DUNMORE SOLAR PROJECT

SOLAR GLARE HAZARD ANALYSIS REPORT

April 2021

Prepared By:

Green Cat Renewables Canada Corporation

Prepared For:

Dunmore Solar Inc.

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Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

EXECUTIVE SUMMARY

Dunmore Solar Inc. (Dunmore Solar) is developing a utility-scale solar photovoltaic (PV) project called Dunmore Solar Project (Project). The Project is located northeast of the Hamlet of Dunmore in Cypress County, Alberta. Dunmore Solar retained Green Cat Renewables Canada Corporation to conduct a solar glare hazard analysis for the potential of glare at dwellings and along road routes near the Project.

Green Cat utilizes ForgeSolar's GlareGauge software to assess user-input PV arrays for potential glare on identified roadways and dwellings. The software evaluates the occurrence of glare on a minute-by-minute basis. If glare is predicted, each minute of glare as a function of retinal irradiance and subtended angle is plotted on a hazard plot. Retinal irradiance and subtended angle predict the ocular hazard associated with the glare as either green (low potential for after-image), yellow (potential for temporary after-image), or red (potential for retinal damage). The software does not consider obstacles such as trees, hills, buildings, etc. between the PV array and glare receptor.

Green Cat followed the guidelines provided in AUC *Rule 007* for the receptors to be included in a solar glare assessment, but *Rule 007* does not specify any modelling parameters or glare threshold limits.[1] Green Cat also referred to the information provided in Zehndorfer Engineering's *Solar Glare and Glint Project Report*[2], which was written to inform the AUC's update to *Rule 007*, and precedent set by recent AUC proceedings.

Green Cat evaluated the area within 4,000m of the Project for aerodromes and within 800m for any other receptors. The assessment considered the following receptors near the Project:

- Five residences;
- Highway 41 (Buffalo Trail);
- Township Road 124; and
- A private, unregistered aerodrome.

The glare analysis indicates that the Dunmore Solar Project is not likely to have the potential to create hazardous glare conditions for the dwellings or transportation routes assessed. The private, unregistered aerodrome is not anticipated to be affected by glare from the Project. The actual glare impacts that will be experienced on roads in the field are anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the solar PV arrays. Glare predicted to affect dwellings is minor in intensity and is not expected to have a significant adverse effect on residents. Observers are also expected to simultaneously see direct sunlight originating from the same general direction as the glare, so glare impacts may be less pronounced.

[1] *AUC Rule 007: Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations and Hydro Developments, subsection 4.3.2 SP14, (March 2021).*

[2] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*

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1 INTRODUCTION

Dunmore Solar Inc. (Dunmore Solar) retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the Dunmore Solar Project (the Project). The solar photovoltaic (PV) project is located 10 km northeast of the Hamlet of Dunmore, and 13 km east of the City of Medicine Hat in Cypress County, Alberta. The proposed solar project will have a total capacity of 205 MW_{AC}, utilizing a fixed tilt racking system.

The assessment considers the glare impact of the Project on dwellings and transportation infrastructure within approximately 800m of the site. The evaluated routes include Highway 41 (Buffalo Trail) and Township Road 124. The nearest registered aerodrome is the Medicine Hat Airport, which is approximately 17 km west of the Project. Due to its distance, this aerodrome was not considered in this analysis. Through public stakeholder consultation, Dunmore Solar identified one private, unregistered aerodrome within 4,000m of the Project, so it has also been analyzed in this assessment.

Glint and glare refer to light reflected off smooth surfaces, either momentarily and intense (glint) or less intense for a more sustained period (glare). Solar PV technology is specifically designed to absorb as much sunlight as possible and modules are generally coated in an anti-reflective coating. Solar PV sites have been developed alongside major transport routes and airports around the world, including adjacent to road infrastructure. This suggests that solar PV technology, such as the Dunmore Solar Project, can safely coexist with roads and airports.

It is considered that a developer, in this case Dunmore Solar, should provide safety assurances regarding the full potential impact of the installation on routes, roads, and dwellings in the form of a glare assessment.

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2 BACKGROUND INFORMATION

The potential for glint and glare from solar PV modules on the surrounding roads, residential properties and nearby aerodromes should be fully considered when planning a solar project.

Glint and glare are both caused by the reflection of light from a surface, in this case sunlight from a solar module. Glare is caused by a continuous but less intense reflection of a bright light, whereas glint is caused by a strong, momentary reflection of sunlight. Reflections from smooth surfaces produce more direct "specular" reflections, and rougher surfaces disperse the light in multiple directions, creating "diffuse" reflections. **Figure 2-1** shows these two types of reflections from a solar PV module.

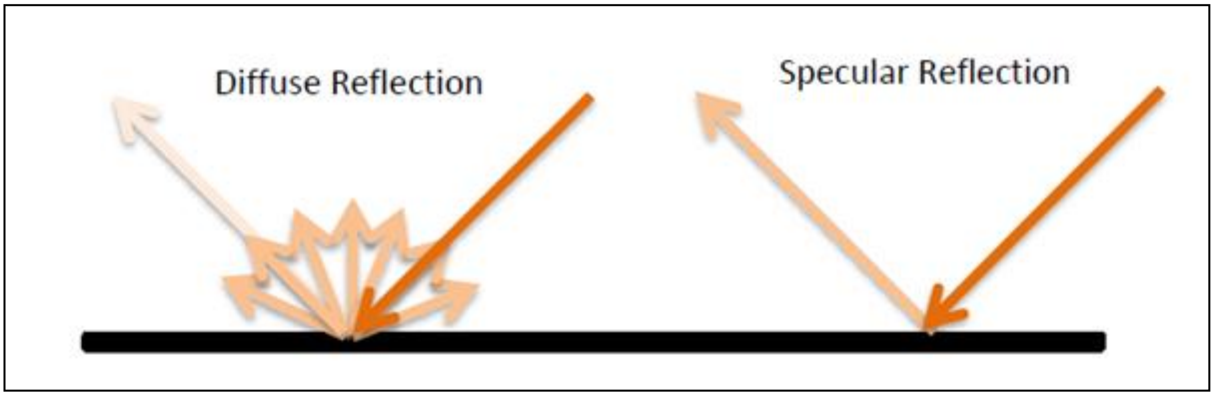

Figure 2-1 – Types of light reflection from solar modules.

Calculation of potential glare requires the azimuth and elevation angle of the sun, and the consequent angles of incidence and reflection at the array, at all times throughout the year.

The angle of incidence is the angle at which the sun strikes the module (measured from normal/perpendicular to the surface). The angle of reflection is equal and opposite the angle of incidence. Light transmission through the glass and absorption by the PV module is greatest when the light is normal to the glass surface, while more light is reflected at shallower angles. As shown in **Figure 2-2**, a low incidence angle in a fixed tilt system is associated with the sun being high in the sky such that the sun's rays are shining at close to a right angle with the module surface. The highest incidence angles will occur in the early morning and late evening when the sun is low in the sky.

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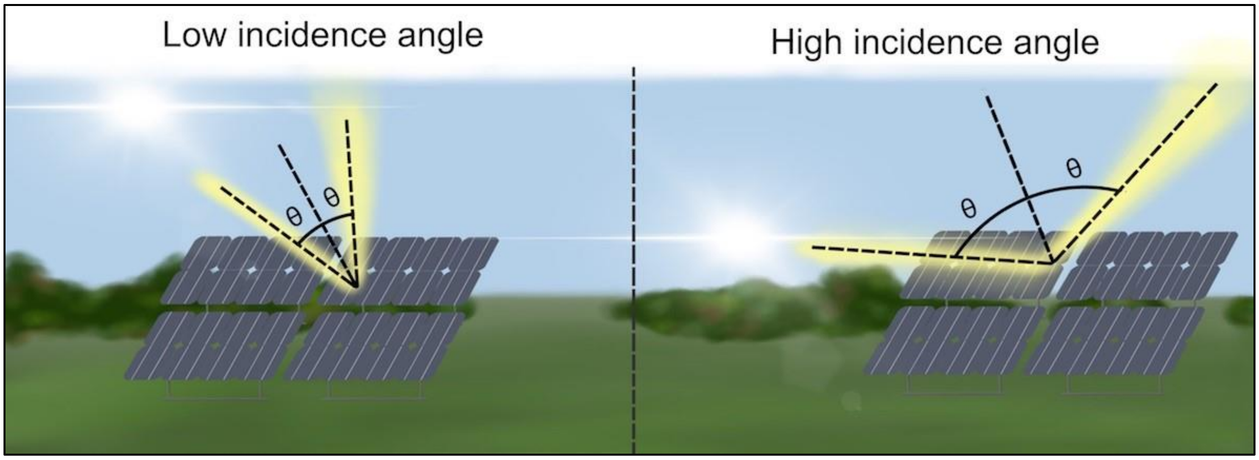

Figure 2-2 – Angles of Incidence relative to Sun's position

Throughout the day the sun will track across the sky; therefore, the angle at which the light is incident on the module will vary. **Figure 2-3** shows the two angles (azimuth and elevation/zenith) required to define the orientation of the sun with respect to the solar module.

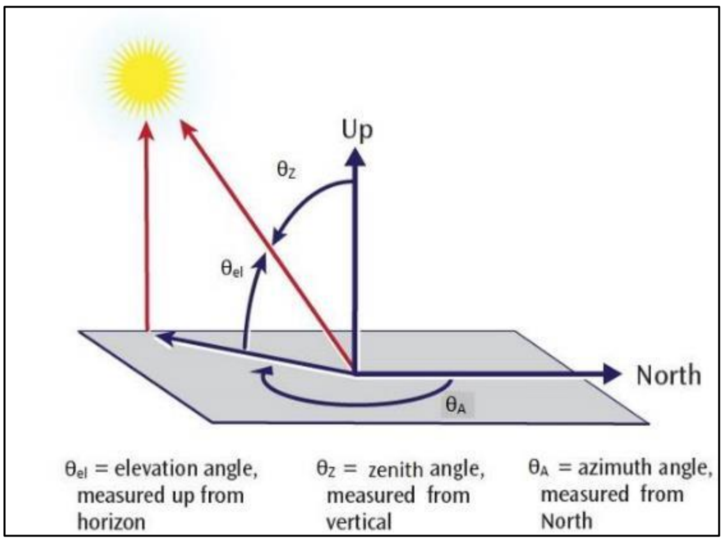

Figure 2-3 – Sun's position relative to solar module

There are many factors that affect the glare level. These include but are not limited to:

- The type of solar module
- The module's tilt angle and orientation
- Size of solar development
- Shape of solar development
- Location of solar development
- Distance between solar development and observer
- Angle to observer
- Relative height of observer

The following section describes the proposed development and the associated infrastructure in detail.

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3 PROJECT DESCRIPTION

The proposed project site is located in southeastern Alberta, approximately 10 km northeast of the Hamlet of Dunmore, and 13 km east of the City of Medicine Hat. The Project location is shown in **Figure 3-1**.

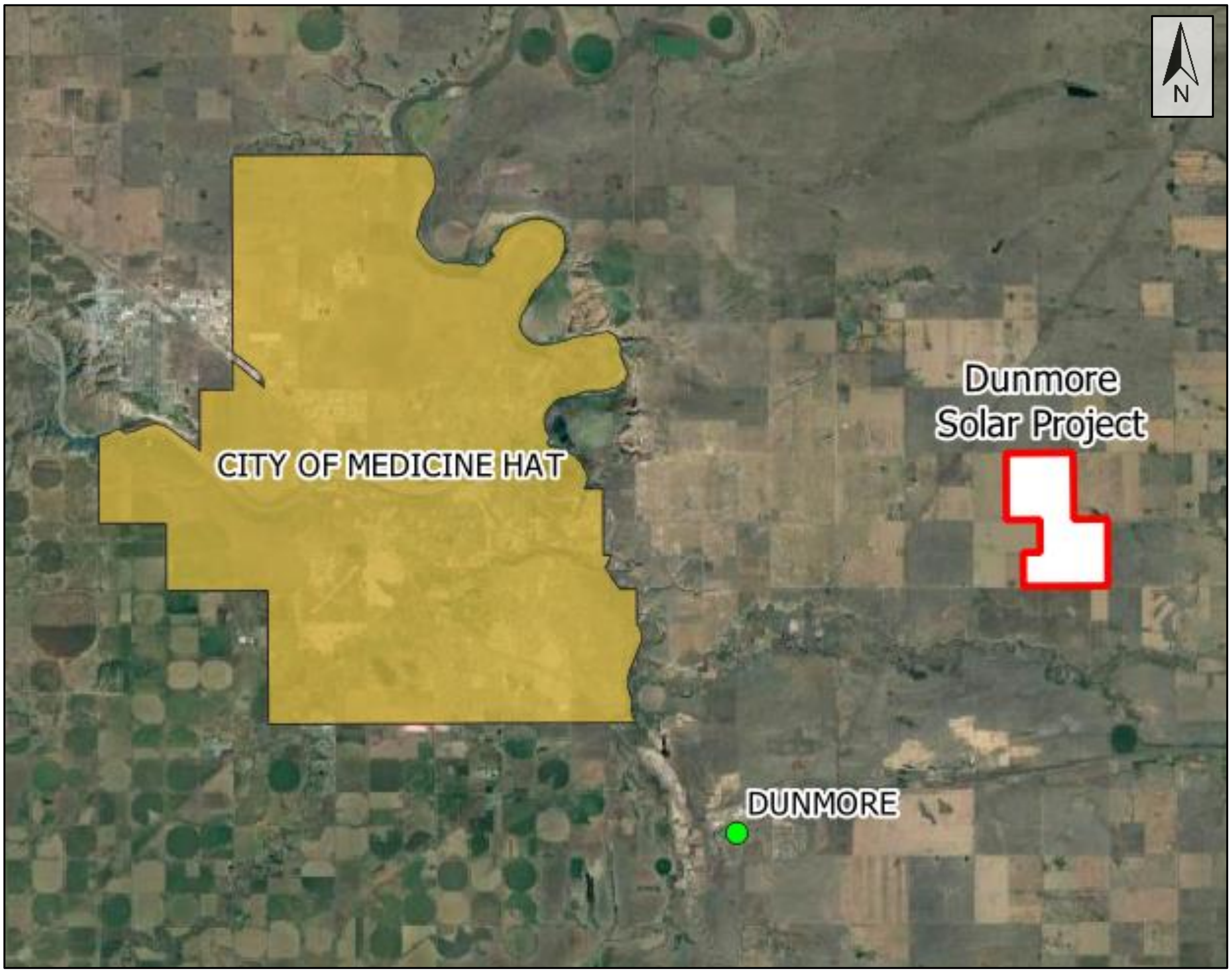

Figure 3-1 – Dunmore Solar Project Location

The Project covers an area of approximately 1,400 acres, with an array footprint of about 800 acres. The Project layout includes a total generating capacity of 205 MW_{AC}. It is understood that a future re-design may allow the project to up to 216 MW_{AC} of generating capacity. If the layout, array footprint and technology do not require significant updates, a capacity increase of this magnitude is not expected to materially change the results of the glare assessment. The PV modules will be mounted on fixed tilt racking secured to the ground with piles.

4 LEGISLATION AND GUIDANCE

There is currently no adopted legislation for assessing the impacts of glare for solar energy development, and standardized guidance only specifies what receptors to included in an assessment without guidelines for acceptable thresholds.

The AUC have released an update to *Rule 007* that will take effect September 1, 2021. *Rule 007* states that solar glare assessment reports must include receptors within 800m from the boundary of the project and aerodromes within 4,000m from the boundary of the project.[3] It continues to state the following requirements:

- Describe the time, location, duration, and intensity of solar glare predicted to be caused by the project.
- Describe the software or tools used in the assessment, the assumptions, and the input parameters (equipment-specific and environmental) utilized.
- Describe the qualification of the person performing the assessment.
- Identify the potential solar glare at critical points along highways, major roadways, and railways.
- Identify the potential solar glare at any aerodrome within 4,000 metres from the boundary of the project, including the potential effect on runways, flight paths and air traffic control towers.
- Include a map (or maps) identifying all solar glare receptors, critical points along highways, major roadways and railways, and aerodromes that were assessed.
- Include a table that provides the expected intensity of the solar glare (e.g., green, yellow, or red) and the expected duration of solar glare at each identified receptor, critical points along highways, major roadways and railways, and any registered and known unregistered aerodromes that were assessed.

This report will abide by: requirements in *Rule 007*; suggestions made in Zehndorfer Engineering's *Solar Glare and Glint Project Report* from September 2019[4], which was written to inform the AUC's update; and precedent set by recent AUC proceedings.

As observed in the Zehndorfer document, solar glare assessments in Canada typically utilize Sandia National Laboratories' Solar Glare Hazard Analysis Tool (SGHAT) through ForgeSolar's software called GlareGauge. Zehndorfer note that: "*the typical Solar Glare Assessment in Canada consists of more than just the plain SGHAT report. It describes the geometric situation, highlights glare duration and suggests glare-reducing measures.*"[5] This approach has been adopted for this assessment.

Zehndorfer also comment that: "*with respect to dwellings, geometrical considerations can be useful. The inclination angle towards a window makes a difference, because light rays perpendicular towards the glass will penetrate the window, while window recesses will shade flat-angled rays of light.*"[6]

[3] Bulletin 2020-30, *Rule 007 Draft Revised Version (August 2020).*
[4] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*
[5] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019) PDF page 8.*
[6] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019) PDF page 6.*

In addition to Zehndorfer's report, the US Federal Aviation Administration (FAA) have provided the *Technical Guidance for Evaluating Selected Solar Technologies on Airports*.[7] This document, last updated in April 2018, states that potential for glare might vary depending on site specifics such as existing land uses, location, and size of the project. A geometric analysis may be required to assess any reflectivity issues coming from the solar modules. FAA guidelines have also been informed by the 2015 study, *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach*, by Rogers, et al. This study concludes that glare of sufficient size and intensity in an airplane pilot's view, within ±25° of heading, may have an adverse impact on the pilot's ability to read their instruments or land their plane. The study also indicates that glare beyond ±50° of heading is not likely to impair a pilot.[8]

4.1 GEOMETRIC ANALYSIS – USE OF THE SOLAR GLARE HAZARD ANALYSIS TOOL (SGHAT)

The SGHAT is a validated tool specifically designed to estimate potential glare according to a Solar Glare Hazard Analysis Plot at a certain module height, tilt, type, and observer location. It is widely accepted as the most comprehensive tool to assess potential glare impacts to road users.

This software allows for the analysis of potential glare on flight paths, routes, and stationary observation points.

[7] *Technical Guidance for Evaluating Selected Solar Technologies on Airports, pg. 40 (FAA, April 2018).*
[8] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (Rogers, J. A., et al., July 2015).*

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5 ASSESSMENT METHODOLOGY

The SGHAT is configured to enable an analysis on flight paths using a 2-mile approach to a runway when landing. There is a private, unregistered airstrip approximately 3,900m northwest of the Project, so it has been included in this assessment.

The recent decision for Proceeding 25296 set out the AUC's understanding of the viewing angles relevant to pilots: *"The Commission understands the FAA study to conclude that yellow-grade glare has an adverse effect on pilots within a +/- 25 degree viewing angle range and that yellow-grade glare between 25 and 50 degrees has the potential to adversely affect pilots"*.[9] This suggests that flight paths approaching a runway should model a pilot's perspective looking straight out the cockpit windshield with a peripheral range of ±50° to provide context on potential glare during final descent. Further analysis of a narrower ±25° field of view (FOV) encompasses the region where a pilot's vision is more susceptible to glare impacts. Glare occurring outside of this range is less likely or not expected to adversely impact a pilot.[10] No airports were reported within 4,000m of the Project and thus no flight paths were considered in this assessment.

For ground-based routes, the Zehndorfer report recommends modelling the FOV within ±15° from the vehicle operator's heading.[11] This covers the region where a person's vision will be most focussed, which is the critical area of concern. A more conservative ±25° FOV can also be modelled to identify routes that may be peripherally impacted by glare. This wider FOV is based on the information presented in the Rogers report for airplane pilots, adapted to suit vehicle operators using ground-based routes. Both passenger and commercial vehicles are considered in the analysis.

In line with the blackline draft of AUC *Rule 007'*s guidelines for assessing the impacts of glare on dwellings and road users, the assessment evaluated:

- Five dwellings near the Project;
- Highway 41 (Buffalo Trail);
- Township Road 124; and
- A private, unregistered aerodrome.

Note, if the modules are not visible to the individual receptor then no glare can be observed at that receptor.

5.1 ASSESSMENT INPUT PARAMETERS

The solar arrays and transportation routes were plotted using an interactive Google map, and site-specific data was also entered into the software prior to modelling. The following sections provide details of the parameters specified for the analysis calculations in the GlareGauge software.

[9] *Decision 25296-D01-2021 (AUC, February 11, 2021), para. 53.*
[10] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (Rogers, J. A., et al., July 2015).*
[11] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*

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5.1.1 PV Array

The general PV array areas were plotted on the interactive Google map as shown on **Figure 5-1** on the following page. The Project was split into 34 sub-arrays to ensure each footprint covered less than 25 acres. If an array covers more than 25 acres, the accuracy of the model results become compromised by approximations used by the software. The modelled sub-arrays include more land than the proposed PV array coverage to avoid conflict between complex array geometry and software calculation limitations. This results in a more conservative analysis.

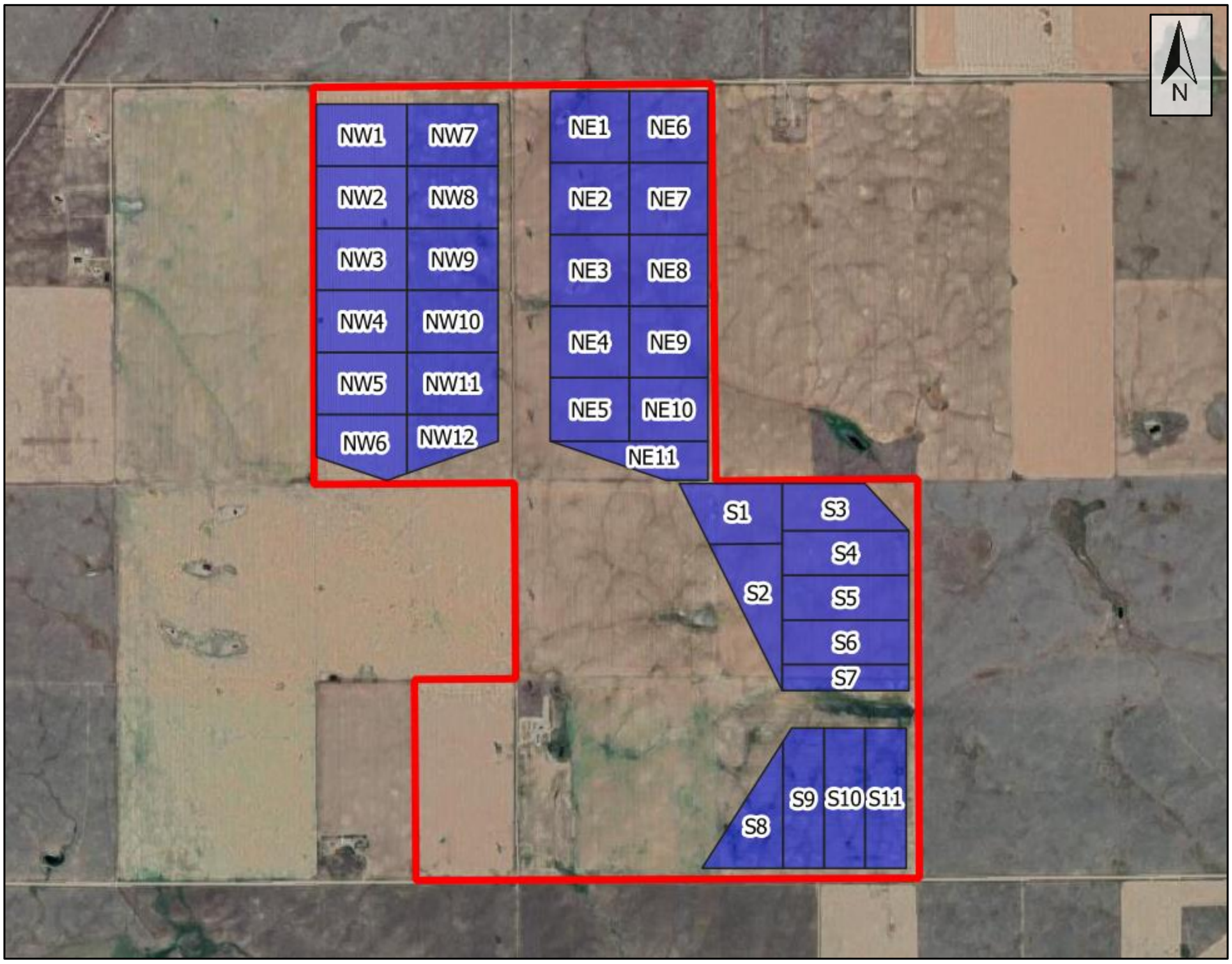

Figure 5-1 – General PV array areas plotted in GlareGauge software

The Project details in **Table 5-1** were specified in the model. Dunmore Solar had not finalized the racking design at the time of modelling, so GCR used a typical module ground clearance as the basis for the array heights.

Table 5-1 PV Array Specified Parameters

Required Inputs	Specified Parameters	Description
Axis Tracking	None	Modules are mounted on fixed tilt racking
Orientation	180° (south)	Azimuthal position measured from true north
Fixed Tilt Angle	20°	Fixed tilt angle of modules
Module Surface Material	Smooth glass with anti-reflective coating	Surface material of modules
Minimum Module Height Above Ground	0.5m	Approximate height at the bottom of the array
Maximum Module Height Above Ground	2.0m	Approximate height at the top of the array

Solar PV modules are designed to maximize light absorption and conversion to electricity. Specifying different types of glass and coatings used on the modules can affect a system's energy production and glare potential. Smooth glass with anti-reflective coatings will generally reflect less light, i.e., create less glare, than uncoated glass. Incorporating texture into the glass surface will also help diffuse incident light, reducing the intensity of the reflection.

Both the minimum and maximum module heights are modelled to show the variance in potential glare from different parts of the arrays. Longer durations of glare are often predicted for the bottom module elevation than the top, but the lower parts of arrays are more likely to be visually screened by other rows of arrays in practice (which is not modelled by GlareGauge). Glare results are not additive between the evaluated heights, and glare time frames predicted for each height typically coincide.

The elevation variation across the site is minimal, ranging from 746m to 772m above mean sea level (AMSL). Ground elevations are generally lower in the southern half of the Project than the north half.

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5.1.2 Route Paths

Two route paths were evaluated for glare impacts from the Project. Sections of Highway 41 and Township Road 124 within approximately 800m of the Project boundary were modelled as two-way routes to represent vehicles travelling in both possible directions. **Figure 5-2** shows the routes in relation to the Project. Township Road 130 at the north end of the Project boundary was not included in the analysis because drivers travelling on this road will not be able to see the reflective front faces of the solar modules. The combination of the array orientation, tilt, and relative locations of the arrays and road will not allow glare to reflect from the Project onto Township Road 130.

Two horizontal viewing angles were evaluated for motorists: ±15° and ±25° (30° and 50° total field-of-view). The ±15° range encompasses the region where a person's vision will be most focussed, which is the critical area of concern.[12] The ±25° range is a more conservative view that indicates the routes that may be impacted by glare. The road routes were set at 1.5m elevation to represent the typical height of passenger vehicles and 3.0m to represent the typical height of commercial trucks. Commercial vehicles are typically more susceptible to glare than passenger vehicles due to their increased height.

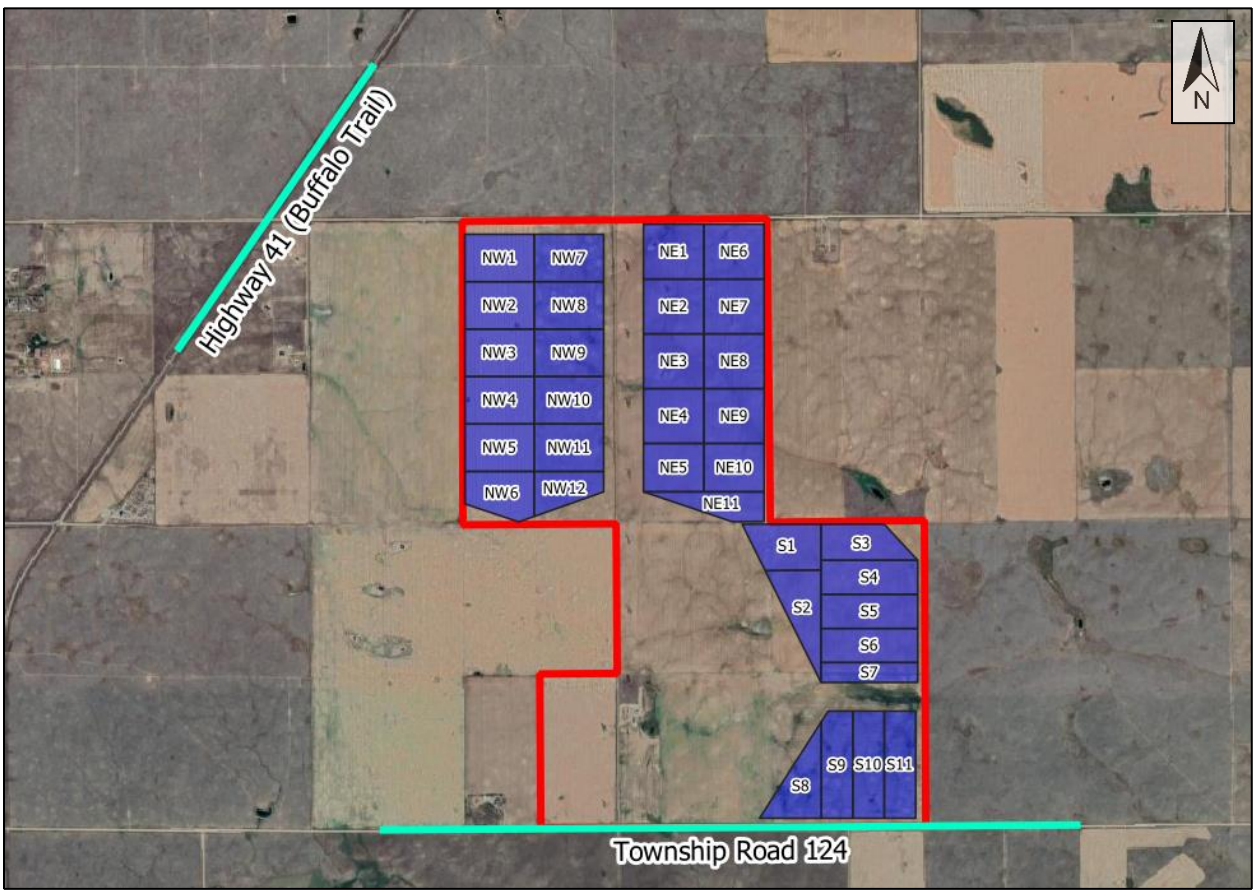

Figure 5-2 – Roads near the Project

[12] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*

5.1.3 Dwellings

Five dwellings were assessed within approximately 800m of the Project boundary. Dwellings were modelled at 4.5m above ground to represent the worst-case scenario where an observer can see the Project from a second-storey window. The model assumes that receptors have an unobstructed view of the arrays, i.e., the view is not affected by any part of the building being evaluated. **Figure 5-3** shows the dwellings in relation to the Project.

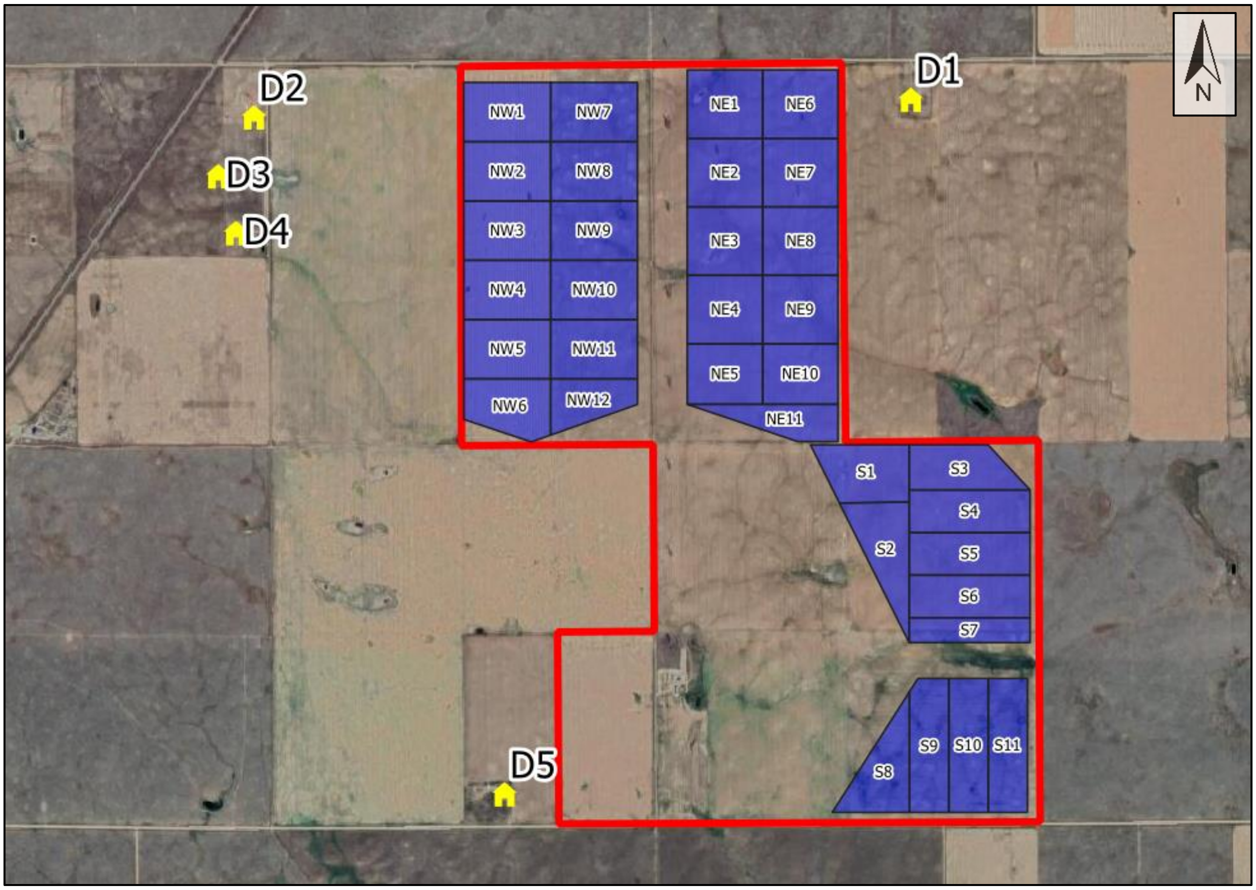

Figure 5-3 – Dwellings near the Project

5.1.4 Flight Paths

Two flight paths approaching a private, unregistered aerodrome 3,900m northwest of the Project were included in this glare assessment. This is an uncontrolled aerodrome, so it was not necessary to model an air traffic control tower. The receptors at the aerodrome can be seen in **Figure 5-4**.

The two-mile (3.2km) long flight paths utilize a typical glide slope of three degrees, ending 50 feet (15m) above the runway threshold. The SGHAT simulates flight paths with a maximum downward viewing angle of 30° from horizontal, accounting for obstructions in the cockpit below the windshield. This analysis has set the horizontal viewing angle for airplane pilots to ±50° from center (100° total field-of-view). This encompasses a conservative region where glare may affect a pilot while landing their airplane. A ±25° horizontal range has also been modelled as this is the region where yellow-grade glare is expected to adversely impact pilots.[13] Glare occurring outside of this range is not expected to adversely impact the pilot.

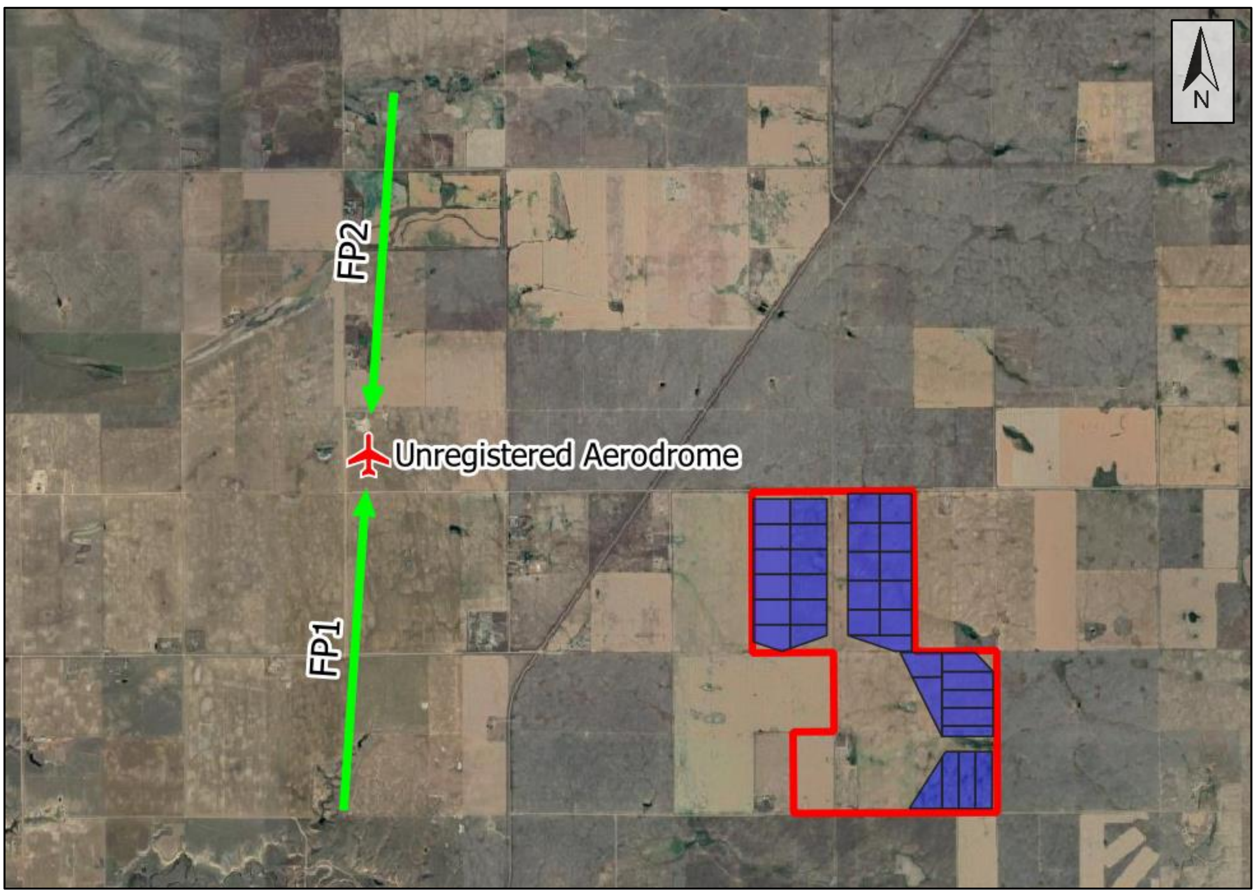

Figure 5-4 – Flight Paths near the Project

[13] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (Rogers, J. A., et al., July 2015).*

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5.1.5 Other Assumptions

The following assumptions have been made in setting the parameters for this analysis:

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not account for physical obstructions between reflectors and receptors that may mitigate impacts. This includes buildings, tree cover and geographic obstructions.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values may differ.
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare analysis does not account for change in weather patterns. It is assessed as clear sunny skies throughout the year.
- To increase accuracy of modeling results, parts of the array may be divided into sub-sections if the footprint covers a large surface area.
- Default parameters, as alluded to in the following section, highlight ocular metrics used in this assessment as has been acceptable according to the Sandia National Laboratories methodology on assessing potential glint and glare hazards.[14] These are shown below in **Table 5-2.**

Table 5-2 Default Parameters

Glare Gauge Parameters	
Direct Normal Irradiance, DNI (amount of solar radiation received in a collimated beam on a surface normal to the sun during a 60-minute period)	Varies and peaks at 1000 W/m^2
Ocular Transmission Coefficient (absorption of radiation within the eye before it reaches the retina)	0.5
Pupil Diameter (Typical daylight adjusted length)	0.002m
Eye Focal Length (distance where rays intersect in the eye)	0.017m
Sun Subtended Angle	9.3 mrad

[14] *Ho, C.K., C.M. Ghanbari and R.B. Diver, 2011, Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation, Journal of Solar Energy Engineering-Transactions of the ASME, 133 (3)*

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5.2 GLARE ANALYSIS PROCEDURE

Although effects from glare are subjective, depending on variables such as a person's ocular parameters and size/distance from the glare source, the SGHAT has a generalized approach to specify the hazard that glare may produce. GCR calculated the potential glare for observation points and route receptors using the SGHAT. GCR's commentary on the levels of glare found and related sources of mitigation, if required, are intended to help decisionmakers evaluate potential impacts.

The SGHAT User's Manual v3.0[15] states that: *"If glare is found, the tool calculates the retinal irradiance and subtended source angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results are presented in a simple, easy-to-interpret plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard."*

The colour codes are based on a red, yellow, and green structure to categorize the level of danger to a person's eyes. Glare classification is dependent on the glare intensity and the apparent size of the glare area as viewed from the eye. The severity of glare is proportional to the effects of an after-image, which can be described as a lingering image of glare in the field of view, or a flash blindness when observed prior to a typical blink response time. The descriptions for each category are as follows:

- Green: Glare is present but there is a low potential for temporary after-image;
- Yellow: Glare is present with the potential for temporary after-image; and
- Red: Glare is present with the potential for permanent eye damage.

The level of glare is derived using the graph below that plots the level of irradiance against the angle that is occupied by the glare in the field-of-view.

ForgeSolar have developed a plot to categorize glare based on its intensity at the eye and its size in the observer's field-of-view. The plot is divided into the red, yellow, and green regions described above. The hazard associated with directly viewing the sun unfiltered is also plotted for comparison. **Figure 5-5** shows an example of the hazard plot.

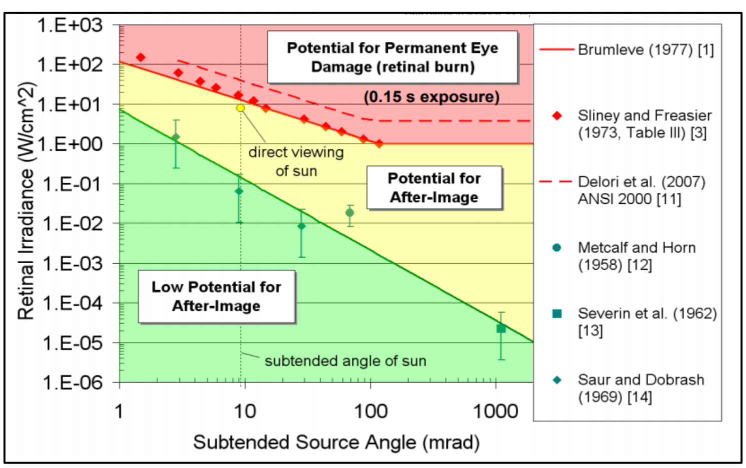

Figure 5-5 – Hazard plot depicting the retinal effects of light

[15] *Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v 3.0, Ho and Sims, Sandia National Laboratories, 2016.*

Ho et al. developed a model to estimate potential impacts to eyesight with regards to retinal irradiance (amount of light entering the eye and reaching the retina) and subtended source angle (the size of the glare divided by the distance from the emitting source). Significant damage, including retinal burn, may occur at high retinal irradiances and large subtended angles. This is highlighted in the red region. The yellow section denotes the potential for a temporary after-image. The size and impact of the after-image is dependent upon the subtended source angle.[16] At a low retinal irradiance and small subtended angle, the hazard will be in the green section where there is very low potential for after-image.

5.2.1 Limitations

The SGHAT utilizes the central point of a PV array for some calculations, rather than the actual glare spot location, due to algorithm limitations. This may affect the results for large PV footprints, so large arrays can be broken into smaller sub-sections to provide additional information on expected glare. This primarily affects the analysis of flight path receptors;[17] however, it is considered for dwellings and roadways as well. The SGHAT provides a warning to the user if the PV array encompasses too large of a surface area. It states the size of the array *"may reduce the accuracy of certain calculations if receptors are near the array."*

The SGHAT will convert the footprint of a concave polygon to a convex polygon.[18] For example, an array that is in the shape of a 'C' has a concave section and GlareGauge will modify the 'C' shape into a semi-circle. By closing the 'C' shape, the size of the PV array is increased thus potentially over-estimating the size of the array, and consequently over-predicting the glare effects. This change in geometry is required by the glare-check algorithm during analysis. Large PV arrays with concavities should be modelled as multiple arrays to avoid over-estimating the size of the PV array and the resultant glare.

The limitations of the software have been carefully considered to ensure the PV array was not too large and the shape of the array is not concave in order to represent the glare impacts as accurately as possible.

An unavoidable limitation of the SGHAT is that a *"random number of computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including [air traffic control towers]."*[19]

[16] *Evaluation of glare at the Ivanpah Solar Electric Generating System, C.K. Ho et al., Elsevier Ltd., 2015.*
[17] *ForgeSolar "Help" page.*
[18] *ForgeSolar "Help" page.*
[19] *ForgeSolar "Help" page.*

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6 ASSESSMENT OF IMPACT

The following section presents the findings of the glare assessment. The results are factual based on the model parameters used, which are considered to be as realistic as possible. AUC *Rule 007* provides guidelines for the receptors to be included in a solar glare assessment, but modelling parameters and glare threshold limits are not specified. Therefore, this analysis also considers the principles laid out in the Zehndorfer Engineering Report[20] and recent AUC proceedings, as described in **Section 5**.

The GlareGauge software considers the glare potential for a full one-year period in one-minute intervals to account for the variations between seasons, DNI, and sun angle.

6.1 ROUTE PATH RESULTS

The tables below present the glare results for the route paths assessed from the minimum and maximum module heights. Results are shown for passenger and commercial road vehicles at 1.5m and 3.0m above ground, respectively. Results in **Table 6-1** used a ±15° FOV, which was modelled to capture potential glare within a vehicle operator's critical visual range. Results in **Table 6-2** were evaluated with a ±25° horizontal FOV to highlight routes that may experience glare from an extended visual range. Equivalent levels of glare within ±15° will have a greater impact on the observer than glare outside that range.

Table 6-1 Annual route path glare levels for passenger and commercial vehicles and trains, ±15° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)	
Module Height	*0.5m*	*2.0m*	*0.5m*	*2.0m*	*0.5m*	*2.0m*
Highway 41 (passenger)	0	0	0	0	0	0
Highway 41 (commercial)	0	0	0	0	0	0
Township Road 124 (passenger)	3	0	833	77	0	0
Township Road 124 (commercial)	1	3	1,707	833	0	0

Table 6-2 Annual route path glare levels for passenger and commercial vehicles and trains, ±25° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)	
Module Height	*0.5m*	*2.0m*	*0.5m*	*2.0m*	*0.5m*	*2.0m*
Highway 41 (passenger)	0	0	0	0	0	0
Highway 41 (commercial)	0	0	0	0	0	0
Township Road 124 (passenger)	11	0	834	77	0	0
Township Road 124 (commercial)	21	11	1,712	834	0	0

Township Road 124 is adjacent to the southern edge of the Project, coming within approximately 50m of the nearest arrays. Drivers of commercial vehicles on this road are expected to be the most-impacted receptors on roadways near the Project. Considering a ±15° FOV, observers driving along this road are expected to see yellow glare for a maximum of 1,707 minutes/year. The glare is predicted from late March to September around 06:15 MST for up to seven minutes per day, and 18:30 MST for up to eight minutes

[20] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*

per day (up to 15 minutes/day total).[21] The predicted glare is split into distinct morning and evening periods because both directions of travel were modelled for the route. Drivers travelling east will see glare during the morning, while drivers travelling west will see glare during the evening. The glare originates from the same general direction as the sun for these periods and directions of travel, so the glare impact may be eclipsed by the direct effects of the sun. More glare is expected to originate from the lower module elevations than the higher elevations for this receptor, and the change between FOVs is insignificant.

The figures below represent the predicted glare for commercial vehicles on Township Road 124 from the bottom of the arrays, assuming there are no obstructions between the arrays and receptor. Results are presented for a ±15° FOV. **Figure 6-1** shows the daily time periods during which glare is predicted, and **Figure 6-2** shows the daily duration of predicted glare.

Figure 6-3 presents the glare hazard plot for glare expected to affect commercial vehicles with a ±15° FOV on Township Road 124. The hazard plot shows that the yellow glare seen from the route will have approximately 10 times the subtended angle as the sun, but it will be around 470 times dimmer than the sun. The glare is also around two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation. The glare for this route is expected to originate from sub-arrays S8-11 in the southern-most portion of the Project.

[21] *These results apply to a portion of the route, not just a single point along the road. The results describe a time period during which a vehicle operator may see glare from the Project arrays, but it is highly unlikely that an observer will be affected by the glare for the full duration. A vehicle operator will only see a fraction of the glare since they will be travelling past the area, not standing still while looking at the solar PV arrays.*

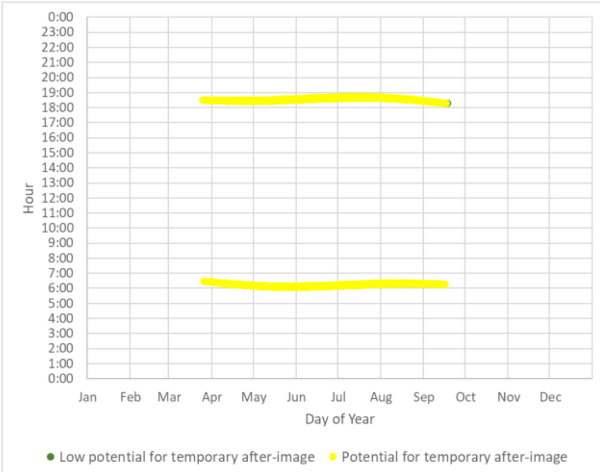

Figure 6-1 — Annual predicted glare occurrence for TWPRD124C, ±15° FOV

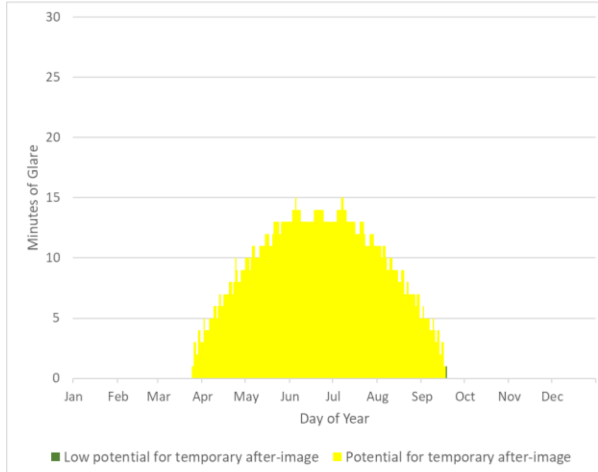

Figure 6-2 — Daily duration of glare for TwpRd124C, ±15° FOV

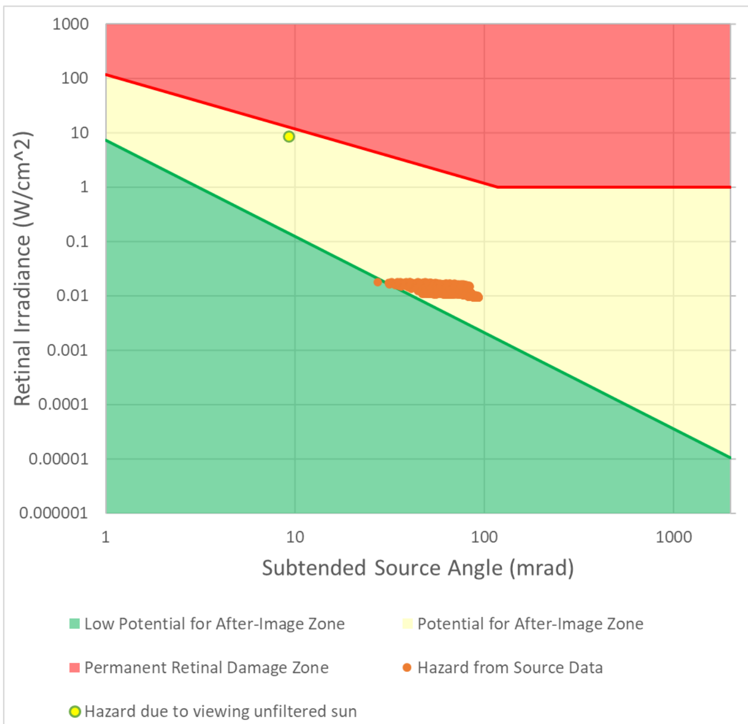

Figure 6-3 — Hazard plot for TWPRD124C, ±15° FOV

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6.2 DWELLING RESULTS

The dwellings were assessed at 4.5m above ground to represent the worst-case scenario where an observer can see the Project from a second-storey window. **Table 6-3** below provides the glare results for the dwelling assessed at the minimum and maximum module heights.

Table 6-3 Annual glare levels for dwellings assessed at a second-storey elevation (4.5m)

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)	
Module Height	***0.5m***	***2.0m***	***0.5m***	***2.0m***	***0.5m***	***2.0m***
D1	11	5	2,146	2,573	0	0
D2	290	337	515	416	0	0
D3	1,040	1,114	699	386	0	0
D4	1,671	1,601	1,417	1,607	0	0
D5	1,211	1,274	233	265	0	0

Dwelling D1 is located approximately 350m east of the north section of the Project. Observers at this location are expected to see yellow glare for a maximum of 2,573 minutes/year. The glare is predicted from March to September around 18:25 MST for up to 28 minutes/day. There is also a significant decrease in glare during summer months. The glare originates from the same general direction as the sun for these periods, so the glare impact may be eclipsed by the direct effects of the sun. More glare is expected to originate from the higher module elevations than the lower elevations for this receptor.

The figures below represent the predicted glare for D1 from the top of the arrays. **Figure 6-4** shows the daily time periods during which glare is predicted, and **Figure 6-5** shows the daily duration of predicted glare.

Figure 6-6 presents the glare hazard plot for glare expected to affect D1. The hazard plot shows that the glare seen from D1 will have approximately seven times the subtended angle as the sun, but it will be around 445 times dimmer than the sun. The glare is also over two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation. The glare at D1 is expected to originate from the northern-most Project arrays (sub-arrays NE1, NE6, NW1, and NW7).

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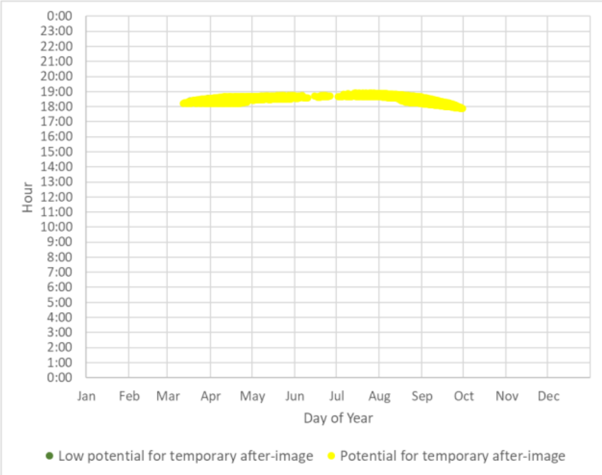

Figure 6-4 — Annual predicted glare occurrence for D1

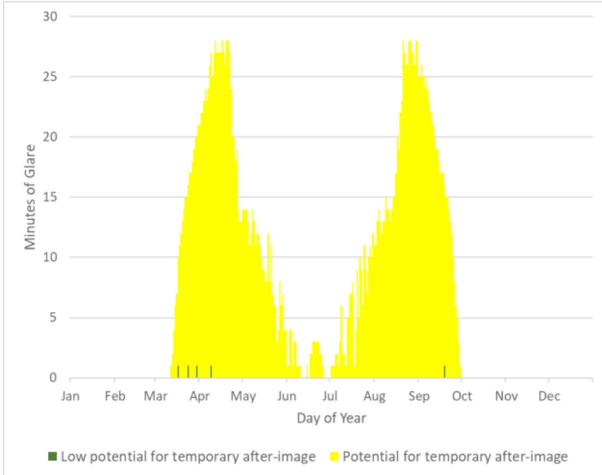

Figure 6-5 — Daily duration of glare for D1

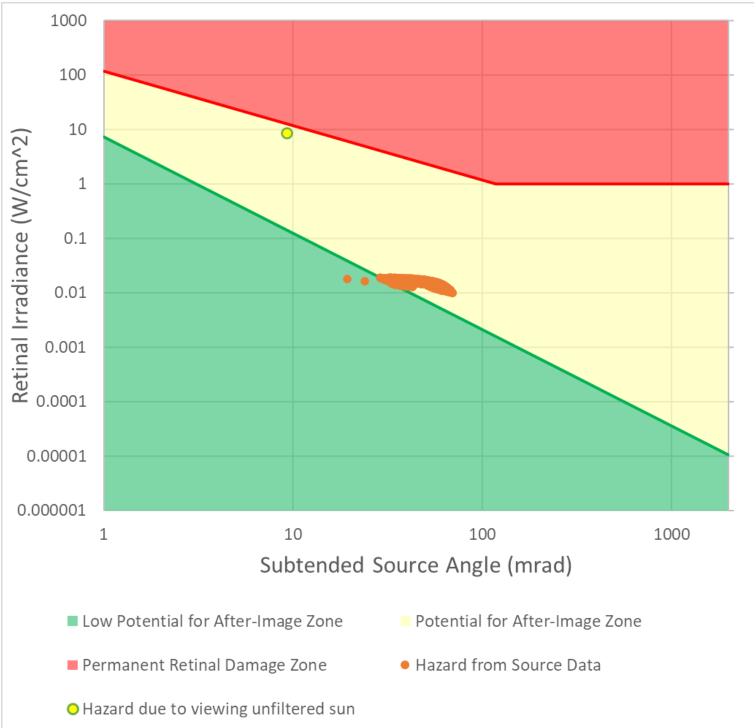

Figure 6-6 — Hazard plot for D1

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6.3 FLIGHT PATH RESULTS

Table 6-4 below presents the glare results for the flight paths assessed from the minimum and maximum module heights. The flight paths were evaluated with a conservative ±50° horizontal field-of-view to capture potential glare a pilot may see while landing an airplane. The flight paths were also modelled with a ±25° FOV to assess glare within a pilot's critical visual range. Equivalent levels of glare within ±25° will have a greater impact on the observer than glare outside that range.

Table 6-4 Annual glare levels for Unregistered Aerodrome Flight Paths

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)	
Module Height	***0.5m***	***2.0m***	***0.5m***	***2.0m***	***0.5m***	***2.0m***
FP1 (±50° FOV)	0	0	0	0	0	0
FP1 (±25° FOV)	0	0	0	0	0	0
FP2 (±50° FOV)	0	0	0	0	0	0
FP2 (±25° FOV)	0	0	0	0	0	0

There is no red, yellow, or green glare predicted for any of the flight paths when assessed at the minimum and maximum module heights.

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7 SUMMARY

Solar modules are specifically designed to absorb light rather than reflect it. Moreover, most modules are now manufactured with anti-reflective coatings that help further mitigate the intensity of reflections.

The assessment of the Dunmore Solar Project was undertaken using GlareGauge software. The results are based on the assumptions and limitations set out in previous sections of this report. The arrays were modelled at the minimum and maximum module elevations with a 20° fixed tilt angle, oriented due south. Array heights were not available, so the model was specified with a typical module ground clearance as a basis for the analysis.

The ground-based route paths assessed for glare impacts included both directions of travel on Highway 41 and Township Road 124 within approximately 800m of the Project. The road routes were modelled at both passenger vehicle and commercial vehicle heights. All routes were evaluated with a horizontal viewing angle of ±15° to capture potential glare within a vehicle operator's critical visual range, as well as ±25° to identify routes that may observe peripheral glare.

Highway 41 is not expected to observe glare at any level from the Project. Township Road 124 is expected to observe the most glare of the modelled routes, especially at commercial vehicle heights. Short durations of yellow glare may be observed between late March and September in the morning and evening, depending on the direction of travel. It is highly unlikely that an observer will be affected by the full duration of glare in the predicted periods. Vehicle operators will only see a fraction of the predicted glare since they will be travelling past the site, not standing still while looking at the solar PV arrays. Based on satellite imagery, all roads anticipated to observe glare are rural gravel or dirt roads that are not expected to have high traffic volumes. The level of glare predicted along the transportation routes is not expected to create hazardous conditions.

There are five dwellings within approximately 800m of the Project and evaluated in this assessment. Dwellings were evaluated at a height of 4.5m above ground to represent an observer looking out a second-floor window toward the Project to provide a conservative analysis. Observers in dwelling D1, the most-impacted residence, are expected to observe short durations of glare from the Project in the evenings between March and September. The glare originates from a direction similar to the sun during these periods, so the direct sunlight may lessen the perceived glare impact. The level of glare predicted at the observation points is not expected to create hazardous conditions or have a significant adverse effect on residents.

A private, unregistered aerodrome was identified within 4,000m of the Project. Two flight paths approaching the airport were evaluated in the analysis, utilizing a horizontal viewing angle of ±50° to assess potential glare within a pilot's peripheral visual range, as well as a ±25° FOV for a pilot's critical visual range. Neither of the flight paths are expected to experience glare at any level. As no glare is predicted, no mitigation is required for the flight paths.

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8 CONCLUSION

In conclusion, the Dunmore Solar Project is not likely to have the potential to create hazardous glare conditions for the dwellings or transportation routes assessed. The private, unregistered aerodrome is not anticipated to be affected by glare from the Project. The actual glare impacts that will be experienced in the field along ground-based routes are anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the solar PV arrays. Glare predicted to affect dwellings is minor in intensity and is not expected to have a significant adverse effect on residents. Observers are also expected to simultaneously see direct sunlight originating from the same general direction as the glare, so glare impacts may be less pronounced.

9 GLARE PRACTITIONER'S INFORMATION

Table 9-1 summarizes the information of the co-authors and technical reviewer of the solar glare hazard analysis.

Table 9-1 Summary of practitioners' information

Name	Jason Mah	Cameron Sutherland
Title	Renewable Energy EIT	Technical Director
Role	Glare Analyst, Co-Author	Technical Reviewer, Co-Author
Experience	– Analyst on 30+ glare assessments in Alberta and the USA – Technical support for AUC information requests and hearings – BSc Chemical Engineering	– Expert witness experience in technical solar development in Canada for Brooks II Solar Project, East Strathmore Solar Project, and Fox Coulee Solar Project – Technical oversight, technical review, or authorship of 30+ glare assessments for 20+ proceedings in Alberta – MSci Physics – MSc Renewable Energy Systems Technology

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