Appendix L – Methodology for risk assessment

Compliance with Appendix L means:

(a) Use of Steps 1 to 6 below (the default methodology); or

(b) Use of a recognised risk assessment methodology included in a regional, city or district plan or recognised in the consideration of a resource consent application. This may include risk assessment methodologies incorporated in Regulations or industry codes of practice.

Appendix L sets out the default methodology to be used to analyse and evaluate risk where such analysis and evaluation is required under Policies NH 8A and NH 9B and no alternative methodology has been included in a relevant regional, city or district plan or is recognised in the consideration of a resource consent application. A diagram showing the default Appendix L methodology is shown in Figure 4 at the end of Appendix L.

Although it is obligatory to use the default methodology to give effect to Policies NH 8A and NH 9B where no other methodology has been approved, there are stages and tasks within the methodology where discretion is to be exercised. These include:

- whether the assessment of consequences is quantitative or qualitative
- interpretation of aspects of the consequences table
- whether assessment of hazard events with likelihoods other than those specified in Table 20 ought to be undertaken.

Therefore, in respect of the matters such as those listed above, compliance with Appendix L requires judgement by the suitably qualified and experienced practitioner carrying out the assessment.

The following default methodology incorporates two different risk metrics broadly described in the explanation accompanying Policy NH 8A.

Steps 1-4 relate to maximum risk as determined by combining likelihood and consequence through use of the Risk Screening Matrix.

Use of the annual individual fatality risk (AIFR) metric is also required in certain circumstances as described in Step 5 below.

Defining the event of maximum risk

Natural hazards manifest as hazard events. Typically, different sized hazard events occur with different frequencies (for example, very large events occur much less frequently than smaller events). Events of different likelihoods will have different consequences. Hence in any area subject to a natural hazard there may be a range of different risks associated with the same natural hazard. For the purpose of risk evaluation, it is important to identify the *maximum risk* being the event with the combination of likelihood and consequence that yields the greatest risk.

In conceptual terms, natural hazard risk can be plotted as a curve with likelihood on the vertical axis and risk (the product of likelihood and consequence) on the horizontal axis (see Figure 3). There is a point on that risk curve that represents the greatest risk, indicated on Figure 3 as “Maximum risk”.

The maximum risk will be associated with an event of a particular likelihood (indicated by event likelihood “L_{MR}” on Figure 3). The likelihood that represents the greatest risk will vary for each hazard. For each hazard the maximum risk event should be identified for evaluation against risk thresholds (being the categories of risk described in Policy NH 2B). Note the maximum risk will not necessarily be the event with the greatest potential consequence.

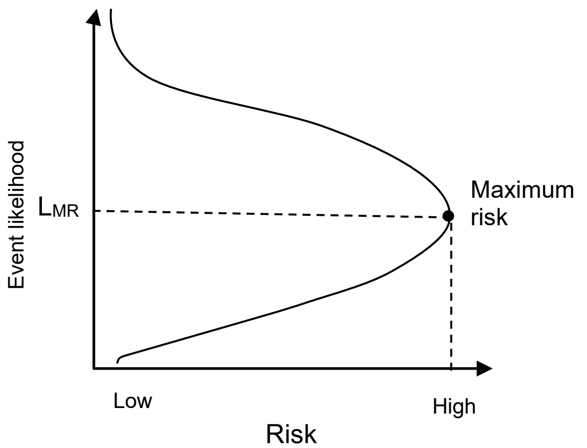

Figure 3 Conceptual curve of maximum risk.

For multiple hazards, follow the approach set out in Beban and Saunders, 2013[10], page 51.

Risk assessment in the absence of hazard susceptibility areas mapped in accordance with Policy NH 7A

In the period before regional and district plans give effect to Policy NH 7A, consent applicants, requiring authorities lodging notices of requirement, and proponents of private plan changes may be required to undertake risk assessment in accordance Policy NH 9B.

In those situations the risk assessment steps 1–5 of this Appendix should be preceded by an initial assessment of the development site's susceptibility to the range of natural hazards set out in Policy NH 7A. This should be required from the applicant as part of the assessment of environmental effects consistent with clause 7 of Schedule 4 to the Act (or as part of the information otherwise required as part of a notice of requirement or private plan change). The Regional Council, together with the territorial authorities, will hold information about the extent of natural hazards prior to hazards susceptibility mapping under Policy NH 7A. That information, together with published information from other agencies, is expected to form the basis of applicants' hazard susceptibility statements within their AEEs. Only in exceptional circumstances would applicants be expected to commission primary research to fulfil this requirement during this interim period.

Primary Analysis (Steps 1 – 4)

Step 1 – Selecting starting likelihood for risk assessment

Because it is not possible to know in advance of assessment which event likelihood corresponds with the maximum risk, it is often necessary to analyse events of a range of likelihoods. However, in each case, there is a preferred starting point (likelihood) for the analysis. This varies by hazard as indicated in Table 20.

Table 20[11] Likelihoods for risk assessment

Hazard	Column A: Likelihood for initial analysis+ AEP (%)#	Column B: Likelihood for secondary analysis+ AEP (%)#
Volcanic hazards (including geothermal)	0.1	0.2 0.005
Earthquake (Liquefaction)	0.1	0.2 0.033
Earthquakes (Fault rupture)	0.017	0.2 0.005
Tsunami	0.1	0.2 0.04
Coastal erosion	1	2 0.2
Landslip (Rainfall related)	1	2 0.2
Landslip (Seismic related)	0.1	0.2 0.033
Flooding (including coastal inundation)	1	2 0.2

+The term "initial analysis" refers to the starting point for risk analysis as described in Step 1 of this methodology. It is the first scenario to be assessed for risk. The term "secondary analysis" refers to any subsequent scenario that is assessed for risk in accordance with Step 5 of this methodology.

#AEP (Annual Exceedance Probability) is the probability that a natural hazard event of a certain size will occur, or will be exceeded, in a time period of one year. For example, an inundation level with a 2% AEP means that there is a 2% chance in any one year of that level being equalled or exceeded.

Those undertaking a risk assessment should begin by assessing the consequences of an event of the likelihood shown in Column A of Table 20.

Step 2 – Determining potential consequences

In accordance with Table 21 (consequence table), the following consequences of the hazard event shall be considered:

[10] Beban, J. G.; Saunders, W. S. A. 2013. Incorporating a risk-based land use planning approach into a district plan, *GNS Science Miscellaneous Series* 63. 52 p.

[11] Table 20 likelihoods, presented to guide the identification of the event with the highest risk, are derived from ranges suggested by relevant hazard specialists.

(a) The percentage of buildings of social/cultural significance within the hazard assessment area that would have functionality compromised.

(b) The percentage of affected buildings within the hazard assessment area that would have functionality compromised.

(c) The percentage of critical buildings within the hazard assessment area that would have functionality compromised.

(d) The percentage of the population serviced by a lifeline utility affected by disruption of the lifeline utility and the length of time the service is likely to be compromised.

(e) The number of human deaths within the hazard assessment area.

(f) The number of injuries to people within the hazard assessment area.

Determining consequences

The default methodology provides for two means of determining the level of consequences:

- The quantitative method; and
- The qualitative method.

While the method to be used is generally to be determined by the party undertaking the risk assessment based on the vulnerability of the community to natural hazards and the resources available, the quantitative method must be used where:

- The hazard has generated a damaging event in the recent past and there is a high likelihood that events of a similar scale will continue, or occur again; or
- The hazard susceptibility area is greenfield land and is proposed to be developed with an ultimate urbanised footprint of five hectares or more; or
- The hazard susceptibility area has been subject to previous quantitative risk assessment and the development proposal that gives rise to the need for risk assessment would materially increase the potential consequences of an event.
- For the avoidance of doubt:
- unless a quantitative method must be used, a risk assessment may use a combination of quantitative and qualitative measurement; and
- determination of consequences should take into account any existing risk reduction measure that may be in place and any risk reduction proposed.

Quantitative determination of consequences

Quantitative determination will typically involve the use of various models and reference data sets applied and interpreted by technical experts. Assumptions and estimates may underpin the models and methodologies used and hence even quantitative determination will often represent “best estimates”.

Although quantitative determination of consequences will often require technical expertise, a number of relatively simple approaches and data sources are available for use by the regional council and city and district councils.

Potential impacts on buildings - matters (a) to (c).

For earthquake and flood (inundation) consequences in relation to buildings, a degree of quantification will be possible by applying standards specified in the Building Code and building importance levels specified in AS/NZS 1170.0:2002. Analysis should assume full compliance with those standards in determining the potential consequences of an event on a greenfield development.

Where the spatial scale of the risk assessment incorporates existing development the degree of compliance with the Building Code should be modelled or estimated based on the age of buildings, historic building consent data or other survey method.

A degree of discretion will need to be exercised in determining whether buildings would have been “functionality compromised” and in determining whether a lifeline utility is out of service or just has service compromised. In the context of damage to buildings, “functionally compromised” will generally occur when a building cannot continue to be used for its intended use immediately after an event. However the nature and duration of loss of functioning will be relevant and judgement will need to be made as to whether the extent of likely damage has a serious or manageable impact on normal social and business functioning. This will form part of arriving at “best estimates”.

Potential impacts on lifeline services – matter (d).

In determining the level of consequence of an event on a lifeline utility, relevant industry standards and guidelines shall be assumed to have been followed unless the council has evidence to the effect that is not the case (in which instance an allowance for an estimated level of non-compliance should be made in the analysis).

Potential impacts on lives and safety - matters (e) and (f).

Estimates of lives lost and injuries sustained will be based on particulars of the hazards and context *(*e.g. likely warning time of an event and provision for evacuation (including vertical evacuation), occupancy rates of buildings) and frequency of occupancy.

Qualitative assessment of consequences

In many cases a qualitative assessment of the potential consequences of the hazard event may be sufficient.

As noted earlier, except for the specific circumstances listed above, those required to undertake risk assessment may choose either the quantitative or qualitative method (or some combination).

Where a qualitative approach is taken, judgement is to be exercised using best available information to estimate the level of each potential consequence and the assignment of an overall consequence rating and the corresponding likelihood rating.

Qualitative assessment should be undertaken by a suitably qualified and experienced practitioner. The council has the discretion to decide who it considers is suitably qualified; the term is not defined in the Statement. However, guidance on who a suitably qualified and experienced practitioner might be is provided in Box 1 at the end of this Appendix.

Qualitative assessments should be recorded in an assessment report with all assumptions and estimates made explicit. Where significant land use policy decisions are to be based on the findings of these qualitative assessments, reports should be peer reviewed by a person with appropriate natural hazard risk expertise to confirm that assumptions made are reasonable based on available information.

Step 3 – Assign a consequence level

Based on Step 2 a consequence level of insignificant, minor, moderate, major or catastrophic should be assigned by applying Table 21.

It is possible that the hazard event analysed will have different levels of consequence across each of the five types of consequence that have been measured, modelled or estimated. Where that is the case, the applicable consequence level will be the one that corresponds to the row in Table 21 that represents the highest measured or estimated consequence.

Step 4 – Determine the risk level

Based on the likelihood (AEP from Table 20) and the consequence level derived from Table 21, the level of risk is to be determined using the Risk Screening Matrix below.

Risk Screening Matrix

	Consequences				
Likelihood[12] (AEP %)	Insignificant	Minor	Moderate	Major	Catastrophic
≥2	Low risk	Medium risk	Medium risk	High risk	High risk
<2–1	Low risk	Low risk	Medium risk	Medium risk	High risk
<1–0.1	Low risk	Low risk	Medium risk	Medium risk	High risk
<0.1–0.04	Low risk	Low risk	Low risk	Low risk	Medium risk
<0.04	Low risk	Low risk	Low risk	Low risk	Medium risk

Key

High risk

Medium risk

Low risk

[12] The likelihood ranges allow for the evaluation of multiple hazards, e.g. flooding, landslip, tsunami, fault rupture. (Saunders, W.S.A.; Beban, J.G.; Kilvington, M. 2013. Risk-based approach to land use planning, *GNS Science Miscellaneous Series 67*)

Secondary Analysis

Step 5 – Iterate risk assessment and calculate annual individual fatality risk (AIFR) if necessary

Although steps 1–4 will categorise the risk associated with a natural hazard event of a certain likelihood, it will not demonstrate what event likelihood represents the greatest risk nor does it identify the AIFR.

That being the case, if the initial assessment determines natural hazard risk to be low or medium, further steps will be required. As outlined below, those further steps involve applying the likelihoods of Column B of Table 20. The use of those likelihoods will help to identify the point of maximum risk (refer Figure 3).

The following sequencing of steps is designed to minimise the further analysis that is required. However, in any particular situation it may be prudent to undertake comprehensive risk assessment beyond the minimum required approach set out below.

(a) Where the initial assessment results in a risk level categorisation of *High*:

  (i) No further assessment is required (but see (ii) below). The risk for the purpose of Policy NH 3B is High. (While there might be a greater risk associated with a less likely event the management approach associated with that hazard will not change.)

  (ii) Further iterative assessment may be undertaken to test the effect of alternative or additional mitigation options in an effort to reduce the risk level.

(b) Where the initial assessment results in a risk level categorisation of *Medium*:

  (i) Calculate the annual individual fatality risk (AIFR) using the following formula:

  AIFR = (D x P)/N

  Where:

  D = number of anticipated (modelled) deaths from the event

  N = population (maximum number of people present within the hazard assessment area at any point in time over a 24 hour period)

  P = the computed annual exceedance probability. Note that values of AEP expressed as a percentage (as in Table 20) must first be divided by 100.
  E.g., from Column A of Table 20, using Flooding AEP(%) of 1:
  P = 1/100 = 0.01

  (ii) If the AIFR is greater than 1 x 10^{-4} re-categorise the risk as High.

  (iii) If the AIFR is 10^{-4} or less, steps 1–5 should be repeated using the event likelihood(s) specified in Column B of Table 20.

  (iv) If the risk screening matrix categorises risk from any secondary assessment as High, the risk for the purpose of Policy NH 3B is High.

  (v) If the risk screening matrix does not categorise risk from any secondary assessment as High the risk for the purpose of Policy NH 3B is Medium.

(c) Where the initial assessment results in a risk level categorisation of *Low*:

  (i) Undertake secondary assessment by repeating steps 1–5 using the event likelihoods specified in Column B of Table 20.

  (ii) If the risk screening matrix categorises the risk from any secondary assessment as Medium, calculate the annual individual fatality risk (AIFR) using the formula described in Step 5 (b) above. If the AIFR is greater than 1 x 10^{-4} re-categorise the risk as High.

  (iii) If the risk screening matrix categorises the risk from any secondary assessment as Low, calculate the annual individual fatality risk (AIFR) using the formula described in Step 5 (b) above.

  - If the AIFR is 1 x 10^{-4} or less and greater than 1 x 10^{-5} re-categorise the risk as Medium.

- If the AIFR is 1×10^{-5} or less the risk is Low.

(d) Despite (b) and (c) above, re-categorise the risk as:

- Medium if the $AIFR^{pic}$ is 1×10^{-4} or less and greater than 1×10^{-6}; or
- High if the $AIFR^{pic}$ is greater than 1×10^{-4}

where the $AIFR^{pic}$ is calculated using the following formula:

$$AIFR^{pic} = (D^{pic} \times P)/N^{pic}$$

where:

D^{pic} = number of anticipated (modelled) deaths in the population in care from the event

N^{pic} = population (maximum number of people in care present within the hazard assessment area at any point in time over a 24 hour period)

P = the computed annual exceedance probability (as defined in (b) above).

If an assessment indicates High or Medium risk, further iterative assessment may be undertaken to test the effect of alternative or additional mitigation options in an effort to reduce the risk level.

Step 6 – Assign a risk level to each hazard assessment area

Following any secondary or subsequent analysis and any further iterations undertaken to test the effect of alternative or additional mitigation options, confirm the final risk level for each hazard assessment area and assign that risk level to the hazard assessment area and assessed actual and potential land use.

Box 1 - Guidance on suitably qualified and experienced practitioners

As a general guide, a suitably qualified and experienced practitioner is a person that is independent, applies good professional practice, and assesses consequences with reference to accepted benchmarks and industry guidelines. Environmental practitioners are not expected to act alone across the large number of disciplines required to deal with natural hazard risk issues. For example, someone may be suitably qualified in understanding the consequences associated with flooding but have no experience in assessing earthquake related consequences. The practitioner is essentially an expert in some specific and relevant fields and experienced in drawing together multidisciplinary inputs and drawing conclusions about likely consequences.

A suitably qualified and experienced practitioner would need to be willing to certify (by signature) that the content of the hazard consequence assessment complies with good practice and professional standards, and to stand by the conclusions of the report. For example, a person certifying a report should be someone who could ultimately stand in the Environment Court and provide expert testimony, and whose experience and qualifications stand up to Court scrutiny.

Table 21 Consequence table with qualitative and quantitative descriptions.

Consequence level	**Built**			**Lifelines utilities**	**Health & safety**
	Social/cultural	Buildings	Critical buildings		
Catastrophic	≥25% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	≥50% of buildings within hazard assessment area have functionality compromised.	≥25% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for > 1 month (affecting ≥ 20% of the town/city population) OR out for > 6 months (affecting < 20% of the town/city population).	>101 dead and/or >1001 injured
Major	11–24% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	21–49% of buildings within hazard assessment area have functionality compromised.	11–24% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 week – 1 month (affecting ≥ 20% of the town/city population) OR out for 6 weeks to 6 months (affecting < 20% of the town/city population).	11–100 dead and/or 101–1000 injured
Moderate	6–10% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	11–20% of buildings within hazard assessment area have functionality compromised.	6–10% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 day to 1 week (affecting ≥ 20% of the town/city population) OR out for 1 week to 6 weeks (affecting < 20% of the town/city population).	2–10 dead and/or 11–100 injured
Minor	1–5% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	2–10% of buildings within hazard assessment area have functionality compromised.	1–5% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 2 hours to 1 day (affecting ≥ 20% of the town/city population) OR out for 1 day to 1 week (affecting < 20% of the town/city population).	≤1 dead and/or 1–10 injured
Insignificant	No buildings of social/cultural significance within hazard assessment area have functionality compromised.	<1% of buildings within hazard assessment area have functionality compromised.	No damage within hazard assessment area, fully functional.	A lifeline utility service is out for up to 2 hours (affecting ≥ 20% of the town/city population) OR out for up to 1 day (affecting < 20% of the town/city population).	No dead No injured

NB for the purpose of Table 21:

- *the term "town/city population" means the catchment of people within the hazard assessment area that is served by the lifeline utility, except that with respect to a lifeline utility that predominantly or exclusively serves a population outside the hazard assessment area, it means the population in the area served by the lifeline utility.*
- *the applicable consequence level will be the one that corresponds to the row that represents the highest measured or estimated consequence.*

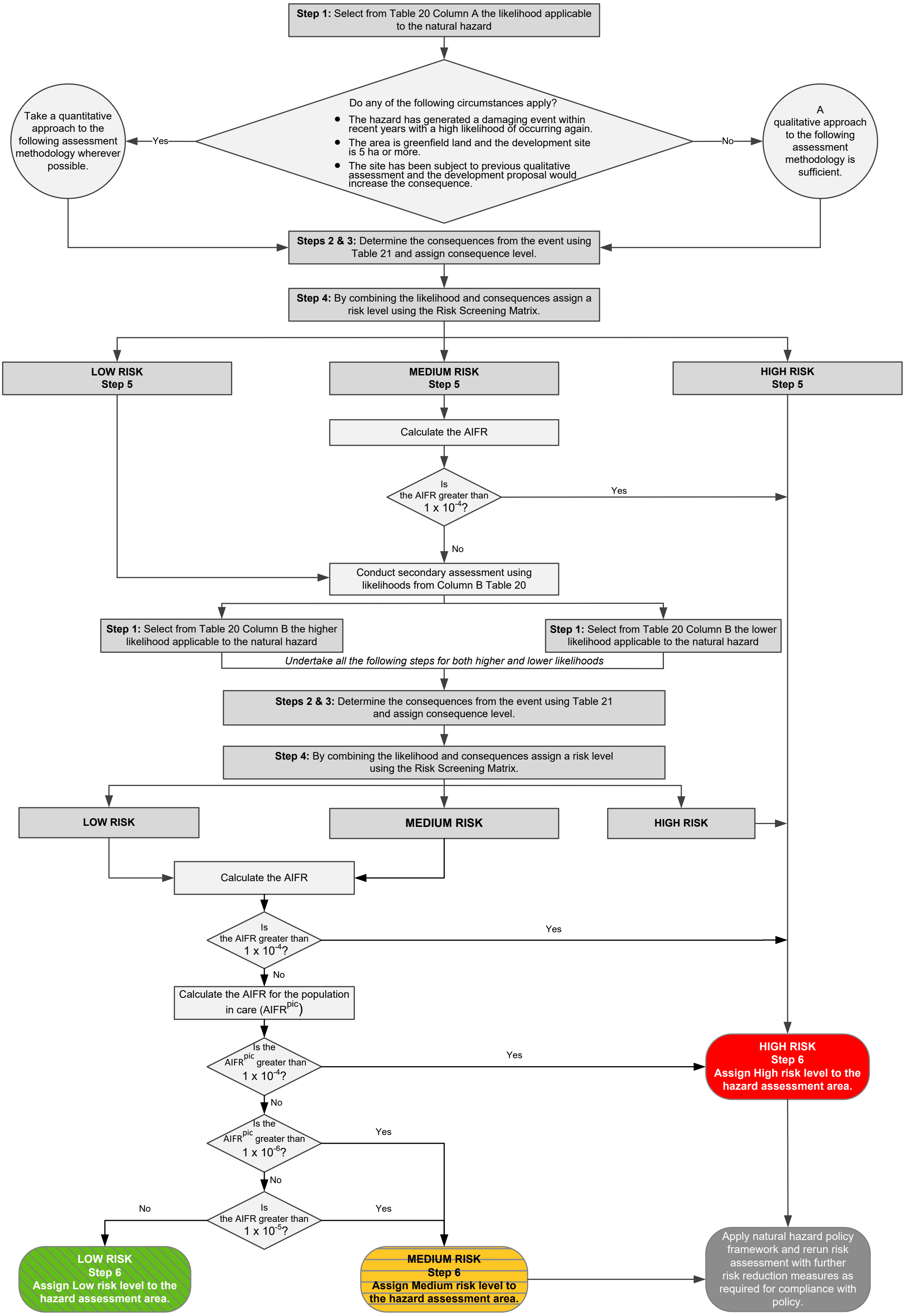

Figure 4: Appendix L Methodology for Risk Assessment Flow Chart.