Greytown Solar Farm
Glint and glare study

Final Report

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ABOUT THIS REPORT

This report assesses the glint and glare impact of the proposed Greytown Solar Farm near Greytown, New Zealand. It was commissioned by Far North Solar Farm Limited.

ABBREVIATIONS

AC	Alternating current
CAA	Civil Aviation Authority
DC	Direct current
FAA	Federal Aviation Administration (United States)
FNSF	Far North Solar Farm Limited
ha	Hectare
ITP	ITP Renewables
MW	Megawatt, unit of power (1 million Watts)
MWp	Megawatt-peak, unit of power at standard test conditions; used to indicate PV system capacity
OP	Observation point
PV	Photovoltaic
SGHAT	Solar Glare Hazard Analysis Tool

TABLES

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1 INTRODUCTION

1.1 Overview

Far North Solar Farm Limited (FNSF) has requested a glint and glare assessment for a proposed solar photovoltaic (PV) installation near Greytown, New Zealand. This assessment will be submitted as part of the consent process for the project. It includes:

- Identification of potential receptors of glint and glare from the proposed solar farm
- Assessment of the glint and glare hazard using the Solar Glare Hazard Analysis Tool (SGHAT) GlareGauge analysis

1.2 Glint and glare

The United States Federal Aviation Administration (FAA) defines glint and glare as follows:[1]

- **Glint** is a momentary flash of bright light
- **Glare** is a continuous source of excessive brightness relative to ambient lighting.

Glint and glare can occur when light reflected off a surface (reflector) is viewed by a person (receptor). Glint typically occurs when either the receptor or the reflector is moving, while glare typically occurs when the reflector and receptor are completely, or nearly, stationary. For a transparent material (e.g., glass, water) the quantity of light reflected depends on the surface itself (i.e., material and texture), and the angle at which the light intercepts it (angle of incidence). A higher angle of incidence will result in a higher proportion of light being reflected, as shown in Figure 1.

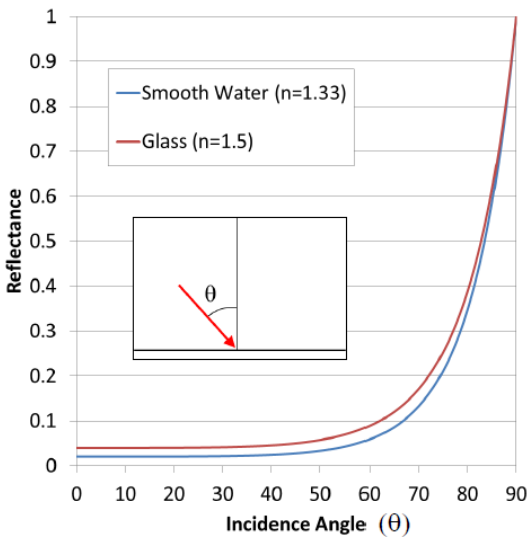

Figure 1: Angles of incidence and increased levels of reflected light

[1] Federal Aviation Administration [FAA], 2018

Potential visual impacts from glint and glare include distraction and temporary afterimage; at its worst, it can cause retinal burn. The ocular hazard caused by glint or glare is a function of:

1. The intensity of the glare upon the eye (retinal irradiance)
2. The subtended angle of the glare source (i.e., the extent to which the glare occupies the receptor's field of vision; dependent on size and distance of the reflector).

The severity of the ocular hazard can be divided into three levels, as shown in Figure 2:

- **Green glare**, which has low potential to cause temporary afterimage
- **Yellow glare**, which has potential to cause temporary afterimage
- **Red glare**, which can cause retinal burn and is not expected for PV.

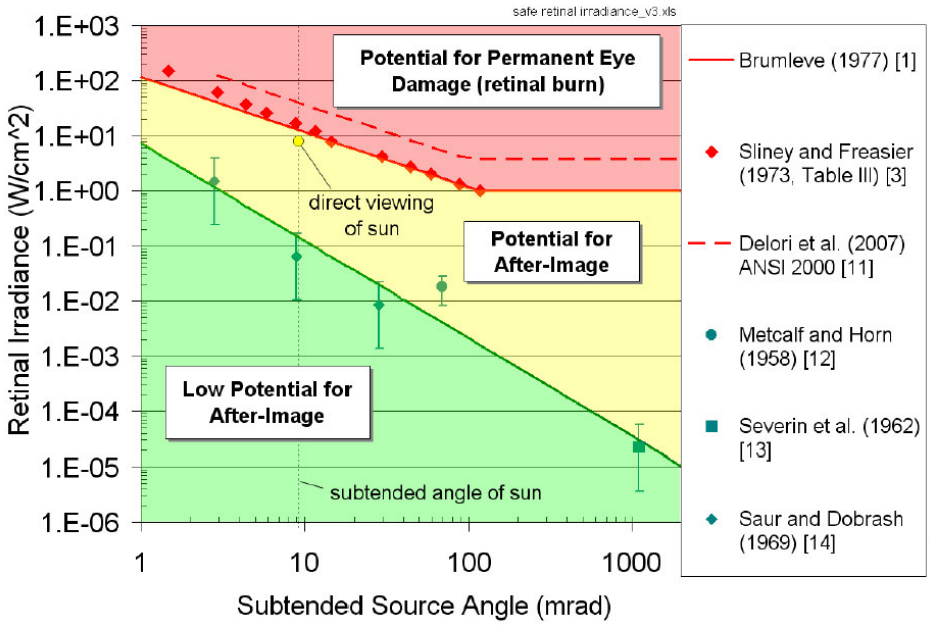

Figure 2: Classification of glare based on severity of ocular effects

1.3 Glare from solar PV

Solar photovoltaic (PV) cells are designed to absorb as much light as possible to maximise efficiency (generally around 98% of the light received). To limit reflection, solar cells are constructed from dark, light-absorbing material and are treated with an anti-reflective coating. PV modules generate less glare than many other surfaces, as shown in Figure 3.

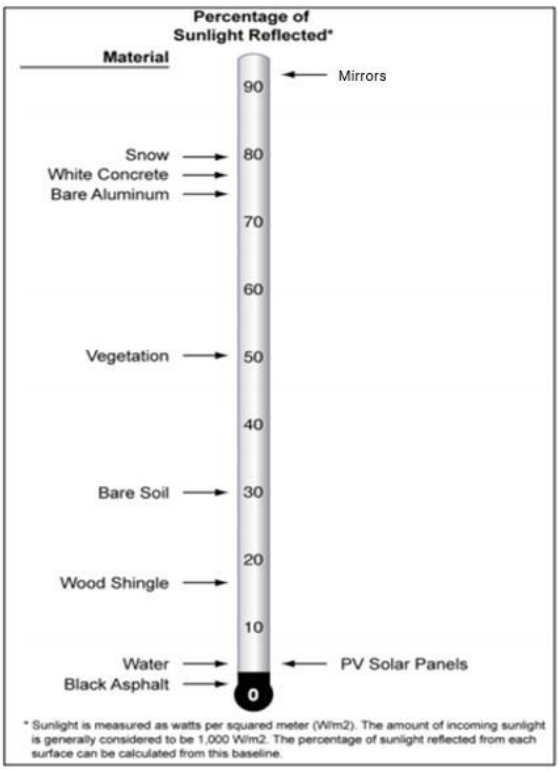

Figure 3: Typical percentage of sunlight reflected from different surfaces (Source: Adapted from Journal of Airport Management, 2014)

The small percentage of light reflected from PV modules varies depending on the angle of incidence. Figure 4 shows an example of this with a solar module. A larger angle of incidence will result in a higher percentage of reflected light.

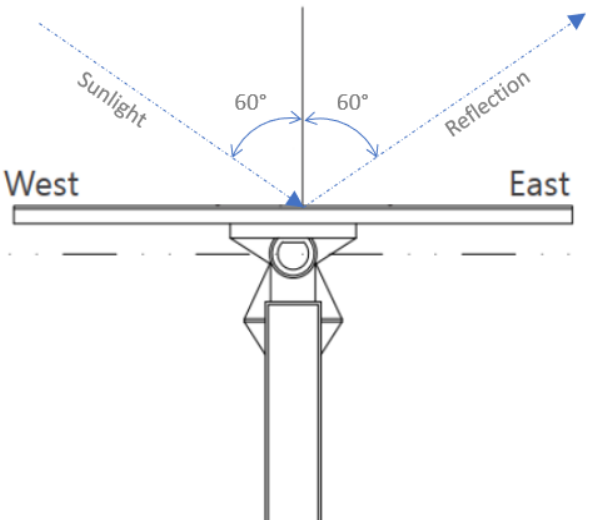

Figure 4: Typical sunlight reflection off the surface of a solar module

The two most common PV mounting structures are fixed tilt and single axis tracking. Fixed tilt arrays are stationary, while single axis tracking arrays rotate the receiving surface of the modules from east to west throughout the day as the sun moves across the sky.

In a fixed tilt PV array, since the sun is moving but the modules are stationary, the angle of incidence varies as the sun moves across the sky. It is smallest around noon when the sun is overhead and largest in the early morning and late afternoon when the sun is near the horizon. There is therefore a higher potential for glare at these times.

The angle of incidence for a single axis tracking system varies less as the reflective surface of the modules rotates on a horizontal axis to follow the sun. Single axis tracking arrays therefore generate less glare than fixed tilt arrays. The tracking varies throughout the year to match seasonal changes in the sun's path (see Figure 5).

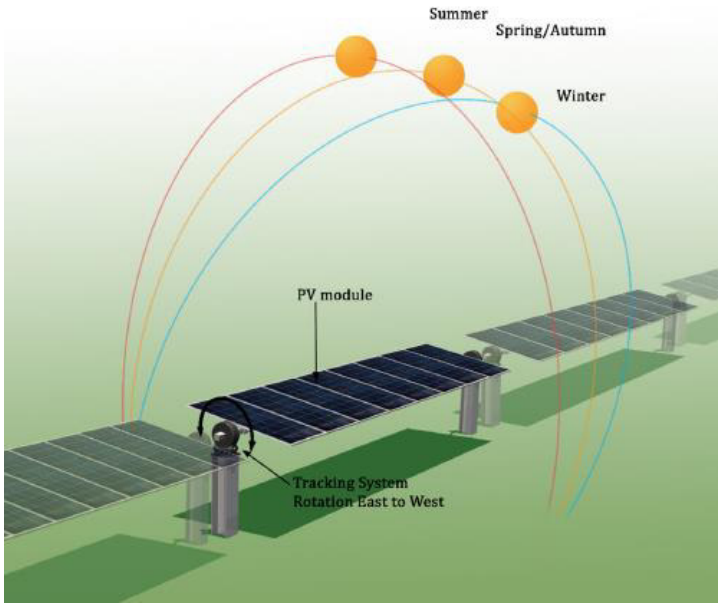

Figure 5: Sun position relative to PV modules on a horizontal single-axis tracking system

2 PROJECT DESCRIPTION

2.1 Site overview

FNSF is proposing a solar farm at the location described in Table 1 and shown in Figure 6. The site is located approximately 4 km south-west of Greytown. An indicative layout is displayed in Figure 7, Figure 8, and Figure 9.

Table 1: Site Information

Parameter	Description
Parcels	Lot 10 DP 3106; Lots 5, 6, & 7 DP 8803; Lot 1 DP 76478; Part Section 122 Moroa DIST; Section 27 Moroa SETT; Lot 1 DP 52574
Address	Moroa Rd
Council	South Wairarapa District Council
Project area	220 ha

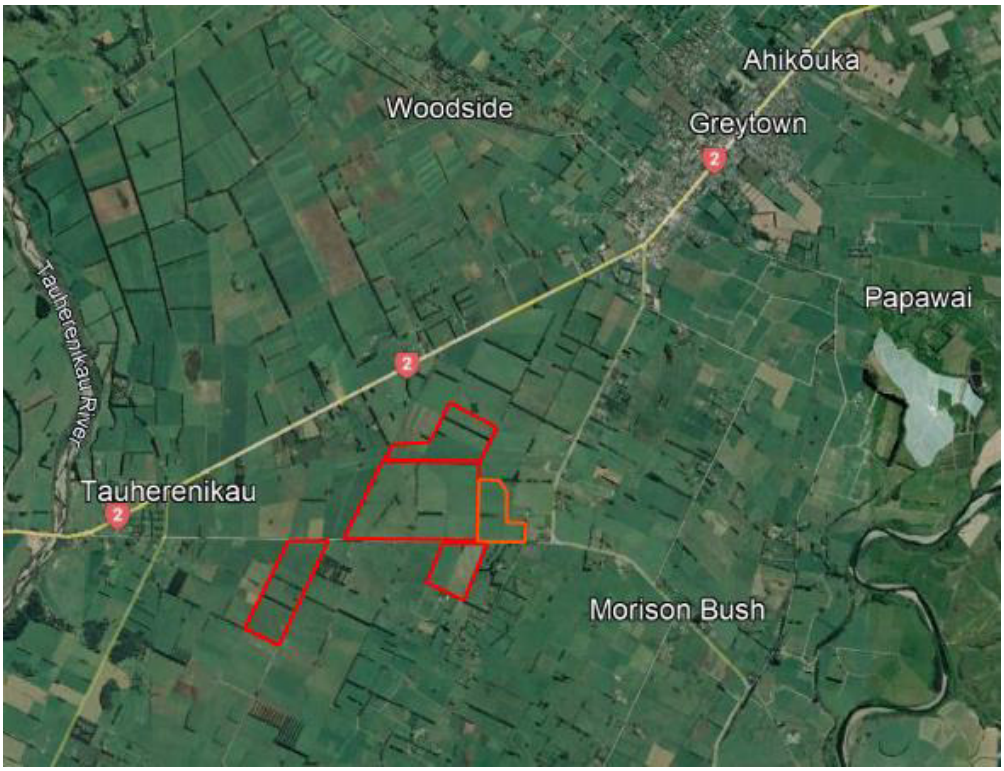

Figure 6: Greytown Solar Farm indicative location and PV layout

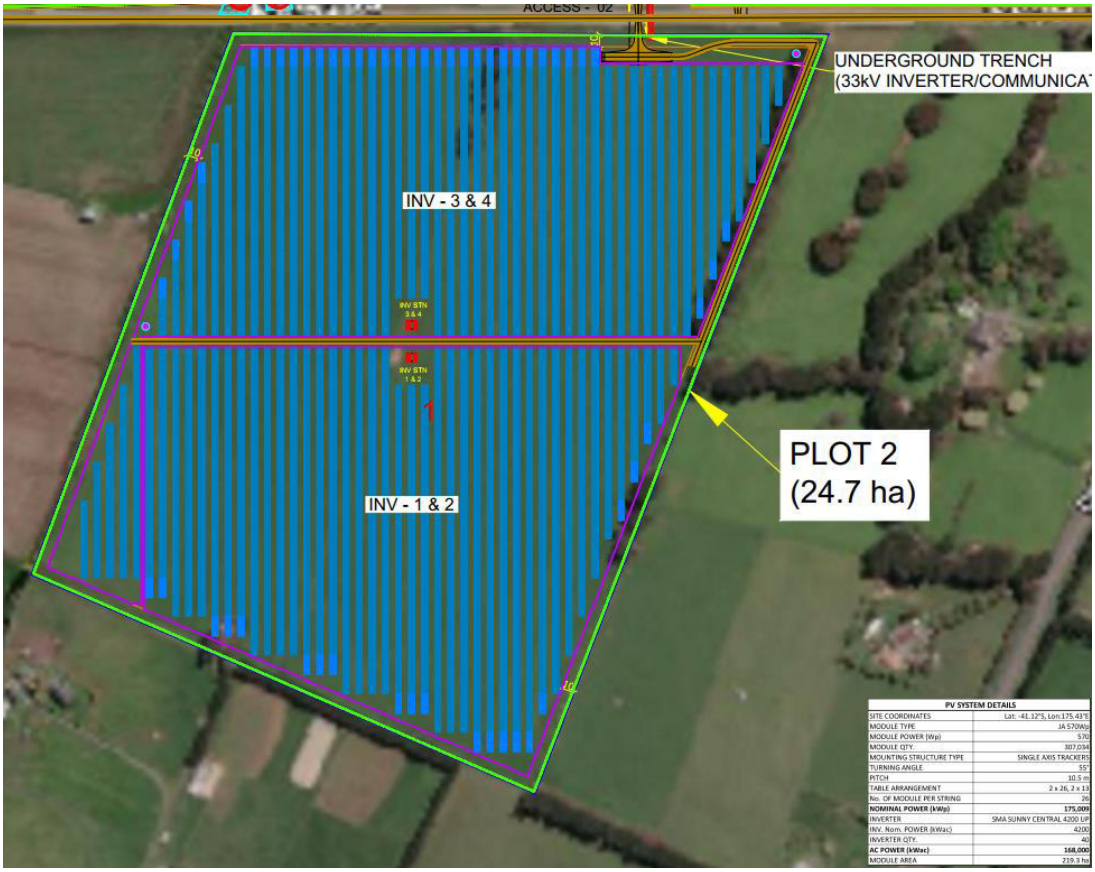

Figure 7: Array layout view 1

Figure 8: Array layout detail view 2

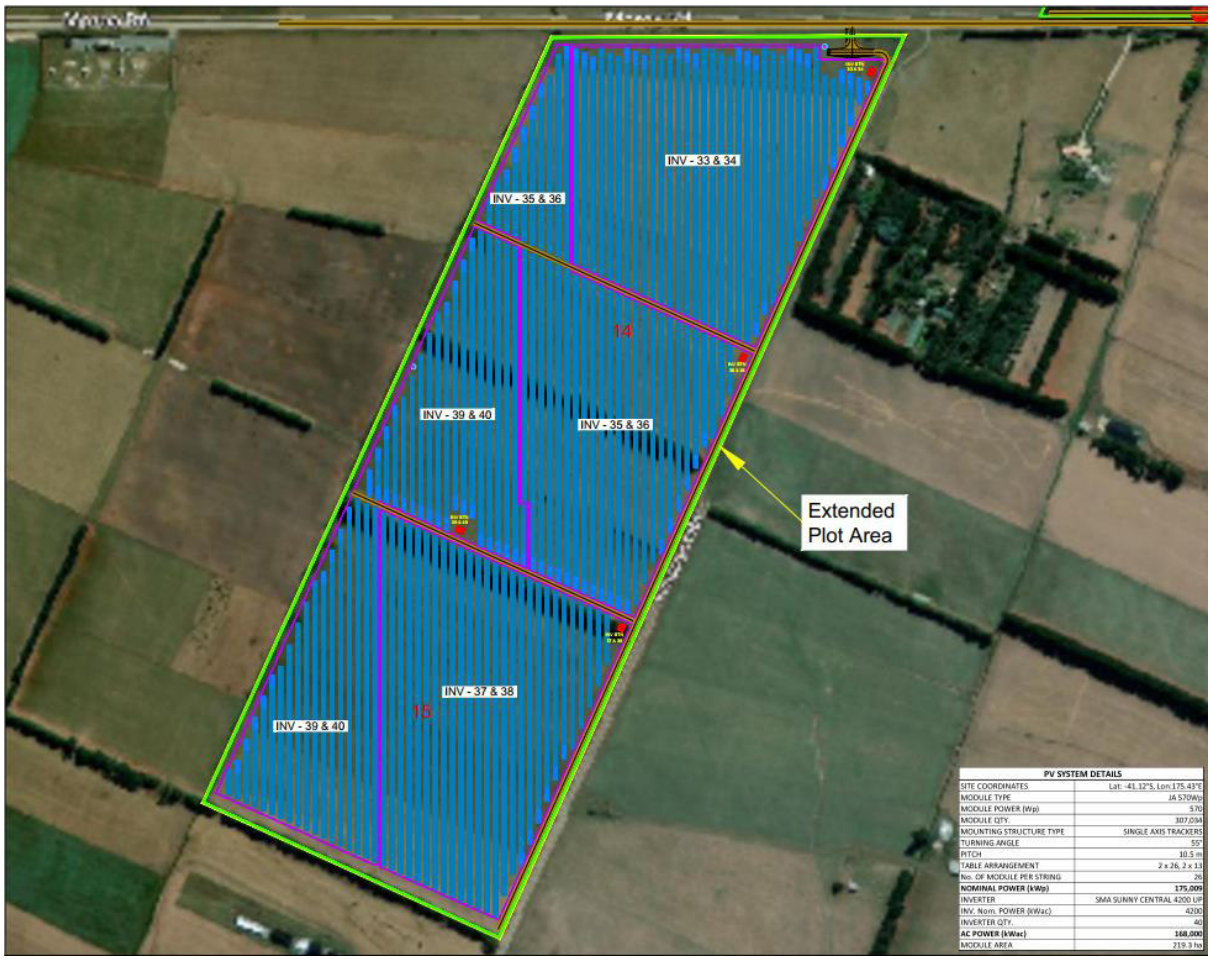

Figure 9: Array layout detail view 3

2.2 Solar farm details

Table 2 summarises the details of the proposed solar farm.

Table 2: Solar farm information

Parameter	Description
Solar farm name	Greytown Solar Farm
Capacity	175 MWp
Mounting system	Single-axis tracking

FNSF is proposing to construct a solar farm with a DC capacity of 175 MWp on an approximately 220 ha site. There will be approximately 300,000 solar modules installed in 6,000 single-axis tracking tables (each table approximately 30 m long) running north-east to south-west. There is approximately 10.5 m spacing between each row and the maximum height of each table is approximately 4 m. The mounting system is constructed on piles that are driven into the ground. The solar farm will include 20 medium voltage (MV) power

stations. Each power station incorporates high/medium voltage switchgear, transformers, and inverters. The solar farm will be surrounded by a vegetation screen with a maximum height of 4 m.

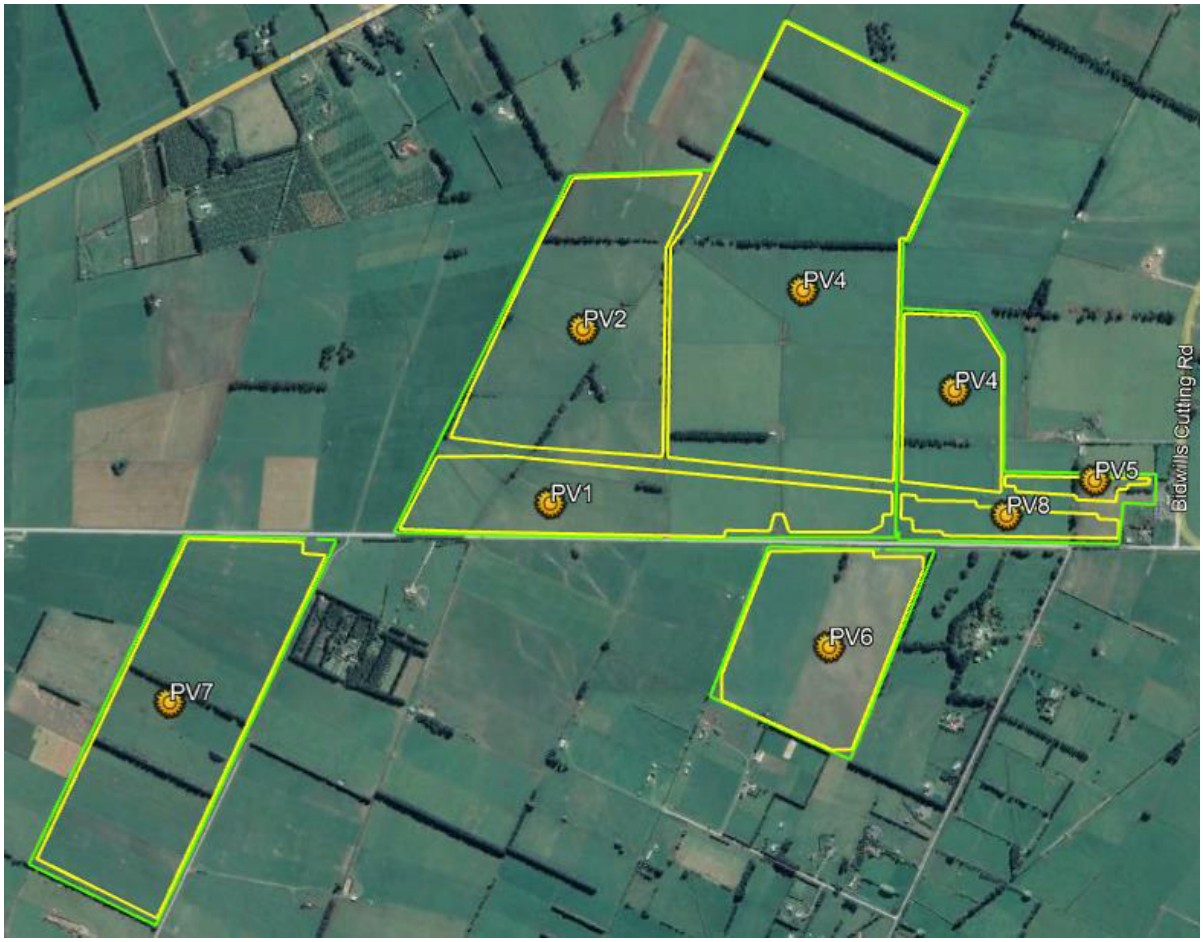

Figure 10: Solar farm model layoutshowing arrays (yellow) surround by proposed screening (green)

3 ANALYSIS

3.1 Overview

The Solar Glare Hazard Analysis Tool (SGHAT) was developed by Sandia National Laboratories to evaluate glare resulting from solar farms at different viewpoints, based on the location, orientation, and specifications of the PV modules. This tool was required by the United States FAA for glare hazard analysis near airports until 2021 and is also recognised by the Australian Government Civil Aviation Safety Authority (CASA).

The GlareGauge software uses SGHAT to provide an indication of the type of glare expected at each potential receptor. It runs with a simulation timestep of one minute. Glint lasting for less than one minute is unlikely to occur from the sun on PV modules due to their slow movement.

Table 3 details the parameters used in the SGHAT model. GlareGauge default settings were adopted for the analysis time interval, direct normal irradiance, observer eye characteristics and slope error. The height of the observation points for road and rail users was assumed to be 1.5 m for a car driver. The height for a person standing was assumed to be 1.65 m.

The solar farm comprises three separate arrays. Each array was modelled separately, and the largest was further divided into five parts to improve the accuracy of the results. The vegetation screening was modelled as an opaque obstruction with a height of 4 m. The division of the array, and the proposed screening is shown in Figure 10.

Table 3: SGHAT specification inputs

Parameters	Input
Time zone	UTC+12:00
Module surface material	Smooth glass with ARC (anti-reflective coating)
Module tracking	Single-axis tracking with backtracking
Backtracking algorithm	Shade
Maximum tilt angle	±55˚
Module axis orientation	0°
Resting angle	0°
Height of modules above ground	2.25 m (height from the ground to the table centre)
Obstruction height	4 m

3.2 Potential receptors

This assessment considers potential visual receptors (e.g., residences and road users) within 2 km of the site. There is no formal guidance on the maximum distance for glint and glare assessments; however, the significance of a reflection decreases with distance for two main reasons:

1. The solar farm appears smaller (smaller subtended angle), and glare has less impact
2. Visual obstructions (e.g., terrain, vegetation) may block the view of the solar farm

Glint and glare impacts beyond 2 km are highly unlikely. This choice of distance is conservative and is based on existing studies and assessment experience.

Seventy-seven observation points and fourteen road routes were identified as potential visual receptors, as shown in Figure 11. Other observation points were excluded from the study due to intervening vegetation and other barriers which block line-of-site to the arrays.

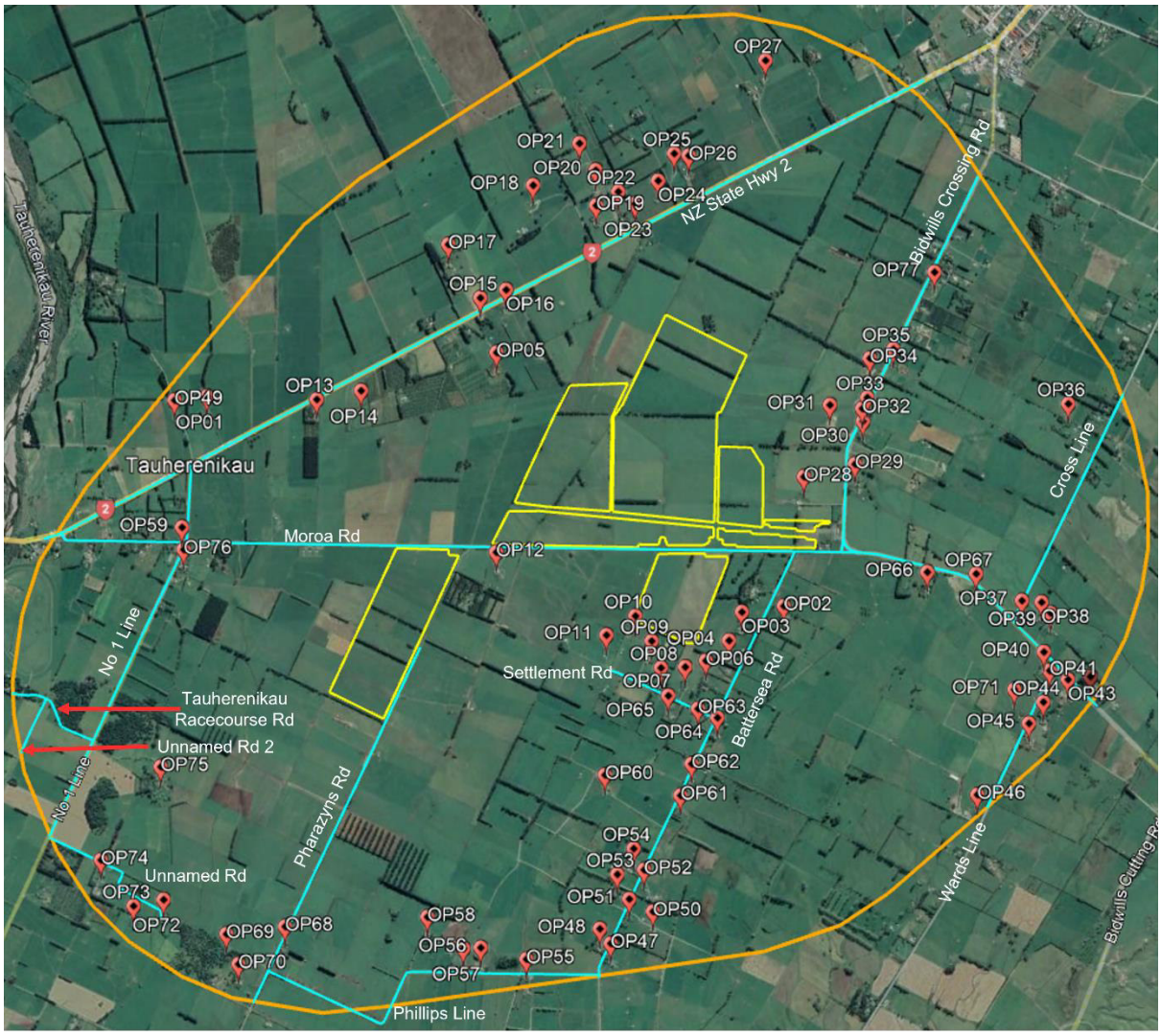

Figure 11: Potential visual receptors within 2 km of the site

The client requested that ITP consider including a potential private airstrip immediately east of the array as shown in Figure 12. The location of the airstrip was difficult to identify, and it does not appear to be a registered aerodrome according to the Civil Aviation Authority New Zealand's list of Aerodrome Coordinates.[2] Hence, ITP has excluded it from this study. The nearest listed aerodrome is Papawai Airfield, approximately 5.5 km northeast of the site.

Figure 12: Runway satellite imagery (Source: Google Maps, 2023)

3.3 Assumptions

The visual impact of solar farms depends on the scale and type of infrastructure, the prominence and topography of the site relative to the surrounding environment, and any proposed screening measures to reduce visibility of the site. ITP modelled a line of tall trees adjacent to NZ State Hwy 2 and the horizon line. Other minor screening was not assessed in detail. The GlareGauge analysis results are therefore considered conservative as the model assumes there is no screening.

[2] Civil Aviation Authority of New Zealand, 2023, Aeronautical Services: NZANR – Aerodrome Coordinates, https://www.aip.net.nz/assets/AIP/Air-Navigation-Register/5-Aerodromes/NZANR-Aerodrome_Coordinates.pdf

The line of tall trees adjacent to NZ State Hwy 2 was modelled using an obstruction object with a height of 5 m as shown in Figure 13.

Figure 13: Obstruction used to model roadside vegetation on NZ State Hwy 2

The horizon line was sourced from the National Institute of Water Atmospheric Research (NIWA) Solarview tool. The horizon line is shown in Figure 14. The line of hills to the north-west of the site introduces a horizon of between 1° and 3° in the afternoon. The horizon limit was modelled by running two ForgeSolar models, one with a minimum sun angle of 0° and the other with a minimum sun angle of 2.5°. For receptors where all glare occurred between May and August, the results from the 2.5° horizon model were substituted for the results from the 0° horizon model as the sun will be below the horizon at these times.

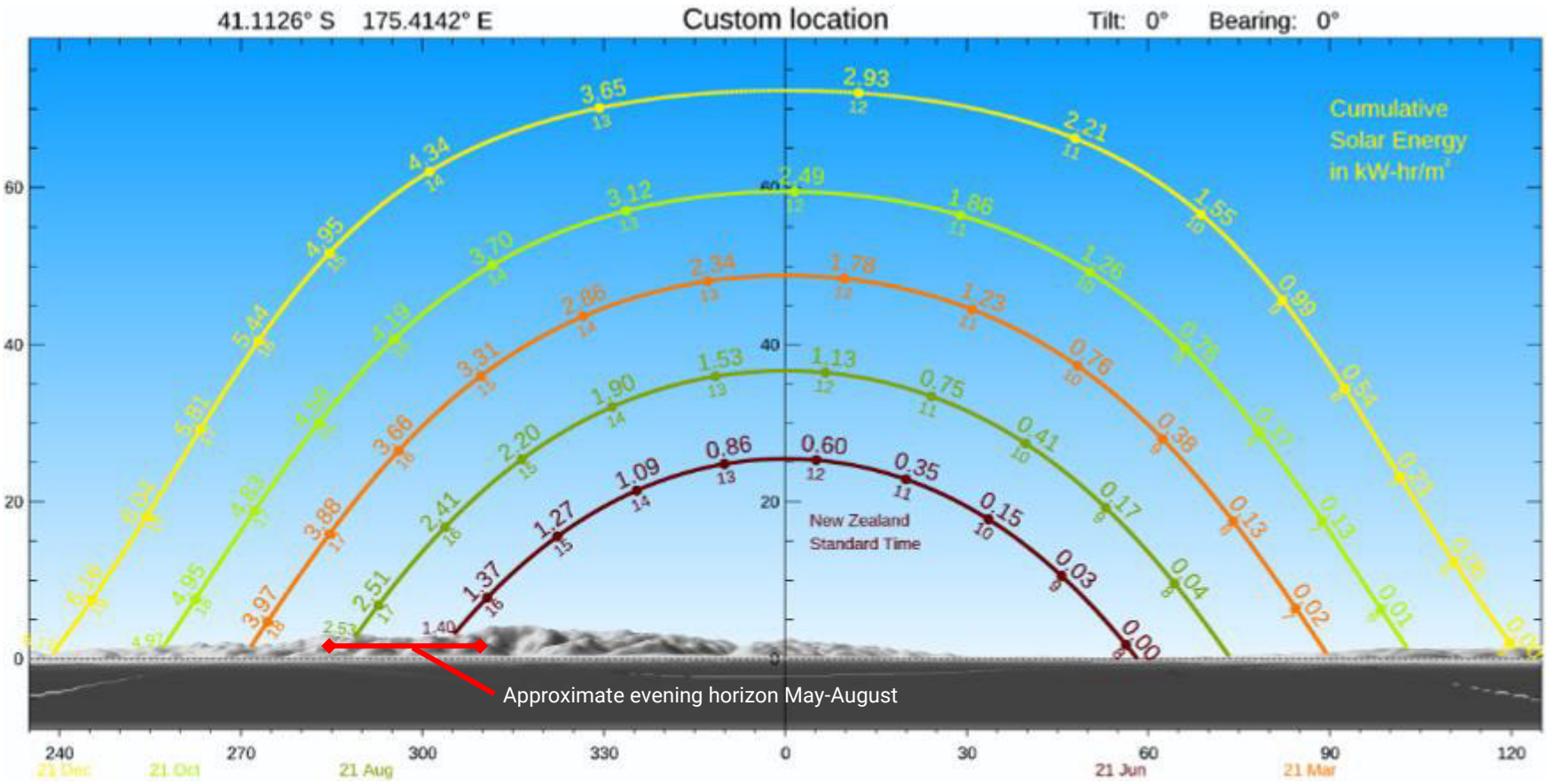

Figure 14: Horizon line at Greytown at different times of year (source: NIWA Solarview)

Atmospheric conditions such as cloud cover will also influence light reflection and the resulting impact on visual receptors. GlareGauge does not model varying atmospheric conditions. The GlareGauge analysis assumes clear sky conditions, with a peak direct normal irradiance (DNI) of 1,000 W/m^2 which varies throughout the day. This is a conservative assumption.

3.4 Results

The results of the GlareGauge analysis are summarised in Table 4. These results count only unique minutes of glare received from any source; they do not detail which of the eight PV areas the glare came from. For observation points where some glare occurred, the impact is described qualitatively. In general, most glare occurred in the early mornings or late evenings when backtracking is active.

The analysis identified 1,373 minutes (23 hours) of cumulative green glare spread across three observation points and three road routes. All other receptors (74 observation points and eleven road routes) received no glare at any time. No observation points or routes received more than 6 minutes of glare in any single day.

The 2.5° horizon model was used for seven observation points and one road route where all glare from the 0° horizon model occurred between May and August. In these cases, the sun will be below the horizon when glare would be expected otherwise. The effected receptors are:

- OPs 40, 41, 42, 43, 44, and 45
- OP 71
- Moroa Rd.

These receptors are highlighted in Table 4. The full results for both horizon models are included in Appendix A.

Table 4: Glare potential at each receptor

Receptor	Location	Horizon model	Green (min/yr)	Yellow (min/yr)	Daily glare potential	Impact	Further mitigation required
OP 1	-41.111, 175.390	0°	125	0	Up to 3 minutes of green glare between 4:30 am and 5:30 am from late November to late January.	Very low	No
OP 2	-41.123, 175.433	0°	0	0	None	None	No
OP 3	-41.124, 175.430	0°	0	0	None	None	No
OP 4	-41.125, 175.429	0°	0	0	None	None	No
OP 5	-41.109, 175.412	0°	0	0	None	None	No
OP 6	-41.126, 175.427	0°	0	0	None	None	No
OP 7	-41.127, 175.426	0°	0	0	None	None	No
OP 8	-41.127, 175.424	0°	0	0	None	None	No
OP 9	-41.125, 175.423	0°	0	0	None	None	No
OP 10	-41.124, 175.422	0°	0	0	None	None	No
OP 11	-41.125, 175.420	0°	0	0	None	None	No
OP 12	-41.120, 175.412	0°	0	0	None	None	No
OP 13	-41.112, 175.398	0°	0	0	None	None	No
OP 14	-41.111, 175.402	0°	0	0	None	None	No
OP 15	-41.106, 175.411	0°	0	0	None	None	No
OP 16	-41.105, 175.413	0°	0	0	None	None	No

Receptor	Location	Horizon model	Green (min/yr)	Yellow (min/yr)	Daily glare potential	Impact	Further mitigation required
OP 17	-41.103, 175.408	0°	0	0	None	None	No
OP 18	-41.100, 175.415	0°	0	0	None	None	No
OP 19	-41.101, 175.419	0°	0	0	None	None	No
OP 20	-41.099, 175.419	0°	0	0	None	None	No
OP 21	-41.097, 175.418	0°	0	0	None	None	No
OP 22	-41.100, 175.421	0°	0	0	None	None	No
OP 23	-41.101, 175.422	0°	0	0	None	None	No
OP 24	-41.099, 175.424	0°	0	0	None	None	No
OP 25	-41.098, 175.425	0°	0	0	None	None	No
OP 26	-41.098, 175.426	0°	0	0	None	None	No
OP 27	-41.093, 175.432	0°	0	0	None	None	No
OP 28	-41.116, 175.435	0°	0	0	None	None	No
OP 29	-41.115, 175.439	0°	0	0	None	None	No
OP 30	-41.113, 175.439	0°	0	0	None	None	No
OP 31	-41.112, 175.437	0°	0	0	None	None	No
OP 32	-41.112, 175.439	0°	0	0	None	None	No
OP 33	-41.112, 175.440	0°	0	0	None	None	No

Receptor	Location	Horizon model	Green (min/yr)	Yellow (min/yr)	Daily glare potential	Impact	Further mitigation required
OP 34	-41.109, 175.440	0°	0	0	None	None	No
OP 35	-41.109, 175.442	0°	0	0	None	None	No
OP 36	-41.112, 175.455	0°	0	0	None	None	No
OP 37	-41.123, 175.451	0°	0	0	None	None	No
OP 38	-41.123, 175.453	0°	0	0	None	None	No
OP 39	-41.124, 175.453	0°	0	0	None	None	No
OP 40	-41.126, 175.453	**2.5°**	226	0	Up to 6 minutes of green glare between 4 pm and 5:30 pm from early May to early August.	Very low	No
OP 41	-41.127, 175.453	**2.5°**	0	0	None	None	No
OP 42	-41.127, 175.457	**2.5°**	0	0	None	None	No
OP 43	-41.128, 175.455	**2.5°**	0	0	None	None	No
OP 44	-41.129, 175.453	**2.5°**	0	0	None	None	No
OP 45	-41.130, 175.452	**2.5°**	0	0	None	None	No
OP 46	-41.134, 175.448	0°	0	0	None	None	No
OP 47	-41.142, 175.420	0°	0	0	None	None	No
OP 48	-41.142, 175.420	0°	0	0	None	None	No
OP 49	-41.112, 175.388	0°	227	0	Up to 4 minutes of green glare between 4:30 am and 6 am from mid-November to early February.	Very low	No

Receptor	Location	Horizon model	Green (min/yr)	Yellow (min/yr)	Daily glare potential	Impact	Further mitigation required
OP 50	-41.141, 175.424	0°	0	0	None	None	No
OP 51	-41.140, 175.422	0°	0	0	None	None	No
OP 52	-41.138, 175.423	0°	0	0	None	None	No
OP 53	-41.139, 175.421	0°	0	0	None	None	No
OP 54	-41.137, 175.422	0°	0	0	None	None	No
OP 55	-41.143, 175.414	0°	0	0	None	None	No
OP 56	-41.143, 175.411	0°	0	0	None	None	No
OP 57	-41.143, 175.409	0°	0	0	None	None	No
OP 58	-41.141, 175.406	0°	0	0	None	None	No
OP 59	-41.119, 175.388	0°	0	0	None	None	No
OP 60	-41.133, 175.420	0°	0	0	None	None	No
OP 61	-41.134, 175.426	0°	0	0	None	None	No
OP 62	-41.132, 175.426	0°	0	0	None	None	No
OP 63	-41.129, 175.427	0°	0	0	None	None	No
OP 64	-41.130, 175.428	0°	0	0	None	None	No
OP 65	-41.128, 175.425	0°	0	0	None	None	No
OP 66	-41.121, 175.444	0°	0	0	None	None	No

Receptor	Location	Horizon model	Green (min/yr)	Yellow (min/yr)	Daily glare potential	Impact	Further mitigation required
OP 67	-41.122, 175.448	0°	0	0	None	None	No
OP 68	-41.142, 175.396	0°	0	0	None	None	No
OP 69	-41.142, 175.391	0°	0	0	None	None	No
OP 70	-41.144, 175.392	0°	0	0	None	None	No
OP 71	-41.128, 175.451	**2.5°**	0	0	None	None	No
OP 72	-41.140, 175.387	0°	0	0	None	None	No
OP 73	-41.140, 175.384	0°	0	0	None	None	No
OP 74	-41.138, 175.382	0°	0	0	None	None	No
OP 75	-41.132, 175.386	0°	0	0	None	None	No
OP 76	-41.120, 175.388	0°	0	0	None	None	No
OP 77	-41.104, 175.445	0°	0	0	None	None	No
Route 1	Bidwills Cutting Rd	0°	616	0	Up to 1 minutes of green glare between 4 pm and 5:30 pm from late April to mid-August.	Very low	No
Route 2 (car)	NZ State Hwy 2	0°	44	0	Up to 3 minutes of green glare between 5 am and 6 am from late January to early February. Up to 3 minutes of green glare between 4:30 am and 5:30 am from late October to mid-November.	Very low	No

Receptor	Location	Horizon model	Green (min/yr)	Yellow (min/yr)	Daily glare potential	Impact	Further mitigation required
Route 2 (truck)		0°	84	0	Up to 3 minutes of green glare between 5 am and 6:30 am from late January to mid-March. Up to 3 minutes of green glare between 4:30 am and 6 am from late September to mid-November.	Very low	No
Route 3	No 1 Line	0°	0	0	None	None	No
Route 4	Moroa Rd	**2.5°**	0	0	None	None	No
Route 5	Moroa & Bidwills Cutting tee-intersection	0°	0	0	None	None	No
Route 6	Battersea Rd	0°	0	0	None	None	No
Route 7	Phillips Line	0°	0	0	None	None	No
Route 8	Settlement Rd	0°	0	0	None	None	No
Route 9	Unnamed Rd 1 (off No 1 Line)	0°	0	0	None	None	No
Route 10	Pharazyns Rd	0°	0	0	None	None	No
Route 11	Tauherenikau-Racecourse Rd	0°	0	0	None	None	No
Route 12	Unnamed Rd 2 (off Taherenikau)	0°	0	0	None	None	No

Receptor	Location	Horizon model	Green (min/yr)	Yellow (min/yr)	Daily glare potential	Impact	Further mitigation required
Route 13	Cross Line	0°	51	0	Up to 2 minutes of green glare between 7 pm and 7:30 pm in February. Up to 2 minutes of green glare between 6:30 pm and 7 pm from mid-October to early November.	Very low	No
Route 14	Wards Line	0°	0	0	None	None	No
Total			**1,373**	**0**			

4 SUMMARY

The results of the GlareGauge analysis indicated that three observation points and three road routes received green glare, which has low potential to cause afterimage. In general, most of the glare occurred during early mornings and late evenings when backtracking is active. No observation points or routes received more than 6 minutes of glare in any single day.

The 2.5° horizon model was used for seven observation points and one road route where all glare from the 0° horizon model occurred between May and August. In these cases, the sun will be below the horizon when glare would be expected otherwise.

The proposed vegetation screen provides effective mitigation of the glare expected from the solar farm. The residual glare is very low impact and does not require further mitigation. These results are conservative as existing roadside vegetation, and other intervening vegetation and structures were not modelled explicitly and will further reduce the glare impact.

5 REFERENCES

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APPENDIX A. FORGESOLAR ANALYSIS REPORTS

The following are provided as an attachment.

1. **23070 – ForgeSolar Analysis Report A 0 deg horizon.pdf:** including results for OP 1 to 40 and all road routes with the minimum sun angle set to 0°.
2. **23070 – ForgeSolar Analysis Report B 0 deg horizon.pdf:** including results for OP 41 to OP 77 with the minimum sun angle set to 0°.
3. **23070 – ForgeSolar Analysis Report A 2.5 deg horizon.pdf:** including results for OP 1 to 40 and all road routes with the minimum sun angle set to 2.5°.
4. **23070 – ForgeSolar Analysis Report B 2.5 deg horizon.pdf:** including results for OP 41 to OP 77 with the minimum sun angle set to 2.5°.

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