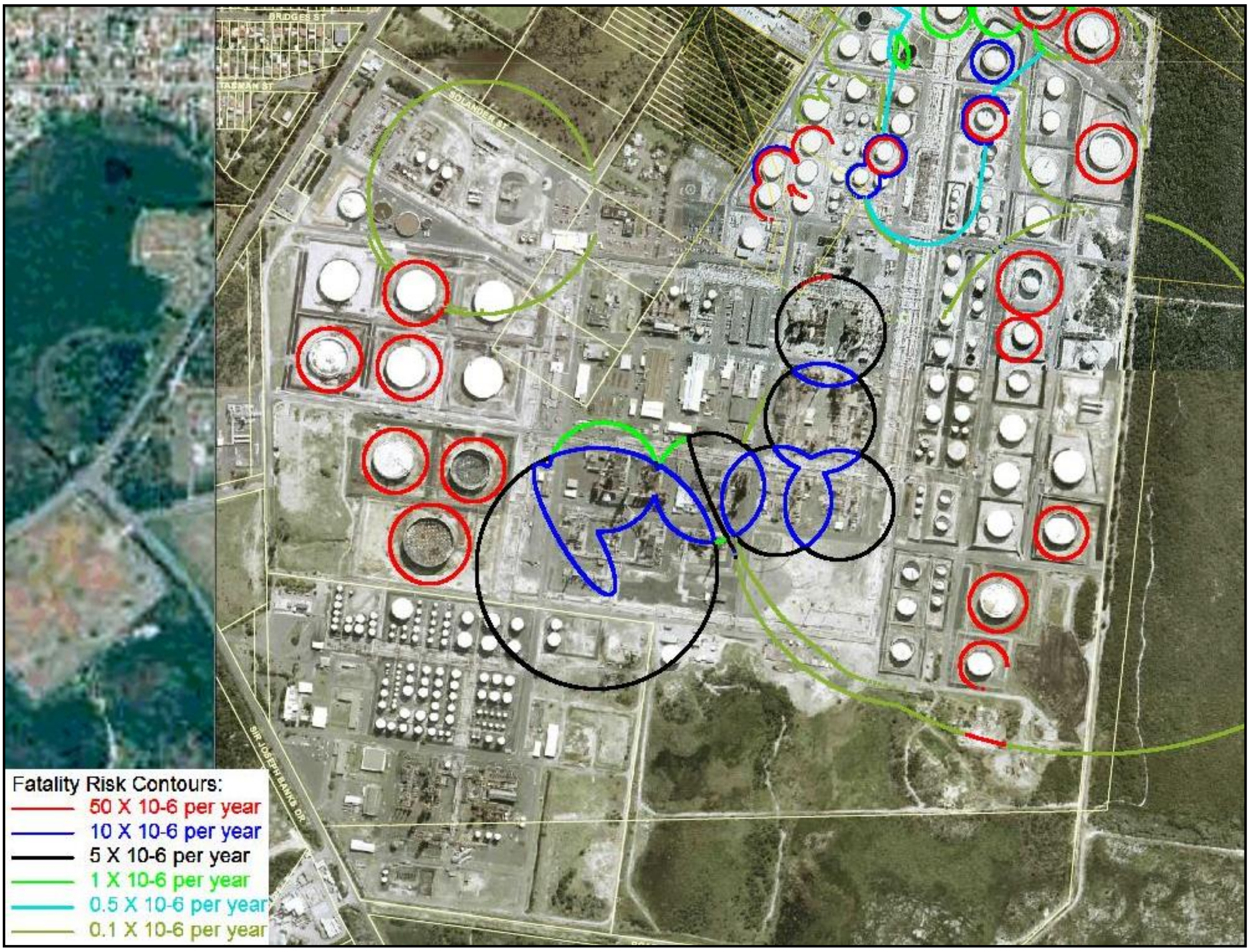
Hazardous Industry Planning Advisory
Paper No 4

Risk Criteria for Land Use Safety Planning



January 2011

HIPAP 4: Risk Criteria for Land Use Safety Planning

23–33 Bridge Street
Sydney NSW Australia 2000
www.planning.nsw.gov.au

ISBN 978-0-73475-923-8
DOP HAZ_007

Foreword

Since the 1980s, the New South Wales Department of Planning has promoted and implemented an integrated approach to the assessment and control of potentially hazardous development. The approach has been designed to ensure that safety issues are thoroughly assessed during the planning and design phases of a facility and that controls are put in place to give assurance that it can be operated safely throughout its life.

Over the years, a number of Hazardous Industry Advisory Papers and other guidelines have been issued by the Department to assist stakeholders in implementing this integrated assessment process. With the passing of time there have been a number of developments in risk assessment and management techniques, land use safety planning and industrial best practice.

In recognition of these changes, new guidelines have been introduced and all of the earlier guidelines have been updated and reissued in a common format.

I am pleased to be associated with the publication of this new series of Hazardous Industry Advisory Papers and associated guidelines. I am confident that the guidelines will be of value to developers, consultants, decision-makers and the community and that they will contribute to the protection of the people of New South Wales and their environment.

Director General

Contents

Executive Summary

Background

The orderly development of industry and the protection of community safety necessitate the assessment of hazards and risks. The Department of Planning has formulated and implemented risk assessment and land use safety planning processes that account for both the technical and the broader locational safety aspects of potentially hazardous industry. These processes are implemented as part of the environmental impact assessment procedures under the Environmental Planning and Assessment Act 1979.

The Department has developed an integrated assessment process for safety assurance of development proposals, which are potentially hazardous. The integrated hazards-related assessment process comprises:

- a preliminary hazard analysis undertaken to support the development application by demonstrating that risk levels do not preclude approval;
- a hazard and operability study, fire safety study, emergency plan and an updated hazard analysis undertaken during the design phase of the project;
- a construction safety study carried out to ensure facility safety during construction and commissioning, particularly when there is interaction with existing operations;
- implementation of a safety management system to give safety assurance during ongoing operation; and
- regular independent hazard audits to verify the integrity of the safety systems and that the facility is being operated in accordance with its hazards-related conditions of consent.

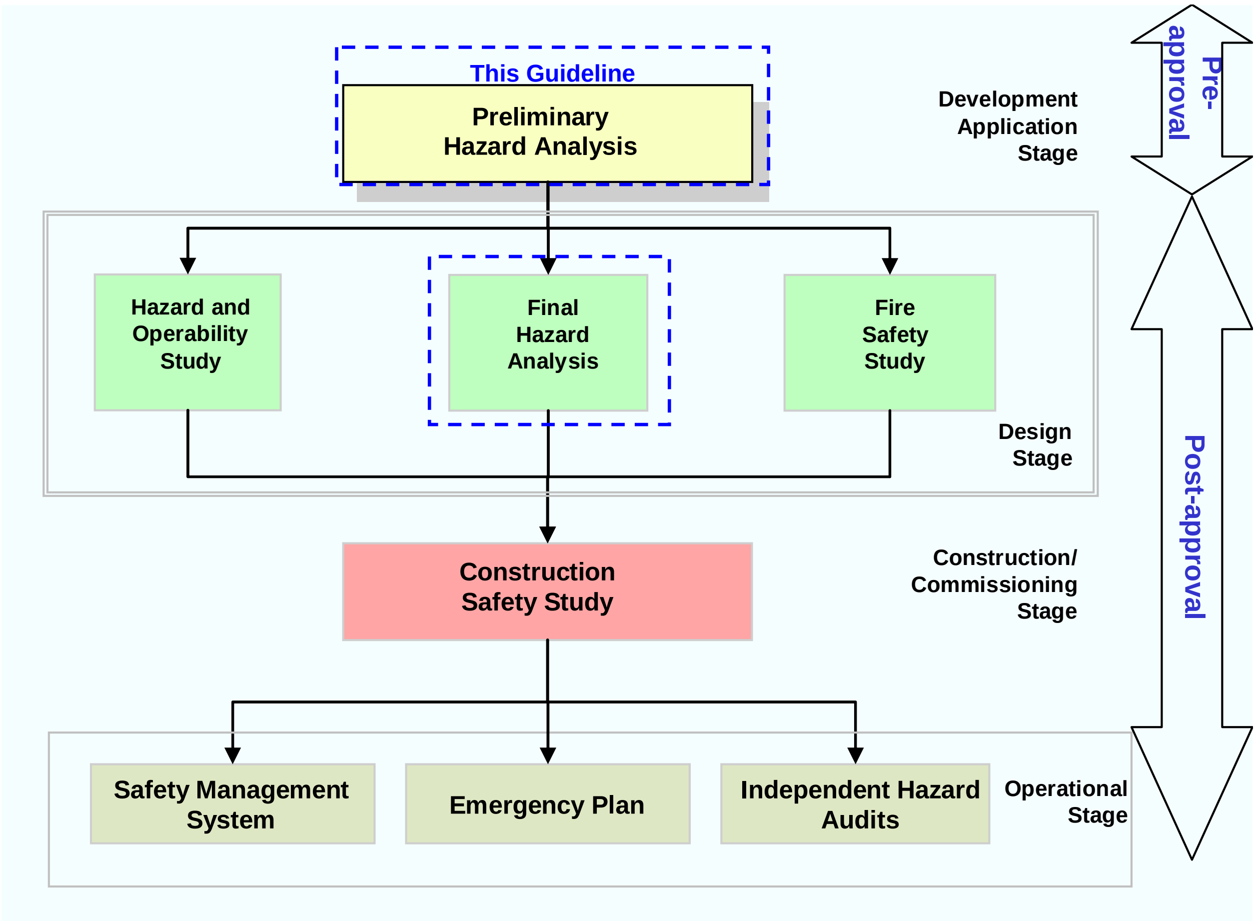
The process is shown diagrammatically in Figure 1.

A number *of Hazardous Industry Advisory Papers (HIPAPS)* and other guidelines have been published by the Department to assist stakeholders in implementing the process. All existing HIPAPs have been updated or completely rewritten and three new titles (HIPAPs 10 to12) have been added.

A full list of HIPAPs is found at the back of this document.

The part of the process covered by this guideline is highlighted in Figure 1.

Figure 1: The Hazards-Related Assessment Process



The Value of Risk Criteria

The identification of hazards and the quantification of risks outside the boundaries of a potentially hazardous development, and the assessment of that risk in terms of the nature of land uses in the vicinity provide the basis for compatible land use safety planning.

The assessment of risk necessitates the establishment of criteria against which judgments can be made as to the compatibility of various land uses. The adoption of formal criteria assists in a consistent approach to risk assessment and in the decision-making process.

In recent years, there has been a growing realisation that the tolerability or acceptability of risk is influenced by factors over and above the physical magnitude of that risk. While risk criteria need to have a sound technical basis, they must take serious account of community concerns.

There are two dimensions of risk which should be considered separately, individual and societal. On the one hand, the individual's concern about their own life or safety is mostly independent of whether the risk is from an isolated incident or a large scale disaster. Society's risk perception, however, is mostly influenced by multiple fatality or injury disasters.

When a risk is to be imposed on an individual or a group of people (e.g. by locating a hazardous facility in an area), the concept of 'acceptability' of that risk for the decision-making process is that it should be low relative to other known and tolerated risks.

In assessing the tolerability of risk from potentially hazardous development, both qualitative and quantitative aspects need to be considered.

Relevant general principles are:

- the avoidance of all *avoidable* risks;
- the risk from a major hazard should be reduced wherever practicable, even where the likelihood of exposure is low;
- the effects of significant events should, wherever possible be contained within the site boundary; and
- where the risk from an existing installation is already high, further development should not pose any incremental risk.

Drawing on these general principles, the guideline presents and discusses quantitative risk criteria related to fatality (individual and societal), injury, property and environmental damage. The criteria can be applied at the strategic level as well as to individual development. Risk criteria are also relevant in examining development in the vicinity of potentially hazardous facilities.

Key Messages

- While there can be some degree of flexibility in the implementation and interpretation of probabilistic risk criteria, where risk levels exceed established criteria, the acceptability of the risk at or from a facility will need to be carefully considered in the light of the economic or social benefits provided by the facility.
- The Department's risk criteria for land use safety planning are relevant at every stage of the planning cycle and not only during the assessment of proposals for new facilities or modifications and additions. Both qualitative and quantitative criteria need to be considered.
- Particular care needs to be taken when assessing rezoning or development around potentially hazardous development to ensure that such development will not introduce or aggravate existing land use safety conflicts.

1 Introduction

SECTION SUMMARY

Land use planning requires an understanding of the hazards and risks posed by a potentially hazardous development to the surrounding land uses.

However, risk assessment cannot be carried out in isolation. It requires criteria against which the acceptability of the estimated risk can be judged.

These guidelines set out suggested risk criteria for various types of risk and land uses. They are equally relevant to the assessment of new potentially hazardous facilities and the assessment of outside development in the vicinity of such facilities.

1.1 Background

The orderly development of industry and the protection of community safety necessitate the assessment of hazards and risks. The Department of Planning has formulated and implemented risk assessment and land use safety planning processes that account for both the technical and the broader locational safety aspects of potentially hazardous industry. These processes are implemented as part of the environmental impact assessment procedures under the Environmental Planning and Assessment Act 1979.

At the core of the department's approach, outlined in *Hazardous Industry Planning Advisory Paper No 3 – Risk Assessment*, are the identification of hazards and the quantification of risks outside the boundaries of a potentially hazardous development, and the assessment of that risk in terms of the nature of land uses in the vicinity. This provides the basis for compatible land use safety planning.

The assessment of risk necessitates the establishment of criteria against which judgments can be made as to the compatibility of various land uses. The basic criteria set out in these guidelines were first published in 1990 and have received broad acceptance since. The guidelines have now been updated, drawing on some 20 years of experience in NSW and internationally.

1.2 Purpose of the Guidelines

The guidelines suggest risk assessment criteria to be considered when assessing the land use safety implications of industrial development of a potentially hazardous nature. These suggested criteria are equally relevant and applicable to the considerations of land use planning and development in the vicinity of potentially hazardous facilities.

The guidelines are relevant to local councils, development proponents and the community. They will assist in efficient and appropriate decision-making concerning the safety planning and impact assessment of potentially hazardous development and surrounding land uses.

The advisory nature of the guidelines and their criteria is emphasised for a number of reasons. Firstly, hazards and risk are only one part of the overall decision-making process. Other considerations, such as the need for the development and social and economic factors should also be taken into account. Consent authorities are advised to weigh all these factors, including risk implications, when making their planning decisions. Secondly, it is more appropriate to focus on the proper use of hazard analysis and risk assessment techniques in assessing the relevancy of technical safeguards and locational safety constraints, rather than attempting to meet criteria in isolation. Thirdly, experience indicates variations in assessment factors from one locality or development to another, including variations in organisational safety management, vulnerability to risk exposure and in emergency provisions and infrastructure, which may not be amenable to uniform treatment. It is therefore appropriate that risk assessment criteria be considered as providing target guidance rather than absolute values in ail cases.

2 Risk Criteria for Land Use Safety Planning

SECTION SUMMARY

Risk criteria need to take account both the physical magnitude of a given risk and community concerns over risks that are imposed rather than voluntarily accepted. Risk criteria are set with the understanding that no aspect of living can be risk free but that any imposed risk should be very small in the context of the generally accepted background risk.

Two aspects of risk need to be considered:

- individual risk, which considers the acceptability of a particular level of risk to an exposed individual; and
- societal risk, which takes into account society's aversion to accidents which can result in multiple fatalities.

While it is useful to have objective, quantitative risk criteria, qualitative principles are equally important. These include:

- all 'avoidable' risks should be avoided;
- particular attention needs to be given to eliminating or reducing major hazards, irrespective of whether numerical criteria are met; and
- as far as possible, the consequences of significant events should be kept within facility boundaries.

Individual risk criteria are suggested for fatality, injury and property damage. In the case of fatality, the criteria differentiate between the various types of land use, acknowledging the need to protect the more vulnerable members of the community.

Societal risk criteria are recommended, based on the ALARP (as low as reasonably practicable) principle. Qualitative criteria are also suggested for risks to the environment.

Finally, the section outlines criteria to be used when considering development in the vicinity of potentially hazardous facilities.

KEY MESSAGES

- No single risk criterion fits all situations. A broad range of criteria need to be considered when considering the acceptability of the risk associated with a development. These include fatality and injury, as well as property and environmental damage
- While numerical criteria are important, they are not an end in themselves. The ALARP principle should be followed at all times.

2.1 Factors Influencing Risk Criteria

2.1.1 The Acceptability of Risk

The systematic evaluation of the acceptability of the risk from a proposed potentially hazardous development requires an agreed set of qualitative and quantitative risk criteria. In recent years, there has been a growing realisation that the tolerability or acceptability of risk is influenced by factors over and above the physical magnitude of that risk.

It is important to recognise that the technical validity of a chosen course of action and the technical accuracy of an assessment have very little correlation with the resulting level of public concern. While risk criteria need to have a sound technical basis, they must take serious account of community concerns, as noted in the following section.

2.1.2 The Categorisation of Risk

Hazards give rise to concerns which can be put into two broad categories:

- **Individual concerns** or how individuals see the risk from a particular hazard affecting them and things they value personally. This is not surprising since one of the most important questions for individuals incurring a risk is how it affects them, their family and things they value. Though they may be prepared to engage voluntarily in activities that often involve high risks, as a rule they are far less tolerant of risks imposed on them and over which they have little control, unless they consider the risks as negligible. Moreover, though they may be willing to live with a risk that they do not regard as negligible, if it secures them or society certain benefits, they would want such risks to be kept low and clearly controlled.
- **Societal concerns** or the risks or threats from hazards which impact on society and which, if realised, could have adverse repercussions for the institutions responsible for putting in place the provisions and arrangements for protecting people, eg Parliament or the Government of the day. This type of concern is often associated with hazards that give rise to risks which, were they to materialise, could provoke a socia-political response, eg risk of events causing widespread or large scale detriment or the occurrence of multiple fatalities in a single event. Typical examples relate to nuclear power generation, railway travel, or the genetic modification or organisms. Societal concerns due to the occurrence of multiple fatalities in a single event are reflected in the term **societal risk**.

Hazards giving rise to societal concerns share a number of common features. They often give rise to risks which could cause multiple fatalities; where it is difficult for people to estimate intuitively the actual threat; where exposure involves vulnerable groups, eg children; where the risks and benefits tend to be unevenly distributed – for example between groups of people with the result that some people bear more of the risks and others less, or through time so that less risk may be borne now and more by some future generation. People are more averse to those risks and in such cases are therefore more likely to insist on stringent government regulation. The opposite is true for hazards that are familiar, often taken voluntarily for a benefit, and individual in their impact. These do not as a rule give rise to societal concerns. Nevertheless, activities giving rise to such hazards (for example, Bungee jumping) are often regulated to ensure that people are not needlessly put at risk.

Criteria for both individual and societal risk are discussed in sections 2.4.2 and 2.4.3 respectively.

2.1.3 Criteria Setting

In order to make informed land use safety planning decisions, the results of any risk evaluation need be assessed against appropriate qualitative and quantitative risk criteria. While some jurisdictions focus on worst case consequences in setting land use criteria, the approach adopted in NSW is risk-based.

Accordingly, the following factors have been taken into account:

(a) The suggested risk criteria should be probabilistic in nature. That is, they should account for both the consequences (effects) and likelihood (probability) of hazardous events. Criteria based on the consequences of events in isolation are considered unrealistic as they ignore the availability of safeguards and may result in unnecessary sterilisation of land. This is not to say that the consequences of hazardous events should be ignored. In principle at least, qualitative criteria should specify the limit of consequences for certain incidents.

(b) All activities have an associated level of risk. It is not possible to eliminate that risk unless the activity itself is eliminated. The criteria are therefore based on the concept of a residual risk, the acceptability of which should be established in relation to various land uses.

(c) Acceptability of a level of risk involves many considerations of which safety is only one, although safety is playing an increasingly important role in planning considerations. Attitudes towards risk acceptability can vary widely depending on local situations. In some cases, certain risks may only be acceptable when they are outweighed by certain advantages which people associate with the considered activity. However, regions of unacceptable risks - whatever the advantages may be - can be shown to exist.

(d) The basis for risk criteria is that, generally, various levels of risks are tolerated on a daily basis, both to individuals and to society as a whole. Where risk is taken with free choice and full knowledge, that risk can be described as voluntary risk. Examples of voluntary risk include smoking, driving and rock climbing, provided that the individual knows and understands the risks.

Where the individual does not have knowledge of the risks or is not entirely free to choose to avoid the risk exposure, then the risk can be termed non-voluntary. Examples of non-voluntary risks include meteorite strike, some illnesses and some natural disasters.

In reality, most types of risk exposure have degrees of both the voluntary and involuntary. People in general are willing to expose themselves to quite high levels of individual risk by undertaking certain activities. On the other hand, society offers growing resistance to risks perceived as being imposed involuntarily on one group of people for the benefits of others, or where the risk exposure of one group does not fit with their share of benefits. The risk from a hazardous industrial development is usually perceived as a non-voluntary risk.

(e) When a risk is to be imposed on an individual or a group of people (e.g. by locating a hazardous facility in an area), the concept of 'acceptability' of that risk for the decision-making process is that it should be low relative to other known and tolerated risks.

(f) There are two dimensions of risk which should be considered separately, individual and societal. On the one hand, the individual's concern about their own life or safety is mostly independent of whether the risk is from an isolated incident or a large scale disaster. Society's risk perception, however, is mostly influenced by multiple fatality or injury disasters.

2.1.4 The Application of Criteria

Because of the uncertainties in the numerical outputs from a risk analysis, there needs to the degree of flexibility in the implementation and interpretation of probabilistic risk criteria. The assessment should consider:

- qualitative as well as quantitative outputs of the analysis;
- sensitivity of the results to changes in critical input assumptions;
- the consequences and likelihood of hazardous events;
- the vulnerability of people and property in the area (on- and off-site);
- the sensitivity of the affected environment;
- the potential benefits of the facility to the local and wider community;
- variations in local conditions;
- existing risk exposures; and
- current and likely future use of the surrounding areas.

While quantitative risk criteria should not be used as absolute numbers, where risk levels exceed established criteria, the acceptability of the risk at or from a facility will need to be carefully considered in the light of the economic or social benefits provided by the facility.

Criteria need to be applied in three broad contexts:

1. Strategic Planning (Zoning)
2. Assessment of Development for Potentially Hazardous Development

3. Assessment of Development in the Vicinity of Potentially Hazardous Development

While a number of criteria may be common to more than one context, there is a need to consider each situation on its merits, as noted in sections 2.3 to 2.5.

2.2 Qualitative Risk Criteria

Irrespective of the numerical value of any risk criteria level for risk assessment purposes, it is essential that certain qualitative principles be adopted concerning the land use safety acceptability of development. The following qualitative criteria are appropriate whether making zoning decisions, assessing the risk implications of a development project of a potentially hazardous nature or the locational safety suitability of a development in the vicinity of a potentially hazardous installation:

(a) All 'avoidable' risks should be avoided. This necessitates the investigation of alternative locations and alternative technologies, wherever applicable, to ensure that risks are not introduced in an area where feasible alternatives are possible and justified.

(b) The risk from a major hazard should be reduced wherever practicable, irrespective of the numerical value of the cumulative risk level from the whole installation. In all cases, if the consequences (effects) of an identified hazardous incident are significant to people and the environment, then all feasible measures (including alternative locations) should be adopted so that the likelihood of such an incident occurring is made very low. This necessitates the identification of all contributors to the resultant risk and the consequences of each potentially hazardous incident. The assessment process should address the adequacy and relevancy of safeguards (both technical and locational) as they relate to each risk contributor.

(c) The consequences (effects) of the more likely hazardous events (i.e. those of high probability of occurrence) should, wherever possible, be contained within the boundaries of the installation.

(d) Where there is an existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.

2.3 Risk Criteria for Strategic Planning

When considering strategic planning, the primary emphasis needs to be on the suitability of land for the proposed range of uses, having regard to existing risk exposure and the sensitivity of the current land use.

For example, it would be inappropriate for land to be zoned for residential or more sensitive uses if there was already a significant risk exposure from nearby industrial activities. Similarly, zoning for the purpose of industry with a potential for accidental release of ecotoxic materials would be inappropriate in an environmentally sensitive area, such as in proximity to threatened species habitat or near a natural watercourse or waterbody.

The criteria set out in section 2.5 (Risk Criteria for Development in the Vicinity of Potentially Hazardous Facilities) are relevant to strategic planning as well as for the assessment of specific development proposals.

2.4 Risk Criteria for Potentially Hazardous Development

2.4.1 General

In assessing the tolerability of risk from potentially hazardous development, both qualitative and quantitative aspects need to be considered. Relevant general principles are:

- the avoidance of all *avoidable* risks;
- the risk from a major hazard should be reduced wherever practicable, even where the likelihood of exposure is low;
- the effects of significant events should, wherever possible be contained within the site boundary; and
- where the risk from an existing installation is already high, further development should not pose any incremental risk.

The main quantitative criteria considered are fatality, injury property and environmental damage. The most relevant criteria are discussed below.

2.4.2 Individual Risk

2.4.2.1 Fatality

'Individual fatality risk' is the risk of death to a person at a particular point.

Table 5 in Appendix 1 indicates a range of various risks to which people are exposed as the result of various activities. Further context is provided by Table 1, which shows the Annual risk of death for various United Kingdom age groups based on deaths in 1999 (Annual Abstract of Statistics, 2001/Health Statistics Quarterly – Summer 2001).

Table 1: Annual Risk of Death from All Causes in the UK

Population group	Risk as annual experience	Risk as annual experience per million
Entire population	1 in 97	10,309
Men aged 65-74	1 in 36	27,777
Women aged 65-74	1 in 51	19,607
Men aged 35-44	1 in 637	1,569
Women aged 35-44	1 in 988	1,012
Boys aged 5-14	1 in 6,907	145
Girls aged 5-14	1 in 8,696	115

Regulators have concluded that if a risk from a potentially hazardous installation is below most risks being experienced by the community, then that risk may be tolerated. This is consistent with the basis of criteria selling used in these guidelines, as well as those adopted by most authorities nationally and internationally.

The Department has adopted a fatality risk level of one in a million per year (1×10^{-6} per year) as the limit for risk acceptability for residential area exposure. This risk criteria, which is demonstrably very low in relation to the background risk shown in Table 1, has been adopted by the Department when assessing the safety implications of industrial development proposals. It is also appropriate in considering land use proposals in the vicinity of potentially hazardous facilities.

In setting criteria, it is also necessary to account for variations in the duration of exposure to that risk at any particular point by any one individual. People's vulnerability to the hazard and their ability to take evasive action when exposed to the hazard also need to be taken into account.

The one in a million criteria assumes that residents will be at their place of residence and exposed to the risk 24 hours a day and continuously day after day for the whole year. In practice this is not the case and this criterion is therefore conservative.

People in hospitals, children at school or old-aged people are more vulnerable to hazards and less able to take evasive action, if need be, relative to the average residential population. A lower risk than the one in a million criteria (applicable for residential areas) may be more appropriate for such cases. On the other hand, land uses such as commercial and open space do not involve continuous occupancy by the same people. The individual's occupancy of these areas is on an intermittent basis and the people present are generally mobile. As such, a higher level of risk (relative to the permanent housing occupancy exposure) may be tolerated.

A higher level of risk still is generally considered acceptable in industrial areas.

Accordingly, the following risk assessment criteria are suggested for the assessment of the safety of location of a proposed development of a potentially hazardous nature, or for land use planning in the vicinity of existing hazardous installations:

(e) Hospitals, schools, child-care facilities and old age housing development should not be exposed to individual fatality risk levels in excess of half in one million per year ($0.5x\ 10^{-6}$)

(a) Residential developments and places of continuous occupancy, such as hotels and tourist resorts, should not be exposed to individual fatality risk levels in excess of one in a million per year (1×10^{-6} per year).

(b) Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres, should not be exposed to individual fatality risk levels in excess of five in a million per year (5×10^{-6} per year).

(c) Sporting complexes and active open space areas should not be exposed to individual fatality risk levels in excess of ten in a million per year (10×10^{-6})

(d) Individual fatality risk levels for industrial sites at levels of 50 in a million per year (50×10^{-6} per year) should, as a target, be contained within the boundaries of the site where applicable.

Whilst individual fatality risk levels should include all components of risk - i.e. fires, explosions and toxicity - there may be uncertainties in correlating toxic concentrations to fatality risk levels.

The interpretation of 'fatal' should not rely on any one dose-effect relationship, but involve a review of available data.

Table 2 summarises the preceding criteria for the various categories of land use.

Table 2: Individual Fatality Risk Criteria

Land Use	**Suggested Criteria (risk in a million per year)**
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Industrial	50

2.4.2.2 Injury Risk

Relying entirely upon fatality risk criteria may not account for the following factors:

- Society is concerned about risk of injury as well as risk of death.
- Fatality risk levels may not entirely reflect variations in people's vulnerability to risk. Some people may be affected at a lower level of hazard exposure than others.

It is therefore appropriate that risk criteria also be set in terms of injury, i.e. in terms of levels of effects that may cause injury to people but will not necessarily cause fatality.

Heat Radiation

Table 6 in Appendix 1 indicates the effects of various heat fluxes (radiation) as the result of a fire incident. The ultimate effect would depend on the duration of people's exposure to the resultant heat flux.

For the purpose of injury, a lower heat radiation level (relative to that level which may cause fatality) is appropriate. The 4.7 kW/m^2 heat radiation level (see Table 6) is considered high enough to trigger the possibility of injury for people who are unable to be evacuated or seek shelter. That level of heat radiation would cause injury after 30 seconds' exposure. Accordingly, a risk injury criterion of 50 in a million per year at the 4.7 kW/m^2 heat flux is suggested. The department's experience with the implementation of that criterion indicates that it is achievable and appropriate.

The suggested injury risk criterion for heat radiation can therefore be expressed as follows:

- Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year.

Explosion Overpressure

Table 7 in Appendix 1 indicates the effect of various levels of explosion overpressures resulting from explosion scenarios.

Using a similar analysis to that adopted in establishing a heat flux injury level, it can be suggested that an explosion overpressure level of 7 kPa be the appropriate cut-off level above which significant effects to people and properly damage may occur.

Accordingly, an injury risk criteria of 50 in a million at the 7 kPa explosion overpressure level is suggested. The department's experience with implementation confirms this level as appropriate.

The suggested injury/damage risk criterion for explosion overpressure can therefore be expressed as follows:

- Incident explosion overpressure at residential and sensitive use areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year.

Toxic Exposure Criteria

Depending on the concentration, the nature of the material, the duration and mode of exposure (i.e. via the respiratory tract, lungs, skin or ingestion), the effects of toxicants range from fatality, injury (e.g. damage to lungs and respiratory system, damage to nervous system, emphysema, etc.) to irritation of eyes, throat or skin through to a nuisance effect. Effects can also be classified as acute, chronic or delayed.

There are a number of assessment criteria and dose-effect relationships that vary from one chemical to another. Toxic criteria applicable to one chemical may not necessarily be appropriate for others. The department's experience conclusively shows that the formulation of a uniform specific criteria to cover all toxic effects is not appropriate or valid. Instead, each case should be justified on its merits using a thorough search of available and known dose-effect relationships as the basis for assessment. Incidents with injurious impact on people should be kept to low frequencies.

The suggested injury risk criteria for toxic gas/ smoke/dust exposure are as follows:

- Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year.
- Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year.

2.4.2.3 Risk of Property Damage and Accident Propagation

The siting of a hazardous installation must account for the potential of an accident at the installation causing damage to buildings and propagating to a neighbouring industrial operations and hence initiating further hazardous incidents - the so-called 'domino effect'. The siting process must also account for existing risk conditions at the proposed site.

The principle of setting risk criteria to reflect the potential for accident propagation is that the risk of an accident at one plant triggering another accident at another neighbouring plant should be low and that adequate safety separation distances should be provided as part of siting and layout of plant and equipment.

Heat radiation levels of 23 kW/m^2 as the result of fire incidents at a hazardous plant may affect a neighbouring installation to the extent that unprotected steel can suffer thermal stress that may cause structural failure (see Table 6 in Appendix 1). This may trigger a hazardous event unless protection measures are adopted.

Explosion overpressure levels of 14 kPa as the result of explosions at a hazardous plant may damage piping and (low-pressure) equipment at a neighbouring plant. It is therefore appropriate that the probability of these levels of impacts at neighbouring installations be relatively low. A probability of 50 in a million per year is suggested for assessment purposes.

The explosion overpressure level of 14 kPa is also sufficient to cause significant damage to buildings (see Table 7) and as such is appropriate as the basis for a risk of damage criteria. A probability of 50 in a million per year is also suggested for assessment purposes.

The criteria for risk of damage to property and of accident propagation can therefore be stated as follows:

Incident heat flux radiation at neighbouring potentially hazardous installations or at land zoned to accommodate such installations should not exceed a risk of 50 in a million per year for the 23 kW/m^2 heat flux level.

Incident explosion overpressure at neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at nearest public buildings should not exceed a risk of 50 in a million per year for the 14 kPa explosion overpressure level.

These criteria do not remove the need to consider higher consequence levels at lower frequencies. The hazard analysis should consider the whole picture, not just the nominated quantitative criteria.

2.4.3 Societal Risk

Developing criteria on tolerability of risks for hazards giving rise to societal concerns is difficult. Hazards giving rise to such concerns often involve a wide range of events with a range of possible outcomes. The summing or integration of such risks, or their mutual comparison, may call for the attribution of weighting factors for which, at present, no generally agreed values exist as, for example, the death of a child as opposed to an elderly person, dying from a dreaded cause, eg cancer, or the fear of affecting future generations in an irreversible way.

Nevertheless, the Department has provisionally adopted indicative criteria as shown in Figure 3 for addressing societal concerns arising when there is a risk of multiple fatalities occurring in one event. These were developed through the use of so-called FN-curves (obtained by plotting the frequency at which such events might kill N or more people, against N). The technique provides a useful means of comparing the impact profiles of man-made accidents with the equivalent profiles for natural disasters with which society has to live. The method is not without its drawbacks but in the absence of much else it has proved a helpful tool if used sensibly.

The suggested criteria take into account the fact that society is particularly intolerant of accidents, which though infrequent, have a potential to create multiple fatalities. The criteria are broadly consistent with those adopted in a number of other jurisdictions and have been refined by consideration of the results from land use safety studies conducted by the Department in and around the industrial installations in the Port Botany and Botany/Randwick industrial areas.

The indicative societal risk criteria incorporate an ALARP (As Low As Reasonably Possible) approach.

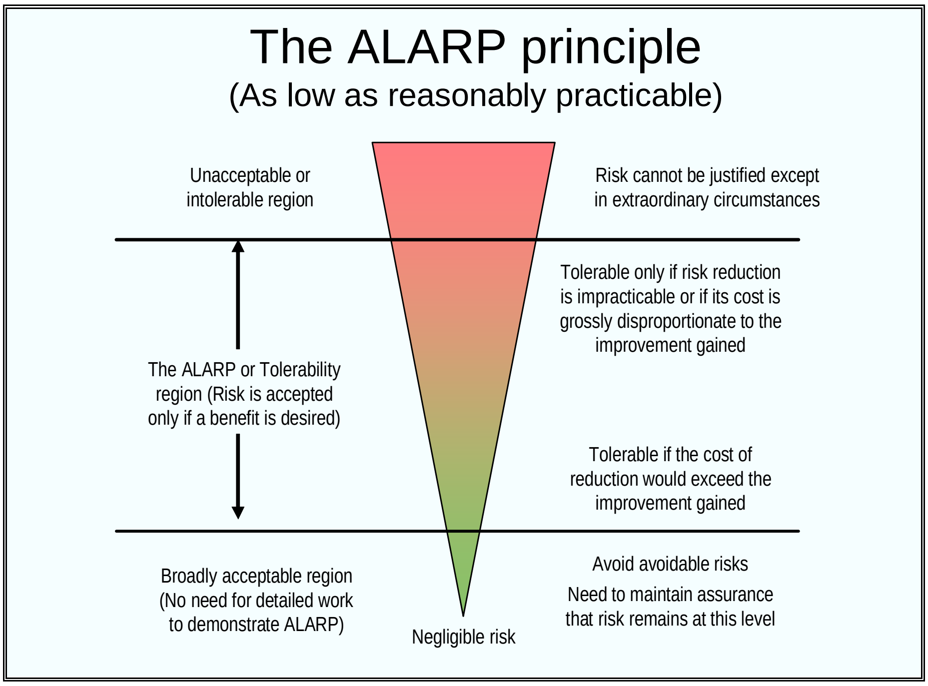
2.4.3.1 The ALARP Principle

ALARP is a principle that may be applied in relation to the degree of risk reduction that may be sought from a particular activity. For example, this principle is a basic requirement of the UK Health and Safety at Work Act, 1974. It has been described by the UK Health and Safety Executive (HSE) in the following terms: 'In weighing the costs of extra safety measures the principle of reasonable practicability (ALARP) applies in such a way that the higher or more unacceptable a risk is, the more, proportionately, an employer is expected to spend to reduce it'.

Risk levels and ALARP were developed by the HSE in the document ‘The Tolerability of Risk from Nuclear Power Stations' (HSE, 1988). Above a certain level, a risk is regarded as intolerable and is forbidden whatever the benefit might be. Below such levels, an activity is allowed to take place and in pursuing any further safety improvement account can be taken of the cost. The HSE suggests the limit of tolerable risk to a worker is 10^{-3}/year; the limit of tolerable risk to a member of the public is taken as 10^{-4}/year. The risk to a member of the public that might be regarded as acceptable, as opposed to tolerable, is then taken as 10^{-6} per year.

The concept is illustrated in Figure 2.

Figure 2: Applying ALARP



In a NSW Occupational Health and Safety context, the Courts have given consideration to the term "reasonably practicable" when used as part of a legal defence. Comment has been made that "reasonably practicable" is a narrower term than "physically possible", implying that a computation must be made in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed on the other; and that if it be shown that there is a gross disproportion between them - the risk being insignificant in relation to the sacrifice - the defendants discharge the onus on them.

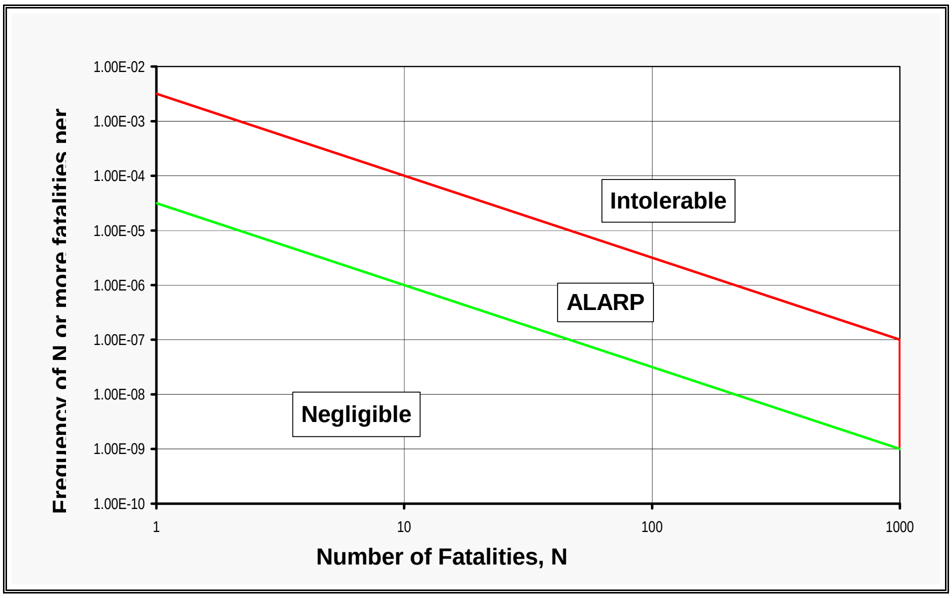
The Courts have noted that the greater the magnitude of the risk and the greater the gravity of the harm, should the event occur, the higher is the duty to take precautions, even if these are expensive or difficult to adopt.

Without necessarily endorsing the HSE criteria or attempting to establish specific criteria for potentially hazardous facilities, the broad ALARP principle is endorsed in these guidelines. It should be noted that, irrespective of numerical risk criteria, the broad aim should be to 'avoid avoidable risk.'

The indicative societal risk criteria reflect these regions as three societal risk bands: negligible, ALARP and intolerable, as shown in Figure 3.

It should be emphasised that the criteria in Figure 3 are indicative and provisional only and do not represent a firm requirement in NSW.

Figure 3: Indicative Societal Risk Criteria



Below the negligible line, provided other individual criteria are met, societal risk is not considered significant. Above the intolerable level, an activity is considered undesirable, even if individual risk criteria are met. Within the ALARP region, the emphasis is on reducing risks as far as possible towards the negligible line. Provided other quantitative and qualitative criteria of HIPAP 4 are met, the risks from the activity would be considered tolerable in the ALARP region.

2.4.4 Environmental Risk

In addition to the risk to people and property, the siting and impact assessment process for potentially hazardous installations must consider the risk from accidental releases to the biophysical environment.

In the case of the biophysical environment, fire and explosion hazards are of less relevance in comparison to the effect of these hazards on people. Acute and chronic toxicity impacts are those which must be chiefly addressed. Generally, there is less concern over the effects on individual plants or animals. The main concern is instead with whole systems or populations.

The assessment of the ultimate effects from toxic releases into the natural ecosystem is difficult, particularly in the case of atypical accidental releases. Data are limited and factors influencing the outcome variable and complex. There may be no immediate loss of plants or animals or other observable effects from single releases but there may be cumulative and synergistic effects. It is therefore appropriate to ensure that a thorough review of available data is undertaken and best available information used in the assessment process.

In many cases, it may not be possible or practicable to establish the final impact of any particular release. It may be appropriate in such circumstances to assess the likelihood of identified concentrations of concern occurring in the air, water or soil. Where such intermediate criteria are used, the assessment should err on the conservative side.

Because of the complexities of such assessment and case-to-case differences, it is inappropriate to specify hard and fast criteria. The acceptability of the risk will ultimately depend on the value of the potentially affected area or system to the local community and wider society. For example, where a rare or endangered ecosystem or species is involved, a much lower risk level is necessary than where the potentially exposed area or system is degraded and/or common.

Relevant factors in the capacity of a population or ecosystem to recover include the extent of other stresses and the possibility of repopulation of affected areas.

2.4.4.1 Wright's Criteria

Wright (1993) describes several factors which need to be recognised

- ecosystems are complex, open and dynamic;
- the time-scale to cause measurable impact or recovery from impacts may be longer than human life;
- persistent materials which are bio-available, and have the potential to bio-accumulate should be avoided, discharge will cause irreversible net change;
- the relative scale of the environmental impact must be considered in all environmental dimensions (spatial, temporal etc.);
- the ecosystem has inherent or built-in variability and recoverability;
- cause and effect relationships are often difficult to measure;
- interdependency exists between different eco-sub-systems; and
- acceptability of risks to the environmental resources is dependant on human values..

There is also the problem of synergistic effects. This means, for example, that two chemicals which are individually inert in the environment, interact to create major difficulties.

Wright also suggests that it is possible to calculate the likelihood and size of accidental or intermittent releases and then make judgement on what the consequences of such releases would be. The table of consequences are:

Table 3: Table of Environmental Consequences

Consequence Type	Description
Catastrophic	Irreversible alteration to one or more eco-systems or several component levels. Effects can be transmitted, can accumulate. Loss of sustainability of most resources. Life cycle of species impaired. No recovery. Area affected 100 km^2.
Very serious	Alteration to one or more eco-systems or component levels, but not irreversible. Effects can be transmitted, can accumulate. Loss of sustainability of selected resources. Recovery in 50 years. Area affected 50 km^2.
Serious	Alteration/disturbance of a component of an ecosystem. Effects not transmitted, not accumulating or impairment. Loss of resources but sustainability unaffected. Recovery in 10 years.
Moderate	Temporary alteration or disturbance beyond natural viability. Effects confined<5000 m^2, not accumulating or impairment. Loss of resources but sustainability unaffected. Recovery temporarily affected. Recovery < 5 years
Not detectable	Alteration or disturbance within natural viability. Effects not transmitted, not accumulating. Resources not impaired

On the basis of these considerations, the Department suggests the following criteria:

- Industrial developments should not be sited in proximity to sensitive natural environmental areas where the effects (consequences) of the more likely accidental emissions may threaten the long-term viability of the ecosystem or any species within it.
- Industrial developments should not be sited in proximity to sensitive natural environmental areas where the likelihood (probability) of impacts that may threaten the long-term viability of the ecosystem or any species within it is not substantially lower than the background level of threat to the ecosystem.

2.5 Risk Criteria for Development in the Vicinity of Potentially Hazardous Facilities

2.5.1 General Principles

The suggested risk assessment criteria in section 2.4.2 apply when assessing the land use safety implications of industrial development of a potentially hazardous nature. However, they are equally relevant and applicable to the considerations of land use planning and development in the vicinity of potentially hazardous facilities.

The following criteria should be read in conjunction with section 2.4.2.

2.5.2 Individual Fatality Risk

2.5.2.1 Residential and Sensitive Land Uses

The individual risk criteria in section 2.4.2 relating to risks to residential and sensitive land uses from new industry proposals are significantly more stringent than those which apply to less sensitive uses, such as industrial and commercial activities.

Consequently, while existing industry should ideally meet the same residential and sensitive land use criteria as new proposals, it is recognised that this may not be possible in practice. The following principles apply to residential and sensitive use development in the vicinity of existing industry:

- the half in a million per year individual fatality risk level is an appropriate criterion above which no intensification of sensitive use development should take place;

- the one in a million per year individual fatality risk level is an appropriate criterion above which no intensification of residential development should take place;
- residential intensification may be appropriate where mitigating measures can be implemented to reduce risk exposure to less than the one in a million per year individual fatality risk level, provided the pre-mitigation residual risk levels are below the 10 in a million per year individual fatality risk level; and
- no residential intensification should take place where pre-mitigation residual risk levels are in excess of the 10 in a million per year individual fatality risk level.

2.5.2.2 Other Land Uses

Table 4 sets out the recommended individual risk level above which development of the types specified would not be appropriate.

Table 4: Individual Fatality Risk Criteria – Other Land Uses

Land Use	Suggested Criteria (risk in a million per year)
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10
Industrial	50

Where these criteria are initially exceeded, commercial and industrial land development may be appropriate where mitigating measures can be implemented to reduce risk exposure to less than the target individual fatality risk level.

2.5.3 Individual Injury Risk

In the case of proposed development for residential and sensitive uses, possible injury and irritation impacts should also be considered. The suggested criteria are as for new industrial development set out in section 2.4.2.2.

Heat Radiation

The suggested injury risk criterion for heat radiation is:

- Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year.

Explosion Overpressure

The suggested injury/damage risk criterion for explosion overpressure is:

- Incident explosion overpressure at residential and sensitive use areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year.

Toxic Exposure Criteria

The suggested injury risk criteria for toxic gas/ smoke/dust exposure are:

- Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure at a maximum frequency of 10 in a million per year.

Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year.

2.5.4 Societal Risk

Societal risk criteria particularly focus on multiple fatality situations. Hence, it is generally not meaningful to address societal risk when considering development applications for single dwellings in the vicinity of a potentially hazardous facility.

However, where a development proposal involves a significant intensification of population in the vicinity of such a facility, the change in societal risk needs to be taken into account, even if individual risk criteria are met.

Examples of such situations would include medium to high density residential development (although this would not normally be considered to be appropriate in such a location), sporting facilities where large numbers of spectators are likely to be present and shopping complexes.

In such instances, the incremental societal risk should be compared against the indicative criteria of Figure 3. Provided the incremental societal risk lies within the negligible region, development should not be precluded. If incremental risks lie within the ALARP region, options should be considered to relocate people away from the affected areas. If, after taking this step, there is still a significant portion of the societal risk plot within the ALARP region, the proposed development should only be approved if benefits clearly outweigh the risks.

3 Guidance Notes on Implementation

SECTION SUMMARY

The implementation notes set out a number of principles to be followed in implementing the suggested risk criteria. In particular, they underline the importance of a holistic approach, which recognises:

- the need to apply the relevant criteria to all components of the risk;
- the limits and uncertainties associated with risk quantification;
- that the criteria represent targets rather than absolute limits; and
- the need to differentiate between risks posed by new and existing facilities.

The following notes are provided to assist in the implementation of the risk assessment criteria suggested in this document:

1. The fatality and societal risk criteria should include all components of risk: fire, explosion and toxicity. The Department of Planning's Hazardous Industry Planning Advisory Paper no. 3, *Risk Assessment* and no 6, *Hazard Analysis*, outline the risk assessment process used in the estimation of off-site risks for hazardous industry.

2. The implementation of the criteria must acknowledge the limitations and, in some cases, the theoretical uncertainties associated with risk quantification. Two approaches are usually adopted to account for such uncertainties: a 'pessimistic' approach, i.e. assumptions err on the conservative side with overestimation of the actual risk; or 'best estimates' using realistic assumptions with an estimated risk that could either be an overestimate or an underestimate of the actual risk.

   To account for any uncertainties and limitations, when the department provides advice on risk assessment and evaluating risk implications of development proposals, it uses the most up-to-date and validated assessment tools and techniques. The assumptions used in the assessment process by the department err on the side of caution — i.e. the department prefers to adopt conservative assumptions that may reflect an overestimation of the actual risk. This approach is justified on planning grounds.

   The criteria suggested in these guidelines are set at a realistic level to reflect this conservative approach in the assessment process.

3. In the context of (2), a degree of flexibility in the implementation and interpretation of the absolute values of the risk criteria may be justified in some cases. There may also be variations in local conditions. Consideration of vulnerability of people and situations is necessary.

   The criteria are best implemented when used as targets rather than absolute levels. Nevertheless, any substantial deviations from such targets should be fully justified.

   It is advisable that in all cases the assessment process emphasise the hazard identification and risk quantification process and procedures rather than entirely relying on absolute risk levels.

4. Given the probabilistic nature of the assessment process, care must be exercised in interpreting/ assessing compliance with a risk criterion in terming plants which exceed the suggesting criteria as 'unsafe'. Nevertheless, a higher resultant risk

level relative to the suggested criteria indicates land use safety incompatibility and locational safety constraints.

5. In applying the industrial criteria of 50×10^{-6} for externally generated risk, regard should be had to the presence of workers on site and to the nature of activities and their relationship to each other. Where an industrial site or part of a site involves only the occasional presence of people such as in the case of a tank farm, a higher level of risk may be acceptable (provided that incident propagation risk criteria are satisfied). In the case of similar adjacent facilities, such as bulk liquid storage terminals, which if under single ownership would be acceptable (i.e. satisfying requirements for occupational health and safety and other internal safety requirements), it may be appropriate to allow higher site to adjoining site risk levels.

6. The implementation of the risk criteria should differentiate between existing land use situations and new situations in terms of applicability to reflect a tighter locational and technological standard applying now than at earlier times. In the case of existing industry, compliance with a risk criterion is part of an overall strategy to mitigate existing risk levels by reducing both the risks and the number of people exposed to those risks.

   For existing situations, an overall planning approach is necessary. In terms of criteria, the following principles should apply:

   - The criteria suggested in section 2.5 are relevant.
   - Safety updates/reviews and risk reduction at facilities where resultant levels are in excess of the 10×10^{-6} individual fatality risk level should be implemented to ensure that operational and organisational safety measures are in place to reduce the likelihood of major hazardous events to low levels. A target level is to be established on an area basis.
   - Intensification of hazardous activities in an existing complex accommodating a number of industries of a hazardous nature should only be allowed if the resultant 1×10^{-6} individual fatality risk level is not exceeded by the proposed facility and subject to cumulative risk threshold considerations.
   - Mitigating the impact on existing residential areas from existing hazardous activities (in addition to safety review/updates) should essentially include specific area-based emergency plans. Emergency planning should be on the basis of consequences for credible scenarios with emphasis on areas within the 1×10^{-6} risk contour.

Appendix 1

Risk Criteria in Context

The following tables, drawn from the first edition of the guidelines, contain useful background information on the risks of various types of activity and the consequences of individual exposure to heat radiation and explosion overpressure.

While some of the information is slightly outdated, it provides a context against which some of the suggested numerical risk criteria can be compared and demonstrates the significant degree of conservatism in the criteria when compared against risks from normal daily activities.

Table 5: Risks to Individuals in NSW[1]

	Chances of Fatality per million person years
Voluntary Risks (average to those who take the risk)	
Smoking (20 cigarettes/day)	
• all effects	5000
• all cancers	2000
• lung cancers	1000
Drinking alcohol (average for all drinkers)	
• all effects	380
• alcoholism and alcoholic cirrhosis	115
Swimming	50
Playing rugby football	30
Owning firearms	30
Transportation Risks (average to travellers)	
Travelling by motor vehicle	145
Travelling by train	30
Travelling by aeroplane	
• Accidents	10
Risks Averaged over the Whole Population	
Cancers from all causes	
• Total	1800
• Lung	380
Air pollution from burning coal to generate electricity	0.07-300
Being at home	
• accidents in the home	110
Accidental falls	60
Pedestrians being struck by motor vehicles	35
Homicide	20
Accidental poisoning	
• total	18
• venomous animals and plants	0.1
Fires and accidental burns	10
Electrocution (non-industrial)	3
Falling objects	3
Therapeutic use of drugs	2
Cataclysmic storms and storm floods	0.2
Lightning strikes	0. 1
Meteorite Strikes	0.001

[1] Source: Edited from D. J. Higson, Risks to individuals in NSW and in Australia as a Whole, Australian Nuclear Science and Technology Organisation, July 1989.

Table 6: Consequences of Heat Radiation

Heat Radiation (kW/m^2)	Effect
1 .2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 1 5-20 seconds and injury after 30 seconds' exposure (at least second degree burns will occur)
12.6	• Significant chance of fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	• Likely fatality for extended exposure and chance of fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of fatality for people exposed instantaneously

Table 7: Effects of Explosion Overpressure

Explosion Overpressure	Effect
3.5 kPa (0.5 psi)	• 90% glass breakage • No fatality and very low probability of injury
7 kPa (1 psi)	• Damage to internal partitions and joinery but can be repaired • Probability of injury is 10%. No fatality
14 kPa (2 psi)	• House uninhabitable and badly cracked
21 kPa (3 psi)	• Reinforced structures distort • Storage tanks fail • 20% chance of fatality to a person in a building
35 kPa (5 psi)	• House uninhabitable • Wagons and plants items overturned • Threshold of eardrum damage • 50% chance of fatality for a person in a building and 1 5% chance of fatality for a person in the open
70 kPa (10 psi)	• Threshold of lung damage • 100% chance of fatality for a person in a building or in the open • Complete demolition of houses

Additional Information

Relevant Department of Planning Publications

Hazardous Industry Planning Advisory Papers (HIPAPs):

No. 1 - Emergency Planning
No. 2 - Fire Safety Study Guidelines
No. 3 - Risk Assessment
No. 4 - Risk Criteria for Land Use Safety Planning
No. 5 - Hazard Audit Guidelines
No. 6 - Hazard Analysis
No. 7 - Construction Safety
No. 8 - HAZOP Guidelines
No. 9 - Safety Management
No. 10 - Land Use Safety Planning
No. 11 - Route Selection
No. 12 - Hazards-Related Conditions of Consent

Other Publications:

Applying SEPP 33: Hazardous and Offensive Development Application Guidelines

Multi-level Risk Assessment

Locational Guideline: Liquefied Petroleum Gas Automotive Retail Outlets

Locational Guideline: Development in the Vicinity of Operating Coal Seam Methane Wells

Electronic copies of some of these publications are available at:
www.planning.nsw.gov.au