Expert Review:
Radiological Issues for the Proposed Fingerboards Mineral Sands Project

Assoc. Prof. Gavin M. Mudd
Environmental Engineering, RMIT University, Melbourne

Home Address: [redacted]

Report Completed: 29 January 2021

A: Executive Summary & Key Issues

A1 Based on the available data from the Fingerboards EES, the region is not significantly elevated in environmental radiation, although further work is clearly required to confirm this over the full proposed project area. This is important in helping to determine potential rehabilitation criteria (if the project proceeds).

A2 Considerable further work is required to ascertain the levels of radionuclides naturally present in crops and vegetables as well as in surface water and groundwater.

A3 Almost all of data and information which would be required for statutory radiation licences and approvals remains left for 'future work', limiting the ability to assess the standards and procedures for the proposed Fingerboards project.

A4 Export of the heavy mineral concentrate raises concerns about relevant uranium and thorium safeguards given the potential to extract these nuclear source materials. This issue, a matter of national environmental significance, is poorly addressed and, in reality, effectively dismissed ignored in the Fingerboards EES.

A5 The targets for rehabilitation sound reasonable but lack detailed quantitative or qualitative criteria to facilitate monitoring and assessment.

A6 There is a complete lack of specific and detailed financial costings for project rehabilitation.

A7 The lack of time allowed for maintaining, monitoring and then assessing the rehabilitation of former mining areas is of major concern – will this take 5 years or considerably longer, and how will this be funded by the proponent?

1. My Background

1. I am an Environmental Engineer with 25 years' experience in the environmental assessment and management of mining, especially groundwater, radiological and sustainability aspects.

2. My formal qualifications are a Bachelor of Environmental Engineering (Honours) from RMIT University (awarded May 1995) and a Doctorate (PhD) from Victoria University (awarded October 2001).

3. My current primary role is Associate Professor in Environmental Engineering at RMIT University, Melbourne, Australia. I also undertake community consulting from time to time as well as being Chair of the Mineral Policy Institute, Australia's only dedicated non-government organisation focussed on improving the environmental and social performance of the mining industry.

4. My full curriculum vitae ('CV') is provided as Attachment A to this report.

5. I have conducted research and published numerous peer-reviewed scientific papers on the radiological aspects of uranium mining and environmental radiation (see CV), as well as participating in the Alligator Rivers Region Technical Committee ('ARRTC') for 11 years – the federal body which oversees the research used to underpin regulation of uranium mining in the Kakadu National Park region of the Northern Territory.

2. Expert Report Instructions

6. I provide my full instructions and brief from Environmental Justice Australia ('EJA'), dated 5 January 2021, as Attachment B to this report.

7. I have reviewed and relied upon on the following specific reports for the Fingerboards project:

   a. *Fingerboards Environment Effects Statement*. Prepared by Kalbar Operations Pty Ltd, April 2020 (herein referred to as the *'EES'*; see https://ees.fingerboardsproject.com.au/download).

   b. *Fingerboards Project Radiation Assessment Report*. Prepared by SGS Radiation Services Pty Ltd for Kalbar Operations Pty Ltd, April 2020, Job No. 18-10990, 134 pages (Technical Appendix A011 to the Environment Effects Statement for the Fingerboards Project).

   c. *Fingerboards Mineral Sands Project: Provision of Expert Advice to the Inquiry and Advisory Committee*. Prepared by K. H. Joyner for the Fingerboards Inquiry and Advisory Committee (part of the Environment Effects Statement and assessment and approvals process).

8. If there are other documents or reports I have used, they are cited in the normal scientific manner and listed in the Bibliography.

9. For this report, I include below the principal relevant points of my instructions:

   "6. We request that you undertake a review of the Radiation Assessment Report (Technical Study, Appendix A011) (Tab 2.2.2) and relevant sections of Geochemistry and Mineralogy Report (Technical Study, Appendix A002) (Tab 2.2.1) and prepare an expert witness statement providing your opinion on:

   a. the adequacy of the baseline data collected by the project proponent to confidently describe pre-development conditions (as relevant to radiation);

b. the appropriateness of the methodology used to identify and evaluate the effects of the project, including characterisation of the likely sources of radiation;

c. whether the actual or likely effects of the project in relation to radiation are identified and or appropriately assessed;

d. the adequacy of the proposed management measures, including those set out in the Environmental Management Framework (Tab 2.1.5 / Environmental Management Framework (Chapter 12));

e. any other matters related to the Radiation Assessment Report you identify which you consider relevant within the limits of your expertise; and

f. any appropriate qualifications or conditions that should be attached to findings or conclusions, such as uncertainties or gravity of threats or impacts.

7. In preparing your expert witness statement, please also review and respond to Dr Ken Joyner's Review of the Radiation Assessment Report (Tab 3.1.2)."

10. Given the above points, I structure my report around these key issues:
    a. the adequacy of the characterisation of baseline or pre-mining radiological conditions;
    b. the adequacy of the monitoring and management of radiological issues during proposed operations;
    c. the adequacy of the proposed rehabilitation criteria after mining and remediation works have been completed;
11. This review is entirely my own work and no-one else influenced my understanding nor contributed to my views. My views are based on my experience over the past 25 years.
12. I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.

3. Pre-Mining or Baseline Radiological Conditions

3.1 External Gamma Radiation

13. The work presented in SGS (2020) includes 156 measurements of gamma radiation levels (page 14, Table 1).

14. The average value outside the project area is given as 0.09 ± 0.01 µGy/hr (based on 33 measurements), which compares favourably with Australia's average background gamma level of 0.093 ± 0.027 µGy/hr (Schery *et al*, 1989).

15. The average value inside the initial mining area is given as 0.13 ± 0.02 µGy/hr (based on 107 measurements). The Perry Gully area is stated as 0.33 ± 0.04 µGy/hr (based on 7 measurements) whilst the Perry Gully Southern Wall area is stated as 0.14 ± 0.02 µGy/hr (based on 9 measurements). The significance of this is not discussed by SGS (2020), but these slightly elevated levels are presumably due to direct exposure at the surface or shallow sub-crop of mineral sands ore (i.e. a reflection of the monazite containing uranium and thorium).

16. SGS (2020) state that the radiation meter used has a resolution of 0.0001 µSv/hr for a range up to 0.2 µSv/hr (page 14), but the measurement resolution is not provided at greater than this level. From Appendix H, some 21 measurements are above the equivalent of 0.2 µSv/hr. The resolution (or measurement error) should be explicitly stated for levels >0.2 µSv/hr.

17. SGS (2020) acknowledged that the large project area and land access issues limited their ability to take more extensive measurements (page 13). Despite this, there appears to be no attempt to map the measurements as site locations are simply given in eastings and northings (Appendix H), not latitude-longitude, making it difficult to accurately map these locations.

18. Section 13, the 'Future Work Plan', notes the need for further gamma radiation measurements, including a finer resolution survey – yet I believe this work should have already been completed and presented through the EES process.

19. SGS (2020) also fails to cross-reference or compare against available aerial radiometric mapping, either from Geoscience Australia or the Geological Survey of Victoria ('GSV'). Using GSV's 'GeoVic' online mapping tool[1], the map below was generated (Figure 1; full map provided as Attachment C). Unfortunately, there is no legend or scale for the radiometric results, leaving the map as a relative scale only with light blue being low and red being high. The map suggests that an area of mineral sands mineralisation appears as a red anomaly west of Glenaladale, although this needs to be assessed in detail with respect to geology and mineralisation – something which the EES fails to do (and is beyond the scope of this report to complete). The radiometric map does not automatically mean excessive gamma radiation levels, as the map is a relative view only, but it is useful in understanding the extent and variation of gamma radiation levels in the Glenaladale region.

[1] Available at https://gsv.vic.gov.au/sd_weave/anonymous.html

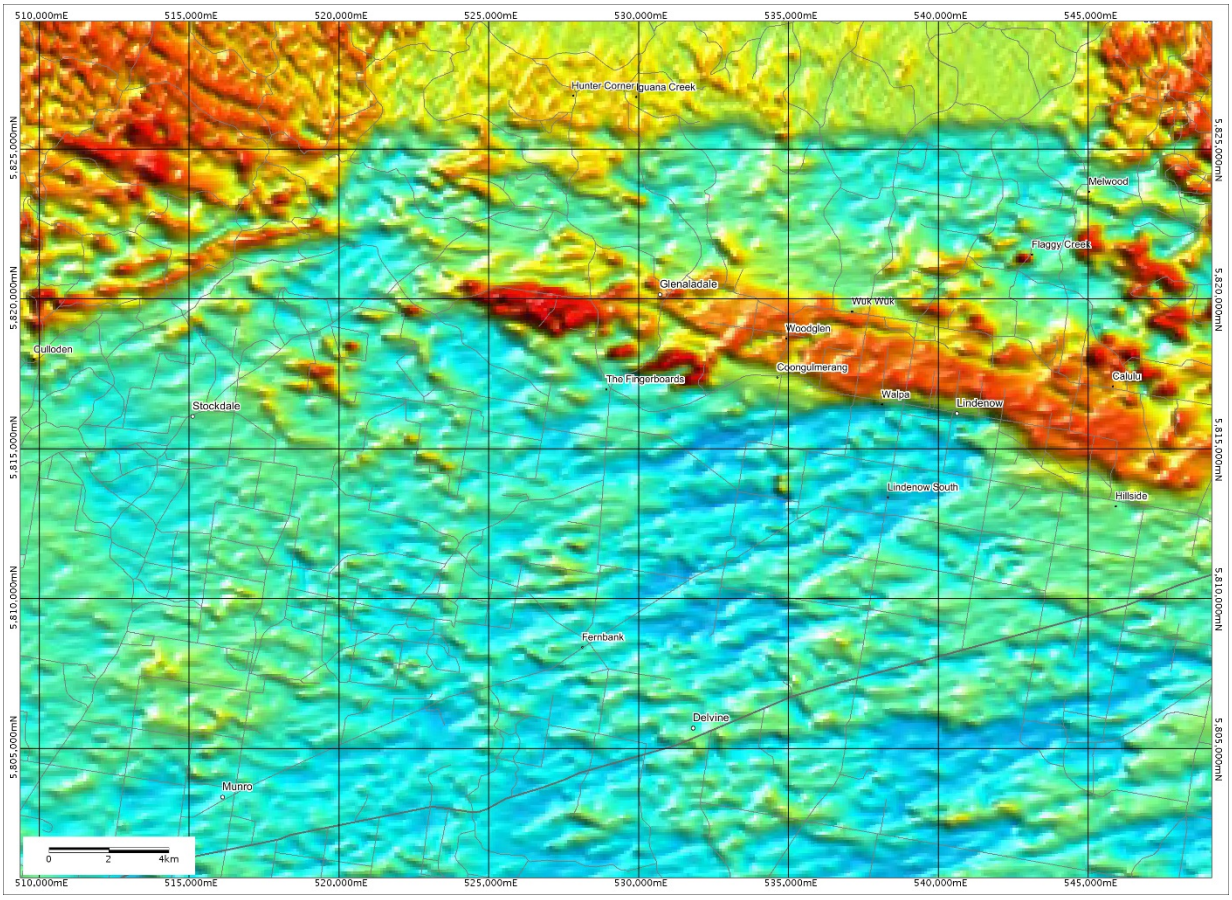

Figure 1: Aerial radiometric map (based on total count) of the Glenaladale area (generated using the GeoVic online service; full file provided as Attachment C)

3.2 Radionuclides in Soils

20. The work presented in SGS (2020) includes 10 soils tested for radionuclide content (page 16, Table 2). This is a very small number of tests for such a large project area. Given the variability shown (varying by a factor of almost one hundred), a much larger number of soil samples should have been collected for testing – especially considering rehabilitation criteria and the suitability of different soils and materials for proposed rehabilitation designs.

21. The average concentration of uranium and thorium in upper crustal rocks and soils is 2.7 and 10.5 mg/kg, respectively (Rudnick & Gao, 2014).

22. The values in Table 2 (SGS, 2020) are given as activity concentrations in Bq/kg, which were converted to weight concentration[2] in units of mg/kg. For uranium (as U-238), the lowest value is at Kalbar House at ~0.38 mg/kg, compared to the highest value ~28 mg/kg at Perry Gully ridge. The average uranium concentration is ~7.0 mg/kg. For thorium (derived from equilibrium with Th-228), concentrations range from ~1.7 to ~295 mg/kg and averaged ~71 mg/kg. The averages probably reflect the influence of monazite in the surficial geology, although not leading to significant enrichment (i.e. uranium at ~7.0 versus 2.7 mg/kg or thorium at ~71 versus 10.5 mg/kg). Furthermore, Table 3 gives results suggesting an average uranium and thorium of ~1.7 and ~12.3 mg/kg, respectively, in regional soils – again suggesting natural or very low levels.

[2] Activity concentrations converted to weight concentration using the online service (based on standard procedures): http://wise-uranium.org/cunit.html

23. Additional testing on radionuclides in soils is given in Appendix A002 of the EES, 'Geochemistry & Mineralogy Summary Report' (Kalbar, 2020). Results are given in Tables 2 to 4 (pages 24 to 25). For topsoils and regional sampling sites, the range for uranium was 0.8 to 6.9 mg/kg, averaging 3.0 mg/kg, whilst for thorium the range was 2.2 to 29.4 mg/kg, averaging 12.2 mg/kg – suggesting no significant enrichment compared to average crustal abundance (see point 21 previously).
24. Section 13, the 'Future Work Plan', notes the need for further assessment of radionuclides in soils, considering "locations relative to the Project area, crop type, cultivation methods, fertilizer use, and gamma survey field measurements" (page 68, SGS, 2020) – yet I believe this work should have already been completed and presented through the EES process.
25. Overall, the levels of radionuclides in surface soils in the project area and region do not appear to be significantly enriched in uranium and thorium, providing good evidence to facilitate potential criteria for site remediation and rehabilitation (in the event the project proceeds).

3.3 Radionuclides in Crops

26. This sub-section (5.3) is very short and rather terse – plus the values given in Table 4 are calculated only and nor directly measured. The transfer factors are not given, nor a basic explanation of the calculations undertaken to derive the values in Table 4. Although it is asserted that the transfer factors are appropriate for the region, there is no direct evidence presented to support this – such as previous scientific studies nor direct sample analyses of crops from the Glenaladale region.
27. Section 13, the 'Future Work Plan', notes the need to assess radionuclides in vegetables in Lindenow – yet I believe this work should have already been completed and presented through the EES process.

3.4 Radionuclides in Groundwater and Surface Water

28. Results for radionuclides in groundwater and surface water are given by SGS (2020) in Tables 5 and 6, respectively. The analyses include Ra-226 and Ra-228 derived from the uranium and thorium decay chains, respectively. The results are below the guideline levels for Australian drinking water (<0.5 Bq/L for Ra-226+Ra-228), this again reinforces the naturally low levels in groundwater and surface water of the project area and surrounding region.

3.5 Radon and Thoron[3] Aspects

29. The results reported by SGS (2020) in sub-section 5.8, especially Table 8, suggest relatively low levels of radon and thoron in the ambient atmosphere. Specifically, reported radon levels ranged from <15 to 48 Bq/m^3 and thoron levels ranging from <20 to 119 Bq/m^3. There is virtually no discussion of the variability in the measured radon and thoron results, such as barometric pressure, temperature, rainfall, soil moisture and humidity (e.g. Schery *et al*, 1989; Mudd, 2008). The values reported by SGS (2020) are within natural global variability (see Table 3 in Mudd, 2008) and reinforce the view that current radon and thoron levels are not of major concern.

[3] Thoron is the common name used for radon derived from the thorium-232 radioactive decay chain, namely Rn-220.

30. The comment about the allegedly elevated radon result at 'Hotel in Bairnsdale' is mere speculation and stated without any reference to specific building materials nor any test results of that material. Based on my experience over many years, it should be understood that stones used in buildings can vary widely in radionuclide content but are rarely sufficiently elevated to cause concern from a radiological exposure perspective. Furthermore, the comment is made without any discussion of factors which act to increase or decrease radon levels in buildings such as a hotel (e.g. operated as a closed facility and not open to the outdoor environment). The result simply demonstrates variability of radon levels in the region, nothing more can be discerned without much more widespread testing and assessment.

31. Section 13, the 'Future Work Plan', notes the need to conduct detailed radon surveys, especially to understand baseline levels and factors affecting variability – yet I believe this work should have already been completed and presented through the EES process.

4. Management of Radiological Risks During Proposed Operations

32. SGS (2020) appears to correctly identify the full range of acts, regulations and codes which will required to be met for the proposed Fingerboards project. A major weakness, however, is that many of these plans are still to be finalised and are therefore not available for review as part of the EES and public consultation. For example:

    a. Kalbar will need to apply for a Management Licence under Victoria's Radiation Safety Regulations – but no specific details are given in sub-section 7.2;

    b. Sub-section 7.5 discusses the relevant radiation codes, but there is minimal actual detail on how Kalbar propose to implement these requirements for the proposed Fingerboards project;

    c. Sub-section 7.6 and Section 12 discusses the need to consider radiation effects for flora and fauna (i.e. environmental radiation exposure for biodiversity), yet this work is it to be completed in the future with no discussion of how Fingerboards may develop such an assessment (a Radiation Environment Plan) – leaving nothing for discussion or comment as part of the EES;

    d. Sub-section 7.7 discusses the issue of transport of designated radioactive materials (namely the HMC) but argues that they will most likely be exempt, stating they "will need to have process controls in place to ensure" (page 35). There are no such details provided, however, leaving such critical issues to be determined in future outside the EES process and denies the public transparency and the opportunity to comment;

    e. Sub-section 10.1 discusses the requirements for radiation protection and management for workers and the public. Whilst some specific measures are stated to protect workers, there are no details provided for the radiation monitoring plan, expected to be a requirement of a Management Licence for radiation matters under Victorian approvals. Again, such details should have been presented as part of the whole Fingerboards EES – such plans are widespread in the mineral sands sector and therefore not difficult to develop and include in the EES process;

    f. Section 11 reviews the issue of radioactive waste management. It is agreed that the tailings would not be classified as radioactive waste as per the Australian (and related IAEA) code. The production of the HMC, however, is a designated radioactive material, meaning that a

formal Radioactive Waste Management Plan will be required to meet Australian and Victorian regulations – yet this plan is still to be developed and only very generic issues noted in SGS (2020) (page 67).

33. I believe that the discussion in sub-section 7.4 of the designation of the Fingerboards as a 'nuclear action' under the Commonwealth Environment Protection & Biodiversity Conservation (EPBC) Act is incorrect and fails to understand the purpose of this matter of national environmental significance. The processing of the heavy mineral concentrate will lead to the separation of zircon, titanium oxide minerals (rutile, ilmenite) as well as rare earth minerals. Based on Table 9 (SGS, 2020), these products all contain uranium and thorium well above natural crustal abundance (see point 21), with the rare earths product containing uranium concentrations which are similar to existing uranium mines[4]. At present, to the best of my knowledge, there are no thorium mines operating globally with the only supply generated as a by-product from rare earths concentrate processing and refining (mainly in India, Russia and China, possibly others). The EPBC Act is intended to provide for public transparency over nuclear actions such as uranium mining – especially since Australia has maintained a position in the international nuclear fraternity through uranium exports for peaceful purposes. As a member of the International Atomic Energy Agency (IAEA), Australia is bound by its many requirements, especially that all nuclear source materials are sold for peaceful purposes only and follow strict accounting practices and safeguards. Uranium and thorium are both potential nuclear source materials and are therefore required to be meticulously controlled in production and export. To illustrate this, I present some estimates below in Table 1, contrasting the heavy mineral concentrate (HMC) from the proposed Fingerboards project with selected uranium mines in terms of uranium concentrations in the ore they process and the quantities of uranium produced – or potentially extracted in the case of the HMC. The quantity of uranium recoverable from the Fingerboards HMC, estimated at 185 t, is considerable and would therefore be required to meet IAEA international safeguards requirements – yet this is completely lacking in SGS (2020) and the Fingerboards EES.

Table 1: Comparison of uranium concentrations in Fingerboards HMC compared to selected uranium mines[A]

Project	**Ore / Conc.**	**Uranium**	**Production**	**Company or Data Source**
	t/y	mg/kg	t U	
Ranger	2,488,333	692	1,775	Energy Resources of Australia
Olympic Dam	8,697,000	546	3,768	BHP Group
Rössing	8,619,000	273	2,346	Rössing Uranium
Fingerboards HMC[C]	700,800	278	185	SGS (2020), Table 10

[A]Data represent averages for the years 2018-2020 for Ranger and Olympic Dam (both in Australia) and 2017-2019 for Rössing (in Namibia, Africa). (Note: Olympic Dam also produces copper, gold and silver and contains rare earths, cobalt and tellurium).

[B]Units: Conc. – concentrate; t/y – tonnes per year; mg/kg – milligrams per kilogram or parts per million; t U – tonnes uranium.

[C]Fingerboards data converted from tph (tonnes per hour) to t/y and weighted average uranium concentration and assumes 95% uranium recovery. For thorium, the weighted average concentration in HMC is 1,579, and assuming 95% recovery during processing, this means recoverable thorium of some 1,050 t.

[4] For comparison, the Ranger uranium mine processed ore between 600 to 2,750 mg/kg uranium over its operating life whilst the Olympic Dam copper-uranium-gold-silver mine processes ore averaging around 500 mg/kg uranium (Mudd, 2014, including more recent data from media releases by Energy Resources of Australia Ltd and BHP Group Ltd).

34. In addition, Victoria also has the Nuclear Activities (Prohibitions) Act 1983[5] which remains in force (to my understanding of the law). The relevant clauses are:

    "5 (1) Subject to section 6, but notwithstanding anything else to the contrary in any Act, and notwithstanding the terms of any mining title, a person shall not explore, mine or quarry for uranium or thorium."

    "6 (1) Notwithstanding section 5, a person who is the holder of a mining title and who mines or quarries uranium or thorium in the course of mining or quarrying pursuant to his mining title for some mineral other than uranium or thorium shall not be guilty of an offence under this Act provided that—

    (a) uranium of an amount greater than ·02 per centum by weight or thorium of an amount greater than ·05 per centum by weight is not removed from the land covered by the mining title;

    (b) mined or quarried material containing uranium or thorium is treated in the prescribed manner; and

    (c) he complies with such conditions (if any) as the Governor in Council may from time to time impose in respect of the mining or quarrying in which he is, or is to be, engaged."

    "8 (1) A person shall not construct or operate—

    (a) a mill for the production of uranium or thorium ore concentrates (except where permitted under section 6);"

35. My expertise is, of course, in Environmental Engineering and not as a lawyer – but, based on my extensive experience in uranium mining issues, points 33 and 34 raise serious legal (and moral) questions about the export of HMC which is expected to be processed in a manner (i.e. acid leaching to extract the rare earths) whereby the uranium and thorium might be readily recovered. This needs much further detailed consideration and very meticulous assessment.

5. Post-Mining Criteria for Site Remediation and Rehabilitation

36. This section reviews Chapter 11 of the Fingerboards EES.

37. In general, the commitments made in Table 11.2 are generally good but often lack quantitative criteria, making implementation and assessment more difficult. Some specific comments include:

    a. "Surface water and groundwater quality reflect original (pre-mining) baseline chemistry" (Table 11.2, page 11-10) – yet there remains insufficient data upon which to define and quantify baseline chemistry (especially radionuclides, see point 28);

    b. "Rehabilitation to ensure that radiation dose at surface and radon levels in atmosphere is less than or equal to baseline levels found within the project area" (Table 11.2, page 11-12) – yet there remains insufficient data to properly define and quantify baseline radiological conditions (see Section 3 previously).

38. There appears to be no recognition of the length of time required to actively monitor and maintain the site to ensure that the numerous rehabilitation targets and associated criteria are achieved. That is, will monitoring and site maintenance occur for 5 years after the cessation of

[5] See https://www.legislation.vic.gov.au/in-force/acts/nuclear-activities-prohibitions-act-1983/026

mining and rehabilitation, or will this be for 25 years, or perhaps longer? There appears to be no discussion of this at all in the EES, despite it being widely recognised in the mining industry that rehabilitation may take several years to decades to achieve (e.g. Bell, 2006; Mulligan, 2006). As a contrasting example, the rehabilitation, monitoring and maintenance of the McArthur River zinc-lead-silver mine in the Northern Territory is expected to take 1,000 years (see METServe, 2017) – demonstrating the extreme acid and metalliferous drainage risks presented by that site.

39. Although the EES has used the Victorian rehabilitation bond calculator (sub-section 11.6.4), there is no reference or citation for this – despite the various aspects described as part of the estimate, full details are completely missing.

40. The preliminary estimate of the rehabilitation bond has not been given in the EES (sub-section 11.6.4). In order to comment on the economics of a project and to demonstrate transparency and accountability (especially on the development of the cost estimate, see point 39), the estimated rehabilitation bond must be provided. This is critically important because if the project ceases unexpectedly (e.g. technical problems, poor markets, company financial issues, etc), as acknowledged in sub-section 11.6.3, the Victorian Government will have to use the bond to complete site remediation and rehabilitation works. If the bond is insufficient, this leaves a potentially very large liability for the Victorian Government as well as the risks and impacts being borne by the local Glenaladale and regional community. Further east in Gippsland, the former Benambra copper-zinc mine went bankrupt in the mid-1990s with a negligible bond being held by the Victorian Government – costing millions of taxpayer funds to redress. Elsewhere in Victoria, the Anglesea and Hazelwood coal mines have both been closed with bonds being between 10-100 times less than the estimated costs of rehabilitation – although at both sites the operating companies are continuing to fund site remediation and rehabilitation works.

6. References Cited

41. Bell, L C (Editor), 2006, *Mine Closure and Completion*. Leading Practice Sustainable Development Program for the Mining Industry, Commonwealth Department of Industry, Tourism and Resources, October 2006, Canberra, ACT, 63 pages.

42. METServe, 2017, *McArthur River Mine Overburden Management Project – Draft Environmental Impact Statement*. Prepared by Mining & Energy Technical Services Pty Ltd (METServe) for McArthur River Mining Pty Ltd and Glencore Plc, Darwin, NT, March 2017.

43. Mudd, G M, 2008, *Radon Sources and Impacts: A Review of Mining and Non-Mining Issues*. **ReViews in Environmental Science and Biotechnology**, Volume 7, Issue 4, pages 325-353.

44. Mudd, G M, 2014, *The Future of Yellowcake: A Global Assessment of Uranium Resources and Mining*. **Science of the Total Environment**, Volume 472, pages 590-607.

45. Mulligan, D R (Editor), 2006, *Mine Rehabilitation*. Leading Practice Sustainable Development Program for the Mining Industry, Commonwealth Department of Industry, Tourism and Resources, October 2006, Canberra, ACT, 63 pages.

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47. Schery, S D, Whittlestone, S, Hart, K P & Hill, S E, 1989, *The Flux of Radon and Thoron From Australian Soils*. **Journal of Geophysical Research**, Volume 94, Issue D6, pages 8567-8576.

48. SGS, 2020, *Fingerboards Project Radiation Assessment Report*. Prepared by SGS Radiation Services Pty Ltd for Kalbar Operations Pty Ltd, April 2020, Job No. 18-10990, 134 pages (Technical Appendix A011 to the Environment Effects Statement for the Fingerboards Project).

Signed: Gavin M. Mudd (29 January 2021)

Attachment A:

Curriculum Vitae for Gavin M. Mudd (short form)

Assoc. Prof. Gavin M. Mudd

Curriculum Vitae (short form): July 2020

Associate Professor – Environmental Engineering

Current Position

School of Engineering, *RMIT University*, Melbourne, VIC, Australia

[redacted]

Email: [redacted]

Qualifications

Doctorate (PhD) *Victoria University*, Melbourne, Australia (awarded Oct. 2001)

B. Env. Eng. (Hons) *RMIT University*, Melbourne, Australia (awarded May 1995)

Current and Previous Appointments

- January 2017 to present – **Associate Professor in Environmental Engineering**, *School of Engineering*, *RMIT University*, including teaching, research and administration.
- May 2003 to January 2017 – **Assistant Lecturer / Lecturer / Senior Lecturer / Course Director in Environmental Engineering**, *Dept. of Civil Eng*, *Monash University*, including teaching, research and administration.
- Nov. 2009 to Feb. 2010 – **Visiting Fellow**, Institute of Environmental Studies, Uni. of New South Wales, Sydney
- July to Oct. 2009 – **Visiting Fellow**, Dept of Civil & Environmental Eng, University of Auckland, New Zealand
- Approximately 20 months **consulting experience** - contaminated sites, environmental assessment, groundwater, solute transport and unsaturated flow modelling, laboratory testing of mine wastes, liaison with government and industry organisations, working with and for Aboriginal people.
- July 2000 to April 2002 - **Research Fellow in Mine Waste Hydrology**, *Dept. of Civil Eng*, *University of Queensland*.
- March to July 1998 (Semester One) - **Lecturer in Earth Sciences/Geomechanics**, Victoria Uni.
- March 1995 to June 2000 - **PhD Research** - groundwater impacts and management of coal ash disposal.

Research Interests & Performance (as of 14 July 2020)

- **H-index: Scopus** – **35**; 3,368 total citations from 100 documents/papers.
- **H-index: Google Scholar** – **43**; 6,213 total citations from 202 documents/papers.
- **Edited Books** – **1** edited conference proceedings (SSEE 2009 Conf., Melbourne, Australia, Nov. 2009).
- **Book & Encyclopaedia Chapters** – **27** edited book and encyclopaedia chapters, several under review or in active preparation.
- **Journals** – **84** journal papers (~90% ISI listed journals), several more under review or in active preparation.
- **Major Research Reports and Handbooks** – **39** research and technical reports and contributions to industry, government and academic institutions and community handbooks.
- **Conference Papers – 56** peer reviewed and **86** non-peer reviewed papers and/or presentations.
- **Sustainable Mining** – environmental impacts, geochemistry, leachability & management of mine wastes, acid mine drainage, sustainable resource management; commodities include uranium, gold, nickel, copper, lead-zinc-silver, platinum group elements, iron ore, cobalt, rare earth elements, critical and specialty metals (such as indium, rhenium, molybdenum), lithium, coal, oil and gas.
- **Industrial Ecology** – life cycle assessments, environmental impact assessment, material flow analyses.
- **Hydrogeology & Groundwater Resources** – groundwater management & sustainability, groundwater impacts from mining, geochemistry, flow and solute transport modelling, vadose (unsaturated) zone issues.

Selected Recent Publications

1. **Mudd, G M**, 2020, *Sustainable/Responsible Mining and Ethical Issues Related to the Sustainable Development Goals (SDGs)*. In "Geoethics: Status and Future Perspectives", Editors G Di Capua, P T Bobrowsky, S W Kieffer, C Palinkas, Geological Society of London, UK, In Press.
2. **Mudd, G M**, Roche, C, Northey, S A, Jowitt, S M & Gamato, G, 2020, *Mining in Papua New Guinea: A Complex Story of Trends, Impacts and Governance*. **Science of the Total Environment**, 741, 140375, 19 p.
3. **Mudd, G M**, 2018, *Material Criticality Assessment and Resource Nexus Analysis*. In "Routledge Handbook of the Resource Nexus", Editors R Bleischwitz, Hoff, H, Spataru, C, van der Voet, E and van Deveer, S, Routledge, Oxon, UK, pp 129-148.
4. **Mudd, G M**, Jowitt, S M & Werner, T T, 2018, *Global Platinum Group Element Resources – A Critical Assessment*. **Science of the Total Environment**, 622-623, pp 614-625.

5. **Mudd, G M** & Jowitt, S M, 2018, *Growing Global Copper Resources, Reserves and Production: Discovery is Not the Only Control on Supply*. **Economic Geology**, 113 (6), pp 1235-1267.
6. Werner, T T, Ciacci, L, **Mudd, G M**, Reck, B K & Northey, S A, 2018, *Looking Down Under for a Circular Economy of Indium*. **Environmental Science & Technology**, 52 (4), pp 2055-2062.
7. Jowitt, S M, Werner, T T, Weng, Z & **Mudd, G M**, 2018, *Recycling of Rare Earth Elements*. **Current Opinion in Green & Sustainable Chemistry**, 13, pp 1-7.
8. Weng, Z & **Mudd, G M**, 2017, *Global Rare Earth Supply, Life Cycle Assessment and Wind Energy*. In "Wind Energy", Editor T Letcher, Elsevier, pp 517-534.
9. Northey, S A, **Mudd, G M**, Werner, T T, Haque, N, Jowitt, S M, Weng, Z & Yellishetty, M, 2017, *The Exposure of Global Base Metal Resources to Water Criticality, Scarcity and Climate Change*. **Global Environmental Change**, 44, pp 109-124.
10. **Mudd, G M**, Jowitt, S M & Werner, T T, 2017, *The World's Lead-Zinc Mineral Resources: Scarcity, Data, Issues and Opportunities*. **Ore Geology Reviews**, 80, pp 1160-1190.
11. Werner, T T, Jowitt, S M & **Mudd, G M**, 2017, *The World's By-Product and Critical Metal Resources Part III: A Global Assessment of Indium*. **Ore Geology Reviews**, 86, pp 939-956.
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Research Awards

- **Mann Redmayne Award for best paper published in Applied Earth Sciences (2015)**, Joint Australasian Institute of Metallurgy (AusIMM) and Institute of Materials, Minerals and Mining (IoM3) journal
- **Most-cited paper in Resources Policy (2009-2013) by Elsevier in 2014 (for my 2010 paper in Res. Pol.)**

Major Research Grants & Involvement (Recent and Current)

- **International Round Table on Materials Criticality** – Expert Partner, project aims to develop an international research network on critical materials *(July 2017 to June 2020)*
- **Geoscience Australia** – major research project exploring Australia's potential endowment of critical metals and validating cost models for mining *(June 2018 to June 2019)*
- **International Copper / Nickel / Lead-Zinc Study Groups** – research project examining trends in mine wastes, management policies and economic costs and opportunities *(January to July 2018)*
- **Columbia Water Center, Columbia University** – research project to synthesize detailed water use data for mining to link to life cycle assessment and financial performance of mining companies. *(July to December 2017)*
- **Netherlands Environmental Assessment Agency (PBL)** – research project to map global mineral resources and mining against biodiversity. *(July to December 2017)*
- **CSIRO Wealth From Waste Cluster** – joint CSIRO-university initiative, led by Institute for Sustainable Futures at University of Technology Sydney (UTS), the project is exploring the concept of material flows from mineral resources to products through to recycling and related issues. Monash University was a major cluster partner, along with Yale University, University of Queensland and Swinburne University. *(Project completed, 2013-2016)*
- **CSIRO Minerals Futures Cluster** – joint CSIRO-university initiative, led by Institute for Sustainable Futures at UTS, with my involvement through Monash helping to explore the concept of 'peak minerals' and related environmental issues in the mining industry. *(Project completed, 2009-2012)*
- **Others** – Institute for Sustainable Water Resources (2004-2008); Facility for Advancing Water Biofiltration (2007-2009); eWater CRC (2006-2009)

Teaching Awards

- **Department of Civil Engineering's Award for Excellence in Teaching (2012)**, Monash University
- **Faculty of Engineering Dean's Award for Excellence in Teaching (2012)**, Monash University
- **Vice Chancellor's Citation for Outstanding Contribution to Student Learning (2011)**, Monash University

Post-Graduate Research Supervision

- **4 PhD students and 3 Masters** completed as principal supervisor, **4 PhD students** completed as co-supervisor
- Presently 1 PhD and 1 Masters student as principal supervisor and 1 PhD student as co-supervisor.

Teaching Interests

- Environmental Impact Assessment (EIA), Environmental Risk Management, Groundwater Management.
- Sustainable Engineering and Industrial Ecology (tools such as life cycle assessment, material flow analysis).

Undergraduate Teaching

- **Environmental Engineering** – Environmental Engineering, Groundwater & Hydrogeology, Environmental Impact Assessment & Management, Environmental Risk Assessment, Environmental Policy, Final Year Research Projects.
- **Guest Lectures** – Geography, Environmental Science, Civil Engineering, Mining Engineering.

University Administration

- **Course Director – Environmental Engineering** (BEnvEng, BEnvEng/BSci, BEnvEng/BArts, BEnvEng/BComm)
- **University** – Environmental Sustainability Stakeholder Committee
- **Faculty of Engineering – Academic Progress Committee (APC)**

External Committees

- **Present** (September 2009 to present) – **Alligator Rivers Region Technical Committee (ARRTC)**, environment representative, national committee overseeing research on environmental aspects of uranium mining in the Alligator Rivers Region of the Northern Territory. ARRTC is a statutory committee of the Australian Government and membership is government-appointed based on relevant scientific expertise.
- **Prior** (Nov 2006 to Nov 2010) – **Society for Sustainability and Environmental Engineering (SSEE; Victorian Branch)** – Victorian committee of national society, part of Engineers Australia (SSEE is now the Sustainable Engineering Society or SEng).
- **Prior** (May 2004 to Dec 2006) – **Great Artesian Basin Co-ordinating Committee (GABCC)** – national inter-governmental committee for oversight of groundwater management of the GAB. The GABCC is a statutory committee of the Australian Government and membership is government-appointed based on relevant expertise.

External Consulting & Community Engagement

- **General Mining** – as requested, providing technical advice on environmental issues and mining (e.g. gold mining in WA, Indonesia, New Zealand and Papua New Guinea; copper heap leaching; mineral sands mining; existing and proposed coal mining; coal seam gas; mining legacies and lack of mine rehabilitation, etc.).
- **Uranium Mining** – pro-active role in providing detailed technical review and advice on uranium mining issues in the Kakadu National Park world heritage area (Ranger, Jabiluka), and globally (e.g. Malawi, USA, Canada).
- **Mineral Policy Institute (MPi)** – Chair of the Board (2010-present). MPi is the only Australian non-government organisation dedicated to research and advocacy on the environmental and social issues around the mining industry. MPi's work includes projects in Papua New Guinea, Malawi, Australia, New Caledonia and others, covering issues such as deep sea mining, mine waste management, corporate governance and accountability, community empowerment and development, mining legacies, and related aspects of modern mining.
- **Groundwater** – technical advice on groundwater chemistry and impacts from mining or other sites (e.g. coal seam gas), groundwater resources and management.
- **Environmental Impact Assessment** – providing technical advice on EIA processes, critiquing EIS's, links to environmental management systems and environmental regulation.
- **Community Seminars** – I have always maintained a strong community engagement, presenting regularly at community seminars, workshops and conferences, with a major focus in recent years being the groundwater and environmental issues involved with unconventional gas developments (e.g. 2013 I gave ~25 community talks).

Professional Memberships

Current:
- Society of Economic Geologists (**SEG**)
- Sustainable Engineering Society (**SEng**)

Former:
- International Association of Hydrogeologists (**IAH**)
- Australian Mining History Association (**AMHA**)
- Australasian Institute of Mining & Metallurgy (**AusIMM**)
- International Society for Industrial Ecology (**ISIE**)

Attachment B:

My Instructions from Environmental Justice Australia, 5 January 2021

Environmental Justice Australia

5 January 2021

Assoc. Prof. Gavin Mudd
Environmental Engineering
School of Engineering
RMIT University

By email only: [redacted]

Dear Associate Professor Mudd

Fingerboards Mineral Sands Mine Project, Glenaladale, Victoria – radiation

We act on behalf of [redacted], a not-for-profit community group formed in response to the proposed Fingerboards mineral sands mine project (the **project**).

We write to you as an expert chemical and environmental engineer. The purpose of this letter is to seek your expert opinion on the radiation effects of the project, with a focus on the sources and characteristics of monazite in mineral sands mining.

We request your expert opinion be provided as an expert witness statement to be submitted to the Fingerboards Mineral Sands Project Inquiry and Advisory Committee. We request that your expert report be provided by **22 January 2021**, with a draft/preliminary report provided by **15 January 2021.**

References to Tab numbers in bold in this letter are to the documents in an electronic brief which we provide to you via DropBox [redacted]

Background

1. Kalbar Operations Pty Ltd (**Kalbar**) propose to develop an open pit mineral sands mine covering an approximate area of 1,675 hectares within the eastern part of the Glenaladale mineral sands deposit in East Gippsland, Victoria. The site is located near the Mitchell River and approximately 2km south of Glenaladale, 4km south-west of Mitchell River National Park and 20km north-west of Bairnsdale.

Environmental Justice Australia
ABN 74052124375

PO Box 12123
A'Beckett Street PO
Melbourne VIC 8006
L3, 60 Leicester St, Carlton

T (03) 8341 3100
F (03) 8341 3111
E admin@envirojustice.org.au
W www.envirojustice.org.au

2. The proposal includes the development of an open pit mineral sands mine, two mining unit plants, wet concentrator plant, water supply infrastructure, tailings storage dam and additional site facilities (i.e. site office, warehouse, workshop, loading facilities and fuel storage). The proposed mining methods involve open pit mining to extract approximately 170 million tonnes (Mt) of ore over a projected mine life of 20 years to produce 8 Mt of mineral concentrate. Heavy mineral concentrate, separated into magnetic and non-magnetic concentrates, are proposed to be transported via road, rail or a combination of both for export overseas (**Tab 2.1.2 / Project Description**).

3. On 18 December 2016, the Minister for Planning issued a decision determining that an Environment Effects Statement (**EES**) was required for the project due to the potential for a range of significant environmental effects. The purpose of the EES is to provide a sufficiently detailed description of the proposed project, assess its potential effects on the environment and assess alternative project layouts, designs and approaches to avoid and mitigate effects (**Tab 1.1 / Scoping Requirements**).

4. An Inquiry and Advisory Committee (**IAC**) has been appointed to review the EES and public submissions (**Tab 1.2 / Terms of Reference**). The IAC will hold public hearings for 7-8 weeks, after which it will produce a report for the Minister for Planning. Following receipt of the IAC's report, the Minister for Planning will then make an assessment as to whether the likely environmental effects of the project are acceptable (**Minister's Assessment**).

5. All EES documents are available online at: https://ees.fingerboardsproject.com.au/download.

Instructions

6. We request that you undertake a review of the Radiation Assessment Report (Technical Study, Appendix A011) (**Tab 2.2.2**) and relevant sections of Geochemistry and Mineralogy Report (Technical Study, Appendix A002) (**Tab 2.2.1**) and prepare an expert witness statement providing your opinion on:

    a. the adequacy of the baseline data collected by the project proponent to confidently describe pre-development conditions (as relevant to radiation);

    b. the appropriateness of the methodology used to identify and evaluate the effects of the project, including characterisation of the likely sources of radiation;

c. whether the actual or likely effects of the project in relation to radiation are identified and or appropriately assessed;

d. the adequacy of the proposed management measures, including those set out in the Environmental Management Framework (**Tab 2.1.5 / Environmental Management Framework (Chapter 12)**);

e. any other matters related to the Radiation Assessment Report you identify which you consider relevant within the limits of your expertise; and

f. any appropriate qualifications or conditions that should be attached to findings or conclusions, such as uncertainties or gravity of threats or impacts.

7. In preparing your expert witness statement, please also review and respond to Dr Ken Joyner's Review of the Radiation Assessment Report (**Tab 3.1.2**).

8. As an expert you are able to consider any such material you consider relevant to your enquiry. Please identify in your report any further materials you consult outside of the briefed materials.

9. In the interests of avoiding duplication, we advise that our client has also retained experts from Murrang Earth Sciences to review the Technical Studies addressing Landform, Geology and Soil, with a focus on rehabilitation and tailings.

Expert Witness Code of Conduct

10. We have enclosed a copy of the *Guide to Expert Evidence provided by Planning Panels Victoria*, which is the relevant guidance for hearings before the IAC (**Tab 3.1**).

11. In preparing your final expert witness statement, please ensure that you include:

a. your name, address, qualifications, experience and area of expertise

b. details of any other significant contributors to the report (if there are any) and their expertise

c. all instructions that define the scope of the statement (original and supplementary and whether in writing or verbal)

d. details and qualifications of any person who carried out any tests or experiments upon which the expert has relied in preparing the statement

e. the following declaration:

'I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.'

Important dates

12. We request that a draft report be provided by **15 January 2021.** We request your expert witness report be provided by **22 January 2021.**

13. The IAC will conduct public hearings over a period of 7-8 weeks, commencing on **15 February 2021**. We anticipate [redacted] will make their case in the first week of March 2021. Accordingly, please advise of the days on which you will **not** be available to give evidence before the Inquiry and Advisory Committee in the first week of March 2021.

14. We further advise that the IAC may direct experts to get together to confer as part of an 'expert conclave' in early February. An expert conclave usually involves experts on the same topic convening for a half day in an attempt to clarify the matters which are agreed and or disagreed and generally narrow the issues in dispute. We do not have any further information on the expert conclave at the moment, but we anticipate learning more once the IAC publishes its written directions.

Confidentiality

15. This request for an expert opinion and the subsequent expert witness statement, as well as any correspondence relating to this request, is for the purposes of the Fingerboards mineral sands mine project EES process, including the public hearings before the IAC. It is therefore confidential and is protected by legal professional privilege.

Fees

16. [redacted]

Please contact Virginia Trescowthick if you have any questions or require further information.

Yours faithfully

Virginia Trescowthick

Lawyer

Attachment C:

Aerial Radiometric Map of the Glenaladale area generated using the Geological Survey of Victoria's online GeoVic mapping system

Map generated 25 January 2021

https://gsv.vic.gov.au/sd_weave/anonymous.html

Department of Jobs,
Precincts and Regions

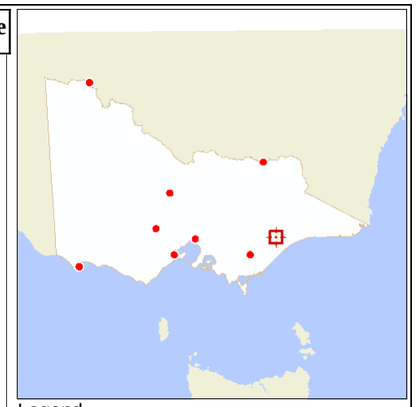
Radiometric Map Glenaladale

510,000mE 515,000mE 520,000mE 525,000mE 530,000mE 535,000mE 540,000mE 545,000mE

5,825,000mN 5,820,000mN 5,815,000mN 5,810,000mN 5,805,000mN

Hunter Corner
Iguana Creek
Melwood
Flaggy Creek
Glenaladale
Wuk Wuk
Woodglen
Culloden
Coongulmerang
The Fingerboards
Calulu
Walpa
Stockdale
Lindenow
Lindenow South
Hillside
Fernbank
Delvine
Munro

0 2 4km



Legend

Towns (100K)
- Large Town
- Town
- Locality

Roads (250K)
- Major Roads
- Other Roads

Victoria Boundary (25K)
- Boundary
- Coastline

GN MN

GDA

VICTORIA State Government

Generated from GeoVic 3

Map Created Mon Jan 25 2021 16:41:41 GMT+1100 (AEDT)

Map Scale: 1:120,608

Projection: MGA 55