Proposals for revised policies to address societal risk around onshore non-nuclear major hazard installations

Initial regulatory impact assessment

Objectives

1 Societal risk is a term used to describe the likelihood of a number of people being harmed in an incident.

2 HSE is launching a consultation exercise to consider whether current arrangements to manage societal risk are suitable and sufficient. That is, that they achieve an appropriate balance between limiting the risk of incidents that may impact on large numbers of people, the benefits of the on-site activities (e.g. clean drinking water), and the benefits of developing land for residential, commercial or recreational use. Both on-site risk reduction measures, and modifications to the planning system, will be included in the consideration.

3 The consultation exercise on societal risk, of which this RIA forms part, complements the consultation exercise on land use planning around large petroleum storage sites which was launched on 27 February 2007. Whereas the RIA for land use planning around large petroleum storage sites considered the costs and benefits of changes to the land-use planning system to manage off-site risks posed by large petroleum storage sites such as Buncefield, the aim of this RIA is to explore the wider issue of how to account for societal risk in the management of all major hazard sites (excluding nuclear and pipelines). To avoid over-emphasis on Buncefield type sites, the RIA for land use planning around large petroleum storage sites considered only individual risk – it did not attempt to take in to account societal risk.

Background – why is action needed

Managing risk on and around major hazard installations

4 Major hazard installations is the term given to industrial sites that, because of the nature and quantity of the substances present, have the potential for accidents that could cause serious harm to people on-site and in the surrounding area. Examples include:

- Chemical plants such as sites where toxic gases are manufactured and used.
- Liquefied petroleum gas (LPG) and liquefied natural gas (LNG) storage facilities.
- Refineries.
- Water treatment plants.
- Sites where highly flammable liquids are used, stored and distributed

5 The hazards presented by such installations can extend beyond site boundaries and can impact on surrounding communities. Effects depend on the type of installation but examples include the possible release of a cloud of toxic gas or a fire/explosion involving flammable substances.

Managing risks at source

6 The risks from major hazard installations are primarily managed through on-site accident prevention and mitigation measures required under specific health and safety legislation, the most notable of which is the Control of Major Accident Hazard Regulations 1999 (COMAH) which implements a European Directive known as Seveso II.

7 Under COMAH, operators of major hazard installations must 'take all measures necessary' to prevent major accidents. The Health and Safety Executive (HSE), which enforces these measures, considers this to be equivalent to reducing risks *'as low as is reasonably practicable'* (ALARP), as required under the Health and Safety at Work Act (1974)[1].

8 Installations within scope of COMAH are split between 'top-tier' and 'lower-tier' sites, depending on the amounts of hazardous substances that are present and hence the level of hazard they pose. Top-tier sites are subject to more rigorous regulatory controls and are required to submit a safety report to HSE describing the site, processes, hazards and risk and demonstrating that their risks are ALARP.

Mitigating residual off-site risks

9 The residual off-site risks of major hazard installations are managed through the planning and development system. Local authorities are obliged to consult HSE on planning applications around these sites (specifically those within a consultation zone determined by HSE). HSE then advises planning authorities on whether the development should go ahead, based on an assessment of the off-site risks from the site. The decision to grant planning permission remains with the planning authority, but experience shows that HSE's advice is followed in the vast majority of cases. HSE also has the right to request a 'call-in' of a decision to Ministers if it so wishes.

Assessment of the risks posed by major hazard sites

Individual risk

10 Health and safety legislation such as COMAH has, for many years, required major hazard sites to be designed, constructed and operated in such a way that the risk of an accident occurring is ALARP.

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[1] The term ALARP captures the primary legal requirement in British health and safety legislation, which says that those who create risks must reduce those risks so that they are as low as is reasonably practicable. '*Reasonably practicable*' is not defined in law, but the Courts have decided that in practice it means implementing measures to reduce the risk up to the point at where the cost of any further measures would be '*grossly disproportionate*' to the additional risk reduction that would be achieved. What is meant by '*gross disproportionate*' is again not specified but it means that the higher the risk, the more effort and money should be spent on reducing that risk. But it also means that there are limits to the expenditure plant operators must make on safety at their plants.

11 To date, HSE and site operators have used individual risk as the basis for making assessments of the risk posed by major hazard sites and decisions as to what on-site measures need to be carried out to ensure that it is ALARP.

12 Individual risk relates to the likelihood that a person in a particular location will be killed or seriously harmed in the event of an incident. It is not dependent on the size of the population.

13 HSE's advice to planning authorities is also largely based on individual risk and only takes limited account of the total number of people who could be affected, in that individual developments with larger numbers of people are advised against more often than those with smaller numbers. There is no consideration of cumulative developments, and so, as long as small-scale developments are allowed, population is likely to build up over time, raising the potential number of people who could be affected by an accident.

Societal risk

14 The introduction of COMAH has meant that in the past few years site operators have had to provide HSE with additional information about the potential effects of major accidents at their sites – information about their likelihood, how far the effects might be felt off-site and how much harm might be caused to people in the event.[2]

15 HSE has used the new information it has been given to estimate societal risk for major hazard sites[3]. Societal risk differs from individual risk in that it takes into account the total number of people who may be harmed at the same time by a single incident. The level of societal risk from an installation is determined by three factors:

- The probability of an incident occurring on a major hazard site.
- The nature of the incident.
- The density and location of the population working on or living around the site.

16 The size and density of the population living around the relevant sites is the key factor in estimates of societal risk. If the population is spread fairly evenly throughout the area around a site, then it is more likely that, say, a toxic gas cloud (which could go in any direction) would find its way to a populated area and cause harm to a significant number of people. Similarly, the concentration or density of the population will also affect societal risk – the more buildings (e.g. houses) in any particular area, the more people could be harmed by a gas release going over that area.

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[2] It will be emphasised throughout this RIA that such events are extremely unlikely due to the precautions operators must have in place to prevent them. Nevertheless, a significant number of people could be harmed if such an incident did take place.

[3] Societal risk is not a new concept. In the 1960s and 1970s, sophisticated risk assessment techniques were developed which enabled experts, for the first time, to analyse in numerical terms the likelihood and consequences of various accident scenarios at major hazard installations. But such techniques were, and still are, very difficult and costly to carry out, requiring a lot of time and money. The techniques HSE has developed have been able to use the information from site operators to make a fairly quick but approximate estimate of societal risk levels. Accordingly, the estimates should be treated with some caution.

17 Additional development in the area surrounding major hazard sites which result in further build-up in population are likely to raise the level of societal risk since the total number of people which could be affected in the event of an incident has increased. However, the risk of an incident – and therefore the individual risk – would remain the same.

Individual risk versus societal risk: an illustrative example

18 The distinction between individual risk and societal risk can be illustrated using the following hypothetical example. Consider two sites A and B. Site A is located in a sparsely populated area while Site B is situated in an inner city area that is densely populated. Let us assume that both sites have the same probability of an identical incident occurring. However, the population living around Site A is 1,000 people while at Site B it is 100,000 people.

19 On the basis of individual risk, the two sites would pose the same degree of individual risk to a person at the same distance away from each site. In contrast, on the basis of societal risk – which takes into account the number of people which would be affected in one incident – Site B would pose a higher degree of risk than Site A because there is a higher likelihood that the incident would kill or harm a large number of people. This reflects the fact that the population density around Site B is higher than around Site A.

20 The estimation of societal risk is not an exact science and is consequently less reliable than the estimation of individual risk. This is because societal risk is largely dependant upon how the additional impacts are modelled.

Accounting for societal risk in practice

21 If HSE were to use societal risk as the basis for assessing whether the risks posed by sites are ALARP, this could result in site operators being required to introduce on-site risk reduction measures to reduce levels of societal risk that will have increased as a result of decisions taken by planning authorities to approve developments around their site. Thus, even though there may have been no change in on-site activity, site operators could have costs placed upon them as a result of decisions, and changing circumstances, over which they will have had no control.

22 The impact of these costs could, however, be offset partially or indeed entirely by the requirement already placed upon HSE when policing the ALARP principle to ensure that the costs of any requested measures are proportionate to the likely benefits in terms of the reduction in risk achievable. Planning authorities are also required to consider the compatibility of new development with existing industrial and commercial development and to recognise that such development may result in costly new restrictions being imposed on industry (PPG4).

23 In any case where proposed development around a site would raise societal risk levels it may be entirely appropriate for consideration to be given by site operators to what on-site measures might counter such an increase and then for operators, developers and planning authorities to allocate the costs of implementing

these between relevant parties, on an economically rational basis so that development could go ahead.[4]

The rationale for using societal risk

24 The problem with using individual risk as the basis for measuring risk on or around major hazard installations is that it does not take into account the total number of people that could be affected by an incident. Even if individuals correctly take into account the risks they face, they have no reason to include the societal risk arising from multi-fatality incidents. Similarly, if guidance to local planning authorities is based largely on individual risk it will fail to make allowance for the total number of people that could be affected by an incident.

25 If industry bases risk management on individual risk only, which can be described as incomplete information about the full impact of an incident as it does not allow for societal risk, it might be argued that the overall risk posed by the site is not being taken into account.[5] If land use planning advice is based on incomplete information about the full impact of an incident, then population densities around hazardous sites may become higher than would otherwise have been the case if societal risk had been taken into account.

26 Indeed, the estimates of societal risk which HSE have calculated suggest that there are a number of sites where the population in the surrounding areas has built up over time and raised societal risk levels to a point where it would now be sensible to take account of it when considering future development proposals around the sites and when operators assess on-site risk reduction measures.

27 However, while using societal risk as the basis for assessing the risk of major hazard sites may address one type of market failure – that of incomplete information – it gives rise to another in the form of costs that fall upon one party as a result of the actions of another.

28 Such costs arise because societal risk is determined by the density and location of the population who could be affected by an incident. As further development takes place near the site, so the population density and consequently the level of societal risk rises – even if the risk to an individual person is still the same. This implies that the level of the cost falling on other parties also increases.

29 Yet, developers – indeed planning authorities or HSE – do not currently take into account the rise in societal risk brought about by the decision to build near the site and its implications either for the site operator or indeed other developers who may wish to build near the site in the future.

30 The result may be that the site operator is required to put in place even more stringent on-site risk reduction measures that could be very costly to implement. For

[4] No formal mechanism exists to redistribute costs between industry and developers and there is no legal requirement for companies to do more than is reasonably practicable but this is clearly an idea that could be given further consideration.
[5] It is important to emphasise however that the risks to individual people from such sites are no higher than before.

developers planning to build in the future, the implications may be that the proposed development is either rejected or potentially scaled back (because societal risk would rise too much). In both cases businesses incur a cost, either in the form of additional safety improvements that would not otherwise have been required, or in the form of revenue foregone because the scope for further development in the surrounding area may be restricted.

Costs of managing risk on or around major hazard sites on the basis of societal risk as well as individual risk

31 The costs borne by industry and developers will depend partly on the way in which societal risk is managed. Societal risk can be managed in three different ways:

- By carrying out additional accident prevention and mitigation measures on-site.
- By maintaining the existing density of housing/ commercial development and/or wherever possible reducing development density to ensure population in the vicinity of major hazard sites remains below that which would increase societal risk to the point at which it becomes a concern.
- By a combination of the above.

Cost to industry from using societal risk to assess and manage on-site risks

32 The costs to industry of carrying out additional on-site accident prevention and mitigation measures may take different forms. These may include:

- Direct costs - major hazard installations may, for example, have to pay to install new and improved storage vessels or hire more health and safety staff.
- Indirect costs – firms may incur efficiency losses arising from restrictions placed on its activities or the adoption of new practices which increase on-site costs or reduce overall revenue (e.g. a firm may decide to transport toxic chemicals by pipeline rather than tanker which would prove relatively more expensive).
- Investment costs – firms which face tight budget constraints may find that additional on-site measures can only be afforded by foregoing further investment in new capital, research and development and skills and training, reducing in turn potential productivity growth.
- Reputation costs – if as a result of measuring risk on the basis of societal risk a major hazard installation is perceived as more risky than before its share valuation may fall, adversely affecting its ability to borrow capital. The firm may also have to pay higher insurance premia since the extent and severity of an incident is now perceived to be greater[6].

Costs to developers from using societal risk in land use planning

33 Where a development does not go ahead because of HSE advice, the cost of maintaining risk levels is effectively borne by developers in the form of the entire abandonment (or at least scaling down) of potential housing, commercial and recreational amenity projects. The relevant cost is therefore the ‘opportunity cost’ of

[6] It could however be argued that the reputation of major hazard sites may be enhanced if they are seen to implement measures which reduce further on and off-site risks.

not developing in a particular location – the cost arising out of the fact that developers cannot build on their first choice site. If they wish to continue with the development they may have to choose a new site that may be less profitable (for example, because the costs of development is comparatively higher).

34 In the RIA for land use planning around large petroleum storage sites the opportunity cost of restricting development was calculated as 10% of the uplift in the value of land associated with planning permission being granted[7]. The cost of each option was then calculated using an estimate of the number of development applications likely to be turned down. For example, under option 3 the number of development applications likely to be turned down was estimated to be around 30 per year, which meant that the opportunity cost was estimated to be around £10m in net present value terms (discounted over 30 years). This relatively low cost reflects the fact that, according to available data, we would not in any event expect there to be many developments proposed on land affected by the new restrictions.

35 It is not possible to produce an equivalent estimate of the number of planning applications turned down as a result of incorporating societal risk into the land use planning process. This is because the new proposals are at an early stage and the extent of restrictions around each site has not been determined. Nor has there been any analysis of how new restrictions are likely to translate into planning applications being refused that would previously have been granted. Broadly, the cost of incorporating societal risk into land use planning will reflect the number of planning applications turned down: if the proposals result in more than 30 planning applications being turned down each year (that would otherwise have been approved) then costs will exceed those estimated for the restrictions proposed around large petroleum storage sites.

36 As well as the opportunity cost of not being able to develop a chosen location, developers may also experience additional planning application costs. Making a planning application is costly in terms of the time taken, the resources required and the payment of planning fees. If, as a result of a change in the way we treat societal risk, plans have to be revised then this costly process may have to be repeated. This may also delay development while plans are being adjusted to take into account the new treatment of societal risk.

Costs to wider society and the economy

37 The introduction of measures to manage societal risk may also have the following negative effects on society and the economy:

- Reduce provision of new and more affordable housing – Following the Barker Review of Housing Supply, the UK Government is committed to making housing more affordable by increasing the supply of housing. If new measures aimed at managing societal risk lead to a reduction in the amount of land available for development, then this may restrict the number of new houses being built, and consequently, the extent to which houses become more affordable.

[7] See http://www.hse.gov.uk/consult/condocs/cd211.htm

- Moreover, given that many brownfield sites are located around major hazard installations, restrictions on the amount of brownfield land for development may have some small effect on the UK Governments ability to achieve its target of 60% of new dwellings built on brownfield land by 2008[8].
- Reduce provision of new and better local amenities – If, as a result of new measures, some proposed developments now do not take place or do on a relatively smaller scale, then local residents may be denied access to improved amenities and facilities such as hospitals, leisure centres and new shops.
- Restrict economic growth at the local level – Limits on development can adversely affect the local economy by constraining wealth and job creation. Restrictions on new housing developments may mean that local businesses do not benefit from a larger local labour force and customer base and make the area less attractive for prospective firms considering establishing there.
- Impede regeneration at the local level – Some of the major hazard installations are located in areas of deprivation (e.g. pathfinders) or areas targeted for regeneration. Given that these areas have already been identified as requiring government assistance, measures which create additional impediments to development may have a more significant impact in these areas than others.
- Potential decline in local house prices – Although individual risk at major hazard sites would remain unchanged, the perception of risk may be affected. If residents, or potential new residents, in the area perceive there to be an increase in risk then it is likely that demand for housing around these sites would fall, leading to a possible decrease in the price of local housing. These price falls may be further compounded if the new measures limit the provision of new amenities in the locality.

Costs to government

38 There will be some costs borne by the HSE and planning authorities in the form of administration, communication and implementation of new land use planning regulations. These additional costs currently remain unquantified: we would welcome views from local planning authorities on what costs they may face.

Benefits of managing risk on and around major hazard sites based on societal risk rather than individual risk

39 The benefit of restricting land use around hazardous sites is that the off-site consequences of an incident will be smaller; because more developments in the vicinity of a site have been advised against, there will be fewer people affected. Therefore, we may expect to see lower numbers of fatalities and injuries, reduced medical costs and less damage to surrounding property and economic infrastructure. At the extreme, if there are no people living or working close to a hazardous site then the off-site health and safety consequences resulting from an incident will be zero (for the purposes of this analysis).

[8] The UK Government first announced the target that 60% of new dwellings should be built on brownfield land by 2008 in the policy statement "*Planning for the Communities of the Future*" and was later reiterated in "*Planning Policy Statement 3: Planning for Housing*." The rationale for the brownfield target is to protect environmentally valuable greenfield land and to regenerate, often contaminated or derelict, brownfield land.

40 While reducing/restricting the size of the population around a hazardous site has benefits in terms of increased safety and reduced economic and environmental damage, it also gives rise to costs in the form of lost opportunities for developers to make use of this land and individuals being able to benefit from housing, amenities and workplaces in a particular location. In short, there is a trade-off between reducing risk and developing the land.

Individual risk: where do the benefits and costs equate

41 In terms of individual risk, HSE explored the trade-off between safety and development in the RIA for land use planning around large-scale petrol storage sites. As the analysis looked only at individual risk, no account was taken of the possibility of an incident affecting a large number of people simultaneously (societal risk).

42 In analysing the safety benefits for an individual of not being exposed to risk, the analysis in the petrol storage sites RIA closely followed the valuation techniques set out in Evans et al (1997)[9]. The RIA calculated the 'balancing' level of risk - the level of risk at which the safety benefits to an individual of not living near a hazardous site (i.e. of not being exposed to risk) are equal to the costs imposed through not developing land. Following Evans et al, the opportunity cost of lost development was assumed to be 10% of the 'development value' of land and safety benefits were monetised on the basis of the Department for Transport's estimate for the value of a fatality prevented (£1.4 million in 2006).

43 The petrol storage sites RIA found that, on the basis of individual risk, the balancing point between development and safety is $8.8*10^{-5}$, or 88 chances per million (cpm). Below this level of risk the opportunity cost of not developing land exceeds safety benefits, while at levels of risk above 88cpm the safety benefit to an individual of not being exposed to risk exceed the opportunity cost of not developing land. In respect of both costs and benefits this calculation is for an average case – an individual with the same willingness to pay for risk reduction measures as the population-wide mean, living in a home with 2.4 people, occupying land with the average development value for England and Wales.

How does societal risk change the balancing point?

44 Societal risk is concerned with the occurrence of multiple fatalities at one point in time. The idea is that the cost to society of simultaneous multiple fatalities is greater than the cost associated with the same number of fatalities occurring at different times or places (a discussion of empirical evidence surrounding this proposition can be found in Annex 2). Giving more than proportionate weight to multiple fatality events is known technically as scale aversion (reflecting a particular aversion to incidents with a large consequence in terms of number of fatalities)[10]. Clearly, the effect of incorporating scale aversion into our analysis will be to shift the 'balancing point' between the benefits of safety and the cost of not developing land in favour of safety.

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[9] AW Evans *et al* "Third Party Risk Near Airports And Public Safety Zone Policy", NATS, 1997
Evans et al, paragraphs 11.16 – 11.37

[10] Some people also consider that further (or different) weight should be applied in certain contexts to reflect 'societal concerns'. These are context-specific and subject to judgment.

45 In Annex 1 we attempt to show this algebraically by adapting the formula used to calculate the balancing point to account for societal risk. It is important to stress that while much progress has been made to develop sophisticated risk assessment techniques which can be used to estimate the level of societal risk posed by major hazard sites, relatively less work has been done attempting to monetise societal risk (i.e. to put a money value on this kind of risk). Thus, there is no accepted methodology that would allow societal risk to be captured in the formula used to calculate the balancing point between reducing risk and developing land. As a result, the analysis set out in Annex 1 represents very early thinking on how this could be achieved.

46 Within the limited confines of the analysis described in Annex 1, we show that the effect of incorporating societal risk is to shift the balancing point in favour of safety. Using only individual risk the boundary where development should not be allowed is where risk exceeds 88cpm. Depending on the functional form for societal risk and value of H (number of households) chosen, this falls to between 28 and 4.4 cpm when societal risk is included. However, there are no empirical data underlying the equations we use to monetise societal risk, and hence any conclusions should be treated with extreme caution.

Other benefits

47 In terms of better regulation, these proposals could lead to a reduction of regulatory intervention through a clearer indication of the potential risk associated with a draft development plan and a better steer early on. They could also help encourage investment around a site as it would cut down on the length of time (hence cost) of any development below the threshold.

Hypothetical cases

48 Three hypothetical examples based on information gathered from site visits carried out during summer 2006 have been constructed to illustrate the issues discussed above. They suggest that:

49 Further development around major hazard sites can lead to significant increases in the level of societal risk

50 Reductions in the level of societal risk may in some cases be achieved through additional on-site measures but at considerable cost to the site operator who may be unwilling to implement them immediately because of the long life-span of some equipment

51 Potentially large economic benefits in the form of new employment opportunities and new amenities may be foregone if proposals for further residential and commercial development around the site is rejected or scaled back

Hypothetical case #1

52 A company uses highly flammable liquids, which are stored on an industrial site in a 125 tonne bulk storage vessel. The level of societal risk associated with the site is already high. The company has already taken many steps to reduce the risk of an accident associated with the use and storage of these highly flammable liquids.

53 Inventories are run as low as possible (levels are kept at 75 tonnes), and the company uses 50-60 tonnes each day. The vessel could be replaced with a new design (approximate cost of £1.3m) or with two smaller vessels (approximate cost of £2.1m). However, as the existing tanks are only 12 years old and after inspection found to be fit for purpose for another 30 years or so, the above expenditure is not planned and unlikely to be carried out willingly. It is likely that calculations would show that such an investment would not be reasonably practicable.

54 The site is located in a sparsely populated area. The local planning authority has plans for major housing development (some 15,000 houses) and commercial development including a major employment zone (1000s of jobs). Since most of the new development falls outside the existing consultation zone, the increase in societal risk would be minimal (less than10%).

55 In this case it is likely that after balancing the increased level of societal risk against the benefits of development, the development would be permitted.

Hypothetical case #2

56 A company stores highly toxic chemicals in four 70 tonne single skinned storage vessels. Inventories are run as low as possible (levels are kept at around half capacity). The level of societal risk associated with the site is currently very high. The company aims to replace the tanks in 5 years time at a cost of some £5-8m.

57 The site is located in a key area of regeneration. About a dozen brownfield sites have been identified within the consultation zone for new housing (4,500 new houses on 130ha) and business and employment development (150ha). One area within the current zone has been identified as a prime employment site and one of regional importance for attracting inward investment.

58 If all these potential developments go ahead, the larger population densities would cause societal risk levels to increase by around 65%. This increase would however be offset if the company installs replacement storage vessels in 5 years time.

59 In this case the advantages of the proposed development and the disadvantages of higher societal risk levels are more finely balanced but it would not be unreasonable to permit the development particularly in view of the planned replacement of the storage vessels.

Hypothetical case #3

60 A company stores toxic gas in two 30 tonne storage tanks on site. The level of societal risk associated with the site is relatively high. The two storage tanks are kept at around 90% capacity. The tanks – which have a lifespan of 30 years – are only 10 years old and judged to be in very good condition by inspectors. Consequently, the

company has no plans to replace them in the foreseeable future. The gas could be generated on the site, but the cost of £5-6m would represent a major financial burden for the company, and is not one they consider reasonably practicable. The company has already carried out a cost-benefit analysis, and had considered to moving to 'just in time' deliveries to reduce the quantity of material stored in their tanks. However, such a move would increase individual risk considerably.

61 The site is located in a densely populated area with many residential properties within the middle and outer zones of the existing consultation. The local planning authority has plans for housing development (1,100 dwelling units on 28ha), employment development (12ha) and retail development (25ha) on several brownfield sites in the consultation zone and has earmarked a further forty or so sites for redevelopment.

62 If all the developments were to take place in the existing consultation zone, current societal risk levels would increase by up to 200% to a level which would raise concern.

63 In this case the increase in societal risk levels would suggest that it may be sensible to scale back the level of proposed development.

Small firms test

64 There will be no disproportionate impact on small firms

Competition assessment

65 There will be no effect upon competition

Conclusion

66 Although there has been no increase in the risk of an accident occurring at major hazard sites, we need to consider whether the additional information and risk measurement methodologies that are now available to HSE, should be incorporated into the future management of risk.

67 HSE's work to date indicates that there are only a limited number of existing sites where the introduction of societal risk calculations may result in future advice on planning applications, or future advice to site operators, being different from that which might otherwise have been the case. This is because:

- Only a relatively small proportion of all major hazard sites give rise to a level of societal risk that makes such consideration appropriate.
- Of these, only those using or storing toxic materials or flammable materials stored under refrigeration would require consideration of societal risk beyond the existing consultation zone.
- The existing basis on which advice is given to PAs by HSE (largely on individual risk) would already prevent many of the developments within the existing consultation zone that could increase SR.

- Whilst SR considerations at some sites storing toxic materials may be necessary beyond the existing consultation zone (and up to about twice that distance from the plant), only very large developments would have any large impact on SR levels beyond the existing consultation zone.
- Around many of the sites being considered, there are limited opportunities to develop due to their location, e.g. the land around them is already built up.

68 In those limited number of instances where consideration of societal risk will affect the advice offered by HSE, this RIA indicates that a suitable generic framework can be established to determine the balance of costs and benefits resulting from the modified approach to risk management.

69 The RIA indicates that for affected sites, incorporating societal risk will, as a general rule may change the balancing point between safety and development, with a greater emphasis on safety. This change is likely to generate additional costs for both major hazard operators and developers.

70 Importantly, the RIA establishes that the precise costs and benefits associated with any change to current practice from utilising societal risk are site specific. They are driven by the unique interaction between the individual characteristics of the major hazard site and the composition and spatial configuration of its local surroundings. Thus it is not possible to estimate aggregate costs and benefits at this stage, as we do not know the precise number of sites that would be affected, nor exactly how they would be affected. The extent to which the developer and the site operator allocate the costs will depend on the scope for further on-site reduction of risk. The cost to the site operator will depend on the exact nature of the on-site risk reduction. The cost to developers will depend on the extent to which they are not able to develop at their preferred location. Losses to the community will depend on the extent to which planned amenities can no longer proceed. These factors are all specific to the site in question. In addition it still remains with the Local Planning Authority to make the final decision, taking into account the HSE's advice.

71 Assessing the consequences of incorporating societal risk will need to be examined on a case by case basis utilising the generic approach developed within this initial RIA and taking into account the results of the public consultation.

Annex 1: Algebraic interpretation of the trade-off between reducing risk and developing land

There is no consensus on the extent of societal risk and how it should be valued. For the purposes of the analysis presented in Annex 1 we have adopted an approach using quadratic functions, allowing us to demonstrate both the uncertainty and volatility surrounding estimates of societal risk. The objective is to illustrate the concept of societal risk by incorporating it in a formula that relates the value of risk reduction to the number of households affected in a single incident. In the absence of a consensus from which we may derive estimates for societal risk, we can only illustrate the effect that different formulas would have. A review of the literature is included in Annex 2.

Below we build an algebraic interpretation of societal risk based upon previous analysis conducted on individual risk.

The equation for individual risk is as follows:

Equation 1

$$\text{NPV} = \text{nvr x} \left[\frac{\left(1 - \frac{1}{(1+d)^m}\right)}{\left(1 - \frac{1}{(1+d)}\right)} \right]$$

where
NPV = the net present value of risk reduction (i.e. NPV of safety benefits)
d = the discount rate
m = the discount period (years)
n = the number of people per household
v = the value of a statistical life
r = the level of risk

This equation provides a means for calculating the balancing point in the context of individual risk. It states that, provided the reduction in the risk of death for any given individual is small, the monetary value of the benefit of n people each experiencing a small risk reduction, r, will be given by n* v* r, where v is the value of statistical life. Thus, if the average household contains n occupants, each of whom enjoys a small reduction r in the annual risk of death every year for m years, then the overall discounted present value of this risk reduction will be given by n *v* r* f (m, d) where f (m, d) is the discount factor applicable to a constant sum arising each year for m years at a discount rate d per annum. By manipulating the equation used to calculate individual risk we can arrive at the balancing point where costs equal benefits. The balancing point using individual risk will be the same regardless of the number of people affected by an incident.

Accounting for societal risk will have the effect of lowering the balancing point. To adjust the equation for individual risk to include societal risk we need to introduce a new term that takes account of the number of households (H) potentially affected in a single incident. This function, f(H), should reflect the nature of societal risk, in that the cost of a multiple-fatality event must be greater than the same number of separate individual fatalities occurring at different times. To reflect this scale effect we have used a quadratic function, as follows:

Equation 2

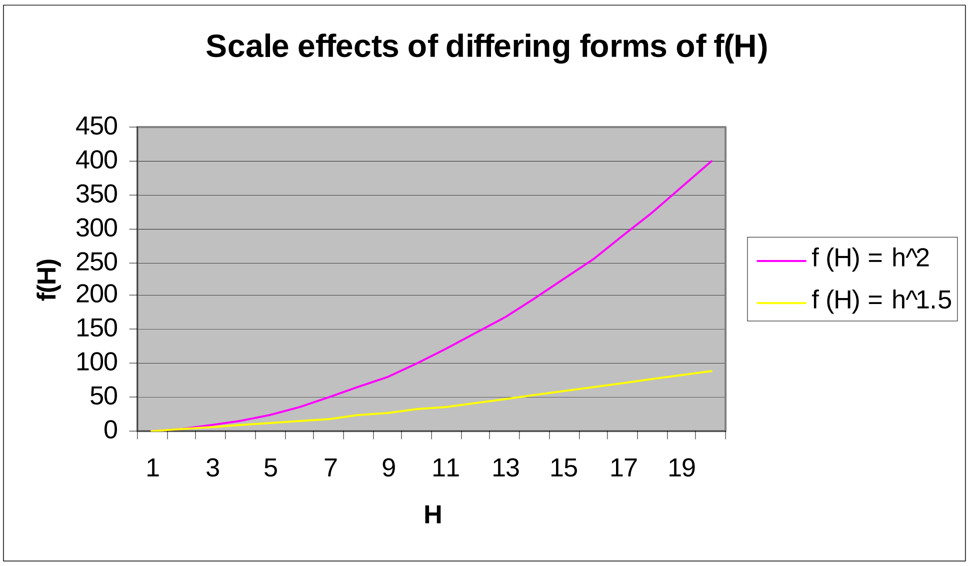
$$\text{NPV} = f(H)nvr\left[\frac{\left(1 - \frac{1}{(1+d)^m}\right)}{\left(1 - \frac{1}{(1+d)}\right)}\right]$$

Where:

f (H) = H^2
H = is the number of households potentially affected simultaneously by a single incident

It is important to realize that there is no agreed functional form for f (H), reflecting economists' uncertainty over how monetise societal risk and hence how to capture it in the formula used to calculate the balancing point. In addition to the function f (H) = H^2 we have also looked the effect of using the functional form f (H) = $H^{1.5}$. In both cases the important point is that there is a non-linear relationship between the number of households affected by a single incident and the value of societal risk. Figure 1 illustrates.

Figure 1



To estimate balancing risks including a societal risk function we have used the assumptions for other variables used in the analysis of individual risk around fuel storage sites, namely:

d = 1.5% [11]
m = 30 years
n = 2.4
v = 1.4 million

Using these estimates, Table 1 shows the impact of incorporating societal risk on the balancing point between developing land and reducing risk. It looks at two different functional forms for f (H) and values for H of 10 and 20. Because we assume there are 2.4 individuals per household, when H is 20 there would be 48 fatalities from a single incident. The balancing levels of risk have been calculated by simply rearranging equation 2 to be expressed in terms of r.

The question addressed in the societal risk consultation document is how the likelihood of an incident affecting a large number of people simultaneously (societal risk) should be incorporated into land use planning advice. It does not address where the appropriate boundary between developing and not developing should lie: at 100cpm, 10cpm, 1 cpm or some other risk level.

HSE operates a zoning scheme, reflecting the fact that the nearer an individual is to a major hazard site the greater the level of harm or risk would be. In each case, the risk relates to an individual sustaining the so-called ‘dangerous dose’ or specific level of harm. The three zones represent levels of individual risk of 10 cpm in the inner zone, 1 cpm in the middle zone and 0.3 cpm in the outer zone per year respectively of

[11] This is the standard discount rate for health-related benefits taken from the Treasury green book.

receiving a dangerous dose or defined level of harm. HSE advice is most restrictive where risks exceed 10cpm and least restrictive where the risk is between 1 and 0.3 cpm.

Table 1 - Impact of societal risk on the balancing point between reducing risk and developing land

	H	
f(H)=	10	20
H^2 $H^{1.5}$	$8.8x10^{-6}$ $2.8x10^{-5}$	$4.4x10^{-6}$ $2x10^{-5}$

Table 1 demonstrates that including a term for societal risk shifts the balancing point between reducing risk and developing land, when compared to the calculation based solely on individual risk. Before incorporating societal risk, the NPV of the opportunity cost of not developing a plot of land for housing (£7,200) equates to the NPV of safety benefits at a level of risk of 8.8 x 10^{-5} (88 cpm). Including societal risk, using the functional form f (H) = H^2 and setting H= 20, increases the value put on safety to such an extent that it equates (in NPV terms) to £7,200 at a risk level of 4.4 x 10^{-6} (4.4 cpm).

Table 1 also reveals that the form of the function f(H) appears to have a greater impact on the balancing level of risk than the size of H, at least in the cases chosen. Looking solely at results with H equal to 20, moving from a quadratic function to a function equal to $H^{1.5}$ shifts the balancing level of risk by an order of magnitude from 4.4 x 10^{-6} (4.4 cpm) to £7,200 at $2x10^{-5}$ (20 cpm). Using the function where f(H) = $H^{1.5}$ instead of f(H) = H^2 produces results at a level of risk closer to that faced under individual risk. This demonstrates that the level of risk is highly sensitive to the assumption made about the form of f(H).

In the above treatment the simple (practically rare) situation is considered where a collection of developments share the same level (frequency) of individual risk and can all be affected by all accidents of interest. Much more complex situations are normal. "Risk integrals" (link ref CRR 283), which can be estimated with a selected degree of scale aversion, can provide a measure of societal risk before and after a development (or set of developments). In place of the very simple functional forms adopted above, it may be possible to develop a function that would provide a value for societal risk through monetising the RI index via an appropriate formula. We have not attempted such an exercise.

There are a number of practical reasons which could justify the gap between the balancing point suggested by economic analysis and the levels of risk used in practice:

- Uncertainty about the estimates used to value safety, for instance about the appropriate value per fatality prevented.
- Uncertainty about the estimates used to calculate the opportunity cost of not developing land. For instance, where industrial developments would be permitted but housing would not, the opportunity cost of not developing land is likely to be lower than when all types of development are prohibited. This is

because the opportunity cost reflects the uplift from industrial development land to housing development land, in contrast to the uplift from farmland to housing development land.

- Incompleteness of estimates. For instance, they do not attempt to value the safety benefits of avoiding non-fatal injuries (if there were 7 major injuries averted per fatality then the level of benefit associated with averting a fatality would increase by a factor of two).
- Use of historical data. In recent years there has been a shift in the relative price of safety and land in favour of developing land, caused by a very rapid increase in development values (see Fig 1 from the petrol storage sites RIA). This has meant that the balancing level of individual risk has increased from an estimated 37cpm in 1993 to 88cpm in 2006.
- The impossibility of quantifying all potential impacts on the real world of policy options.

Annex 2: Literature review of societal risk and scale aversion

There is no clear consensus about how societal risk should be valued. We present below some of the views expressed in the literature.

Beattie et al (2000[12]) attempted to measure the extent of scale aversion (i.e. societal risk) by asking members of the public to rank a multiple-fatality accident involving X people against X number of single fatality accidents. Their results show that, perhaps surprisingly, members of the public presented with informed choices show very little scale aversion. In their view, averting 10 individual fatalities is of nearly equal benefit to averting 10 simultaneous fatalities. The conclusion from Beattie et al's willingness-to-pay study is therefore that societal risk is a socio-political construct, rather than one that reflects individuals' informed preferences.

Nevertheless, it is clear that many private sector companies, including those involved in major hazard industries, do assume that a single incident affecting a large number of people is worse than many small incidents affecting an equal number of people, and place a disproportionate premium on safety measures that reduce the risk of large-scale incidents. Moreover, contrary to the work by Beattie et al, other studies have asserted that there should be a disproportionate premium associated with large scale incidents. A list of some of these studies follows below:

"catastrophic potential - people are more concerned about fatalities and injuries that are grouped in time and space (airplane crashes) than about fatalities and injuries that are scattered or random in time and space (auto accidents);" [Covello, V.T. and Merkhofer, M.W. 1994. Risk Assessment Methods. Plenum Press, New York. 319 pp. cited in 'An Introduction to Risk Communication and the Perception of Risk; Douglas Powell, University of Guelph ©1996 at http://www.foodsafetynetwork.ca/risk/risk-review/risk-review.htm]

"Experience suggests that: …A large number of incidents spread over a wide area is much more acceptable than if the same effect took place at one time in one place. (consider the impact if all the annual deaths from lung cancer took place at one location on one day)". [Royal Academy of Engineering Report 'The Social Aspects of Risk']

"The slope of the FN curve is designed to reflect the society's aversion to single accidents with multiple fatalities as opposed to several accidents with few fatalities" ['Risk acceptance criteria for Hydrogen Refueling Stations' February 2003, report by Norsk Hydro ASA and DNV, European Integrated Hydrogen Project [EIHP2]

"The formula (5) accounts for risk aversion, which will certainly influence acceptance by a community or a society. Relatively frequent small accidents are more easily accepted than one single rare accident with large consequences, although the expected number of casualties is equal for both cases." ['Societal risk and the concept of risk aversion', Vrijling and van Gelder, Department of Civil Engineering, Delft University of Technology]

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[12] "Valuation of Benefits of Health and Safety Control" – see http://www.hse.gov.uk/research/crr_pdf/2000/crr00273.pdf

“An additional factor is a common aversion to technologies that could cause multiple fatalities. This is taken account in the Dutch societal risk criteria where (for fatalities of 10 or more); a decrease in frequency of two orders of magnitude is required for an order of magnitude increase in fatalities.” [‘Kiev assessment: draft chapter on technological and natural hazards’ submitted by the European Environment Agency (EEA) to UN economic commission for Europe, committee on Environmental policy ad hoc working group on environmental monitoring, 20 September 2002]

“As discussed earlier, other factors, such as public acceptance or non-acceptance of risk, aversion to single events with a large number of fatalities, the fear of certain types of catastrophic events, and special infrastructure impacts may enter into an assessment.” [Intermodal Explosives Working Group report, U.S. Department of Transportation, Feb 2003]

“Extensive research shows that everyday concepts of risk contain many more dimensions then just these two and are significantly richer than the traditional statistical concept of risk. An example of one dimension of risk which has been studied by many is the fear of catastrophe. This means that an accident where 100 people die is regarded as far worse than 100 accidents, each with one fatality.” [‘Risk and safety in transport’ (RISIT) Research programme, Norway Ministry of Transport and Communications]

“Yet, it is well known that people are more averse to accidents in which a considerable number of people die, or are injured, than to a series of smaller accidents, each of which produces a few fatalities, even though the total number of fatalities are the same.” [‘European Environmental Priorities’ at http://arch.rivm.nl/ieweb/eep/chapter1.pdf]