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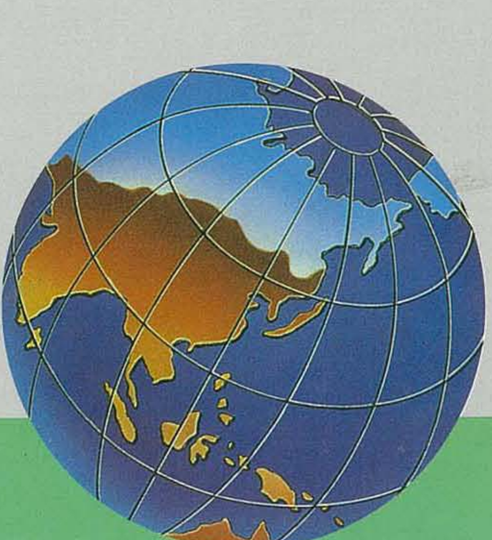
SHIU WING STEEL MILL
TUEN MUN AREA 38

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

FINAL REPORT
VOLUME 2
APPENDICES

AXIS
Environmental



SHIU WING STEEL LIMITED

SHIU WING STEEL MILL
TUEN MUN AREA 38

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

FINAL REPORT
VOLUME 2
APPENDICES

MARCH 1994

AXIS ENVIRONMENTAL CONSULTANTS LTD

APPENDICES

APPENDICES

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APPENDIX 1

APPENDIX 1

TERMS OF REFERENCE

DRAFT

Terms of Reference for an
Environmental Impact Assessment of the proposed
Shiu Wing Steel Work in Tuen Mun Area 38

SWS - EIA

1. Background

1.1 The existing Shiu Wing Steel mill is located on the south western shores of Tseung Kwan O near to the village of Tiu Keng Leng (Rennie's Mill). Government is discussing with the Company on the possibility of the latter's relocation to the site which could accommodate a larger and modern steel works with modern environmental control facilities.

1.2 The Company has agreed to undertake an environmental impact assessment (EIA) to ensure that adequate environmental protection and pollution control measures can be adopted for the proposed steel works development and also that the infrastructure and utility services required for the development are acceptable.

2. Objective of the Environmental Impact Assessment

2.1 The objective of the assessment is to provide information on the proposed Shiu Wing Steel Works in Tuen Mun Area 38 and supporting infrastructure in relation to the nature and extent of the cumulative environmental impacts, marine operational impacts as well as the land use constraints imposed by the proposed development. This information will contribute to decisions on :-

(i) the conditions for the planning, design, operation and development of the proposed project; and

(ii) the acceptability of any adverse environmental consequences that are likely to arise from the construction, operation and decommissioning of the steel works including arc furnace, rolling mill and all other related facilities.

3. Scope of the Environmental Impact Assessment

3.1 The scope of the assessment is as follows :-

(i) to describe the characteristics of the the proposed steel mill and related facilities and the locational requirements for their development;

(ii) to identify and describe the elements of the present and planned future community and environment likely to be affected by the proposed development including potential impacts on marine activities, land transportation, visibility reduction effects, updrafts caused by generation of hot air and effects on performance of radio navigational aids;

(iii) to minimise pollution, environmental disturbance and nuisance arising from the total development and its construction, operation and decommissioning;

(iv) to identify, predict and evaluate the net impacts and the cumulative effects, including transboundary pollution, if any, expected to arise from the proposed steel mill and any associated facilities during construction, operation and decommissioning of the development in relation to the present and planned future community and neighbouring land uses;

(v) to identify and specify methods, measures and standards in the detailed design, which are necessary to mitigate these impacts and reduce them to acceptable levels;

(vi) to design and specify requirements for environmental baseline and compliance monitoring to be undertaken to ensure that the conditions in 3.1(v) above are met; and

(vii) to design and specify requirements for compliance and post-project audit, which will be undertaken to review the data from 3.1(vi) above to ensure that statutory requirements, policies and standards are met and the necessary remedial works are identified to remedy any unacceptable consequential or unforeseen environmental impacts of the works.

4. Requirements of the Environmental Impact Assessment

4.1 The assessment reports should comprise self-contained documents collectively to fully cover the scope of the assessment listed in 3 above including :-

(i) a review of available data on steel works and related infrastructure in terms of planning and environmental implications;

(ii) undertake necessary survey work and baseline monitoring to achieve the scope and objectives of the assessment;

(iii) predictions of the long-term and short-term environmental impacts arising from the construction, operation and decommissioning of the total development;

(iv) recommendations on the likely impacts associated with the development;

(v) proposed measures to effectively mitigate any significant environmental impacts in the short and long term;

(vi) functional requirements for environmental monitoring and audit programme to be undertaken by the company so that the cumulative environmental impacts of the total development can be monitored and assessed; and

(vii) an environmental section for inclusion in an operations manual detailing operating guidelines and procedures to ensure that the scope and objectives of the assessment are met.

4.2 To liaise with relevant Government departments and offices, their Consultants and all other parties involved in aspects of this and any other projects likely to be affected by the development.

4.3 To provide relevant inputs at specified times as required during the course of the assessment.

4.4 The assessment shall consist of the following :-

(i) an <u>Inception Report</u> which includes :

  (a) the methodology for the various items of the study;

  (b) a work programme which indentifies and clearly describes the major tasks, and clearly defines the critical activities in the programme; and

  (c) a schedule for the submission of the reports necessary to fulfil the requirements of the assessment.

(ii) an <u>Initial Assessment Report</u> which

  (a) satisfies the requirements of the scope in section 3 above;

  (b) provides an initial assessment and evaluation of the net environmental impacts and cumulative effects arising from the proposed project sufficient to identify those issues of key concern during construction, operating and decommissioning phases of the development, which are likely to influence decisions on the project;

(c) defines measurable parameters likely to be affected by the proposed steel work, and identifies any environmental monitoring studies which are required both to provide a baseline profile of existing environmental conditions and to monitor impact and compliance during implementation commissioning, operation and future decommissioning of the steel work;

(d) provides an initial definition of environmental audit requirements for compliance and post-projects audit, which shall include a review of the monitoring data both to identify compliance with regulatory requirements, policies and standards and to define any remedial works required to redress unanticipated or unacceptable consequential environmental impacts; and

(e) proposes a detailed programme of investigation and reporting able to meet all other objectives and scope of the assessment;

(Technical requirements for the Initail Assessment Report is enclosed in Appendix 1.)

(iii) such <u>Key Issue Reports</u> identified as necessary through the Initial Assessment Report or the review of the Initial Assessment Report by the Director of Environmental Protection;

(iv) any revisions or supplements to the above as might be required to be carried out by the Director of Environmental Protection; and

(v) an <u>Executive Summary Report</u> (in both English and Chinese) highlighting the major aspects of the net environmental impacts and the cumulative effects including transboundary pollution from the total development (if any), the issues of concern to the community, recommendations for implementation of the steel works and the basis for these, as well as their implications. It is intended that the information contained therein and the way that it is written should assist the Government in undertaking any requirement for public consultation.

4.5 To produce the following deliverable items to the Director of Environmental Protection :-

- 40 copies of the Draft Initial Assessment Report;
- 50 copies of the Final Initial Assessment Report;
- 40 copies of each Draft Key Issue Report;
- 50 copies of each Final Key Issue Report; and
- 100 copies of the Executive Summary Report.

5. Liaison and Administration

5.1 Shiu Wing Steel Limited or their nominated Consultant shall be responsible for completing all aspects of the assessment.

5.2 A Government Study Management Group (SMG) will be convened by the Director of Environmental Protection to provide guidance to the Company and their Consultants and monitor the progress of the project. Meetings will be held monthly or as determined by the Director of Environmental Protection and should be attended by the Project Director and, when appropriate, other representatives of the Company.

5.3 For the purpose of this assessment, the Company or their nominated Consultants should liaise in the first instance with the chairman of the SMG [Head of the Environmental Assessment & Planning Group (EAPG)] or his nominated representative.

5.4 The Director of Environmental Protection will complete an evaluation of the Initial Assessment Report and, subject to his amendments, agree a programme for completing the remainder of the assessment. The basis of this evaluation shall be the completeness and reliability of the initial assessment and the extent to which the programme outlined will meet the objectives and scope of the assessment. A similiar evaluation will be completed for each Key Issue Report and for the assessment as a whole.

5.5 The Director of Environmental Protection will make recommendations to the Secretary for Planning, Environment and Lands and relevant Government departments and offices on the findings of the Environmental Impact Assessment study and on any necessary and appropriate environmental control measures. These measures will normally be included as conditions in the various licences and approvals required for the development. The implementation of these measures will be the responsibility of the Company.

5.6 The Company and their Consultants will be required to brief District Boards and any other boards or committees within or outside the Government as deemed appropriate by the Study Management Group. A public relations programme should be drawn up to provide information on the EIA study and the proposed steel works, to address public concerns and to make recommendations for refining the programme in response to public demand.

5.7 The Company's Consultants will be expected to communicate and correspond direct with other Government departments and offices to obtain information in connection with the project, copying such correspondence to the SMG Secretary. Close liaison will however be maintained throughout the project with the chairman of the SMG, who will cooperate with and assist the Company and their Consultants to obtain information and arrange meetings with Government officers.

Environmental Assessment and Planning Group
Environmental Protection Department.
August 1990

Technical Requirements for the Initial Assessment

The Content of the **Initial Assessment Report** should include at least the following in outline, with the detailed assessments contained in the Key Issues Reports:-

1. The existing environmental situation at the site including but not necessarily limited to :

   (i) the physical characteristics of the site and its surroundings in terms of existing and proposed land use, land status, water, climate, landscape character, conservation value and sites of special scientific interest and sites of special archaeological interest;

   (ii) the ecological characteristics of the site and its surroundings including habitats, communities and species;

   (iii) the human activity patterns in the area including demographic aspects, employment structure, transport and mariculture

   (iv) infrastructure services in the area including electricity, gas, water, sewerage, solid waste disposal, finance, education, housing and telecommunication;

   (v) social and community services in the area with respect to health service facilities, emergency services including fire and ambulance and fung shui;

   (vi) the air pollution dispersion capacity of the site and the airshed within which the site is located; and

   (vii) existing levels of environmental pollution at the site in terms of air pollution, water pollution, noise and existing levels of radioactivity.

2. Impacts during the construction Phase for the project including the quantitative determination of impacts, the mitigation effects of proposed control measures, evaluation of effects on the existing environment, assessment in view of current and impending statutory requirements and an evaluation of control procedures for construction of the facility and associated infrastructure. The discussion of impacts should include, but is not necessarily limited to, the following consideration :

   (i) the method of construction should be analysed and potential major sources of dust and noise should be identified;

(ii) the impact of dust and noise producing processes, plant, vehicles and machinery from activities on nearby sensitive receivers should be assessed;

(iii) marine transport and storage of plant, materials and equipment and any possible interference with normal navigation and usage of adjacent facilities in the general locality;

(iv) land transport and storage of plant, materials and equipment and its effect on the urban transport networks;

(v) requirements for additional infrastructure and utility services;

(vi) the impacts of construction activities on the aquatic environment should be considered including effects of on site and off site marine borrowing, dredging, reclamation, jetty, berth, seawall construction, disposal of dredged spoil and effects from silty runoff on water quality and circulation;

(vii) socio-economic impacts and environmental effects on nearby residents and fung shui sensitive uses such as temples, places of worship and graveyards should be identified and assessed; and

(viii) visual impact of the total facility.

3. Impacts during the <u>Operating Phase and after the decommissioning</u> of the total facility involving normal, abnormal, transient and emergency operations should include, but should not necessarily be limited to, the following considerations :-

(i) the direct and indirect environmental impacts and cumulative effects on a local and a regional scale, due to air pollutants from the proposed steel works and associated facilities should be determined, including but not limited to SO_2, NOx, particulates, odour, chemicals, visibility, photochemical reactions and other fugitive emissions and their synergistic effects under normal and abnormal operating conditions arising from at least the following activities, taking into account discharge standards as advised by the Director of Environmental Protection :

(a) steelmaking/refining;
(b) casting;
(c) rolling/scarfing; and
(d) storage, handling and transport of slag, scale, scrap and other materials.

This assessment should consider also the consequences of a failure or malfunction in the air pollution control systems and recommend any standby or backup facilities.

(ii) aqueous emissions and water pollutants including toxic substances arising from at least the following activities should be identified and quantified with due consideration for adequate interception, handling, treatment and disposal to comply with discharge and disposal guidelines to be approved by the Director of Environmental Protection and to define the necessary controls to minimise marine pollution :

(a) breaking up and cleaning scrap and fabricated items for feedstock;

(b) steelmaking emissions in scrubber waters, suspended solids and indirect cooling water treatment blowdown;

(c) casting emissions in, direct cooling water of soluble and floatable lubricating oils, fluorides, suspended solids and scale;

(d) rolling emissions in direct cooling water of soluble and floatable lubricating oils, suspended solids, scale, acids, alkalies, heavy metals and metalloids and indirect cooling water treatment blowdown;

(e) sewage arising from on site personnel; and

(f) surface transport run-off water emissions of suspended solids;

(iii) the disposal of any solid wastes arising from the operations including at least the following should be quantified and the various possible methods of disposal and utilisation assessed:

(a) steelmaking arisings of skimmer, electric arc furnace and ladle slag, refractories and baghouse dust;

(b) casting arisings of ladle and tundish slag from exothermic compounds, refractories and filter cake;

(c) rolling arisings of mill scale, oily mill scale, filter cake and ferrous sulphate; and

(d) surface transport arisings of spillages and mud.

(iv) the cumulative impact of noise producing plants, vehicles, machinery and noise emissions arising from steelmaking, casting, rolling and other activities on site, and surface transport on noise sensitive receivers should be assessed. Special consideration should be given to nightime activities;

(v) surface transport and storage of plant, equipment, raw materials and finished goods effects on the urban transport network with special attention to the implications of noise, road safety, traffic congestion on the nearby residential areas including those along Lung Mun Road and Wong Chu Road;

(vi) surface transport and storage of plant, equipment, raw materials and finished goods effects on the marine transport network and any possible interference with normal navigation and usage of adjacent facilities;

(vii) the heat effect to be produced by the arc furnace on the workers in the vicinity of the steel mill and the micro-climate;

(viii) visual impacts of the total facility; and

(ix) any other significant pollutants, environmental effects and implications identified in the course of the study.

4. Emissions should be identified and quantified and mitigation measures should be proposed, for all significant impacts identified in 2. and 3. above.

5. Environmental monitoring requirements including baseline, impact and compliance monitoring.

6. Environmental audit requirements including compliance and post-project audit which will review the environmental monitoring data to identify compliance with regulatory requirements, policies and standards, and any remedial works required to redress unacceptable consequential or unanticipated environmental impacts.

7. The assessments should be carried out as follows :

(a) construction noise should be assessed in accordance with the relevant Technical Memoranda issued under the Noise Control Ordinance;

(b) construction dust should be assessed with reference to the relevant Hong Kong Air Quality Objectives;

(c) the impacts due to the aerial emissions from the proposed steel work and associated facilities should be predicted with the aid of a modelling study and mathematical models of which the choice of models, parameters to be studied, procedures and specifications should be approved by the Director of Environmental Protection;

(d) the impacts due to the aerial emissions should be evaluated with reference to the relevant Hong Kong Air Quality Objectives. For air pollutants which are not specified in the Hong Kong Air Quality Objectives or which are considered in the context of transboundary air pollution, reference should be made to appropriate international standards to be agreed with the Director of Environmental Protection.

(e) the operating and decommissioning assessment should be made with reference to the guidelines contained in the Environmental Chapter of Hong Kong Planning Standards and Guidelines; and

(f) the water quality impact from any construction, solid or liquid wastes, accidental leakages, spillages if any, and cooling water on Hong Kong Waters should be assessed using mathematical modelling or other techniques approved by the Director of Environmental Protection.

8. Effective mitigation measures for all significant impacts identified in sections 2 and 3 above should be proposed to minimise the occurrence and consequences of predicted cumulative impacts, both in terms of the layout and landscaping of the facilities, equipment selection and design and also in terms of management and operational procedures.

9. The EIA study should clearly define acceptable and measurable limits to emissions of all kinds. The limits shall form the basis of the emission standards to be incorporated in appropriate licences.

10. The results of the environmental monitoring and audit programme undertaken by the company should also provide information of relevance to any ongoing operational assessments of the facility and to help evaluate maintenance, operational and after-care requirements of the steel works.

11. The design and specifications of the proposed steel works should comply with the Best Practicable Means as required under the Air Pollution Control Ordinance. The sufficiency of the Best Practicable Means should be assessed and any required additional mitigating measures should be identified and specified (please see general guidelines in Appendix 2).

***** END ******

APPENDIX 2

APPENDIX 2

OCCUPATIONAL HEALTH AND SAFETY

APPENDIX 2 : OCCUPATIONAL HEALTH AND SAFETY

INTRODUCTION

Occupational health and environmental protection are closely related. It is valuable to plan the working environment at an early stage to prevent damage. Provision of adequate lighting, good ventilation, isolation and protection of the worker from noise and other nuisances are important.

Possible hazards are:

- Physical agents such as falling objects, fire, vibration and unsafe equipment.
- Chemicals used in steelmaking or other sources.
- Electromagnetic radiation from welding equipment or other sources.
- Strain due to noise, heat or pressure.
- Disease due to contamination of water or food.

SOURCES OF DAMAGE

At Shiu Wing Steel Mill the following procedures can be hazardous.

- Steelmaking. Exposure to iron oxide, lead, alloying additions, carbon monoxide, sulphur dioxide, fluorides, combustion products, heat and noise.
- Alloying. Nickel, bismuth, chromium, manganese, tungsten, molybdenum, and selenium can be generated as dust or fumes.
- Re-heating furnace. Carbon monoxide, sulphur dioxide and heat.
- Hot-rolling mills. Noise and heat.
- Cold mills. Noise, oil mist, organic solvents and nitrogen oxides.
- Supporting activities inside the steel plant such as welding and burning, laboratory activities, electrical departments etc.

POTENTIAL HEALTH EFFECTS

The major health risks are from inhalation of gases, dusts and mists, contaminants reaching the stomach, attack or absorbtion of liquids through the skin and radiation. Some of the effects are noticed immediately after exposure while others tend to cause damage only after a long period of exposure, for example carcinogens.

Some of the physiological effects of the materials are listed below.

A distinction between respirable and non-respirable should be drawn as the former is more hazardous. Some particular dust may cause reduced breathing, cough and shortness of breath and in the most severe cases a shortened lifespan. Iron oxide has no adverse health effects but an accumulation of particles in the lungs may occur. Manganese in dust may, on chronic exposure, lead to damage of the central nervous system, impaired motorfunctions and emotional disturbances. Lead in high exposure may lead to anaemia, kidney damage, nervous system problems, and emotional disturbances. Silica is known to cause emphysema and silicosis after a long period of exposure (10 to 25 years).

Noise in excess can cause various degrees of hearing loss, damage to the inner ear and continuous buzzing in the ear (tinnitus) which is a mental strain.

Exposure to heat can cause acute effects such as dehydration, salt depletation, cramps, muscle spasms, exhaustion, stroke and in severe cases coma and death.

Hazardous gases include carbon monoxide, that can lead to headache, dizziness, weakness and for very high exposure death; nitrogen oxides, which may give rise to lung and respiratory tract problems; and sulphur dioxide, which is an irritant to the mucous membranes and can predispose to bronchitis and other lung diseases.

Extreme light can effect the eyes (inflammation, cataract) and the skin (erythema and ultimately skincancer).

PROTECTIVE MEASURES

To protect workers from the effect of health hazards there are basic requirements such as:

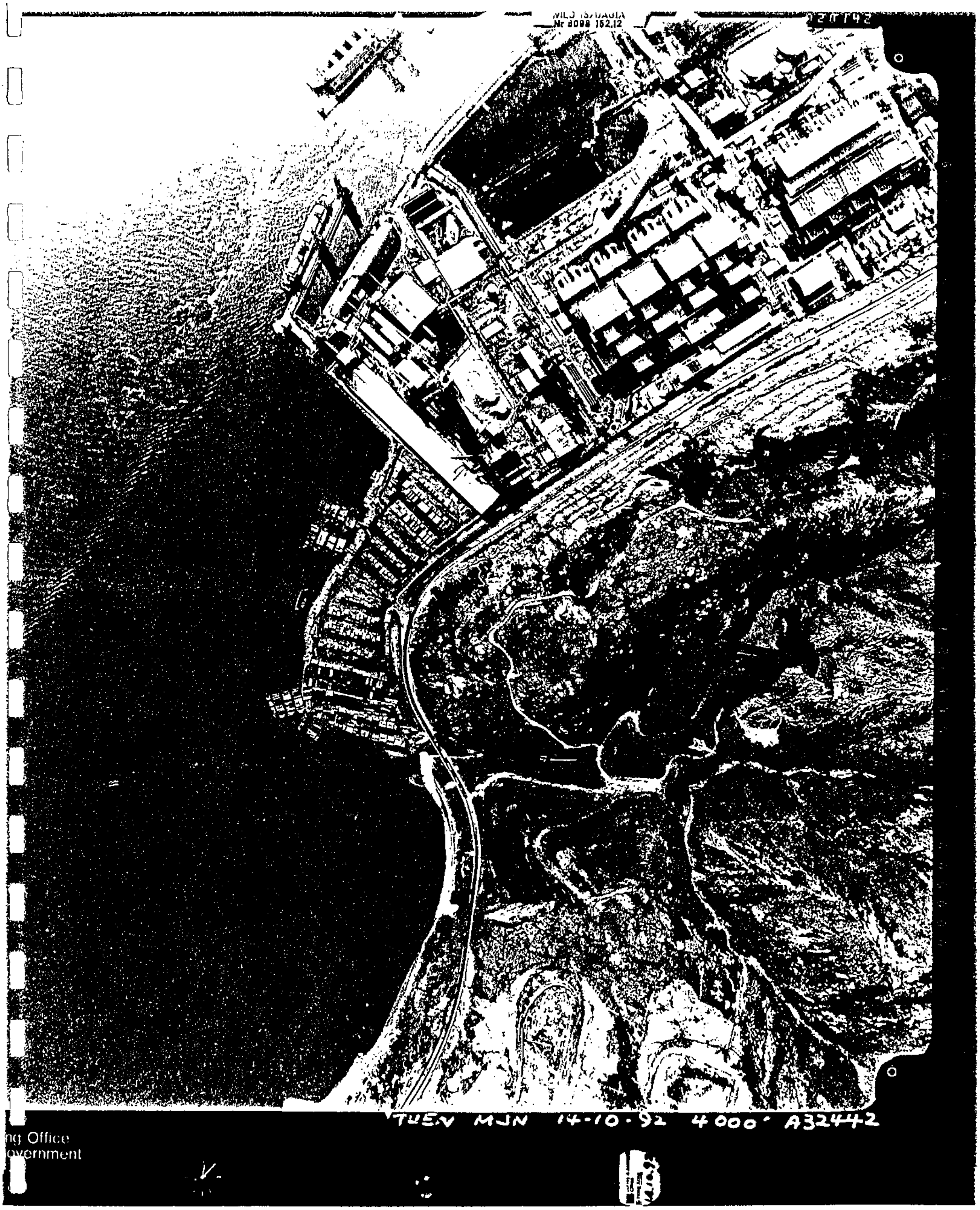
- Adequate pollution control procedures.
- Information about dangers in the working environment.
- Control of exposure to dust and gases within safe limits.
- Personal protective equipment when it is not possible to avoid exposure to health hazards, such as hard hats, safety shoes, ear plugs etc.

In addition, it is important to carry out effective monitoring, undertake medical surveillance as necessary, utilise warning-signs and labels, and keep proper records to allow continuous improvement.

APPENDIX 3

APPENDIX 3

AERIAL PHOTOGRAPH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APPENDIX 4A

APPENDIX 4A

EAF AIR POLLUTION CONTROL GUIDELINES

BEST PRACTICABLE MEANS REQUIREMENTS FOR IRON AND STEEL WORKS (ELECTRIC ARC FURNACE)

1. INTRODUCTION

These notes list the minimum requirements for meeting the best practicable means for Iron and Steel Works (Electric Arc Furnace). It should be noted that in granting a licence under the Ordinance, the Authority, i.e., the Director of Environmental Protection, will also consider all other relevant aspects and may impose more stringent and/or additional control requirements by taking into account individual process characteristics, local topography and air quality and any other factors.

Any iron and steel works in which the installed furnace capacity exceeds one tonne, or, if the mode of operation is continuous, one tonne per hour, and in which a ferrous metal melting process for casting is carried out will be subject to control under the Air Pollution Control Ordinance. Electric arc furnace process is a large emission sources of dust, metal oxide fumes and smoke if not properly controlled. U.K. and U.S.A. have already imposed emission standards for these works under respectively the BATNEEC and USEPA NSPS requirements.

2. DESIGN OF CHIMNEY:

(Chimney includes structures and openings of any kind from or through which air pollutant may be emitted.)

(a) Chimney height:

To be determined by mathematical or physical dispersion modelling techniques acceptable to the Authority. The aims are to ensure:-

(i) the relevant Air Quality Objectives (AQO) will not be threatened;

(ii) the emission of non-AQO pollutants, in particular, heavy metals and carcinogenic organic compounds, will not cause any adverse effect on human health or environment;

(iii) no undue constraint will be incurred to existing and future development or land use.

The final chimney height should be agreed with the Authority but as a general guideline, the chimney height in a flat terrain situation, should as far as practicable be at least Building Height + 1.5 x Building Width or Building Height, whichever is the lesser. Suitable adjustment should be made to take into account local meteorological data, local topography and background air pollutant concentrations. In any case, the chimney height shall not be less than 8 meters above ground level and shall not be less than 3 meters above the building roof top.

For non-combustion processes, the same guideline should be observed as far as practicable and in any case, the chimney height shall not be less than 3 metres plus the building height.

(b) Efflux velocity:

The efflux velocity, whenever practicable, should be at least 1.5 times of the wind speed at the chimney top. In any case, it shall not be less than 15 m/s at full load condition.

(c) Exit temperature:

For combustion process, the exit temperature should not be less than the acid dew point, and in any case, it shall not be less than 80°C.

(d) Mode of discharge:

Releases to air from chimneys should be directed vertically upwards and not restricted or deflected by the use of, for example, plates, caps or cowls.

In order to obtain maximum thermal buoyancy, hot emissions should as far as practicable be discharged from the minimum number of chimneys, i.e., a multi-flue chimney design should be used.

3. EMISSION LIMITS:

All emissions to air, other than steam or water vapour, shall be colourless and free from persistent mist.

(a) Metal Melting Process:

Particulates:	30 mg/m^3
Lead and its compounds (as lead):	2 mg/m^3
Cadmium and its compounds (as cadmium):	1 mg/m^3
Fluoride (as hydrogen fluoride):	10 mg/m^3
Sulphur dioxide:	Potential emission from burning of diesel fuel with a maximum allowable sulphur content of 0.5% by weight (air dry basis)
Smoke:	Less than Ringelmann Shade 1 and no substantially visible emission during lighting-up period

(b) Other Processes:

Particulates:	50 mg/m^3

(All figures are expressed at reference condition, 0°C, 101.325 kilopascals, without correction for water vapour content. The introduction of dilution air to achieve the emission concentration limits shall not be permitted.)

4. FUGITIVE EMISSION CONTROL

(a) Boundary Ambient Standards

Total suspended particulates	260 μg/m^3 (24-hour average)
Respirable suspended particulates	180 μg/m^3 (24-hour average)
Odour	2 odour units

(Note : An odour unit is the measuring unit of odour level and is analogous to pollution concentration. In this context, the odour level is defined as the ratio of the volume which the sample would occupy when diluted with air to the odour threshold, to the volume of the sample. In other works, one odour unit is the concentration of odorant which just induces an odour sensation.)

(b) Engineering Design/Technical Requirements

To be agreed with the Authority. As a general guideline, the loading, unloading, handling and storage of fuel, raw materials, products, wastes or by-products should be carried out in a manner acceptable to the Authority so as to prevent the release of:-

(i) visible dust emissions; and/or
(ii) emissions of organic vapours; and/or
(iii) other noxious or offensive emissions.

Without prejudice to the generality of the above general requirements, the following control measures shall be implemented:-

Material Handling

Dusty materials, or potentially dusty materials, for example iron scraps, lime, and other steel-making additives should be handled in the totally enclosed system. Purpose-built silo should be used for the storage of the dusty materials whenever practicable.

Iron Melting/Refining, Slagging and Molten Steel Tapping

Fume emission from the electric arc furnace during the iron melting/refining process shall be collected and vented to suitable arrestment plant to meet the emission limits.

'Doghouse' type total furnace enclosure shall be used to contain all emissions from the electric arc furnace operation. The contained emissions shall be collected and vented to suitable arrestment plant to meet the emission limits.

The roof bi-parting doors and all side doors of the 'doghouse' enclosure shall be closed during the iron melting/refining, slagging and molten steel tapping processes in such a manner that no visible emission escapes from any leaks or openings. Whenever any roof bi-parting door or side door is not fully closed, air-curtain jets shall be provided and activated to seal the opening of the 'doghouse' enclosure.

House Keeping

A high standard of housekeeping shall be maintained. Adequate provision should be made for the containment of liquid and solid spillages. All spillages should be cleared as soon as possible and in the case of solid materials this should be achieved by the use of vacuum cleaning or other appropriate methods. Dry sweeping of spillages shall not be permitted.

5. MATERIAL/FUEL RESTRICTION

Gaseous fuel is the recommended fuel to be used but the Authority may also accept the use of liquid fuel with the following specifications:-

Sulphur content : Not greater than 0.5% (by weight)

Viscosity : 6 centistokes (at 40°C)

6. MONITORING REQUIREMENTS

Parameters and sampling frequency will be determined by the Authority. In any case, the emission of particulates, lead, cadmium and fluoride shall be tested at least annually. In addition, the following parameters should be monitored continuously as a minimum requirement:-

(a) In-stack Monitoring

Particulate matter (opacity).

(b) Process Monitoring

Production rate and other essential operating parameter(s) which may significantly affect the emission of air pollutants.

(c) Ambient Monitoring

At site boundary and/or : any other locations acceptable to the Authority	Total suspended particulates and/or respirable suspended particulates (at least one 24-hour sample per 6 calendar days)

7. COMMISSIONING

Commissioning trials (to be witnessed by the Authority whenever appropriate) should be conducted to demonstrate performance of the air pollution control measures and a report of commissioning trial should be submitted to the Authority within 1 month after completion of the trial.

8. OPERATION AND MAINTENANCE

Requirements include not only the provision of the appliances, but the proper operation and maintenance of equipment, its supervision when in use and the training and supervision of properly qualified staff. Specific operation and maintenance requirements may be specified for individual equipment.

Malfunctioning and breakdown of the process or air pollution control equipment which would cause exceedance of the emission limits or breaches of other air pollution control requirements should be reported to the Authority within 3 working days.

General Guideline On Air Pollution Control
for Iron and Steel Works - Electric Arc Furnaces

Furnace Particulate Emission Control

1. Primary collection and arrestment devices are required to control emissions generated from steel making process of electric arc furnace(s), and the extracted emissions shall be vented to a properly designed dedusting device, which can meet the prescribed emission limit.

2. Secondary collection and arrestment such as 'doghouse' type total furnace enclosure are also required to contain emissions arising throughout the complete operating cycle of charging, melting refining, slagging and tapping processes. The contained emissions shall be vented via such system to properly designed dedusting device, which can meet the prescribed emission limit.

Fugitive Emissions Control for Materials Handling and Storage

3. The delivery, handling and storage of raw materials for the steel making process shall be controlled in such a manner as to minimize emissions to atmosphere.

Fuel Restriction

4. Any ancillary conventional fossil fuel using equipment for the production of steel shall use fuel conforming to the requirements as stipulated under the Air Pollution Control (Fuel Restriction) Regulations 1990.

Chimney

5. Chimney height for all the relevant pollutant control equipment is determined by the maximum mass rate of pollution so generated and the impact on the environment taking into account of effects like topography, nearby buildings and background emissions.

BEST PRACTICABLE MEANS

Steel Production Plant

Facilities	Air Pollutants	BPM Requirements
1. Electric Arc Furnace Furnace Emissions	Particulate	Total collection of furnace emission 30 mg/m3*
Shop Roof	Fugitive Part.	No visible emission
Associated Process	Particulate	50 mg/m3*

(eg. desulphurisation, refining outside the furnace etc.)

* All gas volume are expressed as at standard temperature and pressure of 0 degree Celsius and 101.325 kilopascal.

The height of chimney shall be at least 3 metres above any building to which it is attached or adjacent; and the corresponding efflux velocity shall not be less than 15m/s at full load operation.

Monitoring / Sampling

6. Regular source testing and ambient monitoring at site boundary shall be conducted and the results be submitted to the Authority for scrutiny.

APPENDIX 4B

APPENDIX 4B

METEOROLOGICAL DATA

APPENDIX 4B : METEOROLOGICAL DATA

FROM 89. 1. 1 TO 89.12.30 CHEK LAP KOK

PASQUILL STABILITY CLASS "A"
WIND SPEED CLASS (MPS)

WIND SECTOR	.51 TO 1.50	1.51 TO 3.00	3.01 TO 4.50	4.51 TO 6.00	6.01 TO 7.50	7.51 TO 9.00	9.01 TO 10.50	GREATER THAN 10.50	TOTAL	MEAN SPEED
NNE	.000230	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000230	1.05
NE	.000806	.000345	.000000	.000000	.000000	.000000	.000000	.000000	.001151	1.29
ENE	.000576	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000576	1.26
E	.000345	.000115	.000000	.000000	.000000	.000000	.000000	.000000	.000460	1.27
ESE	.000345	.000230	.000000	.000000	.000000	.000000	.000000	.000000	.000576	1.38
SE	.000345	.000230	.000000	.000000	.000000	.000000	.000000	.000000	.000576	1.52
SSE	.000115	.000115	.000000	.000000	.000000	.000000	.000000	.000000	.000230	1.55
S	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.00
SSW	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.00
SW	.000115	.000115	.000000	.000000	.000000	.000000	.000000	.000000	.000230	1.40
WSW	.000230	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000230	1.45
W	.000115	.000115	.000000	.000000	.000000	.000000	.000000	.000000	.000230	1.70
WNW	.000345	.000460	.000000	.000000	.000000	.000000	.000000	.000000	.000806	1.49
NW	.000230	.000576	.000000	.000000	.000000	.000000	.000000	.000000	.000806	1.60
NNW	.000460	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000460	1.25
N	.000576	.000460	.000000	.000000	.000000	.000000	.000000	.000000	.001036	1.38
CALM									.000000	
TOTAL	.004834	.002762	.000000	.000000	.000000	.000000	.000000	.000000	.007597	1.40

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS = 0
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8688

PASQUILL STABILITY CLASS "B"
WIND SPEED CLASS (MPS)

WIND SECTOR	.51 TO 1.50	1.51 TO 3.00	3.01 TO 4.50	4.51 TO 6.00	6.01 TO 7.50	7.51 TO 9.00	9.01 TO 10.50	GREATER THAN 10.50	TOTAL	MEAN SPEED
NNE	.001151	.000806	.000576	.000000	.000000	.000000	.000000	.000000	.002532	2.13
NE	.002187	.002647	.000345	.000000	.000000	.000000	.000000	.000000	.005180	1.84
ENE	.002647	.001727	.000576	.000000	.000000	.000000	.000000	.000000	.004949	1.77
E	.002072	.001611	.001266	.000345	.000000	.000000	.000000	.000000	.005295	2.32
ESE	.001036	.000921	.001381	.000115	.000000	.000000	.000000	.000000	.003453	2.74
SE	.001381	.000806	.000460	.000000	.000000	.000000	.000000	.000000	.002647	1.82
SSE	.001151	.000230	.000115	.000345	.000000	.000000	.000000	.000000	.001842	2.08
S	.000691	.000000	.000576	.000345	.000000	.000000	.000000	.000000	.001611	2.89
SSW	.000115	.000115	.000230	.000230	.000000	.000000	.000000	.000000	.000691	3.55
SW	.000345	.000115	.000230	.000000	.000000	.000000	.000000	.000000	.000691	2.12
WSW	.000345	.001036	.000230	.000115	.000000	.000000	.000000	.000000	.001727	2.30
W	.000806	.004949	.006446	.000576	.000000	.000000	.000000	.000000	.012776	3.15
WNW	.001957	.008863	.006676	.000345	.000000	.000000	.000000	.000000	.017841	2.82
NW	.003453	.003913	.002072	.000230	.000000	.000000	.000000	.000000	.009669	2.23
NNW	.001957	.000460	.000230	.000115	.000000	.000000	.000000	.000000	.002762	1.60
N	.001266	.000921	.000576	.000345	.000000	.000000	.000000	.000000	.003108	2.35
CALM									.000000	
TOTAL	.022560	.029121	.021984	.003108	.000000	.000000	.000000	.000000	.076773	2.48

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS = 0
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8688

```
FROM 89. 1. 1   TO 89.12.30    CHEK LAP KOK

                                         PASQUILL STABILITY CLASS "C"
                                            WIND SPEED CLASS (MPS)

             .51      1.51      3.01      4.51      6.01      7.51      9.01   GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO      THAN                 MEAN
SECTOR      1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL      SPEED
-----------------------------------------------------------------------------------------------------------

  NNE    .000000   .000921   .002878   .001151   .000000   .000115   .000000   .000000   .005064       3.95
   NE    .000000   .001036   .002647   .000460   .000115   .000000   .000115   .000230   .004604       4.21
  ENE    .000000   .001036   .002993   .000806   .000115   .000000   .000000   .000000   .004949       3.83
    E    .000000   .000576   .003568   .003338   .001957   .003338   .001036   .001151   .014963       6.44
  ESE    .000000   .000115   .001381   .002762   .003338   .001496   .001266   .000576   .010935       6.76
   SE    .000000   .000115   .000691   .000460   .000576   .000115   .000000   .000115   .002072       5.59
  SSE    .000000   .000115   .001842   .000460   .000460   .000115   .000000   .000000   .002993       4.60
    S    .000000   .000230   .002072   .002878   .001381   .000460   .000000   .000000   .007021       5.25
  SSW    .000000   .000345   .001036   .001036   .000576   .000000   .000000   .000000   .002993       4.67
   SW    .000000   .000230   .000576   .000345   .000000   .000115   .000000   .000000   .001266       4.35
  WSW    .000000   .000460   .000806   .000345   .000691   .000345   .000000   .000000   .002647       5.19
    W    .000000   .001611   .004834   .000921   .000000   .000000   .000000   .000000   .007366       3.62
  WNW    .000000   .000576   .006906   .001611   .000115   .000115   .000000   .000000   .009323       4.03
   NW    .000000   .001151   .003108   .002072   .001151   .000460   .000460   .000345   .008748       5.24
  NNW    .000000   .000230   .001036   .000460   .000460   .000115   .000115   .000000   .002417       4.94
    N    .000000   .000921   .002993   .001496   .000345   .000230   .000000   .000000   .005985       4.28

 CALM                                                                                  .000000
-----------------------------------------------------------------------------------------------------------

TOTAL    .000000   .009669   .039365   .020603   .011280   .007021   .002993   .002417   .093347       5.05

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =    0
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8688


                                         PASQUILL STABILITY CLASS "D"
                                            WIND SPEED CLASS (MPS)

             .51      1.51      3.01      4.51      6.01      7.51      9.01   GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO      THAN                 MEAN
SECTOR      1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL      SPEED
-----------------------------------------------------------------------------------------------------------

  NNE    .000576   .003683   .014157   .018992   .009208   .004144   .000576   .001266   .052601       5.44
   NE    .001842   .003108   .010935   .008172   .004489   .003453   .001266   .002072   .035336       5.48
  ENE    .001727   .001957   .009899   .008287   .005755   .004949   .002187   .002878   .037638       6.05
    E    .001842   .002762   .012431   .024632   .035797   .036372   .030041   .034415   .178292       8.13
  ESE    .000806   .001496   .010014   .023941   .030157   .017610   .010359   .010589   .104972       7.25
   SE    .000806   .000345   .004949   .003798   .004719   .002993   .001381   .002072   .021064       6.46
  SSE    .000230   .000921   .003913   .001381   .002302   .000576   .000000   .000000   .009323       4.93
    S    .001266   .000806   .009208   .009784   .005410   .001496   .000115   .000115   .028200       5.06
  SSW    .000691   .000806   .008402   .003798   .001036   .000345   .000000   .000000   .015078       4.31
   SW    .000576   .000230   .003453   .001842   .000806   .000115   .000000   .000000   .007021       4.32
  WSW    .000806   .001036   .004604   .001036   .000230   .000000   .000000   .000000   .007712       3.66
    W    .001266   .002072   .004259   .000806   .000460   .000115   .000000   .000000   .008978       3.51
  WNW    .001036   .001151   .008057   .003108   .000921   .000230   .000000   .000345   .014848       4.33
   NW    .000806   .001036   .006331   .010474   .009093   .004604   .002417   .001266   .036027       6.18
  NNW    .001266   .001036   .007136   .006215   .003913   .000806   .000576   .000345   .021294       5.01
    N    .000460   .001381   .008402   .011855   .010474   .002878   .000921   .000000   .036372       5.52

 CALM                                                                                  .000000
-----------------------------------------------------------------------------------------------------------

TOTAL    .015999   .023826   .126151   .138122   .124770   .080686   .049839   .055364   .614756       6.49

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =    0
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8688
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FROM 89. 1. 1   TO 89.12.30   CHEL LAP KOK


                                    PASQUILL STABILITY CLASS "E"
                                      WIND SPEED CLASS (MPS)

             .51      1.51      3.01      4.51      6.01      7.51      9.01    GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO      THAN                  MEAN
SECTOR      1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL      SPEED
---------------------------------------------------------------------------------------------------------

  NNE    .000000   .004489   .002762   .001151   .000000   .000000   .000000   .000000   .008402       3.25
   NE    .000000   .004489   .002647   .000576   .000000   .000000   .000000   .000000   .007712       3.16
  ENE    .000000   .003223   .003223   .000921   .000000   .000000   .000000   .000000   .007366       3.26
    E    .000000   .002993   .004604   .002647   .000000   .000000   .000000   .000000   .010244       3.69
  ESE    .000000   .001842   .009899   .002762   .000000   .000000   .000000   .000000   .014503       3.85
   SE    .000000   .000576   .001842   .000115   .000000   .000000   .000000   .000000   .002532       3.55
  SSE    .000000   .000345   .001381   .000000   .000000   .000000   .000000   .000000   .001727       3.41
    S    .000000   .001266   .005525   .001036   .000000   .000000   .000000   .000000   .007827       3.70
  SSW    .000000   .001496   .004489   .000576   .000000   .000000   .000000   .000000   .006561       3.59
   SW    .000000   .000345   .001036   .000345   .000000   .000000   .000000   .000000   .001727       3.70
  WSW    .000000   .000806   .000576   .000115   .000000   .000000   .000000   .000000   .001496       2.99
    W    .000000   .001266   .000345   .000000   .000000   .000000   .000000   .000000   .001611       2.70
  WNW    .000000   .001151   .001151   .000115   .000000   .000000   .000000   .000000   .002417       3.20
   NW    .000000   .001036   .000806   .000345   .000000   .000000   .000000   .000000   .002187       3.39
  NNW    .000000   .001151   .001727   .000230   .000000   .000000   .000000   .000000   .003108       3.33
    N    .000000   .001727   .001727   .000691   .000000   .000000   .000000   .000000   .004144       3.47

 CALM                                                                                  .000000
---------------------------------------------------------------------------------------------------------

TOTAL    .000000   .028200   .043738   .011625   .000000   .000000   .000000   .000000   .083564       3.49

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =    0
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8688


                                    PASQUILL STABILITY CLASS "F"
                                      WIND SPEED CLASS (MPS)

             .51      1.51      3.01      4.51      6.01      7.51      9.01    GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO      THAN                  MEAN
SECTOR      1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL      SPEED
---------------------------------------------------------------------------------------------------------

  NNE    .003568   .002072   .000000   .000000   .000000   .000000   .000000   .000000   .005640       1.50
   NE    .006215   .003338   .000000   .000000   .000000   .000000   .000000   .000000   .009553       1.44
  ENE    .006561   .007366   .000000   .000000   .000000   .000000   .000000   .000000   .013927       1.65
    E    .009669   .006446   .000000   .000000   .000000   .000000   .000000   .000000   .016114       1.52
  ESE    .011050   .005410   .000000   .000000   .000000   .000000   .000000   .000000   .016459       1.43
   SE    .010359   .002878   .000000   .000000   .000000   .000000   .000000   .000000   .013237       1.29
  SSE    .007482   .001496   .000000   .000000   .000000   .000000   .000000   .000000   .008978       1.26
    S    .005870   .004604   .000000   .000000   .000000   .000000   .000000   .000000   .010474       1.62
  SSW    .003453   .001842   .000000   .000000   .000000   .000000   .000000   .000000   .005295       1.50
   SW    .002187   .001611   .000000   .000000   .000000   .000000   .000000   .000000   .003798       1.52
  WSW    .003223   .001151   .000000   .000000   .000000   .000000   .000000   .000000   .004374       1.30
    W    .003108   .001496   .000000   .000000   .000000   .000000   .000000   .000000   .004604       1.36
  WNW    .002647   .000576   .000000   .000000   .000000   .000000   .000000   .000000   .003223       1.24
   NW    .001727   .000230   .000000   .000000   .000000   .000000   .000000   .000000   .001957       1.18
  NNW    .002072   .000921   .000000   .000000   .000000   .000000   .000000   .000000   .002993       1.47
    N    .002532   .000806   .000000   .000000   .000000   .000000   .000000   .000000   .003338       1.31

 CALM                                                                                  .000000
---------------------------------------------------------------------------------------------------------

TOTAL    .081722   .042242   .000000   .000000   .000000   .000000   .000000   .000000   .123964       1.45

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =    0
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8688
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FROM 89. 1. 1    TO 89.12.30    CHEK LAP KOK

                                         PASQUILL STABILITY CLASS "G"
                                            WIND SPEED CLASS (MPS)

               .51     1.51     3.01     4.51     6.01     7.51     9.01  GREATER
WIND            TO       TO       TO       TO       TO       TO       TO     THAN               MEAN
SECTOR        1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL     SPEED
----------------------------------------------------------------------------------------------------

      NNE  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
       NE  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
      ENE  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
        E  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
      ESE  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
       SE  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
      SSE  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
        S  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
      SSW  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
       SW  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
      WSW  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
        W  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
      WNW  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
       NW  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
      NNW  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00
        N  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00

 CALM                                                                              .000000
----------------------------------------------------------------------------------------------------

TOTAL      .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000  .000000       .00

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                   =    0
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8688

                                      ALL PASQUILL STABILITY CLASSES
                                            WIND SPEED CLASS (MPS)

               .51     1.51     3.01     4.51     6.01     7.51     9.01  GREATER
WIND            TO       TO       TO       TO       TO       TO       TO     THAN               MEAN
SECTOR        1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL     SPEED
----------------------------------------------------------------------------------------------------

      NNE  .005525  .011971  .020373  .021294  .009208  .004259  .000576  .001266  .074471      4.67
       NE  .011050  .014963  .016575  .009208  .004604  .003453  .001381  .002302  .063536      4.13
      ENE  .011510  .015308  .016690  .010014  .005870  .004949  .002187  .002878  .069406      4.37
        E  .013927  .014503  .021869  .030962  .037753  .039710  .031077  .035566  .225368      7.19
      ESE  .013237  .010014  .022675  .029581  .033494  .019107  .011625  .011165  .150898      6.13
       SE  .012891  .004949  .007942  .004374  .005295  .003108  .001381  .002187  .042127      4.26
      SSE  .008978  .003223  .007251  .002187  .002762  .000691  .000000  .000000  .025092      3.23
        S  .007827  .006906  .017380  .014042  .006791  .001957  .000115  .000115  .055134      4.17
      SSW  .004259  .004604  .014157  .005640  .001611  .000345  .000000  .000000  .030617      3.69
       SW  .003223  .002647  .005295  .002532  .000806  .000230  .000000  .000000  .014733      3.38
      WSW  .004604  .004489  .006215  .001611  .000921  .000345  .000000  .000000  .018186      3.10
        W  .005295  .011510  .015884  .002302  .000460  .000115  .000000  .000000  .035566      3.08
      WNW  .005985  .012776  .022790  .005180  .001036  .000345  .000000  .000345  .048458      3.41
       NW  .006215  .007942  .012316  .013122  .010244  .005064  .002878  .001611  .059392      5.07
      NNW  .005755  .003798  .010129  .007021  .004374  .000921  .000691  .000345  .033034      4.19
        N  .004834  .006215  .013697  .014388  .010820  .003108  .000921  .000000  .053983      4.70

 CALM                                                                              .000000
----------------------------------------------------------------------------------------------------

TOTAL      .125115  .135820  .231238  .173458  .136050  .087707  .052831  .057781 1.000000      5.14

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS =    0
NUMBER OF VALID OBSERVATIONS   = 8688
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FROM 90. 1. 1 TO 90.12.30   CHEK LAP KOK


                                     PASQUILL STABILITY CLASS "A"
                                       WIND SPEED CLASS (MPS)

              .51       1.51      3.01      4.51      6.01      7.51      9.01    GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO       THAN                 MEAN
SECTOR       1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL      SPEED
-----------------------------------------------------------------------------------------------------------

  NNE     .000000   .000232   .000000   .000000   .000000   .000000   .000000   .000000   .000232      1.70
   NE     .000349   .000465   .000000   .000000   .000000   .000000   .000000   .000000   .000813      1.46
  ENE     .000349   .000465   .000000   .000000   .000000   .000000   .000000   .000000   .000813      1.51
    E     .000116   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000116      1.50
  ESE     .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000000       .00
   SE     .000232   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000232      1.10
  SSE     .000116   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000116      1.00
    S     .000232   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000232      1.05
  SSW     .000116   .000116   .000000   .000000   .000000   .000000   .000000   .000000   .000232      1.60
   SW     .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000000       .00
  WSW     .000116   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000116      1.00
    W     .000232   .000349   .000000   .000000   .000000   .000000   .000000   .000000   .000581      1.50
  WNW     .000349   .000232   .000000   .000000   .000000   .000000   .000000   .000000   .000581      1.36
   NW     .000813   .000349   .000000   .000000   .000000   .000000   .000000   .000000   .001162      1.32
  NNW     .000232   .000232   .000000   .000000   .000000   .000000   .000000   .000000   .000465      1.57
    N     .000813   .000000   .000000   .000000   .000000   .000000   .000000   .000000   .000813      1.21

 CALM                                                                                   .000000
-----------------------------------------------------------------------------------------------------------

TOTAL     .004067   .002440   .000000   .000000   .000000   .000000   .000000   .000000   .006507      1.38

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                    =  130
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8606


                                   PASQUILL STABILITY CLASS "B"
                                       WIND SPEED CLASS (MPS)

              .51       1.51      3.01      4.51      6.01      7.51      9.01    GREATER
 WIND         TO        TO        TO        TO        TO        TO        TO       THAN                 MEAN
SECTOR       1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL      SPEED
-----------------------------------------------------------------------------------------------------------

  NNE     .000813   .000930   .000349   .000000   .000000   .000000   .000000   .000000   .002092      2.03
   NE     .003021   .003835   .000930   .000232   .000000   .000000   .000000   .000000   .008018      2.03
  ENE     .001278   .003254   .001162   .000000   .000000   .000000   .000000   .000000   .005694      2.37
    E     .000697   .002208   .001627   .000349   .000000   .000000   .000000   .000000   .004880      2.84
  ESE     .000697   .001046   .000116   .000349   .000000   .000000   .000000   .000000   .002208      2.49
   SE     .001278   .000232   .000116   .000349   .000000   .000000   .000000   .000000   .001975      2.00
  SSE     .000000   .000465   .000697   .000232   .000000   .000000   .000000   .000000   .001394      3.36
    S     .000581   .000581   .000813   .000813   .000000   .000000   .000000   .000000   .002789      3.27
  SSW     .000232   .000581   .000465   .000116   .000000   .000000   .000000   .000000   .001394      2.74
   SW     .000581   .000349   .000116   .000116   .000000   .000000   .000000   .000000   .001162      2.24
  WSW     .000930   .002208   .001394   .000116   .000000   .000000   .000000   .000000   .004648      2.60
    W     .001278   .006507   .005926   .000930   .000000   .000000   .000000   .000000   .014641      2.99
  WNW     .002905   .011039   .007437   .000349   .000000   .000000   .000000   .000000   .021729      2.68
   NW     .002789   .005113   .002440   .000465   .000000   .000000   .000000   .000000   .010806      2.37
  NNW     .002092   .001627   .000232   .000116   .000000   .000000   .000000   .000000   .004067      1.73
    N     .003137   .001394   .000232   .000000   .000000   .000000   .000000   .000000   .004764      1.50

 CALM                                                                                   .000000
-----------------------------------------------------------------------------------------------------------

TOTAL     .022310   .041366   .024053   .004532   .000000   .000000   .000000   .000000   .092261      2.51

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                    =  130
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8606
```

```
FROM 90. 1. 1    TO 90.12.30    CHEK LAP KOK


                                  PASQUILL STABILITY CLASS "C"
                                    WIND SPEED CLASS (MPS)

            .51     1.51     3.01     4.51     6.01     7.51     9.01  GREATER
WIND         TO       TO       TO       TO       TO       TO       TO     THAN                MEAN
SECTOR     1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL      SPEED
-------------------------------------------------------------------------------------------------

   NNE  .000000  .000697  .002324  .001046  .000232  .000000  .000000  .000000  .004299      4.08
    NE  .000000  .001627  .002673  .000232  .000000  .000000  .000000  .000000  .004532      3.28
   ENE  .000000  .000465  .002324  .001511  .000697  .000232  .000116  .000116  .005461      4.85
     E  .000000  .000813  .003370  .003254  .002324  .001975  .001627  .001859  .015222      6.74
   ESE  .000000  .000465  .001859  .002673  .002208  .001511  .000813  .000349  .009877      6.34
    SE  .000000  .000349  .000581  .000349  .000349  .000232  .000000  .000116  .001975      5.52
   SSE  .000000  .000581  .000465  .000465  .000000  .000000  .000000  .000000  .001511      3.87
     S  .000000  .000349  .001743  .002092  .000232  .000000  .000000  .000000  .004416      4.55
   SSW  .000000  .000349  .002092  .000697  .000000  .000000  .000000  .000000  .003137      4.08
    SW  .000000  .000232  .001511  .000465  .000000  .000000  .000000  .000000  .002208      3.96
   WSW  .000000  .000813  .001511  .001394  .000349  .000000  .000000  .000000  .004067      4.16
     W  .000000  .001975  .008831  .000930  .000116  .000000  .000000  .000000  .011852      3.56
   WNW  .000000  .001394  .007553  .002789  .000465  .000116  .000000  .000000  .012317      4.04
    NW  .000000  .001859  .004416  .001859  .000465  .000232  .000232  .000000  .009063      4.25
   NNW  .000000  .000465  .001511  .000000  .000116  .000116  .000116  .000000  .002324      4.01
     N  .000000  .000581  .001859  .000581  .000232  .000116  .000000  .000000  .003370      4.14

  CALM                                                                          .000000
-------------------------------------------------------------------------------------------------

TOTAL   .000000  .013014  .044620  .020335  .007785  .004532  .002905  .002440  .095631      4.74

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =  130
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8606



                                  PASQUILL STABILITY CLASS "D"
                                    WIND SPEED CLASS (MPS)

            .51     1.51     3.01     4.51     6.01     7.51     9.01  GREATER
WIND         TO       TO       TO       TO       TO       TO       TO     THAN                MEAN
SECTOR     1.50     3.00     4.50     6.00     7.50     9.00    10.50    10.50    TOTAL      SPEED
-------------------------------------------------------------------------------------------------

   NNE  .001278  .004648  .015222  .010458  .004997  .003021  .000581  .000581  .040785      4.84
    NE  .002324  .003951  .008947  .004764  .001394  .000581  .000581  .000581  .023123      4.21
   ENE  .001278  .003602  .011620  .011736  .008250  .004880  .002208  .003370  .046944      5.84
     E  .001511  .003602  .014757  .036021  .041366  .037997  .033000  .043690  .211945      8.18
   ESE  .001394  .001278  .010690  .021380  .021729  .018940  .009993  .008482  .093888      7.13
    SE  .000581  .000465  .003835  .003254  .002673  .001975  .000232  .000232  .013247      5.49
   SSE  .001162  .000349  .004183  .001394  .000232  .000349  .000116  .000232  .008018      4.30
     S  .000697  .000813  .005113  .008482  .001859  .001162  .000000  .000000  .018127      4.94
   SSW  .001046  .001162  .006158  .003835  .001859  .000697  .000000  .000116  .014873      4.46
    SW  .000581  .000349  .005578  .003602  .002324  .000581  .000465  .000000  .013479      4.97
   WSW  .001046  .002324  .003370  .003602  .001627  .000349  .000232  .000000  .012549      4.37
     W  .001743  .001743  .003602  .002556  .001278  .000581  .000232  .000349  .012085      4.39
   WNW  .001162  .001627  .004183  .001859  .000813  .001162  .000581  .000349  .011736      4.82
    NW  .001046  .002440  .006623  .008018  .005926  .004067  .003254  .001627  .033000      6.18
   NNW  .000232  .001859  .008134  .003486  .004067  .001278  .000697  .000349  .020102      5.14
     N  .001975  .001743  .009412  .008366  .005578  .001743  .000232  .000000  .029050      4.87

  CALM                                                                          .000000
-------------------------------------------------------------------------------------------------

TOTAL   .019056  .031954  .121427  .132814  .105973  .079363  .052405  .059958  .602951      6.50

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =  130
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8606
```

```
FROM 90. 1. 1   TO 90.12.30  CHEK LAP KOK

                                        PASQUILL STABILITY CLASS "E"
                                          WIND SPEED CLASS (MPS)

             .51      1.51      3.01      4.51      6.01      7.51      9.01   GREATER
  WIND        TO        TO        TO        TO        TO        TO        TO      THAN                MEAN
SECTOR      1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL     SPEED
----------------------------------------------------------------------------------------------------------

   NNE   .000000   .003486   .003486   .001162   .000000   .000000   .000000   .000000   .008134      3.44
    NE   .000000   .003718   .002208   .000697   .000000   .000000   .000000   .000000   .006623      3.12
   ENE   .000000   .004648   .006739   .001743   .000000   .000000   .000000   .000000   .013130      3.43
     E   .000000   .003835   .008134   .002208   .000000   .000000   .000000   .000000   .014176      3.65
   ESE   .000000   .002556   .008831   .002673   .000000   .000000   .000000   .000000   .014060      3.79
    SE   .000000   .000930   .001162   .000116   .000000   .000000   .000000   .000000   .002208      3.33
   SSE   .000000   .000232   .000232   .000000   .000000   .000000   .000000   .000000   .000465      3.05
     S   .000000   .000581   .001975   .000930   .000000   .000000   .000000   .000000   .003486      3.70
   SSW   .000000   .001278   .004416   .000465   .000000   .000000   .000000   .000000   .006158      3.58
    SW   .000000   .000697   .003486   .000465   .000000   .000000   .000000   .000000   .004648      3.71
   WSW   .000000   .000813   .001394   .000116   .000000   .000000   .000000   .000000   .002324      3.27
     W   .000000   .001394   .001627   .000116   .000000   .000000   .000000   .000000   .003137      3.22
   WNW   .000000   .001162   .000465   .000349   .000000   .000000   .000000   .000000   .001975      3.15
    NW   .000000   .001278   .001162   .000465   .000000   .000000   .000000   .000000   .002905      3.40
   NNW   .000000   .000349   .000930   .000349   .000000   .000000   .000000   .000000   .001627      3.51
     N   .000000   .001627   .001394   .000232   .000000   .000000   .000000   .000000   .003254      3.40

  CALM                                                                                   .000000
----------------------------------------------------------------------------------------------------------

 TOTAL   .000000   .028585   .047641   .012085   .000000   .000000   .000000   .000000   .088310      3.51

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =  130
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8606


                                        PASQUILL STABILITY CLASS "F"
                                          WIND SPEED CLASS (MPS)

             .51      1.51      3.01      4.51      6.01      7.51      9.01   GREATER
  WIND        TO        TO        TO        TO        TO        TO        TO      THAN                MEAN
SECTOR      1.50      3.00      4.50      6.00      7.50      9.00     10.50     10.50     TOTAL     SPEED
----------------------------------------------------------------------------------------------------------

   NNE   .001627   .003602   .000000   .000000   .000000   .000000   .000000   .000000   .005229      1.90
    NE   .004067   .005229   .000000   .000000   .000000   .000000   .000000   .000000   .009296      1.71
   ENE   .005113   .006391   .000000   .000000   .000000   .000000   .000000   .000000   .011504      1.72
     E   .005810   .007320   .000000   .000000   .000000   .000000   .000000   .000000   .013130      1.71
   ESE   .005578   .003951   .000000   .000000   .000000   .000000   .000000   .000000   .009528      1.60
    SE   .005810   .001975   .000000   .000000   .000000   .000000   .000000   .000000   .007785      1.37
   SSE   .004183   .002208   .000000   .000000   .000000   .000000   .000000   .000000   .006391      1.45
     S   .003370   .003254   .000000   .000000   .000000   .000000   .000000   .000000   .006623      1.60
   SSW   .001975   .001627   .000000   .000000   .000000   .000000   .000000   .000000   .003602      1.67
    SW   .001975   .002440   .000000   .000000   .000000   .000000   .000000   .000000   .004416      1.70
   WSW   .003021   .002789   .000000   .000000   .000000   .000000   .000000   .000000   .005810      1.65
     W   .002673   .003254   .000000   .000000   .000000   .000000   .000000   .000000   .005926      1.74
   WNW   .003486   .001627   .000000   .000000   .000000   .000000   .000000   .000000   .005113      1.48
    NW   .001162   .000697   .000000   .000000   .000000   .000000   .000000   .000000   .001859      1.60
   NNW   .001394   .000813   .000000   .000000   .000000   .000000   .000000   .000000   .002208      1.35
     N   .014641   .001278   .000000   .000000   .000000   .000000   .000000   .000000   .015919      1.10

  CALM                                                                                   .000000
----------------------------------------------------------------------------------------------------------

 TOTAL   .065884   .048455   .000000   .000000   .000000   .000000   .000000   .000000   .114339      1.56

NUMBERS BELOW BASED ON ALL OBSERVATIONS
NUMBER OF INVALID OBSERVATIONS                  =  130
NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8606
```

```
FROM 90. 1. 1   TO 90.12.30   CHEK LAP KOK

                                        PASQUILL STABILITY CLASS "G"
                                          WIND SPEED CLASS (MPS)

             .51       1.51       3.01       4.51       6.01       7.51       9.01     GREATER
  WIND        TO         TO         TO         TO         TO         TO         TO       THAN                  MEAN
 SECTOR     1.50       3.00       4.50       6.00       7.50       9.00      10.50      10.50      TOTAL      SPEED
-------------------------------------------------------------------------------------------------------------------

    NNE  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
     NE  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
    ENE  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
      E  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
    ESE  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
     SE  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
    SSE  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
      S  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
    SSW  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
     SW  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
    WSW  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
      W  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
    WNW  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
     NW  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
    NNW  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00
      N  .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00

  CALM                                                                                           .000000
-------------------------------------------------------------------------------------------------------------------

 TOTAL   .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000    .000000       .00

 NUMBERS BELOW BASED ON ALL OBSERVATIONS
 NUMBER OF INVALID OBSERVATIONS                   =  130
 NUMBER OF VALID STABILITY DEPENDENT OBSERVATIONS = 8606


                                    ALL PASQUILL STABILITY CLASSES
                                          WIND SPEED CLASS (MPS)

             .51       1.51       3.01       4.51       6.01       7.51       9.01     GREATER
  WIND        TO         TO         TO         TO         TO         TO         TO       THAN                  MEAN
 SECTOR     1.50       3.00       4.50       6.00       7.50       9.00      10.50      10.50      TOTAL      SPEED
-------------------------------------------------------------------------------------------------------------------

    NNE  .003718    .013595    .021380    .012666    .005229    .003021    .000581    .000581    .060772      4.24
     NE  .009761    .018824    .014757    .005926    .001394    .000581    .000581    .000581    .052405      3.17
    ENE  .008018    .018824    .021845    .014990    .008947    .005113    .002324    .003486    .083546      4.55
      E  .008134    .017778    .027888    .041831    .043690    .039972    .034627    .045550    .259470      7.42
    ESE  .007669    .009296    .021497    .027074    .023937    .020451    .010806    .008831    .129561      6.22
     SE  .007901    .003951    .005694    .004067    .003021    .002208    .000232    .000349    .027423      3.86
    SSE  .005461    .003835    .005578    .002092    .000232    .000349    .000116    .000232    .017894      3.12
      S  .004880    .005578    .009644    .012317    .002092    .001162    .000000    .000000    .035673      3.99
    SSW  .003370    .005113    .013130    .005113    .001859    .000697    .000000    .000116    .029398      3.79
     SW  .003137    .004067    .010690    .004648    .002324    .000581    .000465    .000000    .025912      3.98
    WSW  .005113    .008947    .007669    .005229    .001975    .000349    .000232    .000000    .029514      3.43
      W  .005926    .015222    .019986    .004532    .001394    .000581    .000232    .000349    .048222      3.33
    WNW  .007901    .017081    .019637    .005345    .001278    .001278    .000581    .000349    .053451      3.35
     NW  .005810    .011736    .014641    .010806    .006391    .004299    .003486    .001627    .058796      4.80
    NNW  .003951    .005345    .010806    .003951    .004183    .001394    .000813    .000349    .030792      4.20
      N  .020567    .006623    .012898    .009180    .005810    .001859    .000232    .000000    .057169      3.36

  CALM                                                                                           .000000
-------------------------------------------------------------------------------------------------------------------

 TOTAL   .111318    .165815    .237741    .169765    .113758    .083895    .055310    .062398   1.000000      5.10

 NUMBERS BELOW BASED ON ALL OBSERVATIONS
 NUMBER OF INVALID OBSERVATIONS =  130
 NUMBER OF VALID OBSERVATIONS   = 8606
```

APPENDIX 4C

APPENDIX 4C

BASIS FOR TSP EMISSION RATES

APPENDIX 4C ESTIMATED TOTAL SUSPENDED PARTICULATE EMISSION RATES

This appendix provides information on how selected emission factors used to estimate emission rates have been developed.

Slag handling

An emission factor of 0.13 kg/t has been assumed. This has been derived from the US EPA 1985 (AP-42) batch loading equation:

$$E = \frac{k \times 0.0009 \, (\frac{s}{5})(\frac{u}{2.2})(\frac{H}{1.5})}{(\frac{Y}{4.6})^{0.33}(\frac{M}{2})^{2}}$$

k = *particle size multiplier*,
s = *silt content (%)*,
u = *wind speed(m/s)*,
H = *drop height (m)*,
Y = *capacity of dumping device* (m^3), *and*
M = *moisture content (%)*.

The following values have been assumed: k=0.73 (US EPA), u=5.14 m/s for Chek Lap Kok in 1989, H=2 m, s=80% (the slag at the existing plant has some solid lumps in it but is otherwise very fine), Y=4.6 m^3 and M=1% (watering of the slag will be undertaken to maintain a moisture level of at least this value). This gives an uncontrolled emission factor of 0.13 kg/t.

If 30,000 t of slag are generated per year then the total uncontrolled emission will be 3,900 kg [30,000 t/a x 0.13 kg/t]. If the plant operates 300 days per year the maximum emission rate averaged over 24-hours would be 0.15 g/s [(3,900 kg x 1000 g/kg)/(300 days x 24 h/day x 3,600 s/h)]. This dust emission could be controlled to approximately 70% by partial enclosure of the working area leaving an emission of 0.045 g/s [0.15 g/s x 0.30].

Vehicle movements

The US EPA's emission factor equation for industrial roads is:

$$E = 0.022 \, I \, (\frac{4}{n})(\frac{s}{10})(\frac{L}{280})(\frac{W}{2.7})^{0.7}$$

I = *industrial augmentation factor*,
n = *numberoflanes*,
s = *surface material silt content (%)*,
L = *surface dust loading (kg/km)*,
W = *mass of average vehicle (t)*.

The values assumed for the above variables are: I=1 (see US EPA (1985) - page 11.2.6-2), n=2, s=12.5% (see US EPA (1985) - Table 11.2.6-1 entry for iron and steel production), L=485 (reference as for s) and W=27 t (20 t payload and 7 t vehicle mass).

Approximately 24,375 return trips will be generated by export of 75% of 650,000 t of product in 20 t trucks assuming a 0.257 km return trip on-site the VKT/a value will be 6,264 km/a and emission will be 3,050 kg/a [(650,000 t/a x 0.75)/20 t/trip x 0.257 km/trip x 0.477 kg/VKT] or 0.115 g/s hourly average based on 300 days operation per year.

For the 25% distributed by sea the emissions from site handling are estimated similarly, but the assumed return trip is 0.240 km. Dust emission is 949 kg/a [(650,000 t/a x 0.25)/20 t/trip x 0.240 km/trip x 0.477 kg/VKT] or 0.036 g/s (hourly average based on 300 days/a operation).

In addition 30% of scrap will be received by road with a return trip of 0.200 km. Emission from on-site transport of scrap is estimated to be 950 kg/a [(650,000 t/a x 0.30)/20 t/trip x 0.200 km/trip x 0.477 kg/VKT] or 0.036 g/s (hourly average based on 300 days/a operation).

Scrap Handling

There are no emission factors for the handling of scrap iron. Particulate emissions will depend on the degree of iron oxide formation and cleanliness of scrap, and will be easily controlled to negligible levels by the application of water sprays. For the purposes of modelling it has been assumed that the particulate emission will be one tenth that which would occur from an excavator loading a dry soil-like material. The emission factor assumed was 0.002 kg/tonne of scrap. Approximately 650,000 t/a of scrap will be processed so the annual emission of particulate matter will be 910 kg/a [650,000 t/a x 0.70 x 0.002 kg/t] for the 70 percent of scrap that comes by sea and 390 kg/a for the 30 per cent received by road. These are equivalent to 0.035 and 0.015 g/s respectively based on 300 days per year.

APPENDIX 5A

APPENDIX 5A

SAMPLING, TESTING AND QUALITY OF MARINE DEPOSITS

Shiu Wing Steel Ltd
Steel Works at Tuen Mun Area 38
Sediment Quality Report

1. Introduction

Shiu Wing Steel Ltd are required to vacate their present mill at Junk Bay which is to be redeveloped. The proposed steel works site is located at TMTL372, Tuen Mun Area 38.

The northern portion of the site is on existing reclamation while the southern portion of the site has to be reclaimed to make up a total site area of about 8.6 hectares. A main vertical seawall along its southwestern boundary and a temporary sloping seawall along its southeastern boundary will be constructed to contain the reclamation fill. Marine deposits will be dredged for the whole site. This report contains an overview of the sampling and testing of marine deposits and an assessment on the quality of the marine deposits.

2. Sampling and Testing of Marine Deposits

A marine site investigation was conducted in September 1991 and a total of 13 drillholes were put down. Piston samples of marine deposits were taken at the time of drilling. In August 1992, the piston samples of 9 selected drillholes were inspected by EPD and were confirmed suitable for laboratory analysis for concentration of heavy metals. Twenty five marine deposit samples were extracted from those piston samples for testing.

Additional marine deposit sampling comprising nine surface grab samples at the drillhole locations and three vibrocores were carried out in October 1992 so that a full coverage of the site was made. Twelve marine deposit samples were extracted from the three vibrocores in accordance with the sampling schedule detailed in Appendix 1 of Works Branch Technical Circular No.22/92 Marine Disposal of Dredged Mud.

A schedule showing the marine deposit samples with depths and Drawing No. 90831/031 showing the location of the samples are attached as Appendix A.

The laboratory analysis of the marine deposit samples were also carried out in October 1992 to determine the concentration of cadmium, chromium, copper, mercury, nickel, lead and zinc in accordance with the analytical methodology detailed in Appendix 1 of Works Branch Technical Circular No. 22/92 Marine Disposal of Dredged Mud. The results are attached as Appendix B.

3. Assessment on Quality of Marine Deposits

Marine deposits are classified based on their level of contamination by the seven heavy metals into Classes A, B and C in accordance with the Environmental Protection Department Technical Circular No. 1-1-92. Class of the marine deposits are detailed in Appendix C. Classes A and B material are taken as uncontaminated material while class C material is taken as contaminated material for the purposes of disposal site allocation.

The surface of the sea bed are likely to be contaminated by copper at the southwestern half of the site as indicated by the marine deposit samples.

Although the samples D7-2.5m and D11-1.5m contained high concentration of nickel, there is no other marine deposit sample having significant nickel content. It is therefore considered that the likely contamination by nickel is very localized and is not a cause for concern.

The extent and depth of contaminated mud designated by EPD as environmentally unacceptable to be disposed of at the gazetted spoil ground deposit samples and is delineated on Drawing No. 90831/031D in Appendix D.

The volume of contaminated marine deposits to be dredged for seawall and reclamation and requiring disposal is estimated to be 20,000 m^3 while that of uncontaminated marine deposits is estimated to be 320,000 m^3.

TCT/jm

Updated 12 Janaury 1993

Shiu Wing Steel Ltd
Steel Works at Tuen Mun Area 38
Schedule of Marine Deposit Samples

Sample depth below seabed (m)	Drillhole									Vibrocore			
	D2	D3	D4	D5	D7	D8	D9	D11	D15	S1	S1A	S2	S3
Surface grab samples	✓	✓	✓	✓	✓	✓	✓	✓	✓				
0.0 - 0.1												✓	✓
0.0 - 0.5											✓		
0.0 - 0.7										✓			
0.9 - 1.0												✓	✓
1.5	✓	✓	✓		✓	✓	✓	✓	✓				
1.9 - 2.0												✓	✓
2.2								✓					
2.5	✓	✓	✓	✓	✓	✓	✓		✓				
2.9 - 3.0												✓	✓
3.5				✓									
4.0		✓	✓				✓		✓				
4.9 - 5.0													✓
5.0				✓									
5.9 - 6.0												✓	
6.5							✓						
7.5				✓									

Results :

Sample Identification		Cadmium content mg/kg	Chromium content mg/kg	Copper content mg/kg	Nickel content mg/kg	Lead content mg/kg	Zinc content mg/kg	Merc cont mg/
D2	1.5m	< 0.1	18	9	13	19	44	0.
D2	2.5m	0.4	10	9	11	4	28	0.
D3	1.5m	< 0.1	23	25	17	42	72	0.
D3	2.5m	< 0.1	33	11	24	23	47	0.
D3	4.0m	< 0.1	13	9	9	14	35	0.
D4	1.5m	< 0.1	17	23	14	41	52	0.
D4	2.5m	< 0.1	17	14	16	28	10	0.
D4	4.0m	< 0.1	16	11	15	20	45	0.
D5	2.5m	< 0.1	39	24	20	36	22	0.
D5	3.5m	< 0.1	17	12	13	24	60	0.
D5	5.0m	< 0.1	19	12	14	25	61	0.
D5	7.5m	< 0.1	12	8	10	17	44	0.
D7	1.5m	< 0.1	30	58	22	47	123	0.

Results :

Sample Identification		Cadmium content mg/kg	Chromium content mg/kg	Copper content mg/kg	Nickel content mg/kg	Lead content mg/kg	Zinc content mg/kg	Mercu conte mg/k
D7	2.5m	< 0.1	36	20	45	55	70	0.1
D8	1.5m	< 0.1	17	21	14	38	49	0.1
D8	2.5m	< 0.1	11	8	9	15	37	0.0
D9	1.5m	< 0.1	25	25	15	46	89	0.1
D9	2.5m	< 0.1	19	24	17	41	84	0.1
D9	4.0m	< 0.1	59	16	25	28	63	0.1
D9	6.5m	< 0.1	14	15	14	39	76	0.0
D11	1.5m	< 0.1	66	53	90	46	116	0.1
D11	2.2m	< 0.1	13	12	10	23	52	0.0
D15	1.5m	0.1	24	54	23	60	163	0.2
D15	2.5m	< 0.1	27	44	18	58	126	0.1
D15	4.0m	< 0.1	9	8	7	15	34	0.0

Supervised by : K.F. Wong

Certified by :
Approved Signature : K.M.

Date : 2/10

Results :

Sample Identification	Copper content, mg/kg	Cadmium content, mg/kg	Chromium content, mg/kg	Lead content, mg/kg	Nickel content, mg/kg	Zinc content, mg/kg	Mercury content, mg/kg
S1 0.0-0.7m	23	<0.1	14	30	9.8	67	0.07
S1A 0.0-0.5m	13	<0.1	8.6	36	5.5	45	0.06
S2 0.0-0.1m	70	<0.1	39	48	32	170	0.18
S2 0.9-1.0m	58	<0.1	30	45	25	130	0.19
S2 1.9-2.0m	24	<0.1	21	46	15	95	0.13
S2 2.9-3.0m	9.9	<0.1	13	21	9.7	59	0.05
S2 5.9-6.0m	4.1	<0.1	6.1	13	1.1	14	0.26
S3 0.0-0.1m	28	<0.1	20	29	28	98	0.27
S3 0.9-1.0m	42	<0.1	24	70	19	130	0.15
S3 1.9-2.0m	8.4	<0.1	9.4	35	7.5	38	0.05
S3 2.9-3.0m	5.4	<0.1	5.6	12	2.5	16	0.03
S3 4.9-5.0m	2.1	<0.1	<1	13	<1	14	0.01
D2	65	<0.1	26	41	19	120	0.14
D3	73	<0.1	27	45	21	140	0.16
D4	56	<0.1	25	39	19	120	0.13
D5	63	<0.1	23	40	18	120	0.17
D7	72	<0.1	26	42	20	130	0.16
D8	60	<0.1	23	39	17	130	0.14
D9	74	<0.1	25	42	20	130	0.14
D11	68	<0.1	27	41	20	130	0.14
D15	62	<0.1	24	40	19	140	0.13

Supervised by : K.F. Wong

Certified by :
Approved Signatory : K.M. Ho

Date : 20/10

Shiu Wing Steel Ltd
Steel Works at Tuen Mun Area 38
Contamination Class of Marine Deposits

Sample depth below seabed (m)	Drillhole									Vibrocore			
	D2	D3	D4	D5	D7	D8	D9	D11	D15	S1	S1A	S2	S3
Surface grab sample	C(Cu)	C(Cu)	B(Cu)	B(Cu)	C(Cu)	B(Cu)	C(Cu)	C(Cu)	B(Cu)				
0.0 - 0.1												C(Cu) B(Zn)	A
0.0 - 0.5											A		
0.0 - 0.7										A			
0.9 - 1.0												B(Cu)	B(Pb)
1.5	A	A	A		B(Cu)	A	A	C(Ni) B(Cr)	B(Zn)				
1.9 - 2.0												A	A
2.2								A					
2.5	A	A	A	A	C(Ni)	A	A		A				
2.9 - 3.0												A	A
3.5				A									
4.0		A	A				B(Cr)		A				
4.9 - 5.0													A
5.0				A									
5.9 - 6.0												A	
6.5							A						
7.5				A									

NB 1. Class A - Uncontaminated material
Class B - Moderately contaminated material
Class C - Seriously contaminated mateial

2. The marine deposits are contaminated by the heavy metals shown in the bracket (Cu-copper, Zn-zinc, Pb-lead, Ni-nickel Cr-chromium)

Shiu Wing Steel Ltd
Steel Works at Tuen Mun Area 38
Draft Specification Clause for Disposal of Contaminated Mud

8.43 Contaminated Marine Mud

(a) Marine mud has been classified as uncontaminated or contaminated according to the levels of metal concentration. Uncontaminated marine mud does not require special dredging, transport or disposal methods while contaminated marine mud requires special care during dredging and transport, and must be disposed of in a manner which ensures effective isolation and minimum loss of pollutants.

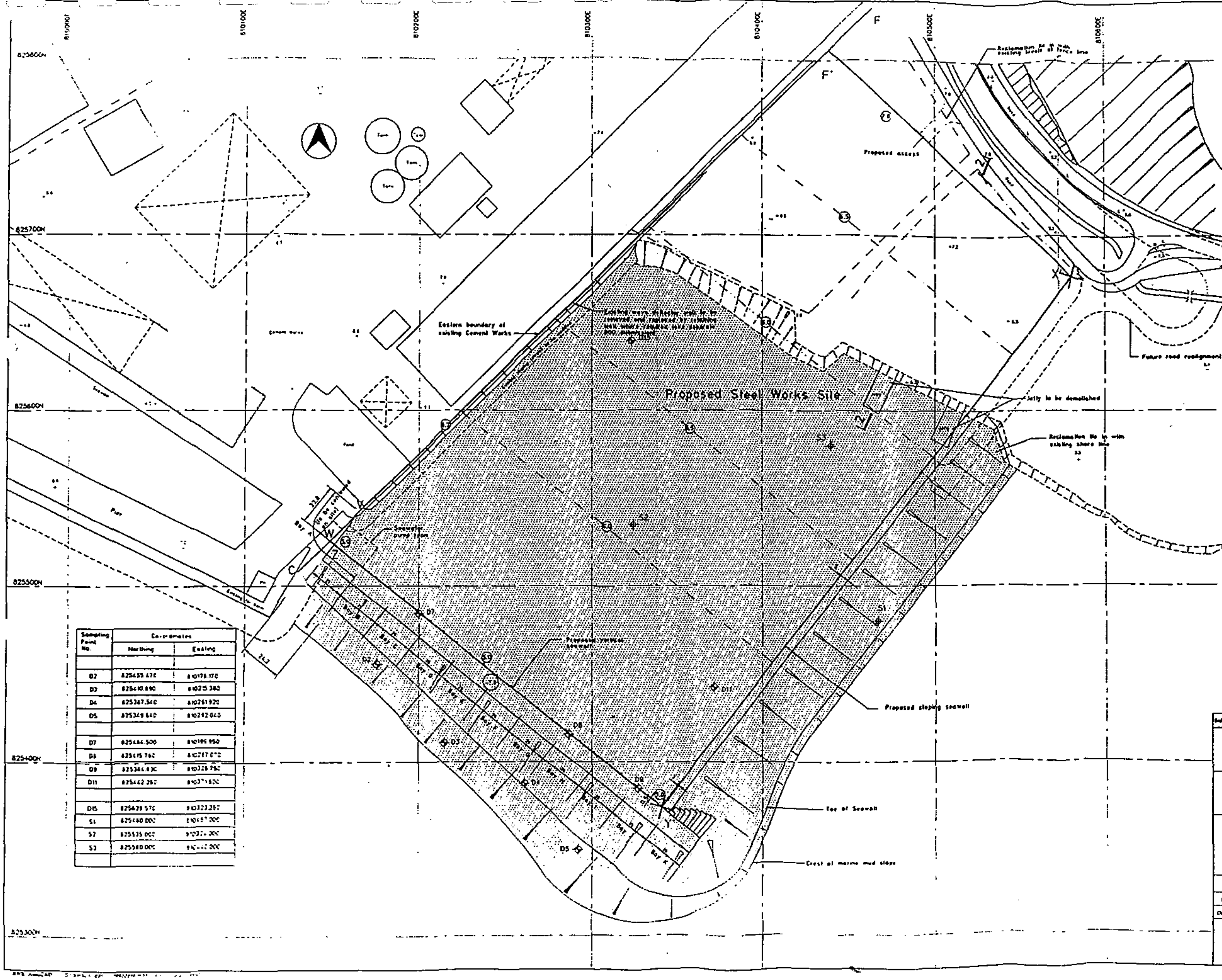
(b) Dredging of contaminated marine mud shall be by methods which will minimize contaminated of the water column and be subject to the conditions laid down in the dredging permit by EPD and other relevant requirements. Additional water quantity monitoring points in the vicinity of the site shall be implemented to monitor the turbidity and dissolved oxygen level in the water in accordance with the requirements of EPD.

(c) The Contractor shall note that the Government is unable to allocate a marine disposal site for contaminated mud for this project at this stage. The Contractor shall accordingly make his own arrangement for disposing the dredged contaminated mud.

(d) The following particulars of the proposed arrangement of disposing the dredged contaminated mud shall be submitted to the Engineer for agreement at least 14 days before dredging of contaminated mud starts:

- the location of disposal site;
- details of Constructional Plant and transport;
- methods of dumping;
- sequence and rate of working;
- the dumping permit and/or written agreement from relevant authorities controlling the disposal site for contaminated mud;
- the dredging permit from EPD.

(e) The Contractor shall comply with all the conditions stipulated in the dumping permit and/or written agreement from relevant authorities.



Notes

1. All dimensions are in metres unless otherwise shown
2. All levels are in metres above Principal Datum (mPD)
3. Coordinates are related to Hong Kong Metric Grid (1980)
4. Existing ground levels shown are approximately only.
5. Legends:

+7.2	Existing level
┬┬	Existing slope
┬┬	Fill slope
┬┬	Cut slope
—	Lot boundary
—⊖—	Proposed line of formation level
⊖	Proposed formation level
⌖	Existing Sampling Point
⊕	Proposed Sampling Point
•	30T Bollard
▨	Dredging (indicative only)

6. Vibrocores to be taken at the proposed sampling points while surface grab samples to be taken at the existing sampling points.

Sampling Point No.	Coordinates	
	Northing	Easting
D2	825455.470	810176.170
D3	825410.890	810215.380
D4	825367.540	810261.920
D5	825349.640	810292.040
D7	825484.500	810195.950
D8	825415.760	810287.070
D9	825346.830	810328.750
D11	825442.280	810371.820
D15	825629.570	810323.250
S1	825440.000	810457.000
S2	825535.000	810324.000
S3	825580.000	810442.000

Suffix	Date	Revision	Drawn	Checked

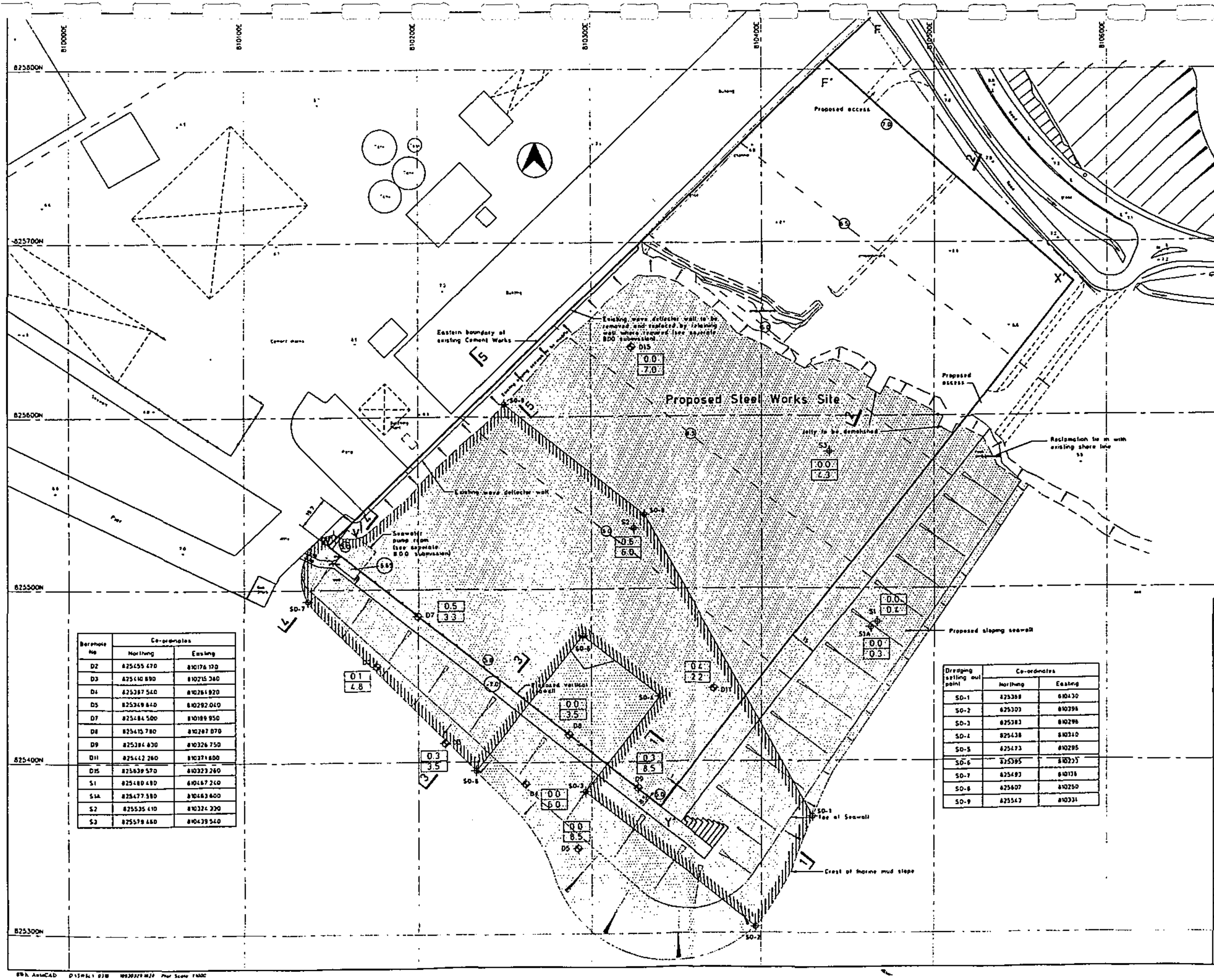
SHIU WING STEEL LIMITED

PROPOSED STEEL WORKS
AT TUEN MUN AREA 38

Marine Deposits Sampling Locations

Drawing No.	90831/031			
Date	12.91	Drawn	LCM	Scale 1:2000
Checked	TCF	Approved	MLC	

Scott Wilson Kirkpatrick
CONSULTING ENGINEERS



Borehole No	Co-ordinates	
	Northing	Easting
D2	825455.470	810176.170
D3	825410.890	810215.360
D4	825387.540	810264.920
D5	825349.640	810292.040
D7	825484.500	810189.950
D8	825415.780	810287.070
D9	825384.630	810326.750
D11	825442.260	810374.600
D15	825639.570	810323.260
S1	825480.490	810467.240
S1A	825477.580	810463.600
S2	825535.410	810324.330
S3	825579.460	810439.540

Dredging setting out point	Co-ordinates	
	Northing	Easting
SO-1	825368	810430
SO-2	825303	810396
SO-3	825383	810296
SO-4	825438	810340
SO-5	825473	810295
SO-6	825395	810233
SO-7	825493	810138
SO-8	825607	810250
SO-9	825543	810331

No.

1 All dimensions are in metres unless otherwise shown

2 All levels are in metres above Principal Datum (mPD)

3 Coordinates are related to Hong Kong Metric Grid (1980)

4 Existing ground levels shown are approximately only

5 Legends:

+7.2	Existing level
⊤⊤	Existing slope
⊤⊤	Fill slope
⊤⊤	Cut slope
—	Lot boundary
—⑥⓪—	Proposed line of formation level
⑤⑤	Proposed formation level
⊕	Borehole (before 1990)
⊕	Borehole (1990)
•	10T Bollard
▭	Dredging (indicative only)
▨	Seriously contaminated mud
0.3	Depth of seriously contaminated mud in metres
3.5	Depth of moderately contaminated mud and uncontaminated mud in metres

6 Classification of marine sediments is in accordance with Environmental Protection Department Technical Circular No 1-1-82

7 The top 0.5m of the mud within the boundary of seriously contaminated mud is disposed of at the Contaminated Mud Pit I at East Sha Chau

Suffix	Date	Revision	Drawn	Checked
D	[illegible]	Dredging setting out points for seriously contaminated mud is added	HN	
C	[illegible]	Depth of seriously contaminated mud at D7, note 7 and extent of seriously contaminated mud revised	HN	
B	01.93	Drawing title revised Note 7 added	LCM	TCT
A	25.11.92	Extent of seriously contaminated mud added Layout of dredging and reclamation and Note 6 revised	HN	TCT

SHIU WING STEEL LIMITED

PROPOSED STEEL WORKS
AT TMTL 372 TUEN MUN
AREA 38

Dredging,
Extent of Co taminated Mud

Drawing No.	90831/031D			
Date	12.91	Drawn	LCM	Scale 1:2000
Checked	TCT	Approved	MLC	

Scott Wilson Kirkpatrick
CONSULTING ENGINEERS

SWk AutoCAD D15WSL1 031B [illegible] Plot Scale 1:1000

APPENDIX 5B

APPENDIX 5B

SEWAGE ARISINGS CALCULATIONS

APPENDIX 5B: SEWAGE ARISINGS

Sewage Volume

Toilets : 60 litres per employee per day x 400 employees = 24m^3/day
Showers : 60 litres per employee per day x 400 employees = 24m^3/day
Kitchen : 500 litres/m^2/day x 40m^2 = 20m^3/day

TOTAL 68m^3/day

BOD load

Toilets : 23g per employee per day x 400 employees = 9.2kg/day
Showers : 3g per employee per day x 400 employees = 1.2kg/da
Kitchen : 300g/m^2/day x 40m^2 = 12kg

TOTAL 22.4kg/day

Suspended Solids load

Toilets : 23g per employee per day x 400 employees = 9.2kg/day
Showers : 3g per employee per day x 400 employees = 1.2kg/day
Kitchen : 300g/m^2/day x 40m^2 = 12kg

TOTAL 22.4kg/day

APPENDIX 5C

APPENDIX 5C

EPD CONTAMINATED MUD DISPOSAL CONDITIONS

APPENDIX B

REQUIREMENTS OF THE CONTAMINATED MUD PIT MANAGEMENT SCHEME

The Contaminated Mud Pit Management Scheme is administered by the Chief Engineer/Port Works, of the Civil Engineering Department. Users are required to comply with the following :-

(a) Notification of dumping - The resident engineer or his representative shall inform the control office by telephone (No. 94829259 or 94970534) within a period of 1 and 3 hours before the scheduled time of arrival at the disposal area. The following information shall be provided in the telephone notification :-

- (i) dumping licence number;
- (ii) dredging location;
- (iii) tug number/name;
- (iv) barge number/name;
- (v) quantity of contaminated mud to be dumped;
- (vi) time leaving the dredging site and the anticipated arrival time at East Sha Chau

The above information should also be entered in the standard form (attached) and submitted to the control office when the barge reports there.

(b) Reporting to the site control office - On arrival, the barge operator shall first report to the control office before commencing any dumping operation. After verification against the notification received, the barge operator will be informed of the location of dumping or, if it is necessary for the barge to wait, the queuing area.

(c) Dumping - After receipt of permission from the control office to proceed with dumping, the barge operator should, with the aid of instruction given by the management team staff, manoeuvre the barge into the dumping site which is enclosed by silt curtains. Dumping should proceed slowly and steadily, in such a way that the silt curtains will not be unduly displaced. Dumping will be stopped immediately if the silt curtains are found to have been dislocated or damaged. The barge operator will be held responsible for their repair or replacement as appropriate.

(d) Barges arriving without licence - Barges without valid dumping licence shall be advised to leave the pit area and the relevant details will be recorded.

(e) Barges arriving without prior notification - Barges with valid dumping licence but arriving without prior notification as required in para.1. shall be required to wait until all relevant details are provided and verified.

(f) Illegal dumping - If barges are found to disobey instructions and proceed with illegal dumping, their details will be recorded.. Appropriate action will be taken by EPD, Marine Police or Marine Department as appropriate.

(g) Leaving the pit - After discharging, the barge operator shall inform the control office of completion of dumping before leaving the pit.

(h) Closure of Pit - The dumping areas will be closed when Typhoon Signal No. 3 is hoisted, in adverse weather or other conditions when the team considers that its management duties cannot be discharged properly. There is no guarantee that prior notice can be given. Any barges arriving when the pit is closed will be advised to leave the dumping area immediately.

(i) Checking of licensed and allocated volume - The resident engineer should keep a running tally of the volume dumped under both the licence and the allocation. If either the licensed or allocated volume is reached, he should notify the team and also stop sending the barge to the dumping ground.

APPENDIX 5D

APPENDIX 5D

COOLING WATER CALCULATIONS

APPENDIX 5D : COOLING WATER CALCULATIONS

Flows:

Steel Mill will discharge 100,000m^3/day

= 1.157 m^3/sec of process water at temperature 10° above ambient.

Receiving Water:

In Hong Kong wet and dry season cases are usually considered. In this case, discharge will be to the surface layer. Typical values of salinity and temperature are:

wet	18ppt	26°C
dry	32ppt	18°C

Density of receiving water from attached chart is:

wet	1,012kg/m^3
dry	1,023kg/m^3

Effluent Density

For 10° increase in ambient temperature, effluent values for salinity, temperature and density are :

wet	19ppt	36°C	1007kg/m^3
dry	32ppt	28°C	1020kg/m^3

Form of discharge

To achieve WQO of less than 2°C increase in ambient temperature of sea water, a 1 : 5 x dilution is required. It is considered that this would be most reliably achieved by a submerged discharge pipe.

Initial Dilution Calculation (Cederwall Equation)

For the mean low low water (MLLW) scenario, a discharge pipe at -2.4 mPD (invert level) and with 0.9m diameter horizontal discharge will give:

Dry Season	3.82 x Dilution
Wet Season	3.13 x Dilution (see attached calculations)

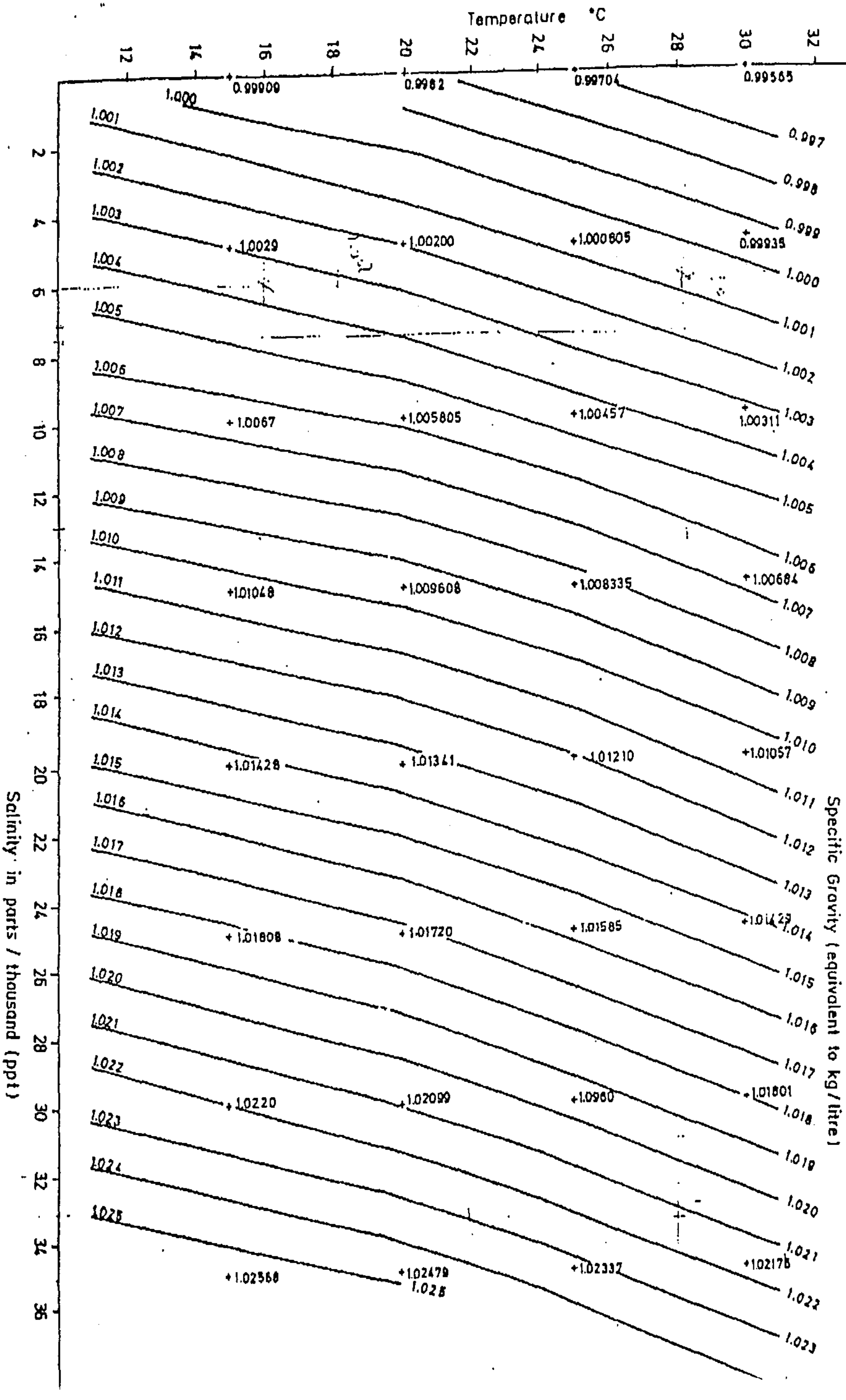
by the time the submerged discharge has reached the surface of the sea.

Far Field Calculations (Brooks Method)

The attached calculations show that at 25 metres from the discharge position, further dilution is sufficient to have resulted in the following small temperature rises at current of 1 m/s:

Dry Season	0.15°C
Wet Season	0.28°C

and thus WQOs are satisfied, within the agreed 100 metre mixing zone.


Temperature °C
12
14
16
18
20
22
24
26
28
30
32
0.99909
0.9982
0.99704
0.99565
Salinity in parts / thousand (ppt)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
Specific Gravity (equivalent to kg/litre)
1.000
1.001
1.002
1.003
1.004
1.005
1.006
1.007
1.008
1.009
1.010
1.011
1.012
1.013
1.014
1.015
1.016
1.017
1.018
1.019
1.020
1.021
1.022
1.023
1.024
1.025
0.997
0.998
0.999
+1.0029
+1.00200
+1.000605
+0.99935
+1.0067
+1.005805
+1.00457
+1.00311
+1.01048
+1.009608
+1.008335
+1.00684
+1.01428
+1.01341
+1.01210
+1.01057
+1.01808
+1.01720
+1.01585
+1.01429
+1.0220
+1.02099
+1.0960
+1.01801
+1.02568
+1.02479
+1.02337
+1.02178

acer

Client: **Axis** Project: **053000**
Job: **Shu Wing Steel Mill** Job:

Division: **Water** Section: **Outfall** Sheet **1** of **5**
Office: **MWU** Subject: **Initial Dilution Wet Season** 0.9m Drg No.

Designed by: Date: Checked by: Date:

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shuwdilw.mcd

Initial dilutions will be calculated using the methods recomended in the WRc Design Guide for Marine Treatment Schemes Ch 6. These recomendations are to use Lees method in the Bouyancy Dominated Far Field (BDFF) ,where current effects dominate mixing and the Cederwall equation in the Bouyancy Dominated Near Field (BDNF), where current effects are minimal and mixing is dominated by plume bpuyancy.

Input Data

Total Flows in Outfall $Q_j :=$ m^3/s

j	Q_j
1	1.157
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0

No of jets $N := 1$
Dia of jets $Dia := 9$ m
Level of jets $JL := -1.95$ mPD

Density of effluent $\rho o := 1.007$ kg/m^3
Density of seawater $\rho a := 1.012$ kg/m^3 $g := 9.81$

Tide levels and Currents No of cases $i := 1..4$ (Max no 10)

	$TL_i :=$	$Ua_i :=$
MHHW	2.2	0
MLHW	1.6	0
MHLW	1.1	0
MLLW	0.6	0

Client: **Axis**

Job: **Shu Wing Steel Mill** Job:

Division: **Water** Section: **Outfall** Sheet **2** of **5**

Office: **MWU** Subject: **Initial Dilution Wet Season** Drg No.

Designed by: Date: Checked by: Date:

Calculations

Flow per jet $q_j := \frac{Q_j}{N}$ m^3/s

Jet velocity $vj_j := \frac{q_j}{\left(\frac{Dia^2}{4}\right)\cdot\pi}$ m/s

Densimetric Froude No $F_j := \frac{vj_j}{\left(\frac{\rho a - \rho o}{\rho a}\cdot g\cdot Dia\right)^{\frac{1}{2}}}$

Bouyancy Flux per Port $B_j := g\cdot q_j\cdot\left(\frac{\rho a - \rho o}{\rho a}\right)$

Water Depth $H_i := TL_i - JL$ m

Initial dilution from Lees equation for BDFF case $SLF_{i,j} := \frac{0.27\cdot Ua_i\cdot\left(H_i\right)^2}{q_j}$

Initial dilution from Lees equation for BDNF case $SLN_{i,j} := \frac{0.27\cdot\left(B_j\right)^{\frac{1}{3}}\cdot\left(H_i\right)^{\frac{5}{3}}}{q_j}$

Initial dilution from Cederwall's equation for BDNF case $SC_{i,j} := 0.54\cdot F_j\cdot\left(\frac{0.38\cdot H_i}{Dia\cdot F_j} + 0.66\right)^{\frac{5}{3}}$

Plume Diameter $Ws_i := 0.26\cdot H_i$ m

Depth of surface field $hs_i := 0.13\cdot H_i$ m

Client: **Axis** Project:
Job: **Shu Wing Steel Mill** Job:

Division: **Water** Section: **Outfall** Sheet **3** of **5**
Office: **MWU** Subject: **Initial Dilution Wet Season** Drg No.

Designed by: Date: Checked by: Date:

Results 1 Lee's equation

$z = 0$ for BDNF case & $z = 1$ for BDFF case

Tide Cases

Total outfall flows m^3/s

Water Depth m — Ambient Current m/s

$Q_1 = 1.157$ $Q_2 = 0$ $Q_3 = 0$ $Q_4 = 0$ $Q_5 = 0$

i	H_i	Ua_i	$SL_{i,1}$	$z_{i,1}$	$SL_{i,2}$	$z_{i,2}$	$SL_{i,3}$	$z_{i,3}$	$SL_{i,4}$	$z_{i,4}$	$SL_{i,5}$	$z_{i,5}$
1	4.15	0	0.96	0	0	0	0	0	0	0	0	0
2	3.55	0	0.74	0	0	0	0	0	0	0	0	0
3	3.05	0	0.57	0	0	0	0	0	0	0	0	0
4	2.55	0	0.43	0	0	0	0	0	0	0	0	0

Tide Cases

Total outfall flows m^3/s

Water Depth m — Ambient Current m/s

$Q_6 = 0$ $Q_7 = 0$ $Q_8 = 0$ $Q_9 = 0$ $Q_{10} = 0$

i	H_i	Ua_i	$SL_{i,6}$	$z_{i,6}$	$SL_{i,6}$	$z_{i,6}$	$SL_{i,8}$	$z_{i,8}$	$SL_{i,9}$	$z_{i,9}$	$SL_{i,10}$	$z_{i,10}$
1	4.15	0	0	0	0	0	0	0	0	0	0	0
2	3.55	0	0	0	0	0	0	0	0	0	0	0
3	3.05	0	0	0	0	0	0	0	0	0	0	0
4	2.55	0	0	0	0	0	0	0	0	0	0	0

Client: **Axis** Project:

Job: **Shu Wing Steel Mill** Job:

Division: **Water** Section: **Outfall** Sheet 4 of 5

Office: **MWU** Subject: **Initial Dilution Wet Season** Drg No.

Designed by: Date: Checked by: Date:

Results 2 Cederwall's equation for BDNF case.

Tide Cases

Total outfall flows m^3/s

Water Depth m

Ambient Current m/s

$Q_1 = 1.157$ $Q_2 = 0$ $Q_3 = 0$ $Q_4 = 0$ $Q_5 = 0$

i	H_i	Ua_i	$SC_{i,1}$	$z_{i,1}$	$SC_{i,2}$	$z_{i,2}$	$SC_{i,3}$	$z_{i,3}$	$SC_{i,4}$	$z_{i,4}$	$SC_{i,5}$	$z_{i,5}$
1	4.15	0	3.67	0	0	0	0	0	0	0	0	0
2	3.55	0	3.46	0	0	0	0	0	0	0	0	0
3	3.05	0	3.3	0	0	0	0	0	0	0	0	0
4	2.55	0	3.13	0	0	0	0	0	0	0	0	0

Water Depth m

Ambient Current m/s

$Q_6 = 0$ $Q_7 = 0$ $Q_8 = 0$ $Q_9 = 0$ $Q_{10} = 0$

i	H_i	Ua_i	$SC_{i,6}$	$z_{i,1}$	$SC_{i,7}$	$z_{i,7}$	$SC_{i,8}$	$z_{i,8}$	$SC_{i,9}$	$z_{i,9}$	$SC_{i,10}$	$z_{i,10}$
1	4.15	0	0	0	0	0	0	0	0	0	0	0
2	3.55	0	0	0	0	0	0	0	0	0	0	0
3	3.05	0	0	0	0	0	0	0	0	0	0	0
4	2.55	0	0	0	0	0	0	0	0	0	0	0

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Job:	Shu Wing Steel Mill	Job:	

Division:	**Water**	Section:	**Outfall**	Sheet 5	of 5
Office:	**MWU**	Subject:	**Initial Dilution Wet Season**	Drg No.	

Designed by: Date: Checked by: Date:

Flow m3/s Q_j	Jet Velocity m/s vj_j	Froude No F_j
1.157	1.819	8.7
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

Tide Cases

i	Water Depth m H_i	Plume Diameter m Ws_i	Depth of Surface Field m hs_i
1	4.15	1.079	0.54
2	3.55	0.923	0.462
3	3.05	0.793	0.397
4	2.55	0.663	0.332

acer

Client:	**Axis**	Project:	**053000**
Job:	**Shu Wing Steel Mill**	Job:	

Division:	**Water**	Section:	**Outfall**	Sheet **1** of **5**	
Office:	MWU	Subject:	**Initial Dilution** DrySeason 0.9 m	Drg No.	

Designed by: Date: Checked by: Date:

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Initial dilutions will be calculated using the methods recomended in the WRc Design Guide for Marine Treatment Schemes Ch 6. These recomendations are to use Lees method in the Bouyancy Dominated Far Field (BDFF) ,where current effects dominate mixing and the Cederwall equation in the Bouyancy Dominated Near Field (BDNF), where current effects are minimal and mixing is dominated by plume bouyancy.

Input Data

Total Flows in Outfall

j	$Q_j :=$ m^3/s
1	1.157
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0

No of jets	$N := 1$	
Dia of jets	$Dia := .9$	m
Level of jets	$JL := -1.95$	mPD
Density of effluent	$\rho o := 1.020$	kg/m^3
Density of seawater	$\rho a := 1.023$	kg/m^3

$g := 9.81$

Tide levels and Currents No of cases $i := 1 .. 4$ (Max no 10)

	$TL_i :=$	$Ua_i :=$
MHHW	2.2	0
MLHW	1.6	0
MHLW	1.1	0
MLLW	0.6	0

Calculations

Flow per jet $q_j := \dfrac{Q_j}{N}$ m^3/s

Jet velocity $vj_j := \dfrac{q_j}{\left(\dfrac{Dia^2}{4}\right)\cdot\pi}$ m/s

Densimetric Froude No $F_j := \dfrac{vj_j}{\left(\dfrac{\rho a - \rho o}{\rho a}\cdot g\cdot Dia\right)^{\frac{1}{2}}}$

Bouyancy Flux per Port $B_j := g\cdot q_j\cdot\left(\dfrac{\rho a - \rho o}{\rho a}\right)$

Water Depth $H_i := TL_i - JL$ m

Initial dilution from Lees equation for BDFF case $SLF_{i,j} := \dfrac{0.27\cdot Ua_i\cdot\left(H_i\right)^2}{q_j}$

Initial dilution from Lees equation for BDNF case $SLN_{i,j} := \dfrac{0.27\cdot\left(B_j\right)^{\frac{1}{3}}\cdot\left(H_i\right)^{\frac{5}{3}}}{q_j}$

Initial dilution from Cederwall's equation for BDNF case $SC_{i,j} := 0.54\cdot F_j\cdot\left(\dfrac{0.38\cdot H_i}{Dia\cdot F_j} + 0.66\right)^{\frac{5}{3}}$

Plume Diameter $Ws_i := 0.26\cdot H_i$ m

Depth of surface field $hs_i := 0.13\cdot H_i$ m

Client: **AXIS**
Job: **Shu Wing Steel Mill**
Job:

Division: **Water** Section: **Outfall** Sheet 3 of 5
Office: **MWU** Subject: **Initial Dilution** Drg No.

Designed by: Date: Checked by: Date:

Results 1 Lee's equation

$z = 0$ for BDNF case & $z = 1$ for BDFF case

Tide Cases

Total outfall flows m^3/s

$Q_1 = 1.157$ $Q_2 = 0$ $Q_3 = 0$ $Q_4 = 0$ $Q_5 = 0$

i	Water Depth m H_i	Ambient Current m/s Ua_i	$SL_{i,1}$	$z_{i,1}$	$SL_{i,2}$	$z_{i,2}$	$SL_{i,3}$	$z_{i,3}$	$SL_{i,4}$	$z_{i,4}$	$SL_{i,5}$	$z_{i,5}$
1	4.15	0	0.8	0	0	0	0	0	0	0	0	0
2	3.55	0	0.62	0	0	0	0	0	0	0	0	0
3	3.05	0	0.48	0	0	0	0	0	0	0	0	0
4	2.55	0	0.36	0	0	0	0	0	0	0	0	0

Tide Cases

Total outfall flows m^3/s

$Q_6 = 0$ $Q_7 = 0$ $Q_8 = 0$ $Q_9 = 0$ $Q_{10} = 0$

i	Water Depth m H_i	Ambient Current m/s Ua_i	$SL_{i,6}$	$z_{i,6}$	$SL_{i,6}$	$z_{i,6}$	$SL_{i,8}$	$z_{i,8}$	$SL_{i,9}$	$z_{i,9}$	$SL_{i,10}$	$z_{i,10}$
1	4.15	0	0	0	0	0	0	0	0	0	0	0
2	3.55	0	0	0	0	0	0	0	0	0	0	0
3	3.05	0	0	0	0	0	0	0	0	0	0	0
4	2.55	0	0	0	0	0	0	0	0	0	0	0

Client: **Axis** Project:

Job: **Shu Wing Steel Mill** Job:

Division: **Water** Section: **Outfall** Sheet **4** of **5**

Office: **MWU** Subject: **Initial Dilution** Drg No.

Designed by: Date: Checked by: Date:

Results 2 Cederwall's equation for BDNF case.

Tide Cases

Total outfall flows m^3/s

$Q_1 = 1.157$ $Q_2 = 0$ $Q_3 = 0$ $Q_4 = 0$ $Q_5 = 0$

i	Water Depth m H_i	Ambient Current m/s Ua_i	$SC_{i,1}$	$z_{i,1}$	$SC_{i,2}$	$z_{i,2}$	$SC_{i,3}$	$z_{i,3}$	$SC_{i,4}$	$z_{i,4}$	$SC_{i,5}$	$z_{i,5}$
1	4.15	0	4.34	0	0	0	0	0	0	0	0	0
2	3.55	0	4.14	0	0	0	0	0	0	0	0	0
3	3.05	0	3.98	0	0	0	0	0	0	0	0	0
4	2.55	0	3.82	0	0	0	0	0	0	0	0	0

$Q_6 = 0$ $Q_7 = 0$ $Q_8 = 0$ $Q_9 = 0$ $Q_{10} = 0$

i	Water Depth m H_i	Ambient Current m/s Ua_i	$SC_{i,6}$	$z_{i,1}$	$SC_{i,7}$	$z_{i,7}$	$SC_{i,8}$	$z_{i,8}$	$SC_{i,9}$	$z_{i,9}$	$SC_{i,10}$	$z_{i,10}$
1	4.15	0	0	0	0	0	0	0	0	0	0	0
2	3.55	0	0	0	0	0	0	0	0	0	0	0
3	3.05	0	0	0	0	0	0	0	0	0	0	0
4	2.55	0	0	0	0	0	0	0	0	0	0	0

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Job: **Shu Wing Steel Mill** Job:

Division: **Water** Section: **Outfall** Sheet **5** of **5**

Office: **MWU** Subject: **Initial Dilution** Drg No.

Designed by: Date: Checked by: Date:

Flow m3/s Q_i	Jet Velocity m/s vj_i	Froude No F_i
1.157	1.819	11.3
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

Tide Cases

i	Water Depth m H_i	Plume Diameter m Ws_i	Depth of Surface Field m hs_i
1	4.15	1.079	0.54
2	3.55	0.923	0.462
3	3.05	0.793	0.397
4	2.55	0.663	0.332

acer

Client:	**Axis**	0.9m	Project:	**053000**	
Job:	**Shu Wing Steel Mill**		Job:		
Division: **Water**	Section:	**Outfall**	Sheet **1** of **5**		
Office: **MWU**	Subject:	**Plume Temp Wet Season**	Drg No.		
Designed by:	Date:	Checked by:	Date:		

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Calculation of temperature of plume using Brooks method (Ref Grace Marine Outfall Systems Ch 7)

The method is considered conservative for tidal currents and the Richardsons Law (4/3 Law) is considered the most appropriate of the 3 options given..

Temp of effluent $\mathrm{Te} := 28$ deg C

Temp of seawater $\mathrm{Ts} := 18$ deg C

Initial Dilution $\mathrm{ID} := 3.13$ Times

Temp of suface field $\mathrm{Tsur} := \dfrac{\mathrm{Te} + \mathrm{Ts}\cdot(\mathrm{ID} - 1)}{\mathrm{ID}}$ $\mathrm{Tsur} = 21.195$ deg C

Initial width of field $B := 0.663\cdot 10^{2}$ cm

$k := 1 .. 4$

Current velocities $u_k :=$ m/s

$$\begin{array}{|c|}\hline 0.1 \\ \hline 0.2 \\ \hline 0.5 \\ \hline 1.0 \\ \hline \end{array}$$

Distance downstream

No of increments $i := 1 .. 10$

Length of increment $l := 25$ m $x_i := l\cdot i\cdot 10^{2}$ cm

$$x_i$$

$$\begin{array}{|r|}\hline 2.5\cdot 10^{3} \\ \hline 5\cdot 10^{3} \\ \hline 7.5\cdot 10^{3} \\ \hline 1\cdot 10^{4} \\ \hline 1.25\cdot 10^{4} \\ \hline 1.5\cdot 10^{4} \\ \hline 1.75\cdot 10^{4} \\ \hline 2\cdot 10^{4} \\ \hline 2.25\cdot 10^{4} \\ \hline 2.5\cdot 10^{4} \\ \hline \end{array}$$

Calculation of diffusion coef

Richardsons Law Power $no := \frac{4}{3}$

Constant (Grace Page 319) average value $\alpha := 0.03$ $cm^{2/3}/s$

Diffusion coef $\varepsilon := \alpha \cdot B^{no}$

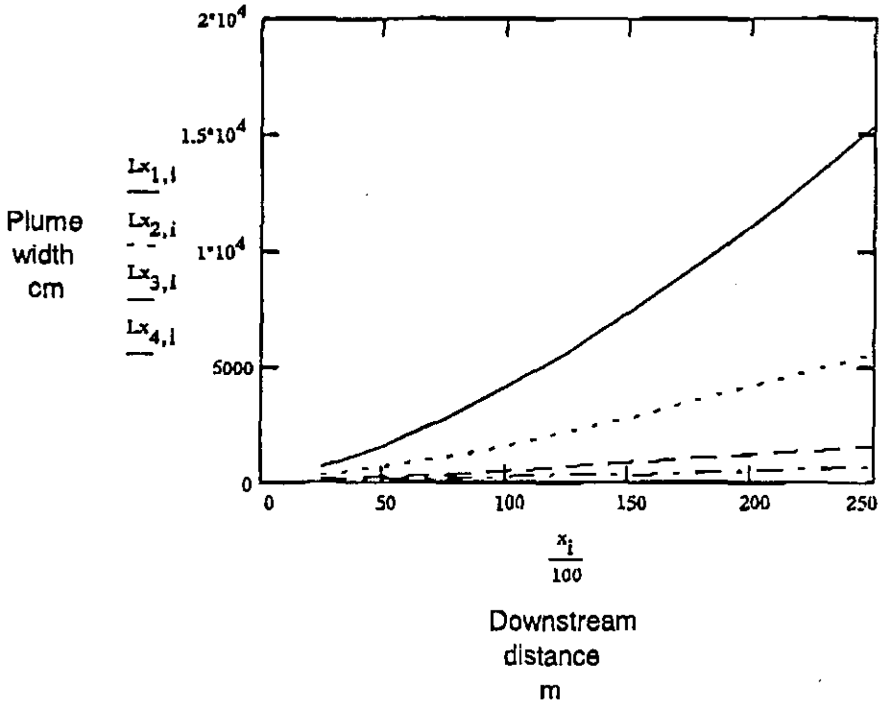
Calculation of plume width

$$\beta_k := \frac{12 \cdot \varepsilon}{u_k \cdot 10^2 \cdot B}$$

Plume width $Lx_{k,i} := \left[\left[\left(\frac{2}{3}\right) \cdot \beta_k \cdot \frac{x_i}{B}\right] + 1\right]^{\frac{3}{2}} \cdot B$ cm

Plume widths cm

Distance downstream cm	$u_1 = 0.1$	$u_2 = 0.2$	$u_3 = 0.5$	$u_4 = 1$
x_i	$Lx_{1,i}$	$Lx_{2,i}$	$Lx_{3,i}$	$Lx_{4,i}$
$2.5 \cdot 10^3$	667.542	315.872	151.197	105.882
$5 \cdot 10^3$	$1.593 \cdot 10^3$	667.542	256.606	151.197
$7.5 \cdot 10^3$	$2.752 \cdot 10^3$	$1.097 \cdot 10^3$	379.107	201.595
$1 \cdot 10^4$	$4.105 \cdot 10^3$	$1.593 \cdot 10^3$	516.58	256.606
$1.25 \cdot 10^4$	$5.628 \cdot 10^3$	$2.146 \cdot 10^3$	667.542	315.872
$1.5 \cdot 10^4$	$7.302 \cdot 10^3$	$2.752 \cdot 10^3$	830.881	379.107
$1.75 \cdot 10^4$	$9.116 \cdot 10^3$	$3.406 \cdot 10^3$	$1.006 \cdot 10^3$	446.075
$2 \cdot 10^4$	$1.106 \cdot 10^4$	$4.105 \cdot 10^3$	$1.191 \cdot 10^3$	516.58
$2.25 \cdot 10^4$	$1.312 \cdot 10^4$	$4.846 \cdot 10^3$	$1.387 \cdot 10^3$	590.451
$2.5 \cdot 10^4$	$1.53 \cdot 10^4$	$5.628 \cdot 10^3$	$1.593 \cdot 10^3$	667.542



Calculation of plume concentration

Time from discharge $t_{k,i} := \frac{x_i}{u_k \cdot 10^2}$ cm/s

Ratio of concentration cmax/co is given by (Grace page 323)

$$a_{k,i} := \left[\frac{\frac{3}{2}}{\left[\left(1 + \frac{2}{3} \cdot \beta_k \cdot \frac{x_i}{B} \right)^3 - 1 \right]} \right]^{\frac{1}{2}}$$

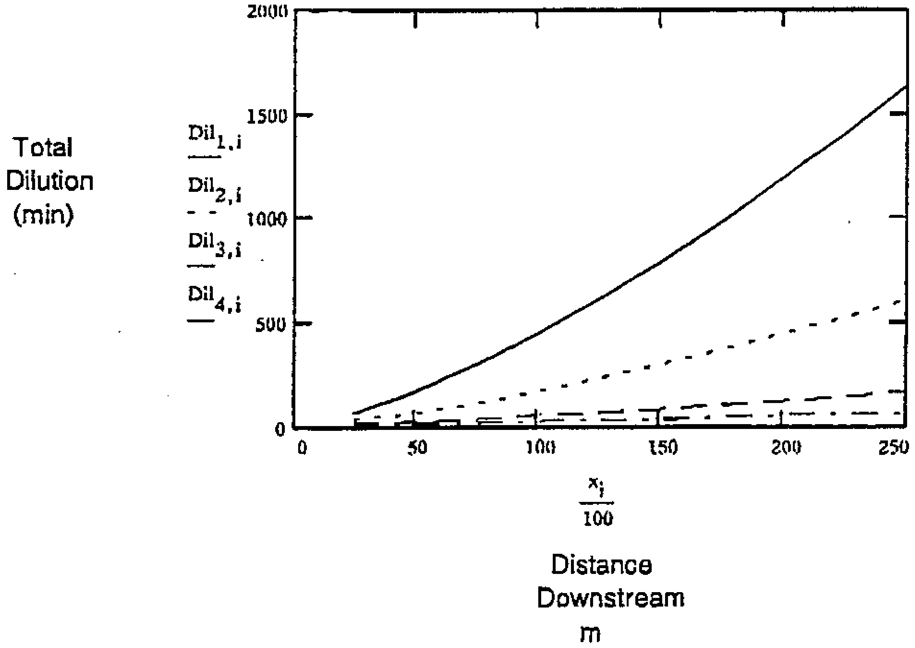
$$erf_{k,i} := \frac{2}{\sqrt{\pi}} \cdot \int_0^{a_{k,i}} e^{-t^2} \, dt$$

Initial concentration $co := \frac{1}{ID}$

Max concentration at position x downstream $cmax_{k,i} := erf_{k,i} \cdot co$

Min total dilution at position x downstream $Dil_{k,i} := \frac{1}{cmax_{k,i}} \cdot ID$

Distance downstream m	Total Dilution			
	$u_1 = 0.1$	$u_2 = 0.2$	$u_3 = 0.5$	$u_4 = 1$
$\frac{x_i}{100}$	$Dil_{1,i}$	$Dil_{2,i}$	$Dil_{3,i}$	$Dil_{4,i}$
25	71.377	33.785	16.276	11.722
50	170.297	71.377	27.457	16.276
75	294.255	117.32	40.541	21.597
100	438.938	170.297	55.237	27.457
125	601.714	229.472	71.377	33.785
150	780.757	294.255	88.842	40.541
175	974.705	364.196	107.536	47.7
200	$1.182 \cdot 10^3$	438.938	127.384	55.237
225	$1.403 \cdot 10^3$	518.192	148.322	63.135
250	$1.636 \cdot 10^3$	601.714	170.297	71.377



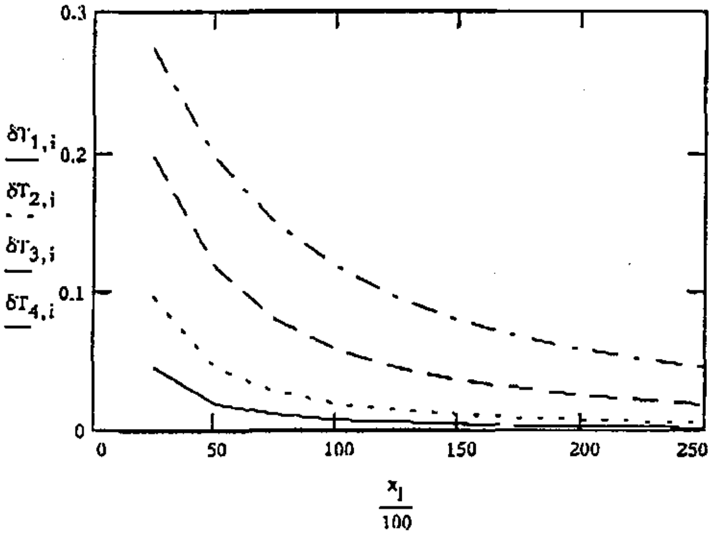
Temp of plume (Centreline) $$Tmax_{k,i} := \frac{Tsur + Ts \cdot \left(Dil_{k,i} - 1\right)}{Dil_{k,i}}$$

Increase in temp over ambient sea $$\delta T_{k,i} := Tmax_{k,i} - Ts$$

Results

Distance downstream m $\frac{x_i}{100}$	Increase in sea temp Deg C $u_1 = 0.1$ $\delta T_{1,i}$	 $u_2 = 0.2$ $\delta T_{2,i}$	 $u_3 = 0.5$ $\delta T_{3,i}$	 $u_4 = 1$ $\delta T_{4,i}$
25	0.045	0.095	0.196	0.273
50	0.019	0.045	0.116	0.196
75	0.011	0.027	0.079	0.148
100	0.007	0.019	0.058	0.116
125	0.005	0.014	0.045	0.095
150	0.004	0.011	0.036	0.079
175	0.003	0.009	0.03	0.067
200	0.003	0.007	0.025	0.058
225	0.002	0.006	0.022	0.051
250	0.002	0.005	0.019	0.045

Increase in Temp deg C



Distance Downstream m

acer

		Client:	**Axis**	Project:	**053000**
		Job:	**Shu Wing Steel Mill**	Job:	
Division:	**Water**	Section:	**Outfall**	0.9m	Sheet **1** of **5**
Office:	**MWU**	Subject:	**Plume Temp Dry Season**		Drg No.
Designed by:		Date:	Checked by:	Date:	

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Calculation of temperature of plume using Brooks method (Ref Grace Marine Outfall Systems Ch 7)

The method is considered conservative for tidal currents and the Richardsons Law (4/3 Law) is considered the most appropriate of the 3 options given..

Temp of effluent $Te := 28$ deg C

Temp of seawater $Ts := 18$ deg C

Initial Dilution $ID := 3.82$ Times

Temp of suface field $Tsur := \frac{Te + Ts \cdot (ID - 1)}{ID}$ $Tsur = 20.618$ deg C

Initial width of field $B := 0.663 \cdot 10^{2}$ cm

$k := 1 .. 4$

Current velocities $u_k :=$ m/s

$$\begin{pmatrix} 0.1 \\ 0.2 \\ 0.5 \\ 1.0 \end{pmatrix}$$

Distance downstream

No of increments $i := 1 .. 10$

Length of increment $l := 25$ m $x_i := l \cdot i \cdot 10^{2}$ cm

$$x_i = \begin{pmatrix} 2.5 \cdot 10^{3} \\ 5 \cdot 10^{3} \\ 7.5 \cdot 10^{3} \\ 1 \cdot 10^{4} \\ 1.25 \cdot 10^{4} \\ 1.5 \cdot 10^{4} \\ 1.75 \cdot 10^{4} \\ 2 \cdot 10^{4} \\ 2.25 \cdot 10^{4} \\ 2.5 \cdot 10^{4} \end{pmatrix}$$

Calculation of diffusion coef

Richardsons Law Power $no := \frac{4}{3}$

Constant (Grace Page 319) average value $\alpha := 0.03$ $cm^{2/3}/s$

Diffusion coef $\varepsilon := \alpha \cdot B^{no}$

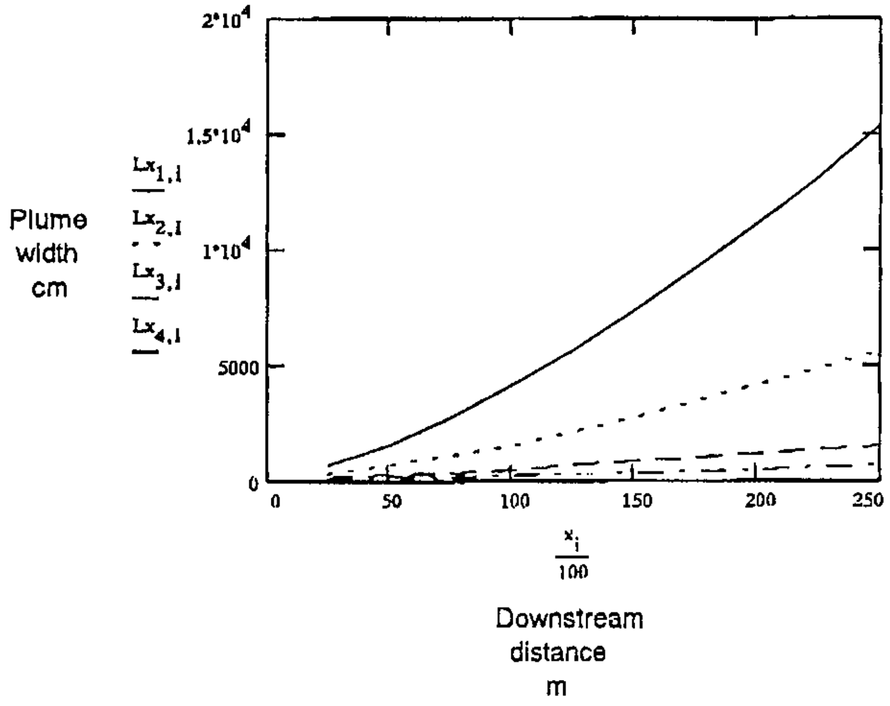
Calculation of plume width

$$\beta_k := \frac{12 \cdot \varepsilon}{u_k \cdot 10^2 \cdot B}$$

Plume width $Lx_{k,i} := \left[\left[\left(\frac{2}{3}\right) \cdot \beta_k \cdot \frac{x_i}{B}\right] + 1\right]^{\frac{3}{2}} \cdot B$ cm

Plume widths cm

Distance downstream cm	$u_1 = 0.1$	$u_2 = 0.2$	$u_3 = 0.5$	$u_4 = 1$
x_i	$Lx_{1,i}$	$Lx_{2,i}$	$Lx_{3,i}$	$Lx_{4,i}$
$2.5 \cdot 10^3$	667.542	315.872	151.197	105.882
$5 \cdot 10^3$	$1.593 \cdot 10^3$	667.542	256.606	151.197
$7.5 \cdot 10^3$	$2.752 \cdot 10^3$	$1.097 \cdot 10^3$	379.107	201.595
$1 \cdot 10^4$	$4.105 \cdot 10^3$	$1.593 \cdot 10^3$	516.58	256.606
$1.25 \cdot 10^4$	$5.628 \cdot 10^3$	$2.146 \cdot 10^3$	667.542	315.872
$1.5 \cdot 10^4$	$7.302 \cdot 10^3$	$2.752 \cdot 10^3$	830.881	379.107
$1.75 \cdot 10^4$	$9.116 \cdot 10^3$	$3.406 \cdot 10^3$	$1.006 \cdot 10^3$	446.075
$2 \cdot 10^4$	$1.106 \cdot 10^4$	$4.105 \cdot 10^3$	$1.191 \cdot 10^3$	516.58
$2.25 \cdot 10^4$	$1.312 \cdot 10^4$	$4.846 \cdot 10^3$	$1.387 \cdot 10^3$	590.451
$2.5 \cdot 10^4$	$1.53 \cdot 10^4$	$5.628 \cdot 10^3$	$1.593 \cdot 10^3$	667.542



Calculation of plume concentration

Time from discharge $t_{k,i} := \frac{x_i}{u_k \cdot 10^2}$ cm/s

Ratio of concentration cmax/co is given by (Grace page 323)

$$a_{k,i} := \left[\frac{\frac{3}{2}}{\left[\left(1 + \frac{2}{3} \cdot \beta_k \cdot \frac{x_i}{B} \right)^3 - 1 \right]} \right]^{\frac{1}{2}}$$

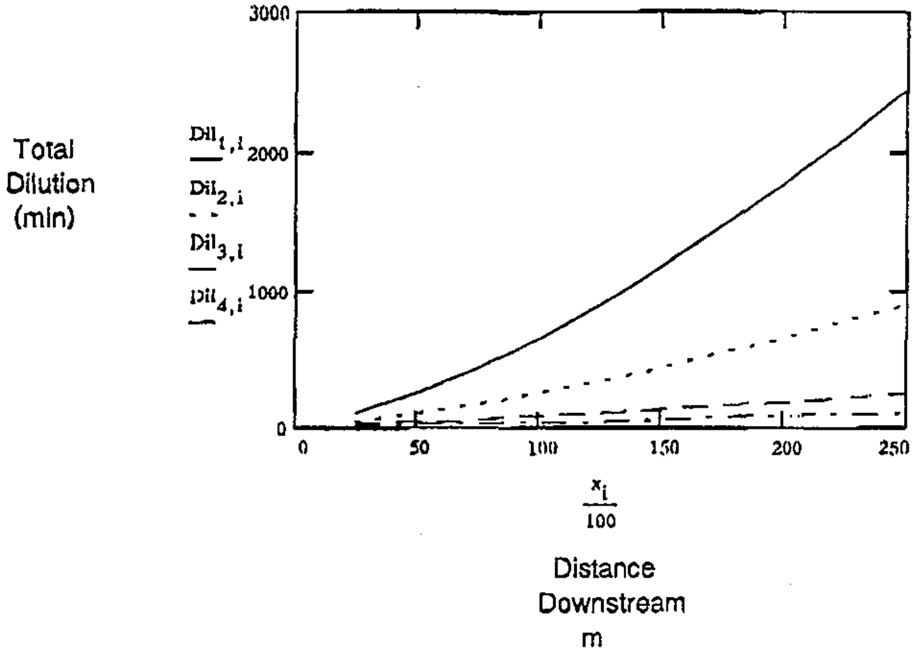
$$erf_{k,i} := \frac{2}{\sqrt{\pi}} \cdot \int_0^{a_{k,i}} e^{-t^2}\, dt$$

Initial concentration $co := \frac{1}{ID}$

Max concentration at position x downstream $cmax_{k,i} := erf_{k,i} \cdot co$

Min total dilution at position x downstream $Dil_{k,i} := \frac{1}{cmax_{k,i}} \cdot ID$

Distance downstream m	Total Dilution			
	$u_1 = 0.1$	$u_2 = 0.2$	$u_3 = 0.5$	$u_4 = 1$
$\frac{x_i}{100}$	$Dil_{1,i}$	$Dil_{2,i}$	$Dil_{3,i}$	$Dil_{4,i}$
25	106.316	50.322	24.242	17.46
50	253.655	106.316	40.897	24.242
75	438.29	174.747	60.386	32.169
100	653.795	253.655	82.275	40.897
125	896.248	341.797	106.316	50.322
150	$1.163\cdot10^3$	438.29	132.329	60.386
175	$1.452\cdot10^3$	542.466	160.174	71.048
200	$1.761\cdot10^3$	653.795	189.737	82.275
225	$2.09\cdot10^3$	771.843	220.925	94.039
250	$2.437\cdot10^3$	896.248	253.655	106.316



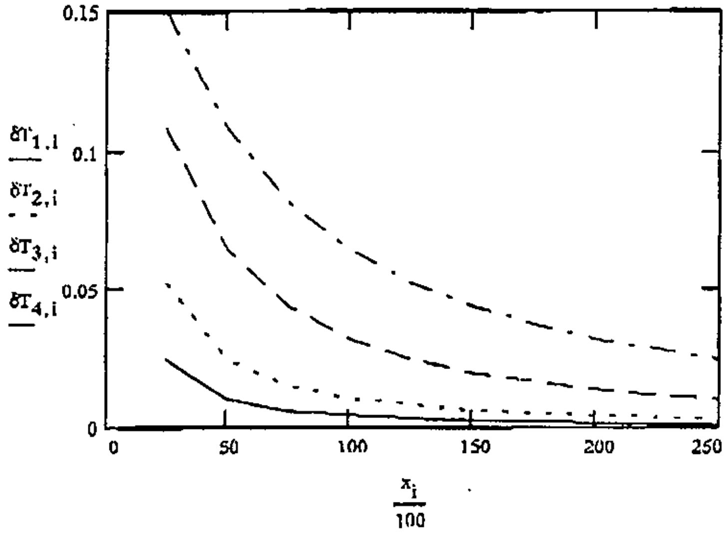
Temp of plume (Centreline) $Tmax_{k,i} := \frac{Tsur + Ts\cdot\left(Dil_{k,i} - 1\right)}{Dil_{k,i}}$

Increase in temp over ambient sea $\delta T_{k,i} := Tmax_{k,i} - Ts$

Results

Distance downstream m	Increase in sea temp Deg C			
	$u_1 = 0.1$	$u_2 = 0.2$	$u_3 = 0.5$	$u_4 = 1$
$\frac{x_i}{100}$	$\delta T_{1,i}$	$\delta T_{2,i}$	$\delta T_{3,i}$	$\delta T_{4,i}$
25	0.025	0.052	0.108	0.15
50	0.01	0.025	0.064	0.108
75	0.006	0.015	0.043	0.081
100	0.004	0.01	0.032	0.064
125	0.003	0.008	0.025	0.052
150	0.002	0.006	0.02	0.043
175	0.002	0.005	0.016	0.037
200	0.001	0.004	0.014	0.032
225	0.001	0.003	0.012	0.028
250	0.001	0.003	0.01	0.025

Increase in Temp deg C



Distance Downstream m

APPENDIX 7A

APPENDIX 7A

AERE HARWELL LEACHATE TEST DETAILS

AERE - R 10737

TESTING OF HAZARDOUS WASTES TO ASSESS THEIR SUITABILITY FOR LANDFILL DISPOSAL

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ABSTRACT

The Waste Research Unit of the Harwell Laboratory has for several years been developing testing methods on behalf of the UK Department of the Environment, with the pragmatic aim of assessing the suitability of a specific hazardous waste for disposal at a particular landfill site. The approach is based on measuring the reduction of contaminant concentrations in leachate due to one or more specific mechanisms.

Much attention has been devoted to measuring attenuation due to initial leaching. Our leaching test is very simple, and is based on repetitive extraction using a very high solid to liquid ratio, defined in such a way as to allow correlation with expected field behaviour over time. Validation experiments using large laboratory columns to simulate leachate generation in a landfill have yielded surprising results, and demonstrate the necessity to verify any small scale test by comparison with field, or simulated field, experiments of this type.

In addition to specific measurements of one attenuation mechanism in isolation, the Unit is currently developing test methods to simulate co-disposal of hazardous with municipal wastes on a laboratory scale. This work is illustrated by a series of large column experiments containing a 'sandwich filling' of four different pesticide wastes.

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1. Introduction

Waste producers, disposal contractors and controlling authorities are all called upon to assess the most suitable management options for particular arisings of "hazardous" waste. The choice is a complex one, requiring a trade-off between many, often conflicting objectives of economics, resource conservation, safety and environmental health. For waste disposal authorities and for disposal site operators, the results of these deliberations need to be translated into suitable licence conditions for individual landfill or waste treatment sites, giving for each a list of acceptable wastes with suitable quantity and concentration limits and other caveats. There is at present considerable support for regional planning, of which coordination of individual site licence conditions to ensure a coherent whole is one vital aspect. However, this paper addresses a problem encountered much earlier in the logical sequence of planning decisions, just how do we assess or measure the "suitability" of a specific hazardous waste for disposal at a particular landfill site?

Two points need to be made at the outset. First, landfill has been chosen not because it is the preferred management option for most wastes, but because in practice it will be one of the first options considered - if landfill is acceptable to the authorities, why should a producer pay more for a sophisticated treatment process (although one should note that landfill is not always the cheapest option). Second, this paper is aimed at testing the suitability of wastes for disposal or treatment. It is not concerned with whether or not a waste happens to be defined as "special", as that definition and the associated tests are directed primarily at preventing hazards to children following spillage in transport or illegal fly-tipping of the waste (Wilson, 1982). When considering the suitability of a hazardous waste for landfill disposal, three general criteria have to be considered:-

(i) the health and safety of site personnel and of local residents;

(ii) the long term persistence of the waste, which could adversely affect future reuse of the land;

(iii) the potential for pollution of surface or groundwater resources.

The Waste Research Unit (WRU) of the Harwell Laboratory has, for the last eight years, been developing simple testing methods to measure performance against various aspects of these criteria. For example, with respect to the health and safety of those adjacent to landfilling operations, a flammability test suitable for use in the field (Waring and Hudson, 1979) and procedures to measure the rate of vaporisation of solvents absorbed on solid waste (Jones and McDugan, 1978), have been reported. More recently the general impact of the vapours released from landfilled wastes has also been investigated (Young and Parker, 1982). With regard to persistence of the waste and after-use, a number of gas works sites have been investigated and the impact of the wide range of wastes associated with this industry assessed (Wilson and Stevens, 1981). However, it is the third criterion, that of the threat to water pollution, which is normally of immediate concern in deciding whether landfill disposal of a given hazardous waste is acceptable. In order to make this decision correctly, testing of the waste may be necessary to help quantify any contamination of the acquifer, and it is with this aspect that the paper is mainly concerned.

2. The Need to Test Hazardous Wastes

To answer the question "Can this waste be safely disposed of at this particular landfill site without causing water pollution?" The application of any test procedure must be flexible to account for the individual nature of each case. In order to achieve this, we have developed a general framework for decision making, within which the tests are designed. This framework may be illustrated schematically as an "attenuation map" (Figure 1). Many mechanisms serve to reduce contaminant concentrations in leachate from those present in the original deposit of hazardous waste (Department of the Environment, 1978). For example, Figure 1 depicts co-disposal of hazardous with municipal waste at an unsealed site underlain by an unsaturated zone. Attenuation at such a site may be due to:-

- the initial leaching of the contaminant from the deposit of hazardous waste
- processes within the municipal waste, including biodegration, sorption, chemical interactions such as neutralisation, oxidation-reduction and precipitation

- processes at the base of the landfill, notably dilution with leachate from other areas of the landfill and co-precipitation of metal ions with ferric hydroxide
- processes occurring in the unsaturated zone, including physical filtration, dispersion, dilution, biodegration, sorption and ion-exchange
- processes within the saturated zone (groundwater aquifer), notably dispersion and dilution.

These mechanisms, either singly or in combination, serve to reduce the concentration of contaminants by many orders of magnitude before surface water or a groundwater abstraction point is reached. For example, if the criterion is taken that the drinking water standard for contaminant X (i.e. concentration (8) in Figure 1) must not be exceeded at the abstraction point, then it is necessary to show in any particular case that attenuation of X from concentration (2) to concentration (8) will occur. Our testing methods are designed to measure attenuation due to initial leaching or to specific mechanisms within the landfill. When these are combined with information on rainfall infiltration and on the quantities of waste deposited (and thus on dilution by leachate from the rest of the site), and on the hydrogeology of the site (yielding an estimate of attenuation beneath the site), an estimate can be made of the likely concentration of X at the water abstraction point. If this is less than the drinking water standard, then disposal of that waste, in that quantity and at that site, will not adversely affect the water supply. As measurements are usually restricted to a few of the most important attenuation mechanisms, leaving attenuation due to many other mechanisms unquantified, this decision making procedure incorporates a built-in safety factor.

Figure 1 was deliberately drawn to include a wide range of attenuation mechanisms. Similar diagrams can be constructed for different modes of landfill: for example, at a sealed site consideration of attenuation beyond the landfill boundary is inapplicable and the comparison is made between concentrations in the collected leachate (5) and an appropriate standard, such as that for discharge of trade effluents to sewer. A similar approach can also be used for a chemical landfill site using the appropriate attenuation factors.

In order to quantify the attenuation factor obtained by the initial leaching from the waste (3), there is a need for a simple laboratory test. Such a test is described here. A second test is also described briefly which models the total attenuation available in a co-disposal site.

3. Laboratory Leaching Test

3.1 Objectives

The initial leaching of the toxic components from a waste as deposited often provides a significant degree of attenuation, and is relatively easy to quantify. There has been much international interest in small-scale leaching tests (e.g. Lowenbach, 1978; Anderson et al, 1979; Perket and Webster, 1981), but much of this has been directed primarily at legal definition of what constitutes a "hazardous" or "toxic" waste. In contrast the WRU leaching test was developed to provide a simple method of quantifying the initial leaching from a waste to help assess any limitations which should be imposed on landfill disposal. The objectives of the test may be defined thus:-

(i) easy interpretation of results for use in decision making;

(ii) accurate prediction of the pattern of leaching behaviour over time;

(iii) validation of the results against field behaviour;

(iv) a relatively short test duration;

(v) unsophisticated laboratory requirements.

3.2 Outline of the test procedure

A full experimental procedure for the test is given in the appendix, together with a worked example to demonstrate how the results from the test are incorporated into the general framework for assessing the suitability of a hazardous waste for landfill disposal. The object of the main text is to outline the test itself and to briefly highlight how the conditions chosen were selected and validated.

The WRU leaching test is basically very simple. It is a repetitive batchwise shaking test, using either distilled water or dilute, buffered acetic acid as the leaching fluid. The duration of each extraction is determined from a preliminary equilibrium test. The novel feature of the test procedure is the high solid to liquid ratio based on the concept of bed volume. The bed volume of a waste is a measure of its void space, or the volume of liquid required to just saturate it. It is defined in the laboratory as the volume of leaching fluid required to just cover and render mobile a sample of waste of known weight.

A sample of waste is shaken with one bed volume of fluid, small samples being taken (and replaced by fresh fluid) after 1, 2, 3, 4, 8 hours etc. In many cases pH and conductivity measurements will give an adequate guide as to whether equilibrium is being approached, other analytical measurements at this stage being confined either to easily determined or to fundamental toxic species. For many wastes, a shaking period of a few hours is adequate to attain equilibrium, but in a worst case equilibrium has not been attained even after 80 hours. A very long "equilibrium time" may indicate kinetic control of leaching; in such cases the time chosen should be based on a balance between the observed behaviour and the degree of contact between the waste and percolating leachate expected in practice.

When the appropriate shaking time has been determined by the equilibrium test a new sample of waste is extracted five times with fresh fluid to provide leachate samples corresponding to successive bed volumes. A portion of the remaining waste is then depleted using ten bed volumes of leaching fluid, to give an average of the leaching expected between six and fifteen bed volumes. Depending on the analytical results the test may be extended to study either very rapid leaching, by replacing the waste rather than the leaching fluid, or slow leaching, by carrying out further extractions, with a low solid to liquid ratio.

From applications of the test procedure to many wastes, three different patterns of leaching behaviour with time may be distinguished:-

(i) the most common situation is where the repetitive test does indeed locate the maximum concentration within the first 5 bed volumes (Figure 2a). Note that a single shaker test with solid to liquid ratio of 1:10 would grossly underestimate such a maximum.

(ii) the maximum concentration sometimes corresponds to the first bed volume of leaching fluid. In such a case, the true maximum in the field could be much higher, as all that has been measured is an average over the first bed volume. In this case, the test should be repeated, extrapolating to even higher solid to liquid ratios by replacing the waste rather than the leaching fluid at each stage. The example of leaching from a phenol lime sludge is shown in Figure 2b.

(iii) after the normal procedure of extractions over 10 bed volumes, concentrations may still be increasing, or no maximum may be indicated at all. In such cases, the test should be extended by depleting the waste with further samples of 10 bed volumes of leaching fluid (Figure 2c).

3.3 Use of bed volume and interpretation of test results

Bed volume, described above as the volume of leaching fluid required to saturate a waste, is designed as a parameter which can be easily determined in the laboratory. There are three important benefits to be gained from using bed volumes to describe the leaching of a waste:-

(i) The bed volume is a property of the waste as received and deposited. For example a sludge which arrives drier in summer than in winter will have a larger bed volume in summer and the leaching properties will vary accordingly. Bed volumes are thus more sensitive to the nature of the waste than leaching behaviour based on a fixed solid to liquid ratio.

(ii) Bed volumes represent relatively high solid to liquid ratios (normally not less than 1:1). The use of much lower solid to liquid ratios (many authors advocate 1:5 or 1:10) can lead to gross underestimation of the leaching immediately following deposition.

(iii) The bed volume of a waste is as easily calculated for a waste in the field as in the laboratory, and the scaling up of laboratory results is therefore reliable and relatively straightforward.

The worked example in the appendix demonstrates how specific results are scaled up using the concept of bed volume. As a more general example, consider a waste with a void space of 50%, giving a bed volume of about 1 litre/kg of waste. If the waste is deposited in a layer 1 metre thick, with a rainfall infiltration rate of 25 cm/annum, then one bed volume of leachate corresponds to about 4 years in the field. If the leaching test gave maximum concentrations after two bed volumes, this will correspond to about eight years in the field. However, if the waste is spread on deposition to a thickness of about 25 cm, then the maximum leachate concentration will occur after two years, although other attenuation mechanisms may possibly be enhanced, leading to a lower maximum concentration observed at the base of the landfill. (It is worth noting that for a 1 metre deposit in this example, the application of a leaching test with a solid to liquid ratio of 1:10 would indicate an average of the leaching over the first forty years.) Clearly such vague information would be inadequate to decide whether or how the waste should be landfilled.

how to measure infiltration

3.4 Choice of leaching fluid

The leaching fluid is chosen according to the landfill situation which is being modelled. Distilled water is useful both for comparative purposes and for the case of mono-disposal of a bulk waste. For co-disposal of hazardous with municipal waste, a simulant for municipal refuse leachate is required. In a very extensive series of trials, we tested a total of ten leaching fluids by carrying out the leaching test on a synthetic metal hydroxide sludge and comparing the leaching profiles for nine metal species. The leaching fluids comprised:-

(i) distilled water;

(ii) 5000 ppm acetic acid, buffered to pHs 3, 4, 5, 6 and 7 with sodium hydroxide;

(iii) an anaerobic model leachate developed in the United States on behalf of the EPA, comprising buffered acetic acid (pH 4.5) with added glycine, pyrogallol and ferrous sulphate to model both the redox potential and complexing effects of real leachate (Stanforth et al, 1979);

(iv) two aerobic model leachates, one being as above but removing the ferrous sulphate and replacing pyrogallol by salicylic acid; and the second a complex mixture of organic acids and inorganic salts, buffered to pH 5.5, developed by the Dutch Institute of Waste Disposal (SVA, 1979);

(v) a sample of real leachate collected from a landfill cell containing 800 tonnes of two year old refuse (total fatty acid concentration about 2.5%).

The results for each metal generally followed a similar pattern (Figure 3). The three model leachates, and acetic acid at pH 3 or 4, invariably gave vigorous leaching, yielding a massive early peak. In particular the two aerobic model leachates gave very high initial leaching and led eventually to the complete dissolution of the sludge by the end of the experiment. Both acetic acid at pH 5 and real leachate showed less vigorous behaviour, generally yielding similar, much lower peaks over a longer time period. Acetic acid at pH 6 or 7, and distilled water, were non-aggressive, often showing negligible leaching. On the basis of these results, a solution of 5000 ppm acetic acid buffered to pH 5 was chosen as a simple but effective model of municipal refuse leachate.

3.5 Validation experiments

At the development stage, it is necessary to validate any small scale leaching test against results from real life in order to ensure that the maximum concentration has indeed been estimated reliably. Too often leaching tests appear to have been developed in isolation (Anderson et al, 1979), with the justification that the conditions of the test are so strenuous that only an overestimate of the problem could result.

Apart from a more accurate modelling of field behaviour being desirable, our experience with the testing carried out with other model leachates indicated another potential problem of assuming that an overestimate is a pessimistic estimate. For example, consider the application of the results for zinc in Figure 3. Using the aerobic model leachates the peak of the zinc release would be expected after four bed volumes, perhaps corresponding to four years in the field. If the waste is deposited, and the site leachate then monitored for zinc concentrations to see the effect of the deposition, with a view to assessing the suitability of landfill disposal, a serious problem could result. After four bed volumes, which equates to four years in the field, the real leachate graph in Figure 3 demonstrates that very little release would have occurred. However, the leaching test carried out with the aerobic model leachate would imply that the peak release had now occurred and that additional attenuation of perhaps 30 to 100 was occurring in the site. On this basis further deposition of the waste might be authorised. However, after ten years when the true peak release of zinc is reached, a considerable quantity of the waste might be in the site, and consequently the leachate would attain zinc concentrations well above those on which the decision to proceed was based. This demonstrates the importance of modelling not only the peak but also the timescale of leaching reliably, if the results of the test are to be used successfully to make pragmatic decisions on the disposal of the waste.

In attempts to validate the small-scale tests, it is difficult to obtain reliable field results. The leachate from a landfill is subject to many attenuation mechanisms other than initial leaching, and observed concentrations are thus almost always lower than a small scale leaching test would suggest. Our solution has been to [illegible] experiments to simulate just the primary leaching process in the field situation.

A series of 15 cm diameter columns were packed with 5-15 cm of a hazardous waste, followed by 100-150 cm of pulverised domestic refuse. The columns were irrigated with water at a natural rainfall rate and allowed to follow their natural degradation cycle. The progress of the columns was followed by monitoring gas evolution: although some air ingress did occur, equilibrium levels of 35-45% were attained for both carbon dioxide and methane after about 150-200 days, showing a satisfactory transition to anaerobic conditions. The construction of the columns was such that one bed volume of leachate passed through the waste about every 80 days. Leachate was collected both at the base of the column and immediately above the layer of hazardous waste. The comparison of results from these column experiments with those from the shaking tests proved to be most instructive, and indeed it was this comparison which led to the leaching test procedure being extended to cover the cases of both early and delayed leaching. Some of the early laboratory tests underestimated observed leaching in the columns by a factor of up to 100, but improvements in the protocol have eliminated such gross discrepancies. A compilation of leaching test versus column results is shown in Figure 4. The general correlation is good, to within a factor of 3. (It should be remembered that attenuation factors are generally measured as powers of ten). Remaining underestimates by the laboratory test can generally be explained either by very early leaching, or by experimental error (the tests were carried out over a four year period and conditions did not always correspond exactly).

The major conclusion from these validation experiments is simple: any small scale laboratory test must be verified by comparison with field, or simulated field, behaviour.

4. A simulated co-disposal test

The WRU leaching test is one example of a test method designed to measure attenuation due to a single mechanism. We have also been working for several years with various experimental systems designed to measure attenuation of components of hazardous waste within a municipal waste landfill site as a whole. These systems are all based on laboratory columns, ranging in size from 60 cm x 10 cm internal diameter to 150 cm x 15 cm internal diameter. The wastes studied have included mineral acids, heavy metals and pesticides.

As an example of this work, a series of six large column experiments will be described briefly. Each contained a "sandwich" filling of pesticide waste between layers of pulverised domestic waste, the columns being irrigated at a natural rainfall rate. Leachate was collected both at the column base and about 1 m above, just below the pesticide layer. Three of the pesticides studied (atrazine, gamma-HCH or lindane, and pirimiphos-methyl) effectively did not leach, while relatively high levels of the supposedly non-persistent MCPA were still being leached after two years. Thus solubility of the pesticide seems to be the dominant mechanism affecting leachate concentrations. These experiments have also yielded information on any effect of the pesticides on the microbiology within the refuse, and destructive sampling to examine persistence is currently being completed (Stevens, Jenkins and Wilson, 1982).

5. Conclusions

The Waste Research Unit at Harwell has developed a variety of simple tests for hazardous wastes prior to landfill disposal. All the tests have been developed within a framework for practical decision making, and attention has been paid to verifying the results against field behaviour. In particular, a simple laboratory leaching test has been developed which can be used by both landfill operators and controlling authorities to provide valuable information on the attenuation provided by initial leaching. This information can then be applied to an individual site considered for disposal, and used to assess the effect disposal of the waste will have on leachate quality. Any further information on attenuation mechanisms operating in the site should be included in this assessment, and it is hoped to extend and develop the tests described here to cover a wider range of these mechanisms in the future.

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APPENDIX

Experimental Procedure for the Waste Research Unit Laboratory Leaching Test and a Worked Example to Illustrate its Application

A Introduction

This procedure is designed to provide complete laboratory directions for carrying out the leaching test. A typical waste will require about a week to be tested, assuming two four-hour repetitive shake tests can be carried out in a day. A list of apparatus which is required is given in Section E, and it is anticipated that beyond the analytical requirements even the most basic laboratory will already contain the necessary items. The two leaching fluids used are distilled water and buffered acetic acid. This test is based on the concept of a bed volume which is a measure of the volume of liquid required to saturate a waste. It is therefore directly related to the pore volume of the waste as deposited on site. The definition of a bed volume is as follows:-

> "The volume of liquid required to just cover and render mobile a given sample of waste"

The bed volume is therefore proportional to the quantity of waste, for example if the bed volume of 100 g of waste is 60 mls, then the bed volume of 50 g of the same waste is 30 mls; it has a bed volume of 60 ml per 100 g.

B Preparation of sample

The leaching test involves two stages, each requiring about 50 to 100 cm^3 of waste. Since most wastes have a specific gravity of 1 to 2, 100 g will often be a suitable quantity. The samples should represent the most toxic portions of the waste, and not necessarily the bulk, since the object of the test is to estimate the maximum likely leaching from the waste following disposal. Two types of waste will require additional preparation following sampling:-

(i) Solid, massive wastes: the waste should be crushed to the size of pea-gravel or smaller;

(ii) Sludges or other very wet wastes: the wastes should be vacuum filtered through a Whatman no. 541 filter paper. The filtrate should be collected and subjected to the same analysis as those samples obtained from the equilibrium test.

C Equilibrium shaker test (duration 4 to 30 hours)

1. Place a suitable sample of waste (e.g. 50 to 100 cm^3) into a 500 ml wide-necked flask.

2. Add one bed volume of model leachate from a measuring cylinder, this should be about 30 to 100 mls. Two model leachates are suggested; for mono-disposal of the waste, distilled water should be used as a simulation of rainfall, but if co-disposal with domestic refuse is considered, 5000 ppm acetic acid buffered to pH5 with sodium hydroxide should be used, to simulate landfill leachate.

3. After adding the model leachate, stopper the flask and shake on a mechanical flask shaker for one hour. The shaking should be vigorous enough to thoroughly mix the contents of the flask, about ten cycles per second for a mechanical shaker.

4. After one hour a suitable quantity of the liquid needs to be recovered for analysis. This should preferably be no more than 10% of the volume of model leachate added in step 2. In order to recover this liquid it will usually be necessary to filter a portion of the flask's contents. A Whatman no. 541 filter paper inserted in a Buchner funnel, with a side-arm test tube or vacuum flask, connected to a suction device is suitable for this purpose. Particularly intractable wastes such as some sludges may require centrifuging before attempting to filter, and millipore apparatus may be used to remove small particles, if the initial filtering does not give a reasonably clear solution.

5. Apart from the liquid sample, the entire contents should be replaced in the flask together with enough model leachate to replace the volume extracted for sampling.

6. The procedure outlined in steps 3, 4 and 5 should be repeated at hourly intervals until four samples have been collected. It is then suggested that the flask is shaken for the rest of the day (e.g. another four hours) and that analysis of the samples collected so far should proceed.

7. If no equilibrium is apparent from the first day's samples, further samples should be taken after shaking for 24, 32, 48, 56, 72 and 80 hours (i.e., morning and afternoon for three days).

8. Analysis Suitable analysis will depend on the species of interest for the particular waste which is under test. However it is suggested that pH and conductivity give a good general guide and that only very important toxic species and easily determined species are analysed individually at this stage. For example, only one or two metal species if a sludge from an electroplating shop is being tested. An atomic absorption spectrophotometer is a suitable tool for rapid analysis of metals, which requires very little sample.

9. Interpretation Many wastes will be found to give steady values of pH, conductivity and species in solution within a few hours of shaking. A shaking time which is sufficient to allow equilibrium to be established with the waste should then be selected for the repetitive shaker test. A period of two to four hours is most usual. A small number of wastes will require up to 80 hours before the samples taken are found to give consistent results indicating equilibrium. For these wastes, a longer repetitive shaking time will be required, and for this reason the test procedure will take an extended time to complete. A maximum shake time of 80 hours is suggested, not only due to the practical problems of such an extended test, but also because percolation rates in a landfill would not normally allow establishment of equilibrium conditions, if that cannot be achieved within 80 hours in a vigorous shaking test. For such wastes the leaching will be controlled by kinetic factors and the determination of an accurate equilibrium time is not necessary. In order to maintain a worst case under these circumstances, a repetitive shaking time should be chosen which corresponds to the maximum concentrations observed in the model leachate during the 80 hour equilibrium test.

10. The repetitive shaker test can now be carried out.

D Repetitive shaker test (time required normally 2 to 9 days)

1. Set up the flask as for the equilibrium test, so that it contains the sample of waste and one bed volume of suitable model leachate.

2. Shake for the time determined by the equilibrium test.

3. After shaking the leachate needs to be separated for analysis. Normally the flask's contents can be successfully vacuum-filtered through a Whatman no. 541 filter paper. As with sampling during the equilibrium test, this may be supplemented by prior centrifuging of the flask's contents and secondary filtering through millipore equipment when necessary.

4. Return as much of the filtered waste as is practical to the flask. If the experiment is to be left overnight it should be at this stage before the next bed volume of model leachate is added.

5. The next bed volume of model leachate should be added to the waste. In most cases this will be the same volume as used originally, but for wastes which are highly soluble or undergo substantial physical changes it is advisable to use the criteria of just covering the waste returned to the flask, instead of automatically adding the same volume again. This approach can also be used to allow continuation of the test if some of the waste is lost during the filtering operation. The volume of model leachate added at each stage should be recorded so that total releases of contaminant can be calculated from the concentrations in the leachate samples.

6. Steps 2 to 5 should be repeated so that leaching over a total of five bed volumes is carried out. After separating the fifth bed volume of leachate, a quantity of the waste equivalent to only one tenth of that originally used should be returned to the flask.

7. Ten bed volumes should be added to the waste in the flask, which will normally mean adding the same volume of model leachate as was done for the first bed volume. As before, wastes which have undergone obvious physical changes should have their bed volumes

redetermined at this stage, especially since ten, rather than one, bed volumes are added. The flask should then be sealed and shaken as before. After shaking, the contents should be separated and the waste returned to the flask.

8. The leachate collected after this stage represents the average leaching over six to fifteen bed volumes, and can be considered as giving an estimate of the leaching after ten bed volumes. It is now advisable to analyse the six samples collected at this stage, together with any fluid removed from the waste during the preparation stage.

9. If further monitoring over a longer period of leaching is required, step 7 can be repeated to give samples indicative of leaching after 20, 30, 40, etc, bed volumes.

10. Analysis The solutions obtained can be analysed for any species or properties likely to be of concern. Since a much larger volume of liquid is retained than in the equilibrium test, a more comprehensive analysis may be carried out and it is these results which may be used to predict the suitability of the waste for landfill disposal. With many wastes the leaching over ten bed volumes will be found to have reduced all species to insignificant levels, but longer term leaching can be carried out by repeating step 7 for as long as is thought necessary.

11. Interpretation The results may be expressed as a plot of concentration against bed volumes leached if the maximum concentration of the contaminant in the leachate is required. Alternatively, the total release may be significant, and a histogram of absolute releases in mg/kg of waste is then most appropriate. In order to plot the latter the volume of each bed volume is required to convert concentrations to absolute quantities of contaminant (see stage 5). Any interstitial fluid recovered from the waste during preparation may be plotted as that leached after zero bed volumes, i.e., before any leachate has interacted with the waste.

Attenuation factors may be calculated as the ratio of the concentration in the waste as deposited to the maximum concentration in the leachate. These may then be used in conjunction with other attenuation factors appropriate to the particular landfill site to decide whether deposition of the waste is going to adversely affect the leachate quality. The concentration factors can also be used to estimate the quantity of waste which can be tolerated at the site to keep the leachate quality within target objectives. A worked example illustrating the interpretation of the leaching test results is given in section F.

E Apparatus required for test

Essential:
500 ml wide necked flask with bung (one per waste model leachate pair)
Mechanical flask shaker (e.g. Gallenkamp or Griffin)
100 ml measuring cylinder
About one litre of (each) model leachate per waste
Buchner funnel (e.g. 9 cm diameter)
Whatman no. 541 filter papers (e.g. 9 cm diameter)
Vacuum side-arm flask (e.g. 250 mls)
Suction pump/Vacuum pump
Spatulas, etc.
Balance
Suitable analytical equipment, preferably including pH meter and conductivity meter
Sample bottles

Also required for awkward wastes:

Pestle and mortar
Millipore filters (e.g. 8 micron pore size)
Millipore filtration equipment
Centrifuge equipment preferably to take at least 100 mls at one time

The two model leachates are:

Distilled water (monodisposal model)

Acetic acid, 5000 ppm buffered to pH 5 with sodium hydroxide (co-disposal model)

F Worked example

A smelting slag which is generated as a 20 tonne load every fortnight requires disposal. Two landfill sites A and B are near the waste arising. The slag has a density of 2g/cm^3 as deposited and the smelting company supply the following information about its composition:-

Smelting Slag Composition

FeO	CaO	SiO_2	Zn	Al_2O_3	Pb	Cd	S	H_2O
31.7%	16.6%	18.5%	10.2%	6.5%	2.4%	0.67%	2.1%	2.0%

From this information, the potential pollutants are likely to be the three metals, zinc, cadmium and lead.

The two sites A and B have the following characteristics:-

	Site A	Site B
Type of site	Dilute and disperse	Containment, leachate to sewer
Size of site	100m x 100m x 10m deep	400m x 400m x 10m deep
Type of waste	Domestic	Mixed
Quantity of waste	100 tonnes per week	3000 tonnes per week
Appropriate water quality standards	Drinking water	Trade effluent consent
zinc	5 mg/l	10 mg/l
cadmium	0.01 mg/l	10 mg/l
lead	0.1 mg/l	10 mg/l

Site A is a small domestic site which is near to hand and lies over an aquifer which is used for a local water supply. There is known to be an approximate 20 fold dilution of the leachate by ground water before the nearest abstraction point, and the operations must not have any discernable effect on the quality of the water abstracted from the aquifer.

Site B is a larger containment site which takes a variety of domestic, commercial and industrial wastes. Leachate is collected and discharged to sewer. The consent limits for the discharge are not more than 50 mg/l total toxic metals, with not more than 10 mg/l for any individual metal. Of the three metals under consideration only zinc is presently discharged at a significant level. The present zinc concentration is 3 mg/l.

From the information available the following attenuation data can be obtained:-

Available Attenuation Data

Attenuation Information	Site A			Site B		
	Zn	Cd	Pb	Zn	Cd	Pb
a Concentration in waste g/kg	102	6.7	24	102	6.7	24
b Concentration in waste mg/l	204000	13400	48000	204000	13400	48000
c Concentration tolerated in leachate mg/l	5	0.01	0.1	7(10-3)	10	10
d Attenuation factor required (b/c)	40800	1340000	480000	29100	1340	4800
Attenuation available (see Figure 1)						
(2) - (3) Initial leaching	To be determined			To be determined		
(3) - (4) Attenuation in site	Not known			Not known		
(4) - (5) Dilution with other leachate	x10	x10	x10	x300	x300	x300
(5) - (6) Attenuation in unsaturated zone	Not known			Not applicable		
(6) - (7) Dilution with ground water	x20	x20	x20	Not applicable		
e Total known attenuation factor	200	200	200	300	300	300
f Additional attenuation required (d/e)	204	6700	2400	97	4	16

An approximate estimate of the dilution available with leachate from the other waste deposited can be obtained by assuming that the leachate generated is proportioned to the tonnage of waste. This is reasonable providing the waste under consideration is deposited in a similar manner, for example not spread as a very thin layer over the other waste.

Since proof of additional attenuation is still required (i.e. values of f are more than one), a leaching test was performed on the slag. 100 g were shaken in a bed volume of 30 mls of 5000 ppm acetic acid buffered at pH 5 to simulate the leachate produced by the other wastes deposited at sites A and B. The results of the equilibrium test were as follows:-

Equilibrium Shaker Test

Time of Shaking (hours)	pH	Conductivity (μmhos cm^{-1})	Zn (mg/l)
1	6.5	9,500	90
2	7.2	11,000	110
3	7.3	11,200	105
4	7.4	11,000	105
8	7.2	9,500	70
24	7.1	10,300	60

The zinc was analysed by atomic absorption spectrophotometry, but no further analysis was thought necessary to demonstrate the appropriate equilibrium time. A repetitive shake time of three hours was adopted since the parameters measured had all appeared to reach a plateau by that time.

The repetitive test gave the results shown below:-

Repetitive Shaker Test

Bed Volume	Zn (mg/l)	Cd (mg/l)	Pb (mg/l)
1	82	4.5	4.2
2	130	7.2	2.8
3	90	8.0	11.5
4	40	2.0	14.0
5	24	1.5	8.0
10	28	1.2	3.0

The maximum concentrations were 130 mg/l for zinc, 8 mg/l for cadmium and 14 mg/l for lead after 2, 3 and 4 bed volumes respectively. These represent minimum attenuation factors of 1600 for zinc, 1700 for cadmium and 3400 for lead. Comparing these results with the additional attenuation which was required it can be seen that only cadmium in site A would need further attenuation, by a factor of 4. It is likely that this will be available within the site, or in the unsaturated zone, but further evidence of such attenuation would be required before the slag could be accepted at site A. At site B however there is more than ample attenuation to keep the leachate within the authorised discharge limits providing the other wastes deposited continue to contribute the present quantities of the three metals.

Having accepted the waste for disposal at site B a further calculation of the long term impact of a regular waste arising is advisable. The site is operated over the entire area as a 2 metre lift, and consequently it takes two years to complete each lift. Assuming each 20 tonne load of slag is deposited as an approximately 1 m thick layer, one bed volume for each deposit will be 6000 litres per load, or 600 litres per square metre. If the infiltration rate at site B is 30 cm per year, the infiltration per square metre will be 300 litres per square metre. One bed volume therefore corresponds to two years leaching in the field. It therefore follows that if the slag deposition were to continue over the whole ten year life of site B the maximum leachate concentration would be the sum of concentrations from the first to fifth bed volumes, from the slag deposited one to ten years ago. The accumulated effect of ten years landfilling of the slag, at a rate of 20 tonnes per fortnight would be concentrations of zinc, cadmium and lead about a factor of three above the maximum concentration from a single bed volume. This is still well within the attenuation potential of site B. As a rule of thumb, it is useful to sum the concentrations from the repetitive leaching test over the lifetime of the site, if the waste being examined is to be deposited on the site for a long period of time in order to take account of the accumulating affect of several loads of various ages above one another in the landfill.

Figure Captions

Figure 1 An attenuation map, showing relative concentrations of a contaminant as leachate moves through and away from a deposit of toxic waste. This particular map illustrates the case of co-disposal with municipal waste at an unsealed site with a significant unsaturated zone.

Figure 2 Typical leaching profiles:

(a) normal case, illustrated by zinc leaching from a tin-arsenic slag.

(b) early leaching, illustrated by leaching from a phenol lime sludge.

(c) delayed leaching, illustrated by leaching of nickel from a synthetic metal hydroxide sludge.

Figure 3 Typical results from comparative leaching tests on a synthetic metal hydroxide sludge, using 10 different leaching fluids.

Figure 4 Comparison of results from laboratory leaching tests and column validation experiments.

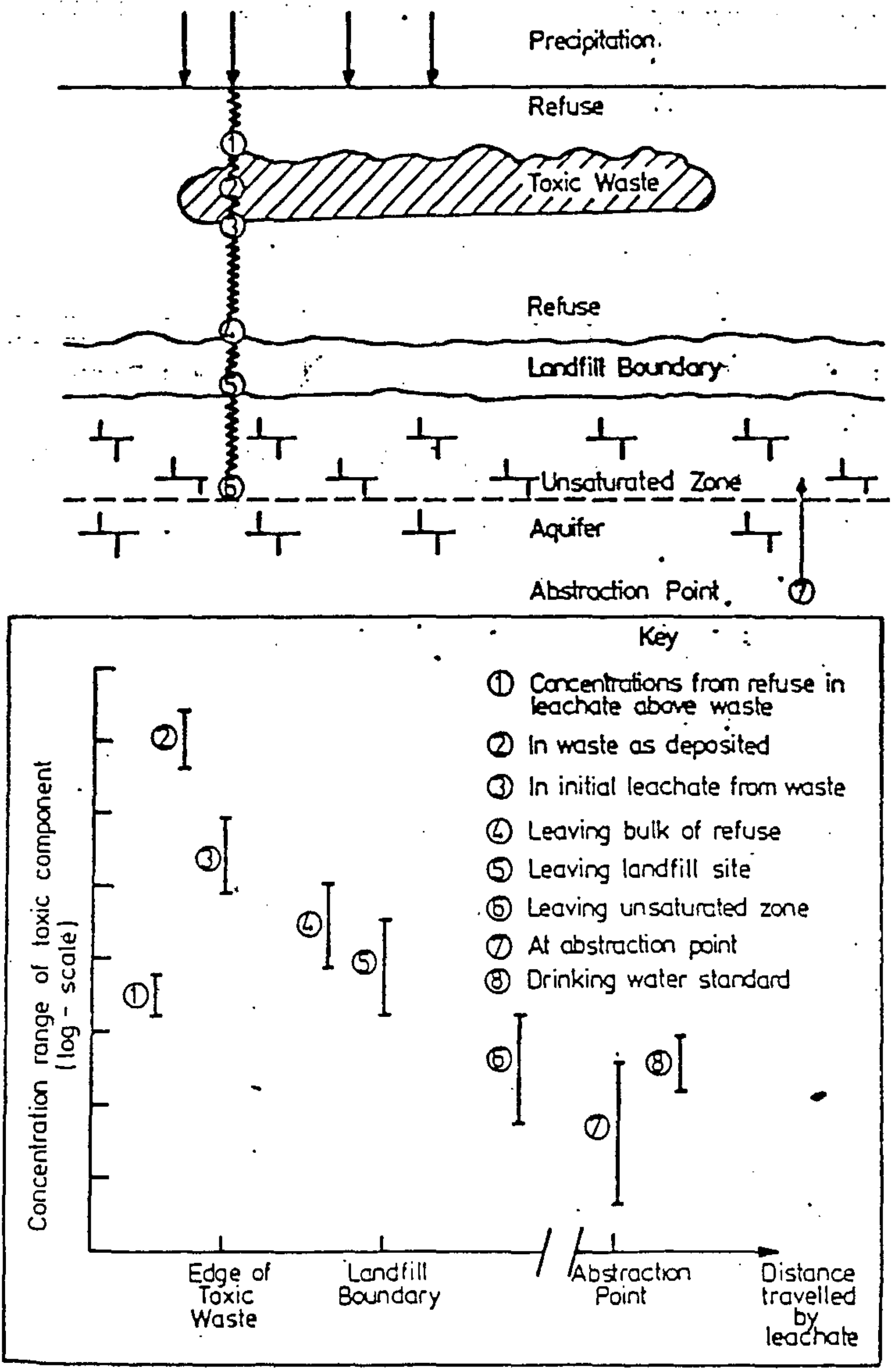
Precipitation
Refuse
Toxic Waste
Refuse
Landfill Boundary
Unsaturated Zone
Aquifer
Abstraction Point
⑦
①
②
③
④
⑤
⑥
Key
① Concentrations from refuse in leachate above waste
② In waste as deposited
③ In initial leachate from waste
④ Leaving bulk of refuse
⑤ Leaving landfill site
⑥ Leaving unsaturated zone
⑦ At abstraction point
⑧ Drinking water standard
Concentration range of toxic component (log - scale)
Edge of Toxic Waste
Landfill Boundary
Abstraction Point
Distance travelled by leachate

FIG.1

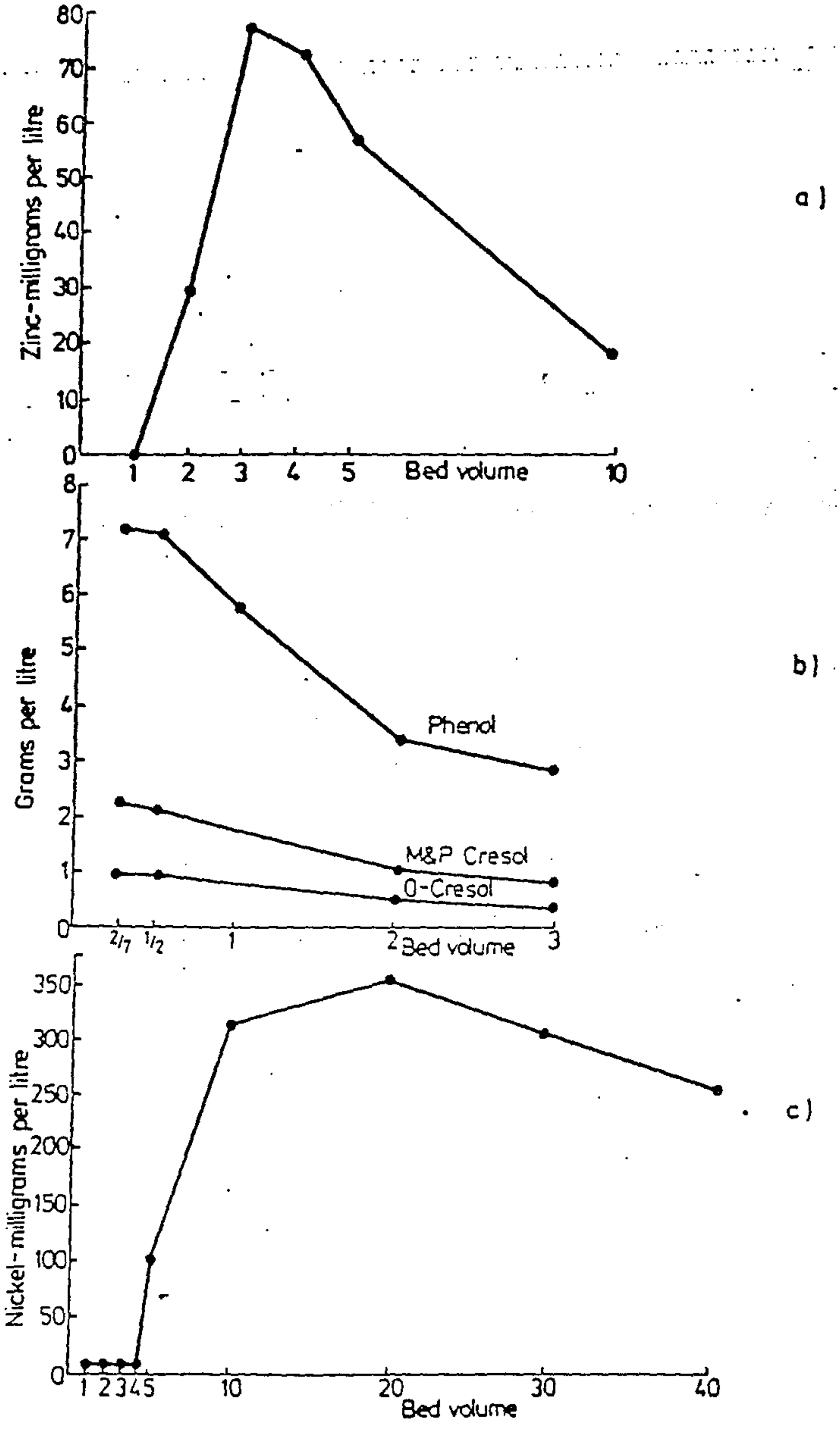
Zinc-milligrams per litre
0
10
20
30
40
50
60
70
80
1
2
3
4
5
Bed volume
10
a)
Grams per litre
0
1
2
3
4
5
6
7
8
Phenol
M&P Cresol
O-Cresol
2/7
1/2
1
2
Bed volume
3
b)
Nickel-milligrams per litre
0
50
100
150
200
250
300
350
1
2
3
4
5
10
20
30
40
Bed volume
c)

FIG. 2

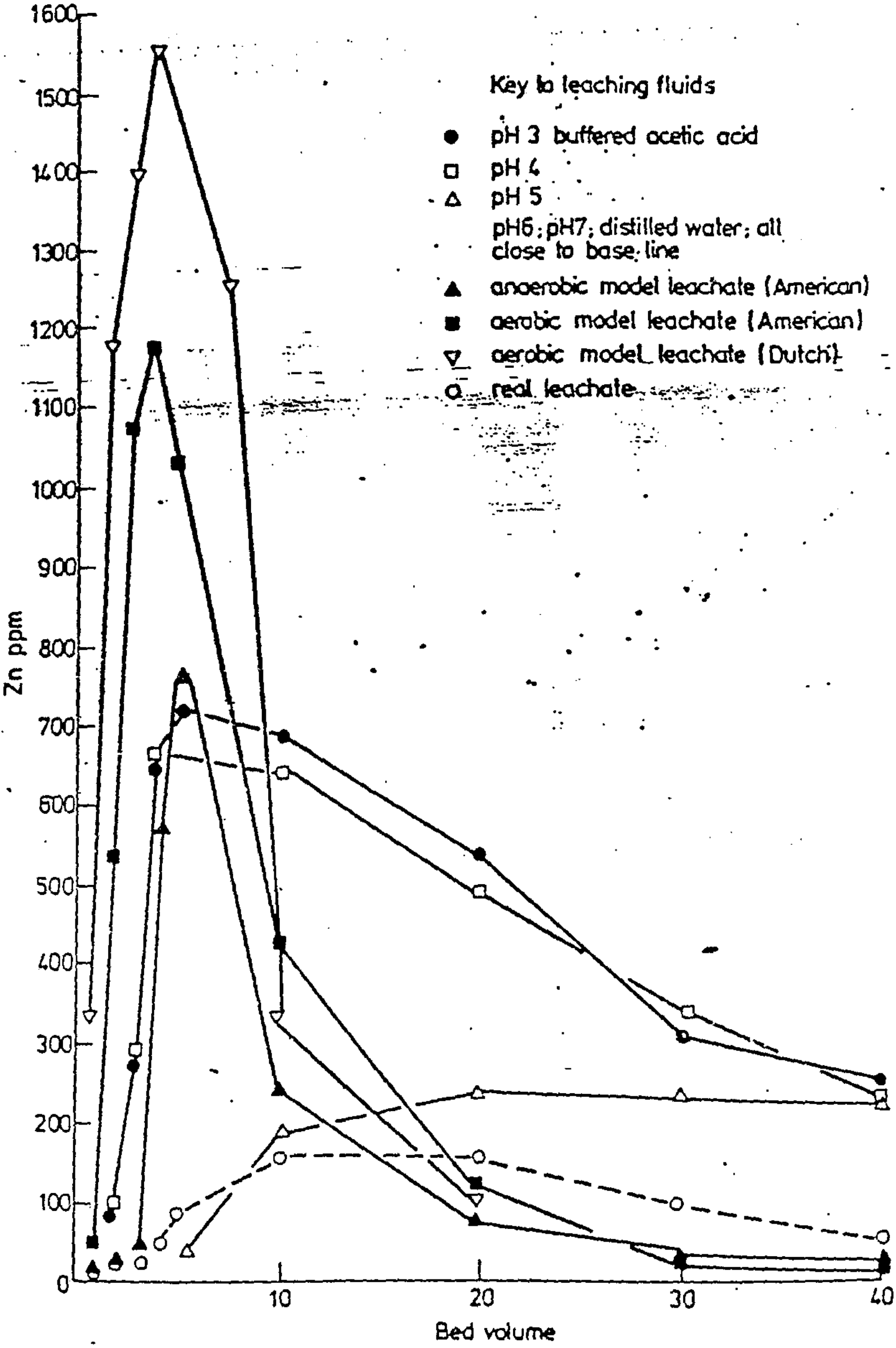
Key to leaching fluids
● pH 3 buffered acetic acid
□ pH 4
△ pH 5
pH6; pH7; distilled water; all close to base line
▲ anaerobic model leachate (American)
■ aerobic model leachate (American)
▽ aerobic model leachate (Dutch)
○ real leachate
Zn ppm
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
Bed volume

FIG. 3

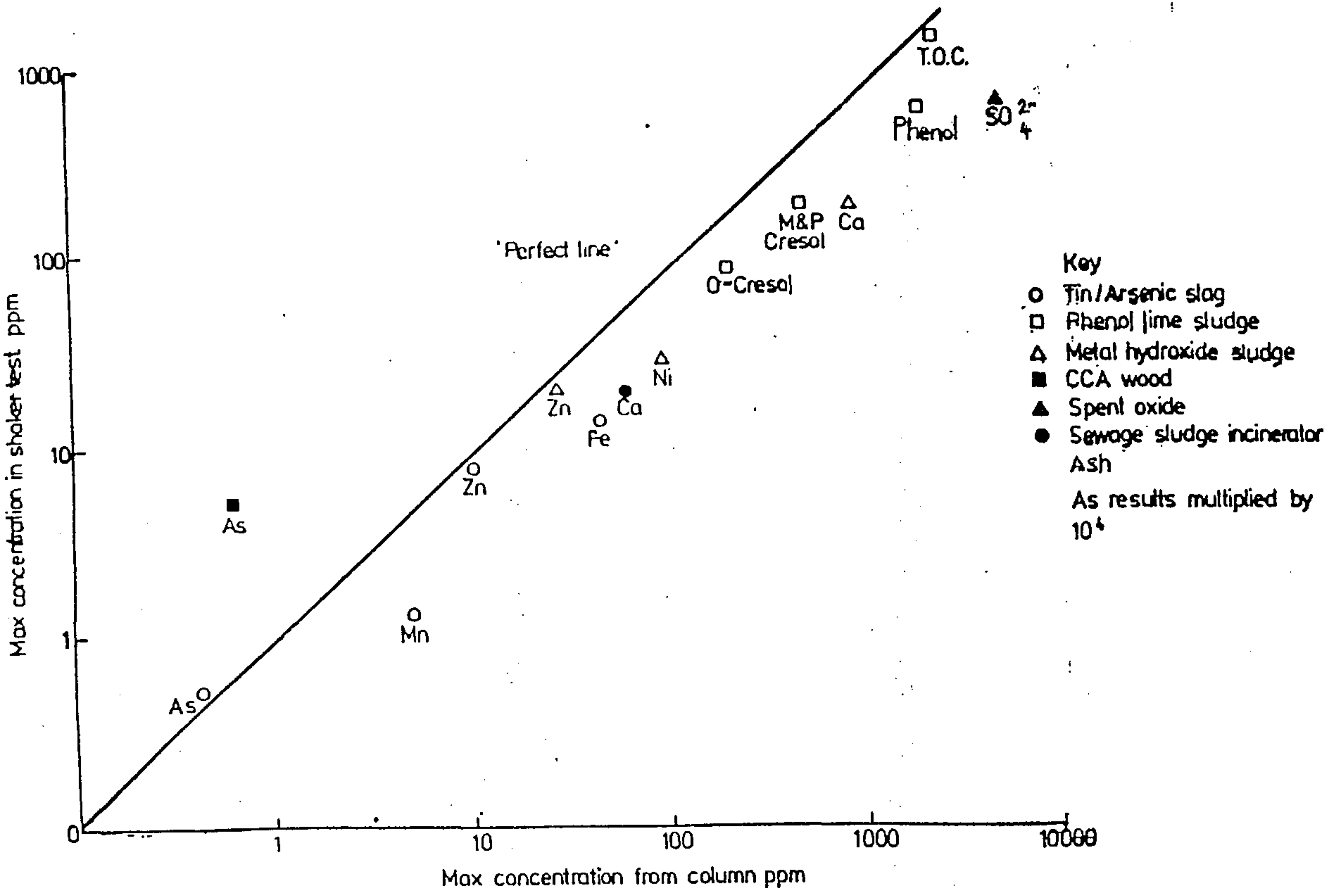
Max concentration in shaker test ppm
1000
100
10
1
0
Max concentration from column ppm
0
1
10
100
1000
10000
'Perfect line'
T.O.C.
Phenol
SO_4^{2-}
M&P Cresol
Ca
O-Cresol
Ni
Zn
Ca
Fe
Zn
As
Mn
As
Key
○ Tin/Arsenic slag
□ Phenol lime sludge
△ Metal hydroxide sludge
■ CCA wood
▲ Spent oxide
● Sewage sludge incinerator Ash
As results multiplied by 10^4

FIG. 4

Available from

HER MAJESTY'S STATIONERY OFFICE

49 High Holborn, London, WC1V 6HB
P.O. Box 569, London, SE1 9NH (Trade and London area mail orders)
13a Castle Street, Edinburgh, EH2 3AR
41 The Hayes, Cardiff, CF1 1JW
Brazennose Street, Manchester, M60 8AS
Southey House, Wine Street, Bristol, BS1 2BQ
258 Broad Street, Birmingham, B1 2HE
80 Chichester Street, Belfast, BT1 4JY
or any bookseller

Printed in England

APPENDIX 7B

APPENDIX 7B

LEACHATE TEST RESULTS

SGS Hong Kong Ltd.
Inspection and Laboratory Testing

Block J, 7th Fl., Kaiser Estate, Phase II,
51, Man Yue Street, Hung Hom,
Kowloon, Hong Kong.
Tel. 364 2272 Telex: 44593 SGSHK HX
Fax. 3633848 (Toys Laboratory) 3349086 (Chemical, Food, Lab Development & Environmental Laboratory)
7643276 (Textile & Packaging Laboratory) 3624647 (General Enquiry)

Test Report

No. 300043/KV Date MAY 06, 1993

SHIU WING STEEL LTD
1209 JARDINE HOUSE
HONG KONG

AXIS ENVIRONMENTAL CONSULTANTS LTD
7/F HONG KONG ARTS CENTRE
2 HARBOUR ROAD
HONG KONG

Axis Environmental Consultants Ltd (hereinafter called AXIS) ref. no. 053 000

Report on the leachate test.

1. Samples Description

SGS Assigned Sample No.	Sample Description Reported by AXIS	Date of Sample Collection Reported by AXIS	Date of Sample Received by SGS	Remark
S9303001 A,B	Dust	Mar 4,93	Mar 16,93	--
S9303001 C,D	Dust	Mar 15-16,93	Mar 16,93	--
S9303002 A,B,C	Slag	Mar 4,93	Mar 16,93	—
S9303002 D,E	Slag	Mar 15-16,93	Mar 16,93	--
S9303003*	Dust	—	—	Mixture of S9303001 A,B,C & D
S9303004*	Slag	--	--	Mixture of S9303002 A,B,C,D & E
S9303005*	Dust/Slag Mixture	--	--	Mixture with a ratio of 1 portion S9303003 : 2 portions S9303004
S9303006	Scale	Mar 4,93	Mar 17,93	—

* These samples were prepared by SGS HK Ltd according to the procedures detailed in Section 3.1.1.

xxxxxxxxxxxx

This test document cannot be reproduced in any way, except in full context, without the prior approval in writing of the laboratory.

Signed for and on behalf of
SGS Hong Kong Ltd.

TC

T.C. WONG

SGS Hong Kong Ltd.
Inspection and Laboratory Testing

Block J, 7th Fl., Kaiser Estate, Phase II,
51, Man Yue Street, Hung Hom,
Kowloon, Hong Kong.
Tel. 364 2272 Telex: 44593 SGSHK HX
Fax: 3633846 (Toys Laboratory) 3349085 (Chemical, Food, Lab Development & Environmental Laboratory)
7643276 (Textile & Packaging Laboratory) 3624647 (General Enquiry)

Test Report	No. 300043/EV	Date MAY 06, 1993

Sampling location reported by AXIS : Shiu Wing Steel Works, Tseung Kwan O

Sample preservation employed as reported by client : No preservation employed. Each sample was stored in a plastic bag at ambient condition when received by SGS.

Testing period : Mar 18 - May 5, 93

2. Test Required

2.1 Dust and slag samples

To perform a leachate test on the submitted dust and slag samples with reference to the method provided in the fax dated Feb 25,93, Mar 3,93 and Mar 16,93 from AXIS. The test consisted of two parts : Equilibrium Shaker Test and Repetitive Shaker Test.

2.1.1 Equilibrium shaker test

The sample was shaken with a leachate for no more than 80 hours. At certain time intervals (1st, 2nd, 3rd, 4th, 24th, 32nd, 48th, 56th, 72nd and 80th hours), the leachate was separated from the sample. The pH value and conductivity of the filtered leachate was measured. Equilibrium was assumed when the difference of conductivity between two successive reading was negligible. The equilibrium time was recorded and was used as the shaking time for the repetitive shaker test. After the achievement of equilibrium, the leachate was filtered for the determination of pH value, zinc, lead, cadmium, total chromium, hexavalent chromium, barium, iron, boron, colour, total residual chlorine, nickel, manganese, mercury, copper, chemical oxygen demand, sulphide, sulphate and total phosphorus contents.

2.1.2 Repetitive shaker test

After the sample was shaken for a period as determined from the equilibrium test (Section 2.1.1) with different bed volumes of the leachate, the leachate sample was extracted from the sample to measure pH value, zinc, lead, cadmium, total chromium and barium contents.

****

2.2 Scale sample

2.2.1 To perform water, oil & grease content analysis on the submitted scale sample.

2.2.2 To perform oil & grease content analysis on the 5000 ppm acetic acid leachate of the submitted sample after shaking with the said leachate for 1 hour.

3. Test Procedures

3.1 Leachate test on the submitted dust and slag samples

3.1.1 Sample preparation

As the submitted samples were contained in more than one container and were collected from different date, it was requested by AXIS that these samples were mixed and crushed before being used for testing.

The submitted samples namely A, B, C & D of S9303001 (4 samples) were crushed to a size passed through 1.00 mm sieve and mixed manually by a glass rod afterwards. A new sample number S9303003 was assigned to this mixture. For the submitted samples A, B, C, D & E of S9303002 (5 samples) were crushed by a hammer into a size passed through 2.36 mm sieve and mixed manually by a glass rod afterward. A new sample number S9303004 was assigned to the mixture. 266 g of S9303003 were weighed and was mixed with 534 g of S9303004 to form a sample mixture and it was assigned as S9303005. Detail on the labelling of the samples is shown in Table 1.

Table 1 Sample number assignment for testing specimen

Description	Sample No. of Raw Sample	Sample No. of Mixed & Crushed Sample
Dust	S9303001	S9303003
Slag	S9303002	S9303004
Dust and Slag Mixture	266 g S9303001 + 534 g S9303002	S9303005

****

3.1.2 Equilibrium shaker test

(a) For each type of sample (dust, slag and mixture), two equal portions of weight 300 g were placed into two separate 500 ml erlenmeyer flask.

(b) Two types of leachates (acetic acid, deionized water) were employed for shaking the samples. A leachate of 5000 ppm acetic acid buffered to pH 5 with 6N sodium hydroxide was prepared. One bed volume (400 ml) of the leachate was transferred from a measuring cylinder to one of the flasks. Deionized water was prepared and 400 ml was transferred from a measuring cylinder to the remaining flask.

(c) The flask was sealed by parafilm and placed on a shaker for shaking.

(d) The shaker was controlled to shake at a frequency of 50 Hz and had a magnitude which was vigorous enough to mingle the leachate thoroughly with the sample in the flask. The shaking lasted for one hour.

(e) A portion of leachate was withdrawn from the flask and filtered through a Whatman no. 541 filter paper.

(f) The leachate sample was then tested for pH and conductivity according to the methods listed in Section 3.1.4.

(g) The tested leachate was poured into the flask.

(h) The procedures (c) to (g) was repeated in order at hourly intervals for a further 3 hours or longer time until equilibrium was achieved (the sample separated from the leachate was at the 24th, 32nd, 48th, 56th, 72nd and 80th hour if equilibrium was not achieved within 4 hours according to the result of conductivity measurements).

(i) The leachate obtained at equilibrium time was analysed for the parameters mentioned in Section 2.1.1 with reference to the analytical methods listed in Section 3.1.4.

* * *

3.1.3 Repetitive shaker test

(a) For each type of sample (dust, slag and mixture), two equal portions of weight 100 g were placed into two separate 500 ml erlenmeyer flask.

(b) Two types of leachates (acetic acid, deionized water) were employed for shaking the samples. A leachate of 5000 ppm acetic acid buffered to pH 5 with 6 N sodium hydroxide was used for shaking one of the sample portions while deionized water was used for shaking of the other sample portion. One bed volume (133 ml) of the leachate was transferred from a measuring cylinder to the flask.

(c) The flask was sealed by parafilm and placed on a shaker for shaking.

(d) The shaker was controlled to shake at a frequency of 50 Hz and had a magnitude which was vigorous enough to mingle the leachate thoroughly with the sample in the flask. The content was shaken for a time period determined from procedure 3.1.2 h.

(e) All the contents in the flask was filtered through a Whatman no. 541 filter paper.

(f) As much of the filtered residue as practicable was recovered from the filtering and returned to the flask.

(g) The filtered leachate was analysed for the parameters mentioned in Section 2.1.2 with reference to the method listed in Section 3.1.4.

(h) The next bed volume of leachate was added to the flask containing the recovered sample. The volume required was that just covered the residue in the flask, instead of adding the same volume mentioned in procedure 3.1.3 b.

(i) The procedures outlined in (c) to (h) were repeated in order until a total number of five bed volumes was used. After the fifth bed volume, only one tenth of the filtered residue was used for next shaking.

****

(j) Ten bed volumes (133 ml) of the leachate was added to the flask.

(k) The flask was sealed by parafilm, shaken, filtered and analysed in the same procedures as outlined in (c) to (g). This stage was regarded as a leaching over six to fifteen bed volumes and the leachate sample was assumed to be the leachate for ten bed volumes.

3.1.4 Analytical methods of the leachate samples

Parameter	Analytical Method
pH	APHA 4500-H+ B
Conductivity	APHA 2510 B
Zinc	APHA 3120
Lead	APHA 3130
Cadmium	APHA 3130
Chromium (Total)	APHA 3120
Chromium (Hexavalent)	APHA 3500-Cr D
Barium	APHA 3120
Iron	APHA 3120
Boron	APHA 3120
Color	Lovibond Model E Tintometer, 25 mm cell
Total Residual Chlorine	APHA 4500 Cl G
Nickel	APHA 3120
Manganese	APHA 3120
Mercury	APHA 3112
Copper	In-house method based on APHA 3130

* * *

4. Test Result

4.1 Dust and slag samples (S9303003, S9303004, S9303005)

4.1.1 Equilibrium shaker test

(a) Sample : Dust (S9303003)

	Water Leachate		Acetic Acid Leachate	
Time (hr)	pH	Conductivity at 25 degree Celsius, mmho/cm	pH	Conductivity at 25 degree Celsius, mmho/cm
1st	11.49	36.39	7.02	20.52
2nd	11.47	39.73	7.22	33.20
3rd	11.43	38.50	7.31	40.20
4th	11.44	40.49	7.38	41.00
24th	11.54	44.63	7.23	48.60
32nd	11.48	50.46	7.28	51.75
48th	11.46	53.75	10.66	61.54
56th	11.53	56.47	10.90	62.90
72nd	11.60	58.66	11.17	68.87
80th	11.56	59.72	11.13	67.22

Sample used : 300 g
Leachate added : 400 ml
Equilibrium time for water leachate : 80 hours
Equilibrium time for acetic acid leachate : 80 hours

****

Sample : Dust (S9303003)

	Water Leachate at Equilibrium	Acetic Acid Leachate at Equilibrium
pH value	11.56	11.13
Zinc	38.8 mg Zn/L	16.3 mg Zn/L
Lead	10.2 mg Pb/L	5.8 mg Pb/L
Cadmium	< 0.001 mg Cd/L	< 0.001 mg Cd/L
Total chromium	0.16 mg Cr/L	0.07 mg Cr/L
Hexavalent chromium	< 0.1 mg Cr/L	< 0.1 mg Cr/L
Barium	0.30 mg Ba/L	0.51 mg Ba/L
Iron	2.72 mg Fe/L	2.13 mg Fe/L
Boron	3.40 mg B/L	4.05 mg B/L
True colour		
- Total	2.6 Lovibond unit	1.2 Lovibond unit
- Neutral Tints	0 Lovibond unit	0.1 Lovibond unit
Total residual chlorine	2.09 mg Cl/L	2.62 mg Cl/L
Nickel	< 0.03 mg Ni/L	< 0.03 mg Ni/L
Manganese	0.41 mg Mn/L	0.20 mg Mn/L
Mercury	0.041 mg Hg/L	0.088 mg Hg/L
Copper	< 0.03 mg Cu/L	0.33 mg Cu/L
Chemical oxygen demand	636 mg O2/L	< 40 mg O2/L
Sulphide	< 0.1 mg S2-/L	< 0.1 mg S2-/L
Sulphate	3870 mg SO4 2-/L	3970 mg SO4 2-/L
Total phosphorus	0.17 mg P/L	< 0.05 mg P/L

* * *

Test Report No. 300043/EV Date MAY 06, 1993

(b) Sample : Slag (S9303004)

	Water Leachate		Acetic Acid Leachate	
Time (hr)	pH	Conductivity at 25 degree Celsius, mmho/cm	pH	Conductivity at 25 degree Celsius, mmho/cm
1st	12.60	0.79	12.52	12.52
2nd	12.59	0.80	12.51	12.68
3rd	12.61	0.82	12.55	12.64
4th	12.64	0.83	12.54	12.72

Sample used : 300 g
Leachate added : 400 ml
Equilibrium time for water leachate : 4 hours
Equilibrium time for acetic acid leachate : 4 hours

	Water Leachate at Equilibrium	Acetic Acid Leachate at Equilibrium
pH value	12.64	12.54
Zinc	0.81 mg Zn/L	0.59 mg Zn/L
Lead	< 0.03 mg Pb/L	< 0.03 mg Pb/L
Cadmium	< 0.001 mg Cd/L	< 0.001 mg Cd/L
Total chromium	< 0.03 mg Cr/L	0.03 mg Cr/L
Hexavalent chromium	< 0.1 mg Cr/L	< 0.1 mg Cr/L
Barium	5.13 mg Ba/L	5.33 mg Ba/L
Iron	0.06 mg Fe/L	0.02 mg Fe/L
Boron	0.04 mg B/L	0.03 mg B/L
True colour		
- Total	1.2 Lovibond unit	0.2 Lovibond unit
- Neutral Tints	0.1 Lovibond unit	0 Lovibond unit
Total residual chlorine	0.17 mg Cl/L	0.20 mg Cl/L
Nickel	< 0.03 mg Ni/L	< 0.03 mg Ni/L
Manganese	< 0.01 mg Mn/L	< 0.01 mg Mn/L
Mercury	0.001 mg Hg/L	0.021 mg Hg/L
Copper	0.64 mg Cu/L	0.77 mg Cu/L
Chemical oxygen demand	68 mg O2/L	< 40 mg O2/L
Sulphide	0.3 mg S2-/L	1.1 mg S2-/L
Sulphate	3 mg SO4 2-/L	3 mg SO4 2-/L
Total phosphorus	0.15 mg P/L	0.17 mg P/L

****

(c) Sample : Slag and Dust Mixture (2:1) (S9303005)

	Water Leachate		Acetic Acid Leachate	
Time (hr)	pH	Conductivity at 25 degree Celsius, mmho/cm	pH	Conductivity at 25 degree Celsius, mmho/cm
1st	12.41	15.75	12.37	19.41
2nd	12.43	18.57	12.38	22.87
3rd	12.45	19.67	12.42	24.57
4th	12.44	20.66	12.40	23.83
24th	12.65	25.55	12.29	25.58
32nd	12.46	27.06	12.05	26.42
48th	12.48	30.11	12.30	29.42
56th	12.50	31.00	12.36	31.86
72nd	--	--	12.32	34.32
80th	--	--	12.34	33.05

Sample used : 300 g
Leachate added : 400 ml
Equilibrium time for water leachate : 56 hours
Equilibrium time for acetic acid leachate : 80 hours

* * *

Test Report

No. 300043/EV Date MAY 06, 1993

Sample : Slag and Dust Mixture (2:1) (S9303005)

	Water Leachate at Equilibrium	Acetic Acid Leachate at Equilibrium
pH value	12.50	12.34
Zinc	10.1 mg Zn/L	12.3 mg Zn/L
Lead	54.2 mg Pb/L	110 mg Pb/L
Cadmium	< 0.001 mg Cd/L	< 0.001 mg Cd/L
Total chromium	0.20 mg Cr/L	0.20 mg Cr/L
Hexavalent chromium	< 0.1 mg Cr/L	< 0.1 mg Cr/L
Barium	0.20 mg Ba/L	0.61 mg Ba/L
Iron	2.48 mg Fe/L	1.28 mg Fe/L
Boron	0.11 mg B/L	0.14 mg B/L
True colour		
- Total	1.3 Lovibond unit	0.4 Lovibond unit
- Neutral Tints	0 Lovibond unit	0 Lovibond unit
Total residual chlorine	0.43 mg Cl/L	0.48 mg Cl/L
Nickel	< 0.03 mg Ni/L	< 0.03 mg Ni/L
Manganese	0.28 mg Mn/L	0.20 mg Mn/L
Mercury	0.003 mg Hg/L	0.033 mg Hg/L
Copper	< 0.03 mg Cu/L	< 0.03 mg Cu/L
Chemical oxygen demand	366 mg O2/L	< 40 mg O2/L
Sulphide	0.1 mg S2-/L	0.2 mg S2-/L
Sulphate	1250 mg SO4 2-/L	1210 mg SO4 2-/L
Total phosphorus	< 0.05 mg P/L	< 0.05 mg P/L

****

4.1.2 Repetitive shaker test

(a) Sample : Dust (S9303003)
Leachate : Water

Bed Volume		1st	2nd	3rd	4th	5th	6th
Leachate added (ml)		133	133	133	133	133	133
Parameter							
pH value		11.57	11.67	11.63	11.54	11.74	11.71
Zinc	(mg/L)	138	24.3	68.1	74.7	57.7	41.9
Lead	(mg/L)	14.6	11.5	9.8	10.8	14.4	18.3
Cadmium	(mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total chromium	(mg/L)	0.31	0.07	0.09	0.06	0.05	0.04
Barium	(mg/L)	0.33	0.11	<0.01	<0.01	0.21	0.41

Sample used : 100 g

Leachate : Acetic acid

Bed Volume		1st	2nd	3rd	4th	5th	6th
Leachate added (ml)		133	133	133	133	133	133
Parameter							
pH value		10.47	11.01	10.88	10.49	10.32	9.48
Zinc	(mg/L)	8.86	73.5	29.4	126	39.5	17.8
Lead	(mg/L)	0.34	12.9	4.6	20.6	6.5	3.0
Cadmium	(mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total chromium	(mg/L)	0.04	0.05	<0.03	0.05	0.03	<0.03
Barium	(mg/L)	0.47	0.15	0.17	0.14	0.11	0.18

Sample used : 100 g

****

(b) Sample : Slag (S9303004)
Leachate : Water

Bed Volume		1st	2nd	3rd	4th	5th	6th
Leachate added (ml)		133	133	133	133	133	133
Parameter							
pH value		12.60	12.66	12.64	12.49	12.54	12.58
Zinc	(mg/L)	2.74	2.73	3.22	2.66	5.43	1.47
Lead	(mg/L)	<0.03	<0.03	<0.03	1.05	0.43	0.37
Cadmium	(mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total chromium	(mg/L)	<0.03	<0.03	<0.03	<0.03	0.06	<0.03
Barium	(mg/L)	7.19	4.50	5.85	2.70	1.89	0.65

Sample used : 100 g

Leachate : Acetic acid

Bed Volume		1st	2nd	3rd	4th	5th	6th
Leachate added (ml)		133	133	133	133	133	133
Parameter							
pH value		12.48	12.58	12.56	12.42	12.39	11.44
Zinc	(mg/L)	4.10	2.68	2.70	3.34	2.21	0.45
Lead	(mg/L)	0.20	0.53	0.48	0.37	0.14	<0.03
Cadmium	(mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total chromium	(mg/L)	0.06	<0.03	0.04	0.05	0.04	0.05
Barium	(mg/L)	8.13	4.33	2.79	2.13	1.22	0.51

Sample used : 100 g

****

Test Report No. 300043/KV Date MAY 06, 1993

(c) Sample : Slag and Dust Mixture (2:1) (S9303005)
Leachate : Water

Bed Volume		1st	2nd	3rd	4th	5th	6th
Leachate added (ml)		133	133	133	133	133	133
Parameter							
pH value		12.38	12.36	12.37	12.24	12.43	11.75
Zinc	(mg/L)	4.51	13.5	47.9	63.9	28.6	42.9
Lead	(mg/L)	30.4	95.6	115	76.0	36.4	7.4
Cadmium	(mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total chromium	(mg/L)	0.28	<0.03	<0.03	<0.03	<0.03	0.04
Barium	(mg/L)	0.12	0.66	6.15	4.18	2.88	0.96

Sample used : 100 g

Leachate : Acetic acid

Bed Volume		1st	2nd	3rd	4th	5th	6th
Leachate added (ml)		133	133	133	133	133	133
Parameter							
pH value		12.30	12.27	12.17	11.87	11.83	11.54
Zinc	(mg/L)	21.8	52.0	18.1	14.0	2.11	25.3
Lead	(mg/L)	100	158	82.8	16.4	2.90	4.16
Cadmium	(mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total chromium	(mg/L)	0.18	0.07	0.03	<0.03	<0.03	0.06
Barium	(mg/L)	0.25	6.70	7.14	6.68	4.43	2.48

Sample used : 100 g

****

4.2 Scale sample (S9303006)

4.2.1 Original sample

Parameter	Result
Water content	10.8 %
Oil and grease content	0.29 % on sample 'as received'
	0.33 % on dried sample (based on calculation from water content)

4.2.2 Leachate of sample

Parameter	Result
Oil and grease content	26.7 mg/L

Note : Weight of sample used = 100 g
Volume of leachate added = 133 ml

APPENDIX 7C

APPENDIX 7C

INTERPRETATION OF LEACHATE TEST RESULTS

APPENDIX 7C : INTERPRETATION OF LEACHATE TEST RESULTS

SUITABILITY FOR LANDFILL

Dust

The leachate test results indicate:

- substantial concentrations of zinc (maximum 138mg/l), lead (maximum 21mg/l), COD (maximum 620mg/l) and sulphate (maximum 3970mg/l) in the alkaline leachate;
- little difference in results between using acid leachate or distilled water as the leaching medium;
- maximum lead concentration, using water as the leachate medium, in the sixth repetitive test. Also, the zinc and lead concentrations in the acid leachate medium tests reach maximum values in the fourth repetitive test. This illustrates the necessity of the repetitive tests because the first set of results do not simulate worst case.

Because of the high leachate contamination levels and its potential to pollute, the potential environmental impact of landfilling dust requires assessment. Below, this is assessed with regard to SENT landfill, which is designated to handle industrial wastes and is thus considered to be the most suitable landfill site for the filter dust.

Dust characteristics : 45 t/day
12% zinc
1.4% lead

SENT landfill characteristics (References 5&6) :
- Lined site
- 6,000 - 7,000 tpd
- 2.5% publicly collected waste
- 53.5% construction waste
- 44% commercial/industrial waste including 175 tpd Chemical Waste.
- Leachate (250-600m^3/day) nitrified and pumped to Tseng Kwan O STW (54,000m^3/day) for screening prior to discharge via Tathong Channel outfall, for tidal flushing. Secondary treatment is planned at the STW post - 2000. Discharge to Sewer should satisfy the TM effluent discharge standards detailed in Table 5.2

Table 7C.1 below examines attenuation data in a manner similar to a worked example detailed in Appendix 7A.

Table 7C.1 : Attenuation of Leachate

		Zinc (mg/l)	Lead (mg/l)	Sulphate (mg/l)	COD (mg/l)
a.	Maximum Concentration in leachate (from test results)	138 mg/l	21	3970	640
b.	Concentration tolerated in leachate (from table 5.2) discharged to sewer	1.5	1	1000	2000
c.	Attenuation factor required (a/b)	92	21	4	-
d.	Attenuation available:				
	Attenuation in site	Not known			
	Dilution with other leachate (6000tpd/45tpd)*	x133	x133	x133	x133
	Attenuation in Unsaturated zone	Not Applicable			
	Dilution with Groundwater	Not Applicable			

* An approximate estimate of the dilution available with leachate from the other waste deposited can be obtained by assuming that the leachate generated is proportioned to the tonnage of waste. This is reasonable provided the dust is deposited in a similar manner, for example not spread as a very thin layer over the other waste.

It can be seen from Table 7C.1 that the necessary degree of attenuation can be achieved.

It has been assumed that there is no zinc leaching from the other wastes deposited. This is a fair assumption as a toxic heavy metal such as zinc would only leach significantly from wastes designated Chemical Wastes, and these comprise only 3% of the total waste anticipated at SENT. Most of these Chemical Wastes are anticipated to be acids/alkalis, which would contain little, if any, zinc.

In addition, it should be noted that:

- Worst case leaching results have been considered. For example, the maximum concentration of 138 mg/l zinc was used; this concentration varied in the tests and was as low as 8.9 mg/l.

- Further attenuation in the landfill site has not been considered as it is difficult to quantify. Thus, the benefits of co-disposal of industrial waste with general waste has not been taken into account.
  It is a widely accepted principle that attenuation of toxic substances will take place in a codisposal site due to a variety of physical, chemical and biological processes which occur within the deposited wastes.

- Tests were conducted upon crushed dust samples. Dust would in practise be disposed to landfill as pellets. In the pelletised form, contact between dust and leachate would be less intimate.

Thus a safety margin is provided.

Slag

The results verify that although slag can contain elevated levels of heavy metals, it is a relatively inert substance. The results show:

- alkaline leaching of zinc (maximum 5.4 mg/l), lead (maximum 1.05 mg/l), barium (maximum 5.3 mg/l) and copper (0.8 mg/l);
- little difference in results between using acid leachate or distilled water as the leaching medium.

At these relatively low levels of leaching, landfilling of slag would not be expected to have any significant environmental impact at WENT landfill which would be the closest landfill to the proposed steel mill site. Dilution by leachate from surrounding waste and attenuation in the landfill site would lower the contamination levels significantly.

Dust/Slag

The leachate test results indicate:

- the presence of substantial concentrations of zinc (maximum 63 mg/l), lead (maximum 158 mg/l), Barium (maximum 7.1 mg/l) and sulphate (maximum 1250 mg/l) in the alkaline leachate.
- The leaching of lead from the mixture is significantly worst than leaching from filter dust on its own.
- little difference in results between using acid leachate or distilled water as the leaching medium.
- contamination levels do not reach maximum values in the first stage of the tests.

Because of the high levels of contamination in the leachate (particularly lead),there does not appear to be any benefit in mixing slag and filter dust for disposal.

Scale

A sample of waste scale was collected from the existing Junk Bay site by AXIS Environmental and found to comprise 10.8% water and 0.33% (dry weight) of oil. Leachate from the scale contained 26.8 mg/l of oil and grease. The oil arises from contamination of recirculating cooling water by lubrication oils.

Scale is an inert substance (> 90% iron oxides) and oil is the only potential contaminant.

Landfilling of scale would not be expected to result in significant environmental impact. Dilution by leachate from surrounding waste and attenuation in the landfill site would lower oil contamination levels.

APPENDIX 8

APPENDIX 8

ABBREVIATIONS

APPENDIX 8 : ABBREVIATIONS

Measurements

Technical units of measurement in this report are based on the International System of Units (SI) wherever possible. These technical units may be broadly grouped as prefixes and measurements. A prefix applies to the unit of measurement that immediately follows it - for example microgram is abbreviated as μg. Superscripts ^{2} and ^{3} following a linear unit indicate area and volume - for example m^2 (square metres) and m^3 (cubic metres). Different units are combined by a full stop (.) to differentiate units of the same exponential sign, and a solidus (/) to indicate 'per'. For example, kilometres per hour is abbreviated as km/h, while megalitres per day per square kilometre is Ml/d.km^2.

The prefixes used in this report are:

k	kilo	1,000
m	milli	0.001
μ	micro	0.000,001

Units of measurement which have been used are:

yr	year
dBA	decibel, frequency weighting network A
°C	degrees Celsius
g	gram
h	hour
ha	hectare
Hz	hertz
l	litre
L_{eq}	equivalent sound power level
L_{90}	sound power level exceeded 90% of the time
m	metre
pH	degree of alkalinity/acidity
%	per cent
s	second
t	tonne

Miscellaneous

AFD	Agriculture and Fisheries Department
AQO	Air Quality Objective
ANL	Acceptable noise level
AS	Australian Standard
ASR	Area Sensitivity Rating
BF	Baghouse Filters
BOD	Biochemical Oxygen Demand
BOD_5	biochemical oxygen demand (five-day test)
BNL	Base Noise Level
BS	British Standard
CCM	Continuous Casting Machine
CED	Civil Engineering Department
CNP	Construction Noise Permit
CWTF	Chemical Waste Treatment Facility
DO	Dissolved Oxygen
EAF	Electric Arc Furnace
EIA	Environmental Impact Assessment
EM&A	Environmental Monitoring and Audit
ENM	Environmental Noise Model
EPD	Environmental Protection Department
FCZ	Fish Culture Zone
FMC	Fill Management Committee
C/IC	Government/Institution-Community
HKPSG	Hong Kong Planning Standards and Guidelines
LAR	Lantau Airport Railway
LRT	Light Rail Transit

MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
MPT	Multi Purpose Terminal
N/A	not applicable
N/D	not detected by analysis in sample
NENT	North East New Territories
NTU	nephelometric turbidity units
NSR	noise sensitive receiver
NWWCZ	North Western Water Control Zone
ODP	Outline Development Plan
OZP	Outline Zoning Plan
PADS	Port and Airport Development Strategy
PD	Principal Datum
PFA	Pulverised Fuel Ash
PNL	Predicted Noise Level
®	registered trade name
RF	Re-heat Furnace
RTT	River Trade Terminal
SIA	Special Industrial Area
RM	Rolling Mill
SIA	Special Industrial Area
SMG	Steering Management Group
SWL	Sound Power Level
SPL	Sound Pressure Level
SR	Sensitive Receiver
SSSI	Site of Special Scientific Interest

SS	Suspended Solids
STT	Short Term Tenancy
STW	Sewage Treatment Works
TM	Technical Memorandum
TSP	Total Suspended Particulate
USEPA	United States Environmental Protection Agency
VEPA	Victorian Environment Protection Authority
WENT	Western New Territories
WPCO	Water Pollution Control Ordinance
WQCZ	Water quality control zone
WQO	Water quality objective
ZVI	Zone of visual influence

APPENDIX 9

APPENDIX 9

GLOSSARY

APPENDIX 9 : GLOSSARY

Atmospheric stability	A measure of the tendency of a vertically displaced parcel of air to return to its original position (stable conditions), increase its displacement (unstable conditions), or remain where it is (neutral conditions). Strong heating of the land surface lends to instability (convection); strong cooling leads to stability (inversions).
AUSPLUME	Air modelling software package developed on behalf of the Victoria Environment Protection Authority, from the US EPA's Industrial Source Complex Model (ISCST) used to simulate the dispersion of dust in the present study.
Baseline Data	Data collected, to be used as a reference for all work or changes occurring from that time on.
Dispersion model	Computer software used to predict dispersion of pollutants.
Equivalent noise level (Leq)	The constant noise level equivalent to the A-weighted sound pressure level of the actual noise at the measurement site over the sampling period.
ISCST	Industrial Source Complex Model. US EPA air dispersion modelling software.
Mitigation measures	measures incorporated into an operation to minimize environmental impact.
Pasquill - Gifford	a relative index used to define atmospheric stability.
Respirable suspended particulates (RSP)	fine atmospheric particulate matter of nominal aerodynamic diameter of 10μm and smaller. These particulates, after inhalation, can penetrate deeply into human respiratory tract.
Sound power level (SWL)	a measure, in decibels, of the acoustic power radiated by a given noise source. It is independent of any reference distance or other extraneous factors.
Sound pressure level (SPL)	a measure, in decibels, of the sound pressure at a particular point. It is dependent upon distance from the source and many other extraneous factors.
Total suspended particulates (TSP)	atmospheric particulate matter comprising size fractions less than about 75μm in diameter.
Windrose	Circular graphical representation upon which wind direction, speed and frequency are plotted.

APPENDIX 10

APPENDIX 10

REFERENCES

APPENDIX 10 : REFERENCES

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AXIS

Environmental

AXIS Environmental Consultants Ltd.