EXHIBIT GS

Corum Preston CJ & Dixon SC

4. Professor Will Steffan's expert report

Expert Report

COURT DETAILS

Court	Land and Environment Court of NSW
Division	Class 1
Registry	Land and Environment Court Sydney
Case number	2017/00383563

TITLE OF PROCEEDINGS

First Applicant	Gloucester Resources Limited ACN 114162597
First Respondent	Minister for Planning
Second Respondent	Groundswell Gloucester Inc.

FILING DETAILS

Filed for	Groundswell Gloucester Inc., Respondent 2
Legal representative	ELAINE ELIZABETH JOHNSON
Legal representative reference	
Telephone	02 9262 6989
Your reference	1825740

ATTACHMENT DETAILS

In accordance with Part 3 of the UCPR, this coversheet confirms that both the Lodge Document, along with any other documents listed below, were filed by the Court.

Expert Report (180612 Will Steffen Final Expert Report with attachments.pdf)

[attach.]

Ex 63.

Expert Report
NSW Land and Environment Court
Proceedings 2017/383563
12 June 2018

Professor Will Steffen
Emeritus Professor, The Australian National University
Senior Fellow, Stockholm Resilience Centre

Executive Summary

1. Anthropogenic climate change is real and poses serious risks for the wellbeing of humans and our societies. These risks rise rapidly and nonlinearly with the rise in global average surface temperature.

2. Recognising that the risks to human wellbeing of unchecked climate change are too high to accept, governments around the world have agreed to limit warming to 1.5-2.0°C (the 2015 Paris accord).

3. The carbon budget approach is the most robust way to determine the rate of emissions reductions required to meet the goals of the Paris accord. This approach limits the cumulative amount of additional CO_2 emissions that can be allowed consistent with the Paris accord.

4. To meet a 2°C carbon budget, a very rapid phase-out of all fossil fuel usage by 2050 at the latest, or preferably earlier, is required.

5. This means that the majority of the world's existing fossil fuel reserves must be left in the ground, unburned. Furthermore, no new fossil fuel developments, or extensions to existing fossil fuel mines or wells, can be allowed.

Introduction

6. I have prepared this report in response to an expert brief provided to me by EDO NSW acting on behalf of Groundswell Gloucester Inc, dated 6 June 2018 (**Appendix A**). I have reviewed Division 2 of Part 31 and the Expert Witness Code of Conduct under the *Uniform Civil Procedure Rules 2005* and I agree to be bound by their terms.

7. A copy of my curriculum vitae, including my relevant qualifications, is attached (**Appendix B**).

Anthropogenic climate change and its impacts

8. Anthropogenic (human-driven) climate change refers to the changes in the climate system caused by human activities, primarily the emission of greenhouse gases into the atmosphere. The most important of these gases is carbon dioxide (CO_2), with about 90% of CO_2 emissions arising from fossil fuel (coal, oil, gas) combustion and the remainder from land-use change (Le Quéré et al. 2017).

9. Greenhouse gases change the climate by trapping outgoing heat (long-wave radiation) from the Earth's surface and retaining it in the lower atmosphere and at the surface, thus increasing the energy of the climate system and raising its average temperature (Intergovernmental Panel on Climate Change (IPCC) 2013).

10. Currently global average surface temperature is about 1°C higher than pre-industrial levels and 2014, 2015, 2016 and 2017 have been the four hottest years on record (National Oceanic and Atmospheric Administration, USA (NOAA) 2018).

11. ~~The rate of climate change is alarming~~. The rise in atmospheric CO_2 concentration is up to 10 times faster than the most rapid changes in the geological record (Lüthi et al. 2008). Since 1970 global average surface temperature has been rising at a rate of 1.7°C per century, compared to a 7,000-year background rate of change of about 0.01°C per century (NOAA 2016; Marcott et al. 2013).

12. Many other features of the climate system, in addition to global average surface temperature, are changing as a result of anthropogenic greenhouse gas emissions (IPCC 2013). These include changes in the basic circulation patterns of the atmosphere and the ocean, increasing intensity and frequency of many extreme weather events, increasing acidity of the oceans, rising sea levels and consequent increases in coastal flooding, and intensification of the hydrological cycle.

13. The impacts of climate change are already being felt around the world. As reported by the IPCC (2013), the most authoritative assessment body on the science of climate change, some of the most important impacts are:
    a) Warmer and/or fewer cold days and nights over most land areas.
    b) Warmer and/or more frequent hot days and nights over most land areas.
    c) Increases in the frequency and/or duration of heat waves in many regions.
    d) Increase in the frequency, intensity and/or amount of heavy precipitation (more land areas with increases than with decreases).
    e) Increases in intensity and/or duration of drought in many regions since 1970.
    f) Increases in intense tropical cyclone activity in the North Atlantic since 1970.
    g) Increased incidence and/or magnitude of extreme high sea levels.

14. The impacts of climate change are also being felt in many ways across Australia, especially in the form of changes in extreme weather events (CSIRO and BoM 2015).

15. The evidence for the influence of climate change on worsening extreme weather include:
    a) The fact that all extreme weather events are now occurring in an atmosphere that is warmer and wetter than it was 70 years ago (Trenberth 2012);
    b) Long-term data records show observed changes in the nature of extreme weather; and
    c) Climate models run with and without the additional greenhouse gases in the atmosphere from human emissions show the increase in likelihood that a specific extreme weather event would have occurred because of climate change.

16. The most important of these climate-related impacts are (CSIRO and BoM 2015):
    a) Australia's average surface temperature has increased by 0.9°C from 1910 to 2014 (and now to over 1.0°C).

b) Many heat-related records were broken in the summer of 2012-2013, and again in the two most recent summers. 2013 was Australia's hottest year on record.
c) Heat waves have increased in duration, frequency and intensity in many parts of the country.
d) Cool-season rainfall has declined in southeast and southwest Australia and wet-season rainfall has increased in northern Australia.
e) Heavy daily rainfall has accounted for an increased proportion of total annual rainfall over an increasing fraction of the Australian continent since the 1970s.
f) Extreme fire weather days have increased at 24 out of 38 monitoring sites from 1973-2010 due to warmer and drier conditions.
g) For 1966-2009 the average rate of relative sea-level rise along the Australian coast was approximately 1.4 millimetres per year.

17. Southeast Australia has experienced many of the impacts that have been observed around Australia as a whole (CSIRO and BoM 2015). In particular, these include:
    a) Changes in heatwaves, such as more frequent occurrence, increasing number of heatwave days and the hottest day of a heatwave becoming even hotter.
    b) Increases in the Forest Fire Danger Index have occurred mostly in the southeast region of the continent.
    c) Strong drying trends in cool-season rainfall since 1990.
    d) Three-fold increase in coastal flooding in the Sydney region through the 20th century.

18. The NSW mid-north coast region and adjacent inland areas have also experienced many impacts of climate change. These include:
    a) The incidence of coastal flooding events has likely increased by approximately three-fold through the 20th century, as observed in Sydney Harbour (the nearest observation station with long-term records) (Church et al. 2006).
    b) Heatwaves have worsened in the following ways: (i) the number of heatwave days is increasing; (ii) the first heatwave of the season is occurring earlier; and (iii) the hottest day of a heatwave is becoming hotter (Perkins and Alexander 2013).
    c) In terms of bushfire weather, there are no long-term monitoring stations in the NSW mid-north coast region, but further inland in central-west NSW there has been a significant increase in the McArthur Forest Fire Danger Index (FFDI) from 1973 to 2013 (CSIRO and BoM 2015). At Nowra on the NSW South Coast, there has also

been an increase in the FFDI from 1973 to 2013, although of a smaller magnitude than for the central-west NSW station (Clarke et al. 2013).

d) Observations show mixed changes in rainfall patterns for the region. For the northern wet season (October to April), rainfall has been above average for the 1997-2013 period. For the southern cool season (April to September), rainfall has been above average along the coast but below average in some inland areas (CSIRO and BoM 2015).

Projections of future climate change

19. Future climate change will be driven in the near-term (several decades into the future) by the further amount of greenhouse gas emissions emitted by human activities, and in the longer term by both human emissions and feedbacks in the climate system (e.g., melting of permafrost, collapse of the Amazon rainforest) that could emit significant additional amounts of greenhouse gases to the atmosphere.

20. The projections for future changes in Australia's climate include (CSIRO and BoM 2016):
    a) Temperatures will continue to increase, with more hot days and fewer cool days.
    b) Oceans around Australia will warm further and acidification will continue.
    c) Tropical cyclones are projected to decrease in number but increase in intensity.
    d) Extreme rainfall events are likely to be more intense.
    e) Harsher fire weather is projected for southern and eastern Australia.
    f) Further decreases in winter rainfall for southern continental Australia, with an increase in droughts.

21. Projected changes in the climate of mid-NSW North Coast region and adjacent inland region (as part of the East Coast region) include (https://www.climatechangeinaustralia.gov.au/en/, based on CSIRO and BoM 2015):
    a) Average temperatures will continue to increase in all seasons (*very high confidence*).
    b) More hot days and warm spells are projected with *very high confidence*. Fewer frosts are projected with *high confidence*.

c) Decreases in winter rainfall are projected for East Coast South with *medium confidence*. Other changes are possible but unclear.

d) Increased intensity of extreme rainfall events is projected, with *high confidence*.

e) Mean sea level will continue to rise and height of extreme sea-level events will also increase (*very high confidence*).

f) A harsher fire-weather climate in the future (*high confidence*).

21. Globally, climate change projections for the rest of the 21st century range from:

a) A low emissions scenario (phasing out fossil fuels by the 2040-2050 period), which leads to a rise in global average surface temperature of 1.5-2.0°C above pre-industrial levels; to

b) A high emissions scenario, which leads to a temperature rise of 4°C or greater by 2100 (Collins et al. 2013).

22. Current global emissions are about 10 billion tonnes of carbon (emitted as CO_2) per annum, and have risen steadily since the mid-20th century, when emissions were about 3 Gt C (billion tonnes of carbon, emitted as CO_2) per year (Le Quéré et al. (2017; Figure 3). If the trend of rising emissions is continued, it would put the world on an emissions pathway between the IPCC RCP6.0 and RCP8.5 scenarios[1] (Collins et al. 2013, based on extrapolation of observed emissions trend in Le Quéré C et al. (2017); consistent with analysis in Climate Action Tracker (2018). Based on scenarios of changes in radiative forcing (i.e., the effect of (i) the atmospheric concentration of greenhouse gases and aerosols and (ii) the reflectivity of the Earth's surface on the Earth's surface energy balance – the difference between incoming solar energy and outgoing heat energy), climate models can simulate the resulting changes to the climate system).

23. Model-based projections of the level of climate change consistent with this emissions trajectory would lead to a global average surface temperature rise of 3-4°C by 2100. Thus, the world is currently on a pathway much closer to 21b) than to 21a) above.

24. The IPCC has summarised the risks to humanity of various levels of climate change through the so-called 'burning embers' diagram (IPCC 2014), Figure 1 below:

[1] "RCP" is Representative Concentration Pathway, which is a scenario for the concentration of greenhouses in the atmosphere. The numbers refer to the 'radiative forcing' for each scenario, in watts per square metre.

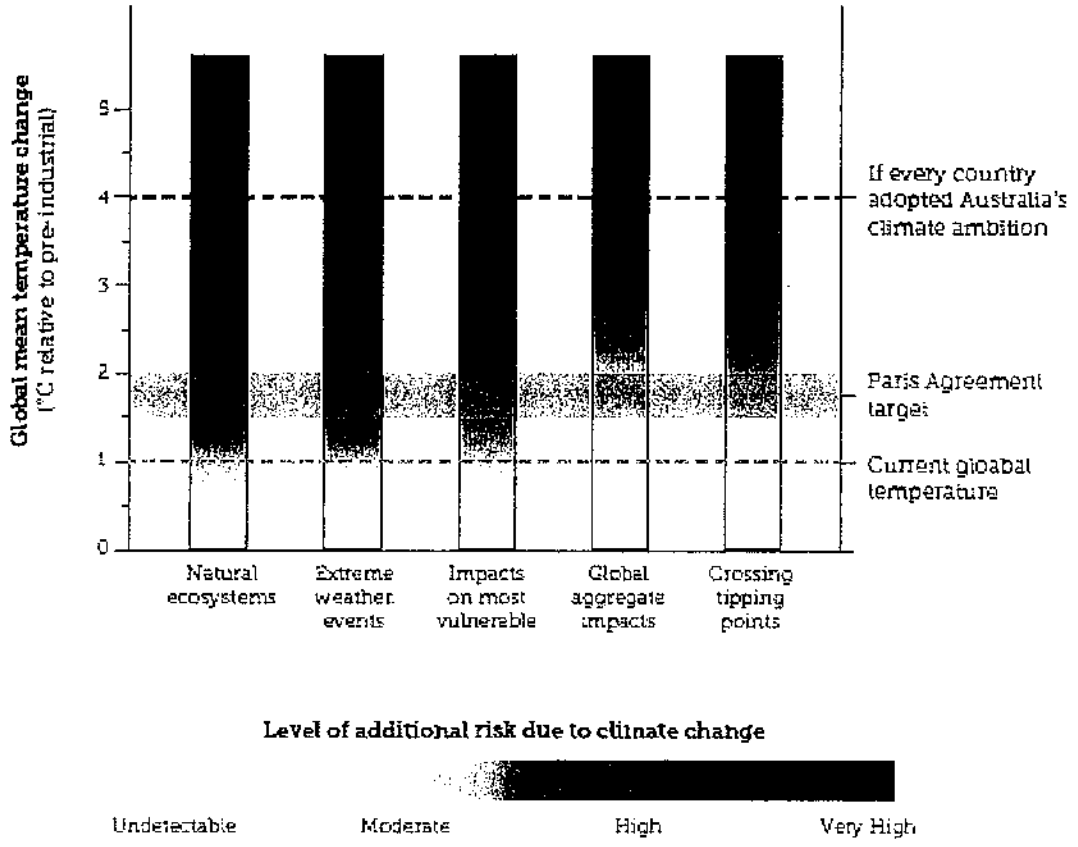

Figure 1: The IPCC 'burning embers' diagram – the reasons for concern about the impacts of climate change with increasing temperature. Adapted from IPCC (2014).

25. Figure 1 shows clearly that the impacts and risks of climate change increase nonlinearly with the increase in global average surface temperature, and connects these risks to levels of climate change using global average temperature as the indicator.

26. Figure 1 shows several levels of temperature:
    a) The current observed level, ca. 1°C above pre-industrial levels;
    b) The 1.5-2°C target range for the Paris accord; and
    c) The level of temperature increase by 2100 (ca. 3-4°C above pre-industrial) that would be reached if every country adopted Australia's level of ambition in terms of targets and policies (Climate Action Tracker (CAT) 2018[2]). In its country analysis dated 30 April 2018, CAT identifies that Australia's emissions are set to far exceed its Paris accord Nationally Determined Contributions (NDC) target for 2030 (itself a target

[2] The Climate Action Tracker is an independent scientific analysis produced by three research organisations tracking climate action since 2009: www.climateactiontracker.org

which, if followed by all other countries would lead to global warming of over 2°C and up to 3°C). Further, CAT assesses that, if all other countries were to follow Australia's current policy settings, warming could reach over 3°C and up to 4°C.

27. The synthesis of information represented by Figure 1 shows that:
    a) Australia is not doing nearly enough to meet its obligations under the Paris accord, which it signed; and
    b) That if every country followed Australia's level of action, the world would be on a trajectory to reach a 3-4°C temperature rise by 2100 and would thus face extremely damaging levels of climate change impacts (point 26c) above and Figure 1).

28. At today's level of climate change – about 1°C above pre-industrial – many impacts are already occurring. For example, many natural ecosystems are already being severely damaged.

29. In Australia alone, the Great Barrier Reef suffered consecutive mass bleaching events in 2016 and 2017 driven by unusually high surface water temperatures as a result of climate change (Hughes et al. 2017); a large area of Tasmania's World Heritage forests was decimated by bushfires driven by unusually dry conditions with high temperatures (Prof D. Bowman, personal comm.); and a mass die-off of mangroves in the Gulf of Carpentaria which was driven by exceptionally high sea temperatures (Duke et al. 2016). Also at a 1°C temperature rise, extreme weather events are worsening in most parts of the world and severe impacts are already hitting the most vulnerable groups of people and countries (IPCC 2013; IPCC 2014).

30. The Paris accord range of 1.5-2.0°C is by no means 'safe'. As shown in Figure 1, at this level of climate change, the following risks/impacts would be expected:
    a) Risks to natural ecosystems would be high; this refers to a rapidly rising risk of extinction for vulnerable species as well as increasing damage to ecosystems, such as bleaching of coral reefs and damage to forests by fires and insect attacks.
    b) Extreme weather events would be far worse than today; for Australia this means far more severe heatwaves, more frequent and intense bushfires, an increase in extreme rainfall, and more frequent and damaging coastal flooding.

c) The risk of widespread impacts on the most vulnerable would rise from moderate towards high; this includes the population of less developed countries who have low resilience and adaptive capacity as well as the most vulnerable people in wealthy countries – children, older people and disadvantaged people.
d) The aggregated impacts of climate change around the world would increase political tensions and instabilities and take its toll on the global economy; as the most vulnerable countries and groups of people suffer increasing impacts, the risk of conflict and migration increases significantly, creating security threats in other parts of the world (UK MoD (Ministry of Defence) 2010; The White House 2015).
e) Some important tipping points, such as the Greenland ice sheet, would be at risk of being crossed, driving an unstoppable rise in sea level of up to 7 metres (Kintisch 2017). The summertime Arctic sea ice would almost surely disappear, accelerating warming in the northern high latitudes and disrupting atmospheric circulation patterns (e.g., the jet stream) (Figure 1; Schellnhuber et al. 2016).

31. A 4°C temperature rise would likely lead to a world that would hardly be recognisable today (IPCC 2014; Figure 1). There is a high to very high risk that:
    a) Most of the world's ecosystems would be heavily damaged or destroyed;
    b) Extreme weather events would be far more severe and frequent than today;
    c) The most vulnerable people would increase greatly in number and, as large areas of the world become uninhabitable, migration and conflict would escalate;
    d) The aggregated impacts around the world would significantly damage the entire global economy; and
    e) A cascade of intrinsic tipping points in the climate system could drive ongoing strong warming even as humanity finally took action to reduce its emissions (Figure 1).

32. A ca. 4°C temperature rise would result if all countries adopted Australia's current climate ambition and policy settings (CAT 2018).

Global and Australian targets for stabilising the climate system

33. In 2015, countries around the world carefully assessed the risks of allowing climate change to continue on a high emissions scenario (cf. Figure 1 and "Projections of future climate change" above) and agreed in the Paris accord on a new international framework for tackling climate change. The accord aims to "*...limit global average temperature rise to well below 2 ℃ and to pursue efforts to limit warming to 1.5 ℃*". The Paris accord is near-universal, with 197 countries signing the agreement.

34. Australia is a signatory to the Paris accord and so has committed to do its part in keeping the global average temperature rise to the 1.5-2.0°C range. Yet Australia's national greenhouse gas emission reduction target of a 26-28% reduction by 2030 compared to a 2005 baseline (United Nations Framework Convention on Climate Change (UNFCCC) 2015) is, based on an expert analysis by Australia's Climate Change Authority (CCA 2015), inadequate to meet Australia's Paris accord obligations.

35. The Climate Change Authority calculated that the appropriate target for Australia, consistent with its Paris accord obligations, would be a 45-65% reduction in emissions by 2030 from 2005 levels (CCA 2015).

36. Australia is not on track to meet its 2030 target, based on a linear emission reduction pathway between 2018 and 2030. Australia's emissions have actually risen over the past three years so Australia is trending in the wrong direction (Australian Government 2018), much less reducing emissions in order to meet the rate required. In fact, if the rest of the world adopted Australia's targets and policy settings, global average temperature would be headed for up to 4°C by the end of the century (CAT 2018), with all of the high-risk consequences outlined above.

37. This leads to the question of how does one scientifically determine what is an adequate rate of emission reductions to meet the Paris accord targets. A commonly used approach based on the well-proven relationship between the cumulative anthropogenic emissions of greenhouse gases and the increase in global average surface temperature (Collins et al. 2013) – the one adopted by the Climate Change Authority in 2015 (CCA 2015) – is the carbon budget approach.

The global carbon budget approach towards climate stabilisation

38. The 'carbon budget' approach is a conceptually simple, yet scientifically robust, approach to estimating the level of greenhouse gas emission reductions required to meet a desired temperature target, for example, the Paris accord 1.5°C or 2°C targets (Collins et al. 2013).

39. The approach is based on the approximately linear relationship between:
    a) The cumulative amount of carbon dioxide (CO_2) emitted from all human sources since the beginning of industrialisation (often taken as 1870); and
    b) The increase in global average surface temperature (Figure 2; IPCC 2013).

40. Once the carbon budget has been 'spent' (emitted), then emissions need to be net zero[3] to avoid exceeding the temperature target.

[3] "Net zero emissions" means the magnitude of carbon dioxide emissions to the atmosphere is matched by the magnitude of carbon dioxide removal from the atmosphere by, for example, "carbon capture and storage – CCS" technologies, sometimes called "Negative Emission Technologies". At present these technologies are in the early development stage, and none are technologically or commercially viable yet.

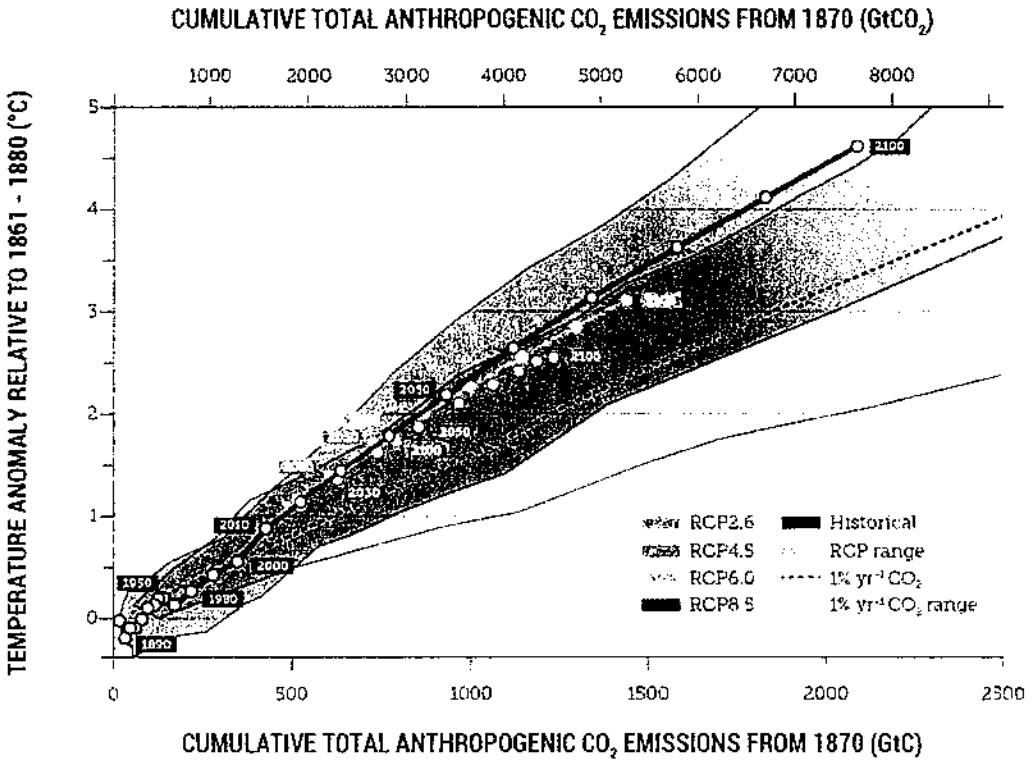

Figure 2: Global mean surface temperature increase as a function of cumulative global CO_2 emissions. The black line is global historical emissions and the coloured lines are climate model projections for various levels of human emissions. The coloured plume represents the spread of results across the models. From IPCC (2013).

41. There are several key areas of uncertainty that influence the carbon budget required to meet a temperature target:

    a) **Probability of meeting the target**. Higher probabilities of meeting a given temperature target (e.g., 2°C) require a more stringent carbon budget. Thus, there is a critical trade-off: relaxing the carbon budget to make it more feasible to meet means that there is a lower probability of achieving the desired temperature target.

    b) **Accounting for other greenhouse gases**. Non-CO_2 gases (e.g., methane (CH_4) and nitrous oxide (N_2O)), which are important contributors to warming, are assumed to be reduced to zero at the same rate as CO_2 is reduced to zero. If non-CO_2 gases are not reduced, or reduced more slowly than CO_2, then the CO_2 budget is reduced accordingly. Most of the CH_4 and N_2O emissions arise from the agricultural sector, where emission reductions are generally considered to be more difficult and expensive to achieve than for the electricity generation sector. Thus, carbon budgets

are often configured on the basis that reduction of CO_2 emissions from the electricity and transport sectors is more technologically feasible and less expensive than for the non-CO_2 gases, and therefore CO_2 emissions should be reduced even further to compensate for the continued emission of non-CO_2 gases.

c) **Accounting for feedbacks in the climate system**. Carbon cycle feedbacks, such as permafrost melting or abrupt shift of the Amazon rainforest to a savanna, are not accounted for in the carbon budget approach. Including estimates for these would reduce the budget further (Ciais et al. 2013). These are likely to be very significant. Quantitative estimates suggest that at a 2°C temperature rise (the upper Paris accord target), about 100-200 Gt C (billion tonnes of carbon, emitted as CO_2) of additional emissions to the atmosphere (about 10-20 years worth of human emissions at current rates) would be emitted (Ciais et al. 2013; Steffen et al. 2018). The upper estimate would virtually wipe out the remaining carbon budget (see Table 1 below).

42. Applying the carbon budget for a 2°C target demonstrates how it can be used. The IPCC estimates that for a greater than 66% probability of limiting global average temperature rise to no more than 2°C, cumulative human emissions since 1870 must be less than 1,000 Gt C (emitted as CO_2) (IPCC 2013). If non-CO_2 greenhouse gases are not reduced at the same rate, the carbon budget must be reduced by up to a further 210 Gt C to 790 Gt C (see 41b) above). From 1870 through 2017 cumulative human emissions have been about 575 Gt C (Collins et al. 2013; Le Quéré C et al.2017). The remaining budget then becomes 215 Gt C.

43. The current rate of human emissions of CO_2 is about 10 Gt C per year (Le Quéré et al. 2017), so at these present rates of emissions, the carbon budget would be consumed in little more than two decades (at about 2040).

44. I summarise this analysis in tabular form below:

Table 1: Carbon budget for a 66% probability of restricting temperature rise to no more than 2 °C

Budget Item/Process	**Gt C**
Base budget based on IPCC (2013)	1,000
Accounting for non-CO_2 greenhouse gases	-210
Historical emissions through 2017	-575
Remaining budget to net zero emissions	**215**

45. The conclusion is that the world has 21-22 years of emissions (at current rates) remaining before the world's economy must reach net zero emissions (215 Gt C divided by 10 Gt C per year = 21.5 years).

46. Applying this budget to emission reduction trajectories emphasises the need to peak emissions by 2020 at the latest, followed by a steep reduction curve thereafter (the area under the curves created by emission reduction trajectories is equal to the cumulative emissions of CO_2, which can then be directly compared to a remaining carbon budget – see Figure 3 below).

Implication of carbon budget approach for the rate of emission reductions

47. The carbon budget approach has strong implications for the trajectory of emission reductions towards their eventual phasing out. Figure 3 shows the importance for the rate of emissions reductions of the peaking year (the year in which global emissions peak before starting their downward trajectory). The area under all of the curves on the graph are the same; they are equivalent to the cumulative carbon budget estimated by Figueres et al. 2017 (cf. Figure 3), either 600 Gt CO_2 or 800 Gt CO_2[4]. To allow comparison to the carbon budget above, expressed as Gt C, these CO_2 budgets become 144 and 198 Gt C, the more generous budget comparing well with the budget estimated above (215 Gt C, Table 1).

[4] The 600 Gt CO_2 budget is the midpoint of a wider range of budgets that represents different ways of calculating the budget for the Paris target range (1.5-2.0°C). The 800 Gt CO_2 budget reduces the probability of meeting the 600 Gt CO_2 budget (Figueres et al. 2017).

48. Figure 3 demonstrates the absolute importance of peaking global emissions as soon as possible, and then reducing emissions strongly thereafter. Although global CO_2 emissions flat-lined for the 2014-2016 period, they rose again in 2017 and are predicted to rise yet again in 2018 (Le Quere et al. 2017). This implies that 2020 is probably the earliest that emissions can peak, and it is important that they do. Delaying the peak just five further years would create a subsequent emission reduction trajectory that would be impossible to follow economically or technologically (Figueres et al. 2017).

49. The clear message from any carbon budget analysis, under any reasonable set of assumptions regarding probabilities of actually meeting the budget and the sensitivity of the climate system to the level of greenhouse gases in the atmosphere, is that fossil fuel combustion must be phased out quickly, at the rate of the curves shown in Figure 3.

50. Most of the world's existing fossil fuel reserves[5] – coal, oil and gas – must be left in the ground, unburned, if the Paris accord climate targets are to be met. I say that because the exploitation, and burning, of fossil fuel reserves leads to an **increase in** CO_2 emissions when meeting the Paris accord climate targets requires a rapid and deep **decrease** in CO_2 emissions.

51. An obvious conclusion that follows from this fact is that: No **new** fossil fuel development is consistent with meeting the Paris accord climate targets. That is, paragraphs 47-50 above demonstrate clearly that to meet the Paris accord, emissions must be reduced rapidly and deeply (cf Figure 3 below), and to do this requires the rapid phase-out of **existing** fossil fuel mines/wells. It is an obvious conclusion that no new fossil fuel developments can therefore be allowed.

[5] "Reserves" are defined by McGlade & Ekins (see below) as a subset of "resources" that are recoverable under current economic conditions and have specific probability of being produced. "Resources" are the remaining ultimately recoverable deposits of fossil fuels that are recoverable over all time with both current and future technologies, irrespective of economic conditions. Thus, "resources are all of the fossil fuels that are known to exist, and "reserves" are the subset of resources that are economically and technologically viable to exploit now.

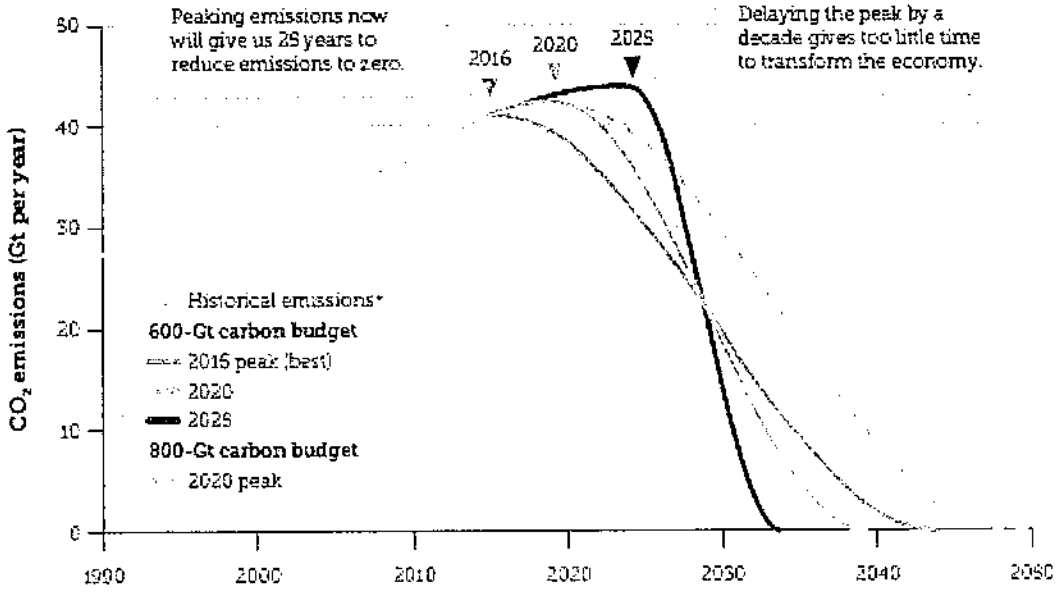

Figure 3. Emission reduction trajectories for meeting the Paris accord target(s). Delaying peak emissions to 2025 is too late for any achievable emission reduction trajectory. Note that the budgets in Gt CO_2; converting them to Gt C would give budgets of 164 Gt C and 218 Gt C, respectively. Budgets are from 2016; converting them to budgets from the end of 2017 would yield 144 Gt C and 198 Gt C, respectively. Source: Figueres et al. 2017

Applying the carbon budget approach to Australia and the Rocky Hill Coal Project

52. An economic analysis of a generous global carbon budget highlights the implications of meeting the Paris accord climate targets for the Australian fossil fuel sector (McGlade and Ekins 2015). Based on a 50% probability of meeting the CO_2 temperature target, the global budget for the 2011-2050 period was estimated by the authors at 300 Gt C, somewhat higher than the budget in Table 1. The study showed that if all of the world's existing fossil fuel reserves were burned, about 780 Gt C would be emitted as CO_2, about 2.5 times greater than the allowable budget. Globally, 62% of the world's existing fossil fuel reserves need to be left in the ground, unburned, to remain within the carbon budget.

53. Meeting the carbon budget consistent with the Paris accord climate targets therefore means that not only must currently operating mines and gas wells be closed before their economic lifetime is completed (obvious from point 52 above – 780 is much larger than

the assumed budget of 300), but also that no approved (but not yet operating) and no proposed fossil fuel projects, based on existing reserves, can be implemented. This analysis applies to the Rocky Hill Coal Project.

54. McGlade and Ekins (2015) then applied an economic analysis to the three types of fossil fuels – coal, oil and gas – and to the various regions of the world that are major producers of fossil fuels. Based on their analysis, 88% of global coal reserves are unburnable for any purpose (it is the CO_2 emissions that matter for the carbon budget approach, not the purpose for which the fossil fuel is burnt). The regional analysis yielded even more stringent conditions for Australia's fossil fuel industry (Australia is the only major fossil fuel producer in the OECD Pacific region; other countries in the region are only minor producers of fossil fuels). Over 90% of Australia's existing coal reserves cannot be burned to be consistent with the Paris accord 2°C target, and certainly not with the more stringent Paris accord 1.5°C target.

55. The conclusions from this – or any other analysis based on a carbon budget – are:

- **Australia's existing fossil fuel industries must be phased out as quickly as possible, with most of the Australian fossil fuel reserves (and nearly all of Australia's coal reserves) left in the ground.**

- **Development of new fossil fuel reserves, no matter how small, is incompatible with any carbon budget assuming a 50% or better chance of the budget meeting the temperature target (see paragraph 41a): that is, a very generous budget) and with Australia's commitments to the Paris accord.**

- **Based on this analysis, approval of the development of the Rocky Hill Coal Mine is inconsistent with the carbon budget approach towards climate stabilisation.**

The fallacy of the "my emissions are too small to matter" argument

56. A common argument made for proceeding with new fossil fuel developments is that the resulting emissions are so small compared to the total global emissions (currently about 9

billion tonnes of carbon per annum) that they do not matter. The argument is made at the national level in terms of Australia's national emissions being such a small fraction (ca. 1.2%) of the global total that they don't matter (i.e., "even we reduce our emissions, it won't have a major effect on the climate"). The argument is made in the Specialist Consultant Studies Part 2A Air Quality Assessment for Gloucester Resources Limited, Amended Rocky Hill Coal Project Report No. 806/14, Section 18.3, p. 2A-162 and again in Section 19: Conclusion, p. 2A-165.

57. These arguments are, in my opinion, fundamentally flawed because they ignore the fact that global greenhouse gas emissions are made up of millions, and probably hundreds of millions, of individual emissions around the globe. All emissions are important because cumulatively they constitute the global total of greenhouse gas emissions, which are destabilising the global climate system at a rapid rate. Just as many emitters are contributing to the problem, so many emission reduction activities are required to solve the problem.

58. [redacted] NR

Professor Will Steffen

12 June 2018

References:

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NSW EDO
DEFENDING THE ENVIRONMENT
ADVANCING THE LAW

Appendix A

EDO NSW
ABN 72 002 880 864
Level 5, 263 Clarence Street
Sydney NSW 2000 AUSTRALIA
E: edonsw@edonsw.org.au
W: www.edonsw.org.au
T: + 612 9262 6989
F: + 612 9264 2414

6 June 2018

Emeritus Professor William Steffen
Fenner School of Environment & Society
The Australian National University
Unit 409, 222 City Walk
Canberra City ACT 2601

By email: will.steffen@anu.edu.au

CONFIDENTIAL AND PRIVILEGED

Dear Prof Steffen

Gloucester Resources Limited v Minister for Planning; Court Proceedings No. 2017/383563
Stratford Coal Pty Limited v Minister for Planning; Court Proceedings No. 2018/23580

1. We act for Groundswell Gloucester Inc. (**GG Inc.**) in the above Land and Environment Court (**Court**) proceedings.

2. GG Inc. is a group of residents with the objectives of encouraging community participation in decisions which determine the economic, social and environmental future of the Stroud Gloucester Valley, and ensuring that the environment of the Stroud Gloucester Valley sustains a healthy, productive and vibrant community.

3. Our client is a party to the above proceedings. There are two concurrent proceedings both against the NSW Minister for Planning, namely a challenge by Gloucester Resources Limited (**GRL**) against refusal of the development application for the Rocky Hill Coal Mine (**Project**), and a challenge by Stratford Coal Pty Limited (**Stratford**) against refusal of the modification application for the Stratford Extension Project (**Modification**).

4. Our client intends to adduce expert evidence on the likely social impacts arising from the Project and the Modification and on the climate change impacts arising from the Project. Our client is seeking a decision by the Court to uphold the refusal of the Project and the Modification.

5. Our client wishes to retain your services to act as an expert witness to assist the Court impartially on matters relevant to your area of expertise.

Background

6. In 2013, a development application and Environmental Impact Statement (**EIS**) for the Rocky Hill Coal Mine (SSD 5156) was placed on public exhibition.

7. In 2015, GRL, as the proponent for the Rocky Hill Coal Mine, wrote to the Department of Planning and Environment (**Department**) requesting that the Project application be placed on hold. This request was made on the basis that GRL was considering an "advanced commercial option" that may result in an amendment of the Project application.

8. An amended development application and revised EIS for the Rocky Hill Coal Mine was placed on public exhibition from 17 August to 14 October 2016.

9. The amended Rocky Hill Coal Mine proposal involved:
   a) developing and operating an open-cut coal mine, to produce up to 2 million tonnes of run-of-mine (**ROM**) coal per year for up to 21 years;
   b) constructing and operating a private coal haul road to link the Rocky Hill Coal Mine with the Stratford Coal Complex, approximately 9 kilometres to the south;
   c) hauling sized ROM coal on the private coal haul road between 7:00 am and 6:00 pm only, Monday to Saturday;
   d) using the private coal haul road to deliver heavy equipment and construction materials to the mine area; and
   e) rehabilitating the site.

10. Concurrently, a development application and EIS for a Modification to the Stratford Extension Project (SSD 4966 MOD 1) (**Modification**) was placed on public exhibition.

11. This Modification to the approved Stratford Mine Complex sought approval to allow the incorporation of a new coal haul road, and the receipt, processing and railing of coal from the Rocky Hill Coal Mine.

12. In October 2017, the Project and the Modification were referred by the Minister for Planning to the (then) Planning Assessment Commission (**PAC**) for determination.

13. As part of the PAC assessment process, the Department recommended that the Project and the Modification be refused.

14. In relation to the Rocky Hill Coal Mine, the Department concluded that the Project was incompatibly located with respect to the southern fringes of the nearby urban area of Gloucester. The Department considered that the Project site was not a suitable site for an open cut coal mine, due to:
   a) proposed land use conflicts with existing established land uses, in particular rural-residential and tourism land uses; and
   b) its incompatibility with the underlying aims and objectives of the strategic land use zonings of the *Gloucester Local Environmental Plan* to protect the scenic

amenity of the Gloucester township and the broader Gloucester Valley by retaining scenic and rural surroundings for the town.

15. In relation to the Modification, the Department concluded that in the absence of any approval for the Rocky Hill Coal Mine, the Modification should also be refused.

16. The PAC refused the Project and the Modification on 14 December 2017.

Legal Proceedings

17. As a preliminary matter, please note that you are not permitted to express an opinion on any question of law in your report and that your report should confine itself to the relevant issues of fact within your area of expertise. However, you need to understand the legal context of this case to understand the relevant questions of fact on which the Court requires your assistance.

18. GRL filed a Class 1 Application (merits appeal) against the Minister for Planning's decision to refuse development consent to the Rocky Hill Coal Mine in December 2017. That application seeks orders from the Court to the effect that the Project application should be approved.

19. Stratford, as the proponent for the Modification, filed a Class 1 Application (merits appeal) against the Minister for Planning's decision to refuse the Modification in January 2018. That application seeks orders from the Court to the effect that the Modification application should be approved.

20. The Minister for Planning is defending the appeals, and the decisions to refuse the Project and Modification applications.

21. The Court has determined that the two appeals should be heard together.

22. On 23 April 2018, the Court ordered that GG Inc. be joined as a party to Gloucester Resources Limited v Minister for Planning, Court Proceedings No. 2017/383563, under section 8.15(2) of the *Environmental Planning and Assessment Act 1979* (**GRL proceedings**).

23. On 15 May 2018, the Court ordered that GG Inc. be joined as a party to Stratford Coal Pty Limited v Minister for Planning; Court Proceedings No. 2018/23580, under section 8.15(2) of the *Environmental Planning and Assessment Act 1979* (**Stratford proceedings**).

24. Our client has filed the following contentions in the GRL proceedings:
    a) The Project and the Modification will have a significant social impact on residents and the community of Gloucester, contrary to the public interest and the principle of intergenerational equity.
    b) The Project is not in the public interest and contrary to the principles of Ecologically Sustainable Development (**ESD**), including intergenerational equity and improved valuation, pricing and incentive mechanisms, because,

in order to limit the rise in global temperatures to below 2 degrees Celsius above pre-industrial levels, the Project should not be approved at the current time.

25. Our client has filed the following contention in the Stratford proceedings:
    The Project and the Modification will have a significant social impact on residents and the community of Gloucester, contrary to the public interest and the principle of intergenerational equity.

26. You are briefed to provide expert advice in relation to climate change science and the role of the Project in climate change impacts.

Overview of the Work Request

Duty to the Court

27. Our client seeks to retain you to act as an expert witness. Your role as an expert witness is to assist the Court impartially on matters relevant to your area of expertise. You are not to act as an advocate for our client and any opinion expressed must be genuinely held by you based on your professional training, knowledge, or experience.

28. In this respect, we draw your attention to Division 2 of Part 31 of the *Uniform Civil Procedure Rules 2005* (**UCPR**), and the Expert Witness Code of Conduct (**Code of Conduct**) contained in Schedule 7 of the UCPR, both of which govern the use of expert evidence in the Court. We **enclose** copies of the relevant UCPR provisions.

29. In particular, we note that clause 2 of the Code of Conduct states that:

    "An expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the party to the proceedings or other person retaining the expert witness, to assist the court impartially on matters relevant to the area of expertise of the witness."

30. Please read those documents carefully before you commence the work requested. **Your expert report must contain an acknowledgment that you have read the Expert Witness Code of Conduct under the UCPR and that you agree to be bound by it.** Otherwise your report will be inadmissible as evidence.

Purpose of your Expert Report

31. Your expert report will be used as evidence in chief of your professional opinion. Information which you believe the Court should be aware of must be contained in your expert report. Whilst you may be able to clarify matters contained in your report at a later date, this is unlikely to extend to the provision of new information.

32. In providing your opinion to the Court you must set out all the assumptions upon which the opinion is based. This may include, for example, facts observed as a result of field or lab work or 'assumed' facts based on a body of scientific

opinion. If the latter, you should provide references which demonstrate the existence of that body of opinion.

33. Your expert report must also set out the process of reasoning which you have undertaken in order to arrive at your conclusions. It is insufficient for an expert report to simply state your opinion or conclusion reached without an explanation as to how this was arrived at. The purpose of providing such assumptions and reasoning is to enable the Court and experts engaged by other parties to the proceedings to make an assessment as to the soundness of your opinion.

Expert Report Requirements

34. The work we require involves the following:
    a) review the relevant documentation;
    b) prepare a written expert report that conforms with the Code of Conduct and addresses the questions in paragraph 35;
    c) attend a conference with your instructing solicitors and barristers at a time to be confirmed;
    d) review the Respondent's expert report(s);
    e) confer with the Respondent's expert(s) at a joint conference(s) and prepare a joint report, which sets out the matters agreed, matters disagreed, and the reasons for agreement and disagreement as a result of the joint conference(s); and
    f) appear as an expert witness in the Court.

35. Please ensure that your expert report addresses the following:
    a) Provide a brief description of the causes and effects of anthropogenic climate change and current anthropogenic climate change projections. In providing your answer, please consider local, regional and global impacts.
    b) Provide a brief description of Australian and global targets for limiting climate change impacts.
    c) Describe the concept of the Carbon Budget.
    d) In your opinion, what actions must be taken to meet the Carbon Budget? In providing your answer, please consider how the Carbon Budget applies to the Project.
    e) Provide any further observations or opinions which you consider to be relevant, having regard to the circumstances of this matter.

36. We request that you provide us with a draft of your report for review before finalising it. We emphasise that the purpose of this is not to influence the conclusions or recommendations you make but to ensure that the language and expression of the report is clear and complies with the formal legal requirements of an expert report.

Relevant Documents

37. All Project assessment documents relevant to the proceedings are available at:
    a) Rocky Hill Coal Mine: http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=5156; and

b) Modification to Stratford Extension Project: http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=7897.

38. In particular we direct you to the following documents:
    a) The relevant UCPR provisions (**enclosed**);
    b) Modification to Stratford Extension Project:
        i) Stratford Statement of Environmental Effects – Main Report: https://majorprojects.accelo.com/public/cb7faf851047657825ca2f217f3f62d0/01.Stratford%20Main%20Text.pdf;
        ii) Instrument of Refusal: https://majorprojects.accelo.com/public/7eb257be9a68ff2e8fb0b91874aa3cd5/Stratford%20MOD%201%20Instrument%20of%20Refusal.pdf;
    c) Rocky Hill Coal Project:
        i) Rocky Hill Coal Project EIS - Executive Summary: https://majorprojects.accelo.com/public/25dac6310d36e472e1a6bb8d1c679038/11.%20Rocky%20Hill%20Coal%20Project%20EIS%20-%20Executive%20Summary.pdf;
        ii) Rocky Hill Coal Project EIS – Air Quality Appendix (including Greenhouse Gas Assessment): https://majorprojects.accelo.com/public/50c16b8a1177ee8d1c80e98b2c48ee33/34.%20Rocky%20Hill%20Coal%20Project%20EIS%20SCSC%20Vol%201_Part%202A%20Air%20Quality.pdf;
        iii) Rocky Hill Coal Project Response to Submissions (Section 2.15 Greenhouse Gases): https://majorprojects.accelo.com/public/00bad530e0d6468a1cf60a53ff75128b/Rocky%20Hill%20Coal%20Project_%20Response%20to%20Submissions.pdf;
        iv) Rocky Hill Coal Amended EIS - Executive Summary: https://majorprojects.accelo.com/public/d72cf487d31e344e694c65e17cb6020c/02.Rocky%20Hill%20Amended%20EIS%20Executive%20Summary.pdf;
        v) Rocky Hill Coal Amended EIS – Air Quality Appendix (including Greenhouse Gas Assessment): https://majorprojects.accelo.com/public/613696aa5aaa27e853710202d5181509/29.Rocky%20Hill%20Amended%20EIS%20SCSC%20Vol%201%20Part%202A%20Air%20Quality.pdf;
        vi) Rocky Hill Coal Amended EIS Response to Submissions (Executive Summary): https://majorprojects.accelo.com/public/584aab933e37564ff7a32c61acfaa3c1/RHCP_RTS%2002_%20Executive%20Summary_%20June%202017.pdf;
        vii) Rocky Hill Coal Amended EIS Response to Submissions (Sections 2.8-2.10): https://majorprojects.accelo.com/public/fb1926a382e3041c397067372cd9fe2c/RHCP_RTS%2004_%20Section%202.1%20to%202.12_%20June%202017.pdf;
        viii) DPE Rocky Hill Coal Project Assessment Report: https://majorprojects.accelo.com/public/39bec827a10ce780dc804786b3315a0f/Rocky%20Hill%20Assessment%20Report%20Final.pdf; and

ix) PAC Determination Report: https://majorprojects.accelo.com/public/d7f79e4f204300ca25b7fb455aae0139/Rocky%20Hill%20Coal%20Project_%20Determination%20Report.PDF.

39. Please let us know as soon as possible if you require further information for the purpose of giving your expert opinion.

Format of Your Report

40. Division 2 of Part 31 of the UCPR Rules sets out information that your report must contain, such as:
    - your qualifications;
    - the facts, and assumptions of fact, on which the opinions in the report are based and your reasons for each opinion expressed;
    - if a particular issue falls outside your area of expertise, clear acknowledgement that it falls outside your field of expertise;
    - any literature or other materials utilised in support of the opinions;
    - details of any examinations, tests or other investigations on which you have relied, including details of the qualifications of the person who carried them out;
    - a brief summary of the report;
    - if you believe that the report may be incomplete or inaccurate without some qualification, the qualification must be stated in the report;
    - if you consider that your opinion is not a concluded opinion because of insufficient research or insufficient data or for any other reason, this must be stated when the opinion is expressed; and
    - if you change your opinion on a material matter after providing an expert's report to us, you must provide us with a supplementary report to that effect.

41. Please format your report as follows:
    - address your report to the Court;
    - sign and date your report;
    - include a summary of your qualifications and experience as an appendix to your report;
    - use 12 point type and at least 2cm page margins;
    - supply a PDF version of your report for printing and binding;
    - number each paragraph of your report;
    - number all pages, including attachments and annexes, continuously from the first page to the last page (excluding any cover page to your report); and
    - annex this letter of instruction to your report.

Timing

42. The timing in relation to this matter is as follows:

Date	Work due
7 June 2018	Draft report to EDO NSW
11 June 2018	Finalised report to EDO NSW
11 June 2018	Report to be filed with the Court
25 June 2018	GRL report to be filed with the Court
16 July 2018	Joint report to be filed with the Court
13 -31 August 2018	Land and Environment Court hearing

43. We will update you on relevant timing for you to give evidence once further information is available.

Fees and Terms

44. Thank you for agreeing to provide your advice in this matter on a pro bono (volunteer) basis. EDO NSW relies on experts such as you to assist in matters with very little financial compensation and we thank you for agreeing to provide this advice on a pro bono basis.

45. Please note the following terms:
    a) your work will only be used by EDO NSW to assist our client;
    b) EDO NSW will take all reasonable steps to prevent your work being used for purposes other than that mentioned above, but we accept no responsibility for the actions of third parties;
    c) regardless of the above points, EDO NSW may choose not to use your work; and
    d) you will not be covered by the EDO NSW's insurance while undertaking the above tasks.

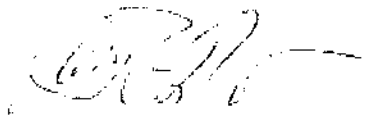
Duty of Confidentiality

46. Please treat your work as strictly confidential until your expert report is provided to other parties and the Court, unless authorised by us.

47. If you would like to discuss this brief further, please contact the author on (02) 9262 6989 or email matthew.floro@edonsw.org.au.

48. We are grateful for your assistance in this matter.

Yours sincerely
EDO NSW



Matt Floro
Solicitor

Our Ref: 1825740

CURRICULUM VITAE
WILL STEFFEN

PERSONAL DATA

FULL NAME:	William Lee (Will) STEFFEN
BUSINESS ADDRESS:	Emeritus Professor The Fenner School of Environment and Society The Australian National University Canberra ACT 2601 AUSTRALIA
TELEPHONE	+61-(0)447-980-495 (m) +61-2-6262-6897 (h)
EMAIL:	will.steffen@anu.edu.au

DATE OF BIRTH:	25 June 1947
PLACE OF BIRTH:	Norfolk, Nebraska, USA
CITIZENSHIP:	Australian (Naturalised, February 1985)
MARITAL STATUS:	Married, with one daughter (born 20/09/86)

EDUCATION AND DEGREES:

PhD (Honoris causa)	University of Canberra, Australia (April 2015)
PhD (Honoris causa):	Stockholm University, Sweden (September 2010)
PhD (Chemistry):	University of Florida, USA (August 1975)
MS (Chemistry):	University of Florida, USA (August 1972)
BS (Chemical Engineering):	University of Missouri, USA (May 1970)

ACADEMIC AFFILIATIONS

Senior Fellow, Stockholm Resilience Centre, Stockholm University, Sweden
Emeritus Professor, The Australian National University, Canberra
Adjunct Professor, The University of Canberra, Australia
Fellow, Beijer Institute of Ecological Economics, Stockholm
Senior Associate, University of Cambridge Institute for Sustainability Leadership, UK
Honorary Professor, Copenhagen University, Denmark

POSITIONS HELD

Sept 2013-present	Climate Councillor (with the independent, publicly funded Climate Council of Australia)
Nov 2011-present	Member, ACT Climate Change Council

Feb 2011-Sept 2013	Climate Commissioner (with Australian Government Climate Commission)
Jul 2008-June 2012	Executive Director, ANU Climate Change Institute, The Australian National University (ANU), Canberra
Aug 2004-Jan 2011	Science Adviser (part-time), Department of Climate Change and Energy Efficiency (earlier Australian Greenhouse Office), Australian Government, Canberra
Mar 2007-Jul 2008	Director, Fenner School of Environment and Society, and Director, ANU Institute of Environment, The Australian National University (ANU), Canberra
Oct 2006-Feb 2007	Pro Vice-Chancellor (Research), The Australian National University, Canberra
Oct 2005-Oct 2006	Director, Centre for Resource and Environmental Studies, and Director, ANU Institute of Environment, The Australian National University (ANU), Canberra
Jul 2004 –Jun 2006	Chief Scientist, International Geosphere-Biosphere Programme (IGBP), Stockholm
Aug 2004-Sept 2005	Visiting Fellow, Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry, Australian Government, Canberra
Mar 1998 - Jun 2004	Executive Director, International Geosphere-Biosphere Programme (IGBP), Stockholm, Sweden
Dec 1990 - Feb 1998:	Executive Officer, Global Change and Terrestrial Ecosystems (GCTE) Core Project, International Geosphere-Biosphere Programme (IGBP), based at CSIRO, Canberra
April 1981 - Nov 1990:	Editor and Information Officer, CSIRO Centre for Environmental Mechanics, Canberra
Aug 1977 - July 1980:	Research Fellow, Research School of Chemistry, The Australian National University, Canberra
Sept 1975 - June 1977:	Postdoctoral Fellow, Department of Chemistry, Cornell University, New York, USA

PROFESSIONAL EXPERIENCE

Research Interests and Experience: -

- Earth System science, with a focus on integration and synthesis towards understanding planetary dynamics involving coupling of biogeochemical cycles

and physical climate; dynamics of abrupt and irreversible changes; integration of natural and human dimensions of Earth System and climate science, particularly around the concept of the Anthropocene; global carbon cycle.

- Sustainability science, with an emphasis on ecosystem services as a unifying concept; global aspects of sustainability; integration of humanities scholarship into sustainability research; participatory research approaches.

- Global change and terrestrial ecosystems, with a focus on regional and global scales; terrestrial carbon cycle; incorporation of ecosystem dynamics in global vegetation models; functional type approach to modelling vegetation dynamics under global change; transect-based analysis of regional vegetation change.

- Structural inorganic chemistry, using x-ray crystallography as the primary tool to study transition metal chemistry; systems studied included tetrahedral zinc(II) complexes, isomerism in the palladium(II) thiocyanate system, stereochemistry of monothiocarbamate-metal complexes, the iron(II) porphyrin system and olefinic diphosphine complexes of tungsten and manganese tricarbonyls.

Science Leadership and Management:

- Creation of the ANU Climate Change Institute (Australian National University) in 2008, and its first Executive Director. Development of transdisciplinary climate change research projects involving natural science, social science, economics and humanities scholars at the ANU.

- Creation of the Fenner School of Environment and Society at the ANU in 2007, and its inaugural Director. Development of the School (60 academic staff and 120 PhD students) as Australia's leading transdisciplinary research and teaching unit on environment and society.

- Leadership as Executive Director of the International-Geosphere Biosphere Programme (IGBP), a multi-disciplinary international research programme on global change involving about 10,000 scientists in 80 countries around the world. Duties included: coordination of research effort involving 10 projects, support to the IGBP Chairman and to the Scientific Committee of the IGBP, management of the IGBP Secretariat (Stockholm) with a staff of 10 and an annual budget of USD 2.5M, publication of overview and synthesis papers on global change and Earth System science, promotion of global change science at international meetings and conferences around the world; numerous presentations at a wide range of fora in ca. 35 countries, liaison with policy communities on the application of IGBP science, and raising funds for IGBP activities.

- Management of the day-to-day operation of the Global Change and Terrestrial Ecosystems (GCTE) Core Project, an international research effort under the auspices of the IGBP, from 1990 to 1998. Duties included overall coordination of GCTE's international Core Research Programme (41 countries, 700 scientists and technicians, USD 33M per annum; establishment and overall direction of GCTE Impacts Centre, Bogor, Indonesia; and raising funds for GCTE activities.

- Leadership role in planning and carrying out a large number of international conferences and policy events, including three in the prestigious Dahlem Conference Series in Germany, Royal Colloquia in Sweden, two IGBP Congresses and the Challenges of a Changing Earth global change conference in Amsterdam in 2001.

Science-Policy Interface:

- Independent expert adviser to the Multi-Party Climate Change Committee. Australian Government. The role of the MPCCC, chaired by the Prime Minister Hon Julia Gillard, was to develop a long-term policy to reduce Australia's greenhouse gas emissions. The MPCCC built the Clean Energy Futures package, the centrepiece of which is an emissions trading scheme but with complementary programs for land carbon sequestration and biodiversity conservation.

- Advice to the Department of Climate Change and Energy Efficiency (previously Australian Greenhouse Office), Australian Government, on the link between science and climate change policy, with an emphasis on the scientific research needed to support policy development. Specific projects include carbon cycle research in support of carbon accounting and reporting; generic climate adaptation strategies across a broad range of sectors; definition of "dangerous climate change" with respect to Article 2 of the UN Framework Convention on Climate Change; and a review of the Australian Climate Change Science Program, towards developing a national framework for climate change research.

- General briefings and inputs at the international level to the development of policy on climate change and other aspects of global environmental change. The work included interaction with the European Union Commission for the Environment; advice to the Swedish Government Departments of Environment and Education and the Stockholm City Government, primarily on application of carbon cycle research; and contributions to the work of the Intergovernmental Panel for Climate Change (IPCC), primarily on implications of carbon cycle dynamics for carbon sinks policy.

- Contributions to development of climate risk management strategy for Australian agricultural sector, Bureau of Rural Sciences (BRS), Australian Government. The project involved consultation with industry/producers through workshop series, and production of decision support tools for climate risk management.

Teaching:

- Contribution to course development at the ANU, focusing on climate change courses at the post-graduate level and professional courses for public servants.

- Lectures on global change and the Earth System at the ANU and at Stockholm University, Sweden.

- Lectures, tutorials, and demonstrations in chemistry at the tertiary level at the ANU and the University of Florida, USA.

Communication and Outreach:

- Member of the independent Climate Commission, formed by the Australian Government in February 2011. Role of the Commission is to engage the Australian public, private sector and community groups on climate science, the economics of climate change mitigation, and international action on climate change. Activities in public forums around the country, business roundtables, site visits, community group engagement, production of reports and communication via the media. With the closure of the Commission in September 2014, became a Councillor with the publicly funded Climate Council of Australia, formed to replace the Commission.

- Numerous presentations on climate change, the Earth System and the Anthropocene to a very wide range of audiences, including governments at high levels, business and industry, non-governmental organisations (NGOs), professional organisations and the general public.

- Participation in a large number of conferences, summits, future think tanks and other events involving participants from all walks of life. Participation in the 2020 Summit in Canberra in April 2008.

- Much experience with the media, both print and electronic, on complex and contentious issues like climate change and sustainability.

- Provision of background support to and appearances in the Swedish documentary film "The Planet", and contributions to several films on the Anthropocene.

- Operation of the editorial, communication, and information services at the CSIRO Centre for Environmental Mechanics 1981-1990.

ADVISORY/HONORARY POSITIONS AND REVIEW PANELS

Apr 2016 – present	Member, International Advisory Board, Centre for Collective Action Research, Gothenburg University, Sweden
Jan 2011 – present	Member, Volvo Environment Prize jury, Sweden (Chair of Jury from May 2013)
Jul 2004 – Dec 2015	Member, National Committee for Earth System Science (NCESS), Australian Academy of Science
Oct 2010 – July 2011	Member, Multi-Party Climate Change Committee, Australian Government
Oct 2009- Dec 2014	Chair, Antarctic Science Advisory Committee, Australian Government
Aug 2009 – May 2011	Member, Science Advisory Committee, APEC Climate Center, Busan, Korea
Jan 2005 – May 2010	Chair, International Advisory Board, QUEST (Quantifying and Understanding the Earth System) programme, UK
Oct 2005 – Nov 2008	Chair, Advisory Panel, Earth and Sun System Laboratory, National Center for Atmospheric Research, Boulder, CO, USA
Jan 2006-Dec 2008	Member, Advisory Board, Australian Bureau of Meteorology
May 2007	Review of the Australian Climate Change Science Program. Australian Government. Carried out with Dr Susan Solomon, NOAA, USA and Convening Lead Author, Working Group 1, IPCC Fourth Assessment Report
Apr 2007	Member of review panel, Potsdam Institute for Climate Impact Research, Germany
Aug 2006 – Dec 2006	Member, PMSEIC (Prime Minister's Science, Engineering and Innovation Council) working group on Australia's S&T Priorities for Global Engagement
Feb 2005	Member of review panel for du Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Paris, France
Apr 2004	Member of review panel for the Tyndall Centre, UK (Climate Adaptation Research)

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Williams, M., Edgeworth, M., Zalasiewicz, J., Waters, C.N., **Steffen, W.**, Wolfe, A.P., Cearreta, A., Galuszka, A., Haff, P., McNeill, J., Revkin, A., Richter, D. deB., Price, S. and Summerhayes, C. (2017) Underground metro systems: a durable 'mega-trace fossil' proxy for urbanisation by humans in the 20th and 21st centuries. In: 'Big History', Routledge, in press.

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J.A., Jeandel, C., Leinfelder, R., McNeill, J.R., Odada, E., Oreskes, N., Price, S.J., Revkin, A., **Steffen, W.**, Summerhayes, C., Vidas, D., Wing, S. and Wolfe, A.P. (2016) Scale and diversity of the physical technosphere: a geological perspective. *The Anthropocene Review* **4**(1): 9-22. doi: 10.1177/2053019616677743

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