APPENDIX 7

RISK ASSESSMENT

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ENVIRONMENT

April 2003

An assessment of risk from handling potentially dangerous substances at the proposed Bathside Bay Container Terminal

Hutchison Ports (UK) Ltd

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Summary

As part of the planning procedures for the proposed development of a container port at Bathside Bay, Harwich, Hutchison Ports (UK) Ltd (HPUK) was requested to carry out an assessment of the potential risks to the local population arising from accidents that might occur during the operation of the proposed facilities.

The request for a risk assessment originates from Tendring District Council (TDC), and arises from the knowledge that the proposed port facilities may handle potentially dangerous substances. Should an accident occur during transport or handling, it is conceivable that a potentially harmful release could occur that might adversely affect both workers on the site and local residents who live outside the site boundaries.

This risk assessment deals with the hazards and risks that could arise within the boundaries of the proposed facilities, from vessels moored at the berths to the exit to the public highway. With respect to vessels in transit through Harwich Haven, and containers that are being transported on the road and rail networks, separate risk assessments have been carried out (see Appendix 8 to the ES, Marine Traffic Analysis, and the Bathside Bay Transport Assessment).

Based on an assessment of the cargo containers currently handled by the Port of Felixstowe, and assuming a similar mix of trade at Bathside Bay, the most hazardous substances that are likely to be handled in bulk tanks are bromine and tetra-ethyl lead. Of these, bromine is considered to present the greatest hazard as far as off-site risk is concerned.

The most undesirable event would be a rapid major failure or loss of containment of a bromine tank, followed by the formation of a large pool of the liquid which could evaporate and form a plume that travels off-site.

Based on the risk analysis carried out, the chance of an event occurring such as the total loss of containment, as described, is extremely low. Furthermore, there are mitigating factors that will be taken into account, which demonstrate that the risk to those living near to the site would be considered to be acceptable.

In real terms, the risk to the individual is well within the level that would be considered to be tolerable under Health & Safety Executive (HSE) guidelines, in fact, the risk is what might be described as ‘broadly acceptable’. In practical terms, the level of risk is equivalent to that of winning six numbers in the National Lottery or slightly greater than being struck by lightning.

The HSE has examined the individual and societal risks arising from the transport of arguably more hazardous substances through ports, including chlorine and ammonia. A similar conclusion on the acceptability of the risk from these substances, namely chlorine, was reached by the HSE.

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1 INTRODUCTION

1.1 General

As part of the planning procedures for the proposed development of a container port at Bathside Bay, Harwich, Hutchison Ports (UK) Ltd (HPUK) was requested to carry out an assessment of the potential risks to the local population arising from accidents that might occur during the operation of the proposed facilities.

The request for a risk assessment originates from Tendring District Council (TDC), and arises from the knowledge that the proposed port facilities may handle potentially dangerous substances. Should an accident occur during transport or handling, it is conceivable that a potentially harmful release could occur that might adversely affect both workers on the site and local residents who live outside the site boundaries.

This risk assessment deals with the hazards and risks that could arise within the boundaries of the proposed facilities, from vessels moored at the berths to the exit to the public highway. With respect to vessels in transit through Harwich Haven, and containers that are being transported on the road and rail networks, separate risk assessments have been carried out (see Appendix 8 to the ES, Marine Traffic Analysis, and the Bathside Bay Transport Assessment).

In this report the term ‘hazard’ is used to represent the potential for harm. Hazard should not be confused with ‘risk’, which is defined as the likelihood of a specified undesired event occurring within a specified period of time or circumstances.

1.2 Report Organisation

This report is organised in the following manner:

Section 1 – Introduction, essentially this section, which describes the reason or need for the risk assessment.

Section 2 – Identification of Hazards and Potentially Hazardous Situations, which considers the major hazards that could arise, both in terms of the substances handled and the handling operations during the temporary presence of the substances in the port. Legislation controlling the handling and storage of dangerous goods is also examined.

Section 3 – Consequences of a Major Accident Event, which considers and addresses credible accident scenarios and the effects that such accidents might have and their severity.

Section 4 – Risk Evaluation, which addresses the likelihood that an undesirable situation might occur that would give rise to a major release. A comparison is made of the likelihood of possible occurrences at Bathside Bay against other risks that are present in everyday life. The levels of control that are placed upon potentially hazardous activities by the UK Health & Safety Executive (HSE) and also typical legislation in other European countries, in this case Holland, are also examined.

Section 5 – presents Conclusions.

2 IDENTIFICATION OF HAZARDS AND POTENTIALLY HAZARDOUS SITUATIONS

The vast majority of non-bulk goods entering and leaving the UK are transported in standardised containers. Large specialised ports have developed which exclusively handle containerised goods, typical examples being Felixstowe and Thamesport and which the proposed Bathside Bay development will resemble. The range of goods that are carried in containers is vast and can include substances that are potentially hazardous should they escape from their packaging or containment.

2.1 The Dangerous Substances in Harbour Area Regulations, 1987 (DSHA)

The DSHA regulations define the substances of concern and places requirements on operators to implement plans to prevent and minimise the consequences of any accidents that might arise from the transport or storage of dangerous substances. An emergency plan is required, which is interfaced with the emergency plans for the fire, police ambulance and other services that may be required in the event of a major accident.

The DSHA regulations require that shippers notify the port operator of the nature and quantity of dangerous goods being imported or exported. By this notification system port operators keep track of the hazardous substances likely to be handled.

The ‘storage’ of dangerous goods – being imported or exported – is also covered within the scope of these regulations, but there is no intention to store such goods in the Bathside Bay site beyond such short time periods as are necessary to effect transfer between marine and other modes of transport.

2.2 Hazardous Substances Handled

The range of dangerous substances that might be handled at Bathside Bay is vast. However, in order to simplify the risk assessment process, considerable study has been undertaken nationally; notably the report commissioned by the Health & Safety Commission Advisory Committee on Dangerous Substances (ACDS, 1991). Within the ACDS report it was not considered practical to assess the likely risk of every potentially dangerous substance, therefore, a screening process was undertaken. The most dangerous substances in terms of releases to air were considered to be chlorine, ammonia, LPG and motor spirit, and these substances were studied in detail. Explosives are a special case and will be subject to separate licensing from the HSE Explosives Directorate; as a result they are not considered further in this assessment.

Posford Haskoning’s Environment Division undertook an independent review of the range of dangerous substances currently handled by HPUK at Felixstowe, which should provide a good comparison to the type of trade that Bathside Bay should experience. The review concentrated upon substances that were handled in ISO tanks, which are a portable tank located within a steel frame, which conforms to ISO dimensions.

Of the dangerous substances handled at Felixstowe the most significant are Bromine and tetra-ethyl lead (TEL). Both of these substances are liquids at ambient temperature, but in the event of a leak or loss of containment then a pool could be formed that is likely to evaporate and form a plume that travels downwind.

There are many other potentially dangerous substances that might also be released as a liquid, which do not evaporate significantly but have the potential to cause pollution of soil or controlled waters. Risks from this type of dangerous substance are considered in the Environmental Statement (see Section 7.6, Water and Sediment Quality).

Whilst ISO (International Standards Organisation) container tanks are the main means of transporting bulk liquids in containers, it is also possible that potentially dangerous substances contained in drums and other forms of packing can be transported in box type containers. Drums and other forms of packaging can become damaged and leak during container handling if appropriate care has not been used when loading the container. However, international conventions stipulate that standards of drum construction become more stringent in proportion to the degree of hazard presented by the given material. In addition, since volume of the dangerous substance is limited by the size of the drum or packaging, the risk is reduced significantly.

2.3 Potential Accident Scenarios

Loss of containment might occur as a result of a number of undesirable events. These are identified as:

- A cargo damaging accident during a crane lift;
- Loss of containment of contents due to leakage;
- Vehicle Collision within the port area;
- Vehicle fires within the port area; and
- Fire on a ship at the berth.

The chance of occurrence of the events described is examined in detail below.

2.3.1 Cargo damaging accident during a crane lift

Based on information derived from a number of ports during the ACDS study, a cargo damaging accident rate of 2×10^{-6} per crane lift was identified. The ACDS study included a number of older ports with cranes that are of a lower level of safety and operational technology than the cranes that will be installed at Bathside Bay. Based on an examination of the incident rate at Felixstowe, carried out by MBTB Ltd (MBTB, 2001), 11 cargo damaging lift incidents occurred in 8,297,000 lifts, over a period of about 5 years. This equates to a chance of an incident of 1.3×10^{-6} per lift. Within this assessment, the Felixstowe accident rate has been used since it is considered most representative of the type and age of cranes that will be used at Bathside Bay, which will be new and constructed to the latest safety standards. In the main, these incidents occurred due to failure of the container rather than the crane.

Owing to the rarity of the event, there is a distinct lack of information on effects of impacts upon ISO tank containers, both in terms of impacts during transport or the container being dropped. In the event of a tank container being dropped or falling over, the most likely scenario is that the tank frame would take the main impact.

Discussions with the HSE and Lloyds Register (*pers. comm*. 27 March 2003) confirmed that the number of incidents where a breach of containment has occurred is extremely low. A conservative estimate, based on professional opinion was 1 in 100 (1×10^{-2}). The standard of tank construction employed for the transport of dangerous goods also has to meet agreed international standards – the greater the hazard the higher the standard of construction.

At Felixstowe, in 2002, approximately 950 ISO tank containers per year that contain bromine and tetraethyl lead were handled. It has been assumed that each container is subjected to three lifts from entering the port to then being placed on the vessel, or *vice versa*.

Based on the accident rates and number of containers handled the chance of a release is estimated as the product of the following:

Number of lifts per year	Cargo damaging Accident Rate	Probability of breach of containment	Chance of release
950 x 3	1.3×10^{-6}	1×10^{-2}	3.21×10^{-5}

Risk mitigation

Risk mitigation measures to be adopted will include the following:

- Use of rail mounted non-slewing gantry cranes;
- Four separate hoist ropes;
- Planned maintenance of plant in accordance with written procedures; and
- Use of inspected and certificated containers.

By adoption of these measures it is considered that risks associated with crane lifts have been reduced to a level that is as low as reasonably practicable (ALARP).

2.3.2 Loss of containment of contents due to leakage

Loss of containment from an ISO tank container is expected to have a similar level of risk as that posed by a storage tank at atmospheric pressure. The expected failure rate of such tanks is given in the Dutch Guidelines for Quantitative Risk Assessment CPR 18E (1999) at 5×10^{-6} per year for a complete instantaneous failure and 1×10^{-4} for a leak of 10mm diameter. This assumes that a single tank is present at a location for one year. In the case of 950 tanks, with an average residence time on site of one week (i.e. approximately 10 ‘tank years’), each of these failure rates would need to have a factor of 10 applied to them. The failure rate and tank construction adopted reflects the requirements for the storage of potentially dangerous materials.

Risk mitigation

To mitigate the risk of leakage and provide spill containment it is best practice to keep portable containment tanks (bunds) at operational ports that handle potentially dangerous cargoes. The Port of Felixstowe has portable bunds. These can be rapidly brought to the site of a leaking container and the container placed within the containment tank. The containment tank will be designed to accept the full quantity of an ISO tank and accommodate the container frame.

2.3.3 Vehicle Collision within the port area

ACDS has derived a collision rate in respect of cargo damaging crash/collisions of 10^{-7} per kilometre of vehicle distance travelled. This compares reasonably well with current Department for Transport statistics (1998) for road vehicle fatal accidents involving HGV's of 1.9×10^{-8} per vehicle km^{-1} travelled. A breach of containment in the event of an accident is assumed to occur on a probability of 1×10^{-2}. Based on a distance travelled from the port entrance and the berth or container storage area of 2km, then the chance of an accident involving a release of container contents is calculated as:

Number of journeys	Length of route	Accident rate per vehicle km^{-1}	Probability of a breach of containment	Chance of release per year
950	2	10^{-7}	10^{-2}	1.9×10^{-6}

Risk mitigation

Risk mitigation with respect to vehicle collisions includes the statutory speed limit within the port of 20 mph, road and operating area illumination at night and observation of activities by video security cameras.

2.3.4 Vehicle fires within the port area

Based on the ACDS report, a derived rate for cargo damaging lorry fires is 2×10^{-9} per vehicle km^{-1}; which in turn was derived from Home Office data on generic lorry fires.

A vehicle fire, if it was uncontrolled, could cause overheating and evaporation of the cargo and relief via overpressure protection devices. In this case it is estimated that a significant loss of containment would occur in 1 in 10 cases of fire. The reasons for this assumption are provided in the mitigation measures listed below.

Based on the journey duration and other factors the chance of occurrence is assessed as:

Number of journeys	Length of route	Accident rate per vehicle km^{-1}	Probability of a breach of containment	Chance of release per year
950	2	2×10^{-9}	10	3.8×10^{-7}

Risk mitigation

Most vehicle fires tend to develop slowly and, given that there will be firefighting facilities within the Bathside Bay development, it is expected that a vehicle fire could be brought under control in the majority of cases before the load is engulfed by fire. Under these conditions, the risk of an uncontrolled vehicle fire within the port is likely to be considerably less than a fire which might occur in a town centre, car park or motorway service area, where the fire service is likely to be some distance away.

2.3.5 Fire on a ship at the berth

In addition to the risk of vehicle fires, there is also the possibility of fire breaking out on board a vessel at the berth. The likely consequences might be a fire being transferred to the cargo. This risk was recognised in the ACDS study, which derived a cargo damaging fire rate of 2×10^{-8} per container ship arrival in port. This rate was based on records kept by the Marine Accident Investigation Branch of the Department of Transport and the fire statistics Unit of the Home Office. The ACDS study considered that this risk could be divided equally between the berth and the port navigation channel.

For a total of 950 containers per year, the chance of occurrence of a cargo damaging accident fire is assessed as:

Number shipments per year	Cargo damaging Accident Rate	Chance of release
950	1×10^{-8}	9.5×10^{-6}

Risk mitigation

The risks arising from fire on a ship will be mitigated by the ready availability of fire and accident response teams and, in addition, vessel fire fighting equipment. A fire is also unlikely to accelerate rapidly, thereby providing time for emergency response and monitoring the situation.

2.4 Summary of Chances of Release

The chances of release from each scenario are compared below:

Release Scenario	**Chance of release per year**
Cargo damaging accident during a crane lift	3.21×10^{-5}
Loss of containment – major failure	5×10^{-5}
Loss of containment – minor leakage	1×10^{-3}
Vehicle collision within the port area	1.9×10^{-6}
Vehicle fire within port area	3.8×10^{-7}
Vessel fire at the berth	9.5×10^{-6}

The total risk for events that might result in major releases is 9.5×10^{-5}. In practical terms this is equivalent to a major release every 10,500 years.

Therefore, with the exception of a minor leak, the chance of a release is considered to be extremely low. However, these release scenarios cannot be considered in isolation and need to be judged against the possible consequences should a loss of containment occur. This is addressed in the next section.

3 CONSEQUENCES OF A MAJOR ACCIDENT EVENT

The worst case accident scenario that has been identified is loss of containment with respect to a tank containing bromine, the escape of bromine liquid into a pool and evaporation to form a toxic vapour cloud. The gas cloud would then be carried downwind and has the potential to cause harm to those downwind of the release.

Bromine is extremely toxic and its effects have been reasonably well defined. It has been reported (NIOSH) that concentrations of 10 ppm (70 mg/m^3) or above cause such severe upper respiratory irritations that the concentrations will not be tolerated voluntarily, and even brief exposures of 40 to 60 ppm (280 to 420 mg/m^3) are dangerous for humans.

The criteria employed in the risk assessment are the Immediately Dangerous to Life or Health Concentration (IDLH) as defined by NIOSH (US National Institute of Occupational Safety & Health). Whilst NIOSH previously used an IDLH of 10 ppm, a revised IDLH of 3 ppm is now used in the US when assessing potentially toxic releases of bromine; such a concentration is a conservative value where emergency action and evacuation would be appropriate action.

A further method of assessment, that illustrates the conservative (precautionary) approach of NIOSH is the Dutch methodology, which identifies a concentration of 342mg/m^3 as the concentration that is likely to result in 1% fatality of those exposed to the passage of a toxic vapour cloud.

3.1 Assessment of a Loss of Containment from a Bromine Container

Significant advances have been made on the predictive methods that are employed to assess major pollution events. These methods employ computer dispersion models, which will predict the likely downwind concentrations of vapour clouds based on the physical properties of the dangerous substances involved, meteorological conditions, leakage rate and other factors.

There are two approaches that can be arguably taken when assessing releases of the type postulated, the first being a conservative approach, at which considerable distress to the local population might occur, justifying emergency action and possible evacuation. The second approach is to consider the case where potentially lethal concentrations downwind of a plume may result.

In the conservative case, where emergency response would be needed, the model used here is part of the computer-aided management of emergencies (CAMEO) suite of software programs. CAMEO includes a set of databases, or modules, a toxic gas dispersion model (‘plume model’) ALOHA (Area Locations of Hazardous Atmospheres) and a graphical facility that will plot plumes. CAMEO and ALOHA are used by the US Environmental Protection Agency's Chemical Emergency Preparedness and Prevention Office (EPA CEPPO) and the National Oceanic and Atmospheric Administration's Office of Response and Restoration (NOAA OR&R).

In the second case, an assessment was made using the Dutch TNO Effects 4.0 model, in combination with the methodology outlined in CPR 18E (1999). This model calculates the effect distance from the source, where the concentration of toxic gas falls to a level that might be expected to result in fatality to 1% of those exposed.

To simulate the release of bromine from a tank container, two scenarios were assessed, these were:

- a small 10mm hole in the tank near the base; and
- a puncture or major loss of containment of 150mm diameter.

3.1.1 Scenario 1 – Small 10mm hole in the tank base area

This scenario, derived from the Dutch CPR 18E guidance, assumes loss of containment via a small leak of 10mm nominal diameter. Also, based on the assessment of chance of occurrence in section 2, it has the highest chance of occurrence, namely 1 x 10^{-3} per year.

The leakage scenario was assessed using the ALOHA model described above.

The ALOHA model was run with the following data input:

Tank contents	-	20 tonnes
Leak location	-	0.1 m from base
Ground conditions	-	concrete or similar hardstanding
Ground temperature	-	ambient
Ambient temperature	-	18degC
Contents temperature	-	ambient
Atmospheric Stability class	-	Class D
Wind speed (at 10m)	-	5 m/sec
Terrain	-	Urban

Full details of the model output are provided in Appendix I.

Based on the input detailed above, and an IDLH at 3ppm, ALOHA predicted that concentrations would exceed the IDLH for a distance of 200m from the pool formed by the leak. The plume width is approximately 100m wide, the core being 40m wide. There is an area of uncertainty either side of the plume, where concentrations within the IDLH criteria may be experienced due to meandering of the wind, this extends to approximately 50m from the plume centreline.

Based on the predicted distances, unless an incident took place very close to the boundary, it is highly unlikely that the plume would exceed the IDLH off the Bathside Bay site.

In this case, no examination was undertaken using the Dutch methodology since the effects are likely to be localised within the boundaries of the Bathside Bay site.

3.1.2 Scenario 2 – Puncture or major loss of containment

In this scenario, it is assumed that a rapid failure occurs, represented by a 150mm hole in the container 100mm from the base, the liquid forms a pool and evaporation of the bromine liquid forms a plume.

Based on the same model input data as Section 3.1.1, ALOHA predicted a plume footprint in excess of the IDLH extending 3100m from the pool and a plume width of approximating to 600m. There is an area of uncertainty either side of the plume, where concentrations within the IDLH criteria may be experienced due to meandering of the wind; this extends to approximately 45 degrees either side from the plume centreline. The average angle formed by the plume is approximately 15 degrees over the first 1500m. At a wind velocity of 10m/sec the plume footprint reduces to approximately 1600m by 200m.

Thus it is likely that a major loss of containment would result in a potentially harmful toxic plume that could pass outside the boundaries of the site.

As a further assessment, a calculation of the likely effects was also performed using the TNO Effects 4.0 model. This defines the plume distance downwind from the vapour source where the concentration criteria falls to the point at which 1% fatality might be expected. In this case, the distances from the source at which this concentration might be expected to be exceeded are between 295m (wind velocity 10m/sec and neutral atmospheric stability) and 1054m (wind velocity 4m/sec and stable atmospheric conditions).

The likelihood of such an event occurring is extremely low. An assessment of the level of risk to the individual and practical comparisons with everyday risks are provided in Section 4.

3.2 Chance of Harm to Individuals Off-Site from a Major Release

The chance of harm to health to an individual at a specific point where the plume might ground is dependent on a number of factors, the most important being:

- the direction of the wind when the release takes place; and
- mitigating factors, such as whether the individual might be indoors or out of doors.

In the case of the wind direction, the plume width may be represented by the sector of a circle having an included angle of 15^o. In such a case, on the basis that wind direction varies, it is possible to approximate that an individual present in a single location for one year may be exposed for only 15/360ths of that year, or 4×10^{-2}. With respect to Harwich, which is generally to the south and east of the Bathside Bay site, the wind is predominantly from the west, south-west and south, as demonstrated by the wind-roses in Appendix II. Thus, the assumption that a person at a location in Harwich town has an expose factor of 4×10^{-2} is reasonably conservative.

Based on the statistical data, as apparent from the wind-roses, the communities of Shotley and Shotley Gate are statistically less likely to be affected than Harwich, due to their location. The area most likely to be affected would be Felixstowe, which lies downwind of the generally prevailing wind direction. However, the distance downwind, which is 3km to the port area and 4km to the start of residential areas, would mitigate the potentially adverse effects.

In reality, it is unlikely that a person would be present at any one location in the open air for 100% of the year. Allowing for periods at work or indoors, a risk reduction factor of 3 is reasonably conservative.

The overall consequence of the mitigation due to wind direction and indoor/outdoor location would be the product of these two factors, namely 1.33×10^{-2}.

The overall chance of an individual being affected at a specific location by exposure to the toxic cloud would be:

Chance of Occurrence of major loss of containment per year	Consequence mitigation factor	Overall risk of exposure to an individual per year
9.3×10^{-5}	1.33×10^{-2}	1.2×10^{-6}

This is very low level of risk, which would be mitigated further when distance is taken into account. As an illustration, under the worst case meteorology, based on an individual continuously present 1000m from the emission source, the likelihood of fatality is 1% of 1 in 100 (1×10^{-2}). Thus the individual risk at that point is the product of these two factors, namely 1.2×10^{-8}. At 500m the risk would increase by a factor of 50, namely 6×10^{-7}, which is 1 in 16 million. (Refer to Appendix I for TNO Effects 4.0 calculation output and fatality[1]/distance details).

This is an extremely low level of risk, which is compared to established risk criteria and practical examples in Section 4.

[1] Described as 'lethality' in Appendix I

4 GENERAL ACCEPTABILITY OF RISK

Risks to the workforce and public at large can be considered to fall into two categories, individual risk and societal risk. These concepts are described and discussed below.

4.1 Individual Risk

Individual Risk (IR) is defined as the likelihood in a year that a person who is continuously present at a particular location will die as a consequence of an accident caused by a dangerous substance occurring.

This area of risk is based on how individuals perceive and relate to risk from a particular hazard and how it may affect them and the things that they value personally. Although the individual may engage voluntarily in activities involving high risks, they are generally less tolerant of risks that are imposed on them unless the risks are negligible. For situations that may secure societal benefits, individuals may be willing to live with risks that are not negligible but such risks should be kept low and clearly controlled.

In the Netherlands the calculated individual risk must comply with the following guidelines:

- For new situations or activities in the Netherlands the maximum acceptable individual risk in critical areas (e.g. houses, schools, hospitals) is set at a probability of one fatality in one million per year (IR = 10^{-6}/year). New situations are defined as:
  - Setting up a new establishment;
  - Changing or expanding an existing situation.
- For existing activities in the Netherlands the maximum acceptable individual risk at critical areas (e.g. buildings) is set at a probability of one fatality in one hundred thousand per year (IR = 10^{-5}/year).

In the UK, acceptable levels of individual risk can vary between 10^{-4}/year to 10^{-6}/year depending on application of the ALARP (as low as reasonably practicable, i.e. cost benefit analysis)

4.2 Societal Risk

Societal concerns relate to risks or threats that, if there is an adverse outcome, could trigger major socio-political issues. Such concerns relate to situations where multiple fatalities might occur in a single event. Examples are nuclear power stations, sea ferries and railway travel.

The societal risk is defined as the likelihood per year that more than a certain number of fatalities will occur outside the specific site to which the QRA is being applied as a consequence of an accident with dangerous substances at the site. The societal risk is normally presented as a FN curve where F represents the likelihood or frequency and N the number of fatalities.

Under the Dutch Guidelines (1999) the accepted norm for the societal risk is an incident resulting in 10 fatalities should not occur on a frequency of more than once in hundred thousand ($1x10^{-5}$) per year, and an incident with more than 100 fatalities may not occur more frequently than one in ten million ($1x10^{-7}$) per year.

By comparison, in the HSE publication *Reducing Risks, Protecting People* (R2P2) (page 46, paragraph 136) the HSE proposes "that the risk of accident causing the death of 50 people or more in a single event should be regarded as intolerable if the frequency is estimated at more than one in five thousand per annum". (This includes on-site personnel and the off-site population). However, R2P2 introduces the concept of ALARP, which applies cost/benefit assessment to the risk. If it can be demonstrated that the cost of risk mitigation is viable to improve the level of risk then the level of tolerability can be reduced further.

Typical rates of individual risk are provided in Table 4.1, which allows comparison of levels of tolerable risk in the UK and Holland with respect to everyday and occupational risks, as well as chance events.

Table 4.1 Comparison of individual risk of death per person per year for typical everyday activities

Cause of Death / Industry Sector	**Frequency (as 1 in 'X')**	**Frequency (as $1x10^x$)**
Death from smoking 20 cigarettes/day	1 in 200	$5x10^{-3}$
Deaths from regular recreational rock climbing	1 in 250	$4x10^{-3}$
The HSE lower level of tolerable risk to workers	1 in 1,000	$1x10^{-3}$
Drinking 1 bottle of wine/day Death in pregnancy (as proportion of births) Deaths in mining and quarrying of energy related materials	1 in 1300 1 in 8200 1 in 9,200	$7.5x10^{-4}$
The HSE lower level of tolerable risk to population at large	1 in 10,000	$1x10^{-4}$
Death in off-shore oil & gas industry Death from all forms of road accident Deaths - Working in the construction industry (UK) Death from lung cancer caused by radon in dwellings Death – Manufacture of basic metals and fabrication of metals Death – Manufacturing industry	1 in 14,564 1 in 16,800 1 in 17,000 1 in 29,000 1 in 34,000 1 in 77,000	
Dutch criteria for minimum individual risk in existing establishments	1 in 100,000	$1x10^{-5}$
Death by murder in UK	1 in 100,000	$1x10^{-5}$
Deaths in the "service industries"	1 in 333,000	
Death – Manufacture of electrical and optical equipment	1 in 500,000	
Dutch criteria for 10 fatality incident The UK HSE "Broadly Acceptable" level of risk Risk of electrocution in the home	1 in 1,000,000	$1x10^{-6}$
Death - Gas incident (fire, explosion or carbon monoxide poisoning)	1 in 1,510,000	
Dutch Criteria for 100 fatality incident	1 in 10,000,000	$1x10^{-7}$
Winning 6 numbers in the National Lottery **Risk at 500m from death by toxic cloud at Bathside Bay** Being struck by lightning (England & Wales 1995-99)	1 in 14,000,000 1 in 16,000,000 1 in 18,700,000	
	1 in 100,000,000	$1x10^{-8}$

* Source – HSE Reducing Risks, Protecting People (2001)

4.3 Individual Risk at Bathside Bay

From Section 3, the chance of death to an individual 500m downwind from a major release of bromine at Bathside Bay was assessed at 6 x 10^{-7} per year. This is considered to be 'broadly acceptable' based on the level of risk quoted by the HSE in R2P2 (2001). It is also well within general conformance criteria under the Dutch guidelines on risk.

This is considered to be a somewhat conservative (precautionary) estimate; it is appropriate to compare this with the findings of the ACDM on the transportation of chlorine by road transport. Chlorine is arguably a greater hazard, since it is carried as a pressurised liquid in road tankers, can vaporise rapidly and is slightly more toxic than bromine.

The ACDM report considered several aspects of risk concerning the transportation and handling of chlorine. The following risk factors were arrived relating to vehicle parking and potential loss of containment, giving rise to leaks:

- The individual risk from chlorine from a parked road tank vehicle at a 50m distance is about 1 in 1 million/yr (1 x 10^{-6}) of receiving a dangerous dose (ACDS para122);

- Similarly, the risk in a rail marshalling yard from the temporary presence of chlorine is given as 5 in 10 million (5 x 10^{-7}) at 180m.

This level of individual risk was considered to be acceptable within the ACDM report and also compares favourably with the risk criteria outlined in Table 4.1

4.4 Societal Risk at Bathside Bay

Based on the level of societal risk from chlorine that arises from the transport of chlorine, as assessed by the ACDS, and given the potentially greater hazard inherent with a large tank of chlorine compared to an ISO tank containing bromine, it would be reasonable to infer that the level of societal risk will be lower with bromine.

The general view of HSE was that the level of societal risk for the transport and handling of liquid chlorine fell within acceptable levels.

5 CONCLUSIONS

Based on an assessment of the cargo containers currently handled by the Port of Felixstowe, and assuming a similar mix of trade at Bathside Bay, the most hazardous substances that are likely to be handled in bulk tanks are bromine and tetra-ethyl lead. Of these, bromine is considered to present the greatest hazard as far as off-site risk is concerned.

The most undesirable event would be a rapid major failure, or the loss of containment from a bromine tank, followed by the formation of a large pool of the liquid which would evaporate and form a plume that could travel off-site.

Based on the risk analysis carried out, the chance of an event such as total loss of containment, is extremely low. Furthermore, mitigation measures can be applied which demonstrate that the risk to those living near to site would be acceptable.

In real terms, the risk to the individual is well within the level that would be considered to be tolerable under HSE guidelines, in fact, the risk is what might be described as ‘broadly acceptable’. In practical terms, the level of risk is equivalent to being struck by lightning and slightly less than the chance of winning 6 numbers in the national lottery.

The HSE has examined the individual and societal risks arising from the transport of arguably more hazardous substances, including chlorine and ammonia. A similar conclusion on the acceptability of the risk from these substances, namely chlorine, was reached by the HSE.

6 REFERENCES

Advisory Committee on Dangerous Substances (ACDS), *Major hazard aspects of the transport of dangerous substances*. HMSO, 1991, ISBN 0 11 885676 6.

CPR 18E (1999), *Guidelines for Quantitative Risk Assessment*, for the Dutch Committee for the Prevention of Disasters by Dangerous Materials, 1999.

HSE (2001), *Reducing Risks, Protecting People* (R2P2).

MTBT (2001), HSE Application Report for a special explosives licence for Berths 1, 2 & 3 Trinity Terminal, Port of Felixstowe, December 2001.

NIOSH Documentation for Immediately Dangerous to Life or Health Concentrations (ILDH).

UK Department for Transport (DfT) statistics (1998)

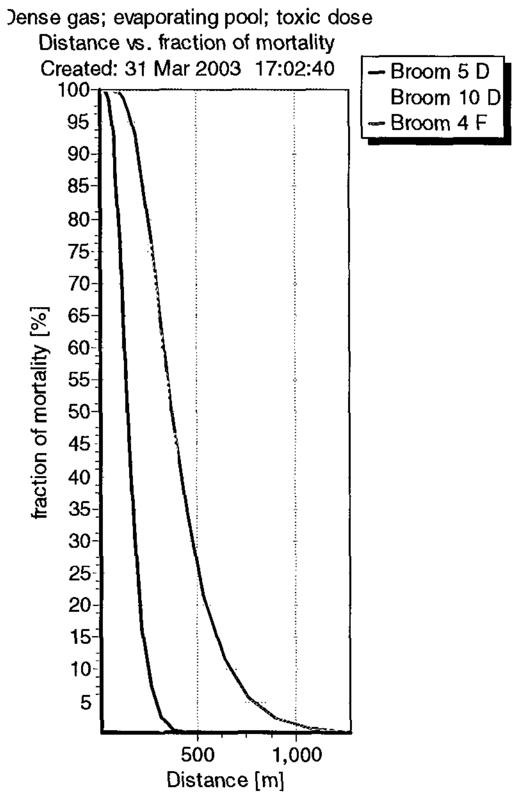
Appendix I

Effects 4.0 Calculation Output

ALOHA Calculation Output

Results from calculation with EFFECTS 4.0

1.1 Graph for three types of weather



1.2 Calulation data

```
---------------------- START OF SESSION 1 MODEL 1 (SCENARIO CALCULATION) ---------------------
--------
INPUT

Case description  .... ...... ..  .... ... .... ...........  : Broom 5 D
Chemical name.... ....  . ..  ...... . .... ..... .. .. .. : Bromine
Total mass released..  ... ... .. ... . ... . .....  ... . : 20000 kg
Temperature of the pool..  ... .....  .. ... ..  . ...     : 15 °C
Fixed pool surface ..... .. ......  . .   . ....  ......... : 323 m2
Type of subsoil. ... . ........  .. ....  ..  ............. : heavy concrete
Roughness subsoil........ ... .....  ...... ........  .. .. : 0.01 m
Temperature subsoil..   .. .  ... ...  ... .........  .. .. : 15 °C
Ambient temperature . ....  .. .. ..  .. ....... .  ... .. : 15 °C
Wind speed at 10 m height.  .. ... ....    . ..  ....  ..  : 5 m/s
Pasquill stability class.. .... ... . ..  ...  ....  ..... . : D (Neutral)
Time t after start release... . ..  .. ....  ............. : 600 s


RESULTS

Evaporation rate at time t. ......... .   ...  ... .....   : 2 16 kg/s
Temperature of liquid at time t  .. ...... . ........... .. : -4.78 °C
Initial liquid height   .... ... ... . .......  ........... : 20 mm
Average evaporation rate.  .  .  ..... ... . ..... ... ..... : 2.007 kg/s
  ..Based upon time  ..  ....   .. .. ... .... ... ...  .. . : 7200 s
Average pool temperature .... ........  .. .... .. .   ..  : 5.5444 °C
Maximum evaporation rate..  ...... .. ..  ...  ....  ....   : 5 421 kg/s
Total mass evaporated.........  .  ....... .  .. . ..... .. : 19232 kg


Administrative & version data:
------------------------------
```

Model name : Evaporation from land; non-boiling liquid fixed pool size
Date calculated : 31 Mar 2003 17:01:51
Driver version(s) : 3.05 (11 Apr 2000)
Executable version(s) : External MODEL_8.EXE 07 Mar 1998 18:26:30
Software library version : 4.0.0.0097
Project file name : Standard project.eff40
Project directory : C:\Program Files\TNO Industrial Safety\Effects 4.0
Database file used : PaarseBoekProbitsTNO.rdb (14 Nov 2002 11:38:08)
Database was located in : C:\Program Files\TNO Industrial Safety\Effects 4.0\Databases

Results array 1
Evaporation rate vs. time
Modified : 31 Mar 2003 17:01:51
Coordinate : (0.0,0.0)

Time [s]	Evaporation rate [kg/s]
0	5.421
0.1	5.418
0.4	5.41
1	5.394
2.2	5.363
4.6	5.304
9.3	5.189
18.8	4.999
37.8	4.647
75.8	4.135
151.7	3.429
303.5	2.735
607.2	2.153
1214.6	1.899
2429.3	1.899
4858.8	1.899
9717.8	1.899
9717.8	1.899

Results array 2
Evaporated mass vs. time
Modified : 31 Mar 2003 17:01:51
Coordinate : (0.0,0.0)

Time [s]	Evaporated mass [kg]
0.1	0.54195
0.4	2.1662
1	5.4074
2.2	11.862
4.6	24.662
9.3	49.321
18.8	97.714
37.8	189.35
75.8	356.21
151.7	643.26
303.5	1111.1
607.2	1853.4
1214.6	3083.9
2429.3	5390.7
4858.8	10004
9717.8	19232
9717.8	19232

---------------------- END OF SESSION 1 MODEL 1 (SCENARIO CALCULATION) -----------------------------

---------------------- START OF SESSION 1 MODEL 2 (SCENARIO CALCULATION) -----------------------------
INPUT

Case description.. : Broom 5 D (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Case description" [SessionDescription]) Reason: Identical identifier
Chemical name.. : Bromine (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Chemical name" [ChemicalName]) Reason: Identical identifier
Mass flow rate of the source.............................. : 2.007 kg/s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Average evaporation rate" [AverageEvaporationRate]) Reason: Exchange command
Duration of the release.................................. : 7200 s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "...Based upon time" [SpecialTimeToCalculateAverage]) Reason: Exchange command

Fixed pool surface.. : 323 m2 (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Fixed pool surface" [PoolSurface]) Reason: Identical identifier
Temperature after release................................. : 58.75 °C (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Temperature of the pool" [PoolTemperature]) Reason: Exchange command
Wind speed at 10 m height................................. : 5 m/s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Wind speed at 10 m height" [WindSpeedAt10m]) Reason: Identical identifier
Pasquill stability class.................................. : D (Neutral) (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Pasquill stability class" [PasquillStabilityClass]) Reason: Identical identifier
Ambient temperature....................................... : 15 °C (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Ambient temperature" [AmbientTemperature]) Reason: Identical identifier
Ambient relative humidity................................. : 70 %
Roughness length description.............................. : Habitated land
Concentration averaging time.............................. : 600 s
Distance from release (X)................................. : 1000 m
Distance perpendicular to wind direction (Y)................ : 0 m
Height (Z).. : 0 m
Fraction of mortality for distance calculation.............. : 1 %
Exposure duration... : 1800 s

RESULTS

Maximum concentration at X................................ : 78 mg/m3
Arrival time maximum concentration at X.................... : 1764 s
Arrival time cloud at X................................... : 228 s
Departure time cloud at X................................. : 2510 s
Dose at X, Y, Z... : 1.792E5 min*(mg/m3)^n
Maximum dose at X, Y, Z................................... : 2.894E9 min*(mg/m3)^n
Maximum distance to fraction of mortality.................. : 366 m
Maximum width to fraction of mortality..................... : 52 m
... at distance to the source.............................. : 187 m

Administrative & version data:

Model name : Dense gas; evaporating pool; toxic dose
Date calculated : 31 Mar 2003 17:02:18
Driver version(s) : 3.04 (11 Apr 2000)
Executable version(s) : External SLAB_RUN.EXE 01 Apr 1999 15:36:28
Software library version : 4.0.0.0097
Project file name : Standard project.eff40
Project directory : C:\Program Files\TNO Industrial Safety\Effects 4.0
Database file used : PaarseBoekProbitsTNO.rdb (14 Nov 2002 11:38:08)
Database was located in : C:\Program Files\TNO Industrial Safety\Effects 4.0\Databases

Results array 1
Distance vs. fraction of mortality
Modified : 31 Mar 2003 17:02:18
Coordinate : (0.0,0.0)

Distance [m]	fraction of mortality [%]
10	100
11.89	100
14.14	100
16.82	100
20	100
23.78	99.977
28.28	99.946
33.64	99.877
40	99.71
47.57	99.33
56.57	98.485
67.27	96.679
80	93.107
95.14	86.778
113.1	76.765
134.5	62.829
160	46.18
190.3	29.724
226.3	16.237
269.1	7.3374
320	2.6944

380.5	0.77721
452.5	0.17608

Results array 2
Toxic dose versus distance
Modified : 31 Mar 2003 17:02:18
Coordinate : (0.0,0.0)

Distance [m]	Toxic dose [s*(kg/m3)^n]
10	0.17364
11.89	0.15012
14.14	0.12774
16.82	0.10722
20	0.08802
23.78	0.07146
28.28	0.056724
33.64	0.044646
40	0.03414
47.57	0.025638
56.57	0.018864
67.27	0.013554
80	0.009534
95.14	0.0066
113.1	0.0044916
134.5	0.0029994
160	0.0019644
190.3	0.0012696
226.3	0.0008076
269.1	0.00050658
320	0.00031452

---------------------- END OF SESSION 1 MODEL 2 (SCENARIO CALCULATION) ----------------------------

---------------------- START OF SESSION 2 MODEL 1 (SCENARIO CALCULATION) -----------------------------

INPUT

Case description.. : Broom 10 D
Chemical name... : Bromine
Total mass released....................................... : 20000 kg
Temperature of the pool................................... : 15 °C
Fixed pool surface.. : 323 m2
Type of subsoil... : heavy concrete
Roughness subsoil... : 0.01 m
Temperature subsoil....................................... : 15 °C
Ambient temperature....................................... : 15 °C
Wind speed at 10 m height................................. : 10 m/s
Pasquill stability class.................................. : D (Neutral)
Time t after start release................................ : 600 s

RESULTS

Evaporation rate at time t................................ : 3.26 kg/s
Temperature of liquid at time t........................... : -7.3 °C
Initial liquid height..................................... : 20 mm
Average evaporation rate.................................. : 3.3702 kg/s
...Based upon time.. : 5687.8 s
Average pool temperature.................................. : 5.3299 °C
Maximum evaporation rate.................................. : 9.295 kg/s
Total mass evaporated..................................... : 19169 kg

Administrative & version data:

Model name : Evaporation from land; non-boiling liquid fixed pool size
Date calculated : 31 Mar 2003 17:01:54
Driver version(s) : 3.05 (11 Apr 2000)
Executable version(s) : External MODEL_8.EXE 07 Mar 1998 18:26:30
Software library version : 4.0.0.0097
Project file name : Standard project.eff40
Project directory : C:\Program Files\TNO Industrial Safety\Effects 4.0
Database file used : PaarseBoekProbitsTNO.rdb (14 Nov 2002 11:38:08)
Database was located in : C:\Program Files\TNO Industrial Safety\Effects 4.0\Databases

Results array 1
Evaporation rate vs. time

Modified : 31 Mar 2003 17:01:54
Coordinate : (0.0,0.0)

Time [s]	Evaporation rate [kg/s]
0	9.295
0.1	9.288
0.3	9.275
0.6	9.248
1.3	9.195
2.7	9.092
5.5	8.896
11	8.541
22.1	7.952
44.3	7.007
88.8	5.726
177.7	4.424
355.4	3.384
710.9	3.256
1421.9	3.256
2843.8	3.256
5687.8	3.256
5687.8	3.256

Results array 2
Evaporated mass vs. time
Modified : 31 Mar 2003 17:01:54
Coordinate : (0.0,0.0)

Time [s]	Evaporated mass [kg]
0.1	0.92915
0.3	2.7854
0.6	5.5639
1.3	12.019
2.7	24.82
5.5	50.003
11	97.955
22.1	189.49
44.3	355.54
88.8	638.85
177.7	1090
355.4	1783.8
710.9	2964
1421.9	5279
2843.8	9908.7
5687.8	19169
5687.8	19169

---------------------- END OF SESSION 2 MODEL 1 (SCENARIO CALCULATION) ----------------------------

---------------------- START OF SESSION 2 MODEL 2 (SCENARIO CALCULATION) -----------------------------

INPUT

Case description.. : Broom 10 D (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Case description" [SessionDescription]) Reason: Identical identifier

Chemical name... : Bromine (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Chemical name" [ChemicalName]) Reason: Identical identifier

Mass flow rate of the source.............................. : 3.3702 kg/s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Average evaporation rate" [AverageEvaporationRate]) Reason: Exchange command

Duration of the release................................... : 5687.8 s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "...Based upon time" [SpecialTimeToCalculateAverage]) Reason: Exchange command

Fixed pool surface.. : 323 m2 (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Fixed pool surface" [PoolSurface]) Reason: Identical identifier

Temperature after release................................. : 58.75 °C (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Temperature of the pool" [PoolTemperature]) Reason: Exchange command

Wind speed at 10 m height................................. : 10 m/s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Wind speed at 10 m height" [WindSpeedAt10m]) Reason: Identical identifier

Pasquill stability class.................................. : D (Neutral) (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Pasquill stability class" [PasquillStabilityClass]) Reason: Identical identifier

```
Ambient temperature........................................ : 15 °C            (copied from
model "Evaporation from land; non-boiling liquid fixed pool size" field "Ambient temperature"
[AmbientTemperature]) Reason: Identical identifier
Ambient relative humidity.................................. : 70 %
Roughness length description............................... : Habitated land
Concentration averaging time............................... : 600 s
Distance from release (X).................................. : 1000 m
Distance perpendicular to wind direction (Y)............... : 0 m
Height (Z)................................................. : 0 m
Fraction of mortality for distance calculation............. : 1 %
Exposure duration.......................................... : 1800 s


RESULTS

Maximum concentration at X................................. : 70 mg/m3
Arrival time maximum concentration at X.................... : 520 s
Arrival time cloud at X.................................... : 111 s
Departure time cloud at X.................................. : 1240 s
Dose at X, Y, Z............................................ : 89360 min*(mg/m3)^n
Maximum dose at X, Y, Z.................................... : 1.345E9 min*(mg/m3)^n
Maximum distance to fraction of mortality.................. : 295 m
Maximum width to fraction of mortality..................... : 40 m
... at distance to the source.............................. : 152 m


Administrative & version data:
------------------------------
Model name                : Dense gas; evaporating pool; toxic dose
Date calculated           : 31 Mar 2003  17:02:27
Driver version(s)         : 3.04 (11 Apr 2000)
Executable version(s)     : External SLAB_RUN.EXE 01 Apr 1999  15:36:28
Software library version : 4.0.0.0097
Project file name         : Standard project.eff40
Project directory         : C:\Program Files\TNO Industrial Safety\Effects 4.0
Database file used        : PaarseBoekProbitsTNO.rdb (14 Nov 2002  11:38:08)
Database was located in   : C:\Program Files\TNO Industrial Safety\Effects 4.0\Databases


Results array 1
Distance vs. fraction of mortality
Modified : 31 Mar 2003  17:02:27
Coordinate : (0.0,0.0)
Distance [m]  fraction of mortality [%]
         10               100
         11.89             99.975
         14.14             99.955
         16.82             99.917
         20                99.849
         23.78             99.716
         28.28             99.447
         33.64             98.942
         40                97.981
         47.57             96.227
         56.57             93.107
         67.27             87.881
         80                79.724
         95.14             68.405
        113.1              53.828
        134.5              38.201
        160                23.944
        190.3              12.743
        226.3               5.567
        269.1               1.9536
        320                 0.54656

Results array 2
Toxic dose versus distance
Modified : 31 Mar 2003  17:02:27
Coordinate : (0.0,0.0)
Distance [m]  Toxic dose [s*(kg/m3)^n]
         10                 0.0807
         11.89              0.07014
         14.14              0.059874
         16.82              0.050208
         20                 0.041976
         23.78              0.034356
```

28.28	0.027432
33.64	0.021672
40	0.016794
47.57	0.012792
56.57	0.009534
67.27	0.00696
80	0.0049674
95.14	0.0034908
113.1	0.0023802
134.5	0.0016014
160	0.001065
190.3	0.0006924
226.3	0.00043992
269.1	0.00027462

---------------------- END OF SESSION 2 MODEL 2 (SCENARIO CALCULATION) ----------------------------

---------------------- START OF SESSION 3 MODEL 1 (SCENARIO CALCULATION) -----------------------------

INPUT

Case description... : Broom 4 F
Chemical name.. : Bromine
Total mass released.. : 20000 kg
Temperature of the pool.................................... : 15 °C
Fixed pool surface... : 323 m2
Type of subsoil.. : heavy concrete
Roughness subsoil.. : 0.01 m
Temperature subsoil.. : 15 °C
Ambient temperature.. : 15 °C
Wind speed at 10 m height.................................. : 4 m/s
Pasquill stability class................................... : F (Very Stable)
Time t after start release................................. : 600 s

RESULTS

Evaporation rate at time t................................. : 1.97 kg/s
Temperature of liquid at time t............................ : -3.13 °C
Initial liquid height...................................... : 20 mm
Average evaporation rate................................... : 1.7096 kg/s
...Based upon time... : 7200 s
Average pool temperature................................... : 5.6167 °C
Maximum evaporation rate................................... : 4.558 kg/s
Total mass evaporated...................................... : 19253 kg

Administrative & version data:

Model name   : Evaporation from land; non-boiling liquid fixed pool size
Date calculated   : 31 Mar 2003 17:01:57
Driver version(s)   : 3.05 (11 Apr 2000)
Executable version(s)   : External MODEL_8.EXE 07 Mar 1998 18:26:30
Software library version : 4.0.0.0097
Project file name   : Standard project.eff40
Project directory   : C:\Program Files\TNO Industrial Safety\Effects 4.0
Database file used   : PaarseBoekProbitsTNO.rdb (14 Nov 2002 11:38:08)
Database was located in   : C:\Program Files\TNO Industrial Safety\Effects 4.0\Databases

Results array 1
Evaporation rate vs. time
Modified : 31 Mar 2003 17:01:57
Coordinate : (0.0,0.0)

Time [s]	Evaporation rate [kg/s]
0	4.558
0.2	4.554
0.5	4.548
1.2	4.535
2.6	4.509
5.5	4.458
11.1	4.364
22.4	4.206
44.9	3.924
90.1	3.491
180.3	2.928
360.8	2.325

721.7	1.858
1443.7	1.596
2887.5	1.596
5775.2	1.596
11551	1.596
11551	1.596

Results array 2
Evaporated mass vs. time
Modified : 31 Mar 2003 17:01:57
Coordinate : (0.0,0.0)

Time [s]	Evaporated mass [kg]
0.2	0.9112
0.5	2.2765
1.2	5.4555
2.6	11.786
5.5	24.788
11.1	49.49
22.4	97.911
44.9	189.37
90.1	356.95
180.3	646.45
360.8	1120.5
721.7	1875.4
1443.7	3122.2
2887.5	5426.6
5775.2	10035
11551	19253
11551	19253

---------------------- END OF SESSION 3 MODEL 1 (SCENARIO CALCULATION) ----------------------------

---------------------- START OF SESSION 3 MODEL 2 (SCENARIO CALCULATION) -----------------------------

INPUT

Case description.. : Broom 4 F (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Case description" [SessionDescription]) Reason: Identical identifier
Chemical name... : Bromine (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Chemical name" [ChemicalName]) Reason: Identical identifier
Mass flow rate of the source.............................. : 1.7096 kg/s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Average evaporation rate" [AverageEvaporationRate]) Reason: Exchange command
Duration of the release................................... : 7200 s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "...Based upon time" [SpecialTimeToCalculateAverage]) Reason: Exchange command
Fixed pool surface.. : 323 m2 (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Fixed pool surface" [PoolSurface]) Reason: Identical identifier
Temperature after release................................. : 58.75 °C (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Temperature of the pool" [PoolTemperature]) Reason: Exchange command
Wind speed at 10 m height................................. : 4 m/s (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Wind speed at 10 m height" [WindSpeedAt10m]) Reason: Identical identifier
Pasquill stability class.................................. : F (Very Stable) (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Pasquill stability class" [PasquillStabilityClass]) Reason: Identical identifier
Ambient temperature....................................... : 15 °C (copied from model "Evaporation from land; non-boiling liquid fixed pool size" field "Ambient temperature" [AmbientTemperature]) Reason: Identical identifier
Ambient relative humidity................................. : 70 %
Roughness length description.............................. : Habitated land
Concentration averaging time.............................. : 600 s
Distance from release (X)................................. : 1000 m
Distance perpendicular to wind direction (Y).............. : 0 m
Height (Z).. : 0 m
Fraction of mortality for distance calculation............ : 1 %
Exposure duration... : 1800 s

RESULTS

Maximum concentration at X................................ : 368 mg/m3
Arrival time maximum concentration at X................... : 1108 s

```
Arrival time cloud at X................................... : 566 s
Departure time cloud at X................................. : 4930 s
Dose at X, Y, Z........................................... : 4.032E6 min*(mg/m3)^n
Maximum dose at X, Y, Z................................... : 3.896E10 min*(mg/m3)^n
Maximum distance to fraction of mortality................. : 1054 m
Maximum width to fraction of mortality.................... : 126 m
... at distance to the source............................. : 378 m
```

Administrative & version data:

```
------------------------------
Model name                : Dense gas; evaporating pool; toxic dose
Date calculated           : 31 Mar 2003  17:02:39
Driver version(s)         : 3.04 (11 Apr 2000)
Executable version(s)     : External SLAB_RUN.EXE 01 Apr 1999  15:36:28
Software library version  : 4.0.0.0097
Project file name         : Standard project.eff40
Project directory         : C:\Program Files\TNO Industrial Safety\Effects 4.0
Database file used        : PaarseBoekProbitsTNO.rdb (14 Nov 2002  11:38:08)
Database was located in   : C:\Program Files\TNO Industrial Safety\Effects 4.0\Databases
```

Results array 1
Distance vs. fraction of mortality
Modified : 31 Mar 2003 17:02:39
Coordinate : (0.0,0.0)

Distance [m]	fraction of mortality [%]
10	100
11.89	100
14.14	100
16.82	100
20	100
23.78	100
28.28	100
33.64	100
40	100
47.57	100
56.57	100
67.27	100
80	99.956
95.14	99.849
113.1	99.533
134.5	98.719
160	96.887
190.3	93.205
226.3	86.837
269.1	77.104
320	63.978
380.5	49.133
452.5	34.405
538.2	21.648
640	11.967
761.1	5.7609
905.1	2.4065
1076	0.89486
1280	0.26601

Results array 2
Toxic dose versus distance
Modified : 31 Mar 2003 17:02:39
Coordinate : (0.0,0.0)

Distance [m]	Toxic dose [s*(kg/m3)^n]
10	2.3376
11.89	1.9554
14.14	1.5606
16.82	1.2258
20	0.9384
23.78	0.7002
28.28	0.50928
33.64	0.36348
40	0.25704
47.57	0.1791
56.57	0.12576
67.27	0.08754
80	0.06036
95.14	0.04197
113.1	0.029088

134.5	0.020148
160	0.01395
190.3	0.009606
226.3	0.006618
269.1	0.004542
320	0.0030924
380.5	0.0021156
452.5	0.0014472
538.2	0.000987
640	0.0006666
761.1	0.00044748
905.1	0.00029964

---------------------- END OF SESSION 3 MODEL 2 (SCENARIO CALCULATION) ----------------------
------

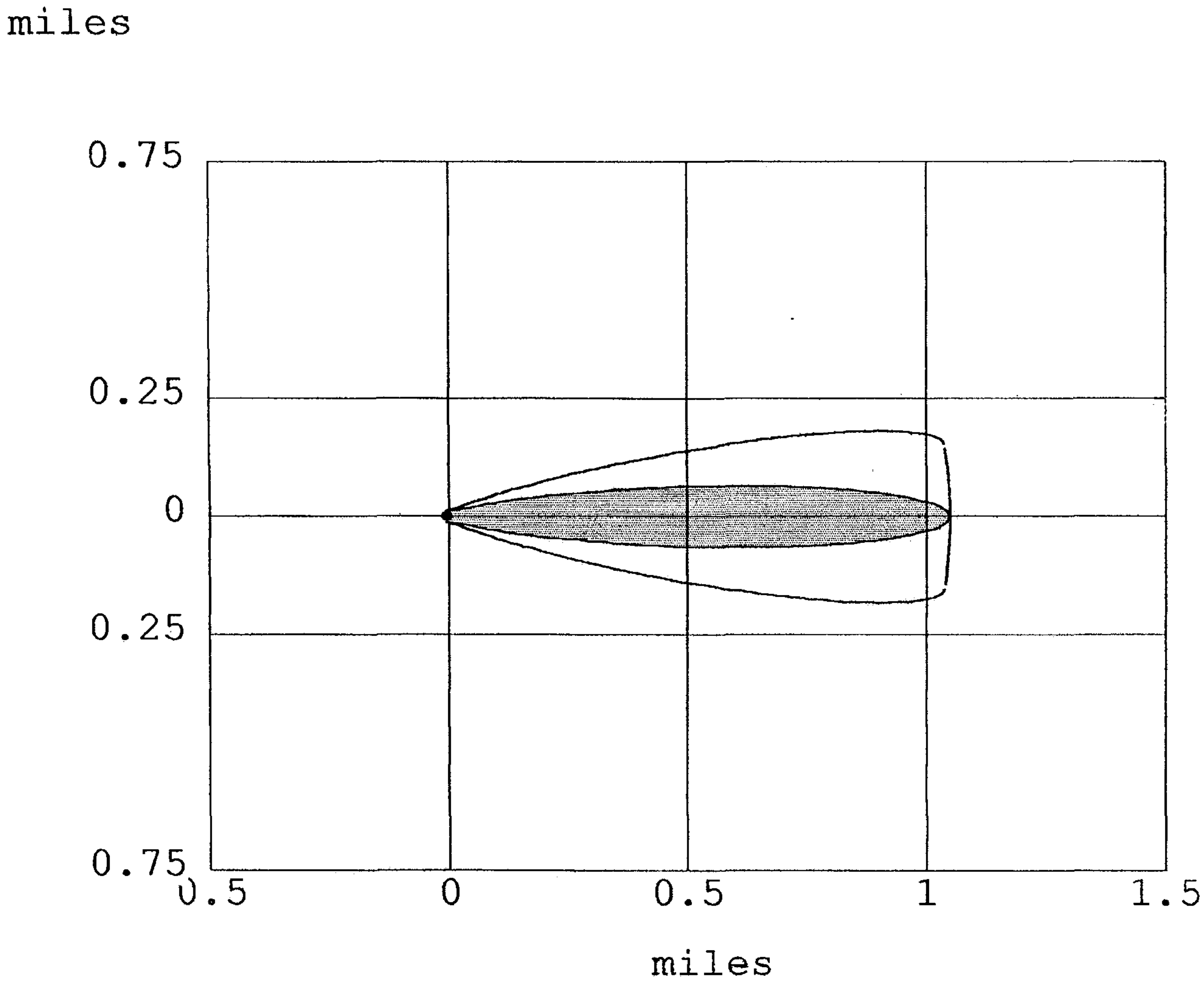
Footprint Window ALOHA® 5.2.3

Time: March 28, 2003 0847 hours ST (using computer's clock)

Chemical Name: BROMINE

Wind: 10 meters/sec from SW at 10 meters

FOOTPRINT INFORMATION:
  Dispersion Module: Gaussian
  User-specified LOC: equals IDLH (3 ppm)
  Max Threat Zone for LOC: 1.1 miles



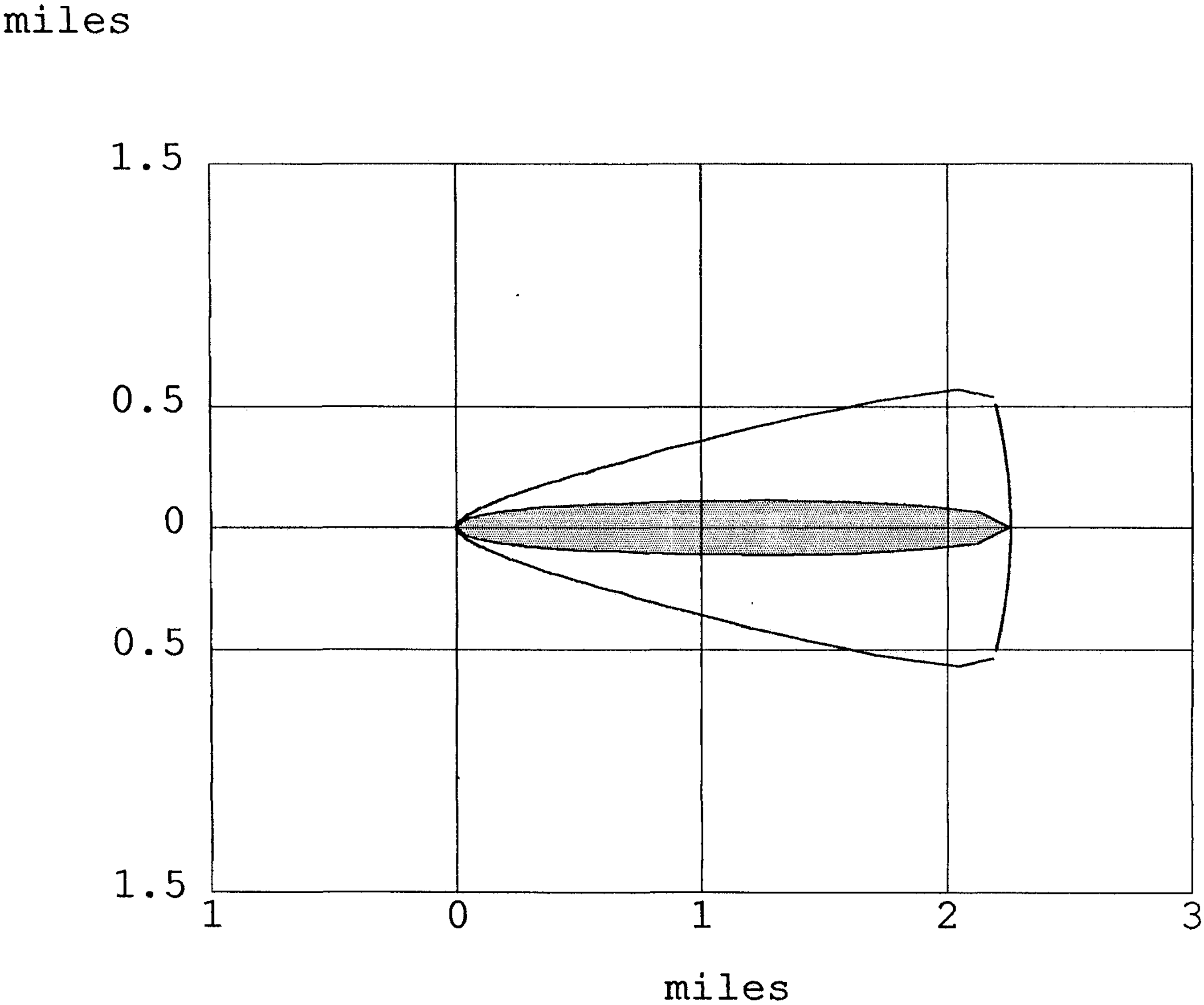
Footprint Window ALOHA® 5.2.3

Time: March 24, 2003 1452 hours ST (using computer's clock)

Chemical Name: BROMINE

Wind: 5 meters/sec from SW at 10 meters

FOOTPRINT INFORMATION:
Model Run: Heavy Gas
User-specified LOC: equals IDLH (3 ppm)
Max Threat Zone for LOC: 2.3 miles



Footprint Window

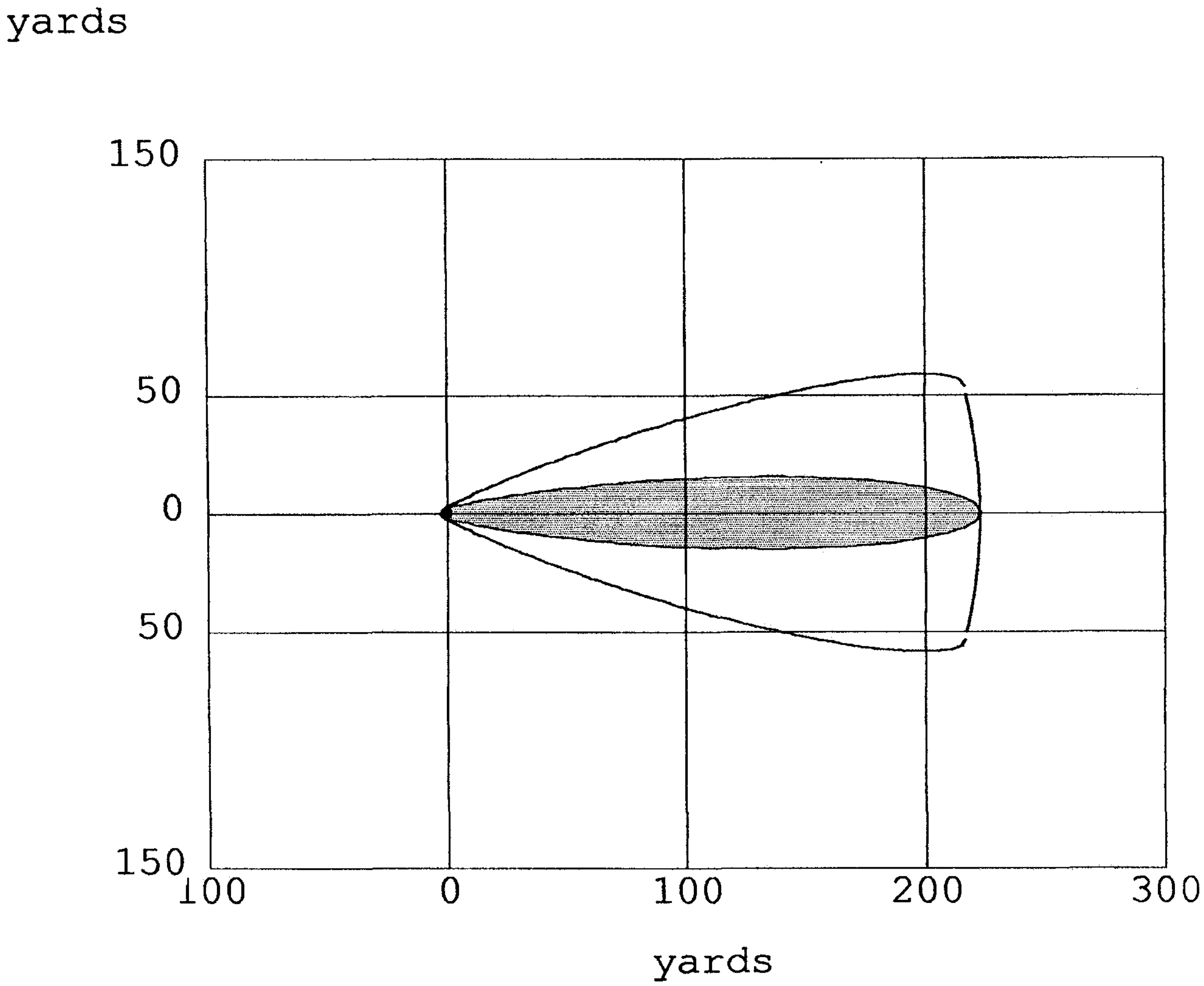
ALOHA® 5.2.3

Time: March 24, 2003 1452 hours ST (using computer's clock)

Chemical Name: BROMINE

Wind: 5 meters/sec from SW at 10 meters

FOOTPRINT INFORMATION:
  Dispersion Module: Gaussian
  User-specified LOC: equals IDLH (3 ppm)
  Max Threat Zone for LOC: 224 yards



Appendix II

Windroses for Bathside Bay Area

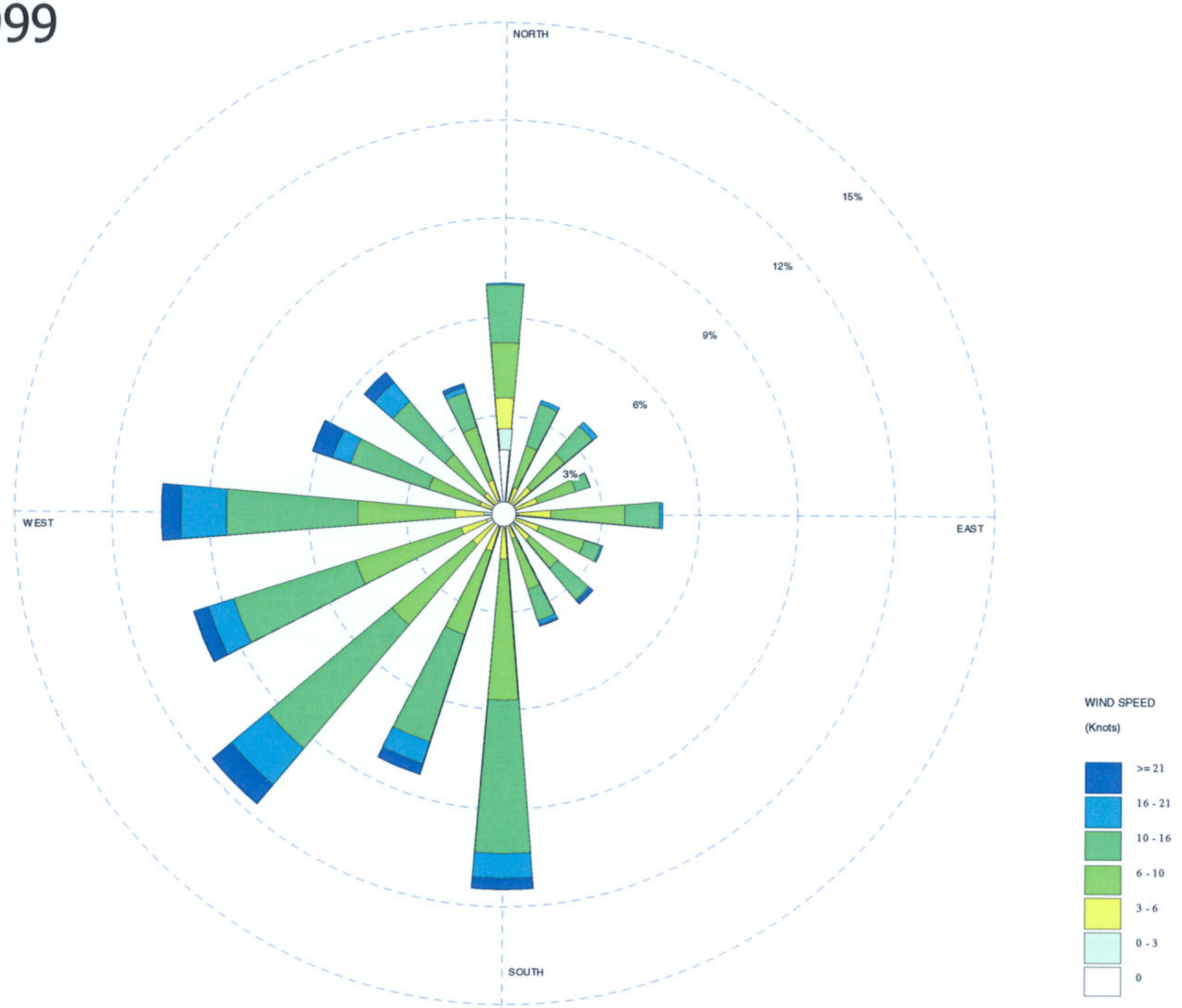
WIND ROSE PLOT:

Bathside Bay
Air Quality Assessment

DISPLAY:
Wind Speed
Direction (blowing from)

COMMENTS:
Wattisham
Windrose 1999

1999



DATA PERIOD:
1999
Jan 1 - Dec 31
00:00 - 23:00

TOTAL COUNT:	CALM WINDS:
8760 hrs.	**0.00%**

AVG. WIND SPEED:
9.82 Knots

COMPANY NAME:
Posford Haskoning

MODELER:
Jamie Ellis

DATE:
11/11/02

ROYAL HASKONING
POSFORD HASKONING

PROJECT NO.:
M1274

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Bathside Bay
Air Quality Assessment

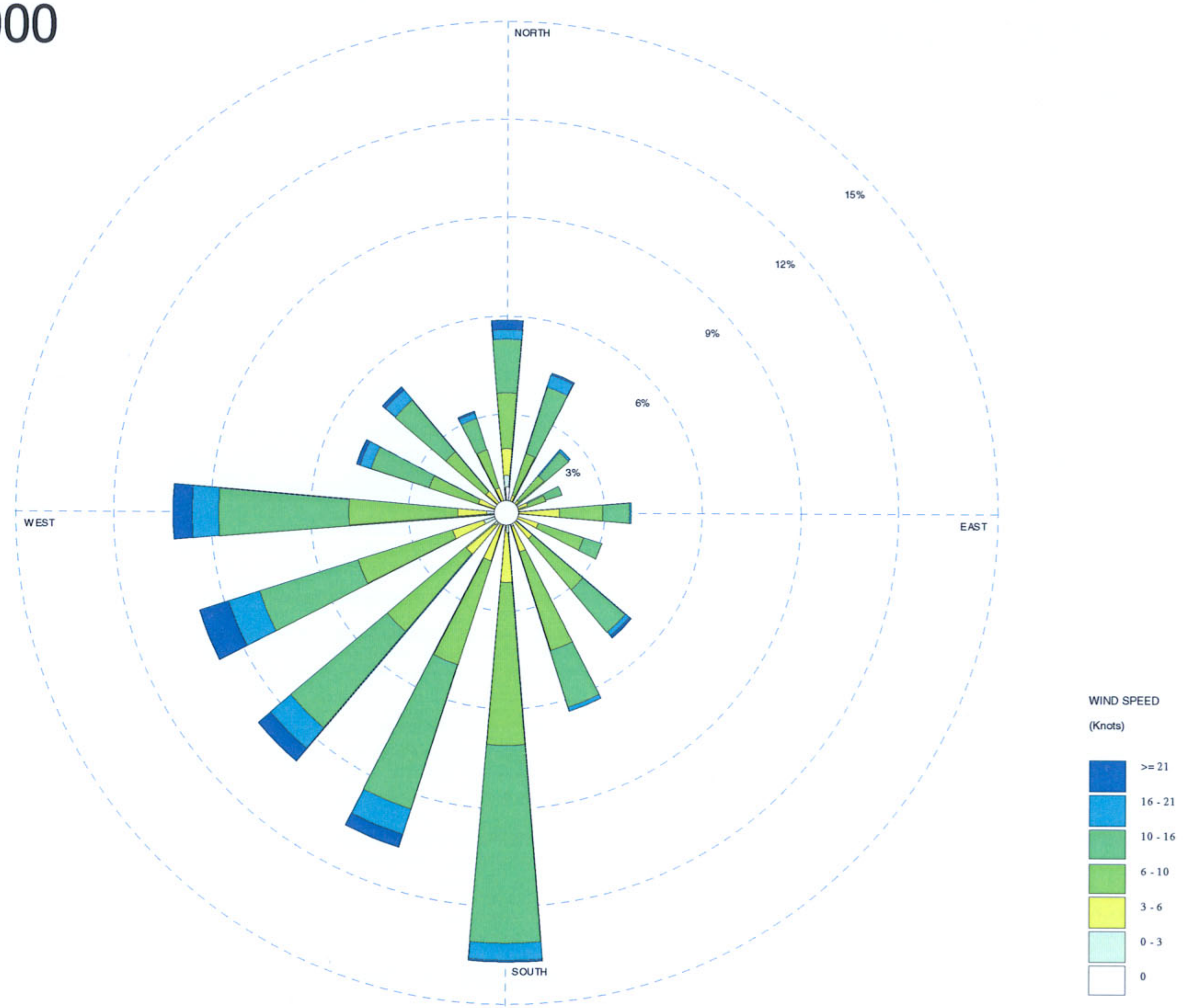
2000

DISPLAY:

Wind Speed
Direction (blowing from)

COMMENTS:

Wattisham
Windrose 2000



DATA PERIOD:

2000
Jan 1 - Dec 31
00:00 - 23:00

TOTAL COUNT:	CALM WINDS:
8776 hrs.	**0.00%**

AVG. WIND SPEED:

9.67 Knots

COMPANY NAME:

Posford Haskoning

MODELER:

Jamie Ellis

DATE:

11/11/02

ROYAL HASKONING
POSFORD HASKONING

PROJECT NO.:

M1274

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Bathside Bay
Air Quality Assessment

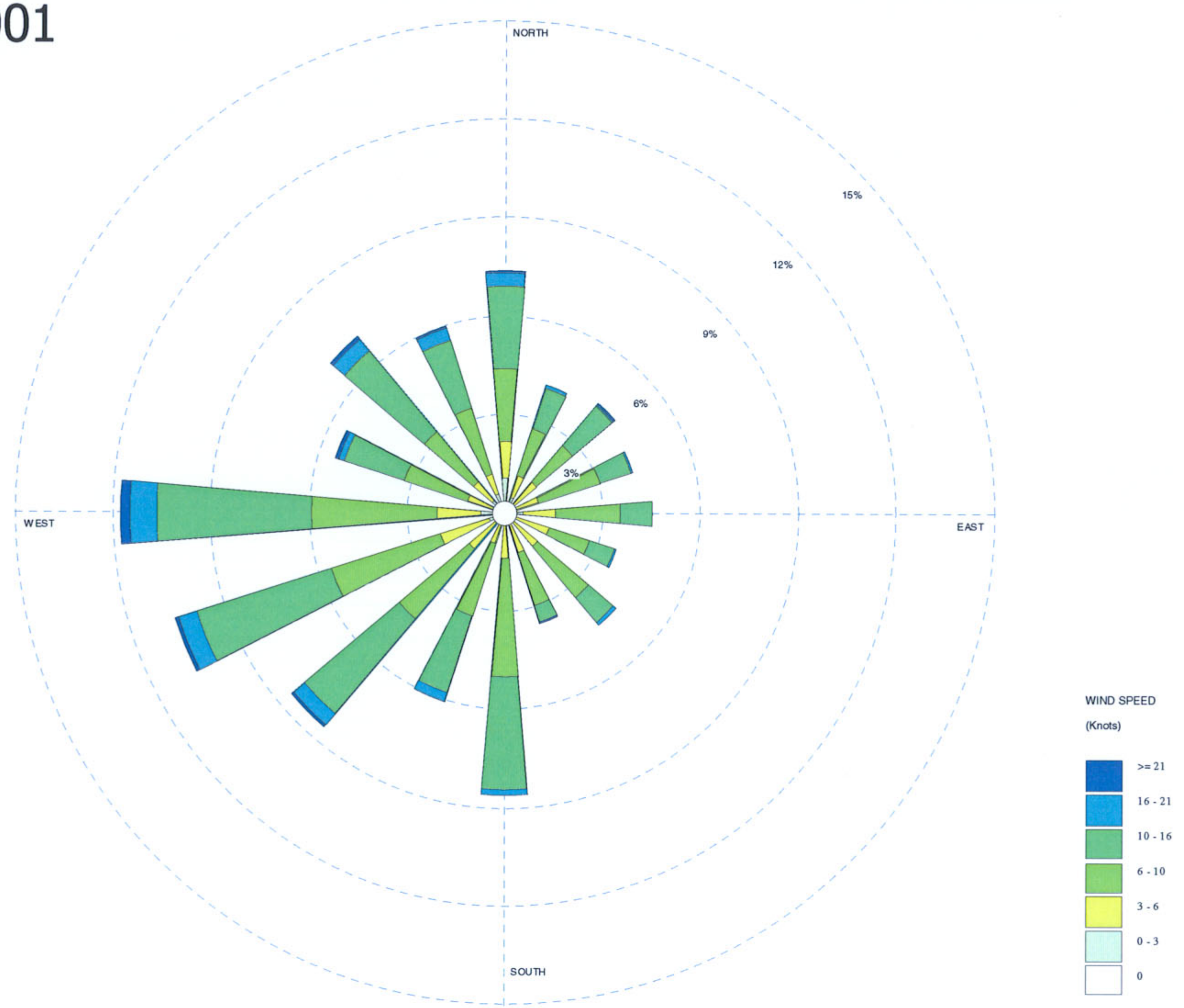
2001

DISPLAY:

Wind Speed
Direction (blowing from)

COMMENTS:

Wattisham
Windrose 2001



DATA PERIOD:	**2001** **Jan 1 - Dec 31** **00:00 - 23:00**
TOTAL COUNT:	**8610 hrs.**
CALM WINDS:	**0.00%**
AVG. WIND SPEED:	**9.04 Knots**
COMPANY NAME:	**Posford Haskoning**
MODELER:	**Jamie Ellis**
DATE:	**11/11/02**
PROJECT NO.:	**M1274**

ROYAL HASKONING
POSFORD HASKONING

WRPLOT View - Lakes Environmental Software