BEFOR THE SELWYN DISTRICT COUNCIL

RC225180

In the matter of	the Resource Management Act 1991	
	Sections 88-120, Resource Management Act 1991	
Between	**Party**	KeaX Limited
	Role	Applicant
And	**Party**	Robyn Casey, Clark and Elizabeth Casey and Dave and Donna Kewish ("Joint Submitters")
	Role	Submitter

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EVIDENCE OF RAYMOND JOHN HENDERSON

Date 16 February 2023

J M van der Wal
Barrister
40 Walker Street Chambers
Christchurch
Also at 14 Queen Street
Blenheim

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NATURE, PURPOSE AND BASIS OF EVIDENCE

1 Raymond John Henderson. I have been requested by Robyn Casey, Clark and Elizabeth Casey and Dave and Donna Kewish ("Joint Submitters"), who have made a joint submission and an individual submission in opposition to Application RC225180 ("the application"), to provide expert evidence. Specifically, I address the risk of contamination and resultant adverse effects, and more generally the sciences around electromagnetic effects, noise and . I also address the mitigation proposed by the Applicant and comments made by the s42A report.

2 My relevant experience and qualifications are:

2.1 29 years working as an ecologist and in ecotoxicology at Landcare Research;

2.2 15 years as director of Pest-Tech Ltd. doing contract research for the Animal Health Board and Department of Conservation;

2.3 Development of cholecalciferol for possum and rat control, then compilation of the necessary documentation for pesticide registration;

2.4 Worked with the Landcare team on developing empirical data, the target and non-target effects, for regulatory dossiers submitted during 1080 re-registration;

2.5 Registered zinc phosphide for pest control after developing a full suite of data on non-target risks, environmental risks, and product efficacy;

2.6 Worked alongside Dr. Eason undertaking research on the ecological impacts of brodifacoum and other 2nd generation anticoagulants within the food web on the conservation estate;

2.7 Eight years undertaking research on the ecology and ecological impacts of chamois in the Canterbury high country;

Assisted in developing management plans for red deer in RHAs, whitetail deer on Stewart Island, and fallow deer in the Blue mountains following extensive research on population dynamics, species ecology, and the ecosystem impacts of each species;

2.8 Engaged in public consultation during pest control for AHB (viz. in 75 poison operations that I supervised these methods of consulting resulted in trouble-free pest-control operations with zero conflicts or

2.9 disputes);

Evaluated reasons for operations failures during possum control and then developed standards for 'bait quality' and effective 'baiting

2.10 strategies' (viz. this lifted mean kills from 81% to >95% during aerial control operations);

Wrote the 'best practice manual' for control of possum populations in

2.11 1998 (viz. is still in use)

2.12 Have written dozens of AEE assessments and 3 RMA applications for pesticide registration.

2.13 Have authored or co-authored around 35 science papers and I'd guess around 130 science reports for clients (DoC and AHB mainly).

3 I have read the Environment Court's Code of Conduct and agree to comply with it. My qualifications as an expert are set out above. I confirm that the issues addressed in this statement of evidence are within my area of expertise (i.e., risk assessment, environmental impacts, HSNO classifications, RMA

4.1 consents

4.2 4 I have read and reviewed the following information:

All documentation tendered by the applicant for RMA consent;

The contents of the 42c report

5 The data, information, facts, and assumptions I have considered in forming my opinions are included in the references submitted by 'notified parties'. This includes 130+ papers and reports from peer-reviewed papers published in science journals. Therefore, the main source of information is from the sciences and HSNO classifications for environmental and health impacts. I have not omitted to consider material facts known to me that might alter or detract from the opinions I have expressed.

6 This evidence addresses:

6.1 The nature of risks posed to the receiving environment from the presence of solar panel and associated infrastructure-specific contaminants;

6.2 The existence of a real risk of these contaminants escaping as a consequence of being present on site; and

6.3 The Applicant's evidence on contamination and ecological risks.

NATURE OF CONTAMINANTS AND RISK OF ESCAPE

7 I acknowledge that I am not an expert planning witness. However, I also understand that it will be the Joint Submitters' planning evidence and legal submissions that contamination effects that will not be appropriately avoided, remedied or mitigated by the Regional Council consent conditions remain relevant. It is in reliance on that that I address these effects.

8 I have a background of assisting with research on the ecotoxicology of brodifacoum. This included measures of the bioaccumulation of brodifacoum in hepatic tissue of target and non-target species, residual effects on kidneys, heart and muscle; and, the impacts of brodifacoum on native fauna within the NZ food web.

9 Elsewhere below I address the basis on which I have become aware that solar panels typically include the following contaminants: metal halides, silica and PFAS. I also address the basis on which I conclude that there is a real risk that these contaminants will be released, and also that this will result to serious

and irreversible consequence. However, before I address that I provide some background to the contaminants.

Contaminant Background

10 Solar technologies are comprised almost entirely of heavy metals, glass that is mainly silica, circuit boards and wire insulation that are mainly per- and poly-fluoroalkyl substances (PFAS), and films for encapsulation that are a mix of ethylene vinyl acetate polymer layers and edge sealants. These materials have a very long half-life in the environment, a long half-life in the tissues of organisms (plants and animals), high aquatic toxicity, high soil toxicity, moderate toxicity by ingestion, high target organ toxicity, and many are either mutagens, carcinogens, or teratogens (Table 1). They are colloquially referred to as 'forever chemicals'.

Table 1. The half-lives, health, and environmental risks of materials used in solar technologies.

Chemical	Metal half-life Liver (d)	Aquatic toxicity 9.1	Soil toxicity 9.2	Terrest. Vert. 9.3	Toxic 6.1	Muta 6.6	Carcin 6.7	Reprod 6.8	Target Organs 6.9
Brodifacoum	114.6	9.1D	n/t		6.1E				6.9B
Aluminium	150 in liver; 7years brain	9.1A, pH 9.1B, pH	9.2B 9.2C		6.1E				6.9B
Lead	36 blood 130 liver	9.1A	9.2B	9.3A	6.1C	6.6B	6.7B	6.8A	6.9A
Silica		9.1B							6.9A
Cadmium	4 -19 yrs	9.1B			6.1C		6.7A	6.8B	6.9A
copper	21 d 435 d brain	9.1A	9.2D	9.3B	6.1B	6.6A			6.9B
Nickel	35 d	9.1B		9.3B	6.1C		6.7A		
Zinc	245 d	9.1A		9.3C	6.1D				6.9B
Silver	50d	9.1A	9.2B	9.3A	6.1C			6.8B	6.9A
Arsenic	10 hrs	9.1A	9.2B	9.3B	6.1C		6.7A		6.9A
Chromium	9 d	9.1A	9.2B	9.3B	6.1A	6.6A	6.7A	6.8A	6.9A
Selenium	150d	9.1C	9.2C		6.6B	6.6B			6.9B
Lithium	1-2d	9.1D	9.2D		6.1D				
Strontium	50.5 d	9.1C	9.2D		6.1D				
Titanium	12.7 d	9.1B			6.1E		6.7B	6.8B	
PFAS	5.5 – 8.5 yrs	9.1A & B	9.2C	9.3B	6.1C			6.8A	6.9B

11 Because the materials in solar technologies have high 'hazards', then the 'exposure' of soils, air, water, and ecosystems must be low for 'risks' to be low. The model 'risk = hazards x exposure' applies to all risk assessments. 'Risks' in the case of leachates from solar technologies are exacerbated by their long half-life which allows them to bioaccumulate in plants and animals.

12 Despite extensive research and especially ongoing research over the last 2 years, there is no effective way to prevent leaching of these substances onto soils and into water. In the last 3 years, just as dozens and dozens of papers have been written on more effective forms of encapsulation, so too dozens and dozens of papers have been written on leaching of materials from solar technologies. Rates of leaching follow a normal decay curve (slow at first with exponential increase as they age). However, there are "pulses" of leachates following storms (hail, lightening, wind, rain) that damage panels, and massive "pulses following fire events.

13 In addition to heavy metals, PFAS, and silica, in a fire event a multitude of additional toxic substances are produced by combustion that are hazardous in soils and water and if inhaled in air are very hazardous. These include hydrogen fluoride, hydrofluoric acid, phosphoric acid, arsenic trioxide, hydrogen cyanide, lead oxide, lead iodide, other heavy metal oxides, sulphurous compounds and the usual combustion products like carbon monoxide.

14 I note that the Canterbury Regional Council has granted two resource consents authorising the discharge of stormwater and the undertaking of earthworks over an unconfined aquifer. Having reviewed those consents and the reports on the basis of which they were granted, it is my view that they have not assessed and provided mitigation measures in the conditions imposed for a number of additional sources of contamination. I also note that the applicant did not seek consent to discharge such additional contaminants.

15 Most of the metal halides in solar technologies are highly toxic to aquatic organisms (HSNO=9.1A or 9.1B), the finely ground silica embedded in glass on solar panels gets into the gills of fish and is very toxic to fish (HSNO=9.1B). The PFAS in circuit boards, insulation on wiring, and in coatings on panels are all

highly toxic to fish (HSNO=9.1A). These substances all appear as leachates off panels that will be washed offsite in stormwater into creeks and then down to Lake Ellesmere. I address those issues below.

16 My previous work with brodifacoum alerted me to the environmental risk of metal halides, silica within glass panels, and PFAS within the food web on farms. The risks of pesticide leaching (e.g., 1080, DDT, and agricultural herbicides) into surface and ground water similarly alerted me to the implications of leachates from solar panels within the water cycle at farms, and the risks from residues washed into drains, creeks, and Lake Ellesmere on aquatic organisms.

17 Brodifacoum is a 2nd generation anticoagulant that adheres to proteins where blood is being filtered (viz. liver, kidney, placenta). Metal halides and PFAS compounds are compounds that similarly adhere to proteins in the body where blood is being filtered (viz. liver, kidney, placenta). Brodifacoum (half-life=114.6 days) bioaccumulates in the liver and kidney until the toxic effects (viz. blocking of enzyme actions in the vitamin-K cycle) cause massive haemorrhage and then death.

18 Metal halides (e.g., half-life of cadmium in liver >10 years, half-life of Pb^{2+} in children≈ 1 year) and half-life of PFAS compounds (3.5-8.5 years) from solar technologies are more persistent than brodifacoum in livers; and they too disrupt enzyme activities in the body as well as other molecular processes. This propensity for every component of solar technologies (metal halides, silica in glass, PFAS) to persist in every plant and animal, and every ecosystem on earth, does not portend well for the future health and welfare of animals, the viability of plants in contaminated soils, and long-term health of soils contaminated with solar technology leachates.

19 Every heavy metal from solar panels has a HSNO classification of 9.1A or 9.1B in aquatic environments (i.e., they are extremely hazardous to fish and other types of aquatic organisms), yet Environment Canterbury has issued not one, but two permits for discharge of stormwater into creeks that drain into Lake Ellesmere.

20 A recent paper by Bebo et al. 2023 demonstrates that a single freshwater fish that is caught in American waters now contains more PFAS than what could be ingested during a month of drinking contaminated water.

21 It is my view that the ECan consents neither control nor prevent PFAS being washed into Te Waihora where Māori harvest wild foods. Silica from the glass in solar panels leached into water has a toxicity to the gills of fish of 9.1B if it is in the form of fine particulates or 9.1C if it has granules that are slightly coarser (viz. these fish effectively suffocate from inadequate oxygen intake as water passes through gills). Metal halides not only severely impact the welfare of waterfowl (e.g., ducks), but these compounds bioaccumulate in tissues; so, fish and waterfowl act as a medium for the transfer of PFAS and heavy metals back to humans. ECan with their discharges of stormwater containing contaminants are in essence contaminating 'wild foods', which is unlawful under the Food Act 1981.

22 Leachates from solar panels on soils bioaccumulate in roots and block enzyme activity (e.g., mycorrhizae in clovers) and suppress enzymes that mediate plant growth. Furthermore, in soils leachates progressively kill or suppress micro-organisms that are essential for soil health (HSNO for metal halides=9.2B, although for Al, Zn, and Ni the HSNO is pH dependent; soil HSNO for PFAS=9.2B or 9.2C with research demonstrating PFAS cause significant change in the bacterial flora of soils). Soils in Italy after 7 years under solar panels experienced a 50% decline in nitrogen, a 61% decline in total organic carbon, reduced water dispersion, as well as several other changes. After 35 years at Brookside under solar arrays, soils will be severely impacted, and the area under solar panels could well be listed as a 'contaminated site' in the event of a fire.

23 Metal halides and PFAS in animals bioaccumulate in livers and kidneys where they affect a multitude of enzymes and molecular transitions that cause necrosis, neurological effects, they cause changes to DNA (mutagenicity), methylation of DNA with changed proteins and abundance of immune cells (e.g., T-cells) which promotes cancer (many of the heavy metals are listed as carcinogens), and reduced immune response to vaccines by children who are exposed in the womb or at a contaminated site.

24 Brodifacoum is presented for primary poisoning of pests at low concentrations of 20ppm in bait (0.002% wt/wt), yet it can kill large animals like pigs and deer (viz. miniscule amounts are lethal once they bioaccumulate). Because it is persistent and bioaccumulates, brodifacoum causes the death of all stoats that feed on possum and rat carcasses (secondary poisoning), and the death of bats that feed on invertebrates (e.g., maggots) on dead animals killed by brodifacoum (tertiary poisoning). Metal halides and PFAS compounds behave in the same way. These 'forever chemicals' have a half-life that that is much, much greater than brodifacoum so they persist in the food web. They are washed into creeks and ingested by small fish and water fleas that cause either lethal or sublethal effects (primary poisoning), these creatures are consumed by larger fish that bioaccumulate PFAS and metal halides (secondary poisoning) and then birds or man eat the fish (tertiary poisoning).

25 Barbo et al. identified that most freshwater fish in the USA are now so polluted with PFAS, that eating just one of them is the equivalent of drinking contaminated water for a month. I could go on-and-on, but the effects of persistent substances in the food web (e.g., brodifacoum) and the even more persistent substances from solar technologies (metal halides and PSAF compounds) in the food web are unerringly similar.

26 When I look at the food web on solar farms this rings alarm bells about the need for more research and extreme caution over what is put onto good agricultural land. Water that drains from the site with suspended contaminants will flow into Te Waihora resulting in a malaise of problems within that ecosystem. Extensive research has been done on metal halides and PSAF compounds falling from solar panels (particularly panels damaged by wind, hail, lightening, rain, snow, fire etc.) and how these leachates bioaccumulate in the roots, stems, leaves, flowers, berries, and fruits of plants.

27 What has not been done is a longitudinal study over 25 or 35 years to monitor temporal change in rates of leaching and the impacts of metal halides on entire ecosystems. Research has been completed on how low concentrations of metal halides affect enzyme reactions in plants (e.g., mycorrhizae that fix nitrogen) and how after just 7 years at a solar farm this reduces soil nitrogen by 50% and the total organic carbon in soils declined by 61%.

28 Research was done in the 1970s and 1980s on how heavy metals going into pasture bioaccumulate in plants eaten by livestock, with subsequent bioaccumulation of Pb, Ni, Zn and As in the tissues of these livestock. Research has yet to be done on the effects of heavy metals and PFAS in grass under solar panels on a) the welfare of livestock, and b) bioaccumulation of metal halides and PFAS in the livers of sheep grazing under panels over an extended period. This would require a combination of toxicology and histology of tissue samples from these animals.

29 Additional research should include the impacts of leached silica on the respiratory systems of livestock (it causes silicosis in humans). Research has been completed on heavy metals and PFAS in the roots of plants and then translocation of these to all parts of the plant. Crops (e.g., rice and wheat) in contaminated areas of Asia now exceed WHO guidelines for heavy metal and PFAS contamination; animals that feed on these plants then produce meats and animal by-products that exceed WHO standards for healthy sources of protein. We see people throughout Asia whose health is now impaired by 'forever chemicals' (viz. metal halides and PFAS); substances that form the bulk of solar technologies. Research on the health implications from heavy metals and PFAS was recently published by Parvez et al. as a chilling reminder of the potential long-term health risks that 'forever chemicals' in solar technologies potentially impose on the Brookside community.

30 I have not formed fixed opinions on the risks associated with solar technologies, and instead kept an open mind as to the long-term implications of solar technologies at Brookside for ecosystems and human health. However, there are substantive linkages within the literature for future risks to both ecosystem health and human health. Plants, berries, fruits and more especially root crops repeatedly consumed from soils that have housed solar technologies have the potential to compromise human health, the welfare of livestock, and ecosystem health. The levels of contaminants in honey will inevitably increase with the passage of time as leachates accumulate at the site (although leachates in honey are unlikely to exceed European guidelines).

31 Residues of heavy metals in sheep, cattle, goats, and other livestock grazing under solar panels needs evaluation. Similarly, the residues of PFAs and heavy

metals in the milk of cows grazing under solar panels may rise from the low levels of 0.001 – 0.005 mg/L in New Zealand to 0.06 – 0.53 mg/L recorded at contaminated sites offshore.

32 I now address more specific issues.

Aquatic Toxicity

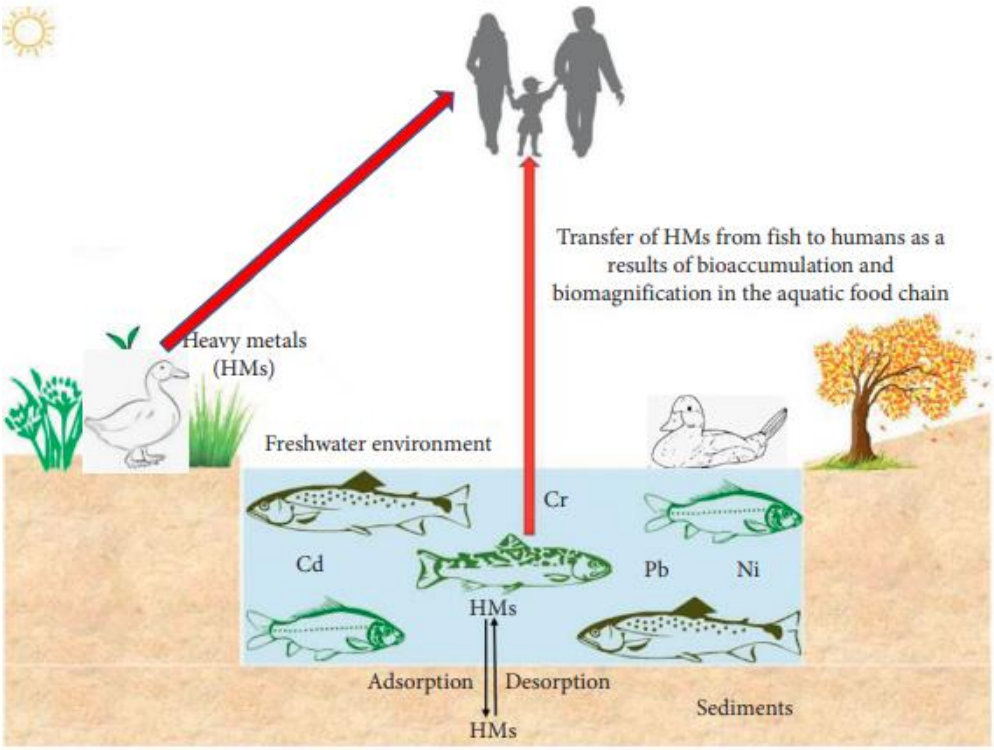
33 Per- and polyfluoroalkyl substances (PFAS) will be leached onto soils, and into groundwater, or be washed into drains and creeks that flow into Te Waihora (Lake Ellesmere). These substances are 'forever chemicals' that persist in the food web of ecosystems, resulting in long-term contamination of every organism that eats them. It is what has happened offshore and is what will happen here in New Zealand. PFAS that bioaccumulate in a single freshwater fish are more toxic to someone that eats it than that person drinking contaminated water for a month (Bebo et al. 2023).

34 An assortment of metal halides of lead (Pb^{2+}), aluminium (Al), zinc (Zn), copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni), arsenic (As), silver (Ag) and other metal halides are typically leached off solar panels during the research that has been done offshore. The specific metal halides at this site are then washed into creeks and eventually down to Te Waihora. All metal halides are highly toxic to aquatic organisms. Several of these metals can be listed as 'forever chemicals' that will persist within the food web of ecosystems, where they bioaccumulate in anything that eats them through primary, secondary, and tertiary poisoning, until eventually they cause target organ toxicity, lowered fertility, and reduced longevity. Aquatic organisms are typically affected by chronic or sub-chronic poisoning.

35 Silica in the form of finely ground granules gets into the gills of fish (Book *et al*. 2019 & 2021) resulting in toxic effects that impair respiration (HSNO=9.1B for very fine granules, or 9.1C for slightly coarser granules of silica).

36 As indicated, Al, Pb^{2+}, Zn, Cd and Ag are leachates from solar technologies that do not require an aquatic organism to ingest them in an hour, a day, a week, or even a month as a lethal dose, because they are persistent substances with a long half-life in tissues that enables them to bioaccumulate until target

organ toxicity eventually debilitates the fish or other types of aquatic organism. Of course, waterbirds (e.g., ducks and herons) that eat fish and aquatic organisms then ingest the 'forever chemicals' through secondary poisoning and they too are poisoned. Finally, man catches the fish and eats it, shoots the duck or swan and eats that, and he too has ingested sublethal quantities of PFAS or metal halides (tertiary poisoning) that have very long half-lives of 0.3 - 16 years in tissues (see figure below from Ali *et al* 2019). The applicant cannot discharge stormwater into drains and creeks; Environment Canterbury must revoke these consents.



: Trophic transfer of heavy metals from freshwater fish to humans in the human food chain

Soil Toxicity

37 The leachates are integrated into soils at concentrations that are toxic to soil micro-organisms (HSNO=9.2B), they reduce total organic carbon and nitrogen, change pH, and alter water dispersion (9.2B). Leachates of metal halides have been demonstrated to affect enzymes in plants that fix nitrogen.

38 Total organic carbon and nitrogen in soils under solar panels were reduced by 61% and 50% respectively after 7 years during a study in Italy. In this review of impacts of photovoltaic panels on soils Moscatelli et al. (2022) states: "The

main results from trials in Italy showed that seven years of soil coverage by solar panels modified soil fertility with the significant reduction of water holding capacity and soil temperature, while electrical conductivity (EC) and pH increased. Additionally, under the panels soil organic matter was dramatically reduced (−61% and − 50% for total organic carbon and total nitrogen respectively compared to the gaps between panels), inducing a parallel decrease of microbial activity assessed either as respiration or enzymatic activities.

39 As for the effect of land use change, the installation of the power plant induced significant changes in soils' physical, chemical and biochemical properties creating a striped pattern that may require some time to recover necessary homogeneity of soil properties after power plant decommissioning".

40 These effects create serious concerns for the long-term viability of fertile soils in New Zealand that are going to be subjected to 35 years of leaching of metal halides and PFAs from solar technologies. Will the sites of USSP-facilities finish as 'contaminated sites'? After decommissioning, will the soils be able to be restored to their pre-USSP state? At this moment in time these are unknown scenarios, but a fire event, storm damage.

41 Having read extensively on and around the subject I suspect worst-case outcomes for soils are a by-product of "pulsed leaching". In either really bad weather events or during fires the lamination on panels is compromised, then large volumes of leachates fall from solar panels. This "pulse" of metal halides will be very toxic to soil micro-organisms and some earthworms. However, when leaching is low earthworms may mitigate some effects on micro-organisms. it is well known that good populations of earthworms can encapsulate some potentially toxic elements (PTEs) in casts, that shields those materials from soil bacteria and organic enzymes (Xiao et al. 2022).

42 However, with constant leaching and/or pulses of heavy metals the macro-organisms are overwhelmed. The worst aspect is earthworms that have bioaccumulated large amounts of heavy metals and PFAS are then eaten by birds (e.g., blackbirds, thrush), which translocate 'forever chemicals' into the

bird food web. The other problem at Brookside is the clay-loam soils, which without irrigation tend to turn into concrete and decimate earthworm populations in topsoil over summer. On large areas of ground there are no earthworms at all. During summer in dry soils, earthworm activity in the topsoil is negligible.

Existence of Real Risk

43 The AEE furnished by the applicant lacked detail on apparatus to be used at the site, materials to be buried in soils on site, the quality of these materials, SOP's for maintenance of apparatus, and details about ancillary equipment,. None-the-less we can extrapolate from published literature on approximate risks.

44 Solar technologies are made almost entirely of metal halides, PFAS, silica, and various forms of combustible films made from fossil fuels plastics (e.g., polyethylene). These are colloquially referred to as 'forever chemicals' that are very persistent within ecosystems. Leaching of these substances from solar technologies will increase through time as panels delaminate in UV light, with the advent of weather events, and with fire.'. However, leaching will in the main be 'pulsed' with high leaching when panels are damaged by hail, lightening, wind, torrential rain, acid rains, the freeze-thaw after snow, and of course leachates will be extremely high after fire.

45 Here in assessment of real risk we use the model RISK=HAZARD x EXPOSURE

46 Hazard is always HIGH because every piece of technology on-site is made of 'forever chemicals'.

Fire Risk

47 In Italy there have been 1600 fires at USSP-facilities up to 2016. There have been several solar farm fires in Australia already. The possibility of a fire at Brookside is not insignificant. The consequences from fire are a massive release of toxic materials into the air, with the encapsulation of materials in panels lost. Essentially there is a huge release of heavy metals, and PFAS onto soils. Brookside becomes a 'contaminated site'.

48 The materials released during a fire at the facility will be converted to oxides, iodides, and other toxic derivatives from combustion that include HF, H_3PO_4, HCN, As_2O_3, CO, NO, and SO_2.; all of which present a very significant risk to human health and the health of aquatic systems around the site. Fire-damaged panels will of course leach vastly increased amounts of metal halides, PFAS, and by-products of the fire because nothing is now encapsulated. These leachates will all flow down into surface waters that surround the proposed development site in the first rains.

Surface water

49 In the event of rain and especially floods, stormwater discharge with leachates is moderate to high. In the above model during heavy rain, we have moderate leachates x moderate-high exposure; so risk to surface water is moderately high. In the event of a fire we have high leachates and the added toxic end-products from combustion, so the leachate hazard is very high and discharge in stormwater is high; so risk to surface waters is very high.

50 These are 'forever chemicals' that accumulate in stream water and Lake Ellesmere. The only way they are removed from the ecosystem is if they are ingested by birds. Aquatic hazard classification = 9.1B.

Aquatic systems

51 In the creeks around the site exists the endangered mudfish (*Neochadda apoda*). If the USSP-facility goes ahead they can bend over and kiss their tails goodbye. The drains along Caldwells Road contain trout and eels that are not going to fare well. Ducks, pukeko, herons, and bitterns (I have only seen these 3 times in vegetation near creeks) that occasionally frequent the waterways will inevitably be contaminated by metal halides and PFAS. The ramifications for those Māori that still harvest eels and flounder from Lake Ellesmere are serious. This scenario should not happen under the 1981 Food Act which references 'wild foods' as a food source that should not be contaminated.

Soils

52 The leachates are constantly added to soils, then dramatically increased in "pulses". Some are taken up by plants that are ingested by stock where the PFAS and heavy metals bioaccumulate in livers and kidneys, a small amount

finishes in nectar and is removed from flowers by bees, others finish in berries (blackberry and rosehip berries) that are eaten and removed from site by birds. The bulk of losses of 'forever chemicals' from the site will be in stormwater (*above*). In summary, we have leachates from panels that will grow at an increasing rate over time, but losses from site are mainly attributed to stormwater and materials going offsite in livestock.

53 Does this reach an equilibrium? The answer to that is probably not. Plant growth with loss of soil nitrogen and loss of organic carbon in soils will slow because of growth factors, rates of leaching will increase as panels age and delaminate. In the second half of the project, we will inevitably see a rise in heavy metals and PFAS in soils. Will they reach a level that make Brookside a contaminated site? That is a scenario no-one knows because long-term monitoring of soils has never been done. In the event of a fire or horrendous storm with wind and hail damage to panels, then Brookside may well become a 'contaminated site'.

54 Overall exposures suggest a long-term hazard rating for soils of 9.2B.

Groundwater

55 Leachates of PFAS and metal halides will leach through damp soils over winter and enter shallow groundwaters (c. 2m BGL). Because of the nature of soils (heavy clay-loam), this process will take time. Nitrates in groundwater at Brookside did not grow appreciably until the 1990s but have since progressively increased. I would guess in the first half of the project PFAS and metal halides in ground water would be negligible to low.

56 In the second half of the project, it may be quite different. For example, soil nitrates in my well in 2008 were <1 mg/L but by 2020 they had grown to 8mg/L. The other factor is extent of contamination; nitrates are ubiquitous throughout Canterbury, PFAS and metal halides are confined to 258ha. Brookside residents do not want 'forever chemicals' in drinking water, and in the near future this will be unlikely to trigger a HSNO classification. Long-term risks are unknown.

'Forever chemicals' in the food web.

57 To quantify risk here I will cite the example of brodifacoum use in North Island podocarp forests. Control of possums and rats in kokako habitat was expedited with baits that contained 20ppm brodifacoum. It was placed in bait stations so there was negligible interference by birds. The bait was effective at controlling target pests, including all stoats that died from eating dead rats and possums (i.e., secondary poisoning).

58 It soon became apparent this form of control was also killing other non-target species with bird deaths increasingly noted, especially raptors as apex predators. Monitoring of bird mortality demonstrated up to 50% of morepork, 70% of falcon were being killed at some locations, 40% of weka, with other species (harrier hawk, black-backed gulls, kea, kaka, endangered short-tailed bats, long-tailed bats, etc, etc). The brodifacoum went right through the food web. At these sites with all the bird deaths I estimate only 8kg of active ingredient went into the ecosystems. Why was it so insidious? Three reasons. The persistence of the material in tissue (half-life in liver=114.6 days), the fact that when it gets into blood it binds to protein where blood was being filtered (liver, kidneys, placenta), and the fact it is so effective at interfering with enzyme systems in the vitamin-K cycle.

59 I now consider PFAS and metal halides as they enter the food web. PFAS have very long half-lives (see Table 1 above). Of the metal halides that bioaccumulate, the serious ones are zinc, cadmium, lead, aluminium, and chromium. They too bind to issue where blood is being filtered (liver, kidney, placenta; *see* food web dossier). Then in amongst a raft of molecular processes and enzyme actions, these 5 very persistent compounds disrupt normal physiology, and cause long-term health problems. The similarities are remarkable; except at the site of the solar farm the amount of 'forever chemicals' leached into the environment will be 3-orders of magnitude higher than the amount of brodifacoum that went into the environment in North Island podocarp forests. What are the exposure routes for birds? These include toxic residues bioaccumulated in earthworms, residues in blackberry, residues in rosehips, residues in nectar, and residues in plants.

60 I expand just a little; we have residues in slugs and snails, residues in invertebrates feeding on flowers, residues in seeds (see food web dossier), residues in plant roots (eaten by the Porina grub that is then eaten by frogs once it metamorphosises into a moth), residues in plant stems, residues in leaves (eaten by insects that are then eaten by fantails).....it goes on and on until we have PFAS and heavy metals spread far and wide. What are the impacts? Birds' eggs are less viable, hatchlings have poor survivorship, fewer birds are fledged, longevity of adults eating contaminated foods is reduced, the immune systems of birds are compromised, there is nephrotoxicity, hepatotoxicity, impaired growth, and believe me for each class of terrestrial vertebrates the list goes on and on. Offshore it is the subject of hundreds of research papers. Heavy metals and PFAS entering the food web are a significant catalyst to loss of biodiversity in ecosystems.

61 This is triggered by the establishment USSP-facility at Brookside comprised of 3,000 tonnes of 'forever chemicals', allowing leachates to discharge to and from the soil that spread for the duration of the consent, which I note the applicant wishes to be indefinite. .

62 For birds and other vertebrate species, the exposure to heavy metals and PFAS is HIGH. Hazard is HIGH. Therefore, Risk = HIGH X HIGH. HSNO classification=9.3B for most adults, and 9.3A for most juveniles. The impacts of the solar farm on ecosystems are serious.

CONCLUSION

63 The long-term impacts of solar technologies on ecosystems are potentially very dire. This conclusion is based on my experience of having been actively involved in ecology and ecotoxicology for 55 years. Every component of solar technologies can potentially bioaccumulate in plants and the livers of animals; and every component of solar panels will be leached into aquatic and terrestrial ecosystems each-and-every day at Brookside for the next 35 years. Worldwide, birds are currently afflicted with PFAs and metal halides in eggs, hatchlings, and fledged birds; and worldwide terrestrial vertebrates are afflicted with PFAS and metal halides in offspring that result in poor survivorship, issues of animal welfare, and declining biodiversity.

64 What is New Zealand doing? We are effectively trading carbon emissions for emissions of heavy metals, and PFAS. We are trading clean air for air polluted with electromagnetic radiation.

65 I have demonstrated with the example of brodifacoum how if we put just a little (0.02 gram in a kilogram of bait, or 0.002% wt/wt) of a persistent compound with a half-life of 115 days into the environment, then it goes everywhere in the food web and potentially kills anything that has meat not only stoats and ferrets (secondary poisoning), but falcon, morepork, harrier hawks, black-backed gulls, weka, kea, short-tail baits, long-tail bats, etc, etc. We are now intending to put not one, but a smorgasbord of more persistent compounds into the environment in the form of PFAS and a variety of heavy metals (viz. half-life's range from 0.2-16 years in the liver). All these substances have deleterious effects on the health and welfare of animals, the health and welfare of birds, the health and welfare of aquatic organisms, and the health and welfare of people.

66 Unlike brodifacoum that is applied to the environment at very small rates, the active compounds from solar technologies will be broadcast at much higher rates. At Brookside they plan to put out 303,833 panels that each weigh 18.5kg (5,620 tonnes) of which 72% is silica and glass; so, 1,574 tonnes of heavy metals in solar panels, to which we must add metals in supports, frames, inverters, transformers, batteries, and wires, plus added PFAS compounds in circuit boards and wire insulation, that brings us to an estimated 3,000 tonnes of heavy metals and PFAS on site. If just 0.01% (a very conservative figure) of that is lost per annum as leachates in good weather, then we are putting 300kg *per annum* into the environment or 10,500 kilograms of PFAS and heavy metals onto soils over the 35-year course of the project.

67 The figures in the literature cite up to 100% of dangerous metal halides leach out of broken panels with acid rains, and typically around 20% from broken panels or panels with 'weak spots' in pH-neutral rain in a year. Of course, these figures do not include leached silica which is just as toxic to fish as leached heavy metals.

68 So, sitting on the risk fulcrum we have 8kg of a substance with a half-life of 115 days on one side that more than halved raptor populations and severely impacted other species of birds and bats, and on the other side of the fulcrum there is 10,500 kilograms of heavy metals and PFAS with an average half-life of 1.3 years (range= 0.2 – 16 years). We banned brodifacoum on the DoC estate because it was persistent and presented a significant risk to native species in the food web. I don't think you need to be Albert Einstein to understand what solar farm leachates (heavy metals and PFAS) will do to ecosystems throughout New Zealand.

69 Heavy metals, and PFAS will not kill adult *Homo sapiens* immediately, but they do have dire consequences for the unborn foetus and the health of babies (see Parvez *et al*. 2021). The consequences for adults with recurring exposures to small quantities of aluminium leachates from solar panels are mainly neurological (Alzheimer's, dementia, confusion, agitation, etc) with slight risks of heart disease (elevated cholesterol), osteoporosis, and liver damage. In comparison, the consequences when a mother is exposed to leachates for her unborn baby and then her infant are severe; with heavy metals and PFAS transferred via the placenta (viz. placentas bioaccumulate very, very high concentrations of 'forever chemicals'); poor AGPAR scores for baby at birth, PFAS and heavy metals in the blood of natal babies that exceed WHO guidelines, diminished cognition, respiratory disorders (bronchitis, pneumonia, asthma, etc), hypothyroidism, fertility issues as children grow (e.g., low sperm counts & sperm motility; delayed pregnancy in post-pubescent girls), elevated cancer risk, increased obesity, and increased risk of diabetes. Essentially expectant mothers should not be living in and around solar technologies because it places her baby at risk (see diagram below).

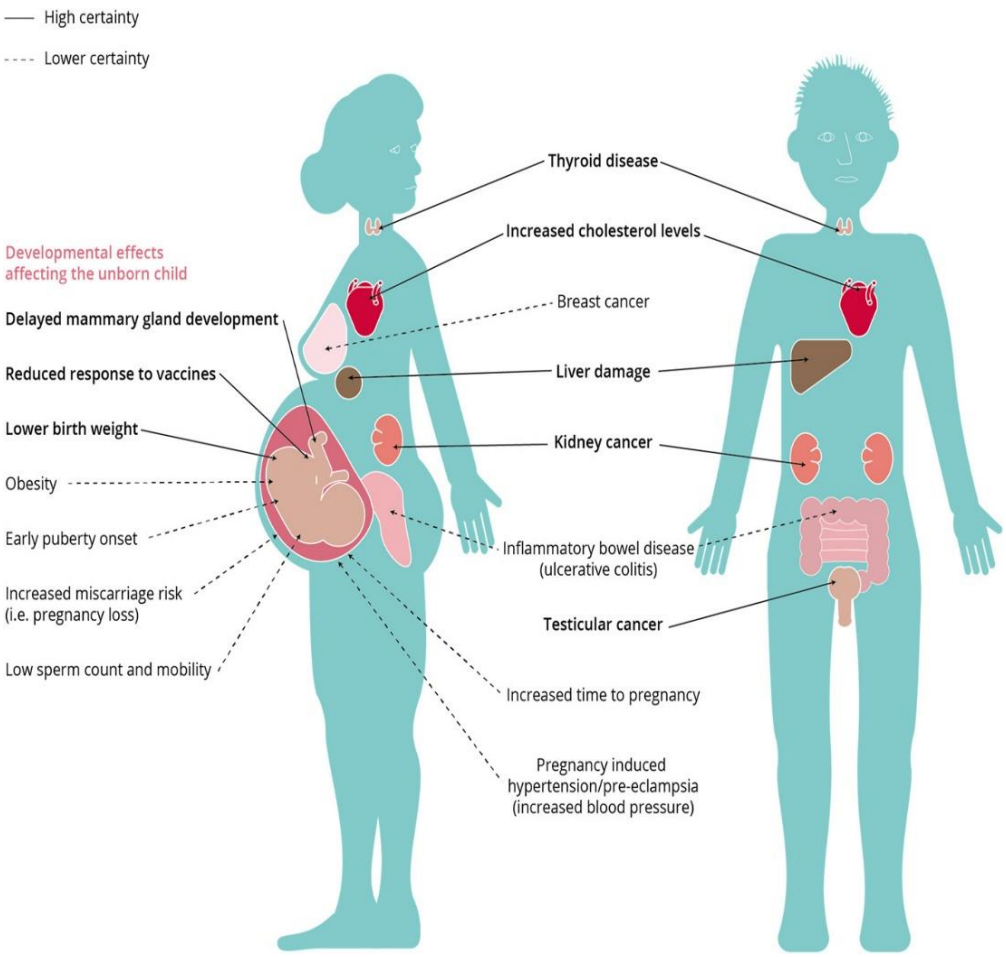


Figure 2. Risks to humans from exposure to PFAS and metals with a long half-life that bioaccumulate in vital organs.

70 Overall, I consider there are very real risks of adverse ecological effects from the establishment of this facility. The risks to soils are moderate to high, the risks to vertebrate ecosystems are moderate (birds and terrestrial vertebrates), and the risks to aquatic ecosystems are high. That risk has not been addressed by the mitigation proposed by the applicant or the conditions imposed by the ECan resource consents.

Dated 16 February 2023

R. J. Henderson.

Raymond John Henderson