rma ecology

Memo

To:	Naomi Humbles, Lodestone Energy	Job No:	2609
From:	Jeroen Lurling Senior Ecologist, RMA Ecology	Date:	3 April 2026
cc:	Graham Ussher, Principal Ecologist, RMA Ecology		
Subject:	Haldon Solar RFI Response: Avifauna effects assessment		

Dear Naomi,

1 Introduction

Lodestone Energy Limited (LEL) is seeking resource consents and approvals under the Fast Track Approvals Act 2024 (FTAA) for the development of a solar farm within a ca. 320 ha area of Haldon Station, Canterbury (**Figure 1**) ('the site'). LEL received a Request for Information (RFI) from the Haldon Solar Expert Panel on 12 March 2026 which included requests related to avifauna:

> As identified in Minute 4 of 16 February 2026, the Panel appointed an avifauna expert as a technical advisor to the Panel. That expert has reviewed the application, including the information listed above, has visited the site and surrounding area, and has prepared a preliminary report that has been provided to the applicant. That preliminary report includes a range of questions, which are repeated below, with some minor modifications. The applicant is referred to that report for further context on the questions below.
>
> The request for information from an expert ecology witness is:
>
> (a) A revised avifauna effects assessment in accordance with the Ecological Impact Assessment Guidelines, or similar.
>
> (b) A fulsome draft Avifauna Management Plan (building on the foundation provided by the Proteus report), which quantifies, as far as reasonably possible, the performance standards and outcomes, in terms of adaptive management approaches, required to give effect to solar farm design changes and compensatory packages to ensure adverse effects on birds have been addressed so that the stated "no net loss"[2] is assured.
>
> Specifically, the avifauna effects assessment should include responses to the following specific questions, which may then influence the draft Avifauna Management Plan:

(1) A species-specific collision-risk assessment for all Threatened and At-Risk species using or traversing the site, including:

(a) Flight frequency analysis based on available GPS tracking datasets and field observations

(b) Flight height distributions and panel interaction zones

(c) Seasonal and diurnal variation in collision exposure

(d) Species-specific vulnerability factors (body size, flight behaviour, habitat requirements, polarised light sensitivity)

(e) Collision probability estimates for:

- Kakī/black stilt
- Black-fronted tern
- Australasian bittern
- Australasian crested grebe
- Other waterbird species using the area

(f) Known breeding, roosting, and foraging locations within 5 km

(2) Panel Technology and Design Risk Analysis - provide technical assessment of the proposed solar array configuration including:

(a) Polarization and UV reflectance signatures of proposed panels

(b) Evidence for efficacy of anti-reflective coatings in reducing bird attraction

(c) Comparative collision risk: 60-degree vs vertical night positioning

(d) Panel spacing effectiveness (3.6 m gaps) in reducing the hypothetical "lake effect"

(e) An updated literature review of proven panel technologies that demonstrably reduce bird mortality

(3) Infrastructure Collision and Electrocution Assessment - provide an assessment of bird collision and electrocution risks from non-panel infrastructure:

(a) Perimeter fencing collision risk analysis

(b) Substation and inverter collision/electrocution potential

(c) Internal road and track collision risk

(d) Lighting impacts (construction and operational)

(e) Building strike risk assessment

(f) Mitigation design for all infrastructure types

(4) Population-Level Impact Thresholds & Adaptive Management Options - provide a population viability analysis determining:

(a) Maximum sustainable annual mortality rates for regional kakī population

(b) Population consequences of 1-2 adult kakī deaths per year

(c) Regional population estimates and trends for black-fronted tern, bittern, crested grebe

(d) Mortality thresholds that would trigger population declines for each Threatened and At-Risk species

(e) Conservation context: relationship to existing conservation investments in the basin

(f) Adaptive management triggers and response mechanisms with defined timelines

RMA Ecology has been engaged to respond to this RFI relating to avifauna, as well as matters relating to the potential effects on vegetation[1], and an overall effects management package[2].

In this memorandum, we respond to part (a) of the RFI as it relates to avifauna. To adequately respond to the RFI, this memorandum includes:

- A description of the desktop methods employed to gather data and assess value and effects;
- A description of the avifauna values identified in the vicinity of the site;
- A description of the ecological context of the site as it relates to avifauna habitat and flight paths;
- A description of the Lake Effect Hypothesis in light of recent studies;
- A summary of the proposals for the construction and operation of the solar farm;
- Identification of potential ecological effects, including:
    - a risk assessment of the likelihood of identified bird species potentially being subject to injury or death due to collision at the completed solar farm;
    - an assessment of habitat loss;
- The proposed measures to mitigate these effects following the framework of the mitigation hierarchy;
- An assessment of the residual level of effect after mitigation;
- An outline of the proposed monitoring programme and adaptive management framework to manage uncertainty related to effects; and
- Options for offsetting and compensation.

The initial ecological assessment of the site was undertaken by AgScience Ltd. That assessment included a very limited amount of data collection for birds, and was not targeted at birds that are most at risk from development of this site. Therefore, there is essentially no site-specific data for bird species use and numbers that is available for our analysis, and the time of year over which this assessment report has been prepared is not appropriate to collect site-based information on bird use of the site.

Therefore, this effects assessment employs a qualitative approach, based on known variables including habitat preferences, site use, species' behaviour, relative mortality risk of similar species or guilds, and recent literature on the lake effect hypothesis. Bird tracking and use data for the wider area presented by the Department of Conservation has also been used, as well as wider records on bird use of the local area available through national databases. Uncertainty is managed through a comprehensive monitoring and adaptive management approach, leading to further monitoring, mitigation and/or compensation.

Credentials and Code of Conduct

Mr Lurling and Dr Ussher (variously, the author and technical reviewer of this report) are qualified and experienced ecologists.

Mr Lurling holds the qualifications of BSc, Postgraduate Diploma in Wildlife Management (Distinction), and GradDip (Geography), specialising in Aquatic Ecology & Water Quality (Distinction).

[1] RMA Ecology (2026). Haldon Solar Botanical values and effects assessment. Memorandum dated 30 March 2026.
[2] RMA Ecology (2026). Haldon Solar Plant, Tekapo: updated ecological effects assessment. Report dated 31 March 2026.

He has 28 years' experience as an ecologist and specialises in the fields of avifauna (with extensive experience in threatened species recovery), wetland ecology, bat ecology, and botany.

Dr Ussher holds the qualifications of BSc, MSc (1st class honours) and PhD in conservation ecology. He has 34 years' experience as an ecologist in New Zealand, with speciality expertise in herpetology, and effects assessment and management, including offset accounting and modelling.

Dr Ussher and Mr Lurling have extensive experience in ecological site assessments, significance assessments, impact assessment, and impact management, including extensive experience on the ground designing, constructing, implementing, monitoring and reporting on interventions to restore, enhance, salvage, and protect ecology values at sites across New Zealand. They are considered to be sufficiently qualified to undertake an assessment of this kind.

Although this document has not been written as a statement of expert evidence, we confirm that at all times we have complied with the Environment Court's Code of Conduct for Expert Witnesses contained in its Practice Note 2023 as well as the UDIA Code of Ethics. No part of this report has been authored by an AI or other software.

We declare that in relation to our role in providing expert ecological assessment and advice for this project we are not, to the best of our knowledge, subject to any real or perceived conflicts of interest.

1.1 Project description

The Haldon Solar project proposes to construct and operate a solar farm on 320-hectares adjacent to Lake Benmore, south of Haldon Arm Road, 14-kilometres southeast of Twizel (**Figure 1**).

The solar farm will have an approximate peak output of 220 Megawatts, and an estimated annual output of 370 GWh, supplied to the national grid.

The project will comprise:

- Photovoltaic (PV) solar panels and mounting structures occupying approximately 320 hectares and reaching 2.2 m in height when stowed at their maximum angle of 60 degrees (**Figure 2, Plate 1**);
- An electrical substation with a footprint of approximately 1.3 ha and components reaching up to 24 m in height (**Figure 3**);
- One (1) new 2DD HST high voltage transmission tower approximately 35 m high, adjacent to the substation (**Figure 3**);
- Two sets of 5 transmission lines, each 37 m in length, linking the substation to the tower and the national grid;
- Inverter cabinets, and associated infrastructure;
- Underground electricity cables;
- A perimeter security and pest exclusion fence, up to 2.0 m high, with relatively fine mesh (25 mm or less), with a top roller cap and no top wires for the solar farm;
- A pest exclusion fence around the adjacent 180 ha offset site; 1.5 m high, with relatively fine mesh (25 mm or less), a roller cap top and no top wires;
- Internal tracks, with no fill or excavation; and
- Site earthworks for roads and the substation.

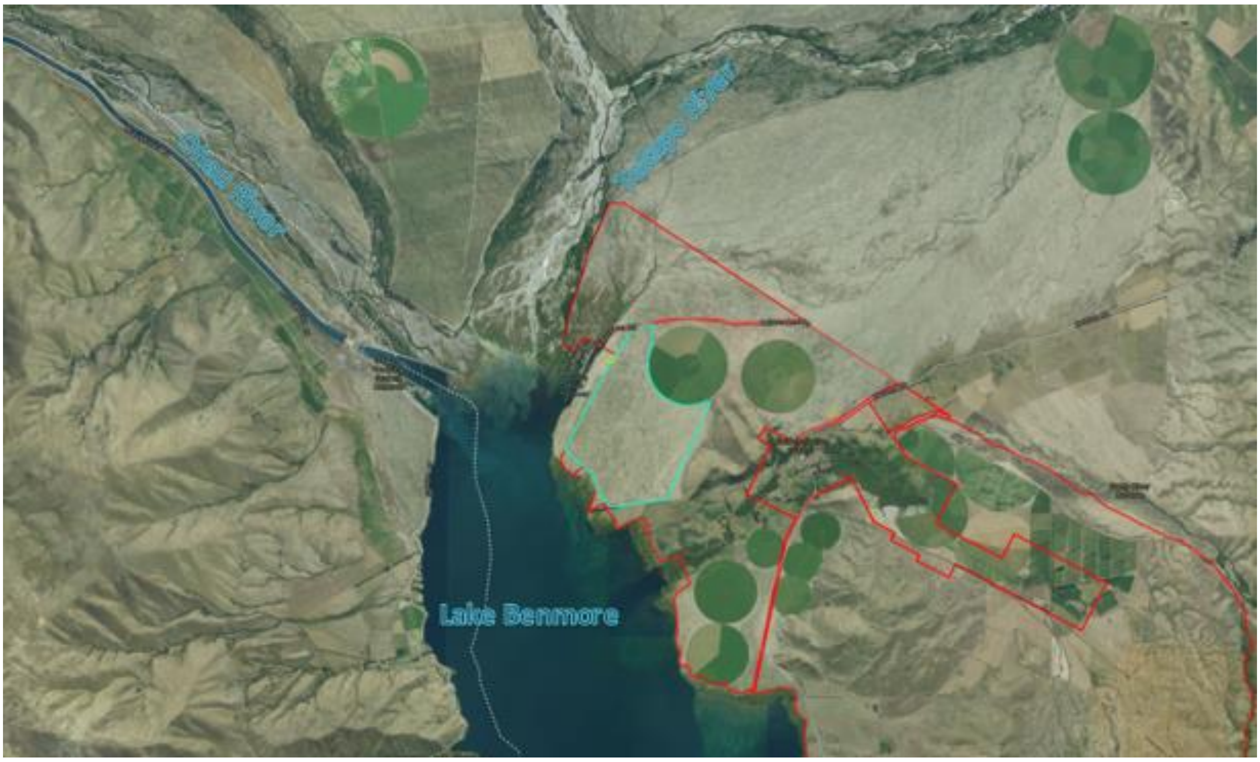

Figure 1 Haldon Solar Farm footprint (“the site”; cyan polygon) and Haldon Station (red polygon).

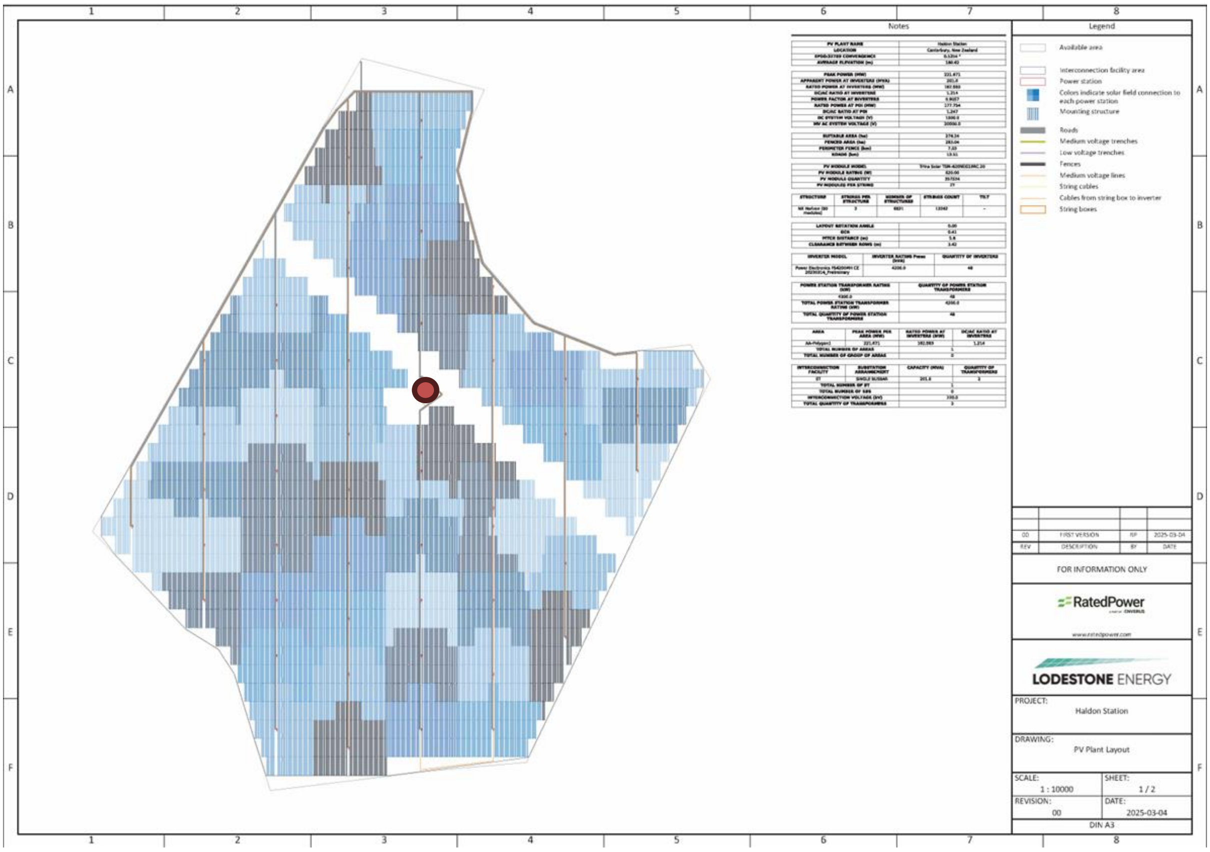

Figure 2 Haldon Solar Farm proposed solar array (“blue polygons) and substation with connection to the national grid (red circle).

Plate 1. Single axis tracker photovoltaic panel design.

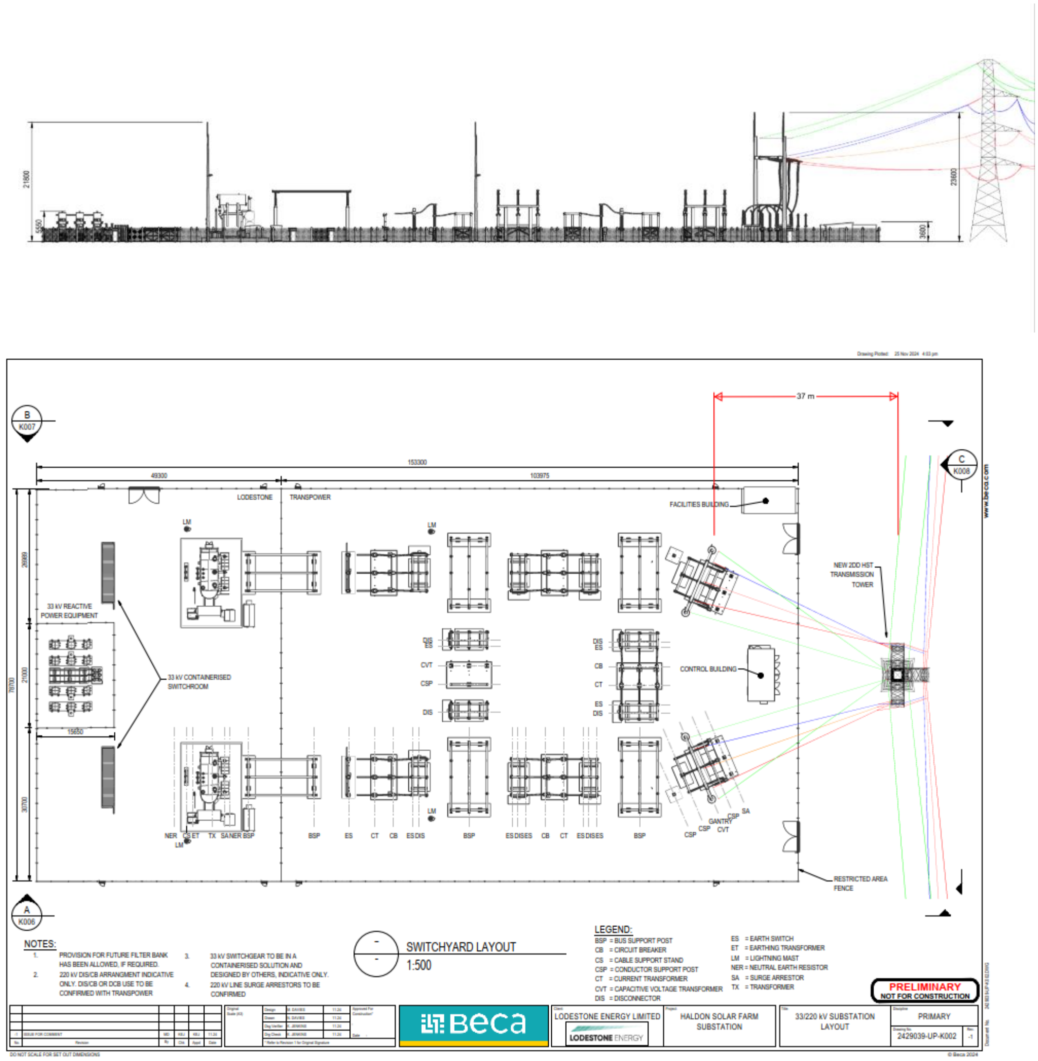

Figure 3. Design (profile and plan views) of the substation, high voltage tower and connecting transmission lines.

2 Avifauna values

1.2 Threatened and At Risk Species

A desktop inventory of Threatened and At Risk bird species recorded in the vicinity of the site was compiled using:

- New Zealand Bird Atlas data (10 km grid resolution, derived from eBird observations);
- eBird records;
- iNaturalist records; and
- Published survey data for the Tekapo River system.

Eighteen Threatened and At Risk species are recorded in the vicinity (5-10 km) of the site (**Table 1**), including:

- Three Nationally Critical species; black stilt, white heron and Australasian bittern;
- One Nationally Vulnerable species; black-fronted tern;
- Four Nationally Vulnerable species; Australasian crested grebe, grey duck, New Zealand falcon and Caspian tern;
- One Nationally Increasing species; Wrybill; and
- Nine At Risk species.

A comprehensive onsite survey of avifauna values was not undertaken as part of this assessment. The desktop assessment identifies all species likely to occur onsite.

Incidental observations onsite during the RMA Ecology botanical survey, and the original effects assessment survey[3] include:

- banded dotterel detected feeding and nesting onsite;
- black fronted tern detected occasionally flying over site, and likely feeding;
- South Island Pied Oystercatcher detected onsite; and
- New Zealand pipit detected feeding onsite, and likely nesting.

[3] AgScience Ltd 2025. Haldon solar project ecological impact assessment. AgScience Ltd, Dunedin.

Table 1. At Risk and Threatened avifauna species detected in the vicinity, their relative use of the site and behaviour.

Species	Threat status	Ecological value	Feeding onsite	Breeding onsite	Predicted Frequency of flyover	Water use behaviour
Kōtuku / white heron	Nationally Critical	Very High	No	No	Moderate	Wet margin feeding and landing
Australasian bittern	Nationally Critical	Very High	No	No	Low-moderate	Wet margin feeding and landing
Kakī / black stilt	Nationally Critical	Very High	Unlikely	No	Moderate	Wet margin feeding and landing
Black-fronted tern	Nationally Endangered	Very High	Recorded	Unlikely	Moderate	Water-diving for feeding - frequent
Grey duck / pārera	Nationally Vulnerable	Very High	No	No	Low-moderate	Water obligate (Water-landing)
Kārearea / NZ falcon	Nationally Vulnerable	Very High	Likely	No	Moderate	Terrestrial - no water landing
Caspian tern	Nationally Vulnerable	Very High	No	No	Low-Moderate	Water-diving for feeding - frequent
Australasian crested grebe	Nationally Vulnerable	Very High	No	No	Moderate-High	Water obligate (Water-landing)
Wrybill	Nationally Increasing	High	No	No	Moderate	Wet margin feeding and landing
NZ pipit	Declining	High	Recorded	Very likely	High	Terrestrial - no water landing
Banded dotterel	Declining	High	Recorded	Recorded	Moderate-High	Wet margin feeding - not usually water landing
South Island pied oystercatcher	Declining	High	Recorded	Possible	Moderate	Wet margin feeding and landing
Black-billed gull	Declining	High	Possible	Unlikely	Moderate	Water-diving for feeding - occasional
Marsh crake	Declining	High	No	No	Low-moderate	Wetland - no water landing
Spotless crake	Declining	High	No	No	Low-moderate	Wetland - no water landing
Black shag	Relict	Moderate-High	No	No	Moderate–High	Water obligate (Water-landing)
Little shag	Relict	Moderate-High	No	No	Moderate–High	Water obligate (Water-landing)
Australian coot	Naturally uncommon	Moderate-High	No	No	Moderate–High	Water obligate (Water-landing)

1.3 Avifauna habitats

The site is dominated by degraded, low-stature grassland and herbfield on **alluvial outwash plains**, which provide feeding and breeding habitat for New Zealand pipit and banded dotterel (**Plate 2**). South Island pied oystercatcher and black-fronted tern occasionally forage within the site and may breed intermittently; however, their preferred habitat is the braided riverbed environment. Black-billed gulls and New Zealand falcon could forage within the site on occasion.

The Mackenzie Basin contains some of the most intact **braided river** systems in New Zealand. The Pukaki River, a braided river system adjacent to the site, forms a delta at Lake Benmore in close proximity to the site boundary (**Figure 1**). The riverbed within 200 m of the site is stable and degraded by willow and other invasive species, limiting its suitability for avifauna feeding and breeding near the site. The open central part of the delta, located 800 m from the site boundary,does support an important overnight roost for shorebirds. To the west, the Ohau River provides key breeding and foraging habitat for black stilt, black-fronted tern, and other braided river specialists, and also forms a delta at Lake Benmore. The combined Tekapo/Pukaki/Ohau Rivers and deltas are defined by Environment Canterbury as a braided river biodiversity regional strategic area[4], and are considered to be internationally significant[5].

The site extends to within approximately 200–300 m of the Lake Benmore shoreline, which provides **aquatic** habitat for waterfowl, with several willow-dominated ‘fingers’ of the lake extending to within 150 m of the southern site boundary at high water levels. The lake margins and delta also offer suitable habitat for a range of wetland bird species. However, willow planting and invasion have reduced habitat quality for wetland and riverine species that prefer more open habitats, such as Australasian bittern and black stilt. The lake is visually separated from the site by a margin of willow and poplar trees.

A network of **wetlands** occurs across the wider Mackenzie Basin (**Figure 4**), although few are present within 5 km of the site. The nearest are several swamp and marsh wetlands along the lower Ohau River, located approximately 2.8–5 km west of the site.

Improved grassland with centre-pivot irrigation adjoins the northeastern boundary of the site (**Figure 1**), providing lower-quality grassland foraging habitat for species such as black stilt, black-billed gull, black-fronted tern, and common pasture-associated birds including pied stilt, paradise shelduck, and southern black-backed gull. Additional centre pivot irrigation is located to the southeast of the site.

In summary, the wider area includes very high value avifauna habitats, including braided riverbeds, lake, delta and wetland. The site itself lies within close to moderate proximity of these habitats, but itself has relatively limited habitat value for avifauna.

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4 https://experience.arcgis.com/experience/a224a21ec0a748c3835e47360ad5c094#data_s=id%3A760b9662df4e462b9c674753c2cf3f70-195685ac765-layer-11-19568e4aa1f-layer-12%3A14

5 O’Donnell, C.F.J. 2000. The significance of river and open water habitats for birds in Canterbury, New Zealand. Environment Canterbury Unpublished Report U00/37.

Plate 2. Alluvial outwash plain onsite, with sparse grassland and herbfield, including areas of bare ground and stonefields.

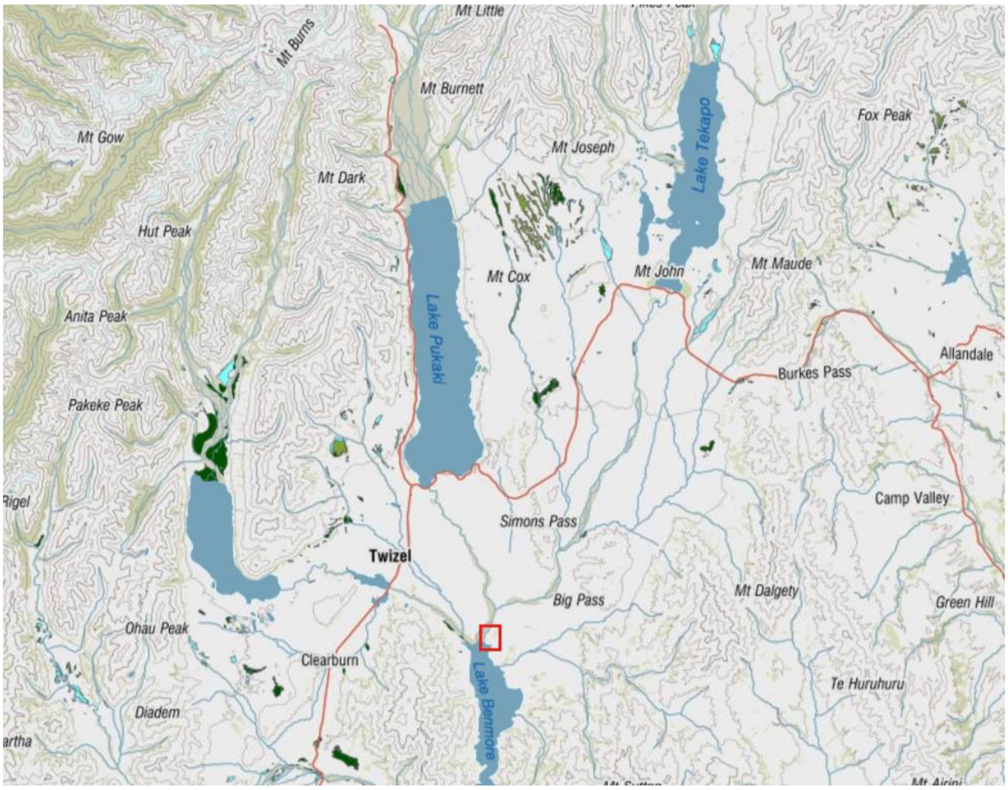

Figure 4. Wetlands (dark green, cyan and mid green polygons), waterbodies (blue polygons) and main waterways (blue lines) within the Mackenzie Basin. The approximate location of the site is indicated by the red box. Note, light green polygons indicate forest and scrub, not wetland. Source: Scinfo[6]

[6] https://ourenvironment.scinfo.org.nz/maps-and-tools/app/Wetlands/wetlands_current

1.4 Flight paths

Sites located within key low-altitude avian flyways have potential elevated risk of bird strike. These flyways often link habitat features, such as rivers, lakes or wetlands. However, movement patterns are typically more strongly aligned with linear landscape elements such as rivers, lake margins, and valleys, which provide navigational cues and energetically efficient travel routes. Habitat type primarily determines where birds forage, roost, or breed, whereas movement between these areas often follows broader landscape structures. Accordingly, the likelihood of bird strike is related to the intersection of infrastructure with established movement corridors as well as habitat presence. Lake Benmore, located in a valley, is likely to be used as a flight path by waterfowl and shorebirds. Most daily movements of braided river birds are likely to align more closely with the braided rivers.

Flight path data from tracking studies presented in the Department of Conservation (DOC) submission on this project confirms that key flyways for threatened braided river bird species such as black-fronted terns and black stilts align with the main braided rivers – the Ohau and the Tekapo. Interpolation of points from tracking data indicates a comparatively low number of black-fronted tern and black stilt flights are likely to extend over the outwash plain that constitutes the site[7].

The site lies adjacent to river and lake features, and approximately 2.5 km from suitable wetland habitat. However, no large or high quality wetland, braided river or lake habitat exists to the east of the site. Hence, flight paths are likely to extend from north to south along the lake, or from west to the Tekapo River delta, skimming the edge of the site, rather than traversing directly over the site. This is supported by the tracking data provided in the DOC submission.

The offset of the solar development from the margin of Lake Benmore and the Tekapo River is expected to minimise strike risk, but overflights or attraction to panels from this distance cannot be ruled out. Most species, including black stilt and bittern, use a network of habitat incorporating lower value or smaller habitat areas (such as the centre pivot irrigation area north of the site where black stilt have been recorded).

Without detailed GPS-tracking data for local populations, the precise intersection between avian flyways and the solar array remains a predicted risk rather than a quantified certainty. Therefore, exposure and strike risk cannot be entirely ruled out for Threatened and At Risk species recorded in the vicinity.

3 Assessment of ecological effects

The level of adverse effects on ecological values can be assessed by considering the value of the species or ecosystem being affected, and the magnitude of its loss at the local (catchment or Ecological District) level.

The tool widely used to assess significance of effects is the matrix approach as described by the Environment Institute of Australia and New Zealand (EIANZ). The EIANZ matrix approach, and the guidelines within which it is included, has been developed as a guide for ecologists undertaking effects assessments under the RMA[8]. The EIANZ guidelines and the impact assessment matrix in

[7] O'Donnell. 2025. Proposed solar farm – Haldon Solar Project, Risks to Threatened and At-Risk bird species from construction and ongoing operation. FTAA review, Department of Conservation.

[8] Roper-Lindsay, J., Fuller S.A., Hooson, S., Sanders, M.D., Ussher, G.T. 2018. Ecological impact assessment. EIANZ guidelines for use in New Zealand: terrestrial and freshwater ecosystems. 2nd edition.

particular, provides a robust, concise and consistent approach to effects assessment, whilst ensuring that individual expert evaluation and opinion is preserved[9].

The three key inputs into an assessment of the level of ecological effect are provided by:

- An assessment of the values of the communities, habitats, ecosystems, and species (Tables 5 and 6 of the guidelines);
- An assessment of the magnitude of the effects on these values (based on criteria listed in Table 8 of the guidelines; measured in the context of the catchment (streams) or District (terrestrial values)); and
- The application of a matrix (Table 10 of the guidelines) which determines the level of effect based on the ecological value of the site or species assessed and the magnitude of effect.

The level of effect resulting from the matrix analysis can range from 'net-gain' (benefit) through to 'very high' (adverse effect).

Level of effect can then be used as a guide to the extent and nature of the ecological management response required, as outlined in the EIANZ Guidance as follows:

- Project effects in the 'Very High adverse' category are unlikely to be acceptable on ecological grounds alone (even with offset or compensation proposals). Activities having very high adverse effects should be avoided. Where very high adverse effects cannot be avoided (and where policy allows), ecological offsetting or compensation that deliver a net biodiversity gain would be appropriate.
- Project effects in the 'High and Moderate adverse' category represent a level of effect that should be managed through avoidance, design, or offset or compensation actions. Wherever adverse effects cannot be avoided, no net loss of biodiversity values would be appropriate.
- Project effects in the 'Low and Very Low' categories should not normally be of ecological concern, although normal design, construction and operational care should be exercised to minimise adverse effects. If effects are assessed taking impact management developed during project shaping into consideration, then it is essential that prescribed impact management is carried out to ensure Low or Very Low-level effects.
- Project effects in the 'Very Low' category can generally be considered to be classed as 'not more than minor' effects.

3.1 Collision with PV panels

3.1.1 The Lake Effect Hypothesis

Solar photovoltaic (PV) arrays have been hypothesised to pose a collision risk to birds via a "lake effect hypothesis" (LEH), whereby horizontally polarised light reflected from panel surfaces may be misinterpreted as water (Horváth et al. 2009; Kagan et al. 2014). Observational evidence indicates that some birds alter flight behaviour in the vicinity of solar facilities, including recorded descent movements (Walston et al. 2016; CEC 2024).

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[9] The guidelines have been updated since they were originally released in 2015. We have applied the 2nd Edition version (released in May 2018) which provides updates to parts of the values, magnitude, and level of effect analysis.

Patterns of bird occurrence and mortality at solar installations in the USA suggest that aquatic and water-associated species (including waterfowl, grebes, gulls and terns) are more frequently represented than other groups, which is consistent with, but does not conclusively demonstrate, attraction to water-like visual cues. Shorebirds and other water-edge species (e.g. stilts, plovers, oystercatchers, and herons) have also been recorded interacting with solar facilities; however, evidence of a consistent behavioural response in these groups is limited, and interactions are likely to be variable and context-dependent.

The strength and consistency of this mechanism remain uncertain, and outcomes are likely to be influenced by site-specific factors including landscape context, proximity to natural water bodies, species composition, PV facility design features and layout.

A literature review of the LEH is provided in the Proteus report[10]. Key points include:

- The impact of solar facilities on bird communities remains relatively understudied compared to other methods of renewable energy generation.

- Empirical support for LEH is limited, with few experimental studies focused on the topic. Overall, the evaluation of LEH is restricted by geographical biases in research, inconsistent monitoring and reporting, over-reliance on key datasets from facilities that may be unrepresentative of modern installation technologies (i.e.. solar concentrator facilities, fixed-tilt panels, panels without anti-reflective coatings), and a lack of direct testing.

- Collectively, the evidence suggests that impacts of solar facilities on avian communities are highly context-dependent, influenced by an interplay of geographic, taxonomic, ecological, and structural factors. Consequently, caution should be exercised when extrapolating findings to novel development contexts in New Zealand.

- Existing evidence suggests that solar facilities are linked to highly variable mortality rates and ecological responses that depend strongly on local context. The high levels of variability in estimated avian mortality rates among solar facilities have been linked to differences in local species assemblages, habitat characteristics, and facility design. Elevated strike risk is more likely to be associated with a combination of these factors, i.e. sites exhibiting high-risk context, with the presence of susceptible guilds or species exhibiting attraction to water, and diving or fast-landing behaviour, and non-ARC fixed-tilt panels.

- Reports of sub-lethal and indirect effects of solar facilities on avian populations are rare; however, they are becoming more frequent.

Several recent (2025-2026) overseas studies indicate that modern utility-scale PV arrays have a zero or low level of avifauna collision mortality.

A 2025 two-year study of six photovoltaic (PV) solar farms in Poland found no recorded bird mortality associated with PV infrastructure, despite surveys covering both the sites and surrounding areas (up to 1 km buffers) and documenting the presence of bird communities, including during peak migration periods. While lower-risk species were more abundant near panels, no carcasses attributable to collision with PV arrays were detected, indicating a very low level of impact.

The authors note that collision risk may increase where PV is combined with other infrastructure (e.g. wind turbines), but conclude that standalone PV developments are associated with minimal

[10] Hamlin, T.J., Jones, T.T., MacKenzie, D.I. (2026). Statistical advice for a solar power installation at Haldon Station, Canterbury, New Zealand.. Report for Lodestone Energy, Proteus Client Report: 219. Proteus, Outram, New Zealand.

avian mortality, subject to typical limitations of carcass detection and scavenger removal (Journal of Water and Land Development, 2025).

Other more recent studies have detected no bird mortalities – for example, 515 bird surveys of solar farm sites at various airports in the United States[11], and a recently published study by Argonne National Laboratory which utilises cameras and AI technology coupled with ground-based fatality monitoring[12]. Analysis of 19,000 hours of video found no diurnal avian collisions, but did record over 68,000 instances of birds using the arrays for feeding, perching, and nesting.

As a New Zealand example observed by the author, a floating solar array within a large reservoir at the Rosedale Wastewater Treatment Plant in Auckland is used regularly as a roost by little shag, black shag, black-backed gulls, mallards, Canada geese, and New Zealand scaup. A regionally important population of 26 New Zealand dabchick (a grebe species) is also present. While these observations do not represent formal strike mortality monitoring, and may not directly translate to the Haldon context, they indicate that water-associated bird species are able to recognise PV arrays as solid structures, utilise them, and persist within a high-use waterbody and flight environment. This is notable given that these same guilds (ducks, geese, grebes, shags, and gulls) are identified in international literature as among those with relatively higher susceptibility to PV collision, primarily due to the lake-effect mechanism.

A 2025 review[13] concluded that data to support the lake effect hypothesis is sparse when data from fixed-tilt panel facilities developed prior to the commercial transition to anti-reflective coating (ARC) are separated from data from modern tracker panel facilities with ARC. Therefore, avian mortality trends associated with older solar facilities or pooled data should not be used to infer mortality at modern utility-scale solar installations because the effect of technology is obscured.

Key points include:

- **The "Ivanpah" Distortion:** Mortality data often conflates Concentrating Solar Power (CSP)—which causes thermal "solar flux" (burns)—with Photovoltaic (PV) arrays. Haldon solar uses PV, which has zero thermal risk.
- **Technology Lag:** 14 of 16 major "Lake Effect" papers cite a single 2014 dataset from a facility without Anti-Reflective Coating (ARC). Modern ARC and Single-Axis Trackers appear to disrupt the polarized light cues that previously attracted waterbirds.
- **Aquatic bird risk**: The proportion of aquatic birds (water obligate and water associated) in mortality data was lower for tracker panels than fixed panels[14] (11.2 % of mortalities were aquatic birds for tracker panels vs 40.8 % aquatic for fixed panels in Smallwood 2022, and

[11] DeVault, T. L., Seamans, T. W., Schmidt, J. A., Belant, J. L., Blackwell, B. F., Mooers, N., Tyson, L. A., & Van Pelt, L. (2014). Bird use of solar photovoltaic installations at US airports: Implications for aviation safety. Landscape and Urban Planning, 122, 122–128.

[12] Hamada Y, Szymanski AZ, Tarpey PE, Waltson LJ. Feb 2026. Artificial intelligence-assisted daytime video monitoring for bird, insect and other wildlife interactions with photovoltaic energy facilities. Diversity 2026: 18, 95. 30 pp.

[13] Karl Kosciuch, Daniel Riser-Espinoza and Marisa Mitchell (2025) . Lake effect or data mirage? How accounting for technology differences at utility scale solar energy facilities can change data interpretation. Environmental Research Letters, Volume 20, Number 12.

[14] Karl Kosciuch, Daniel Riser-Espinoza and Marisa Mitchell (2025) . Lake effect or data mirage? How accounting for technology differences at utility scale solar energy facilities can change data interpretation. Environmental Research Letters, Volume 20, Number 12.

4.1 % aquatic birds for tracker panels vs. 27% aquatic birds for fixed panels in Kosciuch et al. 2020).

- **Detection Bias (Carcass Monitoring):** Traditional studies rely on carcass counts, where 50-70 % of deaths have an "Unknown" cause. These can include background natural mortality (dehydration, predation) unrelated to the solar panels.

There is a growing body of evidence indicating that solar facilities incorporating single-axis tracking systems and anti-reflective coatings present a lower collision risk profile than earlier fixed-panel technologies associated with high reflectivity and cited in early “lake effect” literature.

However, it is important to acknowledge that the global peer-reviewed literature specifically assessing modern ARC-coated, tracking systems remains relatively limited compared to historical datasets derived from fixed, untreated panel configurations. While available evidence strongly suggests that tracking systems and low-reflectance modules reduce or eliminate the polarised light cues associated with mistaken landings, the smaller number of studies focused on these technologies warrants a degree of scientific caution.

Mitigating factors incorporated in the Haldon Solar base design (compared to infrastructure design in commonly cited literature on avifauna strike mortality) include:

- **Photovoltaic panels,** rather than a solar concentrator design. The latter is associated with significant mortality due to radiative flux and singeing of birds flying within the flux path.
- **Single-Axis Tracking (SAT) panel design,** which in several recent studies were associated with zero to low strike mortality, compared to higher variable mortality in older fixed tilt panels (noting other factors may play a part). Lower observed avifauna collision risk at single-axis tracking photovoltaic systems appears to be primarily attributable to reduced horizontal polarisation of reflected light due to panels rarely being horizontally orientated, with additional contribution from increased row spacing that improves visual permeability and reduces the appearance of a continuous reflective surface.

3.1.2 Management of uncertainty

There is currently no empirical dataset describing PV panel avifauna collision mortality at photovoltaic solar farms in New Zealand. International studies are limited in number and are predominantly based on older solar technologies, including concentrated solar power facilities and fixed-tilt panels without anti-reflective coatings. These systems are not directly comparable to the proposed development. Available data on flight paths is also limited. Accordingly, uncertainty remains high.

Uncertainty is addressed in this assessment through:

- Explicit acknowledgement of data limitations;
- Qualitative evaluation of effects linked to risk pathways in the context of modern solar technology, rather than extrapolating mortality rates from older technologies;
- Implementation of a robust monitoring framework designed to detect low-frequency events; and
- Adaptive management linked to clearly defined triggers.

This represents a structured and transparent approach to dealing with uncertainty, consistent with best practice in ecological assessment.

3.1.3 Species specific strike risk assessment

Given the limited availability of species-specific collision data for photovoltaic solar facilities, particularly in New Zealand contexts, a qualitative exposure-based assessment of avifauna strike risk was adopted.

The risk of avifauna strike mortality for PV panels for Threatened and At Risk species was determined using assessment of:

- species detected in the vicinity (**Table 1**).
- likelihood of site use, including:
    - recorded detections onsite (noting data limitations)
    - onsite and nearby habitat
    - known or likely flight paths
- behavioural traits influencing PV collision susceptibility
    - Water landing
    - Water diving
    - Low altitude flight
- international evidence on relative mortality of comparable species or guilds
- limitations of these studies;
- solar array design
- consideration of recent publications assessing bird mortality at modern PV installations utilising solar tracker and anti-reflective coating technologies.

The assessed level of potential effect from solar panel collision prior to mitigation ranged from low to high, with an overall moderate level of effect (**Table 2**).

Species with higher potential photovoltaic collision risk are those that combine low-altitude flight and with frequent movement across or adjacent to the site and behavioural association with water-like visual cues, and high-speed water landings or diving.

Obligate waterfowl including grey duck and Australian crested grebe had the highest level of potential effect, with a potential moderate level of effect water-associated braided river birds and wetland birds.

Terrestrial species such as eastern New Zealand falcon are deemed to have a low strike risk and lower level of effect as there is no plausible mechanism of mortality under the lake effect, and they are distributed throughout the eastern south island.

Further detail on effects assessment of key species is presented below.

Table 2. Species-specific effects assessment for Threatened and At Risk avifauna detected in the vicinity of the site, prior to mitigation.

Species	National threat status	Ecological value	Feeding onsite	Breeding onsite	Estimated flyover exposure	Habitat	Water use	Regional population estimate	Predicted strike risk from LEH	Magnitude of effect	Level of effect
White heron	Nationally Critical	Very High	No	No	Low	Open water, Wetland, Coastal	Wet margin feeding and landing	low 10's	Low	Low	Moderate
Australasian bittern	Nationally Critical	Very High	No	No	Low-moderate	Wetland	Wet margin feeding and landing	30 - 50	Low	Low	Moderate
Black stilt / Kakī	Nationally Critical	Very High	Unlikely	No	Moderate	Braided river, Coastal	Wet margin feeding and landing	Up to 169 (national stronghold)	Low	Low	Moderate
Black-fronted tern	Nationally Endangered	Very High	Recorded	Unlikely	Moderate	Braided river, coastal	Water-diving for feeding	100's - low 1000's (national stronghold)	Low-moderate	Low	Moderate
Grey duck	Nationally Vulnerable	Very High	No	No	Low-moderate	Open water, Wetland	Water obligate (Water-landing)	Unknown, low for non-hybrids	Moderate	Low-moderate	Moderate-High
NZ falcon (eastern)	Nationally Vulnerable	Very High	Likely	No	Moderate	Terrestrial	Terrestrial - no water landing	100's	Low	Negligible	Low
Caspian tern	Nationally Vulnerable	Very High	No	No	Low-Moderate	Braided river, Coastal	Water-diving for feeding - frequent	low 100's	Low-Moderate	Low	Moderate
Australasian crested grebe	Nationally Vulnerable	Very High	No	No	Moderate	Open water	Water obligate (Water-landing)	low 100's (national stronghold)	Moderate-High	Moderate	High
Wrybill	Nationally Increasing	High	No	No	Low-moderate	Braided river, Coastal	Wet margin feeding and landing	1000's (national stronghold)	Low-Moderate	Low	Low
NZ pipit	Declining	High	Recorded	Very likely	High	Terrestrial	Terrestrial - no water landing	1000's	Low	Negligible	Low
Banded dotterel	Declining	High	Recorded	Recorded	Moderate-High	Braided river, (Open	Wet margin feeding - not usually water landing	100's -1000's	Moderate	Negligible-Low	Low

						terrestrial), Coastal					
South Island pied oystercatcher	Declining	High	Recorded	Possible	Moderate	Braided river, (Open terrestrial), Coastal	Wet margin feeding and landing	1000's-10,000's (national stronghold)	Low-Moderate	Negligible-Low	Low
Black-billed gull	Declining	High	Possible	Unlikely	Low-moderate	Braided river, (Open terrestrial), Coastal	Water-diving for feeding - occasional	1000's-10,000's (national stronghold)	Moderate	Low	Low
Marsh crake	Declining	High	No	No	Low-moderate	Wetland	Wetland - no water landing	unknown, likely <100	Moderate	Low-moderate	Moderate
Spotless crake	Declining	High	No	No	Low	Wetland	Wetland - no water landing	10's - low 100's	Moderate	Low-moderate	Moderate
Black shag	Relict	Moderate-High	No	No	Moderate	Open water, Braided River, Coastal	Water obligate (Water-landing)	100's	Moderate–High	Low-moderate	Low
Little shag	Relict	Moderate-High	No	No	Moderate	Open water, Coastal	Water obligate (Water-landing)	100's	Moderate–High	Moderate	Moderate
Australian coot	Naturally uncommon	Moderate-High	No	No	Moderate	Open water	Water obligate (Water-landing)	100's-1000's	Moderate–High	Low-moderate	Low-moderate

3.1.4 Black stilt

The black stilt is a riverine specialist associated with braided river systems, with movements mainly occurring along river corridors and adjacent wetland habitats, as supported by DOC location tracking data. The solar site lacks suitable habitat for feeding or breeding, and tracking data suggests use is limited to infrequent flyover to feed at the irrigated area to the north.

The species is not strongly associated with large areas of open standing water in the same way as water-obligate birds, and does not land on water at speed, reducing its risk of injury if confusing solar panels with a water body.

Given its ecology, the risk of lake-effect-driven attraction to PV panels is considered low prior to mitigation. However, due to the species' critically endangered status and low population size, any potential effects are of higher consequence, resulting in a moderate level of effect prior to mitigation. After mitigation, the magnitude of effect is rated negligible-low and the level of effect low-moderate.

3.1.5 Australasian bittern

The Australasian bittern is a wetland-dependent, cryptic species that undertakes primarily short-distance movements, often at dawn, dusk, or at night, typically at low altitude. While the species is associated with aquatic habitats, it is not a water-obligate flier and does not require open water for landing in the same way as species such as grebes. It generally lands in wetland areas with vegetative cover, and does not land at speed. On this basis, the likelihood of attraction and fatality via a lake effect mechanism is considered low.

Bittern mortality rates at solar farms recorded in Smallwood (2022)[15], as referenced in reviews, relate to three instances of bittern mortality over approximately 26 years of PV facilities in the USA totalling 9000 ha, with different species, landscape context and no confirmed panel collisions. Fatalities included one juvenile lesser bittern with an unknown cause of death, and two other bittern fatalities attributed to transmission line collision.

Numerous bittern records are located within 5-10 km of the site, on the wetlands associated with the Tekapo and Ohau river beds and deltas east of the site. No bittern records occur onsite or within 800 m of the boundary, where suitable habitat is constrained and disturbance from the camp ground and boat ramp may deter bittern. The possibility of bittern flying over or near the PV array remains, but the risk of panel strike is considered low, due to behavioural traits and habitat preferences not strongly aligned with panel attraction, limited exposure onsite, and lack of confirmed PV strike fatalities in the literature.

As the species is critically endangered in New Zealand, with an estimated regional population of 30-50 birds, even a single fatality is likely to be significant, resulting in a moderate level of effect, reduced to low-moderate after mitigation. A monitoring and an adaptive management pathway are proposed to manage uncertainty and potential effects.

3.1.6 Black-fronted tern

The black-fronted tern is a highly aerial, riverine species that forages primarily over braided rivers water but does not require open water for landing. The species is capable of wide-ranging movements and is known to forage over pasture and outwash plain, including over the site. However, the vast majority of interpolated flight paths recorded by DOC track over the braided riverbeds to the east where major breeding and roosting colonies are located. The wider area is of very high importance and use, but the Haldon solar site itself is considered peripheral, with comparatively low-moderate use.

[15] Smallwood KS 2022. Utility-scale solar impacts to volant wildlife. The Journal of Wildlife Management 86: e22216.

Terns have been recorded in PV array fatalities overseas, but application of mortality rates to different species and contexts is advised against due to high variability. The potential magnitude of effect is considered to be low prior to mitigation, as the regional population likely numbers in the low thousands. This results in a moderate level of effect due to the species' endangered status. After mitigation, a precautionary assessment results in a low-moderate level of residual effect.

Loss of foraging habitat is likely to occur, but outwash plain is not core feeding habitat for black-fronted terns, and the proportion of outwash plain in the vicinity affected is low. It is possible that black-fronted terns may continue to forage at the site after PV installation, potentially attracted to insects associated with solar panels.

3.2 Injury and mortality from collision with associated infrastructure

Based on our understanding of associated infrastructure, level of effect from collision with the perimeter fence, transmission tower, substation, and new transmission lines is low to moderate prior to mitigation, and low after mitigation.

Electrical transmission lines present an avian mortality risk through bird strike and electrocution, which is well-established in research literature. This effect is better understood and generally considered a significantly higher source of avian mortality than PV panel collision. Most of the Threatened and At Risk bird species recorded in the vicinity belong to avian groups with elevated susceptibility to collision with power lines, due to a range of morphology and behavioural factors[16] (**Figure 5**). However, new power line strike effects onsite prior to mitigation are considered low-moderate in magnitude due to:

- the short length of new lines proposed (2 sets of 37 m), and their proximity to more visible structures (tower and substation) results in a low level of exposure;
- the location of these lines at least 700 m away from the lake and Pukaki River, and associated known flyways; and
- the proximity of these lines to the substation and transmission tower, more visible features which birds are likely to avoid.

Electrical transmission tower and substation strike risk is considered low, due to the high visibility of these features.

[16] Energy & Nature. 2024. Avian-Power Line Collision Overview of Risk Factors & Effectiveness of Wire Markers. Methodology Report. 91 pp.

Bird groups with higher susceptibility to collision with power lines	Avian morphology factors		Avian behaviour factors				
	Wing size, weight, speed & manoeuvrability	Vision	Flocking / gregarious	Long distance migration	Nocturnal birds & night migration	Foraging / roosting trips	Aerial hunters
Pelicans, herons, egrets, bitterns, ibis, spoonbills	✗	✗	✗	✗	✗	✗	
Cranes, rails, gallinules	✗	✗	✗	✗	✗	✗	
Waterfowl (e.g. ducks, geese, swans)	✗	✗	✗	✗	✗	✗	
Waders, gulls, and storks	✗	✗	✗	✗	✗		
Bustards	✗	✗	✗	✗		✗	
Divers, grebes, and cormorants	✗	✗	✗	✗			
Eagles, hawks, harriers, vultures, and falcons	✗	✗		✗		✗	✗
Owls		✗		✗	✗		
Landfowl (e.g. grouse, pheasants)	✗	✗		✗	✗		
Passerines (incl. corvids)	✗		✗	✗	✗		

Figure 5. Bird groups susceptible to power line collision, and morphological and behavioural factors contributing to susceptibility [17]

Perimeter fence strike risk is a relatively minor component of fatalities recorded at solar farms in the USA, with one meta-analysis concluding an average of 5 % of all solar farm fatalities were detected along fences. At Haldon, this risk is mitigated by the 150 - 200 m setback from river and lake features, and visual and physical separation from these features by a line of willow and poplar trees along the lakeshore. These trees are likely to force transiting birds to fly at altitudes exceeding 10 m, which would place them well above fence height. The PV panels immediately behind the fence are likely to force flight heights over 2 m, also exceeding fence height. Species most at risk of perimeter fence strike are those utilising the habitat within and adjacent to the PV array, due to exposure (time on site and low flight heights).

Species which may potentially continue to use the site as habitat include New Zealand pipit, black-fronted tern and New Zealand Falcon. However, these species all have a higher degree of agility, which is linked to lower collision risk.

Construction of a perimeter fence around the 180 ha offset site is expected to contribute a negligible level of effect on avifauna mortality, as it will replace an existing stock fenceline (of lower height but with lower visibility) along the majority of the perimeter, and will run along the base of a terrace along the remainder of its length. It will incorporate the same design mitigations as the site perimeter fence.

Tracks within the solar farm will result in no increased risk of collision, as no fill material or vertical structures are involved in track construction.

Electrocution primarily affects perching birds that bridge energized and grounded components of structures, and is not typically associated with birds in flight hitting power lines. Exposure to this risk is highest for birds which perch on elevated open structures and utilise the local habitat onsite, such

[17] Energy & Nature. 2024. Avian-Power Line Collision Overview of Risk Factors & Effectiveness of Wire Markers. Methodology Report. 91 pp.

as NZ falcon and NZ pipit. White heron may conceivably perch on panels or substation or tower, but this is unlikely due to their relative scarcity in the vicinity, and propensity to roost in close proximity to waterways and wetlands. NZ falcon are particularly susceptible to electrocution from uninsulated and unscreened live electrical components on pylons, substations, transformers and lines which are close together and susceptible to shorting by birds. One study in Marlborough reported 47 % mortality through electrocution[18].

NZ pipit may continue to utilise the site, and primarily perch on fence posts and other low structures, including potentially PV arrays.

No other Threatened or At Risk species are predicted to be at risk of electrocution.

The overall level of effect from electrocution is moderate prior to mitigation, and Low-moderate after mitigation, due to potential effects on falcon.

3.3 Habitat Loss

Habitat use is summarised in **Table 2**, based on known species habitat requirements and preferences, and observations at the site. The installation of solar panels is expected to effectively remove approximately 320 ha, (plus a 50 m buffer) of available habitat for many bird species breeding and feeding onsite, as they require open areas with clear visibility.

Nesting and feeding habitat is likely to be lost within the array footprint and a 50 m buffer of the panels for banded dotterel and SIPO, as these species require open areas with unobstructed lines of site. Feeding habitat for black-fronted tern and feeding and breeding habitat for pipit will be impacted within the array footprint.

However, the site is not expected to be entirely unsuitable. Some species, such as black-fronted tern, New Zealand pipit, and New Zealand Falcon, may continue to use part or all of the site for feeding, and New Zealand pipit may potentially still be able to breed where suitable conditions remain, aided by predator exclusion provided by the perimeter fencing.

4 Management of effects

4.1 Avoidance

The potential effects on avifauna could be minimised by constructing and operating the solar farm on the similarly sized and adjacent pivot-irrigated pasture, which is located further from habitats and known and likely flight paths of Threatened and At Risk avifauna species.

We understand that this has been considered but the area is not available for lease from the landowner.

4.2 Mitigation

Mitigations to potential effects are listed below, as agreed to by the applicant. Potential mitigations which are being investigated by the applicant, but have not been confirmed at this stage are denoted by an asterisk.

4.2.1 Mitigations for potential avifauna injury and mortality due to collision with PV panels:

- **Anti-Reflective Coatings:** PV panels will utilise high-quality ARC to reduce the polarized light signature.

18 18

- **PV row spacing**; of 3.4 m when horizontal, resulting in vegetated strips which break up the visual reflectance and appearance of a single large water body. Row spacing increases further with greater panel angle.
- **Contrasting panel outlines** (e.g. white or silver) are expected to reduce the visual continuity of panel arrays, thereby diminishing their resemblance to a continuous reflective surface.
- **Vegetation Buffers:** A buffer generally extending 200-250 m between the solar array and Lake Benmore is proposed to "break up" the visual horizon of the solar array, creating physical and visual separation from the lake.
- **Tracking panels** will follow the sun, facing east at a 60 degree angle at sunrise, and gradually angling to horizontal for a short period in the middle of the day, then tracking to the west to end at 60 degrees at sunset. The fact that panels will be at an angle over most of the day (and overnight) is expected to further minimize the likelihood that birds will perceive the panel surfaces as water;
- **Stowing of PV panels at from dusk to dawn.** Panels will be stowed at an angle of 60 degrees from prior to dusk to after dawn, to minimise their horizontally polarised light signature. This will automatically occur, as the panels follow the sun.
- **No night lighting** installed (as it can attract birds), or potentially ground-level motion-activated security lighting at the substation or inverter stations only.

4.2.2 Mitigations for potential avifauna mortality associated with electrocution from associated infrastructure:

'Bird-safe' electrical components associated with solar panels and transformers, will result in a negligible magnitude of electrocution mortality. Proposed mitigations include undergrounding and insulation, and/or exclusion netting. The substation and connecting transmission lines are not able to be made completely bird-safe, but the potential level of effect on falcon is low, due to the limited extent of this infrastructure.

4.2.3 Mitigations for potential avifauna mortality associated with strike risk from associated infrastructure:

- **Perimeter fence visibility enhancements. Fence** visibility enhancements have proven efficacy in reducing bird strike by up to 80 %. Measures include:
    1. **No top wire.** Top wires are low visibility and a significant strike risk.
    2. **Fine mesh** to improve fence visibility by creating a perception of a solid barrier which birds will avoid rather than attempt to fly through.
    3. **Solid top roller cap** will improve visibility and aid avoidance**.**
    4. **Low height perimeter fencing (under 2 m for the solar farm,** – under 1.5 m for the offset area) to reduce the collision risks associated with taller fences.
    5. **Strike deterrents on the perimeter fence:** Options include flappers, flags, coils, tags, or high-contrast clips. Bright or contrasting colours and movement both improve visibility, to reduce strike risk.
- **Strike deterrents on transmission connection lines:** wire markers (such as spheres, spirals, flappers or coils) installed on proposed transmission connection lines at 5-10 m intervals, are

highly effective[19] [20]. Choice of marker and design principles will take account the bird-specific factors determining sensitivity (due to their behaviour, morphology and sensory ecology), as well as the environmental factors (such as weather and light conditions) and site-specific factors (topography, habitat)[21].

4.2.4 Mitigations for avifauna habitat loss:

- Control of mammalian predators including rats, mustelids, hedgehogs and cats within the adjacent 180 ha offset enhancement site are expected to result in marked increases in the breeding success of banded dotterel, New Zealand pipit (and potentially SIPO) within this area, resulting in population increases. Pest control on the 330 ha solar farm site is also expected to result in enhanced adult/nest survival of birds feeding or breeding within the solar farm, including NZ pipit. Species potentially feeding within the solar farm, such as NZ falcon and black-fronted tern, may see reduction in adult mortality, although avian predators are more susceptible when on the nest.

- Mammalian predation is the greatest cause of mortality for these species.

4.2.5 Mitigations for injury or mortality of avifauna nests during construction:

- Pre-works survey of the site to check for nesting native birds. Setbacks of at least 100 m from nesting birds if discovered, and no works within that area until nestlings have fledged or the nest has failed;

4.2.6 Potential mitigations suggested in reviews, which are not able to be implemented for this project:

- **Angling individual panel sets to different angles** to break the polarised light visual cue from above. The applicant has stated this is not technically or economically feasible. The structures adjust the angle of the solar panels throughout the day to ensure they are always facing the sun. . There are technical constraints with regards to setting one row at a different angle to the next.

- **Stowing panels at 90 degrees at sunset, sunrise and night.** The applicant advises the design of the tracker does not mechanically allow for vertical stowing, 60 degrees being the maximum angle possible.

  Furthermore, vertical structures orientated perpendicular to the direction of flight may slightly reduce perception as a waterbody, but are considered undesirable as they tend to result in elevated collision risks for avifauna (Kosciuch et al., 2020), and mortality estimates are significantly higher for buildings than for solar farms (Watson et al 2016).

These proposed mitigations are supported by evidence of varying strengths, from strong empirical studies to plausible mechanisms and established principles from bird strike research in other infrastructure contexts.

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[19] Barrientos R, Alonso JC, Ponce C, Palacín C. Meta-analysis of the effectiveness of marked wire in reducing avian collisions with power lines. Conserv Biol. 2011 Oct;25(5):893-903. doi: 10.1111/j.1523-1739.2011.01699.x. Epub 2011 Jun 15. PMID: 21676031.
[20] Bernardino, J. et al. (2019) "Re-assessing the effectiveness of wire-marking to mitigate bird collisions with power lines: A meta-analysis and guidelines for field studies," Journal of Environmental Management, 252, p. 109651. Available at: https://doi.org/10.1016/j.jenvman.2019.109651.
[21] Energy & Nature. 2024. Avian-Power Line Collision Overview of Risk Factors & Effectiveness of Wire Markers. Methodology Report. 91 pp.

5 Residual effects management

Following mitigation, most potential adverse effects on avifauna are considered to be low or low-moderate (**Table 3**).

Residual effects exceeding a 'minor' threshold due to collision with solar panels, and electrocution (for falcon)remain a possibility post-mitigation.

This assessment predicts the potential for:

- A low-moderate level of residual effects on black-fronted tern, due to low-moderate site use, potential for fence or PV panel strike, and their Nationally Endangered status (**Table 4**).

- A low-moderate level of residual effects on wetland and braided river birds; white heron, Australasian bittern, and black stilt, as they are critically endangered species where even one collision with the fence or panels could be significant for the regional population.

- Low-moderate residual effects on threatened waterfowl; Australasian crested grebe and grey duck from PV panel collision, as they are Nationally Vulnerable, water-obligate species that tend to land on water at speed.

- Low residual level of effect on falcon due to electrocution. Noting, the level of effect due to electrocution from existing transmission infrastructure is likely to be high.

Table 3. Threatened and At Risk avifauna effects assessment after proposed mitigations are applied.

Potential effect	Mitigations	Magnitude of effect	Overall Level of effect
Injury or mortality from collision with PV panels	Apply anti-reflective coating, stow panels at 60 degree angle from dusk to dawn, direct panels away from moonlight, 3.4 m spacing between panel rows	Negligible - Low	Very Low - Moderate
Injury or mortality from collision with perimeter fence and ancillary infrastructure	Fence visibility enhancements Transmission line visibility enhancements	Negligible	Low
Injury or mortality from electrocution by new infrastructure	undergrounded cables, insulate exposed live components, avian-safe clearances, bird exclusion netting	Negligible	Low
Loss of potential feeding and breeding habitat for select species	Predator control within footprint	Negligible - Low	Low
Injury or mortality of nesting avifauna during construction	Pre-works survey for bird nests Construction setbacks of 100 m until fledged	Negligible	Low

Table 4. Species-specific effects assessment of injury or mortality associated with PV collision for Threatened and At Risk avifauna detected in the vicinity of the site, after mitigation.

Species	Threat status	Ecological value	Magnitude of effect	Level of effect

Kōtuku / white heron	Nationally Critical	Very High	Negligible-Low	Low-moderate
Australasian bittern	Nationally Critical	Very High	Negligible-Low	Low-moderate
Kakī / black stilt	Nationally Critical	Very High	Negligible - low	Low-moderate
Black-fronted tern	Nationally Endangered	Very High	Negligible - low	Low-moderate
Grey duck / pārera	Nationally Vulnerable	Very High	Negligible - low	Low-moderate
Kārearea / NZ falcon	Nationally Vulnerable	Very High	Negligible	Low
Caspian tern	Nationally Vulnerable	Very High	Negligible - low	Low-moderate
Australasian crested grebe	Nationally Vulnerable	Very High	Negligible - low	Low-moderate
Wrybill	Nationally Increasing	High	Negligible - low	Very Low - Low
NZ pipit	Declining	High	Negligible	Very Low
Banded dotterel	Declining	High	Negligible	Very Low
South Island pied oystercatcher	Declining	High	Negligible	Very Low
Black-billed gull	Declining	High	Negligible-Low	Very Low - Low
Marsh crake	Declining	High	Low	Low
Spotless crake	Declining	High	Low	Low
Black shag	Relict	Moderate-High	Low	Low
Little shag	Relict	Moderate-High	Low	Low
Australian coot	Naturally uncommon	Moderate-High	Low	Low

It is noted that the current level of bird strike risk associated with the existing high-voltage transmission lines is likely to be substantially greater than that anticipated for the proposed solar farm development. Overhead transmission infrastructure is widely recognised in the literature as a significant source of avian mortality due to collision risk, particularly for large-bodied and low-manoeuvrability species[22] [23]. Accordingly, the incremental increase in bird strike risk resulting from the proposed development is expected to be low in the context of the existing baseline conditions.

5.1 Adaptive management

Due to uncertainty in collision risk, and the possibility of more than minor effects for Threatened avifauna species, an adaptive management approach is proposed.

Robust post-construction monitoring is central to this approach.

Bird strike events that exceed the trigger thresholds listed below, will result in:

1. Reporting to Council and Department of Conservation; and

2. Implementation of further mitigation and compensation options, as described in this assessment and the Avifauna Management Plan, as part of the wider Ecological Management Plan.

[22] Bevanger, K. (1998). Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biological Conservation, 86(1), 67–76.
[23] Bernardino, J., et al. (2018). Bird collisions with power lines: state of the art and priority areas for research. Biological Conservation, 222, 1–13.

5.2 Monitoring

Details of the monitoring programme will be included within the Avifauna Management Plan, which will be prepared and certified as part of the Ecological Management Plan.

The avifauna mortality monitoring programme will employ a robust sampling design, aligning with recommendations within the Proteus statistical assessment[24], to ensure adequate power to detect low probability mortality events of small birds.

At a high level, the survey will include:

- Avian mortality surveys, which are proposed to be carried out by drone overflights using high resolution imagery. Flights will be repeated twice during each survey, with panels angled in different directions, to ensure the area under panels is covered. Ideally, surveys of at least 25 % of the solar array area would be repeated twice per week to ensure detection of infrequent mortality events of small and large birds[25].

- Carcass detection in imagery will occur through AI analysis. Significant testing of this technique is envisaged, with a period of training of the AI model.

- Any bird carcasses detected by the drone will be promptly checked by a human, to identify the species, and cause of mortality where feasible.

- Monitoring will ideally proceed for a term of at least five years, to enable detection of low probability, high consequence events such as mortality of Rare or Threatened species.

- Searcher efficiency (SE) and carcass persistence trials (CP) will be implemented to determine detection probability. SE trials will assess the efficiency of drone surveys and will require an initial period of comparison and calibration to searches by a trained human searcher. Carcass persistence is expected to be improved by proposed predator exclusion perimeter fencing and mammalian predator control. These trials should be initiated prior to construction.

- A reference site will be included so background rates of mortality are able to be established against which the solar farm site can be compared. Alternatively, monitoring at the site itself prior to installation of panels to determine background mortality rates could also be used. Either reference should incorporate an outwash plain intersected by a high voltage transmission line, to account for existing sources of collision mortality. It is critical that the design accounts for this source of mortality, as transmission lines run through the centre of the proposed PV array, and are known to be associated with markedly higher levels of avifauna collision mortality than PV panels.

5.3 Triggers

The trigger for intervention (i.e. when further mitigation measures will be implemented) will occur where any of the following thresholds are met:

- The death of a single individual of a Threatened – Nationally Critical species that can be confidently attributed to collision with solar panels; or

[24] Hamlin, T.J., Jones, T.T., MacKenzie, D.I. (2026). Statistical advice for a solar power installation at Haldon Station, Canterbury, New Zealand.. Report for Lodestone Energy, Proteus Client Report: 219. Proteus, Outram, New Zealand.
[25] Hamlin, T.J., Jones, T.T., MacKenzie, D.I. (2026). Statistical advice for a solar power installation at Haldon Station, Canterbury, New Zealand.. Report for Lodestone Energy, Proteus Client Report: 219. Proteus, Outram, New Zealand.

- A statistically significant increase in mortality above background levels is detected to Threatened or At Risk species and attributable to the solar facility, and

- The resulting mortality is assessed as having greater than a low level of effect on the relevant Threatened or At Risk species' population.

5.4 Further mitigation options

In the event of unacceptable mortality effects (as defined by the thresholds above) an Avifauna Adaptive Management Plan will be prepared and will consider additional mitigations as appropriate.

Mitigation considerations include:

- **Reduction of mortality associated with existing infrastructure:** The applicant will investigate the installation of bird flight diverters on the existing (consented) high-voltage transmission lines crossing the site, or in the vicinity, and/or the retrofit of insulating components on towers to reduce electrocution and collision risks (subject to Transpower approval). Power line collision and electrocution are well-established in the literature as significant sources of avian mortality.

  A targeted search undertaken by the applicant beneath these transmission lines identified several bird carcasses, which is consistent with the elevated risk reported in the literature. It is noted that this observation is indicative only and does not represent a comprehensive avifauna mortality assessment.

  Transmission lines crossing the Tekapo River flyway are considered even greater risk for bird strike, and potentially one of the highest sources of avian mortality in the vicinity following predation. This represents a promising mitigation option.

- **Investigate options to increase panel angle or extend panel stowing** during key periods of strike risk, which may occur during primary migration seasons, fledging of juvenile birds, or times of limited visibility such as foggy weather or around dawn and dusk.

- **Further visual and/or acoustic deterrents.**

5.5 Compensation

In the unlikely event of significant avifauna impacts proposed additional mitigation measures are insufficient or ineffective, or deemed unlikely to be sufficient or effective, compensation will be provided through funding of conservation programmes for braided river birds and/or wetland or terrestrial bird species elsewhere in the Mackenzie Basin.

Such funding will be targeted toward the species affected, and proportionate to the scale of the works required to offset identified impacts.

Compensation funded programmes are anticipated to focus on pest plant and animal control, which constitute key threats for braided river and wetland birds, but will not necessarily be limited to these activities.

The amount of financial compensation or work undertaken by the consent holder is not set out here as it will depend upon the species that has been impacted after all mitigation efforts have been expended, and the severity of the measured effect. We expect that the size of the compensation will be determined in discussion with Council and DOC at that time.

Yours sincerely,

Jeroen Lurling

Senior Ecologist[26]

RMA Ecology Ltd

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