Guidance to Natural Capital Partners on the Treatment of Offsetting for Air Travel in the CarbonNeutral Protocol

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Summary

Aviation as a sector has large impacts on global warming, directly through emission from aircraft engines, accounting for some 2% of global emissions of CO_2, and indirectly through the atmospheric impacts of flight, including contrails and cloud formation. It is also one of the fastest growing sectors; 2020 emission are expected to be some 70% higher than 2005 and forecasts suggest further growth of over 300% by 2050. Mitigation options are largely focussed on direct impacts, for example, improvements in fuel efficiency, use of biofuels and reducing aircraft weight, which are unlikely to contribute to significant reduction or even to offset the effects of growth (see, for example, Lee, Lim and Owen, 2013). The mitigation of indirect impacts, for example by the redesign of aircraft wing tips to modify contrails, are still in early stages of development.

Offsets are therefore an attractive option for managing impacts of flying, both for individuals and companies and in some cases are already offered by aircraft operators. Advances in understanding the full impacts of flight, including indirect impacts, have led to the concept of a multiplier in aviation offset schemes, applied to the carbon emissions of a specific flight to capture the full impacts. There are typically in a range between 1 and 3, reflecting the importance of indirect impacts, but also the relatively low confidence in their actual scale. The CarbonNeutral Protocol contains provisions for evidence-based offsets from aviation, including the use of multipliers. Given the then current state of knowledge, The CarbonNeutral Protocol for 2014, suggested a multiplier of 1 to reflect the high confidence in carbon emissions but with 2 as a multiplier that Clients may elect to apply.

However, since then, the scientific evidence, in particular of some of the indirect effects of flying, has hardened. This has not substantially altered the assessment of scale of radiative forcing of the different components of impact on which the 2014 advice was based, but has provided greater confidence in the assessment of some crucial components. Additionally, evidence of severe impacts of human activity on the climate system is making urgent action to reduce impacts essential if dangerous climate change is to be avoided. The importance of taking a shorter-term view in assessing impacts has grown as a consequence.

It is therefore now recommended, taking a precautionary view in response to the strengthened evidence and the urgent need to reduce impacts of all kinds of economic activity on the climate system, particularly those showing high growth that the multiplier of 2 should be considered as a target multiplier that clients may wish to consider, to be adopted over a period to 2025. Clients should be encouraged to continue to take regard of the evidence and to elect to apply higher multipliers in the longer term. The current evidence suggests this would extend to a multiplier of approximately 2.5 to take account of the best estimate of total impact, including currently highly uncertain impacts on cloud processes.

Introduction

The purpose of this guidance note is to suggest how scientific progress in the understanding of aviation's impact on the climate system can be integrated into The CarbonNeutral Protocol. The focus is on aircraft flights and on the development of an offsetting scheme for their impact on the climate system. Specifically, the note deals with the question: "What factor should be applied to the carbon emissions of aircraft to allow for other effects of air travel on the climate system?"

The 2014 edition of the CarbonNeutral Protocol contained guidance on accounting for aviation, based on the assessment of aircraft impacts on the climate system. It was noted that there were several components to aviation impacts, both direct emissions from aircraft engines, mainly carbon dioxide (CO_2), oxides of nitrogen (NO_x) and particulate matter (PM), and indirect impacts arising, for example, from the formation of contrails and clouds. Radiative forcing (RF) was taken as a metric for comparing the magnitude of impacts from these different components. RF for a particular atmospheric constituent is defined as the difference between incoming solar radiation and outgoing infrared radiation caused by the increase of that agent. For a gas it is the change in radiation due to a change in concentration of that gas. It is expressed in Watts per square meter (W/m^2) or the rate of energy change per unit area of the globe as measured at the top of the atmosphere.

In the 2014 guidance, conclusions about historic long-term impacts were taken from the assessment of available data by Lee et al. (2009). It was noted that, although the total aviation RF, as shown in Figure 1 was some 60% higher than that due to CO_2 alone, the calculated RFs for many components, including some engine emissions were very uncertain in scale and, in some cases in sign with both warming and cooling potential. Given the degree of uncertainty, it was concluded that, although on the balance of evidence the impacts of aviation exceeded the impact of CO_2 alone, it was not possible to give a scientifically credible basis of a multiplier.

In the previous advice, then, the question of a multiplier was left open, at the discretion of the client. The general view taken by Natural Capital Partners' advisors, the Advisory Council, was that accounting for the full impact of aviation on the climate system was complex, with a range of factors operating over a range of time scales, with countervailing impacts and with marked geographic differences. It was also felt at the time that the confidence ranges associated with the quantification of the different factors made it difficult to settle on a single number to represent a departure from the simple factor of 1 applied to the carbon emissions of flight.

The guidance contained in The CarbonNeutral Protocol was that, having considered the evidence, clients could elect to consider only the emission of greenhouse gases (essentially a multiplier of 1) or they could elect to address the wider impacts, including indirect effects of flight, in which case a multiplier of 2 was suggested. Given the difficulties of producing a common basis for calculating RFs from the long term direct impacts, which, in the case of CO_2 operated over periods of a century or more, and the indirect effects, that operated over far shorter time scales, the guidance suggested that the term Aviation Impact Factor was a more useful term of the combined direct and indirect impacts than the RF.

Scientific understanding of aviation's impact on climate change has evolved since the 2014 guidance was adopted, and this paper brings that guidance up to date.

Background to air transport emissions

Carbon dioxide released from fossil fuels is the major human driver of climate change. In order to manage the impacts of fossil fuel use, a range of management measures has been developed. This includes improving energy efficiency, new low carbon technologies and alternative means of delivering energy services. For the residual use of fossil fuels, systems of carbon offsets have been developed to provide further management options.

The basis for calculating offsets required for particular activities or events to render them carbon neutral has been through the measurement of UNFCCC defined GHGs involved, expressed in terms of carbon dioxide equivalence (CO2*e*).

International action on climate change has also focused on direct greenhouse gas emissions, with carbon emissions as the principle focus, and the assessments provided to the international negotiations on climate change by the Intergovernmental Panel on Climate Change (IPCC) are on this basis.

However, the use of fossil fuels also produces other pollutants and some of these have implications for climate change. In the case of aircraft engines, water vapour produced in combustion creates warming in the atmosphere, sulphur dioxide produces cooling. For nitrogen oxides (NO_x), a major constituent in emissions from combustion processes, the action is more complex. In the dynamic chemical process within the atmosphere, NO_x produces ozone which is a greenhouse gas, but also removes another greenhouse gas, methane. Methane is produced by the decay of organic material, for example from coal seams or in animal husbandry and is a powerful climate forcing factor.

Combustion processes also produce a range of particulate pollutants, such as ash and soot, given the collective term Particulate Matter (PM). PM is physically and chemically complex, with individual particles ranging from micrometres in size down to nanometres and with both organic and inorganic constituents. Black carbon, mainly soot, has a strong global warming effect over periods of tens of years and ultra-fine particles (UfP), in the hundreds to tens of nanometres size range, are a highly significant factor in cloud processes.

Several approaches have been suggested to capture the relative effects of the different greenhouse gases and other combustion products in a single metric. Strictly, Global Warming Potential (GWPs) are relevant to the action of long-lived (decades to centuries residence time) and globally well mixed gases. However, they have been applied recently to provide estimates of the action of emissions with a short atmospheric residence time and to non-gaseous (with low potential for global mixing) emissions. For example, GWP gives an index of the activity of atmospheric constituents, referenced to carbon dioxide (which therefore has a GWP of 1) over a given time period. As an illustration of this, over a 20 year period methane has a GWP of about 60 and black carbon of 1000 or more. This has been done in order to understand the value of reducing emission of these “short-lived climate forcers” (SLCFs). Recent assessments by the Climate and Clean Air Coalition have concluded that it is now impossible to remain within a 2ºC target for maximum further warming, unless action is taken on both the currently regulated greenhouse gases and the SLCFs. Many of these SLCFs are already subject to controls because of the impacts they have on local air quality and there are significant co-benefits for both climate change mitigation and health protection to be achieved by joint policy to reduce them. In assessing aircraft impacts on the climate system it is now advised that both short-lived and long-lived greenhouse forcing factors are of significance and should be considered.

Aircraft emissions and global warming

Aircraft operations and their impact on the global environment were the subject of a special IPCC report (IPCC, 1999). This report set the framework for the assessment of impacts and, although the quantification of the scale of impacts has changed as knowledge has improved, it remains an authoritative account of the mechanisms involved. A special report in 2002 by The UK Royal Commission on Environmental Pollution highlighted the importance of aircraft impacts on the global environment and urged the UK Government to take urgent action to press for climate protection charges for aircraft movements globally. The estimate of impacts provided in the 1999 IPCC report were reviewed and updated in an EU research programme, TRADEOFF (Sausen et al., 2005) and Lee et al. (2009) provided a description of mechanisms with a critical review of information on the scale of the different forcing factors associated with aircraft flight.

Since these assessments were published, there have been many further investigations published and the scientific evidence supports the broad conclusion that both direct and indirect effects of flight are real, to varying extents quantifiable and should be taken into account when considering policies and measures for reducing climate impacts of the aviation sector. Lee (2018), in a review of the current state of scientific understanding concluded that, despite considerable improvements in the understanding of some key mechanisms of aviation impacts and developments in improved metrics for characterising them, the 2009 assessment remained a reasonable summary.

Emissions of carbon dioxide are a major factor but the impacts of aircraft NO_x are also significant. This is partly because the NO_x is injected into a part of the atmosphere in which ozone is readily generated but also because the ozone generated has a particularly high warming effect at the altitudes used in aircraft operations. However, NO_x also offsets this warming effect to an extent by removing methane and by removing ozone over longer time scales.

Aircraft engines emit soot as a consequence of incomplete combustion of fuel. This material is a particulate containing black carbon, a short-term climate forcer with a high GWP. Some particulate appears as sulphate, which has a small but significant cooling effect.

Other major factors associated with aircraft are the production of vapour trails (contrails) and what are known as Aircraft Induced Clouds (AIC). These act to produce a warming over the short term, with an RF of similar order to that of aircraft induced ozone and direct emissions of carbon dioxide.

The effects of the different products of aircraft operations are summarised in the figure below, which is taken from the SEI Paper (Kollmus and Crimmins, 2009).

A calculation of Radiative forcing (RF) characterises the overall effects of particular constituents in the atmosphere on climate forcing over a given period, normally since pre-industrial times to a specific year in the present, combining the activity and the concentration of each particular constituent. It is a metric with the real dimensions of “added heating per square meter of the earth’s surface” (mW/m^2) for each component or source. However, as an index applied to aviation it is of limited value as it deals with historic impacts and does not attempt to account for future forcing from the different forcing factors, which would require information about the effects of future emission and decisions about handling differences in atmospheric residence time and the period over which indirect factors operate.

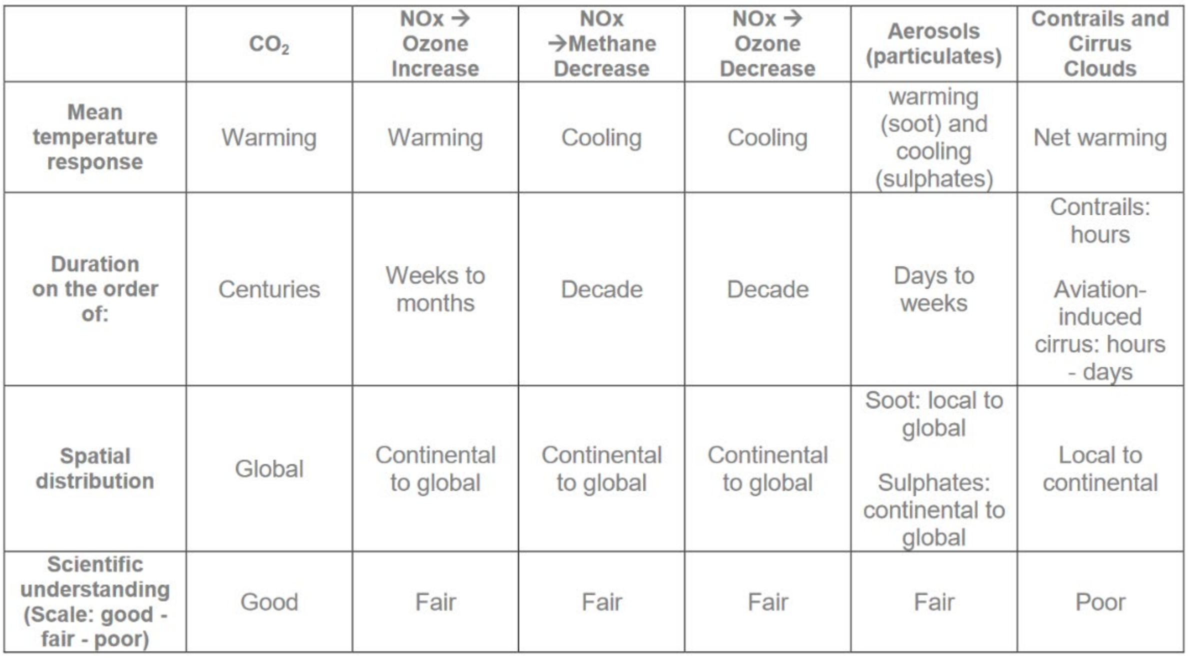
Given estimates of emissions of the different components from different sources (direct and indirect), the RFs can, in the absence of a better metric, be combined to give a “total” radiative forcing due to a particular source. The impacts of a particular component or source can also be presented as a Radiative Forcing Index (RFI) with indexation relative to CO_2. The RFI shows the relative impact of the different emission components and sources and indirect factors over a period related to action of the particular component. However, it should be treated with the caution that it does not strictly compare like for like as it does not account for the differences in atmospheric residence time.

There are other metrics in use, for example Integrated Radiative Forcing (IRF) and Global Temperature Potential (GTP). The advantages and disadvantages of using the different systems of characterisation in respect of aviation are discussed in a Stockholm Environment Institute Paper (Anja Kollmuss and Allison Myers Crimmins, 2009). In summary, although both RIF and GTP both produce estimates of future impacts, they rely critically on decisions about the treatment of short-lived and long-lived forcing components.

However, for most fossil fuel conversion, it seems on most of the characterisation systems studied, the effect of the carbon dioxide emission is the major highly certain factor in climate change impacts. The influence of short-term climate forcers on the overall results is important but should be considered in the light of the time period over SLCFs act. In the case of diesel engine vehicles, for example, the additional warming impact of diesel particulate, a SLCF with a high “GWP”, is only a fraction of the overall impact over a 100 year time period and even over a 20 year period, amounts to less than the direct impact of CO_2 emission.

However, for aviation the situation is different and aircraft have a range of other external effects including the impacts of emissions of nitrogen oxides and carbon soot and contrails and clouds which are to a degree independent of the aircraft engine (the role of the UfP and Black carbon emissions in cloud processes are complex and remain to be clarified and quantified). These additional factors operate at very different time scales and with different effects according to altitude, adding layers of scientific complexity in assessing the full impacts of flight. As a result, the handling of aircraft emissions within an offsetting scheme has proved a particularly difficult and intractable problem.

Table 1 Summary of climatic response to aircraft emissions



	CO_2	NOx → Ozone Increase	NOx →Methane Decrease	NOx → Ozone Decrease	Aerosols (particulates)	Contrails and Cirrus Clouds
Mean temperature response	Warming	Warming	Cooling	Cooling	warming (soot) and cooling (sulphates)	Net warming
Duration on the order of:	Centuries	Weeks to months	Decade	Decade	Days to weeks	Contrails: hours Aviation-induced cirrus: hours - days
Spatial distribution	Global	Continental to global	Continental to global	Continental to global	Soot: local to global Sulphates: continental to global	Local to continental
Scientific understanding (Scale: good - fair - poor)	Good	Fair	Fair	Fair	Fair	Poor

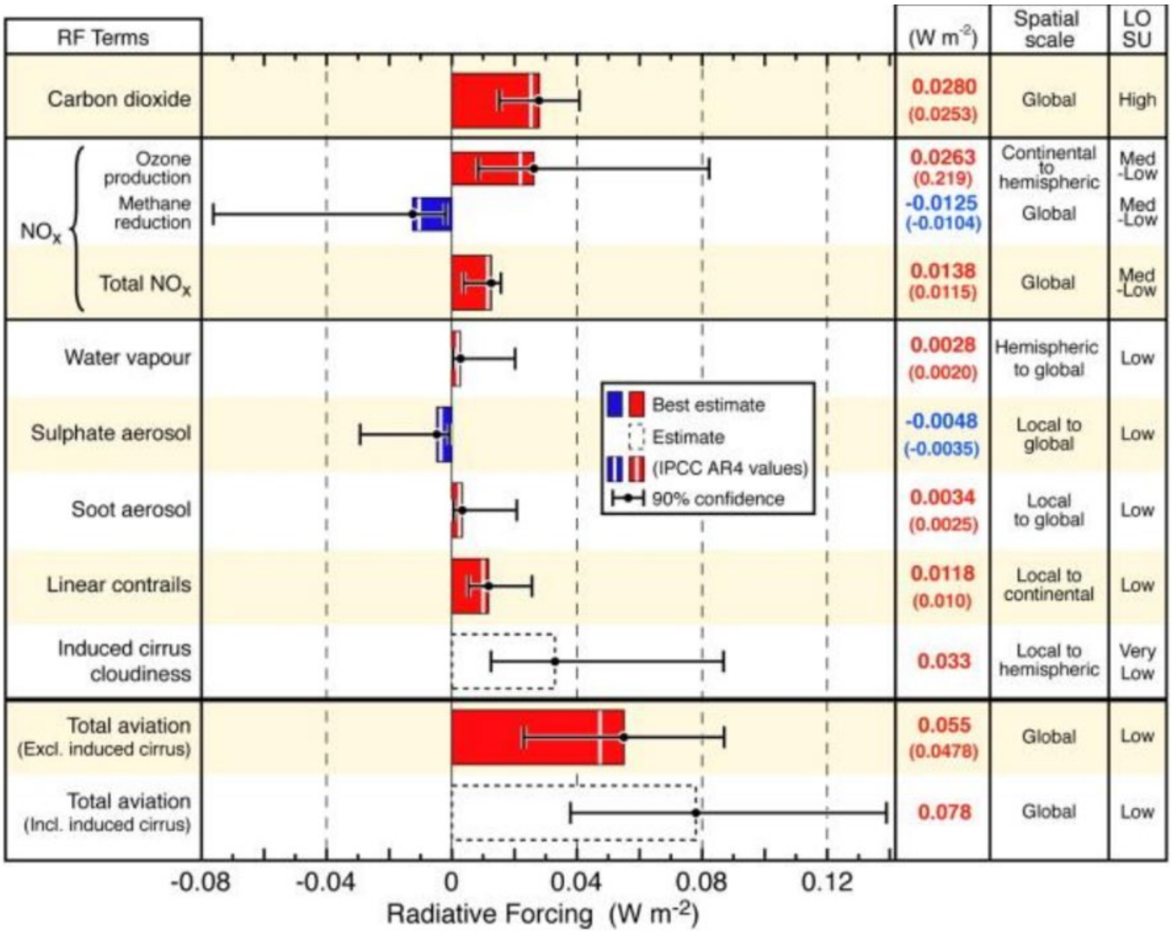
It can be seen from this assessment that the time and geographic scales associated with these different components vary widely; from hours to centuries and from local to global. Given that the different metrics proposed to characterise impacts of the emissions of aircraft on the climate system are limited in their capability to treat a range of time scales and geographic extent, the basis for comparison between the different factors involved in aircraft emission on the climate system is weak. However, this assessment requires context. There is now greater and considerable urgency and the projections for aviation are of substantial continued growth: a more precautionary approach is timely.

The SEI paper concludes that “there is no single metric, no single multiplier and no single answer to the question of how the effects on climate change from air travel should be calculated so that an individual or a company can accurately calculate the climate footprint of their current air travel.” The authors go on, however, to recommend that the metric and underlying assumptions should be chosen to reflect the particular questions and goals concerned. They conclude that any assessment should include managerial and ethical considerations, in addition to scientific ones, with the scientific assessment as a guide.

However, with this caution in mind it is now widely accepted that a broad indication of relative impacts of aviation over the extended period can be roughly characterised by an assessment of relative RF; recognising that this does not necessarily provide a guide to future impacts, assessment of which will depend on the value placed on impacts of SLCFs which is developing rapidly.

Lee et al. (2009) considered information on aviation impacts on global climate, including the then most recent IPCC assessment (IPCC Fourth Assessment, 2007) and produced the following conclusions about long-term historic impacts.

Figure 1 Radiative forcing due to aviation



This figure shows the radiative forcing of the different components of aircraft emission from pre-industrial times to 2005. Although there are wide ranges of uncertainty about the median, historically the median values by themselves show a net positive forcing due to all the factors considered of roughly twice the forcing due to carbon dioxide alone. Lee (2018) concludes that this estimate remains reasonable but that the evidence for the indirect impacts of flight, including aviation induced cirrus (AIC), is now stronger. If the estimates of AIC are included, the net forcing is roughly 2.5 times the CO_2 forcing. However, confidence about the estimates of AIC is very low and without further research the net forcing excluding AIC appears to offer the most secure assumption.

In summary, although a single metric to characterise aircraft emissions is elusive, there is a broad consensus on the historic impact of aircraft flight on the global climate system which is characterised by RF. This suggests that the overall impact of aviation has been roughly twice the impact of CO_2 alone.

Accounting for impacts of emissions from aviation on the global climate

Given the difficulty in identifying a single common metric and the current levels of scientific debate about the way ahead, it is unsurprising that there is a wide range of practices in assessing aircraft impacts on global warming. In a recent review of best practice, Neils Jungbluth and Christolph Melli (2018), found factors of between 1 and 3 applied to CO_2 emissions to capture the full extent of aviation impacts across scientific publications, public bodies and carbon management companies. The basis for these factors also varies considerably, from considerations of aircraft in different phases of flight to simple assumptions about the total CO_2 emission during an entire flight. There is also a difference across this practice in the use for which the factors are intended: accounting for aircraft impacts in reporting systems or policy analysis, life-cycle analysis and impact management, including offsetting.

It is notable in Jungbluth and Melli's review that many practitioners have chosen 2 as the factor to be applied, most commonly to overall CO_2 emissions. This approach has been adopted by the German environmental authority, Das Umweltbundesamt, and is also the approach advanced by the Stockholm Environment Institute. The SEI recommendation is illustrative of an approach which combines scientific guidance and policy decisions on the relative importance of long and short-term forcing agents, together with ethical considerations.

The question of use affects decisions on the approach to be adopted: it is clearly important in policy analysis to have as accurate a characterisation of overall aviation impacts as possible whereas in a management system for assessing levels of offsetting, transparency and equity might be more important considerations.

For Natural Capital Partners, the uses for an aviation emission factor are in reporting emissions accurately and for assessing quantities of offsets required. For these uses, requirements are transparency so that it is clear how the impacts of flights are assessed and recognised, which provides the confidence that the method used has backing from an authority. The requirement for transparency also suggests simplicity and clarity in presentation. The requirement for recognition, failing the authority provided by scientific agreement on a single metric, could fall to an expert body or official system, in particular one recognised by government.

Recommendations

Given that there is no single metric to characterise impacts of air travel on global warming, it is recommended that The CarbonNeutral Protocol take a view of the factor to be applied in assessing air travel guided by the following principals:

Scientifically, there is now consensus that aviation impacts exceed those of CO_2 alone. Contributions from NOx, products of incomplete combustion (soot, black carbon and UfP) and contrails should be included. Although the scientific evidence of effects of AIC remains uncertain its inclusion should be considered within a precautionary approach.

As a policy decision, given the urgency in constraining further warming to the 2 degree centigrade level proposed by UNFCCC, there should be a focus on short-lived climate forcers, in particular on black carbon contrails and ozone.

To provide equity in the distribution of responsibility for flight emissions, passenger density should be taken into consideration. UK Defra suggests differentiation of business from economy flights, which Natural Capital Partners might care to consider.

To capture the non CO_2 effects of aviation, it is suggested that The CarbonNeutral Protocol recommend applying a factor of 2 to CO_2 emissions from a flight, a factor of 2.5 assuming a precautionary approach, or adopt the Defra suggested systems in the interests of adopting a recognised official standard.

It is recognised that this would impose significant further costs and that therefor a period of adaption may be needed but that this should not go beyond 2025.

There remains significant difficultly in deriving a single metric to capture both direct and indirect as well as short term and long term impacts and use of the term “Aviation Impact Factor” as proposed in The CarbonNeutral Protocol should be retained for the multiplier.

In the interest of transparency and given the levels of uncertainty, it is suggested that that The CarbonNeutral Protocol avoids the more complex calculation systems, including uplifts and adjustments for flight patterns. The current scientific understanding of impacts and the uncertainty in quantification cannot support this level of detailed calculation at present.

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