	584	526	519	516	446

Number of Hours of Exceedence of AQO : 800$\mu g.m^{-3}$

Receptor	1	2	3	4	5	6	7	8
No. Hours	0	0	0	0	0	0	0	0

5.116 RTDM was therefore run for the predicted worst case loading curve at July 2000, assuming retrofitting of L5 with FGD and the results are shown in Table 5.9.

TABLE 5.9 : JULY 2000 : 350MW FGD ON UNITS L5-L8, HIGHEST 5 SO_2 CONCENTRATIONS

Receptor	1	2	3	4	5
1. High West	512	509	493	490	468
2. Mt Kellett	532	530	511	509	509
3. Victoria Park	480	478	463	454	453
4. Mt Gough	416	410	407	403	390
5. Reservoir	456	419	394	370	368
6. Aberdeen	371	367	358	347	343
7. Pok Fu Lam	456	409	342	333	313
8. Mt Stenhouse	767	480	475	440	376

Number of Hours of Exceedence of AQO : 800$\mu g.m^{-3}$

Receptor	1	2	3	4	5	6	7	8
No. Hours	0	0	0	0	0	0	0	0

5.117 When compared with the base case condition at 1994 (Table 5.7), there is predicted to be a significant improvement in air quality at all receptors examined. This further supports the view that it is existing emissions from Lamma Power Station that are having the greatest impact on predicted ground level SO_2 concentrations. The addition of two 350MW units is more than offset by the reduction in emissions resulting from retrofitting L5, thus leading to an overall improvement in air quality over the present day.

5.118 Predicted SO_2 concentrations at all sites investigated are in most cases less than the AQO, by a margin ranging between 34% and 54% which suggests that retrofitting of L5 would be a more than adequate mitigation measure. Predicted concentrations at Mt Stenhouse, whilst still remaining within the AQO limit, are however predicted to be close to $800\mu g.m^{-3}$ with this scenario. The apparent anomaly between the maximum predicted concentration at Mt Stenhouse with FGD fitted to Unit L5, and without, is probably caused by a reduction in plume temperature with FGD retrofitting. This would have the effect of bringing the plume from L5 closer to ground level in the near field, with resultant increases in ground level concentrations.

NO_x

5.119 RTDM predictions of 1 hour NO_x concentrations are shown in Tables 5.10 to 5.11.

5.120 For the 1994 base case condition, maximum NO_x concentrations range from $252\mu g.m^{-3}$ to $351\mu g.m^{-3}$. Relatively high concentrations are predicted for The Peak and Mount Stenhouse on Lamma Island.

5.121 Power station emissions contain two principal species of NO_x, nitric oxide (NO) and nitrogen dioxide (NO_2). The dominant component (>95%) is NO. After release to atmosphere, oxidation of NO to NO_2 takes place, with the percentage of conversion being related to distance downwind of the source, atmospheric conditions and the presence of ozone (O_3). Because of these variables, it is not possible to be precise about the oxidation rates applying to the Hong Kong situation. However, from literature data [7] it is considered that 50% of the NO could be converted to NO_2 after a travel distance of 3.6km whilst a level of 30% has previously been used for a conversion rate for distances of 1.7km [8]. These conversion factors have therefore been applied to predicted NO_x concentrations on Hong Kong Island and Lamma respectively and are shown as resultant NO_2 concentrations in parentheses in Tables 5.10 to 5.11.

5.122 For the 1994 base case condition, predicted NO_2 levels at all of the receptors examined are below 1 hour AQO of $300\mu g.m^{-3}$ by a considerable margin. Even if background NO_2 concentrations are taken into account the modelled concentrations suggest the AQO would still be achieved at all receptors studied.

5.123 For the addition of 2 x 350MW units, predicted concentrations of NO_2 are higher than the 1994 base case condition but concentrations still remain within the AQO by a substantial margin at all receptors studied.

5.124 It follows from the above that no further consideration of NO_x mitigation measures is required, even with the proposed extension.

TABLE 5.10 : BASE CASE JULY 1994 : FGD ON UNIT L6, HIGHEST 5 NO_x CONCENTRATIONS ($\mu g.m^{-3}$)

Figures in parentheses are NO_2 values, estimated from conversion factors of 30% for receptors on Lamma and 50% for receptors on Hong Kong Island

Receptor	1	2	3	4	5
1. High West	300 (150)	295 (197)	294 (147)	280 (140)	278 (139)
2. Mt Kellett	351 (175)	314 (157)	309 (154)	309 (154)	308 (154)
3. Victoria Peak	314 (157)	280 (140)	268 (134)	266 (133)	266 (133)
4. Mt Gough	283 (149)	271 (135)	269 (134)	247 (123)	242 (121)
5. Reservoir	289 (144)	229 (114)	223 (111)	218 (109)	217 (108)
6. Aberdeen	252 (126)	245 (122)	232 (116)	232 (116)	221 (110)
7. Pok Fu Lam	281 (140)	222 (111)	213 (106)	194 (97)	193 (96)
8. Mt Stenhouse	319 (106)	282 (94)	279 (93)	267 (89)	238 (79)

TABLE 5.11 : 350MW CASE JULY 2000 : FGD ON UNITS L6-L8, HIGHEST 5 NO_x CONCENTRATIONS ($\mu g.m^{-3}$)

Figures in parentheses are NO_2 values

Receptor	1	2	3	4	5
1. High West	407 (203)	370 (185)	345 (172)	332 (166)	330 (165)
2. Mt Kellett	423 (211)	401 (200)	362 (181)	362 (181)	361 (180)
3. Victoria Peak	368 (184)	354 (177)	334 (167)	323 (161)	308 (154)
4. Mt Gough	342 (171)	324 (162)	312 (156)	312 (156)	297 (148)
5. Reservoir	361 (180)	331 (165)	329 (164)	277 (138)	273 (136)
6. Aberdeen	299 (149)	292 (146)	284 (142)	277 (138)	275 (137)
7. Pok Fu Lam	360 (180)	323 (161)	288 (144)	265 (132)	251 (125)
8. Mt Stenhouse	379 (126)	361 (120)	344 (120)	339 (113)	294 (98)

TSP/RSP

5.125 The results of RTDM runs for TSP/RSP are given in Tables 5.12 to 5.13.

5.126 For the 1994 base case, predicted TSP/RSP concentrations are all extremely low and in no case in excess of the relevant AQO. The maximum predicted 24 hour concentration of TSP was $12\mu g.m^{-3}$, which is less than 5% of the AQO. Even allowing for the very high background TSP values found in Hong Kong, the modelling indicates that the power station contribution is insignificant. Similar remarks apply to predicted RSP concentrations, where the maximum predicted value for the July 2000 case is $12\mu g.m^{-3}$, compared to the AQO of $180\mu g.m^{-3}$.

TABLE 5.12 : JULY 1994 BASE CASE : FGD ON UNIT L6, HIGHEST 5 TSP (RSP) CONCENTRATIONS ($\mu g.m^{-3}$)

Receptor	1	2	3	4	5
1. High West	9 (7)	9 (7)	9 (7)	9 (7)	9 (7)
2. Mt Kellett	12 (9)	12 (9)	11 (9)	11 (9)	11 (9)
3. Victoria Peak	8 (6)	8 (6)	8 (6)	8 (6)	7 (5)
4. Mt Gough	10 (8)	9 (7)	9 (7)	9 (6)	9 (6)
5. Reservoir	8 (6)	8 (6)	8 (6)	8 (6)	8 (6)
6. Aberdeen	8 (6)	8 (6)	8 (6)	8 (6)	8 (6)
7. Pok Fu Lam	9 (7)	9 (7)	9 (7)	9 (6)	9 (6)
8. Mt Stenhouse	11 (9)	11 (9)	11 (9)	11 (9)	10 (8)

5.127 With the addition of 2 x 350MW units, the model predicts only a marginal increase in TSP/RSP concentrations at all receptors studied and in terms of the AQO, the predicted concentration would be insignificant.

TABLE 5.13 : JULY 2000 FGD ON UNITS L6-L8, HIGHEST 5 TSP (RSP) CONCENTRATIONS ($\mu g.m^{-3}$)

Receptor	1	2	3	4	5
1. High West	12 (9)	12 (9)	12 (9)	12 (9)	12 (9)
2. Mt Kellett	15 (12)	15 (12)	15 (12)	15 (12)	14 (11)
3. Victoria Peak	11 (9)	11 (9)	10 (8)	10 (8)	10 (8)
4. Mt Gough	12 (9)	12 (9)	12 (9)	11 (9)	10 (8)
5. Reservoir	12 (9)	11 (9)	11 (9)	11 (9)	11 (9)
6. Aberdeen	11 (9)	11 (9)	11 (9)	11 (9)	11 (9)
7. Pok Fu Lam	13 (10)	12 (9)	12 (9)	12 (9)	12 (9)
8. Mt Stenhouse	15 (12)	15 (12)	15 (12)	15 (12)	14 (11)

Plume Visibility

5.128 The impact of the proposed additional generating capacity on plume visibility was examined using the model VISCREEN.

5.129 The visual impact of a plume can be determined by examination of the two parameters delta-E, a plume perceptibility parameter, and the plume contrast at different light wavelengths. Delta-E is a function of the difference in coloration between the plume and a viewing background in terms of both brightness difference and colour difference. These parameters are calculated when the background is either sky or terrain. VISCREEN calculates the contrast parameters at three different wavelengths (0.45, 0.55 and 0.65 micrometres). If the plume contrast is zero the plume is invisible, if positive the plume is brighter than the background, if negative the plume is darker than the background. If the plume contrasts are different at different wavelengths then the plume is coloured.

5.130 Generally the thresholds for these parameters that indicate adverse impact are taken as 2.00 for delta-E and 0.05 for plume contrast. However, these values depend on the plume thickness and in general a plume is easily perceived when it is thin and more difficult to notice when wider. Thus VISCREEN calculates the appropriate thresholds depending on the plume thickness.

5.131 The output of the model is a table giving delta-E and contrast values for various different angles of view of the plume, together with the calculated threshold limits. These values are produced for when the sun is behind the plume and when it is in front of the plume.

5.132 For this assessment the model was run for an existing plume arising from Units L1-L3 and comparing the results to those for the new units L7-L8. The model was run for stability Class 4 with a wind speed of 5m/s.

5.133 Results for a 90 degree view angle are given in Figures 5.23 and 5.24. The results suggest the visual impact of the plume from the new units will be low and would not be a cause for concern. In comparison with predicted plume visibility factors for existing units, which are known to have very limited visual impacts, the delta-E and contrast values are predicted to be even lower.

Abnormal Operations/Emergency Conditions

5.134 The results of modelling of ground level SO_2 concentrations under emergency oil firing and assumed non availability of FGD plant are shown for three typical wind speeds of $2.5m.s^{-1}$, $5m.s^{-1}$ and $10m.s^{-1}$ in Figures 5.25 to 5.27. These figures give the predicted downwind SO_2 concentrations up to 80km from the point of emission under meteorological conditions typically used by HMIP for the assessment of UK power stations.

5.135 The point of maximum ground level SO_2 concentration is related to wind speed, with higher wind speeds resulting in maximum concentrations arising at sites closer to the source. The atmospheric stability class has a significant effect on ground level concentration estimates and in this case stability class 4(D) was used in accordance with UK HMIP practice. The maximum ground level concentration predicted under the specified conditions are between approximately $110\mu g.m^{-3}$ and $200\mu g.m^{-3}$. These maxima are well within the relevant AQO, even allowing for addition of background concentrations. It is therefore not considered that short term abnormal operating regimes will have any significant impact on overall air quality at sensitive receptors.

5.136 The numerical modelling study results enable an assessment to be made of the areas of Hong Kong likely to be significantly affected by emissions from Lamma Power Station. It should be stressed, however, that whilst the numerical simulation enables broad conclusions to be drawn on the possible air quality impacts of the proposed power station extension, the conservative nature of the models used means that the absolute values of pollutant concentrations predicted are likely to be overly pessimistic. Evidence for this assertion can be gleaned from comparison between modelled and monitored results from HEC's air quality monitoring studies (cf Appendix A). This evidence and comparison suggests a general over-prediction of the model by perhaps 3 to 4 times.

5.137 "Worst case" numerical modelling indicates that the main areas of the Territory likely to be affected by pollutants from Lamma Power Station are the Peak and Mt Stenhouse. To a lesser degree, Cheung Chau could also experience relatively high SO_2 concentrations, with prevailing easterly winds. From an analysis of the modelling data, it is considered that all areas of the Territory predicted to be significantly affected by emissions lie within a radius of 7km of the power station site. This radius was therefore judged to be the minimum necessary to provide adequate geographical coverage in the wind tunnel test programme. However, to allow for a suitable safety margin, a radius of 8.5km was selected for the boundary of the wind tunnel.

Physical Modelling Study

5.138 Owing to the complexity of the terrain within the study area identified by the numerical dispersion modelling, a wind tunnel study was agreed to be necessary. Physical modelling is to be preferred under conditions where the approach wind is likely to be significantly modified by the topography and presence of buildings.

5.139 During the course of defining the nature of the physical modelling study, discussions were held with EPD and the Royal Observatory and a number of papers were prepared. These papers are summarised in [11]. It was concluded that the likely incidence of stable atmospheric conditions or low inversions was sufficiently remote, that the modelling should be done under neutrally stable conditions.

5.140 A model scale of 1:1200 was used and this allowed a study area extending from the Power Station to beyond Victoria Peak to the North East and nearly to Cheung Chau to the West, to be investigated in BMT's Environmental Wind Tunnel. The study area is delimited by the 8.5km radius circle in Figure 5.28. The figure also shows the eight representative wind directions chosen for the tests, together with the identification of the ground level measurement positions.

5.141 An impression of the model in the wind tunnel can be gained from Figure 5.29. The model is aligned along wind direction 2 (213°) - a line joining the centre of the Lamma Power Station to Victoria Peak. For reasons of aerodynamic roughness [11], the model was cut at 20m contours and left unsmoothed, as shown in the photograph. This is consistent with the requirement to create roughness which adequately penetrates the viscous regions of the atmospheric boundary layer at this model scale.

Operating Conditions

Essentially four scenarios were examined.

Test Condition

I	July 1994 :	Units L1-L6 plus Gas Turbines	B2 B1
II	July 2000 :	Units L1-L8 plus Gas Turbines	T4 T1
III	July 2000 :	As II, with L5 retrofitted with FGD	T5/T2
IV	July 2000 :	As III, with L4 and L5 retrofitted with FGD	T6/T3

Scenarios III and IV were included in the testing programme in order to cover the widest range of possibilities. In practice, as demonstrated below, FGD retrofitting is unlikely to be necessary.,

Each scenario was associated with peak loading as shown in Table 5.14.

TABLE 5.14 : PEAK OPERATING CHARACTERISTICS

Units	Load (MW)	Flue Diam (m)	Exhaust Gas Temp (°C)	Exit Vel (m/s)	SO_2 @ Source (kg/hr)	NO_x @ Source (kg/hr)
L1	270	5.11	125	16	1900	850
L2	270	5.11	125	16	1900	850
L3	270	5.11	125	16	1930	850
L4	365	5.62	116	18	2540	1190
L4 (FGD)	365	5.62	80	15	250	1190
L5	365	5.62	116	18	2540	1190
L5 (FGD)	365	5.62	80	15	250	1190
L6 (FGD)	365	5.62	80	15	250	800
L7 (FGD)	365	5.62	80	15	250	800
L8 (FGD)	365	5.62	80	15	250	800
GT2-GT7 (1994)	2x75	5.6	349	29	251	301
GT2-GT7 (2000)	5x87	5.6	375	31	279	287

Tests without the gas turbines operating were necessary to model the lowest wind speeds. This is due to their high temperature, highly buoyant plumes.

Validation

5.142 Physical modelling of dispersion is, by definition, not an exact replication of the real life phenomenon. Not all of the dimensionless parameters can be matched (other than at full scale), so compromises are needed.

5.143 Typically, Reynolds numbers were 10^4 smaller than full scale, but most wind tunnel experiments rely on the relative insensitivity of processes of this sort to Reynolds number over a wide range. Reynolds number sensitivity tests, covering almost an order of magnitude of range, were conducted for neutrally buoyant emissions and the results are presented in [12]. Satisfactorily uniform measurements of ground level concentration were observed, suggesting that the plume and approach flow were adequately turbulent.

5.144 Apart from Reynolds number, the other main parameters can be preserved if the Froude number is matched to full scale. This does, however, fix the wind tunnel speed at the square root of the geometric scale ratio smaller than the required full scale wind speed and thereby limits the lowest speed of study to around 6m/s to 7 m/s. In order to achieve lower speeds complete Froude scaling must be relaxed and choices made amongst other stack parameters, including fluxes of mass, momentum, volume and buoyancy, geometric distortion and velocity ratio between the emission and the wind. These issues are discussed in more detail in [12] and results showing good comparison between the complete Froude scaled tests and the enhanced buoyancy method equivalent measurements. Using the chosen enhanced buoyancy method it was possible to test emissions from the coal fired units down to wind speeds approaching 2m/s.

5.145 Other precursor measurements to determine the validity of the test method are also described in [12] and include detailed definition of the simulated atmospheric boundary layer approaching the study area and its homogeneity over the area of interest.

Interpretation of Measurements

5.146 Concentration measurements were made at ground level and elevated sensor locations and integrated to produce one hour averages for comparison with Hong Kong air quality objectives. For the duration of the test, the wind direction was fixed, but instantaneous deviations in wind angle are an integral part of the simulated turbulent flow. The wind tunnel fairly represents the measured atmospheric turbulence.

5.147 It is, however, apparent, especially at low wind speeds, that the wind rarely blows steadily in one direction over any one hour period. In light winds one hour statistics will often show variations of many tens of degrees. Under such circumstances the dispersing plume will inevitably be smeared, with the likely effect of a reduction in average concentration at any particular sensor. It is probable, therefore, that the wind tunnel measurements may, at times be conservative estimates of the full scale equivalent.

Results - Sulphur Dioxide

5.148 The combination of wind speed, direction, operating condition and sensor location, results in a large number of potential measurements. More than 2000 combinations were examined in the wind tunnel programme, following the plan in [11]. A wind speed range from approximately 2m/s to 15 m/s was covered for the eight wind angles in Figure 5.28. Detailed tables of these results are included in [12].

5.149 A convenient way of examining the overall appearance of the data, is given by the histograms in Figures 5.30, 5.31, 5.32 and 5.33. All measurements made for the four operating scenarios are shown and the trend from 1994 to 2000 and the effect of FGD retrofitting can be determined. It should be noted that the histograms contain all measurements, including duplicate conditions and elevated sensors. They cannot be used to judge the number of occurrences of full-scale events, but do allow comparisons between the Operating Scenarios and graphically show where the bulk of the data lies.

5.150 Each histogram band represents measurements over $100\mu g/m^3$ of SO_2 and is described by its upper limit. Thus "100" covers 0-100; "200" includes 100-200 and so on.

5.151 In all scenarios, the vast majority of the data is well below the AQO. Further examination of the data, as in the following paragraphs, reveals that the AQO is unlikely to be exceeded in practice.

5.152 A small increase in the high concentration tail is seen between 1994 (B1/B2) and 2000 (T1/T4) as units L7 and L8 come on stream, but this trend is reversed with the introduction of FGD on L5 (T2/T5) and L4 and L5 (T3/T6). In Figure 5.33, no values greater than $800\mu g/m^3$ are shown.

5.153 Whilst Figures 5.30 to 5.33, enable comparisons between the operating scenarios to be made, they do not describe the location of the highest values, nor their probability of occurrence. The values of the maximum concentration at the various ground level sensors are given in Table 5.15.

TABLE 5.15 : MAXIMUM GROUND LEVEL CONCENTRATIONS OF SO_2

Direction, Sensor	B1/B2	T1/T4	T2/T5	T3/T6
1,1	223	218	187	152
1,2	1156	1156	960	737
1,3	841	840	715	573
1,4	589	598	506	401
1,5	573	583	492	388
1,6	418	427	363	292
2,11	421	427	379	350
2,1	1063	1107	945	761
2,3	560	590	498	395
2,5	502	528	444	348
2,8	389	415	355	287
2,10	309	350	325	298
3,1	655	717	636	545
3,2	1012	1067	934	784
3,3	216	225	196	164
3,4	303	319	276	228
3,5	327	344	290	230
3,6	143	150	128	104
4,1	335	333	317	298
4,2	683	702	626	541
4,3	578	601	504	394
4,4	389	403	339	266
4,5	376	394	324	244
4,6	172	175	147	116
5,1	675	704	596	473
5,2	590	669	560	475
5,3	275	285	247	203
5,4	297	309	267	218
6,1	439	486	384	276
6,2	827	851	709	548
6,3	745	779	641	485
6,4	382	402	329	247
7,1	605	623	461	277
7,2	464	545	413	264
7,3	767	825	636	421
7,4	420	462	363	251
8,1	287	334	274	206
8,2	480	480	403	317
8,3	261	267	225	178

5.154 For land based sensors, values in excess of the AQO concentration limit only occur at positions 1,2; 2,1; 3,2; 6,2 and 7,3. Reference to Figure 5.28 shows these to be located on Lamma Island, generally on uninhabited, hilly locations.

5.155 With the addition of FGD to L5, this list is reduced to 1,2; 2,1 and 3,2. With the further addition of FGD to L4, all maxima fall below the limit.

5.156 As expected, the incidence of high concentrations at near field locations, occurs in relatively high winds. The pattern with wind speed for the sensors in question is shown in Figure 5.34 for the year 2000 operating condition.

5.157 For this, the most severe emission scenario, concentration values exceed 800μg/m^3 only above around a wind speed of 11m/s, an extremely rare event for the wind directions in question. This is demonstrated by the frequency of high winds histogram of 1988 (Figure 5.35), which shows that for each 22.5° sector the occurrence is no more than a few hours per year, for directions between South and North West. For the "worst" direction (SSW), the maximum is 3.5h. Although an individual plume has a smaller angular influence, this wind sector definition is appropriate to cover the influence of the different chimneys.

5.158 Additionally, the worst cases only arise if there is a coincidence of the burning of high sulphur coal, peak loads and emission with high wind speeds. An estimate of the average hours of joint occurrence for the SSW sector was made on the basis of the distribution of loads during the peak month and the assumption that all SSW winds in question occur during such months. (The load level was chosen to cover SO_2 emissions from 65% to 100% of peak and the SSW sector to ensure the direction of most frequent occurrence (Figure 5.35) was considered).

5.159 The average annual occurrence from this joint probability calculation is about 2 hours. The AQO definition permits exceedences for up to three hours per year, so that AQO is unlikely to be exceeded.

5.160 The pattern of concentration increase with wind speed is repeated for high locations, such as Victoria Peak and Mt Kellett. The plumes at low speed rise well clear of the Peak and similar elevations and extrapolation to lower wind speeds would lead to extremely small values. The measured plume rise is similar to that predicted by the Gaussian model using the Briggs formulation.

5.161 At the distance of Victoria Peak, and taking a low wind speed of 2.7m/s, even the addition of the maximum plume centre-line concentrations results in a total concentration less than the AQO.

5.162 The papers referenced in [11], demonstrated the lack of stable conditions for winds with a westerly component. These have been the major focus of attention in the physical model study, given the distribution of land and developments relative to the Lamma Power Station.

5.163 Nonetheless, it is also relevant to consider the effects of an Easterly wind, carrying emissions toward Cheung Chau. In the neutral atmospheric measurements of the wind tunnel tests, the maximum concentration at Cheung Chau was found to be around 300μg/m^3 at elevations up to 90m. However, if low wind speeds were considered (say less than 5m/s) then concentrations were not more than 80μg/m^3. Such speeds are more applicable to considerations of atmospheric stability other than neutral.

5.164 At Cheung Chau, the influence of reduced dispersion due to stable conditions would probably be to reduce the concentration as a result of inhibited spreading. Given the absence of locally generated ground based inversions over the sea around Lamma [11], a more likely cause of elevated readings might be plume trapping due to a relatively low inversion base (greater than stack height, but significantly less than full plume rise). Such conditions do occur during the winter season, but at worst should bring no more than the neutral plume centre-line maximum closer to the ground. For the lowest wind speed measured (2.7m/s), this value was less than the AQO.

5.165 On the basis of the combined wind probability and concentration results, it appears from the physical model study that exceedence of the Air Quality Objective is unlikely within the study area, even without the implementation of FGD retrofitting.

Nitrogen Dioxide

5.166 Measurements of Nitrogen Dioxide, equivalent to those of SO_2 are given in [12].

5.167 To determine the level of NO_2 in the measured NO_x levels, requires a conversion rate to be assumed. Following [8], it has been assumed that the NO_2 conversion rate is 30% on Lamma and 50% on Hong Kong Island.

5.168 The maximum values of NO_2 at all ground level sensors were well below the AQO, as Table 5.16 shows.

TABLE 5.16 : MAXIMUM GROUND LEVEL CONCENTRATIONS OF NO_2

Direction, Sensor	B1/B2	T1/T4
1,1	41	38
1,2	188	199
1,3	180	192
1,4	157	179
1,5	157	176
1,6	111	128
2,11	71	79
2,1	171	188
2,3	151	193
2,5	134	166
2,8	100	125
2,10	80	116
3,1	97	121
3,2	151	174
3,3	54	63
3,4	76	93
3,5	83	101
3,6	36	42
4,1	47	47
4,2	100	114
4,3	118	145
4,4	100	121
4,5	97	122
4,6	45	51
5,1	103	121
5,2	97	126
5,3	57	72
5,4	71	91
6,1	72	118
6,2	131	160
6,3	119	155
6,4	102	136
7,1	100	117
1,2	77	163
7,3	125	180
7,4	68	107
8,1	74	94
8,2	116	135
8,3	75	87

Dust (Total Suspended Particulates)

5.169 Estimates of TSP concentration were made from the measured plume dilutions on the basis of emissions of 125, 160 and 115kg/hr for (L1-L3), (L4,L5) and (L6-L8), respectively. Maximum 1 hour values of 28μg/m^3 were calculated, which are low compared with the 24hr AQO of 260μg.m^{-3} and the one year average of 80μg.m^{-3}. On the assumption that 79% of the emitted particulate is respirable (c.f. para 5.107) the maximum 1 hour RSP value calculated is 22 μg^{-3}, which is only 12% of the AQO.

Development Plans

5.170 A brief review of the Outline Development Plans for Lamma Island (D/I-LI/1) and Cheung Chau (D/I-CC/I) and the outline zoning plans for Kennedy Town and Mount Davis (S/H1/2), Central (S/H14/2) and Aberdeen and Ap Lei Chau (S/H15/5), has been undertaken.

5.171 Major changes to the character of these areas are not planned and it is believed that the elevated sensor concentration measurements in regions of multi-storey buildings (Aberdeen, Pok Fu Lam, Central) and higher elevations (Victoria Peak, Mount Davis, Cheung Chau) have adequately covered the areas of potential concern. One significant development maybe the proposed Route 7, Western Coastal Highway on Hong Kong Island. This will produce an additional background level of NO_2 in areas close to sensors 3,3; 2,3; 1,4 and 1,6. Table 5.16 indicates that the maximum NO_2 concentration produced by the Lamma Island Power Station should lie in the range of 50 to $200\mu g.m^{-3}$, but again these levels would only be achieved at relatively high wind speeds and have very low frequency of occurrence at any one location. It is unlikely that the possible increase in background NO_2 as a result of traffic using the proposed Route 7, will therefore, be of any real significance in the context of typical ground level NO_2 concentrations resulting from power station emissions.

5.172 The physical model tests therefore support the general findings of the RTDM numerical modelling and confirm that air quality impacts from the proposed new Units L7 and L8 are not significant.

Fugitive Dust

5.173 There are a number of potential fugitive dust sources arising on coal fired power stations. At Lamma, these were identified in detail during the original EIA for the station [9] and appropriate control measures were introduced into the design. These include provision of covers on coal conveyor systems; use of dust suppression sprays on the coal storage area; use of wind boards; use of chemical/water suppressants at coal transfer points; enclosed transfer of PFA to storage silos and use of bag filters during transfer of PFA to vessels for transport off site.

5.174 With the introduction of FGD on Unit L6, additional materials will need to be imported to the Lamma site and waste materials exported. As Unit L6 will be fitted with a limestone-gypsum FGD system, and on the assumption that Units L7 and L8 will be similarly fitted, the environmental impacts of fugitive dust during operation of the new units are confined to those due to any additional handling of limestone and gypsum.

5.175 It is anticipated that the limestone will be brought to the site by vessels in crushed form and transferred to storage areas at the eastern perimeter of the site.

5.176 Gypsum from the FGD plant will be transferred via 40t/h conveyors to a 6000 tonne storage silo. From here, it will be further transferred via conveyor systems before final disposal offsite.

5.177 The provision of the infrastructure for limestone/gypsum handling will be installed as part of the L6 development. The detailed environmental impacts of this infrastructure has not therefore been addressed in the current study. With regard to fugitive dust releases, however, it will be necessary to operate the handling facilities in accordance with the site licence conditions.

5.178 At the present time, detailed design of the limestone/gypsum handling system is being finalised and a conceptual design for the gypsum system is shown in Figure 5.36.

5.179 The delivery, handling and storage of FGD materials will need to be carried out with due regard for minimising fugitive particulate emissions and hence appropriate attention will need to be given to control measures at the detailed design stage. At this stage it is envisaged that such controls will include provision of covered conveyor systems where possible; provision of wind boards on jetty conveyors; minimisation of material drop heights to 1.2m or less during loading/unloading; storage of raw materials under cover and the control of any particulate emissions from FGD material handling to a concentration not exceeding $100mg.m^{-3}$.

5.180 HEC carry out sampling of fugitive dust at various locations within and on the perimeter of the Lamma site. The locations are shown on Figure 5.37. Two types of measurement are made - particulate loading and monthly dustfall.

5.181 Data from the HEC monitoring are summarised in Figures 5.38 to 5.43.

5.182 Dust concentration measurements made at three sites within the power station boundary show a highly variable temporal profile which is characteristic of such data. However, it is clear from these data that concentrations recorded adjacent to the No 2 coal yard and the mobile plant workshops (Figures 5.39 and 5.40) are broadly similar, averaging 0.53 ± 0.5 $mg.m^{-3}$ and 0.40 ± 0.5 $mg.m^{-3}$ respectively. Measurements near the ash disposal control room were generally higher in the early years of monitoring (between 1983-85), but subsequently show concentrations similar to the other two sites. All monitoring shows a pronounced reduction in TSP levels from 1987 onwards, which can presumably be attributed to completion of major construction works on the site, and to the increasing effectiveness of fugitive dust control measures.

5.183 The temporal pattern of dust fallout data since December 1985 is shown in Figures 5.41 to 5.43. These profiles are broadly similar at each site and show periodic peaks and troughs with time.

5.184 Unlike the TSP data, there is no obvious decline in dustfall levels with time at any of the monitoring sites. This suggests that sources of fugitive dust other than the power station make up the majority of the collected deposits.

5.185 From a review of the available particulate monitoring data, it would appear that current levels of TSP are not unusually high for Hong Kong and indicate effective minimisation of fugitive dust releases. Dustfall measurements at the periphery of the power station show relatively high loadings, with pronounced variability. It seems likely that sources outside the power station are primarily responsible for this, although without detailed microscopic and/or chemical analysis of collected deposit, it is not possible to identify particular sources.

5.186 Addition of Units L7 and L8 would require increases in the importation, storage, handling and export of materials to and from the site. However, the legislative and infrastructure controls already largely exist to minimise fugitive dust problems from occurring on the site and it is therefore not considered that the proposed additional generating capacity would have any significant effect on fugitive dust releases.

Trace Species

5.187 Coal contains most of the known elements of the periodic table. During combustion in power stations, the alumino-silicates melt rather than decompose to form fly-ash which retains most of these original elements. The high efficiency electrostatic precipitators at Lamma Power Station retain all but a small fraction of this ash. The sulphidic materials in the coal decompose to form volatile compounds, including organic species. These typically condense on available surfaces as the gases cool.

5.188 Studies on the impact of trace species (e.g. heavy metals, organics) released from coal burning have generally concluded these impacts to be insignificant in relation to other sources of these compounds. Discharges of such trace species from Lamma Power Station are therefore not regarded as a cause for concern.

Transfrontier Pollutant Transport

5.189 In order to assess the possible transfrontier pollution impacts, an ISCLT run was also carried out for the July 2000 350MW case, using a 200km grid. This run was performed to calculate the Lamma Power Station's contribution to the long term annual average sulphur dioxide concentration at long distances from the site. The results in Figure 5.44 indicate that additions to the annual average sulphur dioxide concentrations will be very low at distances between 10-200km from the site and therefore transfrontier effects will be largely insignificant.

Odours

5.190 The potential for odours to arise from coal combustion plant relates largely to the amount of reduced sulphur compounds emitted. Combustion of coal in power stations takes place in a strongly oxidizing atmosphere hence production of reduced sulphur compounds is minimal. HEC report that no complaints of odour have been received from the existing operations of Lamma. Because the new Units L7 and L8 will be coal fired, no significant increase in fuel oil handling is anticipate, thus additional hydrocarbon vapours are not likely to be significant.

5.191 The provision of FGD to Units L6, L7 and L8 will be effective in removing water soluble compounds, such as hydrogen sulphide, from the stack emissions. It is therefore considered that odour impacts from the new units will be insignificant. No further mitigation measures are likely to be needed.

Summary and Conclusions

5.192 Analysis of the potential air quality impacts of the proposed extension has been carried out using dispersion modelling techniques and wind tunnel tests. Dispersion modelling techniques can, however, only be regarded as first order estimates and are likely to over-estimate actual air quality impacts. Indeed, initial comparison of predicted results with monitored data suggests that modelling could be over-predicting pollutant concentrations typically by about a factor of 3-4. The main use of the numerical dispersion modelling has been to identify the areas of possible significant air quality impacts from both the existing power station and proposed extension. Modelled results have therefore enabled the scope of the physical modelling study to be defined.

5.193 Modelling of short term impacts using a first level screening model - ISCST - using "stable" atmospheric conditions indicated that current emissions of SO_2 from Lamma Power Station could lead to relatively high ground level concentrations on Hong Kong Island and South Lamma. ISCST predictions indicated that current emissions may be sufficient to cause breaches of the short term AQO of $800\mu g.m^{-3}$ at several sites. The absolute values predicted by ISCST are undoubtedly far higher than would be achieved in practice, due to both the use of stable atmospheric conditions and the presence of rugged terrain.

5.194 With addition of two 350MW units, there is only a relatively small change in total SO_2 emissions, due to the effects of flue gas desulphurisation and the overall increase in ground level SO_2 concentrations arising from the additional generating plant is predicted to be insignificant in comparison with predictions from the existing station.

5.195 The long term average predicted concentrations of SO_2 from the power station are low and well within the relevant AQO. Addition of Units L7 and L8 would have no significant effect on the long term average concentration of ground level SO_2.

5.196 The model ISCST and its long term version, ISCLT, are designated as first level screening models under USEPA modelling guidelines [6]. They are not designated for use in rugged terrain conditions and are known to generally overestimate concentrations. Further modelling, using a complex terrain model, RTDM, was therefore performed.

5.197 Predicted ground level SO_2 concentrations using RTDM were considerably lower than those predicted by ISCST, although a generally similar pattern of relatively high short term concentrations on Hong Kong Island and South Lamma was indicated. RTDM modelling confirmed that the major cause of the predicted high short term ground level concentrations was the emissions from the existing power station. A small and insignificant increase in ground level SO_2 is predicted with the addition of 2 x 350 MW units. RTDM modelling indicates that the AQO limit of $800\mu g.m^{-3}$ would not be exceeded at any of the receptor sites studied.

5.198 Numerical modelling suggests that there is an adequate margin between predicted maximum SO_2 concentrations and the AQO. However additional modelling of SO_2 impacts was also carried out, assuming mitigation measures were to be applied to the existing generating units. If FGD were to be provided on the existing unit L5, the model predicts that there would be a general improvement in ground level SO_2 concentrations compared to present day conditions, even with the addition of two further units to the power station site.

5.199 Predictions of the ground level NO_x concentrations suggest that the short term AQO of $300\mu g.m^{-3}$ will not be exceeded at any of the receptor sites studied as a result of existing emissions from Lamma Power Station. Addition of units L7 and L8 is predicted to marginally increase ground level NO_x concentrations at all sites, although predicted concentrations remain within the AQO.

5.200 Predictions of the ground level concentration of particulate (TSP) and respirable particulate (RSP) indicate that the existing power station makes only a small contribution to background levels. The addition of a further two units would make no significant difference to the concentration predicted from the existing plant. No significant environmental impacts from particulate emissions are therefore likely to arise from provision of the additional generating capacity.

5.201 The findings of the numerical modelling study were used to define the scope of a wind tunnel testing programme. The numerical modelling study has demonstrated that the overall air quality impacts of the proposed extension are generally small in relation to the predicted impacts arising from the operation of the existing plant.

5.202 Modelling of plume visibility indicated that the emissions from the proposed new units would have a low visual impact, with visibility factors being even lower than those of the existing station, which is known to have a very low plume visibility impact. The effects of plume visibility under normal operating conditions are therefore likely to be insignificant.

5.203 Modelling carried out for abnormal/emergency operating conditions indicated that the air quality impacts are likely to be low and acceptable, given the short term nature of such conditions. No particular mitigation measures are therefore likely to be required to minimise impacts under such conditions.

5.204 The wind tunnel modelling has provided a comprehensive set of dispersion measurements for a range of wind speeds, directions and operating conditions.

5.205 In all areas studied, concentrations of nitrogen dioxide and total suspended particulates fall well below the AQO.

5.206 For receptors on Hong Kong Island, concentrations of sulphur dioxide also fall comfortably below the AQO.

5.207 On Lamma Island, some SO_2 values are predicted to exceed $800\mu g/m^3$ in high winds, generally on uninhabited, hilly locations. However, the frequency of occurrence of such winds (i.e. $>11 m.s^{-1}$) is extremely rare and in order for SO_2 values of this magnitude to occur in practice, they would have to coincide with the power station burning coal at its maximum permitted sulphur level (1%). In addition, all units would have to be operating at full load. The limited probability of these various worst case meteorological and station operational factors acting coincidently means that exceedence of the AQO is most unlikely. Reduction in the SO_2 values to wholly below the AQO level, could be achieved if necessary by the retrofitting of L4 and L5 with FGD. The economic penalty of such retrofitting would, however, be high and difficult to justify.

5.208 On the Western boundary of the study area at Cheung Chau, the physical model predicts low concentrations and even if dispersion is severely limited by an inversion aloft, exceedence of the AQO is not predicted.

5.209 The provision of FGD for the additional units will require additional quantities of limestone and gypsum to be handled on the site. The provision of the materials handling infrastructure will form part of the Unit L6 development and has not been separately assessed in this study. It is recognised, however, that appropriate fugitive dust control measures will need to be included and that these will have to be addressed at the detailed design stage.

5.210 A review of monitoring data on fugitive dusts collected by HEC suggests that dust control on the existing station is adequate to prevent fugitive dust problems arising. Similar dust control measures applied to the new material handling facilities should therefore be equally effective.

5.211 A review of possible odour impacts from the proposed power station has been carried out. Because of the strongly oxidizing nature of coal combustion plant, there is little potential for reduced sulphur compounds to be emitted. The risk of odour impacts arising from the proposed power station extension is therefore considered to be negligible.

5.212 Predictions of the long range transport of pollution show that, whilst gaseous pollutants will be transported outside the Territory, their concentration, and hence impact, will be very limited beyond 10km. Moreover, because of the prevailing wind patterns, long range transport will not be confined to a single area for the whole year. For much of the year, prevailing winds will distribute emissions to the west of the Territory and will therefore deposit in the sea. For periods of the year with prevailing south westerly winds, long range transport of pollutants to Southern China could occur. However, as already noted, the low predicted pollutant concentrations, coupled with the high rainfall at these times of year, are likely to result in insignificant transfrontier effects.

Key Issue Studies

5.213 As a consequence of discussion between EPD, HEC and its consultants following the submission of the draft IAR, an Air Quality Key Issue Study was undertaken to address specific areas of concern in more detail. The key issue study had the following objectives:

- To derive further estimates of concentrations at certain elevated positions on Hong Kong Island;
- To consider impacts on a daily and annual basis;
- To quantify background levels of air pollution and AQO margins in areas where developments are planned on Western Hong Kong Island;
- To consider any planning constraints or mitigation measures which may be suggested by the analysis.

5.214 A draft key issue report (KIR) has been produced and the principal findings may be summarised as follows:

- For the development plans currently under consideration for various parts of Hong Kong Island, no new constraints have been identified with respect to the emissions from the Lamma Power Station and the AQO margin;
- The analysis demonstrated that sufficient margin exists (even under worst case conditions) for the SO_2 AQO under full operating load without the need to retrofit FGD plant to existing units at Lamma Power Station;
- SO_2 levels over Hong Kong are predicted to remain substantially unchanged with the L7/L8 extension and NO_2 levels are predicted to preserve large margins of the AQO.

5.215 Following submission of the KIR to EPD, and their subsequent endorsement, it has been agreed that:

- HEC will enhance their existing air quality monitoring network to include additional monitoring on Lamma Island; and

- HEC will endeavour to adopt more advanced low NO_x combustion technology (200 vppm) for the new generating units.

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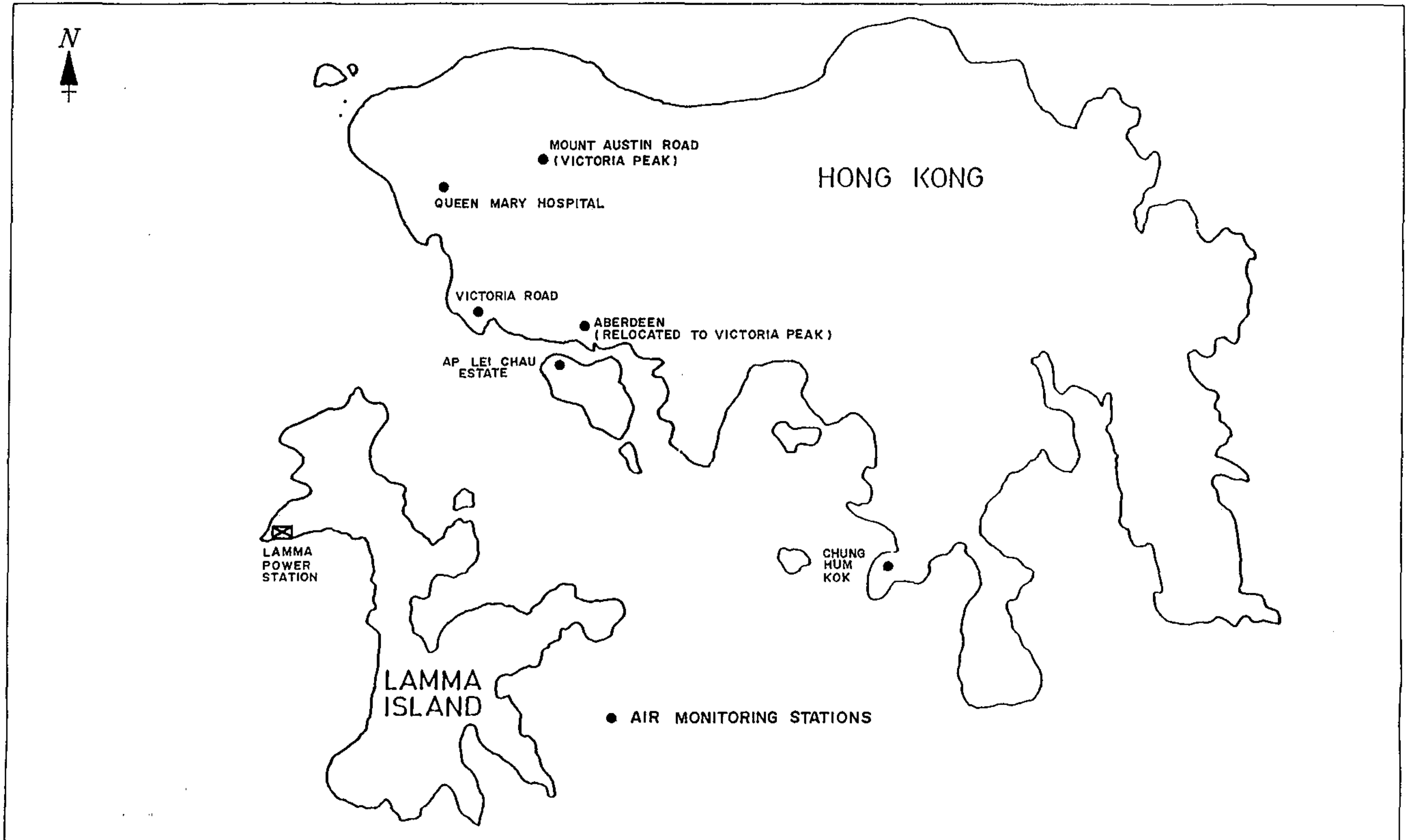
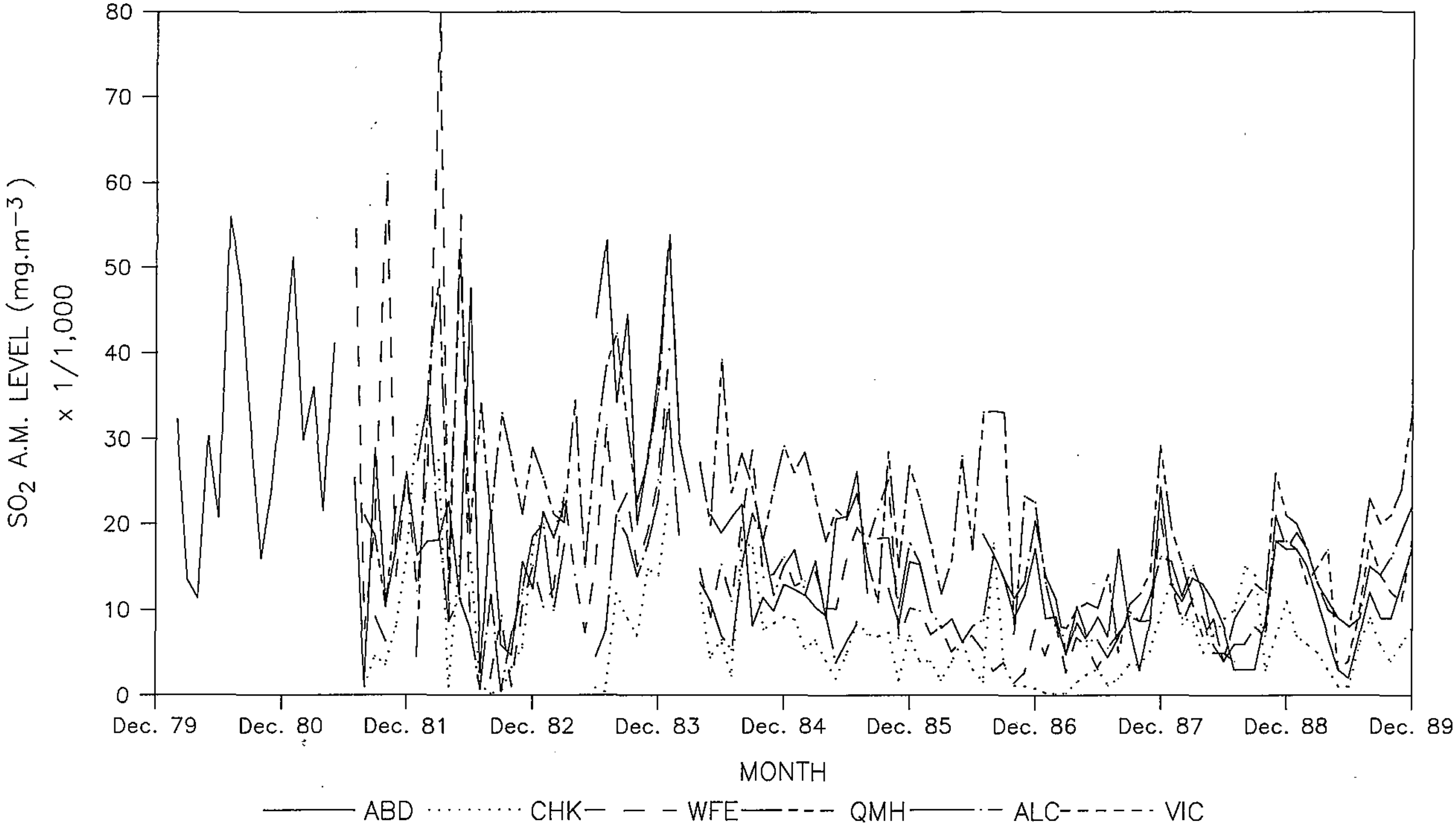
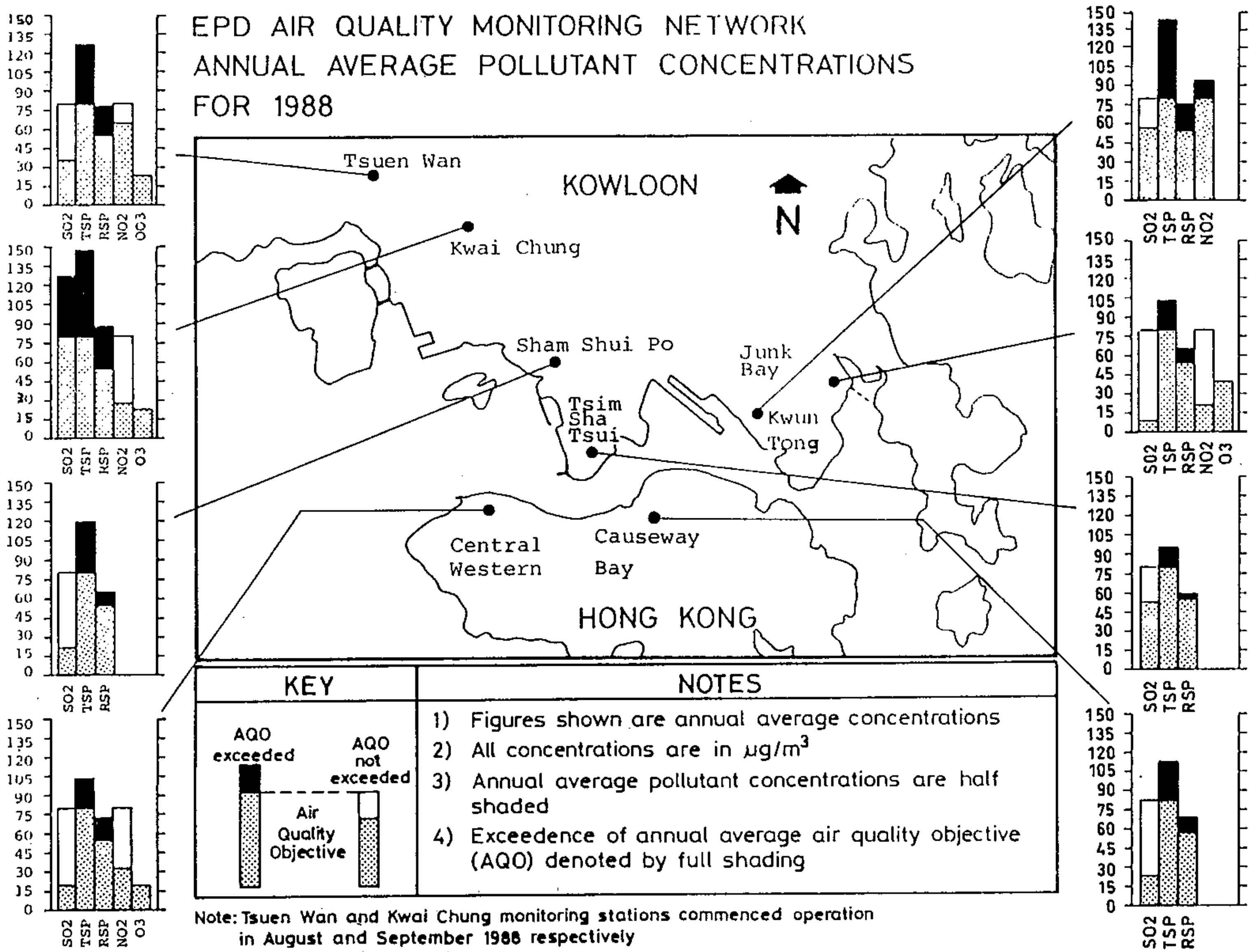


The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: AIR MONITORING SITES OF HEC
		FIGURE: 5.1



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: MONTHLY 1−HOUR SO_2 A.M. LEVEL FIGURE: 5.2



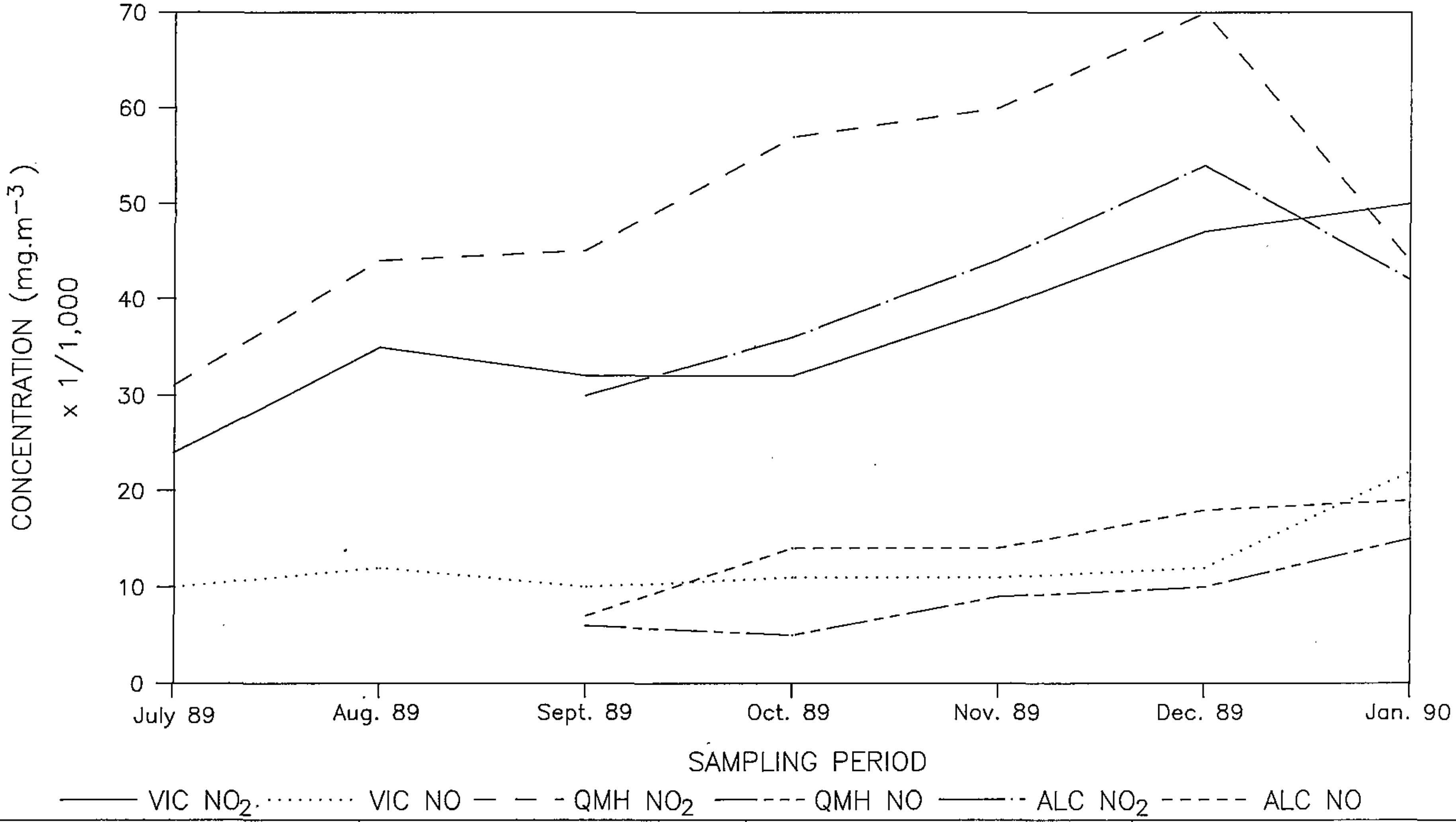
Note: Tsuen Wan and Kwai Chung monitoring stations commenced operation in August and September 1988 respectively

The Hongkong Electric Company Limited

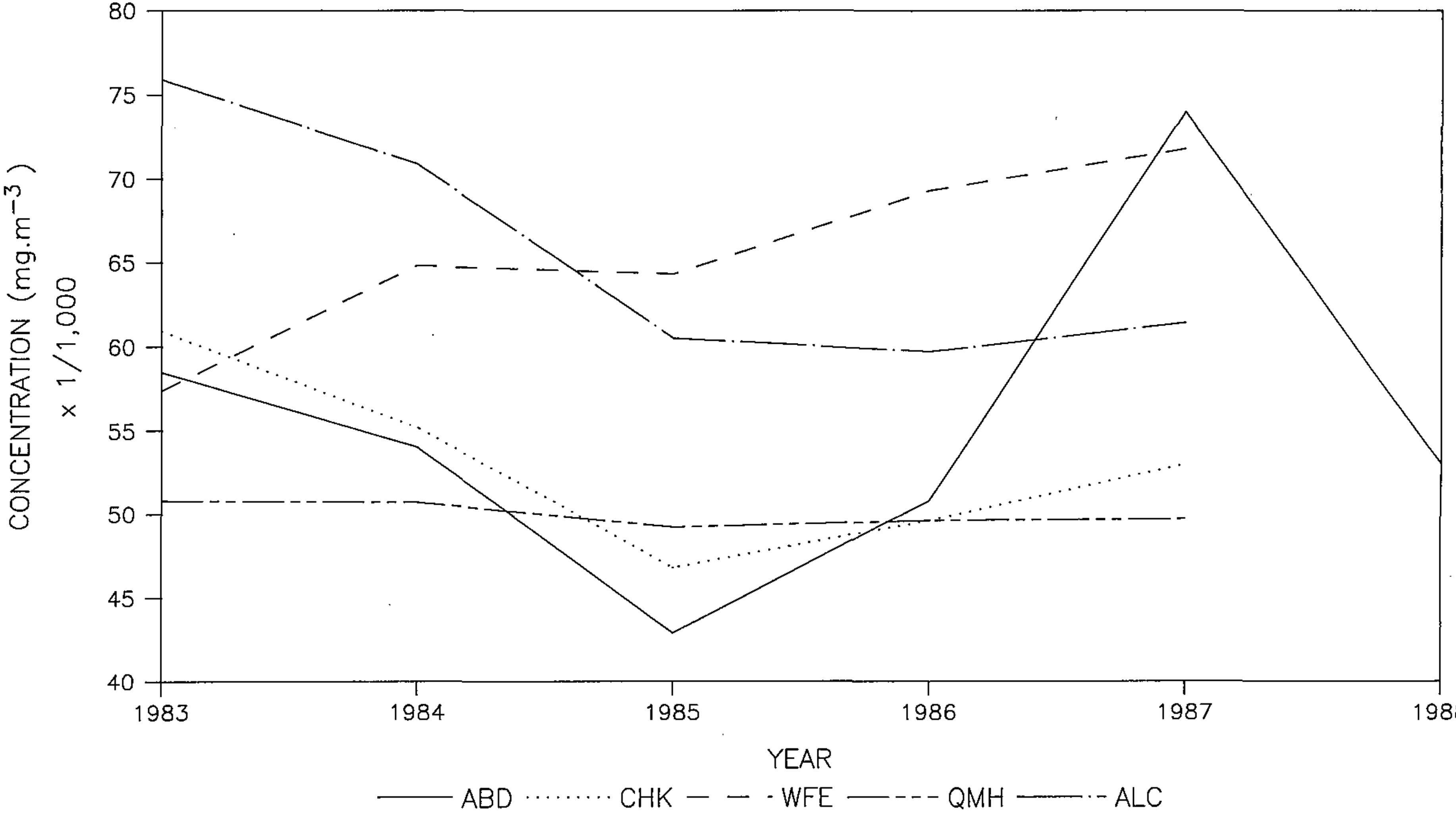
PROJECT: EIA LAMMA POWER STATION

TITLE: ANNUAL AVERAGE POLLUTANT CONCENTRATIONS RECORDED AT AIR QUALITY MONITORING STATIONS DURING 1988

FIGURE: 5.3



	The Hongkong Electric Company Limited hongkong electric	PROJECT: EIA LAMMA POWER STATION	TITLE: MONTHLY AVERAGE OF NO & NO_2 CONCENTRATION FIGURE: 5.4

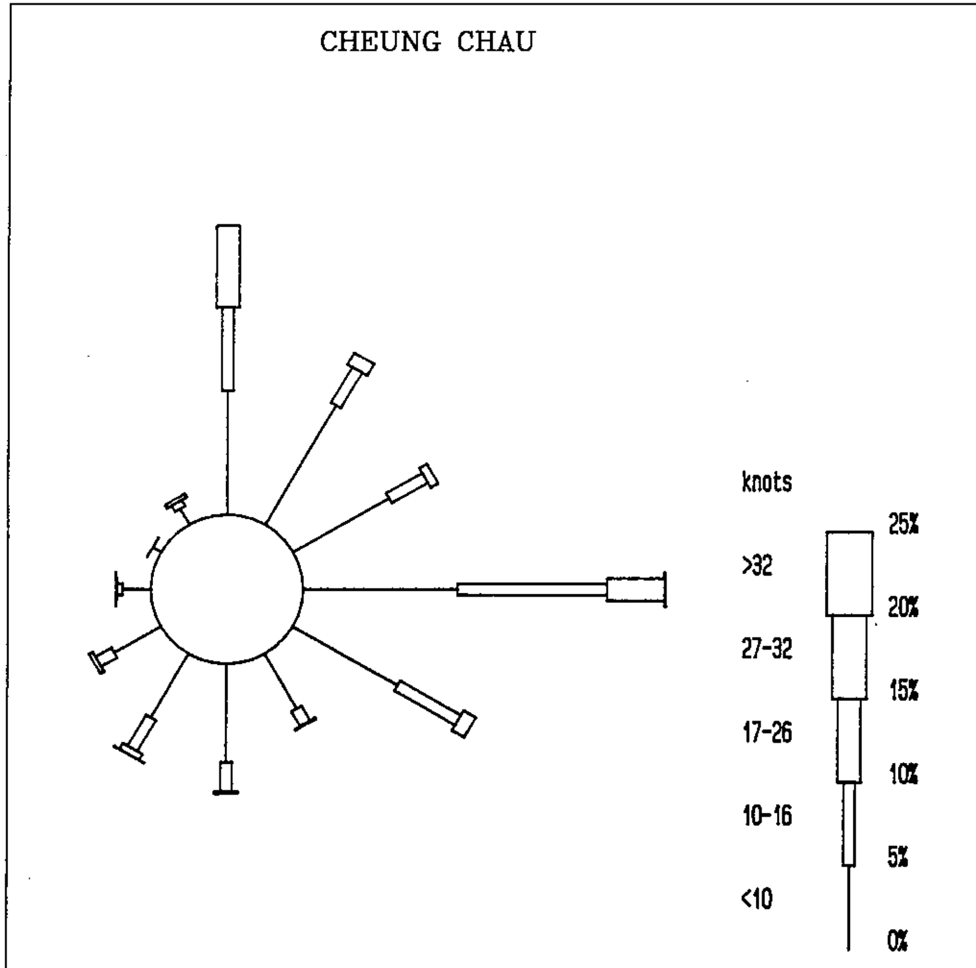


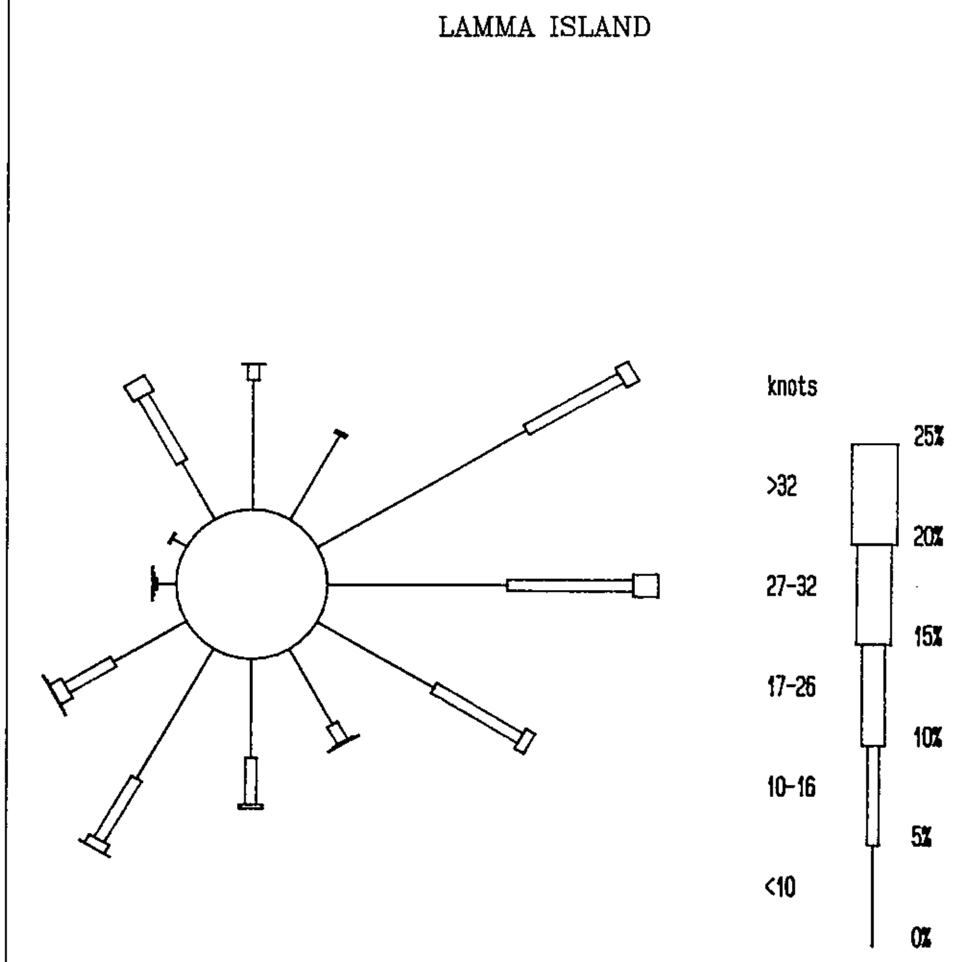
The Hongkong Electric Company Limited

PROJECT: EIA LAMMA POWER STATION

TITLE: YEARLY AVERAGE 24 Hr TOTAL SUSPENDED PARTICULATE CONCENTRATION

FIGURE: 5.5



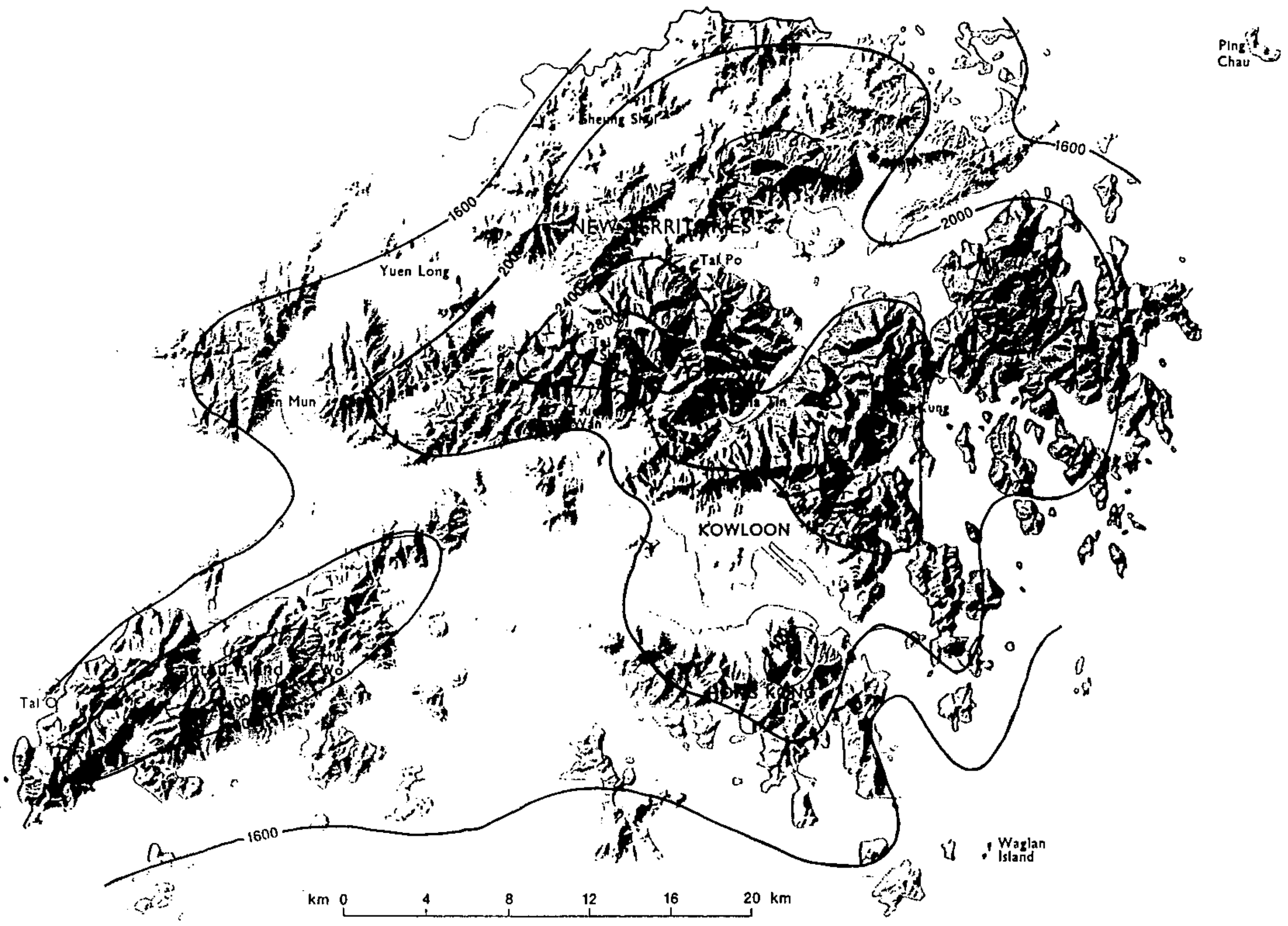


The Hongkong Electric Company Limited

PROJECT: EIA LAMMA POWER STATION

TITLE: WIND ROSES FOR 1988

FIGURE: 5.6

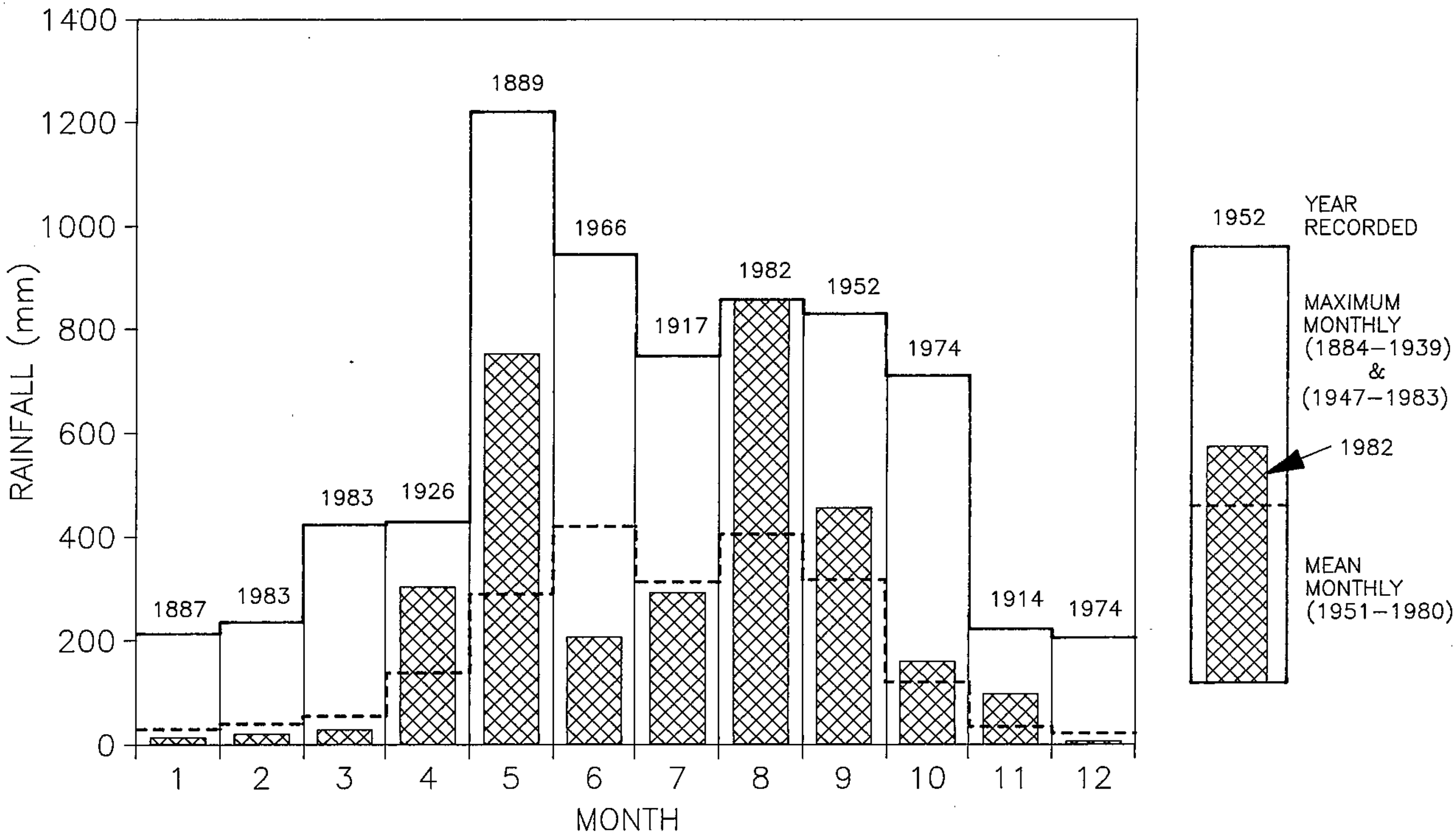


The Hongkong Electric Company Limited

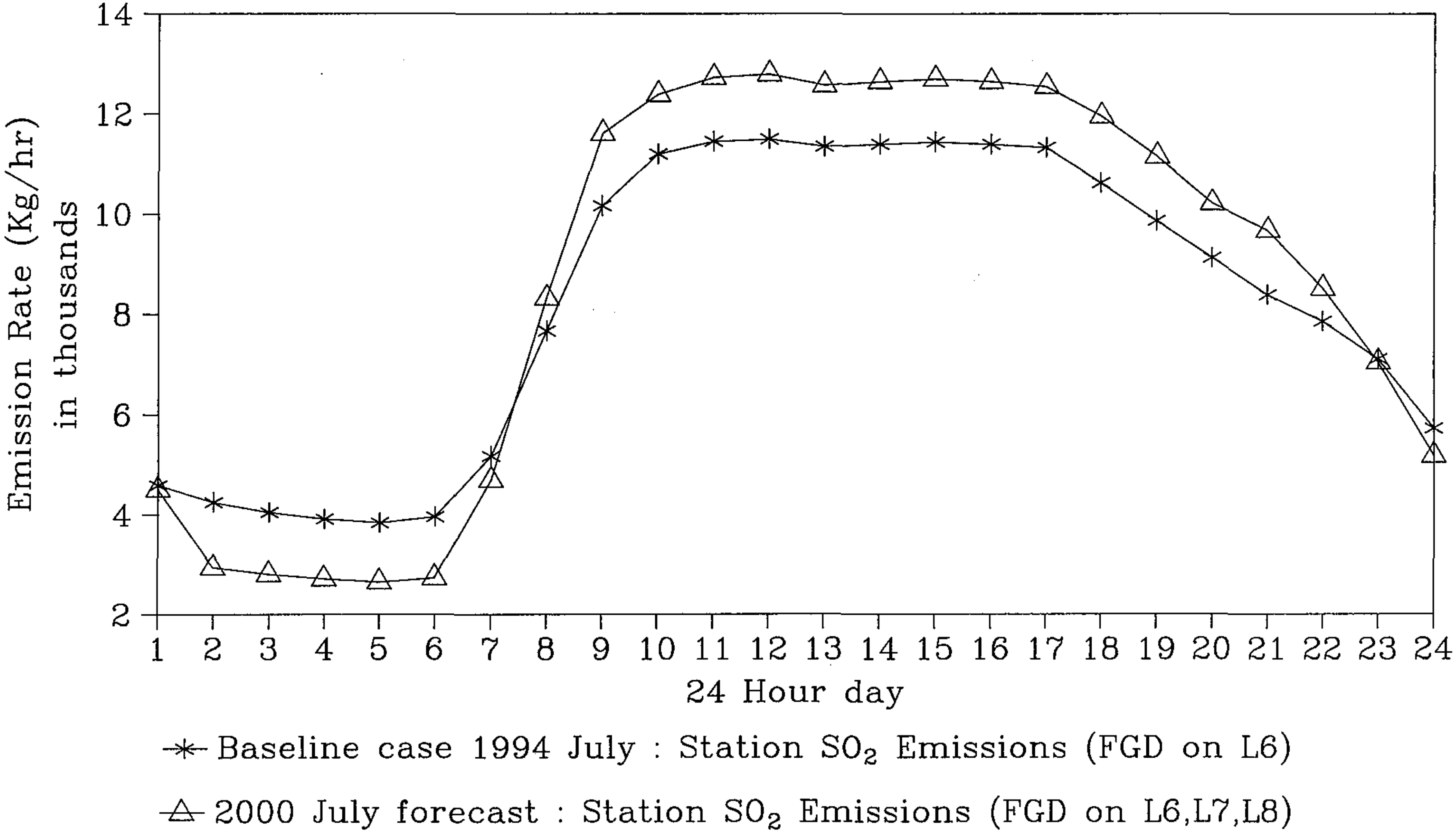
PROJECT:
EIA LAMMA POWER STATION

TITLE: MEAN ANNUAL RAINFALL 1953 – 1982

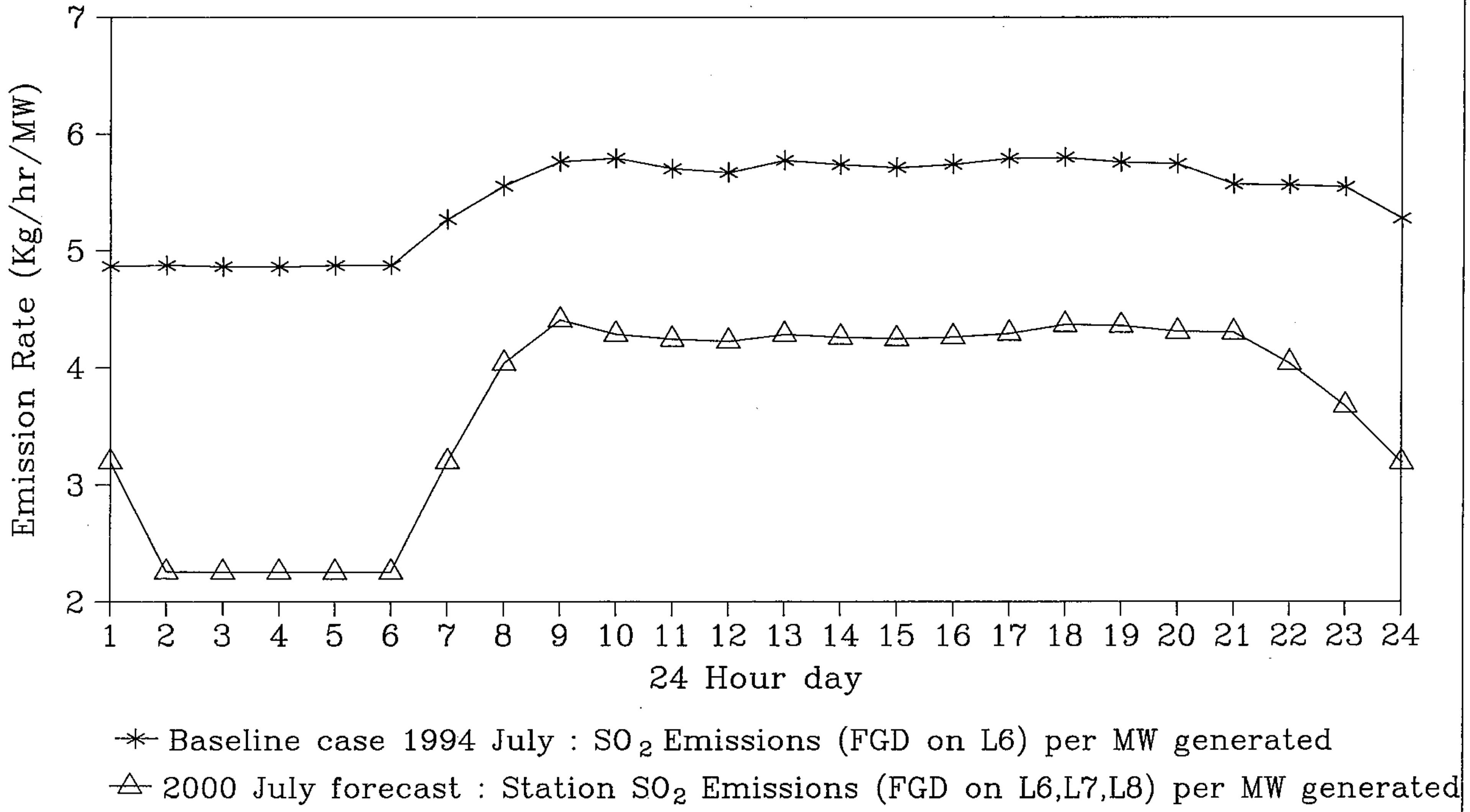
FIGURE: 5.7



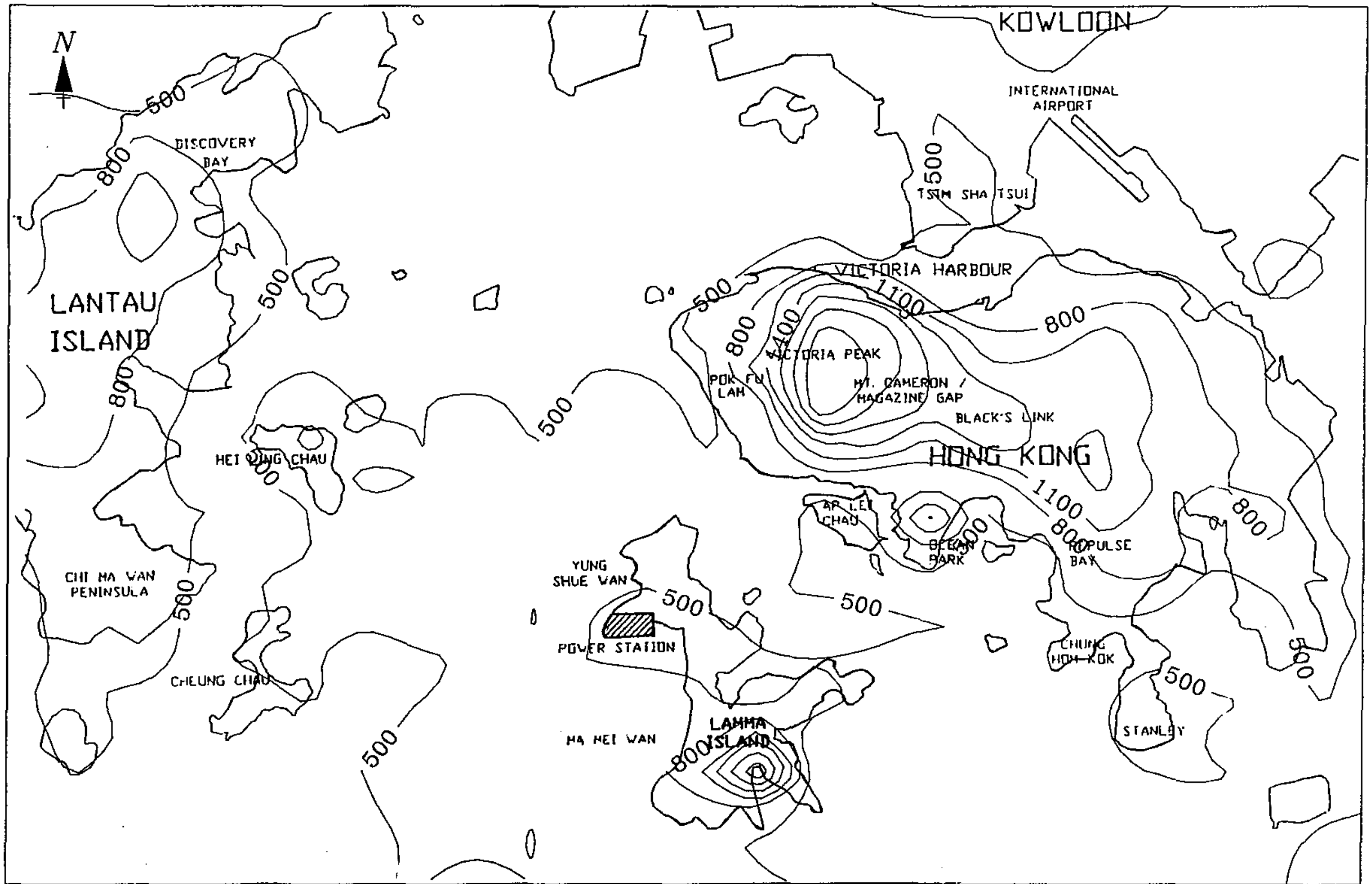
	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: RAINFALL DISTRIBUTION BY MONTH
			FIGURE: 5.8



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: COMPARISON OF HOURLY SO_2 EMISSIONS AGAINST TIME OF DAY
			FIGURE: 5.9



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: COMPARISON OF HOURLY SO_2 EMISSIONS PER MW AGAINST TIME OF DAY FIGURE: 5.10

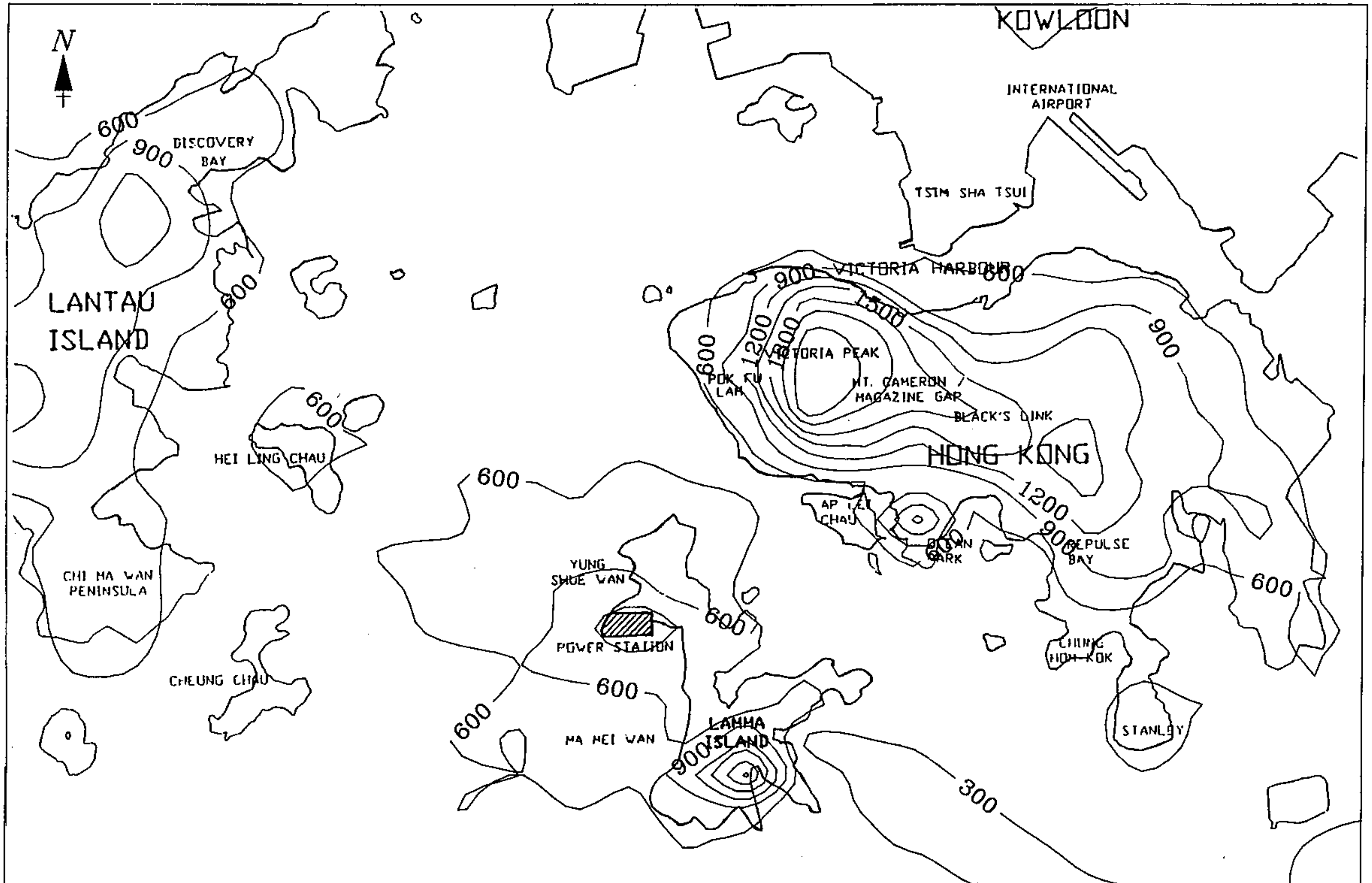


The Hongkong Electric Company Limited

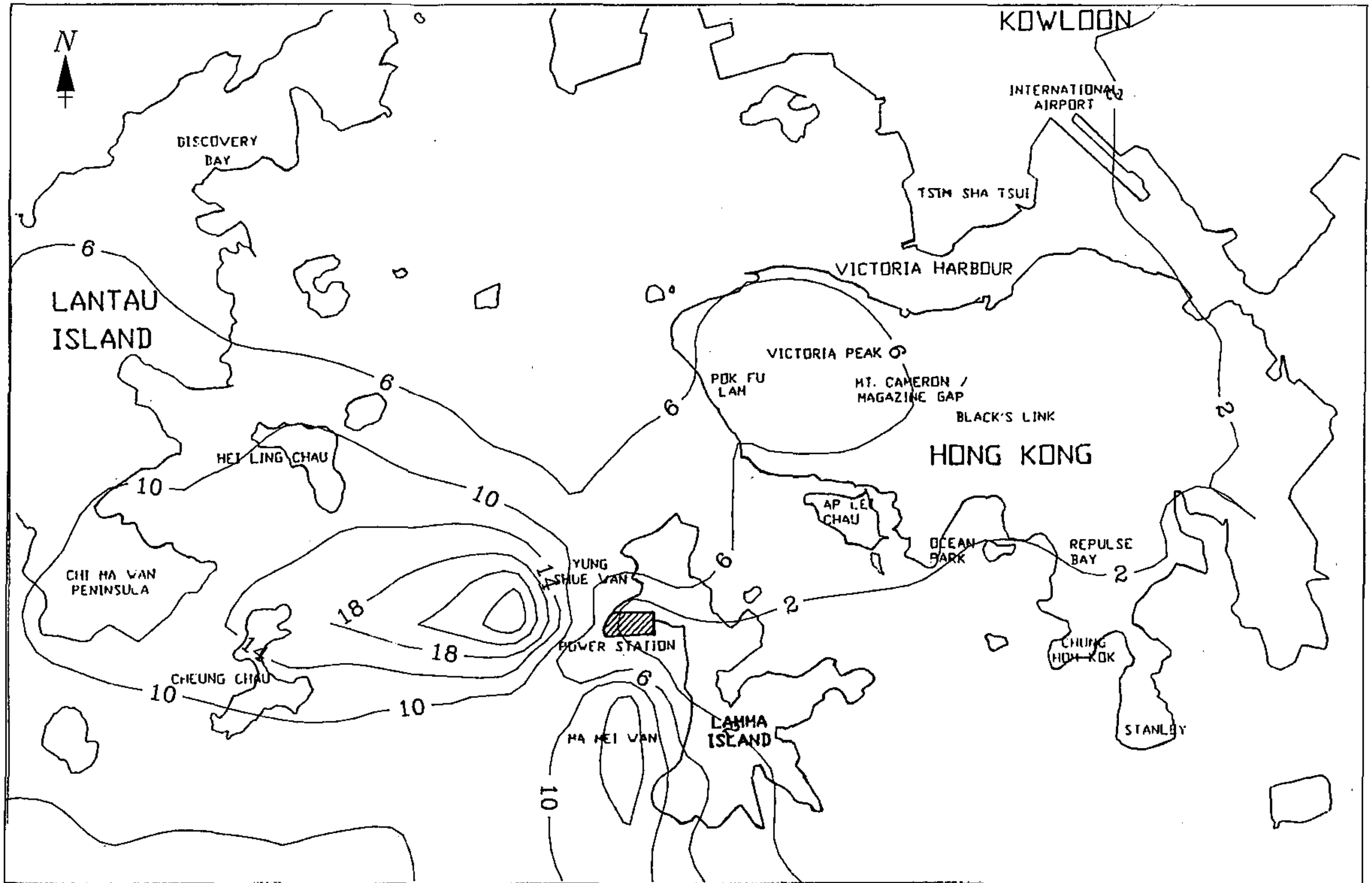
PROJECT: EIA LAMMA POWER STATION

TITLE: JULY 1994
SO_2 CONCENTRATIONS μgm^{-3}
1 HR HIGHEST

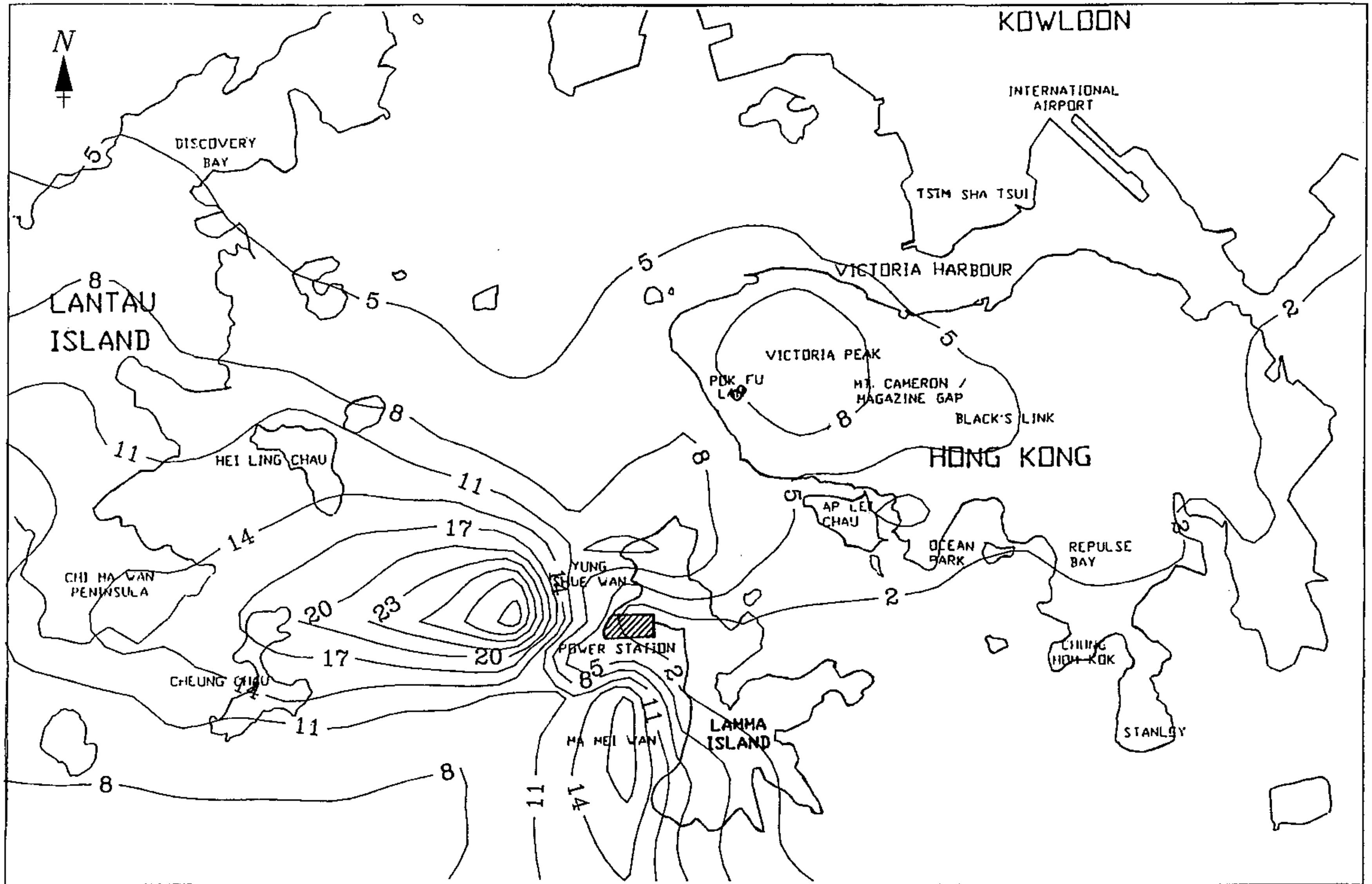
FIGURE: 5.11



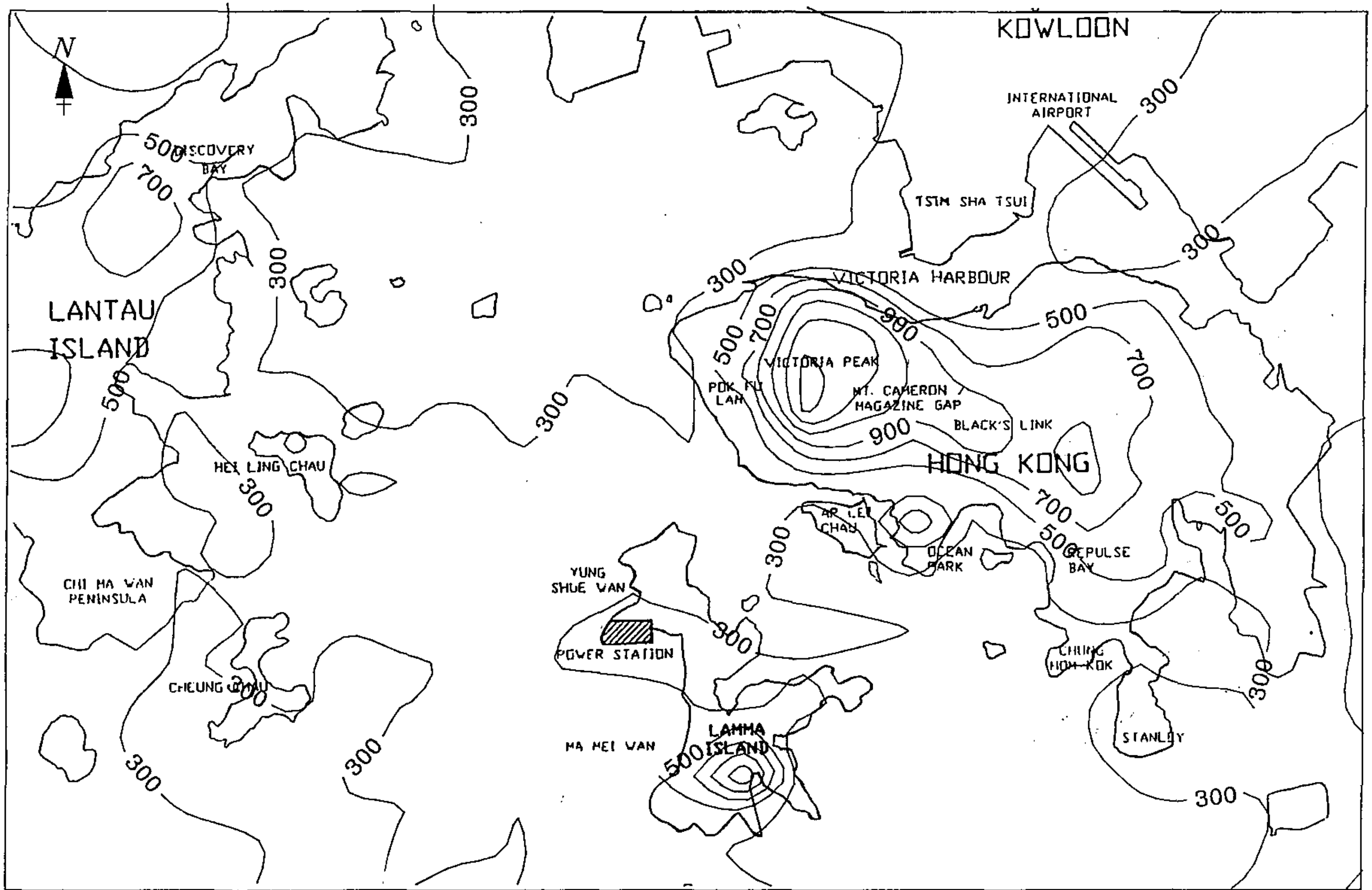
Km 0 1 5	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: JULY 2000 SO_2 CONCENTRATIONS μgm^{-3} 1 HR HIGHEST
			FIGURE: 5.12



Km 0 1 5	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: JULY 1994 SO_2 CONCENTRATIONS μgm^{-3} ANNUAL AVERAGE
			FIGURE: 5.13



Km 0 1 5	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: JULY 2000 SO_2 CONCENTRATIONS μgm^{-3} ANNUAL AVERAGE FIGURE: 5.14



Km

0 1 5

The Hongkong Electric Company Limited

PROJECT:

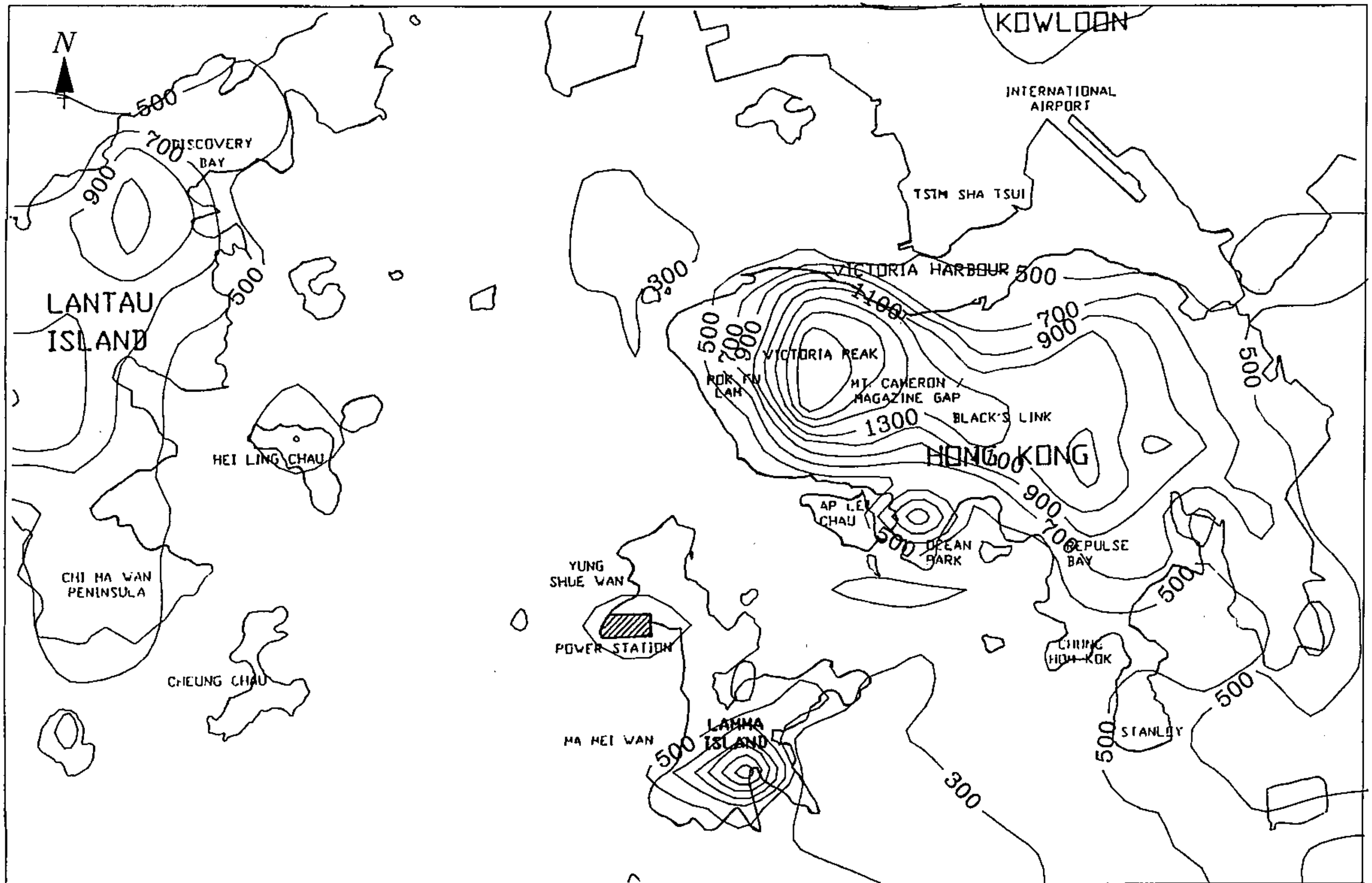
EIA LAMMA POWER STATION

TITLE: JULY 1994

NO_x CONCENTRATIONS μgm^{-3}

1 HR HIGHEST

FIGURE: 5.15



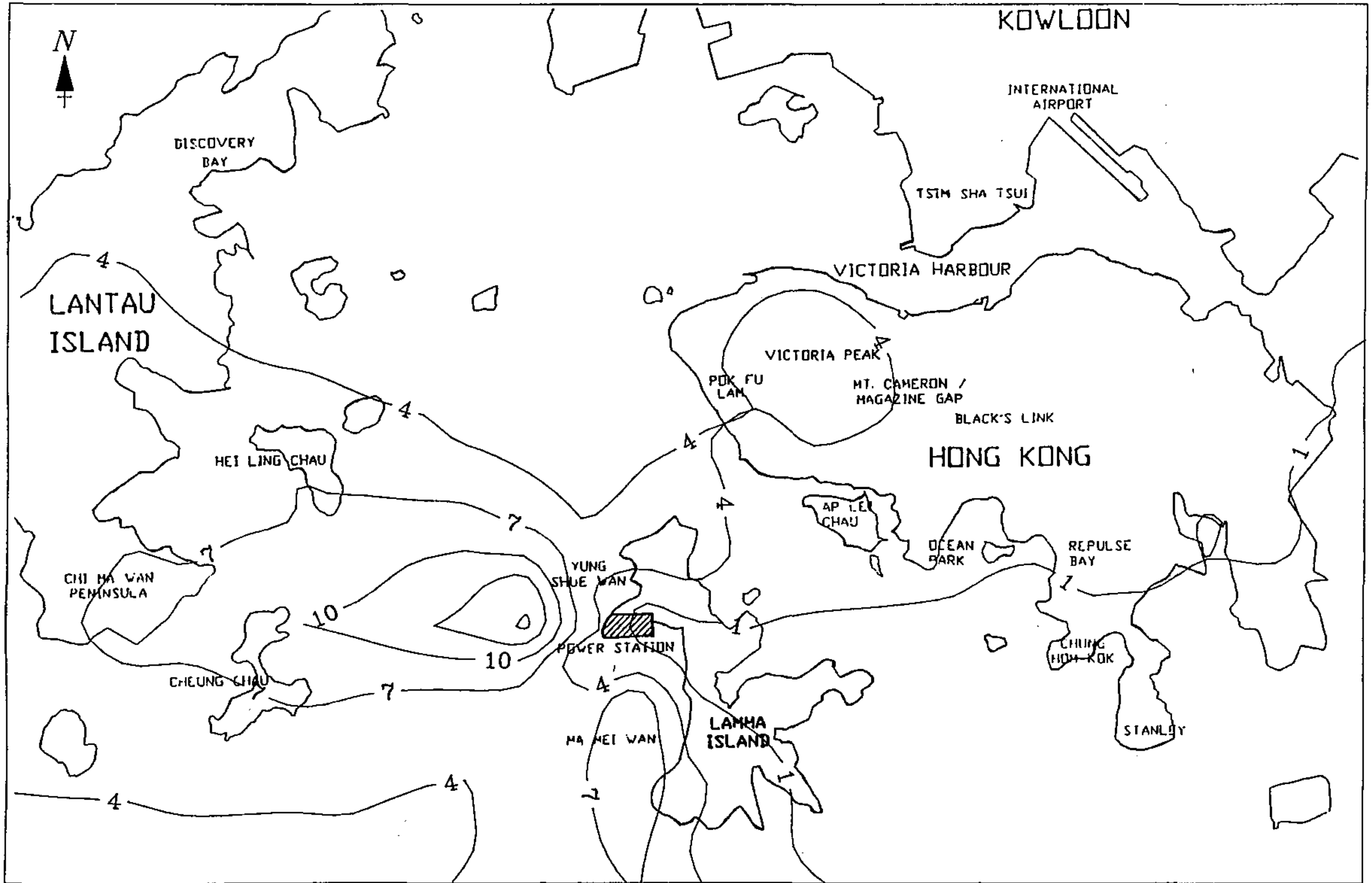
Km
0 1 5

The Hongkong Electric Company Limited

PROJECT:
EIA LAMMA POWER STATION

TITLE: JULY 2000
NO_x CONCENTRATIONS μgm^{-3}
1 HR HIGHEST

FIGURE: 5.16



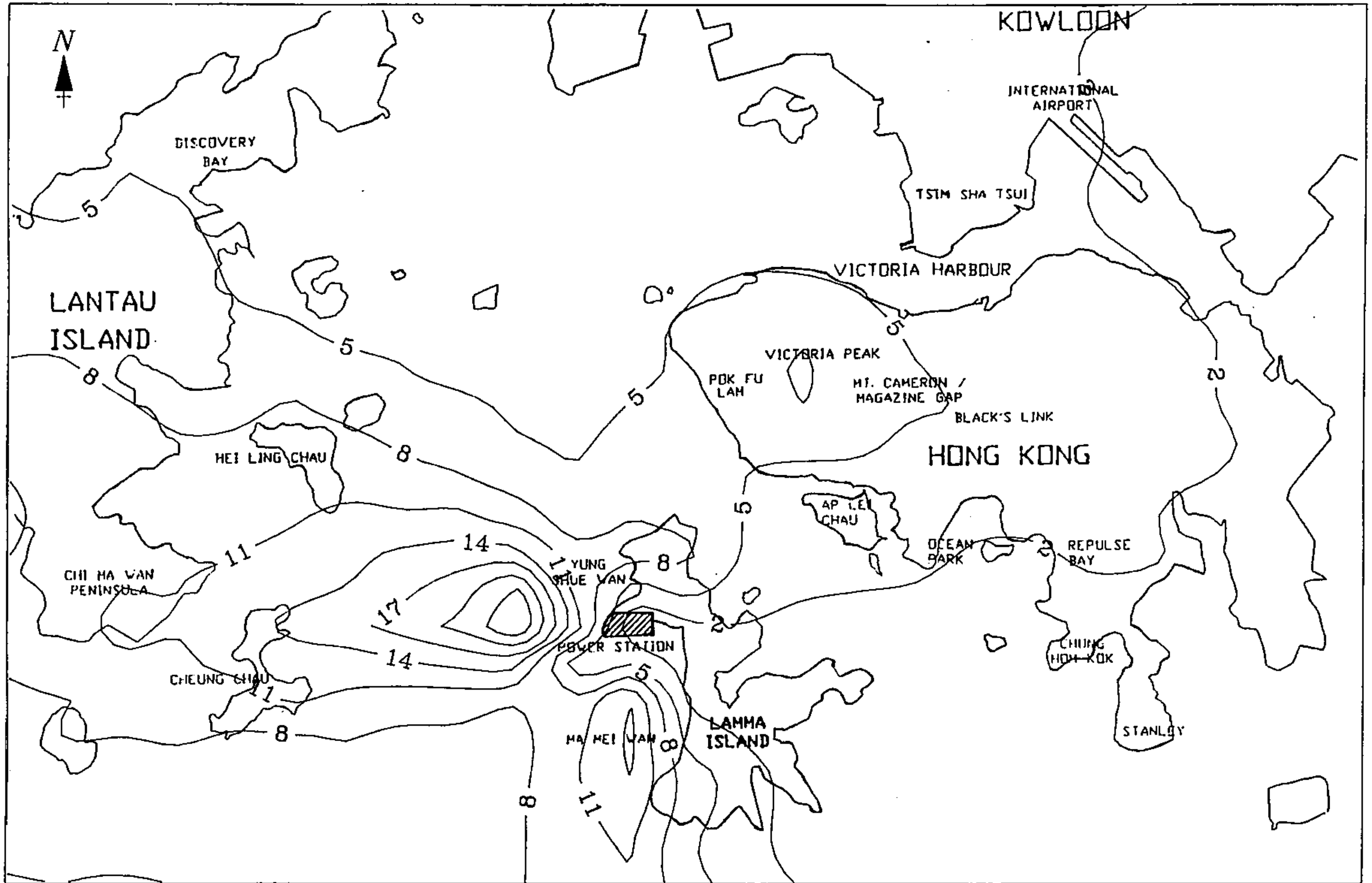
Km
0 1 5

The Hongkong Electric Company Limited

PROJECT:
EIA LAMMA POWER STATION

TITLE: JULY 1994
NO_x CONCENTRATIONS μgm^{-3}
ANNUAL AVERAGE

FIGURE: 5.17



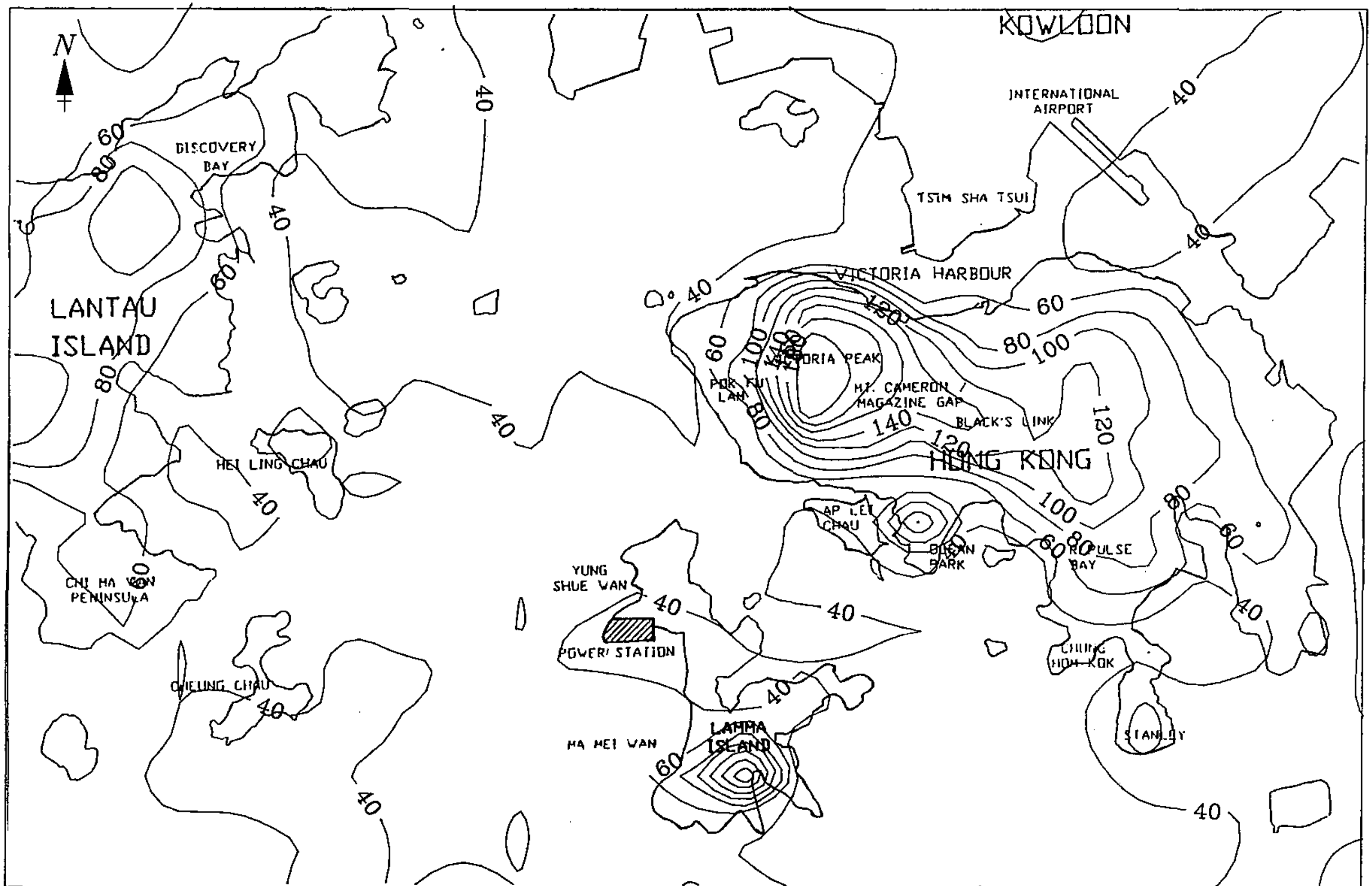
Km
0 1 5

The Hongkong Electric Company Limited

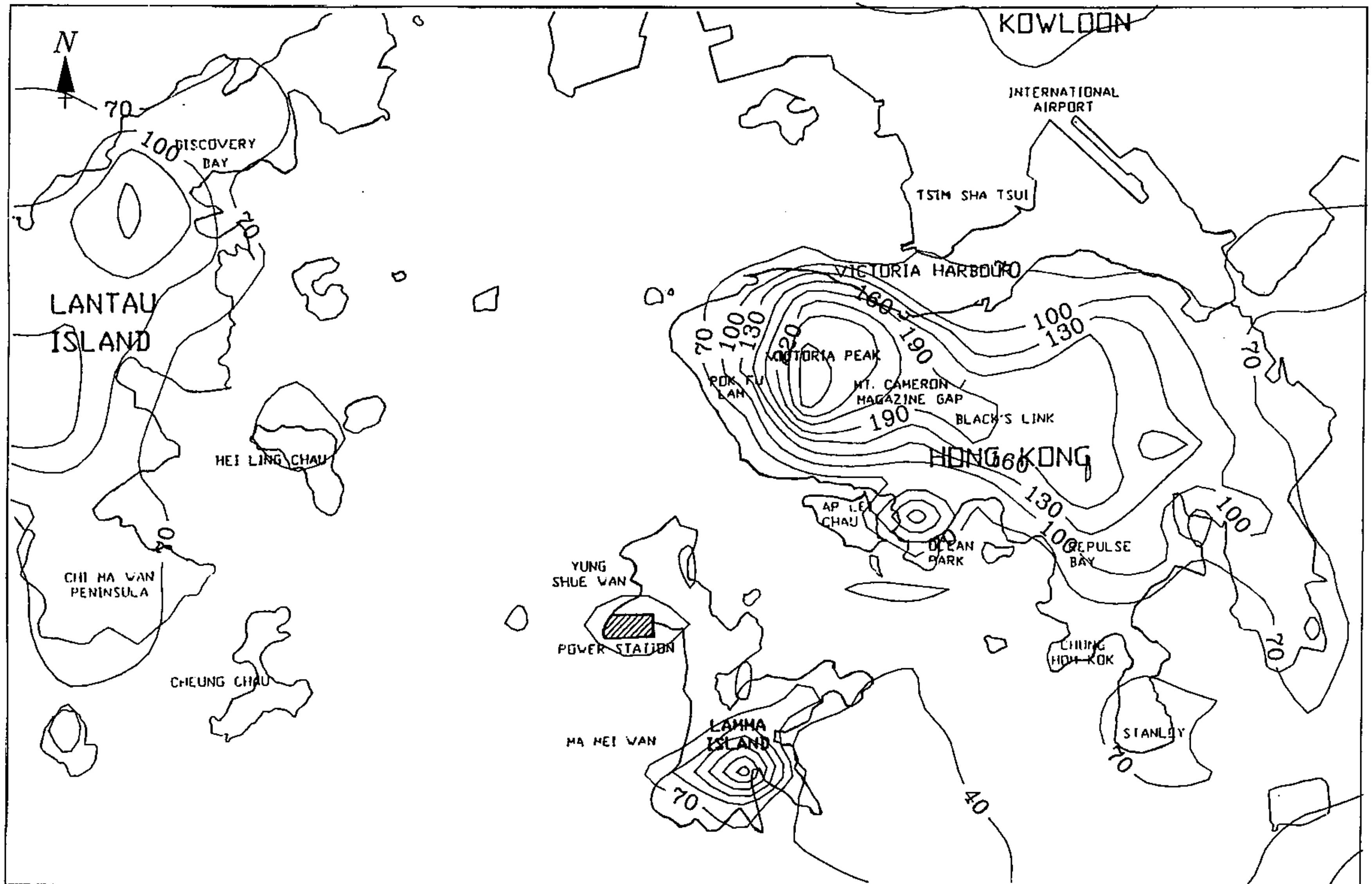
PROJECT:
EIA LAMMA POWER STATION

TITLE: JULY 2000
NO_x CONCENTRATIONS μgm^{-3}
ANNUAL AVERAGE

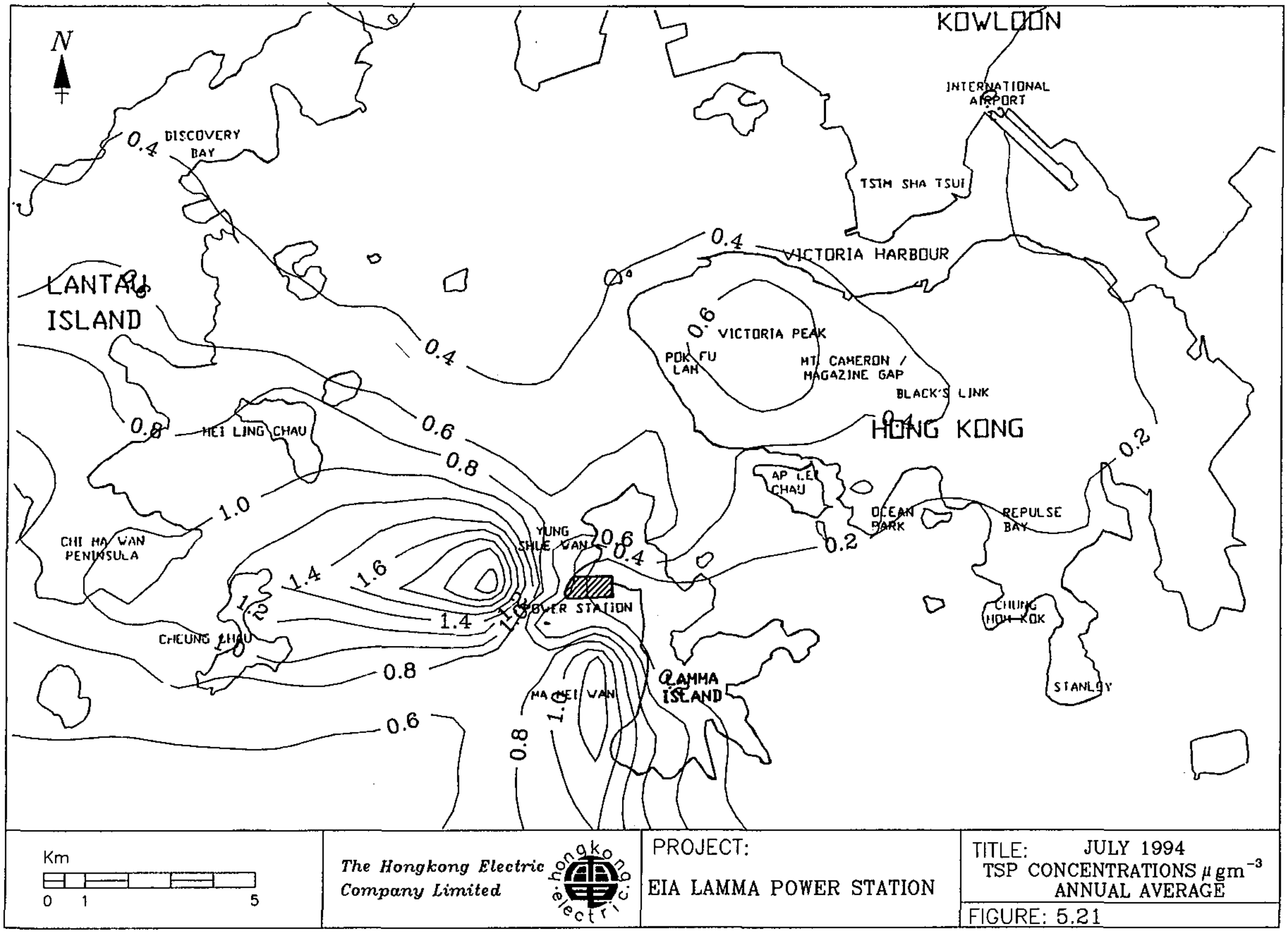
FIGURE: 5.18



Km 0 1 5	*The Hongkong Electric Company Limited* hongkong electric	PROJECT: EIA LAMMA POWER STATION	TITLE: JULY 1994 TSP CONCENTRATIONS μgm^{-3} HIGHEST 24 HOUR AVERAGE FIGURE: 5.19



Km 0 1 5	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: JULY 2000 TSP CONCENTRATIONS μgm^{-3} HIGHEST 24 HOUR AVERAGE
			FIGURE: 5.20

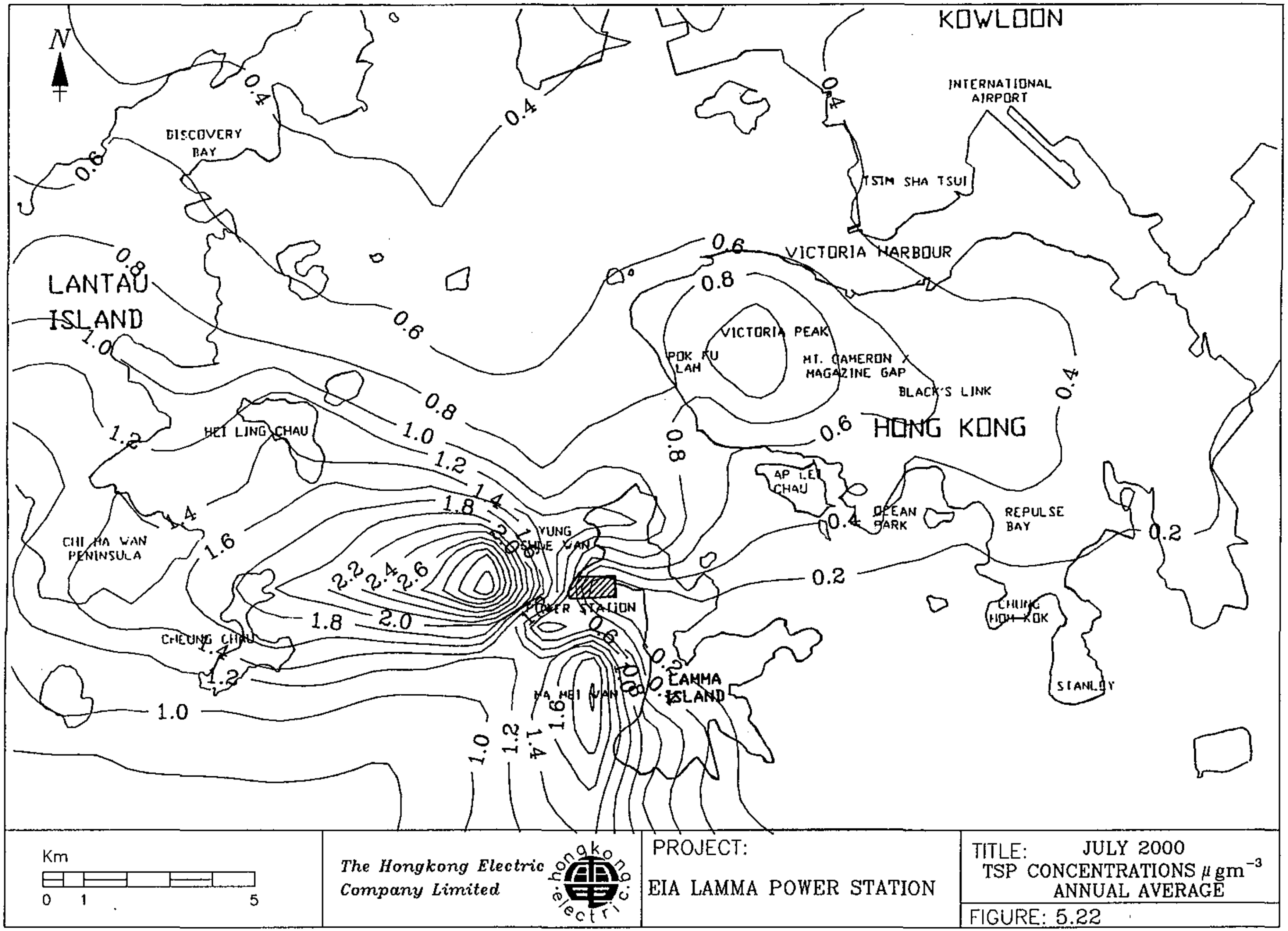


The Hongkong Electric Company Limited

PROJECT:
EIA LAMMA POWER STATION

TITLE: JULY 1994
TSP CONCENTRATIONS μgm^{-3}
ANNUAL AVERAGE

FIGURE: 5.21

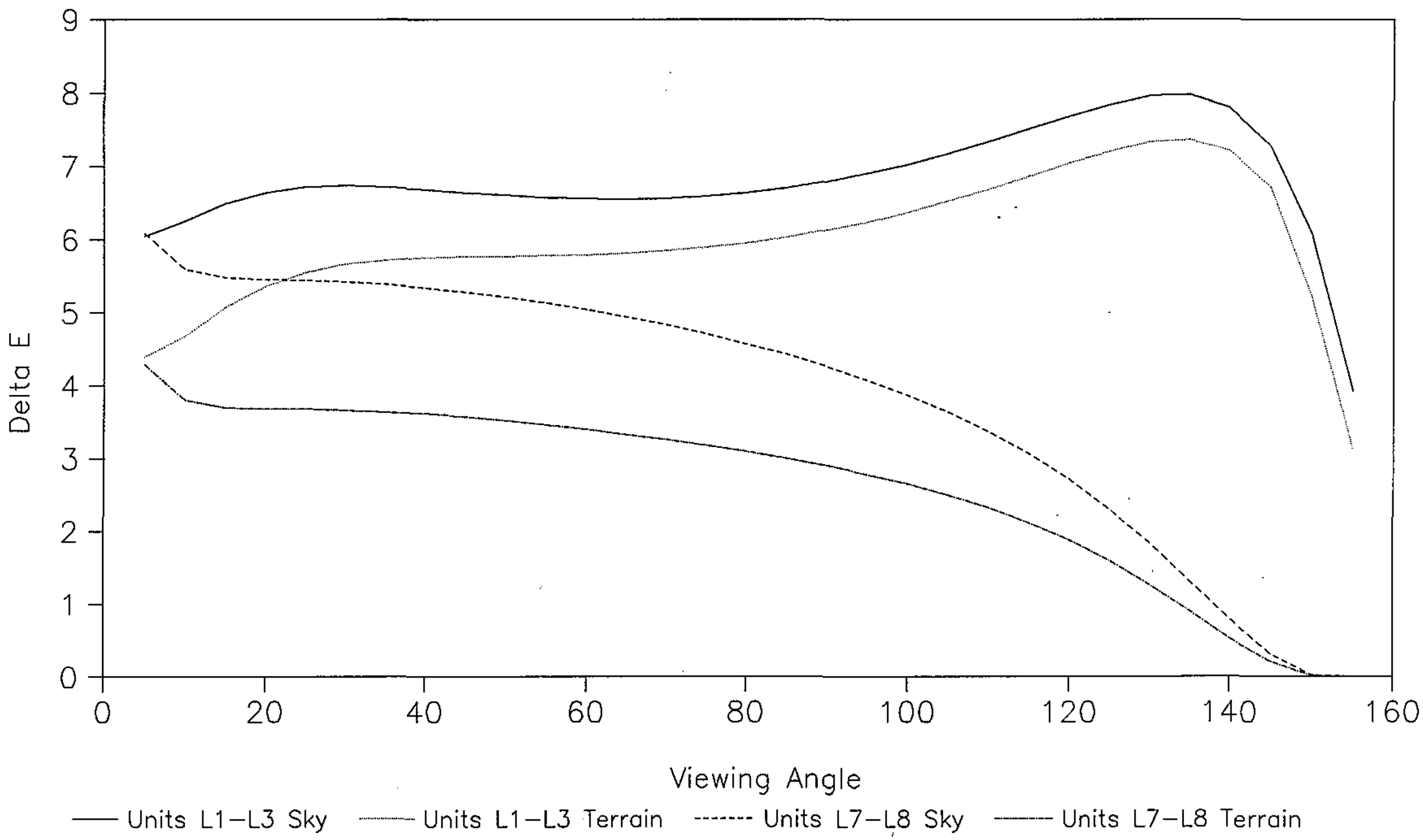


The Hongkong Electric Company Limited

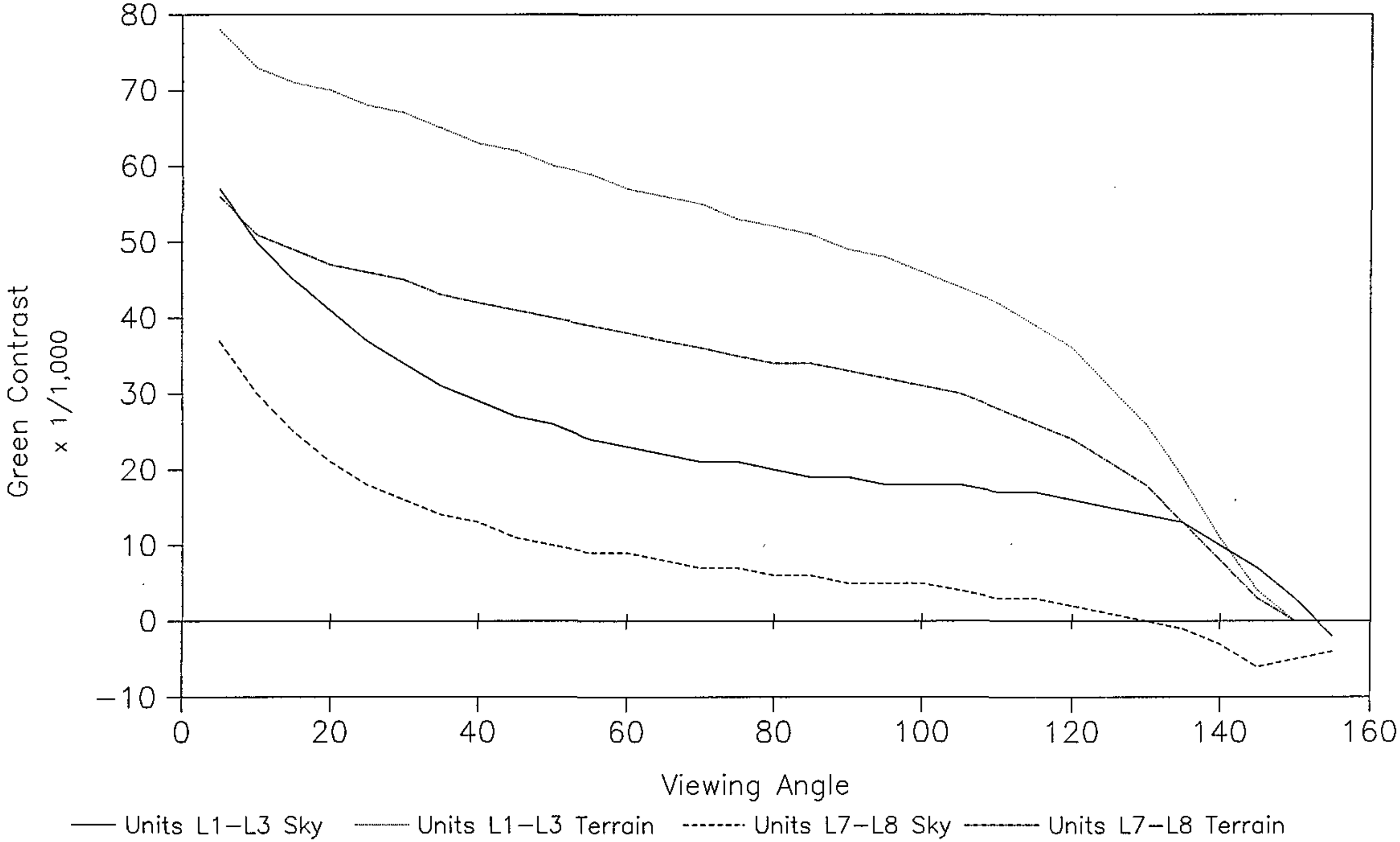
PROJECT: EIA LAMMA POWER STATION

TITLE: JULY 2000
TSP CONCENTRATIONS μgm^{-3}
ANNUAL AVERAGE

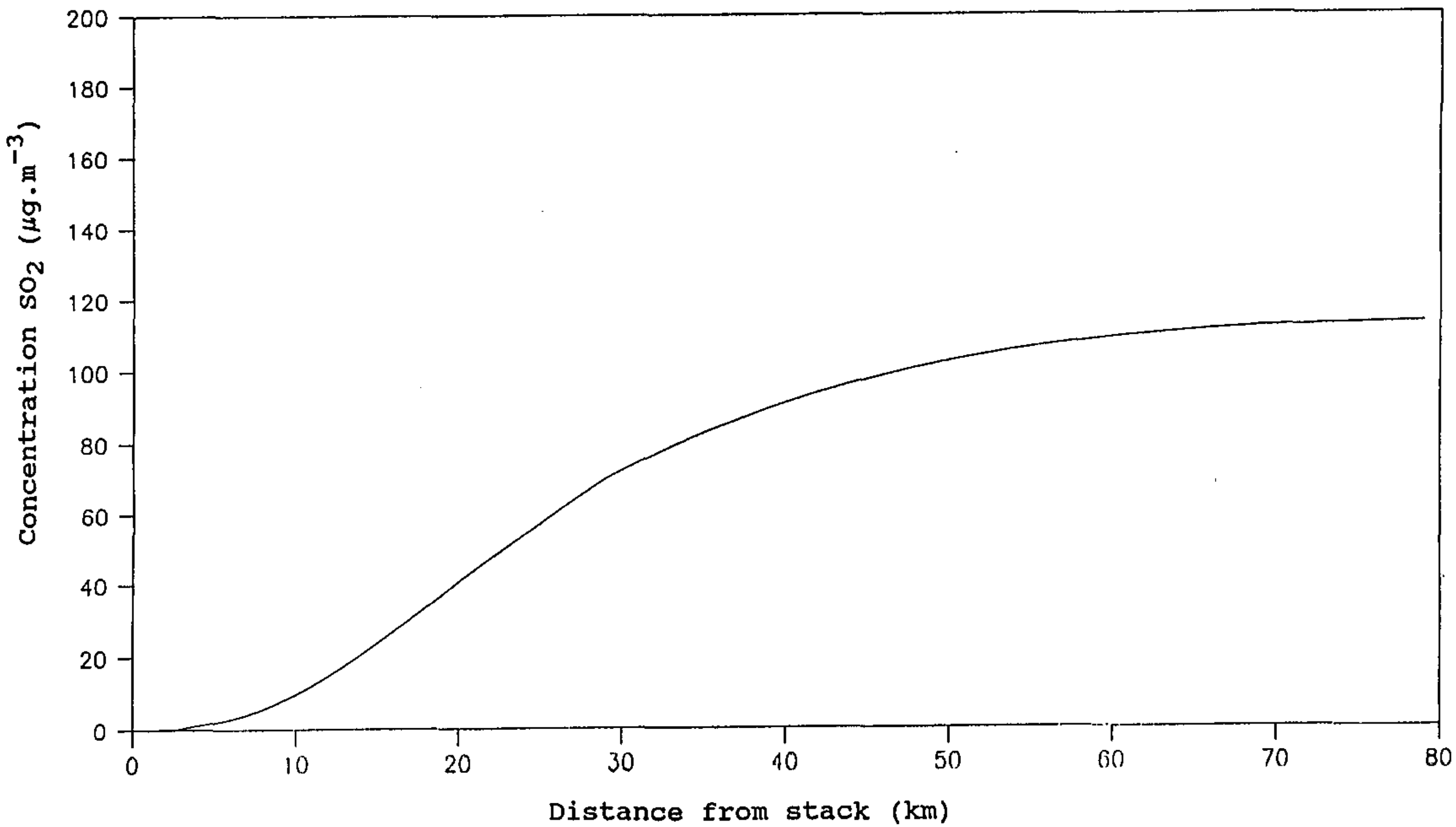
FIGURE: 5.22



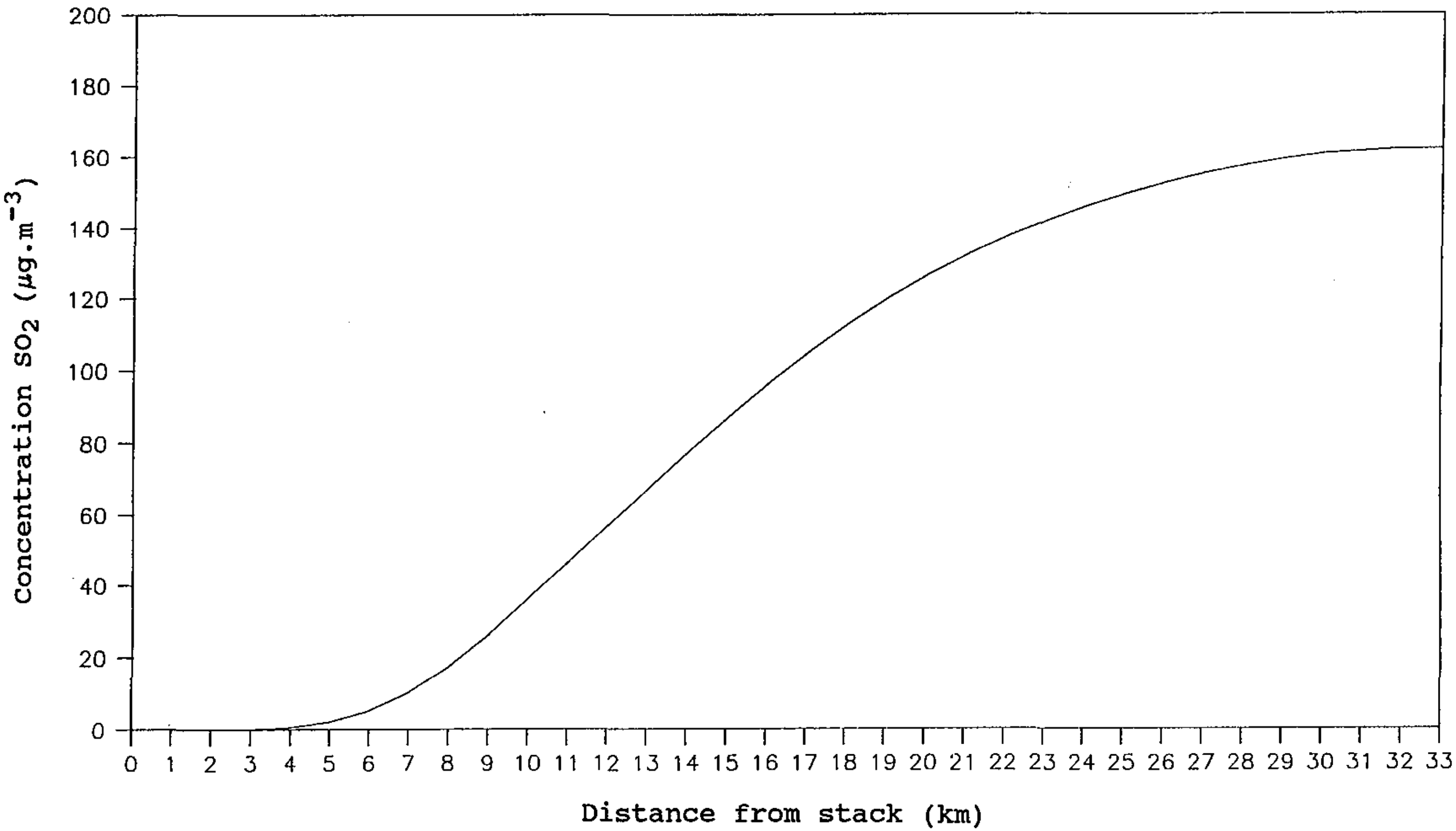
	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: Delta – E plume perceptability factor as a function of viewing angle
			FIGURE: 5.23



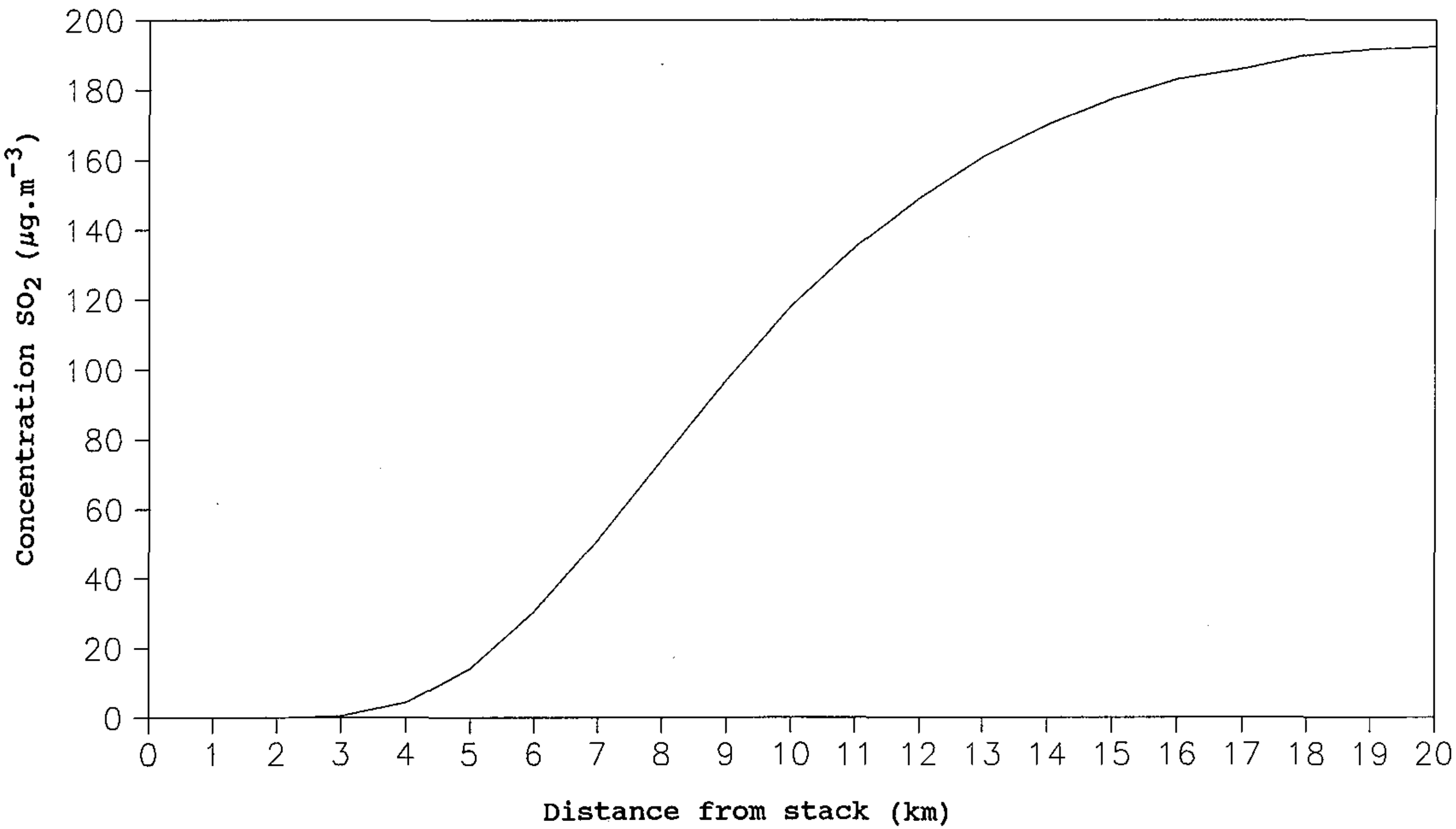
	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: Green contrast parameter as a function of viewing angle
			FIGURE: 5.24



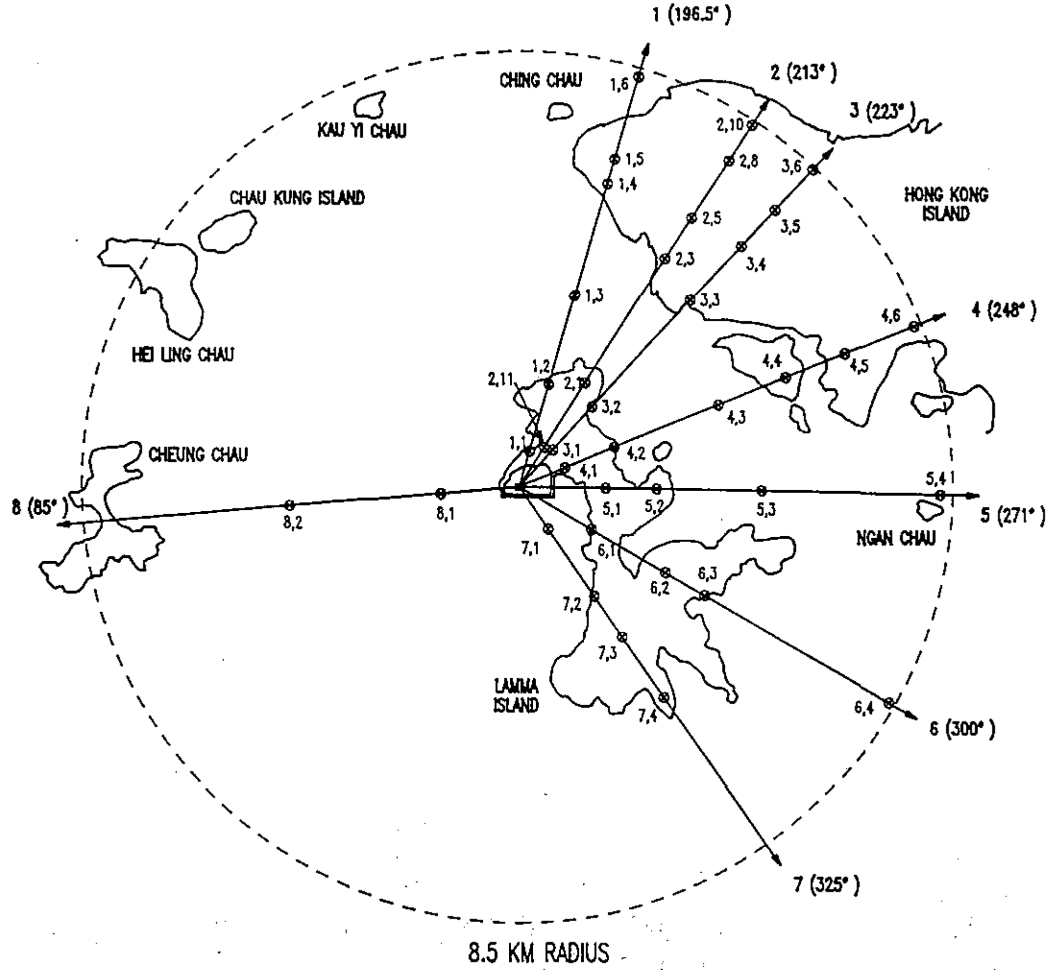
ISCST	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: 350MW – no FGD High Sulphur Fuel (3.5%) Wind speed 2.5m/s, stability 4
			FIGURE: 5.25



ISCST	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: 350MW – no FGD High Sulphur Fuel (3.5%) Wind speed 5.0m/s, stability 4
			FIGURE: 5.26



ISCST	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: 350MW – no FGD High Sulphur Fuel (3.5%) Wind speed 10m/s, stability 4 FIGURE: 5.27



The Hongkong Electric Company Limited

PROJECT: EIA LAMMA POWER STATION

TITLE: STUDY AREA WIND TUNNEL TESTS

FIGURE: 5.28

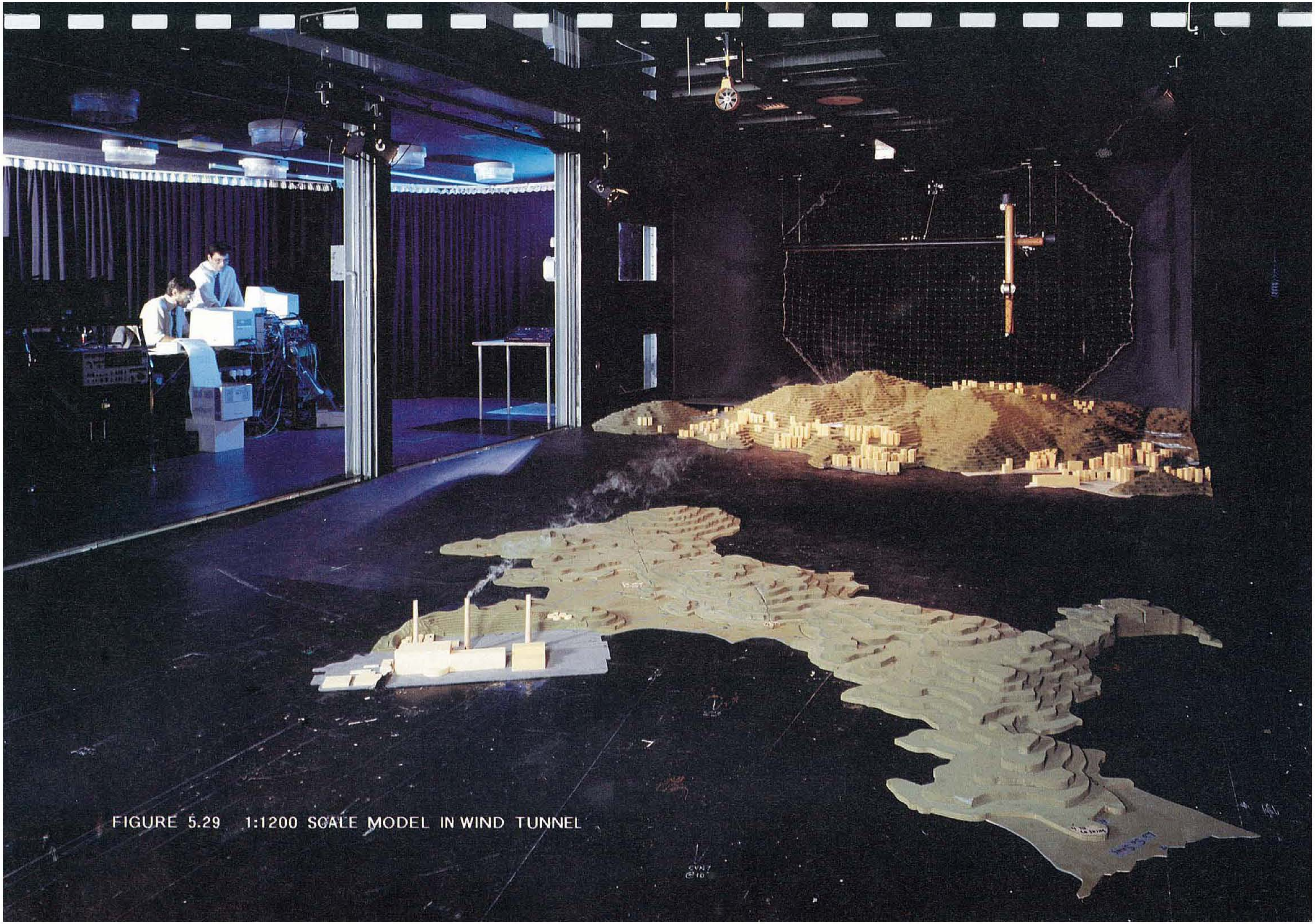
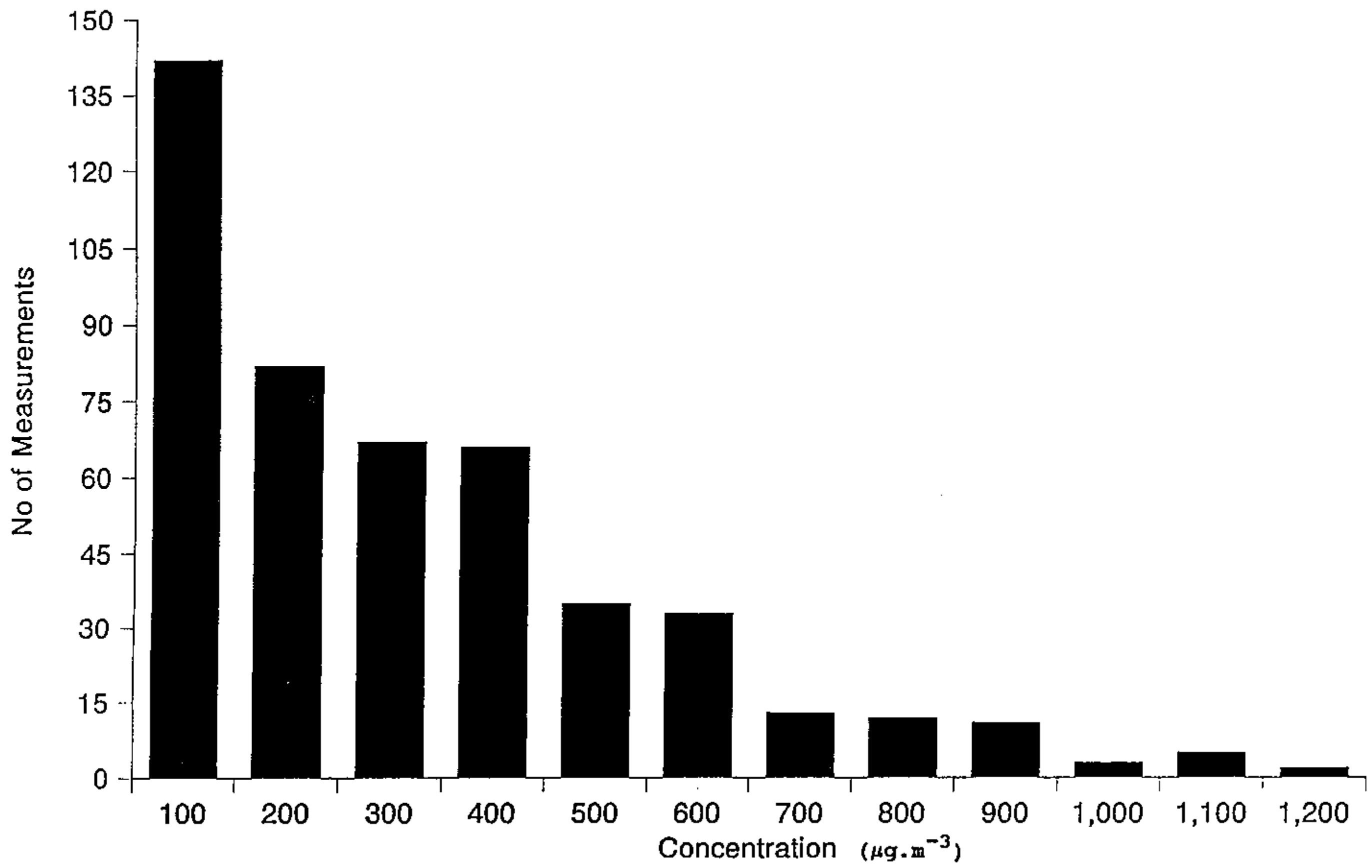


FIGURE 5.29 1:1200 SCALE MODEL IN WIND TUNNEL

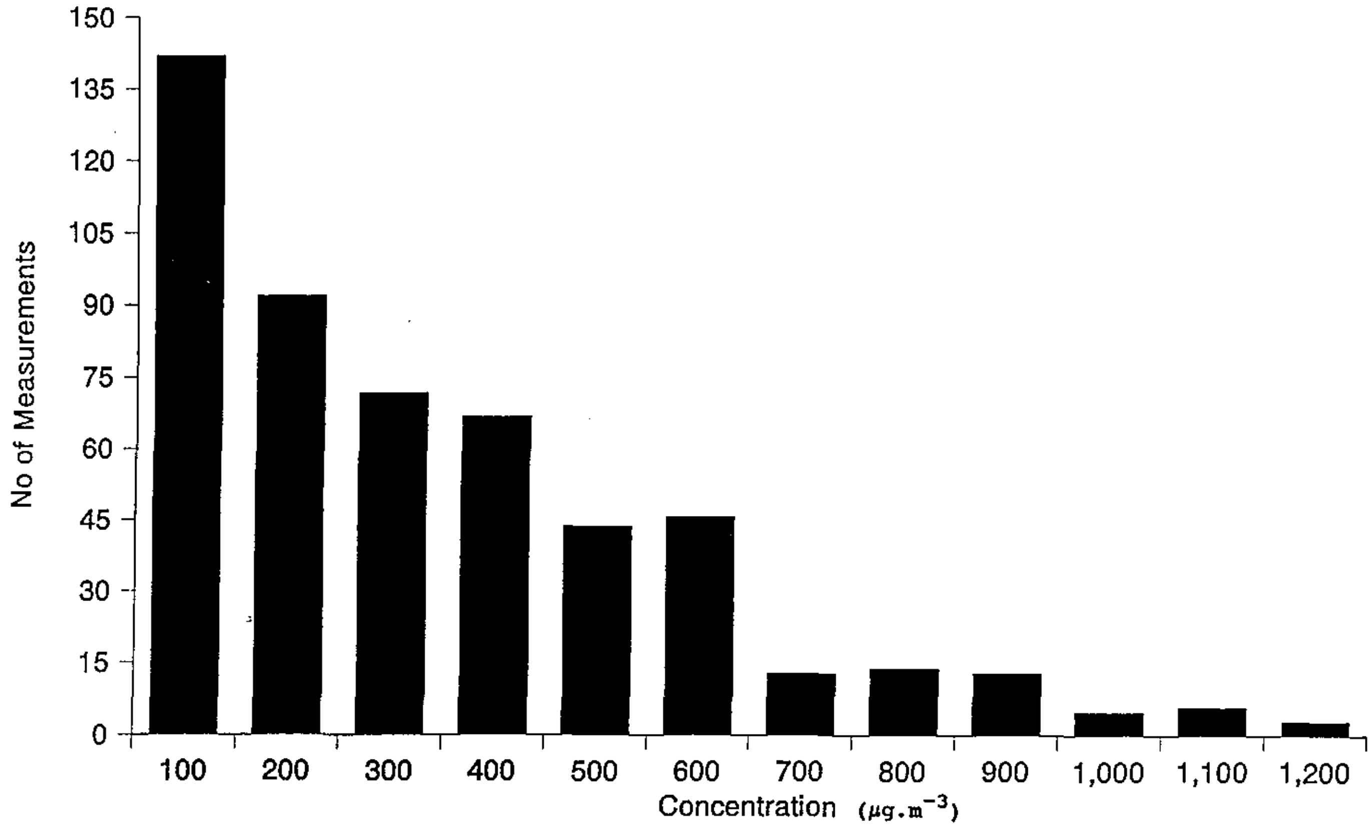


The Hongkong Electric Company Limited

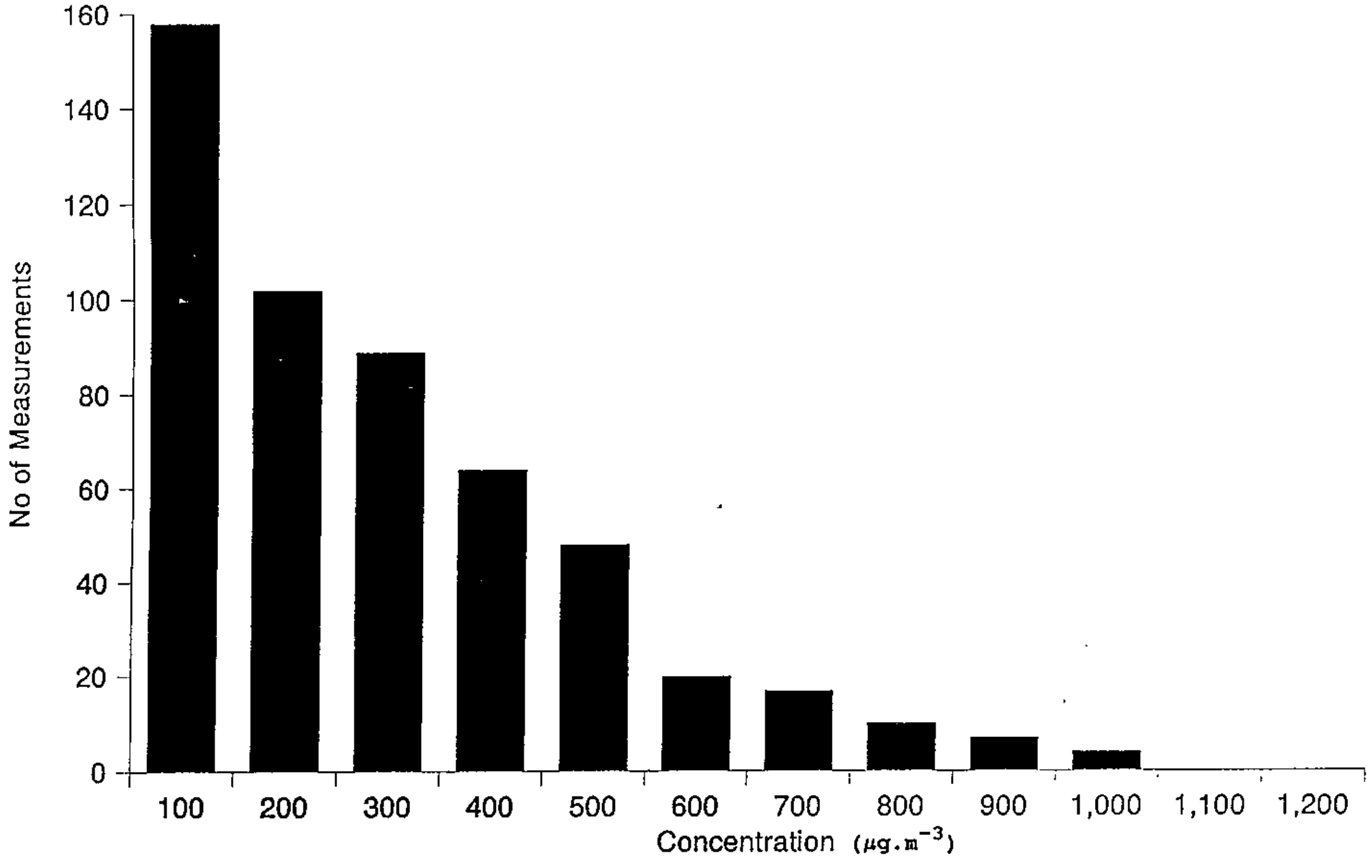
PROJECT: EIA LAMMA POWER STATION

TITLE: SO_2 CONCENTRATIONS FOR CONDITIONS B1/B2

FIGURE: 5.30



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: SO_2 CONCENTRATIONS FOR CONDITIONS T1/T4
			FIGURE: 5.31

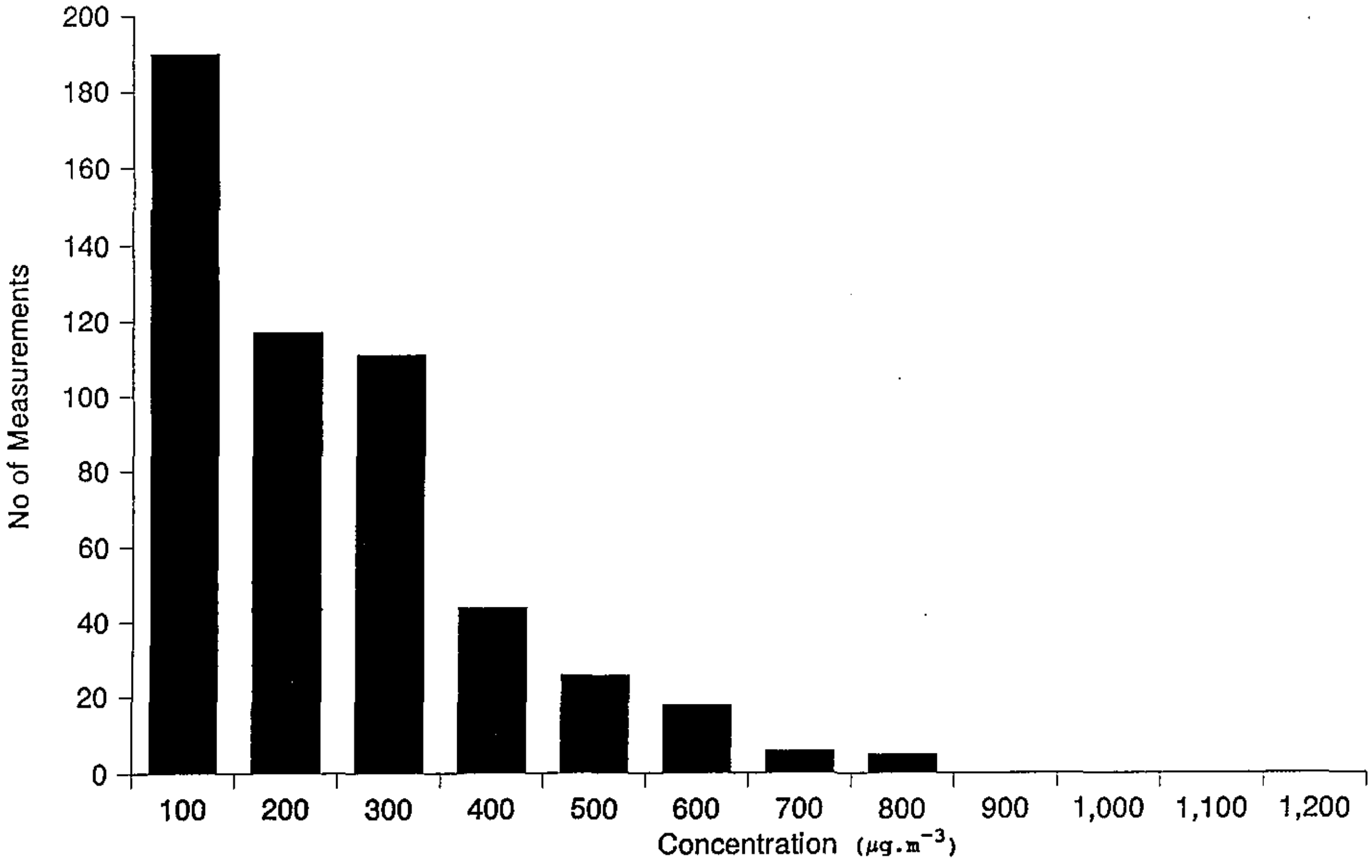


The Hongkong Electric Company Limited

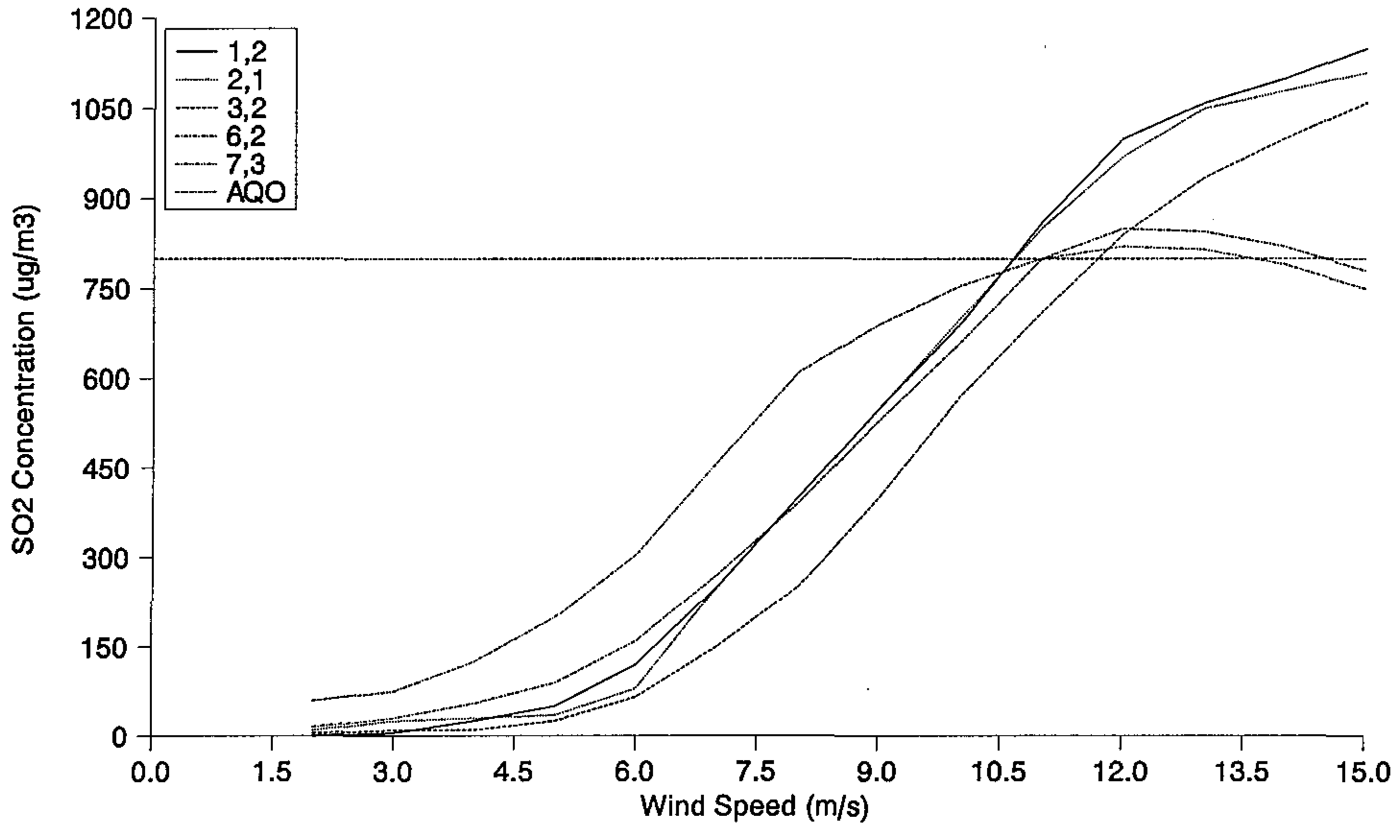
PROJECT:
EIA LAMMA POWER STATION

TITLE: SO_2 CONCENTRATIONS FOR CONDITIONS T2/T5

FIGURE: 5.32



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: SO_2 CONCENTRATIONS FOR CONDITIONS T3/T6
			FIGURE: 5.33

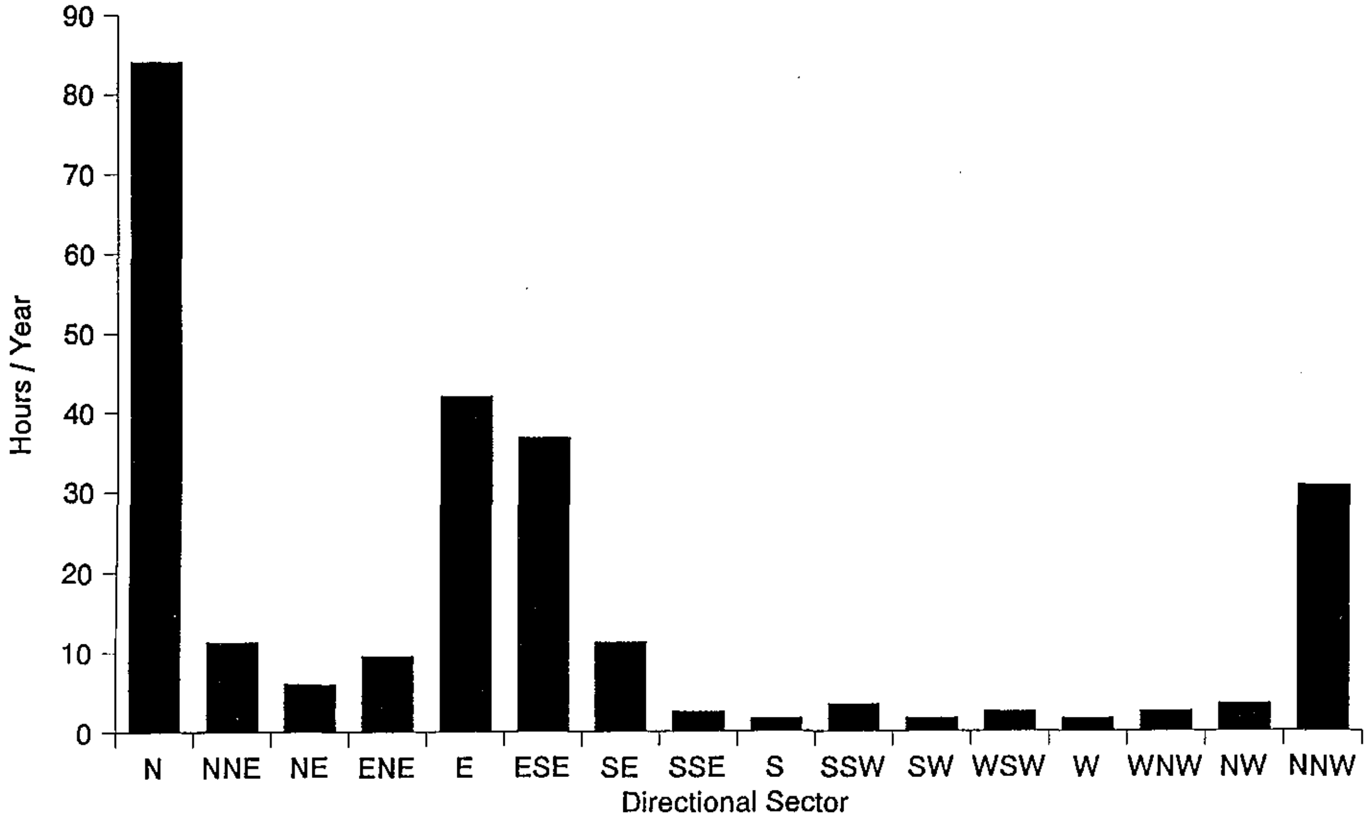


The Hongkong Electric Company Limited

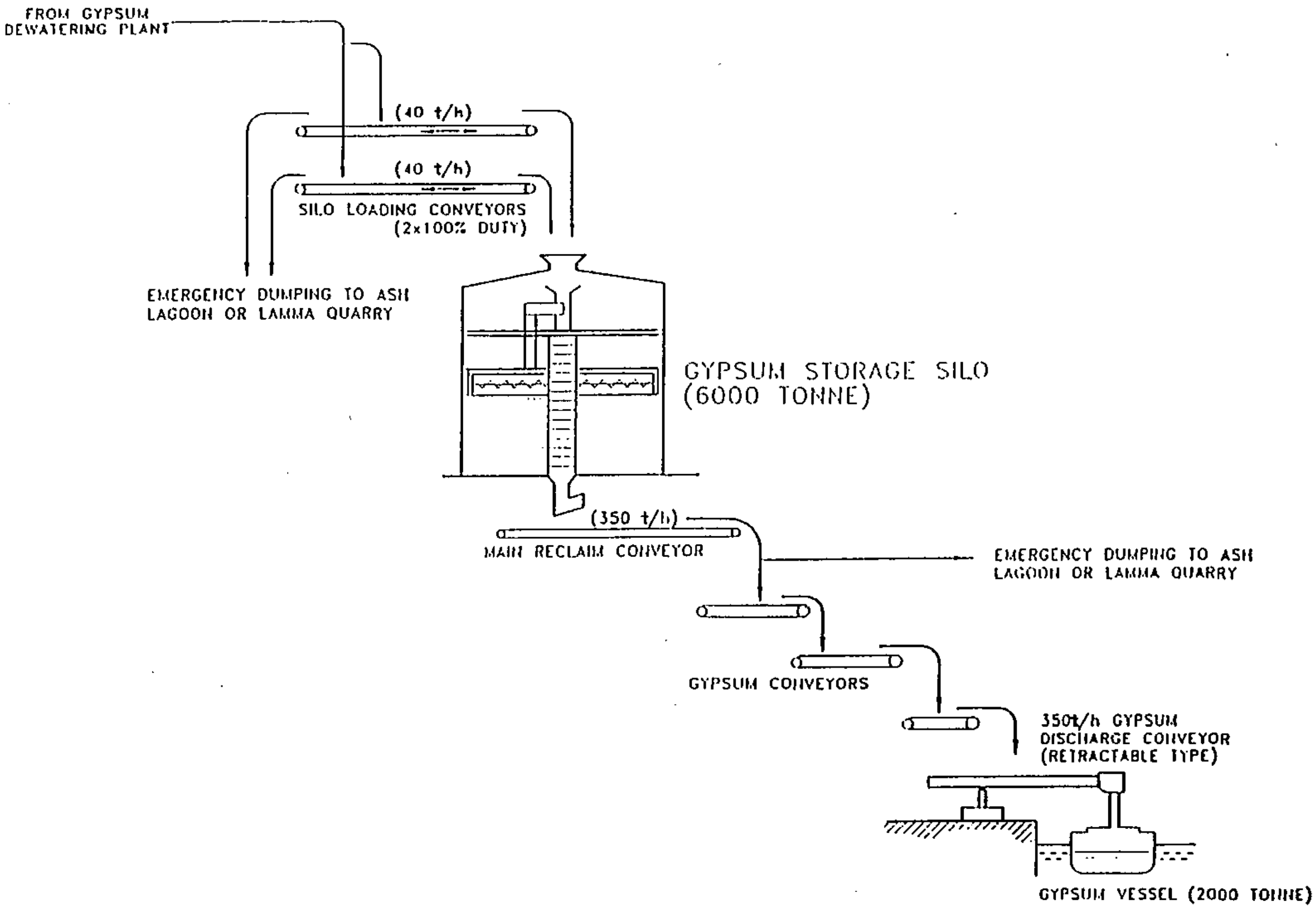
PROJECT:
EIA LAMMA POWER STATION

TITLE: SO_2 CONCENTRATIONS AT SELECTED LAMMA ISLAND LOCATIONS

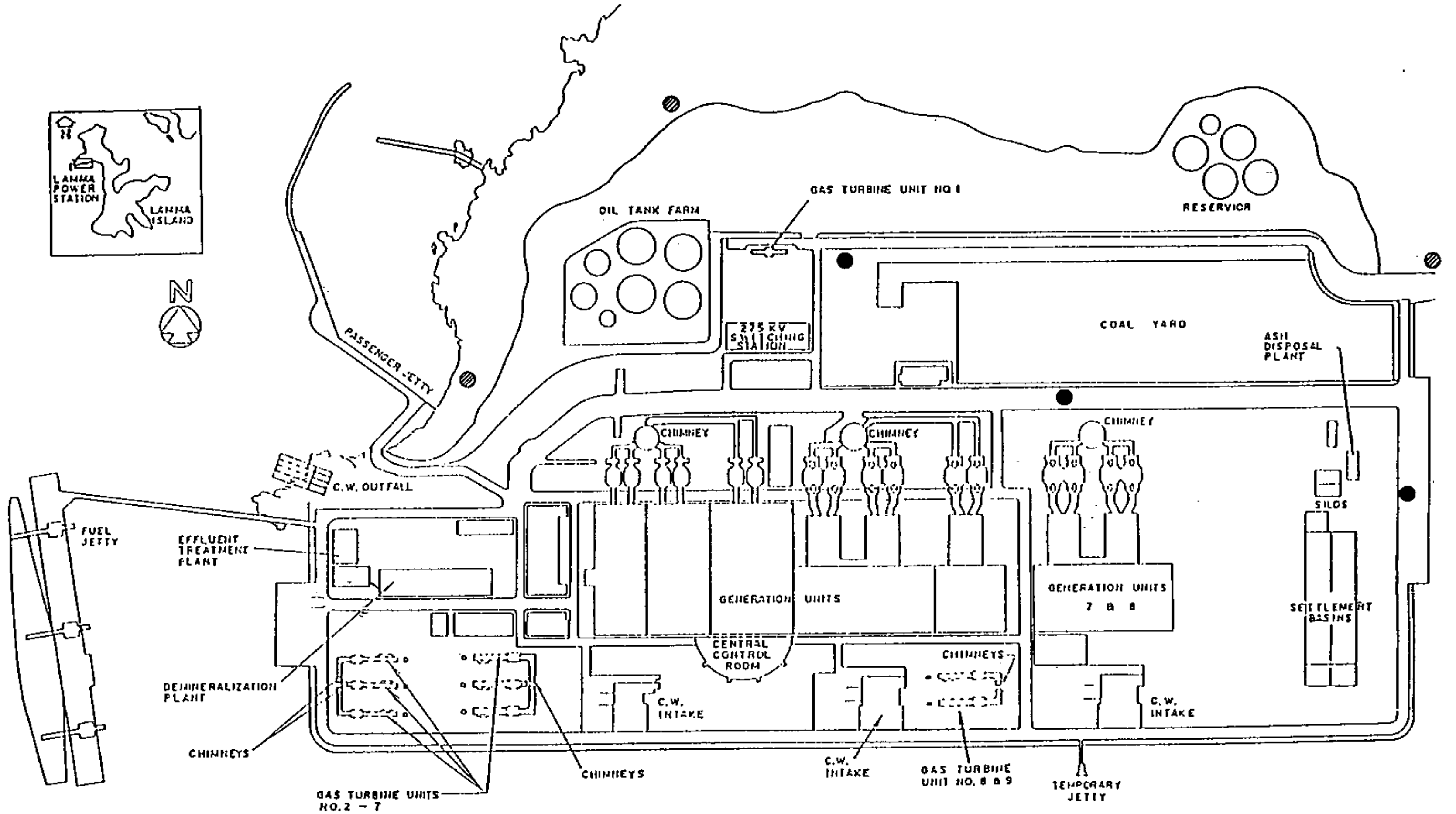
FIGURE: 5.34



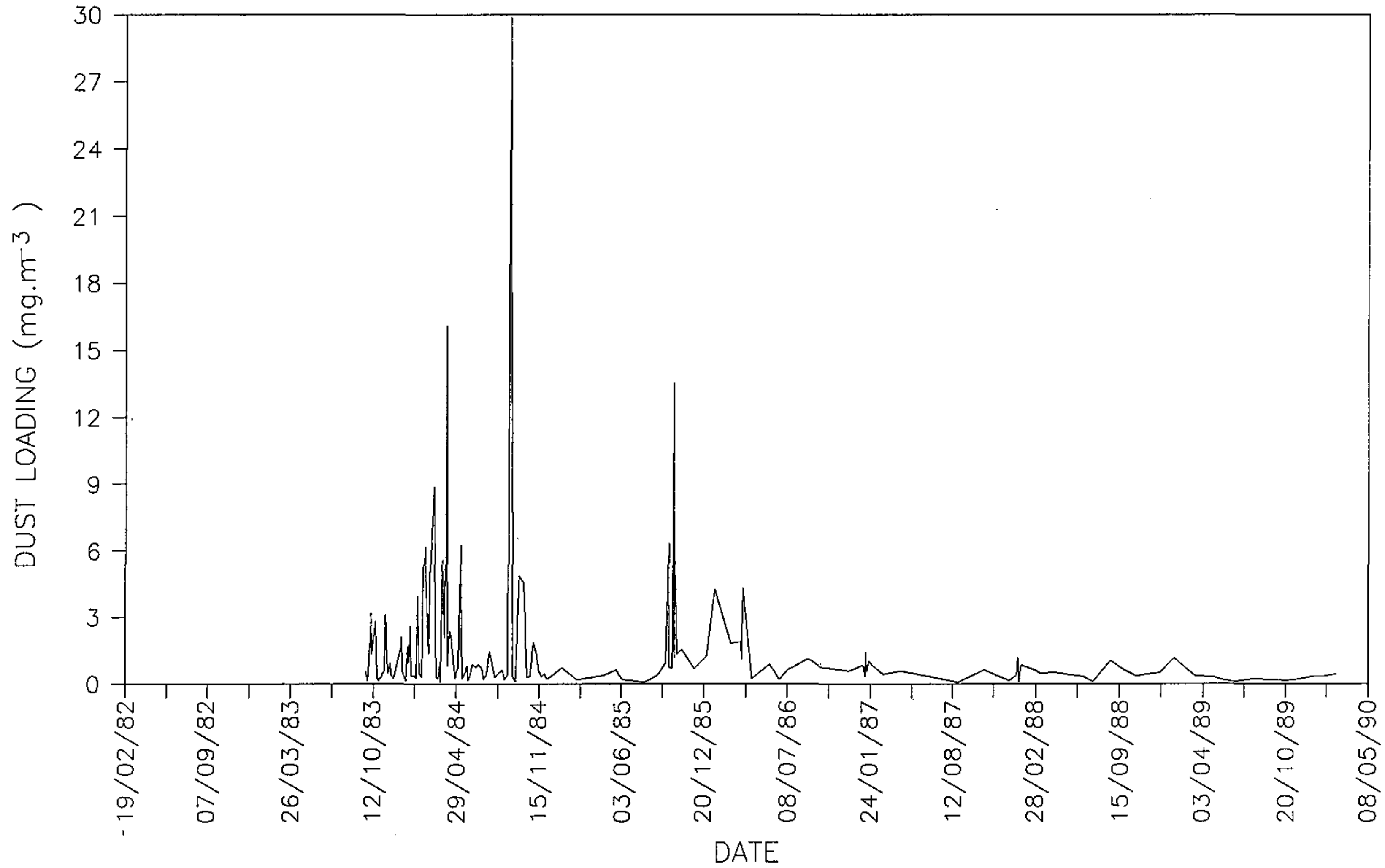
	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: HONG KONG WIND SPEED OCURRENCE wind speeds above 11 m/s
			FIGURE: 5.35



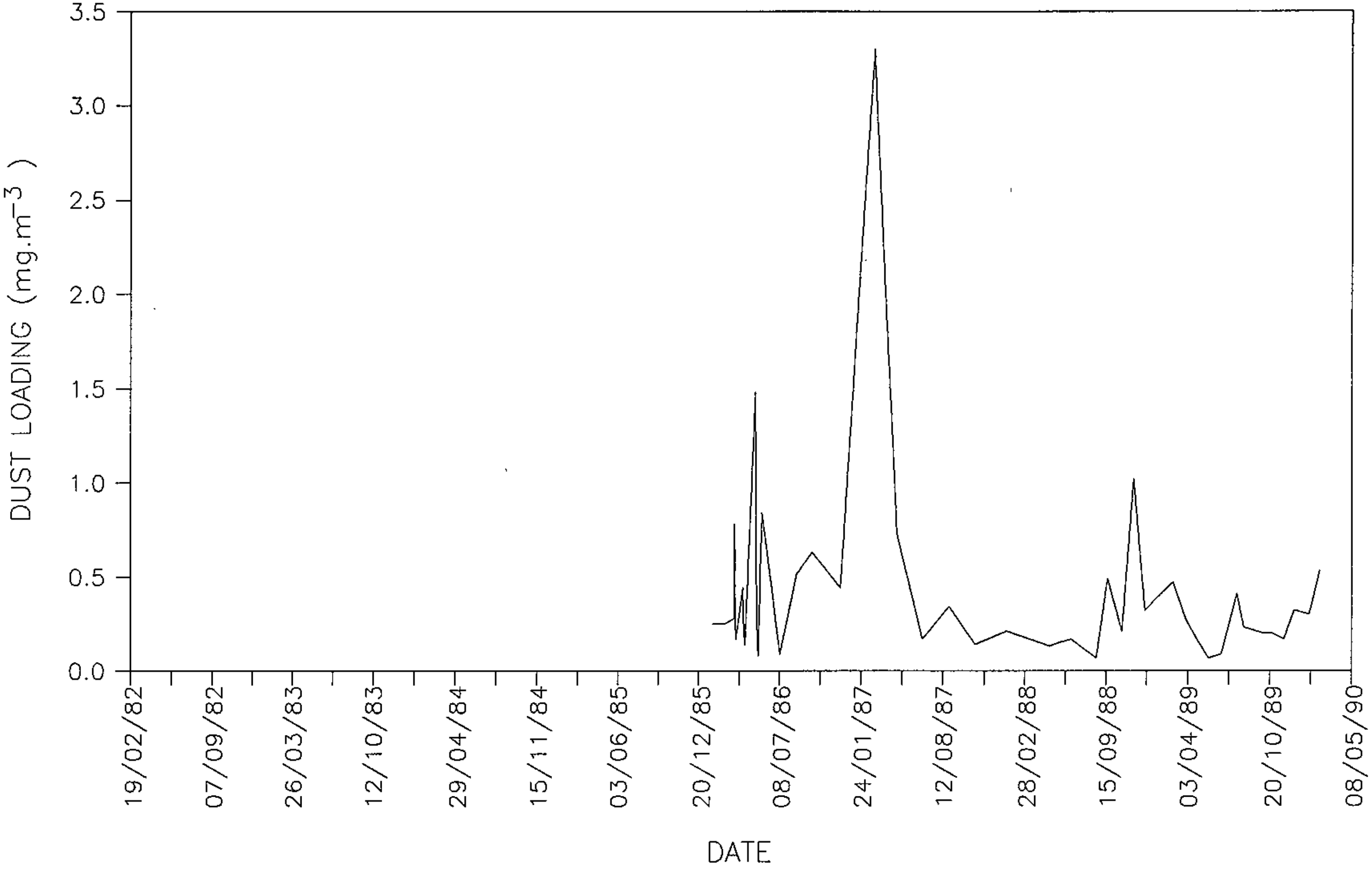
The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: PRELIMINARY GYPSUM STORAGE & DISPOSAL SYSTEM FIGURE: 5.36



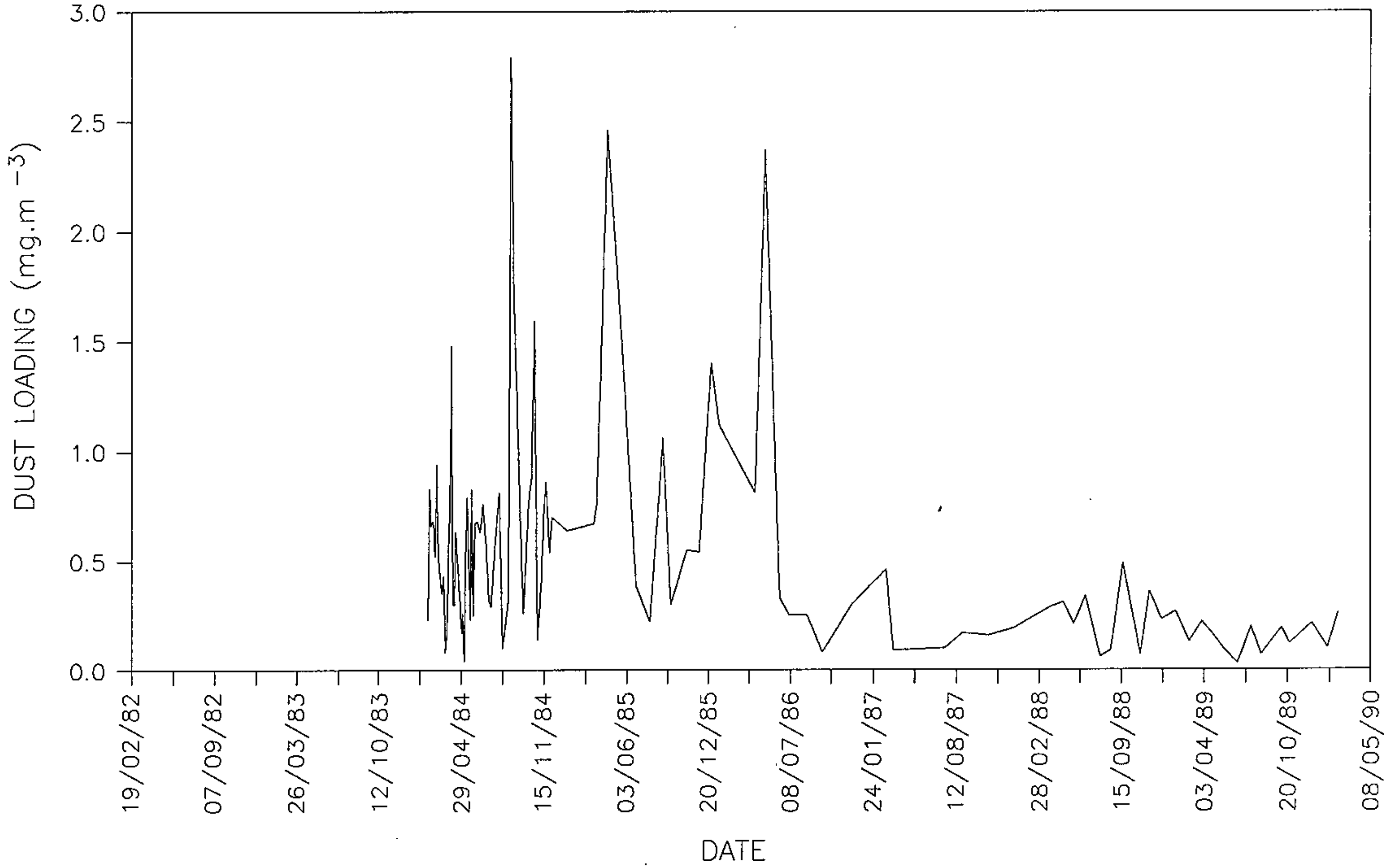
▨ FUGITIVE DUST FALLOUT STATIONS ● AMBIENT DUST LOADING STATIONS	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: LOCATION OF PARTICULATE MONITORING SITES FIGURE: 5.37



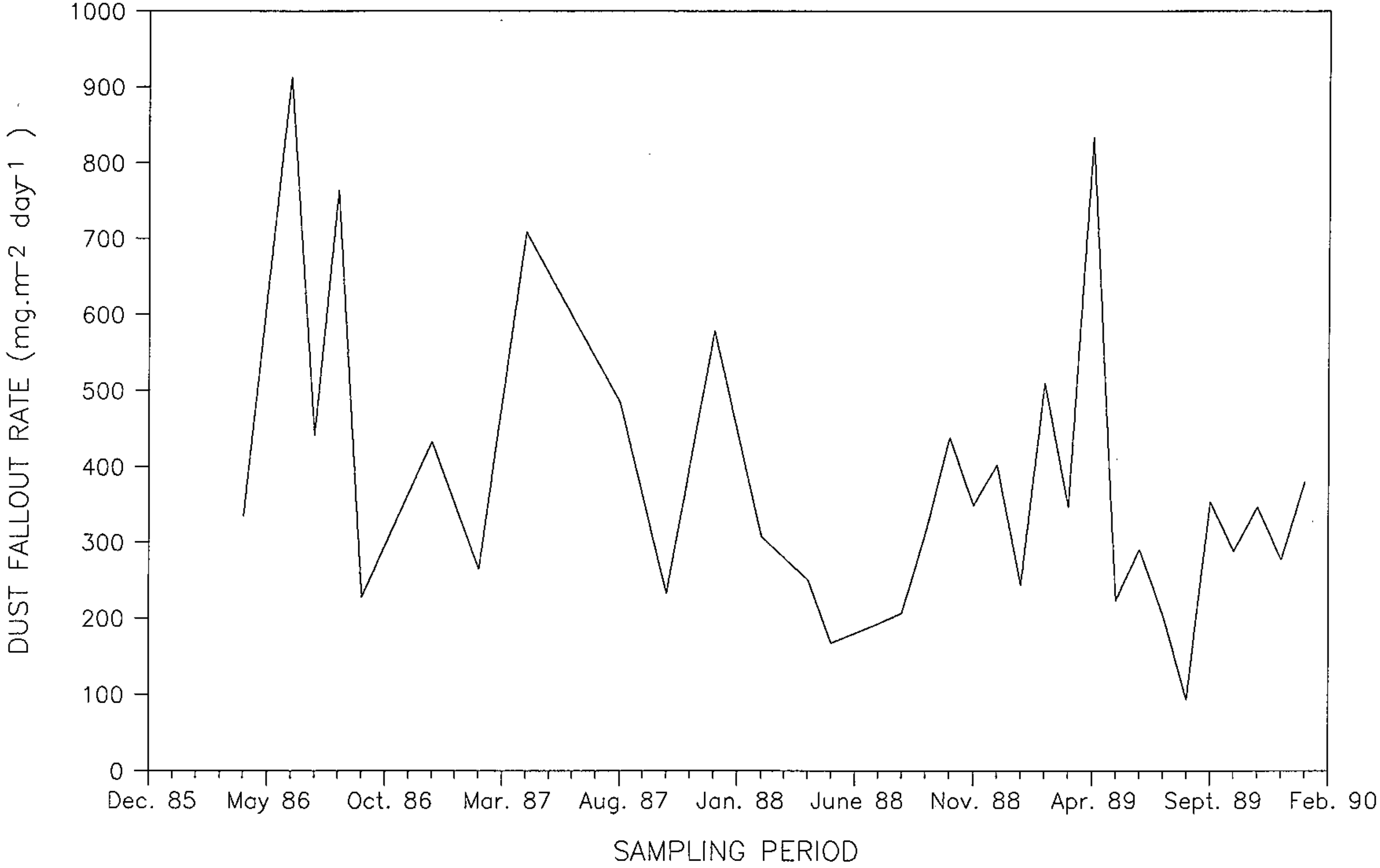
	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: AMBIENT DUST LOADING NEAR THE ASH DISPOSAL CONTROL ROOM
			FIGURE: 5.38



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: AMBIENT DUST LOADING NEAR MOBILE PLANT WORKSHOP
			FIGURE: 5.39



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: AMBIENT DUST LOADING AT MIDWAY OF MAIN ROAD BESIDE No.2 COAL YARD
			FIGURE: 5.40

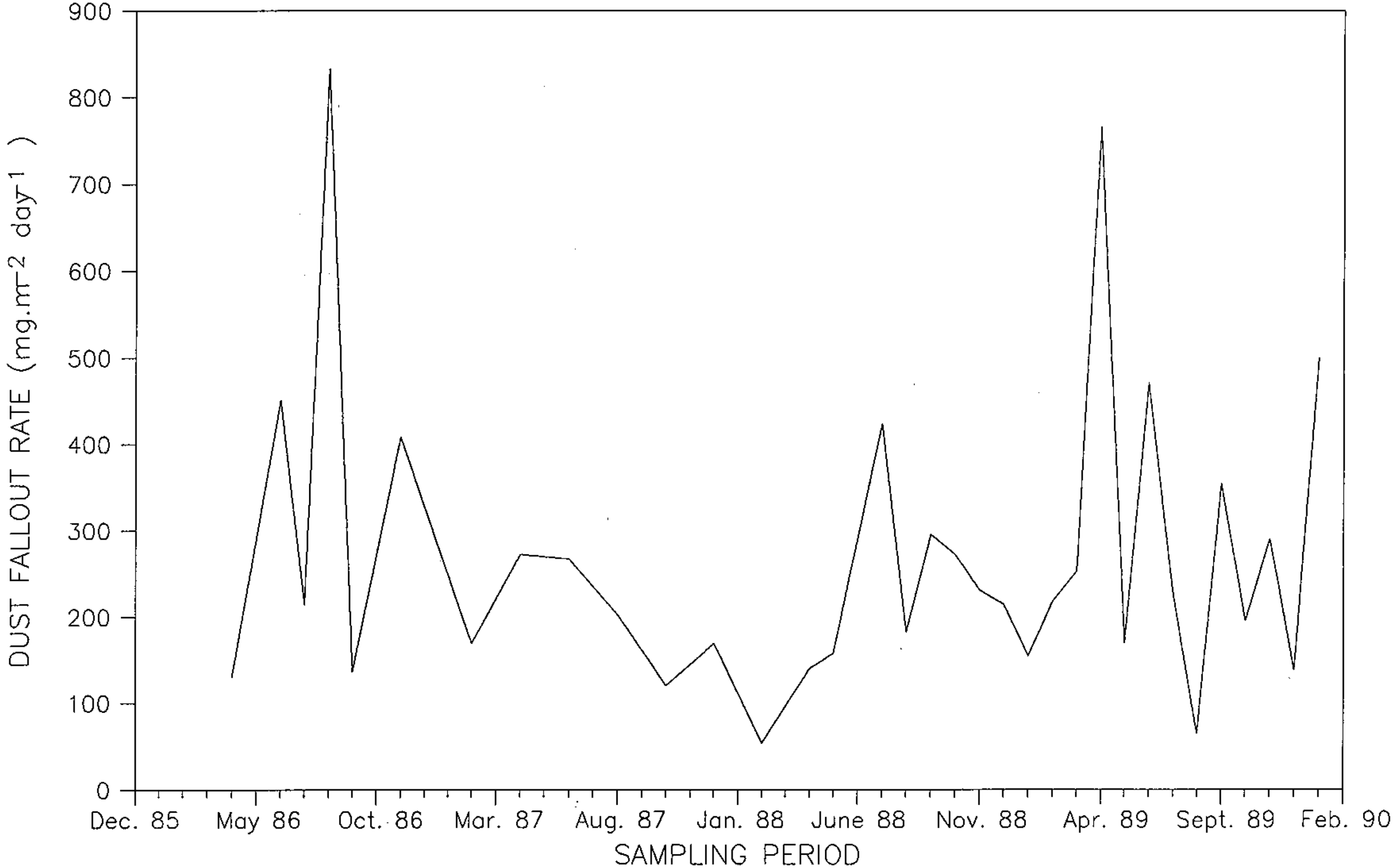


The Hongkong Electric Company Limited

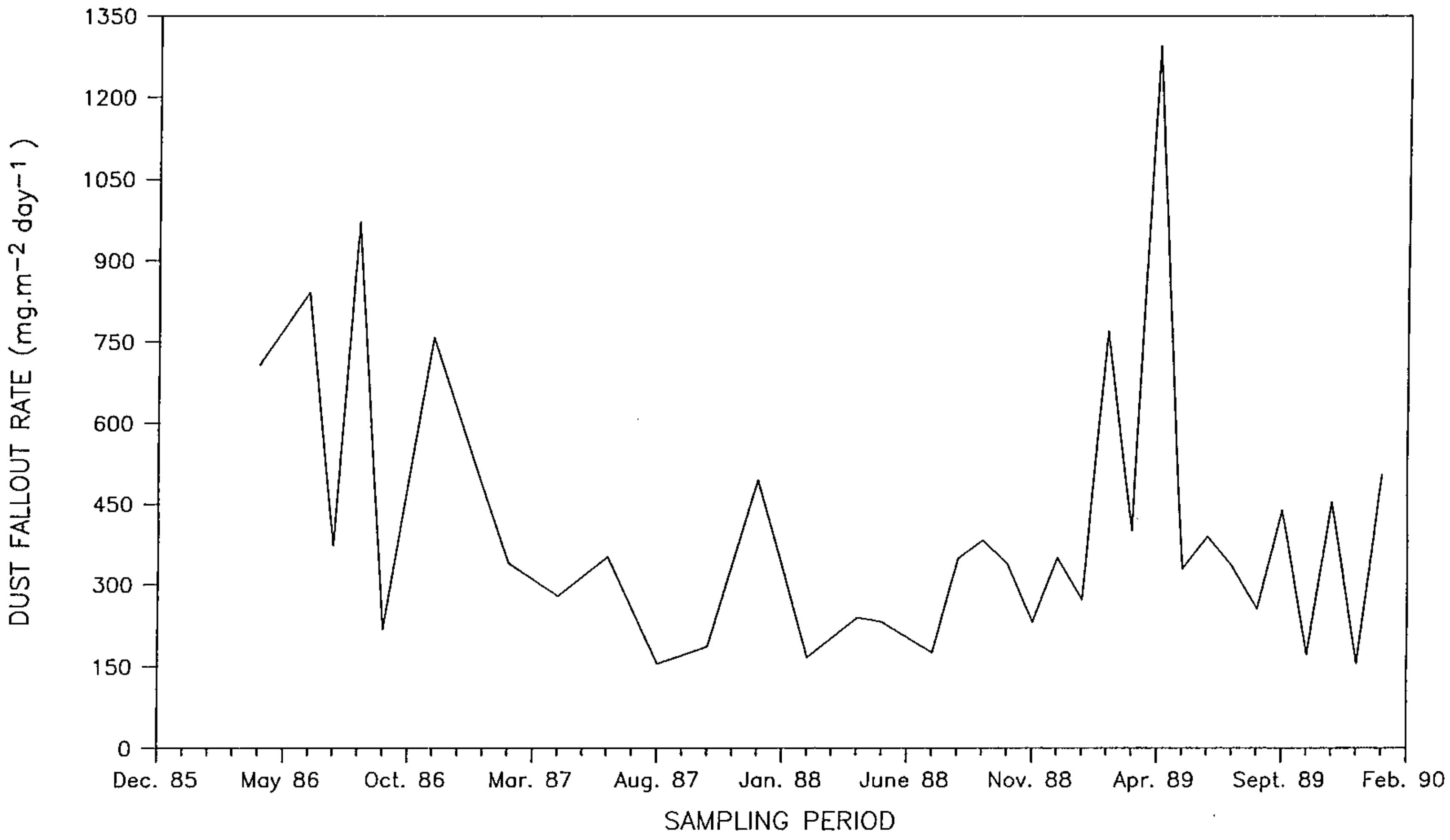
PROJECT: EIA LAMMA POWER STATION

TITLE: FUGITIVE DUST FALLOUT AT STATION WEST

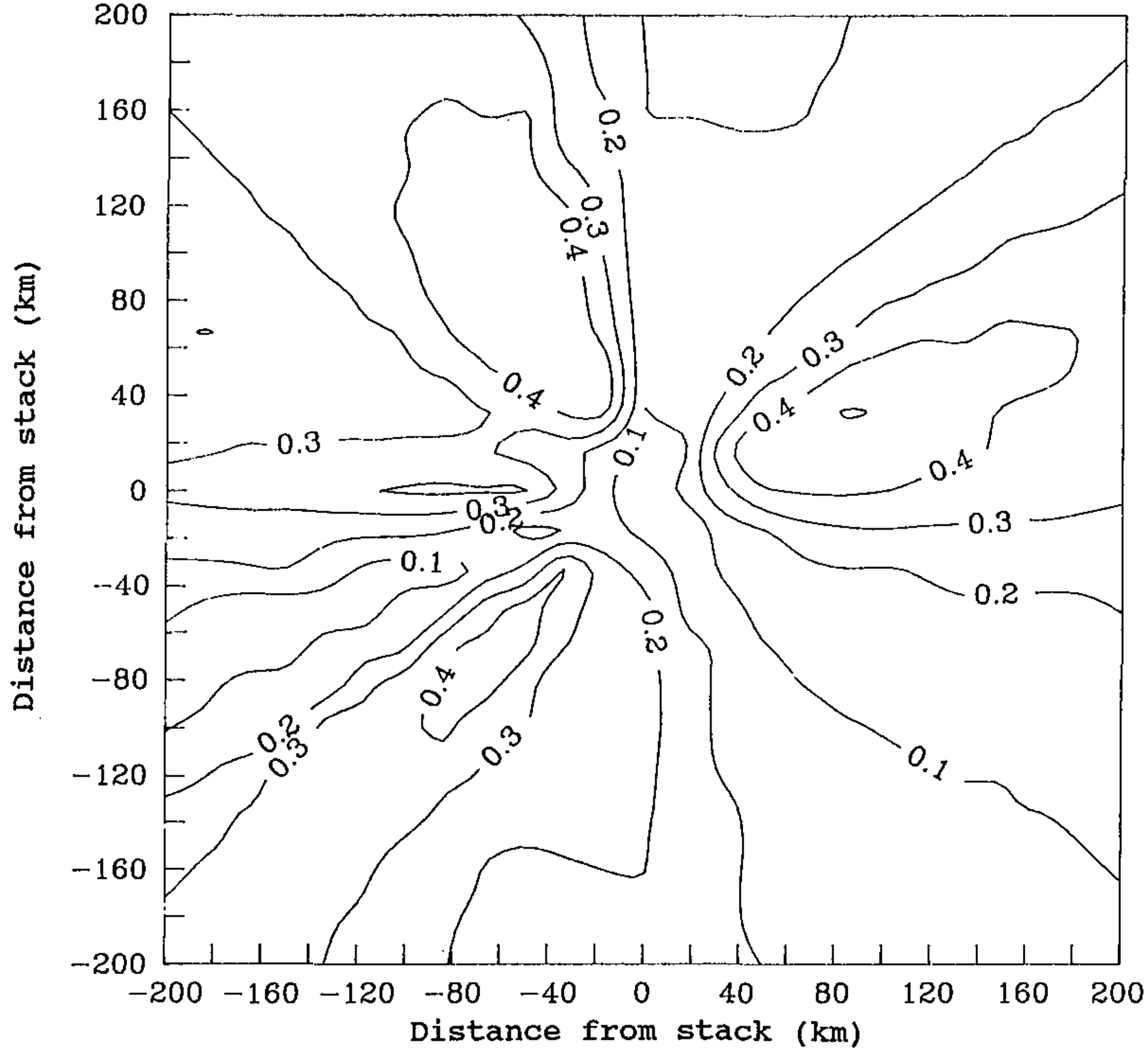
FIGURE: 5.41



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: FUGITIVE DUST FALLOUT AT STATION NORTH
			FIGURE: 5.42



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: FUGITIVE DUST FALLOUT AT STATION EAST
			FIGURE: 5.43



ISCST	*The Hongkong Electric Company Limited*	PROJECT: EIA LAMMA POWER STATION	TITLE: LONG TERM ANNUAL AVERAGE SO_2 CONCENTRATION ($\mu g.m^{-3}$) JULY 2000 FOR 200KM GRID
			FIGURE: 5.44

APPENDIX 5A
CALIBRATION STUDY

5A.0 CALIBRATION STUDY

5A.01 In order to examine the closeness of fit between observed and predicted air pollution levels, a model calibration study was carried out using data on air quality from the HEC air quality monitoring network. Initially, data on SO_2 levels collected from all sites in the HEC network were examined and the measured concentrations occurring during 1988 at the same date and time as the highest five RTDM model predicted concentrations at each site were selected. These data were then plotted and analysed by linear regression analysis. The results are shown for the Aberdeen Station in Figure 5A.1.

5A.02 No statistically significant correlation was found between the observed and predicted SO_2 concentrations at any of the monitoring stations, although predicted concentrations were found to be substantially higher than measured data in all cases.

5A.03 HEC established an additional air quality monitoring station at Victoria Peak in August 1990. The establishment of this station afforded an opportunity to examine the existence of any correlations between RTDM predicted and observed concentrations at elevated receptor locations.

5A.04 For this exercise, wind speed and direction data for Cheung Chau and Lamma were examined for the months of August and September 1990 and those periods with winds blowing from an arc covering 210° to 220° were selected. These wind directions were chosen as being the only ones which would be likely to cause emissions from Lamma Power Station to affect the Peak. Other meteorological inputs to the RTDM model were those from Cheung Chau, irrespective of the origin of wind direction/speed data.

5A.05 For each of the selected wind directions, RTDM was run using station operating emission factors and the predicted SO_2 concentration at Victoria Peak derived. These results were then compared with measured SO_2 levels occurring at the same time as those predicted (Figures 5A.2-5A.3).

5A.06 No statistically significant relationship was found between the observed and predicted results with either Cheung Chau or Lamma wind data. The maximum correlation coefficient (r^2) value was 0.08 which is not statistically significant. Although the two data sets are not consistent, they both illustrate that the model typically over predicts actual concentrations by a significant amount.

5A.07 In order to examine the degree of over-prediction of the RTDM model further, additional statistical analysis was undertaken. For each pair of observed and predicted results from Victoria Peak, the deviation between the two values was calculated. From these values, the percentage error was calculated using the following formula:

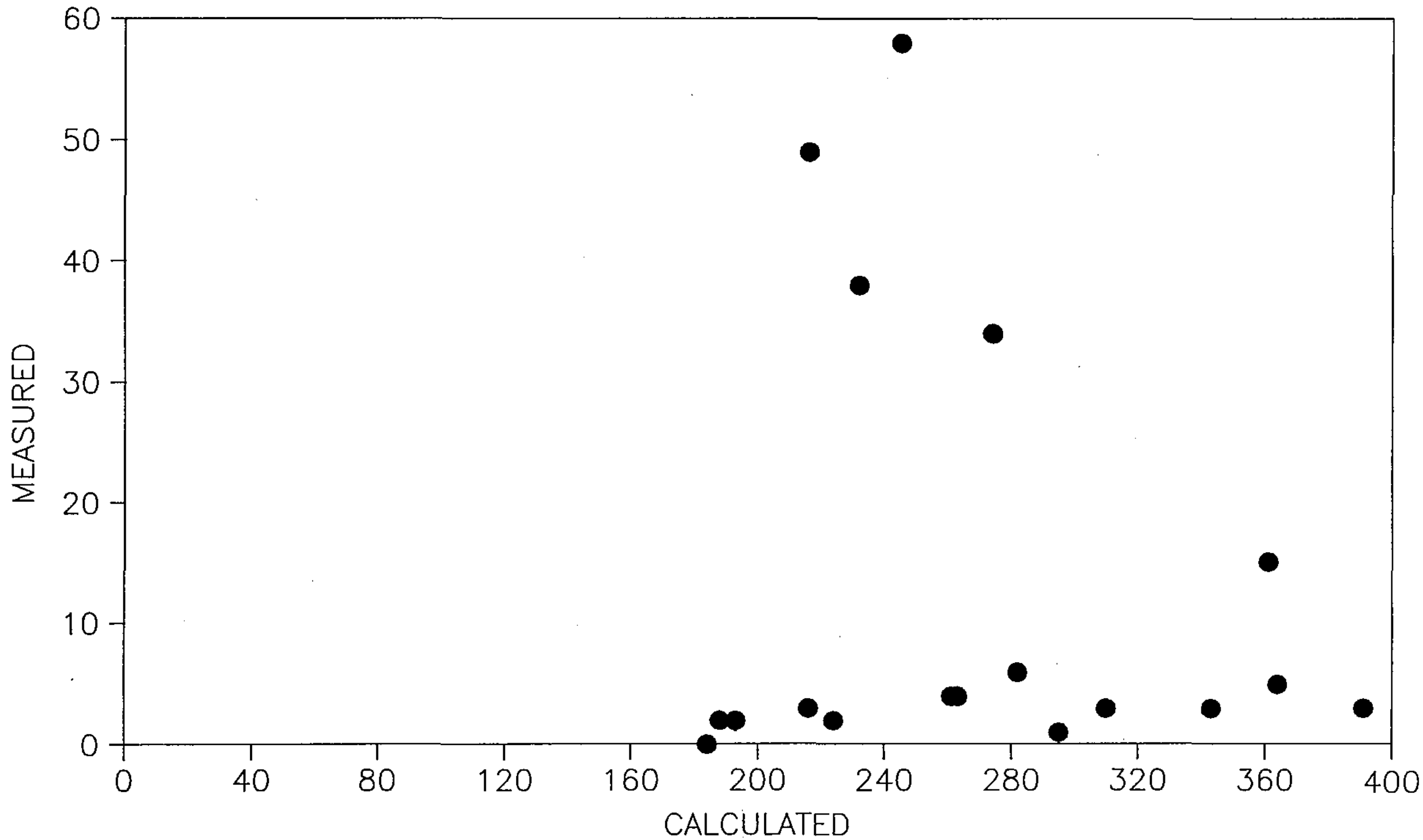
$$\left[\left(\frac{\text{Predicted Concentration}}{\text{Observed Concentration}} \right) \times 100 \right] -100\%$$

5A.08 The formula produces an error of 0% in cases where the predicted concentration is numerically equal to the observed concentration, and a 100% error if the predicted concentration is twice the observed value. Following calculation of individual percentage errors for each data pair, the median percentage error was calculated for the various cases examined.

5A.09 In all cases, the median error indicates that the RTDM model substantially over-predicts compared to the measured concentrations. In the case of the Aberdeen monitoring site, the median error was over 7000%.

5A.10 Analysis of the deviation between observed and predicted concentrations for the Victoria Peak site showed an error range from -100% to 29500%. The median error for predictions using wind speed and direction data from Lamma Power Station (Figure 5A.3) was 788%, whilst that using wind speed and direction data from Cheung Chau (Figure 5A.2) was 1029%. For the Victoria Peak site therefore, it is reasonable to conclude that predicted concentrations over-estimate actual concentrations by a significant amount.

5A.11 The large over-prediction achieved by RTDM is to be expected, given the model's USEPA designation as a screening model. Screening models are designed to identify potential problem areas and as such are conservative (i.e. they are designed to over-predict concentrations). It can be concluded that results obtained from the RTDM runs included in this report are likely to be substantial over-estimates of ground level concentrations.

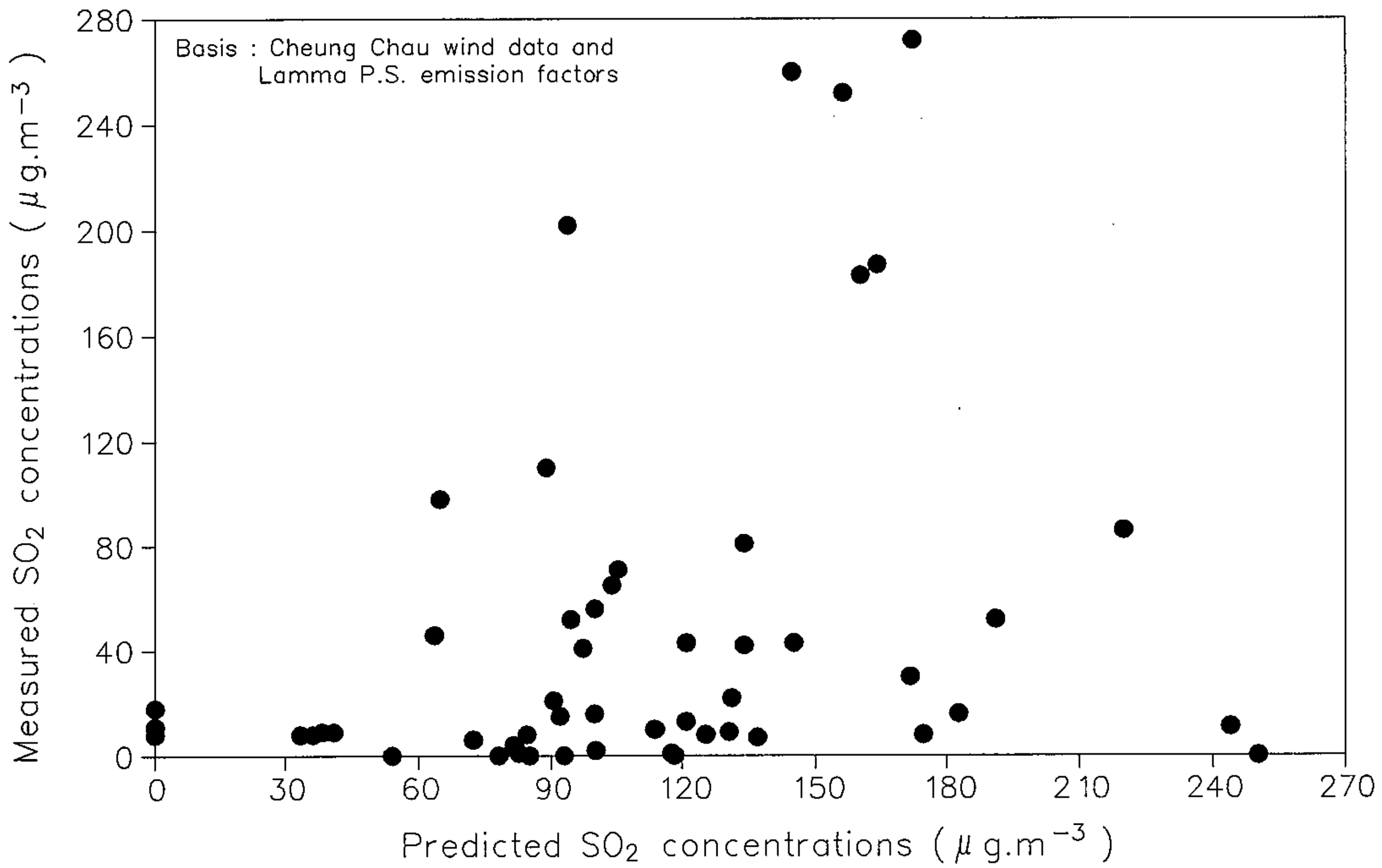


The Hongkong Electric Company Limited

PROJECT: EIA LAMMA POWER STATION

TITLE: COMPARISON OF MEASURED AND CALCULATED SULPHUR DIOXIDE CONCENTRATIONS USING THE RTDM MODEL

FIGURE: 5A.1

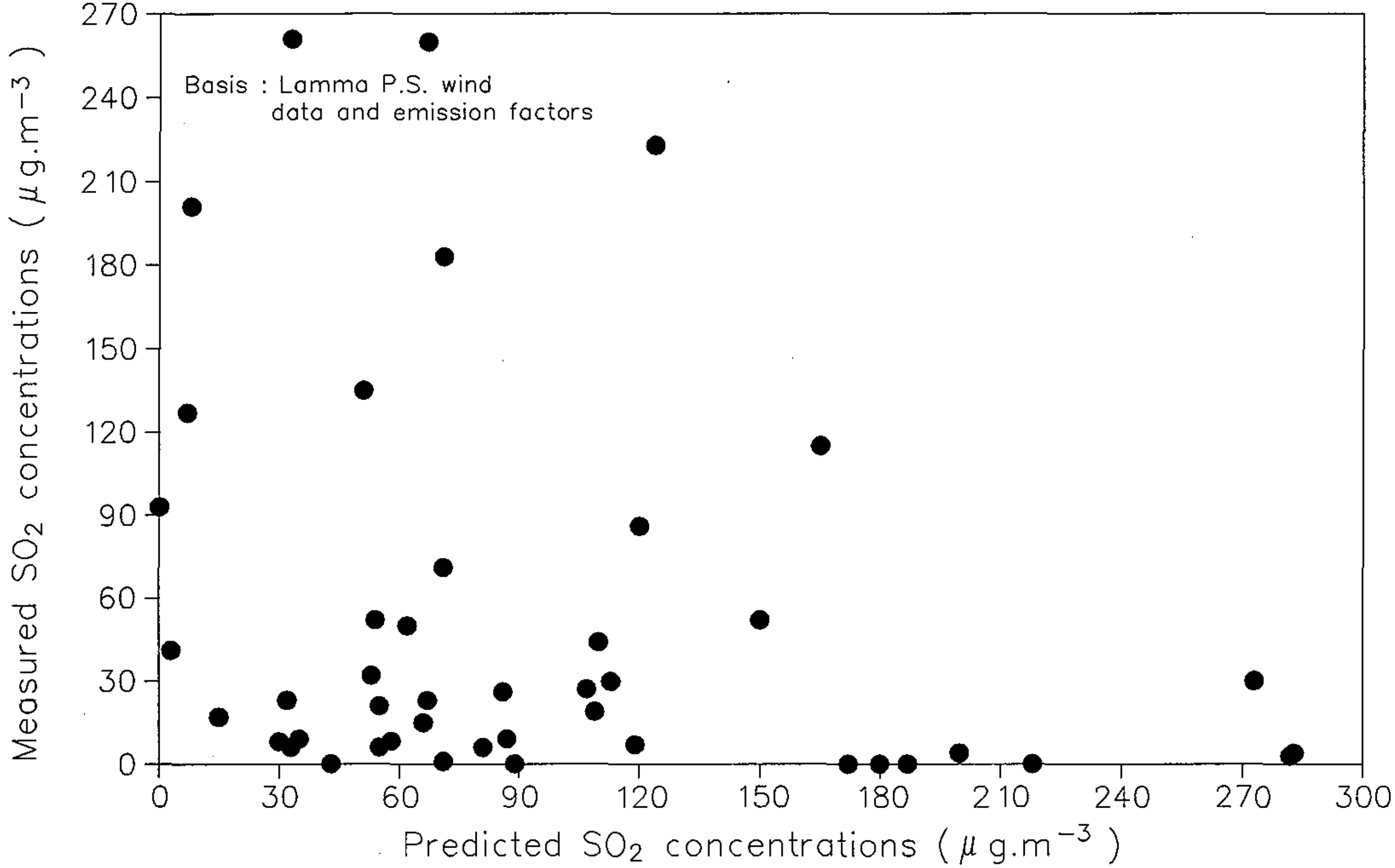


The Hongkong Electric Company Limited

PROJECT: EIA LAMMA POWER STATION

TITLE: Predicted and Measured Concentrations at Victoria Peak, Hong Kong for August 1990

FIGURE: 5A.2



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: **Predicted and Measured Concentrations at Victoria Peak, Hong Kong for August 1990.**
			FIGURE: 5A.3

WATER QUALITY

6.0 WATER QUALITY

Baseline Conditions - Data

6.01 The water quality around Lamma Island has been monitored routinely since 1983 by the Hong Kong Environmental Protection Department and their predecessors. The sites where the quality of the water column is currently monitored are shown on Figure 6.1. Monitoring of the bed sediments has also been carried out at the sites shown on Figure 6.2.

6.02 Data from four of the water quality monitoring sites around Lamma Island (SM5, SM6, SM7, WM1) and also for the two nearest bed sediment monitoring sites (SS3, WS2) have been analysed. The three water quality monitoring sites in the Southern Zone (SM5, SM6, SM7) have been sampled six times each year since 1983. Samples are taken from all three sites on the same day on each occasion. This allows a reasonable comparison to be made of spatial variations in water quality. The data from the Western Buffer Zone site (WM1) have only been collected since 1988. This site is sampled 12 times a year, but on different days from those used to sample the sites in the Southern Zone. Annual samples have been obtained since 1987 from the two sites used to monitor bed sediments around Lamma Island.

6.03 In addition to the routine monitoring by EPD, occasional samples have been obtained by other organisations for specific purposes. These data have not been used to assess baseline conditions as the samples may not be representative of typical conditions around Lamma Island.

Baseline Conditions - Temperature

6.04 Water temperatures around Lamma Island vary seasonally. The temperatures recorded at each site in both surface and bottom layers are shown in Table 6.1. For the sites in the Southern Zone only the data obtained since 1984 has been used, as earlier measurements recorded temperatures only to the nearest degree. The maximum recorded water temperatures in the surface layer are in the range 28.7 to 29.5°C. These temperatures are 1.0 to 1.3°C higher than the maxima recorded in the bottom layer. Minimum recorded water temperatures are in the range 15.4 to 16.1°C in both layers. The minimum recorded surface layer temperatures are up to 0.7°C above those in the bottom layer.

TABLE 6.1 : EXISTING WATER TEMPERATURE EPD MONITORING DATA

Water Temperatures °C								
Site	**SM5**		**SM6**		**SM7**		**WM1**	
Level	**Surface**	**Bed**	**Surface**	**Bed**	**Surface**	**Bed**	**Surface**	**Bed**
Average 1984	22.52	21.84	22.48	21.84	22.34	21.74	-	-
Average 1985	24.52	23.50	24.30	23.48	24.10	23.44	-	-
Average 1986	23.60	23.22	23.45	23.20	23.33	23.20	-	-
Average 1987	23.12	22.65	23.33	22.53	23.02	22.52	-	-
Average 1988	23.35	22.62	23.35	22.47	23.15	22.20	22.39	19.50
Average 1989	22.45	21.58	22.22	21.58	22.28	21.73	22.82	21.92
Period Av	23.49	22.79	23.42	22.74	23.27	22.69	22.60	21.03
Period Max	29.4	28.2	29.5	28.5	28.9	27.9	28.7	27.4
Period Min	16.1	15.6	16.1	15.4	15.9	15.6	16.0	15.9
Number of samples	33	33	33	33	33	33	24	19
Period of record	25/5/84-19/12/89		25/5/84-19/12/89		25/5/84-19/12/89		21/1/88-15/12/89	

6.05 Mean annual water temperatures are similar at the three monitoring sites in the Southern Zone. An interesting feature is that the temperatures at site SM5 are usually highest and those at site SM7 are usually lowest. The difference in average temperatures between these two sites is 0.22°C in the surface layer and 0.10°C in the bottom layer. This difference could be due to the more sheltered water in Ha Mei Wan (site SM5) than in west Lamma Channel (sites SM6, SM7).

6.06 The average water temperatures recorded at site WM1 are noticeably different from those recorded at sites SM5, SM6 and SM7. As samples at site WM1 have never been taken on the same date as those at the other sites, there is little benefit in comparing the results.

Baseline Conditions - Water Quality

6.07 The EPD water quality monitoring data have been analysed to determine average levels of unionised ammonia, inorganic nitrogen and chlorophyll at the four monitoring sites around Lamma Island. The results are presented in Table 6.2. The results from sites SM5, SM6 and SM7 in the Southern Zone may be compared. The samples from site WM1 are taken at a different frequency on different occasions, so may not be directly comparable.

TABLE 6.2 : EXISTING WATER QUALITY EPD MONITORING DATA

Year	Site	Ammonia-N mg/l	Inorganic Nitrogen mg/l	Chlorophyll-a mg/m³
1987	SM5	0.020	0.054	2.16
	SM6	0.018	0.083	2.29
	SM7	0.020	0.115	1.54
	WM1	-	-	-
1988	SM5	0.024	0.096	2.66
	SM6	0.030	0.087	2.71
	SM7	0.056	0.169	3.13
	WM1	0.053	0.149	2.14
1989	SM5	0.018	0.081	3.35
	SM6	0.024	0.092	2.86
	SM7	0.041	0.133	2.62
	WM1	0.054	0.121	3.26
Period Average	SM5	0.021	0.077	2.72
	SM6	0.024	0.087	2.62
	SM7	0.039	0.139	2.42
	WM1	0.054	0.135	2.70

6.08 There are no measurements of metal concentrations in the water column. The concentrations of metal are likely to be very low and there are considerable analytical problems in obtaining an accurate analysis of metals in seawater. Instead, the concentrations of metals are monitored in the bed sediments where they often accumulate. The analysis for toxic metals and polycyclic aromatic hydrocarbons (PAHs) from bed sediment samples taken from two sites around Lamma Island is given in Table 6.3. PAHs have been included as they would indicate any contamination due to the handling or combustion of fossil fuels. The results from these two survey sites show low levels of contamination by all metals and PAHs in comparison with sediments analysed from other areas in Hong Kong waters [1], [2].

TABLE 6.3 : EXISTING BED SEDIMENT ANALYSES EPD MONITORING DATA

Determinand	Metal Concentration in Sediment mg/kg dry solid				Victoria Harbour [2] Range (1988)
	Site SS3	Site WS2	Overall Max	Overall Min	
Arsenic	4.15	3.7	5.4	2.2	-
Boron	21.5	19.0	37.0	11.0	-
Cadmium	1.63*(0.30)	0.46*(0.10)	5.9*(0.59)	0.04	<0.5 - >2.5
Chromium	25.2	23.7	29.0	19.0	50 - >200
Copper	29.7	45.0	65.0	21.0	200 - >800
Iron	28500	23700	50000	22000	-
Mercury	0.175	0.13	0.38	0.08	0.3 - >1.5
Manganese	550	565	630	500	-
Nickel	16.7	16.2	23.0	14.0	-
Lead	41.0	38.7	47.0	35.0	25 - >125
Zinc	81.3	79.2	93.0	66.0	<100 - >300
PAHs	0.127	0.256	0.48	0.053	1.5 - 84.3
Samples Dates	25/8/87 11/1/88 16/8/88 30/6/89	28/8/87 22/8/88 21/4/89			

* 1989 data at both sites are an order of magnitude greater than all previous samples. Bracketed figures assume that this is an error.

Baseline Conditions - Power Station Discharges

6.09 The Hongkong Electric Company have regularly reported on the quality of all effluent discharges from the power station. The monitoring and reporting programme has been set up and agreed with EPD. Reports have been produced twice a year since 1983. Each report covers a 6 month period [3].

6.10 The effluent monitoring reports have been reviewed and the results analysed for some of the more important determinands. The analyses are summarised in Table 6.4 and examined in greater detail in Appendix 6A.

TABLE 6.4 : HISTORIC EFFLUENT WATER QUALITY

Determinand	Unit	Effluent Stream	Period	Mean	Max
Temperature Difference	°C	c.w. outfall	1	7.80	14.0*
Residual Chlorine	mg/l	c.w. outfall	1	0.30	0.89
Grease and Oil	mg/l	Ash settlement	3	0.30	1.5
Mercury	mg/l	Ash settlement	2	0.002	0.013
Cadmium	mg/l	Ash settlement	2	<0.001	0.003
Arsenic	mg/l	Ash settlement	2	0.004	0.043
Chromium	mg/l	Ash settlement	3	0.020	0.190
Copper	mg/l	Ash settlement	4	0.003	0.009
Lead	mg/l	Ash settlement	2	0.002	0.009
Nickel	mg/l	Ash settlement	2	0.003	0.014
Zinc	mg/l	Ash settlement	2	0.036	0.130
Total Coliform	N/100 ml	Sewage	3	-	100,000

Periods of data collection

1 1983-1989
2 1984-1989
3 1985-1989
4 1984

* Temperature difference calculated from the difference between the weekly average condenser inlets and outlets.

6.11 The effluent report monitoring programme has changed somewhat over the years and so analyses from different years cannot always be directly compared. There was a major change in the programme in March 1985 and a further change in August 1989.

Water Quality Criteria and Standards

6.12 The waters around Lamma Island are mainly part of the Southern Water Control Zone where Water Quality Objectives were gazetted in 1988 under the Water Pollution Control Ordinance. The waters north east of Lamma Island form part of the Western Buffer Zone. This area of water is due to be gazetted as a Water Control Zone in 1991 when specific Water Quality Objectives will be set.

For the purposes of this Environmental Impact Assessment all waters affected by the power station discharge will be assessed in relation to the Water Quality Objectives for the Southern Water Control Zone.

6.13 The Water Quality Objectives gazetted for the Southern Water Control Zone are included as Appendix 6B which is taken from [4]. These objectives cover

- Aesthetic Appearance
- Bacteria
- Dissolved Oxygen
- pH
- Temperature
- Salinity
- Suspended Solids
- Ammonia
- Nutrients
- 5-Day Biochemical Oxygen Demand
- Chemical Oxygen Demand
- Dangerous Substances

6.14 The discharges from Lamma Power Station are most affected by the Temperatures and Dangerous Substances objectives. Other objectives which may be relevant are Aesthetic Appearance, Bacteria and Nutrients as the power station discharge may slightly affect these determinands locally. The power station discharges are controlled so that they are unlikely to have a measurable impact on Dissolved Oxygen, pH, Salinity, Suspended Solids, Ammonia, 5-Day Biochemical Oxygen Demand or Chemical Oxygen Demand.

6.15 The water quality objectives for temperature, dangerous substances, aesthetic appearance, bacteria and nutrients are summarised in Table 6.5 which is taken from the Water Quality Objectives stated in Appendix 6B.

TABLE 6.5 : SUMMARY OF KEY WATER CONTROL OBJECTIVES [2]

Water Quality Parameters	Objective	Sub-zone
Temperature	- Change due to waste discharge not to exceed 2°C	Whole zone
Dangerous Substances	- Waste discharges shall not produce significant toxic effects in humans, fish or other aquatic organisms - Waste discharges shall not put beneficial uses of aquatic environment at risk	Whole zone
Aesthetic Appearance	- Visible foam, oil, grease, scum, litter, offensive odour, tints and colours not to be present	Whole zone
Bacteria	- E. Coli not to exceed 1000/100 ml in more than 60% samples	Secondary Contact Recreation Subzone
	- 5-day running median E. Coli not to exceed 1000/100 ml	Bathing Beaches
Nutrients	- Quantity shall not cause excessive algal growth - Annual mean depth average inorganic nitrogen not to exceed 0.1 mg/l	Marine Waters

6.16 The operation of the power station requires the use of large volumes of cooling water for the condensers. This cooling water is released in the cooling water (C.W.) outfall at up to 10°C above ambient. The temperature water quality objective must, therefore, necessarily be exceeded locally. The current discharge consent for the c.w. flow allows water temperatures in excess of 2°C above ambient within a 1500 m radius of the discharge.

6.17 Apart from heated water, the operations at the power station release small quantities of other substances. These releases include residual oxidants from the chlorine used to control fouling of the condensers and trace metals present in the discharges from the ash settlement basin, boiler blowdown and other trade effluents. All these discharges are controlled and monitored at their source in the power station and then discharged with the main c.w. flow to the west of the site, which provides significant dilution at the outfall point. The discharges from the Flue Gas Desulphurisation (FGD) equipment will also come into this category. The choice of discharge route for the FGD effluent could be either via a storm drain discharging on the east side of the site or with the main c.w. flow.

6.18 An aesthetic impact of the power station on the Southern Water Control Zone is the foam produced at the outfall. This foam is of biological origin and results from the chlorination of the cooling water flow to protect the condensers from biological fouling and from thermal stress to organisms entrained in the c.w. flow. The assessment of this foam and means of mitigating its impact are discussed in Chapter 9.

6.19 In addition to the industrial discharges associated with the power station, there are "domestic" wastes and stormwater drainage from the site. The quality of these domestic discharges are controlled and monitored, and the effluent is treated by three sewage treatment plants before discharge. Since relatively few people are employed at the power station, the impact of these discharges is small. These discharges primarily affect the bacteria and nutrient objectives, and their influence on the other water quality objectives is not significant.

6.20 The current discharge consents for all the power station effluents are summarised in Table 6.6. In this table, the discharge from the FGD equipment has been included for Unit L6 using discharge consent conditions which EPD have indicated would probably apply to this effluent.

TABLE 6.6 : EXISTING EFFLUENT DISCHARGE CONSENTS

Effluent Stream	1	2	3	4	5	6
Discharge Quantity (m^3)						
Max discharge/day	6510000	10800	960	-	740	290
Max discharge/hr	-	500	240	9000	-	-
Max discharge/min	4550	-	-	-	-	-
Discharge Quality (max concentration mg/l)						
pH range	-	6-9	6-9	6-9	-	6-9
Temperature Rise (°C)	10	-	-	-	-	-
Max Temperature (°C)	-	43	-	43	-	43
Free Available (Chlorine)	0.5	-	-	-	-	-
Total Residual Chlorine (No 3 STP)	-	-	-	-	1	-
Total Residual Chlorine (No 1 & 2 STP)	-	-	-	-	0.5-1	-
Suspended Solids	-	100	100	250	30	30
Grease and Oil	-	5	5	20	20	20
Mercury	-	-	-	0.1	-	0.1
Cadmium	-	-	-	0.1	-	0.1
Arsenic	-	-	-	2	-	2
Chromium	-	-	-	2	-	2
Copper	-	1	1	2	-	2
Lead	-	-	-	2	-	2
Manganese	-	-	-	2	-	5
Nickel	-	-	-	2	-	2
Zinc	-	-	-	2	-	2
Silver	-	-	-	-	-	2
Barium	-	-	-	-	-	5
Boron	-	-	-	-	-	5
Tin	-	-	-	-	-	5
Total non-ferrous metal	-	-	-	5	-	5
Iron	-	10	10	10	-	10
Cyanide	-	-	-	-	-	0.1
B.O.D.	-	-	-	-	20	-
C.O.D.	-	-	-	-	80	80
E. Coli (No/100 ml)	-	-	-	-	5000	-

Effluent Streams
1. Cooling Water Discharge
2. Effluent Treatment Plant Discharges
3. Boiler Blowdown
4. Ash Settlement Basin overflow
5. Sewage
6. FGD Treatment Plant Discharge (Provisional)

Note
1) Discharge consent for FGD waste based on anticipated flow and consent conditions.

2) Streams 2, 3, 4 discharged into Stream 1.

3) Stream 6 to be discharged to storm drain or into Stream 1.

6.21 In the assessment of the impact of the construction of Units L7 and L8 the quality consent has been assumed to remain unaltered. The permitted discharge volume has been assumed to rise in line with the increased station capacity. The discharge rates assumed for each scenario are listed in Table 6.7.

6.22 The discharge rates assumed in table 6.7 are based upon the c.w. pump design flow rates for normal operation and are marginally lower than the consent limit flows given in Table 6.6. Even the lower assumed discharge rates used in the calculations will, in fact, produce a conservative estimate of total discharge, as the assumed discharge rate would not occur in practice throughout the 24 hour period.

6.23 The temperature of the cooling water for the proposed new Units L7 and L8 has been calculated on the same basis and assumes a design temperature rise across the condenser of 8°C. This will again tend to produce a conservative assessment of actual impact due to the fluctuating load pattern.

TABLE 6.7 : ASSUMED DISCHARGE RATES FOR LAMMA POWER STATION

	Power Station Rating	Discharge Rate m^3/day Effluent Stream					
Description	MW	1	2	3	4	5	6
L1-L6 FGD on L6	1800	6235200	10800	960	216000	740	290
L1-L8 FGD on L4-8	2500	8596800	15000	1340	300000	740	1450

Water Quality Modelling

6.24 The water quality modelling used in this assessment is derived from the results of the WAHMO suite of computer programs which were developed by Binnie & Partners, Hydraulics Research Limited and the Water Research Centre for the Urban Area Development Office of the Territory Development Department [5]. The WAHMO programs reproduce the existing hydraulic and water quality conditions in Victoria Harbour and the Western Anchorage and can simulate the effects of proposed future developments.

6.25 The area covered by the WAHMO hydrodynamic models includes the area around Lamma Island, and data were collected in both the East and West Lamma Channels to check that the model performance was satisfactory. The models have been accepted by the relevant departments of the Hong Kong Government including EPD. The base conditions derived from WAHMO are considered reliable, though the relatively coarse 250m grid of these models limits their accuracy in coastal areas of complex topography.

6.26 Water Quality modelling has been carried out in two parts. The first part examines the overall pollution field set up around Lamma Island by the discharges from Lamma Power Station. The second part examines in more detail the behaviour of the plume and pollution field on the west side of the Island.

6.27 The suite of mathematical models constructed for this study comprises four main models based on the Binnie & Partners in-house DIVAST model. These models are:

- Far Field, Dry Season Model, to examine the impact of cooling water discharges on Hong Kong waters as a whole. The model assumes non-stratified, one-layer flow, appropriate for the dry season;

- Near Field, Dry Season Model, to examine the impact of cooling water discharges on the west Lamma area in greater detail than the Far Field Model. The model again assumes non-stratified, one-layer flow;

- Plume model, using data from the Near Field Model, to examine the behaviour of the cooling water plume in the immediate area of the outfall;

- Far Field, Wet Season Model. The model assumes stratified, two-layer flow, appropriate for the wet season;

Far Field Model - Description

6.28 For the study of the overall pollutant build up around Lamma Island, the output from the 250 m grid WAHMO depth averaged hydrodynamic model has been used directly [5]. The velocities and levels calculated by the WAHMO model have been used to drive the solute portion of B&P's in-house DIVAST model. This model is described in detail in Appendix 6C.

6.29 The SOLUTE DIVAST model has been applied to the parts of Hong Kong water shown on Figure 6.3 to form the Far Field model. The boundaries are formed on the north west side by Lantau Island and on the east side by Hong Kong Island. The north east boundary has been drawn across the Western Anchorage from the north east of Lantau Island to the west of Hong Kong Island passing north of Green Island. The south eastern boundary has been taken from Repulse Bay to almost the limit of the WAHMO 250 m grid model. The south western boundary is close to the corresponding boundary of the WAHMO 250 m grid.

6.30 The southern open sea boundaries of the model are determined primarily by the limits of the WAHMO grid. These boundaries have been taken far enough south of Lamma Island to allow heat to be convected round the southern tip of Lamma Island into the East Lamma Channel. The north east boundary across the western anchorage is about 10 km north of the power station. This may be compared with a flood tidal excursion of 7.5 km in the West Lamma Channel. This boundary allows the model to reproduce any convection of heat around the northern part of Lamma Island.

6.31 The discharge of heat is represented in the Far Field model by adding the correct heat load to the model cell adjacent to the power station c.w. outfall. The heat that is added to the flow is convected and dispersed throughout the area of the Far Field model by the water currents derived from the WAHMO hydrodynamic model. The heat that is added raises water temperatures and promotes heat transfer to the atmosphere. The rate of heat transfer is assumed proportional to the rise in water temperature in each model cell. The small amount of heat which crosses the Far Field model boundaries is assumed not to return to the model area.

6.32 The Far Field pollution model works in the same way as the thermal model. The pollutant massflow is added at the point of discharge and then convected and dispersed by the model currents. There is however no loss of pollutant mass except when it crosses the model boundaries.

6.33 The model results have allowed contours of excess temperature or pollutant concentration to be drawn around the power station and quantify any small changes in water quality due to the power station that may occur along the coastline of Lantau and Hong Kong Islands, as well as the smaller islands between, including the east and south coasts of Lamma Island.

6.34 The Far Field Dry Season model has made the assumption that water temperatures are well mixed with depth. This assumption is valid for looking at conditions some distance from the discharge point where quality changes are small.

6.35 All far field model tests have been run using repeating tides for a period of 20 neap or 10 spring tides to ensure equilibrium has been reached.

Near Field Model - Description

6.36 The study of the detailed dispersal of heat and metals from the Lamma power station has used the existing depth averaged model of the west side of Lamma Island developed by B&P using the DIVAST program. This model is driven by flows and elevations along the boundaries calculated by the WAHMO depth averaged hydrodynamic model. The model has a grid size of 83.3 m (1/3 of the WAHMO grid) and is aligned with the WAHMO grid. This model has already been tested and shows good agreement with the WAHMO results west of Lamma Island. The finer grid allows a better definition of the impact of the dredged channel on tidal flows and a better representation of the bottom topography and coastline of Ha Mei Wan south of the power station. The boundaries of this model are shown in Figure 6.4. The calibration of this model is described in detail in Appendix 6D.

6.37 The Near Field model has been used to show in detail any pollutant built up in Ha Mei Wan and the dispersal of pollutant in the main West Lamma Channel north and south of the outfall. The flows calculated by the Near Field hydrodynamic model which includes the power station c.w. flows are used to drive the Near Field Solute model. This solute model operates in a very similar way to the Far Field solute model described above. The principal differences are on the boundaries and in the way the heat load is added to the c.w. flows. Along the Near Field model boundaries, the temperatures calculated by the Far Field model are used to ensure that water entering the Near Field model area is at the correct temperature.

6.38 The Near Field model includes the abstraction and discharge of cooling water by Lamma power station. The temperature rise that is calculated by the model to occur in the sea at the intake has been added to the water temperature rise across the power station condensers to give the correct discharge temperature. This ensures that heat is conserved in the model. A similar principle is applied to the calculation of pollutant concentration in the model.

6.39 All near field model tests have been run using repeating tides for a period of 10 neap or 5 spring tides to ensure equilibrium has been reached. The smaller area enclosed by the near field model allowed the number of tide cycles to be reduced.

6.40 The depth averaged model cannot model the vertical temperature differences that occur in the outfall plume. This has been examined by a detailed consideration of the outfall plume development. The initial dimensions and temperature of the outfall plume was assessed from a consideration of the relevant literature. The subsequent lateral spreading of the plume was examined using a plume model, which is based on the track of the outfall plume centreline. This model was used to calculate the dispersion of warm water in the surface plume. Zero wind conditions have been used in the plume model to give an indication of average plume trajectory. The approach is described in detail in Appendix 6E.

Wet Season Modelling - Description

6.41 The highest temperatures in Hong Kong waters occur in summer when the water column is stratified. This will limit the movement of the heated water into the lower layers, which will benefit benthic communities but may cause higher excess temperatures in the surface layer. In order to assess this effect, some of the dry season depth averaged tests have been repeated for the wet season using the WAHMO two layer hydrodynamic model output to drive a two layer SOLUTE DIVAST model.

6.42 The two layer SOLUTE DIVAST model uses the solution technique employed in the depth averaged model but repeats the calculations for the lower layer. The heat transferred by vertical dispersion and vertical flows present in the WAHMO model have been included as sources or sinks of heat from each cell of the model. The vertical dispersion coefficient has been set to the value of 0.00001 m^2/s adopted in the WAHMO two layer water quality model.

Model Performance Checks

6.43 The performance of the thermal models has been assessed by comparing observed water temperatures around Lamma power station on two occasions with model tests results designed to simulate those conditions. The first test used a thermal survey carried out on behalf of HEC in March 1985 [6]. This survey monitored the thermal plume on the ebb of a neap tide south of the power station. Following this initial test, a more detailed thermal survey was carried out in September 1990 [7] as part of the investigations for this environmental assessment. The results from this recent survey have also been compared with model predictions.

6.44 In the first thermal survey, carried out on 19 March 1985, Units L1, L2 and L3 were generating 660MW. The thermal plume study [6] recorded water temperatures in the range 15.3 to 17.9°C. The lower temperature is probably close to the ambient temperature. In the period when the ebb tide had started running fully, the maximum temperatures along a southerly transect from the power station outfall decreased from 2.6°C above ambient 200 m south of the outfall to 0.7°C above ambient 4600 m south of the outfall. These temperatures combine near field and plume temperature effects as well as any variation in ambient water temperatures due to tidal movements or solar heating. The measured maximum temperatures are shown on Table 6.8.

TABLE 6.8 : THERMAL PLUME SURVEY TEMPERATURES 19/3/85

Distance S of Outfall km	Observed Max Temp °C	Observed Temp Rise °C	Maximum Predicted Temp Rise °C	Average Predicted Temp Rise °C
0.2	17.9	2.6	3.25 (+0.65)	1.8 (-0.8)
0.3	17.2	1.9	2.8 (+0.9)	1.3 (-0.6)
0.6	16.7	1.4	1.75 (+0.35)	0.85 (-0.55)
4.6	16.0	0.7	<0.1 (-0.6)	<0.1 (-0.6)
Background	15.3	-	-	

* Figures in Parenthesis are the Difference Between Predicted and Observed Temperature Rises.

6.45 The Far Field and Near Field models were run for these conditions using the repeating neap tide derived from the WAHMO depth averaged hydrodynamic model. For this preliminary test, the power station cooling water flow was held constant at 30.66 m^3/s with a condenser temperature rise of 7.25°C as these conditions were measured at the power station on the day of the survey. The surface heat loss coefficient was set at 0.9 m/d as used in the WAHMO water quality models [5] equivalent to 43 W/m^2°C in seawater.

6.46 The near field model predictions in the vicinity of the observed temperature measurements are also shown in Table 6.8. The observed maximum temperature rise is between the average and maximum predicted by the model. There are however considerable changes in temperature between individual model cells near the power station which hinder detailed comparisons. 4.6 km south of the outfall, the model predicts almost no temperature rise though the observations suggested a temperature rise of 0.7°C may have occurred. Near to the discharge point, the predicted maximum rise was 0.6°C higher than actually observed.

6.47 The results from the near and far field model tests of conditions in March 1985 are shown in Figures 6.5 to 6.8. Figures 6.6 and 6.8 indicate the average temperature rises over the course of a complete neap tide around Lamma Island and Figures 6.5 and 6.7 show the envelope of highest temperatures reported in the model results at any state of the tide. The +2°C contour extends for less than 1 km from the power station outfall.

6.48 The model test of conditions in March 1985 did not make any allowance for the diurnal variation in power station load. As a result more heat will have been added to the models in the days prior to the thermal survey than would probably have occurred in practice. However, analysis of meteorological data for March 1985 (Appendix 6F) indicates that the heat transfer coefficient averaged about 20 W/m^2°C in the days immediately preceding the survey rather than the 43 W/m^2°C used in the model tests. These two effects will to some extent counterbalance each other.

6.49 Following these preliminary model tests, a second thermal survey was carried out [7]. The field data obtained in this survey have been analysed as reported in Appendix 6F and the results used to check the performance of the model as described in Appendix 6D. During the period of this survey Units L1 to L5 were operating and during parts of the day, the full rated output of 1450 MW was required from the five steam turbine units.

6.50 The temperatures measured on one day of the field tests, 20th September 1990, at five fixed thermometers on the west side of Lamma Island are summarised in Table 6.9. This day was selected as having tidal conditions similar to those available in the WAHMO neap tide used for the near and far field models. These models were run using the observed diurnal heat load discharge from the power station and the heat transfer coefficient calculated from meteorological conditions as described in Appendix 6F.

6.51 The results from both near and far field model predictions in the model cells nearest to the fixed thermometers are also shown on Table 6.9. The near and far field model predictions of both maximum and mean temperature rises agree within 0.3°C at all sites.

TABLE 6.9 : THERMAL PLUME SURVEY CALIBRATION SEPTEMBER 1990

Distance from Outfall (km)	Observed/ Model	Temperature Rise Mean °C	Maximum °C	Model Estimate of Maximum Temperature Rise °C
1.9(N) - T3	Observed[1]	0.29	0.7	-
	Near Field	0.4 (+0.11)	1.4 (+0.7)	0.90 (+0.2)
	Far Field	0.6 (+0.31)	1.4 (+0.7)	1.00 (+0.3)
1.0(N) - C2	Observed[1]	0.29	1.0	-
	Near Field	0.5 (+0.21)	1.4 (+0.4)	0.95 (-0.05)
	Far Field	0.5 (+0.21)	1.2 (+0.2)	0.85 (-0.15)
0.3(S) - T2	Observed[1]	0.70	2.2	-
	Near Field	1.4 (+0.7)	2.9 (+0.7)	2.15 (-0.05)
	Far Field	1.3 (+0.6)	2.8 (+0.6)	2.05 (-0.15)
1.0(S) - C1	Observed[1]	0.43	1.2	-
	Near Field	1.0 (+0.57)	1.9 (+0.7)	1.45 (+0.25)
	Far Field	0.9 (+0.47)	2.2 (+1.0)	1.55 (+0.35)
3.2(S) - T1	Observed[1]	0.39	0.9	-
	Near Field	0.1 (-0.29)	0.2 (-0.7)	0.15 (-0.75)
	Far Field	0.0 (-0.39)	0.0 (-0.9)	0.0 (-0.9)

Note: (1) Observed temperatures assume an ambient of 27.2°C on 20/9/90
(2) Figures in Parenthesis are the Difference Between Predicted and Observed Temperature Rise

6.52 Comparison of the model results with the recorded temperature rises shows that the recorded maximum temperature rise is between the average and maximum predicted by the two models at all sites except T1. At the other four sites, the recorded maximum temperature is close to the average of the maximum and mean temperatures predicted for each site by the Near Field Model. For all sites except T1, both models over-predict the average and maximum temperature rise by variable amounts between 0.1°C and 1.0°C.

6.53 Although the model generally over-estimates the observed mean and maximum temperatures, a reasonable estimate of the observed maximum can be obtained by averaging the model mean and maximum temperature rises at each site except T1 as indicated in the final column of Table 6.9. Using this basis for estimating the observed maximum temperature rise reduces the discrepancy between observation and model to less than ±30% or ±0.4°C at all sites except T1.

6.54 At site T1 which is 3.2 km south of the power station, both models predict much less temperature rise than observed. This feature is also present in the modelling of the 1985 thermal survey data described above.

6.55 The far and near field model predictions for September 1990 conditions are shown in Figures 6.9 and 6.10. These figures show the envelope of the average of the maximum and mean temperatures predicted at each site which correspond to the envelope of the highest observed temperatures. Figures 6.9a and 6.10a show the envelope of the predicted mean temperature rise at each site. In Figures 6.10 and 6.10a, which show the results for the near field modelling, the observed maximum and mean temperature rises at each fixed thermometer are also shown for comparison with modelled data. The predicted contours derived from the results of the average of the maximum and mean predictions show that the +2°C contour extends about 500 m north of the power station and 1,000 m south east. The area in the model where mean temperatures are predicted to exceed +2°C extends 200 m north and 500 m south east of the outfall. The recorded data indicate somewhat lower mean temperature rises in this area than those predicted by the model. The larger area of warm water to the south of the power station is associated with the ebb tide which coincides with the peak daytime heat load discharged from the power station.

6.56 An HEC survey of intake water temperatures [8] measured temperature rises at the cooling water intakes at a time when the power station was generating 1250 MW in September 1988. Table 6.10 compares these observations with the results from the two near field model tests described above.

TABLE 6.10 : CW INTAKE TEMPERATURES SEPTEMBER 1988

Tide	Power Station Generation MW	CW Temp Rise °C	Temperature Rise °C Intake No 1 Mean (Max)	Intake No 2 Mean (Max)
Observed				
Neap	1260	6.8	0.51 (2.1)+	0.38 (1.8)+
Spring	1240	6.87	0.38 (1.4)+	0.53 (1.4)+
Model Prediction				
Neap	660	7.25	1.4 (2.6)	0.8 (1.5)*
Neap	1450	2.80-7.86	2.3 (4.2)	1.7 (3.3)

+ Time and depth averaged temperature rises for nearest measuring points

* Not in use.

6.57 The comparison in Table 6.10 indicates that intake temperatures in the near field model are higher than those observed by a considerable margin. These comparisons confirm the results from the modelling of the two thermal surveys in Tables 6.8 and 6.9 which also suggested that temperatures near the outfall are too high in the near field model. The observed maximum temperature rise at the intake is between the maximum and average predicted by the models when allowances are made for the increasing heat loads discharged by the power station as its electrical load has risen.

6.58 All the checks of model performance described above show a consistent pattern. There is general agreement between the near and far field model results of each condition. Around and to the north of the power station the observed maximum temperature is midway between the model predictions of maximum and average conditions. More than about 1000 m south of the power station, the models predict smaller temperature rises than the two thermal surveys had measured.

6.59 With the reservations outlined above, the model is able to reproduce the main features of the heat field around Lamma power station although it is clear that the model tends to over-estimate temperature rises in the near field. The calibrations suggest that observed maximum temperatures can be estimated with reasonable accuracy around the power station by averaging the maximum and mean temperature rise predicted by the modelling. This allows the extent of the +2°C contour around and to the north of the power station to be estimated. The extent of the heat field south of the power station is not well represented in the modelling. However, the observations in September 1990 suggest that temperature rises south of the power station are similar to those on the north side.

Model Test Conditions

6.60 The impact on the aquatic environment of the extension of Lamma power station from 1800 to 2500 MW by the introduction of units L7 and L8 has been predicted using the mathematical models described above. The thermal and pollution loads used for all the model tests are shown in Table 6.11.

TABLE 6.11 : MODEL LOADINGS

Case	Rated Capacity (MW)	Flow m³/s)	Temperature Rise (°C)	Pollutant Release (Kg/hr) CW Outfall	Storm Drain
Historic (1985)	750	30.66	7.25	Not Considered	0.0
Calibration (1990)	1450	60.73	2.80-7.86	Not Considered	0.0
Baseline	1800	72.17	8.00	45.00	0.06
Final	2500	99.50	8.00	62.5	0.302

Notes : 1. Heat Rejected

Historic and Calibration - Observed Flows and Temperature Rises
Baseline = 72.17 x 8 x 1.03 x 0.94 x 4.186 = 2340MW
Final = 99.5 x 8 x 1.03 x 0.94 x 4.186 = 3226MW

6.61 Cooling water flows and temperature rises shown in Table 6.11 reflect the total heat discharged into the seawater at the outfall when the station is operating at the stated capacity. Heat losses have been calculated from unit guaranteed heat rates with an allowance added for auxiliary plant losses. Differences between the seawater temperature rise used in the study and the EPD consent value allow some margin for operation. Total heat rejected remains reasonably constant throughout such variations in cooling water temperature rise.

6.62 The loss of heat from the water surface depends on the water temperature and the meteorological conditions. Detailed analyses have been carried out for March 1985 and September 1990 in Appendix 6F. These analyses cover the range of water temperatures experienced and are in broad agreement with the analysis carried out as part of the environmental statement for the original Lamma power station by Cremer and Warner [9]. These analyses indicate that a heat loss coefficient of 25 W/m²°C is appropriate for dry season conditions when water temperatures are normally below 20°C. In the warmer water associated with wet season conditions, a heat loss coefficient of 40 W/m²°C is probably more appropriate.

6.63 The pollutant tests have been based on the release of a substance that is soluble and conservative. The results make no allowance for sedimentation and so will probably overestimate the concentration of metal or other pollutant in the water column. The concentration of each metal in the discharges has been based on the historic performance of the ash settlement basin (Table 6.4 and Table 6A.3) and the proposed consent conditions for the FGD waste (Table 6.6) which forms part of the design specification for treatment of this stream. The concentrations assumed for each metal in this assessment are given in Table 6.12. The model has been run for an input of a single soluble pollutant and the impact of each individual metal has been assessed by scaling the results to the correct input load. The loads discharged to the c.w. outfall and the storm drain on the east side of the site have been modelled separately. The concentration fields associated with each discharge point have been combined to obtain an overall concentration field for each pollutant.

Table 6.12 : ASSUMED EFFLUENT WATER QUALITY FOR LAMMA POWER STATION

	Effluent Concentration (µg/l)		
	Stream 4		Stream 6
	Maximum Sample[1]	Maximum Annual Average[2]	Design Standard[3]
Mercury	15	2.5	100
Cadmium	5	0.9	100
Arsenic	45	6.2	2000
Chromium	200	79.1	2000
Copper	10	3.5	2000
Lead	10	6.0	2000
Nickel	15	4.5	2000
Zinc	140	59.0	2000

Notes:

(1) Based on values in Table 6A.3 rounded up

(2) Based on values in Table 6A.3

(3) Based on values in Table 6.6

6.64 For thermal modelling, the water quality objective is written in terms of the extent of the +2°C contour. Preliminary model tests showed that this occurs in spring tide conditions when the higher water velocities convect the warmed water further from the power station.

6.65 For other pollutants, the water quality objectives or recommended standards are written in terms of annual averages. For these pollutants preliminary tests showed average concentrations were highest with neap tide conditions. Although neap tide conditions will overestimate annual average conditions, they have been used to provide a conservative result which will probably overestimate the concentrations of these pollutants around the power station.

Dry Season Thermal Modelling Results

6.66 The main results from the dry season thermal modelling of the 1800 MW baseline configuration of Lamma power station are given in Figures 6.11 and 6.12 for the far field and near field models respectively. The predicted maximum extent of the thermal field when the power station is extended to generate 2500 MW is shown on Figures 6.13 and 6.14 for the far field and near field models respectively. All these figures show the predicted maximum extent of the +2°C, +1°C and +0.2°C contours. These contours are calculated from the average of the maximum and mean temperature rise predicted for each model cell. These predicted envelopes probably underestimate the extent of the temperature field to the south of the power station as noted in the model performance assessment. Conversely, the envelopes probably over-estimate the extent of the temperature field to the north. Predictions of mean temperature rise are given in Figures 6.11a to 6.14a.

6.67 The contour of greatest interest is the area where temperatures exceed +2°C at some stage during the tidal cycle. Spring tidal conditions, when velocities are large, move the envelope of maximum temperatures further from the power station outfall than neap tides. The model predicted straight line distance between the c.w. outfall and the most distant point of the mean and maximum +2°C contour is tabulated in Table 6.13. The furthest point on the predicted contour is always north of the power station because of the pattern of water velocities in the hydrodynamic models. In practice there would be a larger area south of the power station where temperature rises would exceed +2°C at some stage during the tide than Figures 6.11 to 6.14 and 6.11a to 6.14a indicate. The maximum distance of the +2°C contour south of the power station is probably similar to the predicted value on the north side. For the baseline 1800 MW station the distance to the mean +2°C contour is about 250 to 650 m from the power station. The maximum extent of the +2°C contour could be about 1450 to 1850 m from the power station outfall. When the power station output is raised to 2500 MW, the mean +2°C contour will move about 300 m further from the power station. The furthest point where +2°C may occur moves to about 2350 to 2550 m from the power station.

TABLE 6.13 : MAXIMUM AND MEAN DISTANCE FROM CW OUTFALL TO +2°C CONTOUR

Season	Model	Layer	Rated Power Station Output (MW)	Maximum distance (m)	Mean distance (m)
Dry	Far	-	1800	1460	250
Dry	Near	-	1800	1830	630
Dry	Far	-	2500	2370	560
Dry	Near	-	2500	2530	930
Wet	Far	Upper	1800	2020	790
Wet	Far	Lower	1800	900	0
Wet	Far	Upper	2500	2260	1120
Wet	Far	Lower	2500	1900	0

Wet Season Thermal Modelling Results

6.68 During the wet season, the less saline water originating from the Pearl estuary flows over the more saline ocean water. This causes the water in the surface layers to have a weaker flood current and a stronger ebb current. The waters in the lower layer have a stronger flood current and a weaker ebb current. The cooling water discharged from the c.w. outfall is released into the surface layer and is convected by the surface layer currents. As the surface layer does not occupy the full water column in both the west Lamma and east Lamma Channels, the heat from the power station is dispersed into a smaller water volume. This is likely to cause higher temperatures.

6.69 In the deeper waters around Lamma Island there is more saline water in the lower water or bed layer. The interface between the two layers is set between -5 and -6m PD. Initially the power station heat is confined to the surface layer. Gradually, primarily through mixing between the layers, some of the heat in the surface layer is transported into the bed layer.

6.70 In the WAHMO model this mixing process is relatively rapid and as a result the model predictions tend to underestimate the difference in water quality between the surface and bed layers. This rapid mixing which results from the WAHMO two layer hydrodynamic model output will also affect the results obtained from the solute DIVAST two layer water quality model used in this study. As a consequence, the model will tend to over-estimate the temperature rise in the bed layer and under-estimate the temperature rise in the surface layer.

6.71 The predicted temperature rises during a wet season spring tide associated with the 1800 MW existing station are shown in Figures 6.15 to 6.16. The first figure shows conditions in the surface layer and the second, conditions in the bed layer. The contours of estimated maximum water temperature rise are calculated as the average of the maximum and mean temperature rises predicted by the wet season model in each cell of each layer. This is the same method of estimating the extent of the thermal field as adopted for the dry season modelling. Figures 6.15a and 6.16a show the mean temperature rise predicted in the wet season model. The results for the 2500 MW power station are presented in the same manner in Figures 6.17 to 6.18 and 6.17a to 6.18a for the maximum and mean predictions respectively.

6.72 The temperature rises in the surface layer near the power station are higher than in the bed layer as expected. The impact of the stronger ebb tide in the less saline upper layer is evident from the more southerly boundary of the +2.0°C contour south of the power station.

6.73 Comparisons of the results in the surface layer with the corresponding dry season results can be made visually by comparing Figure 6.15 with Figures 6.11 for the 1800 MW station. A similar comparison of Figure 6.17 with Figures 6.13 also allows a comparison between wet and dry season results for the 2500MW case. The estimated maximum distance of the +2°C temperature contours from the c.w. outfall in both layers during the wet season spring tide are compared with the dry season estimates for both the 1800 and 2500MW stations in Table 6.13. In the wet season the maximum distance occurs south of the power station instead of north as occurs in the dry season. The maximum distance is greater in the surface layer in the wet season than in the dry season.

6.74 The +2°C contour has a maximum extent of about 2000 m and a mean extent of about 800 m from the existing 1800 MW station in the upper layer in the wet season. Extension of the power station to 2500 MW could increase these distances to 2250 and 1100 m respectively. These increases are of the order of one cell in the wet season model. In the lower layer temperatures are lower and the +2°C contour is closer to the power station.

6.75 To the south of the Lamma c.w. outfall the area affected by a maximum temperature rise of +2°C during the wet season spring tide is likely to be more extensive than in the dry season because of the stronger ebb flows in the surface layer.

Plume Modelling Results

6.76 The buoyant jet released from the c.w. outfall gradually loses its initial momentum and is eventually convected away with the tidal current as a buoyant surface plume. The studies carried out by Jirka et al [10] and Chu and Jirka [11] describe some of the principle features of this complex transformation in the discharge characteristics of the c.w. As the plume is convected with the tidal flow, it entrains cooler water from both sides. This causes the plume to become wider and its temperature to decrease. This process has been described by Wiegel [12]. Eventually the temperature in the plume approaches the local ambient temperature and the density differences which suppress vertical mixing become small. In this situation the thermal stratification breaks down and the water temperatures become uniform with depth as assumed in the hydrodynamic models. The plume modelling is described in Appendix 6E.

6.77 These studies suggest that in the conditions encountered near the Lamma c.w. discharge, the discharge will occupy the full water depth until 90 to 100m offshore where the water is around 10m deep. Once the base of the discharge becomes detached from the sea bed, the discharge gradually loses the characteristics of a jet and begins to take on the characteristics of a buoyant plume floating on the water surface. This transition may not be complete until the plume is 250 to 300m offshore. Photographs of the discharge from the Lamma power station c.w. outfall clearly show that it is visible on the water surface as disturbed water as far offshore as the coal jetty which is 250m offshore.

6.78 At this distance offshore, the theoretical studies [10, 11] suggest that the c.w. discharge will have been diluted by a factor of about 4. The studies also suggest that as the size of the c.w. discharge increases, the dilution factor will gradually reduce from 4.1 for an 1800MW installation to 3.8 for a 2500MW installation. In addition, the greater discharge of the larger installation will delay its transition from a jet to a plume until it is further offshore. Increasing the power station capacity from 1800 to 2500MW might move the plume approximately 25m further offshore.

6.79 As the jet entrains the surrounding water and becomes transformed into a plume its temperature will be reduced. The reduction will depend on the temperature difference between the c.w. discharge at the outfall (including the effects of any recirculation) and the water surrounding the outfall. Using data from the near field model, the temperature of the discharge just after its transformation into a buoyant plume is complete will be close to 2°C above ambient. The calculations suggest that the plume from the 2500 MW power station could be between 0.1 and 0.2°C warmer than that from the existing 1800 MW station.

6.80 The results from the theoretical studies [10, 11] also indicate that the initial depth of the plume will be between 7 and 8m deep. The plume from the 2500MW installation is estimated to be about 10% deeper than that from the existing 1800 MW station.

6.81 The details of the transformation of the discharge from a jet to a buoyant plume will change depending on ambient tidal velocities and the flow of the cooling water discharge. The temperature of the discharge relative to the seawater around the outfall is also of importance as this determines the local buoyancy of the plume. Inevitably in this complex flow field, the predictions of plume dimensions and temperature must be considered as reasonable approximations to the actual dimensions and temperatures that might occur in a particular set of circumstances.

6.82 The initial width of the buoyant plume has been assumed to be inversely proportional to the tidal velocity so that during neap tidal periods, the plume width will be roughly twice that found during spring tide periods. Of course as velocities constantly change during the tidal cycle, the width and characteristics of the plume will also change. During the majority of the tidal cycle when tidal velocities exceed about 0.1m/s the hot water from the plume will be attached to the shore and the plume would be classified as a "shoreline attached jet" in the analyses of Jirka et al [10] and Chu and Jirka [11].

6.83 The principal initial dimensions and temperatures of the plume that have been assumed are listed in Table 6.14.

TABLE 6.14 : ASSUMED INITIAL PLUME DIMENSIONS

Power station Output (MW)	Tide	Plume Depth (m)	Size Width (m)	Initial Excess Temperature °C
1800	neap	7.2	207	1.96
1800	spring	7.2	104	1.96
2500	neap	7.8	243	2.11
2500	spring	7.8	121	2.11

6.84 Once the initial transformation of the discharge from a jet into a buoyant plume is complete, the plume spreads laterally due to turbulent diffusion. There is very little vertical entrainment because vertical turbulent motion is suppressed by the density difference between the plume and the underlying water. The spreading of the plume in this part of its evolution has been described using a model of plume spreading developed by Brooks and described by Wiegel [12]. This model which follows the plume as it spreads and cools and is convected by the tidal flows is described in Appendix 6E.

6.85 The assumptions about the initial plume dimensions and temperatures have been combined with the plume spreading model to define how long after plume spreading starts, the temperature difference between the plume and the surrounding water is reduced to 0.5°C. The results of this analysis are presented in Table 6.15 which also indicates the total time that would elapse before the temperature difference reduces to 0.2°C. Sometime during this period as plume density differences become small, the plume will spread vertically to occupy the full depth of the water column.

TABLE 6.15 : TIME FOR PLUME TEMPERATURE TO DECLINE

Power Station Output (MW)	Tide	Initial Plume Temperature Excess °C	Time(mins) When Temperature Excess is Reduced to 0.5°C	0.2°C
1800	neap	1.96	83	490
1800	spring	1.96	21	130
2500	neap	2.11	130	750
2500	spring	2.11	35	210

6.86 The model test results indicate that plumes will persist almost four times longer after discharge during neap tide conditions because of the greater initial plume width. The results in Table 6.15 also suggest that the plume from a 2500MW station is likely to persist much longer than the plume from the existing 1800MW station.

6.87 The area around the power station where plumes with temperature excesses of at least 0.5°C are predicted to occur are shown in Figure 6.19 for the 1800MW station and in Figure 6.20 for the extended 2500MW station. The results for spring and neap tides are superimposed to illustrate the larger area affected by the surface plume during neap tides.

6.88 Comparison of the plume modelling results in Figures 6.19 and 6.20 with the thermal modelling results presented in Figures 6.11 to 6.18 shows that the area affected by the plume lies within the area where a maximum temperature rise of 2°C is predicted. Thus the plume development is unlikely to control the extent of the temperature mixing zone around the power station.

Pollution Modelling Results

6.89 The near and far field dry season models were run to examine metals released into the sea around Lamma Island from the ash settlement basin overflow and the FGD waste treatment plant effluent. For modelling purposes, the ash settlement basin overflow (Stream 4) was assumed to be released into the c.w. outfall and discharged to the west of the power station as in the current situation. Two options were modelled for the FGD waste stream (Stream 6). The effluent was assumed to be released into either a storm drain discharging on the east side of the power station or into the c.w. outfall.

6.90 The models were run for neap tides as these cause higher average pollutant concentrations around the power station than spring tides and are therefore representative of "worst case" conditions. The models were run for the pollutant massflows given in Table 6.11 which represents a nominal 5 mg/l pollutant concentration in Streams 4 and 6.

6.91 The modelled results from the near field and far field dry season tests show a very similar distribution of pollutants. The mechanism for loss of pollutant from the far field model is convection through the open sea boundaries. In practice, the majority of metals or other pollutants would be subject to processes which would remove some of the pollutant mass from the water column, given sufficient time. Thus the model results will overestimate the metal concentrations in the water column.

6.92 The pollution modelling tests were repeated for wet season neap tide conditions to check whether the stratification of the water column and different water flow patterns that occur in summer would affect the dispersal of pollutants.

Metal Release From The Power Station in the Dry Season

6.93 The assumed concentrations of each individual metal in the ash settlement basin discharge and in the FGD treatment plant effluent are given in Table 6.12. Two scenarios were considered. The quality of the ash settlement basin discharge was based firstly on the highest concentration of individual metal recorded in that effluent since 1984 and secondly on the highest annual average concentration of each metal in the effluent since 1984. The data on which these assessments are made are given in Table 6A.3 of Appendix 6A. The FGD effluent water quality is based on the treatment plant specification which is intended to meet the effluent water quality discharge standards set out in Table 6.6. It should be noted that these predictions assume an FGD effluent load based upon 5 FGD systems being installed at Lamma. This assumption was made on the basis that if the air quality impact assessment indicated a significant reduction in SO_2 emissions was needed to meet Air Quality Objectives (AQO), then retrofitting of existing Units L4 and L5 might have to be considered. However, from the results of detailed numerical and wind tunnel tests given in Chapter 5, retrofitting of L4 and L5 should not be needed to achieve the AQO. The total metal loadings arising from the FGD effluent used for modelling purposes are therefore much higher than will arise in practice.

6.94 The concentrations of each metal in the two effluent streams given in Table 6.12 have been combined with the effluent flow associated with the appropriate power station generating capacity given in Table 6.7 to give the total massflow of each metal entering the sea around Lamma Power Station. The resultant concentration of each metal in the sea has been determined by scaling the model test results to the massflow of each metal in each effluent stream.

6.95 The peak concentrations of each metal in effluent discharge from the baseline 1800 MW power station are compared with the peak concentration after development of the 2500 MW power station in Table 6.16. These results assume that the concentrations of each metal in the ash settlement basin overflow are at the maximum value measured since 1984 and that the FGD waste is discharged to a storm drain. This represents the highest concentrations of each metal that might occur in the discharge from Lamma Power Station.

TABLE 6.16 : ESTIMATED MAXIMUM CONCENTRATION OF METALS IN DISCHARGE (STREAM 6 TO STORM DRAIN)

Metal	Recommended Standard* (mg/m^3)	Maximum Concentration ($\mu g/l$) Baseline (1800 MW)	Developed (2500 MW)
Mercury	0.3	0.55	0.78
Cadmium	2.5	0.19	0.31
Arsenic	25	1.74	5.81
Chromium	15	7.35	10.62
Copper	5	1.15	5.59
Lead	25	1.15	5.59
Nickel	30	1.17	5.62
Zinc	40	5.18	7.60

* Annual average

Concentrations based on Stream 4 to c.w. outfall and Stream 6 discharge to storm drain.

6.96 As already noted, there are no WQO's for heavy metals in Hong Kong seawater. In the absence of any local standards, it is necessary to have recourse to international standards. For this assessment, the most applicable of such standards are the EC Environmental Quality Standards and these have been used to assess the impact of discharged metals.

6.97 The metal concentration results given in Table 6.16 relate to the highest recorded concentration of each metal in the ash settlement basin discharge, rather than the annual average concentration as used to define the EC Environmental Quality Standards (EQS). The effluent discharges have therefore also been assessed using the highest annual average concentration of each metal given in Table 6.12. The results given in Table 6.17 show that mercury concentrations just satisfy the recommended EC standard in the 2500 MW case. The copper concentration in a small area of sea water (0.7ha) is, however, predicted to be higher than the recommended standards. All other metals satisfy the recommended standards with a significant margin. Chromium comes closest to its recommended standard but maintains a factor of safety of 2.5. The predicted exceedence of the standard for copper is due to the contribution of copper to the effluent stream from the FGD effluent. As noted above, these predictions are based on a worst case assumption of 5 FGD units. In practice, with fewer FGD units it is probable that none of the metals would actually exceed the EC standards for sea water.

TABLE 6.17 : IMPACT OF ANNUAL AVERAGE METAL RELEASE ON WATER QUALITY IN THE DRY SEASON (STREAM 6 TO STORM DRAIN)

Metal	Recommended Standard* (mg/m^3)	Maximum Concentration ($\mu g/l$)		Area of Sea Exceeding EC Standard (ha)	
		Baseline 1800 MW	Developed 2500 MW	Baseline 1800 MW	Developed 2500 MW
Mercury	0.3	0.10	0.29	0	0
Cadmium	2.5	0.06	0.28	0	0
Arsenic	25	1.13	5.56	0	0
Chromium	15	3.00	6.02	0	0
Copper	5	1.12	5.54	0	0.7
Lead	25	1.13	5.56	0	0
Nickel	30	1.13	5.55	0	0
Zinc	40	2.25	5.90	0	0

* Annual average

Concentrations based on Stream 4 to c.w. outfall and Stream 6 Discharge to Storm Drain

6.98 With the FGD effluent released to the east side of the power station the recommended standard for mercury is just satisfied. If the FGD effluent is discharged to c.w. outfall, the standard is satisfied with a much greater margin of safety. The maximum annual average mercury concentration is reduced from 0.29 to 0.15 mg/m^3. There is a fractional reduction in the highest short term concentration of mercury, which remains at 0.78 mg/m^3. The maximum concentrations associated with release of all effluents through the c.w. outfall are given in Table 6.18.

TABLE 6.18 : ESTIMATED MAXIMUM CONCENTRATION OF METALS IN DISCHARGE IN THE DRY SEASON (STREAM 6 TO CW OUTFALL)

Metal	Recommended Standard* (mg/m^3)	Maximum Concentration ($\mu g/l$)	
		Baseline 1800 MW	Developed 2500 MW
Mercury	0.3	0.55	0.78
Cadmium	2.5	0.19	0.28
Arsenic	25	1.73	2.75
Chromium	15	7.34	10.55
Copper	5	0.46	0.99
Lead	25	0.46	0.99
Nickel	30	0.64	1.24
Zinc	40	5.17	7.53

* Annual average

Concentrations Assume All Effluent is Discharged to c.w. Outfall

6.99 Maximum annual average concentrations that result from discharging FGD waste to the c.w. outfall are given in Table 6.19. Apart from mercury which is calculated to be half the recommended standard even if FGD is fitted to 5 units, all other metals are less than one third the recommended standard with cadmium, arsenic, lead, nickel and zinc being less than one tenth of the recommended standard.

TABLE 6.19 : IMPACT OF ANNUAL AVERAGE METAL RELEASE ON WATER QUALITY IN THE DRY SEASON (STREAM 6 TO CW OUTFALL)

Metal	Recommended Standard* (mg/m³)	Maximum Concentration (μg/l)		Area of Sea Exceeding EC Standard (ha)	
		Baseline 1800 MW	Developed 2500 MW	Baseline 1800 MW	Developed 2500 MW
Mercury	0.3	0.10	0.15	0	0
Cadmium	2.5	0.04	0.07	0	0
Arsenic	25	0.32	0.36	0	0
Chromium	15	2.96	4.47	0	0
Copper	5	0.24	0.66	0	0
Lead	25	0.32	0.79	0	0
Nickel	30	0.26	0.71	0	0
Zinc	40	2.24	3.46	0	0

* Annual average

Concentrations Assumed Effluent is Discharged to c.w. Outfall

6.100 These studies therefore demonstrate that concentrations of all metals will be lower in the water column if the c.w. outfall is used to discharge the FGD effluent. This would therefore appear to be the environmentally best option.

Metal Releases from the Power Station in the Wet Season

6.101 The wet season pollution modelling was carried out assuming that the FGD effluent (Stream 6) was discharged to the c.w. outfall. The metal concentrations in both upper and lower layers shown in Table 6.20 are based on the peak concentrations of each metal in the ash settlement basin. The maximum concentrations in the upper layer of the water column during the wet season are 50 to 55% of the corresponding maxima during the dry season. The maximum metal concentrations in the lower layer are much lower than the corresponding maxima occurring in the upper layer. The peak metal concentrations in the lower layer are around 8% of the peak concentration calculated for dry season conditions.

TABLE 6.20 :ESTIMATED MAXIMUM CONCENTRATION OF METALS IN DISCHARGE IN THE WET SEASON (STREAM 6 TO CW OUTFALL)

Metal	Recommended Standard* (mg/m³)	Maximum Concentration (μg/l)	
		Baseline 1800 MW	Developed 2500 MW
Mercury	0.3	0.29 (0.04)	0.42 (0.06)
Cadmium	2.5	0.10 (0.02)	0.15 (0.02)
Arsenic	25	0.93 (0.14)	1.47 (0.22)
Chromium	15	3.93 (0.57)	5.65 (0.83)
Copper	5	0.25 (0.04)	0.53 (0.08)
Lead	25	0.25 (0.04)	0.53 (0.08)
Nickel	30	0.34 (0.05)	0.66 (0.10)
Zinc	40	2.77 (0.40)	4.03 (0.59

* Annual Average

Note : (1) First Figure is Upper Layer, Bracketed Figure is Lower Layer.

6.102 If the maximum annual average metal release from the ash settlement basin is used as the basis for calculating the power station metal release, the maximum concentrations in each layer during a wet season neap tide are given in Table 6.21. The peak surface layer concentrations are between 50 and 55% of those recorded in the dry season given in Table 6.19. The lower layer concentrations are about 8% of the dry season results. All the calculated concentrations based on the annual average release are less than one third of the recommended EC limit.

TABLE 6.21 : IMPACT OF ANNUAL AVERAGE METAL RELEASE ON WATER QUALITY IN THE WET SEASON (STREAM 6 TO CW OUTFALL)

Metal	Recommended Standard* (mg/m³)	Maximum Concentration (μg/l)		Area of Sea Exceeding EC Standard (ha)	
		Baseline 1800 MW	Developed 2500 MW	Baseline 1800 MW	Developed 2500 MW
Mercury	0.3	0.05 (0.01)	0.08 (0.01)	0	0
Cadmium	2.5	0.02 (0.00)	0.04 (0.01)	0	0
Arsenic	25	0.17 (0.03)	0.19 (0.03)	0	0
Chromium	15	1.59 (0.23)	2.39 (0.35)	0	0
Copper	5	0.13 (0.02)	0.36 (0.05)	0	0
Lead	25	0.17 (0.03)	0.42 (0.06)	0	0
Nickel	30	0.14 (0.02)	0.38 (0.06)	0	0
Zinc	40	1.20 (0.18)	1.85 (0.27)	0	0

* Annual Average

Note : (1) First Figure is Upper Layer, Bracketed Figure is Lower Layer

Nitrate Release From The Power Station During the Dry Season

6.103 Apart from the release of some metals, the FGD plant is anticipated to discharge a certain amount of nitrate nitrogen. Estimates by tenderers for the FGD plant on unit L6 indicate a release of about 18 kg of nitrate per hour. This estimate of nitrate release has been used to estimate nitrate nitrogen concentrations in the water column around Lamma power station. Again, the basis for modelling assumptions has been a maximum FGD effluent load with assumed retrofitting of units L4 and L5. The estimates are therefore very pessimistic.

6.104 Initially tests were made to check the difference between releasing this effluent to a storm drain on the east side of the power station and discharging it through the c.w. outfall. The maximum concentrations in the water column near the outfall and the sea area where concentrations are predicted to rise more than 0.1 mg/l are shown in Table 6.22. These results show that the area affected by high nitrate nitrogen concentrations would be much greater if the effluent were discharged through the storm drain on the east side of the power station. These results confirm that there are environmental benefits in discharging the FGD waste through the c.w. outfall.

TABLE 6.22 : INCREASE IN NITRATE CONCENTRATION ASSOCIATED WITH FGD EFFLUENT (5 UNITS) IN THE DRY SEASON

	Comparison of Discharge Points			
	Storm Drain		CW Outfall	
	Baseline Unit L6	Developed 5 FGD Units	Baseline Unit L6	Developed 5 FGD Units
Nitrate Release (kg/hr)	18	90	18	90
Maximum Water Column Concentration Rise (mg/l)	0.82	4.11	0.07	0.36
Area Where Concentration Rise Exceeds 0.1 mg/l (km^2)	0.65	4.28	0	0.47

6.105 The waters around Lamma Island already contain concentrations of inorganic nitrogen that approach the Water Quality Objective of 0.1 mg/l as an annual average (Table 6.5). At site SM5 in Ha Mei Wan, the period average concentration given in Table 6.2 is 0.077 mg/l, which would suggest a 0.02 mg/l increase could occur before the water quality standard was breached. Release of significant amounts of nitrate could cause this standard to be breached near the discharge point.

6.106 The pollution model has been used to estimate the area around the power station where concentrations of inorganic nitrogen might exceed 0.1 mg/l, assuming a background concentration of 0.08 mg/l. The results are presented in Figure 6.22 for the baseline case and in Figure 6.23 for the developed case. The areas affected and maximum concentrations are indicated in Table 6.23. The area of about 0.5 km^2 which is affected in the baseline case could rise to almost 7.5 km^2 if FGD is fitted to 5 units. The affected area would extend almost 4 km either side of the outfall along the west side of Lamma Island. Without FGD retrofitting, the total sea area affected would reduce to approximately 4.8km^2.

TABLE 6.23 : AREAS AFFECTED BY NITRATE RELEASE FROM FGD EFFLUENT INTO CW OUTFALL IN THE DRY SEASON

	Baseline Unit L6	Developed 3 FGD Units	Developed 5 FGD Units
Nitrate Release (kg/hr)	18	54	90
Background Concentration (mg/l) of Inorganic Nitrogen	0.08	0.08	0.08
Area with Inorganic Nitrogen Concentrations			
above 0.10 mg/l (km^2)	0.47	4.78	7.39
above 0.20 mg/l (km^2)	0	0.04	0.22
above 0.30 mg/l (km^2)	0	0	0.03
Maximum Concentration(1) (mg/l) of Inorganic Nitrogen	0.15	0.30	0.44

Note : (1) Maximum Concentration Includes 0.08 mg/l Background Inorganic Nitrogen

6.107 The predicted breach of the nitrate WQO is due primarily to the existing high background nitrate levels in the waters surrounding Lamma, which exacerbates the consequences of the addition of nitrate from the FGD effluent. The consequences of this release of nitrate into the waters on the west side of Lamma Island are discussed in detail in Chapter 9.

Nitrate Release from the Power Station in the Wet Season

6.108 During wet season conditions, the peak inorganic nitrogen concentrations associated with the discharge of nitrate from the FGD effluent will be lower than those occurring in dry season conditions as a comparison of Table 6.24 with Table 6.23 shows. However, the area where the power station FGD discharge will raise concentrations will be greater in the surface layer during the wet season than in dry season conditions. This apparent contradiction arises because of the higher average surface water velocities in the wet season which provide greater average initial dilution of the effluent, but spread its effect further.

6.109 The area affected by the FGD nitrate release increases rapidly as the number of units fitted with FGD rises. If three units are fitted, the area affected would be $5.6km^2$. If five units are fitted with FGD, the area affected would rise to almost $15km^2$. Consideration of the concentrations in the lower layer which are much lower than those in the upper layer will reduce the area where the depth averaged concentration would exceed 0.1mg/l.

TABLE 6.24 : AREAS AFFECTED BY NITRATE RELEASE FROM FGD EFFLUENT INTO CW OUTFALL IN THE WET SEASON

	Baseline Unit L6	Developed 3 FGD Units	Developed 5 FGD Units
Nitrate Release (kg/hr)	18	54	90
Background Concentration of Inorganic Nitrogen (mg/l)	0.08	0.08	0.08
Area with Inorganic Nitrogen Concentrations[1]			
above 0.10 mg/l (km^2)	0.50 (0)	5.63 (0)	14.75 (0.06)
above 0.20 mg/l (km^2)	0	0	0.25 (0)
above 0.30 mg/l (km^2)	0	0	0
Maximum Concentration[2] (mg/l) of Inorganic Nitrogen			
upper layer	0.119	0.196	0.274
lower layer	0.086	0.097	0.108

Note : (1) First Figure is Area in Upper Layer, Bracketed Figure is Lower Layer Area (When Different)
(2) Maximum Concentration Includes 0.08mg/l Background Inorganic Nitrogen.

Summary and Conclusions

6.110 Detailed modelling of the thermal effluent has been carried out in order to assess the extent of the thermal rise in the surrounding sea water for both the existing and extended power station. The modelling techniques used have been calibrated using field measurements of temperature rises around Lamma, resulting from the existing power station. The results of the calibration studies indicate that the modelling techniques used do allow for a reasonably accurate assessment of the extent of the heat field to be determined, although there are noticeable differences between model predicted and observed maximum temperatures. As a consequence, the true area of sea affected by temperature rises in excess of 2°C cannot be determined precisely at this stage. Furthermore, it should be noted that the modelling studies have been carried out on a conservative basis, assuming constant c.w. flow and heat input at the operational maximum. In practice, the daily load pattern at Lamma shows reduced load (i.e. non-MCR) for several hours of the day. The consequence of this is that modelled heat inputs to the coastal waters will be higher than would actually arise in practice. Similarly, the extent of the actual thermal rise in the seawater would be lower than modelling suggests.

6.111 The evidence derived from recent field surveys suggest the existing power station discharges are unlikely to cause temperature rises in excess of +2°C to extend beyond the 1.5 km radius adopted historically as the mixing zone. The margin, however, appears rather small for some of the more unusual tidal conditions that can occur. The addition of further thermal inputs from the provision of additional generating capacity increases the risk that the +2°C contour will occasionally extend beyond 1.5 km. The assessment of marine ecology in Chapter 9 indicates this is of minor environmental significance.

6.112 Because of the variability of tidal conditions and uncertainties in the modelling, further analysis will be needed to detail the mixing zone required for the operation of L7 and L8. Such studies should be carried out at the Key Issue stage. However, the modelling studies that have been carried out to date, are sufficient to assess the marine ecological impact of this discharge.

6.113 The model predicts that the thermal discharge from the existing 1800 MW installation may cause mean water temperature rises in excess of +2°C within about 800 m of the power station and maximum temperature rises of +2°C within about 2000 m of the outfall during the wet season. The modelling also suggests that the maximum temperature contours in the wet season extend further from the outfall on the south side than on the north side. Increasing the power station capacity to 2500 MW will increase the area affected, especially during the summer when water temperatures are highest and the water column is stratified. The modelling suggests mean temperature rises of +2°C may occur within about 1100 m of the power station and at certain tide states this temperature rise might occur up to about 2500 m from the power station during the wet season.

6.114 The ecological impact of the thermal discharge is described in Chapter 9. In essence, the effect of the increase in thermal discharge is not considered to be ecologically of any significance, even if the +2°C contour were to extend beyond 1.5 km.

6.115 The other discharges from the power station due to sewerage wastes will rise in line with the increase in the workforce. These discharges are relatively small and will have little environmental impact, provided the treatment facilities are able to maintain the existing quality of effluent.

6.116 The ecological impact of the increased trade effluent discharges, including those discharged from the FGD plant is described in Chapter 9. It is considered that the liquid effluent from the FGD plant should be discharged into the c.w. outfall to minimise its impact on the environment. If this is done, the rise in concentration of pollutants around Lamma power station should remain within acceptable international standards. Because of the already high background nitrate level, the release of nitrate with the FGD liquid effluent could cause inorganic nitrogen concentrations to exceed the WQO of 0.1 mg/l in the sea in the vicinity of the power station. Control of the nitrate release by a suitable treatment plant will therefore need to be considered. A detailed assessment of this will need to be studied as a Key Issue.

6.117 The HEC self-monitoring program for liquid effluents provides a good basis for monitoring the discharges from Lamma power station. This program should continue and be expanded to monitor any additional metals or other pollutants (e.g. nitrate) that are anticipated to be released with the FGD effluent.

Key Issue Studies

6.118 As a consequence of discussion between EPD, HEC and its consultants following the submission of the draft IAR, a Water Quality Key Issue Study was undertaken to address specific areas of concern in more detail. The Key Issue Study was designed to address the following issues:

i) **Discharges from FGD Plant**

The Unit 6 Flue Gas Desulphurisation (FGD) wastewater treatment plant has now been chosen. The effluent flows from the chosen plant are expected to be lower than assumed in the IAR and as a result, the loadings of all metals from this wastewater source will be less. Moreover, as the Air Quality Key Issue Report confirmed that retrofitting of existing units with FGD would not be required, the total maximum wastewater quantities from the FGD effluent stream will be lower than anticipated in the IAR. The revised figures were used in calculations of impact. The plant contractor also anticipates a reduction in nitrogen concentration in the FGD effluent from that originally assumed in the IAR. The currently anticipated nitrogen effluent load will be a factor of four lower for each unit fitted with FGD than assumed in the IAR. The use of more advanced low NO_x combustion technology in the boilers for L7 and L8 will further reduce the nitrogen concentration in the FGD effluent from these units. The impact of the changes in the FGD wastewater discharge were analyzed in the KIS.

ii) **Effluent Loadings**

In the draft IAR, the load of each effluent discharged from Lamma Power Station was calculated, along with the flow and concentration of effluent. This allows the impact of these effluents to be assessed on the basis of their load as well as their concentration. Effluent loading is now a factor in the setting of discharge consents following the procedures set out in the Technical Memorandum on Effluent Standards. The KIS therefore considered the significance of impacts in terms of effluent loading.

iii) **Mixing Zone**

The water quality modelling in the IAR indicated that the tidal currents disperse the cooling water effluent north and south of the power station with relatively little spreading westwards into the West Lamma Channel. As a result, the area where the temperatures might exceed the Water Quality Objective (WQO) for the Southern Water Control Zone is not circular around the outfall, but elongated parallel to the coast. EPD identified as a Key Issue the need to define the area where temperatures exceeded the WQO as this might provide a better definition of the mixing zone than a simple radius.

iv) **Shoreline Ecosystem**

One consequence of the elongated thermal plume is that a greater length of shoreline is affected by effluents than previously assumed. The impact of heat and pollutants on the shoreline ecosystem was therefore identified as a Key Issue. An assessment of the impact on the shoreline of the various power station effluents was therefore included in the KIS.

v) **Method of Assessment**

The IAR, where possible, assessed environmental impact in relation to the WQOs set out for the Southern Water Control Zone. In the case of metals, there are no quantitative standards for receiving water. The WQO requires the absence of any toxic effect. In order to interpret the quantitative prediction of the water quality modelling in terms of the qualitative objective of no toxic effect, the IAR used European Community (EC) and United Kingdom (UK) water quality objectives. The relationships between these EC and UK objectives and the occurrence of toxic effects in Hong Kong waters was identified as a Key Issue.

vi) **Metal Precipitation and Benthic Uptake**

The IAR assumed the metals in the power station effluents would remain in solution, although it stated that this was a simplification which ignored the probable precipitation and settlement of much of the metal content close to the outfall. The justification for this approach was that it gave a high and thus conservative approach to the concentrations of metal in the water column. The impact of metal precipitation and settlement close to the outfall was identified as a Key Issue.

vii) **Water Quality Monitoring**

Monitoring the impact of the power station extension on the receiving waters was identified as a Key Issue. Proposals for monitoring the receiving waters were therefore examined in the KIS.

viii) **Technical Memorandum Limits**

The Technical Memorandum (TM) on Effluent Standards was published shortly after completion of the draft IAR. It was not possible therefore to take the new standards into account in the IAR. The KIS therefore considered the various effluent streams in the context of compliance with the new standards.

6.119 The KIR is now nearing completion and the principal conclusions of the study can be itemised as follows:

- The total impacts of the heat, metal and nitrogen loads to the surface waters of the West Lamma channel are complex and it is not possible to precisely define the effects on or changes to the ecosystem except in the simplest terms. There are also conflicting effects due to the highly complex interactions of the constituents of the effluents.

- The siting of the power station ensures that there is minimal impact on the inshore waters of Hong Kong. There are no major sewage discharges into waters affected by the thermal plume so that interaction with and augmentation of eutrophication caused by these major sources of algal-nutrients will not occur, as happens in many coastal areas elsewhere in the world.

- The effects of the power station should not result in significant or adverse ecological changes in the inshore waters or on the shoreline around Lamma Island. Experience elsewhere in the world is that the additional heat from power stations causes a beneficial increase in productivity in the waters near the discharge excluding a very small zone very close to the outfall. This is likely to occur at Lamma. Inorganic nitrogen concentrations will probably exceed the WQO in a small area close to the outfall, but the impact of this should be small.

- The maximum annual average metal concentration in the receiving waters, caused by releases from Lamma Power Station, are in all cases predicted to be lower than the Environmental Quality Standards (EQS) adopted for protection of UK waters. In the absence of any local Hong Kong standards, the EQS are judged to be suitable standards for Hong Kong waters.

6.120 The heavy metals released with the industrial effluents arising in the power station are already controlled by the discharge licenses. Historically, samples of the effluent from the ash settlement basin have been at least a factor of 7.5 below the effluent standard currently applied to the basin. A management plan has been drawn up to ensure the existing and future effluents satisfy the concentration and load limits set out in the Technical Memorandum on Effluent Standards.

6.121 The introduction of FGD plant will remove from the flue gases some of the metals which would otherwise be discharged from the power station chimneys. This concentrates the metals in the liquid effluent instead of causing wide spread dispersal and eventual precipitation. These metals would then enter the sea directly or following runoff from land. The FGD wastewater treatment plant for Unit L6 will remove some proportion of these metals which would otherwise enter the sea as a diffuse source.

6.122 The FGD wastewater treatment plant is designed as far as practicable to meet the effluent standard proposed to HEC by EPD. Implementation of the effluent standards set out in the Technical Memorandum will further improve the quality of the effluent discharged to the water environment. The possibilities for improvements to the quality of this effluent to meet the standards laid down in the Technical Memorandum have been subject to separate review.

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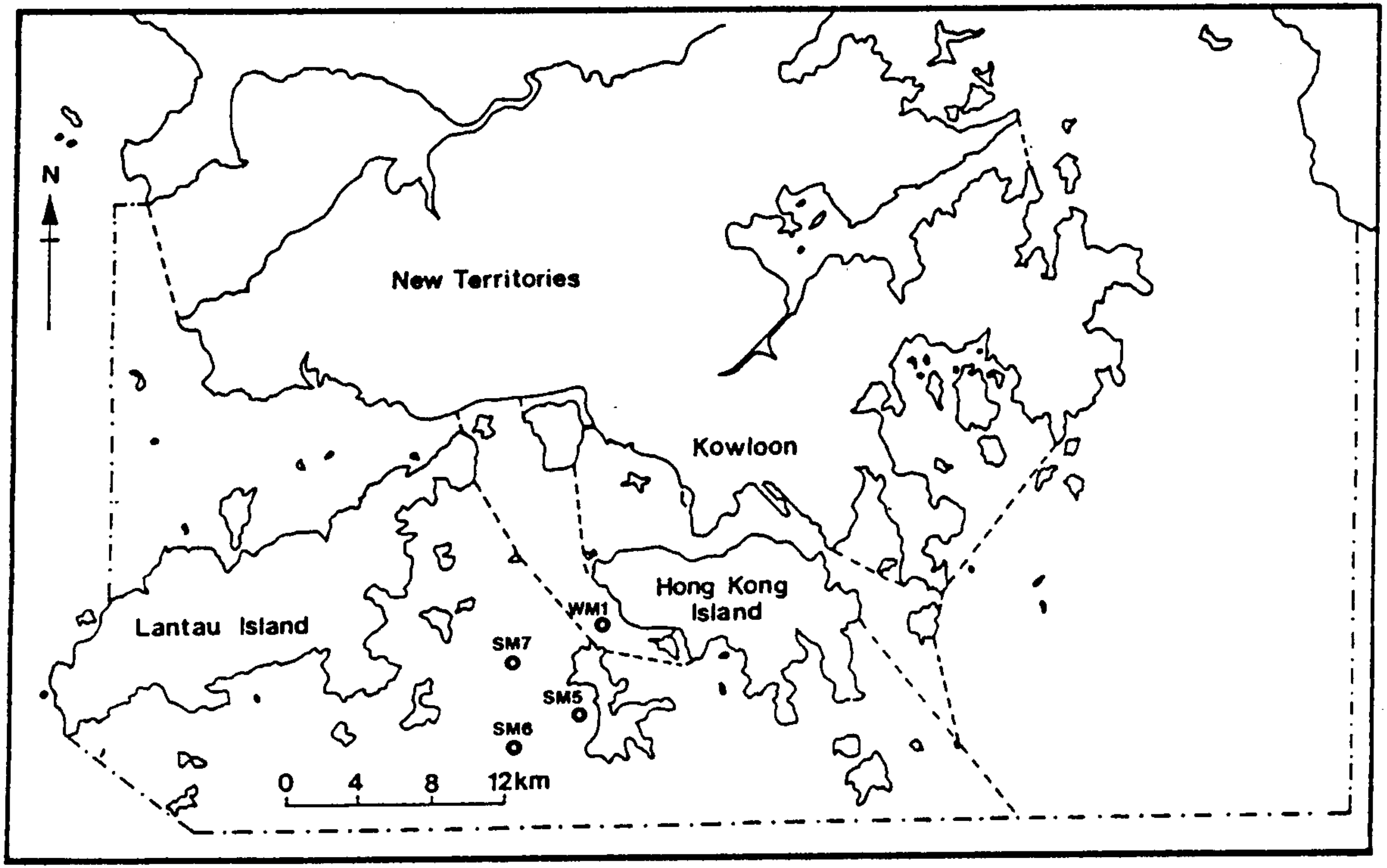

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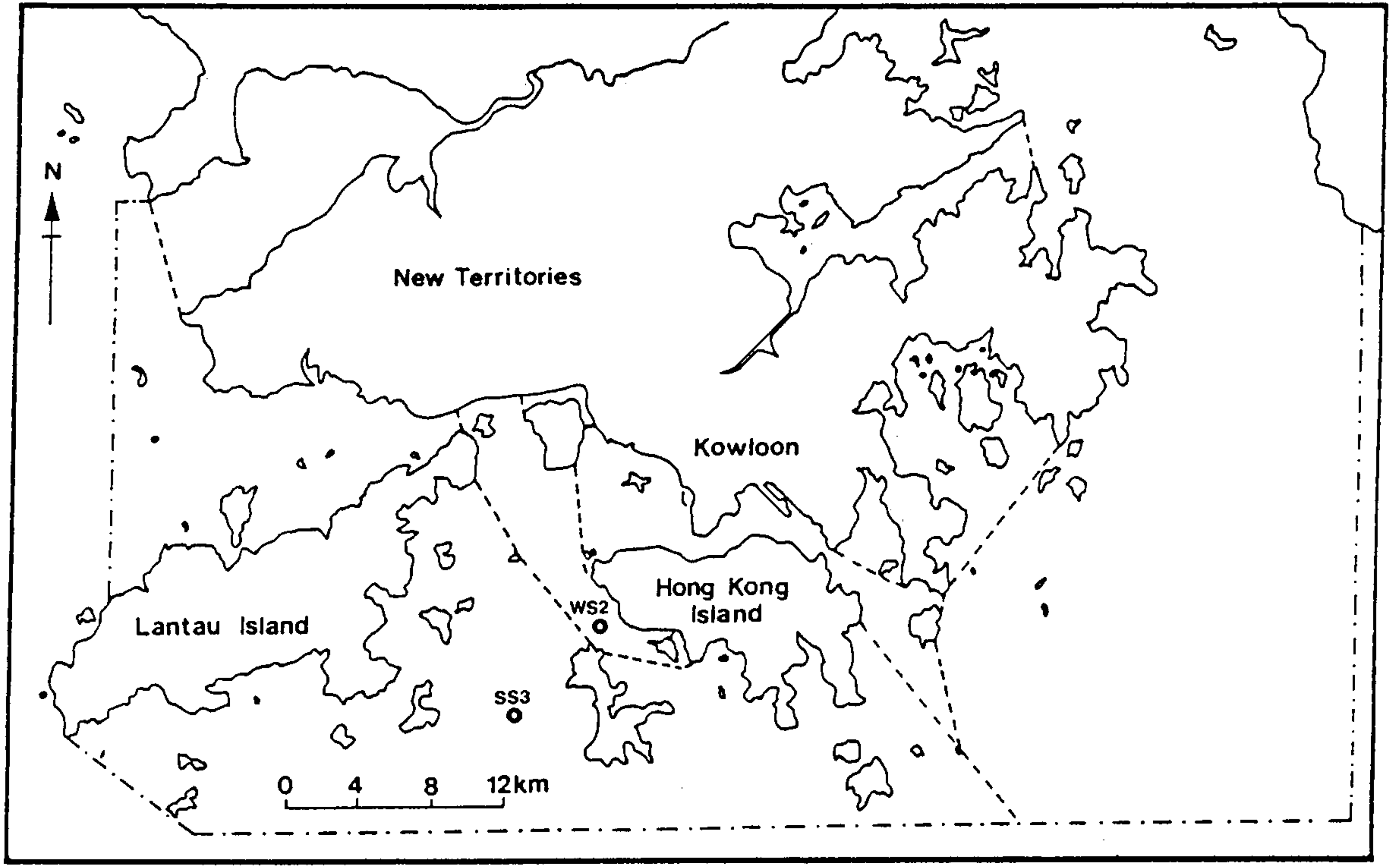
PROJECT: EIA LAMMA POWER STATION

TITLE: EPD WATER QUALITY MONITORING SITES NEAR LAMMA

FIGURE 6.1



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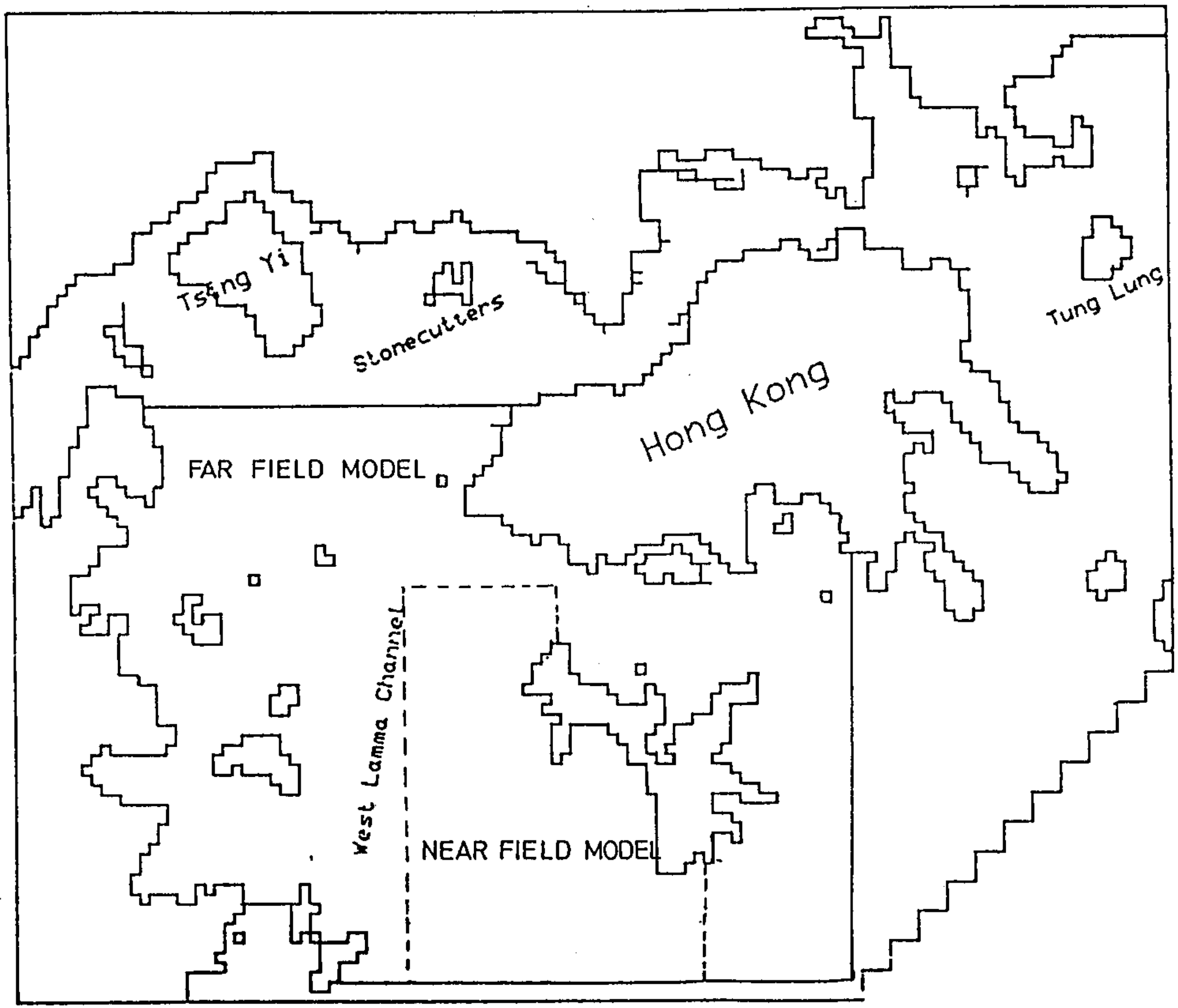
PROJECT: EIA LAMMA POWER STATION

TITLE: EPD BED SEDIMENT MONITORING SITES NEAR LAMMA

FIGURE 6.2



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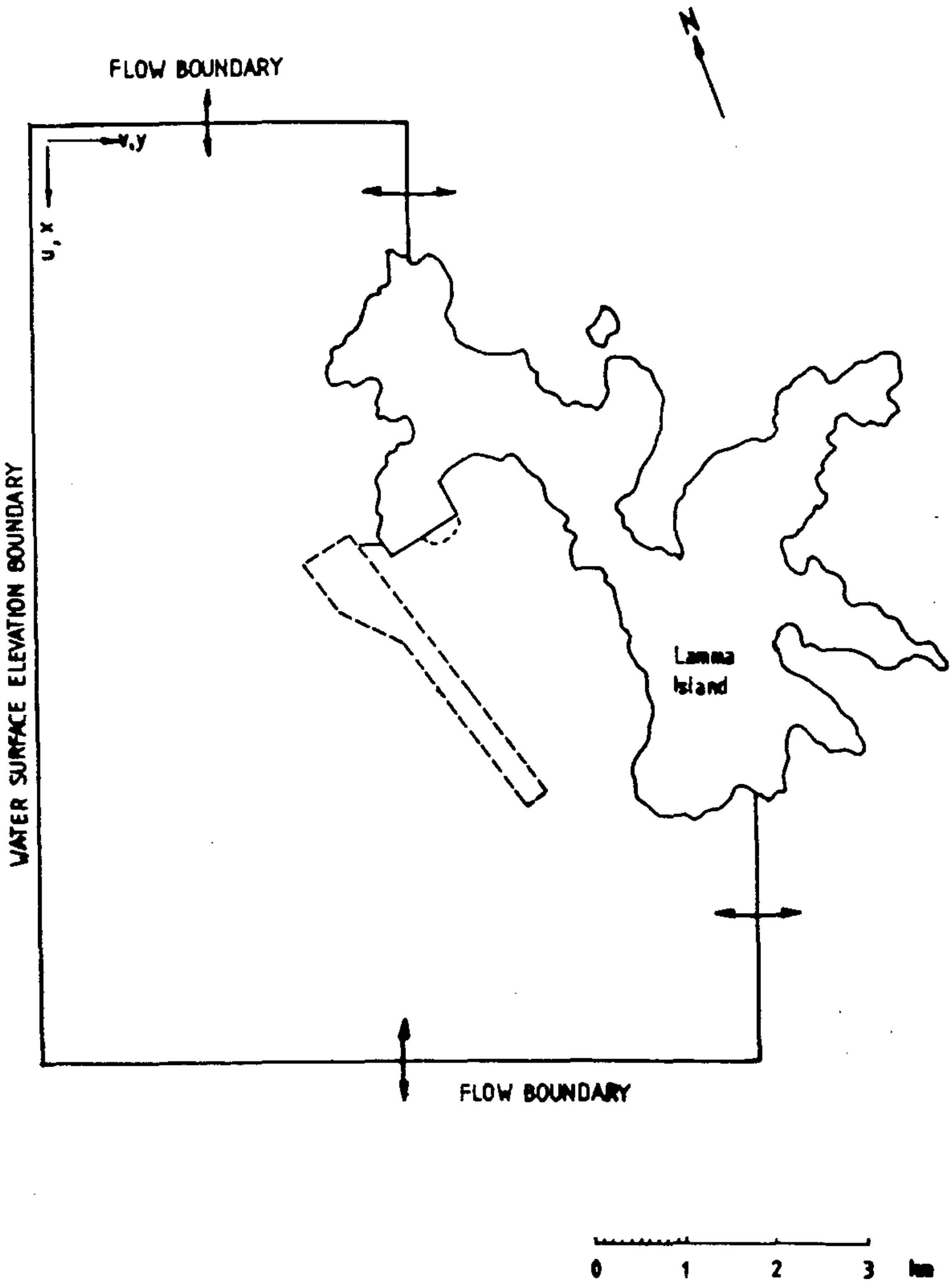
PROJECT: EIA LAMMA POWER STATION

TITLE: FAR FIELD MODEL BOUNDARIES

FIGURE 6.3



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PROJECT

EIA LAMMA POWER STATION

TITLE

NEAR FIELD MODEL-BOUNDARIES

FIGURE 6.4

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PROJECT

EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.5

The Hongkong Electric Company Limited

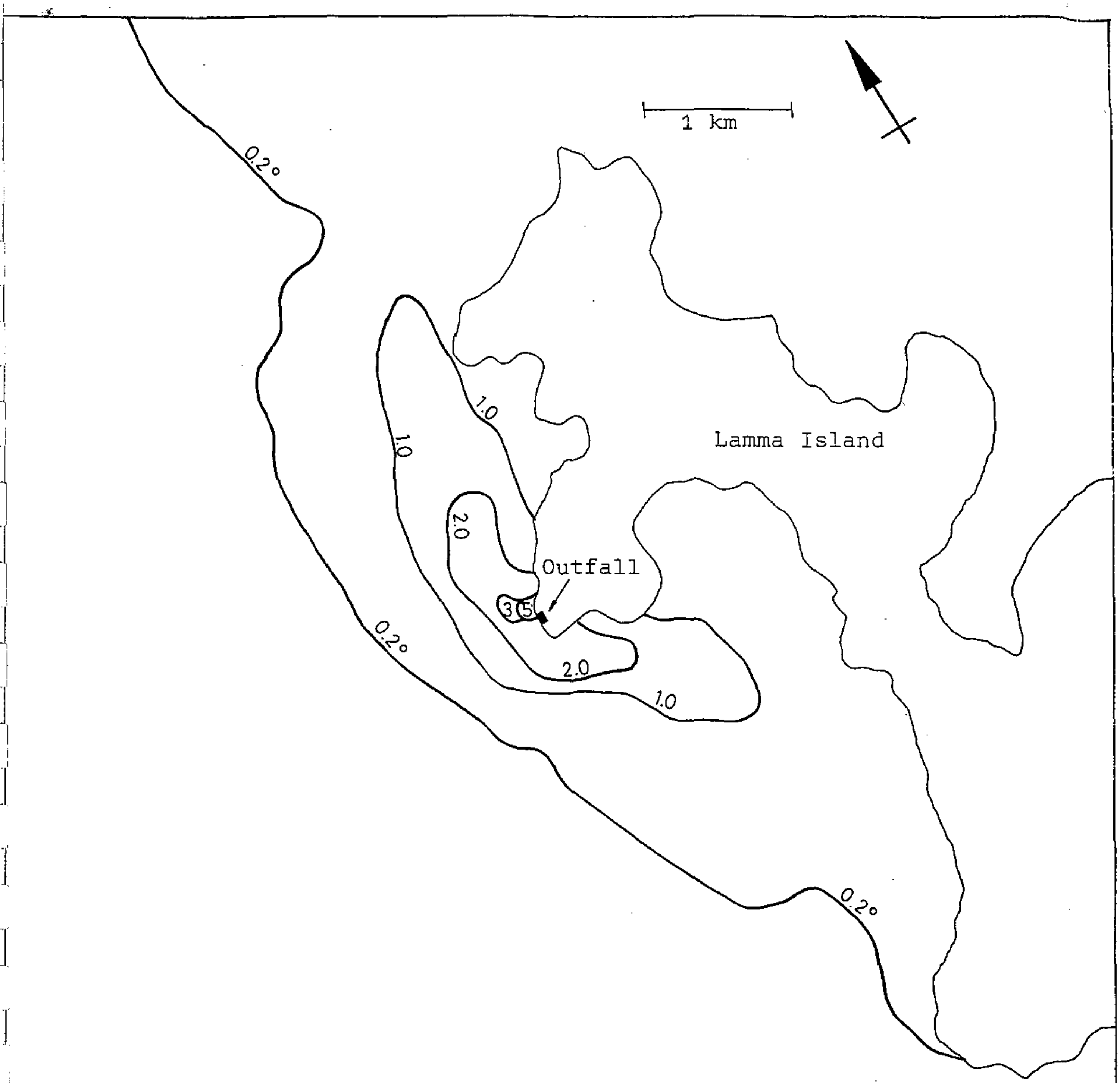
PROJECT

EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.6



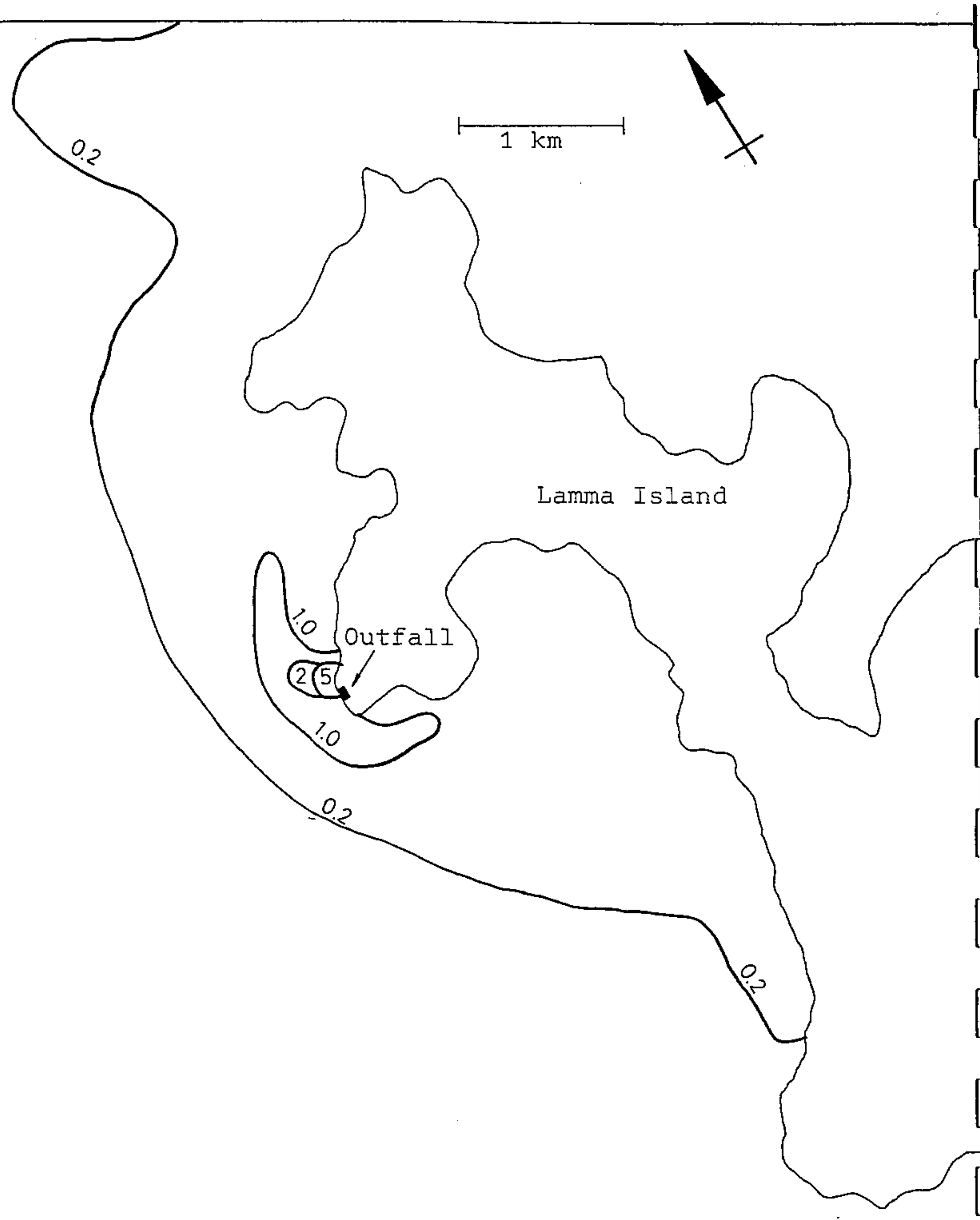
- Test 1.2
- Dry season
- Neap tide
- Historic
- Maximum Temperatures
  Deg C above ambient

The Hongkong Electric Company Limited

PROJECT
EIA LAMMA POWER STATION

TITLE
Near Field Model-Results

FIGURE 6.7



- Test 1.2
- Dry season
- Neap tide
- Historic
- Average Temperatures
  Deg C above ambient

The Hongkong Electric Company Limited

PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.8

	The Hongkong Electric Company Limited	PROJECT **EIA LAMMA POWER STATION**	TITLE Far Field Model-Results FIGURE 6.9

The Hongkong Electric Company Limited

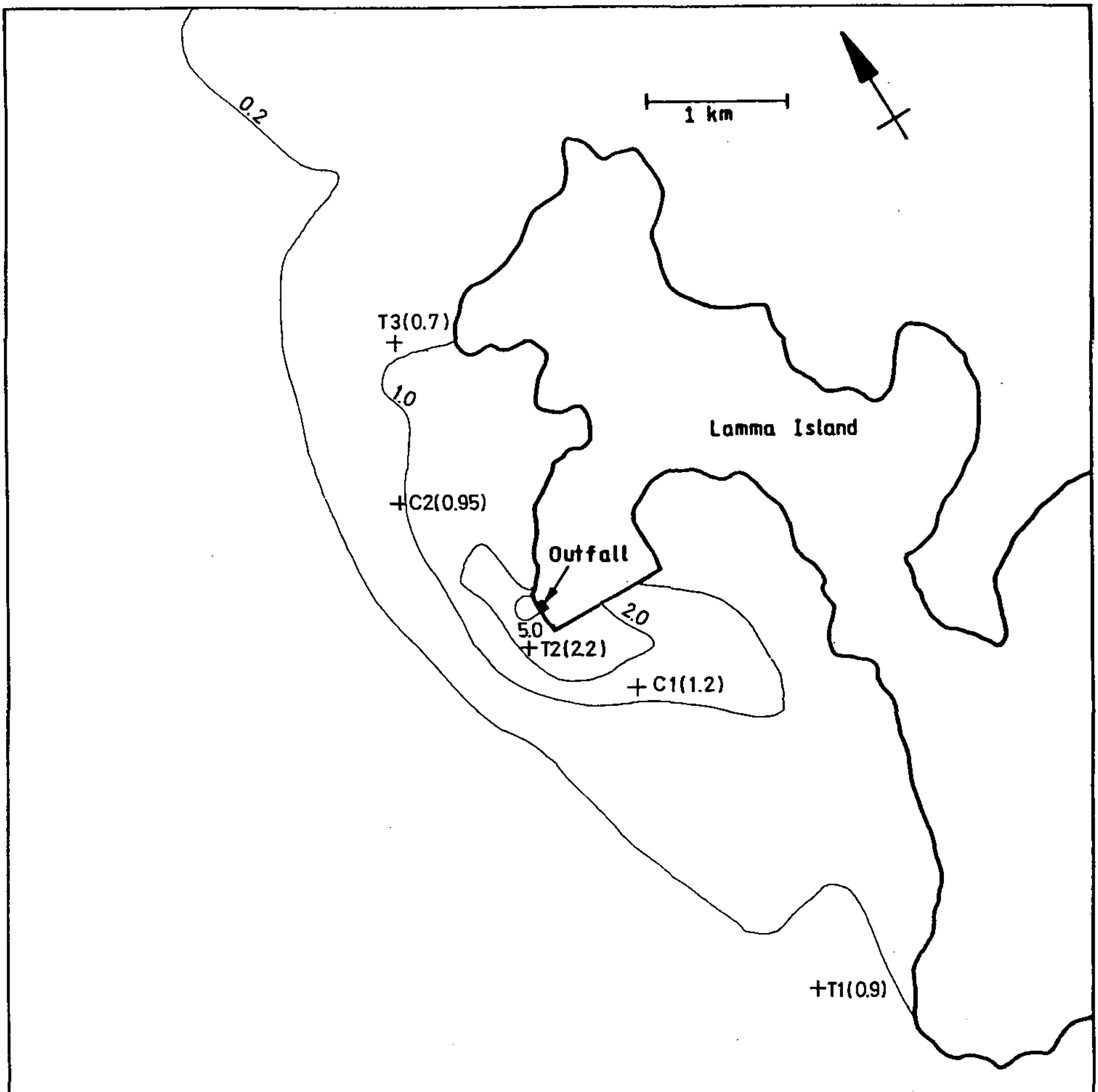
PROJECT

EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.9a



+ Fixed thermometers (mean temperature rise)

The Hongkong Electric Company Limited

- Dry season
- Neap tide
- Calibration (1990)
- Maximum temperature above ambient °C

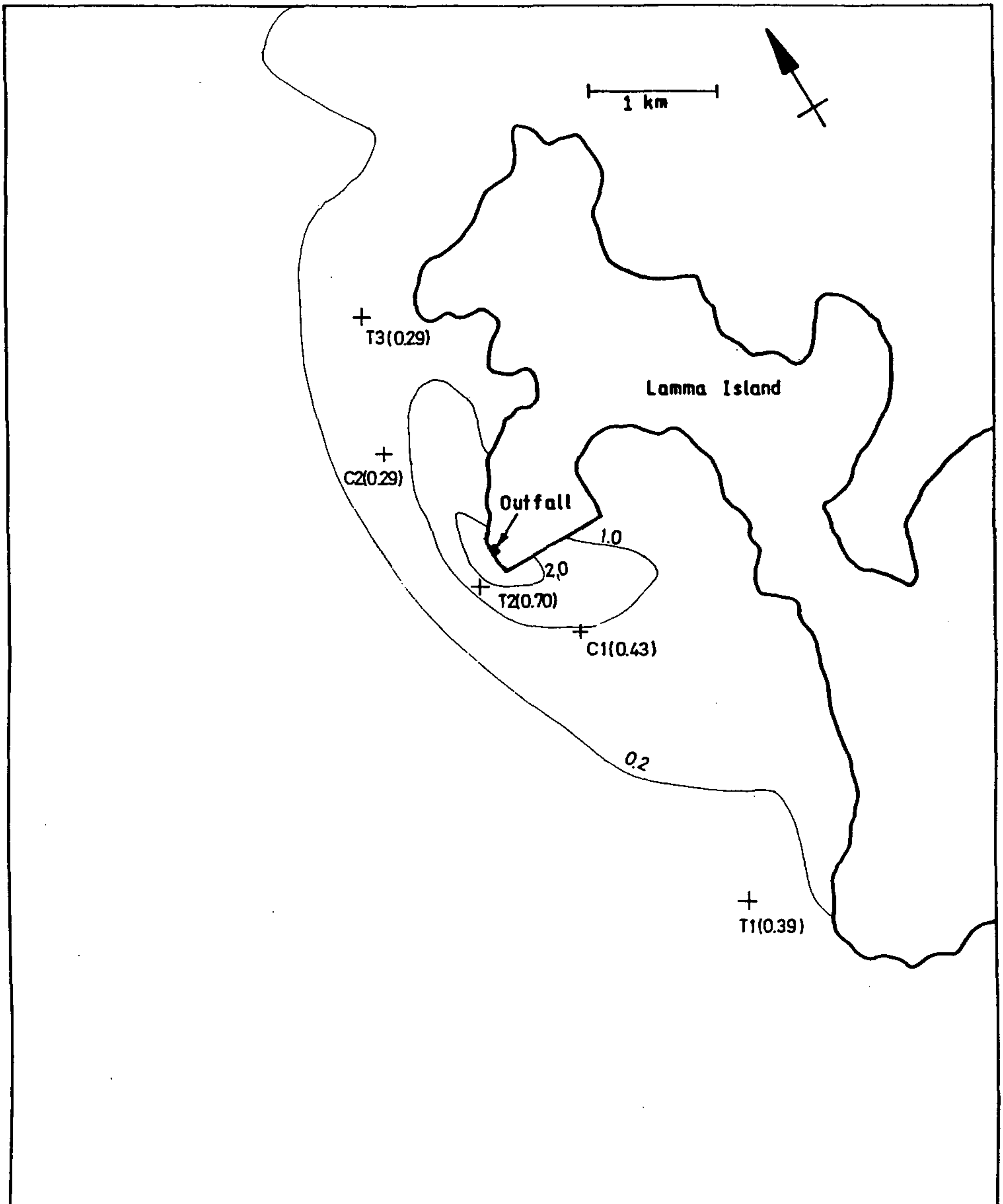
PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.10



+Fixed thermometers (mean temperature rise)

The Hongkong Electric Company Limited

- Dry season
- Neap tide
- Calibration (1990)
- Mean temperature above ambient °C

PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.10a

The Hongkong Electric Company Limited

PROJECT

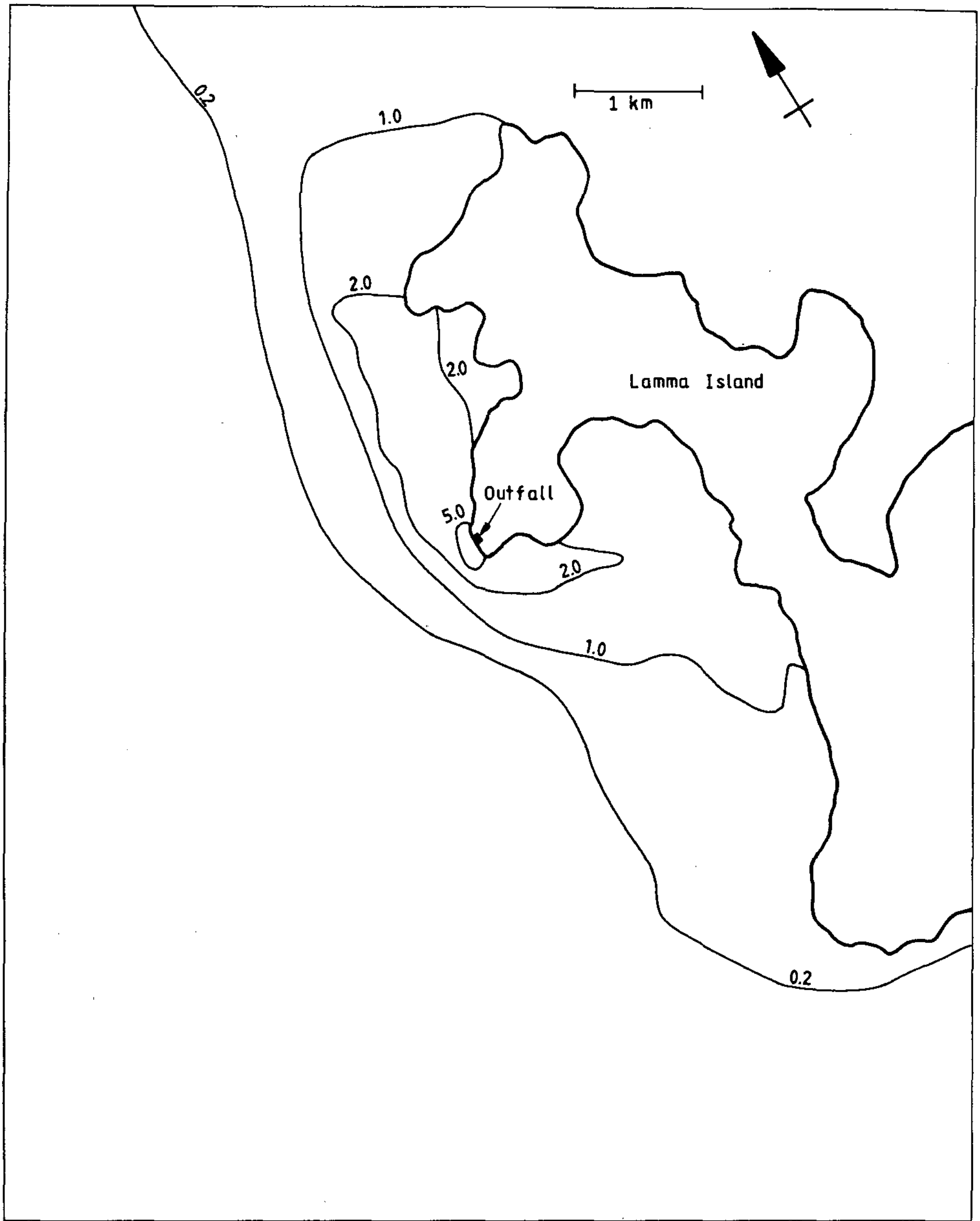
EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.11

	The Hongkong Electric Company Limited	PROJECT EIA LAMMA POWER STATION	TITLE Far Field Model-Results FIGURE 6.11a



The Hongkong Electric Company Limited

- Dry season
- Spring tide
- 1800 MW
- Maximum temperature above ambient °C

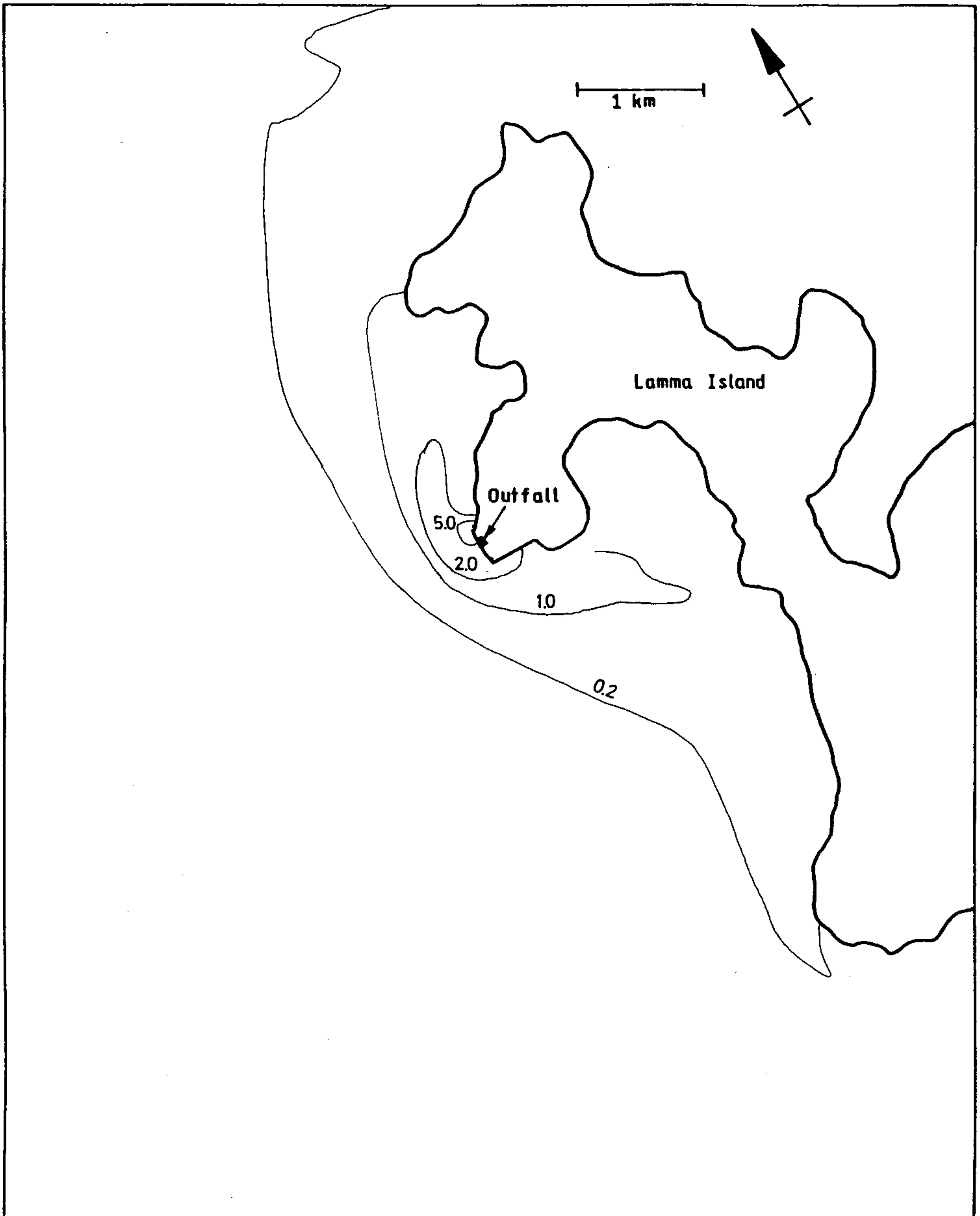
PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.12



The Hongkong Electric Company Limited

- Dry season
- Spring tide
- 1800 MW
- Mean temperature above ambient °C

PROJECT

EIA LAMMA POWER STATION

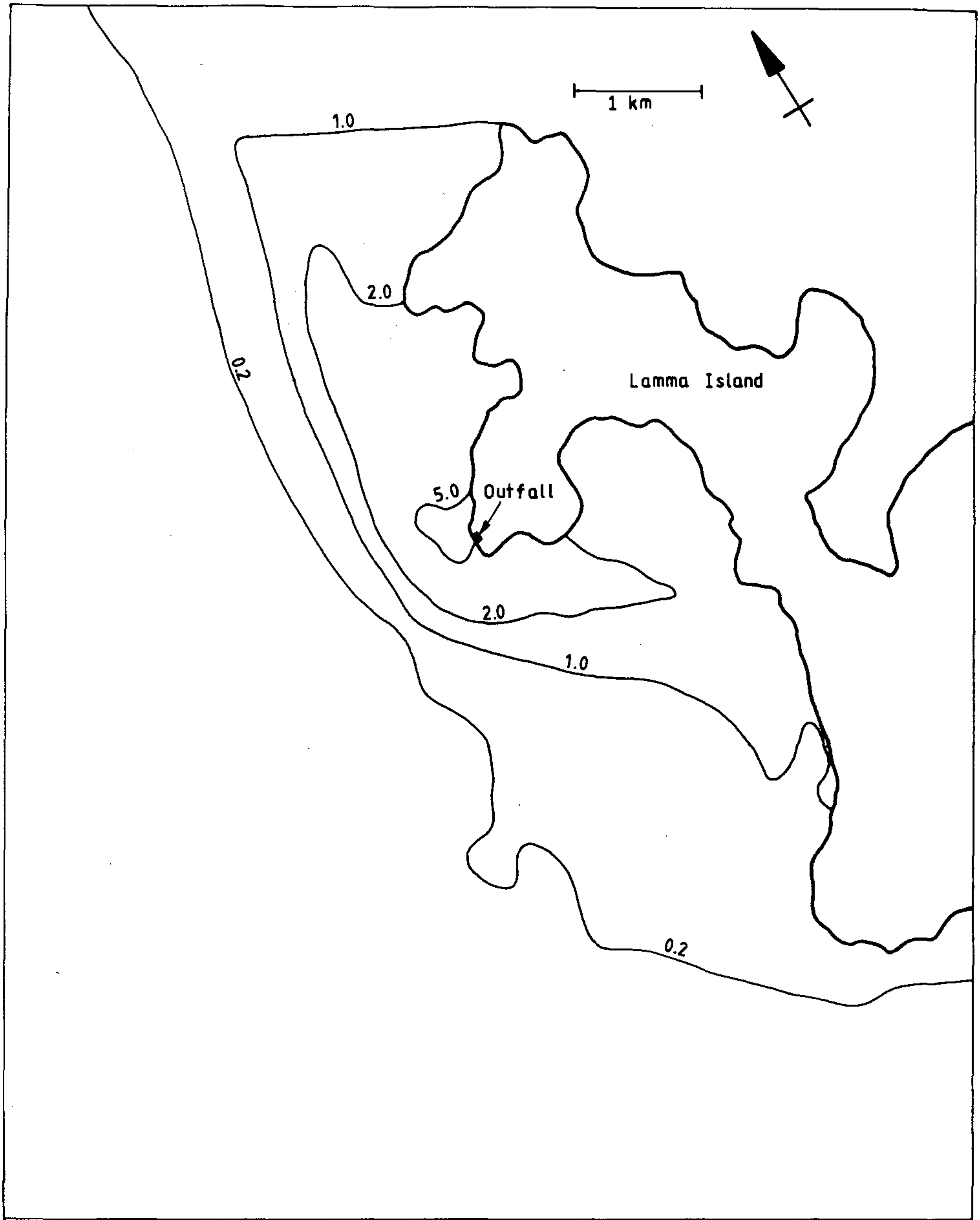
TITLE

Near Field Model-Results

FIGURE 6.12 a

	The Hongkong Electric Company Limited	PROJECT **EIA LAMMA POWER STATION**	TITLE Far Field Model-Results FIGURE 6.13

	The Hongkong Electric Company Limited	PROJECT **EIA LAMMA POWER STATION**	TITLE Far Field Model-Results
			FIGURE 6.13a



The Hongkong Electric Company Limited

- Dry season
- Spring tide
- 2500 MW
- Maximum temperature above ambient °C

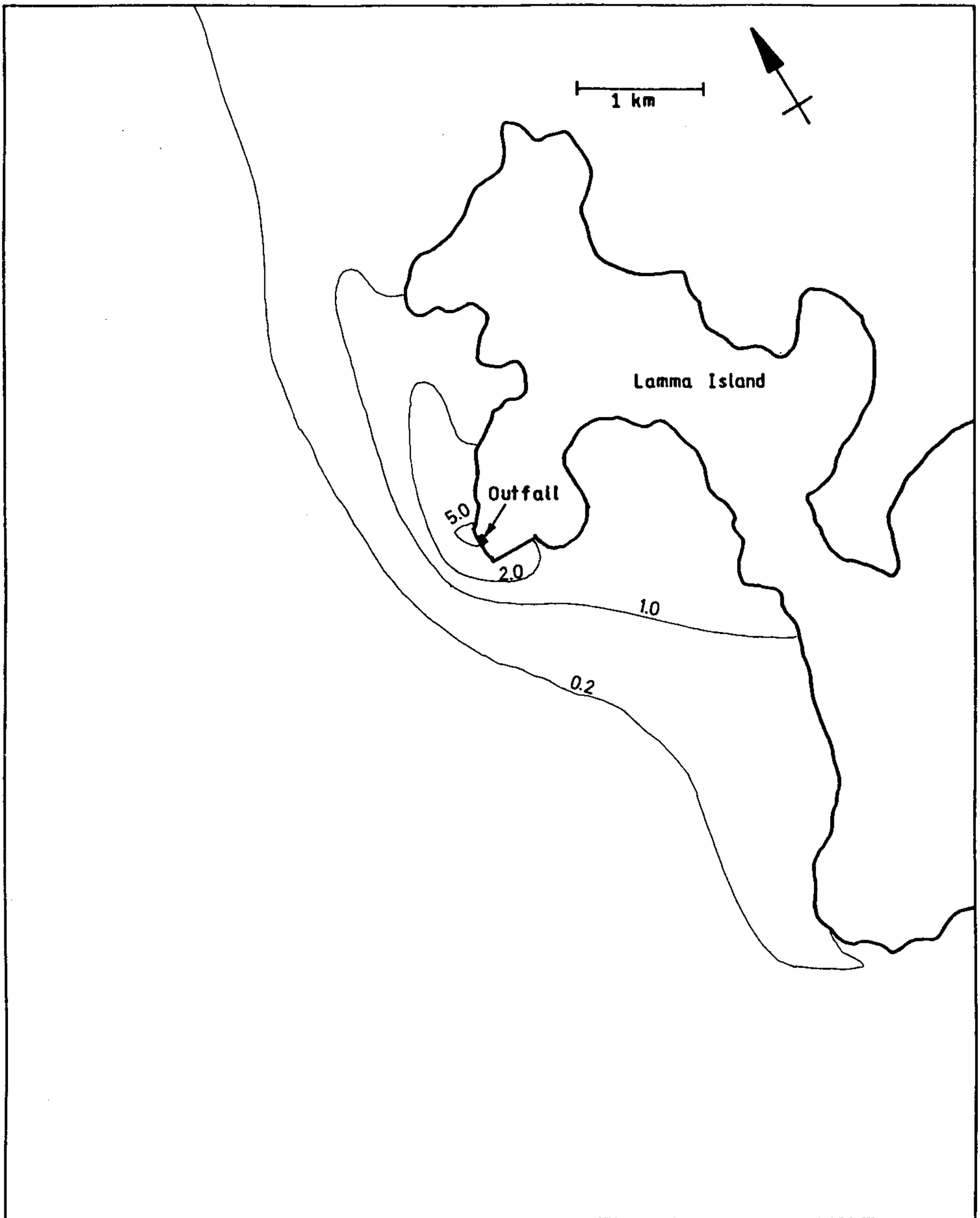
PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.14



The Hongkong Electric Company Limited

- Dry season
- Spring tide
- 2500 MW
- Mean temperature above ambient °C

PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.14a

The Hongkong Electric Company Limited

PROJECT

EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.15

The Hongkong Electric Company Limited

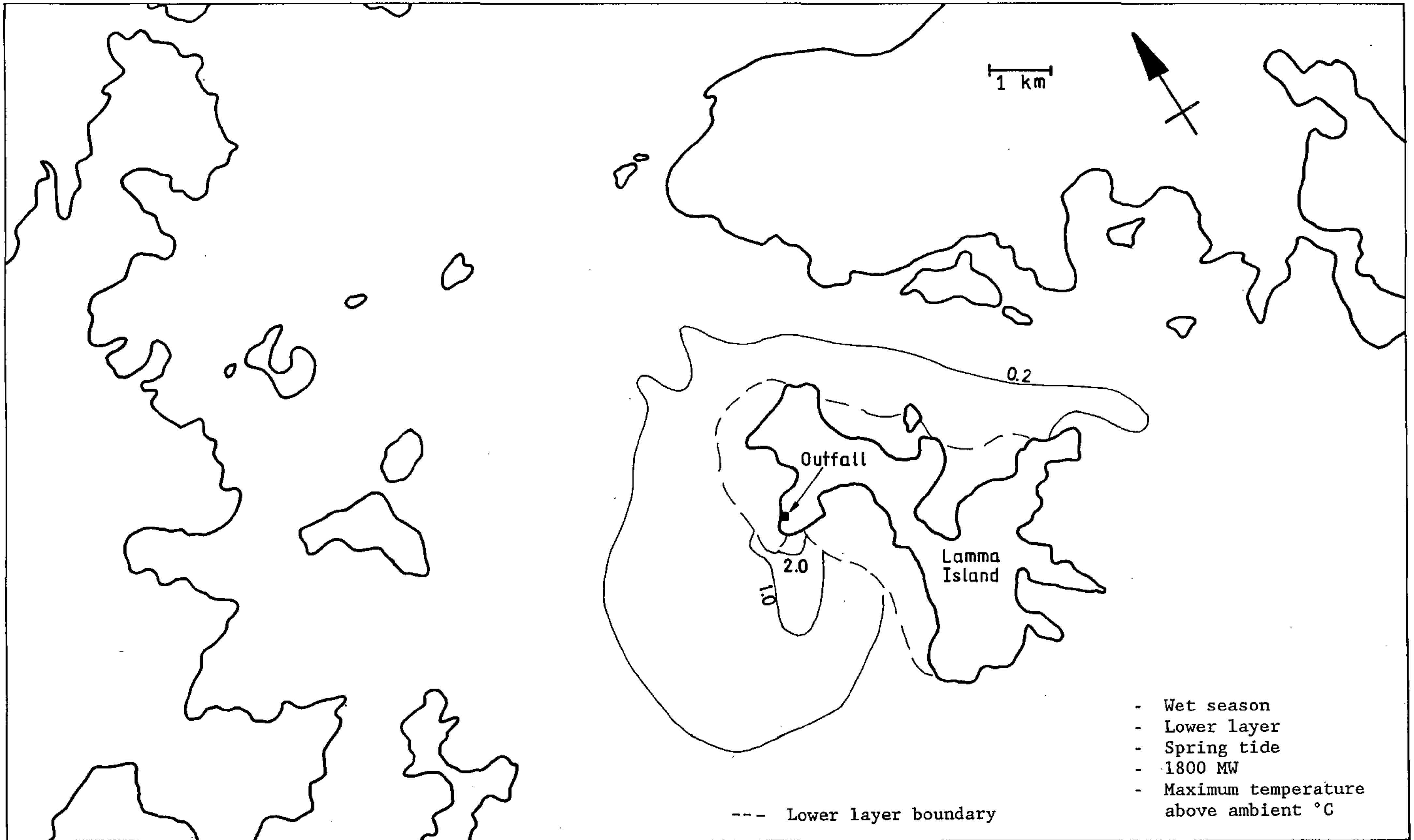
PROJECT

EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.15a



The Hongkong Electric Company Limited

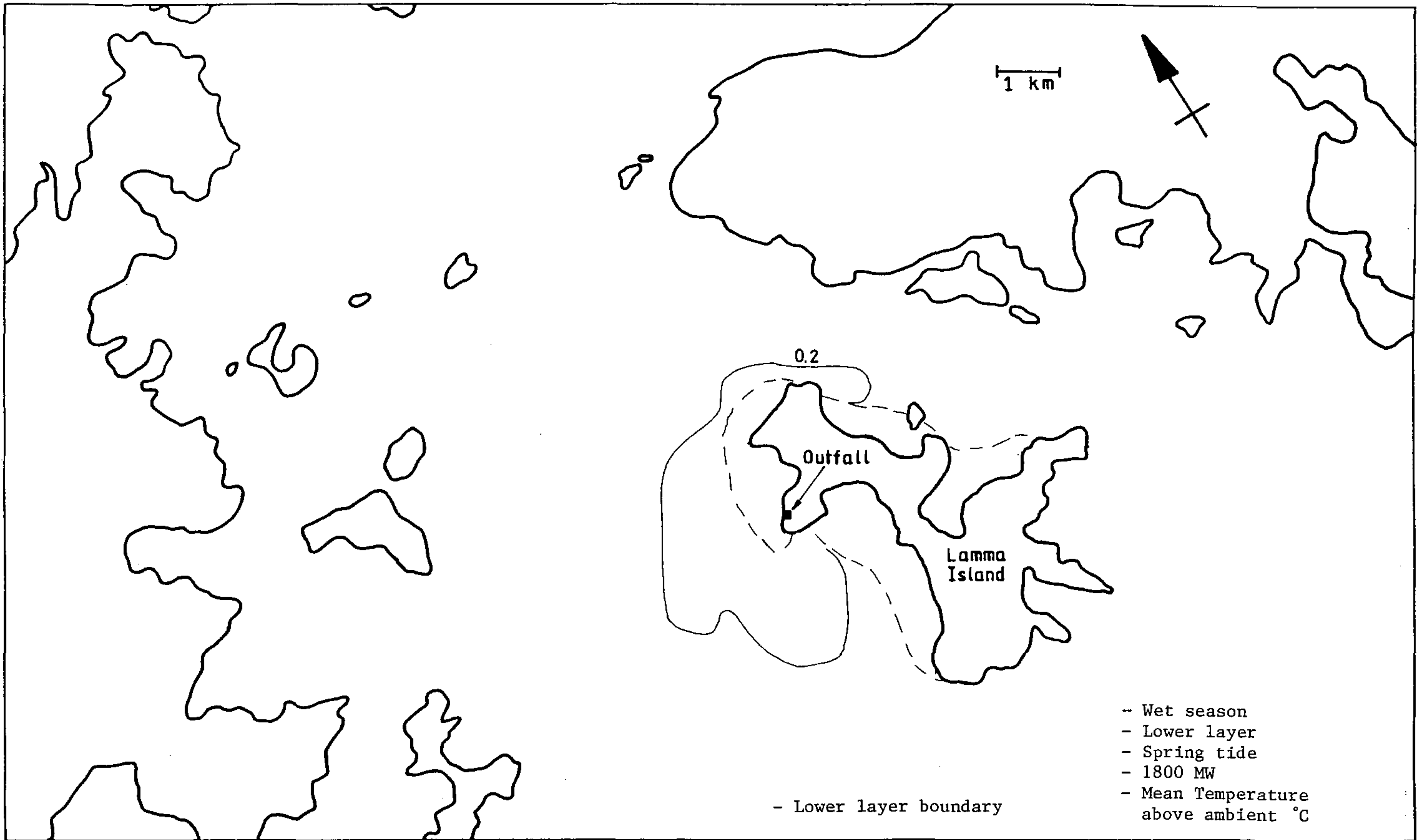
PROJECT

EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.16



The Hongkong Electric Company Limited

PROJECT

EIA LAMMA POWER STATION

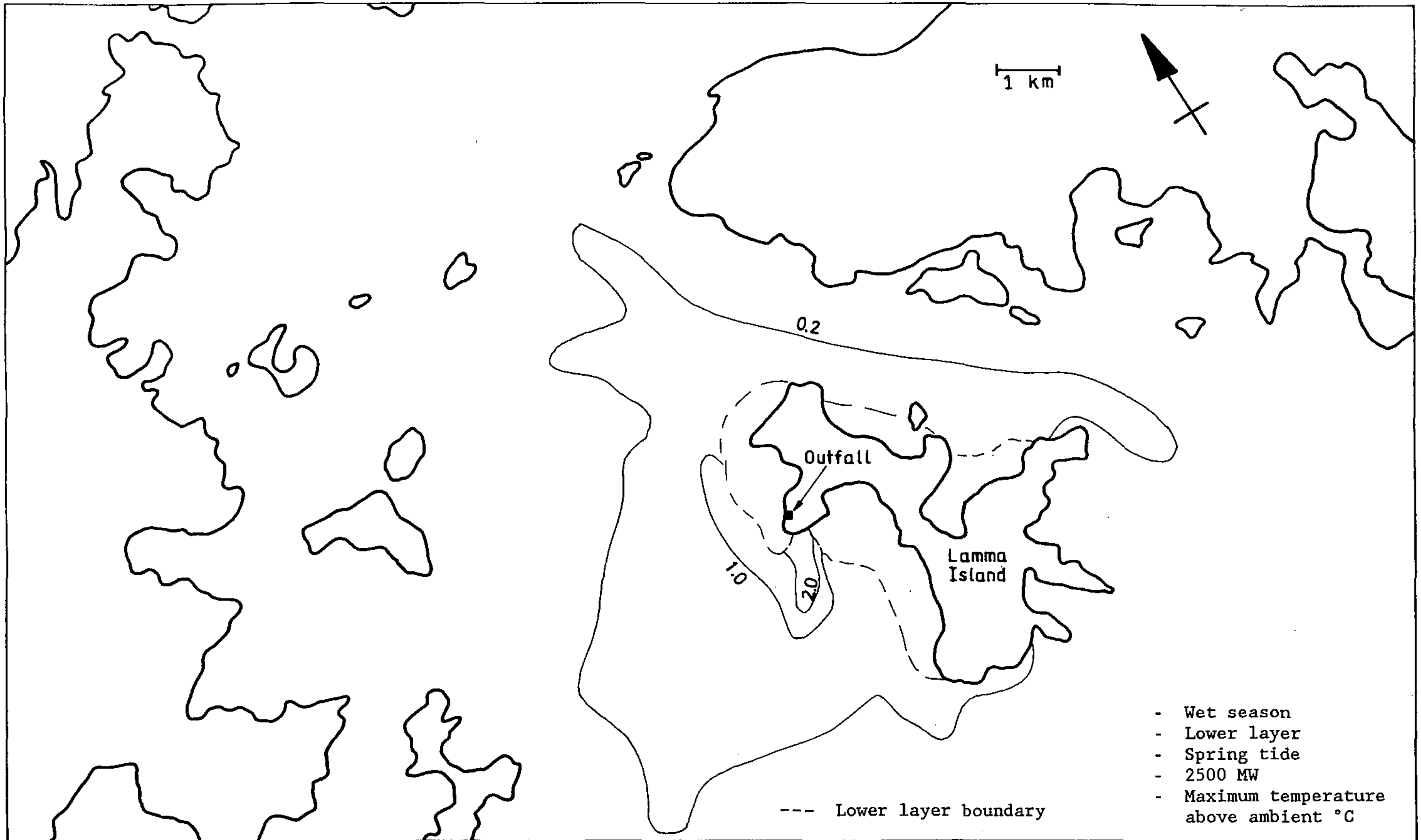
TITLE

Far Field Model-Results

FIGURE 6.16a

	The Hongkong Electric Company Limited	PROJECT **EIA LAMMA POWER STATION**	TITLE Far Field Model-Results FIGURE 6.17

	The Hongkong Electric Company Limited	PROJECT **EIA LAMMA POWER STATION**	TITLE Far Field Model-Results FIGURE 6.17 a



The Hongkong Electric Company Limited

PROJECT

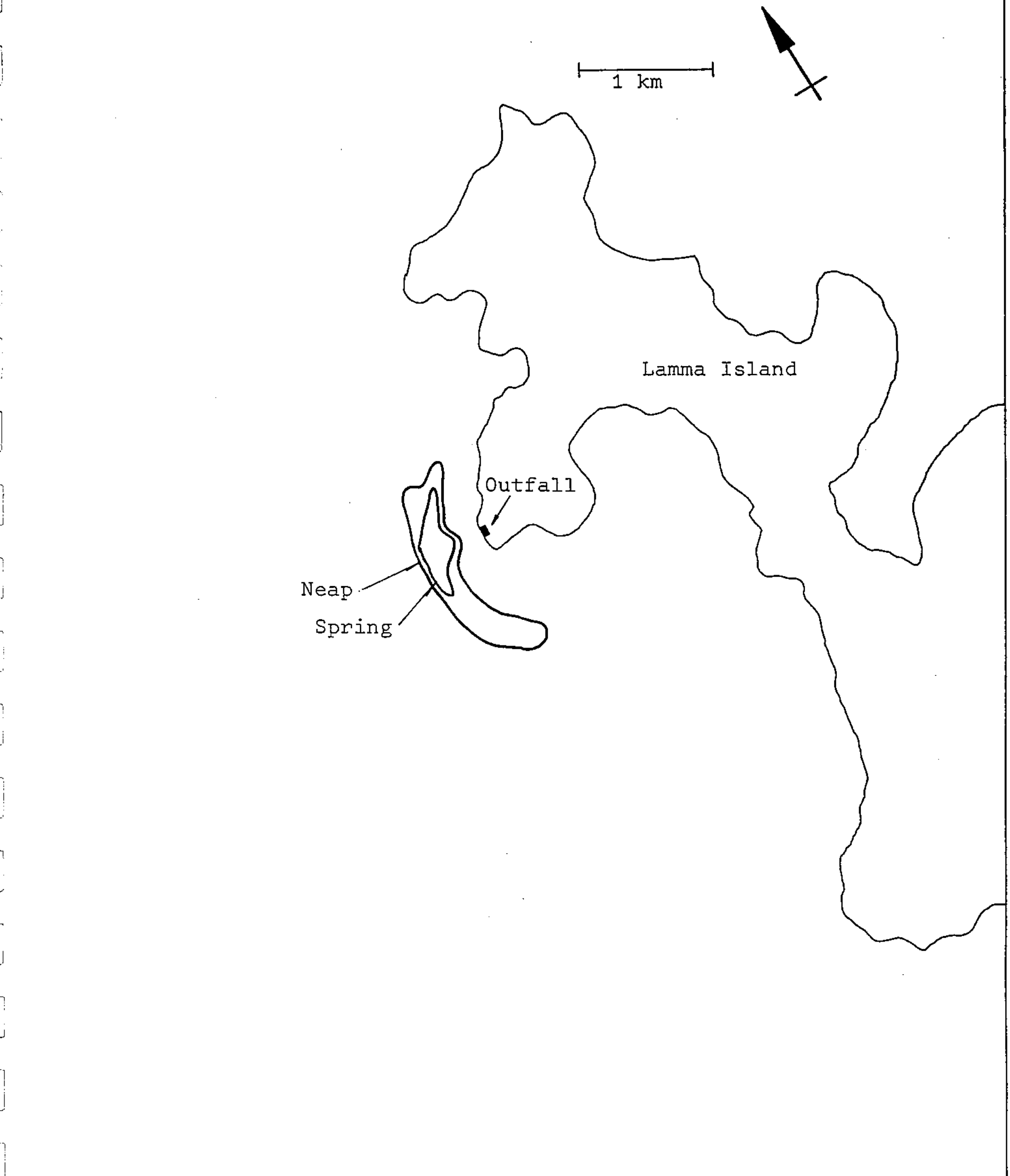
EIA LAMMA POWER STATION

TITLE

Far Field Model-Results

FIGURE 6.18

The Hongkong Electric Company Limited	PROJECT EIA LAMMA POWER STATION	TITLE Far Field Model-Results
		FIGURE 6.18a



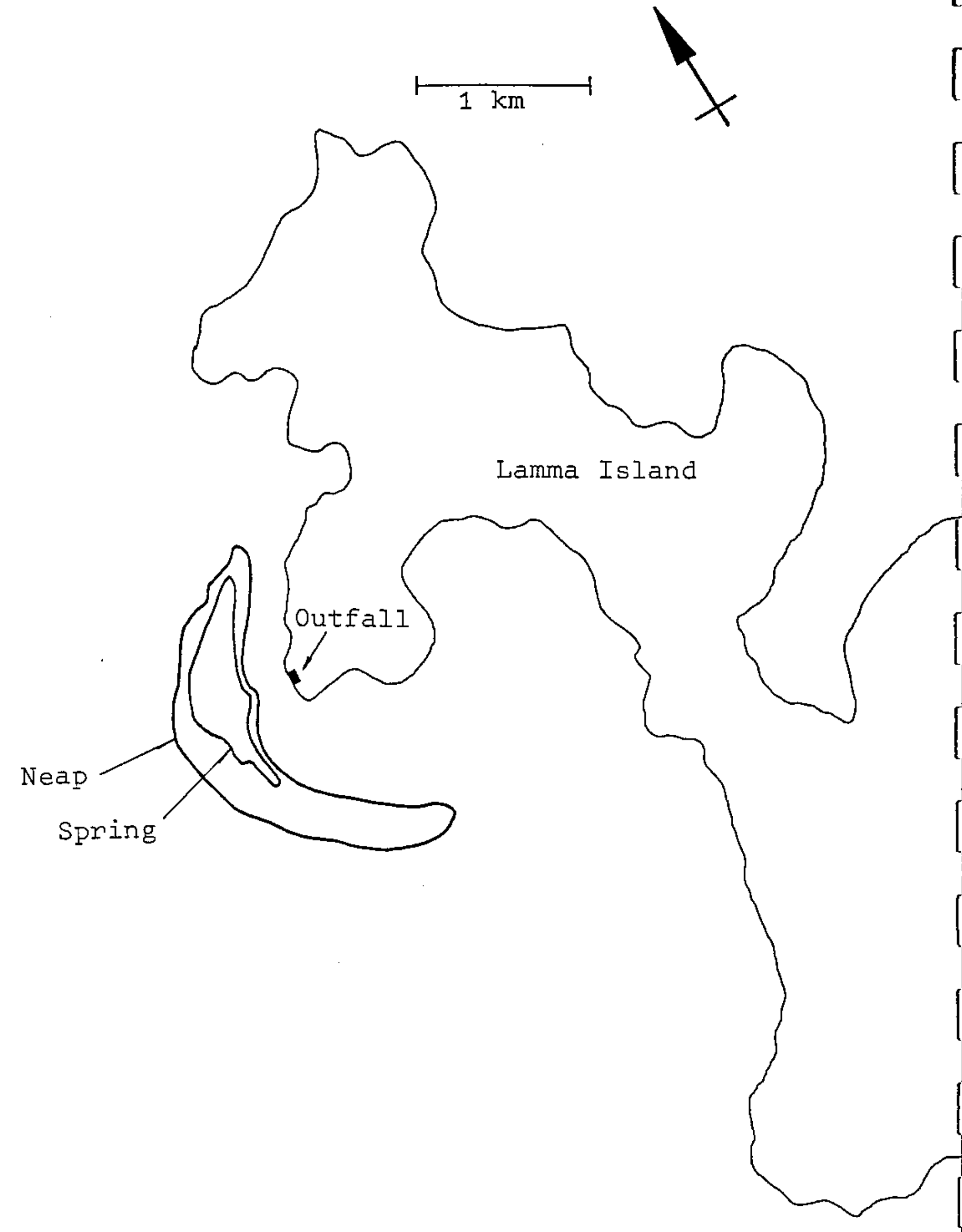
The Hongkong Electric Company Limited

- Dry season
- Neap and spring tides
- 1800 MW
- Envelop of 0.5°C plume

PROJECT
EIA LAMMA POWER STATION

TITLE
Plume Model-Results

FIGURE 6.19



The Hongkong Electric Company Limited

- Dry season
- Neap and spring tides
- 2500 MW
- Envelope of 0.5°C plume

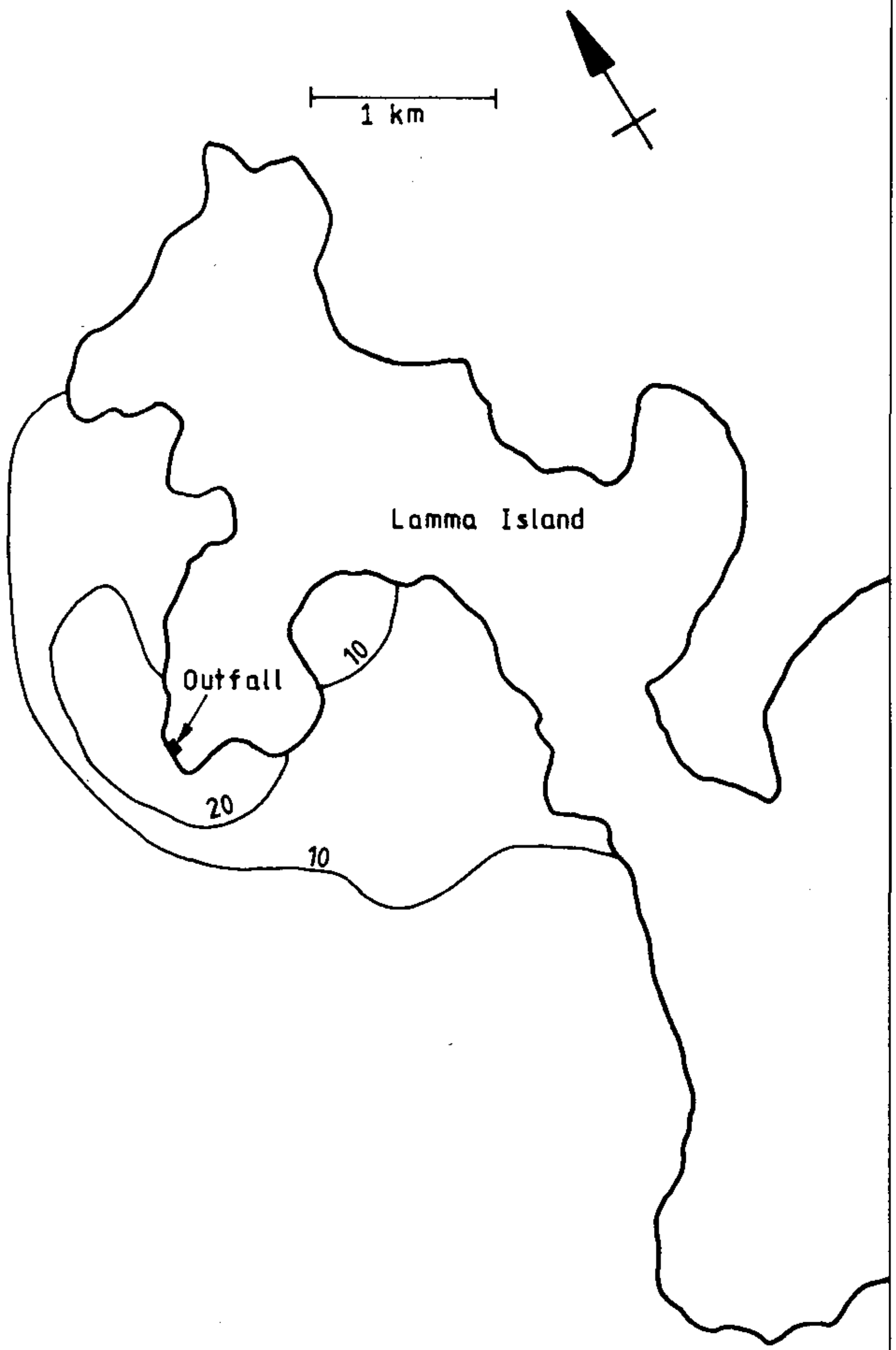
PROJECT

EIA LAMMA POWER STATION

TITLE

Plume Model-Results

FIGURE 6.20



The Hongkong Electric Company Limited

- Dry season
- Neap tide
- FGD on one unit
- Inorganic nitrogen concentration increase $\mu g/l$

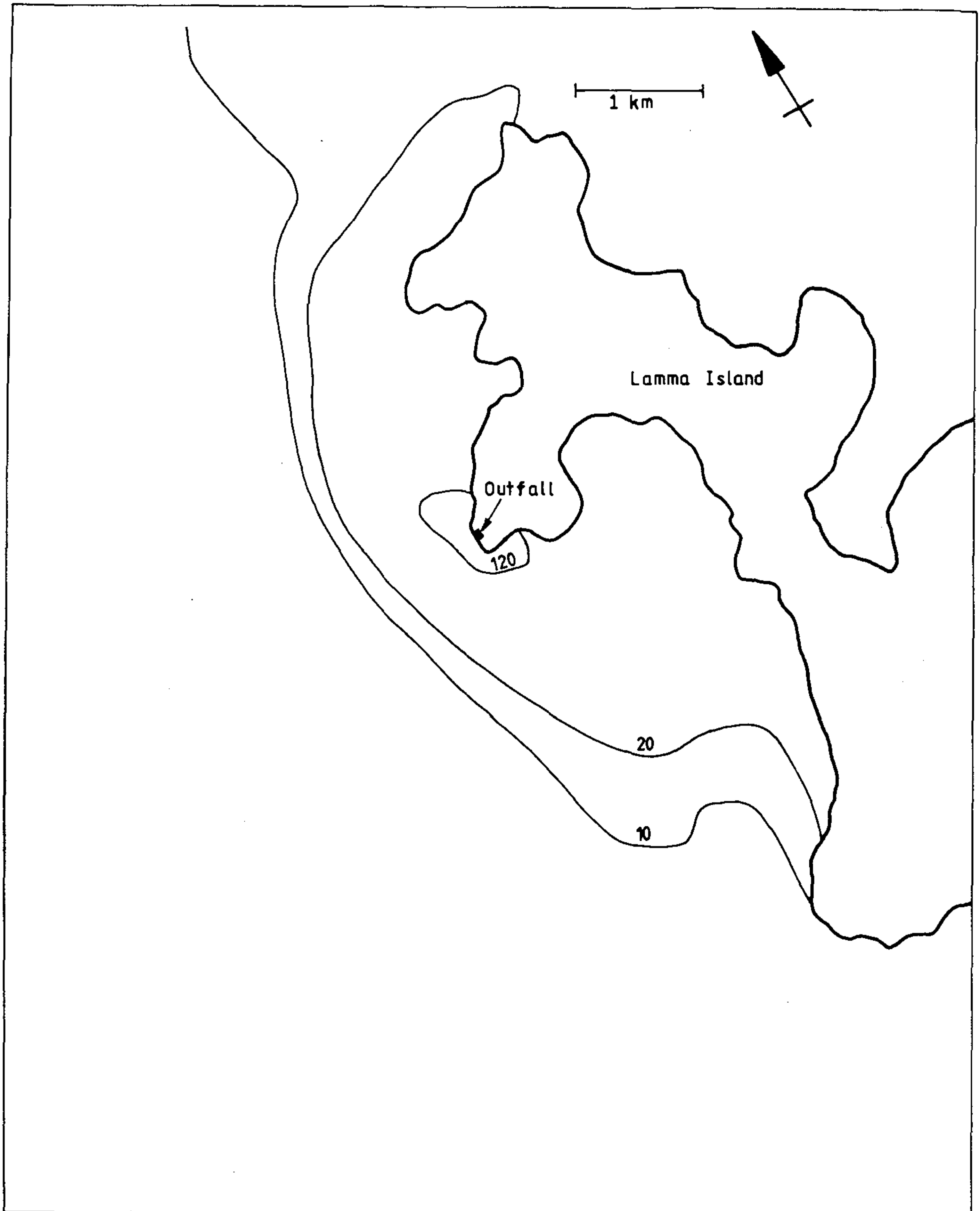
PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.21



The Hongkong Electric Company Limited

- Dry season
- Neap tide
- FGD on five units
- Inorganic nitrogen concentration increase μg/l

PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE 6.22

APPENDIX 6A
ANALYSIS OF HEC SELF MONITORING PROGRAM FOR EFFLUENT

APPENDIX 6A

ANALYSIS OF HEC SELF MONITORING PROGRAM FOR EFFLUENT

6A.1 The Hongkong Electric Company have undertaken a self monitoring programme of their liquid effluents. The results from this programme are reported every six months to EPD. The basic monitoring programme has remained much the same over the years, though modifications have been made with agreement from EPD. Major modifications took place in March 1985 and August 1989.

6A.2 The analysis of some of the results from the self monitoring programme are shown in Tables 6A.1 to 6A.5. These tables cover

- Table 6A.1 Cooling water flow and temperature rise
- Table 6A.2 Total residual chlorine concentration
- Table 6A.3 Ash Settlement Basin Trace Metal Analysis
- Table 6A.4 Sewage Treatment Plant Bacteria Numbers
- Table 6A.5 Heavy metals in Barnacles

6A.3 The analyses in Table 6A.1 show that the amount of waste heat discharged in the cooling water flow has risen steadily since in 1983. Although the waste heat has increased fairly steadily, the annual average temperature, as calculated from the annual average c.w. inlet and outlet temperature for all condensers, has reduced from 10°C to 6°C. This has been achieved by a large increase in cooling water flows at the time when units L4 and L5 were commissioned in 1987/8.

6A.4 Continuous chlorination of the cooling water is used to prevent fouling of the main condensers and other auxiliaries. The discharge consent limits the amount of residual free chlorine present at the outfall to 0.5 mg/l. The measurements of total residual chlorine at the outfall presented in Tables 6A.2 show that this parameter has averaged 0.39 mg/l since 1985. There have been a few isolated measurements when total residual chlorine has exceeded 0.5 mg/l. However, as the discharge consent applies to free residual chlorine which comprises 80-90% of the total, the current discharge consent has been satisfied in all years since 1986 when the present discharge consent was promulgated.

6A.5 The concentrations of trace metals in the ash settlement basin overflow shown in Table 6A.3 have never exceeded the current discharge consent of 0.1 mg/l for Mercury and Cadmium and 2.0 mg/l for the other non-ferrous heavy metals. An overall limit of 5 mg/l for all non ferrous heavy metals has also been set. These discharge consent limits have not been approached in any sample. All metal analyses have indicated metal concentrations at least 7.5 times less than the consent limit. The average concentrations for each metal are more than 50 times below the consent limit.

6A.6 The concentrations of trace metals in the ash settlement basin fluctuate, possibly depending on the source of coal. The maximum concentration of at least one of the metals has been recorded in each year of record apart from 1987. However, the total non-ferrous metal concentration seems to have risen from around 0.03 mg/l in 1983/4 to 0.15 mg/l in 1989. This rise is due to increasing concentrations of the two commonest metals, chromium and zinc. The concentration of all the other metals has remained stable, averaging less than 0.01 mg/l for each individual metal each year. The increasing production of ash as the power station generates more electricity is likely to decrease the detention time in the settlement basin and so reduce its efficiency. This factor may be the reason for the increasing concentrations of chromium and zinc over the past six years.

6A.7 The numbers of Total Coliform bacteria in the effluent from the three sewage treatment plants varies widely. This is quite common. However the median numbers of Coliforms recorded in these effluents shown in Table 6A.4 indicate the licence consent of 5000/100 ml of E. Coli has been satisfied in every year apart from 1985, the first year of monitoring.

6A.8 As part of their effluent monitoring programme HEC have collected barnacles once or twice a year growing near the cooling water outfall and also from a site on the east side of Lamma Island. The metal content in the soft tissue has been measured and the results reported in the effluent reports. These results are summarised in Table 6A.5. The most interesting feature of these results is that the metal concentrations in barnacles collected near the cooling water outfall are marginally lower than those collected from the other side of the Island.

6A.9 The differences between the two sites are not significant. These results suggest that Lamma power station is not causing major contamination of barnacle tissue. There is no way of telling, however, whether in the absence of the power station, concentrations of metal in barnacles found in the west Lamma Channel near the outfall would be the same or lower than in barnacles found in the east Lamma Channel.

TABLE 6A.1 : COOLING WATER FLOW AND TEMPERATURE RISE**

Year	Cooling Water Discharge Flow (m^3/h) Average	Temperature Rise (°C) Average	Temperature Rise (°C) Maximum	Average Heat Load MW
1983	88330	10.27	14.0	1053
1984	93500	9.71	13.5	1054
1985	93500	9.95	11.5	1080
1986	104400	7.06	8.2	856
1987	164350	5.88	7.0	1122
1988	217450	5.66	6.5	1429
1989	216500*	6.05	7.0	1521

Note ** temperature rise calculated from the weekly difference between maximum condenser inlet and outlet.

* based on Jan-June data only

TABLE 6A.2 : TOTAL RESIDUAL CHLORINE CONCENTRATION

Year	Total Residual Chlorine mg/l Annual Mean	Maximum Sample
1983	0.115	0.35
1984	0.073	0.32
1985	0.390	0.89
1986	0.334	0.57
1987	0.368	0.53
1988	0.402	0.53
1989	0.406	0.56

Notes:

1. Date prior to March 1985 show much lower residuals than subsequent measurements. This is because the measurement position was changed from a position in the plume 50 m away from the discharge point to the outfall seal pits.

2. Free Residual Chlorine is between 80% and 90% of total residual chlorine.

TABLE 6A.3 : ASH SETTLEMENT BASIN TRACE METAL CONCENTRATIONS

Determinand	Mean Concentration mg/m³ 1984	1985	1986	1987	1988	1989	Av	Max	Min
pH	7.6	7.7	7.8	7.7	7.8	8.0	-	8.3	7.2
Grease and oil mg/l	nm	1.0	0	0	0	0.4	0.3	1.5	0
Mercury	2.5	1.1	1.4	1.0	1.5	2.2	1.6	13.2	0
Cadmium	0.4	0.9	0.9	0.4	0.9	0.2	0.6	2.9	0.01
Arsenic	6.2	1.3	4.5	2.9	4.4	4.0	3.9	43.0	0
Chromium	nm	1.8	0.8	4.2	14.3	79.1	20.0	189.5	0.3
Copper	3.5	nm	nm	nm	nm	nm	3.5	8.6	0.5
Lead	1.5	6.0	1.1	0.8	0.5	0.9	1.8	8.6	0
Nickel	2.8	2.1	4.5	2.9	4.0	3.5	3.3	14.0	0
Zinc	15.5	21.5	45.6	32.6	40.0	59.0	35.7	132.0	3.2
Total non ferrous++	32.3+	34.5x	58.9x	44.7x	65.7x	148.6x	70.4	252.8x*	13.8+*

Note: nm not measured
+ excludes chromium
x excludes copper
* value obtained from single sample
++ sum of non ferrous metals, except where indicated

TABLE 6A.4 : SEWAGE TREATMENT PLANT BACTERIA NUMBERS

Year	Total Coliform numbers/100 ml Median Plant 1	Plant 2	Plant 3	Overall Maximum	Overall Minimum
1985	4000	7000	nm	100000	0
1986	300	3500	2500	34000	100
1987	2100	4000	3300	20000	30
1988	1100	1500	1000	15500	100
1989	40	300	160	4000	0

Note: nm not measured

TABLE 6A.5 : HEAVY METALS IN BARNACLES

Determinand	Average Conc mg/kg CW Outfall	Average Conc mg/kg Remote Site	Maximum Conc mg/kg CW Outfall	Maximum Conc mg/kg Remote Site
Mercury	0.042	0.046	0.078	0.109
Cadmium	2.09	1.83	9.4	5.7
Arsenic	3.51	3.84	12.33	16.26
Chromium	1.02	1.11	1.89	1.70
Lead	1.48	2.40	6.1	9.1
Nickel	2.25	2.30	3.73	3.86
Zinc	2303	2587	4750	5000

APPENDIX 6B
WATER QUALITY OBJECTIVES FOR SOUTHERN WATER CONTROL ZONE

APPENDIX 6B

WATER QUALITY OBJECTIVES FOR SOUTHERN WATER CONTROL ZONE

A. **Aesthetic Appearance**

(a) Waste discharges shall cause no objectionable odours or discolouration of the water. Whole zone

(b) Tarry residues, floating wood, articles made of glass, plastic, rubber or of any other substance should be absent. Whole zone

(c) Mineral oil should not be visible on the surface. Surfactants should not give rise to a lasting foam. Whole zone

(d) There should be no recognisable sewage-derived debris. Whole zone

(e) Floating, submerged and semi-submerged objects of a size likely to interfere with the free movement of vessels, or cause damage to vessels, should be absent.Whole zone

(f) Waste discharges shall not cause the water to contain substances which settle to form objectionable deposits. Whole zone

B. **Bacteria**

(e) Waste discharges shall not cause the level of Escherichia coli to exceed 1000 per 100 ml in more than 60% of the samples collected during the whole year. Secondary Contact Recreational Subzones

(b) The level of Escherichia coli should not exceed 1000 per 100 ml, calculated as the running median of the most recent 5 consecutive samples. Samples should be taken 3 times in one calendar month at intervals of between 3 and 14 days. The sampling programme extends from March to October inclusive in any year. Bathing Beach Subzones

C. **Dissolved Oxygen**

(a) Waste discharges shall not cause the level of dissolved oxygen to fall below 4 milligrams per litre for 90% of the sampling occasions during the year. Values should be calculated as the water column average (arithmetic mean of at least 3 measurements at 1 metre below surface, mid-depth, and 1 metre above seabed). In addition,the concentration of dissolved oxygen should not be less than 2 milligrams per litre within 2 metres of the seabed for 90% of the sampling occasions during the year. Marine waters excepting Fish Culture Subzones

(b) The dissolved oxygen level should not be less than 5 milligrams per litre for 90% of the sampling occasions during the year. Values should be calculated as water column average (arithmetic mean of at least 3 measurements at 1 metre below surface, mid-depth, and 1 metre above seabed). In addition, the concentration of dissolved oxygen should not be less than 2 milligrams per litre within 2 metres of the seabed for 90% of the sampling occasions during the year. Fish Culture Subzones

(c) Waste discharge shall not cause the level of dissolved oxygen to be less than 4 milligrams per litre. Inland waters of the Zone

D. pH

(a) The pH of the water should be within the range of 6.5-8.5 units. In addition, waste discharges shall not cause the natural pH range to be extended by more than 0.2 units. Marine waters excepting Bathing Beach Subzones: Mui Wo(A), Mui Wo(B), Mui Wo(C), Mui Wo(E) and Mui Wo(F) Subzones.

(b) The pH of the water should be within the range of 6.0-9.0 units. Mui Wo(D) Subzone and other inland waters.

(c) The pH of the water should be within the range of 6.0-9.0 units for 95% of samples. In addition, waste discharges shall not cause the natural pH range to be extended by more than 0.5 units. Bathing Beach Subzones

E. **Temperature**

Waste discharges shall not cause the natural daily temperature range to change by more than 2.0 degrees Celsius. Whole Zone

F. **Salinity**

Waste discharges shall not cause the natural ambient salinity level to change by more than 10%. Whole Zone

G. **Suspended Solids**

(a) Waste discharges shall neither cause the natural ambient levels to be raised by 30% nor given rise to accumulation of suspended solids which may adversely affect aquatic communities. Marine waters

(b) Waste discharges shall not cause the annual median of suspended solids to exceed 20 milligrams per litre. Mui Wo(A), Mui Wo(B), Mui Wo(C), Mui Wo(E) and Mui Wo(F) Subzones

(c) Waste discharges shall not cause the annual median of suspended solids to exceed 25 milligrams per litre. Whole Zone

H. **Ammonia**

The ammonia nitrogen level should not be more than 0.021 milligram per litre, calculated as the annual average (arithmetic mean) as unionised form. Marine waters.

I. **Nutrients**

(a) Nutrients shall not be present in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants. Marine waters

(b) Without limiting the generality of objective (a) above, the level of inorganic nitrogen should not exceed 0.1 milligram per litre, expressed as annual water column average (arithmetic mean of at least 3 measurements at 1 metre below surface, mid-depth, and 1 metre above seabed).

J. **5-Day Biochemical Oxygen Demand**

Waste discharges shall not cause the 5-day biochemical oxygen demand to exceed 5 milligrams per litre. Inland water of the Zone

K. **Chemical Oxygen Demand**

Waste discharges shall not cause the chemical oxygen demand to exceed 30 milligrams per litre. Inland waters of the Zone

L. **Dangerous Substances**

(a) Waste discharges shall not cause the concentrations of dangerous substances in marine waters to attain such levels as to produce significant toxic effects in humans, fish or any other aquatic organisms, with due regard to biologically cumulative effects in food chains and to toxicant interactions with each other. Whole Zone

(b) Waste discharges of dangerous substances shall not put a risk to any beneficial uses of the aquatic environment. Whole Zone

Objectives taken from Ref 6.3

APPENDIX 6C
DESCRIPTION OF THE DIVAST COMPUTER MODEL

APPENDIX 6C

DESCRIPTION OF THE DIVAST COMPUTER MODEL

Computer Model - DIVAST

6C.1 The program DIVAST is a two-dimensional flow and pollutant model. The model simulates flow patterns in rivers, lakes, estuaries, bays, and coastal areas. Currents and water levels are calculated as a function of time, taking into account the hydraulic characteristics of the seabed, and the boundary currents and water-levels. The model also predicts the movement, decay and reactions of pollutants within the calculated flow field.

Features of DIVAST

6C.2 The model was developed by Professor R.A.Falconer, now of Bradford University, and is based on a programming technique similar to that used in the Leendertse (Rand Corporation) model, with enhancements to the solution technique and program capabilities that allow modelling of:

- contractions and jetting
- islands and breakwaters
- sand banks that can dry out at low water
- pollutant sources and sinks

6C.3 The program is structured in a very general form and project specific requirements can be easily added. Hence the program is highly versatile. DIVAST has been successfully used to model:

- circulation in and flushing from harbours and reservoirs
- water temperature rise caused by cooling water
- solute distributions, resulting from discharge of sewage and industrial effluent
- sediment transport characteristics
- eddy shedding from obstructions.

6C.4 The developments carried out by B&P include structuring the program into a modular form and making the model fully data driven. The type of problem and the layout of the area simulated are defined by the input data file rather than being specified inside the program. The operation of the program has also been altered to allow:

- simplified specification of the flow field
- starting a simulation with the end conditions from a previous run
- running the water movement model without the solutes model
- routing of pollutants through a steady state flow field, which is not recalculated at each time step

- modelling several water quality parameters which can interact, decay and have sources or sinks either from the bed or the water surface
- calculation of net current residuals, for instance over a tidal cycle
- calculation of bed shear stresses and plotting of maximum shear stress maps
- calculation of sediment transport rates and plotting of net sediment movement
- creation of artificial float tracks
- modelling of barrage hydraulics.

6C.5 The flow solutions and pollutant solution used in DIVAST are independent. In most applications, the flow solution calculated by DIVAST is used to drive the pollution part of DIVAST. However, a flow solution calculated by DIVAST may also be used to drive the SOLUTE DIVAST pollutant solution.

Solution Techniques

6C.6 The model simulates the time-history of water levels, flows, and solute concentrations, throughout an area of interest. The study area is represented by a 2-dimensional grid in a horizontal plane on the earth's surface. The different properties of this body of water, such as land/water boundaries, bed topography, and bed roughness, are described on this grid system. Time is considered at a series of points during the period being simulated. At each point in time, the continuity and momentum equations are solved to give the water-levels, velocities, and concentrations, throughout the grid.

6C.7 The model DIVAST solves the general form of the momentum and continuity equations for flow and solutes using an Alternating Direction Implicit finite difference technique. The boundary conditions and the solution grid are defined by the input data. The model is therefore capable of being applied to a wide variety of problems in its current state. However if necessary the governing equations can readily be changed to include the peculiarities of the problem in hand.

6C.8 The hydrodynamic equations which govern the behaviour of the body of water are:

(i) CONTINUITY EQUATION - The equation for the conservation of mass of water, integrated over depth. It includes terms for flux and storage.

(ii) MOMENTUM EQUATION - The equation for the conservation of momentum of water, integrated over depth. Since momentum is a vector quantity, there are two of these equations, one for the x-, and one for the y-, directions. It includes terms for local and convective accelerations, Coriolis force, hydrostatic pressure gradient, wind stress, bed friction, and turbulent transfer of momentum.

(iii) SOLUTE MASS BALANCE EQUATION - The equation for the conservation of mass of solute in the water, integrated over depth. It includes terms for local effects, advective effects, turbulent diffusion/dispersion, decay, aeration, benthic uptake and interaction of pollutants.

6C.9 The continuity and momentum equations are solved for the first half-time step in the x-direction. Variables in the y-direction are assumed to be explicitly known. The variables in the x-direction are solved for implicitly, using a Gaussian Elimination technique for solving simultaneous equations.

6C.10 The equations are then solved for the second half-time step in the y-direction. Variables in the x-direction are known from the previous half-time step, and are assumed not to change during the second half-time step. That is, the variables in the x-direction are known explicitly. The variables in the y-direction are solved for implicitly, using the Gaussian Elimination technique.

6C.11 This is then repeated in the x-direction, then the y-direction, then the x-direction, and so on, with time moving by a full-time step for each x-/y- sweep. This method is known as the Alternating Direction Implicit (ADI) method. This method is supplemented by an improved solution technique, the 'QUICK' solution, which uses Quadratic Interpolation to give better representation of concentration fronts

Model Assumptions

6C.12
- The bed topography is known.
- The bed topography may change rapidly, but water-levels change gradually.
- The bed roughness is known.
- The curvature of the earth across the study area is ignored.
- The Coriolis force is constant over the whole area.
- The atmospheric pressure is uniform across the study-area.
- The water-levels, or discharges, at the open boundaries are known.
- The water behaviour can be represented by the shallow water wave equations.
- The pollutant or pollutants are represented by first order kinetics, which may be linearly proportional to pollutant concentrations, one of the other pollutant concentrations or temperature excess or dissolved oxygen deficit.

Boundary Conditions

6C.13 Before the simultaneous equations for a reach can be solved, the boundary conditions at the lower and upper bounds must be known. There are three possible ways of defining the limits of the model. These are as follows:

- CLOSED BOUNDARIES, which occur when the end of the reach is adjacent to dry land.
- KNOWN DISCHARGE OPEN BOUNDARIES, where the discharge is known at all times during the simulation period. For example, the hydrograph of a river, or the discharge through an outfall, might be known.
- KNOWN WATER-LEVEL OPEN BOUNDARIES, where the water-levels are known at all times during the simulation period. For example, the boundary between the study area and the open sea might be prescribed by a curve or the boundary might be a lake or reservoir of known level. The level is specified by either a series of water levels at constant or varying time intervals or by one or more tidal harmonic constituents.

Solute DIVAST

6C.14 The portion of DIVAST which solves the pollutant equations, SOLUTE DIVAST, may be run independently of the main hydrodynamic component of DIVAST. This approach allows the pollutant program to be run for differing loadings or pollutants without repeating all hydrodynamic model calculations. The DIVAST model has been upgraded to allow hydrodynamic data to be output to an intermediate file at specified time intervals. This file is read by SOLUTE DIVAST to obtain flow and level data for pollutant runs.

6C.15 To use this version of the program, the bed topography, water levels and currents must be provided as data for SOLUTE DIVAST. This data may also be provided by another hydrodynamic model, providing it uses a compatible square grid system to represent the model area. The WAHMO 250 m grid size depth averaged hydrodynamic model and its output satisfies these conditions. The grid size used in SOLUTE DIVAST is of necessity identical to the original hydrodynamic model output. For the present study, the Far Field, Dry Season, Model uses the WAHMO data to drive the SOLUTE DIVAST model.

Two Layer Solute DIVAST

6C.16 For the present study, the capability of SOLUTE DIVAST has been enhanced to calculate pollution advection and dispersal in a two layer stratified system. This Far Field, Wet Season, Model, uses output from the two layer WAHMO seasonal hydrodynamic model. Again, a 250 m grid is used for the analysis.

6C.17 The two layer model solution first calculates the pollutant solution in the surface layer. This calculation includes as a pollutant source any upward pollutant massflow calculated during the previous solution for the lower layer. This vertical pollutant flow arises from a combination of the massflow associated with vertical water movement added to the diffusive massflow based on the concentration difference between the layers. At the conclusion of the surface layer solution, the pollutant concentration associated with any downward flow from the surface layer to the lower layer will be calculated. This downward pollutant massflow will provide sources of pollutant in the appropriate cells in the lower layer. The pollutant solution is then calculated for the lower layer. The solution is then repeated in the upper layer for the next timestep using updated vertical pollutant massflows as pollutant sources.

APPENDIX 6D
WEST LAMMA (NEAR FIELD) DIVAST MODEL

APPENDIX 6D

WEST LAMMA (NEAR FIELD) DIVAST MODEL

Introduction

6D.1 In 1989, Binnie & Partners were commissioned through Binnie Consultants Limited by Hongkong Electric Company Limited to develop a computer model to reproduce water movements on the west side of Lamma Island. The model was required to predict the dispersal of leachate and movement of sediment arising from the construction of an ash lagoon at Lamma Power Station.

6D.2 This existing model is appropriate for use as the Near Field Model required for the EIA of Units 7 and 8. The model has been modified slightly to improve the detailed topography close to the cooling water outfall. The existing solute solution has been retained for analysis of metal dispersion. A thermal dispersion solution has been added taking account of the loss of heat from the water surface.

6D.3 The following paragraphs describe the development and assessment of the West Lamma Model.

Flow Simulation DIVAST Model

6D.4 A hydrodynamic model of the flow patterns in the area was developed using the DIVAST (Depth Integrated Velocities and Solute Transport) flow simulation model, described in Appendix 6C.

WAHMO Models

6D.5 The WAHMO suite of computer programs were developed by Binnie & Partners, Hydraulics Research Ltd and the Water Research Centre for the Urban Area Development Office of the Territory Development Department [5]. The programs reproduce the existing hydraulic and water quality conditions in Victoria Harbour and can simulate the effects of proposed future developments.

6D.6 The area covered by the WAHMO models includes the west Lamma area, which is of particular interest to this study. Results from the WAHMO models were therefore obtained from the Environmental Protection Department for use as boundary conditions to the DIVAST model.

6D.7 The WAHMO model used to obtain these boundary conditions was the Global intertidal water movement model. This is a depth averaged 2-D flow model of similar formulation to DIVAST. This model includes all Hong Kong Territorial waters and the whole of the Pearl river estuary. The calculations are performed on a 750m grid in the outer area and a 250m grid on the inner area. The two grids are dynamically linked together. The west Lamma area lies within the 250m grid portion of the WAHMO model.

Extent of the DIVAST Model

6D.8 The extent of the model constructed for this study was limited to an area of approximately 50 square kilometres along the western coast of the island shown on Figure D1. Results from the WAHMO model indicated that the predominant flow direction along the western coast of Lamma Island runs approximately from north to south. It was considered that the chosen location of the model boundaries was not likely to produce undue constraints on the flow patterns within the model, since they were located far enough from the area of interest around Ha Mei Wan.

6D.9 A grid size of 83.33 metres was adopted throughout the model. This value was chosen to give good definition of the coastline, the dredged channel and the proposed lagoon. The grid size is a reduced by a factor of three from the WAHMO 250m grid used to generate the boundary conditions; this procedure is considered good modelling practice for nested models.

6D.10 The advantages of aligning the model grid with the dredged channel were investigated. It was concluded that the model grid adopted would correctly model water movements across the dredged channel whatever grid alignment was chosen, due to the small size of the grid compared with the width of the channel. A grid orientation of 30 degrees from North was finally adopted, since it:

- gave the best flow conditions at the main flow boundaries, and
- was identical to that used in the WAHMO model, simplifying data transfer.

Bathymetric Data

6D.11 The bathymetry of the area was digitized into a 'MOSS' 3-dimensional terrain modelling system using depth readings from Admiralty Charts of the area. Details of the dredged channel were confirmed using a plan supplied by the Hong Kong Electric Company. The position of the grid was determined in Universal Transverse Mercator (UTM) co-ordinates and transformed to Hong Kong grid co-ordinates using triangulation data.

6D.12 Depth data at the grid nodes were produced by interpolation from the digitized bathymetric model.

Boundary Conditions

6D.13 Before the equations for the mathematical model can be solved, the boundary conditions around the edge of the model must be known. There are three possible ways of defining the limits of the model, these being closed boundaries, known discharge open boundaries and known level open boundaries.

6D.14 For the present study the boundary conditions were compiled from tidal data generated by the WAHMO model. The data available consist of simulated velocities and water surface elevations for typical repeating spring and neap tides. For the area under investigation, data were available at 250 metre intervals, and at 20 minute intervals throughout the tidal cycle. Tests were carried out from low water to low water, with a 12.33 hour simulation for the neap tide, and 25 hours for the spring tide, as in the WAHMO model.

6D.15 In view of the predominant flow directions, the boundary conditions were initially applied as follows:

(i) a water surface elevation was imposed along the north-western boundary, as the flow was, in general, approximately parallel to the boundary;

(ii) the flow normal to the boundary was imposed at the north-eastern and south-western limits of the model. In this case, the remaining component of flow was computed within the model. The flow parallel to the boundary was considered to be of secondary importance;

6D.16 The locations of the open flow and elevation boundaries are shown in Figure D2.

6D.17 For all open boundaries, the appropriate value of flow or elevation was computed by quadratic interpolation between the WAHMO output data. Similarly, boundary conditions at each timestep were determined by quadratic interpolation throughout the tidal cycle.

6D.18 The initial conditions were also determined using output from the WAHMO model. The average value of water surface elevation was calculated at the beginning of the tidal cycle, and imposed across the entire model. The model was then allowed to run through an initial tidal cycle, in order to achieve a dynamic starting condition for the predictive runs.

Method of Calibration

6D.19 The accuracy of simulation has been assessed by three methods. Initially, the results were compared with data generated by the WAHMO model. The results were subsequently compared with data recorded during September 1990 at several locations off the western coast of Lamma Island. In addition, simulated flows in the dredged channel were compared with values predicted using a method published by EGS in 1982. Details of this method are described in the Tidal Stream Atlas [13]. The results of the calibration tests are described in detail in sections 6D.22 to 6D.43.

6D.20 After a number of tests, a bed friction factor of k_s = 200 mm was adopted throughout the model. This value is identical to that used in the WAHMO model of the surrounding area. The eddy viscosity was computed as a function of depth and shear velocity, and therefore varied with time and location. The DIVAST model was found to be relatively insensitive to changes in these parameters.

6D.21 Using the Courant condition for stability, a timestep of 24 seconds was found to be suitable for computations.

Comparison With WAHMO Results

6D.22 Calibration points were chosen at three locations within the model. Two of these points lay outside of the bay and the deep water dredged channel; the third lay within the shallow bay.

6D.23 For the neap tide, the simulated velocities at points 1 and 2 are very similar to those predicted by the WAHMO model. This is seen to be the case for both components of velocity. For point 3, located within Ha Mei Wan Bay, some differences are evident, especially towards the end of the tidal cycle. Some minor irregularities in the graphical output are due to rounding effects in the velocity outputs, and do not indicate any major disagreement between the models. The velocity calibrations are shown in Figures D.3 to D.5.

6D.24 Similar agreement is found in the spring tide calibrations at points 1, 2 and 3. Again, the comparison for point 3 shows some differences. The velocity calibrations are shown in Figures D.6 to D.8. For both the neap and spring tides, differences between the two models are primarily due to the increased grid resolution, and hence the accuracy of the DIVAST model. In the model constructed for the present study, the representation of the dredged channel and the bay are significantly more accurate than the WAHMO data. Simulated flows in this area are sensitive to any changes in bathymetry. Current refraction, which aligns the tidal current with the deep water zone of the dredged channel, is more pronounced in the DIVAST model than in the WAHMO output. In the bay, large changes in flow direction occur over a small distance. Phase lags also differ between the two models. The more detailed bathymetry of the DIVAST model should improve the detailed representation of currents in comparison with those computed in the WAHMO model.

6D.25 Water surface elevations compared well between models throughout the area modelled for both tidal conditions investigated.

6D.26 A comparison of velocities near the boundaries was also carried out. These agreed less well, especially in the velocity component parallel to the boundary. These effects die out within several grid cells of the boundary, and appear to be non-existent in the area of interest. The existence of irregularities close to the boundaries is associated with nested models and is also observed in the linked models of the WAHMO suite. The effect is illustrated on the south-western boundary of the Lamma model, where the boundary conditions are affected by the proximity of the transition, in the WAHMO model, from a 250 metre grid to a 750 metre grid.

6D.27 A further check against the WAHMO results was carried out by plotting flow snapshots at peak flows in the flood and ebb, and comparing them with the results presented in the WAHMO reports. There was close correspondence between the two models.

Comparison with Recorded Velocities

6D.28 The second stage of calibration involved comparisons with recorded data. Velocities were sampled at two locations west of Lamma Island during September 1990. These locations are shown in Figure 6F.1 of Appendix 6F. The recorded velocities are analysed in detail in Appendix 6F.

6D.29 Over the period of measurement, the neap tide recorded on 22nd September 1990 was considered to be the most similar to the modelled neap tide. No suitable spring tide was recorded, and as a result the comparison has been limited to the neap tide only. Recorded and simulated velocities for the calibration period are presented in Figures D.9 and D.10.

6D.30 At location C1, in the shallow water of Ha Mei Wan, the magnitude of the resultant velocity predicted by the DIVAST model is approximately 70 per cent of that recorded at the current meter. Some allowance must be made for the fact that the simulated velocities are depth averaged and hence have lower values than those recorded relatively close to the surface. It is notable that at slack water, the current meter readings indicate a substantial velocity, whereas the DIVAST model predicts only very small velocities at the turn of the tide. This may be partly attributed to sensitivity of the meter at low velocities. In terms of direction, there is a difference of up to 20° between modelled and recorded data at certain phases during the tide. At low and high water the model predicts a considerably more rapid reversal in flow, with the recorded velocities changing direction gradually over a period of about 2 hours. Both the recorded and modelled velocities indicate that there is a net southerly movement of the water at this location.

6D.31 At location C2, off the north west coast of the island, the recorded velocities show considerably different characteristics from those at C1. During the flood tide, the peak velocity is approximately 0.25 m/s. The DIVAST model produces an equivalent value of about 0.19 m/s, with a corresponding peak velocity of 0.20 m/s on the ebb tide. The maximum ebb velocity recorded by the current meter was greater than 0.45 m/s. The reasons for this increase velocity are complex. As described in appendix 6F, this effect is probably caused by the brackish water/saline water interface present at this site during this period. This may account for some of the discrepancy between recorded and modelled values. At this location, the flow direction predicted by the DIVAST model agrees with the recorded data. The WAHMO and DIVAST models both predict similar velocities at location C2.

6D.32 During the calibration exercise, various parameters, including bed friction and eddy viscosity were varied. However, the model is relatively insensitive to these parameters, and the boundary conditions seem to dominate the flows throughout the model.

Comparison with Predictions from Tidal Stream Atlas

6D.33 In the Tidal Stream Atlas, a method is given for predicting velocities in the dredged channel west of Lamma Island. Using the tidal ranges for the modelled neap and spring tides, velocities were predicted for a location in the turning circle at the north of the channel. The velocities were predicted in terms of along-channel and cross-channel components, which were then combined to give a resultant velocity.

6D.34 Velocities predicted by the DIVAST model were extracted at the appropriate location in the channel. The results produced by both methods are shown in Figure D11 to D12. Figure D11 shows the magnitude and direction of the resultant velocity, for the neap tide. Figure D12 shows the same for the spring tide. In each case the variation of velocity with time is very similar but the magnitude predicted by the DIVAST model is approximately 70% of that produced using the Tidal Stream Atlas method. This applies throughout the tidal cycle. The predicted directions are in good agreement for both the neap and spring tides. There are several reasons for the discrepancy in the magnitude of velocities. The method used in the Tidal Stream Atlas probably relies on near surface velocities. The DIVAST model predicts depth-averaged velocities, which are smaller than velocities recorded close to the surface. However, the difference between the two predictions reinforces the hypothesis that, although the general flow patterns are predicted well, the hydrodynamic model underestimates the magnitude of velocities in the area west of Lamma Island.

Overall Hydrodynamics of DIVAST Model

6D.35 The velocities and water levels predicted by the DIVAST model agree well with those calculated in the WAHMO suite at equivalent locations. The better reduction of bathymetry in the smaller DIVAST grid will give better resolution of the detail of these flows.

6D.36 Comparisons between the velocities predicted in the DIVAST model with observations from various sources indicate that the model underestimates velocities near Lamma power station. The current directions in the main channel are in good agreement but there are discrepancies between the model and observed current directions in Ha Mei Wan. Attempts to alter the magnitude and direction of velocities predicted by DIVAST were unsuccessful. The most likely cause of the differences between velocities predicted by both DIVAST and WAHMO models in the area around Lamma power station is that the flows around the DIVAST model boundary do not quite agree with those that occur in nature.

6D.37 During the calibration of the WAHMO model, one location 3 km west northwest of the power station was checked and showed reasonable agreement with the model on both spring and neap tides. Nevertheless the area west of Lamma is not in the area where the WAHMO calibration was checked with greatest care. Studies are underway within CESD to extend the WAHMO models south of Lamma Island and check their representation of flows in the west Lamma channel area. When these results become available, the velocities predicted by the WAHMO model should improve near the power station which will allow improved predictions by DIVAST.

Thermal Calibration of DIVAST Model

6D.38 Following the thermal survey carried out during September 1990 (as described in Appendix 6F), a calibration test was performed using the DIVAST model. The test involved modelling 20 tidal cycles preceding the neap tide between 0330 hours and 1610 hours on the 20th September 1990. In this case, the tide was very similar to the modelled neap tide, and the thermal loading was more representative of normal conditions than that of the 22nd September. During this twenty cycle period, temperatures recorded at the power station were used to derive input data for thermal loading. The loading pattern was simulated using daily average values for the first 18 tides, and hourly averages for the final 2 cycles. The heat loss coefficient used in the model was also derived from data recorded during September 1990, and was varied on a daily basis. Boundary conditions for the test were produced by carrying out an initial test using the far-field model. The results were then used to control the temperatures at the boundaries of the near field model. The data used to drive both near field and far field models were taken from Tables 6F.2, 6F.4 and 6F.5 of Appendix 6F as appropriate.

6D.39 The dispersion coefficients were computed as a function of depth and shear velocity, and therefore vary with time and location. The computed dispersion coefficient increases almost linearly with velocity and also water depth. A constant dispersion coefficient was added to the turbulent dispersion coefficient to account for other dispersion processes. The coefficients were usually within the range of 2 to 10 m^2/s, which is comparable with the uniform value of 10 m^2/s adopted for the WAHMO depth-averaged water quality models.

6D.40 The results of the calibration test are shown in Figures D.13 and D.14. The results are shown in terms of temperature excess above ambient. Analysis of the temperature records (as described in Appendix 6F) indicates that an appropriate ambient temperature for the calibration test might be 27.2°C. The temperatures recorded on 20 September had this value subtracted to produce temperature excesses for comparison with the model predictions. The average and maximum temperature excesses calculated from the observations at Stations T1, T2, T3, C1 and C2 are also illustrated. In Table 6D.1 the average and maximum temperature excesses at the recording stations are presented with the corresponding values from both the near-field and far-field models.

6D.41 The results shown in figures D.13 and D.14 indicate that the model overestimates temperatures north of the outfall, and in Ha Mei Wan. The simulated results at T2 are subject to inaccuracy due to the proximity of the outfall. At Station T1, the model tends to underpredict the recorded values. Predicted temperature rise, using the average of the mean and maximum predictions is shown in Figure D.15, together with the maximum observed values. This figure illustrates that this method of estimating temperature rise is closest to the observed data.

6D.42 The prediction of higher excess temperatures by the thermal model is directly linked to the general underprediction of velocities in the hydrodynamic model. The reduced velocities result in limited convection of heat away from the outfall. Dispersion is also reduced. The low convection can only be overcome effectively by increasing velocities in the model. In addition to this, there is uncertainty about the correct value for the ambient temperature. All the absolute temperature comparisons between the model and the observations are sensitive to variations in the ambient temperature.

6D.43 Comparison of the temperature differences recorded in the survey and those predicted by the DIVAST model shows that, in general, the model tends to overpredict. However, with the exception of Station T1, the recorded maximum values lie within the range defined by the average and maximum results predicted by the model. Using the results from the near-field model, and computing values mid-way between the average and maximum temperature excesses, produces the results presented in Table 6D.2. Comparing these with the recorded maximum temperature excesses demonstrates similarity in all cases except for T1. Using the DIVAST model results in this way gives a sufficiently accurate estimate of the temperature excesses around and to the north of Lamma power station

TABLE 6D.1 : COMPARISON OF RECORDED TEMPERATURE EXCESSES WITH THOSE PREDICTED BY THERMAL MODELS

	Mean Temperature Excess			Maximum Temperature Excess		
Location	Recorded* value °C	Near-field model °C	Far-field model °C	Recorded* value °C	Near-field model °C	Far field model °C
T3	0.29	0.4 (+0.1)	0.6 (+0.3)	0.7	1.4 (+0.7)	1.4 (+0.7)
C2	0.29	0.5 (+0.21)	0.5 (+0.21)	1.0	1.4 (+0.4)	1.2 (+0.2)
T2	0.70	1.4 (+0.7)	1.3 (+0.6)	2.2	2.9 (+0.7)	2.8 (+0.7)
C1	0.43	1.0 (+0.57)	0.9 (+0.47)	1.2	1.9 (+0.7)	2.2 (+1.0)
T1	0.39	0.1 (-0.29)	0.0 (-0.39)	0.9	0.2 (-0.5)	0.0 (-0.9)

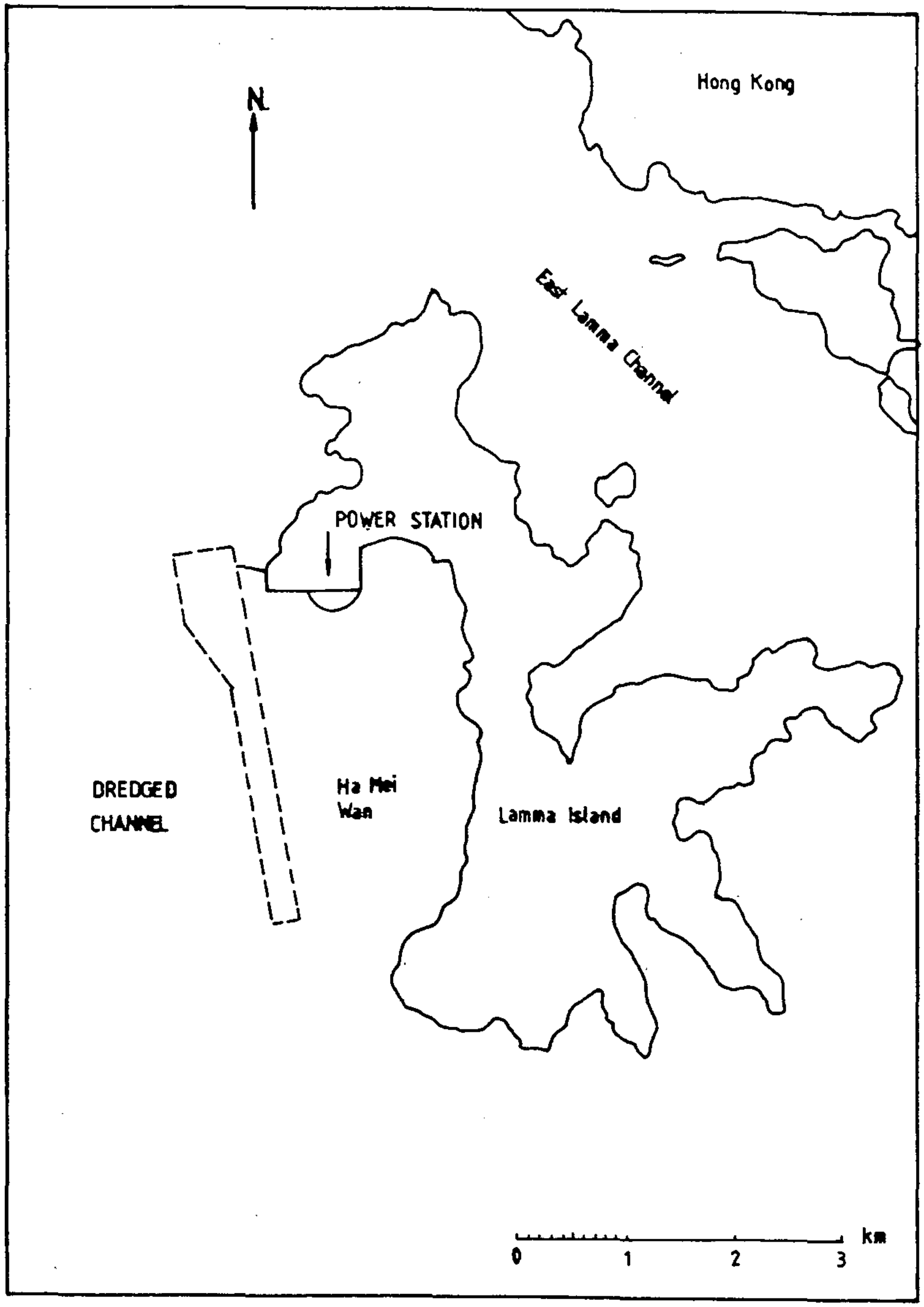
* Recorded values calculated using ambient temperature of 27.2°C

Figures in Parenthesis are the Differences Between Predicted - Observed Temperature Excess

TABLE 6D.2

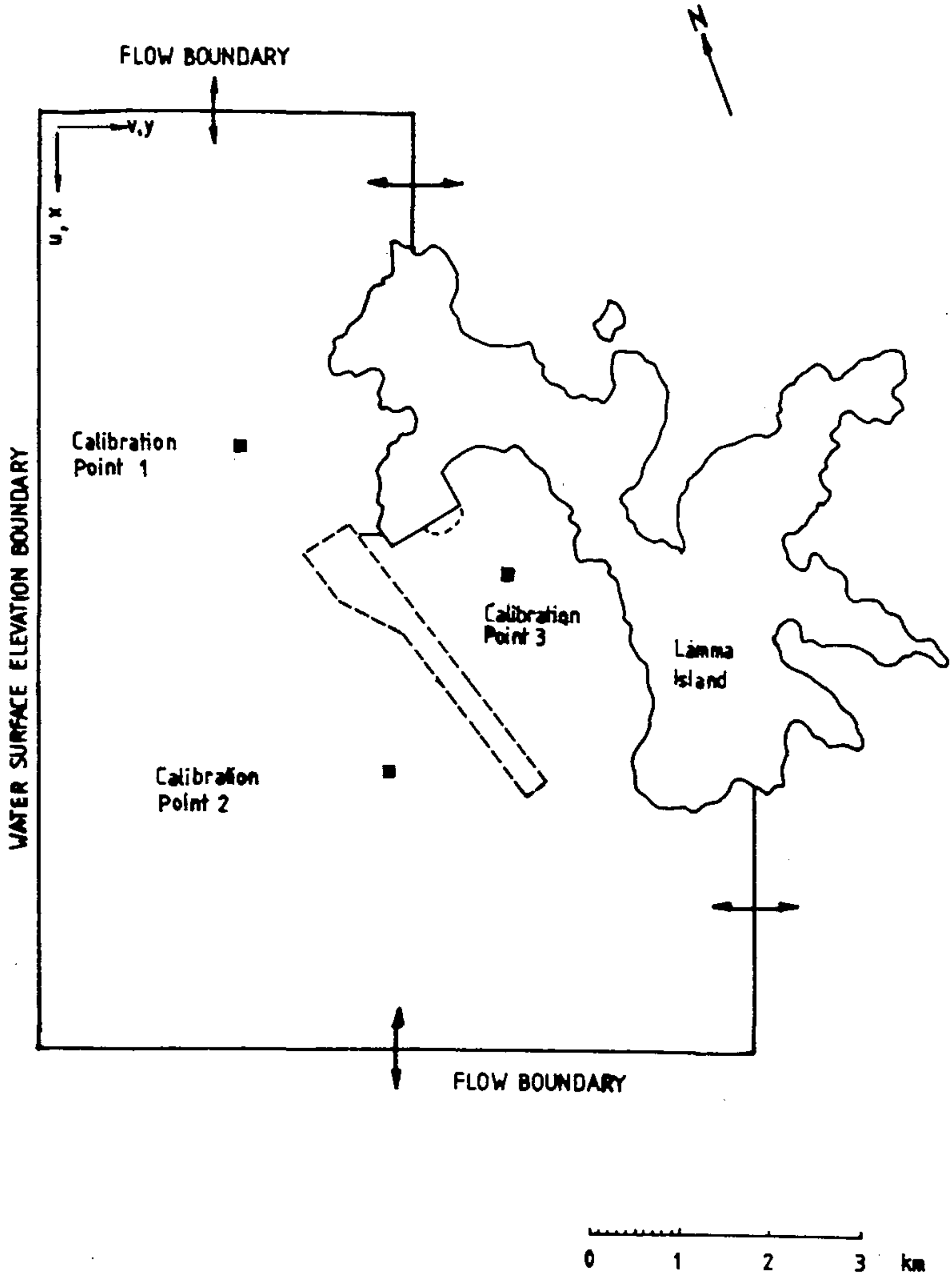
	Temperature Excess (°C)		Model estimate of maximum temperature excess (°C)	
Location	Distance from Outfall (km)	Maximum* Recorded Value	Near Field Model	Far Field Model
T3	1.9 (N)	0.7	0.90	1.00
C2	1.0 (N)	1.0	0.95	0.85
T2	0.3 (S)	2.2	2.15	2.05
C1	1.0 (S)	1.2	1.45	1.55
T1	3.2 (S)	0.9	0.15	0.0

* Recorded values calculated using ambient temperature of 27.2°C



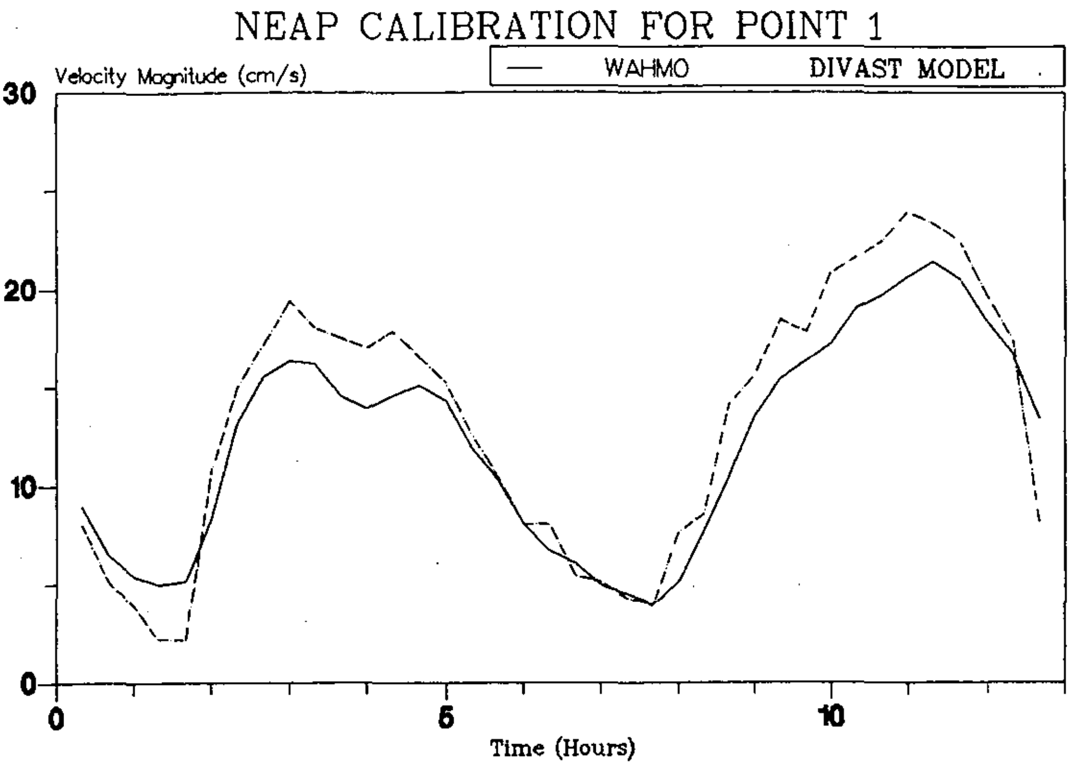
LAMMA ISLAND

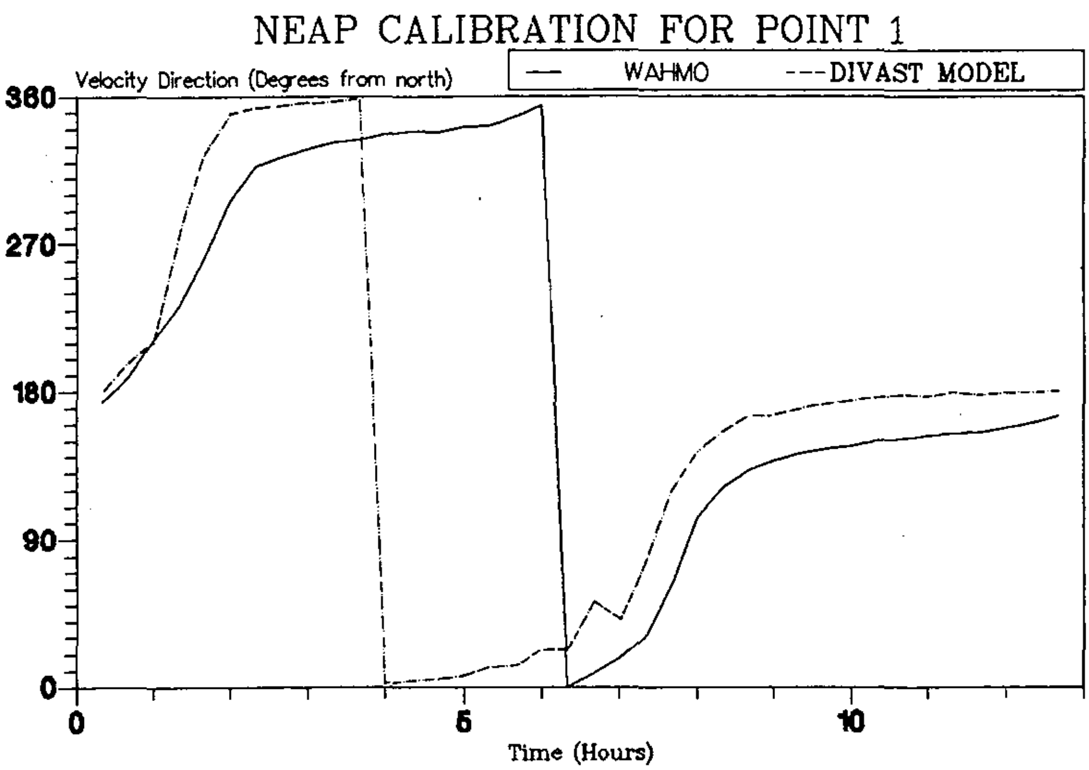
Figure D1



LOCATION OF MODEL BOUNDARIES AND CALIBRATION POINTS

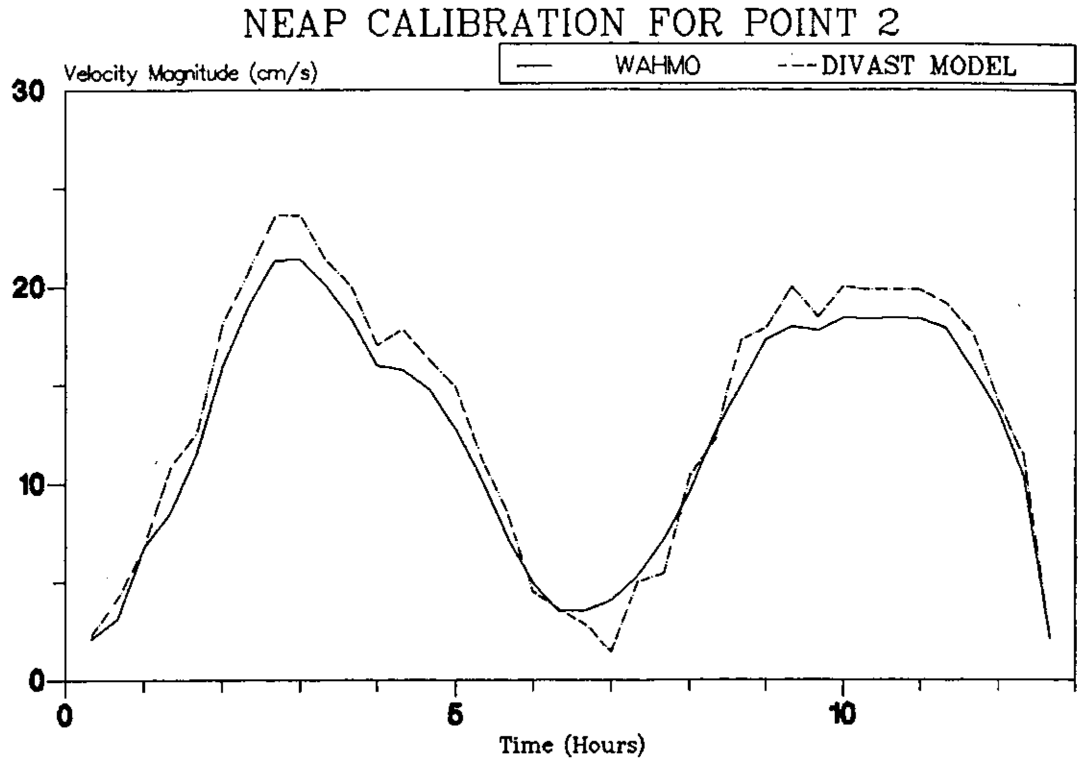
Figure D2

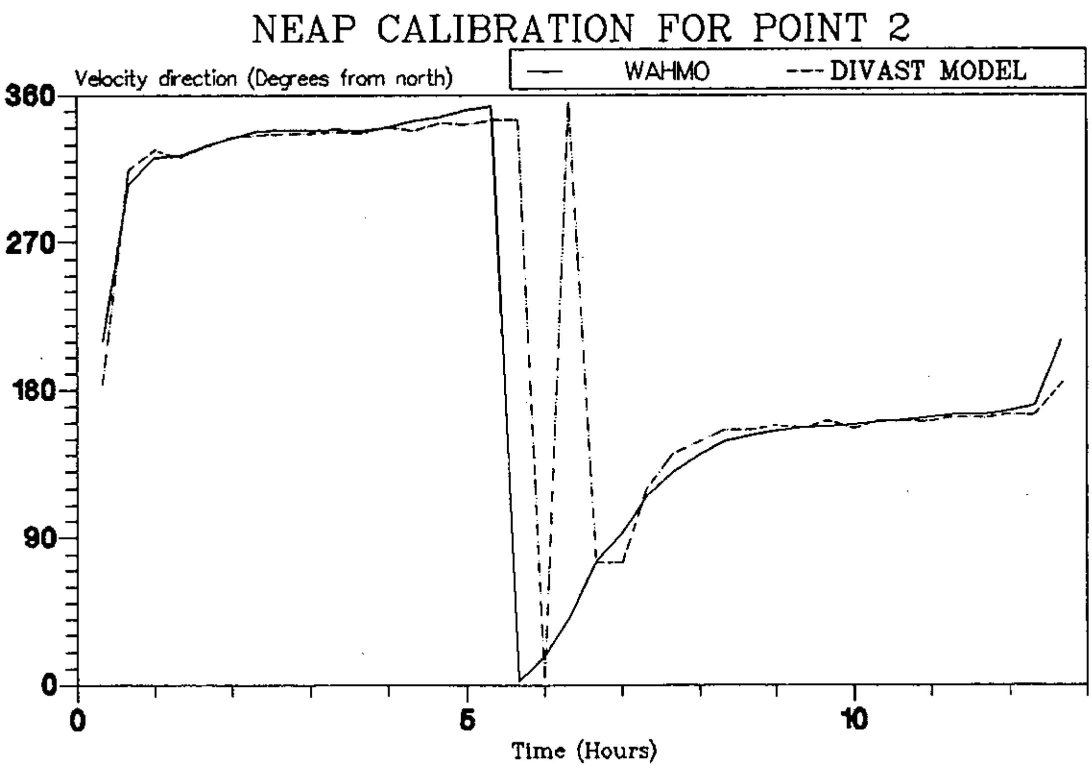




Velocity calibration curves
- neap tide - point 1

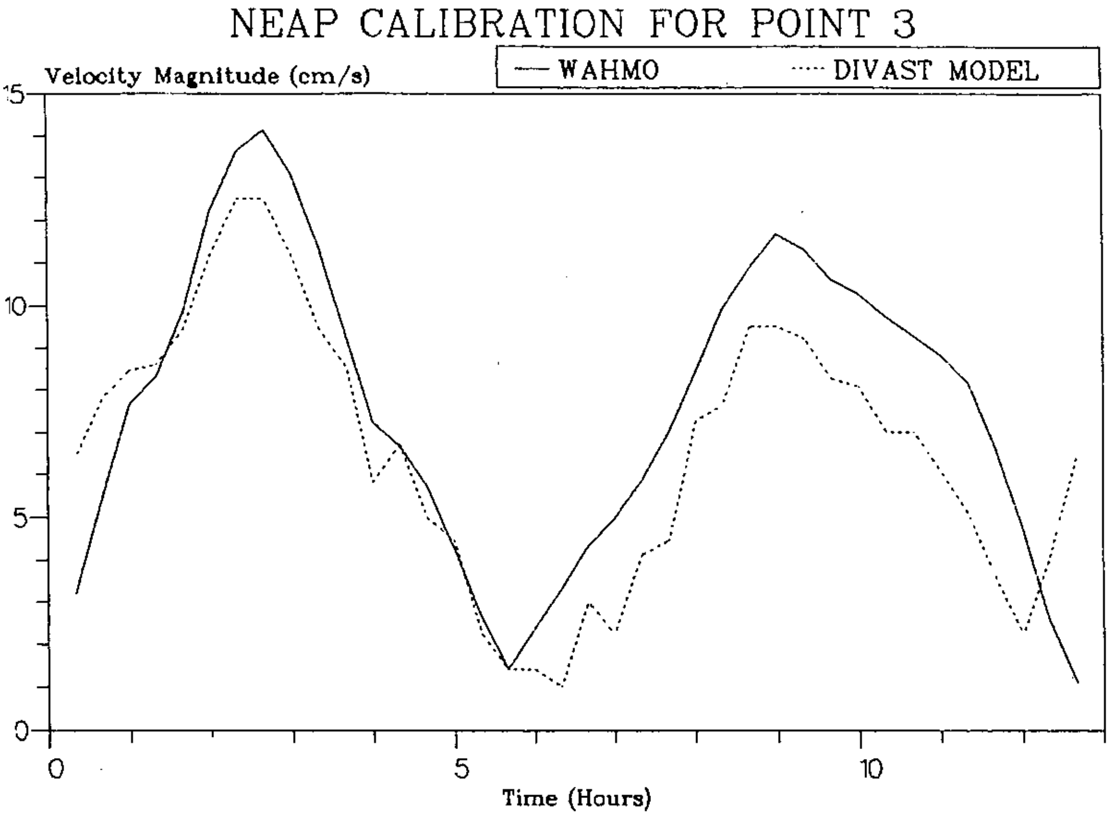
FIGURE D3

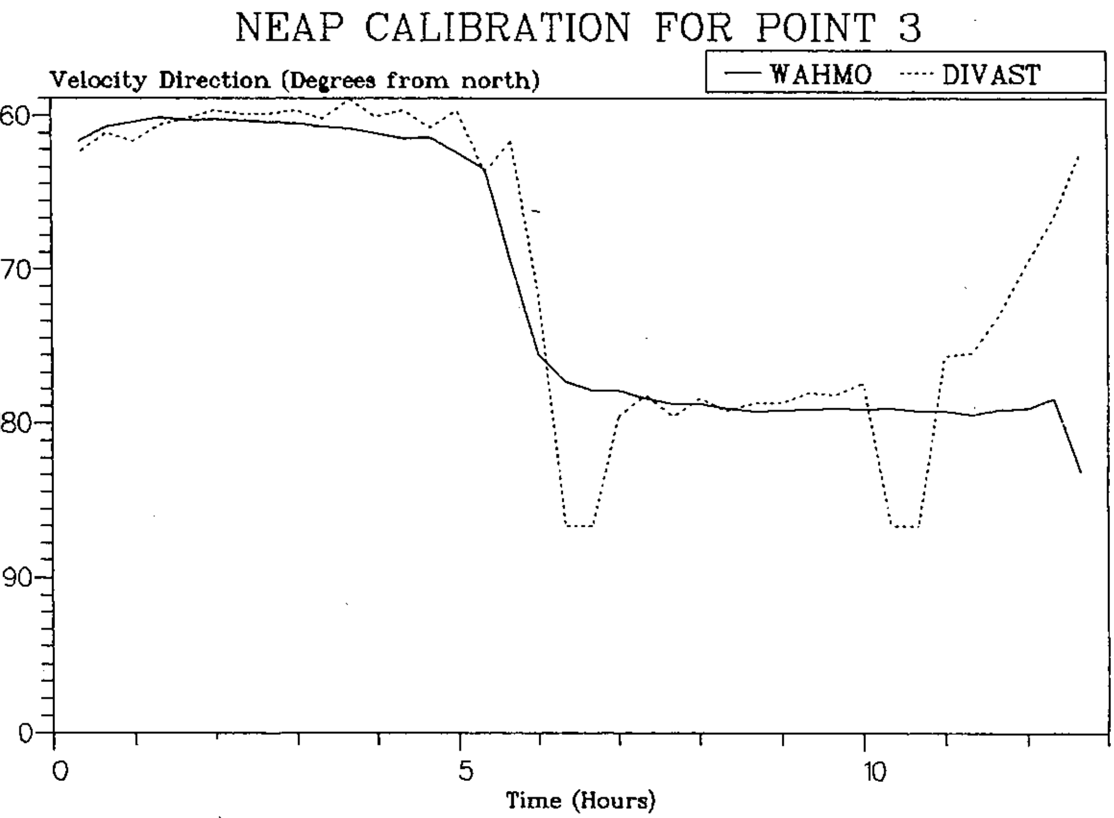




Velocity calibration curves
- neap tide - point 2

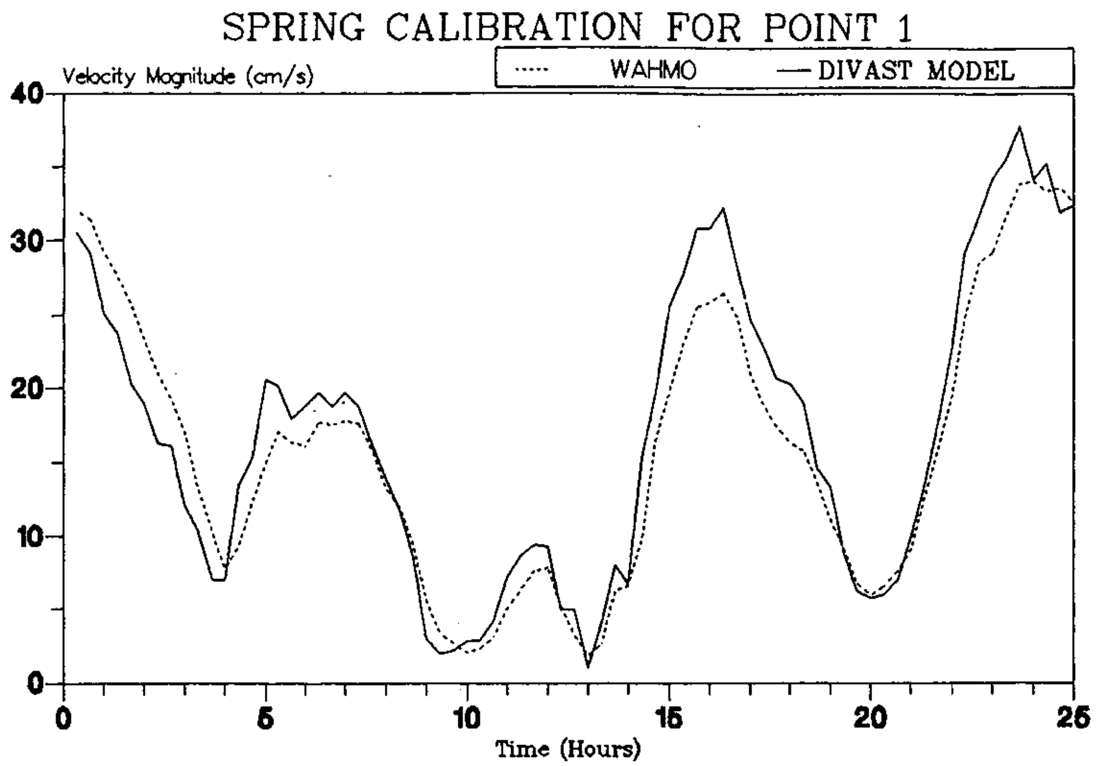
FIGURE D4

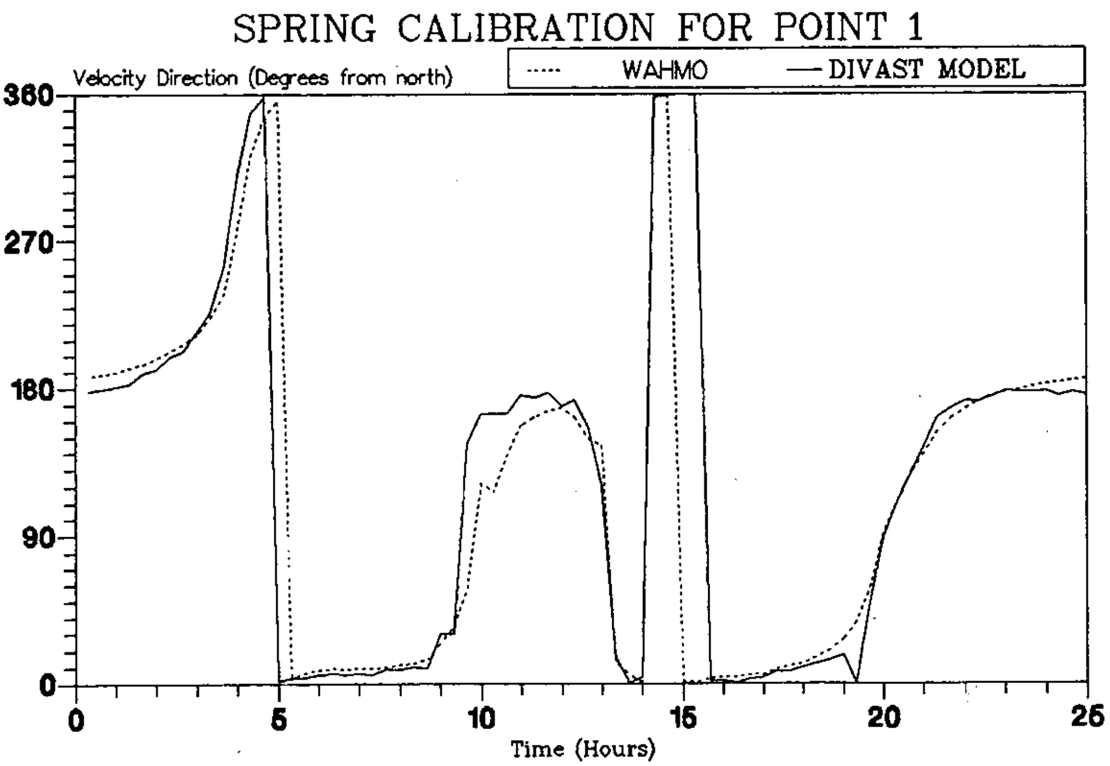




Velocity calibration curves
- neap tide - point 3

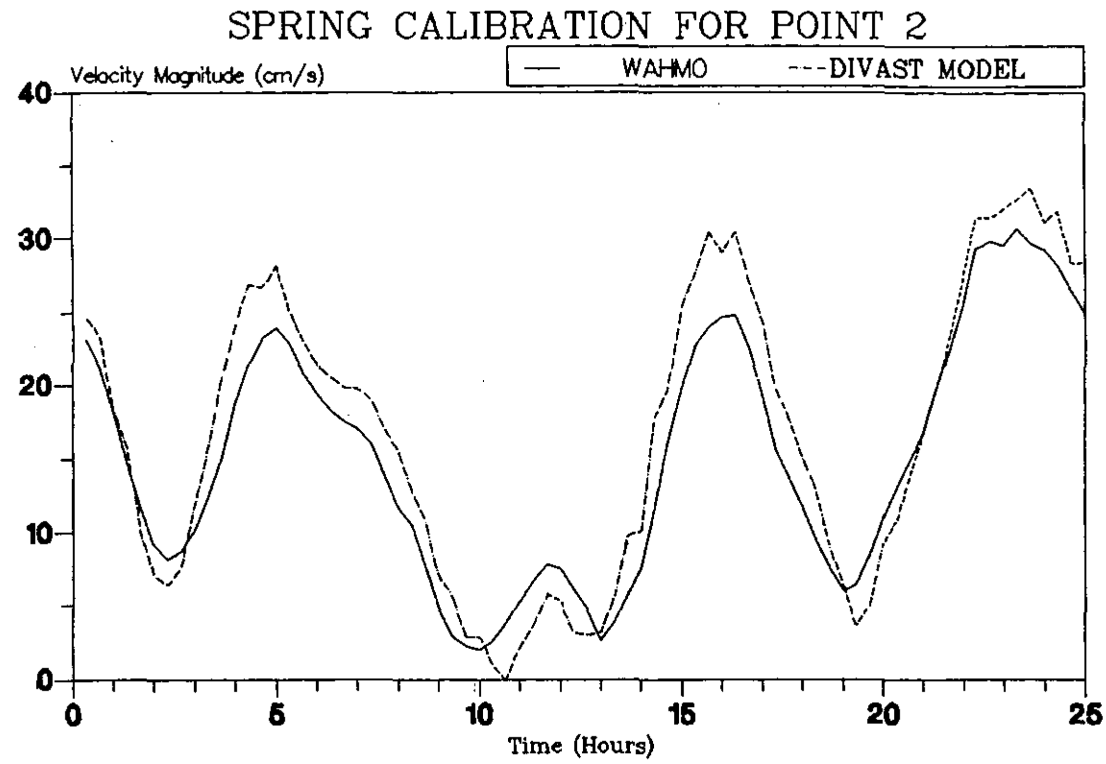
FIGURE D5

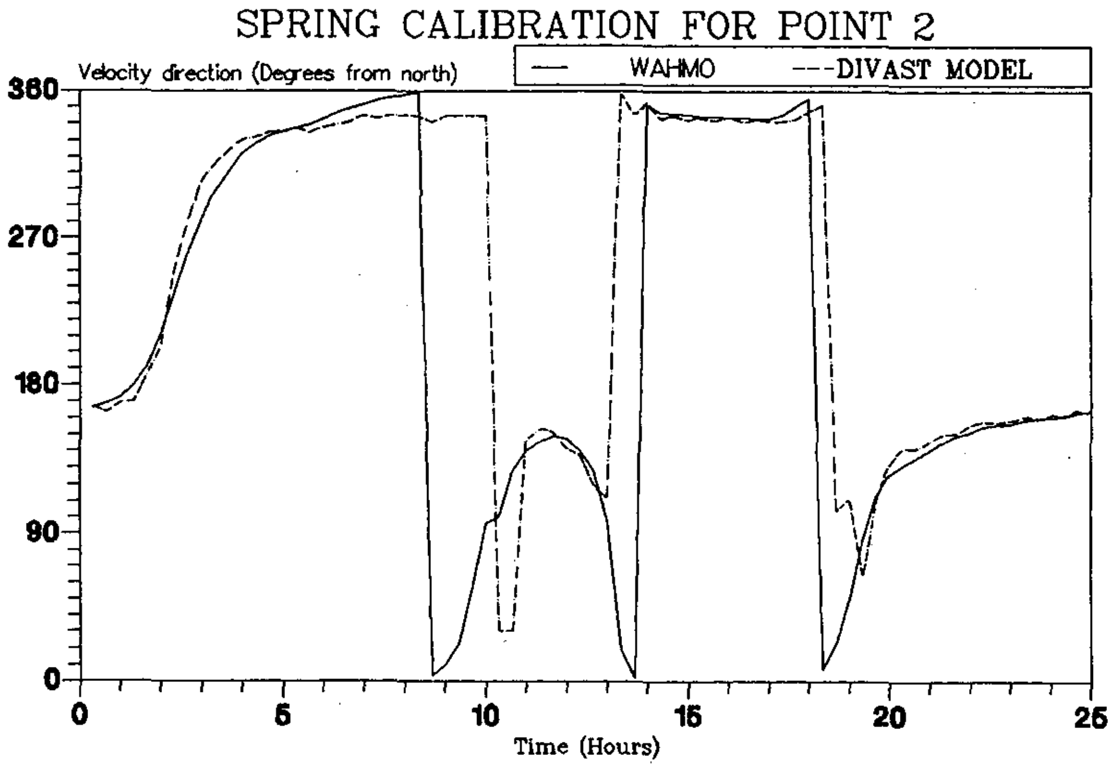




Velocity calibration curves
- spring tide - point 1

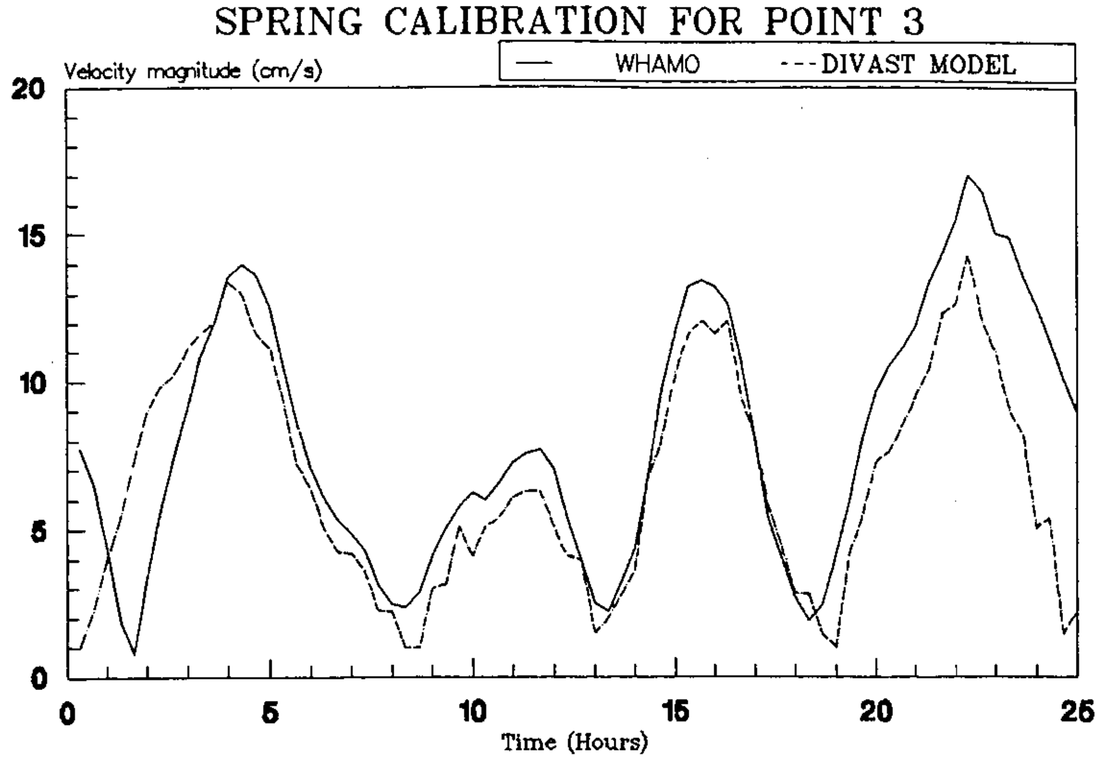
FIGURE D6

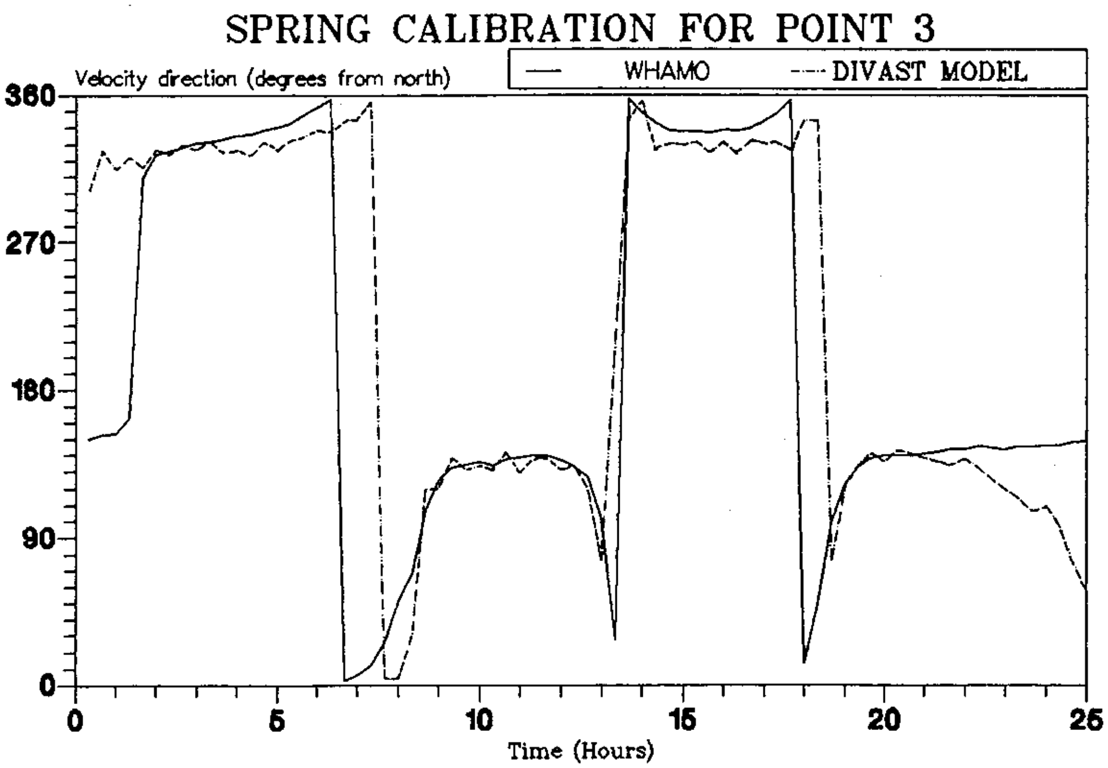




Velocity calibration curves
- spring tide - point 2

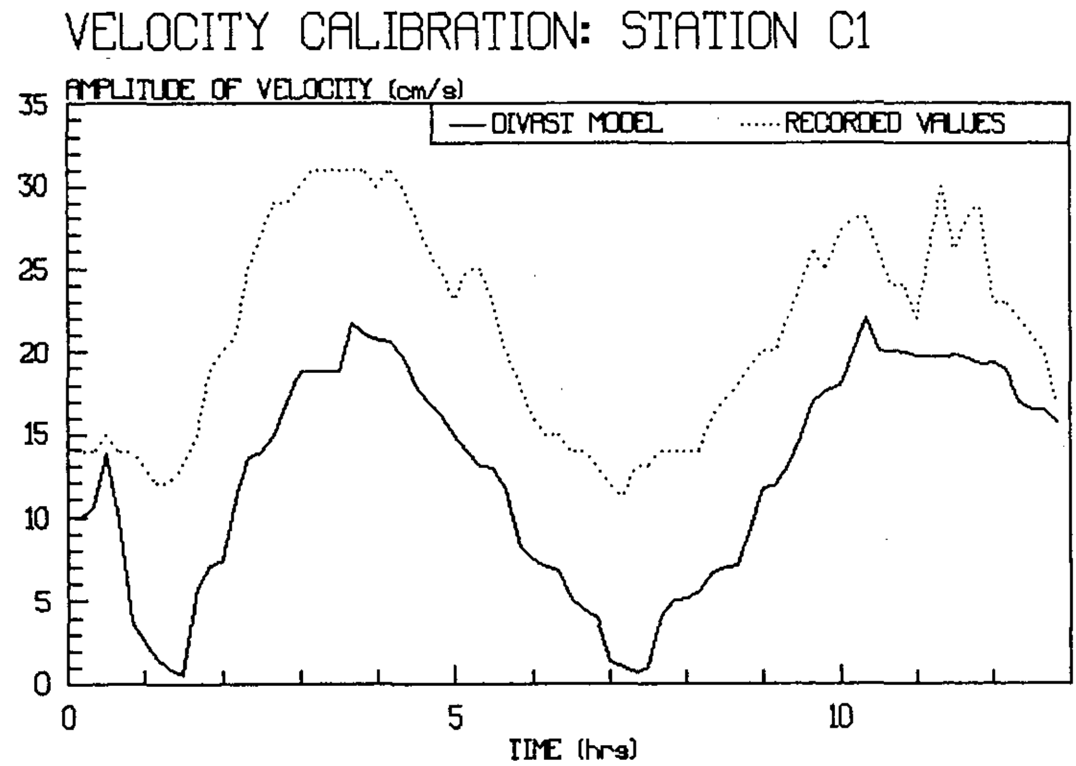
FIGURE D7

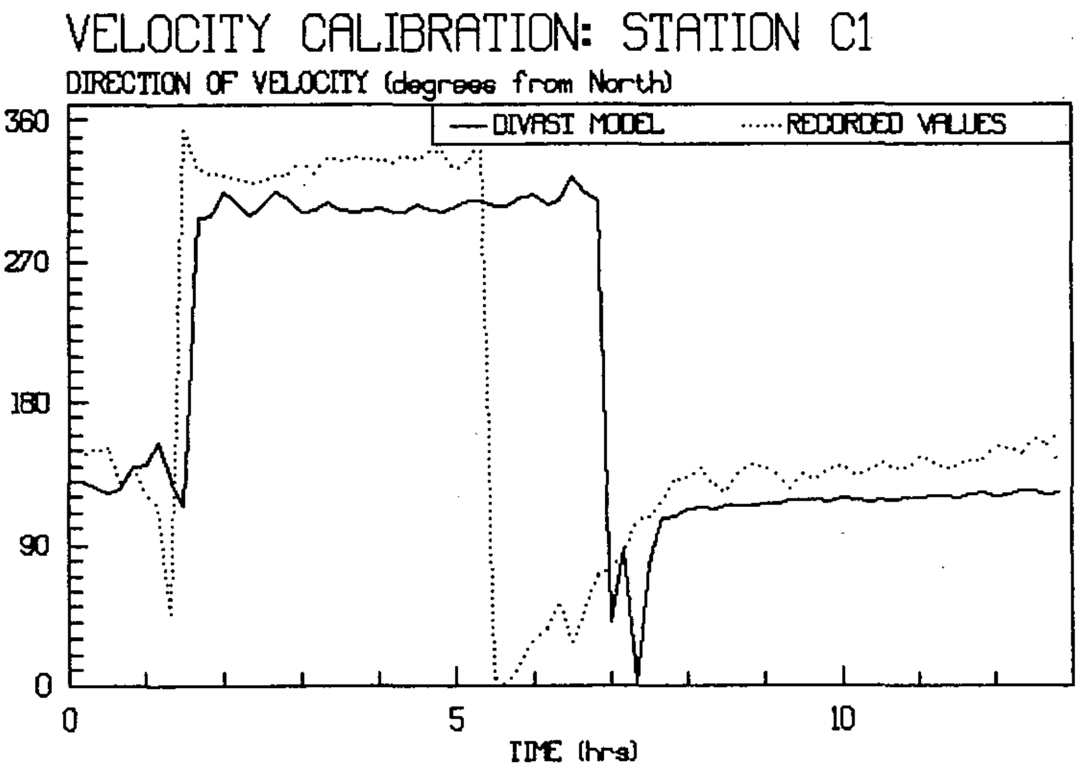




Velocity calibration curves
- spring tide - point 3

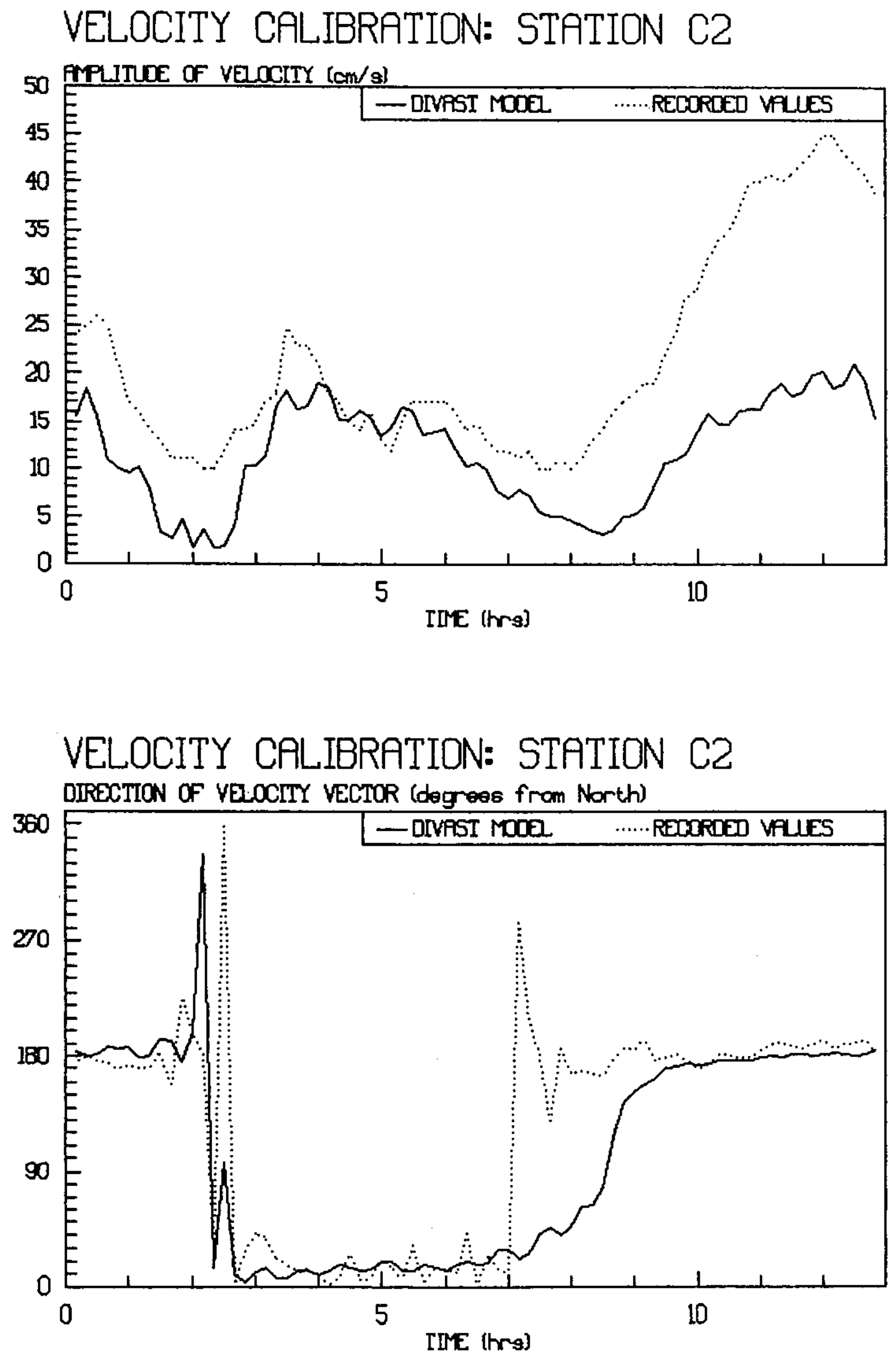
FIGURE D8





Recorded and modelled velocities
- Neap Tide (22/9/90)

FIGURE D9



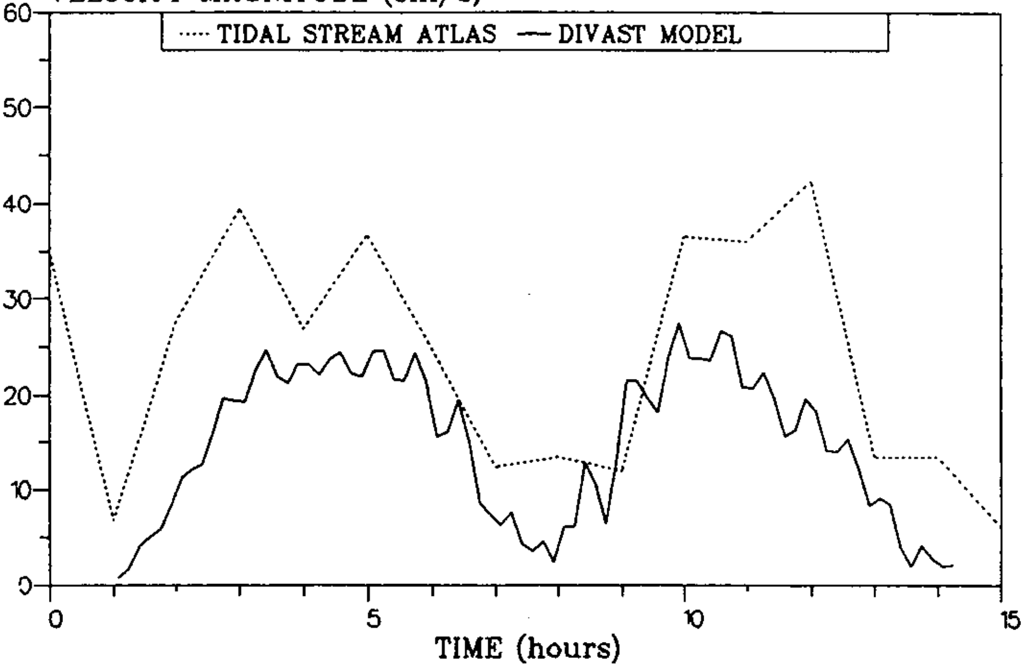
Recorded and modelled velocities
- Neap Tide (22/9/90)

FIGURE D10

PREDICTED VELOCITY IN DREDGED CHANNEL

NEAP TIDE

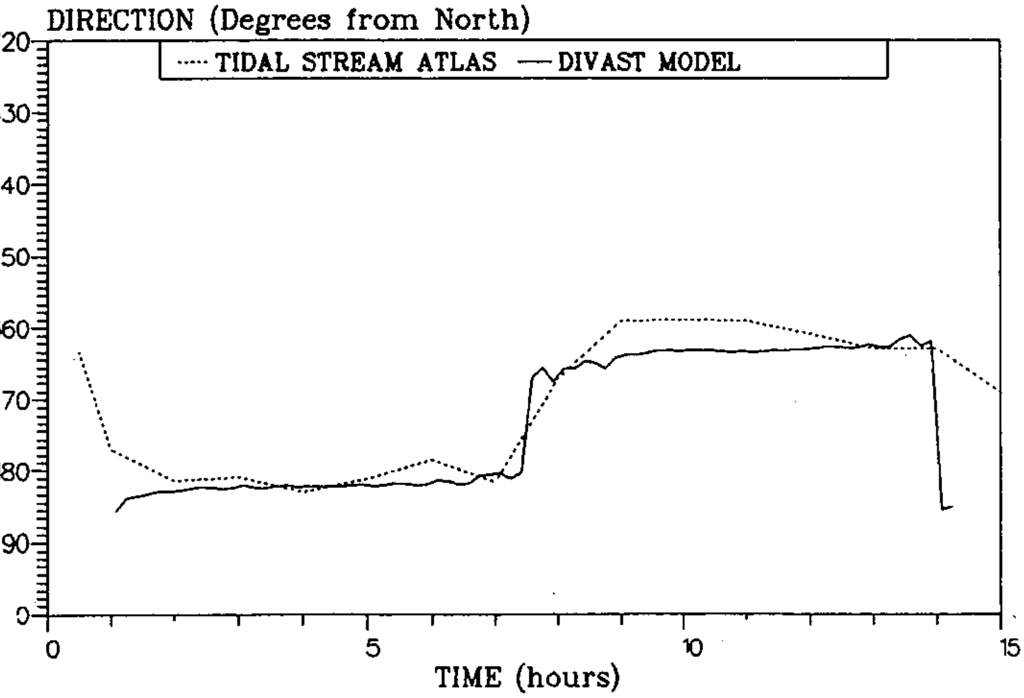
VELOCITY MAGNITUDE (cm/s)



PREDICTED VELOCITY IN DREDGED CHANNEL

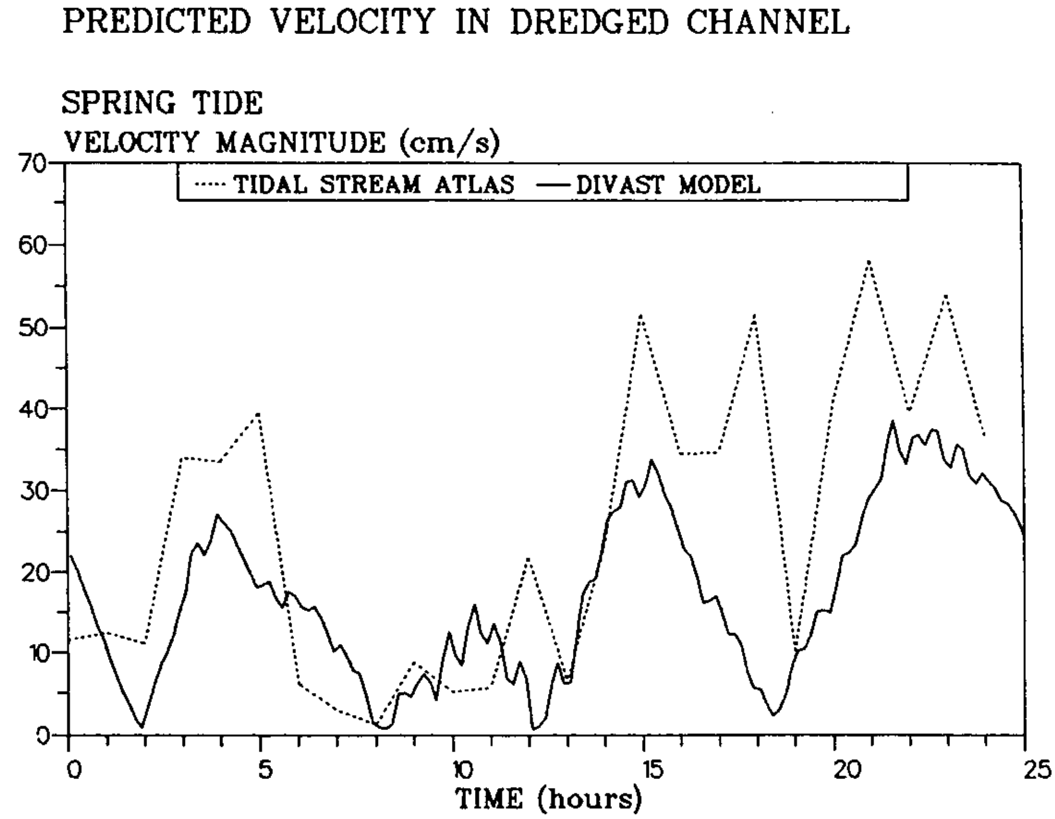
NEAP TIDE

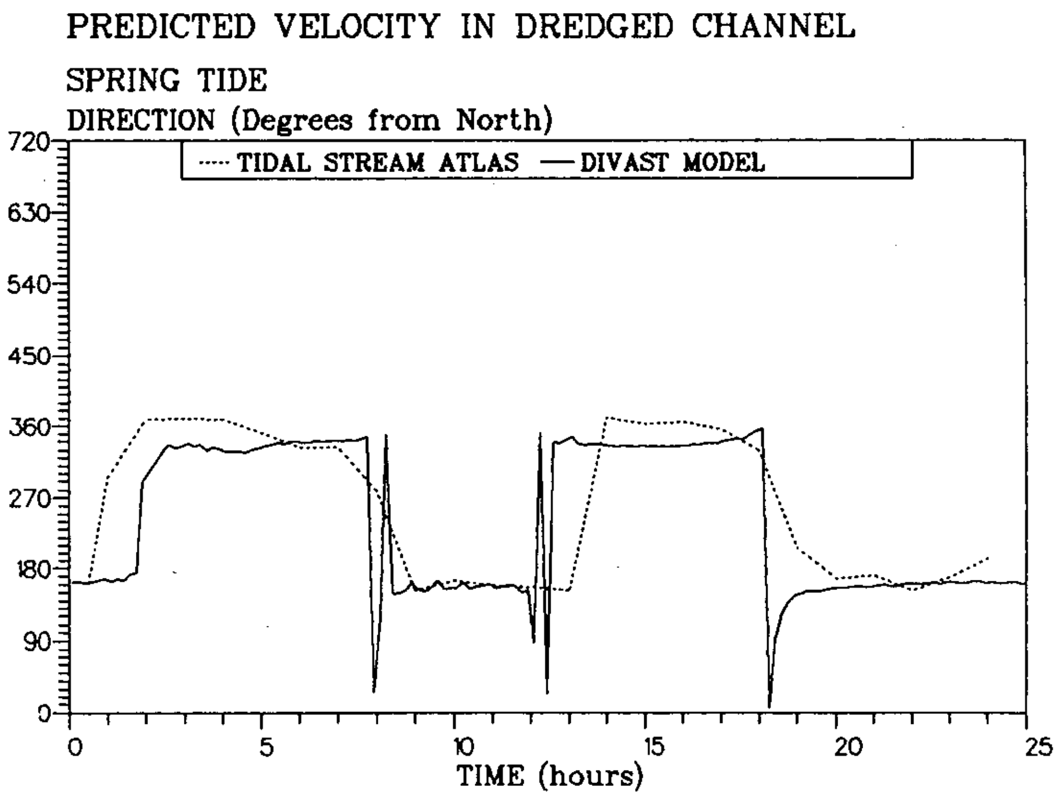
DIRECTION (Degrees from North)



Comparison of predicted velocities
- Neap Tide

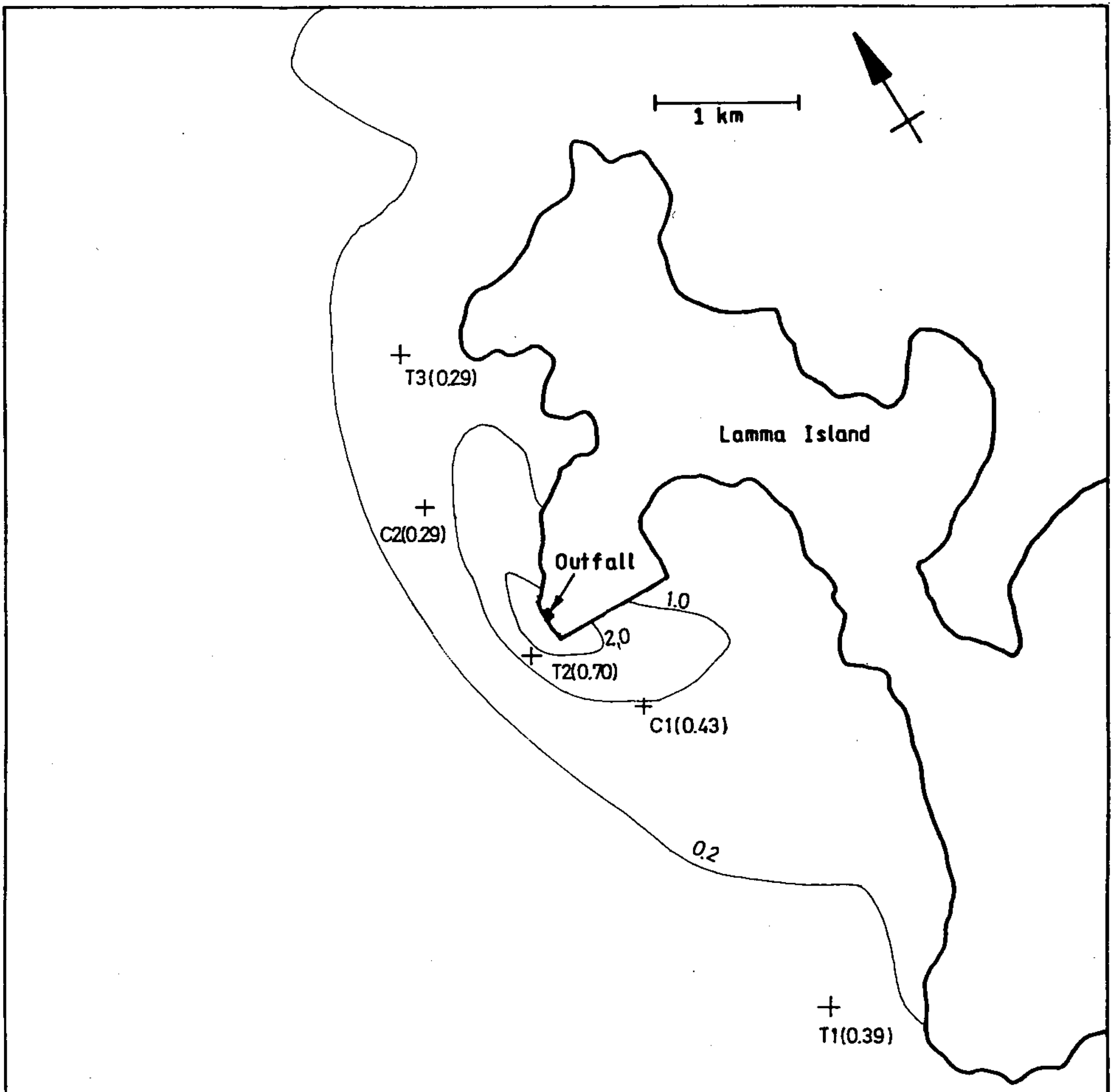
FIGURE D11





Comparison of predicted velocities
- Spring Tide

FIGURE D12



+Fixed thermometers (mean temperature rise)

The Hongkong Electric Company Limited

- Dry season
- Neap tide
- Calibration (1990)
- Mean temperature above ambient °C

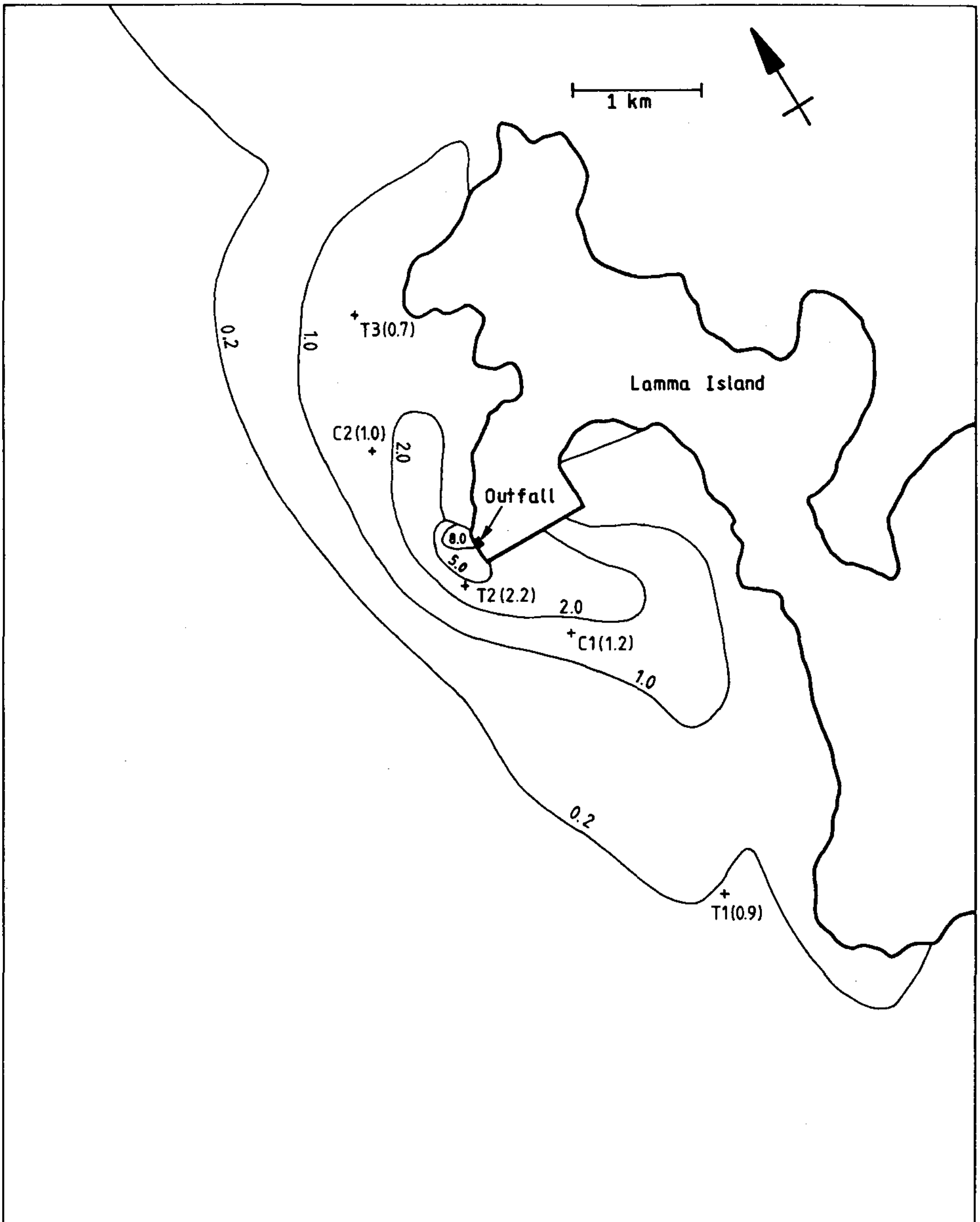
PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE D13



The Hongkong Electric Company Limited

Comparison of observed and model maximum temperatures for 20 September 1990

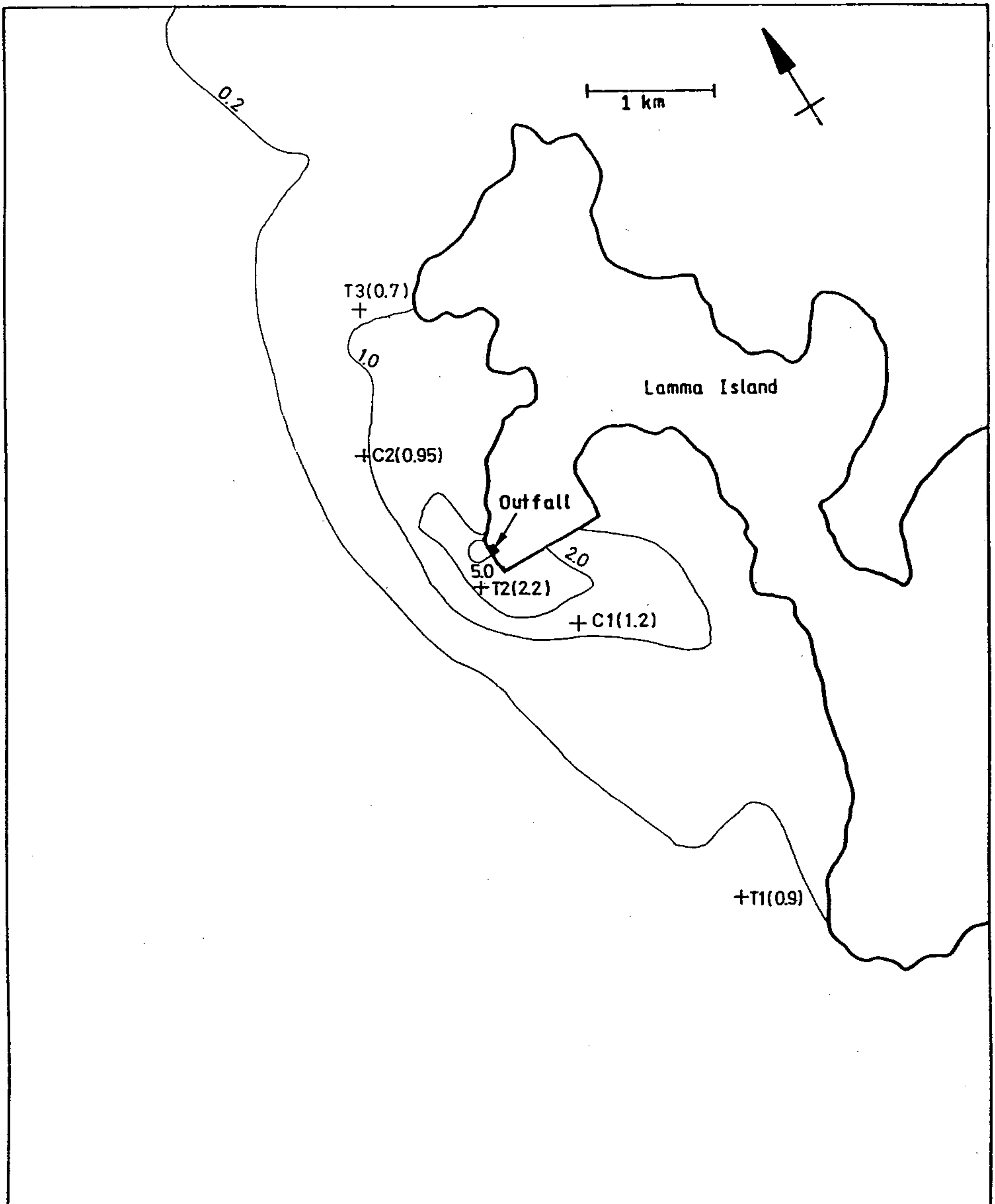
PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE D14



+ Fixed thermometers (mean temperature rise)

The Hongkong Electric Company Limited

Comparison of model estimate of maximum temperature rise with observed maximum rise

PROJECT

EIA LAMMA POWER STATION

TITLE

Near Field Model-Results

FIGURE D15

APPENDIX 6E
THE PLUME MODEL

APPENDIX 6E

THE PLUME MODEL

Introduction

6E.1 Analysis of the near field processes is considered in two parts. These are:

- the plume movement with time;
- the plume temperature with time;

6E.2 The first of these is determined using a computer model which uses the DIVAST hydrodynamic data to plot the position of float tracks.

6E.3 The plume temperature is estimated using a mathematical representation of the temperature decrease due to eddy dispersion and lateral mixing as well as heat loss to the atmosphere. This model applies after the plume has stabilised with respect to the surrounding flows. The plume's initial velocity has then decreased to the point where the plume does not move relative to the local water mass. The initial temperature and width of plume are calculated for this situation and input to the temperature model.

6E.4 The model results give a time averaged picture of the plume giving the extent of temperature elevation above ambient caused by the cooling water discharge in the surface layer for the chosen tide conditions. The ambient temperatures are determined using data from the near field model.

Plume Movement

6E.5 Subsequent to the stabilisation of the plume with respect to the surrounding flows, plume movement is obtained using a float track model with hydrodynamic data from the main DIVAST model.

6E.6 The float track model is a proven module of the DIVAST program. The module linearly interpolates velocity data at the DIVAST cell boundaries to obtain the velocity at a given position and time. This velocity is used directly to determine the displacement of a mass of water over a timestep, and these displacements are stored as a series of co-ordinates related implicitly to time.

Plume Temperature

6E.7 There are a number of mechanisms by which the outfall plume reduces in temperature. These involve the transfer of heat energy from the outflow into the surrounding environment. The dilution of the plume, as it moves first through, and then with, the local flows, is, however, by far the most significant mechanism. There is some heat loss to the atmosphere and therefore a reduction in the plume temperature but this is much less significant in the near field plume model than distant from the outfall. These two methods of temperature reduction are used in this study, other mechanisms being considered only to justify their exclusion.

Plume Dilution Due to Eddy Dispersion

6E.8 Random eddy motions and the non-uniformity of current patterns are inevitable components of any turbulent flow. Such motions will cause mixing of the cooling water with the ambient water and will bring about dilution of the plume. These dispersion processes can be described using a Fickian analogy to define the steady-state two-dimensional convection dispersion equation.

6E.9 The dispersive flux in the direction of water movement has been ignored because it is generally much less than the convective flux due to the velocity. Vertical dispersion is also considered to be negligible as this is usually found to be several orders of magnitude less than the lateral dispersion.

6E.10 The solution to the plume dispersion equation described by Wiegel [12] was originally developed by Brooks for conservative pollutants. Although his analysis is restricted to unidirectional flow, it is informative in that it gives an estimate of the likely duration during either the ebb or flood tide. Brooks' analysis, as applied here to the summation of the instantaneous plume shapes, gives envelopes of temperature rise within which, at some stage of the cycle, the particular temperature would occur. At any one time however there will only be a relatively small area at this temperature, the remainder being at a lower temperature.

6E.11 The mixing of the plume is described in the model by a lateral mixing coefficient. This is a function of many physical phenomena, including vertical density gradients, wind effects, tidal currents and local topography. The dispersion coefficient of 10 m^2/s used in the WAHMO studies has been adopted for this study.

Surface Heat Loss

6E.12 Although surface heat losses are not the primary mechanism by which temperatures are reduced in the plume they are not negligible. The rate at which heat passes into the overlying air is proportional to the difference between the water temperature and the natural equilibrium temperature. The equilibrium temperature, depending on solar radiation and meteorological conditions, is the temperature which the sea would naturally attain in the absence of any heated discharge.

6E.13 Temperature reduction due to evaporative cooling is calculated as a function of time or water age by considering exponential decay. In this study, a typical heat transfer coefficient value of 40 $W/m^2/°C$ was used.

Plume Dimensions

6E.14 The existing CW outfall at Lamma Power Station is a 22.5 m wide by 3 m deep culvert which discharges the cooling water at a velocity of about 1 m/s just below the water surface. This jet of water is directed offshore. The addition of units L7 and L8 will require an additional outfall which we have assumed will discharge water at the same velocity from a 8.5 m wide by 3 m deep culvert at the same level. For the analysis of how the plume develops immediately after discharge, the extra outfall has been assumed to be alongside and parallel to the existing outfall.

6E.15 The behaviour of the warm jet of cooling water discharged by the outfall will be determined by the buoyancy and momentum of the jet, and the depth and velocity of the offshore tidal stream. The plume model is used to calculate the movement of the plume once its initial momentum has been dissipated and the discharge behaves as a buoyant plume moving with the tidal flow. The mechanisms that occur in the initial discharge phase cause some dilution of the discharge which reduces the initial temperature of the plume and increases its cross sectional area.

6E.16 The theory describing the evolution of a buoyant near surface jet discharged into a crossflow is complex. Papers describing this process have been published by Jirka et al [10] and Chu and Jirka [11]. Using the equations and relationships proposed in these papers, the initial dimensions and dilution of the plume have been calculated. The results are presented in Table E1. These plume dimensions and dilutions have been used as input to the plume model.

6E.17 The water which is available to dilute the CW discharge will be above ambient temperature. For the purposes of plume modelling the initial dilution of the CW discharge takes place with water close to the outfall, which has a temperature significantly above ambient. The assumed temperature of this dilution water, which is shown in Table E1, is based upon modelled water temperatures near the outfall, but 'upstream' of the discharge. The plume dimensions, and dilutions indicate that after taking account of recirculation and local water temperature rises, the water in the plume will be around 2°C warmer than the surrounding water.

TABLE 6E.1 : INITIAL PLUME DIMENSIONS AND TEMPERATURES

Power Station Output (MW)	660	1800	2500
CW discharge (m^3/s)	30.7	72.2	99.5
Tide velocity (neap) (m/s)	0.2	0.2	0.2
Tide velocity (spring) (m/s)	-	0.4	0.4
Calculated Plume depth (m)	5.3	7.2	7.8
Neap plume width (m)	126	207	243
Spring plume width (m)	-	104	121
Plume dilution	4.4	4.1	3.8
Condenser temperature rise (°C)	7.25	8.0	8.0
Initial plume temperature excess (°C)	1.65	1.95	2.11

APPENDIX 6F
THERMAL SURVEY SEPTEMBER 1990

APPENDIX 6F

Thermal Survey September 1990

6F.01 The purpose of the September 1990 thermal survey, which was specified by B&P and carried out by Electronic and Geophysical Services Ltd (EGS), was to enable a thermal calibration review to be undertaken of the numerical heat dispersion model, based on a comparison between model results and field data.

Thermal Survey

6F.02 The thermal survey, which was carried out during spring (diurnal) tides and neap (semi-diurnal) tides during the period 13 to 25 September 1990, included measurements of:-

- water temperature at five fixed points
- water velocity and salinity at two fixed points
- water level at Lamma power station
- water temperature transects along 9 lines in the vicinity of the power station.

The sites of these measurements are shown on Figure F1, and the details of each part of the survey programme are outlined below. The full results are contained in the EGS survey report [7].

a) Fixed station temperature measurements at Stations T1, T2 and T3 located respectively at the south end of the dredged channel, at the Main Jetty and at the Shek Kok Tsui lighthouse north of the power station, were taken at 10 min intervals continuously during the period 13-25 September. The temperature probes, which were accurate to 0.1°C, were at a fixed level of 2 m below Chart Datum.

b) Fixed station thermal, salinity, conductivity and current velocity and direction measurements at Stations C1 and C2 located respectively about 1 km south and north of the main jetty were taken at 10 min intervals continuously during the period 18-25 September. The instruments were maintained at a constant depth of 4 m below the sea surface. The temperature measurements were accurate to 0.1°C, the salinity measurements to 0.1 parts per thousand (ppt), the conductivity measurements to 0.1 milli-siemens/cm, the current velocity measurements to 0.01 m/s and current direction to 5°.

c) Tidal measurements were made continuously during the period 13-25 September at the West Heavy Loading Jetty using a Seba Alpha recording tide gauge.

d) Temperature transect measurements were carried out, over two 52-hour periods during 19-21 September and 23-25 September, along a total of 9 east-west transect lines covering an area of sea between some 2 km north to 1 km south and 1.5 km east and 1 km west of the outfall location. The temperature probe, which was accurate to 0.1°C, was towed at two different depths, 2 m and 4 m below the sea surface. At mid flood and mid ebb all 9 transect lines were employed; at high water, the 5 transect lines at and to the north of the outfall were employed (3 lines for the 4 m measurements); and at low water the 5 transect lines at and to the south of the outfall were employed (3 lines for the 4m measurements).

Supplementary Sea Temperature Data

6F.03 Sea surface temperature measurements taken twice daily at North Point for the period 1-30 September were supplied by the Hong Kong Royal Observatory. The temperatures were given to the nearest 0.5°C.

Power Station Heat Load Data

6F.04 HEC supplied data defining the flow and temperature rise in each power station condenser every hour during the period 3-25 September.

Hong Kong Meteorological Data

6F.05 Data on wind velocity and direction measured continuously at Lamma Power Station were supplied by HEC, covering the period 1-29 September. This gave the hourly averages, maximum values and standard deviations of the wind velocity and direction.

6F.06 The Hong Kong Royal Observatory supplied daily average meteorological data for the period 1-30 September. This data included information on air temperatures, humidity, rainfall, radiation and evaporation as well as wind speed and direction at Waglan Island. Similar data were also supplied for March 1985 when the previous thermal survey was undertaken [6].

Analysis of Meteorological Data

6F.07 The heat discharged with the power station cooling water is dispersed by the tidal currents around the discharge point. This heat raises local water temperatures and thus the heat losses from the water surface due to radiation, evaporation and sensible heat transfer. These surface heat losses limit the rise in water temperature that would otherwise occur.

6F.08 Studies by the UK CEGB [14] on Lake Trawsfynydd in Wales have shown that the rate of heat loss from the water surface is a function of the water temperature, the air temperature, the humidity, the wind speed and atmospheric stability. The equation developed by CEGB is:

Heat Loss =

$$5.5 \times 10^{-8} (T_o + 273)^4 + (a + bU) (V_o - V_a + 0.61 (T_o - T_a))$$

where T_o is water temperature
T_a is air temperature
U is wind speed
V_o is water surface vapour pressure
V_a is air vapour pressure
and a & b are fitting coefficients.

6F.09 The values of the fitting coefficients depend on atmospheric stability and whether wind measurements are made over land or sea. The values of the coefficients recommended by CEGB are given in Table 6F.1.

6F.10 In the original environmental statement for Lamma Power Station prepared by Cremer & Warner [9] the same method of calculating heat transfer coefficient was used. In that statement coefficient values relating to over water wind measurements from Cheung Chau in a stable or unstable atmosphere were used. In this reassessment, the coefficients relating to over land wind measurements from Waglan Island in a neutral atmosphere were used instead. The measured wind speeds at Waglan Island were reduced to convert the wind speeds measured at the anemometer which is positioned 20 m above the ground surface to the standard height of 10 m required in the heat loss equation.

6F.11 Heat loss calculations have been made for each day in September 1990 and March 1985 to define the heat transfer coefficient on each day. The results are contained in Table 6F.2. On individual days the calculated heat transfer coefficient varied from 15.2 to 52.2 W/m² °C. Higher coefficients occur in September than March because of the warmer water.

6F.12 The monthly average heat transfer coefficient for the two months is compared in Table 6F.3 with the values assumed in the environmental statement for the original power station [9]. The results from the two methods are in good agreement when the differences in water temperature are taken into account.

6F.13 In the thermal validation studies the values for the heat transfer coefficient for each day given in Table 6F.2 have been used. For predictions of baseline and future conditions, a heat transfer coefficient of 40 W/m² °C has been used for the wet season and 25 W/m²°C for the dry season to reflect the differences in water temperature.

TABLE 6F.1 : FITTING COEFFICIENTS IN HEAT LOSS EQUATION

Coefficient	a (Wm^{-2} $mbar^{-1}$)	b (Jm^{-3} $mbar^{-1}$)
Land based anemometer		
- stable atmosphere	0	1.8
- neutral atmosphere	2.2	1.8
- unstable atmosphere	4.4	1.8
Sea based anemometer		
- stable atmosphere	0	2.5
- neutral atmosphere	1.8	2.5
- unstable atmosphere	3.6	2.5

Note:

Land based anemometer 10 m above land surface
Sea based anemometer 3 m above water surface

TABLE 6F.2 : CALCULATED HEAT TRANSFER COEFFICIENTS, MARCH 1985, SEPTEMBER 1990

	Heat Transfer Coefficient W/m² °C	
Date	March 1985	September 1990
1	24.3	21.2
2	21.2	37.0
3	29.2	35.1
4	24.5	30.5
5	24.2	19.4
6	27.3	24.1
7	22.6	30.1
8	20.5	37.2
9	27.0	42.7
10	34.2	49.7
11	30.3	30.5
12	25.5	29.7
13	24.2	28.5
14	31.2	24.8
15	25.1	37.6
16	15.2	46.0
17	17.4	42.4
18	17.8	44.5
19	20.8	52.2
20	20.6	39.3
21	20.1	33.5
22	21.2	39.3
23	25.3	33.8
24	33.4	21.7
25	22.2	25.5
26	19.5	32.8
27	20.5	25.7
28	24.1	26.4
29	44.4	39.1
30	30.4	40.9
31	30.1	-

Note : Average daily water temperatures at North Point were:-
March 1985 15.25 - 17.75°C
September 1990 26.75 - 28.5°C

TABLE 6F.3 : COMPARISON OF HEAT TRANSFER COEFFICIENT VALUES

Source	Water Temperature °C	Heat Transfer Coefficient W/m² °C
Ref 9	15 - 20	20.5 - 27.3
Ref 9	20 - 25	24.0 - 32.2
Ref 9	25 - 30	28.3 - 38.2
Met data for March 1985	15.25 - 17.75	25.0 (15.2 - 44.4)
Met data for September 1990	26.75 - 28.5	34.0 (19.4 - 52.2)

Power Station Heat Load

6F.14 The total heat rejection by the power station each day has been calculated by adding together the performance of each condenser every hour. The total heat rejected each day from 3 to 25 September 1990 is given in Table 6F.4. The amount of heat rejected each day is fairly similar except on Sundays (9, 16 and 23 September) when the amount of heat rejected is noticeably smaller.

6F.15 During the course of each day, the amount of electricity generated by the power station fluctuates to meet consumers' demands. These changes are met by operating more units during the day than the night and by altering the output of individual units. The average daily pattern of heat rejection during the six days 17-22 September 1990 is shown on Figure F.2. The reduced day time heat rejection on two Sundays (16 and 23 September) is also illustrated on Figure F.2.

6F.16 During weekdays the cooling water flow also varies during the day as Figure F.3 illustrates. In practice changes in flow are not steady as each individual cooling water pump is normally run at full flow all the time it is operating.

6F.17 In the thermal validation studies, the cooling water flow has been kept constant at the maximum flow rate of 218,616 m³/hr recorded on 20/9/90. The temperature rise in the cooling water flow has been varied each hour to give the measured heat rejection by the power station. This simplification of the real system adds the correct quantity of heat to the sea around Lamma Island but will predict lower temperatures in the cooling water discharge particularly at night when some pumps are switched off. The effects of this difference between model and prototype are likely to be confined to the area within a few hundred metres of the power station.

6F.18 The heat load and temperature rise in the cooling water system for the period 20 to 21 September 1990 which has been used for model validation are given in Table 6F.5.

TABLE 6F.4 : DAILY HEAT REJECTION BY LAMMA POWER STATION - SEPTEMBER 1990

	Heat Load discharged	
Date	m^3 °C/day	10^{12} J/day
3	32,883,646	135.00
4	33,063,784	135.74
5	33,251,294	136.51
6	33,127,229	136.00
7	33,584,743	137.88
8	31,790,907	130.52
9	25,036,429	102.79
10	29,553,867	121.33
11	27,942,724	114.72
12	29,073,121	119.36
13	30,498,242	125.21
14	32,220,206	132.28
15	30,220,943	124.07
16	24,462,333	100.43
17	31,910,206	131.01
18	31,054,658	127.50
19	29,058,867	119.30
20	29,630,735	121.65
21	30,980,864	127.19
22	28,975,237	118.96
23	25,112,156	103.10
24	30,650,269	125.84
25	30,847,167	126.64

Note : Assume Specific heat of seawater = 4027 J/kg°C
and Density = 1019.5 kg/m^3
at T = 30°C and 32 ppt salinity

TABLE 6F.5 : LAMMA POWER STATION HOURLY HEAT LOAD DISCHARGE 19-20 SEPTEMBER 1990

Day	Tide	Time hour	Heat Load m^3°C/hr	MW	Equivalent Temperature Rise °C
19	LW	1500	1,593,554	1817	7.29
		1600	1,587,112	1810	7.26
		1700	1,604,594	1830	7.34
		1800	1,567,065	1737	7.17
		1900	1,443,221	1646	6.60
		2000	1,371,795	1564	6.27
	HW	2100	1,196,144	1364	5.47
		2200	1,138,757	1299	5.21
		2300	934,478	1066	4.27
		2400	939,489	1071	4.30
20		0100	742,155	846	3.39
		0200	666,133	760	3.05
	LW	0300	692,798	790	3.17
		0400	612,803	699	2.80
		0500	612,311	698	2.80
		0600	665,641	759	3.04
		0700	779,211	889	3.56
		0800	955,896	1090	4.37
		0900	1,444,619	1647	6.61
	HW	1000	1,605,408	1831	7.34
		1100	1,596,847	1821	7.30
		1200	1,633,815	1863	7.47
		1300	1,658,629	1892	7.59
		1400	1,633,029	1862	7.47
		1500	1,719,248	1961	7.86
	LW	1600	1,701,140	1940	7.78

Note: Temperature rise based on a flow of 218,616 m^3/hr (60.73 m^3/s) recorded at 1300 and 1400 on 20/9/90.

Approach to Survey Data Analysis

6F.19 Data from the field work carried out by EGS [7] were provided in a preliminary form in digital and in plotted format. These data have been analysed in various ways to try to obtain an understanding of the physical factors which influence the dispersion of heat in the sea in the vicinity of the Power Station and in the far field areas. These factors are primarily:

- the tidal currents
- salinity/density differences
- meteorological influences
- coastal topography and bathymetry.

Some of these factors are of course seasonal.

6F.20 It is apparent from the data from Station C2, which include salinity data, that in September this location may be near the brackish water/sea water interface in the surface layers. The advance and retreat of this interface, which the data indicate is directly correlated with the tidal cycle, is likely to have a significant effect on the heated water plume behaviour north of the outfall. At other times of the year, the interface is likely to be non-existent or weak and further north (in the dry season) or further south (in the wet season), and plume behaviour may be slightly different.

6F.21 The field work was designed to cover conditions during both spring (diurnal) tides and neap (semi-diurnal) tides, and if possible tides similar to the WAHMO spring and neap tidal ranges. Both types of tides are well represented in the tidal data obtained, except that the range of the diurnal tides (1.9 m maximum) was less than that of the WAHMO diurnal tide (2.2 m).

6F.22 On four occasions during the field work, the diurnal tide level curve shows a 'stand' at Mean Lower High Water (MLHW) with very little level difference between MLHW and the succeeding Mean Higher Low Water (MHLW), or no significant MHLW and MHWL at all. These occasions were 13/14, 14/15 and 15/16 September and 24 September. At these times, the tidal excursion was very small, with consequences for dispersion of the heated water discharge which are described below.

6F.23 In broad terms, in the vicinity of Lamma Island, and specifically on the west side of the island, the flood flow is approximately north-going and the ebb flow approximately south-going.

Characteristics of Stations T1, T2 and T3

6F.24 At Stations T1, T2 and T3 the temperature probes were at a fixed level (-2.0m CD). Since the tidal level did not exceed +2.2 m CD during the time period of measurement, the probe was never more than 4.2 m below the surface.

6F.25 Because of its location, Station T2 on the main Jetty will frequently be in the path of the plume during the ebb tide, and temperature peaks are therefore likely to be associated with ebb flows. In general this was found to be the case.

6F.26 Station T1, located some 3.2 km south of the outfall, will often be near the path of the south-going remnant of the plume, and thus temperature measurements are likely to show small peaks during ebb flows and around low water. In general this was found to be the case.

6F.27 Station T3, located some 1.9 km north of the outfall will at times be near the path of the north-going remnant of the plume, and temperature measurements are likely to show small peaks during flood flows and around high water. In general this was found to be the case, although the salinity difference, observed at C2 and discussed below is likely to have influenced the correlation.

Characteristics of Stations C1 and C2

6F.28 At Stations C1 and C2, the temperature, salinity, conductivity, and current velocity and direction measurements were at a constant depth of approximately 4 m below the sea surface.

6F.29 Station C1, located about 1 km south of the outfall, will usually be in or near the path of the south-going remnant of the plume and temperature measurements are therefore likely to show peaks during ebb flows and around low water. In general, this was found to be the case. Salinity at this station did not appear to be correlated with the tidal cycle, and generally did not vary more than about 0.25 ppt from the daily mean.

6F.30 Station C2, located about 1km north of the outfall will usually be in or near the path of the north-going remnant of the plume, and temperature measurements are therefore likely to show peaks during flood flows and around high water. Salinity at this station showed significantly greater variation over the tidal cycle, with which it appeared to be correlated, with variations up to about 0.75 ppt from the daily mean. Peak temperatures were found to occur during flood flows, with sharp increases in temperature often occurring as the salinity rose rapidly. This is likely to be due to the retreat northwards, during the flood tide, of the interface between the brackish surface layer and the warmer water at the leading edge of the plume.

6F.31 A total of 34 thermal measurement runs along up to 9 transect lines were undertaken during the periods 19-21 September and 23-25 September. The temperature measurements were taken at a depth of 2 m below the sea surface and subsequently at 4 m (on one occasion 3 m) below the surface on the same 'run', the transects at 4 m following the transects at 2 m. Each 'run' took 1 to 1.5 hours to complete. Whereas the 2 m transects extended over an area 1700 m north and 1100 m south of the outfall location, the 4 m transects only extended over an area some 600 m north and 600 m south of the outfall.

6F.32 The results of the temperature measurements were plotted by EGS [10] at a scale of 1:10,000 on 52 separate drawings. Isotherms of temperature, generally at 0.5°C intervals, were drawn through the measurement points. These enabled the location of the plume (or plumes), any 'slugs' of warmed water, and of the plume remnants to be estimated at various stages of the tide.

Analysis of Thermal Survey Data

Water Temperatures

6F.33 The comparison of mean daily temperatures at Stations T1, T2, T3, C1, C2 and North Point given in Table 6F.6 during the period of the field study indicates that, as expected, mean temperatures at T2 are highest, with decreasing temperatures moving outward to C1, and T1, and to C2 and T3. Temperatures at North Point are usually slightly lower than those at T1 and T3. Mean temperatures at T1 and T3 are on average respectively 0.42°C and 0.37°C higher than mean temperatures at North Point. The maximum temperatures recorded each day at Stations T1, T2, T3, C1 and C2 are shown in Table 6F.7. A similar pattern of temperature differences is apparent as the highest temperature each day usually occurs at Station T2. Peak water temperatures decrease with distance from the outfall. The daily minimum temperatures recorded each day at Stations T1, T2, T3, C1, and C2 are shown in Table 6F.8. The minimum temperatures recorded at each gauge on a given day usually agree to within 0.3°C. These minimum temperatures gradually decline upto 20 September before increasing again in the latter part of the survey period.

6F.34 Anomalously low temperatures were reached at T3 around 1900 hrs on 14 and 15th September and to a lesser extent at T1 on 15th September. The minimum temperatures at T3 were lower than those recorded during the afternoon at North Point on these days by up to 1.0°C on 14 September and up to 1.5°C on 15 September. These temperatures, which occurred during 'stands' in the tidal cycle, do not appear to be associated with any heavy rainfall in Hong Kong which might reduce surface temperatures locally. In the absence of salinity measurements for these days (measurements at C1 and C2 started on 18 September), it is not possible to check if the low temperatures correlate with changes in salinity of the surface layer. They might, however, be associated with transient turbulent upwelling from deeper and cooler layers.

6F.35 Heat loss coefficients have been estimated for the area each day during the period of the field study (Table 6F.2) and are shown in Tables 6F.6 and 6F.8. It is seen that there is a reasonable inverse correlation between mean and minimum temperatures at Stations T1 and T3 and the heat loss coefficients, higher heat loss coefficients causing the lower water temperatures.

Ambient Water Temperatures

6F.36 The thermal modelling tests give temperatures above ambient, which is defined as the water temperature which would have occurred in the absence of the power station. This temperature is inevitably rather difficult to measure. There are a number of possibilities in this case. One is to use the mean daily temperature at North Point, another is to use the minimum temperature recorded at the survey sites. In the latter case, the implicit assumption is that recorded temperatures are at a minimum when the monitor is not affected by the thermal plume from the power station. Neither of these definitions is ideal and both can be criticised.

6F.37 Surface water temperatures are recorded at North Point twice a day to the nearest 0.5°C. North Point is not affected by Lamma or other power stations in Hong Kong, but might be influenced by local small sources of heat. The temperatures at North Point are generally slightly lower than the minimum recorded temperatures at the five sites near the power station given in Table 6F.8. There could be some variation in ambient temperature between North Point and Lamma Island on individual days, but such differences will be small on average. The main drawback to the use of North Point temperatures to define the ambient temperature for this survey is that readings are only taken twice a day to the nearest 0.5°C which is not sufficiently accurate for this purpose.

6F.38 An alternative definition of ambient temperature is to use the average minimum recorded each day at the five fixed thermometers. The results in Table 6F.8 show that the average minimum recorded at these fixed thermometers is more consistent from day to day than the North Point temperatures. The main inconsistencies in these readings are associated with the anomolously low temperatures recorded on 14 and 15 September at T1 and T3 discussed above.

6F.39 Comparison of minimum temperatures recorded south of the power station at T1, C1 and T3 are all very similar. Average minimum temperature during the survey period are highest at T2 and lowest at T1 which is furthest from the power station. The difference in average minimum temperature between these sites is less than 0.1°C. North of the power station at sites C2 and T3, average minimum temperatures are 0.1 to 0.2°C lower than those south of the power station. This small difference is apparent most days and is probably associated with the salinity variations observed north of the power station and described below.

6F.40 The minimum temperatures recorded at the fixed thermometers often occurred in the morning. Solar radiation during the day will warm the surface layers of the sea and cause higher water temperatures in the evening. The water will then cool overnight to a new minimum the following morning. The fixed thermometers were set at between 2 m and 4 m below the water surface to minimise this effect. The diurnal temperature effect is illustrated on Table 6F.9 which gives mean and minimum temperatures each morning and afternoon at the three fixed thermometers. In the period 19th to 23rd September when the influence of the power station on temperatures at T1 and T3 is at its minimum, mean and maximum temperatures are about 0.2°C higher in the afternoon than in the morning. At other times, such as 14th to 17th September, when the ambient water temperature was falling, this difference does not exsit. This daily range gives some indication of the variability of temperature readings during the course of the day due to all effects.

6F.41 Problems of ambient definition are compounded where surveys are conducted over several days, as in this case, as the natural sea water temperature shows temporal changes. Over the period 19th to 23rd September for example, the mean pm temperature recorded at site T1 ranged from 25.1°C to 28.3°C. Taking an average over this period for the purposes of defining ambient, would therefore tend to produce a value biased low for the latter period of the survey.

It follows that definition of true ambient is critical in interpreting the results of field data, and in assessing the magnitude of heat rise due to the thermal discharge.

6F.42 The average minimum temperature recorded at the five gauges over the prime survey period (18 to 25 September) is 0.07°C higher than the average at North Point over the same period. Thus both definitions of ambient give similar results on average.

Tidal Currents

6F.43 Tidal current velocities are mainly a function a tidal range, and in general this is reflected in the tidal current velocity data. Current direction measurements indicate that currents in the near surface layer are approximately north-northwest going and south-southeast going in the main flood and ebb flows respectively at Station C1, and approximately north-going and south-going in the main flood and ebb flows respectively at Station C2. These currents are illustrated on Figures F.4 and F.5.

6F.44 At Station C2, the turn of the tide (in a clockwise direction at high water, and in an anti-clockwise direction at low water) is completed within about 2 hours. At Station C1, the turn of the tide (in a clockwise direction at both high and low water) is considerably more protracted taking up to 4 hours to complete, particularly when the tide range is small.

Water Salinity

6F.45 In the wet season, fresh water discharge from the Pearl River leads to stratification of the tidal flow, with the brackish water forming the upper part of the flow. In the dry season, the reduced fresh water discharge leads to well-mixed tidal flow, with minimal salinity difference over the water column. September lies between the two seasons, and this is reflected in the relatively constant salinity in the near surface layer at Station C1, as opposed to the tidally-changing salinity in the mean surface layer at Station C2, which is illustrated in Figure F.6 for 20 September 1990.

6F.46 These results show that at the time of the survey the interface between the brackish and saline water in the near surface layer is near Station C2, but does not reach Station C1. Since, however, the tidal excursion at Station C2 in a north-south direction (Figure F.5) is calculated to be greater than twice the distance between C1 and C2, there is a possibility that the interface is aligned in a more northeast southwest direction, with Station C1 being sheltered by the topography from the main brackish surface flow.

6F.47 The significance of the interface in the near surface layer lies in the way that at this season it probably can form a 'barrier' to the northward flow of the plume, since the density of the cooler brackish water is probably slightly less than that of the warmer, more saline, water of the plume. The short period of higher temperature associated with the increase in salinity on Figure F6 may be due to this feature.

Plume Behaviour

6F.48 The behaviour of the plume has been assessed on the basis of the contours of temperature plotted on the thermal measurement runs. In some cases, the warmed plume or its remnants are less than 0.5°C warmer than background, and identification of the track of the plume remote from the outfall becomes somewhat speculative. In addition, the picture is often confused by what appear to be 'slugs' of warmed water, some of which may be the remains of the plume from the previous tide.

6F.49 There appears to be a tendency for the plume at the surface to sub-divide. During the flood tide, parts of the plume flow north or north north-westwards with the main flow. During the ebb tide, there is a tendency for part of the plume to flow south to south south-eastwards, and part to flow east along the southern frontage of the power station before turning south to south-southeast. This is illustrated on Figure F.7 which shows the envelope of maximum temperatures recorded in the thermal transect measurements on 21 September 1990.

6F.50 At the lower level (4m below the surface) the plume behaviour is similar, but with a slight tendency for the flood flow to impart a more westerly component in the plume direction at this level.

Maximum Surface Layer Temperatures

6F.51 During a "stand" in the tidal cycle and until the succeeding higher high water, there are very low tidal currents and so dispersion of the plume will be slower than usual. In September, the presence of the brackish water/saline water interface forming a partial barrier to the surface plume, may further reduce dispersion and cause high surface water temperatures to persist for some distance from the outfall.

6F.52 From the available thermal measurement plots, an envelope of maximum water temperatures has been drawn on Figure F.8 for 24 September 1990 when there was a pronounced 'stand' during the tidal cycle. The iso-therms have been plotted as absolute values, rather than the excess above ambient temperature.

6F.53 The envelope for 24 September includes areas 1650 m north and 1100 m south of the outfall where water temperatures exceed 29.5°C but did not quite reach 30.0°C. These high temperatures recorded in the temperature transect surveys are supported by temperatures of 29.5°C at C2 and 29.1°C at C1 which are situated about 1000 m from the outfall. The high temperature at Station C2 occurred at 2040 as salinities rose when the brackish water/saline water interface passed the site. The high temperatures recorded on the northern temperature transect occurred just after 2300 and may be associated with the presence of the salinity interface in this vicinity at this time.

6F.54 The average minimum temperature at the five fixed thermometers, rose from 27.8°C on 24 September to 28.0°C the following day (Table 6F.9). These temperatures were recorded at each site in the early morning before 1000. In the afternoon and evening of 24th September when the highest temperatures occurred, the ambient temperature was in the range 28.1 to 28.3°C at T1 and 28.0 to 28.4°C at T3. The temperature recorded at North Point was 28°C on both the evening of 24th September and morning of 25th September (Table 6F.6). These data suggest an ambient temperature that evening of 28.2 ± 0.2°C. The results from the thermal survey indicate that water temperatures 1650 m north of the outfall were probably around 1.7°C above ambient that evening. The combination of tidal and salinity conditions which gave rise to this occurrence will only occur occasionally in the vicinity of Lamma power station.

<u>TABLE 6F.6</u> : DAILY MEAN TEMPERATURES, SEPTEMBER 1990

Date	Heat loss coeff (W/m²°C)	Daily mean temperatures T1 °C	C1 °C	T2 °C	C2 °C	T3 °C	North Point °C am	°C pm
13	28.5	28.11	-	28.36	-	27.99	27.0	27.5
14	24.8	28.22	-	28.68	-	28.19	27.5	28.0
15	37.6	28.24	-	28.50	-	28.07	27.0	28.0
16	46.0	28.06	-	28.25	-	27.91	26.5	27.0
17	42.4	27.86	-	28.11	-	27.64	27.0	29.0
18	44.5	27.66	27.83	28.08	27.76	27.72	27.0	27.5
19	52.2	27.58	27.55	27.83	27.54	27.57	27.0	26.5
20	39.3	27.59	27.63	27.90	27.49	27.49	28.0	28.0
21	33.5	27.79	27.78	28.07	27.67	27.69	27.5	27.5
22	39.3	27.98	28.02	28.18	27.90	27.84	27.0	27.0
23	33.8	28.06	28.08	28.19	28.04	27.98	27.5	28.0
24	21.7	28.19	28.26	28.40	28.27	28.21	27.5	28.0
25	25.5	28.28	28.26	28.40	28.42	28.19	28.0	27.5
Average 18-25/9		27.89	27.93	28.13	27.89	27.84	27.47	

TABLE 6F.7 : DAILY MAXIMUM TEMPERATURES, SEPTEMBER 1990

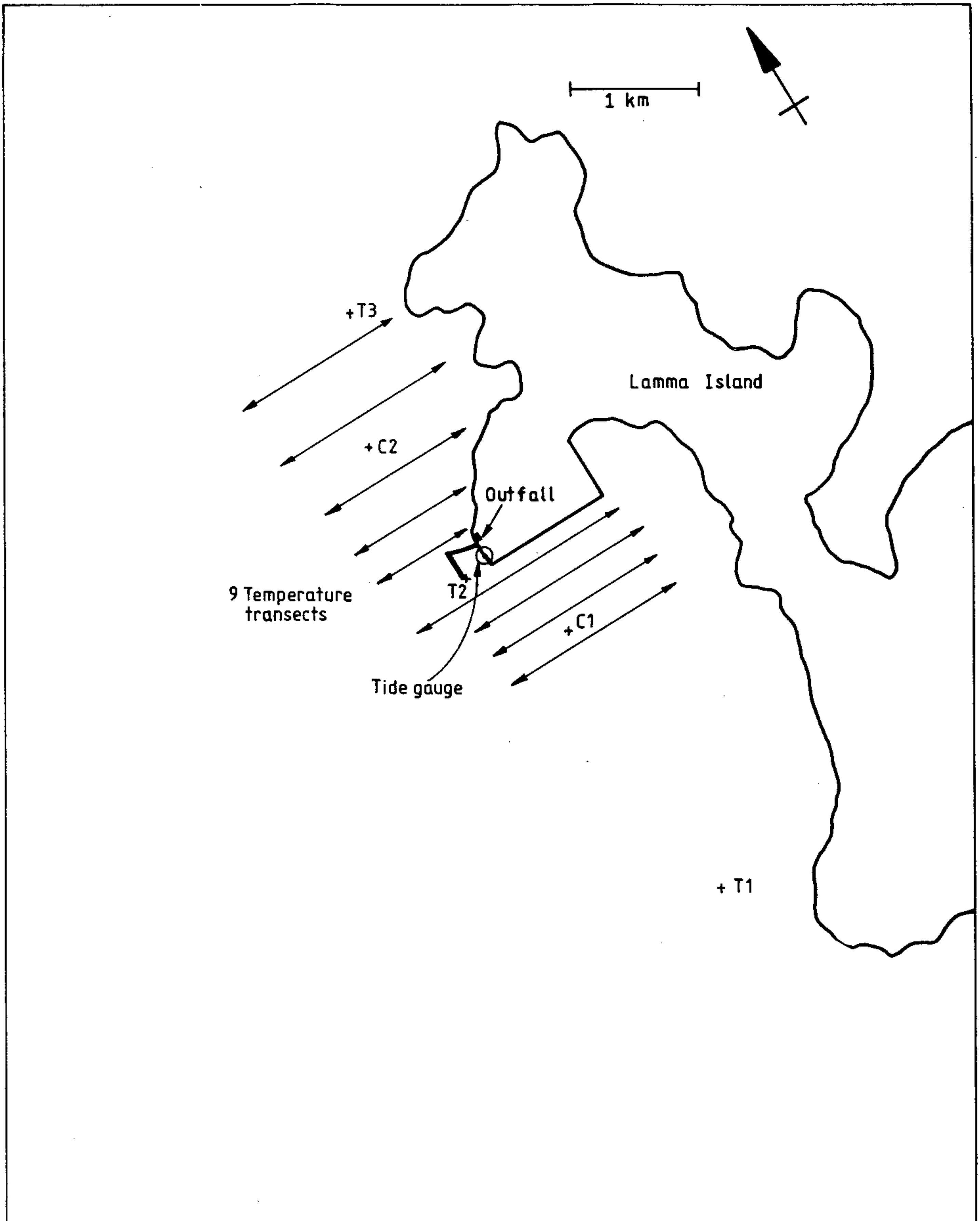
		Daily maximum temperatures				
Date	Heat loss coeff(W/m²°C)	T1 °C	C1 °C	T2 °C	C2 °C	T3 °C
13	28.5	28.4	-	28.8	-	28.9
14	24.8	28.9	-	28.8	-	30.0
15	37.6	28.9	-	28.9	-	29.4
16	46.0	28.4	-	29.0	-	28.5
17	42.4	28.3	-	29.4	-	28.1
18	44.5	27.9	28.4	29.6	28.0	28.1
19	52.2	27.8	28.1	29.3	28.2	27.9
20	39.3	28.1	28.4	29.4	28.2	27.9
21	33.5	28.5	28.9	29.6	28.3	28.2
22	39.3	28.4	28.9	29.5	28.7	28.1
23	33.8	28.3	28.8	29.0	29.2	28.3
24	21.7	28.9	29.1	29.7	29.5	29.1
25	25.5	28.8	28.8	29.3	29.5	28.8
Average 18-25/9		28.34	28.68	29.43	28.70	28.30

TABLE 6F.8 : DAILY MINIMUM TEMPERATURES, SEPTEMBER 1990

Date	Heat loss coefficient (W/m²°C)	T1 °C	C1 °C	T2 °C	C2 °C	T3 °C	Average °C	North Point mean °C
		Daily minimum temperatures						
13	28.5	27.7	-	27.8	-	27.3	27.6	27.25
14	24.8	27.9	-	27.7	-	26.9	27.5	27.75
15	37.6	27.0	-	27.6	-	26.4	27.0	27.5
16	46.0	27.6	-	27.8	-	27.1	27.5	26.75
17	42.4	27.4	-	27.6	-	27.3	27.4	28.0
18	44.5	27.4	27.4	27.7	27.4	27.5	27.5	27.25
19	52.2	27.4	27.3	27.5	27.1	27.2	27.3	26.75
20	39.3	27.3	27.3	27.3	27.1	27.1	27.2	28.0
21	33.5	27.3	27.4	27.5	27.2	27.3	27.3	27.5
22	39.3	27.5	27.6	27.6	27.5	27.5	27.5	27.0
23	33.8	27.7	27.9	27.7	27.6	27.6	27.7	27.75
24	21.7	27.9	27.9	27.8	27.7	27.8	27.8	27.75
25	25.5	28.1	28.1	28.1	27.9	27.9	28.0	27.75
Average 18-25/9		27.57	27.61	27.65	27.44	27.49	27.54	27.47

TABLE 6F.9 : DIURNAL TEMPERATURE VARIATION AT SITES T1, T2, T3 - 13TH TO 25TH SEPTEMBER 1990

Date	Mean Temperature			Minimum Temperature		
	T1	T2	T3	T1	T2	T3
13 am	-	-	-	-	-	-
13 pm	-	28.36	-	-	27.8	-
14 am	28.11	28.37	28.07	27.9	27.7	27.7
14 pm	28.34	29.00	28.30	27.9	28.2	26.9
15 am	28.40	28.28	28.30	27.9	27.6	27.7
15 pm	28.08	28.72	27.83	27.0	28.0	26.9
16 am	28.12	28.30	28.09	27.6	27.9	27.7
16 pm	28.00	28.21	27.73	27.9	27.8	27.1
17 am	27.86	28.07	27.64	27.6	27.8	27.3
17 pm	27.69	28.15	27.64	27.4	27.6	27.5
18 am	-	27.97	27.72	-	27.7	27.5
18 pm	-	28.19	27.71	-	27.7	27.5
19 am	27.65	27.76	27.69	27.4	27.5	27.4
19 pm	27.51	27.90	27.45	27.4	27.5	27.2
20 am	27.50	27.62	27.41	27.3	27.3	27.1
20 pm	27.68	28.18	27.56	27.4	27.5	27.4
21 am	27.55	27.80	27.48	27.3	27.5	27.3
21 pm	28.15	28.38	27.99	27.9	27.9	27.8
22 am	27.81	27.97	27.68	27.5	27.6	27.5
22 pm	28.15	28.38	27.99	27.9	27.9	27.8
23 am	27.98	28.08	27.85	27.7	27.7	27.6
23 pm	28.15	28.29	28.10	28.0	28.0	27.9
24 am	28.08	28.18	27.96	27.9	27.8	27.8
24 pm	28.30	28.63	28.44	28.1	28.0	28.0
25 am	28.32	28.42	28.16	28.1	28.1	27.9
25 pm	-	28.34	-	-	28.2	-
19th to 24th September						
Average am	27.76	27.90	27.68	27.52	27.57	27.45
Average pm	27.97	28.29	27.89	27.77	27.75	27.65
Difference	0.21	0.39	0.21	0.25	0.18	0.20



The Hongkong Electric Company Limited

T1, T2, T3 Fixed Thermometers
C1, C2 Currents, Salinity, Temperature

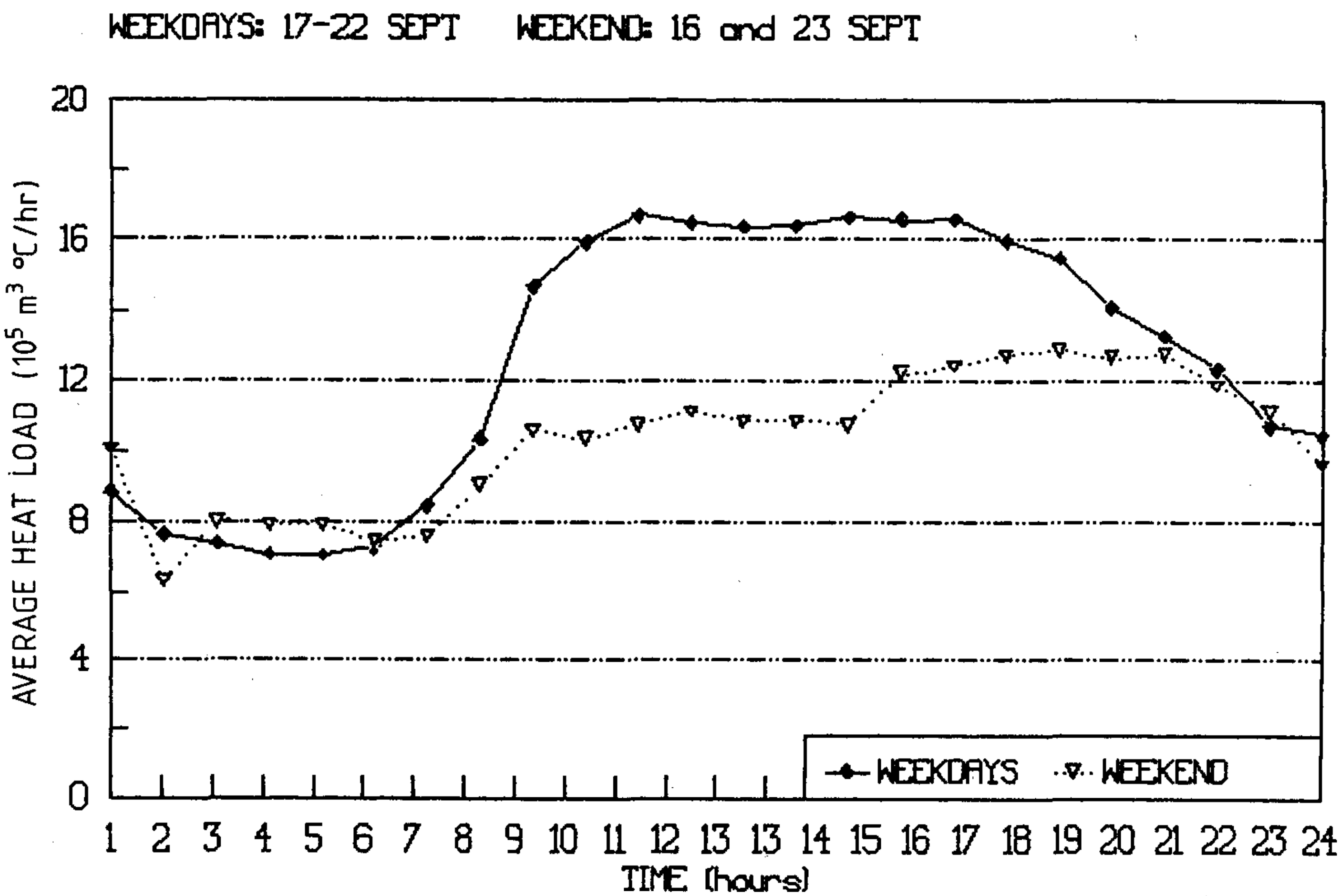
PROJECT

EIA LAMMA POWER STATION

TITLE

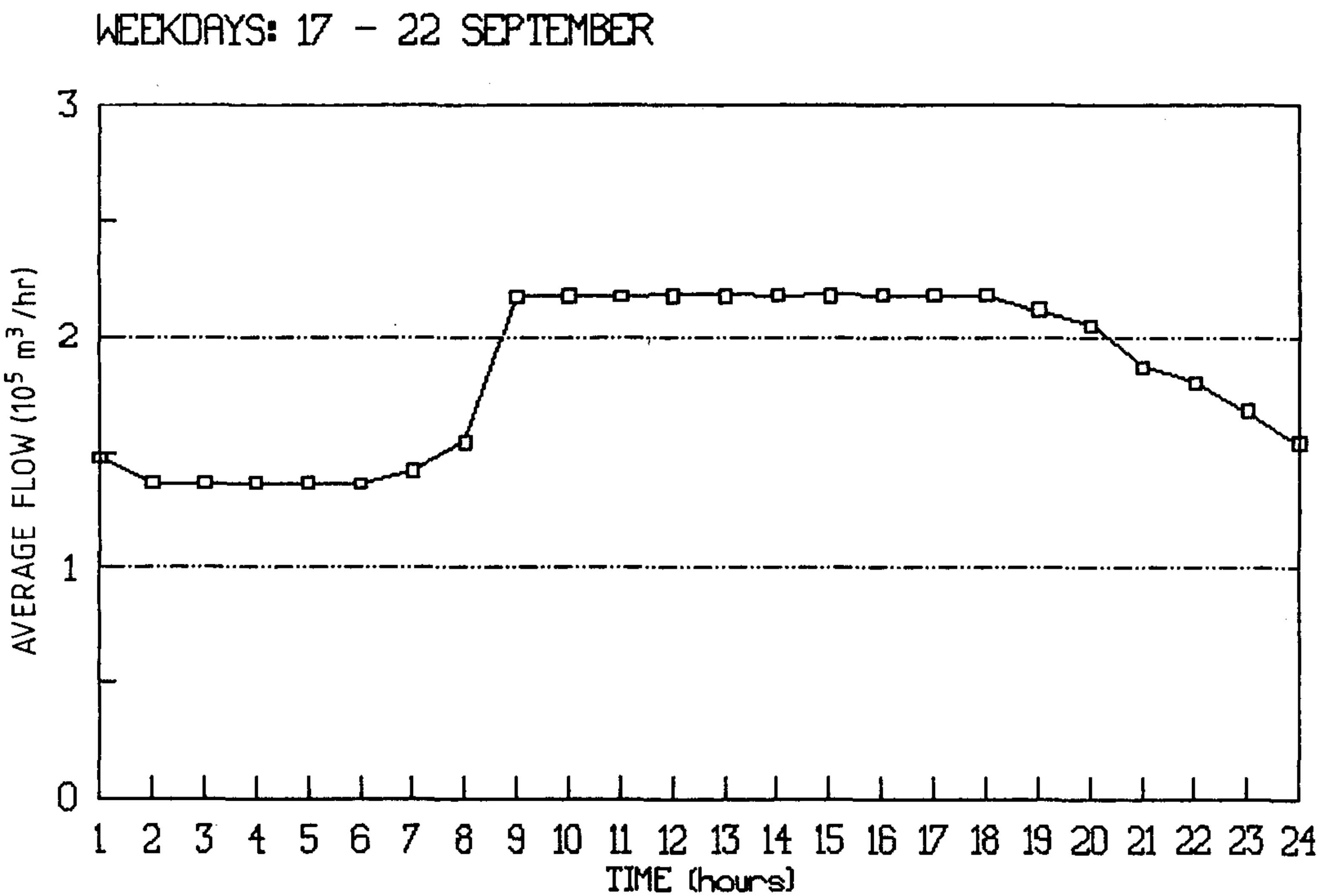
Thermal Survey Location Plan

FIGURE F1

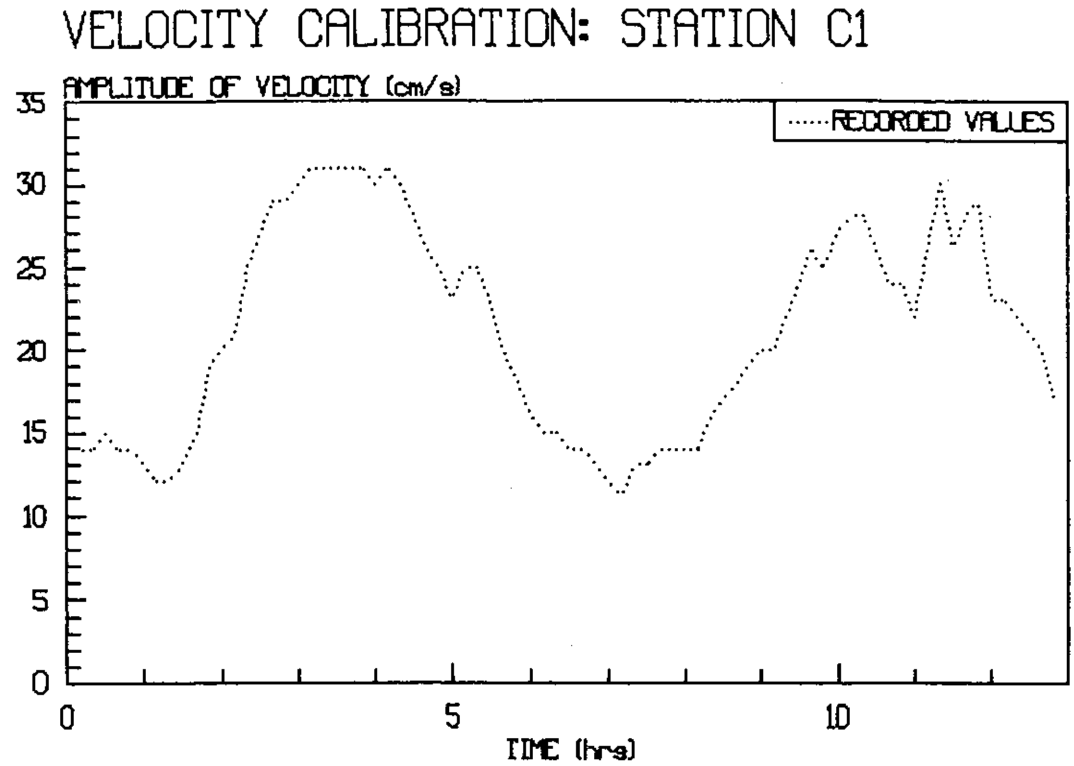


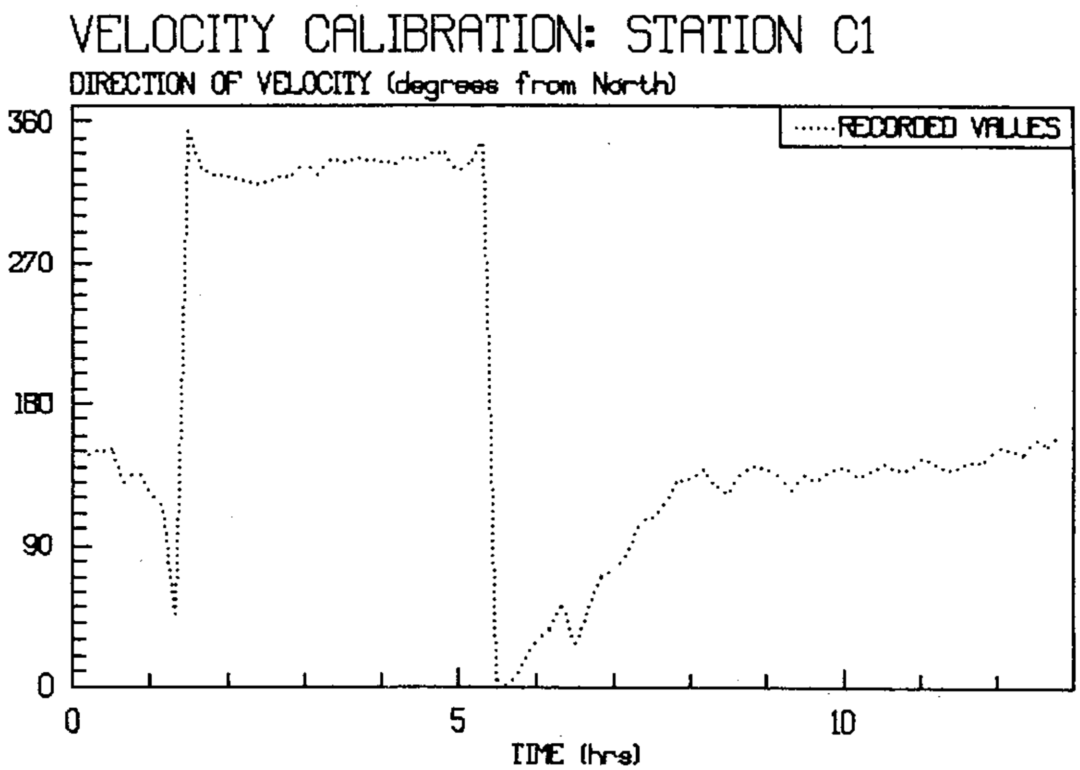
Lamma Power Station
Average hourly heat load

FIGURE F2



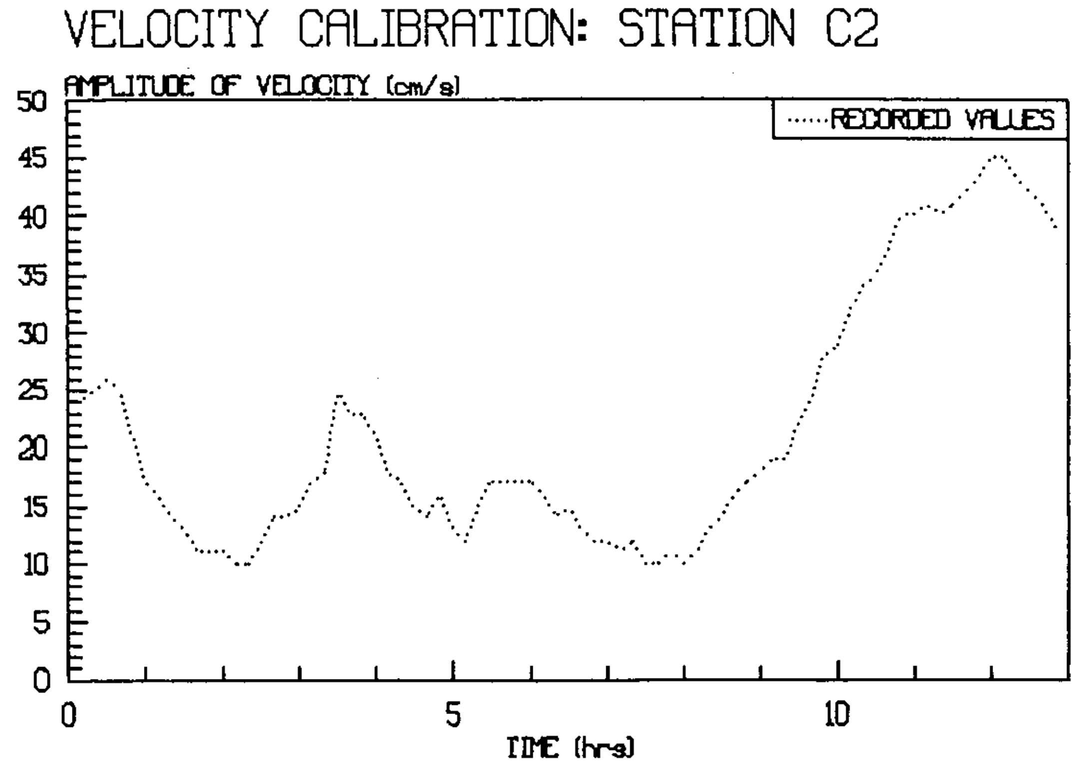
Lamma Power Station
Average weekday CW flow
FIGURE F3

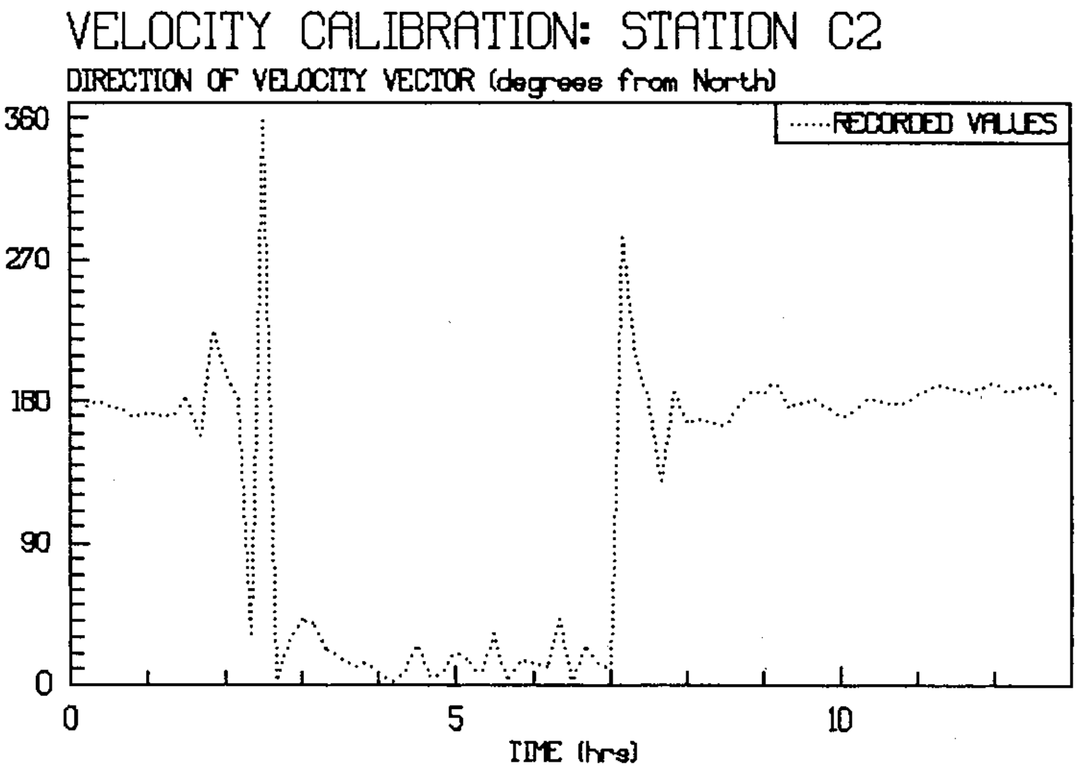




Water Velocity Calibration at C1
22/23 September 1990

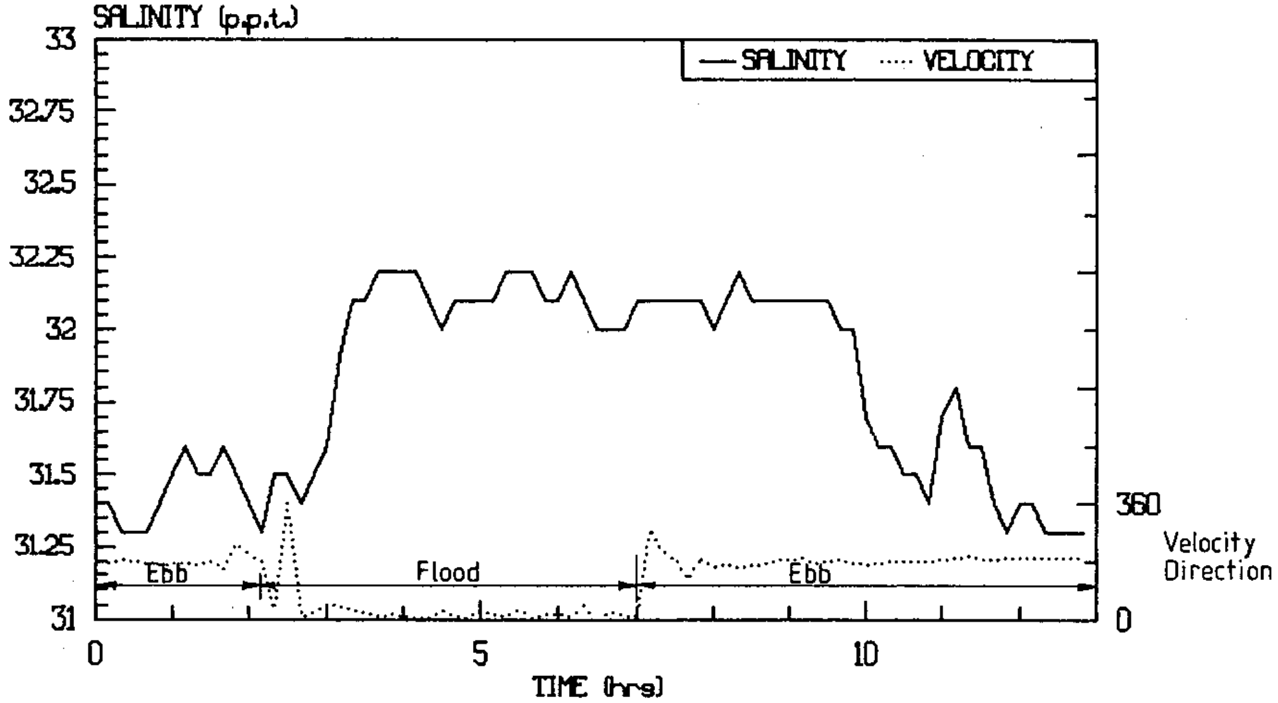
FIGURE F4

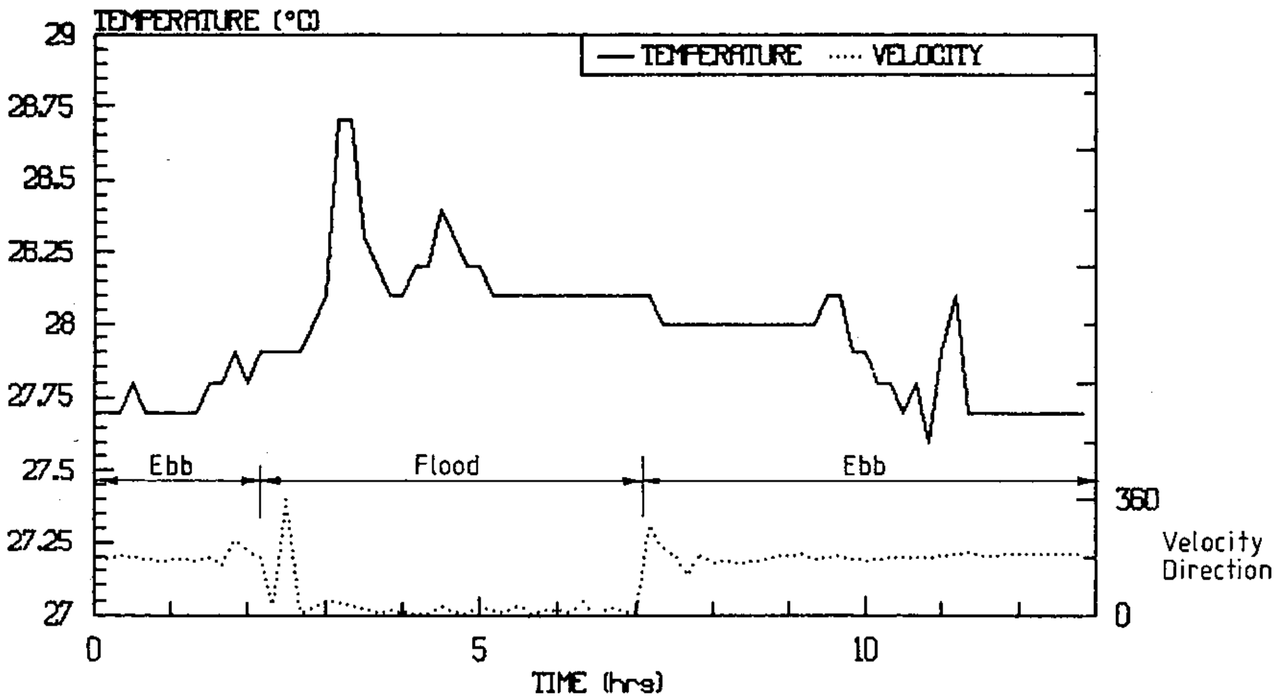




Water Velocity Calibration at C2
22/23 September 1990

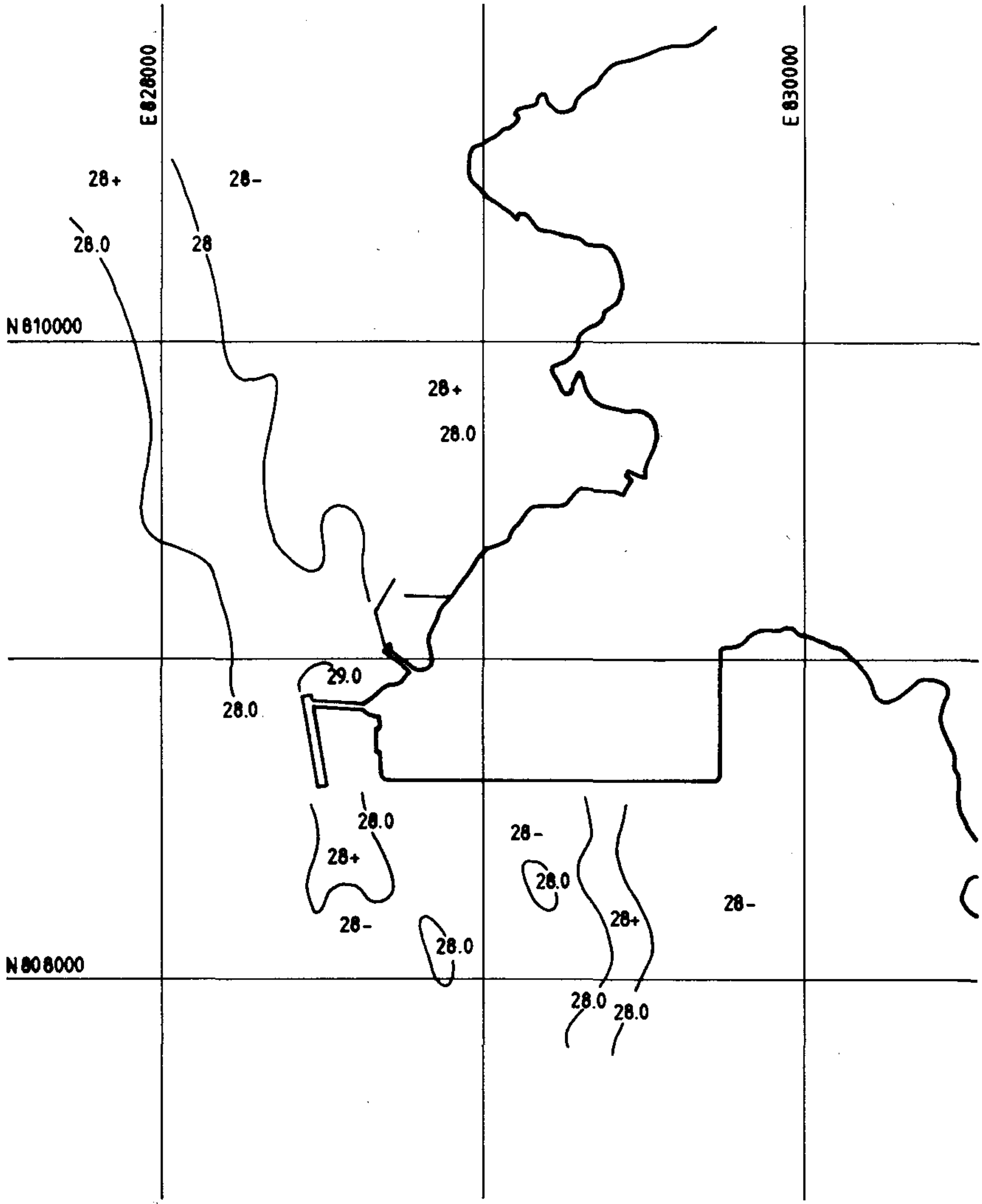
FIGURE F5





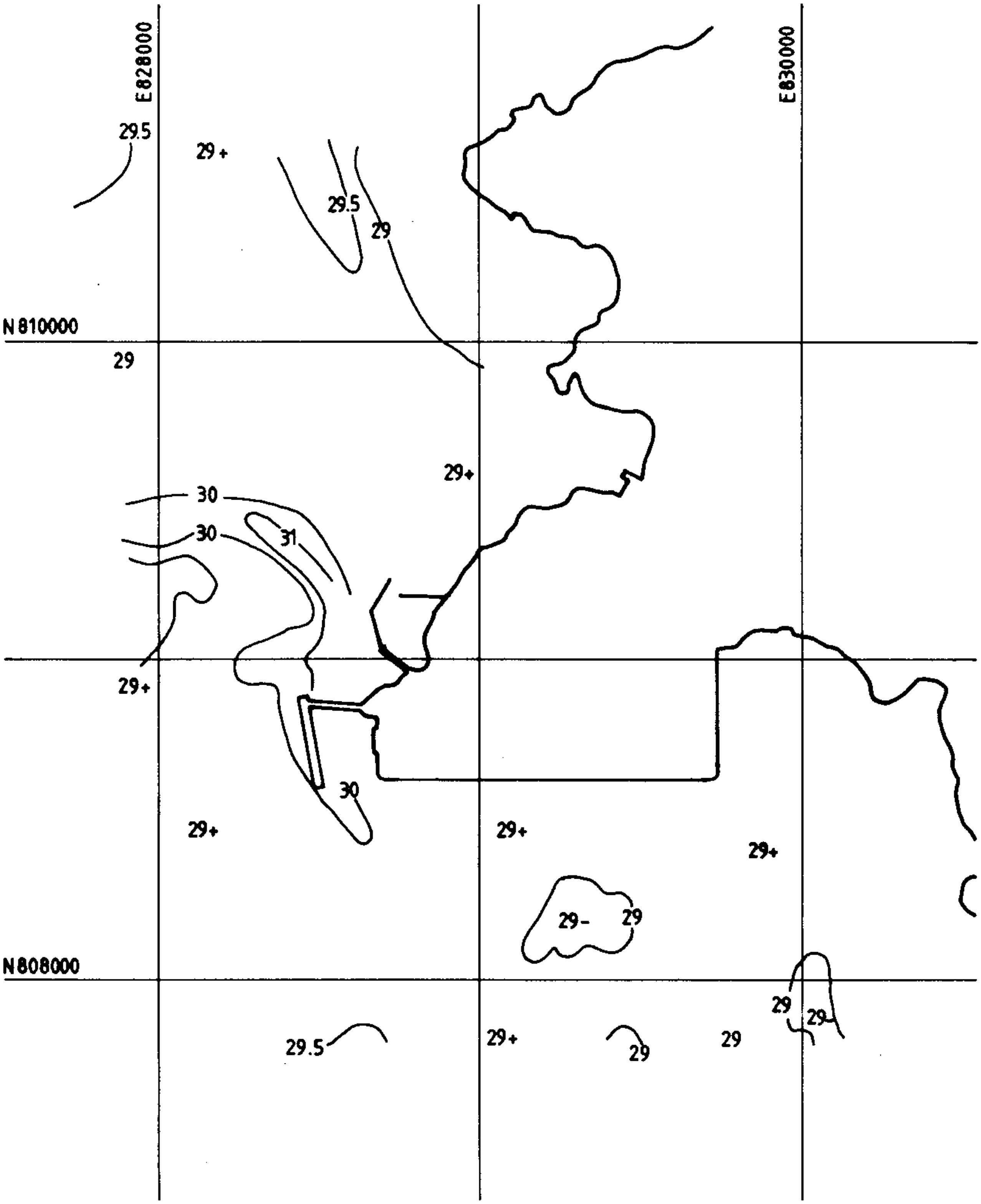
Water Salinity and Temperature at C2
22/23 September 1990

FIGURE F6



Envelope of maximum
temperatures 21 September 1990

FIGURE F7



Envelope of maximum temperatures 24 September 1990

FIGURE F8

SOLID WASTE

7.0 SOLID WASTE

7.01 This chapter considers the environmental consequences associated with the disposal of solid wastes produced by units L7 and L8. Three types of solid waste will be produced in significant quantities, these are as follows:-

- Pulverized fuel ash (PFA)
- Furnace bottom ash (FBA)
- Gypsum from the flue gas desulphurization process (FGD)

In addition, a small quantity of waste sludge will be produced from the FGD waste water. The final disposal route for this material is currently under review.

7.02 Binnie Consultants Limited have already developed a long term ash management strategy for HEC, which has been accepted in principle by Government. This strategy caters for the ash which may be produced by Units L7 and L8, so this problem has been solved in principle [3]. An environmental impact assessment of the recommended ash management strategy has also been carried out [2]. The ash management study calls for active marketing of PFA to ensure that as much as possible goes to industrial users and to landfill formation. If in the longer term these options prove inadequate the best alternative is to restore Lamma quarry using PFA fill. A lagoon next to the power station is needed in any event as a disposal facility during emergencies and to provide storage to accomodate varying demands from industrial users and land filling contracts. The proposed ash management strategy is environmentally acceptable.

7.03 This study has therefore assessed the environmental effects arising from disposal of the remaining solid waste, namely FGD gypsum. Each of the units to which FGD is fitted may produce gypsum at a rate of up to 50,000 tonnes per year. A gypsum waste management strategy formulated for units L7 and L8, identified the following possible disposal options [1]:

- industrial use
- use in land restoration, e.g. Lamma Quarry
- marine disposal in designated dumping grounds or artificial reefs
- co-disposal with PFA in the ash lagoon

7.04 The physical and social effects arising from each of these disposal options are summarized in Figure 7.1, and discussed in more detail later. This figure indicates the issues which are judged to be significant in either a positive or negative sense.

7.05 Some of the gypsum disposal options and effects are similar to those for ash produced at Lamma. The ash management strategy and accompanying initial assessment report have already studied the environmental effects of these proposals. Where there is common ground between the two studies, this report makes reference to the previous one, and discusses any additional effects arising from the disposal of gypsum rather than ash.

7.06 Prior to considering the effects arising from each disposal option, the properties of FGD gypsum are reviewed. Properties can only be estimated at the present time from overseas information, since there is no experience of FGD gypsum in Hong Kong.

Properties of FGD Gypsum

Chemical Composition

7.07 The environmental effects associated with any gypsum disposal method are closely related to the absolute quantities and the chemical compounds present. Information about the chemical composition of gypsum which will be produced at Lamma Power Station is very limited at present. The gypsum chemistry is dependent on coal and limestone composition as well as the design and operation of the FGD system. Details of the chemical composition will only be available when the FGD plant is in operation and the actual material can be tested.

7.08 The estimated composition of gypsum from Lamma Power Station based upon the design specification of the FGD plant, is given in Table 7.1 [5].

TABLE 7.1 : PROPERTIES OF GYPSUM TO BE PRODUCED AT LAMMA POWER STATION

Property	Percentage
Moisture Content %	≤10
Gypsum ('pure') Content %	≥90
Chloride Content %	≤0.02

Note: "Pure" gypsum is $CaS0_4.2H_2O$

7.09 Although the detailed chemical composition is presently unknown, some insight into the likely chemistry of the FGD gypsum can be gained by reference to overseas experience. For example, the chemical composition of gypsum produced by a limestone-gypsum FGD process with forced oxidation in Austria is presented in Table 7.2. This station burns coal of varying quality, hence the values quoted vary considerably.

TABLE 7.2 : TYPICAL CHEMICAL COMPOSITION OF FGD GYPSUM FROM AUSTRIA

Property	Range
pH	6.5 - 9.0
Gypsum(%)	96 - 99
MgO soluble (%)	0.01 - 0.06
Na_2O soluble (%)	0.003 - 0.01
Chlorides (%)	0.001 - 0.003
Sulphite (%)	0.001 - 0.2
Fe_2O_3 (mg/kg)	350 - 500
Al_2O_3 (mg/kg)	200 - 500
MnO_2 (mg/kg)	20 - 50

7.10 It must be stressed, however, that the data shown in Table 7.2 may not be necessarily representative of the composition of gypsum which will be produced at Lamma. Differences in raw material sources and process designs at Lamma will be reflected in the final gypsum properties. It is nonetheless possible to specify with some certainty that the gypsum purity of Lamma will be equal to or greater than 90%. Iron and aluminium oxides are present in the gypsum as PFA impurities. PFA is expected to account for 1% of the gypsum solid waste produced. Iron and aluminium oxides will also occur in the gypsum as a result of impurities of the limestone.

Trace Elements

7.11 The types and concentrations of trace elements in FGD gypsum are reported to depend primarily on the amount of PFA present [6]. In systems which remove most of the PFA, trace element concentrations are determined mainly by those of the limestone. A higher proportion of PFA produces a higher concentration of trace elements. This is illustrated in Figure 7.2 where the concentrations of trace elements in a PFA rich gypsum are compared with those of a "pure" gypsum sample. The absolute values may not be relevant to solid wastes produced at Lamma, however, the relative difference in concentrations is significant. Gypsum frequently contains lower concentrations of trace elements than PFA and these can be present in either the liquid or the solid phases. A large proportion of the more soluble trace elements are removed during dewatering, in particular boron and selenium [9].

7.12 Gypsum is reported to contain less of the dissolved (soluble) elements (Be, Cd, Co, Ni, Se and Zn) which are removed during dewatering, than the more insoluble elements (As, Cr, Pb and V). This behaviour cannot be predicted quantitatively since it is influenced by many factors including limestone and coal composition, FGD process design and pH of the gypsum slurry.

Leachate

7.13 The quality of water which has been in contact with gypsum is an important consideration when assessing the environmental effect of a disposal method.

7.14 Water percolating through FGD gypsum dissolves a range of ions present in the material. Initially, pore water is diluted and removed, while subsequent flow dissolves the gypsum particles. The initial pore volumes of leachate contain concentrations of total dissolved solids (TDS) approximately equal to those found in scrubber liquor. After the initial pore volumes of leachate, the key factor affecting leachate quality is the solubility of the gypsum particles [11]. Gypsum is normally soluble to the extent of about 2000 mg/l in fresh water and accounts for most of the TDS in leachates produced after initial pore water flushing.

7.15 Results of leaching tests carried out on sulphate rich FGD waste are presented in Table 7.3 [12]. The differences in the chemical composition of leachate after 1 and 50 pore volumes (PV) of water have passed through the sample are apparent.

TABLE 7.3 : CHEMICAL CONSTITUENTS IN LEACHATE FROM FGD WASTE AFTER 1 AND 50 PORE VOLUME DISPLACEMENT CONCENTRATIONS

Chemical Constituent	1st PV	50th PV
Arsenic	0.02	0.004
Beryllium	0.01	<0.004
Cadmium	0.015	0.002
Chromium	0.045	<0.003
Lead	0.25	0.010
Mercury	0.0005	<0.00005
Selenium	0.055	0.006
Zinc	0.65	0.04
Chloride	2,600	100
Fluoride	4.0	0.8
Sulphite	50	30
Sulphate	6,500	1,200
Total Dissolved Solids	10,000	2,200
Chemical Oxygen Demand	10	6
pH	6.6	5.5

Note : All units except pH in mg/l

TABLE 7.4 : BEHAVIOUR OF FIVE METALS IN LEACHATES PRODUCED FROM FGD GYPSUM

Parameter		Deionized Medium		Acidic Medium (pH 4.5)	
		4 : 1	20 : 1	4 : 1	20 : 1
Chromium	Concentration (mg/l)	0.13	0.03	0.05	0.07
	Release (mg/g)	0.52	0.60	0.20	1.4
	Leaching Efficiency (%)	3.7	4.2	1.4	9.9
Copper	Concentration (mg/l)	<0.008	0.010	0.011	0.082
	Release (mg/g)	<0.032	0.200	0.044	1.64
	Leaching Efficiency (%)	-	0.88	0.19	7.23
Iron	Concentration (mg/l)	0.04	0.02	0.11	3.61
	Release (mg/g)	0.16	0.40	0.44	72.2
	Leaching Efficiency (%)	0.002	0.004	0.004	0.74
Nickel	Concentration (mg/l)	0.07	0.07	0.16	0.15
	Release (mg/g)	0.28	1.4	0.64	3.0
	Leaching Efficiency (%)	2.0	9.9	4.5	21
Zinc	Concentration (mg/l)	<0.05	0.05	0.23	0.20
	Release (mg/g)	<0.20	0.20	0.92	4.0
	Leaching Efficiency (%)	-	4.3	4.3	19

Note : Mixing period for each test is 24 hours

Concentration = weight of chemical species in leachate per volume of leachate

Release = weight of chemical species in leachate per weight of total sludge sample

Efficiency = weight of chemical species in leachate per weight of chemical species in sludge sample

7.16 Similar data from laboratory tests on gypsum from a power station in the USA are presented graphically in Figure 7.3. The concentration of readily soluble ions such as chloride, are limited in the long term by availability while the concentrations of calcium and sulphate ions are limited by their solubilities [11]. These three ions are the predominant leachate components, although much smaller quantities of other chemicals are also present, as shown in Table 7.3.

7.17 Heavy metal concentrations in leachate are an important aspect of gypsum disposal. Several factors such as pH and water to solid ratios influence the concentrations of heavy metals in solution. The test results presented in Table 7.4 generally show that a higher percentage of heavy metals are leached under acidic conditions, than under neutral conditions. This, however, was not the case with chromium, which showed a contradictory trend of greater dissolution in the deionized medium. Increasing the liquid to solid ratio from 4 : 1 to 20 : 1 resulted in a higher contaminant release and leaching efficiency. Generally, nickel and zinc were leached more efficiently than chromium, copper and iron. The proportions leached however (expressed as leaching efficiency), were a small percentage of the total amount present in the gypsum [6].

7.18 Gypsum produced at Lamma Power Station is not expected to be acidic, hence based on the above findings, only a very small percentage of the heavy metals present are likely to be leached.

7.19 Leachates from FGD wastes can have a high chemical oxygen demand (COD) if significant quantities of calcium sulphite are present. The solid waste from Lamma will be oxidized to convert any sulphite compounds into sulphates, hence a negligible COD is expected [17]. Biochemical oxygen demands (BOD) are also low for gypsum. The discharge of leachate from FGD storage sites is not therefore expected to cause oxygen depletion problems in receiving water courses.

Radioactivity

7.20 Radioactivity is an intrinsic property of all elements and minerals on earth, although absolute levels can vary widely. Coal and limestone are slightly radioactive, and so are the PFA and gypsum derived from them.

7.21 Work carried out in Japan at power plants fitted with wet FGD systems showed the radionuclides ^{40}K, ^{232}Th, ^{235}U and ^{238}U to be mostly absorbed by the preceding electrostatic precipitators. The gypsum product contained only 1.6%, 1.8% and 1.5% of the K, Th and U respectively in the coal [6].

7.22 The radioactivity of one scrubber sludge was compared with that of eleven bottom ash and fly ash (PFA) samples by other researchers [14]. The data shown in Figure 7.4 shows that the activity of the scrubber sludge was in the lower part of the range for ash samples. These results are consistent with the findings of Environment Canada who concluded that the radio-chemical characteristics of FGD sludges are comparable to those found in coal ash [6].

7.23 The above conclusions are based on tests on coal samples from around the world, which have many differing radioactive properties and may not be specifically applicable to Lamma. However, the general principle that gypsum is even less radioactive than PFA from the same power station should apply to Lamma.

Industrial Uses

7.24 Two potential industrial uses for FGD gypsum were identified in the management strategy, namely cement manufacture and wallboard production. Industrial use within Hong Kong is the disposal option preferred by both Government and HEC. The environmental effects associated with the above industrial uses are summarized in Figure 7.1 and are discussed below.

Environmental Effects of Cement Manufacture

7.25 There is one cement manufacturing plant in Hong Kong, owned by the China Cement Company Limited and situated next to the Castle Peak Power Stations at Tap Shek Kok. Raw materials for the cement manufacturing process, including clinker and gypsum, are all imported from other South East Asian countries. Approximately 125,000 tonnes of natural rock gypsum were imported in 1989, mainly from Thailand.

7.26 The cement clinker used by China Cement is mainly supplied from South Korea and Japan. The cement manufacturing industries in these countries represent potential export markets for gypsum produced at Lamma Power Station and by the other power stations in Hong Kong. Similarly, the PRC may offer a substantial market for exported gypsum. Transport should not be a problem since ships bringing cement clinker to Hong kong could return with a cargo of gypsum. Many of the environmental impacts associated with the use of gypsum in the Hong Kong cement industry are equally applicable to overseas uses.

7.27 Since the cement factory is an existing facility, this assessment will focus on the effects due to a switch from natural to FGD gypsum. Existing effects associated with the cement factory are outside the scope of this study. There are several advantages and disadvantages associated with a change of gypsum supply.

Advantages

- provides a beneficial use for gypsum which may otherwise have to be dumped
- conserves natural resources in other countries which presently supply gypsum
- reduces transportation costs and resource consumption associated with shipping

Disadvantages

- FGD gypsum may need drying so that it can be handled by existing cement process plant designed to use natural 'rock' gypsum. Drying will consume additional energy.

7.28 It is believed that the advantages described above outweigh the disadvantages. However the former are dependent on FGD gypsum being of a suitable quality for use in cement manufacture, which cannot be guaranteed at present since raw material properties and FGD process details are unknown. Suitability can only be definitely assessed by testing gypsum produced at Lamma Power Station.

Environmental Effects of Wallboard Manufacture

7.29 Gypsum wallboard is used in the Hong Kong construction industry in both dry walling systems and ceiling tiles. It is currently imported as a finished product mainly from the USA and Australia. To use FGD gypsum produced at Lamma Power Station in locally manufactured wallboard would require the introduction of a new industry to Hong Kong. This would have physical as well as socio-economic effects.

7.30 The process of producing wallboard from gypsum is described here, in order to give an indication of the manufacturing activities and waste streams produced. Natural gypsum rock is pulverized in mills until 85 to 95% passes the 100 mesh sieve, although these stages would not be necessary with FGD gypsum. Free water is removed by heating, and dehydration is carried out at 121°C in calciners to remove chemically bound water and produce calcium sulphate hemihydrate, or beta crystal form. Calcium chloride is added in small amounts to convert some of the beta crystals into alpha crystal form. This reduces subsequent water requirements for slurrying the calcined gypsum (stucco) before it enters the wallboard manufacturing line [4].

7.31 Subsequent processing steps include:-

- milling to obtain a finished stucco size of 99% passing 100 mesh
- slurrying with paper particles
- addition of raw gypsum, starch, glass fibre and foam to reduce the density of the thick slurry
- further mixing and setting between sheets of paper to form boards
- board cutting and final drying in fired heaters

A typical layout for the above process from an existing plant in the USA is shown in Figure 7.5.

7.32 There are environmental advantages and disadvantages associated with developing an industry in Hong Kong to use locally produced gypsum. These are detailed below:-

Advantages

- provides a beneficial use for gypsum which may otherwise have to be dumped

- conserves natural resources in other countries

- reduces transportation costs and resource consumption associated with shipping

- provides local employment opportunities (may or may not be advantageous)

Disadvantages

- new industrial facilities, with waterfront access will be necessary

- there will be indeterminate effects on the existing wallboard import and marketing industry

- waste products will be generated by the manufacturing process, including heat, waste water and atmospheric discharges

- the process used to convert gypsum (calcium sulphate dihydrate) into a form suitable for use in wallboard manufacture (calcium sulphate hemihydrate) is energy intensive. In the USA, energy costs typically account for 23% of the total cost of producing wallboard [4].

7.33 Some of these impacts cannot be assessed here; for example changes in employment and land use, because the location of a suitable manufacturing facility site is unknown.

7.34 Waste streams produced by the manufacturing process are not considered to be significant environmental concerns. They can be eliminated or adequately dealt with if considered during the design process; there is, however, a financial cost associated with treatment of these small scale waste streams.

Summary

7.35 The use of FGD gypsum as a raw material in an existing industrial process is the preferred disposal option because effects arising from other disposal methods are avoided. The only potential option at this time appears to be at Hong Kong's single cement manufacturing plant. However, the use of FGD gypsum in the cement industry depends technically on the chemical composition and properties of the material which cannot yet be accurately predicted as the properties of the gypsum product depends upon many factors, one of which is the source of limestone. Its suitability for use in this process can only be conclusively assessed by carrying out trials using the actual material. Moveover, the economics of this potential option cannot be established at this time.

7.36 Gypsum wallboard is used in local construction but there is no local manufacturing facility and the environmental penalties of establishing one probably outweigh the perceived benefits.

Land Disposal

7.37 The disposal of FGD gypsum on land was identified in the waste management strategy as a feasible option, particularly if the economic or amenity value of the land was increased as a result. Restoration of the quarry at Sok Kwu Wan on the opposite side of Lamma Island to the power station is considered a suitable site. The quarry is presently an unattractive area, which could be visually improved if restored.

7.38 Various physical effects would result from restoring the quarry, some positive and some negative, as summarized in Figure 7.1. These are examined in detail in the following sections.

Background

7.39 There are proposals to restore the quarry using excess PFA from the Lamma Power Station which cannot be utilized by industry [1]. This is a contingency measure to guarantee a disposal option if existing industrial markets become unavailable. Lamma Quarry has a floor area of 320,000 m^2 and potential storage capacity for 9.5 million m^3 of fill material. The rate at which the quarry will be restored is dependent on the quantities of PFA, or gypsum, requiring disposal.

7.40 Plans are already in hand to construct the infrastructure necessary to transport PFA from the power station to the quarry. The PFA will be transported in a 'conditioned' state by conveyor along a purpose built tunnel. The environmental impacts associated with these proposals are examined elsewhere [2].

7.41 Conditioned PFA will be handled within the quarry using normal civil engineering equipment and techniques. The effects of these activities, which are the subject of a separate report, have been accepted in principle by Government [2].

7.42 Gypsum produced by the FGD process can be handled and treated in a similar manner to conditioned PFA since they are both moist powders. The disposal facilities on land for PFA therefore represent an obvious option for gypsum disposal, particularly since the infrastructure and environmental effects of PFA have already been studied and found acceptable.

7.43 This report will not repeat the findings of the previous study into the effects of PFA disposal in Lamma Quarry but will concentrate on any additional effects arising from gypsum disposal [2].

Quarry Development

7.44 It is planned that the quarry will be available for PFA disposal from early 1994 onwards, however a period of 1 year is necessary to carry out preparatory works including, for example, construction of the tunnel portal, conveying system and other electrical and mechanical work. PFA deliveries could therefore, commence in early 1995. A final landform and end use for the restored quarry has not yet been selected by Government. Landscaping proposals were suggested as part of the restoration work using PFA and these included provisions for either recreational facilities or development [2].

7.45 A decision by Government on the end use of the restored quarry is required before a restoration scheme can be finalized. It is presently proposed that PFA used to restore the quarry should be 'rinsed' when required to remove undesirable water soluble compounds and thus prevent a long term leachate problem. A similar philosophy may need to be adopted for the FGD gypsum. We propose at this stage that gypsum disposal would be confined to pre-determined discrete areas of the restoration. This is for two reasons. First, this would create a gypsum stockpile for future abstraction should the need arise. Secondly, by avoiding gypsum filling where subsequent development may take place, any perceived building foundation problem could be avoided.

7.46 When the form and programme for the restoration has been finalized by Government, it will be possible to design a restoration scheme using both gypsum and PFA.

Environmental Effects

7.47 The potential environmental impacts associated with gypsum disposal relate mainly to leachate, dust and community reaction as shown in Figure 7.1. These are discussed below.

Seawater Quality

7.48 Surface run-off or ground water coming into contact with gypsum would dissolve some of its water soluble constituents, and be perceived as a source of pollution if permitted to discharge into Sok Kwu Wan. Leachate and run-off quality need to be considered in the light of existing sea-water quality in the area, and current Government effluent discharge requirements.

7.49 The marine environment in Sok Kwu Wan was monitored as part of another HEC project [15]. Physical and chemical properties of sea-water, sediment, fish and mussels were measured. Some of the data for two sampling locations near the quarry is presented in Table 7.5.

TABLE 7.5 : SEAWATER QUALITY IN SOK KWU WAN

	Testing item	S1			S3		
		S	M	B	S	M	B
Physical parameters	Water depth (m)	-	3.75	-	-	9.25	-
	Secchi disc (Black)	-	1.8	-	-	3.2	-
	Secchi disc (White)	-	2.9	-	-	4.25	-
	Temperature (°C)	16.0	16.0	16.1	16.0	16.0	16.0
	Dissolved O_2 (mg/l)	6.85	7.30	7.25	7.17	7.24	7.40
	pH	8.0	8.0	8.0	8.0	8.0	8.0
	Salinity (o/oo)	28	29	29	28	29	29
	Turbidity (NTU)	0.1	0.1	0.6	0.2	<0.1	0.1
Chemical parameters	NO_3^- N (mg/l)	0.07	0.07	0.07	0.06	0.06	0.06
	NO_2^- N (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01
	PO_4^{3-} P (mg/l)	0.04	0.05	0.05	0.04	0.04	0.03
	SO_4^{2-} (mg/l)	2200	2300	2500	2500	2500	2500
	BOD_5 (mg/l)	2	1	1	1	<1	<1
	COD (mg/l)	20	16	17	32	33	21
Heavy metals (μg/l)	Antimony		$1x10^3$			$1x10^3$	
	Arsenic		2			2	
	Boron		$3.7x10^3$			$4.6x10^3$	
	Cadmium		90			90	
	Chromium		60			70	
	Copper		60			60	
	Lead		800			800	
	Mercury		<1			<1	
	Molybdenum		200			200	
	Nickel		590			660	
	Selenium		<1			<1	
	Tin		700			700	
	Zinc		50			30	

Note	S1, S3	sampling locations
	S	water sample 1 m below surface
	M	water sample at mid depth
	B	water sample 2 m above sea bed

7.50 Seawater quality is generally good, and consistent with the results of other researchers who have studied seawater quality in Hong Kong [15]. Some heavy metal species are present in rather high concentrations, particularly antimony, lead, molybdenum, nickel and tin, indicating that there is pollution in the area.

7.51 Estimates of leachate quality from gypsum disposal sites based on laboratory tests have been presented in Table 7.3. These tests were quite severe since the gypsum was in unrestricted contact with the leaching liquid.

7.52 Site measurement at two disposal sites in the USA were taken by Environment Canada, and are reproduced in Table 7.6 [6]. The FGD processes used at these two power stations are not exactly the same as the one proposed for Lamma, however, the FGD wastes produced are predominantly calcium sulphate rather than calcium sulphite so the results are of some relevance.

7.53 From Table 7.6 it can be seen that the run-off from disposal sites contain the sulphate compounds of alkali metals. Other ions are also present in smaller quantities, such as chlorides and boron. Chlorides can be present in significant quantities as shown in Table 7.3 depending on coal composition and FGD process design.

7.54 Leachate or run-off from the quarry restoration site would have to comply with the EPD's "Interim Effluent Guideline" before discharge into the sea would be permitted. Details of these requirements are listed in Table 7.7.

TABLE 7.6 : CHEMICAL COMPOSITION OF RUN-OFF FROM FGD WASTE DISPOSAL SITES

Parameters	Milton R. Young Generating Station Disposal Site Run-off	Coyote Generating Station Disposal Site Run-off
pH	7.3	9.9
Specific Conductance (μ mhos/cm)	17000	15400
Total Solids	45970	35540
Total Suspended Solids	126	40
Total Dissolved Solids	45100	34330
Turbidity in N.T.U.	42	0.06
Chemical Oxygen Demand	12	72
"OH" Alkalinity as $CaCO_3$	0	210
Sulphate as $SO_4^=$	6920	23200
Sulphite as $SO_3^=$	<1	<1
Chloride	69.0	52.0
Fluoride	33.0	2.4
Orthophosphate as $PO_4^=$	0.20	0.25
Aluminium	3.92	0.90
Arsenic	0.040	0.310
Barium	0.005	0.044
Beryllium	0.0005	<0.0005
Boron	346	35.0
Cadmium	0.07	<0.01
Calcium	442	132
Cobalt	0.05	<0.05
Chromium	0.24	<0.01
Copper	0.013	<0.008
Iron	2.82	0.28
Lead	0.05	0.05
Lithium	2.4	0.4
Magnesium	3200	20.0
Manganese	1.00	0.01
Mercury (μg/l)	<1	<1
Molybdenum	0.4	0.5
Nickel	0.90	<0.05
Phosphorus	1.9	<0.6
Potassium	968	238
Selenium	0.001	0.115
Silica	31.9	4.26
Silver	0.053	0.005
Sodium	6470	10500
Strontium	18.0	13.2
Thorium (μg/l)	<3.5	3.5
Titanium	0.135	0.005
Uranium (μg/l)	13	7.7
Vanadium	0.102	0.358
Zinc	0.23	<0.05
Zirconium	<0.05	<0.05

Note : All Analyses reported in mg/l unless otherwise stated

TABLE 7.7 : EPD INTERIM EFFLUENT GUIDELINE

			EPD Interim Effluent Guideline for Individual Element
Physical parameter	pH (unit)		6-10
	Total suspended solids (mg/l)		30
Heavy metals (all units in mg/l)	Antimony	Sb	5.0
	Arsenic	As	2.0
	Boron	B	5.0
	Cadmium	Cd	0.1
	Chromium	Cr	2.0
	Copper	Cu	2.0
	Iron	Fe	10.0
	Lead	Pb	2.0
	Mercury	Hg	0.1
	Zinc	Zn	2.0

Note : Total non-ferrous metal should not exceed 5 mg/l

7.55 A comparison can be made between the limits stated in Table 7.7 and the possible worst case leachate concentrations in Table 7.3. The worst case values shown in Table 7.3 refer to concentrations in the initial leachate flows. All the experimental data in Tables 7.3 and 7.6 complies with the effluent guidelines apart from boron which exceeds the upper limit by a considerable margin. In view of this, and pending testing of the actual FGD gypsum produced, provision for collection and disposal of initial leachate flushes may be necessary.

Dust

7.56 Gypsum is a cohesionless silt sized material which could create a dust nuisance if allowed to dry out and is then disturbed. It would be produced as a damp powder at the power station and transported by enclosed conveyor belt to the quarry, hence dust is not expected to be a problem during transportation.

7.57 A properly engineered gypsum disposal operation in the quarry, constructed with adequate care, need not create a dust nuisance. Gypsum, if permitted to dry out, forms a crust which is resistant to erosion by wind and light rain when left undisturbed [6]. Water sprinklers could be used during construction to prevent any localized dust problems.

7.58 In the long term, finished slopes would require more permanent forms of protection to prevent erosion and also for aesthetic reasons. These could include chemical stabilization or covering with a layer of soil.

Community Reaction

7.59 The reaction of the local community to the restoration of Lamma Quarry using gypsum as well as PFA has not been addressed to date.

Summary

7.60 The disposal of gypsum in Lamma Quarry would have desirable as well as adverse environmental effects, as summarized below.

<u>Advantages</u>

7.61 The quarry, which is presently an unattractive area, would be restored quicker if gypsum as well as PFA is used. Employment opportunities may be created. A properly engineered restoration scheme would enhance the amenity value or development potential of the site.

<u>Disadvantages</u>

7.62 There may be adverse reaction from the local community to disposing of another "waste" material in the quarry. Although a gypsum fill would be stable, it may not be a good foundation for building loads; its location within the quarry restoration would therefore have to be clearly demarcated if not to restrict future development. This does not however detract from it being a good restoration fill for subsequent landscaping.

Marine Disposal

7.63 Gypsum could be deposited in the sea, in either stabilized or unstabilized form. It is believed that both methods can be practised in an environmentally acceptable manner in Hong Kong and are therefore worthy of further examination. The effects associated with each option are summarized in Figure 7.1 and discussed in more detail here.

Disposal of Unstabilized Gypsum

<u>General</u>

7.64 Unstabilized gypsum could be deposited either on to the seabed in an uncontained manner, or placed into specially dredged "cells" excavated in the soft seabed sediments. The specific environmental effects associated with these options are examined in this section after a general review of the effects of gypsum in the sea.

7.65 Gypsum produced by the FGD process proposed for Lamma will be a silt sized powder consisting primarily of hydrated calcium sulphate. Although reported to be "sticky", it is essentially cohesionless from an engineering point of view [1]. Deposition of such a material on the seabed would have an adverse impact on the marine environment by temporarily smothering the benthic fauna and flora. This is unlikely to be a major constraint if deposited in a designated marine dumping ground, such as the one south of Cheung Chau.

7.66 Gypsum is slightly water soluble, to the extent of approximately 2000 mg/l in fresh water. Solubility in seawater is variable, and depends on salinity. Gypsum deposited into seawater would, in time, almost completely dissolve. However, since many of the ions released from the gypsum occur naturally in seawater, an unacceptable environmental situation is unlikely to develop.

7.67 FGD solid wastes (including gypsum) are classified as non-toxic under the US Resource Conservation and Recovery Act (RCRA) regulations, when tested in accordance with the US EPA extraction procedure [6]. Gypsum generally complies with the Hong Kong Government requirements for materials which are suitable for dumping at sea [16]. These are as follows:-

- material that sinks, is non-toxic and will not present a hazard to shipping, or;

- material that is non-toxic and will dissolve and disperse readily in seawater.

7.68 The preceding information indicates that it may be feasible to dispose of gypsum in the open sea in an environmentally acceptable manner. One aspect which may require further examination is the toxicity of gypsum produced at Lamma, particularly with respect to trace element releases. As described in the previous section on land disposal, boron concentrations may be significant, see Table 7.6. Field trials will be necessary to assess the environmental impacts of placing gypsum in the sea.

7.69 There are two other marine dumping grounds in Hong Kong waters besides Cheung Chau which could be used for gypsum disposal, namely Mirs Bay and east of the Ninepins. However both are much further from Lamma Island than the Cheung Chau grounds and are therefore less attractive alternatives on economic grounds. Mirs Bay is not affected by the oceanic currents which flow along the South China coast, hence dilution and dispersion of dissolved gypsum compounds would not be as rapid as at the other two sites which are influenced by these currents. This report will concentrate on the Cheung Chau dumping ground, however east of the Ninepins is also a feasible option for gypsum disposal.

Existing Marine Conditions South of Cheung Chau

7.70 Excavated mud and other soils are presently deposited at the marine dumping facility south of Cheung Chau. All dumping is carried out under the terms and conditions of a licence issued by the Director of Environmental Protection under the Dumping at Sea Act 1974 (Overseas Territories) order 1975.

7.71 The environmental impacts of dumping clean dredged soils at sea are limited to smothering effects on the seabed [16]. Contaminated wastes such as mud from polluted areas, may exert a heavy oxygen demand on the waters into which they are dumped, and introduce substantial amounts of heavy metals into the ecosystem. Water quality monitoring carried out by EPD indicates that marine dumping appears to have little or no effect upon either the concentration of dissolved oxygen or water turbidity.

7.72 The nearest locations to the Cheung Chau dumping ground at which water and sediment quality are monitored by EPD are the West Lamma Channel and south of Lantau. Recent monitoring results are presented in Table 7.8.

<u>TABLE 7.8</u> : SEAWATER AND SEDIMENT QUALITIES

		West Lamma Channel EPD, 1989			Lantau South EPD, 1989		
<u>Water</u>		Min	Max	Med	Min	Max	Med
Temperature (°C)	surface	17.3	29.5	23.3	16.8	29.5	23.3
	bottom	17.3	28.3	22.3	16.9	29.1	22.4
Salinity (0/00)	surface	25.2	33.2	30.4	22.2	32.8	30.1
	bottom	28.7	34.1	32.0	27.8	33.7	31.3
Dissolved oxygen	surface	71.8	153.1	96.0	69.2	143.4	100.9
(% satur)	bottom	33.7	105.0	81.0	24.2	108.3	87.1
pH		8.04	8.60	8.28	8.15	8.74	8.34
Secchi Disc		1.3	5.0	2.5	1.1	4.0	2.0
Turbidity		1.8	15.7	5.9	3.2	18.1	7.4
Total Suspended Solids, mg/l			1.8	16.7	5.6	2.8	27.77.9
BOD_5		0.3	2.6	1.0	0.6	3.0	1.2
Inorganic nitrogen, mg/l		0.014	0.344	0.150	0.063	0.405	0.138
Total nitrogen, mg/l		0.259	0.735	0.483	0.209	0.704	0.505
Orthophosphate (PO_4-P), mg/l		0.005	0.035	0.013	0.005	0.042	0.014
Total Phosphorous, mg/l		0.020	0.090	0.040	0.020	0.093	0.037
Sulphate (SO_4), mg/l		-	-	-	-	-	-

<u>Bottom Sediment</u>	West Lamma Channel	Lantau South
Cadmium (mg/kg)	<0.5	<0.5
Chromium (mg/kg)	<50	<50
Zinc (mg/kg)	<100	<100
Copper (mg/kg)	<50	<50
Lead (mg/kg)	25 - 50	<25
Mercury (mg/kg)	<0.3	<0.3
Eh (mV)	-250 - -300	-200 - -250

7.73 The data show that the quality of water and sediments are generally good when compared with other areas in Hong Kong's inshore waters. This may be due to the offshore water movements and oceanic currents in the area rapidly dispersing any suspended material.

Marine Disposal Methods

7.74 Gypsum could be deposited at the marine dumping ground by a variety of techniques depending on the equipment used, each one having different environmental effects. These are discussed below:

- disposal from a bottom dump barge. This is the usual method used for dumping on the seabed. It results in some material being held in suspension in the water column, whilst the majority spreads out to some extent smothering life on the seabed. The significance of dispersing gypsum into the water column depends on its chemical composition. Smothering effects are not considered important in areas designated as marine dumping grounds.

- placing on the seabed through a tremie pipe. The immediate impacts of bottom dumping, discussed above, can be minimized by pumping gypsum through a pipe which terminates close to seabed level (i.e. a tremie pipe). This technique limits any smothering effects, as well as reducing the proportion held in suspension. The long term effects are the same as those for bottom dumping, because both methods place gypsum on the seabed and in contact with water.

- containment in dredged cells. The dispersal and dissolution effects of dumping on the seabed can be overcome by burying gypsum in specially dredged "cells" formed in the marine deposits. A cell full of gypsum would be sealed using marine deposits arising from excavation of the next cell. Gypsum contained in such cells would be effectively isolated from the seawater and dissolution would only occur at a very slow rate, if at all.

Environmental Effects

7.75 The major impact arising from the marine disposal of gypsum is the release of chemicals into the marine environment. However many ions present in seawater are also present in gypsum and therefore this is not necessarily a problem. Typical values for major constituents in seawater are given in Table 7.9 [17]. These can be compared with typical values for gypsum given in Table 7.2.

TABLE 7.9 : TYPICAL CONSTITUENTS OF SEAWATER

Ion	Concentration (g/kg)
Cl^-	18.97
Br^-	0.065
SO_4^{2-}	2.64
CO_3^{2-}	0.07
Mg^{2+}	1.28
Ca^{2+}] Sr^{2+}]	0.41
K^+	0.38
Na^+	10.50

7.76 Depletion of dissolved oxygen in the waters into which gypsum will be dumped is not expected to be an area for concern. Biochemical and chemical oxygen demands are largely eliminated in FGD solid wastes which contain more than 90% gypsum [6].

7.77 The actual effect of gypsum disposal on the marine environment depends on chemical composition and in particular the concentration of trace elements such as heavy metals. This cannot be accurately predicted at present. Data presented in Table 7.3 indicates that water which has been in contact with FGD wastes (including gypsum) does not present a significant source of pollution, in fact it generally complies with current discharge requirements. The rate of release of gypsum into solution can be controlled by the method of placement and hence the magnitude of the environmental impact can be adjusted to acceptable levels. As discussed previously, bottom dumping would have the most impact and encapsulation in "cells" the least impact. We understand that Government are considering a similar disposal method for excavated marine deposits from typhoon shelters and nullahs which are contaminated with heavy metals [16]. Marine dumping of sewage and waterworks sludge is also being considered. The disposal of a less environmentally sensitive material such as gypsum is no less feasible.

Disposal of Stabilized Gypsum

General

7.78 Several countries including the USA, Japan and UK are carrying out research projects to enhance the marine environment through the formation of artificial reefs in coastal waters [20]. Power station solid wastes including PFA and gypsum can be used to build the reefs and therefore present environmentally attractive disposal options. Artificial reefs can offer the following environmental advantages:

- to increase the size of natural reefs, thus encouraging an increase in marine population
- to protect spawning and nursery grounds from bottom trawling
- to improve the marine habitat in areas where the seabed is flat and desolate

The feasibility of constructing such reefs in Hong Kong from stabilized gypsum is considered in detail below.

Overseas Experience

7.79 Trials have been carried out by the State University of New York into the environmental and engineering aspects associated with the marine disposal of PFA and FGD solid waste. Blocks of PFA and scrubber sludge (FGD solid waste) in the ratio of 5:1 (dry weight) were fabricated and stabilized using a proprietary process called the Poz-o-Tec process [18]. For comparison concrete blocks were also fabricated. The Poz-o-Tec process involves the mixing of PFA and gypsum with a small proportion of lime and water. The mixture gains strength with time due to a pozzolanic reaction.

7.80 The blocks were submerged in an estuarine environment for nearly two years on the north shore of Long Island, USA. Samples were taken at regular intervals to determine compressive strength of the block, rate of colonization and uptake of heavy metals by the attached growth.

7.81 The concentrations of metals in the marine organisms which colonized the coal waste blocks were no greater than those in the organisms living on the concrete reference blocks placed nearby [18]. A summary of the results is presented in Table 7.10.

7.82 Other researchers have studied the behaviour of blocks and bricks of stabilized PFA and FGD waste placed in a marine environment [18, 19]. Various ratios of constituents were studied and different marine environments in terms of water depth and seabed conditions. The rates at which marine organisms colonized the artificial reefs and diversity of species were monitored and compared with control reefs made of concrete blocks. Results showed that both types of blocks were readily colonized.

7.83 The UK Central Electricity Generating Board have carried out trials to assess the potential of constructing artificial reefs made from PFA and gypsum stabilized with cement. Hollow tiles were deposited to form the reefs on the seabed in Southampton Water off the south coast of England. These artificial reefs proved to be attractive marine habitats for a wide variety of sea life. The success of the initial trials has encouraged the CEGB to develop the method further.

Applicability to Hong Kong

7.84 Bottom trawling can damage the breeding grounds of many fish species. The creation of artificial reefs could discourage this method of fishing, and thereby help to improve the marine habitat. Stabilized gypsum and PFA from Lamma Power Station could be used to construct such reefs.

7.85 Positive environmental impacts would be associated with this method of disposal by improving the marine environment. The release of trace elements into the seawater would be minimal since the stabilization process produces a strong, relatively impermeable block which prevents the dissolution of water soluble compounds. Trials in the USA mentioned earlier, have shown that the trace element concentrations of marine growth on stabilized gypsum blocks are comparable to those on concrete blocks.

TABLE 7.10 : TRACE ELEMENT CONCENTRATIONS IN ORGANISMS GROWING ON ARTIFICIAL REEFS (μg/g DRY WT BASIS)

Date of Collection	Days Since Placement	Concentration in Organism Reef made of : SSFA blocks	Concrete blocks	*t* Test Results [18]
		Copper		
08/16/77	83	46.3	49.7	*ns*
09/13/77	111	59.9	63.5	*ns*
08/16/78	448	80.0	81.2	*ns*
10/15/78	508	53.3	63.1	*A*
		Chromium		
08/16/77	83	22.8	26.9	*ns*
09/13/77	111	22.5	23.1	*ns*
08/16/78	448	30.8	36.4	*ns*
10/15/78	508	17.4	26.6	*A*
		Zinc		
08/16/78	83	287.5	232.7	*ns*
09/13/77	111	201.2	239.2	*B*
08/16/78	448	167.7	174.1	*ns*
10/15/78	508	120.8	115.3	*B*
		Cadmium		
08/16/77	83	0.29	0.60	*ns*
09/13/77	111	0.43	0.55	*ns*
08/16/78	448	0.82	0.72	*ns*
10/15/78	508	0.76	1.02	*ns*
		Lead		
08/16/77	83	40.3	37.8	*ns*
09/13/77	111	33.4	40.4	*A*
08/16/78	448	39.1	36.4	*ns*
10/15/78	508	22.4	32.7	*B*
		Selenium		
08/16/78	448	3.0	3.4	*ns*
10/15/78	508	4.9	6.6	*ns*

Notes:

Concentrations of silver, arsenic, and mercury were below the detection limits of the instrument

ns = insignificant amounts
A = significant amounts at $0.01 < P < 0.05$
(P = probability of difference in means being significant)
B = significant amounts at $P < 0.01$
SSFA = scrubber sludge and fly ash

7.86 The production of blocks containing PFA and gypsum stabilized with lime or cement would require the construction of a purpose built factory. There will be physical and socio-economic impacts associated with such a facility, which are impossible to assess at present since both location and public reaction are unknown. However such issues are not expected to present major obstructions to a carefully formulated scheme.

Summary

7.87 The disposal of unstabilized gypsum in designated marine dumping areas, or specially dredged cells within the marine deposits around Hong Kong appears feasible in both engineering and environmental terms. There are not expected to be any significant adverse environmental impacts associated with the proposals. Government is presently considering the disposal of contaminated mud and sewage sludge at sea, and it is no less feasible to dispose of gypsum in a similar manner.

7.88 The disposal of gypsum in a stabilized form has definite benefits for the marine environment and minimal disadvantages. Trials in the UK and USA have demonstrated this disposal option to be environmentally acceptable in terms of trace element release to colonizing organisms and to the marine habitat in general.

7.89 Stabilization requires 1 part of gypsum to be mixed with approximately 5 parts PFA and a small quantity of cement or lime. The process would therefore use large quantities of PFA, which would be a disadvantage if there were industrial outlets for the ash, as is currently the case, but an advantage otherwise.

Disposal In The Ash Lagoon

7.90 The gypsum waste management strategy identified the ash lagoon, which will be constructed at the south east corner of the power station site, as a potential disposal option for gypsum [1]. Co-disposal of gypsum with ash is not recommended because it would make its re-use as a fill material in land reclamation less attractive. However storage of gypsum in discrete areas above water level is feasible.

7.91 Initial stages of ash storage in the lagoon will concentrate on forming a landscaped mound at the eastern end, designed to screen the works from the general public. This mound will not be removed when ash is subsequently harvested. Gypsum could be placed in the mound, in clearly defined areas above water level with minimal environmental effects.

7.92 An initial assessment of the impacts associated with this disposal option are presented in Figure 7.1. Many of these issues have already been examined as part of the PFA disposal plan for Lamma Power Station [2,3]. PFA and gypsum are expected to have generally similar environmental effects. The effects of land disposal have already been described above and therefore this section will only consider additional impacts relating to the disposal of gypsum in the ash lagoon.

Existing Conditions

7.93 The ash lagoon is programmed to be completed by September 1992, while units 7 and 8 are scheduled to produce gypsum in 1995 and 1997 respectively. It will not be possible to place gypsum in the mound, as described above, until a significant quantity of ash is already in the lagoon. The amount of ash requiring disposal, i.e. exceeding industrial demand, is unknown at present, and hence the availability of the lagoon for gypsum disposal is also unknown.

7.94 Disposal of gypsum in the lagoon will reduce the amount of ash storage capacity. However this is not a problem in the case of units L7 and L8 since Lamma Quarry should be available for ash disposal before these units are commissioned. The lagoon therefore represents a disposal option for gypsum at an indeterminate future date, depending on the rate at which ash is deposited in the lagoon.

7.95 Operation of the ash lagoon has been designed to ensure that environmental effects due to the presence of PFA are maintained within acceptable limits [2]. These procedures are equally applicable if gypsum is used to construct the screening mound instead of PFA.

Environmental Effects of Gypsum Disposal in the Ash Lagoon

7.96 The effects are summarised in Figure 7.1 and discussed below.

Seawater Quality

7.97 A system has already been proposed to ensure that leachate quality (i.e. seawater) within the ash lagoon complies with the EPD's Interim Effluent Guidelines and is therefore suitable for discharge into the sea. A properly designed drainage system would ensure that all leachate or surface run-off which has come into contact with gypsum be discharged into the lagoon and then into the sea in acceptable concentrations.

7.98 The possible chemical composition of surface run-off from gypsum disposal areas is discussed above, and presented in Table 7.6. Boron was reported to be the only element which exceeded the EPD guidelines [6]. If the leachate from Lamma Power Station is also found to contain excessive concentrations of boron, it can be diluted as necessary in the ash lagoon.

7.99 Placing gypsum in the ash lagoon would reduce the quantity of trace elements discharged to the surrounding environment, compared with a similar volume of PFA. Gypsum usually contains less trace elements than PFA [6]. Hence the presence of gypsum would have less adverse environmental effects on the adjacent sea than the present proposals for PFA which have been accepted in principle by Government.

Community Reaction

7.100 Whether gypsum or PFA was placed in the mound would not change the type of construction activities involved or the resulting environmental impacts perceived by the local community. Many of the objections to the disposal of PFA have been overcome and hence the substitution of some of this material by gypsum is not expected to produce significant objections.

Visual Effects

7.101 Gypsum used to construct a mound at the eastern end of the ash lagoon would screen some of the power station site from the public view. This is considered to be a beneficial aspect of the disposal option. The gypsum mound could be landscaped in a similar manner to a PFA mound [2].

Summary

7.102 Gypsum could be deposited in the ash lagoon without producing unacceptable environmental effects. Any effects arising from the disposal of gypsum would be no worse than those for the disposal of PFA, which have already been discussed fully in a previous study [2]. An operating system was designed for the ash lagoon to ensure leachate is of an acceptable quality for discharge to the sea at all times. The system can equally well accommodate leachate arising from gypsum disposal.

7.103 Effects arising from the disposal of gypsum rather than PFA in the mound at the eastern end of the lagoon are similar in terms of short and long term visual impacts, landscaping requirements and construction techniques. The effects of PFA are acceptable and hence the effects of gypsum should be no less acceptable.

The Preferred Scheme

7.104 New generating capacity, either under construction or proposed, at Lamma Power Station will produce large quantities of solid waste in the forms of ash and gypsum. Ash disposal has been examined in a separate study [3]. This study has considered the disposal of gypsum from the wet limestone process with forced oxidation.

7.105 A gypsum waste management strategy for units L7 and L8 identified industrial use in cement manufacture as the preferred disposal option [1]. This option does not require purpose built facilities, and is generally beneficial for Hong Kong from both environmental and economic points of view. There is sufficient existing industrial demand for gypsum in Hong Kong to utilize almost all the expected production from HEC, assuming the FGD gypsum is of the right quality. Future demand may decline and gypsum production could exceed market demand if wet limestone FGD equipment is installed on much of Hong Kong's power generation facilities, hence a contingency disposal option is required.

7.106 Lamma Quarry is the preferred long term disposal option for gypsum which cannot be utilized by industry. Restoration of the quarry using gypsum could improve the appearance of the area and ultimately provide recreational or development facilities when complete. Plans are already being drawn up to restore the quarry using PFA, hence the inclusion of gypsum as a fill material would have minimal additional consequences. The construction procedures and monitoring measures required for PFA, are equally applicable to gypsum. Government planning policies may restrict the areas where gypsum can be deposited to those locations which will not be developed. These have not been identified at present, hence a detailed restoration programme cannot be formulated. The quarry represents a flexible disposal option which can accommodate varying amounts of gypsum.

7.107 Marine disposal in either stabilized or unstabilized form appears to be a feasible option. The latter does not produce any beneficial environmental effects and is therefore considered inferior to the option of restoring Lamma Quarry. It is, however, a low cost disposal method, which can accommodate varying quantities of gypsum, and should be considered as a possible option if the quarry becomes unavailable. Stabilized gypsum used to form artificial reefs is the most beneficial form of marine disposal, however it is capital intensive and relatively inflexible. A significant manufacturing facility would be required to convert all the gypsum produced by HEC into stabilized blocks, potentially up to 150,000 tonnes per year. Conversion into stabilized blocks does not therefore represent a realistic contingency measure for disposal of all the gypsum produced at Lamma.

7.108 Encapsulation within "clean" marine mud is being considered by Government as a disposal method for mud contaminated with heavy metals. Disposal of gypsum by similar means is equally feasible.

7.109 Placing gypsum in the ash lagoon below the water level is not recommended since the re-use potential of the gypsum would be reduced. Gypsum instead of PFA could be placed in the mound at the eastern end of the lagoon with minimal additional environmental effects.

7.110 This Initial Assessment Study has identified several areas where further information is required on the properties of FGD gypsum which will be produced at Lamma Power Station. These are as follows:-

- the geotechnical properties of gypsum necessary for quarry restoration and lagoon mound design,
- leaching behaviour of gypsum, particularly the release of trace elements in both wet and dry disposal situations,
- chemical composition of gypsum and suitability for proposed industrial applications.

7.111 These aspects can be resolved by testing the gypsum produced at the Lamma Power Station. Since raw materials, plant design and operating procedures all influence gypsum properties, overseas experience can only be considered indicative of the likely properties of gypsum produced at Lamma. The above issues will therefore need to be studied as key issues.

FGD Waste Water Sludge

7.112 Units L6, L7 and L8 will each produce a maximum of about 4000 tonnes per year of dry FGD waste water sludge, or 5000 tonnes net weight. The composition of the dry sludge is estimated to be:

	% Dry Wt
$CaSO_4.2H_2O$	80.3 - 88.5
$CaCO_3$	4.0 - 6.6
Particulates	1.7 - 6.9
Inert	
$MgCO_3$)	
CaF_2)	
SiO_2 + acid insoluble)	1.3 - 3.5
Fe_2O_2)	
Al_2O_3)	
Hydroxide	
$Al(OH)_3$)	
$Mg(OH)_2$)	0.4 - 7.1
$Mn(OH)_2$)	

Source: HEC

7.113 As FGD waste water sludge has very similar properties to FGD gypsum, it is intended that the former be disposed of either as low grade gypsum or some other environmentally acceptable means. This option will be subject to more detailed consideration in a separate study which is now being undertaken.

Key Issue Studies

7.114 Following the submission of the draft IAR, a number of concerns were raised by Government on the feasibility of the various disposal options identified for gypsum from the FGD plant. As no FGD gypsum has yet been produced in Hong Kong, there is no local experience of the practical issues that may affect the various gypsum disposal options. A particular concern expressed by the Planning Department was the potential sterilization of the Lamma Quarry for subsequent residential/recreational use due to possible inadequate geotechnical properties of gypsum. It was also noted that before a strategy for disposal could be finally approved, appropriate field trials would need to be carried out with gypsum to test its suitability on engineering, planning and environmental grounds.

7.115 The production of gypsum is a feature of the wet limestone-gypsum FGD process. Prior to acceptance of this particular process for use in Units L7/L8, HEC submitted an evaluation report to EPD. The report identified the wet limestone gypsum FGD process as the most suitable one on environmental and engineering grounds for Units L7/L8. EPD subsequently endorsed the use of the wet limestone-gypsum method for Unit L7.

7.116 As a condition of approval of the wet limestone-gypsum process for Unit L7, EPD have required that HEC enter into a long term contract to "sell back" the gypsum to the FGD system/limestone suppliers. This requirement should ensure that for all practical purposes, the disposal of waste gypsum will take place outside Hong Kong and there should not therefore be any requirement for local disposal. HEC will also endeavour to locate suitable commercial outlets in Hong Kong for the gypsum. Detailed engineering and environmental studies will however be continued to ensure that a viable fall back option is available, should the need arise. It has been agreed that the fallback disposal options study will be completed within six months starting from 21st February 1992.

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EFFECTS / DISPOSAL OPTION	SOCIAL EFFECTS															PHYSICAL EFFECTS							
	SOCIO-ECONOMIC						PSYCHOLOGICAL						POLI-TICAL	BIOTIC		ABIOTIC							
	Land-use	Employment Opportunity	Agriculture	Mariculture	Tourism	Property Values	Visual Impact	Noise	Smell	Lights	Community Reaction	Fung Shui	Planning	Marine Biota	Terrestrial Biota	Air Quality	Sea Water Quality	Groundwater	Land Drainage	Sedimentation	Micro-climate	Archeology	Radioactivity
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Industrial use																							
Cement															*								
Wallboard	○	*													*								
Land disposal							*				⊘					○	○						
Marine disposal																							
Unstabilized											○			○			○			○			
Stabilized	○													*									
Lagooning							○				⊘			○									

Notes :

1. In making our judgement we have assumed that all practicable mitigatory measures would be implemented.

2. Where there is no symbol at an intersection we believe there will be no effect.

3. Our judgement of potentially adverse effects is illustrated as follows :

   ○ - low significance
   ⊘ - medium significance
   ⊗ - high significance

4. Where we judge an effect to be beneficial it is shown *

The Hongkong Electric Company Limited

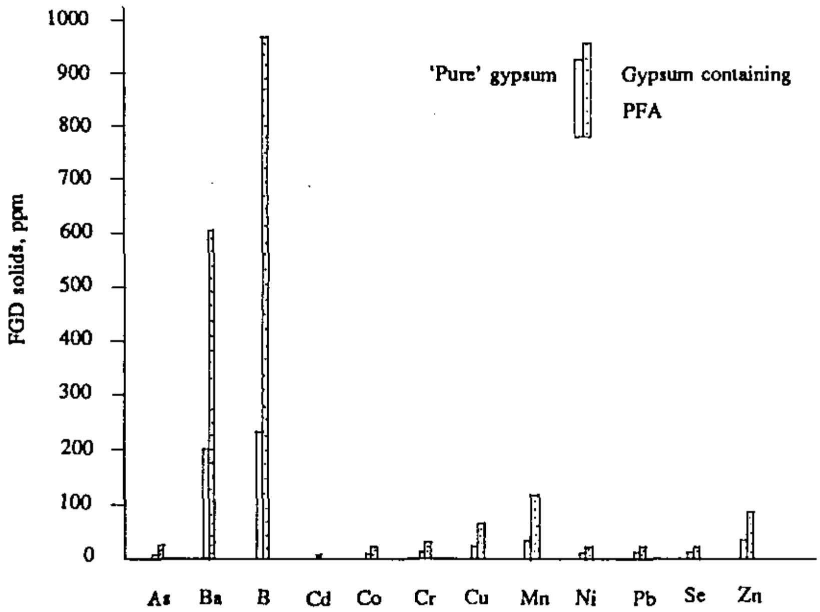
hongkong electric

PROJECT

EIA LAMMA POWER STATION

TITLE JUDGEMENT OF ACTIVITIES AND EFFECTS

FIGURE 7.1



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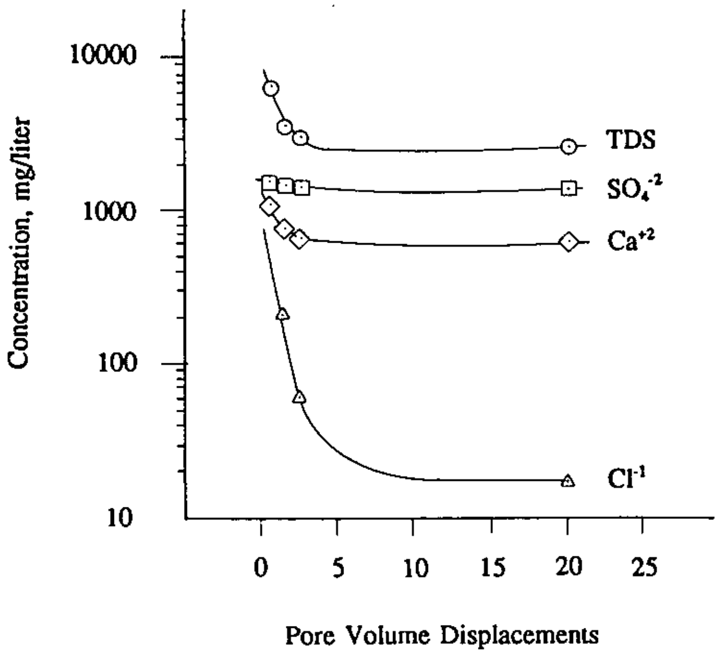
PROJECT

EIA LAMMA POWER STATION

TITLE CONCENTRATIONS OF TRACE ELEMENTS IN TWO FGD SOLID WASTES

FIGURE 7.2



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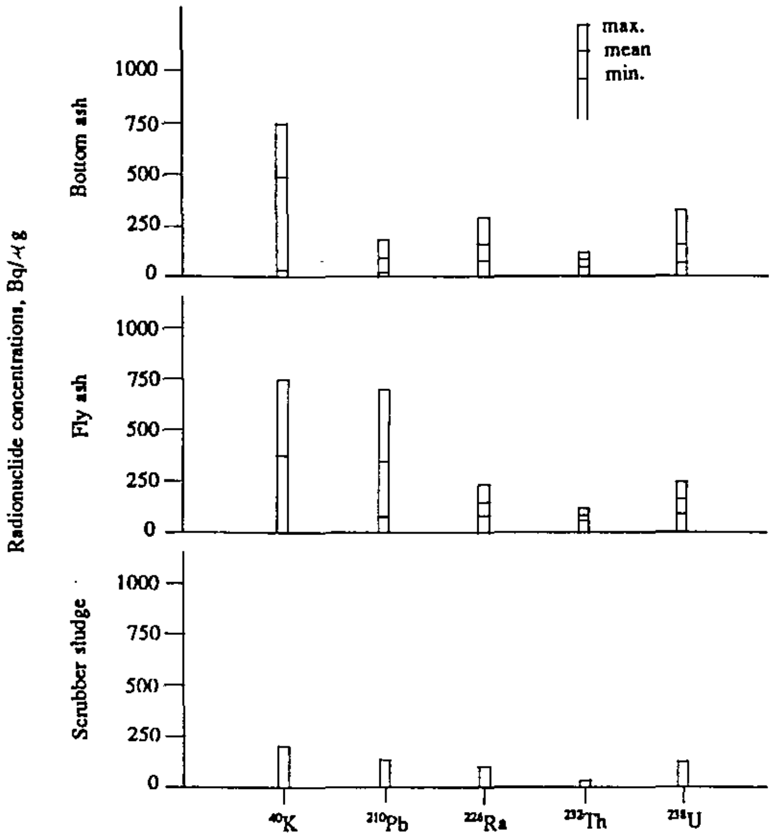
PROJECT

EIA LAMMA POWER STATION

TITLE CONCENTRATIONS OF MAJOR SPECIES IN LEACHATE FROM FGD SLUDGE

FIGURE 7.3



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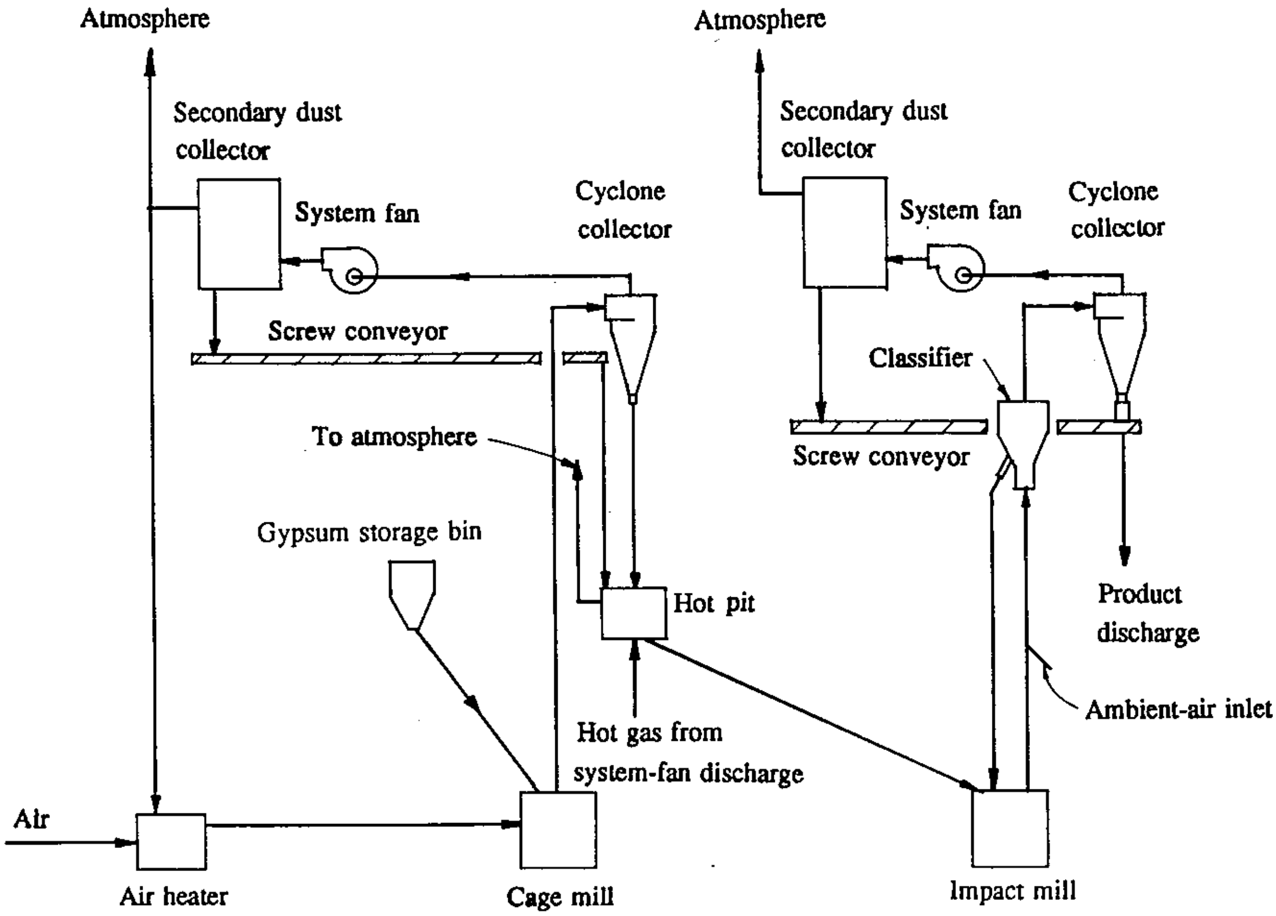
PROJECT

EIA LAMMA POWER STATION

TITLE RADIO-NUCLIDE CONCENTRA-
-TIONS IN SCRUBBER SLUDGE
AND COAL ASHES

FIGURE 7.4



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PROJECT

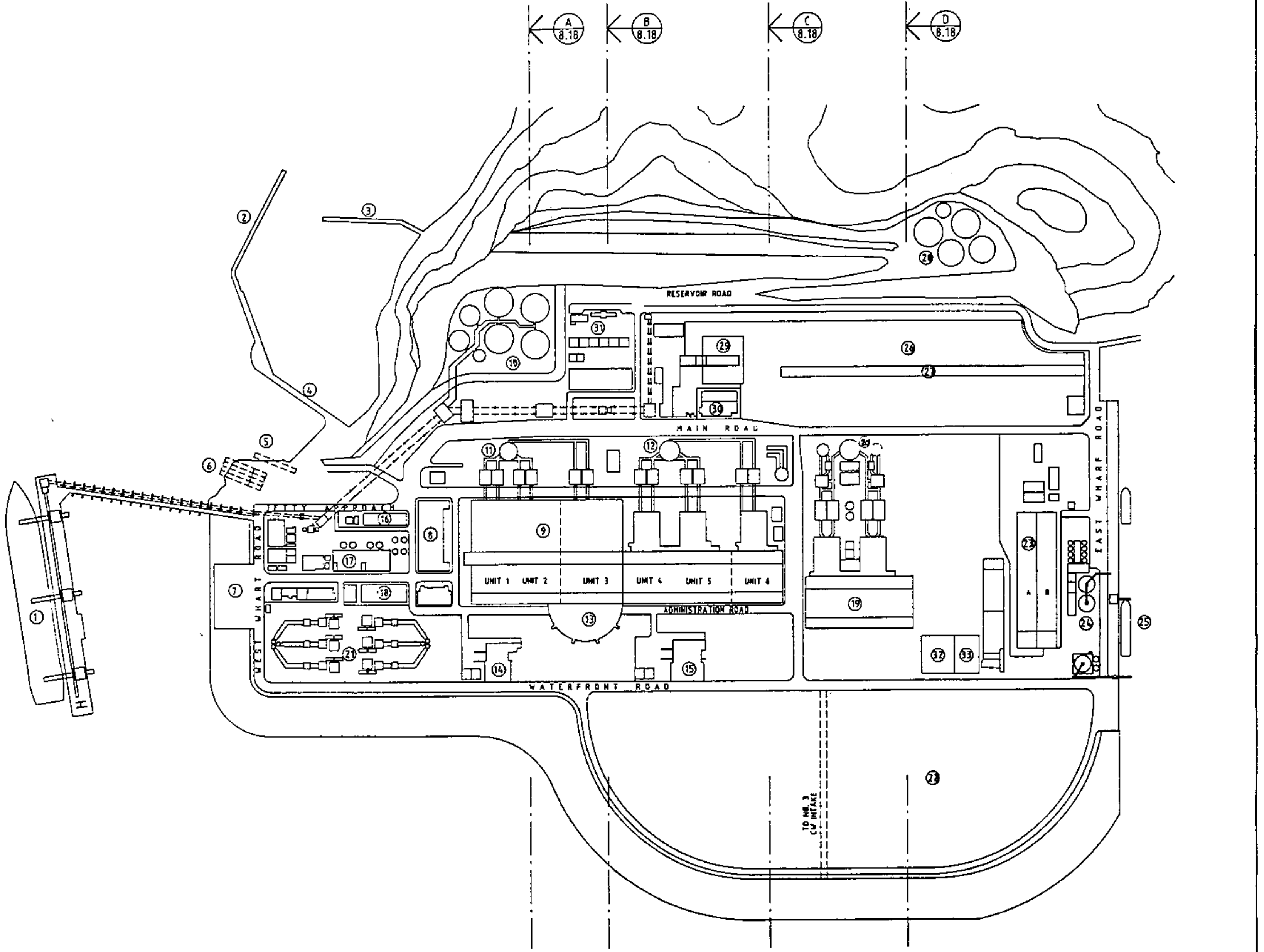
EIA LAMMA POWER STATION

TITLE LAYOUT OF GYPSUM WALLBOARD PLANT

FIGURE 7.5

KEY

1. COAL SHIP
2. BREAKWATER B
3. BREAKWATER C
4. PASSENGER JETTY
5. FUTURE C.W. OUTFALL
6. C.W. OUTFALL
7. WEST HEAVY UNLOADING AREA
8. WORKSHOP & OFFICE
9. STAGE I STATION BUILDING
10. OIL TANK FARM
11. NO. 1 CHIMNEY
12. NO. 2 CHIMNEY
13. ADMINISTRATION BLDG. & CONTROL RM.
14. NO. 1 C.W. INTAKE
15. NO. 2 C.W. INTAKE
16. D.G. STORE
17. DEMINERALIZATION PLANT
18. AMENITY BUILDING
19. 350MW STATION MAIN PLANT
20. NO. 3 CHIMNEY
21. NO. 2-7 GAS TURBINE
22. ASH LAGOON
23. ASH SETTLEMENT BASIN
24. GYPSUM & LIMESTONE HANDLING PLANT
25. EAST JETTY
26. COAL YARD NO. 2
27. STACKER RECLAIMER SUPPORTING STRUCTURE
28. RESERVOIR
29. COAL YARD COVERED STORE
30. FUEL & ASH CONTROL ROOM
31. NO. 1 GAS TURBINE
32. DEMINERISATION PLANT
33. EFFLUENT TREATMENT PLANT



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The Hongkong Electric Company Limited

PROJECT:

EIA LAMMA POWER STATION

TITLE: PROPOSED LOCATION OF THE ASH LAGOON

FIGURE: 7.6

VISUAL IMPACTS, ARCHITECTURAL & LANDSCAPE

8.0 VISUAL IMPACTS, ARCHITECTURAL & LANDSCAPE

Visual Impacts

8.01 In this chapter the visual impact of the proposed additional generating units L7 and L8 to be constructed at Lamma Power Station is evaluated in relation to the already existing landscape developed by reclamation, the completed units L1-L5, unit L6 due for completion in 1992 and the future Ash Lagoon. It also considers the design and appearance of those elements of the plant exposed to view and the buildings to house the plant and for human occupation. The principles of architecture and landscape design within the site are also described.

8.02 The visual impact of the additional Units L7 and L8 with a generating capacity of 350MW each has been examined in detail and forms the basis of the visual impact assessment. (See Figure 8.1) The concerns raised by Lamma representatives have also been given due consideration in formulating the approach to the visual impact study.

Method of Assessment

8.03 The methods of assessment of visual impact used include a description of the existing power station before the addition of L7 and L8, illustrated with photographs and diagrams, and an analysis of the visual impact of the whole development at long and short range, aided by a Zone of Visual Influence diagram relating to the height of the chimneys. Photo- montages and 3D Computer Modelling are used to show the buildings and plant and to demonstrate the effect of the proposed extension on the existing Power Station setting.

The Environment of the Locality

8.04 Lamma Power Station, which is situated at the north western part of Lamma Island is south of Yung Shue Wan and separated from the villages only by the Po Lo Tsui Headland. (See Figure 8.2) The existing Gas Turbine installation is concentrated between the middle and South-Western end of the Station.

8.05 The character of the man-made environment on the site and the extent of the contrast it makes with the existing natural landscape is apparent. To the north of the site, the hinterland remains a pastoral scene where the slow moving changes in the rural culture continue to support the traditional land uses. The villages & scattered farmlands of Tai Wan San Tsuen, Tai Wan Kau Tsuen, Tai Yuen and Wang Long lie beneath the quiet hills, in close proximity to the Power Station. Local residents have, in the past, taken a keen interest in the development of the power station.

8.06 To the east of the site Hung Shing Ye Beach, frequented by weekend visitors and pleasure crafts, still commands an uninterrupted view of the western horizon across Ha Mei Wan, although the Power Station now breaks the skyline to the east.

The Site

8.07 The site for the Power Station with the addition of units L7 and L8 is a flat area measuring 50 hectares, to which has been added a further 12 hectares for an Ash Lagoon.

8.08 The entire site has been reclaimed from the sea; part of the material used for the reclamation being removed from the headland behind the site. This has created a rock face, 400 metres long and rising to 90 metres at its highest point to the north of the site.

8.09 The sea wall 1,650 metres in length is in visual terms a particularly successful termination of the reclaimed area.

The Existing Buildings & Structures

8.10 The station complex includes the following existing buildings and structures which forms the baseline condition for the visual impact assessment :

Main Jetty
Passenger Jetty
West Heavy Unloading Area
Helicopter Pad
Effluent Treatment Plant
Dangerous Goods Store
Demineralization Plant
Amenity Building
Generation Maintenance Building
Coal Conveyors and Towers
Oil Tank Farm
Station Buildings Units L1 - L5, Boiler House, Coal Bunker
Station Chimneys 215m P.D.
Gas Turbine Plant
Electrostatic Precipitators
Lamma Supplies Building
Control Room and Administration Building
Coal Yards No. 1 and No. 2
Raw Water and Fire Services Water Tanks
Fuel and Ash Control Room
Ash Silos
East Heavy Loading Area
Security Fence around Boundary (will be constructed)
Sewage Treatment Plants
275 kV substation

Laundry Building
Transport, Security and F. S. Building
Gas Turbine Chimneys 80m P.D.
Ash Settlement Basins
Stacker Reclaimer Installation (under construction)
Unit 6 FGD Plant (detail design stage)
FGD Gypsum and Limestone Handling Plant (conceptual design stage)
Station Building - Unit L6 under construction
Extended East Heavy Unloading Area (conceptual design stage)

The Ash Lagoon

8.11 The PFA lagoon which is to be constructed at the south eastern boundary of the site will alter the configuration of the sea wall and coastline. For establishing baseline conditions, this study adopts the premise that the ash lagoon is an existing feature of the Power Station setting.

Future Development

8.12 At this early stage the detail design of the Station Building for L7 and L8 is of course still in the process of development and evolution. The architectural strategy has, however, been decided for the major areas concerned to a point where it is possible to make judgements about the visual aspects of the design and its impact upon the landscape setting. Any subsequent changes will be in the detailing which should not affect the substance of this assessment.

8.13 The space available for units L7 and L8 (350MW) between the existing units L1 - L6 and the ash silo and ash disposal plant is sufficient but curtails opportunities for creating adequate landscape reserves within the site.

8.14 The chief factors which affect the appearance and visual impact of units L7 and L8 are :

1) The placing and orientation of the station building

2) The number and disposition of smaller buildings required for various ancillary functions

3) The location of exposed plant

4) The remaining area for landscaping within the site

5) The visual relationship to units L1 - L6

6) Visual cohesion of the station design

7) The number and design of additional chimney stacks.

8.15 With the addition of Units L7 and L8 (350MW) the following changes and additions to the station site will be required :

1) An increase in capacity of the Coal Yard No. 2 after the completion of the stacker reclaimer installation.

2) Addition of L7 and L8 Station Building, Boiler Structures, and electrostatic precipitators, FGD plant and ancillary buildings.

3) One chimney for the two units, currently proposed to be at 215m P.D.

4) Removal of Coal Yard No. 1.

5) A new effluent treatment plant, demineralization plant and sewage treatment plant may also be required for Units L7 and L8, subject to detailed studies.

Visual Influence

8.16 The height of the additional chimney for L7 and L8 has not yet been determined, however, for the purposes of the present study, the same height as the existing two chimneys (215m P.D.) has been adopted. A Zone of Visual Influence (ZVI) diagram has been prepared to show the positions on land from which the existing chimneys are seen. (See Figure 8.3)

8.17 The Lamma Power Station chimneys are visible from a number of places on Lamma Island and from some of the outlying islands and Hong Kong Island. (See Figure 8.4) The zone of visual influence of the additional chimney is no greater than the existing two chimneys.

8.18 Aerial photographs of the existing Power Station were taken in March 1990 at various altitudes from 300 ft to 1,300 ft above sea level corresponding as close as possible to views from residential highrise/lowrise buildings at appropriate locations. (Figures 8.5 & 8.6)

Primary Visual Impact

8.19 The primary visual impact of the addition is the view of the major parts of the L7 and L8 station development seen by residents at Hung Shing Ye, Long Tai Tsuen, Tai Wan Kau Tsuen, Tai Wan San Tsuen, Wang Long and Ko Long whose dwellings are situated to the north and northeast of the site, and to varying degrees overlook the Power Station site. (See Figure 8.7)

8.20 From the ZVI diagram it can been seen that within a 8km radius (5 miles) the only residential area that has a direct view of the station is Cheung Chau, in which case, most of L7 and L8 installation will be blocked by the existing station. (See Figure 8.8)

8.21 As regards the residential areas on Hong Kong Island within 8km radius, i.e. Pok Fu Lam, Victoria Peak, Mt. Cameron, Blacks Link, only the top part of the chimneys will be seen. Moreover, with the decommissioning of Ap Lei Chau Power Station the visual impact of Lamma Power Station will be reduced. (See Figure 8.9, 8.10 & 8.11)

8.22 Fig. 8.12 has been included to illustrate the impact on the future new residential development at Ap Lei Chau.

8.23 From Discovery Bay on Lantau Island, Repulse Bay and Chung Hom Kok on Hong Kong Island within 13km radius, the effect of distance and haze significantly reduces the visual impact. (See Figures 8.13 & 8.14)

8.24 When the existing station was assessed by Urbis, the population figures measured from the 1986 By-census indicated that north Lamma settlements were not heavily populated and that Lamma Island was not densely developed. Recent population figures indicated in the Working Group on Population Distribution Paper 2/90 show 2,960 people living on Lamma Island out of which the majority live in Lamma North. From a recent inspection of the villages relatively little change appears to have taken place apart from a number of new houses.

8.25 A house-by-house count of dwellings with rooms with a view of Lamma Power Station cannot be carried out due to the time and costs involved. There are no figures available to the consultants for the projected population of the villages north of the site. Only the indigenous villagers are entitled to build according to the Small House Policy, hence it can be concluded that the number of people directly affected now and in the future by having a significant part of the Power Station in view from their dwellings will be relatively small.

Secondary Visual Impact

8.26 The secondary visual impact relates to the people indirectly affected by the development. No attempt has been made to assess the number of people involved in the secondary influence as listed below :

1) For the weekend users of the Hung Shing Ye Beach and pleasure crafts at Ha Mei Wan, the Power Station, L7 and L8, and the limestone and gypsum silos will be seen at close quarters.

2) Boat route, ferry traffic and pleasure boat trips to outlying islands will perceive the main features and general scale of the development but will be less aware of the details than the beach-goers. L1 - L6 will shield most of the L7 and L8 view. The existing jetty structure is more noticeable due to the impact of the colour of the exposed plant against the hills.

3) For those visiting the Peak, all three chimneys and the top portion of units L7 and L8 will be visible. The effect of distance and haze will, however, significantly reduce the visual impact.

4) Motorists driving along Tuen Mun Highway will perceive the chimney stacks, however, due to the speed at which they are travelling and the effect of distance and haze, the visual effect is insignificant.

View Points

8.27 From the ZVI it is possible to single out three major view points where the appearance of the development can be seen most prominently in the context of its setting.

Photomontages and several CAD 3 models to illustrate these major view points and compare the existing view with the potential view after adding units L7 and L8 are shown in:

Fig. 8.15 Hai Mei Wan
Fig. 8.16 Frontal View
Fig. 8.17 Yung Shue Wan

8.28 Figure 8.18 representing a true elevation to scale of the land form of Po Lo Tsui headland is included to illustrate the relative scale of L1 - L6, extension units L7/L8 and land form against which it will be seen from the long distance seaward viewpoints.

Architectural Principles

8.29 The basic objective in the architectural design for units L7 and L8 is to achieve a cohesive design for the overall station complex. The question of design similarity or contrast with the existing station has been tackled by a thorough review of the units L1 - L6 as it has developed.

8.30 Looking at the design of the L1 - L6 station and the site layout, the scope for influencing the appearance and visual impact of individual buildings is limited by economic, functional and engineering factors. The areas for choice are :

1) Form

2) Selection of materials

3) Detailed design of the external envelope

4) Colour and texture

8.31 Function, speed of erection and economy dictated use of light metal cladding for the enclosures of the existing buildings housing plant e.g. Boiler House ... etc. This stopped clear of the ground above a masonry plinth to resist damage from vehicles and plant during construction and maintenance. In terms of form and materials, these buildings integrated as part of an industrial landscape.

8.32 The Main Station Building is a simple expression of the functions it contains. The architectural context is one of expression of machinery, turbines, cranes, corresponding to the machine aesthetic environment and the dynamic character of the power generating process. The stepped roof line serves to break up the mass of the building structure and attune it sensitively to the natural setting.

8.33 The construction of the ancillary buildings is of reinforced concrete and expresses an architectural simplicity consistent with the industrial setting of the Power Station.

8.34 The problem of achieving a harmonious relationship between the ancillary buildings and the main station building was dealt with by painting all the walls pale yellow and by treating all the windows as contrasting strips with eaves overhang to act as sun shields. These cast shadows over the windows introducing a strong horizontal emphasis at each floor level. The apparent size of the buildings was thus increased so that the extremes of scale could by this means be brought into a more compatible relationship. (See Figure 8.19)

8.35 The metal cladded steel oil tanks and concrete water tanks were treated as landscape elements and hence left in their natural grey colour, the objective of which was to blend in with the cut slope.

8.36 The station chimney, being the tallest element, has the greatest visual influence, especially at a distance. The concept of grouping the flues together in two common wind shields instead of using individual stacks, tends to reduce the visual impact.

8.37 The concept of colour was to articulate the functional activities such as machinery, exposed plants, jetty, conveyors, which are in strong applied colours; whereas the Main Building profiled sheeting is a neutral colour which serves to subdue the impact of such a large structure.

The following is the colour scheme for the existing Station Complex :

Item	Colour	Munsel No.	B.S. Code
Admin. Building	papyrus by Ramtex	-	BS4800/08B17
Turbine Hall (L1-L6) Boiler House (L1-3) Boiler Encl. (L4-6)	) sea foam) 1731 with) blue band) by Robertson)	-	-
Ash Storage Silo (L1-3) Ash Storage Silo (L4-6)	) cherry red) by Ramtex)))	10R 3.5/7.5	-
Ash Reject Silo (L1-6)	Blue	7.5B 5/10	-
ASB Gantry Crane	Blue	7.5B 5/10	-
Junction Tower T12A/B Leg	Clove	MC-55	-
Stacker - Reclaimer	Maritime	MC-83 Blue	-
Conveyor Structures and Wind Guards	International Orange	-	-
Coal Unloaders	Blue	H10-743	-

L7 - L8 Proposals

8.38 The key problem is to provide a matching piece to the overall station complex especially when two architectural elements (ie. the existing L1-L6 building and the proposed L7 and L8 buildings) of similar form and colour, but distinctly different size, are seen side by side in the landscape. The smaller always looks subordinate to the larger.

8.39 It is proposed that the design for L7 and L8 should be based on the same architectural principles as in L1 - L6 and although it is much shorter in length, a repetition of the features of the design and certain of the colours will give continuity to the overall development. In this regard, advantage should be taken of the difference in the scale of the buildings by :

1) Using a similar colour of cladding (seafoam 1731 with blue band by Robertson) so arranged to produce interesting pattern variations.

2) The disposition of the L7 and L8 Station Building to achieve a harmonious relationship with the existing buildings.

3) The use of fenestration elements e.g. windows and louvres to create a distinctive architectural feature.

4) Examination of the Building shape so that it forms a cohesive piece of the overall development and also serves to express a termination point of the station complex.

5) Restoration of the colours of rusted parts of exposed Plant.

6) Careful selection of colours which may be applied to exposed plant (e.g. conveyors, limestone unloader, limestone and gypsum storage silos etc.) at the eastern jetty, to match the surroundings.

Landscape Principles

8.40 With the planned development of the Lamma Power Station, much of the open space originally designated for landscaping and planting has been taken up by engineering and functional requirements. Screening at low level by tree planting can help to settle the buildings into the local topography, although their scale is such that even the largest forest trees can do little more than provide local screening and will not much affect the long range visual impact.

8.41 A landscape report was prepared by Urbis Planning Design Group (Hong Kong) [1,2] in which an evaluation of the principles and function of landscape design for the station site were dealt with and which forms the basis of the landscape principles within the power station site.

Cut Face

8.42 The scope for soft landscape treatment of the hill is limited to planting above the rock faces. The rock face itself encourages the growth of characteristic rock face vegetation, especially in damper areas near gullies and drainage works. The planting of creepers on the rock face slopes has been implemented but has little effect on both the short range and a long range visual impact.

Grass Slopes

8.43 The limited area of grass slopes and very weathered rock are naturally drained. These are to be planted with a mixture of trees, shrubs and ground cover which will help to blend the colour and texture with the surrounding hills.

Sea Wall Treatment

8.44 With the addition of the Ash Lagoon, an embankment has to be built enclosing the lagoon. Random sized rocks similar to the existing sea wall will be placed around the foot of the embankment and will be used for continuation of adjoining coastline character and will blend in visually with the existing station site.

Ash Lagoon

8.45 Once the ash lagoon has been filled to its full capacity, landscaping in the form of a grass mound will be implemented on the periphery of the lagoon providing a 'natural screen' to the power station behind.

Security Fencing

8.46 The appearance of the proposed Palisade Security fence along the northern boundary can be a dominant feature of the landscape. HEC has given visual consideration to the choice of colour as well as the spacing of the uprights so that it blends in with the natural landscape, as well as providing adequate security.

Planting Constraints and Proposals

8.47 Planting opportunities within the site are considerably constrained by :

1) The engineering requirements and functioning of the station with its considerable demand for underground service routes and availability of above ground staking space for equipments, minor plant ... etc.

2) Climatic conditions.

3) Maintenance free adaptability to exposed windy conditions and to withstand salt-spray carried off the sea by the wind.

8.48 The planting scheme proposes :

- shade planting around the passenger jetty, station buildings and amenity buildings.
- mixed woodland and grass established to the north boundary.
- screen planting at the perimeter of the platforms.

8.49 A revised landscape master plan will be produced after Government have considered the proposed extension units L7 and L8.

8.50 Species suitable for use to suit both environmental and local decorative requirements have been set out in URBIS report [1]. The actual quantities and positions will have to be determined when engineering and other constraints have been finalised.

8.51 The date for planting will depend upon the clearance of the working areas within the Power Station. The site services are to include the provision of an adequate number of watering points to serve the planting areas within the station boundary.

Fung Shui

8.52 The principal Fung Shui concern is the arrangement of the total number of boiler chimneys for the Lamma Power Station as a whole.

8.53 Odd numbers of joss sticks, i.e. one or three, are used for ancestral worship. The proposed arrangement of one additional chimney stack for Units L7 and L8, resulting in three chimneys in a row may have undesirable connotations as the chimneys may be considered to resemble joss sticks. However, the wide spacing between individual chimneys is very different from the close spacing normally associated with three joss sticks. The proposed three stack arrangement may not therefore be significant in Fung Shui terms.

Conclusions

8.54 Looking in detail at the relative scales of Units L1 - L6 and the proposed extension units L7 & L8, there is a need to extend the existing architectural vocabulary for the satisfactory treatment of the station and ancillary buildings.

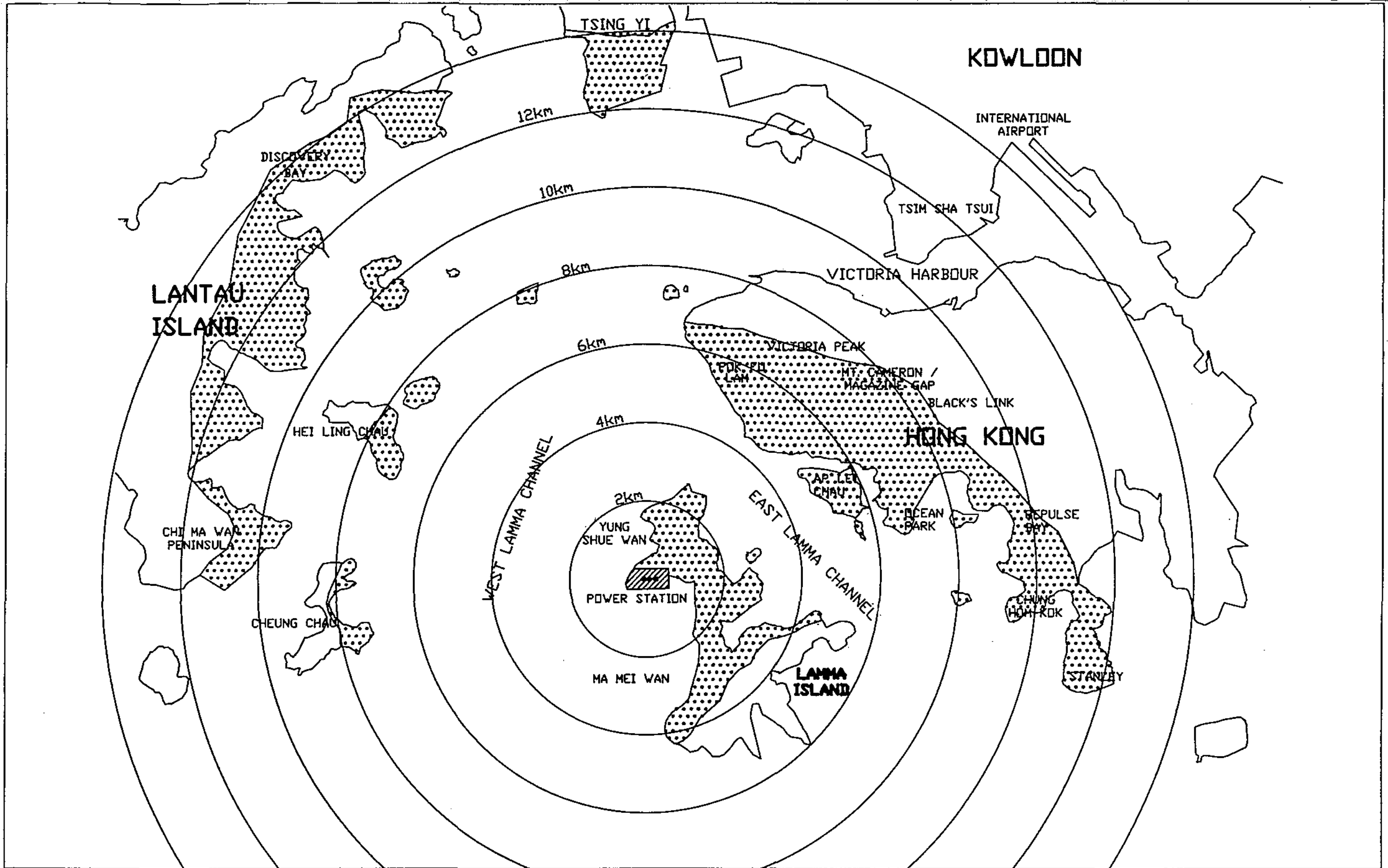
8.55 The zone of visual influence of the additional 215m P.D. chimney is no greater than the two existing chimneys and with the decommissioning of Ap Lei Chau Power Station and the demolition of the chimneys, the visual impact for the residents of Hong Kong Island will be much alleviated.

8.56 Units L7 and L8 will provide a fitting piece to complete the Lamma Station development and will complete the transformation of the existing landscape.

REFERENCES

1. Final Report on Landscape Aspects of the Project Prepared by Urbis Planning Design Group (Hong Kong). January 1979.

2. Final Report on the Visual Impact Assessment for the Proposed Gas Turbine Installation, Lamma Power Station Prepared by Urbis Limited. November 1988.



The Hongkong Electric Company Limited

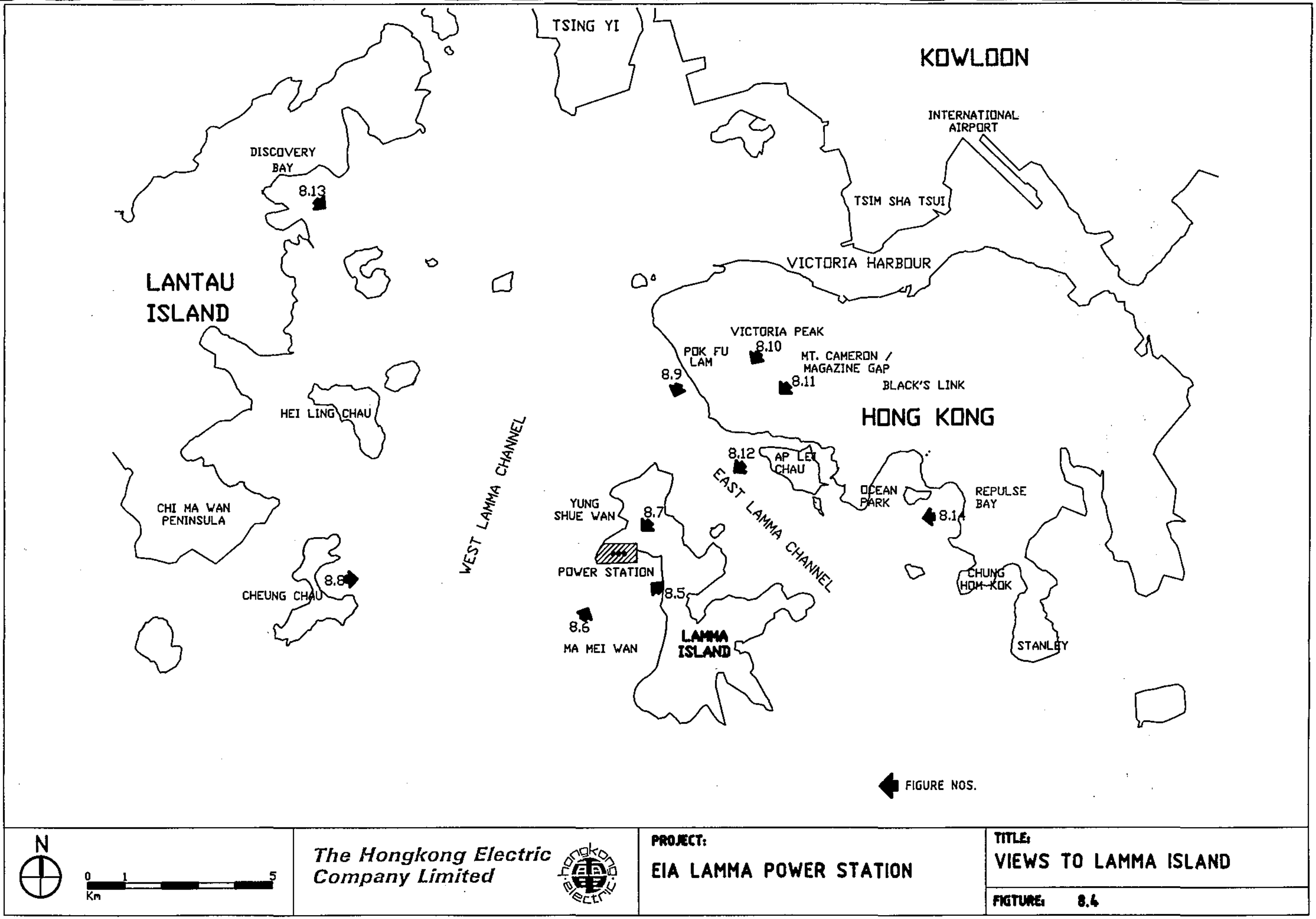
PROJECT:

EIA LAMMA POWER STATION

TITLE:

ZONE OF VISUAL INFLUENCE DIAGRAM

FIGURE: 8.3



The Hongkong Electric Company Limited

PROJECT: EIA LAMMA POWER STATION

TITLE: VIEWS TO LAMMA ISLAND

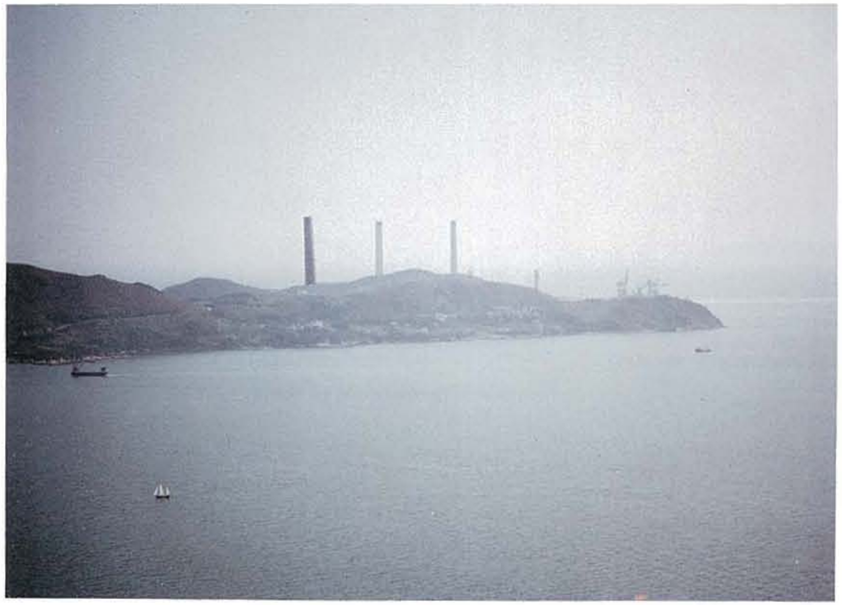
FIGTURE: 8.4

VIEW OF EXISTING POWER STATION FIG.8.5

VIEW OF EXISTING POWER STATION FIG.8.6

VIEW FROM LAMMA NORTH FIG.8.7

VIEW FROM CHEUNG CHAU FIG.8.8

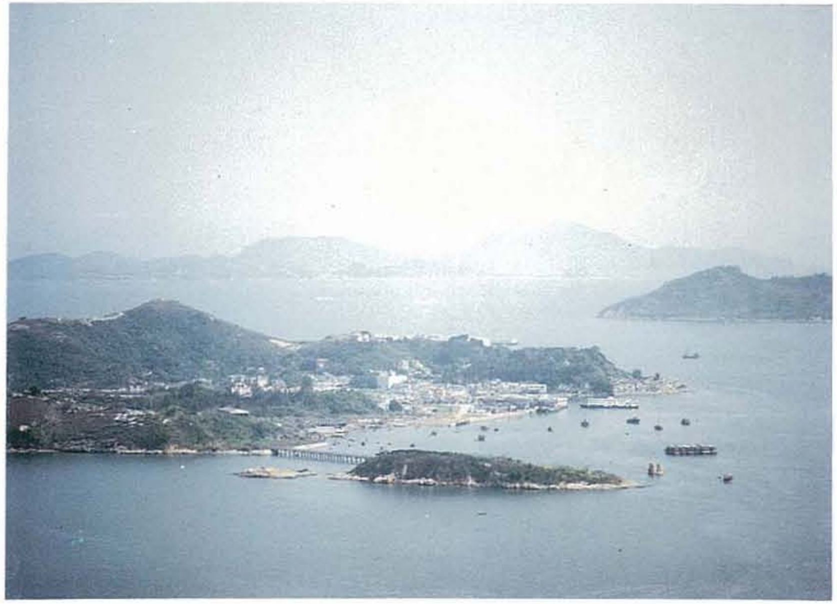


VIEW FROM POK FU LAM FIG.8.9

VIEW FROM PEAK FIG.8.10

VIEW FROM MAGAZINE GAP
(AP LEI CHAU POWER STATION
IN FOREGROUND)
FIG.8.11

VIEW FROM AP LEI CHAU FIG.8.12



VIEW FROM LANTAU DISCOVERY BAY FIG.8.13

VIEW FROM REPULSE BAY FIG.8.14

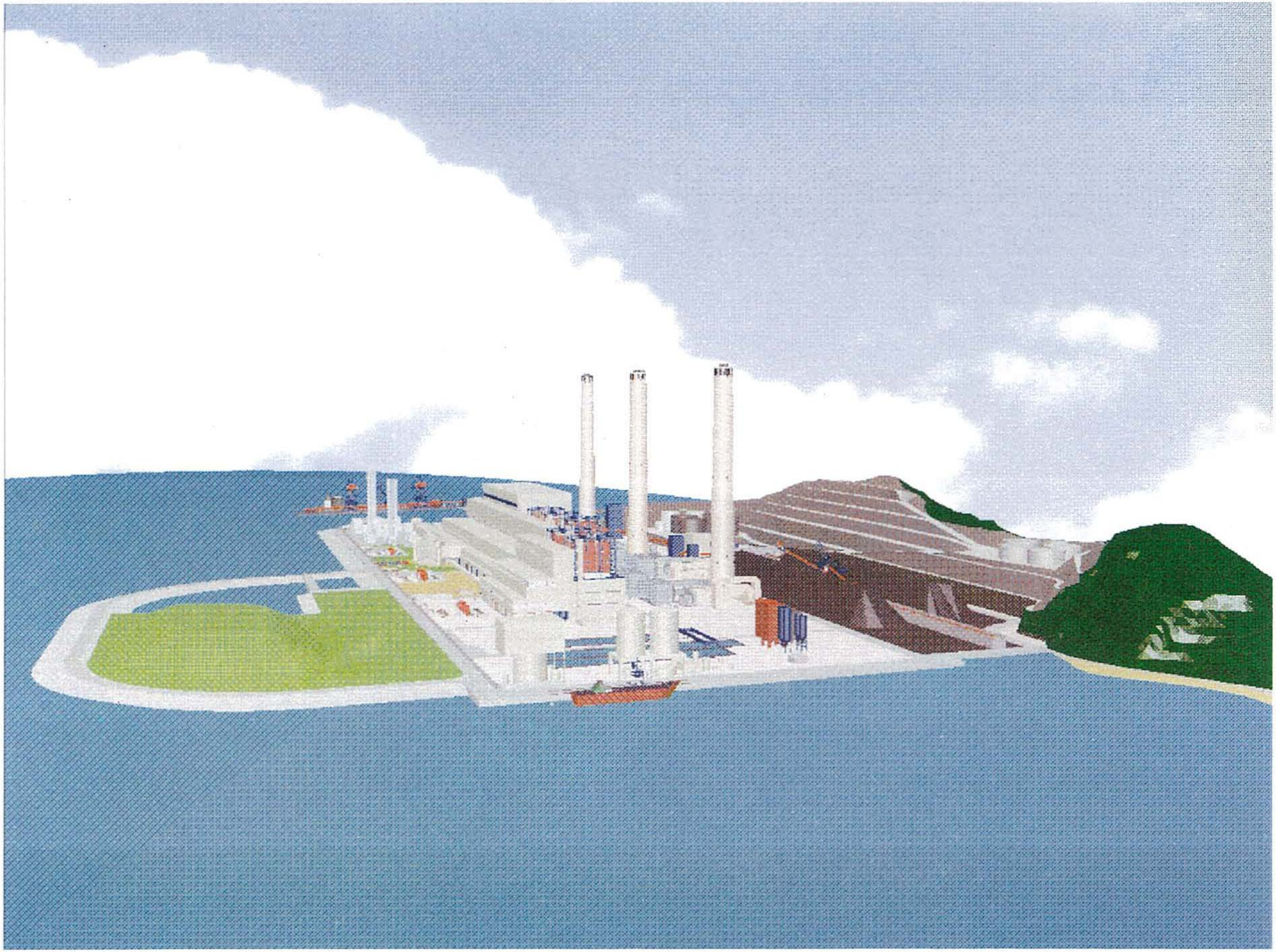


FIG. 8.15 CAD MODELLING : VIEW FROM HA MEI WAN

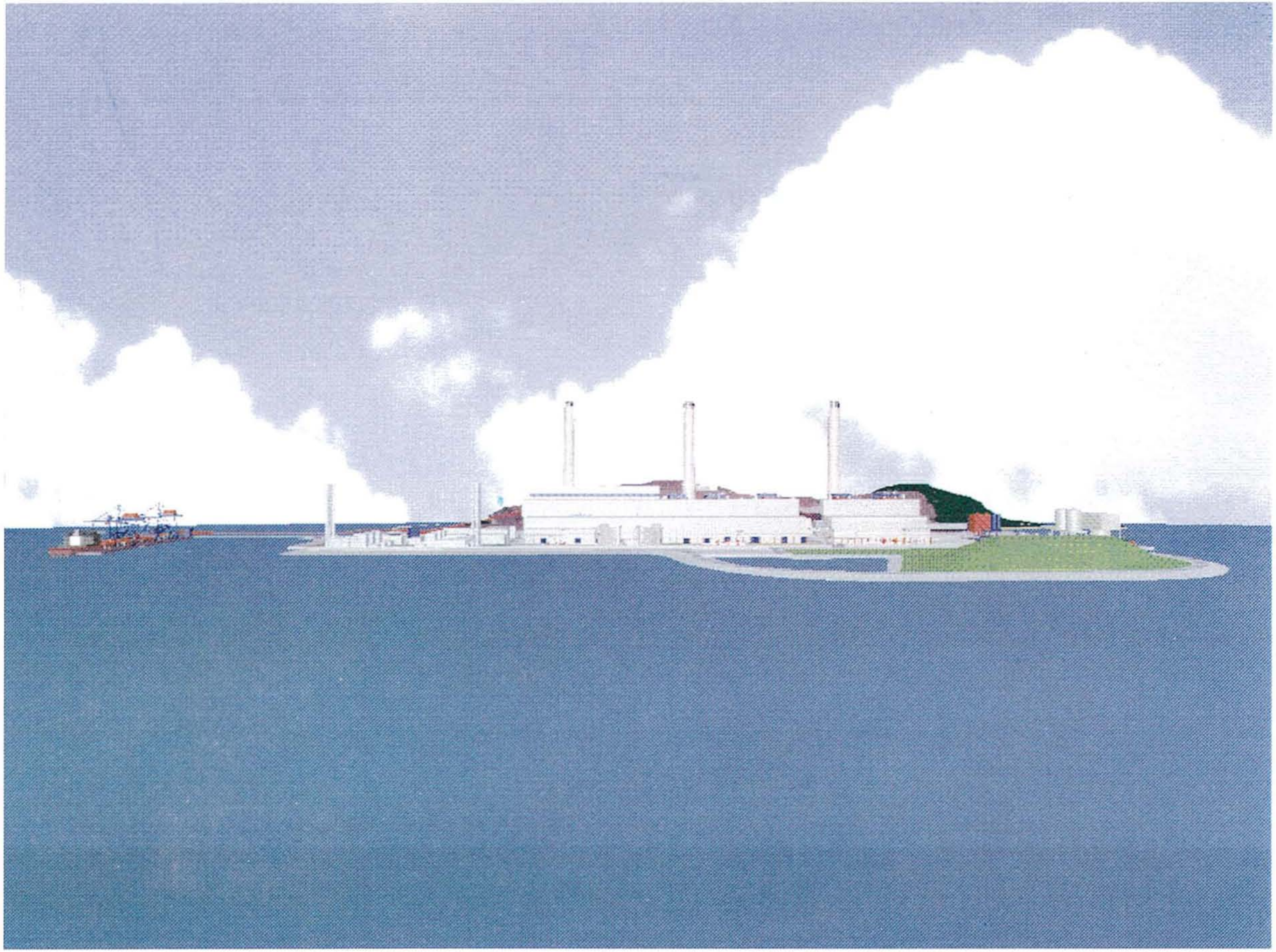


FIG. 8.16

CAD MODELLING : FRONTAL VIEW

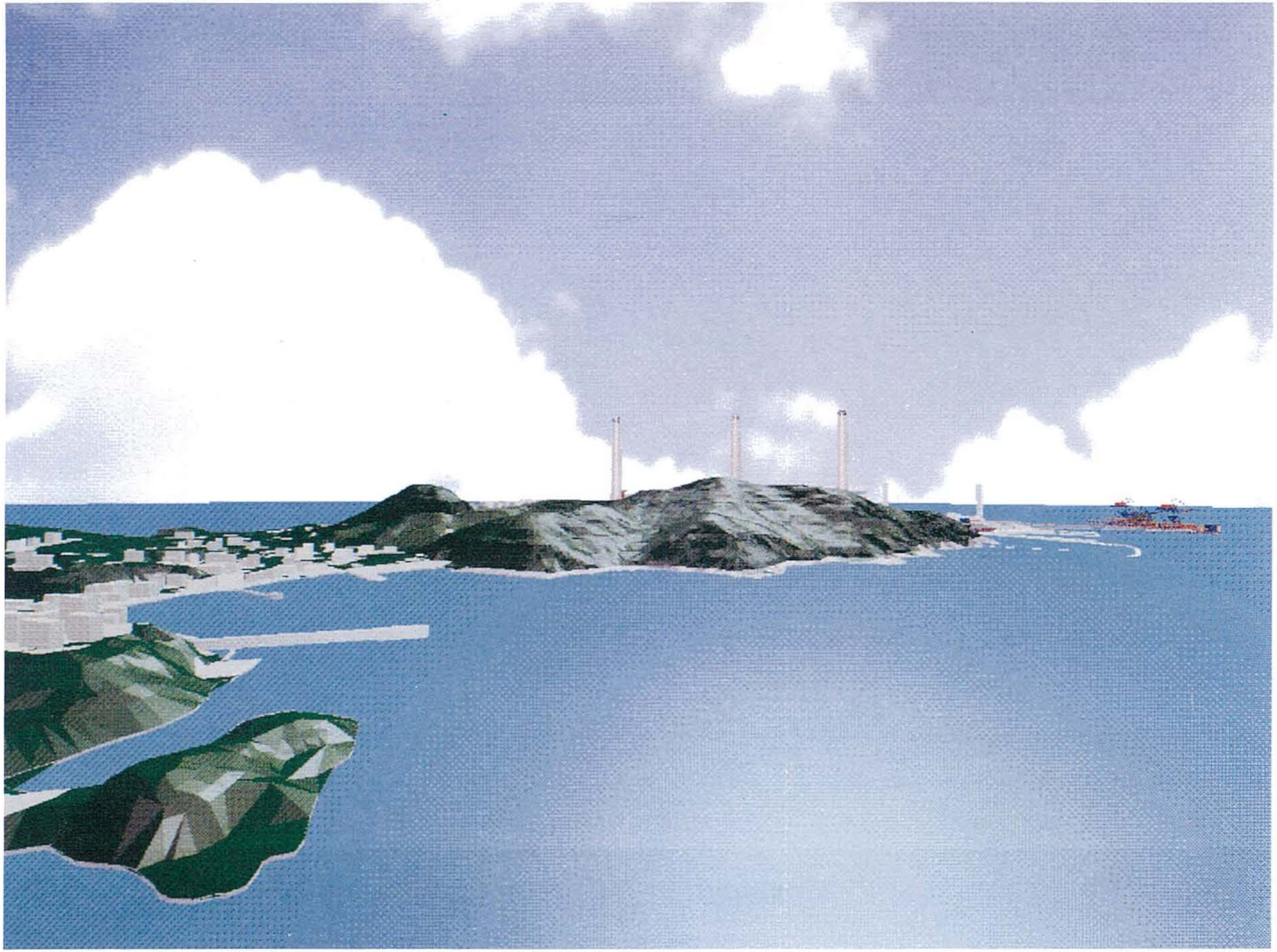
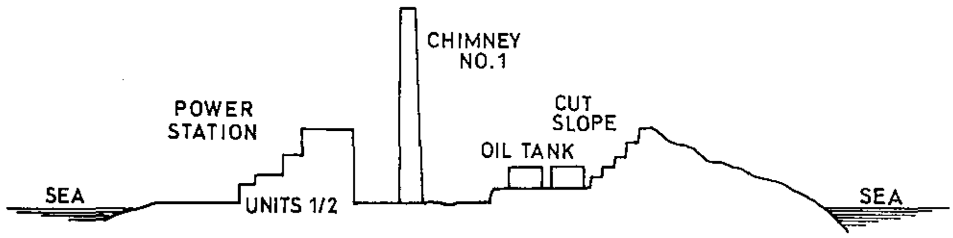
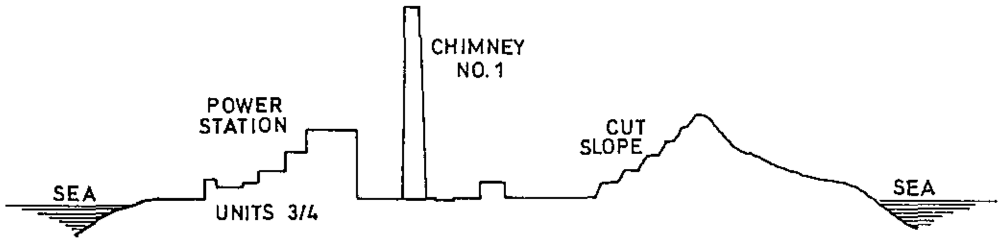


FIG. 8.17

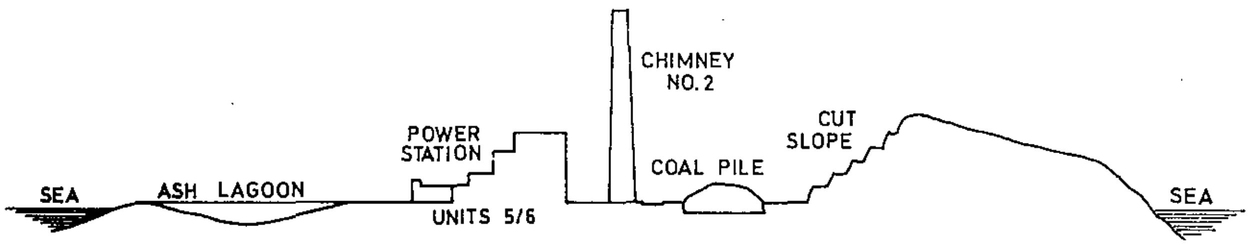
CAD MODELLING : VIEW FROM YUNG SHUE WAN



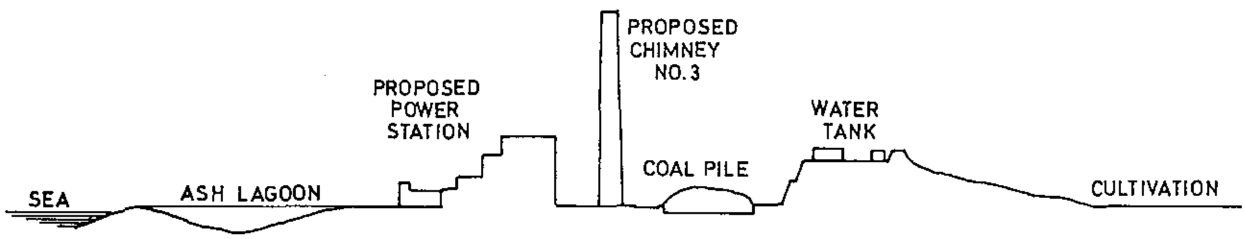
SECTION A / 8.1



SECTION B / 8.1

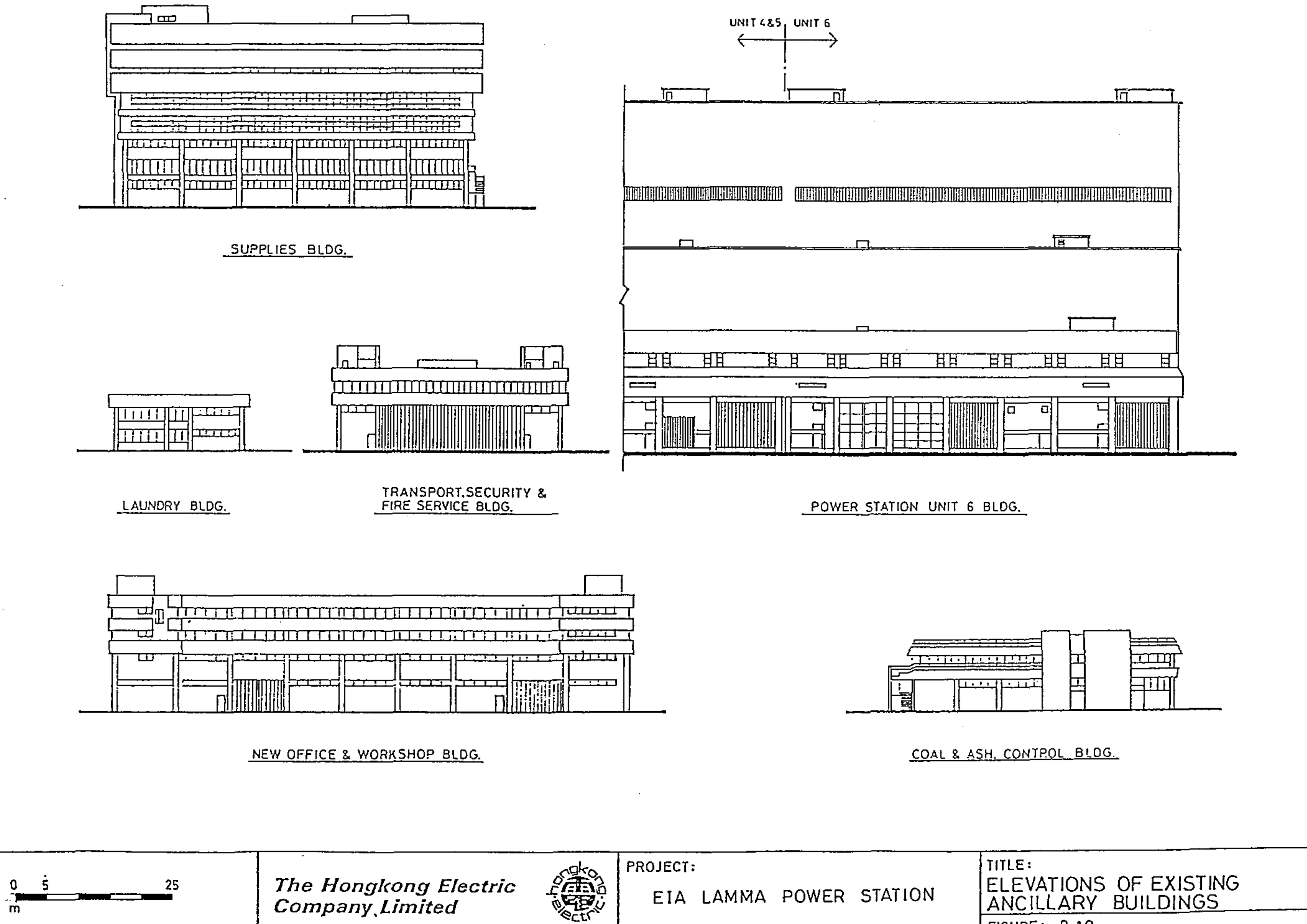


SECTION C / 8.1



SECTION D / 8.1

The Hongkong Electric Company Limited	
PROJECT EIA LAMMA POWER STATION	TITLE STATION PROFILES COMPARED
	FIGURE 8.18



The Hongkong Electric Company, Limited

PROJECT:

EIA LAMMA POWER STATION

TITLE:

ELEVATIONS OF EXISTING ANCILLARY BUILDINGS

FIGURE: 8.19

MARINE ECOLOGY

9.0 MARINE ECOLOGY

Existing Situation

9.01 Site visits to the western shore of Lamma Island have indicated a healthy rocky shore fauna and flora in Ha Mei Wan [1]. There are a number of sandy beaches, several now extensively used for recreation but which had been used for cockle fisheries. The first impression has not been tested by any detailed study of marine life in this area.

9.02 The subtidal fauna was somewhat poor [1] due to the soft mud and muddy sand found in inshore Hong Kong, but included brittle stars and sea slugs, which form the epifauna living on the surface, as well as a burrowing sea cucumber, clams and polychaete worms living within the sediments. This fauna was similar to that recorded in 1974 [2] in deeper water where subsequently dredging has taken place for the Lamma Power Station coal jetty.

9.03 There are no catch data for fish or shrimp caught in the inshore waters of Lamma, though Ha Mei Wan, the major embayment on the western shore, is regularly fished by a few local shrimp trawlers. It is understood that shrimp caught in this bay are mainly small animals and are sold for shrimp sauce manufacture. In addition to shrimp trawlers, AFD have estimated that up to about 50 boats, gill netters, handliners and purseseiners based at Yung Shue Wan may occasionally use these waters. A small number of handliners regularly fish off the cooling water discharge area and along the rocky artificial shore of the reclamation where the cooling water intakes cause local increases in water movements. In 1984/5 HEC carried out a monitoring survey of fish caught on the intake screens [1]. This survey showed that the inshore "fish" population was reasonably diverse, with 15 types of organisms being recorded, eleven being fin fish, the remainder shrimp and squid. The fish species most regularly found was *Siganus oramin*, the rabbit fish, a fish sometimes used in fish culture but otherwise not of particularly high commercial interest.

9.04 The planktonic life of Ha Mei Wan was also monitored at the intakes by HEC in 1984/5. The plant content was moderately low for inshore waters at 2.6 μg/l of chlorophyll. The animal numbers were also low at about 10 per millilitre [1]. Later counts of plant cells found 3 per millilitre in Ha Mei Wan in 1989 [1] which was consistent with the HEC data.

9.05 Summarising the ecological data, Ha Mei Wan has a low density marine fauna and flora, which in species make up is sufficiently diverse to suggest that the region is substantially undamaged, despite the West Lamma Channel being used for night soil dumping up to the early 1970's and the influence of the Lamma Power Station since 1983.

9.06 The water temperature and water quality data available from EPD monitoring surveys have been reviewed in Chapter 6 which has also described the predicted changes in temperature and water quality, derived from mathematical models. These changes are discussed in relation to their influences on marine ecology in the following sections.

Thermal Effects

9.07 The physical effect of temperature increases on marine life is to increase the metabolic rate [3]. Following basic biochemical equilibrium, an increase of 10°C can be expected to double physiological processes where the organisms do not possess any thermo regulatory mechanism e.g. are cold blooded. Thus increases of 1°C are likely to cause increases in respiration, digestion and growth of about 10%, changes which are easily detectable and which can trigger various responses in the animals. Changes of this sort occur naturally, such as in spring when they occur over periods of a week or more and together with other variables, such as day length, control life cycles via reproductive biology.

9.08 If changes occur which are in excess of those which are natural, animals may be stressed in a number of ways which may have lethal or sublethal results. For example, increasing metabolism may mean the organism simply cannot "fuel" this rate of activity if its own food sources (planktonic animals or detritus, normally brought in from other areas by tides) are near to limiting growth; this is commonly the case in winter and spring. Changes which induce early reproduction in animals may mean that the reproductive cells (or gametes) are released too early to meet the gametes from animals of the same species. In such a case reproduction could fail. Even if fusion of the gametes is successful, the larvae may still be unable to grow if they are out of sequence with the availability of their own normal food supplies.

9.09 It is considerations along these lines that has led to the conclusion that changes of about 2°C above the natural or ambient temperature can lead to unacceptable stress and adverse ecological consequences. The HK EPD have set a maximum increase of 2°C for the Southern Water Control Zone on these grounds. The mixing zone, in which the formal Water Quality Objective (WQO) is allowed to be exceeded, is currently designated as 1500 m in radius.

9.10 There is no evidence that inshore fisheries have been affected in an adverse manner by the existing discharges. The present discharge produces localised surface temperatures of up to 5°C above ambient when measured in the field, but which occur only within about 50 m of the discharge point, a scale which cannot be predicted by the modelling used in this appraisal. Fishing in this plume is known to be excellent at most times of the year, because certain species of fish are attracted by the higher ambient temperatures and grow well in this region. There are no studies to show that invertebrate animals which might support fish also grow well in this region, but there is plentiful evidence from other heated discharges around the world to suppose that this is occurring.

9.11 The available information on the maximum temperatures that fish and indeed other marine biota in Hong Kong water could survive has been examined. There is very little information specific to Hong Kong. The work on the red sea bream [3] is the most useful as the work was carried out in Hong Kong and this fish supports both a capture fishery and mariculture in inshore waters, including those of Lamma. Work in China on the black sea bream [4] confirms the finding that these fish have lethal maximum temperatures (LMT) (the temperature above which most of the individuals would die) of around 31-35°C. Red sea bream had a LMT of 32°C whilst the black sea bream, which is a widely distributed fish with a wide salinity and oxygen tolerance, had a LMT of 35°C, in keeping with conditions which occur in many estuaries in the sub-tropics.

9.12 If the LMT's of these fish are considered to be typical of those of other inshore fish, then the fish in the Lamma area are already near their upper temperature limit in summer when maxima of 28 to 29°C already occur. Temperatures which locally exceed 30°C are widely reported in Hong Kong's inshore water at midday [3,5] and difficulties in fish cage mariculture are acknowledged as a regular occurrence in summer due to high temperature and the reduced oxygen holding capacity.

9.13 The predicted increases in temperature with Units L7 and L8 suggest that fish could be affected at times in the summer months on the western coasts of Lamma Island and that the thermal discharge could, at such times, have temperatures lethal to some species. Fish could and would avoid the areas unacceptable to them, but other organisms, whose LMT's can be assumed to be similar but which are less mobile, eg planktonic animals (such as jellyfish) would not be able to move away from these areas. However it is likely that at other periods of the year the warm water zone around Lamma will support greater fish populations than the cooler unheated shores. The fish culture zone in Sok Kwu Wan on the eastern coast of Lamma would not be significantly influenced by the increased discharge so that this major fishery investment would not be adversely affected.

9.14 After discharge, the lower density of the heated water will cause it to float to the surface. Sedentary animals on the seabed are therefore unlikely to be affected apart from a very local area, a feature which has been reported in many instances elsewhere [6,7]. The general increase in temperature of between 0.2 to 1.0°C which will affect much of the inshore water around Lamma may assist those benthic animals whose larvae are planktonic, as growth at this stage in the life history will be more rapid and the animals will settle sooner, thus escaping predation in the water column.

9.15 On balance, the impact of the increased thermal discharge on the marine biota of Lamma is likely to be minor. Those species which cannot physically move away from the heated area and which have LMT's near 32-35°C will become scarce on the western shore. There may be an influx of species which can tolerate the higher temperatures, but there will be relatively few of these species. These eurythermal species may come to dominate the fauna in summer, leading to a high biomass but a lack of diversity among the animals in this region. Attached plants, such as seaweeds, die back after February in Hong Kong. The plant body, the thallus, only actively grows again in autumn from resting stages which survive the summer months. It is likely that these plants will thrive in the heated discharge area, as the already resistant resting stages will survive the summer period of elevated temperatures above 30°C and the adult plant form will be able to take advantage of the warmer water in winter.

Metals And Biocides

9.16 The contents of metal and other chemical residues of the cooling water discharge have been described in Chapter 6. There are no published data for metal concentrations in seawater for Hong Kong, due largely to the technical difficulties in analysing seawater for trace quantities of contaminant. As a result the HK EPD has not set any concentrations for trace metals as a WQO in seawater, the WQO being framed in terms of such substances being present at concentrations below those causing tainting or toxicity to marine organisms or man. However there are specific concentrations set for trace metals in the consent standards for discharges within specific Water Quality Control Zones.

9.17 As described in Chapter 6 the modelling of trace metal dispersion has assumed that the individual discharges which enter the cooling water flows contain metals at the present measured concentrations in the discharges (Table 6.11). The increases in volume of the effluent will naturally cause a proportional increase in the mass flow. The increases in effluent volume will also reduce the retention time in the ash settlement basin. This may reduce the effectiveness of settlement and lead to a rise in concentrations of trace metals in the effluent.

9.18 It is difficult to judge the possible effects of the trace metals on biota without a knowledge of the present distribution. Table 9.1 lists typical concentrations for most of the trace metals found in the North Sea [8], an enclosed sea receiving considerable industrial wastes, but nevertheless still possessing a healthy biota able to support good quality fisheries. Table 9.2 lists values for European Community (EC) environmental quality standards (EQS's) for trace metals which should not be exceeded if marine ecosystems are to be preserved. These standards have been compiled by the Foundation for Water Research (FWR) [9], working under commission for the UK Department of Environment (DoE). The EQS's are based on world wide literature studies on the toxicity of metals to marine biota, at varying salinities and temperatures.

TABLE 9.1 : TYPICAL CONCENTRATIONS OF TRACE METALS IN THE NORTH SEA*

Units are $\mu g/l$

Metal	Concentration
Mercury	0.002
Cadmium	0.02
Arsenic	1.0
Chromium	0.4
Copper	0.2
Lead	0.05
Nickel	0.25
Zinc	1.0

* Reference 8

9.19 Using these EC EQS concentrations, the areas around Lamma that could exceed the limit for marine ecosystem preservation were estimated from the model output for two possible discharge points for the FGD effluent. Discharge of this effluent to the c.w. outfall is recommended and this assessment assumes this discharge point is chosen. These areas have been shown in Table 6.19 for the present (1800 MW) case and at full development (2500 MW).

9.20 The EC limits do not have any legal significance in Hong Kong for ecosystem maintenance. However, in the absence of specific Hong Kong standards, it is considered that the EC limits do provide a means of judging the acceptability of metal discharges to the marine environment of Lamma. As the EQS's are formulated as annual averages for dissolved metal concentrations, the predictions in Table 6.19 are directly relevant. This analysis shows that all metals in the discharge would meet EC EQS with discharges to the cooling water outfall. As noted in Chapter 6 the predictions are conservative and overestimate the concentration that would occur in practice as the model does not include any adsorption onto particulate material and settlement of particulates, or allowed for precipitation of the sparingly soluble metal hydroxides in sea water. If these factors are taken in to account, it can be confidently predicted that all metal discharge would comply with the EC limits.

TABLE 9.2 : CONCENTRATIONS* OF TRACE METALS FOR THE PRESERVATION OF MARINE ECOSYSTEMS

Units are μg/l

Metal	Concentration
Mercury	0.3
Cadmium	2.5
Arsenic	25
Chromium	15
Copper	5
Lead	25
Nickel	30
Zinc	40
Tin	10
Iron	1000

Concentrations are expressed as annual averages for the dissolved component.

* Reference 9

9.21 The significance of trace metals to marine biota varies considerably from organism to organism and from metal to metal. Undoubtedly the most important issue is that some organisms accumulate metal concentrations in flesh or specific organs. This bioaccumulation can lead to biomagnification if carnivores eating polluted organisms also retain their body load of metals. Mercury, cadmium, copper, lead, zinc and chromium have all caused ecological and human health problems due to accumulation through food chains culminating in marine products consumed by man.

9.22 The HK Government has set standards [10] for the concentrations of some trace metals in food, which are shown in Table 9.3. In recent years, increasing numbers of fin fish and shellfish from Hong Kong waters have exceeded these limits and warnings have been issued to the public. Unfortunately the risks of this situation occurring are impossible to assess with the data presently available. Some monitoring of trace metals in barnacles, one set collected near the Lamma cooling water discharge (polluted site) and another from a position on the north coast of the island (the unpolluted site), has been undertaken. The results do not show any clear difference between the two sites (Table 6A.5) and cannot be adequately interpreted without occasional determinations of the ambient water concentrations. At present, the body burden of the barnacles would be below any HK Food Regulation requirements, though these organisms are not eaten.

TABLE 9.3 : MAXIMUM ALLOWABLE CONCENTRATION OF TRACE METALS IN FOOD IN HONG KONG* (mg/kg wet weight)

Metal	Concentration
Cadmium	2.0
Arsenic	10.0
Chromium	1.0
Lead	6.0
Tin	230.0
Mercury	0.5

* Reference 10

9.23 The nitrate nitrogen concentration of the power station effluents has been evaluated in Chapter 6. Nitrate concentrations arise primarily in the FGD effluent. As noted for the metals, in order to comply with international environmental standards, it would appear essential to discharge the effluent in the cooling water stream where there is considerable dilution. In the case of inorganic nitrogen, the WQO is 0.1 mg N/l depth averaged annual mean. Water quality data from 1987 to date shows an annual mean of 0.07 mg N/l near the existing Lamma Power Station discharge point. Table 6.20 shows the distribution of inorganic nitrogen in the West Lamma Channel area.

9.24 The total nitrate effluent discharge is estimated to be 90 kg per hour at full development (2500 MW), assuming FGD were fitted to 5 of the coal burning units, which is roughly equivalent to the total nitrogen in a sewage discharge from 135,000 people. In the case of the power station discharge, however, the initial discharge concentration to the sea would be 251 mg N/m^3, much more dilute than a typical sewage effluent in which nitrogen as organic and ammonia would be about 90,000 mg N/m^3. There would be no deterioration in oxygen as a result of this effluent (as there would be from a sewage discharge) but the nitrate could lead to additional growth of algae either as seaweeds or as planktonic plants. The increase in growth would be much less than would occur from a sewage discharge from 135,000 people as nitrate would be the only nutrient in large quantities. Furthermore, the above estimate of nitrate input is based on an assumed "worst case" scenario of retrofitting 2 units with FGD for air pollution control purposes. The most recent analysis of air quality impacts described in Chapter 5, however, indicates that retrofitting of existing units is unlikely to be required, hence the nitrate estimates will reduce accordingly.

9.25 In marine waters, nitrate nitrogen is commonly the nutrient which controls the growth of algae but other nutrients such as phosphorus and silica are also essential requirements.

9.26 The WQO for nitrate nitrogen has been introduced to prevent entrophication in inshore marine waters. It is possible, though costly, to remove nitrate nitrogen from effluent discharges. The necessity or otherwise to treat the FGD waste stream to reduce nitrate release is a matter which will require detailed consideration as a Key Issue.

9.27 The cooling water intake is chlorinated to prevent barnacles, mussels and slime growths developing in the cooling water circuits and blocking the condenser tubes or reducing the heat transfer efficiency by biofilms. There is a consent requirement of 500 $\mu g/l$ of free available chlorine. This requirement is relatively easily met at present. There is some foam formation at the cooling water discharge point which is probably due to the reactions of chlorine with the mucopolysaccharides of algae and animal plankton. There is immediate consumption of any free residual in the receiving waters firstly by organic matter present in the sea and secondly by photo oxidation of the chlorine compounds in daylight. The greater flows at full development would increase the area in which chlorine reactions occur and in which chlorine compounds are detectable, but this can be expected to be contained within a radius of about 100 m of the outfall. At this point, concentrations would be below 20 $\mu g/l$ which is the chronic toxicity threshold. [6]

9.28 Chlorination of water with dissolved organic material leads to the formation of organo-halides which include volatile and nonvolatile forms such as the trihalomethanes (THM's) which include chloroform. In seawater, bromide reacts with hypochlorous acid and the THM's produced are largely the bromine species of these compounds. In this case, the quantities of chloroform which form are negligible and usually below the levels of detection (0.1 μg/l). The formation of these compounds is proportional to the chlorine dosed and the organic progenitors. Formation is not likely to be high in Lamma, as the algal content of the water is low (chlorophyll at 3 μg/l) and sewage contamination of the seawater (and the cooling water whilst it is inside the power station) is similarly slight. There are no specific standards for organohalides set by EPD and the expectation of concentrations of organo halides of about 10-20 μg/l in the cooling water discharge would give values below 1 μg/l, except within 100m of the outfall. EC limits for chloroform require annual average concentrations below 12 μg/l [12].

Impingement And Entrainment Losses

9.29 The cooling water intake flows bring planktonic animals, and small fish which are not able to swim against the intake velocity, onto drum screens which protect the condensers from blockage. Dead and dying animals removed on the screens at Lamma Power station are removed as trash by backwash systems; these are impingement losses. Those animals and plants which pass through the screens are chlorinated and pass through the condensers where there is a rise in temperature of about 8°C. These organisms are killed by chlorine, mechanical abrasion and shear forces or heat; these losses are the entrainment losses. Both losses will be increased by the proposed development on a pro rata basis with the cooling water flow increase. However the volume of cooling water taken by the power station is negligible compared to the tidal flow in the West Lamma Channel and the biota losses to the power station will have no serious adverse effect on the population of animals in the inshore waters of Hong Kong. There could in fact be some enrichment in the benthic fauna away from the immediate vicinity of the cooling water discharge as the dead animals discharged with the flow settle out to the sea bed.

Spillage

9.30 The increased number of ship movements bringing in additional coal for the power station may result in some additional losses of coal as spillage during unloading. This matter is considered in Chapter 13. There could also be some loss of ash, limestone and gypsum, all of which will be handled at the eastern heavy unloading jetty. The losses of these substances, however, is likely to be negligible due to the loading/unloading conveyor systems in use and the provision of wind boards.

9.31 The amount of spillage should therefore be insignificant as a source of contamination in Ha Mei Wan. There could be some very local occlusion of the sea bed by deposition of spilt material, but this is likely to be maintained within the same area, near the coal jetty and east heavy unloading jetty, and would not cause any general deterioration.

Construction Effects

9.32 There should be minimal impact on the marine ecosystems if due care and attention is maintained by the main contractor during the construction phase. Adequate sewage disposal facilities must be provided for the enlarged workforce on Lamma Island at this time. The area where impacts can be expected is the formation of a cofferdam to allow dry access to the intertidal region so that the new cooling water discharge weir can be formed. This work will clearly damage the intertidal biota in this area but this should recover within a year or two. Close supervision of blasting and prevention of any unnecessary spillage of spoil, fuel or other chemicals should be adequate to ensure that the ecological damage is minimal.

Summary and Conclusions

9.33 An assessment of the possible marine ecological impacts anticipated from the additional generating capacity on Lamma has been undertaken.

9.34 Construction of the additional Units L7 and L8 will result in additions to the thermal discharge from the power station. Whilst the additional thermal inputs will cause local enhancement of temperatures near the outfall, above that already taking place, significant increases in seawater temperature are not expected beyond the immediate environs of the outfall. Whilst some very localised ecological changes may arise as a result of raised temperatures, worldwide experience of the biological effects of thermal effluents suggests these ecological effects will be of limited significance.

9.35 On the positive side, thermal discharges in many parts of the world, including Hong Kong, have proved major attractants to fish, particularly during the cooler months of the year. Local fishermen regularly fish the waters affected by cooling water discharges from Hong Kong's power stations because of the abundance of fish in the warmer water. The additional thermal discharge created by the new units would be expected to enhance this positive fisheries effect.

9.36 The impact of the power station on thermal stress in Sok Kwu Wan is unlikely to be significant as it will only raise water temperatures by up to 0.2°C. Any perceived adverse affects caused by this activity could be compensated by providing growing on facilities in Ha Mei Wan which could make use of the greater growth potential that would be possible due to warmer water in winter in parts of this bay.

9.37 The nitrate discharge due to FGD processes could be significant and some treatment of this waste may be required. Investigations into suitable treatment processes should be undertaken to assess the feasibility of treatment options.

9.38 Chlorination of the cooling water is now practised using electrochlorination. There is no difficulty in achieving the required residual in the discharge or in ensuring that in future the dispersion of the greater flows would be adequate. However there is a minor problem of aesthetic appearance from foam formation which is due to chlorination and perhaps undue agitation at the weir which leads to aeration and foaming. Experiments to optimise chlorine usage are being carried out which could result in lower chlorine use and result in less foam production. Further refinement of the existing mechanical spray system for foam control to maximise efficiency may be required so that foaming from the new outfall does not produce a significant problem. A review of the weir design for the c.w. outlet for Units L7 & L8 is also being carried out to minimize the formation of foam at the c.w. outfall.

9.39 The addition of trace metal to the marine ecosystem is predicted to have limited impacts if all waste water streams are discharged in the c.w. outfall. Under these circumstances, predicted sea water concentrations of the various metals of interest would be within EC Environmental Quality Standards and are therefore considered acceptable.

9.40 With the exception of nitrate releases, which will require more detailed consideration as a Key Issue, the impacts of the proposed new units on the marine ecosystem are judged to be not significant. Should more detailed assessment reveal nitrate inputs to be unacceptable, appropriate treatment of the waste water will probably be required.

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TERRESTRIAL ECOLOGY

10.0 TERRESTRIAL ECOLOGY

Hong Kong - General Ecology

Vegetation and Habitats

10.01 The original climax vegetation of Hong Kong is thought to have been broad-leaved, sub-tropical, oak-laurel forest [1,2]. Little of this natural vegetation survives due to extensive clearance of most lowland forest for timber, agriculture, and, more recently, urbanization. Most of the remaining broadleaf woodland is confined to higher but sheltered areas and comprises typically temperate and sub-tropical genera such as chestnuts (Castanopsis spp.), tanbarks (Lithocarpus spp.), oaks (Quercus spp.), and members of the Lauraceae (e.g. Litsea spp. and camphor tree Cinnamonum camphora), as well as rain forest forms belonging principally to the families Euphorbiaceae (e.g. waxy leaf Breynia fruticosa) and Moraceae (e.g. figs Ficus spp.) [3]. Since the late 1940s these have been supplemented by extensive planting of native and exotic species, including Chinese red pine (Pinus massoniana) and Brisbane box (Tristania conferta), respectively [3,4].

10.02 Despite its small land area, Hong Kong boasts a great diversity of plant life with 225 (51%) of the world's 441 plant families represented. This high natural species diversity, which despite extinctions still amounts to 1843 native plant species, is due to the transitional climate between humid sub-tropical and warm temperate maritime. Although the most sensitive, humid tropical plant genera are excluded by the cool, dry, winter conditions of Hong Kong, much of the typical tropical South-east Asian flora is present. Indeed, the Hong Kong flora shows a greater affinity to that of the humid tropical flora of Java to the south-west than to the that of Japan, approximately equidistant to the north, but where the climate is markedly seasonal. It is largely an extension of the flora of Guangdong Province, China, although Hong Kong's maritime position provides less extreme climatic conditions than inland [2].

10.03 Forest clearance, fire, nutrient-poor soils, and exposure are some of the factors which have interacted with the result that large areas of Hong Kong are covered by grassland and scrubland communities. Although grassland, scrubland, and woodland are interrelated successional stages of the vegetation, (and within these broad categories, different combinations of plants combine to give, say, different types of grassland and scrubland), in Hong Kong this succession is rarely seen but rather the reverse, i.e. degradation from woodland to grassland, is common. Fire is the most destructive single agent in Hong Kong. It is estimated that 0.5 percent of the total area of Hong Kong is burnt accidentally every year, and Table 10.1 shows the effects over the years 1969-1982 [4].

Table 10.1 : COMPARATIVE HILL FIRE FIGURES 1969 - 1982

Fire season	Number of Fires reported	Area affected (ha)	No. of trees Affected
1969-1970	852	346	214,000
1970-1971	366	106	48,000
1971-1972	809	152	300,000
1972-1973	339	109	66,000
1973-1974	1,149	1,372	1,510,000
1974-1975	266	228	63,000
1975-1976	1,212	2,295	1,102,000
1977-1978	535	485	78,600
1978-1979	501	452	43,000
1979-1980	934	2,596	553,000
1980-1981	1,259	820	16,000
1981-1982	839	1,580	140,000
Mean	755	878	344,400

10.04 With the vegetation removed by fire, rain falls onto the unprotected surface of the soil, removing humus and nutrients, and washing away the top soil into water courses. This erosion results in poor soils and makes succession from grassland to woodland, even when uninterrupted by further fires, much harder and slower. Grassland and scrub now covers approximately 60% of the total land area of Hong Kong and is especially extensive on islands e.g. Lantau, Lamma, and south-east Hong Kong Island [1].

Land Animals

10.05 The original forest would have supported a wide range of animal species. However, few larger mammals remain and these, e.g. the Chinese leopard cat (Felis benghalensis) and barking deer (Muntiacus reevesi), are now scarce and dependent on the few larger areas of forest. Barking deer are present in the forest of the Pok Fu Lam Site of Special Scientific Interest (SSSI) near Victoria Peak, on Hong Kong Island, north of Lamma [4].

10.06 Birds are more numerous and diverse with 352 species recorded. Of these, 66 are resident, 119 are winter migrants, 57 are passage migrants, and 14 are summer visitors. Wetland and forest habitats are most important, supporting 145 and 113 species respectively whereas the more extensive agricultural, grass and scrub lands together support only 105 species [4].

10.07 A variety of reptiles and amphibians occur, with most habitats supporting snakes and lizards while amphibians are confined to wetter areas. Invertebrates have not been studied in detail but will be the most abundant and species-rich group in all habitats.

Agriculture

10.08 Much of the low lying land which has not been developed for building is given over to agriculture. In the past there was extensive rice cultivation but in 1990 market gardening of a variety of vegetables, especially leafy and leguminous crops, is more common. Fruit trees, such as lychee Litchi chinensis, are planted commonly around houses.

Lamma Island

Land Use

10.09 Geographically, Lamma Island can be divided into southern and northern parts. The north of Lamma is more heavily populated than the rest of the island, and is used for market gardening, with small areas of woodland. The southern end is largely steeply sloping and uncultivated. This area and the hill slopes of the north end are almost entirely covered by grassland and pockets of scrub (Figure 10.1). At present there is pressure to designate much of the island as a country park under the Country Parks Ordinance 1986 (Cap. 208) for public access and recreation.

10.10 The pattern of land use can be explained to some extent by the geology of the island. The underlying rock is largely granite with small areas of volcanic rock in the north. Soils are, therefore, mainly granite-derived, acidic, and nutrient-poor, and known as red-yellow podsols with local areas of higher nutrient status volcanic soils, termed krasnosems. Modification introduced by wet cultivation of rice on the upper layers of either of these produces a third type called paddy soils [1,5] (Figure 10.2). The deeper, more fertile, volcanic soils found in parts of the north have been cultivated, and woodland has also been planted, or left, for shelter, use for food, and as animal fodder.

Grassland and Scrub

10.11 The original vegetation of Lamma, at least at low altitudes, may have been sub-tropical forest, as in the rest of Hong Kong, but it is possible that the hill tops may have always supported grassland. Today, however, Lamma is unusual in Hong Kong in that the grassland now extends right down to the sea. This is due to a combination of low rainfall, thin soils, high exposure, and a high frequency of burning.

10.12 The annual rainfall over Lamma is 1250-1500 mm, making the island drier than all of Hong Kong except Po Toi [1] (Figure 10.3) but still wet enough to allow forest growth. The removal of the original forest encouraged soil erosion on the steep slopes and resulted in the thin soils of the present which only shallow-rooted plants can exploit. The island is exposed to prevailing winds, particularly cold, dry winter north-easterlies, the south-easterlies of summer, and the predominantly easterly typhoons. These limit tree growth. However, the most important factor maintaining the grassland is the high frequency of fire which allows only the most resistant plants to grow, i.e. those able to regenerate from protected growing points close to, or under, the ground.

10.13 As a consequence, the vegetation is dominated by fire-resistant species capable of surviving under these conditions. These are mainly grasses, a few herbs, and some shrubs. Grasses include the three genera typical of Hong Kong grasslands, Hong Kong orange grass (Ischaemum), minireed (Arundinella) and duck beak (Cymbopogon) - known as the I.A.C. grassland community [1]. Other common grasses are reed-like grass (Neyraudia reynaudiana) and Apluda mutica. The few non-grass herbaceous species are mainly those of the daisy family Compositae, e.g. Aster spp. The fire-resistant fern, Dicranopteris linearis is dominant in some areas.

10.14 Where burning is less frequent, i.e. at intervals of more than three to five years, and in sheltered areas and valleys on north and west facing slopes, scrub develops. The most fire-resistant shrubs include rose myrtle (Rhodomyrtus tomentosa) and the Hong Kong hawthorn (Raphiolepis indica) which occur with various figs (Ficus spp.), litseas (Litsea spp.), and Melastoma spp.. Climbers found throughout grassland and scrub include greenbriers (Smilax spp.), psychotrias (Psychotria spp.) and climbing fern (Lygodium japonicum) [2, 3] In wetter patches such as hollows and streamsides, rushes (Juncus spp.) replace grasses and species of the insect-feeding sundews (Drosera spp.) and bladderworts (Utricularia spp.) may occur. Orchids, e.g. the bamboo orchid (Arundina chinensis), are also confined to damp areas. Eulophia flava, a rare orchid classified as vulnerable within Hong Kong, is known from two localities from the southern part of Lamma [6].

10.15 Much of the grass and scrub area is strewn with boulders which provide a substrate for lichens. One area notable for these is the top of Shan Tei Tong Hill (Mount Stenhouse) [6].

Woodland

10.16 Areas of mature woodland occur at Tai Wan Tsuen in the north, at Lo So Shing at the narrow centre of the island, and at Mo Tat Wan in the east. The Tai Wan Tsuen woodland, just to the east of the power station, and the Mo Tat Wan woodland are semi-natural broadleaf forest with mostly indigenous tree species. Lo So Shing wood has been planted in the last 30 years with introduced species, e.g. Acacia confusa. Fruit trees such as lychee, pummelo (Citrus grandis), and longan (Euphoria longana), have been planted as scattered groups and individuals throughout the cultivated areas. Where agricultural land has been abandoned and is not subject to fire, e.g. near Lo So Shing and between Mo Tat Wan and Yung Shue Ha, areas of dense woodland are regenerating which consist of both native and introduced trees and shrubs, such as those of the widespread tropical pioneer tree Macaranga and the introduced, quick-spreading shrub Lantana.

Agriculture

10.17 The main area of market-gardening on Lamma is just south and east of the power station, between it and the Tai Wan Tsuen wood. Other smaller areas are cultivated mainly in the north of the island. The main crops are leafy vegetables such as the Chinese white cabbage (Brassica chinensis), and legumes, e.g. soybean (Glycine max) and green gram (Phaseolus aureus) grown for bean sprouts.

Birds

10.18 About 450ha of the southern part of Lamma was declared an SSSI in February 1980 on account of a variety of unusual birds, particularly raptors. The relatively undisturbed and rugged hills provide suitable habitats for several birds of prey considered endangered within the territory including white-bellied sea eagle (Haliaetus leucogaster), Bonelli's eagle (Hieraaetus fasciatus), and eagle owl (Bubo bubo). These used to breed near the south coast but since they have not been seen recently, their present status is uncertain. The more common black kite (Milvus migrans) has been recorded within the SSSI.

10.19 Little is known about other terrestrial birds on Lamma. A variety of common species is present as indicated by the list of those recorded in June 1990 (Table 10.2).

Table 10.2 : BIRDS OBSERVED ON LAMMA ISLAND ON 5TH AND 7TH JUNE 1990

Black Kite	Milvus migrans
Black Drongo	Dicrurus macrocercus
Cattle Egret	Bubulcus ibis
Chinese Bublbul	Pyconotus sinensis
Common Tailorbird	Orthotomus sutorius
Crested Mynah	Acrodotheres cristatellus
Crested Bulbul	Pyconotus jocosus
Fork-tailed Swift	Apus pacificus
Japanese White-eye	Zosterops japonica
Koel	Eudynamis scolopacea
Magpie	Pica pica
Magpie Robin	Copsychus saularis
Red-vented Bulbul	Pyconotus aurigaster
Reef Egret	Egretta sacra
Spot-necked Dove	Streptopelia chinensis
Swallow	Hirundo rustica
Tree Sparrow	Passer montanus
Yellow-bellied Prinia	Prinia flaviventris

10.20 Positioned as it is on the southern edge of the Territory, Lamma is well placed to view seabirds from. Notable records include the first sighting for Hong Kong of Swinhoe's Storm Petrel (Oceanodroma monorhis) and the second of Ancient Murrelet (Synthiliboramphus antiquum), both off Lo So Shing. The East and West Lamma Channels are significant for migrant terns and the latter is also important as a winter gull roost site.

Other Land Animals

10.21 There are no records of any large mammals on Lamma Island. The grassland, scrub and agricultural habitats typically support small rodents, e.g. field mouse (Musmusculus homourus) and house shrew (Crocidua murina). On Tsing Yi Island in similar grassland habitats the eastern spiny haired rat (Rattus huang) is also present and may inhabit Lamma [2].

10.22 Many snakes are found in the open habitats on Lamma. However, these are similar to those found on other islands, and include rat snakes (Ptyas spp.) and racers (Elaphe spp.). Lizards are not as numerous but the six-lined grass lizard (Takydromas sexlineatus) is typical of grassland habitats throughout Hong Kong and may occur on Lamma. Freshwater terrapins occur in some of the streams, while sea turtles (family Cheloniidae) have been seen on Lamma beaches, particularly in the south, and may use them for breeding. Turtles and terrapins are protected under the Wild Animals Protection Ordinance 1980 (Cap 170) [7].

10.23 Only one rare amphibian has been found on Lamma, a species of freshwater frog inhabiting streams around Sok Kwu Wan, but this has now been found in other parts of Hong Kong.

10.24 No survey has been carried out on the invertebrate fauna of Lamma. A variety of butterflies and other insects, particularly grasshoppers, occur in the grassland and scrub habitats as on other islands, and the remaining semi-natural woodland will add to the overall diversity.

Assessment of Impacts

10.25 Three emissions from the power station need to be considered in assessing the potential impacts on the terrestrial ecology of Lamma Island and neighbouring parts of Hong Kong, namely sulphur dioxide, nitrogen oxides, and particulates. The major impacts of these substances are their direct effects on plants. Such effects have repercussions for animals, and, although less studied, the direct effects on animals and soils should also be considered.

10.26 The degree to which plants are affected adversely by gaseous pollutants is proportional to the concentration of the pollutant in the atmosphere immediately around the plant. Other conditions such as humidity also affect deposition onto, and uptake by, plants. Chemical changes may occur to the gaseous pollutants in the atmosphere, sometimes in association with other pollutants. Sulphur and nitrogen oxides often become oxidized in the atmosphere and fall in rainfall and mist as sulphuric and nitric acids, hence the term acid rain. In this form they are more damaging to all parts of the ecosystem.

Sulphur Dioxide

10.27 At high concentrations direct uptake of SO_2 into a plant's leaves, as a gas or as sulphuric acid, damages leaf tissues through a range of physiological effects including increasing stomatal resistance to carbon dioxide uptake and reducing chlorophyll content. Since carbon dioxide and chlorophyll are essential for photosynthesis, this damage reduces photosynthetic activity and, consequently, growth and productivity. Injury may be so severe that tissues can no longer be supported leading to death of part or all of the plant [8, 9, 10]. Generally, the critical level above which these effects begin to be evident is around 20-30 $\mu g.m^{-3}$, measured at ground level and averaged over one year but different species vary in their sensitivity to SO_2 [11] (see 10.29 and 10.34 et seq.).

10.28 Trees are more vulnerable to SO_2-induced damage than herbaceous plants, mainly because a greater leaf-surface area per individual is open to uptake. Evergreen species, especially conifers, with all-year-round photosynthetic activity and long individual leaf-life, are more sensitive than deciduous ones. Because of these differences in sensitivity between plants, grassland ecosystems, composed of herbaceous species with a high turnover of above-ground tissues, have been found to be more resistant to SO_2 pollution than forest ecosystems [10].

10.29 Crop plants, although less sensitive to SO_2 pollution than forests, are to varying degrees susceptible to SO_2 deposition. Table 10.3 shows the average annual SO_2 concentrations causing a 5% reduction in yield, for various crops [9]. At lower levels of SO_2 deposition, the addition of sulphur to soils, especially if the soil is of naturally low sulphur content, may have a stimulatory effect on crop growth [12].

Table 10.3 : SULPHUR DIOXIDE CONCENTRATION FOR LONG-TERM EXPOSURE CAUSING ABOUT 5% REDUCTION OF CROP YIELD

Species type	Concentration ($\mu g.m^{-3}$) reducing yield by 5%	Crops
Sensitive	30 - 50	Kidney bean, Chinese cabbage
Intermediate	70 - 80	Soybean
Resistant	90 - 160	Maize, rice

10.30 Effects on animals are more difficult to study than those on plants. However, since all animals are in some way dependent on vegetation, any serious damage to plant growth will be harmful to them. Impact will be greatest to species such as a herbivorous insects when they are dependent on a limited number of plant species susceptible to damage. In grasslands, soil-dwelling invertebrates have been shown to be more affected than above-ground ones (possibly because of effects on soils discussed below). However, pollen and nectar feeding insects such as butterflies, apparently have a special sensitivity to SO_2 at levels above $80\mu g.m^{-3}$ [10].

10.31 Indirect effects on vegetation and animals occur through deposition of SO_2 on soils, especially as acid rain. Three main changes in soil chemistry occur, namely a decrease in pH, a decrease in available calcium, and an increase in the mobility of metals such as aluminium. These effects are greatest in soils of naturally low pH, such as the podsols on Lamma, which have little capacity to buffer against them. These changes in soil chemistry may lead to alterations in the species composition of the vegetation since few plants are adapted to low pH, low calcium, and are tolerant of toxic metals such as aluminium. However, those few will be favoured at the expense of the others.

Nitrogen Oxides

10.32 Nitrogen oxides in the form of nitrous and nitric acids make up a lesser component of acid rain but cause similar effects to those of sulphur dioxide deposition. Critical levels appear to be $30\mu g.m^{-3}$ at ground level averaged over a year [11]. Above this, other effects of nitrogen deposition also occur. The addition of nitrogen, particularly to nutrient-poor soils, has a fertilizing effect. This may be beneficial to crop growth but has deleterious effects on ecosystem stability by encouraging growth of coarse species at the expense of those adapted to nutrient deficient conditions (often the rare species), thereby reducing species diversity.

Particulates

10.33 High levels of particulate deposition cause damage to plants by covering leaves thereby reducing light absorption and plugging stomata so reducing CO_2 absorption. Consequently, photosynthesis, which requires both light and CO_2, declines as do growth and productivity. Some plants are more susceptible than others because of features such as greater leaf wax layers, leaf hairs, and moisture cover, which increase retention of particles. Particulates may erode the natural wax layer of a plant, e.g. on many brassica leaves, and thus reduce their resistance to fungal disease and water-loss [13].

Pollution Indicators

10.34 Lichens are a group of plants resulting from a symbiotic relationship between algae and fungi. Some 18,000 species are known worldwide [14]. Slow growth rates and extreme longevity are features of the group - lichens aged 4,500 years old have been recorded from the northern hemisphere [15]. Lichens have a low chlorophyll content and hence are highly susceptible to SO_2-induced damage. A link between air pollution and a decline in the lichen flora was first established in 1859 and an index of air quality based on the presence or absence of particular groups of lichens was proposed in the UK in 1976 [14]. Since then, over 4,000 research papers have been published on air pollution and lichens [16].

10.35 As with other plants, lichens absorb sulphur from the air and through moisture from the substrate on which they grow. The sulphur disrupts the metabolic processes leading to physical changes including reduction in growth rate, bleaching and colour changes, peeling, changes in form from reproductive to non-reproductive morphs, and ultimately to death. These changes in response to different SO_2 levels can be used in conjunction with presence/absence data to increase the sensitivity of this biological index [14].

10.36 Over 200 species of lichen are believed to exist in Hong Kong of which 140 have been identified [17]. Little work has been carried out on air quality and lichens within the Territory but in 1979, 1400 sixth form biology students carried out a project called the Clean Air and Lichen Survey. The results are shown in Figure 10.4 [1]. Lamma Island fell within the cleanest air category. Since then, no further work has been undertaken on lichens on Lamma. Photographic evidence from the Agriculture and Fisheries Department of the summit show a healthy lichen flora on the rocks, confirming low air pollution levels [6].

10.37 Estimates of the ground level conditions of various pollutants are given in Chapter 5. Predictions of long term average SO_2 levels for the base case of 1994 with units L1-6 in operation show maximum concentrations of about $26\mu g.m^{-3}$ occurring about 3km west of the power station over the West Lamma Channel and a secondary concentration of about $14\mu g.m^{-3}$ over Ha Mei Wan about 3km to the south. Neither of these peak concentrations will therefore affect the terrestrial ecosystems. It is particularly pertinent to note, however, that little adverse effect would be experienced by terrestrial plants even if these concentrations were to have occurred over land. From paragraphs 10.27 and 10.32 it can be seen that the former concentration is just below the critical range at which the most sensitive plants begin to suffer damage from SO_2. Similarly, maximum average concentrations of NO_x fall over the sea but these levels are under $20\mu g.m^{-3}$ and again are below critical levels causing plant damage.

10.38 Air quality predictions for 2000 with units L7 and L8 in operation do not differ appreciably in the pattern or level of pollutant deposition. Critical levels of SO_2 and NO_x are not encountered over land.

10.39 In summary, therefore, maximum long term average levels of air pollutants are predicted generally to be below those considered to be critical for damage to plants, and over land to be well below these thresholds. It appears that Lamma itself will be barely affected in any scenario and evidence of existing lichen flora on Lamma suggests that air quality is not a limiting factor for plant growth.

Particulates

10.40 Predictions of particulate deposition show low levels and similar patterns to those already described above for gaseous pollutants. Particulate deposition is not considered to be a problem for plants under any scenario. Dust arising from construction works is likely to be a greater threat, especially to those market gardens neighbouring the site to the east. However, regular spraying of the construction site with water will control dust levels to an acceptable degree. The size of the potential problem must be viewed in the light of the large amounts of dust already generated from the quarry operations on the north side of Sok Kwu Wan Bay.

10.41 HEC have received periodic complaints from Lamma residents of vegetation damage due to operation of the existing power station. The most recent of these complaints occurred in May 1990 and was concerned with black deposits on vegetation.

10.42 Extensive investigations carried out by HEC revealed no materials in the deposit which could be reasonably ascribed to current operations at Lamma Power station. However, morphological examination indicated the deposit to be a fungus.

10.43 Whilst there is no evidence to suggest that the operations at Lamma Power station are having any damaging effects on the Island vegetation, as would be expected in view of the above review of possible pollution levels, it is clear the local residents do perceive there to be a problem in this regard. It is recommended therefore that special attention is paid to this matter during public consultation exercises.

Conclusions

10.44 Constructing two new power generating units of 350MW with FGD equipment will not result in any adverse effects on the terrestrial ecology of Lamma Island or its neighbouring islands. With the exception of spraying water regularly on the site during construction work, no mitigative measures are necessary since the FGD units will themselves mitigate the increase in gaseous pollutants that would otherwise ensue.

10.45 It must be stressed that siting the new generating capacity at the existing power station on Lamma is, in ecological terms, a good decision since siting that capacity elsewhere would inevitably result in the loss of an undisturbed area. By utilising the present site, this scenario is avoided, as is the disturbance and potential pollution ensuing from its operation.

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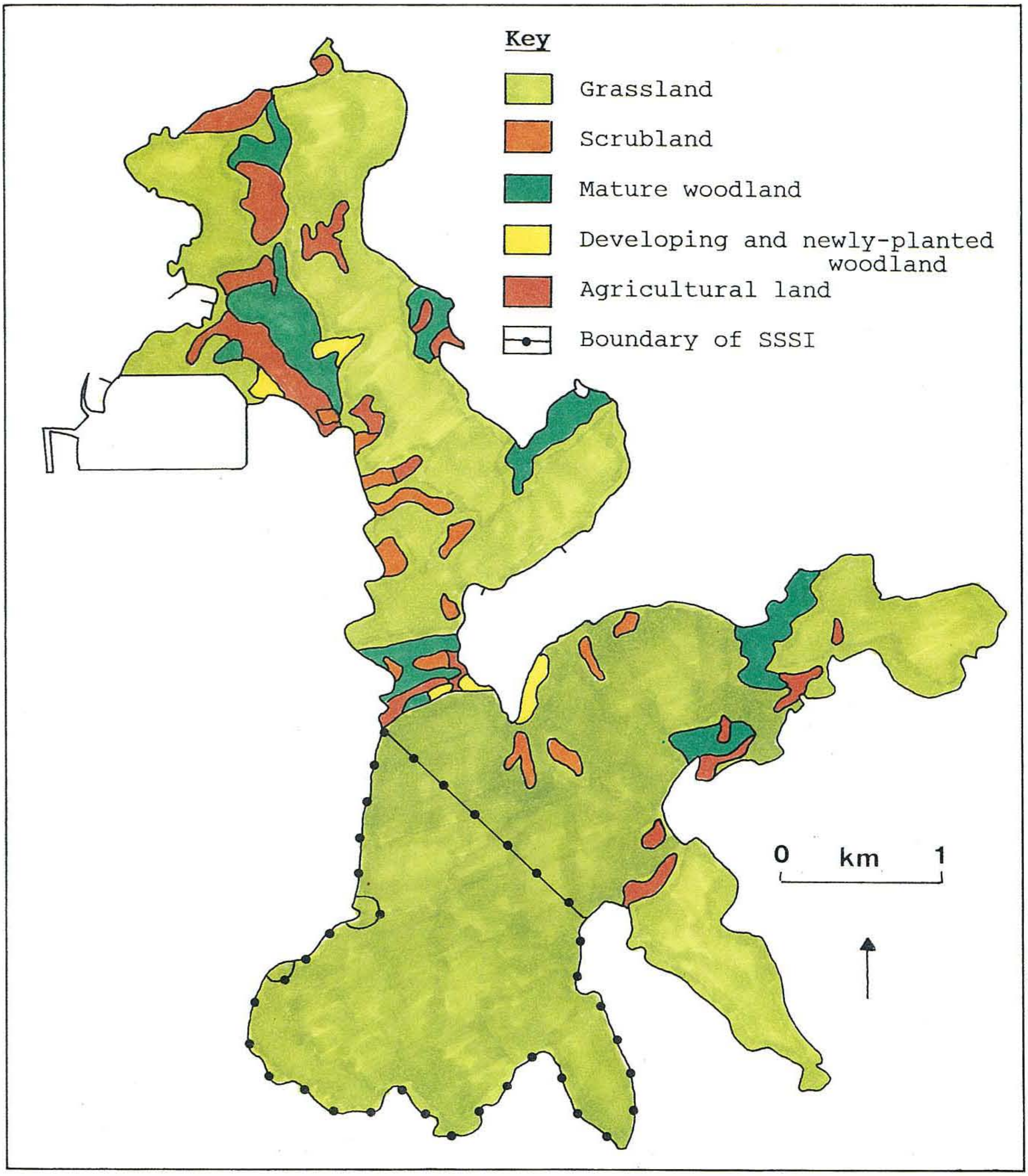


The Hongkong Electric Company Limited

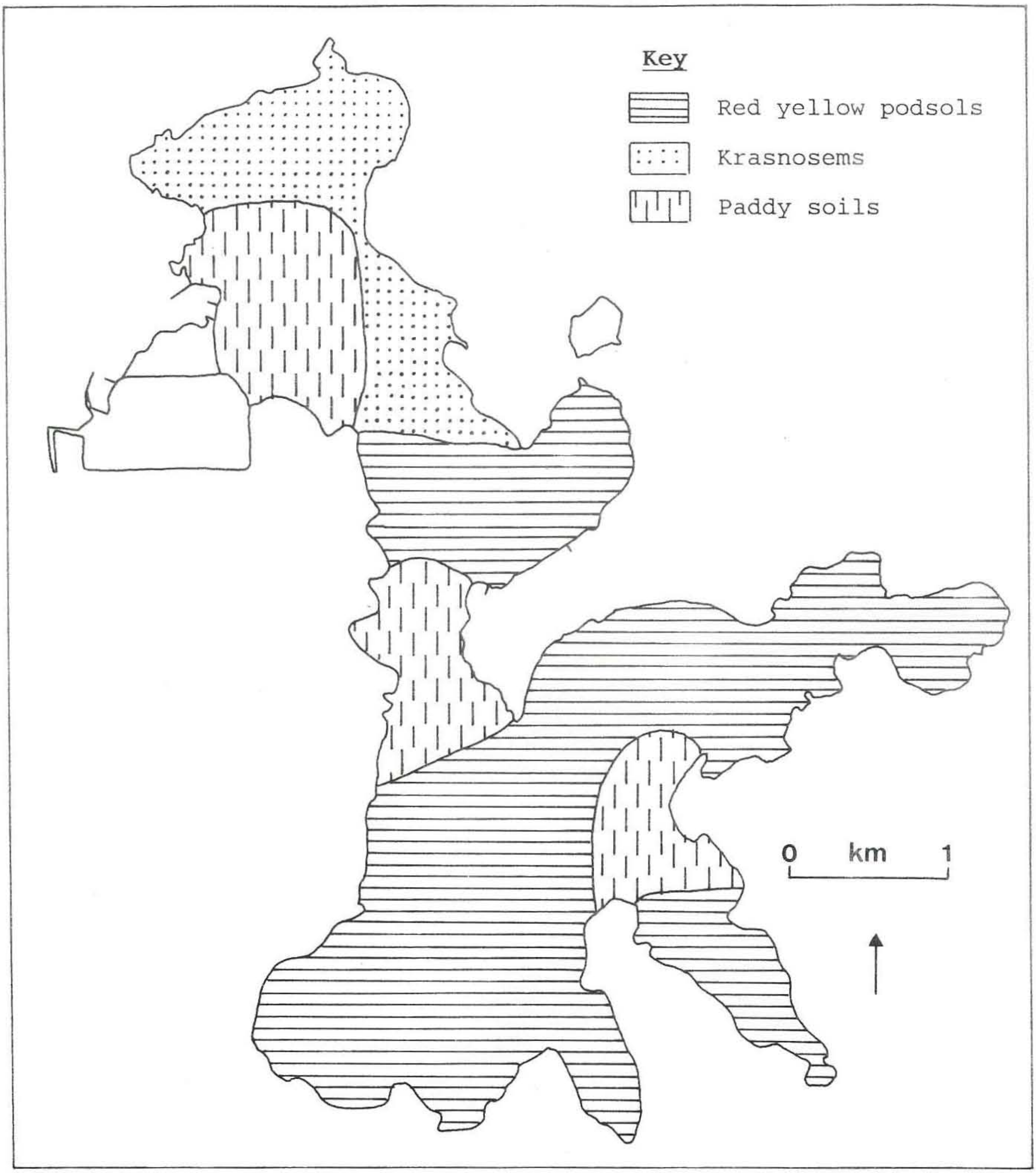
TITLE

LAMMA ISLAND MAJOR HABITAT TYPES AND BOUNDARY OF SSSI

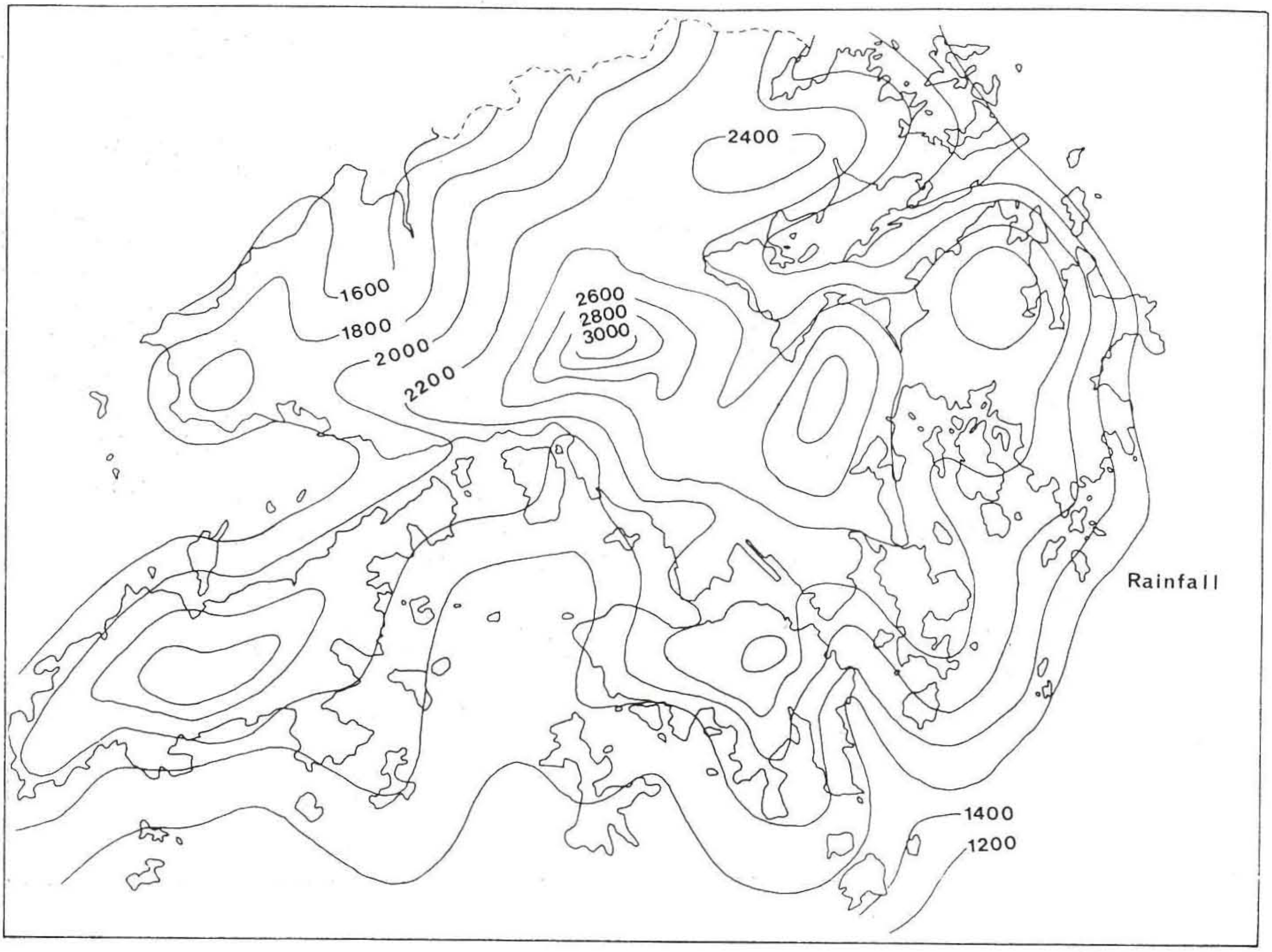
PROJECT

EIA LAMMA POWER STATION

FIGURE 10.1



The Hongkong Electric Company Limited	TITLE LAMMA ISLAND - DISTRIBUTION OF SOIL GROUPS
PROJECT EIA LAMMA POWER STATION	FIGURE 10.2



The Hongkong Electric Company Limited

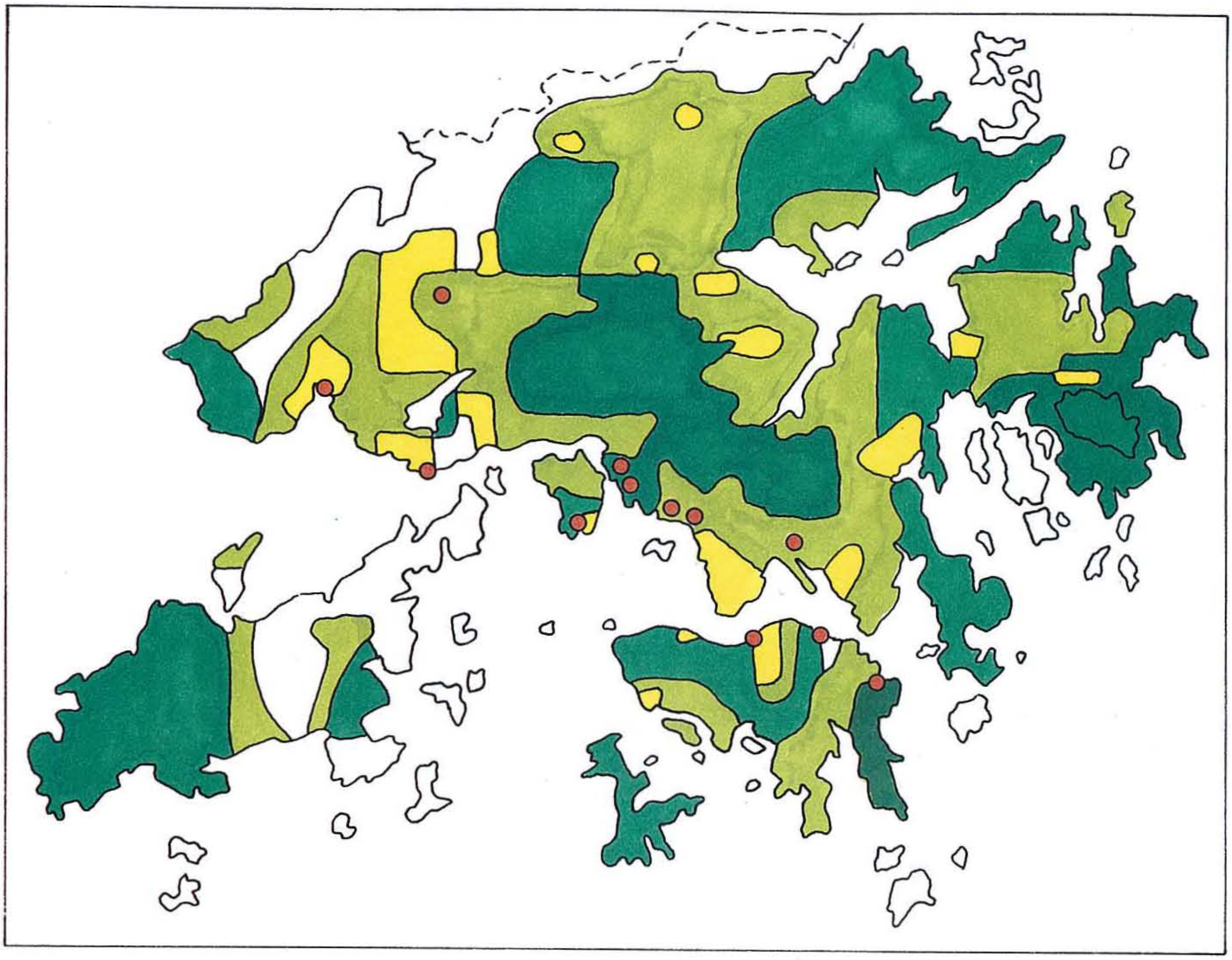
TITLE

HONG KONG RAINFALL MAP
(THROWER, 1984.)

PROJECT

EIA LAMMA POWER STATION

FIGURE 10.3



Key

- Lichen desert
- Struggle zone
- Normal growth zone - crustose lichens
- Normal growth zone - foliose and fruticose lichens
- Insufficient information

Indicators	Pollution Zone
No lichens on any trees, only a green film of the alga Protococcus.	Lichen desert. SO_2 level over 20 μgm^{-3} air for much of the time.
The grey-green scaly lichen Pyxine is the only lichen present on the tree trunks. It never has fruiting cups in this zone.	Inner struggle zone.
Only the bright yellow powdery lichen Lepraria and/or the scaly lichen Lecanora may have many brown fruiting cups.	Outer struggle zone. SO_2 level averages about 100 μgm^{-3} air
Many different crusty lichens present, often with fruiting cups.	Zone of normal growth for crusty lichens.
Large leafy lichens such as Parmotrema present.	Zone of normal growth of leafy lichens. SO_2 averages 50 μgm^{-3} air or less.
Bushy lichens such as Usnea present.	Very clean air.

Scale for assessment of pollution zones using indicator lichens.

The Hongkong Electric Company Limited

TITLE

MAP OF POLLUTION ZONES IN HONG KONG BASED ON RESULTS OF THE CLEAN AIR AND LICHEN PROJECT. 1979.

PROJECT

EIA LAMMA POWER STATION

FIGURE 10.4

NOISE

11.0 NOISE

11.01 Noise control in Hong Kong is carried out through the Noise Control Ordinance, and by the use of the Technical Memoranda, made under the Ordinance, which limits noise from certain activities. For major new developments, planning control of noise takes place via the Environmental Chapter of the Hong Kong Planning Standards and Guidelines (HKPSG).

11.02 For operational noise from a power station the appropriate procedures are detailed in the "Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites".

11.03 In that document the following procedures are required:

a) Determine the appropriate Acceptable Noise Level (ANL) for the Noise Sensitive Receiver (NSR) in question;

b) Conduct measurements to obtain the Corrected Noise Level (CNL) of the noise under investigation;

c) Compare the Corrected Noise Level with the Acceptable Noise Level to determine if a Noise Abatement Notice may be issued.

11.04 From Paragraph 1.05 Section C of the Technical Memorandum, it can be seen that its use is primarily intended to determine whether a Noise Abatement Notice may be issued, or, if one is already in force, to determine whether it is being complied with.

11.05 Before commencement of the noise impact assessment the Hongkong Environmental Protection Department (EPD) were consulted in order to determine the criteria and methodology to be used.

11.06 The EPD requirement when planning new installations is that the Corrected Noise Level from the new installation must not exceed either the appropriate Acceptable Noise Level minus 5dB(A) or the prevailing L_{A90} background noise level, whichever is the lower. This therefore was the criteria used in the assessment and will be referred to as the Target Noise Level.

11.07 The background noise level used for the assessment (the baseline background noise level) is that which occurs in 1994 and derives from the power station in its current operational state plus any effects of Unit L6, which has already been approved.

11.08 Based on the criteria in Paragraph 11.06, if the Acceptable Noise Level minus 5dB(A) is lower than the baseline background noise level, then the corrected noise level from Units L7 and L8 must not exceed the Acceptable Noise Level minus 5dB(A). However, if the baseline background noise level is lower than the Acceptable Noise Level minus 5, then the corrected noise level from Units L7 and L8 can equal, but not exceed, this baseline background noise level.

Noise Units and Standards

11.09 Noise is defined as unwanted sound. The range of audible sound is from 0dB to 140dB. The frequency response of the ear is usually taken to be about 18Hz (number of oscillations per second) to 18,000Hz. The ear does not respond equally to different frequencies at the same level. It is more sensitive in the mid-frequency range than at the lower and higher frequencies and, to take account of this, the low and high frequency components of a sound are reduced in importance by applying a weighting (filtering) circuit to the noise measuring instrument. The weighting which is most widely used and which correlates best with the subjective response to noise is the dB(A) weighting. This is an internationally accepted standard for noise measurements.

11.10 External noise levels are rarely steady, noise levels rise and fall in response to activities within an area. In an attempt to produce a figure that relates this variable noise level to the subjective response, a number of noise indices have been developed. The indices that are relevant to this assessment are the L_{A90} and L_{Aeq}. These are defined below:

i) The L_{A90} noise level

This is the level exceeded for 90% of the time and gives an indication of the noise level during the quieter periods. This is often referred to as the background noise level and is used in the assessment of the disturbance from industrial noise.

ii) The L_{Aeq} scale

This is defined in an HMSO publication [1] as the "notional steady noise level that would provide over a period the same energy as the intermittent noise". In more straight forward terms, it is a measure of the energy within the varying noise. It is a unit commonly used to describe noise from industrial premises.

Target Noise Level

11.11 The most noise sensitive period is the night-time (defined as 23.00 to 07.00 hours). This period has therefore been considered throughout the assessment for each Noise Sensitive Receiver (NSR).

11.12 In general, it is considered that properties at the NSR's under consideration fall under the category defined in the Technical Memorandum as: "(ii) low density residential area consisting of low-rise or isolated high rise developments", although some properties to the east of the power station may be considered under the category "(i) Rural area, including country parks or village type developments". However, these area categories are not specifically defined in the Technical Memorandum, other than Country Park.

11.13 NSR's under consideration also generally fall into the category "indirectly affected" which is defined in the Technical Memorandum as meaning that "the NSR is at such a location that noise generated by the Influencing Factor (IF), whilst noticeable at the NSR, is not a dominant feature of the noise climate of the NSR". NSR's that fall into the category "(ii) indirectly affected" are considered to have an Area Sensitivity Rating of "B". Any NSR's that may be considered to be "directly affected" would fall into category (i) and therefore also have an ASR of "B". From an assessment of the Technical Memorandum it would seem that any NSR considered in this study should therefore be considered to have an ASR of "B".

11.14 As the assessment of the proposed extension is being considered at a baseline year of 1994, the Acceptable Noise Level (ANL) for each NSR has been determined from Table 3 of the Technical Memorandum. Using this table, the ANL for the night period is 55dB(A).

11.15 However, for planning purposes, one of the EPD requirements is that the Corrected Noise Level from Units L7 and L8 should not exceed the ANL minus 5dB(A). The relevant noise level on this basis is therefore 50dB(A).

11.16 Notwithstanding the above, EPD have specified that the night-time ANL to be used for the assessment of Unit L6 FGD is 50dB(A). Hence the Target Noise Level becomes 45dB(A) or the background noise level if this is lower, and this has therefore been used as the criterion to assess the noise impact of L7 and L8.

11.17 In order to determine background noise levels which are representative of NSR's in the area, sites should be located to be typical of noise receivers in the area and measurements should be of sufficient duration to take account of both temporal and meteorological variations. HEC have conducted continuous noise monitoring over several years at two sites - Hung Shing Ye and Ching Lam. The results of monitoring at these two sites are summarised in Table 11.1. In addition, HEC have also conducted continuous monitoring over a period of several days at a location in Yung Shue Long. Measurements of background noise level have also been undertaken by HEC at several other locations during the daytime, over short periods.

11.18 The Hung Shing Ye site is considered to be representative of NSR's to the east as it is at a similar distance from the power station to the NSR's under consideration and, because of the long term nature of the monitoring, temporal and meteorological factors are taken into account. Similarly, the Yung Shue Long site is considered to be typical of NSR's to the north of the power station in terms of distance and location. The measurement period is also considered to be reasonable in terms of temporal and meteorological effects.

11.19 EPD have agreed that long term monitoring data are more representative than short sample measurements and that the HEC data would provide a reasonable estimate of background noise levels at the relevant NSR's. It was also agreed that the current background noise level for the period 23.00 to 07.00 hours would be taken as the arithmetic average of the half hourly L_{A90} noise level measured over the period.

11.20 Results of measurements made by HEC at Yung Shue Long over a two week period during April 1990 have been examined and are given in Table 11.2. The average L_{A90} background noise level for the night-time (23.00 to 07.00 hours) over that period was 42dB(A).

TABLE 11.1 : AVERAGE NIGHT TIME NOISE LEVELS FOR HUNG SHING YE AND CHING LAM

	Night-Time L_{A90} Hung Shing Ye		Night-Time L_{A90} Ching Lam
1980	53.1		-
1981	57.8		-
1982	51.8		-
1983	46.8		-
1984	49.6		50.6
1985	45.3		52.1
1986	47.7		-
1987	46.2		52.7
1988	47.7		51.0
1989	45.9		48.9
1990 (Up to August)	46.8		50.9
AVERAGE 1980-90	49.0	AVERAGE 1984-90	51.0
AVERAGE 1985-89	46.6		

11.21 Average noise levels for the period 1980-1989 at Hung Shing Ye are also given in Table 11.1. The measurements over the past five full years (1985-1989) indicate an average night-time L_{A90} background noise level of 47dB(A). Average measurement at Ching Lam indicate a night time L_{A90} background noise level of 51dB(A).

11.22 For planning purposes, EPD require that neither the background noise level nor the ANL minus 5dB(A) should be exceeded. As the background noise level at the representative NSR's is lower than the ANL minus 5, the background noise level should therefore be taken as the Target Noise Level.

11.23 In the baseline year (1994) there will be additional noise sources on the power station site resulting from the Unit L6 FGD plant and the stacker reclaimer. An estimate of the noise level resulting from these additional noise sources has been made to achieve a 1994 baseline noise level at the representative NSR's. For NSR's to the north of the site, these additional noise sources will make a negligible contribution to the current background noise level, due to the combined effects of screening and distance attention. Hence it can be assumed that the baseline background noise level in 1994 will be closely similar to that currently prevailing. For NSR's to the east, the increase in noise sources will have some effect on the background noise level but, as the current background level is greater than the ANL minus 5 dB(A), this latter noise level (45 dB(A)) will apply.

11.24 Target Noise Level of 42dB(A) for NSR's to the north of the power station, and 45dB(A) at Hung Shing Ye and Tai Wan To to the east have therefore been used in this assessment.

TABLE 11.2 : NIGHT TIME L_{A90} NOISE LEVELS AT YUNG SHUE LONG

Date	Night-time L_{A90}
05/04/90	39.2
06/04/90	38.1
07/04/90	40.9
08/04/90	41.3
09/04/90	42.1
10/04/90	42.4
11/04/90	45.6
12/04/90	43.4
13/04/90	41.0
14/04/90	41.6
15/04/90	41.6
16/04/90	43.7
17/04/90	42.0
AVERAGE	41.8
S.D.	1.8

Calculation Methodology

11.25 There are four major stages in the calculation of the Corrected Noise Level (CNL) at a receptor point some distance from the power station. These are:

a) The determination of the noise level for each source at a reference distance;

b) The propagation at distances away from the power station;

c) The addition of the noise levels, and corrections for tonality and intermittency.

d) Barrier effects

Source Noise Level

11.26 A noise survey of typical plant currently in use at the power station has been undertaken, and the results of the survey are given in Table 11.3. The specification for Unit L6 and information on other plant noise levels has been provided by HEC.

TABLE 11.3 : MEASURED NOISE LEVELS AT LAMMA POWER STATION - 9/4/90

Frequency	ID Fan Unit L4	ID Fan Unit L5	Pulverizing Mills	Boiler Feed Pump (1)	Boiler Feed Pump (2)	Internal Unit L4
25	76.6	80.8	85.8	83.2	85.9	77.8
31.5	79.3	78.4	89.8	84.9	83.7	75.7
40	76.6	75.4	85.2	80.9	80.8	76.2
50	76.9	75.3	84.6	81.6	87.5	80.3
63	74.6	74.3	85.8	80.7	80.8	76.1
80	72.5	73.4	85.6	80.9	82.7	71.2
100	72.4	72.2	85.4	87.3	91.1	70.8
125	73.3	72.3	84.1	85.1	86.3	69.3
160	73.3	73.1	83.1	85.9	89.6	68.5
200	76.4	78.4	82.7	85.4	86.4	73.4
250	86.9	82.8	80.3	84.6	85.4	83.9
315	76.6	74.9	77.9	83.6	83.6	79.1
400	75.1	74.6	77.3	88.7	87.4	72.6
500	80.1	79.1	76.4	91.1	88.1	77.1
630	76.3	77.9	76.7	84.3	84.6	74.8
800	73.0	75.1	77.0	81.2	82.4	77.9
1000	71.8	73.1	74.3	81.9	81.9	75.8
1250	69.9	70.6	72.7	85.7	87.6	71.9
1600	67.3	66.8	72.5	91.1	90.8	70.0
2000	65.8	65.1	72.1	85.8	86.4	69.6
2500	62.8	62.8	72.6	85.8	84.8	68.4
3150	60.8	60.8	69.6	84.8	85.9	66.3
4000	59.8	58.8	67.0	83.9	82.9	63.6
5000	59.1	58.7	62.3	78.4	76.1	60.6
6300	55.8	54.6	58.8	73.8	71.6	57.7
8000	50.8	50.3	54.8	70.4	69.9	63.9
10000	48.3	49.9	50.9	64.8	62.6	65.8
Lin(meas)	91.6	90.5	96.6	99.3	100.4	89.7
A Wtd.	83.7	83.1	85.0	97.3	97.1	84.2

TABLE 11.3 (CONT'D) : MEASURED NOISE LEVELS AT LAMMA POWER STATION - 9/4/90

Frequency	Forced Draft Fan/Motor Unit L4		External Unit L5	Turbine Hall Unit L5	312.5MVA Generator Transformer 2			
	(1)	(2)			15m	3m	3m	3m
25	78.7	75.9	75.3	76.3	66.3	66.9	66.1	67.0
31.5	82.1	73.9	74.6	76.4	64.3	62.8	62.4	62.6
40	79.5	79.9	73.2	73.4	62.6	61.8	63.1	62.8
50	77.9	77.9	70.8	80.9	69.2	70.6	71.6	71.3
63	75.1	75.7	70.1	75.8	65.8	65.6	65.4	66.8
80	71.6	74.3	68.8	75.8	64.1	70.9	67.3	67.9
100	78.4	83.4	68.5	82.4	78.4	90.9	84.4	84.8
125	72.1	76.6	64.0	77.9	69.6	90.3	73.1	74.8
160	69.5	71.4	61.4	79.4	64.3	65.6	66.4	67.1
200	72.6	72.1	61.3	79.1	76.8	65.3	75.9	70.9
250	93.4	78.5	72.4	78.8	67.3	65.9	67.1	69.4
315	86.4	75.6	66.8	77.3	68.1	78.3	63.6	77.7
400	76.4	71.9	59.9	76.9	63.0	70.4	64.1	71.4
500	85.9	85.2	61.6	76.8	63.6	66.9	67.4	70.9
630	80.6	80.8	65.9	75.9	62.9	66.7	70.1	70.8
800	78.1	77.6	64.9	77.3	61.7	65.3	65.3	64.9
1000	75.6	74.9	61.1	75.1	58.1	60.4	61.0	62.8
1250	72.3	71.3	58.7	74.3	56.1	58.6	58.8	60.1
1600	70.6	69.8	60.3	74.4	55.2	56.5	55.9	59.9
2000	69.6	68.9	55.8	72.3	54.6	53.8	54.1	55.3
2500	69.0	69.1	54.1	71.8	52.3	51.4	51.3	51.6
3150	66.4	67.6	51.4	69.0	49.3	47.9	48.4	48.1
4000	62.1	64.8	48.9	68.1	47.4	46.1	45.9	45.9
5000	59.3	65.4	46.6	63.3	43.3	41.7	41.6	42.3
6300	55.8	64.4	44.6	61.4	40.4	39.8	40.1	39.6
8000	51.6	67.6	44.3	55.9	38.8	37.6	37.0	37.3
10000	50.1	59.6	41.1	47.8	37.6	37.3	36.8	37.6
Lin(meas)	93.1	90.8	84.8	90.6	81.6	91.4	86.4	85.9
A Wtd.	89.2	86.2	71.7	84.9	71.4	78.6	73.9	76.6

11.27 The major fixed noise sources at the power station are the Pulverising Mills, Boiler Feed Pump, Forced Draft Fans, Turbo Generator, Primary Air Fans and Mill Seal Air Fans, etc which are all internal, and the ID Fans and Transformers which are external. There are also a number of small noise sources and some intermittent ones, such as coal unloading and handling operations.

11.28 Although there are seven gas turbine generating units on the site, these are primarily used for meeting peak demands and emergencies of the HEC system. It is therefore considered that these would not contribute to the normal night-time noise climate in the area, and therefore would not normally affect the L_{A90} background noise level under consideration.

11.29 A measurement of the external noise level at 1m from the wall of Unit L5 was undertaken, but this measurement was affected by other items of plant operating nearby. Calculations of noise due to internal plant have therefore been based on the assumption that the buildings for Units L7 and L8 will be clad with a single skin of profiled sheet steel, and that measurements of internal noise for Unit L4, taken internally near the wall of the building will be representative of all internal noise sources in Units L7 and L8. The second assumption is considered to be valid as the measured noise level of 84.2dB(A) agrees closely with the general specification for the internal noise level for Unit L6 of 85dB(A) at a distance of 1m from any item of plant.

11.30 The major external items of plant which contribute to the overall noise level are the ID Fans. The effect of the transformers has also been examined, but, due to spectral content, they have a very limited effect on the overall A-weighted noise levels.

11.31 Due to local screening, and in the context of the scale of the major noise sources, it is considered that the small items of plant will not contribute significantly to noise levels at locations remote from the power station. No account has therefore been taken of these units in this assessment.

Propagation

11.32 The factors affecting propagation of noise from the reference distance to a receiver point some distance away are as follows:

(i) Geometric spreading;
(ii) Air Absorption;
(iii) Ground attenuation;
(iv) The effect of barriers;
(v) Topography;
(vi) Reflections due to facades.

Geometric Spreading

11.33 The noise from a point source reduces at a rate of 6dB(A) per doubling of distance, due purely to geometric spreading.

$$\text{i.e. correction for distance} = 20 \log \left[\frac{d}{d_o}\right]$$

where d_o is the reference distance.

11.34 However, noise from larger sources such as buildings does not attenuate at the same rate as a point source. It has been demonstrated [2] that the noise from a large area source such as a boiler room reduces according to the following:

$$L = L_1 - R + 10 \log S - 20 \log (r + \sqrt{S}) - 6$$

where L = Sound pressure level at any point r from a radiating surface in the open air

L_1 = Sound pressure level inside a room
R = Sound Reduction Index of a partition
S = Area of radiating surface
r = Distance from a radiating surface to a point in the open air

11.35 From experience, this gives a more realistic estimate of distance attenuation for large sources. For receptors which are not perpendicular to the radiating surface being considered, the effective area of the surface is taken. The area source algorithm given above in Paragraph 11.33 has therefore been used in the assessment to calculate distance attenuation.

Air Absorption

11.36 In the measurement of aircraft noise, air absorption has been considered of great importance and a great deal of research has been done on the attenuation rates at various frequencies due to this mechanism.

11.37 The additional attenuation due to air absorption varies with temperature and humidity, but ranges from approximately 0.03dB(A) at 100Hz to approximately 19dB(A) at 10,000Hz. However, noise from a power station is predominantly of low frequency and consequently the effect of air absorption on the overall noise level will be correspondingly small. The effect of air absorption has therefore been neglected in this assessment. The effect of neglecting this factor in the assessment would lead to a conservative estimate of noise levels at the NSR's, i.e. a slightly higher noise level will be predicted.

Ground Attenuation

11.38 For this aspect, consideration has only been given to the total effect of excess attenuation as sound passes over different types of ground. No attempt has been made to split this into the component effects of absorption, interference and ground impedance. Ground cover varies from totally reflecting surfaces, e.g. concrete or water, through surfaces such as short grassland to land covered with dense shrubbery.

11.39 It is considered that there is no additional attenuation due to ground effects for hard surfaces such as concrete or water. Therefore, where 'hard' ground predominates between the source and the reception point, no additional correction for ground attenuation has been applied.

11.40 If the sound paths close to the ground are obstructed by barriers, ground attenuation is considerably reduced. Therefore the methodology used takes whichever is the larger attenuation, either the barrier attenuation or the grassland attenuation but not both. This is similar to the methodology used in the DTp Publication, Calculation of Road Traffic Noise (CRTN) [3].

11.41 However, in the context of the power station at Lamma, the additional attenuation due to soft ground has been discounted. This is because the transmission path from the source to the NSR is generally either over water or concrete, or affected by a barrier or topographical feature.

Barriers

11.42 Barrier attenuation has been calculated by the method proposed by Maekawa [4], using the following formulae:

$$\text{Path Difference } D = \sqrt{S^2 + H^2} - S + \sqrt{R^2 + H^2} - R$$

$$\text{Fresnel Number } N = \frac{2 \times D}{\lambda}$$

$$\text{Barrier Attenuation } = 20 \times \log \left[\frac{\sqrt{2 \times \pi \times N}}{\tanh\sqrt{2 \times \pi \times N}} \right] + 5$$

where S = effective source to barrier distance
H = effective barrier height
R = effective barrier to receiver distance
λ = wavelength of sound at the frequency of interest

11.43 In the barrier calculations, it has been assumed that the sources are all point sources. For a large area source, the point of emission is taken to be on the geometric centre of the horizontal plane, and two-thirds the height of the vertical plane, as suggested in the literature [5].

11.44 The effects of trees and shrubs on noise propagation are generally accepted to be very small. Some information is available promoting the use of dense bands of tree planting to provide noise screening [6], but the reductions claimed are small compared with those for conventional barriers. In the absence of any definitive values for these small reductions, it is considered that the effects of trees and shrubs should be neglected.

Topography

11.45 The effects of topography are included in the calculation by including hills and ridges as semi-infinite thin screens and using Maekawa's method [4]. Valleys or a source raised above ground level give reduced ground attenuation due to the increase in mean propagation height. Effects such as "sound funnelling up valleys" and "bouncing off scarps" can usually be explained by the reduced ground attenuation due to a high mean propagation path. However, no additional ground attenuation has been assumed in the calculations.

Factors Affecting The Calculated Noise Level

11.46 The prediction of noise levels undertaken assumes that there is a slight positive wind ($2m.s^{-1}$) from source to receiver, which is also standard practice. However, when noise levels are measured, the value is very dependent on the climatic conditions prevailing at the time of the measurements. For properties close to the source and unshielded from that source, the effects of wind and temperature inversions are quite small, but for properties 2km from the noise source, the source could be inaudible when the wind is blowing from the receiver to the source but be clearly audible when the wind is blowing from the source to the receiver.

11.47 There is very little information on the long distance propagation of noise. However, from information on long distance noise propagation that is available [7, 8 and 9], it has been calculated that the variation in noise can range from an increase of 4dB(A) at a distance of 1km from the source when the wind is blowing from the source to the receiver to a decrease of -8dB(A) when the wind blows from the receiver to the source. Additionally, at distances greater than 1km the noise from the source can be increased by temperature inversions which would tend to increase the noise by approximately 3 or 4dB(A) depending on the strength of the inversion. The incidence of low level inversions with winds blowing towards the receiver is, however, very low (cf Chapter 5), and can be effectively discounted for the purposes of noise assessment.

Noise Impact

11.48 In order to test the various noise prediction assumptions, a calculation of the noise from the existing Units (L1-L5) has been undertaken for the monitoring site at Ching Lam based upon the measurements made on the Lamma site (Table 11.3) and the assumptions given in paragraphs 11.27 to 11.29. The noise level for the existing units was calculated to be 51dB(A), which agrees with the measured L_{A90} background noise level of 51dB(A) at this location, averaged over the period 1985-1989 (See Table 11.1). It is therefore considered that both the assumptions made above, and the calculation methodology are valid.

11.49 However, the spectral content of the noise must also be examined in order to determine the Corrected Noise Level, as prescribed in the Technical Memorandum. The measured noise spectrum of the ID Fans is such that, based on Section 3.3.2 of the Technical Memorandum, correction for tonality should be applied to the calculated noise levels. For the purposes of this assessment, the maximum tonality correction of + 6dB(A) has been used, leading to a "worst case" estimate. In practice, a lower value for tonality may be applicable, but selection of a +6dB(A) correction allows for a suitably conservative assessment and provides a margin for possible errors in the predictive assessment.

11.50 Using the above assumptions, noise levels from the proposed Units L7 and L8 have been calculated for 8 NSR's and the results of these calculations are given in Tables 11.4 and 11.5. The detailed calculations are given in the Appendix 11A, but the calculations for one site are given in Tables 11.6 to 11.9.

TABLE 11.4 : CALCULATED NOISE LEVELS FROM UNITS L7 AND L8

NSR	ANL (Night)	Background Noise Level	Target Noise Level	Corrected Noise Level From L7 &L8
1. Yung Shue Long	50	42	42	23.5
2. Sha Po	50	42	42	28.0
3. Ko Long	50	42	42	25.1
4. Yung Shue Wan	50	42	42	27.0
5. Tai Wan San Tsuen	50	42	42	30.2
6. Wang Long	50	42	42	25.3
7. Tai Wan To	50	47	45	45.8
8. Hung Shing Ye	50	47	45	45.1
9. Ching Lam*	-	51	-	52.3

* Not NSR

TABLE 11.5 : CALCULATED NOISE LEVELS FROM UNITS L1 TO L8 AND GAS TURBINES, COAL SHIP UNLOADER AND STACKER RECLAIMER (CUMULATIVE IMPACT)

NSR	Background Noise Level	Target Noise Level	CNL From L1 to L6 + GT's etc*	CNL From L1 to L8 + GT's etc*
1. Yung Shue Long	42	42	29.2	30.2
2. Sha Po	42	42	34.1	35.0
3. Ko Long	42	42	33.0	33.7
4. Yung Shue Wan	42	42	31.7	33.0
5. Tai Wan San Tsuen	42	42	28.9	32.6
6. Wang Long	42	42	31.3	32.3
7. Tai Wan To	47	45	46.8	47.3
8. Hung Shing Ye	47	45	45.2	46.3
9. Ching Lam**	51	-	65.2	65.4

* Source noise levels for gas turbines, coal ship unloader and stacker reclaimer supplied by HEC
** Not NSR

TABLE 11.6 : NOISE LEVEL AT TAI WAN SAN TSUEN DUE TO 2 ID FANS FOR UNIT L7

	Area 1	Area 2	Area 3	Area 4	Total Area		Path Difference			Distance (metres)
Material							4.42 m			844
Length	1.4									
Height	3.0									
Area	4.2				4.2					
Octave Band	SRI	SRI	SRI	SRI	Facade	Barrier	Distance	Internal	External Noise	
Center					SRI	Attenuation	Attenuation	Noise	Level (dB) at	
Frequency								Level	Facade	844 m
(Hz)										
31.5					0.0	12.4	52.3	0.0	86.0	21.3
63					0.0	15.3	52.3	0.0	82.5	14.9
125					0.0	18.2	52.3	0.0	80.6	10.1
250					0.0	21.2	52.3	0.0	89.4	15.8
500					0.0	24.3	52.3	0.0	85.4	8.8
1000					0.0	27.3	52.3	0.0	80.4	0.8
2000					0.0	30.3	52.3	0.0	73.2	-9.4
4000					0.0	33.3	52.3	0.0	67.5	-18.1
8000					0.0	36.3	52.3	0.0	60.2	-28.4
Max noise level (linear)								0.0	93.1	23.5
Max noise level (dB(A))								0.0	86.4	10.4

TABLE 11.7 : NOISE LEVEL AT TAI WAN SAN TSUEN DUE TO 2 ID FANS FOR UNIT L8

	Area 1	Area 2	Area 3	Area 4	Total Area		Path Difference			Distance (metres)
Material							4.42 m			844
Length	1.4									
Height	3.0									
Area	4.2				4.2					
Octave Band	SRI	SRI	SRI	SRI	Facade	Barrier	Distance	Internal	External Noise	
Center					SRI	Attenuation	Attenuation	Noise	Level (dB) at	
Frequency								Level	Facade	844 m
(Hz)										
31.5					0.0	12.4	52.3	0.0	86.0	21.3
63					0.0	15.3	52.3	0.0	82.5	14.9
125					0.0	18.2	52.3	0.0	80.6	10.1
250					0.0	21.2	52.3	0.0	89.4	15.8
500					0.0	24.3	52.3	0.0	85.4	8.8
1000					0.0	27.3	52.3	0.0	80.4	0.8
2000					0.0	30.3	52.3	0.0	73.2	-9.4
4000					0.0	33.3	52.3	0.0	67.5	-18.1
8000					0.0	36.3	52.3	0.0	60.2	-28.4
Max noise level (linear)								0.0	93.1	23.5
Max noise level (dB(A))								0.0	86.4	10.4

TABLE 11.8 : NOISE LEVEL AT TAI WAN SAN TSUEN DUE TO UNIT L7

	Area 1	Area 2	Area 3	Area 4	Total Area		Path Difference			Distance (metres)
Material	Steel						0.59 m			910
Length	61.0									
Height	56.15									
Area	3425.15				3425.15					
Octave Band	SRI	SRI	SRI	SRI	Facade	Barrier	Distance	Internal	External Noise	
Center					SRI	Attenuation	Attenuation	Noise	Level (dB) at	
Frequency								Level	Facade	910 m
(Hz)										
31.5	13.0				13.0	6.8	24.4	81.4	62.4	31.3
63	11.0				11.0	8.1	24.4	82.1	65.1	32.6
125	8.0				8.0	10.1	24.4	74.4	60.4	25.9
250	14.0				14.0	12.6	24.4	85.4	65.4	28.4
500	29.0				29.0	15.5	24.4	80.0	45.0	5.1
1000	26.0				26.0	18.5	24.4	80.6	48.6	5.7
2000	32.0				32.0	21.5	24.4	74.2	36.2	-9.7
4000	36.0				36.0	24.5	24.4	68.9	26.9	-22.0
8000	39.0				39.0	27.5	24.4	68.4	23.4	-28.5
Max noise level (linear)								89.7	69.8	36.3
Max noise level (dB(A))								84.2	57.8	20.6

TABLE 11.9 : NOISE LEVEL AT TAI WAN SAN TSUEN DUE TO UNIT L8

	Area 1	Area 2	Area 3	Area 4	Total Area		Path Difference			Distance (metres)
Material	Steel						0.59 m			910
Length	61.0									
Height	56.15									
Area	3425.15				3425.15					
Octave Band	SRI	SRI	SRI	SRI	Facade	Barrier	Distance	Internal	External Noise	
Center					SRI	Attenuation	Attenuation	Noise	Level (dB) at	
Frequency								Level	Facade	910 m
(Hz)										
31.5	13.0				13.0	6.8	24.4	81.4	62.4	31.3
63	11.0				11.0	8.1	24.4	82.1	65.1	32.6
125	8.0				8.0	10.1	24.4	74.4	60.4	25.9
250	14.0				14.0	12.6	24.4	85.4	65.4	28.4
500	29.0				29.0	15.5	24.4	80.0	45.0	5.1
1000	26.0				26.0	18.5	24.4	80.6	48.6	5.7
2000	32.0				32.0	21.5	24.4	74.2	36.2	-9.7
4000	36.0				36.0	24.5	24.4	68.9	26.9	-22.0
8000	39.0				39.0	27.5	24.4	68.4	23.4	-28.5
Max noise level (linear)								89.7	69.8	36.3
Max noise level (dB(A))								84.2	57.8	20.6

11.51 It can be seen from Table 11.4 that the calculated noise levels from Units L7 and L8 are below the Target Noise Level at the NSR's to the north of the Power Station, i.e. the EPD criteria for the proposed units can be met. It can also be seen that the most critical NSR's are those to the east of the power station, with a direct line of sight, where the EPD criteria is predicted to be exceeded by 0.8dB at the worst affected site.

11.52 As the noise levels from Units L7 and L8 could marginally exceed the EPD criteria for the two NSR's to the east of the Power Station, mitigation measures may need to be adopted. The noise levels at these locations caused by Units L7 and L8 are primarily due to three main sources; sources within the units themselves, the ID Fans and the FGD units. Acoustically, it is relatively straightforward to reduce these noise levels. However, these three noise sources are of similar magnitude, and an examination of the optimum mitigation meaures would need to be undertaken before a decision on the most cost-effective measures could be made.

11.53 Other sources on site will include loaders, bulldozers, scrapers, a stacker/reclaimer and coal ship unloaders. However, by the baseline year of 1994 it is anticipated that the use of loaders, bulldozers and scrapers at night will not occur, as the stacker/reclaimer will be fully operational. Although it is not proposed to increase the number of these sources to service the proposed Units L7 and L8, the cumulative impact of these items has been assessed and it can also be seen from Table 11.5 that, even with these other sources and the gas turbines operating on an emergency basis, in addition to Units L1 to L8, the ANL is not exceeded at NSR's to the north of the Power Station. Based on criteria in the Technical Memorandum, this should not give rise to the issue of a Noise Abatement Notice.

11.54 Additional intermittent sources of noise include steam discharging during abnormal operations, or during testing of safety valves. Apart from safety valve testing, the occurrence of these noise sources does not occur at fixed times. They are, however, normally only of short duration. Safety valve testing is restricted to daytime only, when the normal ambient noise levels are at their highest and there would be minimum noise impact.

11.55 Unsilenced noise levels from steam discharging can be typically 90 dB(A) at 400m [11]. To mitigate the overall noise impacts of these steam vents, acoustic silencers are normally fitted, and such silencers are already fitted to some of the valves at Lamma Power Station. Based on guidance given in CEGB Standard 989907 [10], noise levels beyond the site boundary would be reduced by silencers to maximum levels of less than 60dB(A) at the most affected NSR. Silencers will be fitted to the main steam discharge valves associated with Units L7 and L8, as in the case of Unit L6, and it is considered that the principal noise emissions from this source should therefore be adequately mitigated.

Commissioning Noise

11.56 During the commissioning stage of the power station, the boilers and steam pipework have to be purged by passing high volumes of steam through the equipment at high pressure. This activity, however, only occurs for a very short time during the commissioning period and is a once and only operation for each unit. It is controlled by commissioning staff and only takes place during the daytime. If adequate notification is given to local residents of the proposed activity and its duration, it is generally found that residents are tolerant.

11.57 An advanced public notification campaign is initiated prior to steam purging operations, to inform local residents of the requirements and times for purging operations.

Summary and Conclusions

11.58 An assessment of the noise impact of the proposed additional Units L7 and L8 at Lamma Power Station has been carried out. The assessment has been undertaken in accordance with the relevant Technical Memorandum, and noise levels from the proposed units have been compared with criteria proposed by EPD.

11.59 Calculated noise levels at Ching Lam for the existing units are in good agreement with the measured noise levels at this site. The assumptions made and the calculation methodology are therefore considered to be valid.

11.60 The calculated Corrected Noise Levels due to the proposed Units L7 and L8 are below the Target Noise Level at all NSR's considered to the north of the Power Station.

11.61 Calculated noise levels from Units L7 and L8 at NSR's to the east of the power station site indicate a marginal exceedence (+0.8dB(A)) above the proposed EPD planning criteria of 45dB(A). Whilst such an increase is of limited environmental significance, it may be necessary to undertake some limited noise mitigation on the proposed new units to meet the criteria. This issue is best considered at the detailed plant specification stage, when appropriate noise specifications can be provided to plant suppliers.

11.62 The cumulative noise impact of Units L1 to L8 has also been estimated and was found to not exceed the ANL at any of the NSR's, even with auxilliary operations and the emergency Gas Turbines running.

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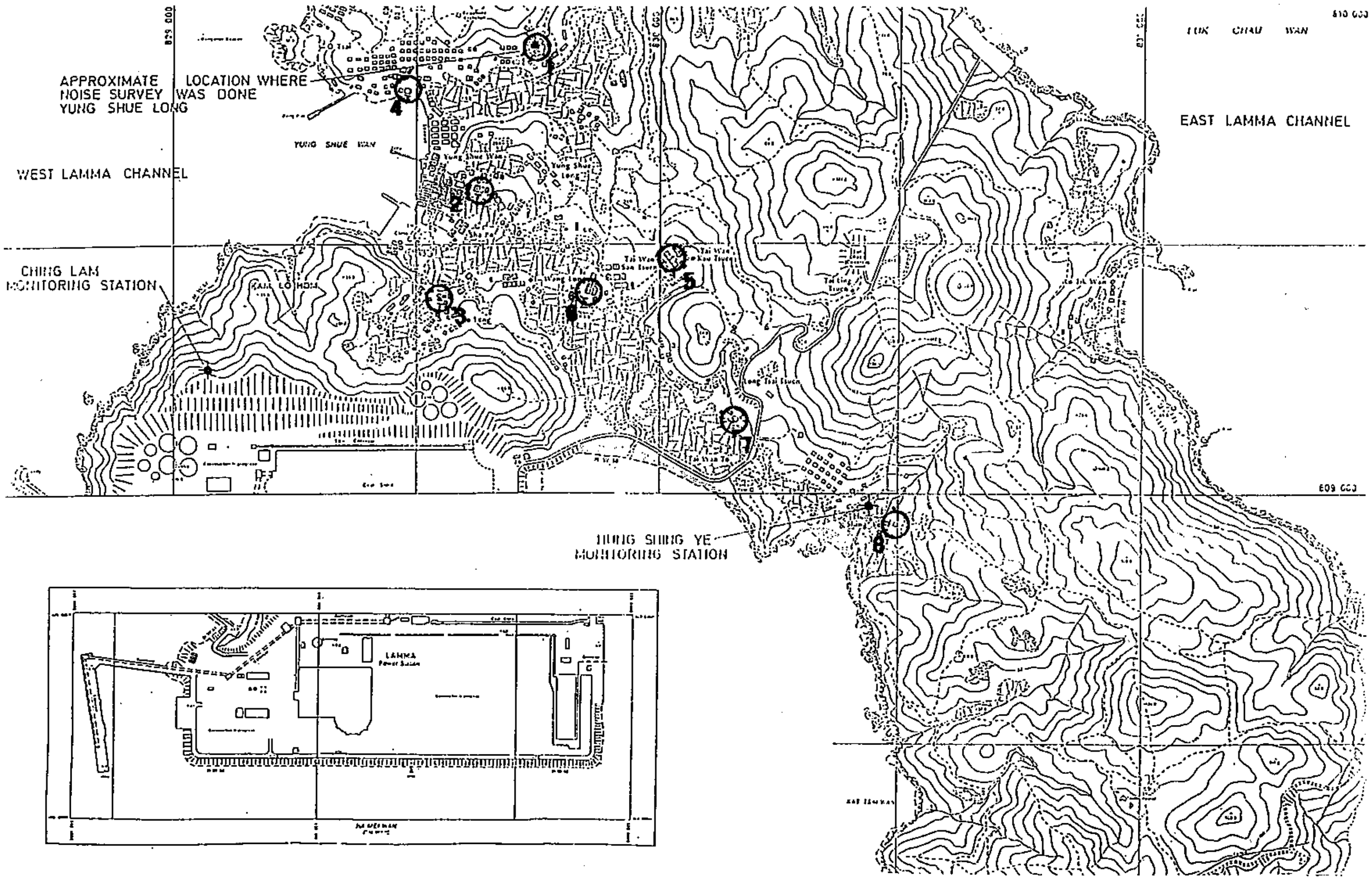


The Hongkong Electric Company Limited

PROJECT: EIA LAMMA POWER STATION

TITLE: LOCATION OF NOISE SENSITIVE RECEIVERS

FIGURE: 11.1

APPENDIX 11A

TABLE 11A.1 : Noise Level at YUNG SHUE LONG due to 2 ID Fans for Unit L7

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material					Area	Path diff	
Length	1.40	0.00	0.00	0.00		5.19 m	(metres)
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		1,068.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	1,068m
31.5					0.0	13.1	54.4	0.0	86.0	18.6
63					0.0	16.0	54.4	0.0	82.5	12.2
125					0.0	18.9	54.4	0.0	80.6	7.3
250					0.0	21.9	54.4	0.0	89.4	13.1
500					0.0	24.9	54.4	0.0	85.4	6.1
1000					0.0	28.0	54.4	0.0	80.4	-1.9
2000					0.0	31.0	54.4	0.0	73.2	-12.1
4000					0.0	34.0	54.4	0.0	67.5	-20.8
8000					0.0	37.0	54.4	0.0	60.2	-31.1
Max noise level (Linear)					0.0			0.0	93.1	20.8
Max noise level (dB(A))					0.0			0.0	86.4	7.7

TABLE 11A.2 : Noise Level at YUNG SHUE LONG due to 2 ID Fans for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance
Material							
Length	1.40	0.00	0.00	0.00		5.19 m	(metres)
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		1,068.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	1,068m
31.5					0.0	13.1	54.4	0.0	86.0	18.6
63					0.0	16.0	54.4	0.0	82.5	12.2
125					0.0	18.9	54.4	0.0	80.6	7.3
250					0.0	21.9	54.4	0.0	89.4	13.1
500					0.0	24.9	54.4	0.0	85.4	6.1
1000					0.0	28.0	54.4	0.0	80.4	-1.9
2000					0.0	31.0	54.4	0.0	73.2	-12.1
4000					0.0	34.0	54.4	0.0	67.5	-20.8
8000					0.0	37.0	54.4	0.0	60.2	-31.1
Max noise level (Linear)					0.0			0.0	93.1	20.8
Max noise level (dB(A))					0.0			0.0	86.4	7.7

TABLE 11A.3 : **Noise Level at YUNG SHUE LONG due to Unit L7**

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		2.27 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		1,164.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	1,164m
31.5	13.0	13.0	13.0	13.0	13.0	10.0	26.4	81.4	62.4	26.0
63	11.0	11.0	11.0	11.0	11.0	12.5	26.4	82.1	65.1	26.2
125	8.0	8.0	8.0	8.0	8.0	15.4	26.4	74.4	60.4	18.6
250	14.0	14.0	14.0	14.0	14.0	18.3	26.4	85.4	65.4	20.7
500	29.0	29.0	29.0	29.0	29.0	21.4	26.4	80.0	45.0	-2.8
1000	26.0	26.0	26.0	26.0	26.0	24.4	26.4	80.6	48.6	-2.2
2000	32.0	32.0	32.0	32.0	32.0	27.4	26.4	74.2	36.2	-17.6
4000	36.0	36.0	36.0	36.0	36.0	30.4	26.4	68.9	26.9	-29.9
8000	39.0	39.0	39.0	39.0	39.0	33.4	26.4	68.4	23.4	-36.4
Max noise level (Linear)					13.8			89.7	69.8	30.0
Max noise level (dB(A))					20.3			84.2	57.8	13.0

<u>TABLE 11A.4</u> : Noise Level at YUNG SHUE LONG due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		2.27 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		1,164.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	1,164m
31.5	13.0	13.0	13.0	13.0	13.0	10.0	26.4	81.4	62.4	26.0
63	11.0	11.0	11.0	11.0	11.0	12.5	26.4	82.1	65.1	26.2
125	8.0	8.0	8.0	8.0	8.0	15.4	26.4	74.4	60.4	18.6
250	14.0	14.0	14.0	14.0	14.0	18.3	26.4	85.4	65.4	20.7
500	29.0	29.0	29.0	29.0	29.0	21.4	26.4	80.0	45.0	-2.8
1000	26.0	26.0	26.0	26.0	26.0	24.4	26.4	80.6	48.6	-2.2
2000	32.0	32.0	32.0	32.0	32.0	27.4	26.4	74.2	36.2	-17.6
4000	36.0	36.0	36.0	36.0	36.0	30.4	26.4	68.9	26.9	-29.9
8000	39.0	39.0	39.0	39.0	39.0	33.4	26.4	68.4	23.4	-36.4
Max noise level (Linear)					13.8			89.7	69.8	30.0
Max noise level (dB(A))					20.3			84.2	57.8	13.0

TABLE 11A.5 : **Noise Level at SHA PO due to 2 ID Fans for Unit L7**

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance
Material							
Length	1.40	0.00	0.00	0.00		9.08 m	(metres)
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		762.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	762m
31.5					0.0	15.4	51.4	0.0	86.0	19.2
63					0.0	18.4	51.4	0.0	82.5	12.7
125					0.0	21.4	51.4	0.0	80.6	7.8
250					0.0	24.4	51.4	0.0	89.4	13.6
500					0.0	27.4	51.4	0.0	85.4	6.6
1000					0.0	30.4	51.4	0.0	80.4	-1.4
2000					0.0	33.4	51.4	0.0	73.2	-11.6
4000					0.0	36.4	51.4	0.0	67.5	-20.3
8000					0.0	39.4	51.4	0.0	60.2	-30.6
Max noise level (Linear)					0.0			0.0	93.1	21.4
Max noise level (dB(A))					0.0			0.0	86.4	8.2

TABLE 11A.6 : Noise Level at SHA PO due to 2 ID Fans for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material							
Length	1.40	0.00	0.00	0.00		9.08 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		762.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	762m
31.5					0.0	15.4	51.4	0.0	86.0	19.2
63					0.0	18.4	51.4	0.0	82.5	12.7
125					0.0	21.4	51.4	0.0	80.6	7.8
250					0.0	24.4	51.4	0.0	89.4	13.6
500					0.0	27.4	51.4	0.0	85.4	6.6
1000					0.0	30.4	51.4	0.0	80.4	-1.4
2000					0.0	33.4	51.4	0.0	73.2	-11.6
4000					0.0	36.4	51.4	0.0	67.5	-20.3
8000					0.0	39.4	51.4	0.0	60.2	-30.6
Max noise level (Linear)					0.0			0.0	93.1	21.4
Max noise level (dB(A))					0.0			0.0	86.4	8.2

TABLE 11A.7 : Noise Level at SHA PO due to Unit L7

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		1.15 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		858.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	858m
31.5	13.0	13.0	13.0	13.0	13.0	8.1	23.9	81.4	62.4	30.4
63	11.0	11.0	11.0	11.0	11.0	10.0	23.9	82.1	65.1	31.2
125	8.0	8.0	8.0	8.0	8.0	12.5	23.9	74.4	60.4	24.0
250	14.0	14.0	14.0	14.0	14.0	15.4	23.9	85.4	65.4	26.1
500	29.0	29.0	29.0	29.0	29.0	18.4	23.9	80.0	45.0	2.7
1000	26.0	26.0	26.0	26.0	26.0	21.4	23.9	80.6	48.6	3.3
2000	32.0	32.0	32.0	32.0	32.0	24.4	23.9	74.2	36.2	-12.1
4000	36.0	36.0	36.0	36.0	36.0	27.4	23.9	68.9	26.9	-24.4
8000	39.0	39.0	39.0	39.0	39.0	30.4	23.9	68.4	23.4	-30.9
Max noise level (Linear)					13.8			89.7	69.8	34.9
Max noise level (dB(A))					20.3			84.2	57.8	18.4

TABLE 11A.8 : Noise Level at SHA PO due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		1.15 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		858.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	858m
31.5	13.0	13.0	13.0	13.0	13.0	8.1	23.9	81.4	62.4	30.4
63	11.0	11.0	11.0	11.0	11.0	10.0	23.9	82.1	65.1	31.2
125	8.0	8.0	8.0	8.0	8.0	12.5	23.9	74.4	60.4	24.0
250	14.0	14.0	14.0	14.0	14.0	15.4	23.9	85.4	65.4	26.1
500	29.0	29.0	29.0	29.0	29.0	18.4	23.9	80.0	45.0	2.7
1000	26.0	26.0	26.0	26.0	26.0	21.4	23.9	80.6	48.6	3.3
2000	32.0	32.0	32.0	32.0	32.0	24.4	23.9	74.2	36.2	-12.1
4000	36.0	36.0	36.0	36.0	36.0	27.4	23.9	68.9	26.9	-24.4
8000	39.0	39.0	39.0	39.0	39.0	30.4	23.9	68.4	23.4	-30.9
Max noise level (Linear)					13.8			89.7	69.8	34.9
Max noise level (dB(A))					20.3			84.2	57.8	18.4

TABLE 11A.9 : Noise Level at KO LONG due to 2 ID Fans for Unit L7

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance
Material							
Length	1.40	0.00	0.00	0.00		11.72 m	(metres)
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		524.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	524m
31.5					0.0	16.5	48.2	0.0	86.0	21.3
63					0.0	19.5	48.2	0.0	82.5	14.8
125					0.0	22.5	48.2	0.0	80.6	9.9
250					0.0	25.5	48.2	0.0	89.4	15.7
500					0.0	28.5	48.2	0.0	85.4	8.7
1000					0.0	31.5	48.2	0.0	80.4	0.7
2000					0.0	34.5	48.2	0.0	73.2	-9.5
4000					0.0	37.5	48.2	0.0	67.5	-18.2
8000					0.0	40.5	48.2	0.0	60.2	-28.5
Max noise level (Linear)					0.0			0.0	93.1	23.5
Max noise level (dB(A))					0.0			0.0	86.4	10.3

TABLE 11A.10 : Noise Level at KO LONG due to 2 ID Fans for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance
Material							
Length	1.40	0.00	0.00	0.00		11.72 m	(meters)
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		524.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	524m
31.5					0.0	16.5	48.2	0.0	86.0	21.3
63					0.0	19.5	48.2	0.0	82.5	14.8
125					0.0	22.5	48.2	0.0	80.6	9.9
250					0.0	25.5	48.2	0.0	89.4	15.7
500					0.0	28.5	48.2	0.0	85.4	8.7
1000					0.0	31.5	48.2	0.0	80.4	0.7
2000					0.0	34.5	48.2	0.0	73.2	-9.5
4000					0.0	37.5	48.2	0.0	67.5	-18.2
8000					0.0	40.5	48.2	0.0	60.2	-28.5
Max noise level (Linear)					0.0			0.0	93.1	23.5
Max noise level (dB(A))					0.0			0.0	86.4	10.3

TABLE 11A.11 : Noise Level at KO LONG due to Unit L7

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		5.66 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		630.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	630m
31.5	13.0	13.0	13.0	13.0	13.0	13.4	21.4	81.4	62.4	27.6
63	11.0	11.0	11.0	11.0	11.0	16.3	21.4	82.1	65.1	27.3
125	8.0	8.0	8.0	8.0	8.0	19.3	21.4	74.4	60.4	19.7
250	14.0	14.0	14.0	14.0	14.0	22.3	21.4	85.4	65.4	21.7
500	29.0	29.0	29.0	29.0	29.0	25.3	21.4	80.0	45.0	-1.7
1000	26.0	26.0	26.0	26.0	26.0	28.3	21.4	80.6	48.6	-1.1
2000	32.0	32.0	32.0	32.0	32.0	31.3	21.4	74.2	36.2	-16.6
4000	36.0	36.0	36.0	36.0	36.0	34.4	21.4	68.9	26.9	-28.9
8000	39.0	39.0	39.0	39.0	39.0	37.4	21.4	68.4	23.4	-35.4
Max noise level (Linear)					13.8			89.7	69.8	31.3
Max noise level (dB(A))					20.3			84.2	57.8	14.0

TABLE 11A.12 : Noise Level at KO LONG due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		5.66 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		630.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	630m
31.5	13.0	13.0	13.0	13.0	13.0	13.4	21.4	81.4	62.4	27.6
63	11.0	11.0	11.0	11.0	11.0	16.3	21.4	82.1	65.1	27.3
125	8.0	8.0	8.0	8.0	8.0	19.3	21.4	74.4	60.4	19.7
250	14.0	14.0	14.0	14.0	14.0	22.3	21.4	85.4	65.4	21.7
500	29.0	29.0	29.0	29.0	29.0	25.3	21.4	80.0	45.0	-1.7
1000	26.0	26.0	26.0	26.0	26.0	28.3	21.4	80.6	48.6	-1.1
2000	32.0	32.0	32.0	32.0	32.0	31.3	21.4	74.2	36.2	-16.6
4000	36.0	36.0	36.0	36.0	36.0	34.4	21.4	68.9	26.9	-28.9
8000	39.0	39.0	39.0	39.0	39.0	37.4	21.4	68.4	23.4	-35.4
Max noise level (Linear)					13.8			89.7	69.8	31.3
Max noise level (dB(A))					20.3			84.2	57.8	14.0

TABLE 11A.13 : Noise Level at YUNG SHUE WAN due to 2 ID Fans for Unit L7

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material							
Length	1.40	0.00	0.00	0.00		8.20 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		938.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	938m
31.5					0.0	15.0	53.2	0.0	86.0	17.8
63					0.0	17.9	53.2	0.0	82.5	11.3
125					0.0	20.9	53.2	0.0	80.6	6.5
250					0.0	23.9	53.2	0.0	89.4	12.2
500					0.0	26.9	53.2	0.0	85.4	5.2
1000					0.0	29.9	53.2	0.0	80.4	-2.8
2000					0.0	33.0	53.2	0.0	73.2	-13.0
4000					0.0	36.0	53.2	0.0	67.5	-21.7
8000					0.0	39.0	53.2	0.0	60.2	-32.0
Max noise level (Linear)					0.0			0.0	93.1	20.0
Max noise level (dB(A))					0.0			0.0	86.4	6.9

TABLE 11A.14 : Noise Level at YUNG SHUE WAN due to 2 ID Fans for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material							
Length	1.40	0.00	0.00	0.00		8.20 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		938.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	938m
31.5					0.0	15.0	53.2	0.0	86.0	17.8
63					0.0	17.9	53.2	0.0	82.5	11.3
125					0.0	20.9	53.2	0.0	80.6	6.5
250					0.0	23.9	53.2	0.0	89.4	12.2
500					0.0	26.9	53.2	0.0	85.4	5.2
1000					0.0	29.9	53.2	0.0	80.4	-2.8
2000					0.0	33.0	53.2	0.0	73.2	-13.0
4000					0.0	36.0	53.2	0.0	67.5	-21.7
8000					0.0	39.0	53.2	0.0	60.2	-32.0
Max noise level (Linear)					0.0			0.0	93.1	20.0
Max noise level (dB(A))					0.0			0.0	86.4	6.9

TABLE 11A.15 : Noise Level at YUNG SHUE WAN due to Unit L7

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		0.97 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		1,038.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	1,038m
31.5	13.0	13.0	13.0	13.0	13.0	7.7	25.5	81.4	62.4	29.3
63	11.0	11.0	11.0	11.0	11.0	9.5	25.5	82.1	65.1	30.2
125	8.0	8.0	8.0	8.0	8.0	11.9	25.5	74.4	60.4	23.1
250	14.0	14.0	14.0	14.0	14.0	14.7	25.5	85.4	65.4	25.3
500	29.0	29.0	29.0	29.0	29.0	17.7	25.5	80.0	45.0	1.9
1000	26.0	26.0	26.0	26.0	26.0	20.7	25.5	80.6	48.6	2.5
2000	32.0	32.0	32.0	32.0	32.0	23.7	25.5	74.2	36.2	-12.9
4000	36.0	36.0	36.0	36.0	36.0	26.7	25.5	68.9	26.9	-25.2
8000	39.0	39.0	39.0	39.0	39.0	29.7	25.5	68.4	23.4	-31.8
Max noise level (Linear)					13.8			89.7	69.8	33.8
Max noise level (dB(A))					20.3			84.2	57.8	17.5

TABLE 11A.16 : Noise Level at YUNG SHUE WAN due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		0.97 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		1,038.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	1,038m
31.5	13.0	13.0	13.0	13.0	13.0	7.7	25.5	81.4	62.4	29.3
63	11.0	11.0	11.0	11.0	11.0	9.5	25.5	82.1	65.1	30.2
125	8.0	8.0	8.0	8.0	8.0	11.9	25.5	74.4	60.4	23.1
250	14.0	14.0	14.0	14.0	14.0	14.7	25.5	85.4	65.4	25.3
500	29.0	29.0	29.0	29.0	29.0	17.7	25.5	80.0	45.0	1.9
1000	26.0	26.0	26.0	26.0	26.0	20.7	25.5	80.6	48.6	2.5
2000	32.0	32.0	32.0	32.0	32.0	23.7	25.5	74.2	36.2	-12.9
4000	36.0	36.0	36.0	36.0	36.0	26.7	25.5	68.9	26.9	-25.2
8000	39.0	39.0	39.0	39.0	39.0	29.7	25.5	68.4	23.4	-31.8
Max noise level (Linear)					13.8			89.7	69.8	33.8
Max noise level (dB(A))					20.3			84.2	57.8	17.5

TABLE 11A.17 : Noise Level at TAI WAN SAN TSUEN due to 2 ID Fans for Unit L7

Material	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Length	1.40	0.00	0.00	0.00		4.42 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		844.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	844m
31.5					0.0	12.4	52.3	0.0	86.0	21.3
63					0.0	15.3	52.3	0.0	82.5	14.9
125					0.0	18.2	52.3	0.0	80.6	10.1
250					0.0	21.2	52.3	0.0	89.4	15.8
500					0.0	24.3	52.3	0.0	85.4	8.8
1000					0.0	27.3	52.3	0.0	80.4	0.8
2000					0.0	30.3	52.3	0.0	73.2	-9.4
4000					0.0	33.3	52.3	0.0	67.5	-18.1
8000					0.0	36.3	52.3	0.0	60.2	-28.4
Max noise level (Linear)					0.0			0.0	93.1	23.5
Max noise level (dB(A))					0.0			0.0	86.4	10.4

TABLE 11A.18 : Noise Level at TAI WAN SAN TSUEN due to 2 ID Fans for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material					Area	Path diff	
Length	1.40	0.00	0.00	0.00		4.42 m	(metres)
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		844.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	844m
31.5					0.0	12.4	52.3	0.0	86.0	21.3
63					0.0	15.3	52.3	0.0	82.5	14.9
125					0.0	18.2	52.3	0.0	80.6	10.1
250					0.0	21.2	52.3	0.0	89.4	15.8
500					0.0	24.3	52.3	0.0	85.4	8.8
1000					0.0	27.3	52.3	0.0	80.4	0.8
2000					0.0	30.3	52.3	0.0	73.2	-9.4
4000					0.0	33.3	52.3	0.0	67.5	-18.1
8000					0.0	36.3	52.3	0.0	60.2	-28.4
Max noise level (Linear)					0.0			0.0	93.1	23.5
Max noise level (dB(A))					0.0			0.0	86.4	10.4

TABLE 11A.19 : Noise Level at TAI WAN SAN TSUEN due to Unit L7

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		0.59 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		910.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	910m
31.5	13.0	13.0	13.0	13.0	13.0	6.8	24.4	81.4	62.4	31.3
63	11.0	11.0	11.0	11.0	11.0	8.1	24.4	82.1	65.1	32.6
125	8.0	8.0	8.0	8.0	8.0	10.1	24.4	74.4	60.4	25.9
250	14.0	14.0	14.0	14.0	14.0	12.6	24.4	85.4	65.4	28.4
500	29.0	29.0	29.0	29.0	29.0	15.5	24.4	80.0	45.0	5.1
1000	26.0	26.0	26.0	26.0	26.0	18.5	24.4	80.6	48.6	5.7
2000	32.0	32.0	32.0	32.0	32.0	21.5	24.4	74.2	36.2	-9.7
4000	36.0	36.0	36.0	36.0	36.0	24.5	24.4	68.9	26.9	-22.0
8000	39.0	39.0	39.0	39.0	39.0	27.5	24.4	68.4	23.4	-28.5
Max noise level (Linear)					13.8			89.7	69.8	36.3
Max noise level (dB(A))					20.3			84.2	57.8	20.6

TABLE 11A.20 : Noise Level at TAI WAN SAN TSUEN due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	61.00	0.00	0.00	0.00		0.59 m	(metres)
Height	56.15	0.00	0.00	0.00			
Area	3425.15	0.00	0.00	0.00	3425.15		910.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	910m
31.5	13.0	13.0	13.0	13.0	13.0	6.8	24.4	81.4	62.4	31.3
63	11.0	11.0	11.0	11.0	11.0	8.1	24.4	82.1	65.1	32.6
125	8.0	8.0	8.0	8.0	8.0	10.1	24.4	74.4	60.4	25.9
250	14.0	14.0	14.0	14.0	14.0	12.6	24.4	85.4	65.4	28.4
500	29.0	29.0	29.0	29.0	29.0	15.5	24.4	80.0	45.0	5.1
1000	26.0	26.0	26.0	26.0	26.0	18.5	24.4	80.6	48.6	5.7
2000	32.0	32.0	32.0	32.0	32.0	21.5	24.4	74.2	36.2	-9.7
4000	36.0	36.0	36.0	36.0	36.0	24.5	24.4	68.9	26.9	-22.0
8000	39.0	39.0	39.0	39.0	39.0	27.5	24.4	68.4	23.4	-28.5
Max noise level (Linear)					13.8			89.7	69.8	36.3
Max noise level (dB(A))					20.3			84.2	57.8	20.6

TABLE 11A.21 : **Noise Level at WANG LONG due to 2 ID Fans for Unit L7**

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material							
Length	1.40	0.00	0.00	0.00		17.88 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		678.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	678m
31.5					0.0	18.3	50.4	0.0	86.0	17.3
63					0.0	21.3	50.4	0.0	82.5	10.8
125					0.0	24.3	50.4	0.0	80.6	5.9
250					0.0	27.3	50.4	0.0	89.4	11.7
500					0.0	30.3	50.4	0.0	85.4	4.7
1000					0.0	33.3	50.4	0.0	80.4	-3.3
2000					0.0	36.3	50.4	0.0	73.2	-13.6
4000					0.0	39.4	50.4	0.0	67.5	-22.3
8000					0.0	42.4	50.4	0.0	60.2	-32.6
Max noise level (Linear)					0.0			0.0	93.1	19.5
Max noise level (dB(A))					0.0			0.0	86.4	6.3

TABLE 11A.22 : Noise Level at WANG LONG due to 2 ID Fans for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material							
Length	1.40	0.00	0.00	0.00		17.88 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		678.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	678m
31.5					0.0	18.3	50.4	0.0	86.0	17.3
63					0.0	21.3	50.4	0.0	82.5	10.8
125					0.0	24.3	50.4	0.0	80.6	5.9
250					0.0	27.3	50.4	0.0	89.4	11.7
500					0.0	30.3	50.4	0.0	85.4	4.7
1000					0.0	33.3	50.4	0.0	80.4	-3.3
2000					0.0	36.3	50.4	0.0	73.2	-13.6
4000					0.0	39.4	50.4	0.0	67.5	-22.3
8000					0.0	42.4	50.4	0.0	60.2	-32.6
Max noise level (Linear)					0.0			0.0	93.1	19.5
Max noise level (dB(A))					0.0			0.0	86.4	6.3

TABLE 11A.23 : Noise Level at WANG LONG due to Unit L7

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material	Steel	Steel	Steel	Steel			
Length	50.00	0.00	0.00	0.00		3.39 m	
Height	74.15	0.00	0.00	0.00			
Area	3707.50	0.00	0.00	0.00	3707.50		758.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	758m
31.5	13.0	13.0	13.0	13.0	13.0	11.4	22.6	81.4	62.4	28.4
63	11.0	11.0	11.0	11.0	11.0	14.2	22.6	82.1	65.1	28.4
125	8.0	8.0	8.0	8.0	8.0	17.1	22.6	74.4	60.4	20.7
250	14.0	14.0	14.0	14.0	14.0	20.1	22.6	85.4	65.4	22.7
500	29.0	29.0	29.0	29.0	29.0	23.1	22.6	80.0	45.0	-0.7
1000	26.0	26.0	26.0	26.0	26.0	26.1	22.6	80.6	48.6	-0.1
2000	32.0	32.0	32.0	32.0	32.0	29.1	22.6	74.2	36.2	-15.5
4000	36.0	36.0	36.0	36.0	36.0	32.1	22.6	68.9	26.9	-27.8
8000	39.0	39.0	39.0	39.0	39.0	35.1	22.6	68.4	23.4	-34.3
Max noise level (Linear)					13.8			89.7	69.8	32.3
Max noise level (dB(A))					20.3			84.2	57.8	15.1

TABLE 11A.24 : Noise Level at WANG LONG due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	50.00	0.00	0.00	0.00		3.39 m	(metres)
Height	74.15	0.00	0.00	0.00			
Area	3707.50	0.00	0.00	0.00	3707.50		758.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	758m
31.5	13.0	13.0	13.0	13.0	13.0	11.4	22.6	81.4	62.4	28.4
63	11.0	11.0	11.0	11.0	11.0	14.2	22.6	82.1	65.1	28.4
125	8.0	8.0	8.0	8.0	8.0	17.1	22.6	74.4	60.4	20.7
250	14.0	14.0	14.0	14.0	14.0	20.1	22.6	85.4	65.4	22.7
500	29.0	29.0	29.0	29.0	29.0	23.1	22.6	80.0	45.0	-0.7
1000	26.0	26.0	26.0	26.0	26.0	26.1	22.6	80.6	48.6	-0.1
2000	32.0	32.0	32.0	32.0	32.0	29.1	22.6	74.2	36.2	-15.5
4000	36.0	36.0	36.0	36.0	36.0	32.1	22.6	68.9	26.9	-27.8
8000	39.0	39.0	39.0	39.0	39.0	35.1	22.6	68.4	23.4	-34.3
Max noise level (Linear)					13.8			89.7	69.8	32.3
Max noise level (dB(A))					20.3			84.2	57.8	15.1

TABLE 11A.25 : **Noise Level at TAI WAN TO due to ID Fan for Unit L8**

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material						0.00 m	
Length	3.00	0.00	0.00	0.00			
Height	3.00	0.00	0.00	0.00			
Area	9.00	0.00	0.00	0.00	9.00		718.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	718m
31.5					0.0	0.0	47.6	0.0	83.0	35.4
63					0.0	0.0	47.6	0.0	79.5	31.9
125					0.0	0.0	47.6	0.0	77.6	30.0
250					0.0	0.0	47.6	0.0	86.4	38.8
500					0.0	0.0	47.6	0.0	82.4	34.8
1000					0.0	0.0	47.6	0.0	77.4	29.8
2000					0.0	0.0	47.6	0.0	70.2	22.6
4000					0.0	0.0	47.6	0.0	64.5	16.9
8000					0.0	0.0	47.6	0.0	57.2	9.6
Max noise level (Linear)					0.0			0.0	90.1	42.5
Max noise level (dB(A))					0.0			0.0	83.4	35.8

<u>TABLE 11A.26</u> : Noise Level at TAI WAN TO due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	16.00	34.00	16.00	0.00		0.00 m	(metres)
Height	17.65	31.10	56.15	0.00			
Area	282.40	1057.40	898.40	0.00	2238.20		772.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	External Noise Level (dB) at 772m
31.5	13.0	13.0	13.0	13.0	13.0	0.0	24.8	81.4	62.4	37.6
63	11.0	11.0	11.0	11.0	11.0	0.0	24.8	82.1	65.1	40.3
125	8.0	8.0	8.0	8.0	8.0	0.0	24.8	74.4	60.4	35.6
250	14.0	14.0	14.0	14.0	14.0	0.0	24.8	85.4	65.4	40.6
500	29.0	29.0	29.0	29.0	29.0	0.0	24.8	80.0	45.0	20.2
1000	26.0	26.0	26.0	26.0	26.0	0.0	24.8	80.6	48.6	23.8
2000	32.0	32.0	32.0	32.0	32.0	0.0	24.8	74.2	36.2	11.4
4000	36.0	36.0	36.0	36.0	36.0	0.0	24.8	68.9	26.9	2.1
8000	39.0	39.0	39.0	39.0	39.0	0.0	24.8	68.4	23.4	-1.4
Max noise level (Linear)					13.8			89.7	69.8	45.1
Max noise level (dB(A))					20.3			84.2	57.8	33.1

TABLE 11A.27 : Noise Level at HUNG SHING YE due to ID Fan for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material							
Length	3.00	0.00	0.00	0.00		0.00 m	
Height	3.00	0.00	0.00	0.00			
Area	9.00	0.00	0.00	0.00	9.00		971.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	971m
31.5					0.0	0.0	50.2	0.0	83.0	32.8
63					0.0	0.0	50.2	0.0	79.5	29.3
125					0.0	0.0	50.2	0.0	77.6	27.4
250					0.0	0.0	50.2	0.0	86.4	36.2
500					0.0	0.0	50.2	0.0	82.4	32.2
1000					0.0	0.0	50.2	0.0	77.4	27.2
2000					0.0	0.0	50.2	0.0	70.2	20.0
4000					0.0	0.0	50.2	0.0	64.5	14.3
8000					0.0	0.0	50.2	0.0	57.2	7.0
Max noise level (Linear)					0.0			0.0	90.1	39.9
Max noise level (dB(A))					0.0			0.0	83.4	33.2

TABLE 11A.28 : Noise Level at HUNG SHING YE due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	16.00	34.00	16.00	0.00		0.00 m	(metres)
Height	17.65	31.10	56.15	0.00			
Area	282.40	1057.40	898.40	0.00	2238.20		971.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	971m
31.5	13.0	13.0	13.0	13.0	13.0	0.0	26.7	81.4	62.4	35.7
63	11.0	11.0	11.0	11.0	11.0	0.0	26.7	82.1	65.1	38.4
125	8.0	8.0	8.0	8.0	8.0	0.0	26.7	74.4	60.4	33.7
250	14.0	14.0	14.0	14.0	14.0	0.0	26.7	85.4	65.4	38.7
500	29.0	29.0	29.0	29.0	29.0	0.0	26.7	80.0	45.0	18.3
1000	26.0	26.0	26.0	26.0	26.0	0.0	26.7	80.6	48.6	21.9
2000	32.0	32.0	32.0	32.0	32.0	0.0	26.7	74.2	36.2	9.5
4000	36.0	36.0	36.0	36.0	36.0	0.0	26.7	68.9	26.9	0.2
8000	39.0	39.0	39.0	39.0	39.0	0.0	26.7	68.4	23.4	-3.3
Max noise level (Linear)					13.8			89.7	69.8	43.2
Max noise level (dB(A))					20.3			84.2	57.8	31.2

TABLE 11A.29 : Noise Level at CHING LAM due to 2 ID Fans for Unit L7

Material	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Length	1.40	0.00	0.00	0.00		0.00 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		490.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	External Noise Level (dB) at 490m
31.5					0.0	0.0	47.6	0.0	86.0	38.4
63					0.0	0.0	47.6	0.0	82.5	34.9
125					0.0	0.0	47.6	0.0	80.6	33.0
250					0.0	0.0	47.6	0.0	89.4	41.8
500					0.0	0.0	47.6	0.0	85.4	37.8
1000					0.0	0.0	47.6	0.0	80.4	32.8
2000					0.0	0.0	47.6	0.0	73.2	25.6
4000					0.0	0.0	47.6	0.0	67.5	19.9
8000					0.0	0.0	47.6	0.0	60.2	12.6
Max noise level (Linear)					0.0			0.0	93.1	45.5
Max noise level (dB(A))					0.0			0.0	86.4	38.8

TABLE 11A.30 : Noise Level at CHING LAM due to 2 ID Fans for Unit L8

	Area 1	Area 2	Area 3	Area 4	Total Area	Path diff	Distance (metres)
Material							
Length	1.40	0.00	0.00	0.00		0.00 m	
Height	3.00	0.00	0.00	0.00			
Area	4.20	0.00	0.00	0.00	4.20		540.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	External Noise Level (dB) at 540m
31.5					0.0	0.0	48.4	0.0	86.0	37.6
63					0.0	0.0	48.4	0.0	82.5	34.1
125					0.0	0.0	48.4	0.0	80.6	32.2
250					0.0	0.0	48.4	0.0	89.4	41.0
500					0.0	0.0	48.4	0.0	85.4	37.0
1000					0.0	0.0	48.4	0.0	80.4	32.0
2000					0.0	0.0	48.4	0.0	73.2	24.8
4000					0.0	0.0	48.4	0.0	67.5	19.1
8000					0.0	0.0	48.4	0.0	60.2	11.8
Max noise level (Linear)					0.0			0.0	93.1	44.7
Max noise level (dB(A))					0.0			0.0	86.4	37.9

TABLE 11A.31 : Noise Level at CHING LAM due to Unit L7

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	50.00	0.00	0.00	0.00		0.00 m	(metres)
Height	74.15	0.00	0.00	0.00			
Area	3707.50	0.00	0.00	0.00	3707.50		570.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	570m
31.5	13.0	13.0	13.0	13.0	13.0	0.0	20.3	81.4	62.4	42.1
63	11.0	11.0	11.0	11.0	11.0	0.0	20.3	82.1	65.1	44.8
125	8.0	8.0	8.0	8.0	8.0	0.0	20.3	74.4	60.4	40.1
250	14.0	14.0	14.0	14.0	14.0	0.0	20.3	85.4	65.4	45.1
500	29.0	29.0	29.0	29.0	29.0	0.0	20.3	80.0	45.0	24.7
1000	26.0	26.0	26.0	26.0	26.0	0.0	20.3	80.6	48.6	28.3
2000	32.0	32.0	32.0	32.0	32.0	0.0	20.3	74.2	36.2	15.9
4000	36.0	36.0	36.0	36.0	36.0	0.0	20.3	68.9	26.9	6.6
8000	39.0	39.0	39.0	39.0	39.0	0.0	20.3	68.4	23.4	3.1
Max noise level (Linear)					13.8			89.7	69.8	49.5
Max noise level (dB(A))					20.3			84.2	57.8	37.5

TABLE 11A.32 : Noise Level at CHING LAM due to Unit L8

	Area 1	Area 2	Area 3	Area 4	Total		Distance
Material	Steel	Steel	Steel	Steel	Area	Path diff	
Length	50.00	0.00	0.00	0.00		0.00 m	(metres)
Height	74.15	0.00	0.00	0.00			
Area	3707.50	0.00	0.00	0.00	3707.50		620.00

Octave band Centre Frequency (Hz)	SRI	SRI	SRI	SRI	Facade SRI	Barrier Atten	Distance Atten	Internal Noise Level	External Noise Level (dB) at Facade	1,164m
31.5	13.0	13.0	13.0	13.0	13.0	0.0	21.0	81.4	62.4	41.4
63	11.0	11.0	11.0	11.0	11.0	0.0	21.0	82.1	65.1	44.1
125	8.0	8.0	8.0	8.0	8.0	0.0	21.0	74.4	60.4	39.4
250	14.0	14.0	14.0	14.0	14.0	0.0	21.0	85.4	65.4	44.4
500	29.0	29.0	29.0	29.0	29.0	0.0	21.0	80.0	45.0	24.0
1000	26.0	26.0	26.0	26.0	26.0	0.0	21.0	80.6	48.6	27.6
2000	32.0	32.0	32.0	32.0	32.0	0.0	21.0	74.2	36.2	15.2
4000	36.0	36.0	36.0	36.0	36.0	0.0	21.0	68.9	26.9	5.9
8000	39.0	39.0	39.0	39.0	39.0	0.0	21.0	68.4	23.4	2.4
Max noise level (Linear)					13.8			89.7	69.8	48.9
Max noise level (dB(A))					20.3			84.2	57.8	36.9

SOCIO ECONOMIC IMPACTS

12.0 SOCIO-ECONOMIC IMPACTS

Objective and Approach

12.01 The objective of this part of the overall environmental assessment is to identify impacts or sensitive issues relating to the power station extension as it impinges on the socio-economic conditions in Lamma itself or, in certain instances, in Hong Kong.

12.02 The extension of the power station is essentially a brownfield project, i.e. prime impact has already taken place with the initial construction of the station. This changes the emphasis of the socio-economic issues to be considered. Employment and economic benefit are still key issues, but to these must be added the question of community perception. Projects of this nature, where intensification of an industrial activity is involved in an otherwise rural community, frequently see the issue of perception being given greater attention. The issues that this assessment addresses are, therefore:

- employment and other micro-economic benefits
- perception

12.03 Central to both issues is an understanding of baseline conditions on Lamma but the assessment of the employment impact considers also the wider labour market conditions in Hong Kong.

Existing Conditions on Lamma

Setting

12.04 Lamma, also known as Pok Liu Chau, is a picturesque island with an area of 13.5 sq km which is roughly one-sixth of the size of Hong Kong Island. The major indentation of Picnic Bay virtually configures the island into two physically discrete units, North and South Lamma. South Lamma has a particularly hilly terrain with three peaks reaching 353, 250 and 147 metres. These are known respectively as Mount Stenhouse, Ling Kok Shan and Ngai Tau. The more difficult terrain in South Lamma has curtailed development there in favour of North Lamma, which has more agriculture quality land and is less remote.

12.05 The coastline of both parts of Lamma is highly indented and affords shelter for a number of small jetties for local boat transport and for communications to Hong Kong (Central, Aberdeen and Kennedy Town). The west coast bays also include three bathing beaches, two of which are gazetted and form part of the listed recreational amenities in Hong Kong.

Population and Settlement

12.06 Unofficial estimates put the 1990 population of Lamma at between 6000-10000 persons. This is in marked contrast to the declining population trend shown by official statistics up to the latest, 1986, By-Census with a population in that year of just under 3000 persons. The virtually static internal economy of the island has disguised the demographic growth which has come since 1986 from North Lamma's development as a dormitory for Hong Kong. Trend extrapolation has led to official figures maintaining the lower levels: figures recently made available from the Working Group on population [1] indicated that at the end of March 1989 there were 2960 people living on Lamma and it was anticipated that when further, full population projections had been made, these might show an even more accelerated decline.

12.07 The current population of Lamma is assumed for the purposes of this study to be of the broad order of 8000 persons. This is supported by rule of thumb estimates of the number of users of power and water. According to HEC, there are 2250 electricity meters on Lamma. If up to one third of these are for commercial/retail outlets and if the remaining two-thirds are for households with an average of 4 persons, then the population is some 6000. If, on the other hand, all metered supplies are to some extent household (eg the family lives above the shop and the one meter supplies both activities), the population is 9000. Estimates based on water supply fall within this broad range also.

12.08 The Lamma Area Committee put the population of the island at 10000 persons but no supporting information was available to justify such a high figure and it has been discounted. However, the Area Committee also said that, with the exception of Lo Tek Wan village, the village population in Lamma has increased by 50% over the last decade: relating this to the 1981 census figure of 3907, a current population of 6000 is implied.

12.09 On the basis of discussion with local building contractors, the rate of new domestic building would appear to be some 30-40 houses annually, all sold to newcomers to the island. At this rate, 135-180 houses would have been completed since the By-Census. Taking a low average of 3 dwelling units per house (some have 6) and again assuming 4 persons per household, this implies an additional population of 1600-2100 in-migrants. On this basis the current combined population, allowing for natural increase, would be upwards of 5500.

12.10 Consideration was also given to the numbers commuting daily by ferry from Yung Shue Wan. There are of the order of 1000 ferry passengers on the rush hour boats: roughly 300 on the 0625 hours, 500 on the 0745 hours and 200 on the 0930 hours. Allowing for a high proportion of schoolchildren on the first boat, a small proportion of non-commuters on the second and third boats and a small number of adult workers using alternative, kaito transport to Aberdeen, it seems reasonable to assume a minimum of 600 and a maximum of 900 commuting wage earners. If the lower figure in the range is used and if the number of households represented is two-thirds of this (that is to say allowance of one-third is made for households with two commuting wage earners) and the figure of 4 persons per household applies, this represents a total population of

1600 persons. This again tallies broadly with the conservative estimates made above indicating a total Lamma population of the broad order of 6000 persons. Any adjustment to the assumptions of course alters the implied population total accordingly.

12.11 An understanding of the background to population change is gained by looking at the official population statistics. These are shown in Table 12.1. The 1981 Census population was 3907, a 62% increase from the 1976 By-Census. It was in response to this increase that the planners were prompted to cater for a target population of 9200 in the Outline Development Plan produced in 1983 (see Section 12.27). The growth in Lamma was proportionally greater than that experienced in the other Outlying Islands and in the New Territories and it probably reflects in part the additional economic boost to the island from the construction of the power station which was ongoing in 1981.

TABLE 12.1 : OFFICIAL POPULATION TRENDS

	1976(a)	1981(b)		1986(a)	
	no.	no.	% change	no.	% change
Lamma	2,410	3,907	+ 62	2,968	- 24
All Outlying Islands	39,580	45,574	+ 15	46,907	+ 3
New Territories	950,060	1,304,119	+ 37	1,881,166	+ 44

a By-Census Counts
b Census

12.12 Between 1981 and the By-Census in 1986, the upward trend in Lamma's population growth reversed and over the period it actually fell by a quarter to stand at 2968 persons. Over the same period the other Outlying Islands were also experiencing reduced growth and intensification of the general trend to urban drift and consequent rural depopulation. It was the creation of the new towns within the New Territories which was responsible for accelerating the general decline in all the outlying populations: the population of the New Territories rose by 44 % over the same 1981-86 period when that of Lamma fell by 24%.

12.13 The majority of the population of Lamma is in North Lamma which in 1986 had 2373 persons or 80% of the total population. Population densities reflected this distribution and, in terms of persons per square kilometre, the ratio was 539 in North Lamma but only 68 in South Lamma. The dominance of North Lamma has increased notably since 1986. South Lamma, disadvantaged by poor transport, has not benefitted from commuting in-migrants. There has been some new investment in mariculture but much of it (particularly that at Lo Tek Wan) has come from non-residents. Many of those resident in South Lamma in 1986 have moved to Hong Kong for employment, keeping their houses on the island as a weekend and holiday base. According to the Lamma (South) Rural Committee the population of the south is less than 1000 persons.

12.14 The main settlement is in North Lamma at Yung Shue Wan, focussing on the bay of the same name and lying immediately to the north of the power station site (Figure 12.1). There is a scatter of tiny villages here, such as Poh Woh Yuen and Tai Yuen, which have coalesced to form Yung Shue Wan. The general axis of settlement runs from Shek Li in the northwest and Pak Kok San Tsuen south to Hung Shing Ye. Secondary settlements are at Sok Kwu Wan, the main focus of South Lamma, and other minor points associated with the mariculture in the east coast bays.

The Island Economy

12.15 Employment on Lamma, in terms of the resident workforce, has seen significant change over the last decade. Table 12.2 shows sectoral employment between 1976 and 1986, ranked by importance in the most recent year. The service sector has become the main employer, giving 20% of the employment in 1986, whereas employment in construction and in agriculture and fishing, which led in 1976, have now dropped to fifth and third place respectively. The changes in North Lamma, which have been the more pronounced, have been towards services, manufacturing and trade/restaurants. In South Lamma, agriculture and fishing remain dominant but there has been a notable increase in trade/restaurants.

TABLE 12.2 : SECTORAL EMPLOYMENT[a] TRENDS IN LAMMA

Sector	1976[b]		1981[c]		1986[b]	
	no.	%	no.	%	no.	%
Services	30	4.1	180	10.8	315	20.1
Wholesale, Retail Trade & Restaurants, Hotels	110	15.1	187	11.1	294	18.8
Agriculture & Fishing	170	23.3	301	17.9	238	15.2
Manufacturing	110	15.1	389	23.2	238	15.2
Construction	190	26.0	320	19.0	161	10.3
Finance, Real Estate etc	10	1.4	69	4.1	140	8.9
Utilities (electricity gas and water)	-	-	100	5.9	105	6.7
Transport, Storage etc	100	13.6	58	3.4	77	4.8
Mining & Quarrying	-	-	32	1.9	-	-
Unclassifiable	10	1.4	46	2.7	-	-
Total	730	100.0	1682	100.0	1568	100.0

a. Refers to occupation of the resident workforce, i.e. the occupation engaged in may or may not be on Lamma and employment taken up on Lamma by non-Lamma residents is excluded.

b. By-Census

c. Census

12.16 As the notes to the table indicate, the employment trends demonstrated relate to the resident labour force of Lamma and not to work opportunities on the island itself : that is to say, they do not indicate travel-to-work patterns. Although information on travel-to-work is not available from census or by-census sources, commuting has clearly become a feature of Lamma's employment and it is this which is reflected in the growth and diversification of employment seen in the table. It is possible that at least two-thirds of the Lamma labourforce commute daily to Hong Kong Island to work.

12.17 The economic activity rate for Lamma appears slightly higher than for Hong Kong: 52.8% compared with 50.8% in 1986. This may be a reflection of the older population structure of the island, putting fewer people in the 'first-time job seeker' category.

12.18 In 1988, employment on Lamma was recorded as comprising 307 jobs, in 86 establishments: an average of 3.5 workers per company. The sectoral breakdown is given in Table 12.3 for reference. Notably these figures exclude any reference to employment in the power station, or in construction, the ferries or 'other' jobs.

12.19 The tannery referred to in the table is at Yung Shue Wan and the cement, lime and plaster manufacture (which includes a mosaic factory) is associated with the quarry on the north bank of Picnic Bay, opposite Sok Kwu Wan village. Mariculture is a significant occupation in South Lamma, both in Picnic Bay and the bay behind George Island. There are roughly 100 fish farms in each location. Food manufacture refers to the production of prawn paste, also at Yung Shue Wan. The number of restaurants is notable and whilst these are important at both Yung Shue Wan and Sok Kwu Wan, they dominate the latter.

TABLE 12.3 : EMPLOYMENT ON LAMMA : 1988

Sector	Number of: Establishments	Employees no.	%
Manufacturing:			
Tanneries & leather finishing	1	15	
Cement, lime & plaster	1	13	
Structural metal products	3	5	
Food products	2	5	
Plastic toys	2	5	
	9	43	14.0
Trade:			
Wholesale	5	8	
Retail	29	58	
Import/export	3	3	
	37	69	22.5
Catering etc:			
Restaurants	18	114	
Hotels & boarding houses	3	6	
	21	120	39.1
Transport & Storage:			
Ocean & coastal water transport	1	1	
Container service	1	13	
	2	14	4.5
Banks & Business Services:			
Banks	1	7	
Business services	3	4	
	4	11	3.6
Community, Social	13	50	16.3
TOTAL	86	307	100.0

Some adjustments are needed to the above to represent current employment on Lamma. Formal, taken up employment is currently understood from fieldwork to be in excess of 1000 jobs. These are in the following sectors:

	Estimated No. Of Jobs	
- Power Station	574	(excluding workman)
- Quarry Products	60	
- Other Manufacturing, Including Foodstuffs	25	
- Commerce	70	
- Catering	120	
- Construction	80	
- Other	100	
	1029	

12.21 The power station is the dominant employer on the island, generating over half of the island's jobs. Nonetheless, only 44 jobs are actually filled by island residents. At most, 4 of these 44 workers are from South Lamma. At the quarry in South Lamma,less than 10 of the 60 or so workers are from Sok Kwu Wan, the rest commuting in daily.

12.22 In addition to the formally employed there are a number of self employed workers. In Hong Kong as a whole, in 1986, 8% of the labour force were either self employed or unpaid family workers. The proportion is nearer 15% in Lamma where there are more primary sector opportunities and it is estimated that there are some 100 self employed workers in agriculture and a further 150 in fishing/fish culture.

12.23 The estimated current employment pattern in Lamma is summarised in Table 12.4.

TABLE 12.4 : CURRENT STRUCTURE OF EMPLOYMENT ON LAMMA

Status	Sector	Est. No. Workers Lamma Resident	From Outside	Total
Employed	Industry	80	579	659
	Construction	80	(a)	80
	Commerce	70		70
	Service	120		120
	Other	200	50	250
		550	629	1179
Self Employed	Agriculture	100		100
	Fisheries	150	(b)	150
		250		250
All Lamma Based Employment		800		1429
Commuters to Hong		600- 900		600-900
TOTAL		1400-1700		na

(a) Excludes the contractor's construction workers currently on site at the power station

(b) Excludes non-resident mariculture workers at Lo Tek Wan: estimated number unavailable.

na not applicable

12.24 There is, then, an emerging dichotomy in the employment situation in Lamma. On a daily basis, roughly 600 workers commute to Hong Kong and roughly 600 workers commute from Hong Kong to Lamma. Those commuting to Hong Kong are mostly office workers, although it was noted that 20-30 construction workers are included in the number. Those commuting to Lamma are mostly power station workers. There is also an increasing number travelling in, generally daily, to work on the fish rafts. Mariculture is a local industry at Sok Kwu Wan but an outsider owned industry at Lo Tek Wan and its external ownership is reflected in its lack of positive impact on the jobs market.

Land Use & Planning

12.25 The greater part of Lamma is, as Figure 12.2 shows, grass and scrub land or woodland. Agricultural land is divided almost equally into actively used and unused. The actively cultivated land is limited to pockets in the northern half of North Lamma, around Pak Kok village and surrounding the village agglomeration of Yung Shue Wan. There are also three small patches on South Lamma, associated with coastal fringe settlement. Most of the unused agricultural land is on South Lamma.

12.26 Vegetable farming is the main form of cultivation, taking up 24 out of the 52 hectares of cultivated land recorded in the Farm Survey of 1987. Some 25 hectares was under orchards. In 1986 (the most recent record) there were over 200 vegetable farms, 9 pig farms, 8 poultry farms and 3 mixed farms. Livestock comprised 619 head of swine, 2265 poultry and 1142 pigeons. Individual livestock estimates are likely to be variable over time and can only be regarded as firm at the time of survey.

12.27 There has been a marked decline in both land designated for agriculture and land which is actively cultivated. The former has been reduced by those native to Lamma applying under law for permission to convert 700 square foot entitlements of agricultural land for building purposes. Since 1988 building has had to be commenced within 6 months of the granting of the change of use. This timescale together with the growing opportunities to create income from house building and renting, coincident with the development of the Yung Shue Wan area as a dormitory for Hong Kong, have consolidated a drift away from agriculture in the younger generation. At the same time agricultural productivity is held to have dropped (see Section 12.61) and island produce is more expensive than competing imports from China.

12.28 Industrial land use is significant on North Lamma with the power station enclave in the west and the quarry in the southeast. In planning terms, Lamma has a conservation oriented schedule of uses, as adopted in 1983 in the Outline Development Plan for the island: countryside conservation areas are allocated 1091 hectares and development areas 297 hectares. The detailed breakdown is given in Table 12.4 and Figure 12.3. In Figure 12.4, the land use plan for Lamma adopted in 1986 by the Development Progress Committee is shown. This maintains the status of the conservancy aspects of the islands land use.

TABLE 12.5 : SCHEDULED USES FOR LAMMA

Designated Use	Area (ha)	%
Total planning scheme	1388.00	100
of which:		
Countryside Conservation Area	1090.88	78.6
Development Area:		
> village development	56.60	
> open space	12.65	
> Government institution & community	7.25	
> residential, zone	7.70	
> industrial	3.96	
> commercial/residential	0.15	
> roads, parking etc	1.60	
> other specified uses	207.21	
	297.12	21.4

Source: Outline Development Plan for Lamma; adopted 1983

12.29 Some 40% of the designated conservation area is taken up by the Site of Special Scientific Interest notified on South Lamma for bird habitats.

12.30 The Outline Development Plan allows for a threefold growth in population, to 9200 persons. This was targetted in 1983. More recently, in 1989 and still awaiting approval, a Layout Plan was developed for Yung Shue Wan (Figure 12.3) which caters for a population in that specific area of 9680 on full development. Substantial infrastructural growth must therefore be considered possible for Lamma. There are no plans for introducing new forms of economic activity and growth can therefore only come from increasing the dormitory role of Lamma. The Yung Shue Wan Layout Plan shows areas of 40.40 hectares of development and 25.53 hectares of countryside conservation. Within the development area, some 20.19 hectares are set aside for village development area; only 0.84 hectares are set aside for industry of all classes.

Amenity & Heritage

12.31 The island of Lamma is picturesque by virtue of both its hilly, sometimes wooded terrain affording good views inland and offshore and also its pleasant village developments. It is popular for walking (there is a youth hostel in the centre of the island) and for water sports. It is also popular for eating and supports an extremely good range of restaurants at both Yung Shue Wan and Sok Kwu Wan. Since the journey time by ferry to either Yung Shue Wan or Sok Kwu Wan is roughly 45 minutes and ferries operate variously from Central and Aberdeen, the island is readily accessible for recreation and is popular with tourists from Hong Kong and overseas alike.

12.32 There is no motorised traffic on Lamma - other than power station vehicles operating mainly on site, but sometimes on the concrete roadways to Pak Kok and Tai Ling Tsuen - and a few diesel operated carts used by local villagers for transport of goods. There is an adequate network of footpaths crisscrossing the island. Several beaches are used for swimming. Two are gazetted : one at Lo So Shing at the isthmus between North and South Lamma and one at Hung Shing Ye, just to the east of the power station. In 1988, over a quarter of a million people used these two beaches. The more readily accessible Hung Shing Ye is, as Table 12.6 shows, the more popular.

TABLE 12.6 : USAGE OF GAZETTED BEACHES ON LAMMA

Beach	1986	1987	1988	1989
Hung Shing Ye	125600	112000	135398	154525
Lo So Shing	147000	77700	94905	112426
Total recorded attendances	272600	189700	230303	266951

Sources: Regional Services Department recorded monthly attendances

12.33 Water skiing and boating is popular off Luk Chau Wan (George Island) and is readily accessible from the moorings area in Aberdeen Channel.

12.34 Lamma is not without its cultural interest. There are 20 or so identified sites of archaeological interest on Lamma. These have been identified from the air as having characteristic physical features and when any building work is being done in areas designated (which includes virtually the whole of Yung Shue Wan) then the Department of Archaeology has the right to inspect the foundation works. In terms of known interest, a site near the police station at Tai Wan beach contains neolithic artifacts and bronzes. In Sha Po old village a 1500 year old skeleton was found in 1989 as was a late neolithic adze.

Labour Market Perspective

12.35 Consideration is given at this juncture to the question of the labour market in the 1990s, in Lamma and in Hong Kong. This is done in order to consider not only the impact of the project on the labour market per se but any impact or influence which the labour market itself may impose upon the project.

Labour Market in Lamma

12.36 The precise size of the Lamma labour force is still a matter for refinement. As seen in Table 12.2, 1568 persons were recorded as employed (both employed and self employed) in the 1986 By-Census. Using the population figure from the same source of 2968, the economic activity rate is 52.8% which compares with 50.8% for Hong Kong (Section 12.16). Using the study estimate of 1400-1700 workers in 1990 (Table 12.4) and the revised study estimate of current population of 6000 persons, the economic activity rate appears to drop below 30%. This could only be explained by such factors as imbalance in population structure through induced growth so that higher percentages are outside the economically active age bands, higher percentage of single earner expatriate and/or commuter households, hidden underemployment in the primary sector. For the purposes of this study, it is proposed to use the reasonably robust current labour force figure of 1700.

12.37 In Table 12.7, two scenarios are postulated for change in the Lamma workforce through the 1990s to 1995. Both assume the "No Expansion" situation for the power station, i.e. they represent a natural projection of the baseline. Scenario 1 represents the conservative view that the population will remain constant at best or decline marginally: Scenario 2 represents the more optimistic view of the Outline Development Plan and assumes that some measure of the planned-for growth will take place - but with the island retaining its dormitory function and no change in its micro-economy.

TABLE 12.7 : LAMMA LABOUR FORCE PROJECTIONS (NUMBERS)

	1986 base	1990 Est.	1995	
			Scenario 1	Scenario 2
Population	2968	6000	6400	8000
Economically active (a)	1780	3168	3200	4000
In labour Force (b)	1568	1700	1718	2148

(a) Those within the age bands 15-59 years. Taken as 52.8% in By-Census Year 1986, 50% thereafter.

(b) i.e. taking up employment

12.38 If the proportions of those employed in the construction sector in earlier years are applied then the following construction labour pool can be expected in Lamma:

	1995 Scenario 1	1995 Scenario 2
10.3% as in 1986	206	309
18.4% as average 1971, 1981, 1986	368	552

Labour Market in Hong Kong

12.39 In Hong Kong as a whole, growth in the labour force has been at an annual rate of 3.4% over the period 1981-1986, a proportional increase greater than that experienced in population which grew by only 2.2% over the same period. This has been brought about by factors such as change in the age structure of the population, in female participation in the workforce and in the number of male migrant workers.

12.40 The labour force in 1986 was 2744800 strong and in the last quarter of 1989 it was 2766900 with an unemployment rate (11/89-1/90) of 1%. The quarterly labour force situation for 1989 is given in Table 12.7 along with the numbers engaged in the construction industry.

TABLE 12.8 : LABOUR FORCE & CONSTRUCTION WORKERS: HONG KONG 1986 & 1989 ('000 WORKERS)

	1986	1989 Quarter:			
		1	2	3	4
Labour Force	2744.8	2768.7	2726.7	2732.0	2766.9
of which:					
Construction	173.2	234.9	226.6	229.2	236.5

Source: Census & Statistics Department

12.41 Of the 173172 workers in construction in 1986, some 140958 or 81% were listed as production and related workers, transport equipment operators and labourers.

12.42 A manpower survey of the building and civil engineering industry [4] was conducted in 1989 amongst 2359 construction sites, offices, firms and institutions. This found, as Table 12.9 shows, both a significant increase in numbers employed in this sector and a developing skills shortage. Indeed the same survey forecasts an average annual demand for 4500-5400 new skilled construction workers between 1990 and 1999: a total of 45000-54000 new jobs over the period which there will be increasing difficulty in meeting. Assuming the two major developmental projects of PADS and Metroplan proceed, construction worker demand will reach unprecedented peaks in much the same timeframe.

TABLE 12.9 : TRENDS IN HONG KONG LABOUR FORCE DEMAND IN THE CONSTRUCTION SECTOR 1987 TO 1999

Job Type	Employees				Increase in no. employed	Vacancies as % of filled jobs	Projected Aver.Ann. new demand
	1987:		1989:				
	no.	%	no.	%	(%)	1987-1989	1990-1999 (no.)
Technologist	8166	9.7	9277	9.8	13.6	5.8	500-600
Technician	14264	17.0	17690	18.6	24.0	6.7	1200-1500
Craftsman	32734	38.9	34537	36.2	5.5	6.4	2800 - 3300
Operative	12642	15.0	14055	14.7	11.2	4.6	na
General worker	16295	19.4	19771	20.7	21.3	7.8	na
	84101	100.0	95330	100.0	13.4	6.4	4500-5400

Source: Building & Civil Engineering Industry Training Board of the Vocational Council; 1989 Manpower Survey Report on the Building & Civil Engineering Industry

Anticipated Project Impacts

Assumptions

12.43 This section comprises a statement of the socio-economic impacts likely to stem from the project. Indication is made where these are preliminary and may be subject to adjustment as the form of the project progresses.

Workforce Requirements

12.44 Impact is in two parts: permanent impact, i.e. the changes to the operational requirement; and temporary, i.e. the construction phase requirements.

a) **Operational Requirement**

Current operational permanent staff at Lamma power station, in 1990, is 574 (excluding workmen). This is made up of 50 senior management staff and 524 other, operational staff. There are an additional 454 workmen engaged on a permanent basis for shift work, maintenance etc. With the coming onstream of unit L6, presently under construction, another 41 operational staff and 30 workmen will be required: no additional on-site management staff will be required. With the coming onstream of new units L7 and L8, a further 64 operational staff and 46 workmen will be required, taking the total, combined, manning requirements to 1209 as shown in Table 12.10.

TABLE 12.10 : ANTICIPATED INCREASE IN OPERATIONAL STAFF TO 1997

Staff	1990 units 1-5	Projected 1992 + unit 6	1995 + unit 7	1997 + unit 8
Senior staff	50	50	50	50
Other staff	524	565	598	629
Workmen	454	484	510	530
	1028	1099	1158	1209
% increase on 1990		6.9	12.6	17.6

Source: HEC

b) **Construction Requirement**

Construction is expected to commence in 1991 and finish seven years later, in 1997. Peak workforce requirement will be in 1993-94. Table 12.10 and Figure 12.4 refer.

TABLE 12.11 : ANTICIPATED CONSTRUCTION WORKFORCE REQUIREMENTS 1991-1997

	1991	1992	1993	1994	1995	1996	1997
Civil	190	550	750	210	50	15	-
E & M	-	--	150	520	220	520	85
	190	550	900	730	270	535	85
HEC	30	30	35	40	35	35	30

Source: HEC

Labour Market Impacts

12.45 There are two aspects to this assessment: the labour market on Lamma and the labour market in Hong Kong, and the impacts on each of the operational and construction phases of the project. Operational impacts are of course permanent whereas construction impacts are temporary.

a) **Operation**

Operational requirements are for an increase in the power station's workforce of roughly one-fifth over the five years from 1992, when unit 6 comes onstream, to 1997 when the final unit, unit 8, comes onstream. The actual requirement is for an additional 181 personnel; 105 skilled and 76 unskilled.

Few of the power station's present workforce are from Lamma. Currently 44 personnel (2.6% of the labourforce) and their families live on the island but these are thought to be largely unskilled workers rather than skilled operatives. It is also assumed that they originate from Lamma rather than having moved to the island for the purpose of employment. Additional skilled workers would therefore also be most likely to come from other parts of Hong Kong and not from Lamma itself. The scenarios in Table 12.7 indicate likely labour force levels in Lamma for 1995 ranging from 1718 to 2148 workers. Applying the 6% taken up of the current labourforce, between 44 and 56 utility workers can be projected. Even assuming that this increased number would be suitable and could be absorbed by the additional Lamma power station requirement, it is clear that the majority of the workers will have to be sourced from Hong Kong.

The question of skills availability in Hong Kong will have some influence on the ease with which these new workers are sourced. Whilst permanent work of this nature, working for a company such as HEC is attractive in itself, the remote location of Lamma and the travel to work involved have already created some difficulties in sourcing, even in competition with other employing industries. If training is offered, the ability to source is increased correspondingly. The problems associated with increasing labour turnover at all levels which HEC, in common with Hong Kong, is facing, are not likely to be any different for the extension of the Lamma power station workforce than for any other industry.

The impact that the additional operational workforce requirements impose on Lamma are given a preliminary assessment in Table 12.12. Again, two scenarios are presented with greater or lesser impact on Lamma.

TABLE 12.12 : OPERATIONAL WORKFORCE IMPACT ASSESSMENT

Issue	Scenario 1 (lesser Lamma Impact)	Scenario 2 (greater Lamma Impact)
Manpower:		
- Lamma	0-5% sourcing i.e. extra 0-9 workers of all skills or 4 if only of unskilled. HEC then maintains similar percentage of Lamma labour force. No overall change.	Doubling of present level to 88 workers, all skills. Still less than 5% of Lamma labour force in power station and HEC becomes largest single employer on the island, helping to overcome future problems of job cuts as quarry becomes exhausted.
- Hong Kong	Negligible impact provided skills base remains in balance overall: imbalance leads to impact on the project from the environment and not vice versa.	

b) Construction

There are generally more obtrusive impacts from construction labour force requirements than from operational. This is of course directly related to the greater numbers required, to the fact that it is a short term requirement and to the perception of nuisance creation which impinges on other sectors of the environment.

Construction will be about 7 years and annual labour requirements average 480 workers and peak at 900 in 1993. This is a significant requirement at a time when:

- a skills shortage is already clearly developing in the building industry;

- there is going to be competition in the labour market from other large projects, all of which are due for at least substantial completion within the same time frame, including:

  . PADS (port and airport development on Lantau)
  . Metroplan projects
  . China Light & Power's 5000MW station

- import substitution in the labour market is unlikely to be encouraged.

12.46 Some modification of the requirement may be possible through modular building specifications for plant and buildings which could act to reduce on-site labour requirements and, under current circumstances, this may mitigate the strain.

12.47 These predictions of impact risk are cautionary only and are stated so that steps may be taken as necessary to meet the problem. It must be noted that no previous construction at HEC's installations has created any problem. At Lamma, 1000 workers were employed in the construction of Phase I and 300-500 for Phase II. No labour shortage or competition within the market was noted at those times. It is only the exceptional infrastructural investment conditions likely to prevail in Hong Kong through the decade that give rise to the comments made above.

12.48 In other regards, opportunities for construction employment can only be regarded as a positive opportunity; this is particularly so for Lamma. HEC operates an informal policy to assist Lamma workers into the power station's projects so that there is economic benefit to the community. The limited economic base of the island offers no prospect for local procurement of plant, materials or services and so injections into the labour market are virtually the only way of introducing local benefits. There were 161 construction workers on Lamma recorded in the 1986 By-Census. Whilst the great majority of these commute to work on projects elsewhere in Hong Kong it does give an indication of the numbers who might wish for an involvement locally and who have some experience. Referring again to the 1995 labour force scenarios in Table 12.7 and this time applying the percentage taken up in 1986 by construction workers, i.e. 10.3%, a range of 177-221 workers is projected for the middle of the decade. Again, even if all are able to be taken up for the power station extension, it does not meet the overall requirement.

12.49 There are local contractors on Lamma: 10 or so are "registered" with the local authorities. These, however, are small concerns, largely undertaking house building or similar small projects. Because of their lack of experience on major projects, they are not likely to be able to benefit from sub-contractors contracts as such. They do, however, offer a medium for the employment of local workers (as, too, does the Island's District Planning Office with which HEC consults as a matter of course.)

12.50 In summary, therefore, construction force labour requirements should be seen as:

- a potential but modest economic benefit to Lamma
- a possible "pinch point" on the Hong Kong labour market overall

12.51 Other impacts normally associated with large construction workforces and their interface with the local community are dealt with later in this section.

Perception

12.52 A key issue is the perception which the community has of the expansion of the power station. This perception must be less than that for a greenfield project, but nonetheless "creeping industrialisation" is always held in contention in a predominantly rural area. Since the greenfield development of the power station on Lamma has already taken place and the station and the community co-exist very well. There can be no real justification for community opposition to the extension of the station now since not only is it within the existing site boundary but a key element of it is the restoration and return to beneficial use of the quarry, the island's major eyesore.

12.53 The existence of the power station on Lamma exerts a strong influence on the character of the island and the community's perception of it. Visually, the station dominates much of the island: its higher elevations are seen clearly from both Yung Shue Wan and Sok Kwu Wan, the lower elevations being screened by high land, and it is totally exposed to the tourist beaches. It is visible on the ferry routes to both North and South Lamma.

12.54 The locating of the power station on Lamma some 10 years ago is perceived by the community as a watershed in the development of the island. Positive impacts directly attributed to it are quoted as:

- improved security of electricity supply (on Lamma) - provision of potable water supply: supply prior to this had been from wells
- increased job opportunities
- workforce spending in Yung Shue Wan, particularly during the years of the initial construction
- the island has become better known because of the station.

12.55 Direct contact between the power station and the community was probably maximum during the original construction phase when there were 2500 workers on the island, spending in shops, cafes and restaurants, and when there was local project spending on items such as contractors' canteen supplies. Small businesses evolved to meet the demand and, for example, three cafes started up, at least one of their owners deciding that this was an opportunity to move out of agriculture.

12.56 Economic and physical interaction between the station and the community has reduced since the station became operational.

- employment of residents is minor (44 jobs);
- procurement of supplies, even for the canteen is nil;
- spending by workforce construction is negligible;
- the station is physically divided from the community by the hill between it and Yung Shue Wan;
- staff are transported in by HEC's own launches to the station's own dedicated jetty within the station compound and do not use the public ferry.

12.57 The profile of HEC within Lamma is, on the other hand, very high and it is perceived as a benefactor. Conscious of its role and image in Lamma, HEC has made very positive efforts to maintain close liaison with the community and with Government's departmental authorities there. It has made positive contributions to the island by, for example, donating a playground and village hall, renovating the school library, repairing footpaths and so on. HEC staff come annually to Lamma to clean-up the beaches. It does its best to maintain a "good neighbour" approach and monitors nuisance elements such as noise.

12.58 Complaints about nuisance are, again, inevitable where industry and rural communities are juxtaposed and such complaints as are received about Lamma power station reflect this. Generally, complaints relate to dust and noise - community perceptions of industry - but these are not of any high frequency (maybe 20 or so annually) and on investigation have been found to relate to one-off incidents e.g. intermittent noise or dust generated by unfavourable wind conditions. Certainly the power station cannot be considered to have the same nuisance effect as the quarry, a major emitter of noise and dust and of extreme visual intrusiveness to the otherwise extremely pretty Sok Kwu Wan area.

12.59 The nature of Lamma as a dormitory community means that people's valuations of tranquillity and amenity are much more sensitised than in communities where there is a greater degree of economic dependence in the locality or directly with the industry concerned.

12.60 Adequate local liaison is needed to ensure that the community is aware of the limited, identifiable differences the extension will bring: i.e. reassurance on visual, air, noise and water quality aspects of the project - the "nuisance" perception - and discussion on ways in which economic benefit might be spread, eg. through locally directed employment opportunities and, possibly, local spending on, say, certain food supplies for the station's canteen.

12.61 Reassurance needs to be given, too, on containment of nuisance in the construction phase of the project. Seven years is a long time and it could well be perceived by the community that additional noise, dust and general nuisance will be created which will exceed agreed, acceptable limits. Good housekeeping practices need to be ensured by the contractors.

Other Issues

12.62 Community concerns may also relate to construction phase use of facilities and infrastructure on Lamma. Brief mention should therefore be made of: transport, accommodation, health facilities and benefits from spending. These are presented in Table 12.13.

12.63 It is indicated in the table that amenity and tourism may be impacted by the project. This concern focuses on Hung Shing Ye beach. This is already exposed to the view of the station and there will be additional visual intrusion in full operation and intrusiveness (and noise) during the construction phase. This may tip the balance against it, certainly during the working week and especially during school holidays. It is not considered that general watersports carried on in the vicinity will be affected.

12.64 The positive impact of spending into the local economy goes some way to mitigating negative impacts. As noted, this is likely to be small. Nonetheless, injection into the economy of wages of the order of HK$30,000+ annually per local unskilled worker should not be overlooked. At the moment, there is minimal indirect spending into the local economy because of the separation of incoming workers from the community: it is virtually impossible for them, say, to go into Yung Shue Wan to eat or to make local purchases. Consideration might be given to letting a local contract for catering for the contractor's workforce.

TABLE 12.13 : OTHER CONCERNS

Concern	Comment on Impact
Transport:	
- Lamma/Hong Kong	No impact. All transport to/from island is by HEC launch.
Accommodation:	
- Lamma	No impact since either local workers will already by definition be housed or any small number seeking to move to Lamma can be accommodated in housing to buy/rent/build.
	During Phase I a few expatriate engineers lived on Lamma. as did a number in Phase II.
Other Infrastructure:	
- Lamma	No impact on island route network, education, health, communications or other infrastructure.
Local Economy:	
- wages	Additional injection into the local economy: EITHER direct spending on wages OR indirect spending out of salary.
- amenity	Limited effects on amenity, recreation and tourism. No effect on the thriving restaurant trade but possibly some effect on Hung Shing Ye beach.

Conclusions and Recommendations

Labour Market

12.65 Labour market impacts during the operational phase should be entirely positive: in the construction phase, the ferrying of the greater majority of the workers direct into the power station site means that negative impact through nuisance and competition for facilities is restricted, whilst at the same time, there is some benefit from a degree of local employment.

12.66 It is felt that every effort should continue to be made to enhance the benefits of the project to the local labour market. There are obvious difficulties in doing this beyond a certain point. HEC has always tried to encourage local participation in its Lamma workforce but it has encountered hurdles such as lack of interest in taking up job opportunities or serious lack of skills. It may well be that the degree of local participation achieved so far is therefore a pracitcal one, representing a reasonable balance in the local workforce. Consideration should be given to approaching the issue indirectly, via the contractor. As an example, the contractor should be encouraged to attain a reasonable proportion of the construction workforce sourced from within Lamma and to spend or award subcontracts locally as far as possible including, say, for the supply of foodstuffs to the workforce, where this is practicable.

12.67 The influence of social and economic conditions on the project is another matter. The project could face difficulties in sourcing skilled and even unskilled labour. Solutions such as modular building off-site seem acceptable and practicable: importing foreign labour does not.

Perception

12.68 It is concluded that there is no serious negative impact on the community from the expansion of the station which might justify opposition to the project. The need for liaison and for a public relations strategy is, however, clear, and the following suggestions are offered.

12.69 The first suggestion relates to the dust issue. Whilst this is a very real issue, in that both dust and impaired agricultural productivity are perceived by Lamma residents as real, there needs to be more detailed identification of the problem. Only one of the HEC analyses has shown any linkage with the station, and this was attributable to a particular set of operational conditions, coupled with unfavourable meteorological conditions. However, the complexity of tracing the real source or sources of the windborne pollution makes convincing residents a difficult task. It is therefore suggested that selective additional monitoring of air quality and deposition is undertaken to an extent adequate to reflect onshore and offshore wind variations and different phases of the cropping cycle. The selection of monitoring points and procedures should be done in collaboration with Lamma's Agricultural Officer who should be requested to monitor in parallel crops and soil for other possible causal factors such as disease, change in agricultural practice and so on.

12.70 In addition to the present form of interaction with Lamma residents, it is suggested that HEC set up a more informal vehicle for contact with the community. Currently, opportunities to meet generally relate to investigation of complaints, but having say an "open day" for school children or a New Year lunch at the station for Lamma's business community could be constructive. This avoids the need to have a topic/complaint in place in order to justify a formal meeting and it might be particularly useful during the construction phase.

12.71 The eventual return of the quarry to beneficial use is a benefit which the community recognises. HEC may wish to consider whether the community could play a part in deciding what the ultimate use should be.

12.72 On-island employment is still a matter of concern on Lamma, particularly as a means of stabilising and developing the community. If permanent job vacancies for the power station could be advertised on the island noticeboards in advance of or as well as in the press, this would be welcomed.

12.73 Construction phase employment is also of interest to the Lamma community. However, whilst all local workers are interested in principle in working locally, they would need to assess the length of contract, type of work involved etc before making any change from other work opportunities in Hong Kong. HEC might wish to consider more formal ways of analysing potential construction employment and asking contractors to liaise with the various Lamma committees to ensure that local workers have every opportunity to participate.

12.74 It is suggested that at the time construction contracts are being let :

a) contractors guidelines relating to community interface/employment are reviewed, and

b) a more precise quantification is made of the labour force and skills availability on Lamma. The present labour force estimates are speculative and should be refined.

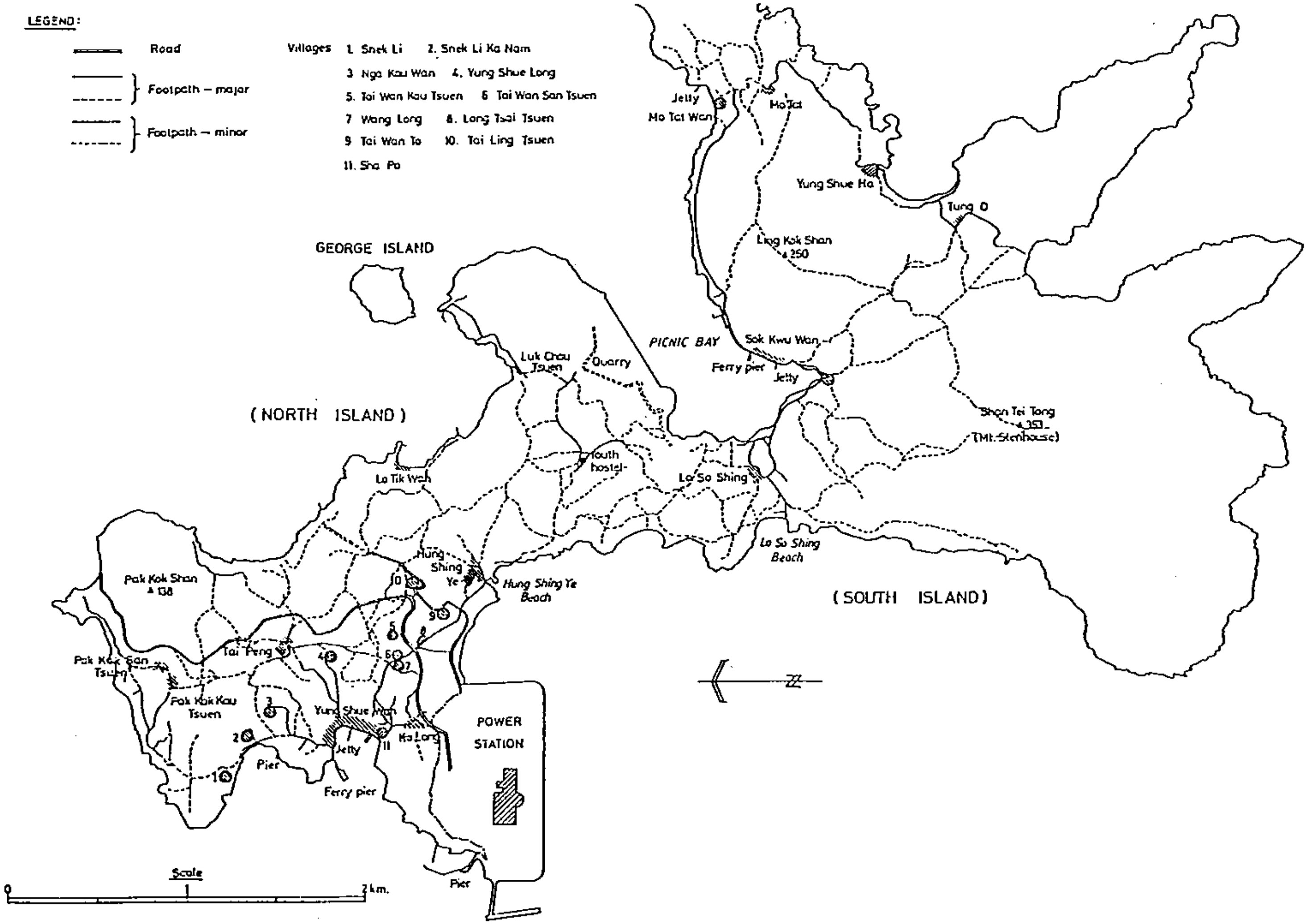
REFERENCES

1. Working Group on Population Distribution Paper 2/90

2. Land Utilisation in Hong Kong, Town Planning Office; Series & Sheet No. LUM/HK/75 Edition 1-1988

3. Lamma Island Outline Development Plan Ref. RU/1/5/1 Plan No. D/F - LI/1.

4. South Western New Territories Sub-Region Land Use Plan (1988). Plan Ref. SRSW-ST85/1B.

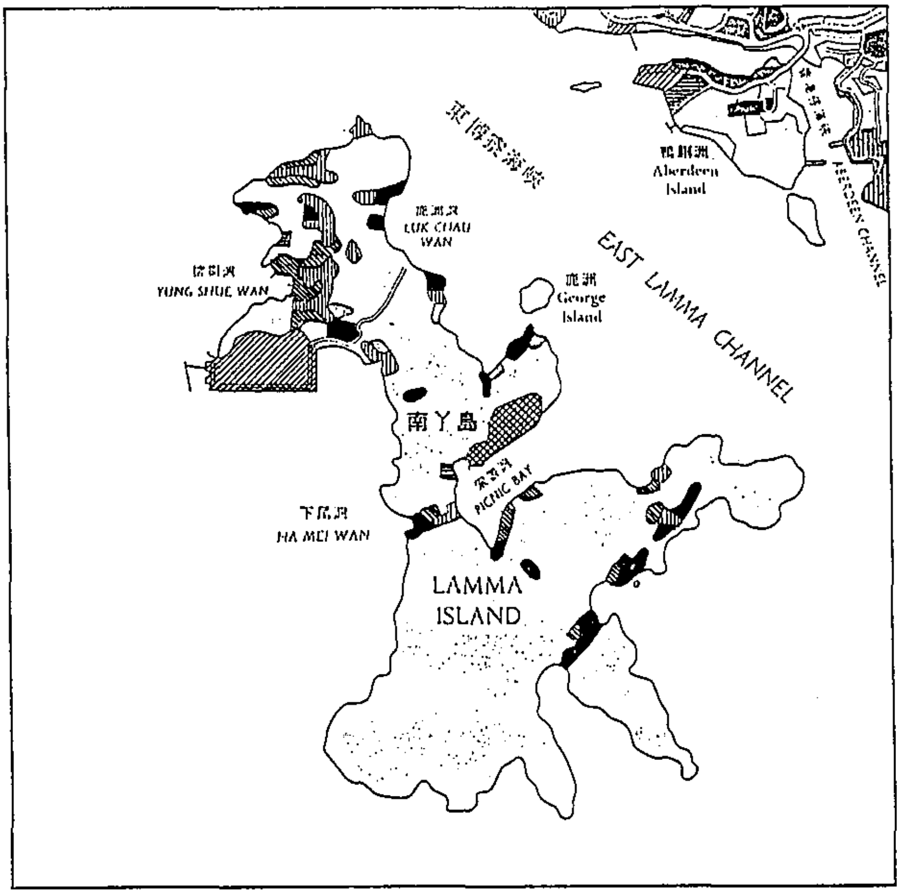


The Hongkong Electric Company Limited

PROJECT:
EIA LAMMA POWER STATION

TITLE: VILLAGES, ROADS & FOOTPATHS

FIGURE: 12.1

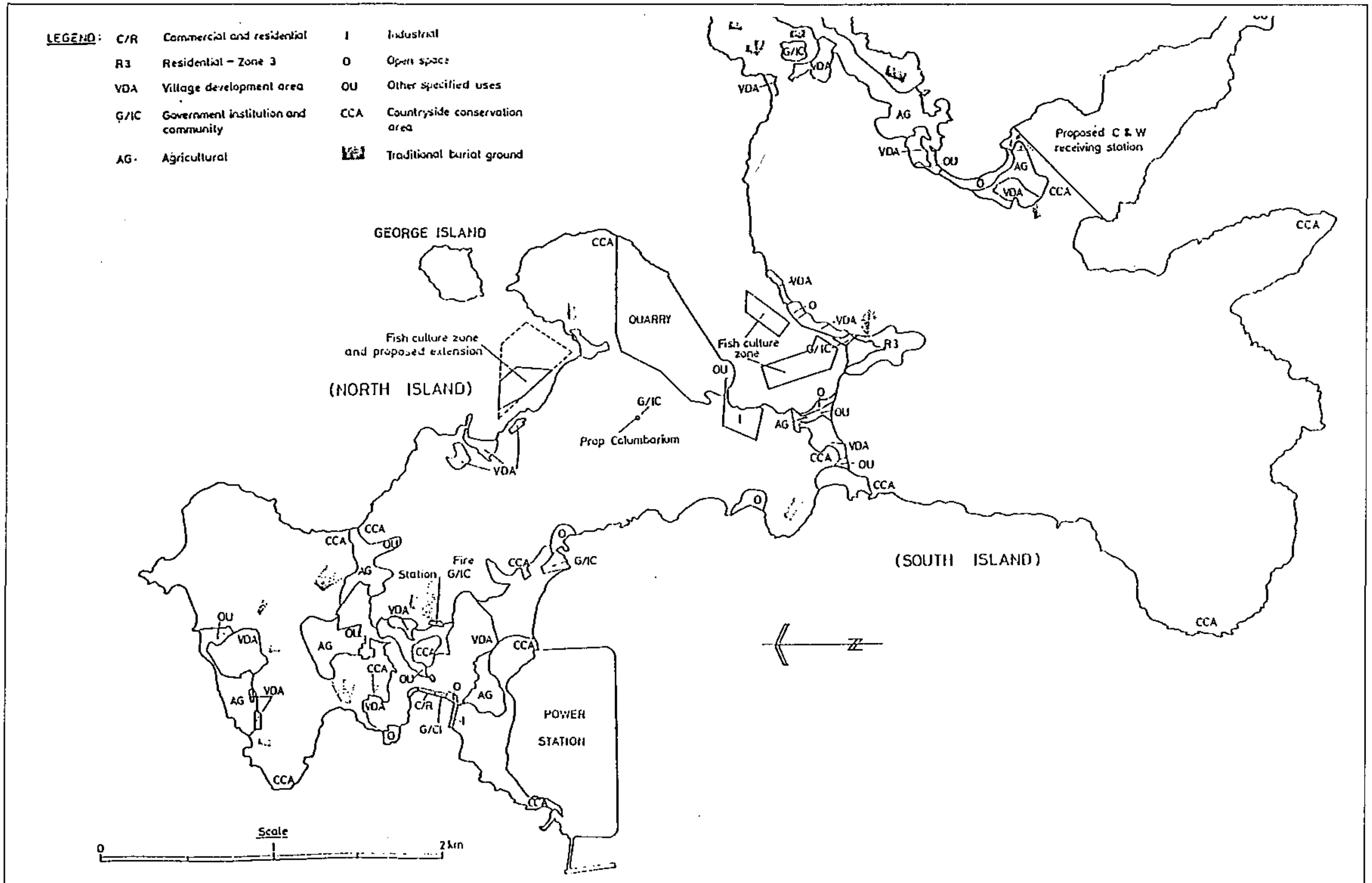


Scale 1:75 000

LEGEND

- Power Station
- Quarry
- Industrial
- Cultivated
- Agricultural (unused)
- Village housing
- Grass, Scrub, Wood, Swamp

The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: PRESENT LAND UTILIZATION LAMMA ISLAND FIGURE: 12.2

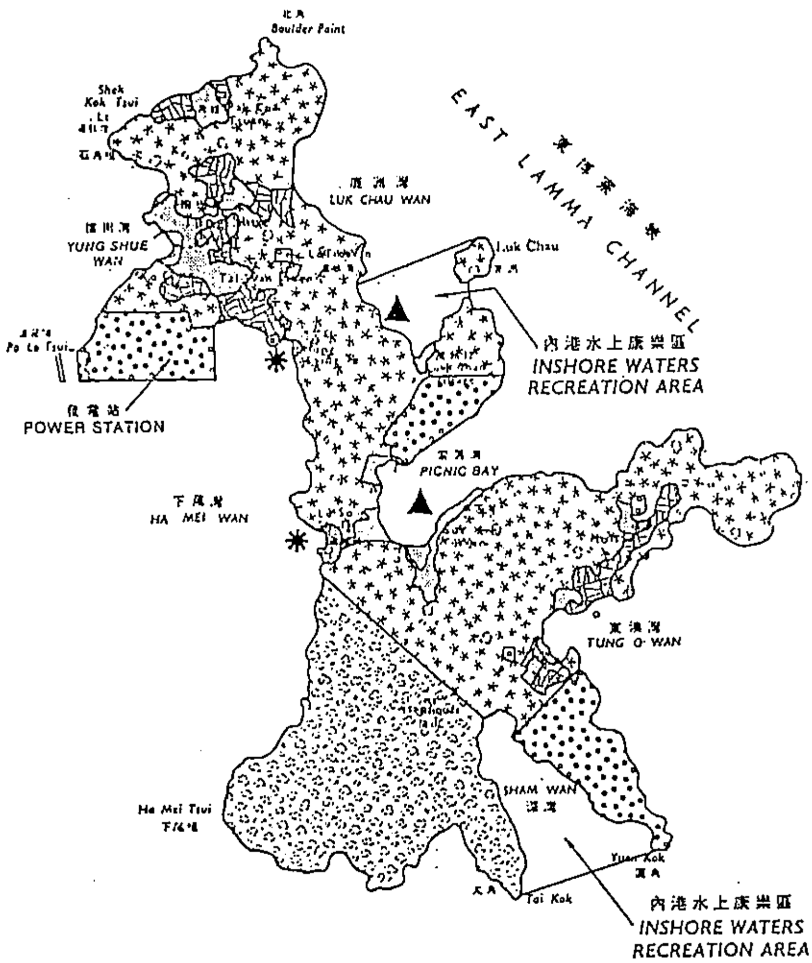


The Hongkong Electric Company Limited

PROJECT:
EIA LAMMA POWER STATION

TITLE: OUTLINE DEVELOPMENT PLAN

FIGURE: 12.3



農業優先區
AGRICULTURAL PRIORITY AREA

鄉村發展區
VILLAGE DEVELOPMENT AREA

郊野保護區
COUNTRYSIDE CONSERVATION AREA

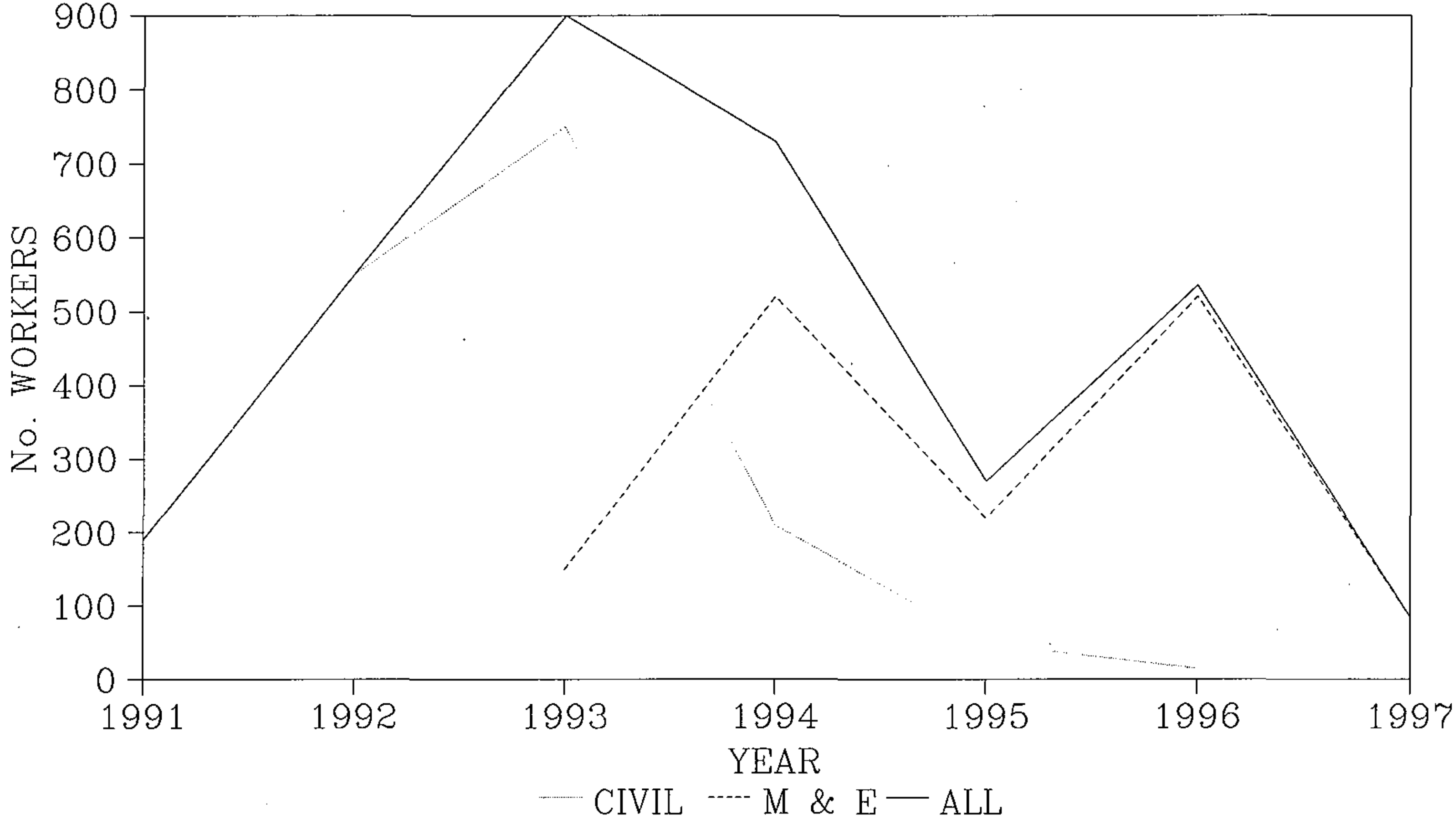
郊野公園，特別地區及特殊科學價值地點
COUNTRY PARK, SPECIAL AREA & SITE OF SPECIAL SCIENTIFIC INTEREST

其他指定用途
OTHER SPECIFIED USES

▲ 憲示海魚養殖區
GAZETTED FISH CULTURE ZONE

✳ 憲示海灘
GAZETTED BEACHES

The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: SW NEW TERRITORIES SUB-REGION LAND USE PLAN
		FIGURE: 12.4



	The Hongkong Electric Company Limited	PROJECT: EIA LAMMA POWER STATION	TITLE: CONSTRUCTION WORKFORCE REQUIREMENTS & PHASING
			FIGURE 12.5

PLATES

PLATE 1	Upper		View over Lamma power station south looking towards Hung Shing Ye beach
	Lower		View north from Hung Shing Ye beach
PLATE 2	Upper		Yung Shue Wan (north) and ferry
	Lower	(L)	Market gardening in Yung Shue Wan
		(R)	Prawn paste drying
PLATE 3	Upper		Sok Kwan Yu restaurants, looking inland
	Lower		Sok Kwan Yu restaurants and waterfront, mariculture rafts in middle foreground, looking over to the quarry face and Hong Kong in the distance

PLATE 1

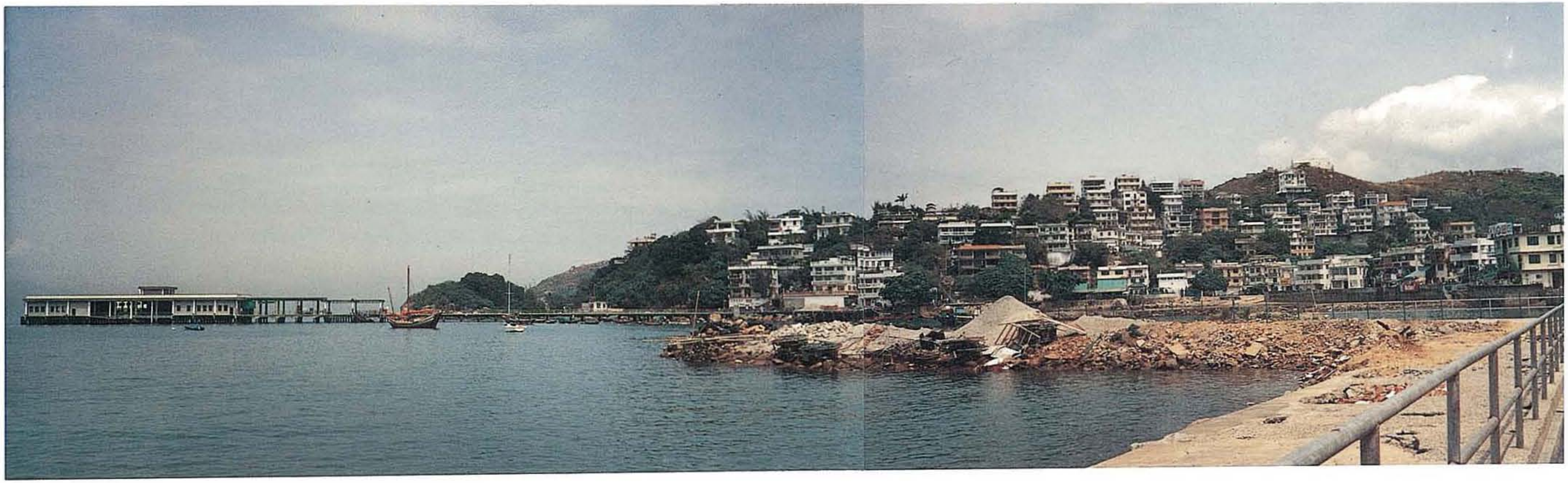
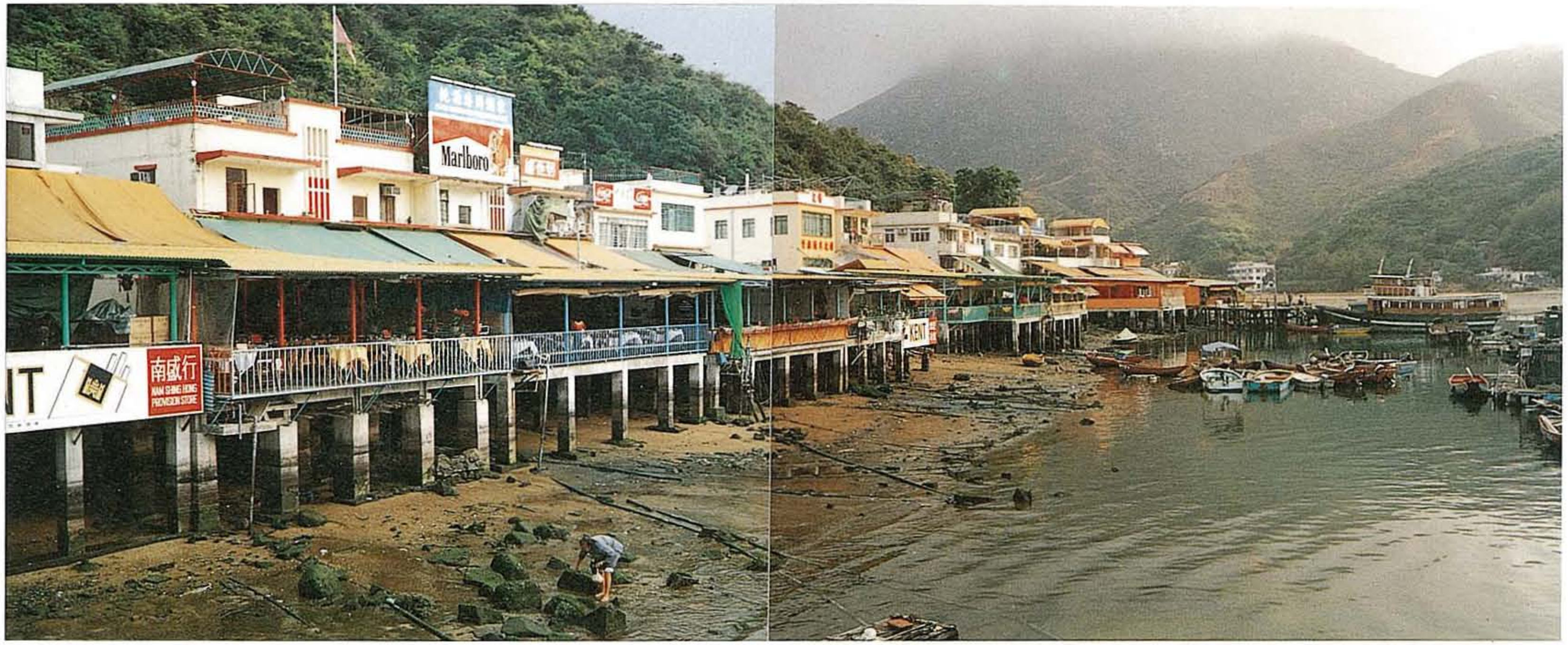


PLATE 2


Marlboro
南盛行
KENT

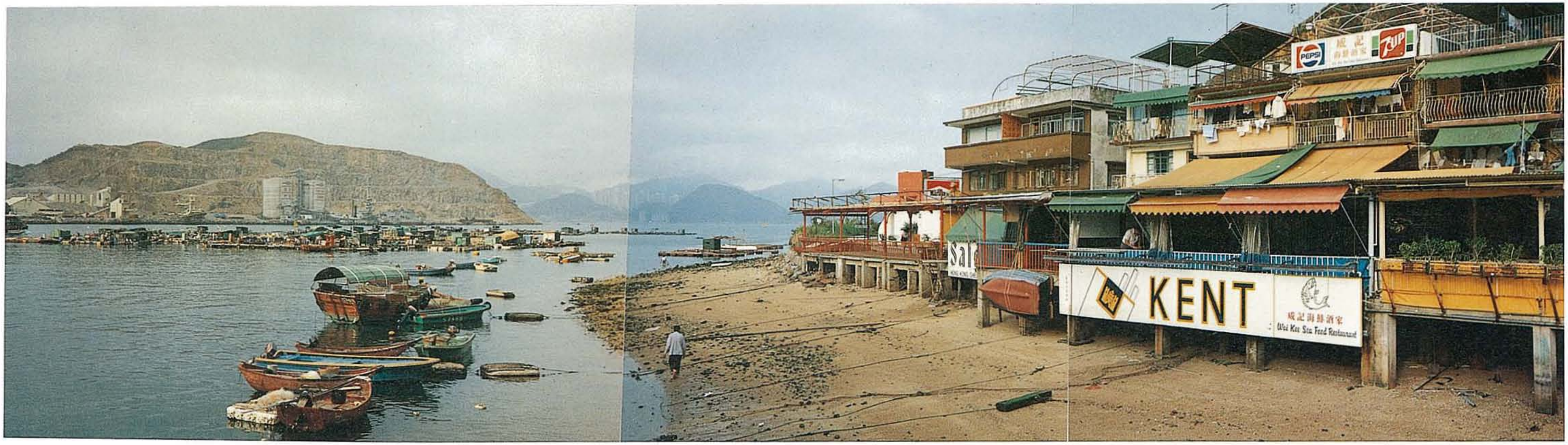

PEPSI
7UP
KENT
Wai Kee Sea Food Restaurant

PLATE 3

MARITIME TRANSPORT

13.0 MARITIME TRANSPORT

Existing Shipping

13.01 The West Lamma Channel, between Lamma Island on the east and Cheung Chau and Hei Ling Chau on the west, has a limiting depth of 8 m below Chart Datum and is in general used by small vessels, mainly fishing vessels and vessels undertaking trials. From a point southeast of Kau Yi Chau to a point south of the western end of Lantau, there are two designated through traffic routes, one passing between Lantau and Cheung Chau, the other south of Cheung Chau and Shek Kwu Chau. The routes are used mainly by Macau traffic. These are the West Lamma Channel Traffic Separation Schemes which each separate east bound and west bound traffic into two lanes, with vessels passing to Starboard in each case. The nearest route is about 1.5 nautical miles from the Power Station Main Jetty at the nearest point. The main deep water approach channel to Hong Kong is the East Lamma Channel, between Lamma Island and Hong Kong Island. This channel also operates under a Traffic Separation Scheme.

13.02 The main traffic at present operating in the vicinity of the Power Station and its jetties comprises bulk carriers bringing in coal, or sailing in ballast, which use the dredged channel to the Power Station Main jetty; small vessels (ash barges and barges bringing in construction materials and plant) which in the main use the East Heavy Unloading Area jetty; and the fuel oil barges, which use the West Heavy Unloading Area jetty. In addition, there are fishing vessels and leisure craft. The ferries bringing personnel to the power station approach from the north to a dedicated jetty away from the area of the other jetties, though they fuel at the West Heavy Unloading Area jetty. By 1994, the baseline date, when Unit L6 will be in operation, and when the extension to the East Heavy Unloading Area jetty has been constructed, vessels bringing limestone in bulk to service the FGD facility and taking gypsum in bulk away from the Power Station will also form part of the traffic.

13.03 The number of shipments of coal and ash in 1989 is given in Table 13.1 together with the range of shipment size and the average size. The number of shipments of coal, ash, limestone, gypsum and fuel oil (ie. heavy oil and light oil) forecast by HEC for 1994, the baseline year, is given in Table 13.2.

TABLE 13.1 : ACTUAL VESSEL MOVEMENTS, 1989

Type of vessel	No. of movements*	Shipment size (Tonne)	
		Average	Range
Bulk coal carriers	38	61160	42600-72700
Ash barges:			
- FBA and rejected PFA	272	1510	716-2014
- Accepted PFA	55	337	204-463
Heavy oil barges	-	-	-
Light oil barges	25	925	343-1044

* A movement is defined in this Table as an arrival plus a departure.

FBA - Furnace Bottom Ash
PFA - Pulverized Fuel Ash
Source : HEC

TABLE 13.2 : FORECAST VESSEL MOVEMENTS 1994

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DFC	TOTAL
NO OF SHIPMENTS:													
CHINESE COAL	2	1	2	2	3	2	3	2	3	1	2	2	25
OTHER COAL	2	2	3	2	3	3	3	3	2	3	2	1	29
LIMESTONE	2	1	1	2	1	2	1	2	1	2	1	2	18
HEAVY OIL	1	1	1	1	1	0	1	0	1	1	1	1	10
LIGHT OIL	1	0	1	0	0	2	2	3	1	0	1	0	11
GYPSUM	3	2	2	2	2	3	2	2	3	2	2	3	28
ASH (WET)	21	18	22	22	28	29	34	32	30	27	23	22	308

VESSEL SIZE (TONNE)

Chinese Coal	52,000
Other Coal	65,000
Limestone	2,000
Heavy Oil	1,000
Light Oil	1,000
Gypsum	2,000
Ash (WET)	1,500

Source : HEC

13.04 Sizes of ships assumed by HEC are as follows:

Type of vessel	Typical Deadweight (Tonne)	Approx. draught (m)	Berthing at
Bulk coal carrier:			
- Coal from Chinese sources	52,000	12 m	Main Jetty
- Coal from other sources	65,000	13 m	Main Jetty
Bulk limestone carrier	2,000		East Jetty
Bulk gypsum carrier	2,000		East Jetty
Ash barge	1,500		East Jetty
Heavy oil barge	1,000		West Jetty
Light oil barge	1,000		West Jetty

13.05 The approach to the Main Jetty for all coal vessels will be by the dredged channel from the south, having taken the pilot onboard and the necessary tugs being in attendance before entering the channel and proceeding. In the turning area with the vessel stopped off the berth, the tugs assist in breasting the vessel broadside onto the berth. On completion of discharge, the coal vessels will be ballasted down for sailing. Tugs assist in the unberthing operation, swinging the vessel in the dredged turning area, and the vessel then proceeds southward to the open sea. The average time for a vessel to transit the dredged channel on arrival and berth, or to unberth, swing and clear the dredged channel on departure, is of the order of one hour. Unloading and the necessary ballasting for sailing are usually completed in four days.

13.06 The movement of the coal bulk carriers is restricted to daylight hours, whereas the other vessels using the Power Station Jetties operate twenty four hours per day. The restriction on the movement of the large bulk carriers is a constraint imposed by the Hong Kong Pilot's Association, who have also laid down tidal "windows" for these vessels to transit the dredged channel. A minimum underkeel clearance (UKC) of 15% is also required. Initially, the channel and turning area were dredged to a level of - 15.9 metres PD; recently, and for the first time since the original capital dredging in 1981, they have been dredged to a level of -16.5 metres PD. This enables vessels with a draught of up to 14.35 metres to berth at the jetty with the 15% UKC agreed with Marine Department.

13.07 The berths of original departure and destinations of the smaller vessels and barges using the East and West Heavy Unloading Area berths are mainly elsewhere in Hong Kong or PRC. This means that the track taken by these vessels and barges is one which passes to the south of the Main Jetty, crossing the dredged approach channel and on occasions the turning area. The majority of these smaller vessels do not take pilots. The limestone and gypsum vessels may or may not be self-propelled and could require tugs, as do the ash barges. Oil barges are self propelled.

13.08 HEC anticipate that the largest vessels that might berth at the East Jetty might be special flat bottomed ocean-going vessels handling materials between the Power Station and other Asian countries. These vessels, although uncommon, have a capacity of 4000 to 6000 DWT. Alternatively, the smaller 2000 DWT vessels might be used to tranship the materials from 5000 DWT ocean-going vessels from other Asian destinations. This transhipment would take place elsewhere in Hong Kong waters.

Assessment of Increase in Shipping

13.09 Following the proposed commissioning of Units L7 and L8 in 1995 and 1997 respectively, there will be an increase in shipments of coal, limestone, gypsum, ash and fuel oil. These are forecast by HEC to reach a maximum in the year 2000 with two new 350MW units. The forecast movements for 2000 are given in Table 13.3.

TABLE 13.3 : FORECAST VESSEL MOVEMENTS 2000 (UNITS L7 & L8 : 350 MW)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NO OF SHIPMENTS:													
CHINESE COAL	3	2	3	3	4	4	3	4	3	3	3	2	37
OTHER COAL	3	3	3	4	5	4	5	4	4	3	3	3	44
LIMESTONE	4	3	4	5	4	5	5	5	5	5	4	4	53
HEAVY OIL	2	1	1	1	2	1	2	1	1	2	2	1	17
LIGHT OIL	1	0	1	0	1	6	11	9	5	1	1	0	36
GYPSUM	7	4	6	7	7	8	8	8	7	8	7	7	84
ASH (WET)	31	28	32	34	42	44	49	48	44	41	35	33	461

VESSEL SIZE (TONNE)

Chinese Coal	52,000
Other Coal	65,000
Limestone	2,000
Heavy Oil	1,000
Light Oil	1,000
Gypsum	2,000
Ash (WET)	1,500

Source : HEC

13.10 The present unloading facilities appear to be adequate to unload or load the tonnages forecast without the need for further new facilities beyond those required for Unit L6.

13.11 In addition to the increases in shipments of coal, limestone, gypsum, ash and fuel oil, there will be additional shipments of materials and plant for the construction of Units L7 and L8, being brought by lighter to the East Jetty. These will generally originate in Hong Kong so that the route of these tugs and lighters will be the same as that of the other small vessels and barges discussed above. Some materials and much of the plant will originate in other Asian countries, but unless these are brought in shallow draught ocean-going vessels capable of berthing at the East Jetty, these materials and plant will be transhipped into lighters in Victoria Harbour.

13.12 The period during which the lighters carrying materials and plant for the construction of Units L7 and L8 will be unloading at the East Jetty is likely to extend from 1991, the proposed date for the award of the Contract for Unit L7, to 1997, the proposed date for commissioning Unit L8. The assumed number of shipments of materials and plant for the construction for L7 and L8 is given in Table 13.4. It should be noted that since the commissioning of L7, (and hence the additional shipments of coal, limestone, gypsum and ash associated with its operation) is not proposed until mid 1995, the peak period for the construction material and plant shipments will have passed before the increase in shipments for the operation of L7 has commenced.

TABLE 13.4 - ASSUMED SHIPMENTS OF CONSTRUCTION MATERIALS AND PLANT TO EAST JETTY, 1991-1996 (350MW UNITS)

Contract	Assumed No of Shipments	Assumed Period of Shipments	Assumed Average No of Shipments/ Week
Civil Works for Units L7 & L8	300	Jan '91-Dec '93	2
Plant for Unit L7	100	Jan '93-Dec '94	1
Plant for Unit L8	100	Jan '95-Dec '96	1

Impacts of the Increased Capacity of the Lamma Power Station on Shipping Movements and Marine Hazards

13.13 The navigational impacts of the increased number of shipments, both as a result of increased operational capacity and for construction purposes, will be primarily those due to increased use of the East Heavy Unloading Area jetty. It is understood that HEC do not anticipate any increase in the size of vessels berthing at the Main Jetty, above those at present berthing there, which are up to 80,000 DWT. Other possible environmental impacts will include noise, dust and spillage. There will be a greater number of occasions of noise, due to unloading or loading operations and due to the increased number of harbour tugs bringing lighters and barges to the East Jetty. The subject of noise is addressed in Section 11 of this Report. Spillage during unloading or loading is addressed below.

13.14 Previous reports have assessed marine hazards principally as regards bulk carriers and their approach at the Main Jetty. The most recent of these has concluded that the navigational aids provided in the channel and turning area, and on the jetty itself, are more than adequate to ensure safe navigation by the bulk carriers, by day and night. In practice, as noted above, the large bulk carriers do not move during night time.

13.15 The arrival time of the large coal bulk carriers is always known in advance, the vessel's estimated time of arrival (ETA) having been advised to the Port Authority and Power Station by radio, telex or fax. As the vessel approaches Hong Kong, VHF radio contact is made between the ship and the Power Station, the Marine Department, tug boats and pilots, using the dedicated VHF marine channels. A previous report has assessed the communications equipment installed at the Power Station complex as more than sufficient to cover all operational requirements and the needs of any envisaged emergency situation.

13.16 The time taken for a vessel to transit the dredged approach channel and berth, or conversely to unberth, swing depart and clear the dredged channel outward, is of the order of one hour in each case. The time taken to unload an average shipment of coal is about three to four days, and in the worst month (May, 2000) it is estimated there would be about 9 shipments. The duration of the coal bulk carriers transiting the channel/berthing/unberthing/or swinging in the turning area should therefore not exceed about 20 hours per month, or about 3% of the time. This is an increase of about 8 hours per month over the 1994 baseline case, in which large bulk carrier movements are likely to occur about 2% of the time. As already stated, these movements will be in daylight hours.

13.17 The movements of the smaller vessels, tugs, barges, etc, between the East Heavy Unloading Area jetty and other berths in Hong Kong will be considerably more frequent. In the worst month (July 2000) it is estimated that there could be 75 shipments per month, ie. an average of nearly 2.5 shipments per day, which would mean between 5 and 6 movements of small vessels to or from the Power Station inner jetties.

13.18 Compared with the more congested Victoria Harbour, the movement of vessels across the dredged channel or turning area will be relatively infrequent. In any event, masters of such small vessels and tugs should be able to see any coal vessels that are underway, since such activity takes place only during daylight hours. Consequently, it is concluded that the probability of a marine hazards due to interaction between the large bulk coal carriers and smaller vessels or barges is extremely remote,even in the worst scenario situation.

13.19 During discussions held with Marine Department, it was noted that in terms of total movements in Victoria Harbour, the number of movements even in the worst scenario situation was very small. Following the Port and Airport Development Strategy Study, proposals exist for new navigation channels to the proposed "port peninsula" development off northeast Lantau. This would pass between Lamma Island and the eastern end of the proposed breakwater from Cheung Chau towards Lamma Island. Marine Department considered that the interaction between movements of Power Station traffic and the new port traffic would have to be addressed by proponents of the port and breakwater development, rather than by HEC and such interactions have not therefore been studied.

Possible Mitigation Measures to Minimise Marine Hazards

13.20 The following recommendations are made with a view to minimising the possible risk of marine hazards resulting from the increase in vessel movements in the vicinity of Lamma Power Station.

(i) The dredged approach channel should be designated by the Hong Kong Marine Department as a Deep Draught Fairway.

(ii) The dredged approach channel, the turning area and the area due South of the Power Station for one mile should be designated a prohibited anchoring area.

(iii) At times of arrival and departure of large bulk carriers which are constrained by their draught, Vessel Traffic Services of Hong Kong (VTS) ensure as far as possible that other traffic in the vicinity is made aware of such movements. This area is continuously monitored, and identified vessels automatically plotted, so that navigational information can be disseminated efficiently.

Spillage

13.21 Spillage during coal unloading is not substantial and is effectively limited to spillage by the two grab unloaders. Spillage by the bucket elevator unloader appears to be non-existent due to the enclosed nature of the equipment and the proximity of the hoppers to the conveyors on the Main Jetty.

13.22 Spillage by the grab unloaders may occur as the grab traverses the hold to the hopper. The grab unloaders are fitted with anti-spillage plates, which extend from the unloader, towards the ship's side. At present, it is estimated that spillage represents a negligible proportion (less than 0.01%) of the total coal being unloaded and it is understood that the studies are currently being conducted by HEC to further minimise spillage. HEC also report that dredging after 8 years of operation of the power station revealed no significant coal deposits.

13.23 The coal conveyors from the main jetty along the access bridge to the shore are covered, as are the coal conveyors within the Power Station. The conveyors on the Main Jetty cannot be covered, since the grab and bucket elevator unloaders need to travel from hold to hold of the ship. Wind-blown spillage from these conveyors is minimised by wind boards alongside the conveyor, as well as by the use of chemical and water sprays.

13.24 At the East Jetty, where at present ash is loaded to barges and where, in the 1994 baseline situation, limestone and gypsum will be unloaded, spillage is likely to be very small. Clearing of debris from the sea bed has been carried out once at the East Jetty berth to minimise accumulated rubbish. This was due as much to sand and gravel spilt while unloading construction materials as to ash being spilt during loading. At present, spillage of ash during loading operations is minimal; the main problem relates to wind-blown ash dust: this problem is being addressed at present, and is likely to be overcome in the near future.

13.25 Limestone will be unloaded with a screw type unloader, which should result in negligible spillage. Gypsum will be loaded with a retractable covered conveyor and chute loader (similar to the ash loader for Units L1 to L3), and spillage is therefore likely to be negligible, provided that wind-blown spillage is minimised.

13.26 There is no evidence of spillage of oil at the West Heavy Unloading Jetty where light oil for the gas turbines and heavy fuel oil is unloaded. An increase in fuel shipments should not change this situation.

Possible Mitigation Measures to Reduce Spillage

13.27 It is recommended that methods of eliminating any gap between the grab unloader spillage plates and the ship's side are investigated to minimise spillage of coal into the sea. A study of methods to minimise spillage of coal into the sea is currently being undertaken by HEC.

Summary and Conclusions

13.28 The main traffic at present in the vicinity of the Power Station consists of coal bulk carriers with shipments of around 60,000 tonnes, which move in daylight only and which are confined to the dredged channel leading to the Main Jetty, and shallow draught lighters and barges, some of which require tugs and some of which are self-propelled, which berth at the East and West Heavy Unloading Area jetties and cross the dredged channel in approaching and leaving the Power Station. The numbers of movements per month of both types of vessels in the baseline case (1994) are likely to increase, in the worst case scenario (July 2000) by about 50% in the case of coal carriers and by about 74% in the case of small vessels. The sizes of coal carriers and of the small vessels are not anticipated to increase.

13.29 There will also be a build-up in movements of lighters and barges bringing construction materials and equipment to the Power Station East Heavy Unloading Area jetty for Units L7 and L8, but this will occur before the increase in small vessel movements as a result of the operation of Units L7 and L8.

13.30 As a result of these increases in the number of movements, the probability of marine hazards, although very low, will marginally increase. The existing procedures of the Vessel Traffic Services of Hong Kong will be able to mitigate this situation. Vessel Traffic Services (VTS) are the controlling body for marine movements in the port, and are best suited to deal with marine traffic patterns and procedures that may develop as the port does.

13.31 Spillage of coal at the Main Jetty is virtually negligible at present, and current studies are expected to lead to a decrease in any spillage. Spillage of other materials at the East and West Heavy Unloading Areas is at present negligible, and measures being brought in will ensure that spillage will not increase as a result of increased movements of small vessels.

ENVIRONMENTAL MONITORING AND AUDITING

14.0 ENVIRONMENTAL MONITORING AND AUDITING

14.01 A programme of environmental monitoring of Lamma Power Station has been in operation since 1980 and a comprehensive database exists for many key parameters in the air and water environment. In addition, a long term noise monitoring study has been carried out at two sites in the vicinity of the power station (Ching Lam since 1984 and Hung Shing Ye since 1980).

14.02 In addition to the long term monitoring conducted by HEC, various shorter term monitoring studies are also undertaken. These include measurements of dust concentration and deposition carried out within or close to the external boundary of the Lamma site; noise measurements at facades of properties where there have been noise complaints; sea water temperature/water quality studies and biological monitoring of trace metals.

Requirements and Purposes of Environmental Monitoring

14.03 The environmental monitoring programme operated by HEC was set up as a condition of the site licence for the development of the Lamma Power Station. It has proved to be extremely useful in assessing any changes in pollution level in the external environment that have arisen following the development. A review of the air quality data collected from the HEC monitoring programme, is given in Chapter 5, of the water quality in Chapter 6 and of the noise data in Chapter 11.

14.04 In broad terms, the monitoring data reflects the changes that have occurred in generating pattern on the HEC system, with a gradual decline in load at the Ap Lei Chau Station, followed by an increase in capacity of the Lamma site. These changes have been reflected in a general improvement in air quality conditions at various monitoring sites on Hong Kong Island.

14.05 The results of environmental monitoring enable a continuing appraisal of the environmental impact of the power station to be made and also provide a means of compliance testing, ensuring that the station is operating within agreed environmental standards. Finally, environmental monitoring provides an essential feedback mechanism to both HEC and Government on the efficiency of environmental controls built into the design of the power station, and of the effectiveness of mitigation measures.

Auditing

14.06 Environmental auditing is an integrated assessment process involving examination of all aspects of an organisation's environmental performance. The procedure can be used to both check compliance with environmental objectives and standards, and also as a planning and management tool to minimise environmental impacts. An environmental audit can be carried out either in house (normally with external guidance); by an external contractor engaged by the particular organisation or by the relevant regulatory body.

14.07 Environmental auditing as an environmental management tool has not yet been formally introduced into Hong Kong, although a system of auditing for compliance purposes has operated successfully for a number of years, through an environmental monitoring review process operated by EPD. In this process air quality data from HEC's air quality monitoring network is passed to EPD at regular intervals and reviewed. In the early years of monitoring, this review included the formation of a Joint Working Party comprising representatives of both Power Companies, EPD (then EPA), the Royal Observatory and Labour Department. The purposes of the Joint Working Party were to disseminate information; pool expertise; solve common problems relating to the operation and use of monitoring equipment and to provide a forum for continuing technical discussions on the data derived.

14.08 The auditing/review process also extends to on-site emission testing whereby stack emissions are periodically tested by EPD using USEPA Reference methods to check compliance with agreed emission standards.

14.09 Liquid effluents generated at the power station are regularly monitored by HEC in accordance with a formal discharge consent, initially issued in January 1986 by EPD and revised in July 1989. The data from this self monitoring programme are submitted to EPD at regular intervals for auditing purposes.

Air Pollution Control (Specified Processes) Regulations, 1989

14.10 Air emissions from the Lamma Power Station are regulated under the terms of a licence (L-7-002) issued by EPD under the Air Pollution Control (Specified Processes) Regulations, 1987. This licence, issued on 6th March 1990 provides for control of some 53 separate emission points on the Lamma site. For each of the separate emission points, the licence specifies regulated limits on discharges in terms of emission rates and concentration. The licence applies to steam boiler Units L1 to L6 and specifies a requirement for flue gas desulphurisation system on Unit L6. It also covers emissions from the gas turbine GT1, whilst another licence, L-7-001, covers the six 125MW gas turbines GT2-GT7 and one black start gas turbine.

14.11 A comprehensive system of sampling and monitoring is specified in the licence. In summary, the requirements are as follows:

1. To provide sampling points on chimneys serving Units L1 to L6, for the purposes of stack gas testing in accordance with USEPA Reference methods 5, 6 and 7 (or equivalent);

2. To fit each of the chimneys serving Units L1 to L6 with a double pass transmissometer and data recorder for in stack opacity monitoring;

3. To fit the chimney serving Unit L6 with a sulphur dioxide analyzer and a nitrogen oxides analyzer, both with recorders;

4. To conduct at least once a year, an analysis of emission rates of particulates, sulphur dioxide and nitrogen oxides in exhaust gases from Units L1 to L5;

5. To monitor the 24 hourly ambient particulate concentration at selected locations by high volume sampler, at a frequency of once every 6 days;

6. To monitor the hourly average SO_2 concentration at Queen Mary Hospital; Victoria Road; Ap Lei Chau; Chung Hom Kok, and, within one year after acquiring a suitable site, The Peak.

There are also requirements to sample stack gases from the 125MW gas turbines, and to monitor fuel usage of the power station.

The results of the various monitoring studies are to be submitted at regular intervals to the Authority (i.e. EPD).

14.12 The majority of the licence requirements have already been implemented by HEC, with outstanding items awaiting the completion of Unit L6 and associated FGD system. HEC installed and commissioned the required air quality monitoring station on The Peak in August, 1990.

Liquid Effluents - Consent to Discharge

14.13 The liquid effluent discharge consent issued to HEC in 1989 specifies all effluent streams and permitted discharge limits. The consent requires that HEC carry out a self monitoring programme in accordance with an agreed frequency schedule, which is reproduced in Appendix 14A.

14.14 The self monitoring programme is already in operation and covers effluents from the cooling water; effluent treatment plant; ash settlement basin overflow and sewage treatment plant.

14.15 Although not specifically required under the terms of the licence, HEC has also conducted biological monitoring in the past which has included:

1. Plankton population and chlorophyll concentration at the c.w. intake and outfall;

2. Species diversity of fishes caught on intake screens, and;

3. Heavy metal concentrations in barnacles.

The results of these various biological monitoring studies are reviewed in Chapter 9.

14.16 From an assessment of the current monitoring work conducted by HEC, it is considered that it is comprehensive in scope and that for the most part, is adequate for compliance auditing purposes. However, the proposed extension of the power station will result in additional discharges to the air and water environment and the adequacy of the existing programme of monitoring needs to be addressed in this context.

Air Quality Monitoring

14.17 The analysis of air quality impacts conducted during the numerical modelling study, clearly identified The Peak area of Hong Kong Island as being one where highest ground level concentrations of air pollutants probably arise. The addition of Units L7 and L8 would make only a small addition to the pollution load.

14.18 With the addition of the Peak (Mt. Austin Road) monitoring station to the HEC network, it is considered that the air quality monitoring network will be sufficient for assessing any impact of the extension on the air environment of Hong Kong Island, as well as for assessing cumulative impacts.

14.19 At present, data from the existing network is forwarded to Government for review/auditing and it is envisaged that a similar arrangement would be adequate for The Peak (Mt. Austin Road) site. However, there would seem little justification for continuing to furnish very detailed monitoring statistics to Government unless a joint review of the data is carried out between HEC and EPD at periodic intervals. Such reviews would help identify any unusual or episodic events leading to high air pollution levels, and would enable agreements to be reached on reduction in monitoring effort where appropriate. The corollary of this is that a regular review process will enable decisions to be taken on redeployment of monitoring sites if current sites no longer fulfil a useful role. This will enable scarce environmental resources to be used in the most effective manner and maximise the benefits of environmental monitoring.

14.20 Monitoring of stack gas emissions is already a requirement for existing units and is to be anticipated for Units L7 and L8, if approved. Assuming the requirement would be for continuous monitoring of the SO_2 and NO_x, in line with that currently required for L6, this would provide a continual check on the performance of pollution control devices incorporated in L7 and L8. A requirement to provide continuous records of concentration for inspection by the Authority together with suitable alarm facilities to warn operations staff of mechanical failure of pollution control plant would provide an adequate basis for monitoring emissions at source.

14.21 During the construction of Units L7 and L8, there is a possibility of fugitive dust arising from general construction activity, as well as the requirement to relocate coal stockpile No. 1. It is considered that periodic monitoring of these activities using high volume air sampling would be a useful means of checking that such dust was adequately controlled to agreed levels. Specific dust control measures should be considered as part of Contractors contracts and regular compliance checking by HEC should be instigated.

14.22 Provision of FGD to Unit L6 will require provision of the necessary infrastructure for handling and storage of limestone and gypsum. There is no experience of bulk handling of these materials on power station sites in Hong Kong and so the need for any additional monitoring to assess environmental impacts cannot be readily ascertained at this stage. However, it is probable that any air impacts associated with the provision of FGD process materials will be adequately monitored by the high volume air sampling programme operated by HEC in accordance with the Air Pollution Control Licence.

Water Quality Monitoring

14.23 The provision of the additional units will result in additional quantities of effluents entering the receiving waters. These additional effluents will require to be monitored prior to discharge, as is currently undertaken for the existing units.

14.24 The power station extension will require provision of an additional cooling water outfall, which will be constructed adjacent to the current outfall. There will therefore be an additional discharge point, which will need to be considered in any additional monitoring work.

14.25 It is anticipated that effluent discharge monitoring of a type and frequency currently specified under the effluent discharge consent will be required for the additional units.

14.26 The additional thermal discharge from the new cooling water outfall will add to the heat load in adjacent waters. The biological impact of this additional heat load has been addressed in Chapter 9. Whilst the assessment of impacts suggests there is no cause for concern, it would be prudent to review the requirements of sea water temperature monitoring in the light of the additional heat loading. The nature of any additional sea water temperature monitoring will require detailed consideration when designs of intake and outfall structures are more advanced.

14.27 A review of the results of the biological monitoring of trace elements in barnacles does not enable any firm conclusions to be drawn on the possible impacts of trace metal discharges from the station. It is clear that considerable variation exists in the biological monitoring data both between sites and over time. No significant increase in barnacle metal content was found over time. The study has now been terminated and there would seem little benefit in reinstating it.

Environmental Auditing

14.28 The procedures for environmental auditing and the current auditing activities have been reviewed above. As noted, formalised EA procedures have not yet been implemented in Hong Kong although Government policy on this process was articulated in the 1989 White Paper "Pollution in Hong Kong" [1].

14.29 A major component of any EA process will be self monitoring and reporting, as currently carried out by HEC. If consent for the extension of the power station is given, it will be necessary to review how best to integrate both the existing and future environmental monitoring programmes into the auditing process. This will require detailed discussions with EPD on the nature and scope of auditing for both the existing power station and the extension, so that a comprehensive auditing strategy is determined.

14.30 It is envisaged that detailed consideration of auditing requirements will be addressed during Phase 3 of the EIA, at which point specific procedures can be determined. At this stage, a number of areas of the power station operation can be identified where auditing may be appropriate. These areas were identified at the Inception Report Stage and are reproduced for completeness below:

1. Regular submission of air quality data summaries from HEC's air quality monitoring stations to EPD for review and comparison with AQO's.

2. An operations management policy to ensure that all maintenance of pollution control equipment is carried out according to manufacturer's recommendations, operational experience, and at the appropriate time intervals.

3. Maintenance of an adequate essential spares inventory to avoid prolonged outages of pollution control equipment.

4. In-house supervisory responsibility of emissions monitoring equipment such that appropriate corrective action can be taken in the event of emissions being in excess of prescribed limits.

5. Enhancement of the existing liquid effluent monitoring programme to cover additional discharges and parameters. Regular submission of effluent data to EPD and assessment of compliance with consent limits.

6. A water quality monitoring programme, particularly for temperature, to check compliance with relevant WQO.

7. Implementation of a construction noise monitoring programme to check contractors compliance with agreed noise limits.

8. Supervision of the construction contract by HEC to check compliance with all environmental controls.

Key Issue Studies

14.31 Following submission of the draft IAR, it was agreed that proposals for environmental monitoring should be the subject of a separate Key Issue Report. This KIR would collate all the monitoring and auditing requirements identified at the IAR stage, and any further requirements arising from other key issue studies.

14.32 The Environmental Monitoring and Auditing KIR has now been submitted to EPD and the principal findings and recommendations are summarised below:

- The proposed extension to Lamma Power Station will require additional source and environmental monitoring in order to provide an on-going check on the performance of pollution control measures incorporated into the design, and also to provide a check on the environmental impacts.

- It is envisaged that the various effluent streams associated with Units L7 and L8 will be monitored prior to discharge on a routine basis according to a regime similar to that required under licence conditions applying to Unit L6. Records from such source monitoring should be maintained and supplied to the Authority at regular intervals.

- Specific monitoring will need to be carried out during construction activities to ensure that noise and dust controls are being properly adhered to by Contractors. As well as physical measurements of noise and dust, frequent inspections by HEC site staff during construction activities should form part of the overall environmental management activities.

- With the establishment of an air quality monitoring system on the Peak in August 1990, it is considered that the air quality surveillance system is sufficiently comprehensive to monitor the air quality impact arising from Units L7 and L8. However, as detailed wind tunnel testing indicated occasional peak SO_2 concentrations on Lamma Island, it was agreed with EPD that additional monitoring would be established on North Lamma.

- Additional water quality monitoring in relation to the increased thermal discharge, metals and nitrogen is recommended so that the actual impact of these releases can be adequately quantified. Specific proposals for such monitoring are contained in the Water Quality KIR. It is proposed that an ad-hoc working group be set up with EPD to finalise the formats, submission frequency and other details of the expanded monitoring programme.

- Compliance auditing should form a key component of the monitoring activities with regular review of data collected by both HEC staff and Government. Appropriate lines of communication, responsibility and management should be in place to ensure that prompt remedial action is taken in the event of non-compliance with environmental objectives. Overall responsibility for ensuring compliance should rest with the Station Manager who should be kept regularly informed of the results of emission monitoring. Regular site audits should be carried out by HEC site staff to serve as an overall check on the environmental performance of the station.

REFERENCE

1. Government of Hong Kong 1989. Hong Kong Government White Paper "Pollution in Hong Kong - A Time to Act".

APPENDIX 14A

Liquid Effluent Discharge Consent
- Self Monitoring Schedule

ANNEX 1 TO CONSENT TO DISCHARGE

LAMMA POWER STATION
D.D.3 lot 1934

SELF MONITORING REQUIREMENT

Effluent Streams	Parameters To Be Monitored	Frequency
Effluent (1) : Cooling Water	Total Residual Chlorine	Bi-Weekly
	Maximum Temperature	Daily
Effluent (2) : Effluent Treatment Plant Discharges	pH, SS of No. 2, 3 & Standby Basin Outlets	Daily
	Fe of No. 2, 3 & Standby Basin Outlet	Bi-Monthly
	pH, SS, Grease & Oil, Cu Fe of No. 1 Basin Outlets	During Discharge
Effluent (3) : Boiler Blowdown	-	-
Effluent (4) : Ash Settlement Basin Overflow	pH, SS	Daily
	Ni, Zn, As, Hg, Cd, Cr, Cu, Mn, Fe, Pb, Grease & Oil	Bi-Annually
	Fe	When No. 1 Basin Effluent of Effluent (2) is Diverted to Ash Setting Basin and its Fe Concentration Exceeds 10 mg/l
Effluent (5) : Sewage Treatment Plant Discharges	SS, BOD_5	Twice Weekly for Each Plant
	Grease & Oil	Monthly for Plants No. 1 & 3 Weekly for Plant No. 2

ANNEX 1

RESPONSES TO GOVERNMENT COMMENTS ON DRAFT IAR

Reference	Comments	Consultants Responses	Additional Comments	Response
	<u>COMMENTS FROM EPD : AIR STREAM</u> <u>Overall Comments</u> 1. Regarding the air quality impact assessment, the numerical modelling studies are for the purpose of scoping the comprehensive physical modelling study. Throughout the IAR, it seems that the consultants have overlooked this major point and have made much evaluation as well as drawn conclusions based on the numerical modelling results. Instead, such evaluations and conclusions should be based on an analysis of the results of the physical modelling study.	1. The IAR makes several references to the use of the numerical modelling for scoping purposes (e.g. paras 5.34-5.37, 5.136-5.137, 5.138, 5.190). It is considered that the numerical modelling has assisted an overall assessment of impact and that neither the physical model nor numerical model should be treated independently. Physical modelling however, is considered to be the more definitive approach and this is emphasised in the IAR.	Nil	Noted
	2. In view of the above, we have combined our comments on the draft IAR and the draft Wind Tunnel Assessment Report and any of our comments should be read in the context of paragraph 1. We strongly suggest the consultants to review and revise their evaluations and conclusions in the IAR, for those made based on the results of the numerical modelling studies, in the light of the physical numerical modelling studies.	2. The report clearly documents the conclusions of the physical model (and numerical model) tests. No revision of the IAR is therefore considered necessary.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	3. We have also much concern that in the physical modelling study, the sensor arrangement is not as comprehensive as we have agreed (ref. HEC's letter D&P/320/00/02a of 31.10.90) and some of the agreed wind speeds have been skipped out in the measurements without any prior consultation and agreement with us. We would like to know the reasons and rationale behind these changes.	3. Sensors - The agreement on elevated sensors was implemented as intended, with some extensions. It was not intended, however, that there should be elevated measurements above all ground level locations. During the course of pre-test discussions the number of elevated sensor locations was increased. The consultants are confident that the coverage was adequate and further analysis of the available information will be undertaken in relation to the final Key Issue Assessment. Wind Speeds - No wind speeds were skipped in relation to the agreed programme. In fact, extra wind speeds were undertaken to extend the low speed end of the tests. The rationale of the test programme, in this respect, was to detail the wind speed variation for some, but not all directions and to check for other directions that the maximum concentrations occurred at similar speeds. The Consultants are confident that the range of sensors and meteorological conditions covered are sufficient to determine the air quality impact arising from L7 and L8.	The characteristic behaviour of concentration with windspeed, which the consultant had found to be adequate for serving as background for estimating worst impact for other more sparsely studied directions, should be provided in the IAR or the KIA report to support the chosen wind speeds in the wind tunnel tests.	The point is noted and has been addressed in the KIR.

Reference	Comments	Consultants Responses	Additional Comments	Response
	4. It is noted that in the estimation of pollutant emissions, the consultants have adopted emission quantities which are lower than the emission limits required by BPMs and/or licensing conditions. We would like to know more about the basis for these emission quantities from the consultants. More importantly, we have to draw the attention of HEC to that if emission quantities lower than the currently specified/adopted limits can be achieved with present installations and technology, they will form the basis for BPM and licensing requirements for the renewal of licence in the future. Therefore, would HEC please confirm that the adopted emission quantities are realistic and will not create any operational difficulty in the future.	4. The pollutant emission quantities for Unit L1 and L5 are calculated based on historical worst situation over the past 5 years. For Unit L6, design data have been used while for L7/L8, the same emission quantities as L6 have been used. In view of the above, the adopted emission quantities are all realistic quantities and would not create any operational difficulty to HEC in the future.	As HEC has no operational difficulties in meeting their proposed emission limits and can design L7/L8 to meet the dust requirements of 50 mg/m^{3}, the emission figures, together with assumptions made in the EIA studies, will form the basis for considering the S.P. licensing of the plant.	Noted
	5. The air quality assessment has focused only on the maximum hourly concentrations. As the AQOs consist of also annual and daily averages, the consultants should evaluate the air quality impact in terms of annual and daily concentrations. This aspect is particularly important in considering the margin left in reaching the AQO limits. These would be different margins left for different time averages.	5. Maximum hourly was chosen as the basis for assessment as it would likely represent 'worst case' conditions. Additional data will be provided on annual and daily averages.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	6. From the results, it seems that the emissions from the Lamma Power Station alone will consume 80% of the hourly AQO ceiling. Take SO_2 as an example. A 20% margin is 160μg/m^3. Hourly concentrations exceeding this value are very common in many areas of Hong Kong, particularly in the vicinity of industrial establishments, urban areas or even restaurants. Therefore, adopting a 20% margin straight, i.e. a 160μg/m^3 hourly concentration limit, to accommodate all other sources will mean a very stringent development constraint for those areas affected and is an issue that needs to be further explored. In this context, it is considered that more work should be done to:- - evaluate further the air quality impact with an aim to determine also the margins left in terms of annual and daily concentrations (comments in 5. are relevant); and - assess how the margins will affect the development potential/ land use options; and identify any requirements and constraints that should be imposed in the areas affected, with and without retrofitting any of the units 1 to 5.	6. During the course of the study the existing Development Plans were examined and referenced briefly in the IAR (Chapter 5) and Wind Tunnel Report. Supplementary work will now be undertaken to address EPD's comments. This work will be presented in a separate Key Issue Report.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	I. <u>INITIAL ASSESSMENT REPORT</u>			
1. Summary	1a. Penultimate para. on Pg. ii The numerical modelling (including RTDM) is merely to define the scope of the wind tunnel tests. It is the Physical Modelling Study to assess whether any AQO exceedence will occur. It will therefore be misleading to state in the Summary without qualifications that the results of RTDM indicated "the predicted ground level concentrations remained within the relevant AQO in all cases".	1a. It is considered that the Summary states quite explicitly that the conclusion referred to relates to the numerical model results. We do not therefore consider this statement is misleading.	Nil	Noted
	1b. 4th para. on Pg. iii It would not be appropriate to base on numerical modelling results to predict the margin between the predicted maximum SO_2 concentrations and the AQO as the numerical modelling is merely to serve scoping purpose. The margin should be estimated from the findings of the wind tunnel tests. Regarding the environmental benefit and economic penalty of retrofitting FGD onto the existing units, the prime factor of consideration should be whether the plant without FGD retrofitting will cause air pollution problems.	1b. Additional work will be undertaken as a key issue to determine the margins based upon physical model results. The environmental benefits of FGD retrofitting cannot be viewed in isolation without consideration of economic impacts. Such an approach would be inconsistent with BPM or BATNEEC.		

Reference	Comments	Consultants Responses	Additional Comments	Response
2. Baseline Air Quality Conditions (Pg. 46)	2a. If the air quality data from EPD's monitoring stations are relevant, more than one year's monitored data should be reviewed.	2a. It is considered that one years data is adequate for the purpose of establishing current baseline. Earlier data may not be entirely representative of current conditions due to changes in emission sources or strength.	Nil	Noted
3. Dispersion Modelling (Pg. 52-56)	3a. The consultants should note that the main objective of the numerical modelling is to define the scope of the wind tunnel tests.	3a. Agreed.		
4. Estimating Airborne Emissions (Pg. 56-60)	4a. The consultants should provide the basis of the "realistic limits" appeared in table 5.5 on Pg. 57. HEC have to note that if a lower emission limit can be achieved without technical or economic difficulties, it will form as the BPM or licensing requirements in next licensing renewal. 4b. In Table 5.5, the particulate emissions from L6 to L8 are 115 Kg/hr each. This emission rate is based on 85mg/m^3, which is the requirement imposed on L6. However, the corresponding requirement for L7 and L8 is 50mg/m^3. The consultants should therefore amend the corresponding emissions rates in the table.	4a. The basis of the realistic limits is the maximum emission levels likely to be experienced under any 'worst case' scenario with all units operating according to a peak load schedule. 4b. If the impact of particulates is found to be environmentally acceptable for an emission rate of 85mg/m^3, then it should also be acceptable for 50 mg/m^3. Please note that L7/L8 can be designed to 50 mg/m^3 based upon a similar design to Unit L6.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	4c. The assumption that no significant change to the ratio of air pollutant against load is not valid for NO_x emission, in particular.	4c. The part-load assumption will not affect the assessment for the worst case scenario which has taken full load data. As the air pollutants are generated from combustion of fuel which is approximately proportional to load output, the assumption of no significant change to the range of air pollutant against load is considered sufficient for environmental assessment purpose. For NOx from the coal-fired units for which reliable part-load emission data are not available, the combustion temperature is also reduced in addition the reduced coal burnt at part-loads and the present assumption should not have caused underestimation of environmental impact. For NOx from the gas turbine units, please note that we have assumed a linear relationship based on the licence NOx and gas flow limits for the two load points stipulated in the licence and have also ignored the variation of $\%0_2$ with load. Such an assumption will undoubtedly give a very environmentally safe impact analysis. We will reword the paragraphs to clarify the assumptions better. Please also note that the present part-load analysis has assumed a peak day load curve throughout the whole year and this would again give an ample safety margin in the environmental assessment.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
5. Short Term (Emergency) Conditions (S.1.2D on Pg. 5 and Pg. 65)	5a. Under the APCO Fuel Restriction Regulations, all liquid fuel to be used by new generating units should not have more than 0.5% sulphur content.	5a. Noted.	Nil	Noted
6. Model Calibration (Pg. 65-66 and Appendix 91-92)	6a. Model calibration demands representative wind data for the specific hours chosen for the calibration. The lack of representative wind data is detrimental to the calibration study and can be the major cause of the weak correlation between the monitored and predicted concentrations. Under this circumstance, the consultant should not draw conclusion on the performance of the model.	6a. It is considered that the wind data is representative for the purpose of the calibration study but it is acknowledged that detailed wind data would be needed for full performance assessment. However detailed performance assessment is outside the scope of the IAR, as stated in Para. 5.87. The data provided in the calibration study are, however, considered useful in assessing a broad scale of agreement between model and field data.		
	6b. Based on Fig. 5A.2 and 5A.3, the model over-predicts as well as under-predicts the concentrations at Victoria Peak, it seems that the claim of the consultant on the numerical modelling being unrealistically pessimistic is not well found. This is further illustrated by their findings in the wind tunnel tests that AQO exceedence can occur against the predictions of RTDM that no AQO exceedence is anticipated.	6b. Figs 5.A2 and 5.A3 indicate that the <u>majority</u> of the calibration data show the model over-predicts actual SO_2 concentration. Whilst <u>some</u> data shows a degree of under-prediction the weight of the evidence demonstrates that numerical results are probably pessimistic. The conclusion is therefore substantiated by the data. No numerical modelling was done for North Lamma where physical modelling predicts possible AQO exceedence, therefore the RTDM results are not inconsistent as is being suggested.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
7. Results of Dispersion Modelling (Pg. 66-73)	7a. The results of the dispersion modelling did not appear to have been put in the context of defining the scope of the wind tunnel tests. In the reports, several sets of predictions by different numerical models were extensively presented. This is conducive to confusion on the actual impact of the stack emissions. Furthermore, it is misleading to plot the predictions of the ISC model for areas at the lee of the mountainous terrain, which were beyond the capability of the model. The consultants should review the section.	7a. The report presents a comprehensive analysis of both numerical and physical test results, and places the numerical model in the context of scoping (e.g. para. 5.37). It is acknowledged that the report is complex as befits a study of this importance. With regard to ISCST, in all cases it will predict higher concentrations in the lee of mountainous terrain due to its conservatism. Its use as an initial screening model is therefore entirely appropriate in the context of the overall study.	Nil	Noted
	7b. The assumption in S5.107 on Pg. 67 that the proportion of respirable particulate in total particulate emission from Lamma Power Station equal to the average figure in Hong Kong is not acceptable. After the collection of the large and heavy particles by the electrostatic precipitators, the emitted portion should be mainly fine and below 10μm. Unless otherwise supported by data of actual particle size analysis or literatures, it is more appropriate to assume all the particulates emitting from Lamma are RSPs.	7b. Manufacturers data for the EP outlet indicates respirable particles (i.e. $<11\mu$m) account for about 79% of total dust emitted. This figure is similar to that used in the IAR and the conclusions reached are therefore considered reliable. However, the point will be addressed in the Final IAR.	Nil	Noted
	7c. A figure showing the locations of the receptors in Table 5.7 and 5.8 on Pg. 69 should be provided.	7c. Figures showing the locations of the receptors will be provided in the Key Issue Report to be produced.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
8. Abnormal Operations / Emergency Conditions (Pg. 74-75)	8a. It is surprising to find in S.5.135 that the maximum ground level SO_2 concentrations under this very severe emission scenario were only between 110μg/m^3 and 200μg/m^3. The prediction should be made by a modelling methodology capable of taking into account the effect of mountainous terrain and the impacts onto elevated receptors. As such, the predictions should be made by, preferably, the wind tunnel tests or RTDM/ISCST. The consultants should review the predictions for this scenario.	8a. The basis of the impact assessment under emergency conditions was to use worst case emission data with 'standard' meteorological data as used by HMIP for power station assessments in the UK. (i.e. Stability Class D, wind speed 5m/s).	Nil	Noted
	8b. It may be desirable if the consultant could advise the anticipated frequency of occurrence of these abnormal operation/emergency conditions, based on the previous experience in the Lamma Power Station, to support the insignificance of these operations.	8b. The frequency of the emergency scenario tested would be extremely rare, if indeed it ever occurred. Even with this extreme emission scenario, however, results indicate impacts will be acceptable. No extreme emission scenario of the type modelled has ever occurred at Lamma and hence the conclusions are considered reasonable.	Nil	Noted
9. Physical Modelling Study (Pg. 75-82)	9a. Please see our comments on the Wind Tunnel Tests Report.	9a. Noted.		

Reference	Comments	Consultants Responses	Additional Comments	Response
10. Fugitive Dust (Pg. 84)	10a. It is practical to achieve the particulates emissions from material handling to not exceeding 50 mg/m^3 without excess financial implication. Unless supported to be impracticable, this limiting value would be imposed to new systems for L7 and L8 during licensing.	10a. It is understood that the limit of 50mg/m^3 would only be applicable to exhausts fitted with bag filters or equivalent devices.		
	10b. In addition to the increase of dust emissions because of the loading/unloading and transportation of FGD materials and wastes, the throughput of coal would also be increased. To ensure the villagers in the vicinity would not experience unacceptable air quality, the consultant should conduct a quantitative assessment and provide an estimation of the emission inventory. Or else, a Key Issue Report should be more preferable.	10b. As discussed with EPD, whilst a quantitative assessment could be undertaken, the uncertainty with regard to emission strengths and site activities means that any such quantified approach must be rather speculative. It is considered that appropriate design controls together with efficient site management should ensure that increases in dust emissions are not significant. Monitoring of dust levels at the site perimeter will provide an ongoing check on the performance of dust control measures.	We concur with the consultants that the fugitive dust emissions during the operation of the plant can be tackled by appropriate design controls, efficient site management and dust monitoring at site perimeter. HEC should approach us as soon as possible for agreement on the details of these measures.	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
11. Trans-frontier Pollutant Transport (Pg. 86)	11a. The ISCLT run seems to have been made with the suppression of all stable situations to neutral. However it has been established in s.5.27 that only the frequency of stable conditions associated with W/SW winds is extremely rare. It would then be over-optimistic to convert all stable conditions to neutral. The consultant should review the predictions and assess how they are affected by the model limitations. 11b. The consultant should advise if the acidic deposition would be an issue and needs to be addressed.	11a. ISCLT was run for a full years meteorological data and included all stability conditions. 11b. It is not considered that the small increase in SO_2/NOx predicted to arise from Units L7 and L8 will make any significant contribution to acidic deposition.	Nil	Noted
12. Odours (Pg. 86)	12a. The odour emission caused by the hydrocarbon vapour emissions during fuel oil handling has not been addressed. As a boundary odour limit of 2 o.u. would be imposed in the specified process license, it would be desirable if the consultant could advise if any further mitigation measure is necessary to meet such limit.	12a. HEC report that no complaints of odour have been received from the existing operations of Lamma. Because the new units L7 and L8 will be coal fired, no significant increase in fuel oil handling is anticipated, thus additional hydrocarbon vapours are not likely to be significant. No further mitigation measures are likely to be needed.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
13. Air Quality Monitoring (Pg. 330)	13a. The exact monitoring program should be determined after the acceptance of the conclusions and recommendations of the impact of the stack emissions of the power station. However, as far as the source monitoring is concerned, it is considered that the continuous monitoring of particulate emission should also be included. In addition, in order to provide a tighter and continual check on the performance of pollution control devices, the requirement of the transmission of the instantaneous source monitoring signals to ACG's office would also be imposed during the licensing of the premises.	13a. Noted. It is understood that current arrangements for data submission to Government by HEC are satisfactory and comply with existing legislative requirements. The matter will need to be reviewed at the next licence renewal.	Nil	Noted
	13b. The consultant should also advise how the effectiveness of the dust control measures during construction phase be monitored.	13b. Regular site inspection by HEC environmental staff is recommended to ensure compliance with dust control measures. High volume air sampling at the perimeter of the site on a regular basis is also planned during the construction phase.		

Reference	Comments	Consultants Responses	Additional Comments	Response
14. Dust Control (Pg. 40)	14a. It should be pointed out that the TSP AQO of 260$\mu g/m^3$ would be applicable to the site boundary. The consultant should advise if the proposed dust control measures would be sufficient to attain and maintain this AQO under all conditions. A quantitative approach would be more desirable. 14b. The Section, S.4.56, appears to conclude that water spraying will be sufficient to reduce the dust emissions due to construction activities. Other mitigation measures, e.g. hard surfacing, haul roads, surface treating stockpiles, limiting vehicle speed, etc. should also be considered and the appropriate contract conditions be imposed.	14a. As noted above, a quantitative analysis at this stage is not considered to be helpful due to the uncertainties in prediction. The best approach is to ensure effective management of dust control measures during construction. 14b. The precise nature of contract conditions are best determined when details of construction activities are available. At this time; the full range of mitigation measures suggested can be considered and implemented as necessary.	Nil	Noted
15. Other Comments	15a. The consultant should advise if the emission of toxic air pollutants, including heavy metals, polycyclic organic matters and dioxins, would be an area of concern.	15a. Toxic air pollutants are not normally considered during EIA's of power stations as they are generally insignificant in impact terms. This is not therefore regarded as an area of concern.	Although the impacts of toxic air pollutants including heavy metals, polycyclic organic matters and dioxins may be insignificant, a brief description to this effect should be included in the IAR for the sake of completeness.	A statement to this effect will be added to the IAR.

Reference	Comments	Consultants Responses	Additional Comments	Response
	II **WIND TUNNEL TESTS REPORT**			
1. Executive Summary	1a. Please clarify whether "the implementation of FGD" in the 6th para. on Pg. 6 refers to "the retrofitting of FGD to any of L1 - L5".	1a. The remark applies to retrofitting FGD. Only retrofitting FGD to L4 and L5 was examined in the study.	Nil	Noted
2. S.3 Approach to Model Tests	2a. S.3.2.2. Scaling Techniques (Pg. 11-13) The enhanced scaling techniques were said to have been used in the simulation of the stack plume. The consultants should clarify under what circumstances have each been used.	2a. The term "enhanced scaling" refers to the use of exaggerated buoyancy in the plume, providing a method to test at very low wind speeds. In the early phase of the tests, two types of enhanced scaling were used. Method 2 was chosen as providing the most consistent match to exact scaling. All the complex terrain results were obtained using this method.		
3. S.5 Test Procedures and Concentration Measurements	Figure 5.1 (Plume Height Versus Downwind Distance) a.1 The plume rise said to be based on ISCST, which adopts Briggs Plume Rise Model, appears to be excessive. We have estimated the plume rise by the same Plume Rise Model and found that the plume is expected to reach its final plume height of about 600m above ground at about 2Km downwind for a wind speed of 2.7m/s and neutral condition. In comparison, the far-field plume rises in the figure are all higher. Please clarify whether the simulated plume rise is excessive.	a.1 It is believed that the plume rise is consistent with the Briggs formulation and that the results presented are accurate. An analysis of the method used to calculate plume rise is attached to these comments.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	a.2 The enhanced scaling type 2 is said in s.5.4.9 to be used for the majority of the measurements. It is rather undesirable that the plume rise measurements for enhanced scaling type 2 was not as comprehensive as those for type 1. It would be helpful if further information is provided on Melbourne's validation to support the enhanced scaling technique.	a.2 The consultants accept EPD's point. It is noticeable, however, that the plume rise results compare favourably by the different methods. The referenced paper by Melbourne is attached to these responses for further information.	Nil	Noted
	3b. S.5.4 Detailed Concentration Measurements for Ground and Elevated Receptors (Pg. 21-23) b.1 The NO_x emissions in table in s.5.4.3 on Pg. 22 are lower than the licensed limits. HEC have to note that the limits of these emissions would be adjusted accordingly in the next license renewal.	b.1 Response to point 4 above also applicable to this comment.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	b.2 The sensor arrangement is not as comprehensive as we have agreed (Ref. the letter from HEC of reference D&P/320/00/02a dated 31st October 1990). The sensor arrangement in the measurements have left out the following receptors:- i) elevated receptors at Sandy Bay (sensor [1,4]) ii) elevated receptors around Pok Fu Lam (sensor [2,5]) iii) elevated receptors at Wah Fu Estate (sensor [3,3]) iv) elevated receptors at Ap Lei Chau (sensor [4,4]) The consultants should, based on the available results of the measurement or otherwise, estimate the impacts to the above receptors. b.3 Furthermore, comments on the air quality impacts to the following major development areas should also be made based on the measurements:- i) Aberdeen; ii) Wong Chuk Hang.	b.2: b.3: The misunderstanding over the programme, with regard to elevated sensors has been responded to in "Overall Comments 3." However, in response to EPD's request, further analysis will be undertaken and estimates made for the identified locations and also for Aberdeen and Wong Chuk Hang. This work will be contained within the Key Issue supplement described in "Overall Comments 6."	See point 3 of overall comments.	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	b.4 It had been agreed that wind speeds including 2.7m/s, 5.4m/s, 8m/s, 12m/s and 15m/s would be used in the measurements. In the measurements, some of the wind speeds had been skipped without giving justification. The consultants should provide the justification and assess if the estimated worst impacts at those receptors would be affected.	b.4 The agreed wind speed programme was undertaken and this comment has been partly addressed in "Overall Comments 3." The characteristic behaviour of concentration with wind speed was established for near field, mid and far field locations and this information became a background for estimating worst impact for other more sparsely studied directions.	See point 3 of overall comment.	Noted.
	b.5 Our concern is not limited to ground level receptors. Please provide tables similar to Tables 5.46 and 5.47 and figures similar to Figures 5.7 to 5.12 for elevated receptors.	b.5 All elevated receptor measurements are presented in the report, but not in this format. They were assessed in drawing the conclusions in the Wind Tunnel Report. Figures and Tables of the type requested will be included in the Supplementary Report on the Air Quality Key Issue and will include the further estimates addressed in 3.b.2.		
	b.6 In Table 5.42, the NO_x concentration for (15m/s, 30m height and T2) is 583.7$\mu g/m^3$ and the corresponding SO_2 concentration is 285.3$\mu g/m^3$. Please clarify whether they are correct.	b.6 583.7 should read 283.7.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	b.7 Some figures in Tables 5.46 and 5.47 are inconsistent with those presented in the preceding tables. For example, the SO_2 concentration for sensors [2,11]. [8,2] under T1/T4 scenario and others; the SO_x for sensors [1,1] under T1/T4 scenario and etc. The consultants should make a thorough check and amend the two tables.	b.7 A number of small changes have been made to the tables. The revised versions will appear in the final wind tunnel report.	See point 3 of overall comment.	Noted.
4. S.6 Discussion of Results	4a. In comparing the predicted concentrations with the AQOs, background concentrations had not been added. While we accept that under those adverse scenarios for the power station to cause air pollution problems, the Lamma Power Station would be the major pollution source, it would still be desirable for the sake of completeness to have background concentrations added to their estimation. 4b. The consultants should estimate the accuracy of the wind tunnel tests and its implication on the conclusion of the study.	4a. Background concentrations will be assessed further in the context of the action to "Overall Comments 6." 4.b The accuracy estimates will be included in the final wind tunnel report.	See point 3 of overall comments.	Noted.

Reference	Comments	Consultants Responses	Additional Comments	Response
	4c. S.6.4 Sulphur Dioxide c.1 The joint probability of AQO exceedence was estimated to be 2 hours under neutral conditions. However, it is possible that lower wind speed at slightly unstable conditions and/or in the presence of background concentration will cause AQO exceedence. It would be desirable to take these conditions into account while making the estimate. c.2 Furthermore, it would be necessary to make use of long term meteorological data (at least, a period of 5 consecutive years) for the estimation of the probability of AQO exceedence.	c.1 The highest concentration within the plume will occur when the plume is least spread. Whilst at a particular wind speed, a particular ground level receptor might well receive more concentration in an unstable atmosphere, it is unlikely that the maximum will occur this way if at a higher speed the plume more obviously touches down. If, as seems likely, the plume is more tightly contained in a strongly wind blown situation, then this will lead to the highest concentration values. c.2 Long term data was in fact used. Data from 1979-1988 was utilised.	See point 3 of overall comments.	Noted.
	c.3 Although most of the exceedence occurs at uninhabited hilly locations, it should be noted that the village Pak Kok Tsuen is rather close to sensor [1,2].	c.3 We agree that Pak Kok Tsuen is close to sensor [1,2]. It would not, however, seem that the AQO will be exceeded at this location, due to the infrequent incidence of appropriate winds. If in addition, allowance is made for the average sulphur content of coal burned at Lamma (0.7% average 1982-89), then the likelihood of ever breaching the $800\mu g/m^3$ limit is virtually eliminated.	Since the development potential constraints of the plant will be assessed as a KIA, we therefore do not intend to raise further comments on the air quality impacts in Pak Kok Tsuen. However, we would like to point out that in principle, average coal sulphur content being less than 1% is not acceptable to us as a mitigatory factor.	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	III WIND TUNNEL TESTS - CONSIDERATIONS AND PROGRAMME			
	1. This report has now been overtaken by events. At the moment, our concern is whether the IAR report coupled with the Wind Tunnel Tests Report have satisfactorily resolved all air quality issues. It seems therefore unnecessary to comment on this report.	1. Accepted	Nil	Noted
	2. Page 4 of the report is missing.	2. The missing text is "... November and the reporting December 1990".		

Reference	Comments	Consultants Responses	Additional Comments	Response
	<u>COMMENTS FROM DIRECTOR OF AGRICULTURE AND FISHERIES</u>			
1. Page 218, para. 9.14 Last sentence	1. It is true that an increase in temperature may accelerate the growth of planktonic larvae, thus allowing earlier development. However, as stated in the last sentence of para. 9.08, this effect may not be beneficial as 'the larvae may still be unable to grow if they are out of sequence with the availability of their own normal food supplies'. This sentence is therefore not totally correct.	1. In paragraph 9.14 the effects of temperature increases of 0.2 to 1.0°C in Lamma inshore waters are discussed. Changes of this order come within the range of natural variations as might occur between individual years. The effects noted would be detectable e.g. higher growth rate earlier spatfall by maybe 1 or 2 weeks , but can be expected to be marginal in effect. In comparison the earlier reference to major disruption of reproductive timing (Para 9.08) was in relation to "Changes ... in excess of those which are natural ..." (Para 9.08) which were further defined in Para 9.9 first sentence "changes of about 2°C above the natural or ambient temperature can lead to unacceptable stress and adverse ecological consequences." Increases of this order will only occur in the mixing zone and therefore have only a very local effect on populations of invertebrates. In our view Para 9.14 makes this point in the second sentence and then goes on to deal with smaller temperature increases within natural limits.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
2. Page 218 Para 9.15 Last sentence	2. The fact that seaweeds appear only in winter months means that local winter temperature is more favourable for their growth. As such, the adult plant form may not be able to take advantage of the warmer water in the heat discharge area.	2. AFD's comment is not contested as there are no data for Hong Kong or South East Asia stocks of seaweed which would allow an accurate prediction. There may be temperate climate species which could be adversely affected in the manner AFD suggests. If however, this is the case these would be replaced by more robust species able to accept temperatures which have already been shown to be within normal between year variations.	Nil	Noted
3. Page 221, Para 9.22 Last sentence	3. According to Table 6A.5, the average cadmium concentration at cw outfall, and chromium concentration at both cw outfall and remote site have already exceeded the permissible levels in the Hong Kong Food Adulteration (Metallic Contamination) Regulations.	3. The data referred to in Table 6A.5 are on a dry weight bases, which give a higher concentration per cent mass than the wet weight used in the HK Food Adulteration (Metallic Contamination) Regulations. On a wet weight basis all measured concentrations would be below the relevant criteria.		
4. Page 216, Para 9.03 3rd sentence	4. The data mentioned actually refers to those vessels based at Yung Shue Wan. I suggest to insert 'based at Yung Shue Wan' between 'purse-seiners' and 'may'.	4. Agreed, will be amended in Final IAR.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	<u>COMMENTS FROM PLANNING DEPARTMENT</u>			
	1. I have doubts on whether or not the contract for the existing quarry in Sok Kwu Wan would be extended. Principal Government Geotechnical Engineer would be in the better position to advise you on this matter.	1. Comment noted, but to our knowledge no firm decision has been made at this time.	Additional comments reserved pending the KIR submission.	Noted
	2. The Lamma Quarry area might eventually be reserved for low density residential/recreational use. According to paragraphs 7.62 and 7.66 of the draft report, gypsum is slightly water soluble and may not be a good foundation for building loads. Under the circumstances, I am concerned that the proposal to dispose of FGD gypsum within the Lamma Quarry area might sterilise the development potential of a valuable site.	2. This concern is appreciated, but please note that we have stressed in the report the need to design the restoration within the framework of engineering and planning objectives - planning requirements and constraints would therefore be taken into account.		
	3. I cannot support the proposal to reserve areas within the Lamma Quarry for your company to create a gypsum stock pile for future abstraction since it would deter planners from formulating land use proposals for the whole quarry site.	3. Comment noted, but given a long restoration period, there could be some scope for temporary stockpiling.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	4. Before this office can agree to the idea that FGD gypsum might be used for beneficial restoration, the following issues should be investigated by the consultants: a) detailed design and methodology demonstrating that FGD gypsum can be used as a fill material for recreational uses; b) laboratory test and pilot studies proving the detailed feasibility of FGD gypsum being a good restoration fill for subsequent landscaping proposal; and c) the engineering properties of stabilized gypsum demonstrating the scale of building proposals which could be contemplated within a FGD gypsum/PFA co-disposal site.	4. We are satisfied that the feasibility of gypsum land-filling is established from overseas experience and we agree that further work will be needed at the Key Issues Stage to relate the details of this experience to the quarry restoration option.	Additional comments reserved pending KIR submission.	Noted.
	5. The draft Yung Shue Wan Layout Plan as indicated in Para 12.30 of the draft report is under revision; and	5. Noted.	Nil	Noted
	6. The Planning Department is reviewing the development potential of the Lamma Island. The planning proposals as indicated on the adopted Lamma Island Outline Development Plan area, therefore is subject to amendments.	6. Noted.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	<u>COMMENTS FROM GOVERNMENT SECRETARIAT</u>			
	Letter ref ESB CR 12/4576/76 (90) VII dated 28/1/91. 1. My only concern is on the conclusion made by the Consultants as stated in Page viii of the Summary. The Consultants concluded that "Environmentally there are no major unacceptable impacts predicted to arise from the provision of the additional generating capacity at Lamma....". Does this imply that it is unnecessary to further retrofit the existing generating units with FGD? I understand that this is only an Initial Assessment Report. However, I should be most grateful if the Consultants can be more specific in their conclusions, and recommend whether further retrofitting of FGD in the existing generating units is necessary.	1. On the basis of the analysis presented in the report, the development of units L7 and L8 could go ahead without unacceptable environmental impacts and without the need for retrofitting existing units with FGD.	HEC should clarify whether the response is merely based on the preliminary view of the Draft IAR, which needs to be further investigated by a KIA as agreed in the previous SMG meeting.	As stated in the Consultants response this view is based upon the analysis presented in the report, which necessarily represents the conclusion of the initial assessment. More detailed analysis and conclusions will be provided in the KI report, as agreed at the SMG meeting.

Reference	Comments	Consultants Responses	Additional Comments	Response
	2. Letter ref ESB CR/12/4576/76(90) VII dated 7/3/91. 2a. As I mentioned at the meeting yesterday, the Government had carefully examined the latest Financing Plan submitted by HEC. Approval had been given for unit L7 to proceed as proposed but in the case of unit L8, the decision had been withheld pending further study by your company. It would be useful, therefore, in the carrying out of the EIA, the position as just described should be taken into account. It cannot be assumed that L8 would proceed unless and until this has been accepted by the Government and it would therefore be desirable for your consultants to highlight whether any changes would require to be made to their findings in the event that L8 does not proceed in accordance with the timeframe as originally envisaged.	2a. The draft IAR is based on the agreed Terms of Reference (TOR) from EPD assuming that both L7 and L8 to be installed in Lamma Power Station and is aimed to investigate whether or not the proposed installation is environmentally acceptable. The analysis has also shown that the proposed installation of both L7 and L8 is environmentally acceptable. Any delay in L8 installation program beyond 1997, if required, would be due to actual lower electricity growth rate than in the original load demand forecast. This means the total pollutant loadings from the Lamma Power Station would be lower than that assumed in the IAR in the delayed L8 installation program. As a conclusion, the environmental impact due to the delayed L8 installation program would not be in any way worse than that found in the IAR. Therefore, there is no need for a separate report discussing the effect of delay in L8 installation program.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	2b. I was informed at the meeting that the economic and costing analysis of the EIA will be covered at a later stage of the study. I would take this to mean that the EIA would not be finalised until all the relevant factors including the costing analysis have been considered. I am sure you agree that there is a need to view the matter from an overall perspective before the finalisation of the EIA.	2b. The Economic Assessment and Tariff Comparison Report is part of the EIA and will be prepared basically following the TOR for the EIA.	Nil	Noted
	2c. It will be useful for your consultants to indicate, in the study of FGD retrofitting, the cost that is going to be involved. Our general concern is whether it will be cost-effective to retrofit bearing in mind the plants in question would already have a shorter remaining useful life. Our current understanding is that the capital cost of retrofitting FGD in old units can be 30-40% higher than the cost for new units and it would be useful if your consultants could be asked to advise on the relevant cost-effectiveness.	2c. According to the information from the suppliers, the capital cost of FGD retrofitting to the existing unit is very close to that of installing one to a new unit. The minor difference in cost lies mainly on the erection portion. Whether it is cost-effective or not to retrofit FGD, or indeed the need to retrofit at all, to the existing units totally depends on the government's decision subject to the findings and recommendations of the final IAR.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	2d. We understand that in some plants in the United States, they are only required to reduce sulphur dioxide emissions by up to 70% if they use very low sulphur coal. Does it mean that if we are to aim at 90% removal as is required by DEP, coal with a slightly higher level of sulphur content could be burnt for generating electricity in the future ? You may wish to consult DEP on this matter.	2d. Technically speaking, there is no difficulty for FGD equipment to handle coal with higher levels of sulphur content in achieving 90% SO2 removal efficiency. The EIA was carried out according to EPD requirements on SO2 removal efficiency of 90% and coal sulphur content of 1%.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	<u>COMMENTS FROM DIRECTOR OF ELECTRICAL AND MECHANICAL SERVICES</u>			
	1. According to Para 3.1 (xi) of the TOR of the study, one of the objectives of the study (which I believe) is :- "to identify and assess the economic, cost and tariff implications of the installation on the site and, if necessary, the different environmental pollution control measures/standards and monitoring requirements associated with each of the alternative retrofit options for Units L1 to L5 on the site". The above report does not seem to have fully addressed this issue. Perhaps the Consultants should be asked to highlight what they have accomplished in their study in this respect, and to indicate what are their findings/assessments and conclusions.	1. The economic implications of any pollution control measures required for Units L1 to L5 can only be assessed once the need for such measures have been identified and agreed. The studies conducted to date do not suggest that retrofitting will be needed, hence it would be inappropriate to consider the economic/tariff issues at the IAR stage. A full assessment of such issues will be conducted once the need for additional pollution control measures has been identified more precisely.	Nil	Noted

Reference	Comments	Consultants Responses	Additional Comments	Response
	COMMENTS FROM EPD : NOISE STREAM			
1. General	1. Whilst the criteria used in the noise assessment by determining an acceptable Target Noise Level in Section 11 is supported, the Report lacks, in general, a consistent approach in the assessment with reference to different Technical Standards (TS) published under the Noise Control Ordinance. Details of any comments are listed below.	1. It is noted that the criteria adopted is supported by EPD. It is considered that the report has consistently followed the methods contained in the relevant Technical Standards, and this is reflected by the text in the IAR.	Nil	Noted
2. Section 4.12	2. In August 1989, legislation was not 'passed' but 'enforced' prohibiting the carrying out of general construction work.	2. Agreed. This will be modified in the final version of the IAR.		
3. Section 4.13	3. Exemption of the provisions of the Noise Control Ordinance may only be made by the Governor in Council. Legislation was not 'passed' but 'enforced' in November 1989 prohibiting 'percussive piling' between 7 pm to 7 am and on holidays, and restricting the hours of operation at other times by means of a system of Construction Noise Permits.	3. Agreed. This will be modified in the final version of the IAR.		

Reference	Comments	Consultants Responses	Additional Comments	Response
4. Section 4.15 to Section 4.34; Section 4.43	4. It should be noted that according to the relevant Technical Memorandum (TM) in assessing night-time construction noise, the unit of noise level is L_{Aeq} (5 min). For daytime construction noise assessment, we recommend the use of L_{Aeq} (30 min). Unless it is anticipated that the average monthly L_{Aeq} figures suitably represent the respective L_{Aeq} index under consideration, the results as represented in Tables 4.7 to 4.9 should be reviewed for meaning full comparison with the appropriate ANLs as stipulated in the TM.	4. In the context of the current knowledge of likely plant to be used, the average noise levels given in Tables 4.7 to 4.9 give a good indication of the likely impact from construction. A more detailed assessment would not be possible until exact details and specification of plant to be used is available. This would occur at the time a construction permit for evening or night time working is applied for.	Since noise from construction work in restricted hours would be controlled under the Noise Control Ordinance, it is acceptable that detail assessment could be done when applying for the Construction Noise Permit.	Noted
5. Section 4.39	5. For the purpose of interpreting Table 4.4, it would be desirable to list down the Influencing Factor being considered. The ASR assigned to each site in Table 4.4 does not match the IF classification. Clarification will be needed.	5. IF classification given in Table 4 should be "not affected" and this will be modified in the final version of the IAR. This approach is already reflected in the ASRs shown in Table 4, which is classed as 'A'.	Nil	Noted
6. Section 11.12	6. The NSRs under consideration should fall within the category of rural area.	6. EPD's comments have been noted, and a noise level consistent with an ASR of 'A' has been adopted for the assessment as noted in paragraph 11.16.		
7. Section 11.13	7. Whilst the type of IF is not identified, the NSRs should be assigned an ASR of 'A' for assessment. Should this ASR be adopted, the Target Noise Level for each NSR should be reviewed.	7. EPD's comments have been noted, and a noise level consistent with an ASR of 'A' has been adopted for the assessment as noted in paragraph 11.16.		

Reference	Comments	Consultants Responses	Additional Comments	Response
<u>FGD GYPSUM</u> Overall Comments 1. **Section 7** WMG	1. In general there is a lack of detail in the assessment and a lack of definitive proposals. It seems that the FGD issue will not be really tackled until the FGD is actually being produced. It could be that at that stage most of the "preferred" disposal means will be ruled out - eg. the quality is not suitable on geotechnical grounds for quarry restoration and marine disposal is not acceptable on environmental grounds, there would then be left the lagoon proposal which is the least desirable one. The consultants must make more firm proposals at the next stage of the EIA and not wait until the waste is produced. This must be resolved at the Key Issue stage (Issues identified in Section 7.111 must be fully addressed.)	1. The main objective of the assessment studies to date has been to identify the principal options for FGD Gypsum disposal and to evaluate whether or not these options are environmentally acceptable. In view of the status of the IAR as an initial assessment report, it is considered that Section 7 of the Report adequately addresses the objective. There is clearly a need for more detailed assessment of the preferred option, including field trials, when gypsum becomes available.	It is insisted that the consultants must make more firm proposals at the next stage of the EIA. It is not acceptable to wait until the waste is available and to make the proposals by that time.	Trial test could only be carried out for those preferred options when gypsum becomes available. On the other hand HEC is currently trying to seek a fall-back option of a long term contract with foreign buyers to take away the gypsum produced.
<u>INDUSTRIAL USE</u> 1. **Section 7.111** WMG	1. As trials are necessary to establish the suitability of the FGD gypsum for cement and wallboard manufacturing, detailed plans for the trial should be developed.	1. Noted. Appropriate plans for such trials will be prepared when gypsum material becomes available.	1. Noted	

Reference	Comments	Consultants Responses	Additional Comments	Response
	2. The properties and variability of the FGD gypsum could make the material unsuitable for industrial uses. Are there any opportunities to control the FGD process to produce gypsum with the desirable properties to allow reuse.	2. The quality of gypsum specified by HEC for Unit 6 as given in table 7.1 of section 7.08 and likely for units L7 and 8 is based on practice widely adopted in power utility with FGD installation and is believed to be suitable for industrial applications. It is reckoned that further control of the properties of gypsum in terms of higher purity and lower moisture content is unnecessary.	2. Proper (not further) control of the properties of FGD gypsum produced is needed to ensure that the gypsum is suitable for industrial application. The quality of gypsum specified by HEC must be suitable for industrial application.	HEC is confident that the FGD gypsum produced will be suitable for industrial use and the quality of FGD gypsum is a specification required to be met by the FGD supplier.
2. **Section 7.105** WMG	1. Industrial use would need buffer capacity and back-up unless uses were guaranteed by long-term contract.	1. The present design has included one Gypsum Silo with a storage capacity of 6,000 tonnes. Based on the anticipated production rate of approximately 4.018 kp/h when burning Rietspruit Coal 13,308 kp/h for Pingshuo Coal and 3,836 kp/h for Tatung Coal for one 350 MW units, the silo is capable of holding about three weeks gypsum production for three 350 MW units. Provision has also been made to construct an additional Gypsum Silo of the same capacity and this will double the holding period to about six (6) weeks. The present arrangement for buffer storage is deemed to be adequate.	Noted	

Reference	Comments	Consultants Responses	Additional Comments	Response
<u>LAND DISPOSAL</u> 1. **Section 7.111** WMG	1. Lamma Rocks Products Ltd has expressed its desire to continue the leasehold of the Lamma Quarry. How would this affect the overall plan for placement of FGD gypsum in the quarry.	1. The consultant is not aware of any proposals for the quarry after 1993.	1. I presume point 2 is addressing this point.	We do not know what plans Government have for extending the quarrying lease at Lamma. Our proposals for PFA and gypsum have been formulated in line with Governments' instruction that we are to assume that quarrying will cease at the end of 1993. We are unaware of any instructions to the contrary.
	2. Detailed plans and implementation programmes for land disposal trials should be developed.	2. A thorough review of restoration plans will be needed if quarrying is to continue.	2. Response is awaited.	
1. **Section 7.45** WMG	1. It is not clear if the production of "rinse" water has been accounted for in Section 6. 2. Will there be sufficient "discrete areas of the restoration" for the anticipated production of FGD gypsum.	1. We have said that a similar philosophy to PFA rinsing may be necessary. 2. This depends on Government land use requirements which are not yet decided.	1. Do the consultants mean that the impact on water quality by the rinse water has been taken into consideration in Section 6.. 2. Noted	The impact on water quality by "rinse water" has not been taken into consideration in Section 6. Until detailed plans for gypsum filling are formulated we cannot know whether there will or will not be "rinse water", nor can we know what its likely quality will be.

Reference	Comments	Consultants Responses	Additional Comments	Response
2. **Section 7.45** SCG	1. Whilst FGD waste does not constitute a toxic or hazardous material, it does constitute a difficult waste, particularly when requiring disposal in large quantities. As the quantities of waste likely to be generated from the power station has not yet been precisely determined, it is difficult to be more specific. Certainly, land based management of large volumes of this waste will be problematic.	1. Comment noted.		
	2. The metal content of FGD Waste Water Treatment Plant is of concern and this would need to be fully evaluated in terms of the acceptable loading rates (as trace metals) before any agreement to co-dispose at landfill could be made. This option requires to be looked at in greater detail.	2. This is the subject of a different study.		
3. **Section 7.113** WMG	1. Consideration should be given to incorporating the disposal of the sludge into the gypsum utilisation/disposal scheme, as it is very similar to gypsum.	1. This is the subject of a different study.	As the FGD waste water sludge is the by-product solid waste of the Units L7 and L8 needed to be disposed, disposal of FGD waste water sludge should be included in the study of this IAR.	A separate study on FGD waste water sludge will be submitted to EPD for endorsement.
<u>MARINE DISPOSAL</u>				
1. **Section 7.111** WMG	1. The environmental acceptability of marine disposal of gypsum should be assessed thoroughly. In this connection, detailed laboratory tests and field trials should be conducted.	1. Comment noted.		

Reference	Comments	Consultants Responses	Additional Comments	Response
2. **Section 7.74** WMG	1. There is a significant shortage of available capacity at marine dumping grounds due mainly to PADs developments. The situation may be improved after the PADs developments are complete, but this cannot be confirmed at this stage. There are also international conventions on dumping at sea which may make it difficult to implement such a policy.	1. Comment noted.		

Reference	Comments	Consultants Responses	Additional Comments	Response
FGD EFFLUENT 1. **Section 6.17** LCG	1. The discharge of FGD effluent should be 'treated' effluent. The consultants should also clarify the term 'c.w. flows', is it referring to the existing c.w. outfall or the proposed additional cooling water outlet?	1. We agree the FGD liquid effluent will be treated. The effluent from unit 6 FGD treatment plant will be to the existing CW outfall. The effluent from units L7 and L8 could be to either outfall. The choice would depend on engineering factors, but would not alter receiving water quality as the two outfalls are side by side.		
2. **Section 2.2** LCG	1. The consultants assume that effluent from L7 and L8 will be subject to similar consent of units L1 to L6. This is not the case. The effluent has to comply with the limits as stipulated in the TM. The same rationale will also be applied to FGD waste water and other waste streams	1. The premise for the IAR, agreed at the beginning of the study with EPD, was that new effluents arising from units L7 and L8 would be to the same standard as existing discharges. The effect of the TM on effluent standards will be considered in the Key Issues report.	Regarding the extent of applicability of the TM in their letter to EPD dated 22nd January, 1991 (Ref: D&P/320/23/01), HEC have already put forward a detailed enquiry. EPD's reply on 8th March, 1991 (Ref: EP52/W2/XD057) state clearly our stand on this issue. In simple terms, our statement made here are still valid. Please also refer to our letter ref: (17) in EP2/N9/17111 dated 14 June, 1991 addressed to HEC's Dr. C M KO.	The applicability of the TM in the context of the IAR is as noted in the consultants response and as confirmed at the meeting of 15 April 1991 with EPD Water Policy Group. Reference to the TM effluent standards will be made in the KIR.
3. **Section 7** LCG	1. The disposal of FGD gypsum, the consultants should note that the discharge limits as presented in TM should be used for Table 7.7 and Section 7.54. Hence it is necessary to review Section 7.55 whether or not leachate from FGD waste water and run-off from FGD waste disposal sites complies with the effluent discharge standards.	1. Comment noted. At the time the report was written the TM had not been published.		

Reference	Comments	Consultants Responses	Additional Comments	Response
	2. There is no discussion on how the FGD waste water from L7 and L8 is treated. However, it is noted in Figure 2.4 and it seems that all effluent from L6, L7 and L8 are to be discharged to one FGD waste water treatment plant. Then effluent from the treatment plants will have to comply with TM.	2. See response to 2 above. The issue of the TM effluent standard will be considered as a key issue.		
4. General WPG	1. The nitrate effluent discharge is extremely high - 50 kg/hr which is equivalent to the total nitrogen in a sewage discharge from 135 000 people (p 222) as compared to max discharge of 180 kg/day stated in Table 10a of the Technical Memorandum. This needs to be further assessed as a key issue. The same applies to the thermal plume effect.	1. The nitrate discharge from the FGD plant has been reviewed now that the FGD unit 6 plant contractor has been chosen. This will reduce anticipated nitrate load in effluent. This matter will be addressed in the Key Issues Report. The area affected by the thermal plume will also be covered in the Key Issues Report.		
5. General LCG	1. The Technical Memorandum (TM) has come into effect on 23.1.91 and it will be used as the basis for setting licence standards under the Water Pollution Control Ordinance (WPCO).	1. See response to 2 above. The issue of the TM efluent standard will be considered as separate issue.	Comment same as above. The TM should not be considered as a separate issue.	Same response as at Section 2.2.