Safety Implications of Business Aviation at Farnborough Airport

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Safety Implications of Business Aviation at Farnborough Airport: Summary

1. On behalf of Rushmoor Borough Council, ESR Technology has undertaken a study of the safety implications for the local environment of future business aviation at Farnborough Airport. This study has considered the current annual movements and aircraft mix, to verify the existing safety implications of the Airport, and possible options for increased annual flight movements. The study has employed quantitative risk assessment to estimate the safety implications of these various scenarios.

2. Risk assessment is often used in support of the regulation of activities that may pose a risk to life. Quantitative risk estimates typically characterise risk in terms of two key parameters:

   - The probability of occurrence (or frequency) of the hazardous event.
   - The severity of the consequence, for example in terms of the severity of injury to those affected and the numbers of individuals killed or injured.

3. Two distinct measures are typically employed to express fatality risk in a quantitative manner:

   - Individual risk: the probability of a fatality being suffered by a hypothetical individual exposed to the hazard in question, typically expressed as the probability of fatality per year of exposure.
   - Societal risk: a quantitative measure of the risk associated with events in which there may be multiple fatalities, typically characterised in terms of the probability of an accident causing an identified number of fatalities.

4. Risk management decision making based on the findings of risk assessment requires that the significance of risks be evaluated and that their acceptability is determined, taking account of the benefits associated with the potentially hazardous activity which presents the risks concerned and the measures that may be available to reduce risks. This approach is well accepted in the UK and involves recognition that, in the constrained urban planning environment within the UK, it is not possible to eliminate all risks and that some level of risk must be tolerated in return for the benefits of development and of potentially hazard activities, including aviation.

5. A framework for assessing the significance of the risks associated with potentially hazardous activities has been developed by the Health and Safety Executive by reference to risks encountered more generally in modern society. An example risk of relevance to most people would be the risk of death from a road traffic accident which is broadly estimated at the level of 1 in ten thousand per annum. This level of risks equates with the limit of tolerability proposed by the HSE as the maximum to which some members of the public might reasonably be exposed in the wider interests of society. Risks that lie below the level of 1 in a million per annum are generally identified as being of essentially no regulatory concern and “broadly acceptable”. Risks between these two limits would normally be subject to regulatory scrutiny, increasingly so the higher the risk and the closer that it approaches the upper limit. In accordance with UK health and safety legislation, such risks should be managed to be “as low as reasonably practicable” (ALARP). This sort of approach has been applied to assess the significance of risks associated with operations at Farnborough Airport.

6. Although aircraft crashes are rare events, the majority of accidents take place during take-off and landing, close to runway ends and under flight paths to and from them. Accordingly, risks at sites relatively close to the ends of busier runways where this accident risk is concentrated may be subject to a level of risk that is higher than the general background risk from aircraft crash. Risks from aircraft crash to sites on the ground in the vicinity of Farnborough Airport have been estimated by use of an empirical model based on historical accident data that takes account of three key factors as follows:

   - The likelihood (frequency per annum) of an aircraft crash during take-off or landing operations at any given airport, derived on the basis of the historical crash frequency per movement and annual rate of movements at the airport in question.
   - The probability of impact at any given location relative to the runway end and extended centreline, derived on the basis of mathematical functions that correlate the observed distribution of crash locations.
   - The severity of the consequence of an impact on the ground, again derived on the basis of historical accident data and taking account of the size of an aircraft operating at the airport in question, as characterised in terms of its maximum take-off weight allowed (MTWA).

7. This risk modelling approach is used as the basis for the UK Public Safety Zone (PSZ) policy which seeks to prevent an increase in the numbers of people living and working in areas close to busier runways that are subject to significantly elevated risks. PSZs are applied to restrict new development at both ends of the runway at Farnborough and this policy requirement is an important aspect of this study of the safety implications of the airport since it leads to development restrictions. However, there is an important distinction to be drawn between PSZ policy and planning policy in relation to development of a new airport or expansion of an existing one which is considered in this study. PSZ policy is intended to control development close to existing airports and not specifically to address the circumstances which might arise when a new airport or significant development at an existing airport is proposed. The broader safety implications of operations at Farnborough have therefore been considered, taking account in particular of the risks to people in existing areas of development, both inside and outside the PSZs.

8. The current consent for business aviation at Farnborough places a limit of 28,000 on the annual number of movements. In accordance with recent operational experience, the impact of these operations has been assessed assuming that 95% of the total movements, equivalent to 26,602 movements per annum, involve fixed-wing aircraft, the proportion of easterly to westerly movements in the year is 22.5% to 77.5%, the average weight of aircraft is 17.1 tonnes and the crash rate during take-off and landing of aircraft operating at Farnborough is 2 per million movements. Estimates of the 1 in 10,000, 1 in 100,000 and 1 in 1 million per annum individual risk contours have been made using these modelling assumptions and the risk model of the Department for Transport that was developed to support PSZ policy. We believe that there are elements of pessimism in this modelling approach and that the risks predicted will be over-estimates to some extent.

9. The area to the north-east of the runway subject to more significant risk at and above the level of 1 in 10,000 per annum is predicted to be contained within the airfield boundary. To the south-west, the area subject to this level of risk extends slightly beyond the airfield boundary into undeveloped land. To the north-east of the airport, risk at or above the level of 1 in 100,000 per annum extends over an elongated triangle of land centred about the runway extended centreline across South Farnborough and into Mytchett. To the

south-west of the airport, the main area subject to this level of risk is predominantly but not completely free of any development and extends slightly into a small area of development in the South of Church Crookham. These developed areas comprise mainly residential housing but include also the Farnborough College of Technology. Risk at or above 1 in 1 million per annum covers a wider triangle of land extending approximately 10 km from both runway thresholds. In practice, beyond Mytchett to the north-east and Church Crookham to the south-west, the areas covered by this contour are predominantly undeveloped.

10. The impact of the current operation can be assessed by reference to the areas of developed land covered by the various risk contours and the estimated population resident within these areas, as summarised below:

    - 14.3 ha of developed land exposed to individual risk above 1 in 100,000 per annum.
    - Estimated 946 individuals exposed to individual risk above 1 in 100,000 per annum.
    - 132.5 ha of developed land exposed to individual risk between 1 in 1 million and 1 in 100,000 per annum.
    - Estimated 8,748 individuals exposed to individual risk between 1 in 1 million and 1 in 100,000 per annum.

11. It is estimated that accidents involving 1 or more fatalities would occur approximately once in every 290 years. The average number of fatalities estimated for a crash event is 12. It should be noted that the probability of an aircraft crash anywhere at or in the vicinity of the airport is 1 every 19 years and the majority of these are expected not to result in any third party fatalities. As noted earlier, we consider there to be elements of pessimism in the model employed to make these risk estimates and both the probability of occurrence of a crash and the average number of fatalities caused can be expected to be lower than these values.

12. When judged against the identified criteria for evaluating risk significance and tolerability, the risks associated with the current operations at Farnborough can be seen to be far from trivial but by no means exceptional, taking account of other risks normally accepted in return for the benefits of modern society and the risks from aviation accepted at other airports. Under such circumstances the risks to residential and urban areas as a whole in the vicinity of Farnborough Airport may be considered acceptable, provided that they are being managed so as to be as low as reasonably practicable and that the remaining risk that does arise may be justified by the benefits derived from operation of the airport.

13. Cost-benefit analysis is sometimes employed to support risk management decision making and to assist in the effective allocation of resources for risk control and risk reduction. For example, it is used by the Department for Transport in the appraisal of road safety measures and the approach involves use of a financial value for prevention of a fatality. Such an approach was employed in the development of PSZ policy to establish the balance point between the lost opportunity cost of foregoing potential development land and the benefit of preventing fatalities. The value of preventing a fatality previously identified by the DfT equates approximately to £1.25 million in today's terms.

14. Based on this value of preventing a fatality and the findings of the risk assessment, in particular the estimate of the probability of once in every 290 years for an accident causing an average of 12 fatalities, a financial value of the safety detriment associated with the current operations of the airport can be made. This safety detriment is estimated to be £52,000 per annum. The economic value of the operation of the airport would need to shown to be significant when compared with this safety detriment of £52,000 per annum in order for the airport operation to be considered acceptable. If it were not then

the measure of closing the airport to eliminate the risk would be justified in cost-benefit terms by the safety benefit that would be achieved. In our view, there are a number of pessimisms in the DfT modelling approach that has been employed in making the above estimate. The pessimisms introduce an element of "gross disproportion" into the balance, in accordance with the practice outlined by the HSE that the balance be deliberately skewed towards safety benefits where potentially significant risks are concerned.

15. Consideration has also been given to the risks arising from helicopter operations. In practice, since the number of helicopter operations is much lower than that for fixed-wing aircraft operations and the average weight of helicopters operating at Farnborough is generally relatively small, the risk associated with helicopter operations can be expected to be quite small compared with the risk from fixed-wing aircraft movements. Detailed quantitative estimates of these risks have therefore not been undertaken. The risks estimated for fixed-wing operations alone are considered to be adequately representative of the risks from airport operations as a whole, given the pessimisms in the risk modelling approach employed.

16. In considering the potential impacts associated with increased numbers of movements, we note first that the estimated risk is directly proportional to the likelihood of a crash, as measured in terms of the probability per annum of a crash, which is directly proportional to the annual rate of movements. Quite simply, therefore, increasing the annual number of movements can be expected to increase the risk, in direct proportion to the increase in the level of movements. Individual and societal risk estimates have been made assuming 35,000, 50,000 and 60,000 movements per annum and these confirm the increase in the level of risk in line with this expectation. The risk contours defining the limits of 1 in 10,000, 1 in 100,000 and 1 in 1 million per annum individual risk widen increasingly and extend further from the runway threshold with increasing numbers of movements. For annual movements up to 50,000, it is estimated that risks at or above 1 in 10,000 per annum will not extend into any developed areas. The areas subject to risk between 1 in 10,000 to 1 in 100,000 per annum and 1 in 100,000 to 1 in 1,000,000 per annum are summarised in the table below. For 50,000 movements per annum, the probability of events involving 1 or more fatalities is estimated to be approximately 1 in 160 years, as compared with 1 in 290 years for the current operations.

Areas and Numbers of Individuals Exposed to Different Risk Levels

Annual Movements	1 in 10,000 to 1 in 100,000 pa		1 in 100,000 to 1 in 1,000,000 pa	
	Area affected / ha	Individuals	Area affected / ha	Individuals
28,000	14.3	845	132.5	7,821
35,000	19.7	1,162	165.7	9,778
50,000	25.2	1,486	240.5	14,189
60,000	29.3	1,727	276.0	16,286

17. In summary, the safety impacts associated with the current operations and the potential increase in risk in the event of an increase in movement numbers should, in our view, be considered to be significant but not exceptional. In an operational sense, these risks are regulated through the UK Civil Aviation Authority and other bodies and can be considered to be "as low as reasonably practicable". It is clear that a considerable amount of effort is devoted to aircraft safety, both by aircraft and airport operators both of whom are subject to regulatory oversight through a process of licensing in accordance with international standards and practices.

18. Nevertheless, some residual risk will remain, albeit very small, when the appropriate safety measures have been taken by the operators. In the planning context, if a new

runway or the reconfiguration of an existing runway were being considered, it would be appropriate to assess whether the risks associated with it were as low as reasonably practicable, for example taking account of the proposed runway location and the relative locations of developed areas. However, Farnborough is an existing facility and such considerations do not apply in this case: the risks for the existing configuration may essentially be considered to be as low as reasonably practicable. The key question to be determined when considering the acceptability of potential future growth is therefore whether the increased risk would be justified by the benefits associated with that potential growth.

19. In addressing that question, we would note first that, although we identify the risks as being by no means trivial, we would not consider them to be exceptional when compared with risks encountered at other airports. Nor are they exceptional when compared with the risks that arise from a range of hazards accepted in society. The risks are below those proposed by HSE as possibly intolerable if imposed on some members of the public in the wider interests of society. On that basis, making a broad comparison between the risks at Farnborough and those tolerated elsewhere at airports and in the vicinity of other potential hazards, we identify no reason on grounds of safety alone that further development of the airport should necessarily be considered inappropriate. However, the risk is significant and should therefore be weighed in the balance with other factors. Society does not impose such risks on members of the public lightly but, where there is considered to be a sufficient benefit, such risks may be considered justified if unavoidable. It is estimated that an increase in movements to 50,000 per annum would increase the financial value of the safety detriment associated with the operations from £52,000 per annum to £92,860. The economic benefit arising from the increased movements would need to be shown to exceed this safety detriment in order for such an increase to be justified.

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1 Background to the Study

1.1 Rushmoor Borough Council has commissioned a study of the safety implications for the local environment of future business aviation at Farnborough Airport. The study is intended to provide evidence to support the preparation of the Farnborough Airport Area Action Plan and the Core Strategy which are elements of the Local Development Framework (LDF). The project has the following main objectives:

1. In the context of current annual movements and aircraft mix, to verify the existing safety implications of the Airport.
2. To consider these implications in the context of options for increased annual flight movements of: i) 35,000; ii) 50,000; iii) 60,000+.
3. To consider the effect of potential future restrictions on weight and types of aircraft (including helicopters) on safety, within the scenarios set out under point 2 above.
4. Review the existing implications of the current Public Safety Zones at Farnborough Airport and how they may change under the above scenarios.

1.2 First, an account of some key concepts in risk assessment relevant to the study is provided and the regulatory context in which the safety implications will need to be evaluated is described. The safety implications of current operations are then assessed and expressed in terms of quantitative estimates of risk, as measured in terms of the probability of an accident causing fatalities to people on the ground in the vicinity of the airport. The safety implications of the identified potential options for increased annual flight movements are then assessed in similar quantitative terms.

1.3 Specific scenarios for weight restrictions were not identified as part of the brief for the study. The implications of future restrictions on weight and types of aircraft operating at Farnborough have been assessed by reference to the conditions relating to this issue that apply to the current consent for business aircraft operations at Farnborough, having regard to likely future demand from different aircraft types.

1.4 The current and potential future safety impacts of business aviation at Farnborough are then reviewed in the context of the Local Development Framework, having regard to two distinct issues:

- The implications in respect of the potential for future development of operations at Farnborough, in particular an increase in annual movement numbers, having regard to the impact on existing development in the vicinity of the airport;
- The implications in respect of land uses in the vicinity of the airport, including the nine sites identified in the Key Sites Background Document of particular relevance to the Farnborough Airport Area Action Plan.

2 Introduction to Risk Concepts

2.1 Basic Measures of Risk

2.1 Risk assessment is often used in support of the regulation of activities that may pose a risk to life. Techniques for assessing risk in quantitative terms were first developed to evaluate the safety implications of major hazard activities such as the nuclear and chemical process industries and have subsequently been applied to the assessment of risks associated with aviation. They have been applied to the assessment of risks from airport operations to those living in the vicinity of airports, typically known as "third party risks". Risk assessment has supported the evaluation of proposals for development near existing airport operations and the development or expansion of airport operations near existing housing or other development.

2.2 Quantitative risk estimates typically characterise risk in terms of two key parameters:

- The probability of occurrence (or frequency) of the hazardous event.
- The severity of the consequence, for example in terms of the severity of injury to those affected and the numbers of individuals killed or injured.

2.3 The primary focus in this study is the assessment of the risk of fatalities[i]. Two distinct measures are typically employed to express fatality risk in a quantitative manner:

- Individual risk: the probability of a fatality being suffered by a hypothetical individual exposed to the hazard in question, typically expressed as the probability of fatality per year of exposure.
- Societal risk: a quantitative measure of the risk associated with events in which there may be multiple fatalities.

2.4 Societal risk, as measured quantitatively, is a more complex concept than individual risk. It must take account of the possibility of different events affecting a range of numbers of individuals. The numbers affected on the ground by an aircraft crash can be expected to vary according to the size of the aircraft involved and the density of development at the crash site. The societal risk measure must in some way accommodate all potential scenarios. Societal risk is typically expressed in terms of two parameters:

- The frequency (F) of events;
- The severity of the consequences, in terms of the number (N) of fatalities.

2.5 Quantitative risk estimates are usually presented graphically in terms of an "FN curve" which shows the estimated frequency (F) of events in which N or more fatalities are expected. Examples of this means of representing societal risk are shown later in this report.

2.6 Societal risks can also be expressed quantitatively in terms of an "expectation value" which represents the expected number of fatalities in any one year of operation of the potentially hazardous facility. For example, an event causing 1 fatality with a probability of 1 in a hundred years would correspond with an expectation value of 0.01 fatalities per annum. An event causing 10 fatalities with a probability of 1 in a thousand years would

[i] In practice, the consequence model employed in this study includes an element of pessimism and the estimates of the numbers of fatalities identified can be expected to reflect the total of fatalities and serious injuries.

have the same expectation value. In practice, the expectation value for a hazard is likely to be made up of a range of scenarios with different probabilities that result in a range of numbers of fatalities. The expectation value can be a useful means in some circumstances of providing a relatively simple summary of the magnitude of societal risk.

2.2 Evaluation of Risk Significance

2.7 Using the results of risk assessment to support risk management decision making requires that the significance of risks be evaluated and that decisions are made regarding their acceptability, taking account of the benefits associated with the potentially hazardous activity which presents the risks concerned and the measures that may be available to reduce risks.

2.8 A framework for assessing the significance of the risks associated with any given activity is provided by reference to other risks encountered in modern society. For example, the HSE have a clearly defined policy on land use planning in the vicinity of major industrial hazard sites, as set out in the HSE guidance document on risk criteria for land-use planning in the vicinity of major industrial hazards [1]. Both individual risk criteria, as employed in the UK Public Safety Zone (PSZ) policy described in Section 3.2, and societal risk criteria are applied. The societal criteria take specific account of the likelihood of an accident involving multiple deaths and place more significance on avoiding accidents the more frequent they are likely to be and the larger the numbers of fatalities caused. These societal risk criteria have been applied in a variety of contexts, as described in various HSE guidance documents, including the paper on *Quantified risk assessment: Its input to decision making* [2], the paper on *The tolerability of risk from nuclear power stations* [3], the report on *Major hazard aspects of the transport of dangerous substances* [4] and the HSE's latest general guidance on public risk management decision making, *Reducing risks, protecting people* [5].

2.9 Under the HSE's approach, risks may be tolerated in return for the benefits of industrial activities within a "risk tolerability" framework developed in the context of UK health and safety legislation. In order to identify quantitative criteria against which to assess the significance of any quantified risk estimate, the HSE made reference to the levels of risk that are encountered and tolerated for a range of activities that are undertaken in modern society. An example risk of relevance to most people would be the risk of death from a road traffic accident which was estimated to be approximately 1 in 10,000 per annum[ii] and equates with the limit of tolerability of individual risk under the UK PSZ policy. Risks that lie below a lower (negligible) risk level will generally be identified as being of essentially no regulatory concern or "broadly acceptable". Risks above an upper (significant) risk level may be considered "intolerable" and would certainly not be accepted without considerable scrutiny. Risks between these two limits would normally be subject to regulatory scrutiny, increasingly so the higher the risk and the closer that it approaches the upper limit. In accordance with UK health and safety legislation, such risks should be managed to be "as low as reasonably practicable" (ALARP).

2.10 Under UK health and safety legislation [6], the term "reasonably practicable" has a specific meaning, derived from its interpretation in case law [7] by Lord Asquith in 1949, as follows:
"Reasonably practicable" is a narrower term than "physically possible." It seems to me to imply that a computation must be made by the owner in which the quantum of risk is

[ii] More recent estimates indicate that this risk has fallen in recent years and currently stands at around 1 in 30,000 per annum.

placed on one scale and the sacrifice involved in the measure necessary for averting the risk (whether in money, time or trouble) is placed in 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 discharged the onus on them. Moreover, this computation falls to be made by the owner at a point in time anterior to the accident. The questions he has to answer are, firstly, what measures are necessary and sufficient to prevent any breach (of the statute), and secondly, are these measures reasonably practicable."

2.11 The legal requirements under UK health and safety law may therefore be summarised as follows; first, hazards and potential mitigating measures should be assessed to determine which of any potentially available safety measures would provide a safety benefit that outweighs their cost; second, measures that are found to be cost-beneficial should be taken and a justification should be provided for any decisions not to implement other measures on the basis that the cost would be disproportionate to the benefit and the benefit of the activity justifies the residual risk that cannot be avoided. In the current planning context, the focus is on evaluating the acceptability of any residual risks which remain after those responsible for operations at Farnborough have, under the licensing regimes overseen by the relevant aviation regulatory authorities, taken the necessary steps to ensure that these residual risks are as low as reasonably practicable.

2.3 Airport Third Party Risk Modelling

2.12 Although aircraft crashes are rare events, the majority of accidents take place during take-off and landing, close to runway ends and under flight paths to and from them. Accordingly, risks at sites relatively close to the ends of busier runways where this accident risk is concentrated may be subject to a level of risk that is higher than the general background risk from aircraft crash.

2.13 A number of models have been developed to provide estimates of the risks from aircraft crash to sites on the ground in the vicinity of airports, taking account of three key factors as follows:

- The likelihood (frequency per annum) of an aircraft crash during take-off or landing operations at any given airport, derived on the basis of the historical crash frequency per movement and annual rate of movements at the airport in question.
- The probability of impact at any given location relative to the runway end and extended centreline, derived on the basis of mathematical functions that correlate the observed distribution of crash locations.
- The severity of the consequence of an impact on the ground, again derived on the basis of historical accident data and taking account of the size of an aircraft operating at the airport in question, as characterised in terms of its maximum take-off weight allowed (MTWA).

2.14 Historical crash rates vary according to the types of aircraft and operations involved and are typically found to be of the order of 1 in a million to 1 in 10 million per take-off or landing movement. An estimate of the annual risk of aircraft crash at any given airport can be made by reference to the historical crash rates and the annual numbers of movements of different aircraft types at the airport. For a fairly sizeable airport handling 100,000 movements per annum, the above historical crash rate per movement would give an annual crash rate anywhere at or in the vicinity of the airport of 1 in 100 years, for example.

2.15 Most accidents occur either at or very close to the ends of runways and along the runway extended centreline along which aircraft flight paths are concentrated, shortly after

take-off and shortly before landing when most accidents take place. By reference to mathematical functions derived from the analysis of historical crash locations and the estimated annual crash rate as described above, an estimate can be made of the annual probability of aircraft crash centred at any given location relative to the runway. Taken together with an estimate of the size of the area affected in the event of an aircraft crash, estimated on the basis of the size of the various aircraft operating at an airport, an estimate of the risk at any location can be determined.

2.16 To estimate individual risk at a given location, consideration is given to the hypothetical individual resident at that location. The estimated risk is simply the probability that the location in question would be affected by possible crashes, taking account of the locations at which possible crashes might be centred in the immediate vicinity of the location in question and the extent of the crash site. To estimate societal risk, it is necessary to consider specifically which sites are occupied at potential crash locations and the densities of occupation. By consideration of the size of the area affected by crashes of all relevant sizes of aircraft at all relevant occupied sites an estimate can be made of the probabilities and number of fatalities associated with a range of possible aircraft crash scenarios.

2.17 This sort of approach to risk assessment has been applied to operations at larger airports in the UK. Through consideration of risk significance, based on the sorts of principles outlined above, well defined planning policies have been developed to protect people from the risks of aircraft crash, as discussed in more detail in Section 3.

3 Regulatory Context

3.1 Outline of Regulatory Issues

3.1 There are a number of distinct planning issues arising in different regulatory contexts that may need to be considered when assessing aviation risks for the purposes of the LDF process. In the first instance, a distinction needs to be drawn between the control of development near existing airports and the control of airport development near existing development. Nationally, new development in the vicinity of airports is controlled in accordance with UK Public Safety Zone (PSZ) Policy. That policy does not specifically address the circumstances that arise when a new airport or significant development of an existing airport is proposed. However, third party risk is a factor to be taken into account and weighed against other factors when airport development proposals are being considered. At Farnborough, in addition to these national policies, specific policies apply that arise from the Rushmoor Local Plan and which are implemented through conditions attached to the planning consent for operation of Farnborough for business aviation. In summary, there are three distinct regulatory issues to be considered as follows:

- UK national PSZ policy for the control of new development near existing airports;
- The generic planning context for control of airport development, having regard to its potential impact on existing developments;
- Local planning conditions that apply specifically at Farnborough.

These three issues are considered in turn below.

3.2 UK National PSZ Policy

3.2 A Public Safety Zone (PSZ) policy was introduced in the UK in 1958, following three aircraft accidents in the vicinity of airports during take-off and landing within a period of three years, one of which caused the deaths of the occupants of a house beneath the approach path to Manchester Airport. That PSZ policy restricted new development within a defined area at the ends of the runways at busier airports in the UK.

3.3 Concerns over the efficacy of this policy were raised [8] in evidence submitted in May 1994 to the Public Inquiry into the Second Runway at Manchester Airport and heard in January 1995, specifically relating to the definition of the area in which development was controlled and its effectiveness at managing risk to third parties. In response, the DETR began a review of policy later in 1995 that investigated the possibility of defining the location and size of PSZs on the basis of the estimated level of risk to third parties in the vicinity of an airport, as described in the DETR study report [9]. On the basis of the findings of this study a revised PSZ policy was introduced in 2002 in which the specification for the size and shape of PSZs is based on the estimated risk, as measured in the terms of the likelihood of fatality for the hypothetical resident at a given location relative to the end of the runway, as defined in DfT Circular 1/2002.

3.4 The current UK PSZ policy, defined in DfT Circular 1/2002, is “risk-based” in approach and seeks to identify those areas at greatest risk close to the ends of busy runways and apply targeted control of development within them. Under such a policy it is accepted that, in the constrained urban planning environment within the UK, it is not possible to eliminate all risks and that some level of risk must be tolerated in return for the benefits of development and of aviation. The process for the estimation of third party risk that is employed for determining the appropriate size and shape of the PSZs at UK airports

involves application of an empirical model for risk estimation, based on historical aircraft accidents (the DfT model [10]).

3.5 The DfT model estimates individual risk through the assessment of three key factors as follows:

- The likelihood (frequency per annum) of an aircraft crash during take-off or landing operations at any given airport, derived on the basis of the historical crash frequency per movement and annual rate of movements at the airport in question.
- The probability of impact at any given location relative to the runway end and extended centreline, derived on the basis of mathematical functions that correlate the observed distribution of crash locations.
- The severity of the consequence of an impact on the ground, again derived on the basis of historical accident data and taking account of the size of an aircraft operating at the airport in question, as characterised in terms of its maximum take-off weight allowed (MTWA).

3.6 The PSZ is derived by reference to the risk (likelihood of fatality due to an aircraft crash) to the hypothetical individual resident permanently at a given location relative to the runway end and extended centre-line. The areas of the PSZs correspond essentially to the 1 in 100,000 per annum individual fatality risk contours. The DETR Study Report concluded that this level of risk represents an appropriate balance point between the risk to residents and the lost opportunity cost of foregoing development land within its proposed land use planning policy. This balance point was determined by means of "constrained cost-benefit analysis". According to the findings of this approach, within the 1 in 100,000 per annum risk contour, the lost opportunity cost of foregoing development land is justified by the safety benefit provided by avoiding development in the areas subject to these higher levels of risk. However, beyond the 1 in 100,000 per annum risk contour, the lost opportunity cost could not be justified by the reduced safety benefits to be gained from restricting housing development in areas subject to these lower levels of risk. Therefore the policy identified no need for any restriction on any type of development outside the PSZ.

3.7 Application of the constrained cost-benefit approach also involves identification of an upper limit of risk tolerability[iii], above which risk to an individual is not tolerated whatever the cost in terms of loss of availability of land. A risk above 1 in 10,000 per annum was judged to be in excess of that considered acceptable, both for new and existing development, and the policy requires clearance of housing where this risk level is exceeded. The current risk contours were calculated for each airport to which the policy applies, including Farnborough Airport, on the basis of forecasts made in 2000 about the numbers and types of aircraft movements in 2015. It was intended that these individual risk contours should be remodelled at intervals of about seven years, based on forecasts about the numbers and types of aircraft movements fifteen years ahead.

[iii] This tolerability limit represents the constraint in the "constrained cost-benefit analysis" approach and represents the point at which, for the purposes of equity and to avoid a small number of individuals being exposed to what is considered an excessive risk, the use of cost-benefit analysis to justify the imposition of risks at this level is no longer considered appropriate.

3.8 As set out in DfT Circular 1/2002 at para. 1, the basic policy objective is that there should be no increase in the number of people living, working or congregating in PSZs and that, over time, the number should be reduced as circumstances allow. The essential elements of policy are as follows:

- There is a general presumption against new or replacement development inside the PSZ. Specifically, policy states that no new or replacement dwellings should be permitted within PSZs. Nor should new or replacement non-residential development be permitted, except for certain low density occupancy uses.
- Occupied residential properties and normal all-day workplaces within the 1 in 10,000 per annum risk contour should be emptied. Airport operators are expected to compensate those affected and demolish any buildings and clear land in this area.

3.9 In summary, there are two main implications for the Local Development Framework process at Farnborough of UK national PSZ policy as follows:

- As a minimum, there is a requirement for new development in the vicinity of the airport to be controlled in accordance with PSZ policy, as defined above.
- In the event that the level of aircraft activity at the airport were to be allowed to increase above the current limit of 28,000 movements per annum, the size of the PSZ can be expected to be increased, according to the estimated increase in risk, directly in proportion to the increase in activity[iv].

3.10 As far as we are aware, the development control requirements of PSZ policy are the minimum that must be applied but there are no formal restrictions on a local planning authority that would prevent additional restrictions being applied for the purposes of minimising third party risk. However, if additional restrictions were to be applied it would be necessary that these be shown to be consistent with the general principle of health and safety law that risks should be managed to be "as low as reasonably practicable" (ALARP) and not unduly onerous or restrictive when account is taken of the safety benefit that might be gained. UK national policy can be considered to be a "one size fits all" policy based on a generic assumption concerning the lost opportunity cost of foregoing the use of potential development land. When account is taken of local circumstances, there may be situations in which risk could be reduced further without any real lost opportunity cost being incurred, for example where there are several options for meeting development needs for which different levels of risk would arise. Such considerations may be of relevance in the context of the development of the LDF Core Strategy and Farnborough Airport Area Action Plan.

3.3 Airport Development Planning Control

3.11 In the event of development of a new airport or expansion of the level of activity at an existing airport it can be expected that there will be an increase in the likelihood of a crash in the vicinity of the airport runway. According to the risk model, as described earlier, the crash risk is directly proportional to the level of activity. There will therefore be an increase in the risk to the hypothetical individual, as estimated by the risk model and, according to the runway location relative to developed sites, there may be a real

[iv] An increase in risk would be expected for an increase in movement numbers, at least where the other modelling assumptions made when estimating risk remain unchanged. However, as discussed further below, we understand that there have been some changes to some of the modelling assumptions employed in the determination of the 1 in 100,000 per annum risk contour at Farnborough by NATS. This has led to a situation in which the future forecast risk levels for an increased number of movements may be less than previously estimated for the current movement limit.

increase in third party risk. Such a development would require that a new or revised PSZ be introduced.

3.12 The Department for Transport has clearly stated [11] that it draws an important distinction between PSZ policy and planning policy in relation to development of a new airport or expansion of an existing one. PSZ policy is intended to control development close to existing airports and not specifically to address the circumstances which might arise when a new airport or significant development at an existing airport is proposed. The department has stated that, in such cases, it would not regard the fact that existing development would fall within any revised PSZ which might be introduced as sufficient reason, in itself, for not permitting the proposed airport development. It would regard third party risk as a factor to be taken into account by a local planning authority when considering airport development proposals, to be weighed with other matters such as job creation and other economic benefits, noise and surface access.

3.13 In the planning context, we therefore identify two potential harmful impacts that may arise from a proposal to build a new airport or expand an existing one:

- New or increased risks may be imposed on members of the public living or working in the vicinity of the airport development proposal, according to the location of existing development relative to the airport runway;
- Implementation of the proposal may lead to the need to establish new PSZs or revised PSZs of increased size, perhaps leading to the loss of potential development land within the new 1 in 100,000 per annum risk contour and to a requirement for clearance of developments within the 1 in 10,000 per annum contour.

3.14 The extent of these impacts can be expected to be dependent upon local circumstances, taking account, on the one hand, of the amount of existing development in the vicinity of the proposed development and, on the other, of the extent to which introduction of new or revised PSZs would, in practice, lead to a real loss of development land, given other practical or planning constraints on development that might apply.

3.15 We are aware of no formal specification of the way in which these impacts should be assessed as part of the evaluation of an airport development planning proposal. Clearly, the extent of the new or revised PSZ can be determined by use of the standard modelling approach which will allow the potential loss of future development land and any requirements for clearance of existing development to be determined. The definition of the PSZ will also allow the determination of the amount of existing development that would be exposed to an annual individual risk of 1 in 100,000 or more to be determined. That measure will provide some basis for assessing the significance of the level of risk.

3.16 Assessments of the third party risk implications of options for provision of new runway capacity were undertaken as part of the programme of detailed technical studies that supported the recent Aviation White Paper [12]. The approach employed in those studies was to determine the numbers of individuals exposed to annual individual risks at or above defined levels. As well as assessing the numbers of individuals exposed at risk levels of above 1 in 10,000 per annum and between 1 in 10,000 and 100,000 per annum, which correspond with the risk standards adopted for the purposes of PSZ policy, these studies included determination of the numbers of individuals exposed to risks between 1 in 100,000 and 1 in 1,000,000 per annum. That is to say, it was considered appropriate in that context to take account of risks that would fall outside the limits of the PSZs, at least up to the level of an annual individual risk of 1 in 1,000,000 per annum.

3.17 It may be noted that, in developing criteria for the evaluation of risk significance, as described earlier in Section 2.2, the HSE has previously identified the 1 in a million per

annum individual risk level as being essentially that below which risks can typically be regarded as broadly acceptable and below significant regulatory concern. The 1 in 100,000 per annum criterion employed to define the limit of PSZs may be considered by the regulatory authorities to be appropriate in defining the balance point as regards development near existing airports but it does not necessarily represent the limit below which risk can be disregarded when considering new airport development. Consideration of individual risks up to at least the level of 1 in a million per annum has previously been considered appropriate when evaluating airport development proposals.

3.18 ESR Technology considers that the above approach of determining the numbers of individuals exposed to annual risks within defined intervals provides a useful basis for evaluation of third party risks associated with airport development proposals. However, as far as the total "societal risk" is concerned, it should be recognised that, by its very nature, the third party risks associated with aircraft crash may be spread over a relatively large area at relatively low levels of annual individual risk, including levels below 1 in 1,000,000 per annum. On that basis, we consider that there may be some additional merit in determining "societal risks" as measured in terms of the F/N curve described in Section 2.1, or in terms of the "expectation value", taking account of accident scenarios at sites beyond the 1 in 1,000,000 per annum risk contour.

3.19 The key point in this respect is that, by the very nature airport operations and the nature of the development around airports, airport operations tend to lead to a relatively small number of individuals being exposed to a relatively high risk and increasingly large numbers of people being exposed to increasingly smaller risks. In utilitarian cost-benefit terms, there is no clear difference between the exposure of 10 individuals to a risk of 1 in 10,000 per annum, the exposure of 100 individuals to a risk of 1 in 100,000 per annum or the exposure of 1,000 people to a risk of 1 in a million per annum. All three scenarios would represent the same probability of fatalities. By the same token, as far as the statutory law is concerned, there is no cut off at a probability of 1 in a million per annum and the exposure of 10,000 people to a risk of 1 in 10 million would be of equal concern. It is for that reason that we consider it better to use a risk assessment method for explicitly determining societal risks when evaluating safety impacts of this type.

3.4 Local Third Party Risk Policy at Farnborough

3.20 Specific local third party risk and other restrictions apply to operation of the former military aerodrome at Farnborough as a civil aerodrome, as set out in the planning permission. A set of specific policies in respect of the Aerodrome were developed as part of the Rushmoor Local Plan (2001 – 2011) Review, which took place prior to the granting of the planning permission. A set of conditions were applied to the planning permission, in accordance with the policies established by the Rushmoor Local Plan (2001 – 2011) Review. The key conditions that apply in respect of third party risk are Conditions 13 and 14[v], as set out below.

Condition 13 Risk Contours - 1 in 10,000 Risk:

"No flying pursuant to this permission shall commence until it has been first demonstrated and agreed in writing with the Council that the 1 in 10,000 per annum risk contour at either end of Runway 07/25[vi] does not extend to areas where people live, work or congregate or beyond the area at the eastern end of the runway where Policy FA1 of the

[v] The numbering of the conditions identified here relate to the revised planning consent, following the weekend movement limit appeal decision. These were conditions 16 and 17 in the original consent.
[vi] The original runway designators were 07/25. Changes in magnetic north have led to a review and the new designators are 06/24.

Rushmoor Local Plan (1996-2011) Review applies. Thereafter, no flying pursuant to this permission which results in the 1 in 10,000 per annum risk contour at either end of Runway 07/25 extending to areas where people live, work or congregate or beyond the area at the eastern end of the runway where Policy FA1 of the Rushmoor Local Plan (1996-2011) Review applies shall take place."

Reason – In the interests of safety.

Condition 14 Risk Contours – 1 in 100,000 Risk

"No flying pursuant to this permission shall commence until the extent of the 1:100,000 per annum risk contour has been first agreed in writing with the Council. Thereafter all flying pursuant to this permission shall conform to the agreed 1:100,000 per annum risk contour and the maximum extent of the 1:100,000 risk contour shall not be changed without the prior approval of the Council in writing."

Reason – In the interests of safety.

3.21 Conditions 13 and 14 seek to enforce Policy FA2.2(D) of the Rushmoor Local Plan Review which states:

"Proposals for flying which would result in the 1 in 10,000 per annum risk contour at either end of Runway 07/25 extending to areas where people live, work or congregate or beyond the area at the eastern end of the runway where Policy FA1 applies will not be permitted.

Proposals for flying which would result in the 1 in 100,000 risk contour extending beyond the operational aerodrome will only be permitted where the adverse effects on the safety of the surrounding area are outweighed by reasons of overriding public interest, including any economic and employment benefits of the proposals. A thorough assessment of benefits would need to accompany any planning application for use of the airfield for business aviation."

3.22 At the time the current planning permission was granted, it was evidently considered appropriate by the relevant planning authorities that these restrictions be placed on the operations in order to limit the level of third party risk that might arise from them.

3.23 Two other conditions of relevance to the current assessment of the safety implications of business aviation at Farnborough apply to current operations. These conditions place a limit on the number of movements and on aircraft size which are both factors that determine the level of risk. These conditions are as follows:

Condition 8 Numbers of Flights: "No more than 28,000 movements per annum shall take place of which no more than 5,000[vii] shall be at weekends or bank holidays."

Reason – To protect the amenities of surrounding residential properties and to accord with the Rushmoor Local Plan (2001-2011) Review.

Condition 12 Weight: "With the exception of up to 1,500 movements per annum by Boeing Business Jets (derived from the Boeing 737) and/or A319 Airbus Corporate jets (details of which shall first be agreed in writing by the Local Planning Authority and such aircraft shall not exceed 80,000 kg maximum take-off weight), no such aircraft exceeding 50,000 kg maximum take-off weight and no helicopters exceeding 10,000 kg maximum take-off weight shall take-off or land at the Aerodrome pursuant to this permission."

Reason – To protect the amenities of surrounding residential properties.

[vii] The condition attached to the original permission, now amended, was that there would be no more than 2,500 movements at weekends.

3.24 For the purposes of determining and agreeing risk contours with Rushmoor Borough Council in accordance with these conditions, risk calculations were made using the DfT model, taking account of the nature of the activity at Farnborough Airport. The primary parameters that determine the extent of the contour are the annual number of movements and the size of the aircraft concerned. In general, for a given assumed aircraft size, the greater the assumed annual number of movements the greater the size of the contour. Similarly, for any given number of movements, the greater the average size of aircraft the greater the size of the contour. The planning conditions concerning the number of flights and the maximum weight of aircraft place an upper limit on the size of the risk contour, irrespective of the planning conditions relating to the 1 in 10,000 and 1 in 100,000 per annum risk contours.

3.25 TAG, the operators of Farnborough Airport, provided forecasts concerning anticipated future operations which served as the basis for establishing both the risk contours agreed with Rushmoor Borough Council and the PSZ as required by national policy. The assumed 28,000 movements per annum is the limit established by Condition 8 of the planning consent, as identified above. The assumed breakdown of movements according to aircraft type and weight was based on estimates made by the airport operator and is below the limit permitted by Condition 12. An average aircraft weight of 24.37 tonnes was assumed in the determination of the agreed contours. The assumed split of runway usage is consistent with recent operational experience, as dictated by the prevailing wind conditions. In practice, the risk levels are relatively insensitive to normal variations in this parameter from year to year, according to weather conditions.

3.26 The average size of aircraft operating at Farnborough has, in practice, been found to be somewhat lower than that assumed for the purposes of determination of the agreed contour. Average aircraft weights for the fleet mixes operating at Farnborough in recent years may be summarised as follows:

- 2005: 16.6 tonnes
- 2006: 15.9 tonnes
- 2007: 16.3 tonnes
- 2008: 17.1 tonnes

3.27 Annual movement levels are currently close to the maximum permitted according to Condition 8. Given that the average size of aircraft for the current operations at Farnborough is somewhat below that assumed for determination of the agreed contours, it is to be expected that the risks associated with them are below the limits identified in Conditions 13 and 14.

4 Verification of Existing Safety Implications

4.1 Modelling Assumptions

4.1 Third party risk estimates determined according to the generic modelling approach summarised earlier will be dependent upon a number of modelling assumptions falling into two key categories as follows:

- Key parameters that characterise the risk model, such as the crash rate per movement of different types of aircraft or operation and the dependence on aircraft size of the area affected on the ground in the event of an accident;
- Key parameters that characterise the airport operation, such as the number of movements and the aircraft fleet mix.

As is inevitable with this sort of approach to predictive risk modelling, there are uncertainties associated with both categories of assumption.

4.2 As has been noted earlier, for the purpose of determining the risk contours that are employed in the context of Conditions 13 and 14 and for determining the PSZ applied at Farnborough, the DfT model as defined in the NATS R&D report [10] was employed. Key modelling assumptions employed at that time were a crash rate of 2.23 per million movements for all aircraft operating at Farnborough (the crash rate attributed to executive jets in the DfT model) and an average aircraft weight of 24.37 tonnes.

4.3 ESR Technology has previously undertaken a detailed review of the DfT model and believes that it contains elements of pessimism and will, as a consequence, provide over-estimates of risk when applied to operations at Farnborough. We understand that some of the key modelling assumptions in the published version of the model may have been revised slightly, taking account of more recent historical data. However, the details of any such changes have not, to our knowledge, been made publicly available. We understand that any changes that have been made are relatively minor.

4.4 For the purposes of verification of the existing safety implications, we have employed the previously published version of the DfT model, whilst noting that this approach is likely to provide over-estimates of the actual level of risk experienced in the vicinity of the airport.

4.5 As regards the operational assumptions, there are a number of key parameters that influence the risk estimated according to the DfT model as follows:

- The number of annual movements;
- The average aircraft size;
- The split of easterly to westerly movements, according to the requirements arising from the prevailing wind conditions;
- The fleet mix and crash rate statistic associated with different aircraft types.

4.6 For the purposes of determining risk contours in the context of the conditions relating to the planning permission for business aviation at Farnborough, the assumption was that there would be 28,000 movements per annum of which 97% (27,160) would be fixed wing aircraft movements for which third party risk modelling was applicable. In practice, we understand that recent operations have involved a slightly higher proportion of helicopter movements. For the purposes of the current assessment, 95% of movements,

equivalent to 26,602 movements per annum, have been assumed to involve fixed-wing aircraft.

4.7 As has been noted earlier, an average aircraft weight of 24.37 tonnes was assumed in the determination of the agreed contours used as the basis for compliance with the conditions relating to safety that apply to the current planning consent. In practice, the fleet mix operating at Farnborough in recent years represents an average aircraft weight of approximately 16 to 17 tonnes. For the purposes of assessing the safety implications of current operations, an average aircraft weight of 17.1 tonnes has been assumed, consistent with operations in 2007.

4.8 Based on operational experience between 2004 and 2007, westerly operations predominate. The proportion of easterly to westerly movements in any year over that time period has varied between 21.4% to 78.6% and 24.6% to 75.4%. The average proportion over the whole period of 22.5% to 77.5% is identified as reasonably representative of the entire range and has been used as the basis for the risk calculations presented here.

4.9 Operations at Farnborough involve predominantly executive jet aircraft types but aircraft types using the airport include a significant number of turbo-prop aircraft and some Boeing 737 types. In accordance with the previously published version of the DfT risk model, the following statistical crash rates are attributed to the different aircraft types: executive jets, 2.23 per million movements; turbo prop aircraft, 0.29 per million movements; Boeing 737 jet types, 0.15 per million movements. Based on past operational experience and future predictions, the following proportion of the fleet has been assigned to the different aircraft types; executive jets, 88.4%; turbo prop aircraft, 8.4%; Boeing 737 types, 3.2%. By applying the identified statistical crash rates to the above proportions of movements, an average crash rate of 2 per million movements has been derived and this value has been assumed for all aircraft operating at Farnborough. In our view, this value is pessimistic and its use will lead to over-estimates of the risks. We would consider the statistical crash rate of 0.15 per million movements identified for commercial jet airliners such as the Boeing 737 as representing the lower limit of what might be expected for operations at Farnborough. On that basis, we would expect the use of a crash rate of 2 per million movements to over-estimate risk by no more than about a factor of ten at the most.

4.2 Individual Risk Estimates

4.10 The current PSZs applied at Farnborough are based on the 1 in 100,000 per annum risk contour and, as discussed above were made using the DfT model and an assumed crash rate of 2.23 per million movement and average aircraft weight of 24.37 tonnes. The limits of the PSZ are shown in Figures 1 and 2. To the south-west of the airport, the main area of elevated individual risk is located over areas which are predominantly but not completely free of any development, the tip of the PSZ extending slightly into a small area in the South of Church Crookham. To the north-east of the airport, immediately beyond the airport boundary, the main area of elevated individual risk defined by this risk contour is over areas that are developed, extending across South Farnborough and into Mytchett. These developed areas comprise mainly residential housing but include also the Farnborough College of Technology.

4.11 ESR Technology has made estimates of the 1 in 10,000, 1 in 100,000 and 1 in 1 million per annum individual risk contours using the modelling approach and assumptions identified in Section 4.1 above. These estimates are shown in Figure 3. As is to be expected given the lower crash rate and aircraft weight assumed in making these

estimates, the 1 in 10,000 and 1 in 100,000 per annum risk contours extend a shorter distance from the runway thresholds than the contours previously agreed as the basis for compliance with Conditions 13 and 14. The distances that the different contours extend from the threshold along the runway extended centreline are summarised in Table 4.1.

Table 4.1: Extents of Risk Contours for 28,000 Movements per Annum

	1 in 10,000	1 in 100,000	1 in 1 million
North-east side	805 m	3,575 m	10,850 m
South-west side	1,195 m	3,375 m	8,450 m

4.12 Broadly speaking, the 1 in 100,000 per annum risk contour covers a similar area as identified above for the PSZ although the size of this area is reduced slightly. The 1 in 10,000 per annum risk contour to the north-east is contained within the airfield boundary and lies outside the area where Policy FA1 of the Rushmoor Local Plan (1996-2011) Review applies, in accordance with Condition 13. To the south-west, the 1 in 10,000 per annum risk contour extends slightly beyond the airfield boundary but covers only undeveloped land. The 1 in 1 million per annum risk contour is considerably wider and extends much further from runway thresholds. In practice, beyond Mytchett to the north-east and Church Crookham to the south-west, the areas covered by this contour are predominantly undeveloped.

4.13 The impact of the current operation can be assessed by reference to the areas of developed land covered by the contours and the estimated population resident within these areas, as summarised below:

- 14.3 ha of developed land exposed to individual risk above 1 in 100,000 per annum.
- Estimated 946 individuals exposed to individual risk above 1 in 100,000 per annum.
- 132.5 ha of developed land exposed to individual risk between 1 in 1 million and 1 in 100,000 per annum.
- Estimated 8,748 individuals exposed to individual risk between 1 in 1 million and 1 in 100,000 per annum.

The above estimates of the numbers of individuals exposed was based on a nominal population density of 59 residents per hectare, derived on the basis of 25 households per hectare and 2.36 persons per household which we understand to be typical of housing developments in England and Wales.

4.3 Societal Risk Estimates

4.14 As noted earlier in Section 2.1, societal risk may be characterised in terms of two factors:

- The frequency (F) of events;
- The severity of the consequences, in terms of the number (N) of fatalities.

Quantitative risk estimates are usually presented graphically in terms of an “FN curve” which shows the estimated frequency (F) of events in which N or more fatalities are expected.

4.15 Estimates for the risk for current operations made according to the operational and risk modelling assumptions outlined in Section 4.1, as presented in terms of an FN curve, are shown in Figure 4. A key finding is the prediction according to this modelling approach that accidents in areas occupied by third parties that are expected to give rise to at least 1 fatality have an estimated probability of 0.00347 per annum, equivalent to slightly less

than once in 290 years. It should be noted that the probability of an aircraft crash anywhere at or in the vicinity of the airport for an assumed 28,000 movements per annum (95% fixed-wing) would be 0.053 (1 in 19 years) and the majority of these are expected not to result in any fatalities. As noted earlier, we consider that the assumed crash rate is pessimistic and that the above figure for the event probability is likely to be an over-estimate. The average number of fatalities in each crash event is estimated to be around 12. We identify elements of pessimism in the crash consequence model employed in the DfT model and would similarly expect this number of fatalities to be an over-estimate.

4.16 As well as showing this risk estimate, Figure 4 shows HSE criteria for assessing the significance of risk. In applying an approach based on "risk tolerability" criteria, the HSE have recognised that it is not possible to eliminate all risks in modern society and that some risk must be tolerated in return for the benefits of undertaking an activity. In order to identify quantitative criteria against which to assess a quantified risk estimate, the HSE made reference to the levels of risk that are encountered and tolerated for a range of activities that are undertaken in modern society.

4.17 A number of criteria are identified, for example derived from the Health and Safety Commission study of the major hazard aspects of the transport of dangerous substances [4]. This study identified an "upper (significant) risk level" and a "lower (negligible) risk level" and also a "local scrutiny level". The upper risk level represents that derived for the major activities at Canvey Island whereas the lower local scrutiny level recognised that, for smaller facilities, a more stringent criterion might apply, given that the economic benefit associated with it would be proportionately lower. Risks that lie below the lower (negligible) risk level will generally be identified as being of essentially no regulatory concern. Risks above the upper (significant) risk level may be considered "intolerable" and would generally not be accepted without considerable scrutiny. Risks below these two limits would normally be subject to regulatory scrutiny, increasingly so the higher the risk and the closer that it approaches the upper limit. In accordance with UK health and safety legislation, such risks should be managed to be "as low as reasonably practicable" (ALARP). The reference point of 50 deaths with a frequency of 5,000 years represents what HSE has proposed [5] most recently as an event that should be regarded as intolerable where there is a choice whether to accept the hazard or not.

4.18 Such criteria have been employed in the assessment of risk significance in a number of contexts but have not been explicitly recognised as appropriate for determining the tolerability of third party risks associated with aircraft crash. In the absence of any criteria specifically identified for use in that context, these available criteria nevertheless provide a valuable reference point.

4.19 When judged against these criteria, the societal risks associated with the current operations at Farnborough can be seen to be far from trivial but by no means exceptional, taking account of other risks normally accepted in return for the benefits of modern society and the risks from aviation accepted at other airports. Under such circumstances the risks to residential and urban areas as a whole in the vicinity of Farnborough Airport may be considered acceptable, provided that they are being managed so as to be as low as reasonably practicable and that the remaining risk that does arise may be justified by the benefits derived from operation of the airport. The elements of pessimism in the modelling assumptions made in deriving this risk estimate should also be borne in mind when evaluating the significance of the safety impacts of current operations at Farnborough.

4.20 As noted earlier in Section 2.1, societal risks can also be expressed in terms of an "expectation value" that represents a measure of the risk arising from all of the possible

events represented by the FN curve. The risk assessment has identified a series of scenarios leading to a range of numbers of fatalities, from 1 up to a few hundred, and the frequency with which events causing each number of fatalities is to be expected. For each scenario involving a different number of fatalities, an annual expectation value can be determined, which is the number of fatalities expected on average in a year for that scenario. For example, a frequency of 1 in 10,000 years for events causing 30 deaths would correspond to 30 / 10,000 = 0.003 deaths per year. By summing the expectation values for each type of event (i.e. those causing 1 or 2 or more deaths up to the maximum predicted number of deaths), the overall expectation value for all types of events can be determined, providing a single numerical value that represents, on average, the risk associated with aircraft crash.

4.21 This expectation value for current operations is estimated to be slightly below 0.042 deaths per annum (1 death in every 24 years). As noted earlier in Section 3.2, cost-benefit analysis was employed in the development of PSZ policy to establish the balance point between the lost opportunity cost of foregoing potential development land and the benefit of preventing fatalities. This approach involves establishing a financial "value of preventing a fatality" which, for the purposes of the DETR study [9] was identified as £744,000 in 1997 and as £1.145 million in 2006, which would translate to approximately £1.25 million in today's terms. Based on that value of preventing a fatality the expectation value expressed financially would be £52,000 per annum. The economic value of the operation of the airport would need to shown to be significant when compared with this safety detriment of £52,000 per annum in order for the airport operation to be considered acceptable.

4.22 As noted earlier, we consider that the modelling approach employed in determining these societal risk estimates includes some elements of pessimism but it should always be recognised that risk modelling is subject to uncertainty. On that basis, the above estimates might be considered to be at the upper limit of what might reasonably be expected in practice and as such provide a cautious basis against which to evaluate the balance between the economic benefit of the airport and the safety detriment associated with it.

4.23 It should be noted that, in accordance with the general principles identified in Section 2.2, there is a requirement placed on those responsible for operations at the airport to ensure that risks to the public arising from those operations are managed so as to be as low as reasonably practicable (ALARP). It is clear that a considerable amount of effort is devoted to aircraft safety, both by aircraft and airport operators both of whom are subject to regulatory oversight through a process of licensing in accordance with international standards and practices. It is our understanding that operations at Farnborough meet the required standards and may therefore be considered to be managed in accordance with the general "ALARP" principle. Nevertheless, some residual risk will remain, albeit very small, when the appropriate safety measures have been taken. Consideration of the balance between the economic benefit of the activity and the risk associated with it, as may need to be undertaken by the planning authorities when considering airport development, is made after it has been established that all reasonably practicable measures have been taken by the operators. The assumption made here is that the regulatory process applicable to operations, for example the process of licensing of TAG as the airport operator by the UK Civil Aviation Authority, should have ensured that the initial "ALARP" requirement placed on the operators has been met.

4.24 In that case, it is appropriate for the planning authority to consider the balance between the residual risk and the economic benefit associated with the activity. The approach identified above, in terms of the expectation value and the safety detriment evaluated by reference to the value of preventing a fatality, is one means by which this balance might

be evaluated. Other reference points are available which might support the evaluation of this balance point, for example, the level of risks arising from other airport operations. ESR Technology has undertaken risk assessments, including assessment of both individual and societal risk, at a diverse range of airports in the UK and overseas. On that basis, we conclude that the risks associated with current operations at Farnborough are consistent with those encountered at other airports and are by no means exceptional. That is to say, the risks accepted at Farnborough are within the spectrum of risks that are accepted from operations at other airports both in the UK and internationally.

4.4 Risks arising from Helicopter Operations

4.25 The risks described above in Sections 4.2 and 4.3 are those estimated to arise from fixed wing aircraft operations. The DfT and similar third party risk models do not provide any basis for making quantitative estimates of the risks associated with helicopter operations. Making such estimates presents some difficulties due to the uncertain nature of flight paths used by helicopters when flying to and from an airport. This means that, whereas it may be possible to estimate incident frequencies and crash consequences in a manner similar to that employed for fixed-wing aircraft operations, crash location modelling using an equivalent approach is not feasible. However, practical limits on the likely scale of the risk can be established by consideration of the nature of helicopter operations, as compared with fixed-wing aircraft operations.

4.26 The key general feature of helicopter departure and arrival routes to note is that these operations are not constrained to follow runway aligned paths close to the airport to the same extent as fixed-wing operations. For environmental and safety reasons, helicopter routes in the vicinity of airports tend to avoid flight over developed areas where this is practical. Departure and arrival routes to be employed at Farnborough are defined in the Aeronautical Information Publication (AIP) from which it can be seen that designated routes follow paths that are quite different from those employed by fixed-wing aircraft.

4.27 As far as individual risk estimates are concerned, this observation is important since it means that risks associated with helicopter operations will not be concentrated in areas where the risk from fixed-wing operations is relatively high. Instead they will be more diffusely spread over other areas. Given that helicopter movement numbers are much lower than fixed-wing aircraft movement numbers (approximately 5% of the total from 2005 to 2007) and that the average weight of helicopters operating at Farnborough is generally lower than that for fixed-wing aircraft operations, the risk associated with helicopter operations can be expected to be quite small compared with the risk from fixed-wing aircraft movements. On the basis that the risk from helicopter operations will be both much smaller in total than that from fixed-wing operations and will be less concentrated over the runway aligned flight paths employed for fixed-wing operations, it can be concluded that this risk would not have a significant effect if taken into account in the estimation of the individual risk contours. That is to say the individual risk contours estimated on the basis of fixed-wing operations alone will be a reliable indicator of those arising from all operations, including helicopter operations.

4.28 As far as societal risk estimates are concerned, the departure and arrival routes flown by helicopters will determine the likelihood of aircraft crash onto a developed site. Review of the information provided in the AIP indicates that some of the designated departure and arrival routes do involve some flight over developed areas. Without detailed information concerning the proportion of helicopter operations that follow the different routes and concerning the distribution of crash locations, precise estimation of the proportion of helicopter crashes in the vicinity of Farnborough that would be expected to impact on developed areas is not possible. From review of the designated departure and arrival

routes, it would appear that this proportion is likely to be not greatly different from that for fixed-wing operations. Crash rates for helicopters have previously been determined by ESR Technology to be similar to the rate of 2 per million movements assumed in the societal risk assessment presented in Section 4.3. On that basis and noting that helicopter operations represent approximately 5% of movements at an average weight that is considerably less than the average for fixed-wing aircraft movements, it is to be expected that helicopter operations would add to the total societal risk by less than 5% of estimated societal risk which is well within the limits of the uncertainties associated with other aspects of the risk model.

5 Implications of Increased Annual Flight Movements

5.1 Outline of General Implications

5.1 As noted earlier, the risk model provides estimates of risk on the basis of three factors:

- The likelihood (frequency or probability per annum) of an aircraft crash during take-off or landing operations.
- The probability of impact at any given location relative to the runway end and extended centreline.
- The severity of the consequence of an impact on the ground.

5.2 As regards the implications of an increase in annual movements, the key point to note is that the estimated risk is directly proportional to the likelihood of a crash, as measured in terms of the probability per annum of a crash, which is directly proportional to the annual rate of movements. Quite simply, therefore, increasing the annual number of movements can be expected to increase the risk, in direct proportion to the size of the increase in the level of movements.

5.3 In terms of the individual risk measure, the implications of an increase in annual movement numbers is therefore an increase in the area covered by any given individual risk contour, for example the 1 in 100,000 per annum contour used as the basis for definition of the PSZs, at least if it is assumed that all other modelling assumptions remain unchanged. The geographical extent of the increase is determined by the nature of the mathematical functions that describe the crash location distributions. Individual risk estimates, expressed in terms of the areas on the ground subject to different risk levels and the areas of developed land subject to these risk levels are presented in Section 5.2.

5.4 In terms of the societal risk measure, the event frequency will increase simply in proportion to the increase in annual movements. Quantitative estimates of the increased risk are given in Section 5.3.

5.2 Individual Risk Estimates

5.5 Individual risk estimates, in terms of the 1 in 10,000, 1 in 100,000 and 1 in 1,000,000 annual individual fatality risk contours, have been made using the modelling approach outlined in Section 4.1. The assumed movement numbers are as defined by the identified options for increased annual flight movements (35,000, 50,000 and 60,000). Maps showing the three contours for each of the four movement number scenarios are shown in Figures 5 to 7. Comparisons of the 1 in 10,000 per annum, 1 in 100,000 per annum and 1 in 1,000,000 per annum risk contours for the 50,000 movement per annum case with those for the current case are shown in Figures 8 to 10.

5.6 The distances that the different contours extend from the threshold along the runway extended centreline increase with increasing numbers of movements, as summarised in Table 5.1. For comparison, Table 5.1 also shows the lengths of the agreed contours employed in relation to Conditions 13 and 14 attached to the current planning consent for business operations at Farnborough and the contours calculated by NATS for 50,000 movements per annum and presented in the Environmental Statement in respect of the application for a variation to Condition 8 of the current consent. Key points that can be drawn from review of the risk contour plots are summarised below.

Table 5.1: Extent of Risk Contours for 28,000 Movements per Annum

	1 in 10,000	1 in 100,000	1 in 1 million
28,000 movements			
North-east side	805 m	3,575 m	10,850 m
South-west side	1,195 m	3,375 m	8,450 m
35,000 movements			
North-east side	995 m	4,025 m	12,050 m
South-west side	1,425 m	3,675 m	9,350 m
50,000 movements			
North-east side	1,355 m	4,975 m	14,350 m
South-west side	1,785 m	4,175 m	11,050 m
60,000 movements			
North-east side	1,555 m	5,525 m	15,550 m
South-west side	1,965 m	4,525 m	11,950 m
Agreed Contour			
North-east side	1,064 m	3,637 m	-
South-west side	1,383 m	3,408 m	-
NATS 50,000 estimate			
North-east side	1,143 m	4,387 m	-
South-west side	1,678 m	3,984 m	-

1 in 10,000 per annum risk contours

5.7 For 28,000 movements, the 1 in 10,000 per annum risk contour estimated on the basis of current operations according to the DfT model is well within the previously agreed contour. Some increase in the number of movements could be accommodated within the agreed contour. However, for 50,000 movements, it is anticipated that the 1 in 10,000 per annum risk contour to the north-east of the airfield, whilst not extending beyond the airport boundary[viii], would extend slightly into the area where Policy FA1 of the Rushmoor Local Plan (1996-2011) Review applies. As a result, we estimate that expansion to 50,000 movements per annum cannot be accommodated without breaching Condition 13 of the current consent. The 1 in 10,000 per annum risk contours calculated by NATS for 50,000 movements is slightly shorter than those estimated by ESR Technology evidently reflects slightly different modelling assumptions. Nevertheless, the NATS estimates predict that this contour would extend beyond the limit of the agreed contour. The currently agreed contour extends to the boundary of the area where Policy FA1 of the Rushmoor Local Plan (1996-2011) Review applies. Any increase in the length of the contour beyond the agreed length would therefore extend in to this area, in breach of Condition 13.

1 in 100,000 per annum risk contours

5.8 In the event of growth in movement numbers, it is estimated that the 1 in 100,000 per annum risk contour would extend further into developed areas on the eastern side of the airport site. The extent to which this contour would cover developed areas would increase with increasing movement numbers, as discussed in further detail below. Growth of this contour to the west of the aerodrome would also occur, affecting increased areas of development, although the areas affected would remain relatively small compared with the areas affected on the north-east side of the aerodrome. We

[viii] The estimates made in accordance with the assumptions outlined in Section 4.1 indicate that the 1 in 10,000 per annum individual risk contour would extend slightly outside the airport boundary, across the A325 and into the developed area to the east of the road whereas the estimates made by NATS indicate that this contour would be contained within the airport boundary. In practice, for the purposes of UK PSZ policy, the NATS estimates would be adopted for determining the area within the 1 in 10,000 per annum risk contour where the policy of demolition applies and can be considered to be a more reliable basis for determining the areas where clearance of development would be required.

understand that the majority of the development within areas covered by this contour is residential in nature but it is noted that it includes also the Farnborough College of Technology.

1 in 1,000,000 per annum risk contours

5.9 For the current case of 28,000 movements, the 1 in 1,000,000 per annum risk contour is predicted to extend well beyond the main areas of development along the runway extended centreline at Mytchett in the north-east and Church Crookham in the south-west, in to what are largely undeveloped areas. In terms of the impact on developed areas, the increasing width of this contour with increasing movement numbers would mean that an increasing number of properties and individuals would be exposed to risks at or above this level.

5.10 For the current case of 28,000 movements per annum, the 1 in 1,000,000 per annum risk contour also covers a part of the DERA site on the north-east side of the airport runway. An increasing amount of the DERA site would be covered by this contour in the event of an increase in annual movements.

5.11 When judged against risk tolerability criteria identified by the Health and Safety Executive, these risks should be considered to be far from trivial since they involve the imposition of annual individual risks in excess of 1 in a million over substantial areas of residential development. The sizes of the areas that would be affected by the different future movement scenarios and the associated numbers of residents potentially exposed to these risks have been estimated. The areas of developed land affected by the 1 in 100,000 and 1 in 1,000,000 per annum contours were first determined. The numbers of people potentially affected was then estimated, based on an assumed nominal population density of 59 persons per hectare (2.36 persons per household and 25 houses per hectare). A summary of these estimates is provided in Table 5.2 below.

Table 5.2: Areas and Numbers of Individuals Exposed to Different Risk Levels

Annual Movements	1 in 10,000 to 1 in 100,000 pa		1 in 100,000 to 1 in 1,000,000 pa	
	Area affected / ha	Individuals	Area affected / ha	Individuals
28,000	14.3	845	132.5	7,821
35,000	19.7	1,162	165.7	9,778
50,000	25.2	1,486	240.5	14,189
60,000	29.3	1,727	276.0	16,286

5.12 The growth in the area subject to risk at the 1 in 100,000 to 1 in 1,000,000 per annum level is predicted to be broadly in proportion with the increase in annual movements.

5.3 Societal Risk Estimates

5.13 As described earlier, societal risk may be characterised in terms of two factors:

- The frequency (F) of events;
- The severity of the consequences, in terms of the number (N) of fatalities.

Quantitative risk estimates are usually presented graphically in terms of an “FN curve” which shows the estimated frequency (F) of events in which N or more fatalities are expected.

5.14 Assuming that the fleet mix will not change with an increase in annual movements, the effect of an increase in annual movement numbers will be to increase the frequency of

crash events and the probability that these will impact at sites on the ground that are developed and occupied by people. Estimates for the risks associated with current operations were presented in Figure 4, in terms of an FN curve. The frequency of events causing one or more fatality was estimated to be 0.00347 per annum, according to the DfT model and the modelling assumptions outlined in Section 4.1. The effect of increasing the movement numbers would be to increase the frequency of crashes causing one or more fatality in direct proportion to the increase in the numbers of movements: i.e. by factors of 1.25, 1.79 and 2.14+ for annual movement increases to 35,000, 50,000 and 60,000+, respectively. The expectation values (expected number of fatalities on average in any year) would also increase by this factor, as would the safety detriment as measured in financial terms by reference to an assumed value of £1.25 million for a "statistical life". These estimates are summarised for the various options for increased annual flight movements in Table 2 below.

Table 2: Key Societal Risk Characteristics for Increased Flight Movement Options.

Annual Number of Movements	Risk as percentage of current case	Frequency of 1+ fatalities	Expectation value (fatalities/yr)	Safety detriment (£/yr)
28,000	-	0.0035	0.042	52,000
35,000	125%	0.0044	0.053	65,000
50,000	179%	0.0063	0.075	92,860
60,000+	214%+	0.0075+	0.090+	111,500+

5.15 Figure 11 shows F/N curves for the current movement limit of 28,000 movements per annum and a potential future option of 50,000 movements per annum, together with criteria for assessing the significance of risk identified previously. Against the identified risk significance criteria these societal risks should be regarded as being far from trivial though by no means exceptional.

6 Implications of Weight Restrictions

6.1 General Considerations

6.1 The risk model predicts that risks will increase with increasing size of aircraft, as characterised in terms of the maximum take-off weight of the aircraft. Where restrictions on aircraft weight are applied and these have a real impact on the fleet mix operating at an airport such that larger aircraft that would otherwise operate there do not do so, there would be a reduction in the average aircraft weight. This reduction in average aircraft weight would lead to a reduction in the risk, if it is assumed that other modelling parameters such as annual movement numbers remain unchanged.

6.2 However, the extent to which any real effect may be generated by a defined limit will depend on the extent to which there is demand from aircraft types that are subject to restrictions. Another factor to consider that will influence the magnitude of any reduction in risk will be the extent to which the movements concerned are eliminated completely or whether operations are transferred to other un-restricted types. In practice, if restrictions were to be placed on particular aircraft types or weights, it may be that the annual number of movements may be reduced, unless operations are limited by a cap on annual movements and demand has already reached that limit.

6.3 In order to evaluate the implications of weight restrictions more specifically in quantitative terms it is useful to define some operating scenarios with defined weight restrictions. The invitation to tender does not identify any specific scenarios for future restrictions on the weight and types of aircraft to be considered in this context. The wording of the current condition relating to aircraft weight and types is as follows:
"With the exception of up to 1,500 movements per annum by Boeing Business Jets (derived from the Boeing 737) and/or A319 Airbus Corporate jets (details of which shall first be agreed in writing by the Local Planning Authority and such aircraft shall not exceed 80,000 kg maximum take-off weight), no such aircraft exceeding 50,000 kg maximum take-off weight and no helicopters exceeding 10,000 kg maximum take-off weight shall take-off or land at the Aerodrome pursuant to this permission."

6.4 The implications of weight restrictions have therefore been assessed by reference to the above condition and potential future scenarios that are similar in principle. In order to define realistic scenarios, consideration has first been given to likely demand for use of Farnborough Airport of different aircraft types. Consideration has been given separately to fixed-wing and helicopter operations.

6.2 Assessment of Fixed-Wing Operations

6.5 Data concerning movements by different aircraft types has been gathered by TAG in support of its annual performance programme. Analysis of these data allows trends in movement numbers according to weight category to be evaluated. For the purposes of this assessment, movement numbers within the following weight categories have been determined and reviewed: below 5 tonnes; 5 to 20 tonnes; 20-40 tonnes; 40-50 tonnes; 50-80 tonnes. These data are summarised in Table 6.1 below.

Table 6.1: Summary of Movement Numbers by Weight Categories

Aircraft weight category	2004		2005		2006		2007	
	Number	%	Number	%	Number	%	Number	%
Up to 5 tonnes	2,958	17.2	2,152	11.1	3,215	13.9	972	3.9
5 – 20 tonnes	10,335	60.2	12,292	63.2	15,108	65.5	18,158	72.4
20 - 50 tonnes	3,444	20.1	4,562	23.4	4,382	19.0	5,678	22.6
50 – 80 tonnes	438	2.6	452	2.3	365	1.6	274	1.1
Total	17,175		19,458		23,070		25,082	

6.6 There are a number of general features that can be identified from review of the data:

- The numbers of movements in the restricted 50-80 tonne category are well below the current annual movement limit of 1,500 and have declined in recent years, both in absolute terms and as a proportion of total annual movements.
- The numbers of movements in the below 5 tonne category fell quite sharply between 2006 and 2007. It is understood that this may reflect deliberate policy by the airport operators to eliminate less profitable operations of smaller aircraft in order to ensure that the most profitable operations can be accommodated within the current constraints of movement numbers.
- The numbers of movements in the 5-20 tonne category has grown significantly, both in absolute terms and as a proportion of the total number of movements, from 60.2% to 72.4% over the period 2004 to 2007.
- The numbers of movements in the 20-50 tonne category have grown in line with the general growth of operations and have comprised around 20% of operations throughout that period.

6.7 On that basis, the annual movement limit on aircraft in the 50-80 tonne category of 1,500 can be seen not to have a real impact on the operational fleet mix or on safety since the demand is significantly below that limit. Provided that the current business aviation model continues to be followed by the airport operator, it would appear that this situation is likely to continue. In order for weight restrictions to have a real impact, i.e. in order for risk to be reduced by reduction of the number of movements of heavier aircraft that may be deemed to make a higher than average contribution to the risk overall, a greater restriction on aircraft weight than that currently imposed through the above planning condition would need to adopted. Even then it would seem likely that the impact would be relatively small.

6.8 The extent of the reduction in risk for a defined scenario in which all aircraft operations at weights above 50 tonnes are eliminated can be estimated quantitatively relatively simply by reference to the numbers of movements of aircraft of different weights and to the consequence model which defines the dependence of risk on aircraft weight. In order to determine relative risk, there is no need to apply the more complex elements of the crash location model and assess where impacts with developed sites on the ground would occur since these factors will be identical for both operational scenarios. The contribution to the annual risk by each aircraft type is directly proportional to the crash consequence area for that aircraft type and its annual number of movements. For any given operational scenario, the risk will be directly proportional to the sum over all aircraft types of the number of movements (n) multiplied by the crash consequence area (destruction area, DA): Risk $\alpha \sum n.\ DA$.

6.9 Based on the 2007 movement data, it is estimated that the total risk would reduce by 2.44% by eliminating all operations in the 50-80 tonne category which comprise 1.1% of the total movements. The relative risk reduction exceeds the reduction in movement numbers since the aircraft of the higher weight category each make a slightly higher contribution to risk due to the larger crash consequence area associated with them. The assumption in that case is that the weight restriction would lead to those specific aircraft movements being shifted to alternative airports. However, there is a possibility that journeys would still be taken to and from Farnborough but using different aircraft types. If all movements associated with aircraft in the 50-80 tonne category were to be replaced by aircraft of weight below 50 tonnes, rather than being eliminated altogether, the reduction in risk associated with the weight restriction would be less than 2.44%.

6.10 Another factor to consider is the impact of the ban on all aircraft above 80 tonnes maximum take-off weight. The key point in this respect is whether, in practice, there would be any significant demand associated with aircraft of weight in excess of the limit. In our opinion, it is unlikely that there would be significant demand in the business aviation sector for use of the airport by heavier aircraft. In any event, the use of the airport by heavier aircraft would be limited in practice by the available runway length. Operation of aircraft the size of the Boeing 757 which has a maximum take-off weight of 120 tonnes should be practical from a runway of the length at Farnborough, perhaps with some minor penalty in terms of the payload that could be carried, but operation of aircraft significantly larger than that would seem not to be practicable. The expectation is therefore that, if the 80 tonne weight restriction were not to be imposed, it would have a minimal impact on the risk since relaxation of that constraint is likely to lead to a relatively small number of movements of aircraft in that weight category.

6.11 By reference to the utilisation of the airport by aircraft in the 50-80 tonne category, it would be expected that demand from the business aviation sector from aircraft above 80 tonnes will be significantly below the 1.1% level currently identified for the 50-80 tonne category. The increased risk associated with the larger aircraft arises from the increased area affected in the event of a crash. In this context risk is considered to be a combination of event frequency and severity of consequence and the effect of the increased aircraft size would be to increase the number of fatalities on the ground in the event of a crash whilst the probability of a crash would remain the same. By reference to the crash consequence model, it is found that the risk for the Boeing 757 would be approximately 23% higher than that associated with the Boeing 737 which is the largest aircraft within the 50-80 tonne category that currently operates at Farnborough.

6.12 If the same number of new movements at a weight of 120 tonnes were to be attracted as there currently are movements in the 50-80 tonne category, the total risk arising from fixed-wing operations would increase by about 3%. In practice, demand can be expected to be somewhat lower and any increase in risk associated with removal of the condition banning aircraft in excess of 80 tonnes would therefore be expected to be somewhat less than 3%.

6.13 It is to be stressed that the suggested outcome in terms of future movement numbers within the restricted weight categories identified above is what ESR Technology considers to be most likely, for the reasons identified. It should be recognised that circumstances might arise in which greater demand from aircraft within these weight categories might arise if the restrictions were to be lifted but, on the basis of our current understanding, we consider this to be unlikely.

6.3 Assessment of Helicopter Operations

6.14 As identified above, under the terms of the current planning consent, no helicopters in excess of 10 tonnes maximum take-off weight are permitted to operate at Farnborough. On the basis of analysis of recent operations, we identify a weight of 3.3 tonnes for the average helicopter movement at Farnborough. In practice, given the weights of the available types of helicopter used for the types of operation undertaken at Farnborough and the associated nature of demand, it would appear to be quite unlikely that there would be a significant number of operations of rotary wing aircraft (helicopters) in excess of 10 tonnes if this condition were to be lifted. The basis of the argument in this respect is entirely analogous to that presented earlier in respect of fixed-wing aircraft operations.

6.4 Summary

6.15 In summary, it may be concluded that restrictions of the numbers of particular aircraft types and within certain weight categories are unlikely to have any real impact on risk. There is unlikely to be sufficient demand from larger aircraft types from which higher risks may arise for any noticeable effect to arise. The conditions applied to the current planning consent may provide some assurance that risks from heavier aircraft will be avoided but it is our understanding that these risks are likely to be avoided in any event given the business aviation market served by Farnborough.

7 Review of Implications

7.1 In presenting the findings of the study in the previous sections of this report, some indication of the safety implications of the current and possible future business aviation operations at Farnborough and has already been given. The key findings are summarised here. As noted earlier, there are two distinct issues relating to the safety implications of business aviation at Farnborough that need to be reviewed as follows:

- The implications in respect of the potential for future development of operations at Farnborough, in particular an increase in annual movement numbers, having regard to the impact on existing development in the vicinity of the airport;
- The implications in respect of land uses in the vicinity of the airport, including the ten sites identified in the Key Sites Background Document of particular relevance to the Farnborough Airport Area Action Plan.

These two aspects are discussed in turn below.

7.1 Implications for Airport Development

7.2 As discussed in Section 4, the safety impacts of the current business aviation operations at Farnborough are significant when judged against criteria employed by the HSE for evaluating risk significance in the context of the protection of the public from hazardous facilities. However, the risks are typical of those associated with airport operations in the UK and should not be considered in any way exceptional. Key aspects of the safety implications of current operations may be summarised as follows:

- Individual risk. It is estimated that approximately 7,821 individuals resident in an area of approximately 132.5 hectares are subject to risks above 1 in a million per annum and below 1 in 100,000 per annum. It is estimated that 845 individuals resident in an area of approximately 14.3 hectares are subject to risk at or above 1 in 100,000 per annum below 1 in 10,000 per annum. HSE would regard risks below the level of 1 in a million per annum as "broadly acceptable" whereas a risk level of 1 in 100,000 per annum imposed on some members of the public in the wider interests of society would be considered significant but tolerable, taking account of the scale of the benefit provided. HSE would generally regard a somewhat higher annual risk of 1 in 10,000 as intolerable.
- Societal risk. The probability of an accident at Farnborough giving rise to one or more fatalities is estimated to be approximately 1 in 290 years and the average number of fatalities anticipated for an accident is around 12. This risk level is above that considered "broadly acceptable" by HSE but below that previously identified as potentially "intolerable"[ix]. The risk may be expressed as an "expectation value", the average number of fatalities in any one year of operation, of around 0.042 deaths per annum (1 death in every 24 years). By reference to the financial "value of preventing

[ix] The HSE has typically provided guidance on the acceptability of defined quantitative levels of societal risks in the context of the safety regulation of major hazard sites. Such criteria are not necessarily applicable to aircraft crash hazards but we consider that they nevertheless provide a useful reference point. Statutory law in the UK does not impose any specific limit on risk tolerability and, in accordance with the "ALARP" principle, requires that an appropriate balance is maintained between risks, costs and benefits. We therefore recommend that the safety implications of the airport be judged primarily in the latter context rather than against any tolerability criteria identified by the HSE.

a fatality" of £1.25 million, this risk may be expressed in financial terms as a safety detriment of £52,000 per annum. As we have identified earlier, we consider that there are elements of pessimism in the modelling approach employed in this assessment and that the above values are likely to be over-estimates of the risk.

- Loss of development land. Due to UK Public Safety Zone (PSZ) policy, development is currently restricted in a significant area of land outside the airport boundary, comprising about 25 hectares to the east and 35 hectares to the west of the airport. Areas to the east are already predominantly developed whereas those to the west are predominantly undeveloped. We understand that scope for additional development within the area covered by the PSZs would be limited in any event due to other constraints. Anticipated changes in the approach by which the PSZ is calculated are expected to reduce the extent of the PSZ for an annual movement limit of 28,000. In the absence of any detail concerning these changes, the scale of any possible reduction in the size of the PSZ cannot be defined.

7.3 In the event of an increase in movement numbers it is expected that the risk would increase since the probability of an accident is directly proportional to the level of activity. The scale of the increase in risk would be dependent on the scale of the increase in movement numbers. For an increase to 50,000 movements per annum, the following key implications are identified:

- Individual risk. The individual risk at any point is expected to increase in direct proportion with the increase in movement numbers (i.e. by about 80%). As a consequence, the 1 in 100,000 per annum risk contour would grow to the point that it is estimated to would extend over approximately 25.2 hectares of developed land. An estimated 1,486 individuals would be subject to risks at or above this level. The 1 in a million per annum risk contour would increase in size considerably, covering an estimated 240.5 hectares of developed land, and an estimated 14,189 individuals would be exposed to that level of risk or more. This would represent an increase in the numbers exposed to these levels of risk by about 80%, in line with the increase in the numbers of movements.
- Societal risk. The societal risk would increase in direct proportion with the number of movements since that factor determines the likelihood of a crash and the aircraft size which determines the scale of the accident consequence is not expected to change significantly. An increase in the accident probability to 1 in 160 years would be expected. The expectation value and the financial value of the safety detriment would increase by a corresponding factor to around 0.075 per annum (about 1 death in every 13 years) and £92,860, respectively. We again note that the above values are likely to be over-estimates of the risk.
- Loss of development land. The PSZ would be larger than would otherwise be the case. In the event that the current annual movement limit of 28,000 were to be retained, it is expected that the PSZ would reduce in size, due to changes to the modelling assumptions concerning aircraft crash rate and aircraft size that we understand will be applied in the estimation of revised PSZs. Based on estimates provided by NATS in the Environmental Statement associated with the application for a change in Condition 8 of current consent for business aircraft operations at Farnborough, whereas the PSZs for 50,000 movements per annum would extend further from the threshold than the current PSZs they would be narrower and cover a similar area. That is to say it is anticipated that the areas of the future PSZs would not exceed the areas of the current PSZs.

7.4 In summary, the safety impacts (that is to say the risks of third party fatalities) associated with the current operations at Farnborough Airport and the potential increase in risk in the event of an increase in movement numbers should, in our view, be considered to be

significant but not exceptional. In an operational sense, these risks are regulated through the UK Civil Aviation Authority and other bodies and can be considered to be "as low as reasonably practicable". In the planning context, if a new runway or the reconfiguration of an existing runway were being considered, it would be appropriate to assess whether the risks associated with it were as low as reasonably practicable, for example taking account of the proposed runway location and the relative locations of developed areas. However, Farnborough is an existing facility and such considerations do not apply in this case: the risks for the existing configuration may essentially be considered to be as low as reasonably practicable. The key question to be determined when considering potential future growth is therefore whether the increased risk would be justified by the benefits associated with that potential growth.

7.5 In addressing that question, we would note first that, although we identify the risks as being not at all trivial, we would not consider them to be exceptional either when compared with risks encountered at other airports. Nor are they exceptional when compared with the risks that arise from a range of hazards accepted in society. The risks are below those proposed by HSE as possibly intolerable if imposed on some members of the public in the wider interests of society. On that basis, making a broad comparison between the risks at Farnborough and those tolerated elsewhere at airports and in the vicinity of other potential hazards, we identify no reason on grounds of safety alone that further development of the airport should necessarily be considered inappropriate. However, the risk is significant and should therefore be weighed in the balance with other factors. Society does not impose such risks on members of the public lightly but, where there is considered to be a sufficient benefit, such risks may be considered justified if unavoidable.

7.6 The estimated annual financial value of the safety detriment, evaluated by reference to the average number of fatalities anticipated in any year and the value of preventing a fatality, provides a formal measure that might be employed when considering this balance. It takes account of all accident scenarios involving fatalities and represents a relatively simple measure of societal risks as a whole. As presented previously in Section 5, the safety detriment is estimated as £52,000 per annum for current operations of 28,000 annual movements and is predicted to rise to £92,860 for the potential future case of 50,000 annual movements.

7.7 In our view, there are a number of pessimisms in the DfT modelling approach that has been employed in making the above risk estimates. The pessimisms introduce an element of "gross disproportion" into the balance, in accordance with the practice outlined by the HSE[x] that the balance be deliberately skewed towards safety benefits. That is to say, if the benefit of the airport with annual movements of 50,000 were considered to be greater than the pessimistic value for the cost, expressed as the annual safety detriment of £92,860, a proposal to increase movements to that level would pass the test of "gross disproportion" and, in terms of safety at least, could be considered tolerable.

7.8 The increase in the sizes of the individual risk contours that would arise from an increase in annual movements to 50,000 has implications regarding compliance with Conditions 13 and 14 of current planning consent. It is predicted that the 1 in 10,000 per annum would extend slightly into the area where Policy FA1 of the Rushmoor Local Plan (1996-2011) Review applies, although it would be contained within the airport boundary. An increase in annual movements to 50,000 would therefore not comply with Condition 13 of the current consent. In practice, it would appear that the slight intrusion of this contour

[x] See for example the discussion on the use of cost benefit analysis as a utility based criterion in decision making in paragraph 119 in reference 5 and other references to "gross disproportion" in reference 5 and other HSE publications.

into this area would not result in any specific harm of the nature that Condition 13 is intended to address. UK PSZ policy essentially requires the clearance of buildings that are subject to risk in excess of 1 in 10,000 per annum. We understand that the purpose of Condition 13 is to avoid the need for clearance of buildings where Policy FA1 of the Rushmoor Local Plan (1996-2011) Review applies. In practice, since the 1 in 10,000 per annum individual risk contour for 50,000 movements per annum would be located over an access road to which no specific restrictions apply and would not intrude into any buildings, no specific harm associated with the need for clearance of buildings would arise.

7.9 The 1 in 100,000 per annum individual risk contour for 50,000 movements per annum is estimated to extend along the runway extended centreline beyond the limit of the contour currently agreed in the context of Condition 14. As has been noted earlier, due to a reduction in the width of this contour, compared with that for the previously agreed contour, the area subject to individual risk at or above the level of 1 in 100,000 per annum for the future scenario of 50,000 movements would be no greater than that originally estimated for the currently consented annual movement limit of 28,000. On that basis, the level of harm as judged on the basis of the area subject to risk at or above this level would be no greater than that previously considered acceptable, given the benefits associated with operations subject to the existing consent for 28,000 movements per annum. Condition 14 allows for the agreed 1 in 100,000 per annum risk contour to be changed at the discretion of the Council. If the risks associated with an increase in annual movements to 50,000 that are implied by the contour were to be considered acceptable, such an increase could be accommodated without a breach in Condition 14 by making a change to the agreed contour.

7.2 Implications for Development in the Vicinity of the Airport

7.10 The Key Sites Background Document identifies 9 areas in the vicinity of the airport, other than those within the business aerodrome operation area, with a range of current uses and to which a range of development related policies currently apply. The implications of the safety impacts of business aviation activities at Farnborough for the future of these sites have been considered. [Note: the numbering of the surrounding sites below reflects the numbering to be included in the Preferred Approach version of the Area Action Plan.] Consideration has also been given more generally to the implications for development across other areas where risks arising from airport operations are more concentrated.

7.11 Clearly, PSZ policy will have a bearing on future use and development at these sites. However, as noted in Section 3.2, the development control requirements of PSZ policy are the minimum that must be applied. As far as we are aware, there are no formal restrictions on a local planning authority that would prevent additional restrictions being applied for the purposes of minimising third party risk. In our view, UK national PSZ policy, based on cost-benefit principles applied in respect of a generalised “lost opportunity cost” in respect of development land represents a relatively simplistic “one size fits all” approach that may fail to take advantage of opportunities to achieve higher standards of public safety without incurring any real costs. When account is taken of local circumstances, there may be situations in which risk could be reduced further without any real lost opportunity cost being incurred, for example where there are several options for meeting development needs for which different levels of risk would arise. We would therefore recommend that such possibilities are considered as part of the LDF process.

Site 2: Farnborough Business Park

7.12 This site lies to the north and east of the airfield. Parts of the site in its extreme south-east corner are located within the PSZ and are evidently subject to risks at elevated levels. Except for certain low density uses, as identified in the DfT Circular, new development is not allowed in this area.

7.13 Most of the site is outside the PSZ and subject to risks above the 1 in a million per annum level but below the 1 in 100,000 per annum, for both the current case of 28,000 movements per annum and future cases with higher movement numbers. As we have noted in Section 3.2, the requirements of UK PSZ policy may be considered to be a minimum and, where practicable, it may be preferable to limit development across areas of the site that are outside the PSZ but subject to risk levels that, although below the 1 in 100,000 per annum level, would nevertheless be considered non-trivial. Sites closer to the boundary of the 1 in a million per annum contour will be subject to lower risk than those closer to the 1 in 100,000 per annum contour and development would generally be preferable at lower risk sites if this can be accommodated. However, development up to the limit of the PSZ would be in accordance with national policy and therefore generally considered acceptable if there were demand for it.

7.14 The Key Sites Background Document identifies the site as being redeveloped to provide a mix of commercial and residential uses. Permission for some new development has already been granted. As a general rule, risks might be minimised if lower density uses could be accommodated in higher risk areas and higher density uses limited to lower risk areas within the site and we suggest that this principle is applied when considering future developments, whilst recognising that there may be other factors to be balanced with any safety benefit that might be gained by using this approach.

Site 3: Land South of RAE Road.

7.15 The majority of this site lies within the current PSZ and all of the site lies within the 1 in 1 million per annum risk contour predicted for the current case and future cases with higher movement numbers. New development is therefore not permitted over a large part of the site and, in accordance with the comments above in relation to Site 2, it may be preferable to avoid major new development across other parts of the site that are exposed to elevated risk levels, in particular those involving high densities of occupation.

Site 4: Society of British Aerospace Companies / Farnborough International.

7.16 This site lies immediately to the south of the operational area of the airfield towards the eastern end of the runway. The site lies largely within the 1 in 1 million per annum risk contour predicted for the current case and future cases with higher movement numbers. In accordance with the comments made above in respect of Site 2, it would be preferable that any new development be located in lower risk areas of the site if this can be accommodated. We expect that parts of the site closer to the operational area of the airfield may be subject to risk levels higher than those indicated by the risk contour plots, associated with overrun and lateral veer-off from the runway that we believe may not be taken fully into account by the DfT model. The site is currently leased by Farnborough International Ltd and is used to accommodate temporary buildings associated with the biennial Farnborough Airshow. Clearly, such activities benefit from their location close to the airfield and its runway and the risks arising from the proximity of these facilities to the runway may therefore be considered acceptable. In risk terms, this use may be considered to be relatively low since it involves occupation of the site for a limited period only though there will be a high density of occupation during the periods that it is in use.

7.17 The Key Sites Background Document identifies Local Plan Policy FA6 as safeguarding the site for use during the airshow and also supporting the development of permanent exhibition halls, conference facilities and a hotel where this is compatible. In the interests of safety, where facilities for more general use at times other than the airshow are being considered, these might be better accommodated as far to the south of the site as is practicable provided that this would not compromise their use in support of the airshow.

Site 5: Queen's Gate.

7.18 This area lies to the south of the airfield, outside the current PSZ, mostly outside the 1 in 1 million per annum risk contour predicted for the current case but mostly within this contour for the future case of 50,000 movements per annum. Outline planning permission has been granted for redevelopment of the site for residential and commercial building developments. Whilst we note that some parts of the site are predicted to be subject to risks above the 1 in 1 million level the risk levels across it are generally at the lower end of the range between 1 in 100,000 per annum and 1 in 1 million per annum. Taking account of the pessimism we identify in the DfT modelling approach, we conclude that risk will generally be acceptable across the site for the current case and for the future case of 50,000 movements per annum.

Site 6: Farnborough Aerospace Centre.

7.19 The risk profile of this area is essentially the same as that described above for Site 5. The site is currently occupied predominantly by BAe Systems and is identified by Local Plan policy E3 for business, industrial and storage developments or redevelopment. Given the relatively low risks to which the site is exposed and would continue to be exposed if activity at the airport were to increase substantially, it is judged that restriction of future uses at the site in the event of redevelopment is unlikely to provide any significant safety benefit. It should be noted, however, that the triangle of land to the north east of this area is subject to risk at a potentially significant level. The part of this area subject to the greatest risk is currently used for car parking which represents a low density occupation use that would be permitted within PSZ. Office developments in this area lie further to the south and are subject to lower risk levels that would generally be considered acceptable. Current site uses are therefore identified not to be in any conflict with airport safety impacts. It is noted that airspace safeguarding requirements will restrict the heights of developments closer to the runway such that major development involving high density of occupation in sites exposed to higher risk is therefore not likely. Risks to sites bordering the operational area of the airport to the south of the runway are considered in more detail in the following section.

Sites 7 and 8: Civil Enclave and The "T" Area

7.20 These are both relatively small previously developed sites located to the south of the airfield on the edge of the operational area of the airport. The Civil Enclave comprises a mixture of office development currently in use and cleared and hard standing areas where local plan policies allow employment uses. The "T" Area has been cleared of all buildings and comprises hard standing employed for the airshow. Local plan policies allow employment use in the "T" area, limited to the footprint of previous development.

7.21 Both areas lie between the two landing thresholds which represent the origins of the PSZs and so lie outside the PSZs. The northern perimeters of both areas lie immediately adjacent to the operational area of the airport. Risks in these areas have not explicitly been modelled in the assessments presented earlier and summarised by the risk contour plots. However, extrapolation between easterly and westerly limits of the risk contours indicates that the northerly parts at least of these areas are subject to relatively

significant risk. We believe that there is a case for extending the sorts of controls applied through PSZ policy to such areas that lie to the side of runways and between the operational runway ends. Most accidents occur on or very close to the runway and associated runway strip that extends 150 m either side of the runway centreline and represents the key operational part of the airfield employed for take-off and landing. Incidents on the airfield may lead to lateral veer-off from the runway and, whereas most events of these types will be contained within the 300 m wide runway strip a small proportion may deviate further from this area. Sites to the sides of runways may therefore be subject to relatively high risk and building in these areas will therefore be better avoided in the interests of public safety. Since the risk falls off quite rapidly with increasing distance from the runway, sites to the south of these areas are subject to somewhat lower risks and office development use would therefore not be in conflict with public safety in these areas.

7.22 In practice, major high density development close to the runway where risks are relatively high will be restricted by normal airspace safeguarding requirements.

Site 9: AAIB.

7.23 This area lies south of Site 8 and further from the operational area of the aerodrome. Given its separation from the operational area of the aerodrome, this site can be expected not to be subject to any significant risk from lateral veer-off events. Risks from crashes directly from flight are relatively low at this location. Overall, continued office development use would therefore not be in conflict with public safety in this area.

Site 10: Cody Technology Park.

7.24 This area lies to the north and west of the airfield and comprises the largest completed employment area adjacent to the airport. Most of the site lies well outside the 1 in 1 million per annum risk contour predicted for the current case and the currently developed part of the site lies outside this contour for the future case of 50,000 movements per annum. Given the relatively low risks across the site, we identify no conflict between the current use of the site and the safety impacts of the airport.

Site 11: Flight Safety International.

7.25 This area lies to the north side of the runway and immediately west of the Farnborough Business Park (Site 2). In common with most of Site 2 this site is outside the PSZ and is subject to risks below the 1 in a million per annum, for both the current case of 28,000 movements per annum and future cases with higher movement numbers. Given the low levels of risk to which this site is exposed, we identify no conflict between the current use of the site and the safety impacts of the airport.

Areas located close to the runway extended centre-line.

7.24 As set out in Section 3.2, areas located close to the runway extended centre-line that are subject to relatively high risks are controlled according to UK national PSZ policy. Significant areas of existing development are contained within the PSZ and are exposed to risk levels that are deemed acceptable whilst being recognised as significantly elevated due to the airport operations. The key development implication of the safety impact of business aviation at Farnborough is the restriction of future development in areas within the PSZ. However, we understand that, due to other planning policies and constraints on development, proposals for new development at sites located within the PSZ that are currently undeveloped are generally unlikely to arise in any event The implications for development in these areas are therefore limited in practice.

7.25 As noted earlier in Section 3.10, the development control requirements of PSZ policy are the minimum that must be applied but there are no formal restrictions on a local planning authority that would prevent additional restrictions being applied for the purposes of minimising third party risk. In the event that, taking account of location conditions, there were scope for adoption of a more cautious approach without significant adverse impact on development requirements we recommend that this be considered. However, if additional restrictions are to be applied it would be necessary that these be shown to be consistent with the general principle of health and safety law that risks should be managed to be "as low as reasonably practicable" (ALARP) and not unduly onerous or restrictive when account is taken of the safety benefit that might be gained.

References

1 Risk Criteria for land-use planning in the vicinity of major industrial hazards, UK Health and Safety Executive, HMSO, 1989
2 Quantified risk assessment: Its input to decision making, UK Health and Safety Executive, HMSO, 1989
3 The tolerability of risk from nuclear power stations, UK Health and Safety Executive, 1992
4 Major hazard aspects of the transport of dangerous substances, Health and Safety Commission, 1991
5 Reducing risks, protecting people, Health and Safety Executive, 2001
6 The Health and Safety at Work etc. Act of 1974, Sections 2 and 3, set out the general principles of an objectives based approach to safety regulation as follows:

> Section 2. It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees.
> Section 3. It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health and safety.

7 Edwards v. the Coal Board 1949
8 M.J.Eddowes, Risk of Ground Fatalities from Aircraft Crash at Manchester Airport, Proof of Evidence submitted to the Manchester Airport Second Runway Public Inquiry, 1994
9 Third Party Risks Near Airports and Public Safety Zone Policy: A Report to the Department by Consultants, Department of the Environment, Transport and the Regions, October 1997
10 R&D Report 0007 A Methodology for Calculating Individual Risk due to Aircraft Accidents near Airports, National Air Traffic Services, 2000
11 See for example letters to Farnborough residents (e.g. letter of 19 December 2001 to Mr Milne) in relation to this issue.
12 The Future of Air Transport White Paper, Department for Transport, December 2003

Figures

Figure 1: PSZ for the south-west side of the Airport

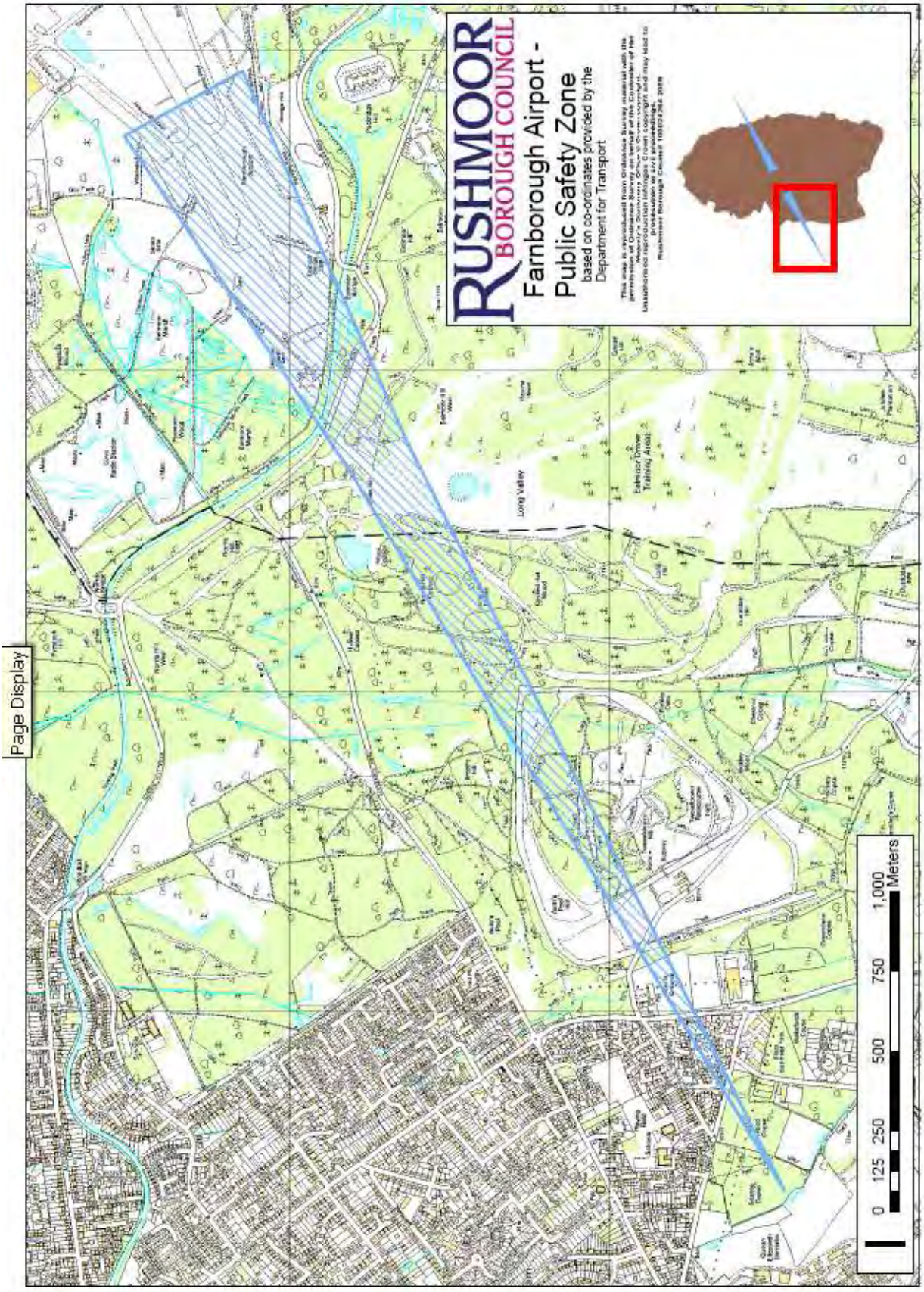


Figure 2: PSZ for the north-east side of the Airport

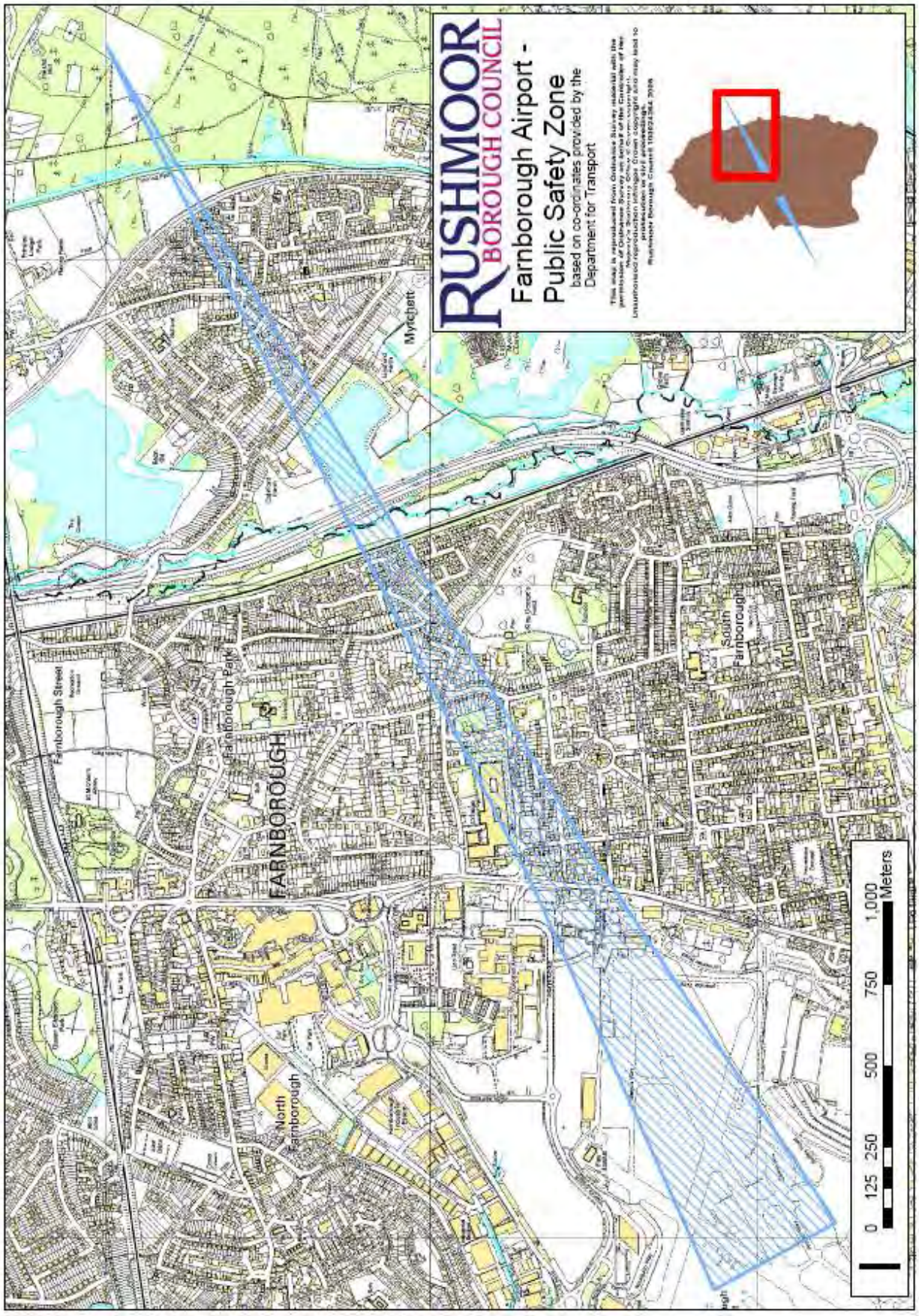


Figure 3: Individual Annual Risk Contours for 28,000 movements per annum

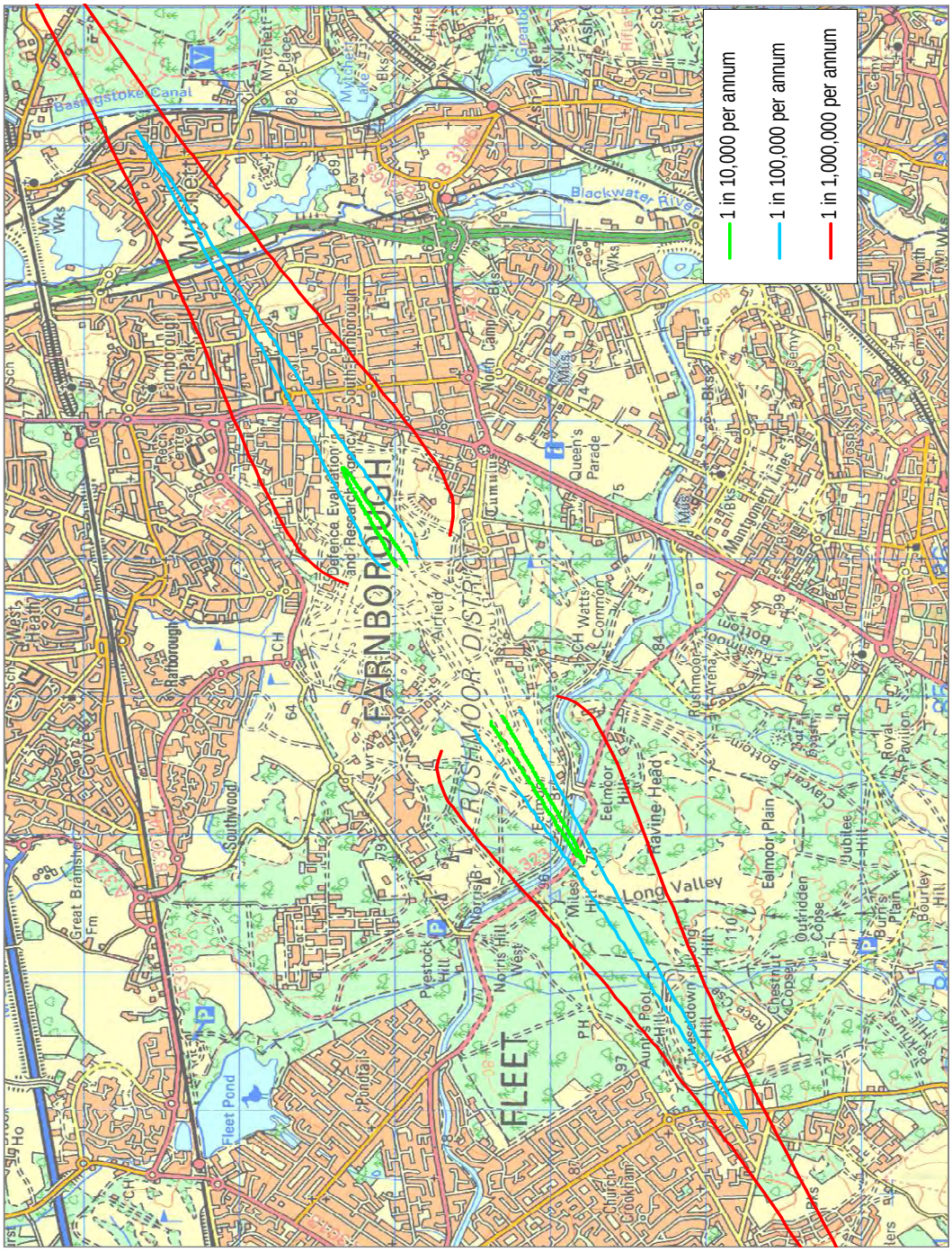


Figure 4: FN curve for societal risks associated with current business aviation operations of Farnborough Airport

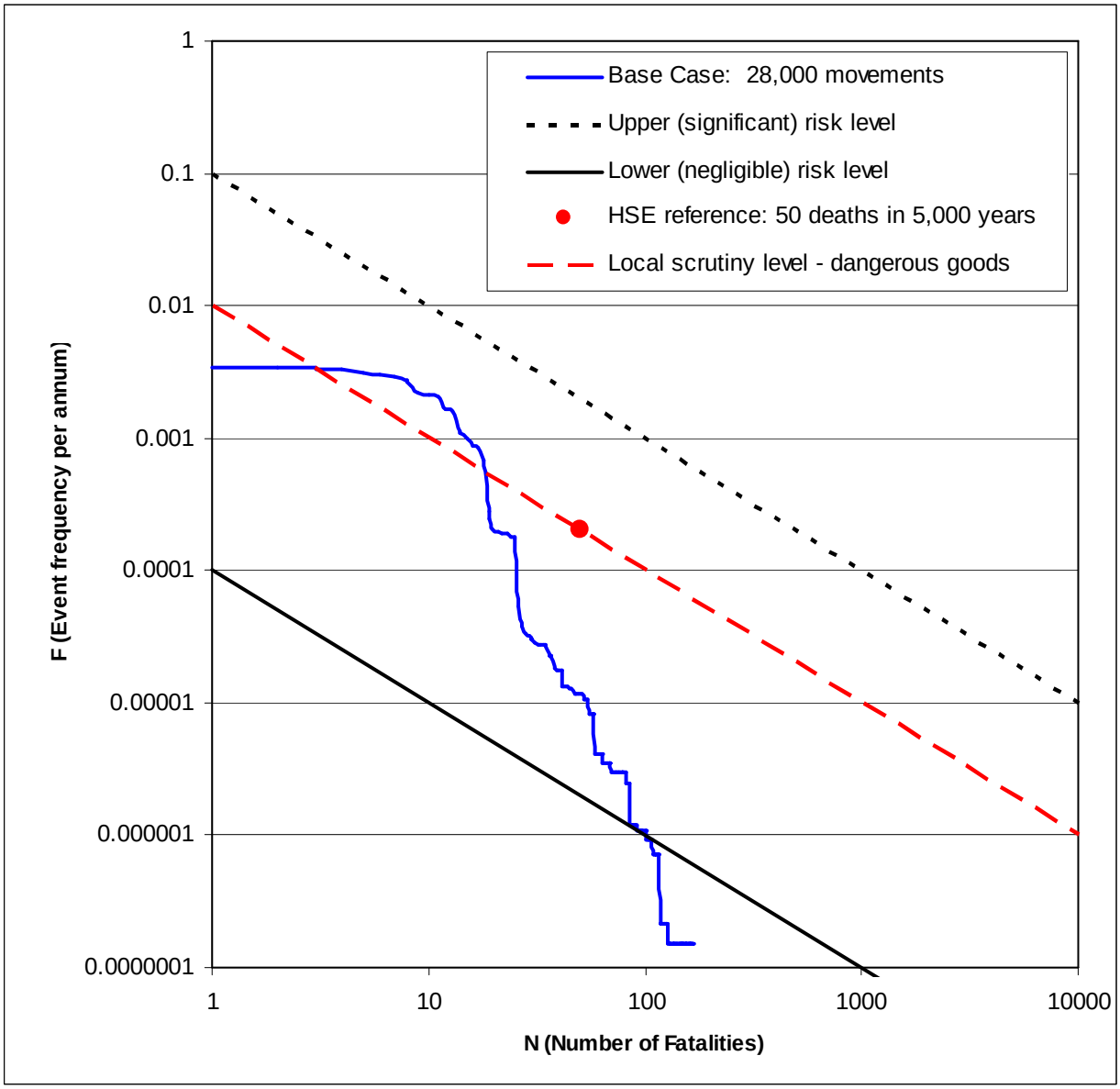


Figure 5: Individual Annual Risk Contours for 35,000 movements per annum

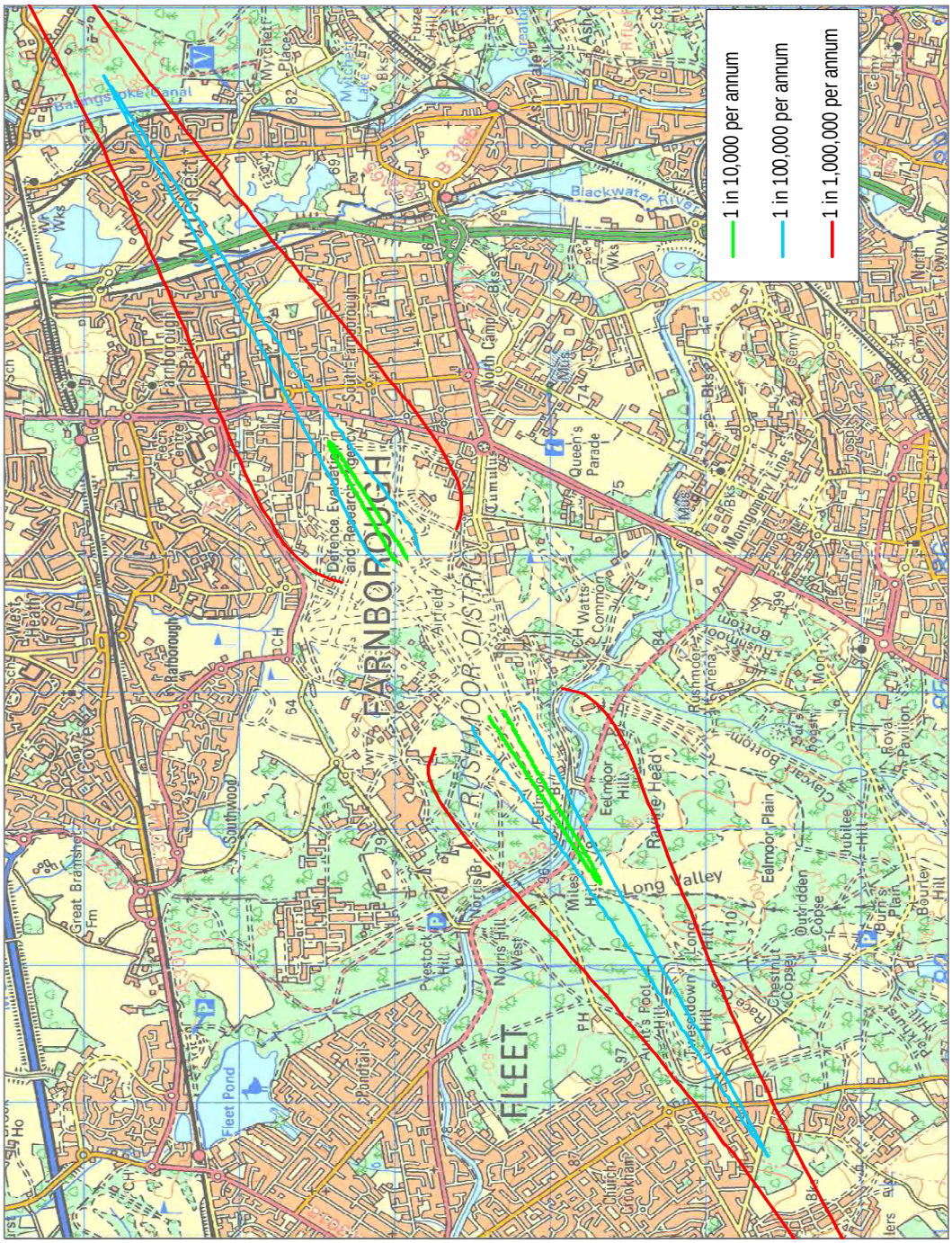


Figure 6: Individual Annual Risk Contours for 50,000 movements per annum

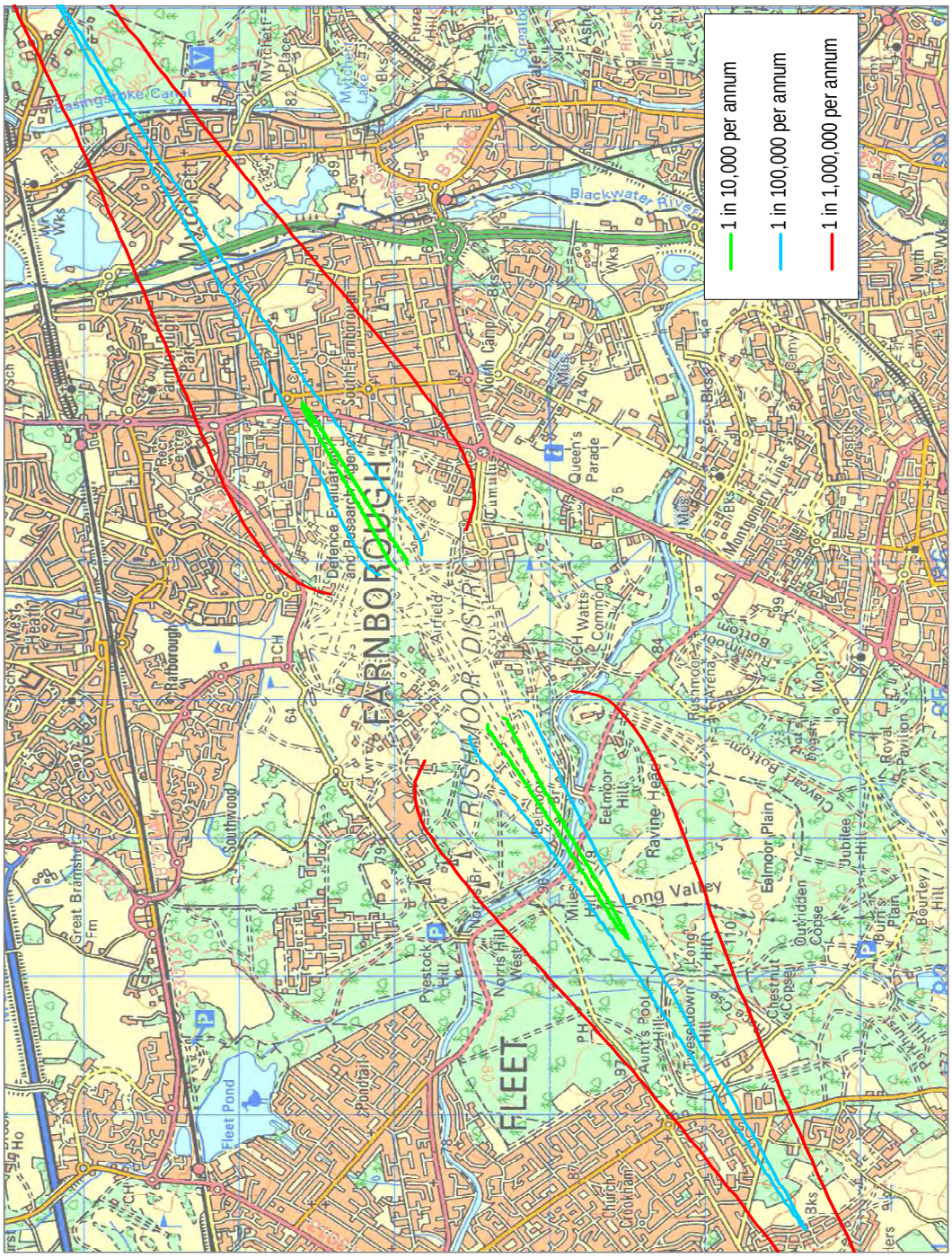


Figure 7: Individual Annual Risk Contours for 60,000 movements per annum

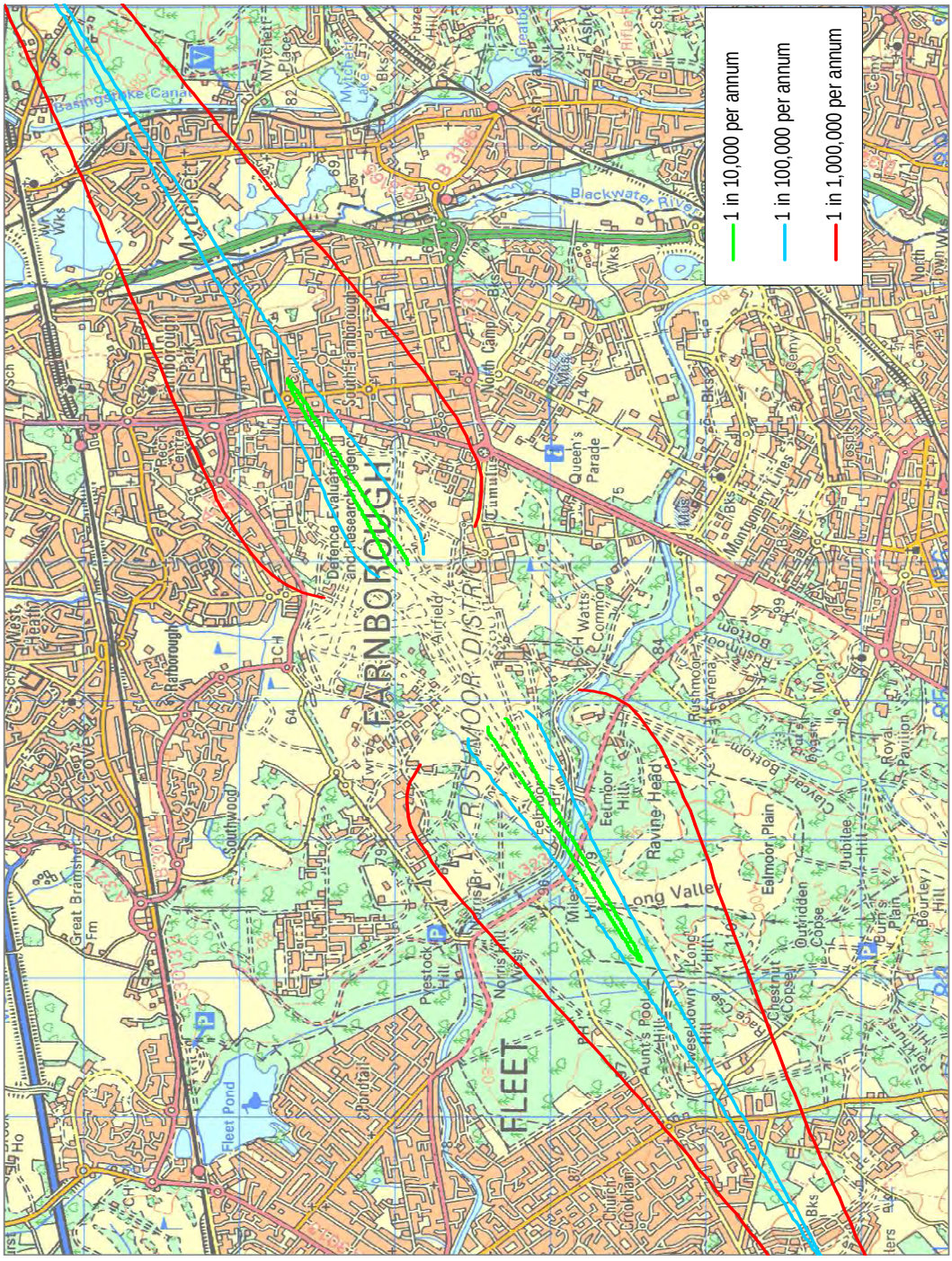


Figure 8: 1 in 10,000 Annual Individual Risk Contours for 28,000 and 50,000 movements per annum

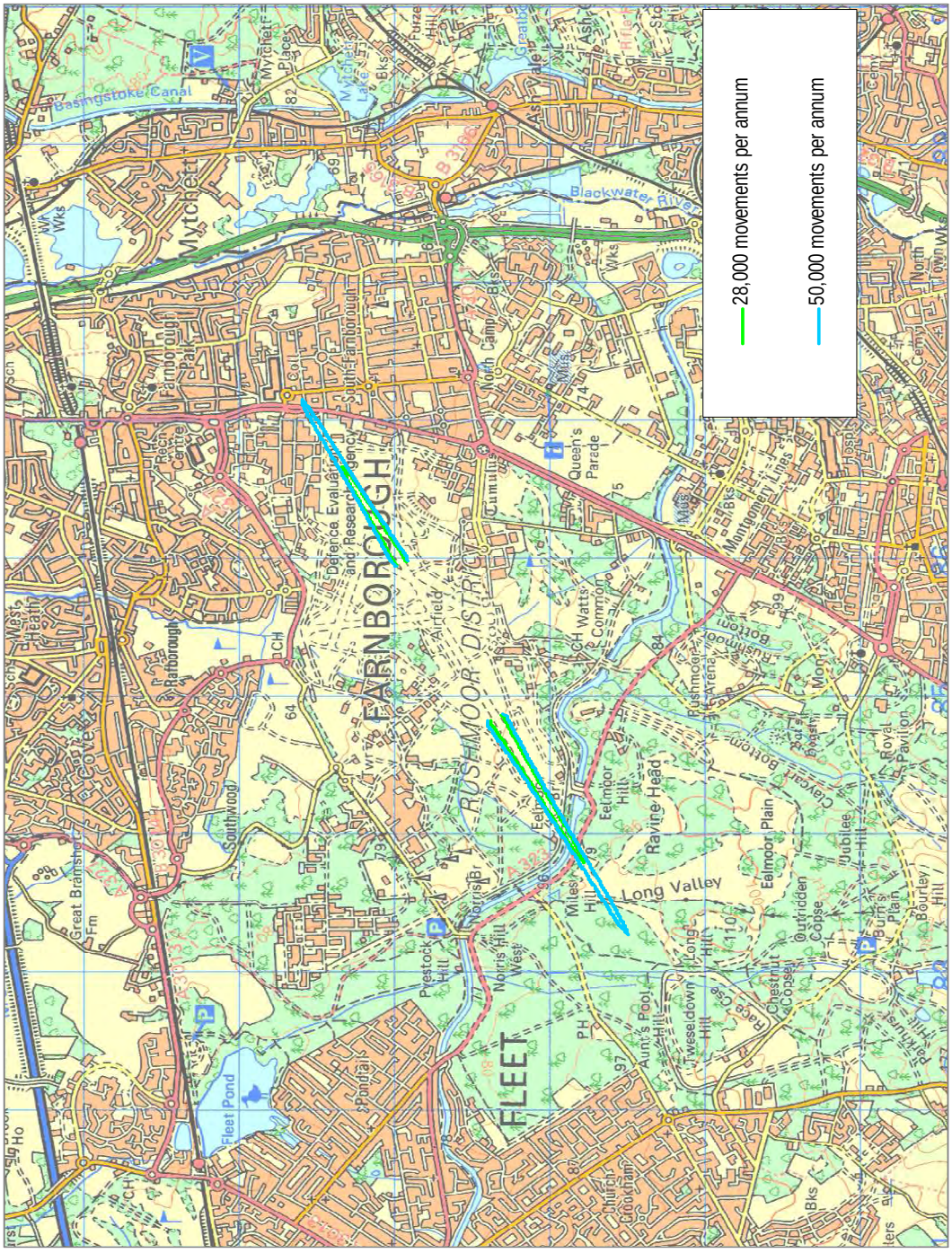


Figure 9: 1 in 100,000 Annual Individual Risk Contours for 28,000 and 50,000 movements per annum

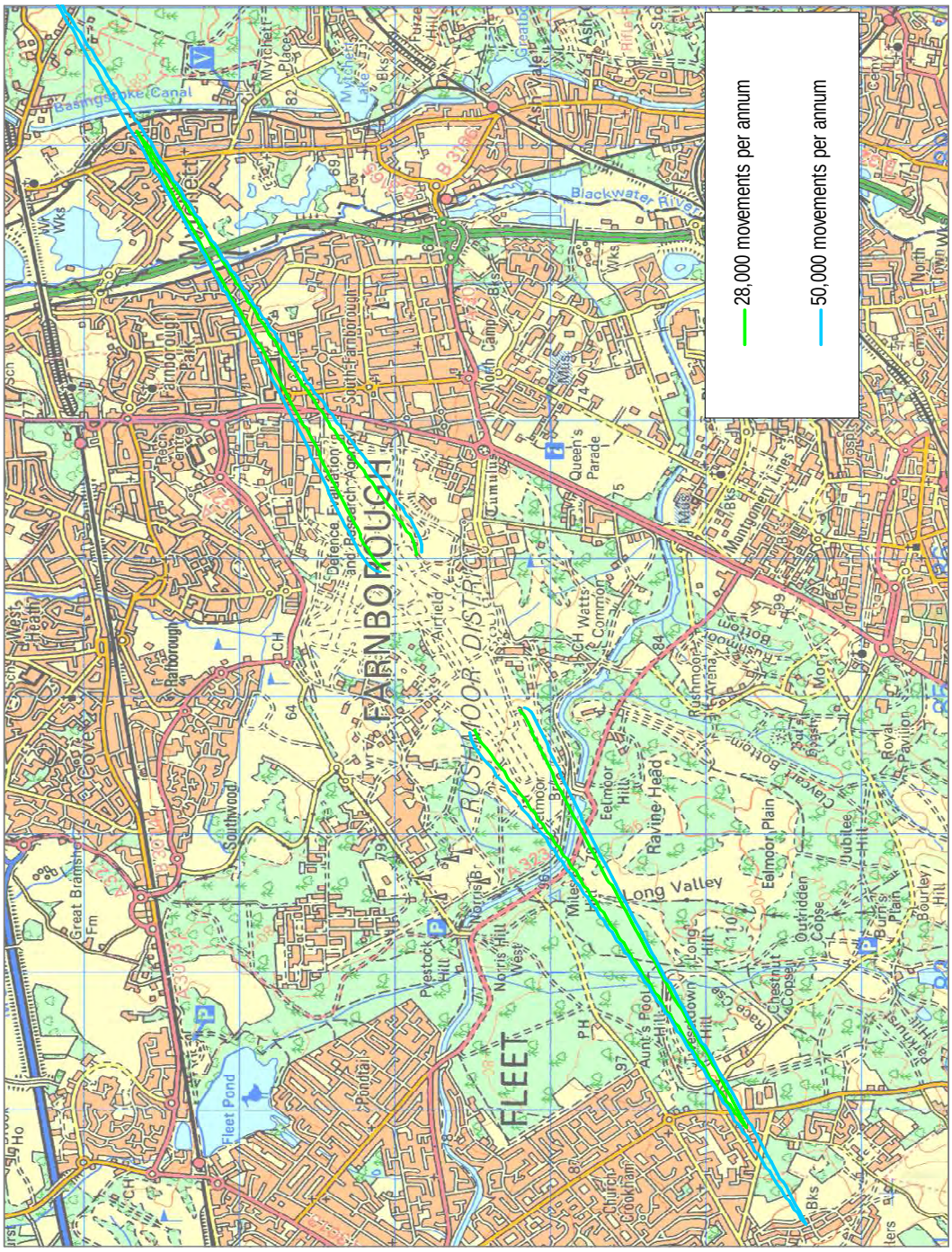


Figure 10: 1 in 1,000,000 Annual Individual Risk Contours for 28,000 and 50,000 movements per annum

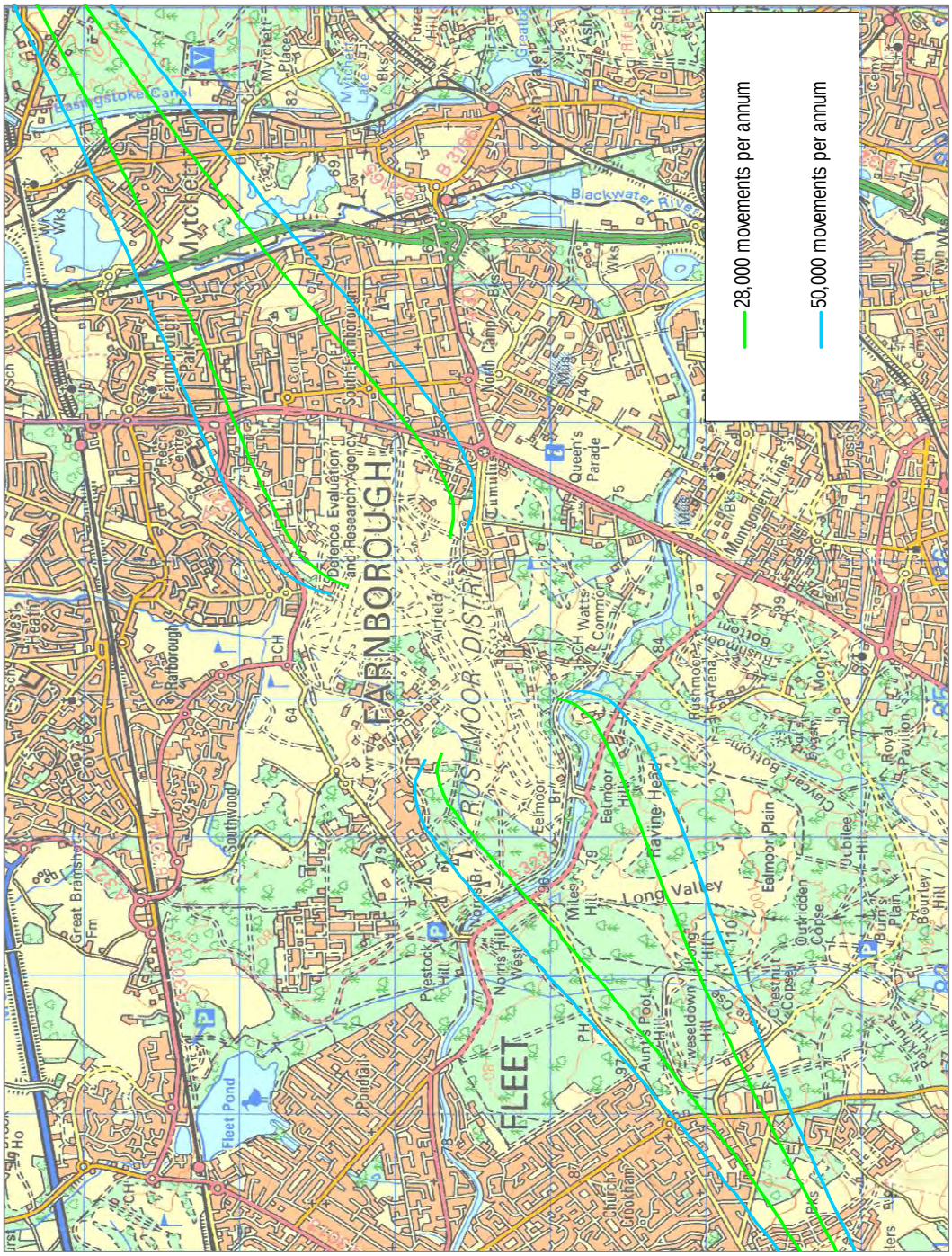
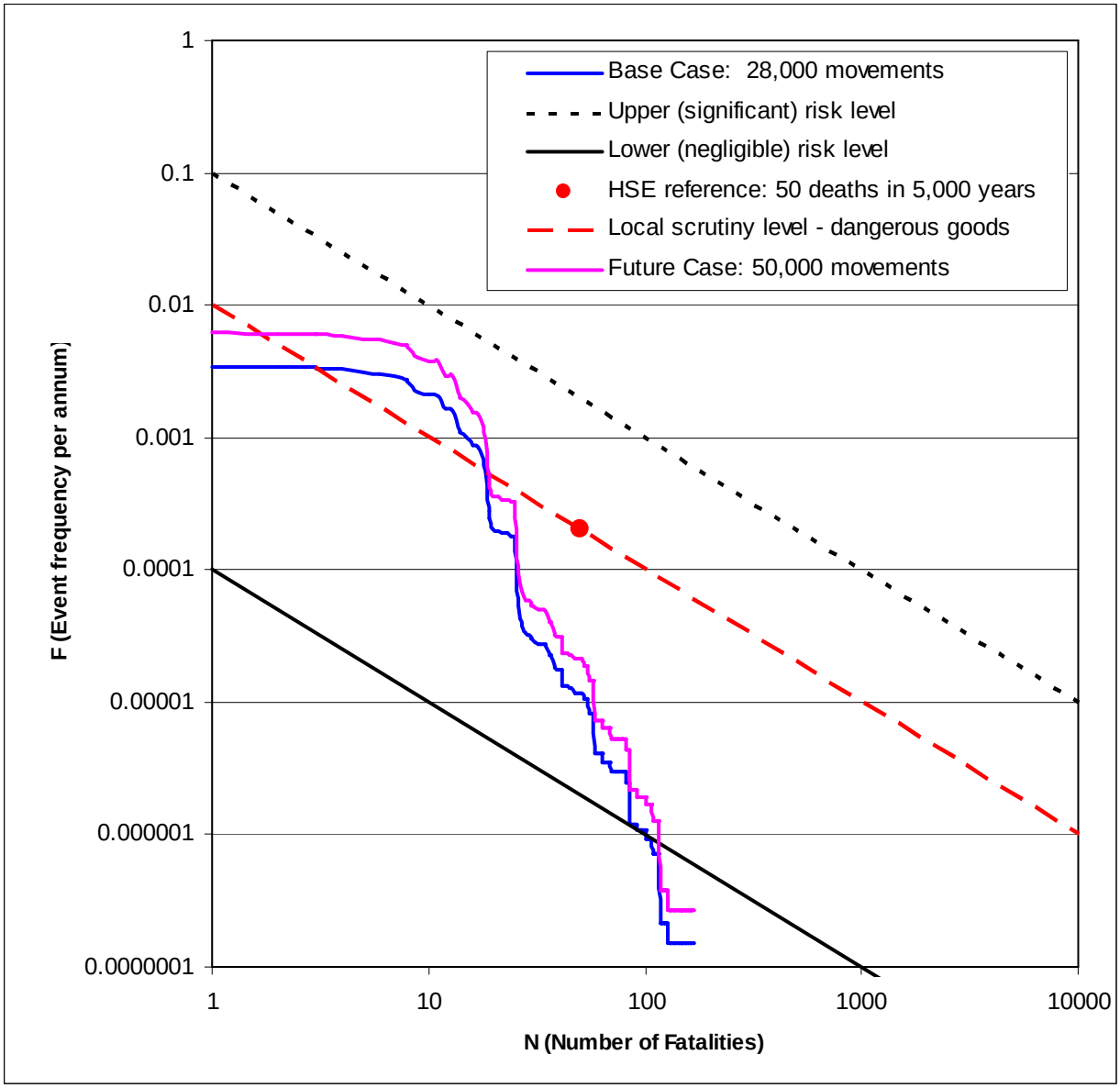


Figure 11: Societal Risks for Current Case and 50,000 movements per annum



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