APPENDIX 3.7-F: SUPPLEMENTAL ARTIFICIAL LIGHT ANALYSIS ON TERRESTRIAL WILDLIFE SPECIES

1.1 Introduction

Artificial light at night (ALAN) is here defined, for the project, as all exterior artificial light sources used during construction and operations to light the site, as well as vehicle-mounted lighting. This analysis describes the potential biological effects of that lighting, within the context of California Environmental Quality Act (CEQA) thresholds of significance and National Environmental Policy Act (NEPA) impact definitions.

This analysis applies to all terrestrial wildlife species in the study area, though it is more focused on special-status species because their existing limited populations are more vulnerable to significant impacts compared to common species having large and robust populations. Impacts on birds have been previously treated in the Wildlife Corridor Assessment (Authority 2020, Appendix C, Sections 4.5 and 6.2.3).

In this document, exposure to ALAN is assumed to occur consistent with the project as described in Chapter 2, Alternatives, of the Final Environmental Impact Report/Environmental Impact Statement (EIR/EIS), including implementation of impact avoidance and minimization features (IAMFs) and mitigation measures in the Final EIR/EIS. IAMFs and mitigation measures relevant to ALAN include the following:

- BIO-IAMF#12: "Use of facility lighting that does not attract birds or their prey to project sites. These include using non-steady burning lights (red, dual red and white strobe, strobe-like flashing lights) to meet Federal Aviation Administration requirements, using motion or heat sensors and switches to reduce the time when lights are illuminated, using appropriate shielding to reduce horizontal or skyward illumination, and avoiding the use of high-intensity lights (e.g., sodium vapor, quartz, and halogen). Lighting will not be installed under viaduct and bridge structures in riparian habitat areas."
- BIO-MM#44: Nighttime light disturbance would be avoided near sandhill crane roost sites by not conducting any nighttime work from 1 hour before sunset to 1 hour after sunrise within 0.75 mile of observed roost sites between January 1 and March 15.
- BIO-MM#51: Nighttime light disturbance would be reduced in and adjacent to suitable habitat where known California condor roosting habitat occurs at Lover's Leap south of State Route 152. Nighttime lighting would be focused, shielded, and directed away from the nighttime roost site. The project biologist would be on site during nighttime light use to determine the lighting risk to condors and to implement lighting avoidance measures (e.g., lighting shields) if necessary.
- BIO-MM#60: Effects on San Joaquin kit fox would be minimized; construction activities within 200 feet of any occupied dens would cease 0.5 hour after sunset and would not begin earlier than 0.5 hour before sunrise to avoid indirect impacts from artificial light on the species.
- BIO-MM#76a: "The Authority will avoid conducting ground-disturbing activities within known wildlife movement routes during nighttime hours, to the extent feasible, and will shield nighttime lighting to avoid illuminating wildlife movement corridors in circumstances where feasible."
- BIO-MM#77a: This measure specifies, for the design of wildlife crossings, "Design entrances to minimize light reflection from train lights" and "Avoidance of artificial light at approaches to wildlife crossings."
- BIO-MM#80: This measure requires the Authority to install 17-foot-high noise/visual barriers within a portion of the Grasslands Ecological Area (GEA) Important Bird Area (IBA), and within the Upper Pajaro River IBA, and a guideway enclosure within the main GEA IBA centered approximately at Mud Slough, to minimize effects on birds.

In this analysis, impacts of artificial light on wildlife are described as significant if either of the following CEQA significance thresholds would be exceeded:

- Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Wildlife or U.S. Fish and Wildlife Service.
- Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors or impede the use of native wildlife nursery sites.

The Council on Environmental Quality NEPA regulations (40 Code of Federal Regulations [C.F.R.] Parts 1500–1508)[1] provide the basis for evaluating project impacts. As described in Section 1508.27 of these regulations, the criteria of context and intensity are considered together when determining the severity of the change introduced by the project.

- **Context—**For the analysis of impacts on biological and aquatic resources, the context would be the existing resources within the resource study area: the status of sensitive communities and species that occur or that could occur along the project corridor and the regulatory setting pertaining to biological and aquatic resources.
- **Intensity—**For the analysis of impacts on biological and aquatic resources, the intensity or severity of an impact would reflect the magnitude of the change between the existing and projected conditions—specifically, the degree to which the construction and operations of the project could affect these resources.

This analysis is organized as follows.

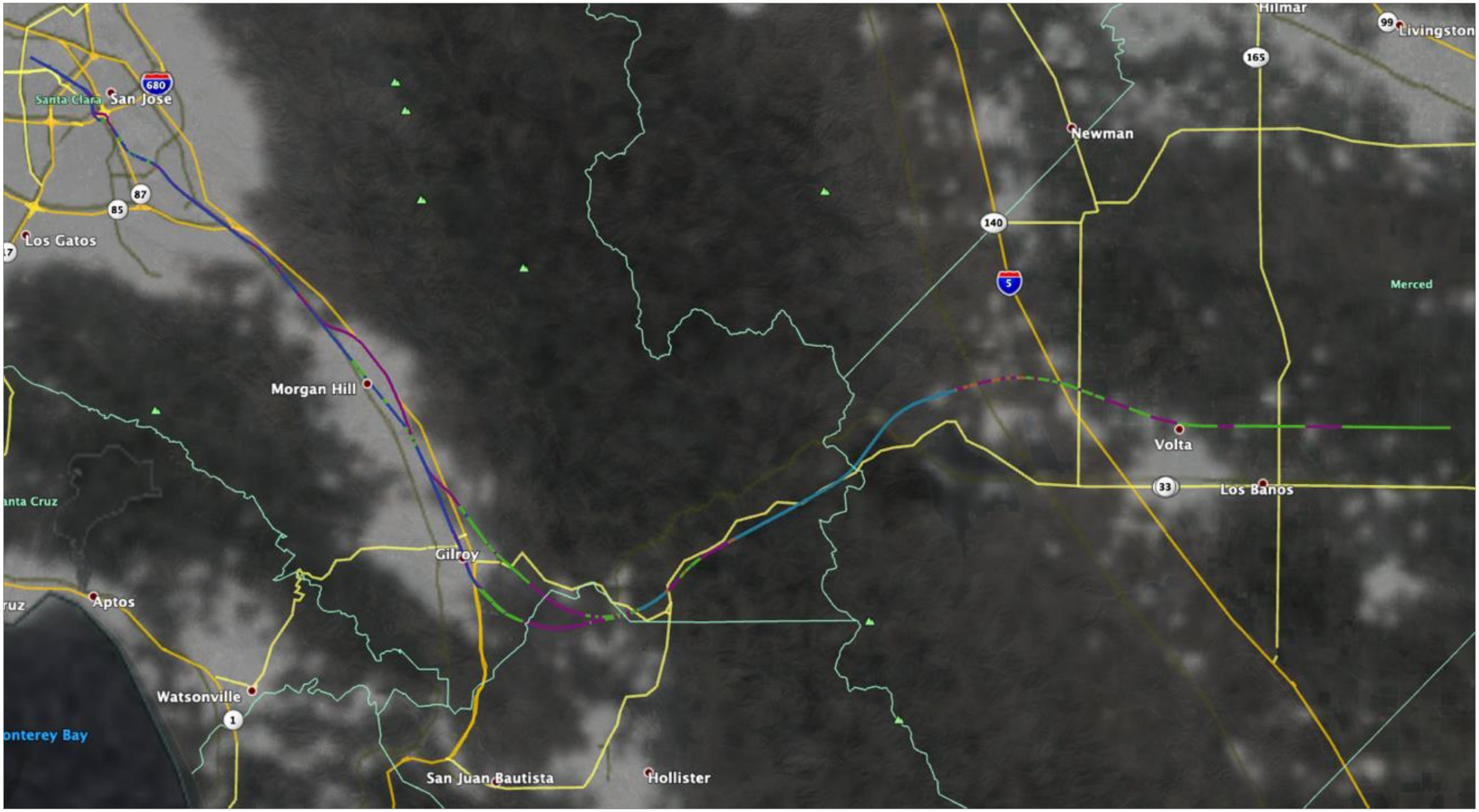
- Wildlife exposure to ALAN in the study area, considering both existing conditions and changes from that condition that would occur with construction of the project.
- Potential wildlife responses to ALAN, based on review of published studies of the subject.
- Impact assessment, including remarks on special-status species likely to be affected.
- Potential IAMFs to reduce the assessed impacts.

1.2 Artificial Light Exposure in the Study Area

ALAN alters natural light regimes spatially, temporally, and spectrally (Gaston et al. 2013). Spatial changes describe where ALAN occurs. Temporal changes affect both the timing and duration of ALAN exposure and include dynamic components, such as flickering and flashing. Spectral changes concern the color of the ALAN and are typically determined by the lighting source (e.g., LED, halogen, sodium vapor lamp). ALAN in biological systems can function as both a resource and as an information source (Gaston et al. 2013). As a resource, light may drive photosynthesis, or its absence may be critical to dark physiology processes. As an information source, light controls circadian clocks and photoperiodism, influences visual perception, and affects spatial orientation. The effects of ALAN on light as an information source have produced the most diverse and widely studied biological consequences.

The existing ALAN environment in the study area is depicted in Figure 1, which shows a satellite view of the study area at night (November 9, 2020, which was a cloudless night).

[1] The project is being evaluated under NEPA regulations as adopted prior to changes that occurred in 2020.



Source: Satellite imagery from NASA 2021

FEBRUARY 2021

Figure 1 Study Area at Night

As shown in Figure 1, the study area generally has a high level of existing light exposure from San Jose to the southern outskirts of Gilroy, though levels are appreciably lower in the Coyote Valley area. Note, however, that the alignment in Coyote Valley is colocated with an existing double track mainline used by Caltrain and by freight traffic; thus, the area has existing high exposure to operational train lighting. East of Gilroy, ALAN levels are low or very low throughout most of the alignment. Accordingly, this analysis determines potential ALAN effects to only occur in Coyote Valley and throughout the alignment east of Gilroy, where project activities have the potential to substantially alter ALAN exposure relative to existing conditions. The limits of areas (as defined in the Preliminary Engineering for Project Design Record drawings in Volume 3 of the Final EIR/EIS) with existing low ALAN exposure are shown in Table 1.

Table 1 Construction Stationing Limits of Areas with Existing Low ALAN Exposure

Area	Stationing Limits			
	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Coyote Valley	B680 to B1000	B720 to B1070	B630 to B1000	B670 to B1020
East of Gilroy	B1810 to B5335	B1810 to B5335	B1450 to B5335	B1750 to B5335

The project could cause biological effects attributable to ALAN by the following mechanisms.

- **Construction site lighting**. Site lighting is on site (i.e., within the combined temporary plus permanent impact footprint), with spillover to neighboring areas that may include wildlife habitat. Spillover would be minimized as required by BIO-MM#76a; this effect is detailed in Section 1.3.1, Continuous Lighting Effects. Light sources (spectrum) are currently dominated by metal halide light plants but would potentially be dominated by LEDs by the time the proposed work is performed. LED is a broad-spectrum source. Light intensity would vary with proximity to the light plant but would be designed to meet the Occupational Safety and Health Administration (OSHA) standard for general construction, 5 foot-candles[2] (54 lux; 29 C.F.R. § 1926.56), at the limits of the construction area. ALAN duration is potentially throughout the hours of darkness. Although directed toward the site, light sources would be visible to wildlife outside the project footprint. Night work within areas with existing low levels of ALAN and, thus, potential impacts due to construction site lighting, is only proposed in Coyote Valley and at the tunnel portals. At these locations, lighting would be minimized by implementation of BIO-MM#76a.
- **Construction vehicle lighting**. Vehicles going to and coming from the project site or vehicles operating within the project footprint may briefly direct light (headlights or spotlights) toward areas outside the project footprint. Though of short duration and limited spatial scope, lights of this intensity can influence wildlife behavior or physiology.
- **Operational site lighting**. This lighting occurs at stations and other facilities, such as the maintenance-of-way facility (MOWF) and the traction power stations. Operational site lighting would comply with BIO-IAMF#12. Operational site lighting is directed toward the site and is predominantly of a fairly low intensity. At the traction power stations, it consists of security lighting, approximately 5 lux. At the stations and MOWF, it is approximately 20 to 50 lux. Operational site lighting is continuous throughout the hours of darkness, except to the extent that it can sometimes be stopped consistent with BIO-IAMF#12. Although directed toward the site, light sources would be visible to wildlife outside the project footprint and could affect

[2] Many different units are used to measure light. This analysis primarily uses lux, which is a measure of the amount of light falling on a surface. Other common units include the lumen, which is one lux per square meter; the foot-candle, which is one lumen per square foot; and the candela, a measure of the intrinsic brightness of any point on a source of illumination. For conversion between these units, see https://www.compuphase.com/electronics/candela_lumen.htm (accessed January 19, 2021).

wildlife through the same mechanisms discussed for construction site lighting. The impact would be permanent.

- **Operational train lighting**. This lighting consists of train headlights and incidental light that may be visible at train windows. Headlights are required by Federal Railroad Administration (FRA) regulations and must have an output of 200,000 candelas. Three train headlights are required, but FRA allows a waiver that uses one headlight except at at-grade crossings; such crossings exist in Alternative 4 but not the other alternatives. The California High-Speed Rail Authority (Authority) intends to seek such a waiver, and only use three headlights near at-grade crossings; there are no such crossings within the areas specified in Table 1 (Volume 2, Appendix 2-B, Railroad Crossings, of the Final EIR/EIS). Spectrum is undefined but would likely be LED. This stimulus is bright, brief, and repetitive, occurring once at any given site for every night train passage.[3] Incidental light from train windows is of very low intensity, less than 1 lux, diminishing rapidly with distance from the train. Operational train lighting would be essentially invisible to wildlife in sections of the alignment confined by tunnels, trenches, or noise/visual barriers and would be minimized at wildlife crossings as specified by BIO-MM#77a.
- **Operations maintenance activity lighting**. This lighting includes vehicle headlights and work-site lighting of intensity comparable to construction site and construction vehicle lighting. The principal maintenance activities would be fence inspection, track inspection, and track or overhead contact system work. Fence inspection is performed during daylight hours. Track inspection inspects the entire project approximately every day. It is potentially performed at night but consists exclusively of track inspection, with all lighting directed at the track and confined within the fenceline; thus, there would be no illumination of wildlife habitat except by the headlight of the inspection train. Track or overhead contact system work also occurs entirely within the fenceline, but there could be incidental illumination of habitat in the same manner as described for construction work, and habitat could be illuminated by the headlight of the maintenance train. This lighting would affect no more than 1 mile of track per night and would be infrequent (intervals of months to years).
- **Cumulative impacts**. All forms of ALAN associated with the project are expected to make a regional contribution to light pollution and thus to skyglow, which has been associated with a variety of biological effects.

Light sources generally attenuate according to an inverse square law; with a doubling of distance from the light source, intensity decreases by a factor of four. Table 2 summarizes some common light sources relevant to this analysis and their brightness in lux.

Table 2 Illuminance Levels of Common Light Sources

Source	Brightness (lux)
Full sunlight	103,000
Cloudy day	1,000–10,000
Most homes	100–300
OSHA construction lighting requirement	54
Average street lighting	15
Average security lighting	5

[3] See Final EIR/EIS Table 2-14 for estimates of train frequency. The maximum would be 148 trains per day from 7 a.m. to 10 p.m. and 28 trains per day from 10 p.m. to 7 a.m. Over the course of the year, the night is an average of 12 hours long, with 1 hour less if civil, nautical, or astronomical twilight, respectively, are considered. There would be an average of approximately 35 evening trains and 4 morning trains each night, and these numbers vary with time of year and whether daylight savings time is observed.

Source	Brightness (lux)
Full moon	0.1–0.3
Urban skyglow	0.15
Quarter moon	0.01–0.03
Clear starry night	0.001
Cloudy night	0.00003–0.0001

Source: Gaston et al. (2013)
Note: OSHA = Occupational Health and Safety Administration

1.3 Wildlife Responses to Artificial Light

This section discusses research related to the effects on wildlife of three forms of project-related ALAN: continuous lighting directed onto the project site that is visible to wildlife located outside the project site, intermittent lighting from vehicle or train headlights that is directed toward wildlife habitat, and lighting from all project sources that contributes to skyglow. No research appears to have assessed the effects of light from high-speed trains in other countries or locations.

1.3.1 Continuous Lighting Effects

Research into the biological effects of ALAN and its minimization has focused almost exclusively on emissions from streetlights (Gaston and Holt 2018), a form of continuous lighting directed at an animal (or plant) or its habitat. This impact would occur under the project to the extent that the air over a project site may function as foraging habitat for birds or bats and by illumination of habitat proximal to the illuminated area. Consequently, the project largely avoids the impacts that have been attributed to ALAN simply by minimizing continuous direct illumination of habitat. However, project illumination of aerial habitat would be biologically important to the extent that it is an insect attractant, and both birds and bats may approach to forage on the insects; examples include short-eared owls and bats (Rydell 1991; Canario et al. 2012). Although some bats approach and forage near such lighting, others avoid such lights (Bolliger et al 2020). Which species respond in these different ways is difficult to predict, as even bats within the same genus have sometimes been found to behave quite differently (Rotics et al. 2011).

The extent of potential illumination of habitat proximal to the illuminated area was recently investigated during night work at a high-speed rail (HSR) construction site near Corcoran, California (Bakersfield to Fresno Project Section). At this location, metal halide light plants were used to illuminate the work site. Lights were directed downward and toward the work area. The OSHA construction lighting standard of 5 foot-candles was met within approximately 130 feet from the light plant. Beyond that distance, illumination diminished rapidly, reaching a value of approximately zero relative to background at 250 feet from the light source; background was 0.04 to 0.25 lux despite the absence of a moon, indicating substantial skyglow (H.T. Harvey and Associates 2020). Based on this evidence, it is expected that effects due to unintended illumination of habitat adjacent to a work area may be encountered at distances of up to 250 feet from an operating light plant.

Apart from effects on flying animals, no research appears to have examined the effect of lighting that is not directed at organisms or their habitat, except in the case of skyglow effects, discussed in Section 1.3.3, Skyglow Effects. Since lux levels would drop to ambient within 250 feet from lights located within the project footprint, such impacts are unlikely.

1.3.2 Intermittent Lighting Effects

Vehicle headlights are the predominant mobile source of ALAN. Gaston and Holt (2018) found that “the ecological impacts that might arise from these have received almost no attention, or only passing reference, either within the literature on impacts of artificial nighttime lighting, or on the ecological impacts of roads. Where they have been considered, the focus has been on the dazzling of vertebrates and the resultant potential for these causing collisions with vehicles.”

These researchers suggested that headlights could cause biological effects through the following mechanisms (Gaston and Holt 2018).

- Headlights are focused so as to illuminate at higher intensities than commonly experienced from other sources and well above activation thresholds for many biological processes.
- Headlights are projected largely in a horizontal plane and thus can carry over long distances.
- Headlights are introduced into much more extensive areas of the landscape than experience street lighting and similar forms of ALAN.
- Headlights typically have a broad spectrum that substantially overlaps with wavelengths that influence many biological processes.
- Headlights are often expressed as a series of pulses of light (produced by passage of separate vehicles), a dynamic known to have biological impacts.

Bennie et al. (2016) found that an automotive headlight measuring 10,000 lux at 1 meter (m) produced 25 lux at 50 m and 1 lux at 100 m; this is a substantially slower drop-off than predicted by the inverse square law, a result achieved due to sophisticated reflector design in the headlight. These results suggest a value of 0.1 lux (equivalent to a full moon) at a distance of 320 m. Comparable performance in a train headlight rated at 200,000 candela (the FRA requirement[4]) would result in a brightness of 0.1 lux (equivalent to a full moon) at a distance of 1,400 m. However, train headlight drop-off as a function of angle is extreme; FRA requires only 3,000 candela at 7.5 degrees off-axis, which would diminish to full-moon brightness (0.1 lux) at a distance of 170 m. These results indicate that at any time approximately 31,066 m^2 would be illuminated by the train's headlight to a brightness greater than the full moon. Due to the extremely low curvature of the HSR track, that light is projected essentially straight down the track, and the central 21,350 m^2 would be within the fenceline. Thus, only 9,716 m^2 (2.4 acres) of habitat would be illuminated at any time and to a relatively low (but variable) intensity; moreover, this would affect habitat only within 26.5 m from the fence (similar to the area most affected by train noise). Also, note that beyond a distance of 1,007 m, the elevated light levels would only be within the fenceline and thus would not illuminate habitat. Since the area of increased illumination extends over a distance of 1,007 m and the train's speed would be 220 miles per hour (98.35 m per second) in the portions of the alignment east of the Gilroy station where baseline light levels are low or very low, the elevated illumination would last up to 10.23 seconds each time a train passed.

Headlights typically have "white" light, with a color temperature of approximately 3,500 to 4,000 degrees Kelvin; white light has a "greater likelihood of substantial emissions in key parts of the action spectra of many biological processes." Concerns have particularly been raised around emissions in the blue part of the spectrum, which may affect melatonin levels and circadian rhythms of many species (Gaston and Holt 2018).

Although the vast majority of studies of the biological impacts of ALAN have focused on continuous lighting, laboratory studies on other organisms have shown that shorter exposure to pulsed lighting can have substantial effects. Examples gleaned from a literature review by Gaston and Holt (2018) include the following.

- For the moths *Helicoverpa armigera* and *Mamestra brassicae*, 0.5-second pulses of green light decreased activity in one species, with no effect on the other.
- For the mosquito *Anopheles gambiae*, 6-, 10-, or 30-minute pulses of 150 to 870 lux produced suppression of biting activity.

[4] 49 C.F.R. Section 229.125(a)(1) requires "If a locomotive is equipped with a single-lamp headlight, the single lamp shall produce a peak intensity of at least 200,000 candela and shall produce at least 3,000 candela at an angle of 7.5 degrees and at least 400 candela at an angle of 20 degrees from the centerline of the locomotive when the light is aimed parallel to the tracks."

- For the Japanese horse-mackerel *Trachuras japonicus*, pulses of 3.0, 1.36, 0.62, and 0.15 cycles per second, at peak of 100 lux, produced general aversion to intermittent light or attraction and school confusion.
- For the rat *Rattus norvegicus*, a 1 millisecond pulse at 2,000 megawatt per square centimeter reduced pineal N-acetyltransferase and melatonin content.
- For the rat *Rattus norvegicus*, a 5- to 60-minute pulse every 2 hours at 200 to 250 foot-candles produced greater visual cell damage than continuous light exposure.
- For the rat *Rattus norvegicus*, five 1-minute pulses every 2 hours using two standard 100 watt incandescent lamps produced decreased peak nighttime serum melatonin concentrations.
- For the Syrian hamster *Mesocricetus auratus*, a 1- or 5-second pulse at 32,000 microwatts per square centimeter depressed pineal melatonin production.
- For the Djungarian hamster *Phodopus sungorus*, a 1-minute pulse at 40 to 200 lux reduced melatonin synthesis during the consecutive night.

Although these represent laboratory studies of organisms not found in the study area, they do suggest that exposure to intermittent ALAN can affect melatonin production in a variety of mammals and could have varied and potentially adverse behavioral effects in other species. Melatonin is a hormone that regulates circadian rhythms in most vertebrates. It has been linked to a wide variety of essential behaviors, such as reproduction, the sleep cycle, body temperature, and timing of seasonal changes. These results suggest a broad potential for ALAN associated with headlights to affect circadian rhythms of wildlife in adverse ways.

Besides these specific studies, pulsed lighting has been shown to elicit avoidance behavior in many animals, with limited evidence for adaptive responses (Gaston and Holt 2018); and to be less of an attractant than continuous lighting (Gehring et al. 2009). Thus, wildlife may avoid areas exposed to pulsed lighting; this would affect animal movement and habitat fragmentation (Gaston and Holt 2018).

1.3.3 Skyglow Effects

Skyglow from ALAN is primarily caused by upwardly emitted artificial light being scattered in the atmosphere by water and dust. Ground-reflected artificial light can also contribute. Skyglow can increase background nighttime sky brightness to levels of 0.2–0.5 lux, comparable with late twilight and moonlight (Gaston et al. 2017). Skyglow has the potential to disrupt both circadian clocks and photoperiodism in some species (Gaston et al. 2013). It may also mask natural light signals used for navigation, including moon position and polarized atmospheric light (Gaston et al. 2013). Skyglow alone can be sufficient to mask natural monthly and seasonal regimes of lunar sky brightness and to increase the annual number and regime of full moon equivalent hours available to organisms during the night (Davies et al. 2013). ALAN has been found to substantially alter the timing of avian reproductive biology, even at light levels comparable to a full moon (i.e., 0.3 lux; Dominoni et al. 2013).

1.4 Impact Assessment

An impact would occur if the project would have a substantial adverse effect on wildlife movement or if it were to, either directly or through habitat modifications, adversely affect any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Wildlife or U.S. Fish and Wildlife Service. Eleven special-status mammal species are potentially affected: mountain lion, San Joaquin kit fox, Tule elk, badger, ringtail, dusky-footed woodrat, Fresno kangaroo rat, Townsend's big-eared bat, western mastiff bat, pallid bat, and western red bat.

Impacts are assumed possible due to exposure to continuous or intermittent lighting. The project is assumed to not make a substantial contribution to skyglow in the study area for the following reasons, thus skyglow impacts are not assessed.

- Continuous project light sources are required, as part of project design, to minimize illumination consistent with existing requirements under law and regulation and to use lighting that does not direct light upward. Consequently, continuous light sources have a low potential to contribute to skyglow, relative to current conditions, under which upward-directed light sources are abundant throughout most of the study area.
- Intermittent project light sources are directed laterally and thus have limited potential to contribute to skyglow.

Impacts of continuous and intermittent project lighting are evaluated here on a species-by-species basis, concluding with an evaluation of potential impacts on non-special-status wildlife.

1.4.1 Mountain Lion

Mountain lion would potentially be affected in areas where the project alignment overlaps modeled lion habitat in Coyote Valley and in most of the Pacheco Pass Subsection. Within this area, effects could occur, except in those areas where the alignment is in a tunnel or where operational lighting is hidden by noise/light barrier walls. Because the project would minimize lighting of modeled habitat from continuous sources of construction lighting and operations lighting, this lighting would have little potential to affect mountain lion. Intermittent sources of both construction and operations lighting would at times be directed toward modeled habitat. Exposures would be brief but could potentially last for periods of minutes in the case of construction lighting and up to 10 seconds in the case of operational train lighting. These exposures would be minimized due to the installation of noise/light barriers at critical wildlife crossings in Coyote Valley and Pacheco Pass; thus, effects on mountain lion passage corridors would be minor. Elsewhere, areas affected at each exposure to intermittent lighting would be on the order of up to 9,716 m^2 (2.4 acres). Exposure to intermittent light has been found to potentially affect melatonin metabolism and to elicit avoidance responses, as discussed in Section 1.3.2, Intermittent Lighting Effects, although no literature has been found addressing intermittent light effects on mountain lion or, indeed, upon any large mammals. Nonetheless, there is a clear potential for adverse behavioral and physiological effects resulting from intermittent light exposure from both construction and operations sources.

1.4.2 San Joaquin Kit Fox

San Joaquin kit fox would potentially be affected in areas where the project alignment overlaps modeled kit fox habitat, most significantly in the Pacheco Pass Subsection east of the easternmost Pacheco Pass tunnel near the O'Neil Forebay, where individuals are more likely to occur (as they move north from occupied areas in Panoche Valley to the south). Within this area, effects could occur, except that nighttime construction would not occur in this area, and operational lighting would be hidden at locations with noise/light barrier walls; these walls are located at a critical wildlife crossing east of Pacheco Pass and would serve to minimize effects on kit fox movement corridors. Continuous sources of operations lighting would minimize lighting of modeled habitat and thus have little potential to affect kit fox. Intermittent sources of operations lighting would at times be directed toward modeled habitat. Exposures would be brief, lasting up to 10 seconds in the case of operational train lighting. Areas affected at each exposure would be on the order of up to 9,716 m^2 (2.4 acres). Exposure to intermittent light has been found to potentially affect melatonin metabolism and to elicit avoidance responses, as discussed in Section 1.3.2, although no literature has been found addressing intermittent light effects on kit fox or, indeed, upon any large mammals. Nonetheless, there is a clear potential for adverse behavioral and physiological effects resulting from intermittent light exposure from both construction and operations sources.

1.4.3 Tule Elk

Tule elk would potentially be affected in areas where the project alignment overlaps modeled Tule elk habitat in the Pacheco Pass Subsection. Within this area, effects could occur, except in those areas where the alignment is in a tunnel or where operational lighting is hidden by noise/light barrier walls; these walls are located at a critical wildlife crossing west of Pacheco Pass and would serve to minimize effects on Tule elk movement. Construction lighting would be limited to tunnel portals. Because the project would minimize lighting of modeled habitat from continuous sources of construction lighting and operations lighting, this lighting would have little potential to affect Tule elk. Intermittent sources of both construction and operations lighting would at times be directed toward modeled habitat. Exposures would be brief but could potentially last for periods of minutes in the case of construction lighting and up to 10 seconds in the case of operational train lighting. Areas affected at each exposure would be on the order of up to 9,716 m^2 (2.4 acres). Exposure to intermittent light has been found to potentially affect melatonin metabolism and to elicit avoidance responses, as discussed in Section 1.3.2, although no literature has been found addressing intermittent light effects on Tule elk or, indeed, upon any large mammals. Nonetheless, there is a clear potential for adverse behavioral and physiological effects resulting from intermittent light exposure from both construction and operations sources.

1.4.4 Badger and Ringtail

Badger and ringtail would potentially be affected in areas where the project alignment overlaps modeled badger or ringtail habitat in Coyote Valley and in most of the Pacheco Pass Subsection. Within this area, effects could occur, except in those areas where the alignment is in a tunnel or where operational lighting is hidden by noise/light barrier walls; these walls are located at critical wildlife crossings in Coyote Valley and Pacheco Pass and would serve to minimize effects on wildlife movement. In the Pacheco Pass Subsection, construction lighting would be limited to tunnel portals. Continuous sources of both construction lighting and operations lighting would minimize lighting of modeled habitat and thus have little potential to affect badger or ringtail. Intermittent sources of both construction and operations lighting would at times be directed toward modeled habitat. Exposures would be brief but could potentially last for periods of minutes in the case of construction lighting and up to 10 seconds in the case of operational train lighting. Areas affected at each exposure would be on the order of up to 9,716 m^2 (2.4 acres). Exposure to intermittent light has been found to potentially affect melatonin metabolism and to elicit avoidance responses, as discussed in Section 1.3.2, although no literature has been found addressing intermittent light effects on badger, ringtail, or, indeed, upon any large mammals. Nonetheless there is a clear potential for adverse behavioral and physiological effects resulting from intermittent light exposure from both construction and operations sources.

1.4.5 Dusky-Footed Woodrat and Fresno Kangaroo Rat

Dusky-footed woodrat would potentially be affected in areas where the project alignment overlaps modeled woodrat habitat in Coyote Valley and from south of Gilroy to western Pacheco Pass. Fresno kangaroo rat would potentially be affected in areas where the project alignment overlaps modeled kangaroo rat habitat in the Central Valley east of Interstate 5. Within these areas, effects could occur, except in those areas where the alignment is in a tunnel or where operational lighting is hidden by noise/light barrier walls; such a barrier is located in the Grasslands Ecological Area and would serve to minimize effects on wildlife movement. In the Pacheco Pass Subsection, construction lighting would be limited to tunnel portals, and, in the Central Valley, construction lighting would be avoided. Because the project would minimize lighting of modeled habitat from continuous sources of construction lighting and operations lighting, this lighting would have little potential to affect woodrat or kangaroo rat. Intermittent sources of both construction and operations lighting would at times be directed toward modeled habitat. Exposures would be brief but could potentially last for periods of minutes in the case of construction lighting and up to 10 seconds in the case of operational train lighting. Areas affected at each exposure would be on the order of up to 9,716 m^2 (2.4 acres). Exposure to intermittent light has been found to potentially affect melatonin metabolism and to elicit avoidance responses, as discussed in Section 1.3.2; adverse effects on three rodent species have been identified, although no literature has been found addressing intermittent light effects on woodrat or kangaroo rat. Nonetheless, there is a clear potential for adverse behavioral and physiological effects resulting from intermittent light exposure from both construction and operations sources.

1.4.6 Townsend's Big-Eared Bat, Western Mastiff Bat, Pallid Bat, and Western Red Bat

These bat species are potentially present throughout the project alignment. To the extent their foraging habitat is aerial, it overlaps both the construction and operational project footprints. In areas having existing high levels of ALAN, project lighting would not substantially alter that condition, and project impacts would thus be minor, likely indistinguishable from existing conditions. Projects impacts would also be minor in tunnels. Elsewhere, the project could introduce continuous lighting to areas where it is currently absent, with a potential for effects. Continuous lighting from construction could occur only in Coyote Valley and at the tunnel portals. Continuous lighting from operations will primarily occur at traction power stations located in areas where ALAN is currently low, at stations, at tunnel portals, and at the MOWF. Lighting at tunnel portals serves as a minimization measure to discourage bat roosting in and near tunnels, which would otherwise expose them to mortality via train strike.

As discussed in Section 1.3.1, continuous project lighting is likely to be an attractant to flying insects and thus to bats. Some bats avoid lighting in spite of its effects on flying insects; however, in view of the potential food source represented by continuous project lighting, one or more of these species would likely forage near ALAN sources. The principal adverse impact of ALAN on bats is that it limits habitat access for those species that are averse to light (Azam et al. 2015). If one or more of these four species are light-averse, they would lose access to areas illuminated by continuous project lighting. Moreover, because species' foraging patterns could be affected, these species could be exposed to more indirect effects, such as increased predation risk or altered competitive relationships with less light-averse species (Azam et al. 2015). This risk can be assessed for each species.

Townsend's big-eared bat (*Corynorhinus townsendii*, sometimes called *Plecotus townsendii*). This bat is primarily a forest species and a dark-loving bat. Species of *Plecotus* have been shown to be averse to light, avoiding lighted roadways (Rydell 1992). Thus, project ALAN may represent an adverse impact on this species by reducing habitat, altering competitive relationships with less-sensitive bat species, and contributing to habitat fragmentation. Impacts associated with construction throughout the alignment would be temporary, and impacts associated with continuous lighting at project facilities and with operational maintenance lighting would be permanent.

Western mastiff bat (*Eumops perotis*). A variety of bats in the genus *Eumops* have commonly been observed foraging over and near streetlights and other ALAN sources (Rydell 2006). If the western mastiff bat shows similar behavior, project ALAN is less likely to have adverse impacts on this species.

Pallid bat (*Antrozous pallidus*). The pallid bat has an unusual foraging strategy, primarily preying upon ground-dwelling invertebrates that it captures by detecting the sounds they make (Jones et al. 2016). Thus, areas illuminated by continuous project lighting, which are almost entirely parking areas and other areas that do not provide foraging opportunities, do not constitute habitat for pallid bats, and continuous lighting does not constitute an impact on this species.

Western red bat (*Lasiurus blossevillii*). Some species in the genus *Lasiurus* have been observed foraging over and near streetlights and other ALAN sources, including the red bat *L. borealis* (Rydell 2006). If the western red bat shows similar behavior, project ALAN is less likely to have adverse impacts on this species.

All four bat species are subject to impacts of intermittent light from construction and from train operations. Intermittent sources of both construction and operations lighting would at times be directed toward bat habitat. Exposures would be brief but could potentially last for periods of minutes in the case of construction lighting and up to 10 seconds in the case of operational train lighting. Areas affected at each exposure would be on the order of up to 9,716 m^2 (2.4 acres). Exposure to intermittent light has been found to potentially affect melatonin metabolism and to elicit avoidance responses, as discussed in Section 1.3.2, although no literature has been found addressing intermittent light effects on any species of bat. However, studies have found that melatonin is critical to circadian and seasonal variations in bat physiology; for example, it is involved in seasonal metabolic changes in the pallid bat reproductive cycle (Beasley et al. 1984; Beasley and Leon 1986). There is a clear potential for adverse behavioral and physiological effects resulting from intermittent light exposure from both construction and operations sources.

1.4.7 Non-Special-Status Wildlife

Non-special-status wildlife includes a wide variety of vertebrate species. These species would potentially be affected in areas where the project introduces ALAN to areas that are currently relatively dark, in Coyote Valley and from south of Gilroy to the eastern end of the alignment. Within these areas, effects could occur, except in those areas where the alignment is in a tunnel or where operational lighting is hidden by noise/light barrier walls, which are located at multiple critical wildlife crossings and would serve to minimize effects on wildlife movement. Because the project would minimize lighting of wildlife habitat from continuous sources of construction lighting and operations lighting, this lighting would have little potential to affect wildlife. Intermittent sources of both construction and operations lighting would at times be directed toward wildlife habitat. Exposures would be brief but could potentially last for periods of minutes in the case of construction lighting and up to 10 seconds in the case of operational train lighting. Areas affected at each exposure would be on the order of up to 9,716 m^2 (2.4 acres). Exposure to intermittent light has been found to potentially affect melatonin metabolism and to elicit avoidance responses, as discussed in Section 1.3.2. This would create local and temporary habitat quality reductions; however, none of the non-special-status wildlife populations are known to be vulnerable to population-level effects as a result of such impacts.

1.5 Measures to Reduce Effects

The project incorporates BIO-IAMF#12 to minimize ALAN effects on wildlife by avoiding directing continuous light sources toward wildlife habitat, avoiding use of high-intensity lights to the extent allowable (the sole exception being train headlights, which are required to be of high intensity), minimizing directing light upward or laterally, and avoiding illumination of wildlife crossings or of streams or areas of riparian habitat.

In consideration of this IAMF and other relevant mitigation measures in the Final EIR/EIS, lighting effects remain from the use of continuous lighting that may serve as an attractant to wildlife occupying nearby habitat, and the use of intermittent lighting associated with vehicles used for construction, maintenance, or operations.

There are five types of mitigation measures to address ALAN impacts (Gaston et al. 2012; Schroer and Holker 2017): (1) maintaining and creating dark areas; (2) reducing light trespass so as to direct ALAN where it is needed and to prevent it from being directed elsewhere; (3) reducing the intensity of ALAN; (4) reducing the duration of ALAN by switching off lighting sources when they are not needed; and (e) reducing biological impacts of ALAN by using illumination sources that provide sufficient human benefit while minimizing wavelengths having high biological activity. The first two of these measures have been addressed to the extent feasible, using the measures named above. The following additional measures are recommended to further reduce lighting impacts within the areas identified in Table 1.

- Minimize intensity and duration of construction lighting: Design construction lighting to be consistent with the minimum lighting levels approved by OSHA for general construction—5 foot-candles (54 lux; 29 C.F.R. § 1926.56). When performing construction in or adjoining habitat for special-status species, notify wildlife agencies of planned activities and discuss means to minimize construction effects at the proposed site. To the extent feasible, minimize duration of lighting, for example by using methods other than lighting to ensure security of the construction site during the hours it is not in use.

- Minimize intermittent construction lighting: Minimize direction of construction vehicle headlights towards offsite locations. Use low beams or turn off headlights when safety considerations permit.
- Minimize intensity and duration of operational lighting: Provide operational facility outdoor lighting consistent with minimum OSHA requirements established by 29 C.F.R. Section 1926.56. To the extent feasible, minimize duration of lighting, for example by using methods other than lighting to ensure security of facilities during hours they are not in use.
- Minimize intensity of train lighting: Provide headlights consistent with the minimum standard allowed under 49 C.F.R. Section 229.125, that is a single-lamp headlight of at least 200,000 candelas. Off-axis performance of the headlight should likewise conform to regulatory minimum standards. Obtain an FRA variance to allow use of a single headlight except near at-grade crossings.
- Minimize use of lighting at short wavelengths: A variety of studies have shown that shorter (blue) wavelengths have deleterious effects on bats. These can be eliminated, particularly if LED lighting is used and intensities are minimized (Kerbiriou et al. 2020; Lewanzik and Voight 2017). Lamps should have the lowest color temperature feasible for the desired application; green and red lighting appears to have the least wildlife impact and will be appropriate for some applications, such as security lighting (Longcore and Rich 2016). To the extent feasible, filter or specify all lamps to remove wavelengths shorter than 530 nanometers; this will avoid the wavelengths shown to cause melatonin disruption in humans and many other vertebrates (Kayumov et al. 2005).
- Implement noise/visual barriers to shield view of the operational train at essential wildlife crossings.[5]

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[5] See Volume 2, Appendix 3.7-E, Supplemental Noise Analysis on Terrestrial Wildlife Species, of the Final EIR/EIS, where the location and design of additional noise/visual barriers are described.

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