DRAFT

OCOTILLO WELLS SOLAR PROJECT

FIXED PHOTOVOLTAIC PANEL GLARE STUDY

September 16, 2013 | Prepared by POWER Engineers for The Gildred Companies

the GILDRED companies

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POWER ENGINEERS

Ocotillo Wells Solar Project
Draft Fixed Photovoltaic Panel Glare Study

PREPARED FOR: *GILDRED BUILDING COMPANIES*
PREPARED BY: *POWER ENGINEERS*

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ACRONYMS AND ABBREVIATIONS

3D	Three-dimensional
KOP	Key Observation Point
MW	megawatts
NAIP	National Agriculture Imagery Program
NED	National Elevation Dataset
POWER	POWER Engineers, Inc.
Project	Ocotillo Wells Solar Project
PV	Photovoltaic
CPV	Concentrating Photovoltaic

1.0 INTRODUCTION

POWER Engineers, Inc. (POWER) has prepared three glare studies for Gildred Building Companies' Ocotillo Wells Solar Project (Project). This report specifically addresses the potential effects related to fixed photovoltaic (PV) panel technology. The other two reports discuss single axis and dual axis tracking concentrating photovoltaic (CPV) technologies (POWER 2013a, 2013c).

The proposed Project is located in northeastern San Diego County, just east of the community of Ocotillo Wells, California (see Figure 1). The proposed Project may utilize fixed PV solar arrays producing up to 42 megawatts (MW) of electricity. The panels would be oriented along an east-west axis generally facing to the south to maximize solar absorption during the daylight hours (see Figure 2). Specifically, this study answers the following questions related to fixed PV technology:

- Will glint/glare be visible to sensitive visual receptors (see Section 3.1)?
- If glint/glare is visible, how long will it occur, where will it occur and when will it occur (see Section 4.0)?
- If glare does occur, what is it comparable to (see Section 5.0)?

2.0 DEFINITIONS AND DESCRIPTIONS

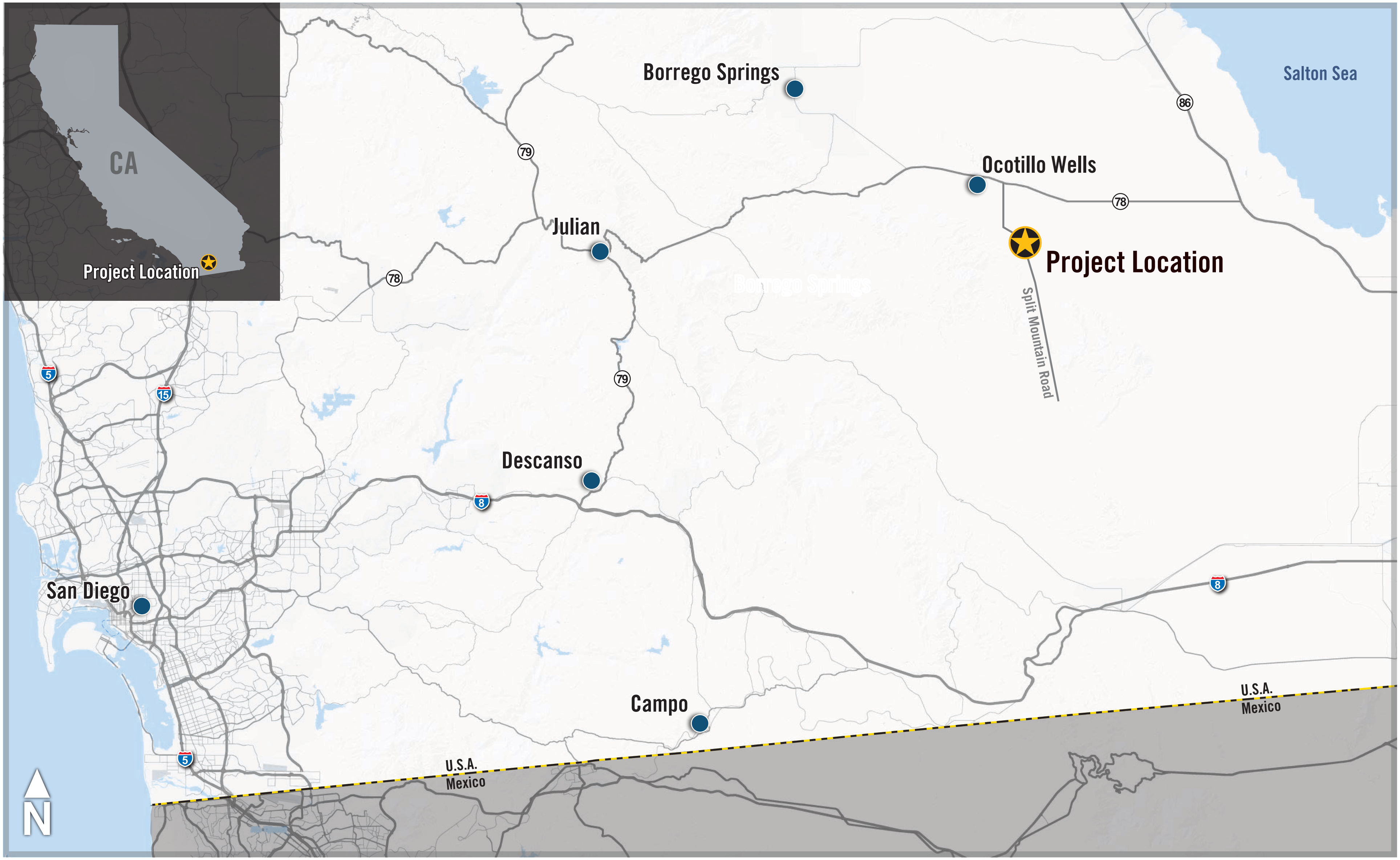
The following definitions and descriptions are important to understanding the methodology and results of the study:

Fixed Photovoltaic Panel – Photovoltaic panels, also known as PV panels, are designed to absorb solar energy and retain as much of the solar spectrum as possible in order to produce electricity. The Project will utilize fixed PV panels, mounted directly to a stationary foundation (see Figure 3).

Glare – A continuous source of brightness, relative to diffuse or surface scattered lighting. For purposes of this study, glare is caused by the sun reflecting off solar panels (see Figure 4).

3D Geometric Analysis – A computer simulation incorporating a 3-dimensional (3D) terrain model, 3D solar equipment, and a solar algorithm to determine the date, time and duration of glare which may be visible during the landing approach.

Key Observation Points (KOP) – KOPs refer to viewers with potential sensitivity to glare. For this study, KOPs included sensitive public vantage points and residential structures within 1.5 miles of the Project (see Section 3.1).



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Ocotillo Wells Solar Project - Glare Study

Figure 1 - Project Location

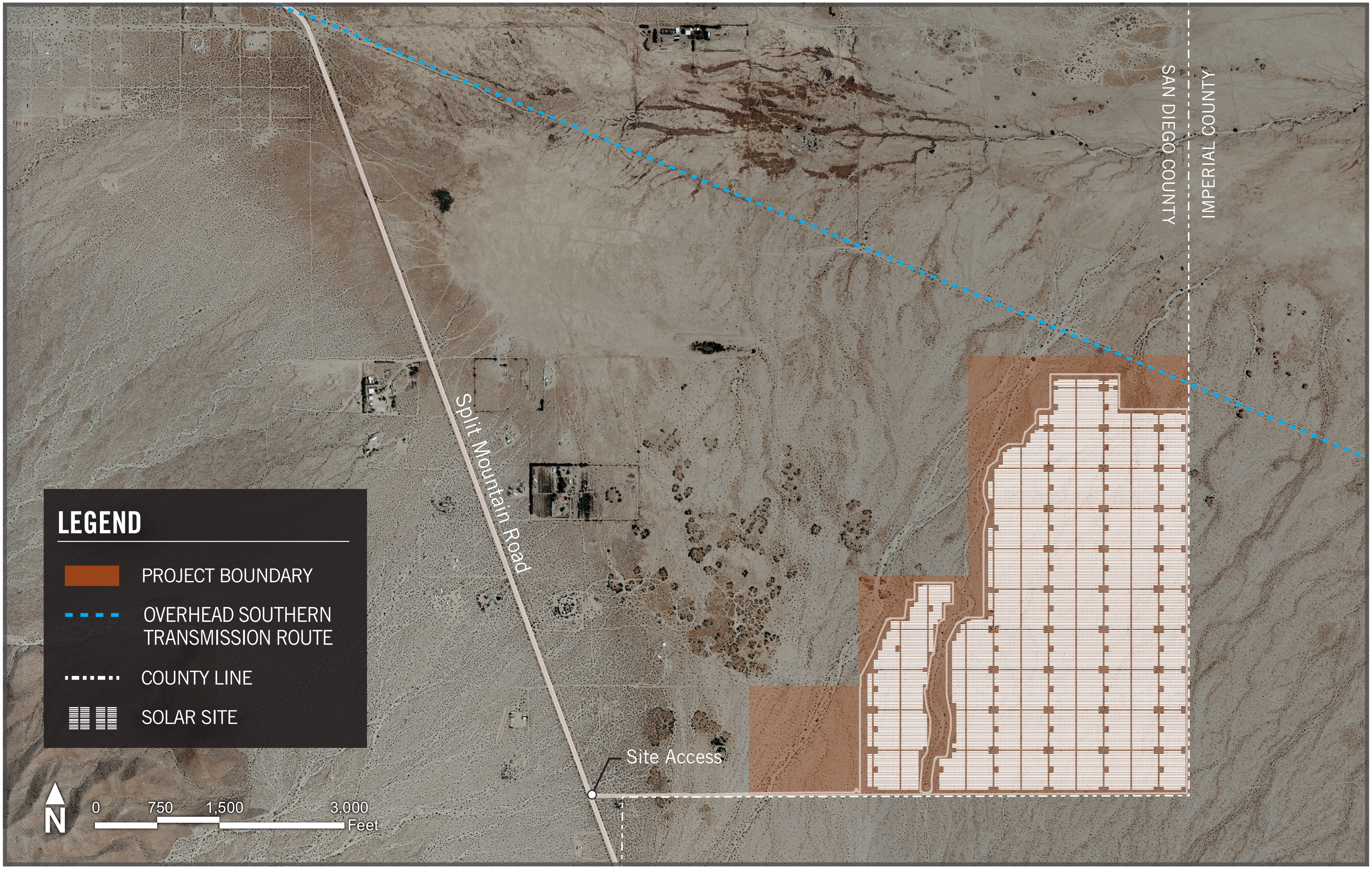

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Figure 2 - Site Map

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Figure 3 - Fixed Photovoltaic Panel

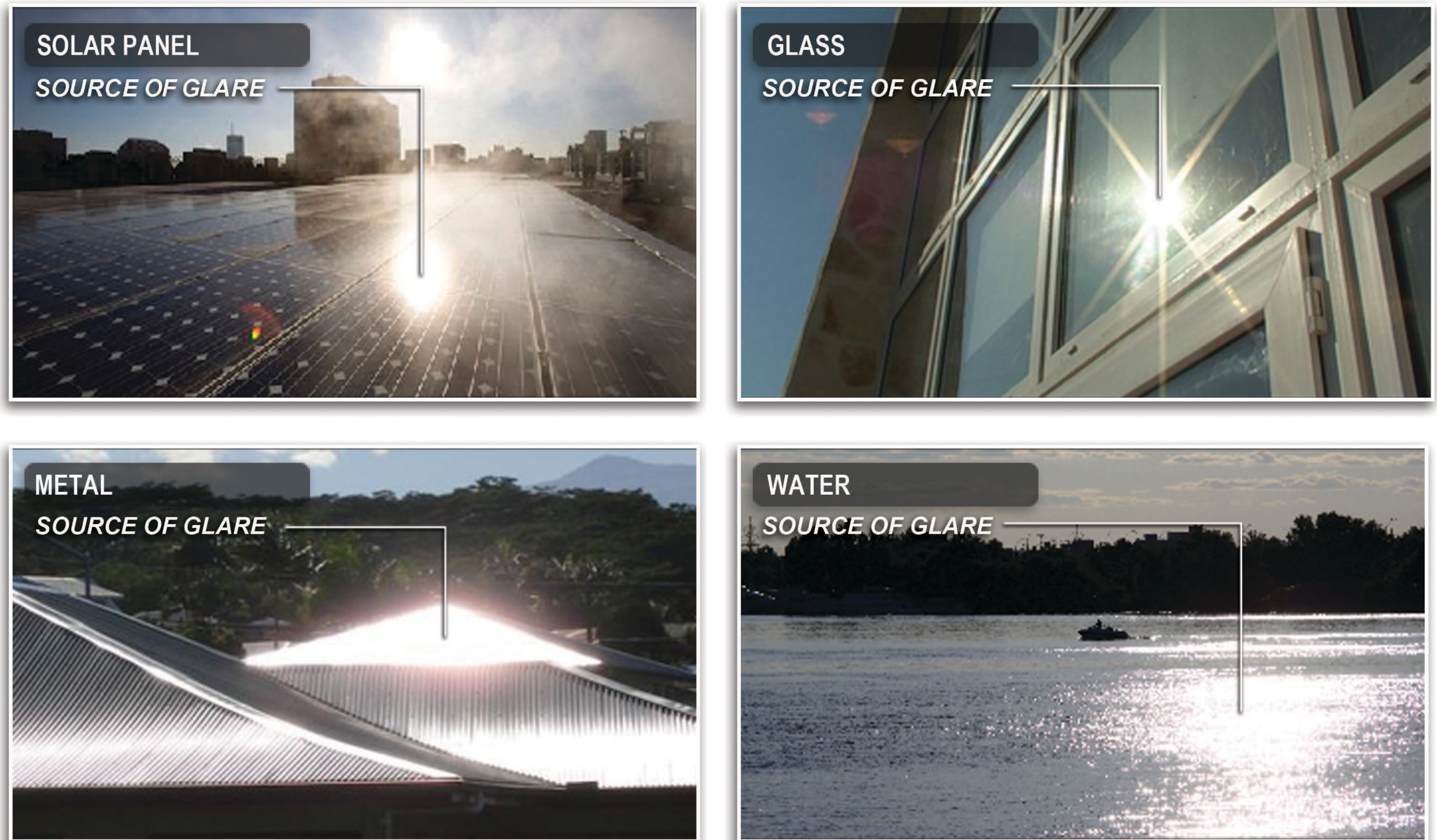

Figure 4 - Examples of Glare

3.0 METHODOLOGY

This study was commissioned by The Gildred Companies to determine if glare from proposed solar operations would be visible to any nearby residential locations, transportation, and recreational viewers. The analysis considers the changing positions of the sun throughout the day and year, and its influence on a fixed PV panel. POWER used the following methodology to determine the location and duration of glare:

1. *Identify Potential Glare Issues* – This study focused on potential issues where glare may be visible to sensitive viewers. The findings are based on these locations (see Section 3.1).

2. *Characterize Glare Behavior* – 3D simulations were developed to accurately create and study glint/glare based on the behavior of the solar equipment (see Section 3.2). 3D elements within the digital scene included terrain models, 3D solar equipment, and a 3D sun system. This information was assembled in a 3D computer program to create an accurate virtual representation of the Project and surrounding area (see Section 3.3).

3. *Evaluate* – Visual analysts studied the 3D simulations under different lighting conditions and at different times of the year. These simulations were used to evaluate and document when glare may be visible to KOPs. The results of this evaluation can be found in Section 4.0.

3.1 KOPs

Solar operations were studied from four public KOPs (KOPs A-D, see Figure 5A) and 16 residential locations (KOPs 1-16, see Figure 5B). Public KOPs were provided by The Gildred Companies. Residential KOPs include residential structures within 1.5 miles of the Project Site. Residences beyond 1.5 miles were not included because no glare is possible due to minimal glare angles from the resulting technology. Impacts to the Ocotillo Airport operations were considered but omitted from this study due to orientation and distance from the Project. Each KOP is described below:

- **KOP A** – View from State Highway 78 approximately three miles north of the proposed technology. Viewers from this location would mainly consist of vehicles traveling along State Route 78.
- **KOP B** – View from Split Mountain Road adjacent to the existing San Felipe Substation approximately 1.85 miles northwest of the proposed technology. Viewers from this location would mainly consist of vehicles traveling along Split Mountain Road.
- **KOP C –** View from Anza-Borrego Desert State Park approximately 1.25 miles southwest of the proposed technology. Viewers from this location would mainly consist of vehicles and visitors traveling within the State Park, utilizing trails or other recreational facilities.
- **KOP D** – View from Split Mountain Road to the Project site located approximately 0.3 mile west of the proposed technology. Viewers from this location would mainly consist of vehicles traveling along Split Mountain Road.

- **KOP 1 -** The residential structure located approximately 5,900 feet northwest of the proposed technology.
- **KOP 2 -** The residential structure located approximately 4,750 feet northwest of the proposed technology.
- **KOP 3 -** The residential structure located approximately 4,150 feet northwest of proposed technology.
- **KOP 4 -** The residential structure located approximately 6,600 feet west of the proposed technology.
- **KOP 5 -** The residential structure located approximately 5,050 feet west of the proposed technology.
- **KOP 6 -** The residential structure located approximately 5,000 feet west of the proposed technology.
- **KOP 7** - The residential structure located approximately 5,400 feet west of the proposed technology.
- **KOP 8 -** The residential structure located approximately 4,150 feet west of the proposed technology.
- **KOP 9 -** The residential structure located approximately 4,550 feet west of proposed technology.
- **KOP 10 -** The residential structure located approximately 3,600 feet west of the proposed technology.
- **KOP 11 -** The residential structure located approximately 2,450 feet west of the proposed technology.
- **KOP 12 -** The residential structure located approximately 1,850 feet west of proposed technology.
- **KOP 13 -** The residential structure located approximately 4,050 feet west of the proposed technology.
- **KOP 14 -** The residential structure located approximately 4,200 feet west of the proposed technology.
- **KOP 15 -** The residential structure located approximately 1,650 feet west of the proposed technology.
- **KOP 16 -** The residential structure located approximately 3,550 feet west of the proposed technology.

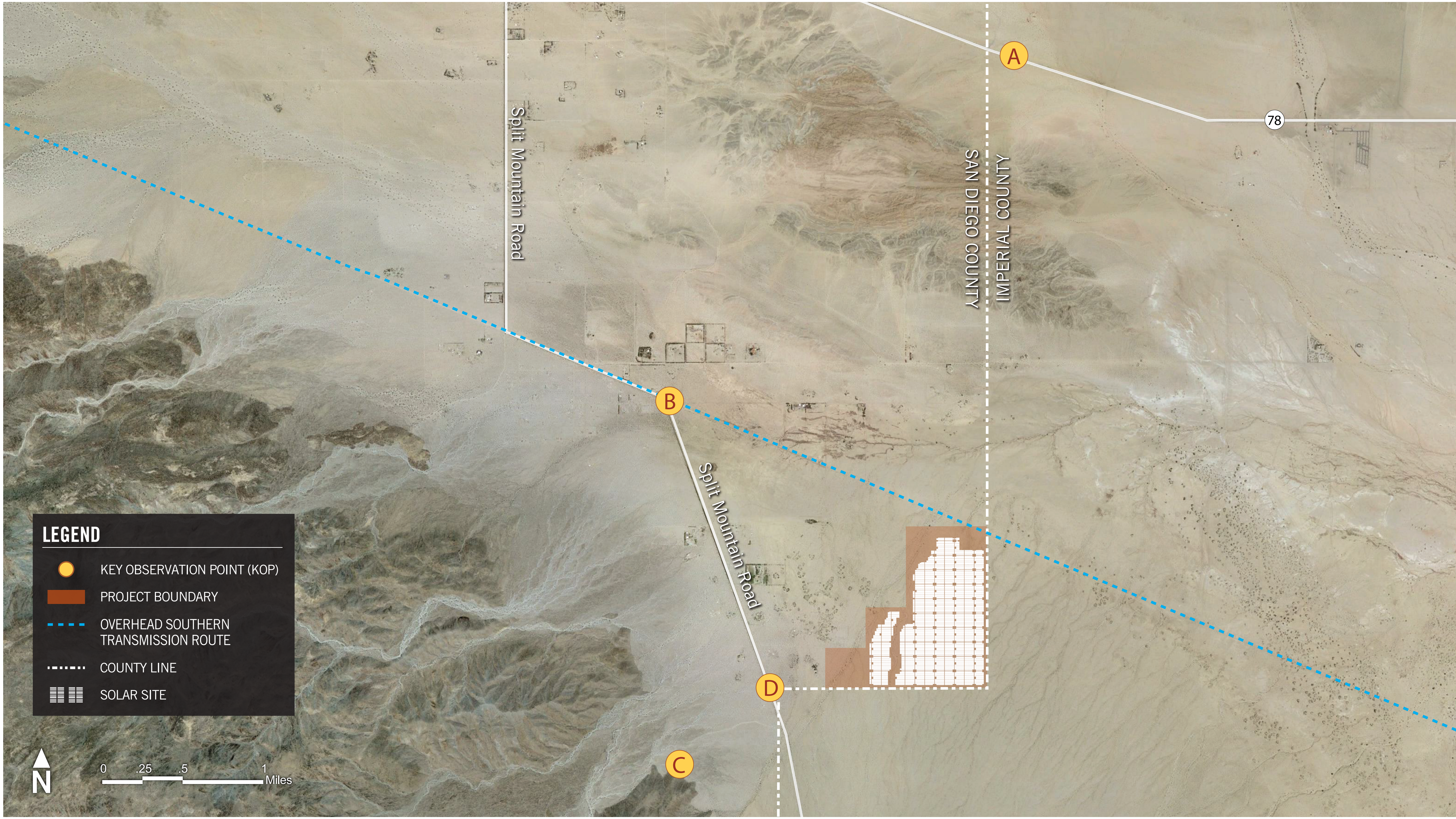

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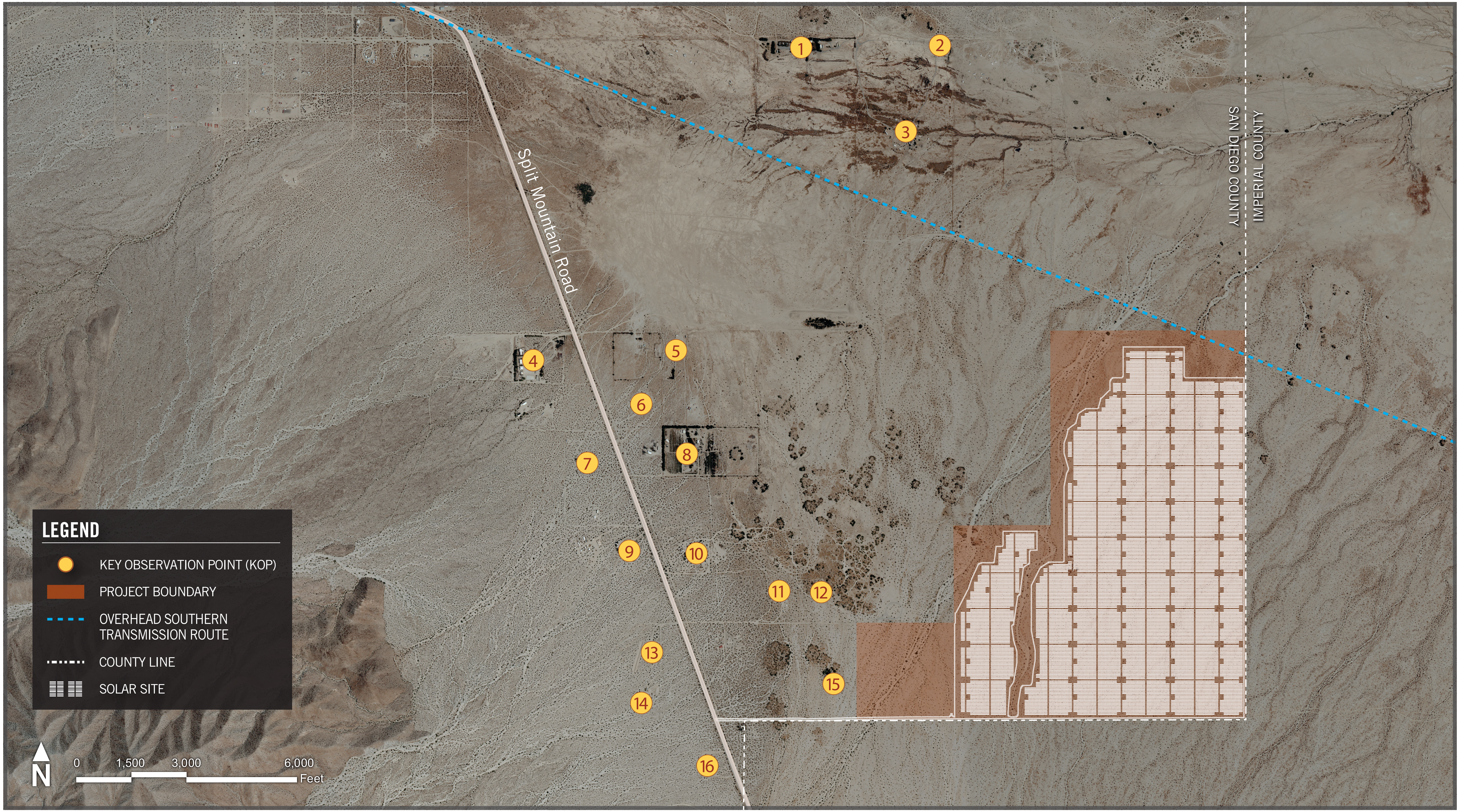
Figure 5A - Key Observation Point (KOP) Map



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Ocotillo Wells Solar Project - Glare Analysis

Figure 5B - Key Observation Point (KOP) Map

3.2 Characterize Glare Behavior

In order to characterize glare behavior, POWER created a 3D representation of the site, the sun, and the solar equipment. The 3D Model allowed analysts to accurately determine when and where glare may be visible to local residential structures. Specifically, the 3D Model incorporated the following:

- **3D Terrain Models** – The Gildred Companies provided POWER with contours of the Project Site. This information was converted into a 3D surface model and used to place the proposed 3D solar arrays. POWER acquired five foot contour data from the National Elevation Dataset (NED) and aerial imagery from the National Agriculture Imagery Program (NAIP) for the use of 3D residential structure placement.

- **Solar Sun System –** The 3D computer simulations incorporated an accurate, solar algorithm based on the latitude and longitude of the actual Project. All calculations were performed using 3D software designed for calculating and animating solar cycles. Sun calculations and results were based on hours of operational daylight and solar clocks for the following times of year (see Figure 6):

    - Summer Solstice (June 21st, 2013) – where the length of sunlight hours are at its peak and the sun has reached its northern most extremes.
    - Winter Solstice (December 21nd, 2013) – where the length of sunlight hours are at its lowest and the sun has reached its southernmost extremes.
    - Fall Equinox (September 22rd, 2013) – where the day and night are equal in length.
    - Spring Equinox (March 20th, 2013) – where the day and night are equal in length.

- **3D Solar Equipment** – POWER developed 3D models of the fixed PV panels based on manufacturer specifications including panel design and height. PV panels will be oriented facing south with a tilt of 25 degrees (see Figure 7). Panel layout and orientation was provided by The Gildred Companies. It is important to note the 3D geometric analysis does not measure the intensity of glare. This study is focused specifically on the location, duration and conditions in which glare may occur.

3.3 Glare Evaluation - 3D Geometric Analysis

Once the 3D site was assembled, analysts animated the trajectory of the sun to determine when and where glare may be visible to KOPs. Studying the occurrence of glare is essentially a 3D geometric analysis, which takes into account the position of the sun in relation to the angle of the solar panels to emit a path of glare. Each KOP was evaluated during daytime hours of operation during spring, summer, fall and winter (results can be found in Section 4.0).

Spring Equinox

March 20, 2013
12 hours 8 minutes of daylight
Sunrise - 6:48 a.m.
Sunset - 6:56 p.m.

Summer Solstice

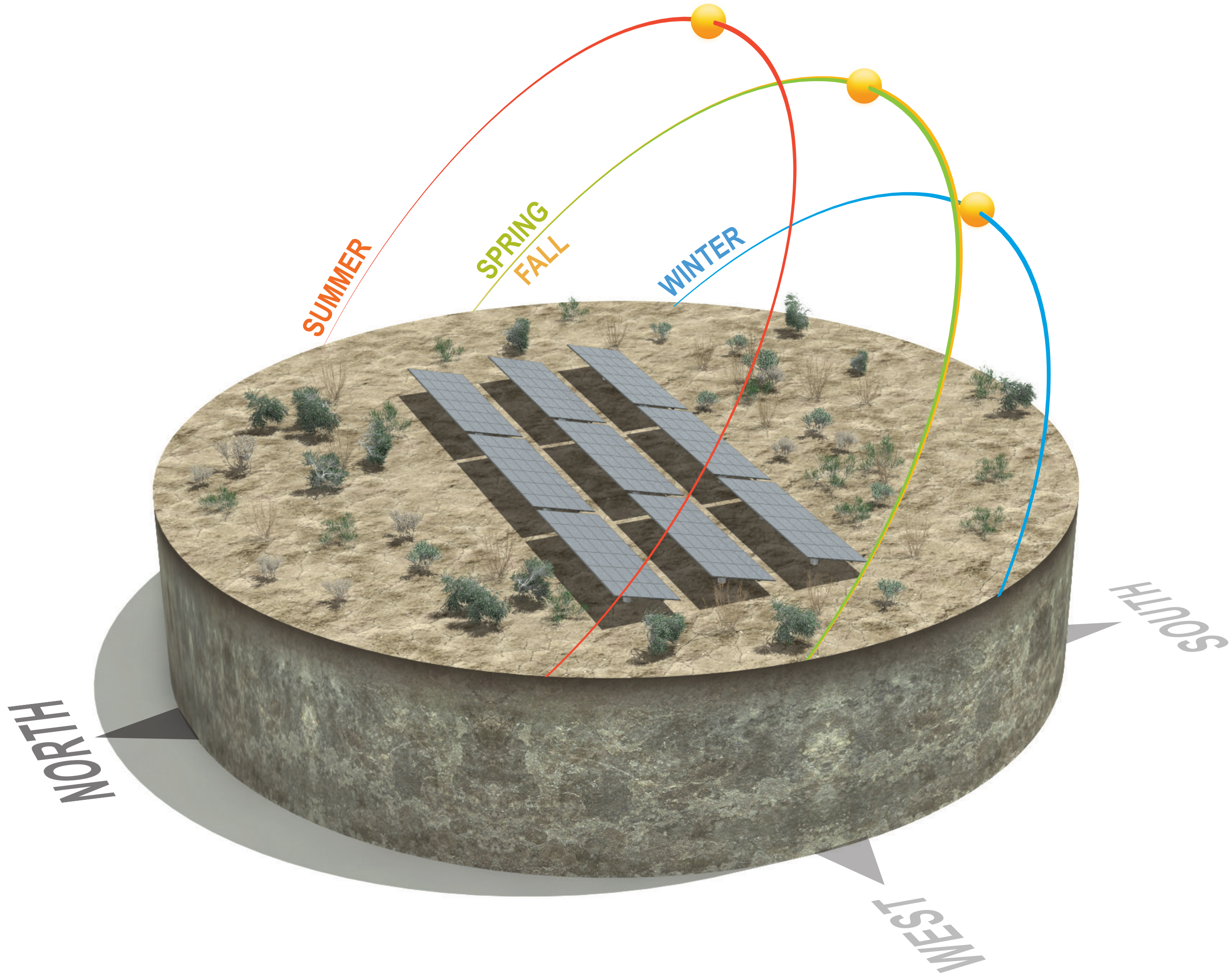
June 21, 2013
14 hours 20 minutes of daylight
Sunrise - 5:36 a.m.
Sunset - 7:56 p.m.

Fall Equinox

September 22, 2013
12 hours 8 minutes of daylight
Sunrise - 6:33 a.m.
Sunset - 6:41 p.m.

Winter Solstice

December 21, 2013
9 hours 58 minutes of daylight
Sunrise - 6:44 a.m.
Sunset - 4:42 p.m.



The sun changes its east-west orientation throughout the day. It also changes its north-south position throughout the year. The sun reaches its highest position in the sky at noon in the summer months and its lowest position in the sky at noon during the winter months.

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Ocotillo Wells Solar Project - Glare Study

Figure 7 - Fixed Panel Orientation

4.0 RESULTS

Review of the 3D geometric analysis determined glare will be visible to KOPs in the morning hours of the Spring and Fall Equinoxes and the Summer Solstice. Visible glare will occur for less than 15 minutes per day. The following is a detailed description of glare results per season and are considered worst case scenarios (see also Appendix A - Results):

- **Spring (6:45 a.m. – 7:00 a.m.) –** KOPs 4-15 may experience glare from the east from a distance greater than 1,650 feet.
- **Summer (7:15 a.m. – 7:30 a.m.) –** KOPs C, D, and 10-16 may experience glare from the northeast from a distance greater than 1,850 feet.
- **Fall (6:30 a.m. – 6:45 a.m.) –** KOPs 4-15 may experience glare from the east from a distance greater than 1,650 feet.
- **Winter -** No glare is anticipated from proposed solar operations due to the orientation of the solar technology and distance from KOPs.

5.0 DISCUSSION

As solar operations continue to increase in the United States, so does the concern for glare. An often asked question is, "If glare is experienced, what will the intensity be? What is it comparable to?" Glare is primarily produced from the top plate of the PV module, which reflects the sun's image back to the viewer (making the glare comparable to building glass, and water (see Figure 8). As demonstrated in the SunPower report, PV panels typically produce glare similar to building glass or water.

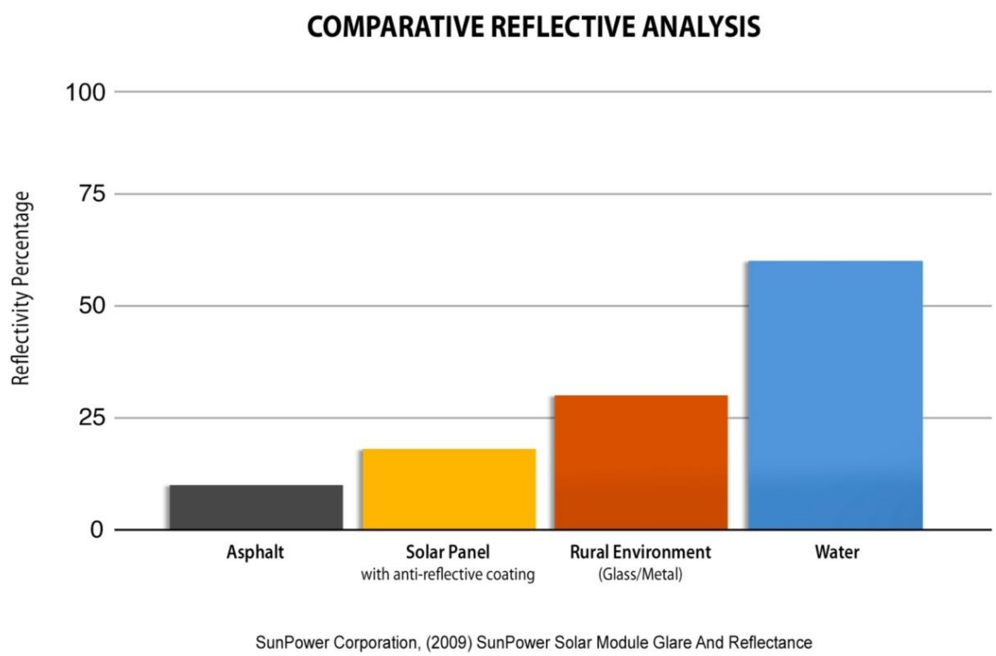
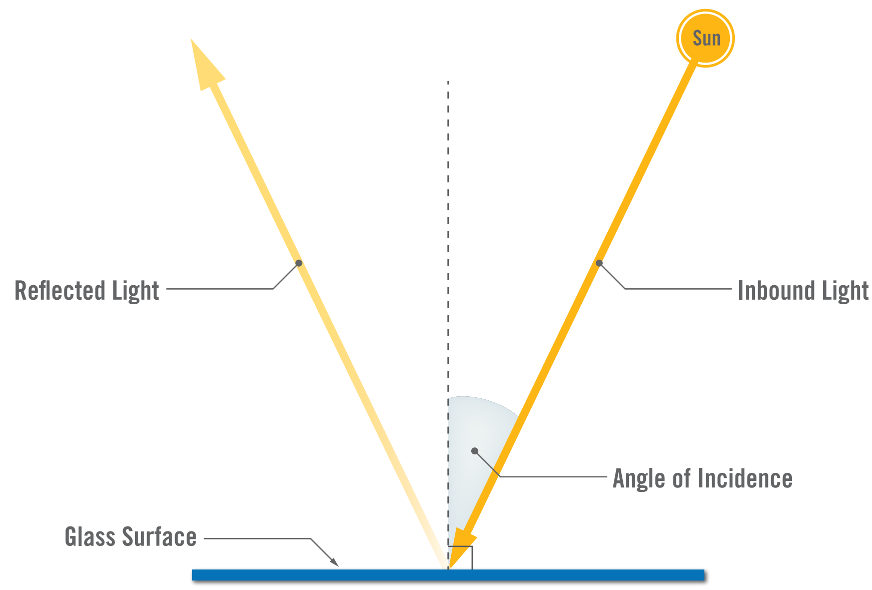
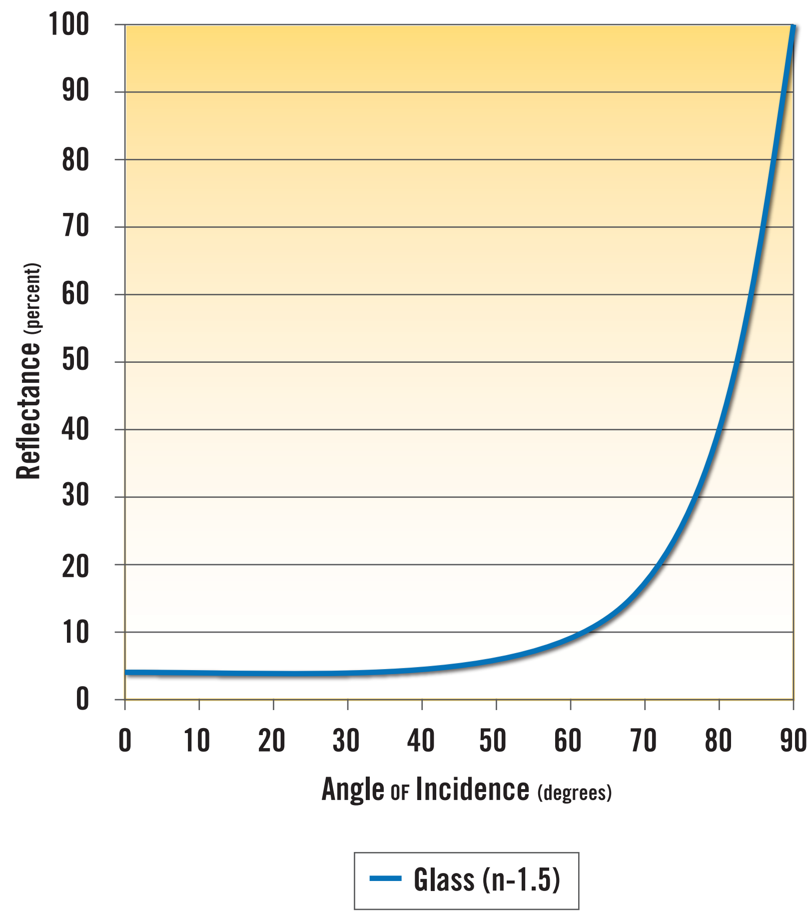


FIGURE 8 COMPARATIVE REFLECTIVE ANALYSIS

In recent years, there have been many studies reporting different levels of glare percentages associated with PV panels and panel glass. Studies range from 2% glare intensity (FAA 2010) to 25% intensity (SunPower 2009). It is important to understand that glare intensity is directly related to the angle of incidence of the sun striking the panel, and may account for the wide range of past results. As reported in a presentation by Sandia Labs, glare intensity is at its lowest when the angle of incidence is at its lowest, near perpendicular to the sun (see Figure 9). Static PV panels can see a varying range of reflection values as the sun changes position throughout the day. Angle of incidence and glare are at their lowest around noon where the sun can pass directly through the panel glass. In the early mornings and late evenings, incidence angles and glare values are higher as a result of the sun glancing off static panel glass.


Sun
Reflected Light
Inbound Light
Angle of Incidence
Glass Surface


100
90
80
70
60
50
40
30
20
10
0
Reflectance (percent)
0
10
20
30
40
50
60
70
80
90
Angle of Incidence (degrees)
Glass (n-1.5)

6.0 CONCLUSION

Occurrences of glare resulting from the proposed Ocotillo Wells Solar Project are anticipated to occur briefly in morning when the sun is lowest in the sky. Potential glare occur will for less than 15 minutes around the Spring and Fall Equinox and Summer Solstice (see Appendix A for graphical results). During the early mornings and late evenings, the angle of incidence will be high. The intensity of glare will be similar to viewing a sun setting over a body of water.

It is POWER's professional opinion that glare resulting from the proposed solar operations near the Ocotillo Wells Solar Project will have a low overall impact to nearby residential structures for the following reasons:

- The glare analysis reported a low occurrence of potential glare from proposed solar operations for a period of 15 minutes or less in the early morning hours.
- Viewers of potential glare would be at least 1,650 feet away from the Project.

7.0 SOURCES

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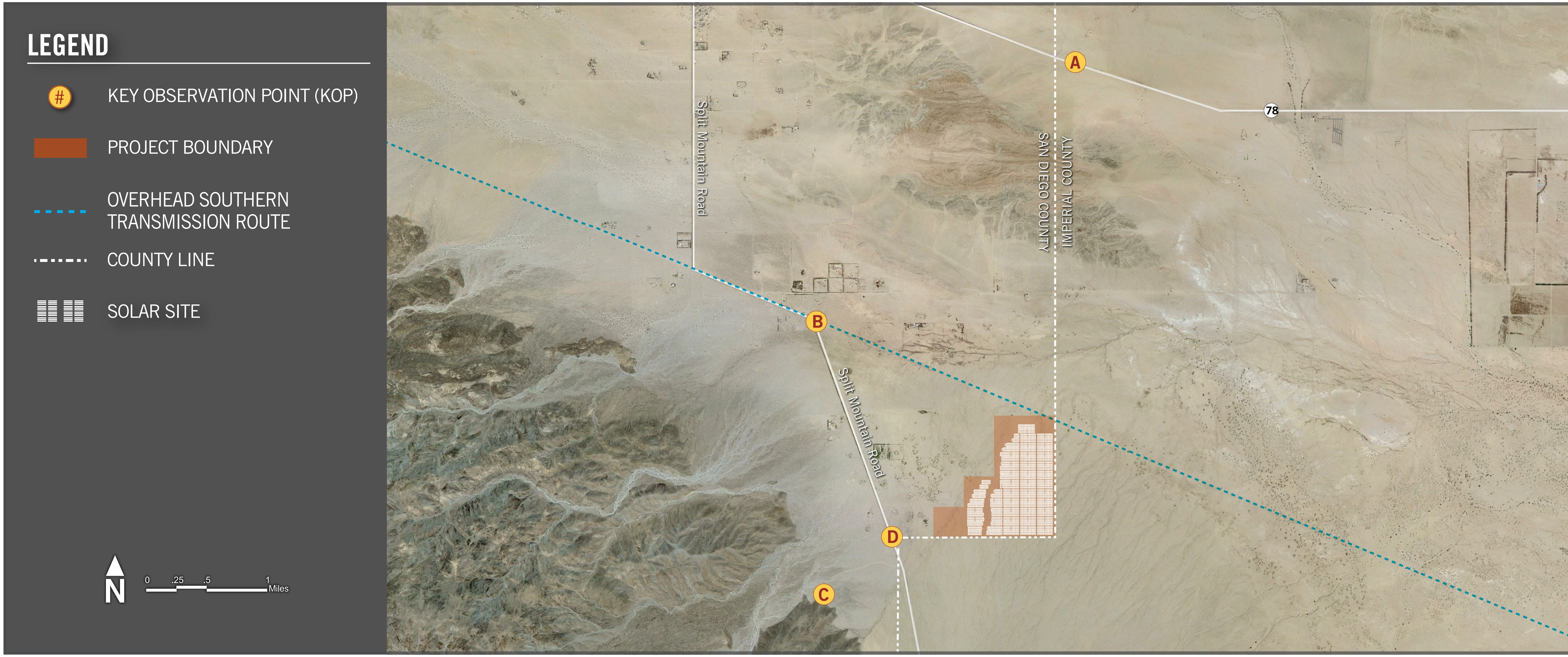
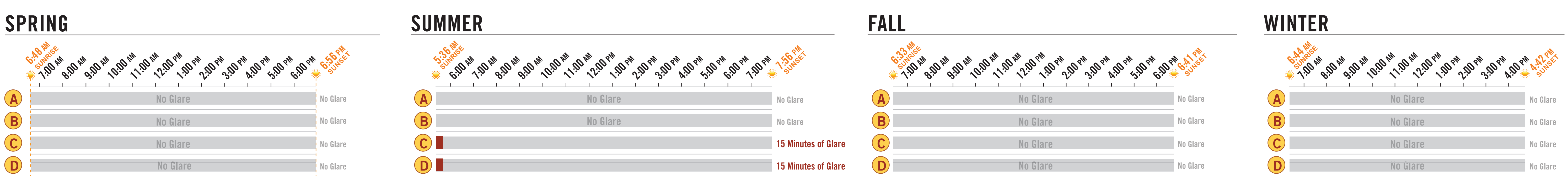
APPENDIX A RESULTS





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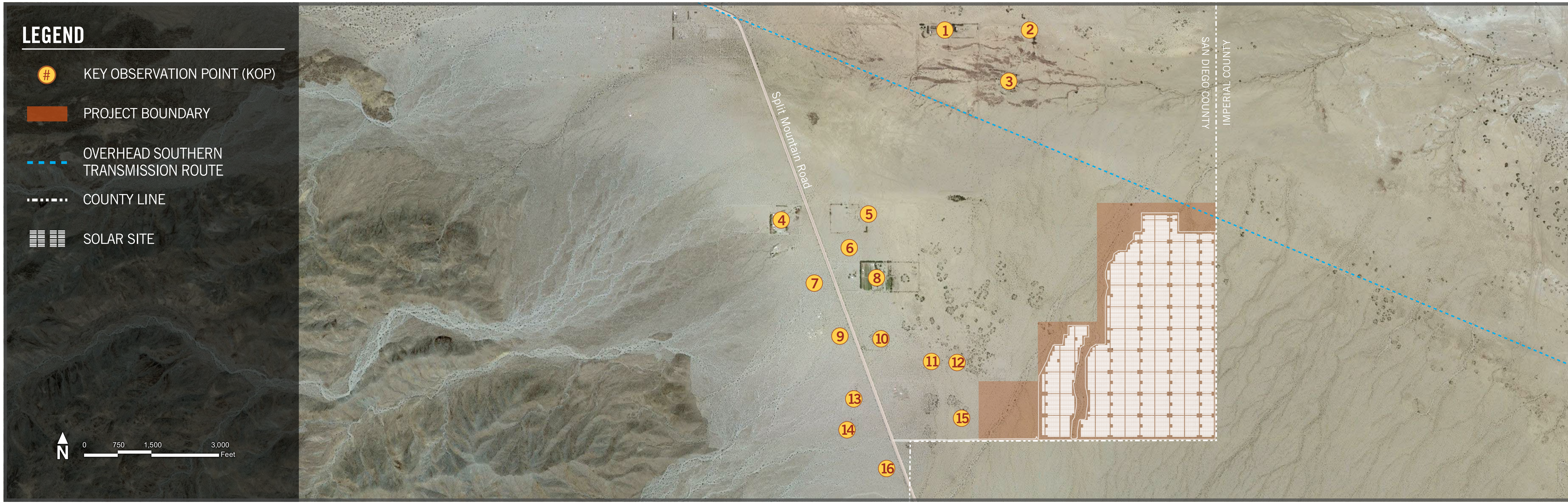
Ocotillo Wells Solar Project - Glare Study

Fixed Photovoltaic Panel Results



KOP	SPRING (6:48 AM Sunrise – 6:56 PM Sunset)	SUMMER (5:36 AM Sunrise – 7:56 PM Sunset)	FALL (6:33 AM Sunrise – 6:41 PM Sunset)	WINTER (6:44 AM Sunrise – 4:42 PM Sunset)
1	No Glare	No Glare	No Glare	No Glare
2	No Glare	No Glare	No Glare	No Glare
3	No Glare	No Glare	No Glare	No Glare
4	15 Minutes of Glare	No Glare	15 Minutes of Glare	No Glare
5	15 Minutes of Glare	No Glare	15 Minutes of Glare	No Glare
6	15 Minutes of Glare	No Glare	15 Minutes of Glare	No Glare
7	15 Minutes of Glare	No Glare	15 Minutes of Glare	No Glare
8	15 Minutes of Glare	No Glare	15 Minutes of Glare	No Glare
9	15 Minutes of Glare	No Glare	15 Minutes of Glare	No Glare
10	15 Minutes of Glare	15 Minutes of Glare	15 Minutes of Glare	No Glare
11	15 Minutes of Glare	15 Minutes of Glare	15 Minutes of Glare	No Glare
12	15 Minutes of Glare	15 Minutes of Glare	15 Minutes of Glare	No Glare
13	15 Minutes of Glare	15 Minutes of Glare	15 Minutes of Glare	No Glare
14	15 Minutes of Glare	15 Minutes of Glare	15 Minutes of Glare	No Glare
15	15 Minutes of Glare	15 Minutes of Glare	15 Minutes of Glare	No Glare
16	No Glare	15 Minutes of Glare	No Glare	No Glare

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Fixed Photovoltaic Panel Results