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MEMO

Date:	March 28, 2023
Project:	1270 E. Garvey Street, Covina, California
Subject:	Peer Review of Lighting Study
To:	Michele Finneyfrock AICP mfinneyfrock@dudek.com , DUDEK 38 North Marengo Avenue, Pasadena, CA 91101 O: 626.204.9823
From:	Francis Krahe, PE

Francis Krahe & Associates is pleased to provide this memo which summarizes the review of the Lighting Study (hereinafter referred to as Study) prepared by Watchfire for the proposed illuminated sign at 1270 E. Garvey Street, Covina, California (hereinafter referred to as Project). Specifically, this memo reviews the methods of analysis, accuracy, and conclusions of the Study, including the appropriate regulations and standards for analysis that apply to exterior lighting with respect to lighting impacts at sensitive use properties surrounding the Project.

A. Background

This review of the Study by Francis Krahe & Associates evaluates the Study lighting analysis in determining potential lighting impacts to adjacent light sensitive use properties and recommends modifications where the Study is not consistent with the current standards for light trespass and glare.

Discussions of lighting issues include precise definitions, descriptions or terminology of the specific lighting technical parameters. Attached as Appendix B is a Glossary of Lighting Terminology as defined by the Illuminating Engineering Society of North America (IESNA) that summarizes explanations of technical lighting terms that may be used in this memorandum.

1. Project Description

The Study evaluates light impacts from the proposed Project, which includes two illuminated signs within a sign pylon located at 1270 East Garvey Street, Covina, California. One sign faces east (East Face), one sign faces west (West Face). The Study analyzes the potential light impacts from the proposed Project as defined by the Project Sign Concept prepared by Watchfire dated November 30, 2022 included herein as Appendix A. The Sign Concept identifies the Project signs as two illuminated LED sign panels, each sign face at 14 feet tall and 48 feet wide, or 672 square feet each.

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B. Evaluation of the Study

1. Project Description

The maximum mounting height of the Signs is not defined in the Concept Plan or the Study.

2. Evaluation of Sensitive Use Properties

The purpose of the Study is to evaluate light trespass and glare at night at sensitive use properties, where increased light may affect the use of these properties. The Study does not clearly define the locations of sensitive use properties adjacent to the Project, and the distances from the Project to each sensitive use location. The Study refers to residential properties and an adjacent park, but does not identify these locations by address or via the map illustrations. Furthermore, the Vanilee Hotel & Suites is a sensitive use property, where increased light may be detrimental to the properties guests at night, and which is located close to the Project.

The Study should clearly define all adjacent and surrounding residential use and sensitive use properties in the City of Covina, West Covina, and the distance from the Project to each property.

3. Lighting Regulations and Standards

The Study indicates the "Watchfire Signs has adopted brightness standards endorsed by both the International Sign Association (ISA) and the Outdoor Advertising Association of America (OAAA)". The Study references standards adopted by Illuminating Engineering Society of North America (IESNA), and as defined by OAAA, and referenced in Study Exhibit A. published March 2008, and IESNA TM-11-00.

The standards by OAAA and IESNA are not the most current recommended practice standards for evaluation of light trespass and glare. The ANSI/IES Standards replace the IESNA 10th Edition Handbook, which superseded the 9th Edition IESNA Handbook and various Recommended Practice (RP) References published by IESNA prior to 2011. IESNA TM-11-00 has been superseded by IESNA RP-39-19; Recommended Practice: Off-Roadway Sign Luminance, published 2019. Additional pertinent IESNA reference publications include: American National Standards Institute (ANSI)/Illuminating Engineering Society (IES) OL-IM-01 Lighting Fundamentals, Metrics and Calculations; ANSI/IES OL-IM-02 Lighting Design, Engineering, and Specifications; ANSI/IES OL-IM-03 Lighting Design Criteria and Illumination Recommendations; and ANSI/IES OL-IM-04 Lighting Equipment Testing Procedures and Measurements.

City of Covina Municipal Code does not include regulations for light trespass or glare. Therefore, the Project should be evaluated with respect to the light trespass and glare regulations of the California Green Building Code.

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The Project is adjacent to the City of West Covina and to residential properties to the south of the 10 Freeway at 3650 E. Holt Avenue and 3700 E. Garvey Avenue S. within the City of West Covina. The City of West Covina Municipal Code includes lighting regulations as follows:

"Sec. 26-318. - Illumination.

(a) Signs shall be designed, installed, and maintained in such a manner that the spillover of any illumination of signs onto residential property shall not exceed two (2.0) foot candles above ambient light levels, and the spillover of glare produced by the illumination of signs shall not negatively impact any surrounding properties."

The Study should clearly identify these regulations and note the threshold applied in the Study (0.30 fc) is more conservative than the City of West Covina regulations.

The 2019 California Code of Regulations, Title 24, includes regulations which mandate limits to light trespass and glare at any new sign property line or centerline of adjacent transportation right of way according to the outdoor lighting zones adopted by CEC. However, the CEC grants exceptions to signs which comply with the energy use and lighting controls requirements within CEC Sections 130.3 and 140.8..

California Green Building Code, Chapter 5, paragraph 5.106.8, Light Pollution reduction stipulates compliance with the California Energy Code for Lighting Zones 0-4 for light trespass and Backlight, Uplight, and Glare as per IES TM-15-11. However, Exception 1 allows for exclusion as noted in Section 140.7.

5.106.8 Light pollution reduction. [N] Outdoor lighting systems shall be designed and installed to comply with the following:

1. The minimum requirements in the *California Energy Code* for Lighting Zones 0-4 as defined in Chapter 10, Section 10-114 of the *California Administrative Code*; and
2. Backlight (B) ratings as defined in IES TM-15-11 (shown in Table A-1 in Chapter 8);
3. Uplight and Glare ratings as defined in *California Energy Code* (shown in Tables 130.2-A and 130.2-B in Chapter 8) and
4. Allowable BUG ratings not exceeding those shown in Table 5.106.8 [N], or
   Comply with a local ordinance lawfully enacted pursuant to Section 101.7, whichever is more stringent.

Exceptions: [N]

1. Luminaires that qualify as exceptions in Section 140.7 of the *California Energy Code.*

SECTION 140.7 PRESCRIPTIVE REQUIREMENTS FOR OUTDOOR LIGHTING includes the following requirements.

(a) An outdoor lighting installation complies with this section if it meets the requirements in Subsections (b) and (c), and the actual outdoor lighting power installed is no greater than the allowed

outdoor lighting power calculated under Subsection (d). The allowed outdoor lighting shall be calculated according to outdoor lighting zone in Title 24, Part 1, Section 10-114.
Exceptions to Section 140.7(a): When more than 50 percent of the light from a luminaire falls within one or more of the following applications, the lighting power for that luminaire shall be exempt from Section 140.7:

…

7. Lighting of signs complying with the requirements of Sections 130.3 and 140.8."

The Study should include information to demonstrate the Project complies Sections 130.3 and 140.8, and therefore, the Project is within the exceptions to Section 140.7(a), and therefore qualifies as an exception to the light trespass and glare requirement defined in CEC Section 5.106.8 above.

The CEC sections that apply to the Signs are included below to define the required lighting controls to qualify as an exception within Section 140.7.

"California Energy Code (Title 24, Part 6)
Section 141.0 ADDITIONS, ALTERATIONS AND REPAIRS TO EXISTING NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, … AND TO INTERNALLY AND EXTERNALLY ILLUMINATED SIGNS

Additions, alterations, and repairs to existing … internally and externally illuminated signs, shall meet the requirements specified in Sections 100.0 through 110.10, and 120.0 through 130.5 that are applicable to the building project, and either the performance compliance approach (energy budgets) in Section 141.0(a)2 (for additions) or 141.0(b) 3 (for alterations), or the prescriptive compliance approach in Section 141.0(a)1 (for additions) or 141.0(b)2 (for alterations)...

Section 100.0 Scope, (d) Outdoor lighting and indoor and outdoor signs. The provisions of Part 6 apply to outdoor lighting systems and to signs located either indoors or outdoors as set forth in Table 100.0-A. …

Table 100.0 - A APPLICATION OF STANDARDS

OCCUPANCIES	APPLICATION	MANDATORY	PRESCRIPTIVE	PERFORMANCES	ALTERATIONS/ ADDITIONS
Signs	Indoor and Outdoor	110.9, 130.0, 130.3	140.8	N.A.	141.0, 141.0(b)2H

"…

and paragraph 6 page 3, states:

"Signs. Sections 130.0, 130.3 and 140.8 apply to newly constructed signs located either indoors or outdoors, and Section 141.0 applies to sign alterations located either indoors or outdoors."

The requirements of SECTION 110.9, MANDATORY REQUIREMENTS FOR LIGHTING CONTROLS stipulate the type and method of outdoor lighting control systems and the types and methods of daylight sensors required for Signs to provide automatic reduced sign lighting after sunset and before sunrise.

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The requirements of SECTION 130.0 LIGHTING SYSTEMS AND EQUIPMENT, AND ELECTRICAL POWER DISTRIBUTION SYSTEMS – GENERAL, include the following pertaining to outdoor signs:

> "(a) The design and installation of all lighting systems and equipment in nonresidential, high-rise residential, hotel/motel buildings, outdoor lighting, and electrical power distribution systems within the scope of Section 100.0(a), shall comply with the applicable provisions of Sections 130.0 through 130.5."
> SECTION 130.3 SIGN LIGHTING CONTROLS, includes the following section that pertains to outdoor signs:
> "(a) Controls for sign lighting. All sign lighting shall meet the requirements below as applicable:
> 2. Outdoor signs. Outdoor sign lighting shall meet the following requirements as applicable:
> A. All outdoor sign lighting shall be controlled with a photocontrol in addition to an automatic time-switch control, or an astronomical time-switch control.
> B. All outdoor sign lighting that is ON both day and night shall be controlled with a dimmer that provides the ability to automatically reduce sign lighting power by a minimum of 65 percent during nighttime hours. Signs that are illuminated at night and for more than 1 hour during daylight hours shall be considered ON both day and night."
> SECTION 140.8 PRESCRIPTIVE REQUIREMENTS FOR SIGNS ….
> Maximum allowed lighting power.
> For internally illuminated signs, the maximum allowed lighting power shall not exceed the product of the illuminated sign area and 12 watts per square foot. For double-faced signs, only the area of a single face shall be used to determine the allowed lighting power.
> Alternate lighting sources. The sign shall comply if it is equipped only with one or more of the following light sources: ….
> Light emitting diodes (LEDs) with a power supply having an efficiency of 80 percent or greater''

The Study should demonstrate the Project complies with the exceptions to Section 140.7(a), and therefore qualifies as an exception to the light trespass and glare requirement defined in Section 5.106.8 above. If the Signs comply with the exceptions, then the CEC light trespass and glare limits do not apply to the Project, and the Study does not require further analysis of the Project's light trespass or glare at the Project property line or at the center line of the adjacent transportation right of way, with respect to the CEC requirements for outdoor lighting.

4. Threshold

The Study defines a light trespass threshold of 0.30 fc, which is an appropriate, conservative maximum illuminance threshold for this Project. The Study does not clearly define where this threshold applies.

The Study does not define a threshold for glare. Glare should be evaluated relative to the existing lighting conditions at and surrounding the Project within the field of view from the adjacent sensitive use properties. The locations of the sensitive use properties and the field of view from these sensitive use properties should be defined in the Study to illustrate and analyze if the East Face or West Face are visible from any of the adjacent sensitive use properties, and if so, the existing lighting conditions within the field of view from the sensitive use property.

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The Study utilizes a maximum luminance of 300 cd/m^2, which may be an acceptable, conservative threshold for maximum luminance. However, no basis for this threshold or any evaluation of the threshold is presented in the Study.

Furthermore, the Study should analyze the impact to drivers' visibility based on the California Vehicle Code's maximum luminance value relative to the driver's field of vision, as well as the California Outdoor Advertising Act for the distance between outdoor illuminated signs. The Project signs face the Interstate 10 (I-10) highway, which is governed by the California Department of Transportation (CALTrans), which has regulations specific to lighting within California highways. Impacts to drivers' visibility traveling on the highway should be analyzed according to the requirements stipulated by the California Vehicle Code, Chapter 2, Article 3 which stipulates limits to the location of light sources that may cause glare and impair the vision of drivers.

> "ARTICLE 3. Offenses Relating to Traffic Devices [21450 - 21468] (Article 3 enacted by Stats. 1959, Ch. 3.), Section 21466.5. No person shall place or maintain or display, upon or in view of any highway, any light of any color of such brilliance as to impair the vision of drivers upon the highway. A light source shall be considered vision impairing when its brilliance exceeds the values listed below.
>
> The brightness reading of an objectionable light source shall be measured with a 1-1/2 degree photoelectric brightness meter placed at the driver's point of view. The maximum measured brightness of the light source within 10 degrees from the driver's normal field of view shall not be more than 1,000 times the minimum measured brightness in the driver's field of view, except that when the minimum measured brightness in the field of view is 10 footlamberts or less, the measured brightness of the light source in footlambert shall not exceed 500 plus 100 times the angle, in degrees, between the driver's field of view and the light source."

5. Analysis of the Proposed Sign

The Study indicates the proposed sign will operate at 7,500 nits (cd/m^2) during the day and 300 nits (cd/m^2) at night.

We believe the calculated light trespass illuminance is not accurate. FK&A calculated the sign illuminance for the 14 ft high by 48 feet wide sign utilizing the illuminance calculation software AGI. The results of these calculations are presented in Table 1. The calculated light trespass through the AGI software is considerably higher than the data presented in the Study. For example, the illuminance at 200 feet from the sign at 0 degrees is presented in the Study at 0.17 fc. The calculated illuminance in Table 1 at 200 feet 0 degrees is 0.51 fc.

Study must demonstrate more effectively that sensitive use properties are located at a distance from the East Face or West Face where the illuminance from the Project will be less than 0.30 fc. Study should clarify the distance to the hotel property and confirm the

light trespass will be less than 0.30 fc. Furthermore, the Study provides no basis for conclusions that night time luminance at 300 nits (cd/m^2) will not create a new source of glare when visible from sensitive use properties in the vicinity of the Project.

Table 1: Sign Illuminance Calculation Data AGI

	Degrees	
Distance (ft)	**0**	**70**
100	1.83	1.02
200	0.51	0.24
300	0.23	0.10
400	0.13	0.05
500	0.08	0.03

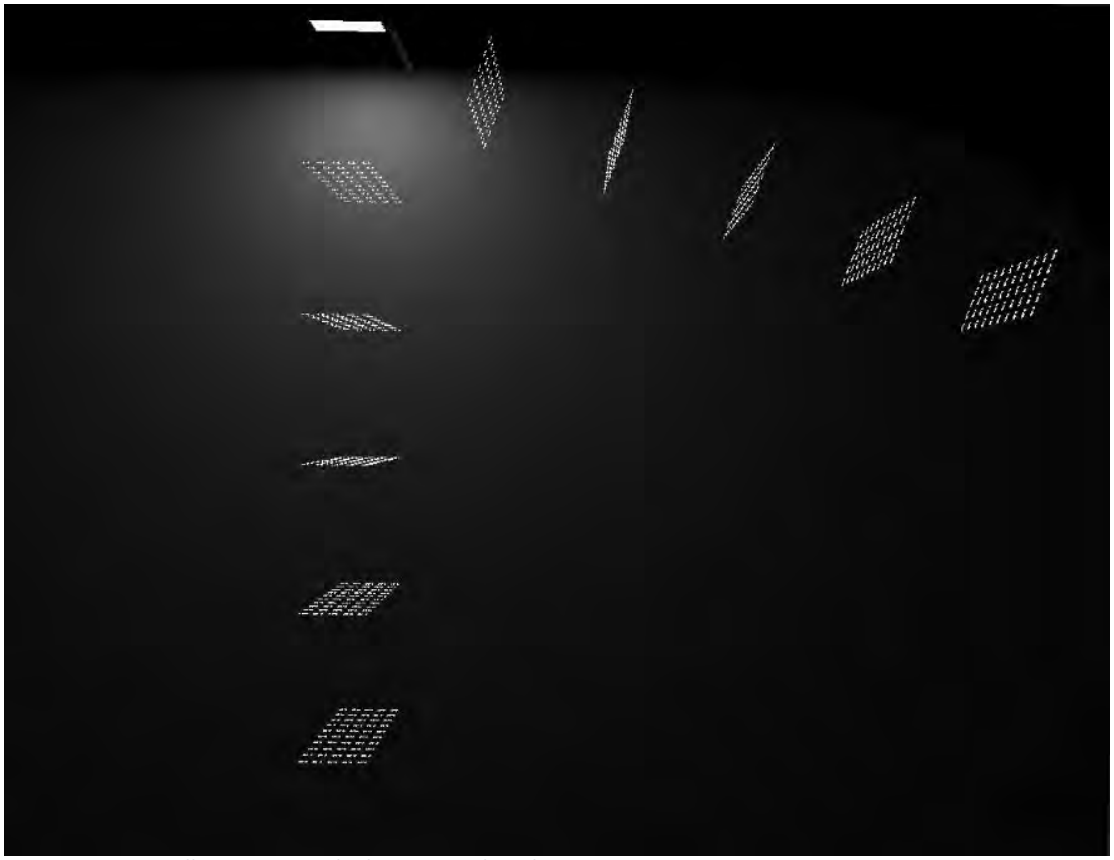

Figure 1: Sign Illuminance Calculation Rendered View

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C. Appendix A

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LIGHTING STUDY

Watchfire Signs has been manufacturing outdoor electric signs since 1932 and LED signs since 1996. Currently, we have more than 60,000 LED signs in operation worldwide.

History of Optica

I Measurements and Calculations

Outdoor signs using incandescent light bulbs commonly measured illuminance using meters that report brightness in foot-candles. This unit is the standard measurement partly because a light bulb is a source of light that illuminates equally in all directions. LED signs are measured with the same meter even though its light does not illuminate equally in all directions. LED signs are designed to be highly directional, which is an advantage. LEDs allow light to be directed toward an intended audience, rather than dispersed in a wider arc out from the face of the sign.

In the LED industry, luminance, or the intensity of visible light, is measured by nits, where one candela per square meter is equal to one nit. However, luminance meters are expensive, difficult to use in the field, and are not ideal for lighting studies commonly used for meeting local permitting requirements. As a result, LED signs are often evaluated using foot-candle measurements.

A foot-candle is the amount of light produced by a single candle when measured from one foot away. For reference, a 100-watt light bulb produces 137 foot-candles from 1 foot away, .0548 foot-candles from 50 feet away, and .0137 foot-candles from 100 feet away.

Watchfire Signs is Compliant with National Lighting Requirements

Watchfire Signs has adopted brightness standards endorsed by both the International Sign Association (ISA) and Outdoor Advertising Association of America (OAAA). These standards were the result of detailed analysis and recommendations for lighting control completed by Dr. Ian Lewin of Lighting Sciences Inc. The studies are based on accepted practices by the Illuminating Engineering Society of North America (IESNA) for evaluating and controlling "light trespass". Watchfire Signs' products meet the requirements set forth by both associations, based on these studies and recommendations, which results in lighting impact of no more than 0.3 foot-candles above existing ambient light levels. This requirement to have the light levels no more than 0.3 foot-candles above ambient light is also within the El Monte Sign Code. Total foot-candles are dependent on size and distance and can be adjusted as needed. Please see below forthe site-specific lighting study and Exhibit A for details surrounding the OAAA lighting standards and practices.

Automatic Brightness Adjustment:

Watchfire's billboard displays are set to have a maximum daytime brightness level of 7,500 nits and a maximum nighttime brightness level of 300 nits. All Watchfire signs automatically adjust brightness levels using a primary 100-step hardware photocell, with a software photocell backup. The hardware photocell will automatically adjust the sign's brightness relative to changes in ambient light levels. If the software photocell is used, the sign will automatically adjust brightness based on the longitude and latitude location of the sign. The sign is appropriately dimmed or brightened based around daily sunrise and sunset. For both options, a sign operator can manually decrease the brightness from standard

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settings, but for safety reasons and in conformance to industry codes, Watchfire cannot allow signs to operate brighter than standard settings.

Night Skies:

All Watchfire signs are designed with night skies in mind. To achieve the best image quality and power efficiency, we are interested in having light reach only the audience. We have implemented technology into our products that prevent them from being brightened in the field after installation and allow for downward adjustment when the impact is too great for a specific area or application. Watchfire has developed specially designed louver panels that not only protect the LEDs from damage but limit the vertical impact of the light output. This technology, coupled with the automated brightness adjustments, limits impact to vertical ambient lighting.

Title 24 Compliance:

Watchfire displays was the first in the industry to meet the requirements for UL Greenleaf certifications set forth by Title 24 of the California Code of Regulations. A copy of the Certificate of Conformance is available upon request.

Redundancy:

All Watchfire displays have intelligent control with Automated Diagnostics down to individual LED level. In the unlikely event that a lighting control fails, or a sign malfunction, the operator and Watchfire are immediately notified. If necessary, there are protocols in place to have the sign go dark along with hardware installed in each display to allow for remote power control.

Equipment used by Watchfire Signs to Measure Luminance
Foot-candles/Lux - Minolta Illuminance Meter T-10
Nits/candela/sq. m – Minolta Luminance Meter LS-100
Sign Calibration – Minolta CS-1000 Spectra radiometer

The proceeding study uses actual lab measurements made on modules using an illuminance meter. These measurements and extrapolations were then scaled up to the size of the sign and distance corrections were made using the inverse square law.

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SIGN LIGHTING STUDY

Sign Details

Size: 14' x 48' Digital Billboard

Location: *1270 E. Garvey St., Covina, CA*

The table below represents a large LED sign, demonstrating the increase in illuminance from the sign during normal night operation. Smaller signs would have less effect than shown below. The values are within the standards of both the ISA and OAAA and indicate that the ambient light broadcast into the surrounding area has minimal effect.

Foot-candles at night under normal operation					
	Horizontal Viewing Angle				
Viewing Distance (ft)	0°	20°	40°	60°	70°
100	0.68	0.63	0.55	0.38	0.23
200	0.17	0.16	0.14	0.10	0.06
300	0.08	0.07	0.06	0.04	0.03
400	0.04	0.04	0.03	0.02	0.01
500	0.03	0.03	0.02	0.02	0.01

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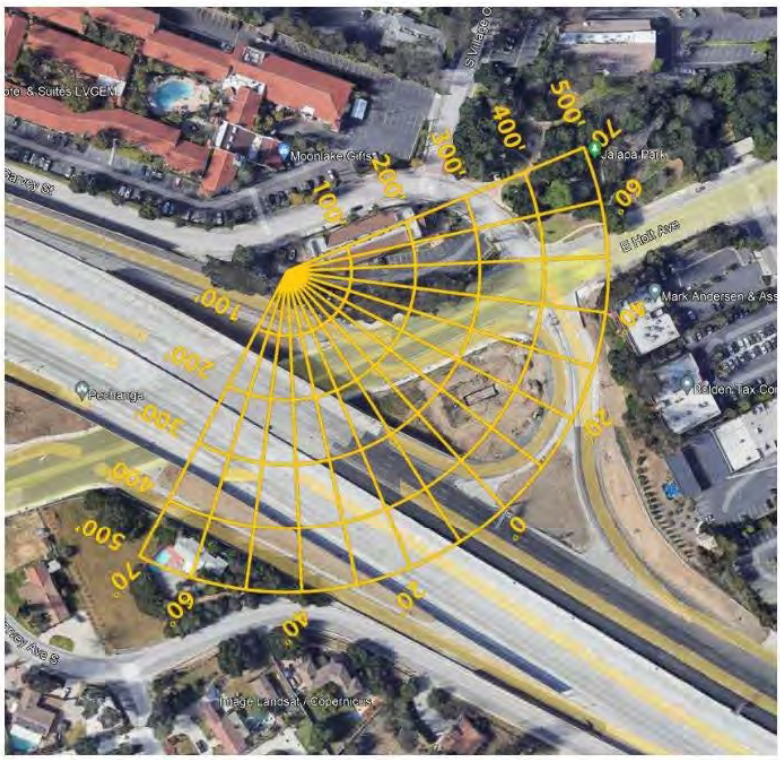
Example Broadcast of Light at Distances and Angles: East Face



Foot-candles at night under normal operation					
	Horizontal Viewing Angle				
Viewing Distance (ft)	0°	20°	40°	60°	70°
100	0.68	0.63	0.55	0.38	0.23
200	0.17	0.16	0.14	0.10	0.06
300	0.08	0.07	0.06	0.04	0.03
400	0.04	0.04	0.03	0.02	0.01
500	0.03	0.03	0.02	0.02	0.01

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Conclusion of the East Face of the LED Billboard

Given the above comparisons and measurements, the area will see an almost undetectable difference in ambient light after installation of the digital LED billboards. The one resident on the south side of the freeway is very far away and at an extreme angle. As the distance increases from the face of the sign, the light dims. When the distance and angle both increase from the face of the sign, the light dims even further. The red box on the grid details the inconsequential light levels to the one resident that is located on the south side of the freeway, which are .01-.02 foot-candles. This low level of foot-candles is equivalent to a 100-watt light bulb well over 100 feet away. Thus, the resident's porch light or streetlights are hundreds of times more impactful than the digital billboard. The green box represents a small portion of Jalapa Park, but the light is similarly very low at .01-.02 foot-candles.

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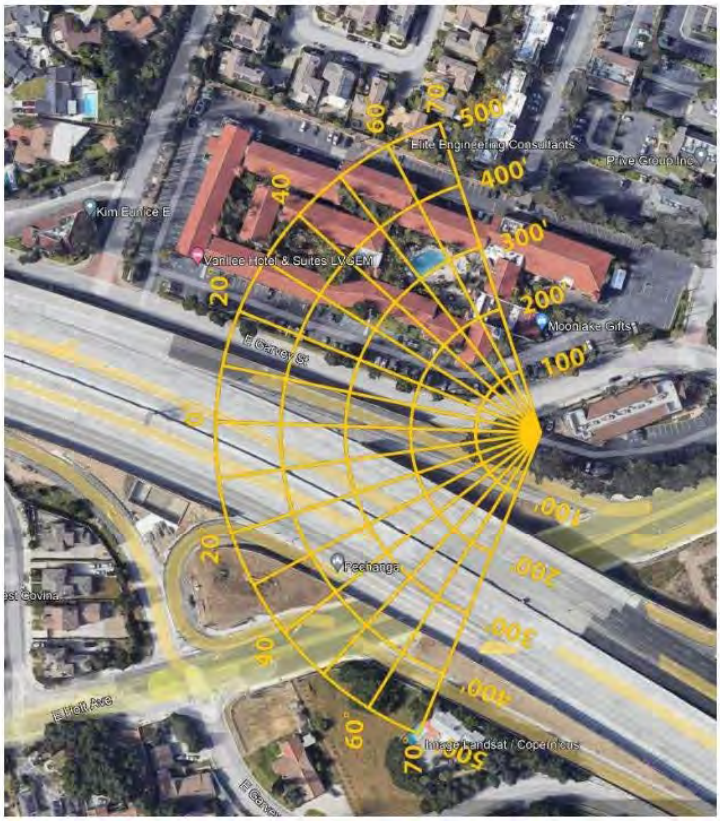
Example Broadcast of Light at Distances and Angles: West Face



Foot-candles at night under normal operation					
	Horizontal Viewing Angle				
Viewing Distance (ft)	0°	20°	40°	60°	70°
100	0.68	0.63	0.55	0.38	0.23
200	0.17	0.16	0.14	0.10	0.06
300	0.08	0.07	0.06	0.04	0.03
400	0.04	0.04	0.03	0.02	0.01
500	0.03	0.03	0.02	0.02	0.01

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Conclusion of the West Face of the LED Billboard

Given the above comparisons and measurements, the area will see an almost undetectable difference in ambient light after installation of the digital LED billboards. The one resident on the south side of the freeway is very far away and at an extreme angle. As the distance increases from the face of the sign, the light dims. When the distance and angle both increase from the face of the sign, the light dims even further. The red box on the grid details the inconsequential light levels to the one resident that is located on the south side of the freeway, which are .01-.02 foot-candles. This low level of foot-candles is equivalent to a 100-watt light bulb well over 100 feet away. Thus, the resident's porch light or streetlights are hundreds of times more impactful than the digital billboard. The green box represents a small portion of one resident north of the Vanlee Hotel, but the light is similarly very low at .01-.02 foot-candles. The blue box on the grid details the inconsequential light levels within the Vanlee Hotel, which are .14 - .01 foot-candles. This would be like standing from about ~30-100' from a 100-watt light bulb. The street lights along East Garvey Street or that are located in the parking lot of the Vanlee Hotel are brighter.

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Exhibit A: OAAA Lighting Standards

Brightness Criteria

A. OAAA Guidelines: The OAAA recommended brightness criteria for digital billboards is as follows:
   - Light produced by a digital billboard should not exceed 0.3 Footcandles over ambient light levels.
   - Measurement should be taken utilizing a Footcandle meter from the following distances perpendicular to the face of the digital billboard):
     - Posters: 150 feet
     - 10'6x36 Bulletins: 200 feet
     - 14x48 Bulletins: 250 feet
     - 20x60 Bulletins: 350 feet

     The measurement distances are based on the average minimum viewing distances for each type of billboard.
   - Digital billboards must have automatic dimming capability.

B. Basis for the Guidelines. These guidelines are based on recommendations by lighting expert Dr. Ian Lewin, Lighting Sciences Inc. (Scottsdale, AZ), in a March, 2008 report to the OAAA. Dr. Lewin developed brightness criteria to meet the following general guidelines:
   - Appropriately Legible Copy. Digital advertising copy is appropriately legible and not overly bright.
   - Simplicity. Provide a guideline that can be easily implemented and enforced. Measurement of the ambient light level of the sign on and off is conducted by a footcandle meter. If the difference in measurements is less than 0.3 footcandles, the digital billboard is in compliance.
   - Established Guidelines. The criteria are based on established scientific methodology and established industry standards from the Illuminating Engineering Society of North America (IESNA) publication TM- 11-00 "light trespass" theory which is an accepted standard in the lighting industry.
   - Flexibility. Ensure proper brightness levels in a variety of lighting environments.

C. Additional Issues/Clarification
   - Automatic Dimming Capability. A digital billboard must be able to automatically adjust as ambient light levels change. An automatic light sensing device (such as photocell or similar technology) should be utilized for adjusting the digital billboard's brightness. Sunset-sunrise tables and manual methods of controlling brightness are not acceptable as a primary means of controlling brightness.
   - Brightness Measurement Methodology. The brightness standard requires the use of a Footcandle meter (also known as a "Lux meter"; ~$100-1000). A Footcandle meter measures the amount of light arriving at the meter (illuminance), as opposed to an absolute measurement of the amount of light emanating from a light source or light sources (luminance). A Footcandle is a measure of lumens (light rays) that fall on one square foot area; Lux is the metric equivalent of a Footcandle.
     In contrast, a Candela Meter / NIT Gun (~$3,000) measures the amount of light emanating from a specific light source (luminance). A NIT gun measures candelas (a measure of luminance or brightness) per meter squared (also known as "NITS"), which is a measure of the brightness emanating from a specific light source. It excludes ambient light (which may include light from many sources) from the measurement. Standard NIT levels and/or utilization of a NIT gun are not a part of the OAAA recommended brightness guideline.

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Appendix B: Glossary of lighting Terminology

Discussions of lighting issues include precise definitions, descriptions or terminology of the specific lighting technical parameters. The following glossary summarizes explanations of the technical lighting terms utilized in this Study and the related practice standards to facilitate discussion of these issues. The following technical terms are defined by IESNA is ANSI/IES LS-1-21, and are used in this Study.

Brightness:	"The attribute of a visual sensation according to which an area appears to emit more light or less light". The magnitude of sensation results from viewing a source of light. This sensation is determined partly by the source of light and partly by the conditions of observation (context). The context establishes the state of adaptation of the eye. For example, auto head lamps appear bright at night and dim during the day, because the eye adapts to the higher brightness of daylight.
BUG Rating:	A luminaire classification system established in *IES TM15-11*, BUG Ratings Addendum that provides for uniform assessment of the directional characteristics of illumination for exterior area lighting. BUG is an acronym composed of Backlight, Uplight, and Glare. BUG ratings are based on a zonal lumen calculations for secondary solid angles defined in *IES TM15-11*.
Candela:	The Standard International (SI) unit of luminous intensity. One candela is one lumen per steradian (lm/sr). Candela is a measure of light energy from a source at a specific standard angle and distance. Candela (cd) is a convenient measure to evaluate output of light from a light source in terms of both the intensity of light and the direction of travel of the light energy away from the source.
Contrast:	Calculated comparison ratio of luminance, where luminance of a subject is compared to a second luminance of an adjacent subject, or to the average luminance within the field of view of an observer. High contrast, where the ratio exceeds 30 to 1, is usually deemed uncomfortable; contrast ratios greater than of 10 to 1 are clearly visible; and contrast ratios less than 3 to 1 appear to be equal.
Glare:	The sensation produced by luminance within the visual field that are sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance or visibility. *Note:* The magnitude of the sensation of glare depends on such factors as the size, position and luminance of a source; the number of sources; and the luminance to which the eyes are adapted.

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Glare is visual discomfort experienced from high luminance or high range of luminance. For exterior environments at night, glare occurs when the range of luminance in a visual field is too large. The light energy incident at a point is measured by a scale of footcandles or lux, and is described in the technical term Illuminance. This incident light is not visible to the eye until it is reflected from a surface, such as pavement, wall, dust in the atmosphere or the surface of a light bulb. The visible brightness of a surface is measured in footlamberts (or metric equivalent candelas per square meter) and is described by the term Luminance.

The human eye processes brightness variations across a very broad spectrum of intensities. The range of brightness generated by direct noon sun versus a moonlight evening is over 5000 to 1. Human eyes are capable of accommodating to this range of intensities given adequate time to adjust. However, the eye cannot process brightness ratios of more than 30 to 1 within a view without discomfort. See ANSI/IES, LS-6-20 Lighting Science: Calculation of Light and Its Effects, 10.2 Calculating Glare.

For the purpose of this analysis, brightness of light sources may be described subjectively by the following criteria:

High Contrast Conditions: View of light fixture emitting surface, such as a lens, reflector, or lamp, where brightness contrast ratio exceeds 30 to 1 (source Luminance to background Luminance ratio in footlamberts).

Medium Contrast Conditions: Brightly lighted surfaces where contrast ratio exceeds 10 to 1, but is less than 30 to 1 (lighted surface Luminance to background Luminance ratio in footlamberts).

Low Contrast Conditions: Illuminated surfaces where contrast ratio exceeds 3 to 1, but less than 10 to 1 (source Luminance to background Luminance ratio in footlamberts).

Illuminance:

The areal density of the luminous flux incident at a point on a surface. Illuminance is the means of evaluating the density of Luminous Flux. Illuminance indicates the amount of Luminous Flux from a light source falling on a given area. Illuminance is measured in footcandles (fc) which is the lumens per square foot, or Lux (lumens per square meter). Illuminance need not necessarily be related to a real surface since it may be measured at any point within a space. Illuminance is determined from the Luminous intensity of the light source. Illuminance of a point

source decreases with the square of the distance from the light source (see Inverse Square Law definition).

Horizontal Illuminance: Illuminance incident upon a horizontal plane. The orientation of the illuminance meter or calculation point will be 180° from Nadir.

Vertical Illuminance: Illuminance incident upon a vertical plane. The orientation of the illuminance meter or calculation point will be 90° from Nadir.

Inverse Square Law: In physics, an inverse-square law is any physical law stating that a specified physical quantity or intensity is inversely proportional to the square of the distance from the source of that physical

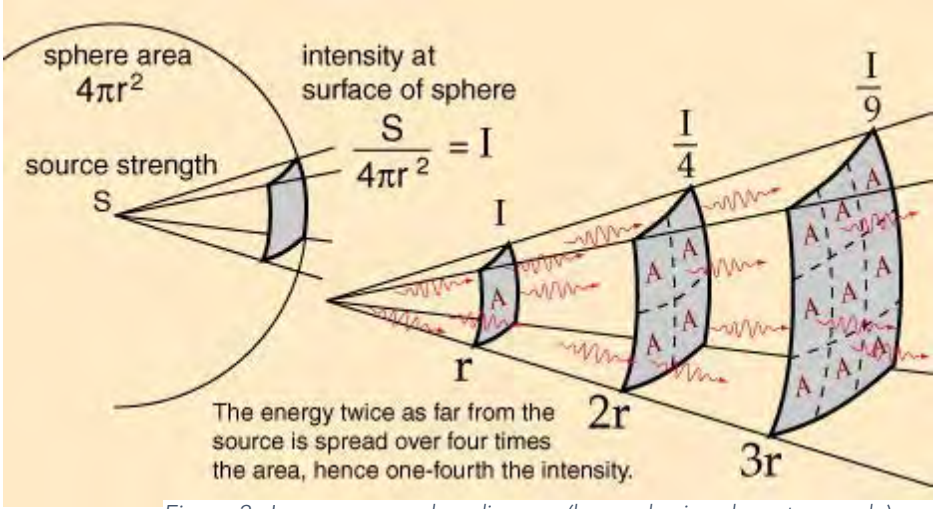

Figure 2: Inverse square law diagram (hyperphysics.phy-ast.gsu.edu)

quantity. The fundamental cause for this relationship can be understood as geometric dilution corresponding to point-source radiation into three-dimensional space (see Figure 4). The divergence of a vector field which is the resultant of radial inverse-square law fields with respect to one or more sources is everywhere proportional to the strength of the local sources, and hence zero outside sources. Newton's law of universal gravitation follows an inverse-square law, as do the effects of electric, magnetic, light, sound, and radiation phenomena. Thus, Illuminance decreases with the square of the distance from the light source.

Output Direction: Lighting products for outdoor use are classified by the extent of total light energy emitted by direction: above or below horizontal, front, or back.

Light Source: Device which emits light energy from an electric power source.

MEMO

Light trespass:	Electric light from subject property incident onto adjacent properties, measured in footcandles or lux, usually analyzed by measurement at or near the adjacent property line.
Lighting Zone (LZ):	Defined by IESNA and adopted by CALGreen.
Lighting Zone LZ2:	Outdoor areas of human activity where the vision of human residents and users is adapted to moderate light levels. Lighting is not uniform or consistent. Lighting is generally desired for safety, security and/or convenience.
Lighting Zone LZ3:	Outdoor areas of human activity where the vision of human residents and users is adapted to moderately high light levels. Lighting is generally desired for safety, security and/or convenience.
Lighting Zone LZ4:	Outdoor areas of human activity where the vision of human residents and users is adapted to high light levels. Lighting is generally desired for safety, security and/or convenience.
Lumen (lm):	**"**SI unit of luminous flux. Radiometrically, it is determined from the radiant power (see *luminous flux*). Photometrically, it is the luminous flux emitted within a unit solid angle (one steradian) by a point source having a uniform luminous intensity of one candela."
Luminance:	Luminance is a measure of emissive or reflected light from a specific surface in a specific direction over a standard area. Luminance is measured in footlamberts (fL) (1/π candela per square foot) or cd/m^2 (candela per square meter), 1fL = 3.43 cd/m^2.
Luminance:	"The quotient of the luminous flux at an element of the surface surrounding the point, and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of the surface on a plane perpendicular to the given direction. The luminous flux may be leaving, passing through, and/or arriving at the surface." Luminance is a measure of emissive or reflected light from a specific surface in a specific direction over a standard area. Luminance is measured in footlamberts (fL) (1/π candela per square foot) or cd/m^2 (candela per square meter). 1fL = 3.43 cd/m^2. Whereas Illuminance indicates the amount of Luminous Flux falling on a given surface, Luminance describes the brightness of an illuminated or luminous surface. Luminance is defined as the

ratio of luminous intensity of a surface (candela) to the projected area of this surface (m^2 or ft^2).

Luminous Flux: Mean value of total candelas produced by a light source. Luminous Flux describes the total amount of light emitted by a light source, units Lumen (lm).

This radiation could basically be measured or expressed in watts. This does not, however, describe the optical effect of a light source adequately, since the varying spectral sensitivity of the eye is not taken into account. To include the spectral sensitivity of the eye the Luminous Flux is measured in lumen. Radiant Flux or 1 W emitted at the peak of the spectral sensitivity (in the photopic range at 555 nanometers produces a Luminous Flux of 683 lumen). The unit of lumen does not define direction.

Skyglow: "The brightening of the night sky that results from the scattering and reflection of light from the constituents of the atmosphere (gaseous molecules and aerosols), in the direction of the observer. Skyglow has two separate components: natural sky glow and artificial sky glow." Natural causes of skyglow include sunlight reflected from the surface of the earth and moon, sunlight illuminating the upper atmosphere, and visible illumination from other interplanetary sources. Human made causes of skyglow include electric light that is emitted directly upward into the sky (uplight), or reflected off of the ground.

Visual Field: "The locus of objects or points in space that can be perceived when the head and eyes are kept fixed." In this Study existing and future lighting conditions are evaluated within the visual field from an observer's position at the Monitoring Sites to the Project site.