APPENDIX M.
SLEEP DISTURBANCE ANALYSIS

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Technical Memorandum

To:	Dave Full, RS&H 311 California Street, Suite 720 San Francisco, CA 94104
From:	Rhea Hanrahan, Principal Consultant Joe Czech, Principal Consultant Vincent Ma, Senior Consultant
Date:	June 28, 2023
Subject:	Oakland International Airport Terminal Modernization and Development Project - Environmental Impact Report, Results of Evaluation of the Potential for Sleep Disturbance
Reference:	HMMH Project Number 311530.000

This memorandum presents the results for the evaluation of the potential for sleep disturbance for the Port of Oakland's (Port) Terminal Modernization and Development Project (Proposed Project) at Oakland International Airport (Airport or OAK). While a sleep disturbance study is not required under the California Environmental Quality Act (CEQA), it is included with the CEQA environmental impact report (EIR) for informational purposes only.

1.0 Background

The goal of a sleep disturbance analysis is to estimate the degree of sleep disturbance (analyzed as the number of awakenings between 10 p.m. to 7 a.m.) at locations within a project's general study area for each modeled scenario to estimate the amount of change relative to existing conditions (2019).

The Technical Memorandum "Oakland International Airport Terminal Modernization and Development Project – Environmental Impact Report Methodology for Evaluation of the Potential for Sleep Disturbance" dated December 21, 2022, provided in **Attachment 1**, provides the background, brief literature review and detailed methodology used to evaluate the potential for sleep disturbance. This Technical Memorandum presents the results of the evaluation.

Sleep disturbance is evaluated as the average number of aircraft noise-induced indoor awakenings (NAWR) at census block locations with residential land use in the vicinity of OAK. A range of NAWR, i.e., NAWR for open windows and closed windows, is presented via color-coded maps. A range needs to be presented because nighttime awakenings, or NAWR, would occur less with closed windows than with open windows.

2.0 Results

Sections 2.1 through 2.3 discuss the results of existing conditions, future year 2028, and future year 2038 scenarios, respectively.

2.1 Existing Conditions

Figures 2-1 and **2-2** show residential areas by census block group shaded based on their centroid's[1] NAWR for existing conditions for windows open and windows closed, respectively. **Table 2-1** lists the statistics for nighttime awakenings. NAWR ranges up to 1.41 for windows closed and up to 2.48 for windows open. Residential areas with the highest NAWR for windows open and closed are near the approach end of Runways 12 and 10L/10R and southeast of the approach end of Runway 30. The average NAWR across all analyzed residential areas ranges from 0.08 to 0.34. Or stated differently, the average NAWR is between 8 and 34 awakenings per 100 annual average nighttime flights, depending on the windows being open or closed.

Most residential areas' NAWR values are primarily affected by two-engine narrow-body jets, such as the Boeing 737 or Airbus A319/A320/A321 series of aircraft. The second highest contribution is from single-engine propeller aircraft, such as the Cessna 172 aircraft. The third highest contribution is from three-engine wide body jets. Single-engine propeller aircraft contribute more to the NAWR than three-engine wide-body jets because single-engine propeller aircraft operations occur more frequently in North Field with more of their flight tracks turning into/coming from residential areas north of OAK. Three-engine wide-body jets operate in South Field on Runway 12/30 with flight tracks mostly going over San Francisco Bay away from the communities.

Table 2-1
NAWR for Existing Conditions Across All Modeled Block Group Centroids

Windows	Minimum	Average	Maximum
Open	0.02	0.34	2.48
Closed	<0.005	0.08	1.41

NAWR: aircraft noise-induced indoor awakenings

2.2 Future Year 2028

Figures 2-3 and **2-4** show the NAWR results for future year 2028, for windows open and windows closed, respectively. **Table 2-2** lists the statistics for nighttime awakenings for future year 2028 and the differences in NAWR relative to existing conditions. NAWR would range from less than 0.005 to 1.53 for windows closed and up to 2.74 for windows open. Block group centroids with higher NAWR would be near the ends of Runways 12 and 10L/10R and southeast of the approach end of Runway 30. The block group centroid with the highest NAWR would be near the predominant arrival paths for commercial jets arriving on Runway 30. The average NAWR across all block group centroids would range from 0.08 to 0.35. Or stated differently, the average NAWR would range between 8 and 35 annual average nighttime awakenings per 100 flights, depending on the windows being open or closed.

[1] Centroid is defined as the geometrical center point of the 2020 US Census block group containing low-, medium-, or high-density residential land use, or mixed use, within the general study area.

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Figure 2-1
NAWR for Existing Conditions, Windows Open

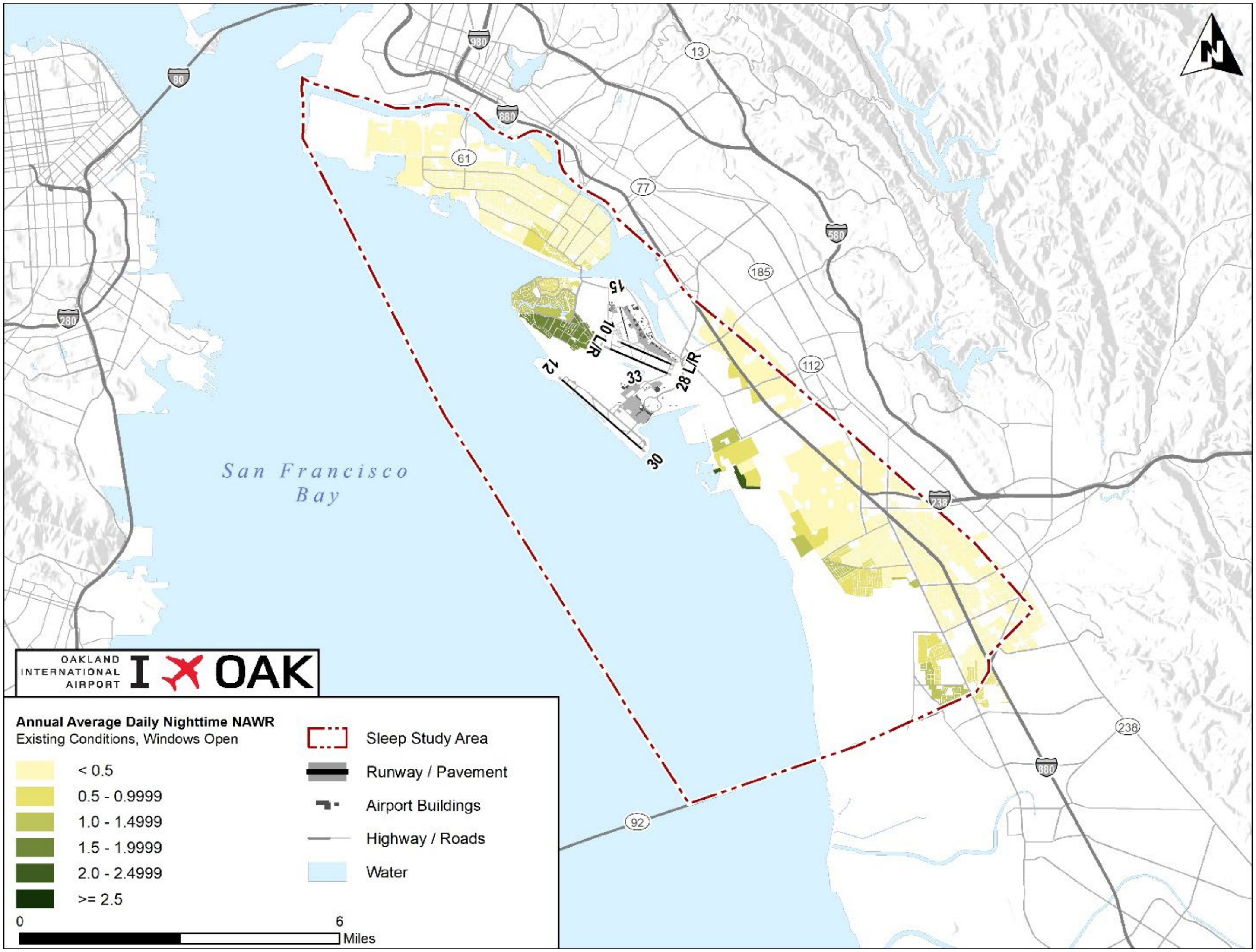

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Figure 2-2
NAWR for Existing Conditions, Windows Closed

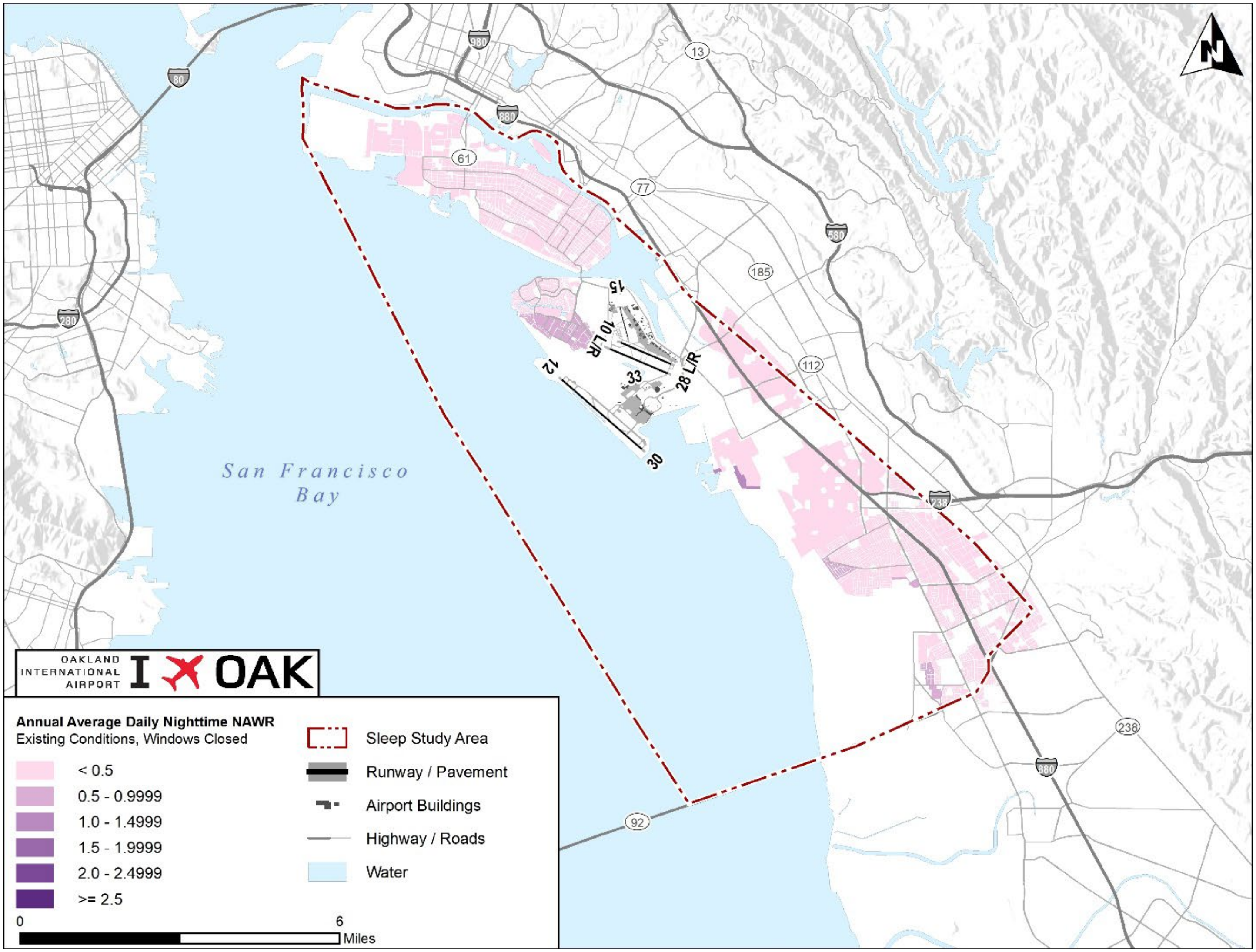

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Figure 2-3
NAWR for Future Year 2028, Windows Open

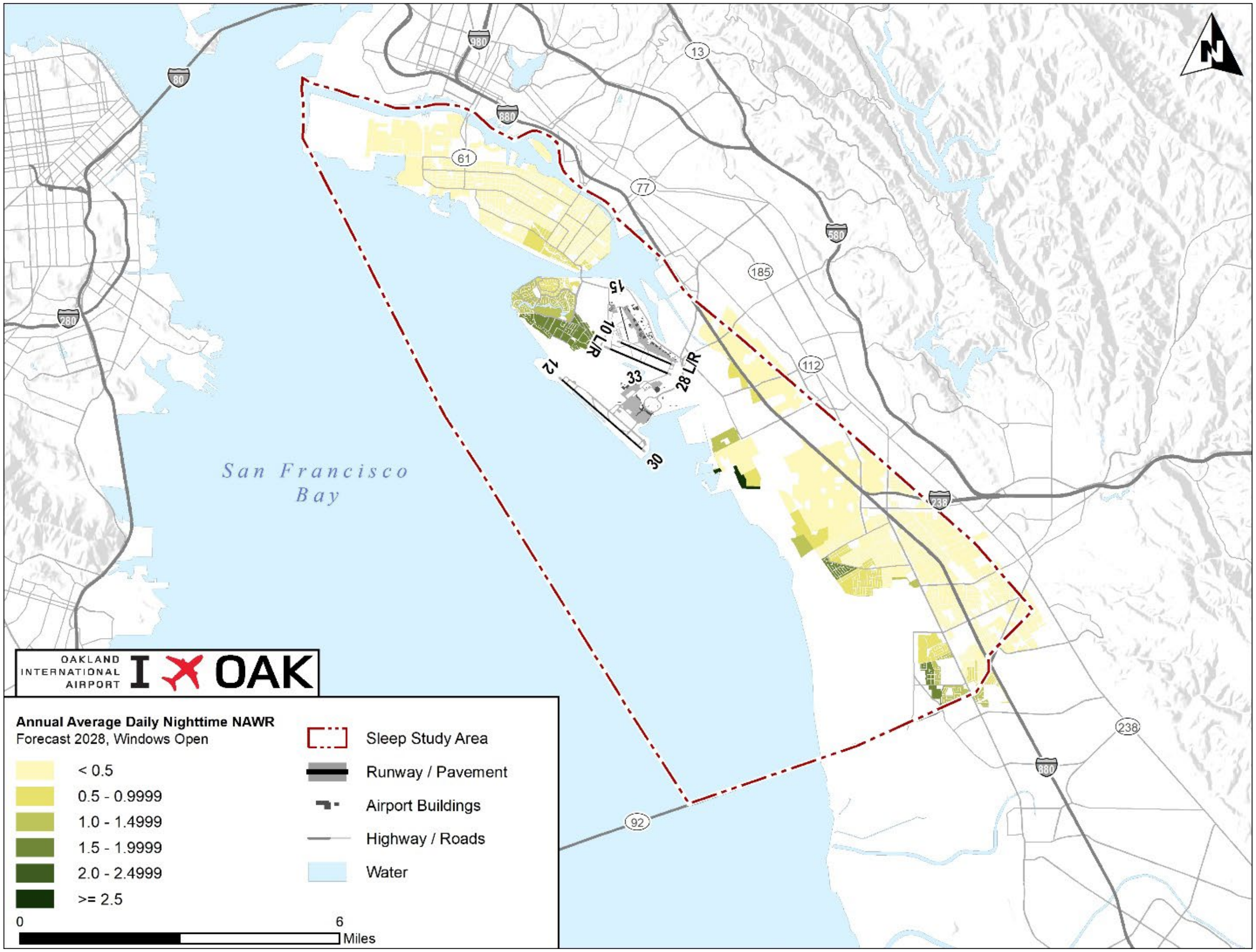

Figure 2-4
NAWR for Future Year 2028, Windows Closed

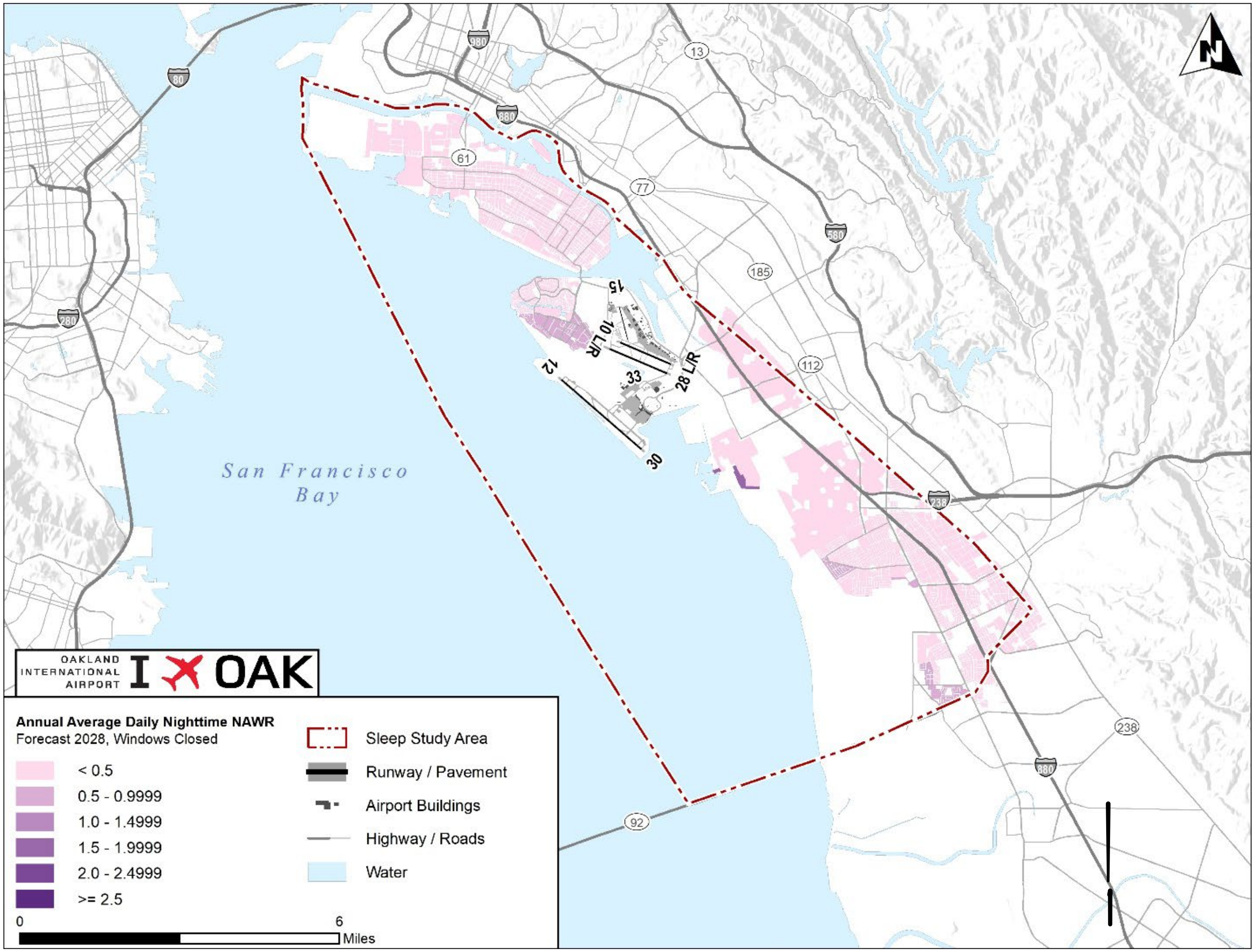

Table 2-2
NAWR for Future Year 2028 Across All Modeled Block Group Centroids Compared with Existing Conditions

Scenario	Windows	Minimum	Average	Maximum
Existing Conditions	Open	0.02	0.34	2.48
	Closed	<0.005	0.08	1.41
Future Year 2028	Open	0.02	0.35	2.74
	Closed	<0.005	0.08	1.53
Change from Existing Conditions	Open	-	0.01	0.26
	Closed	-	-	0.12

NAWR: aircraft noise-induced indoor awakenings

Most residential areas' NAWR values would be primarily affected by two-engine narrow-body jets, such as the Boeing 737 and Airbus A319/A320/A321 series of aircraft, which would be the same as existing conditions.

Figures 2-5 and **2-6** show the difference in NAWR for each block group centroid, between future year 2028 and existing conditions, for windows open and windows closed, respectively. Residential areas in future year 2028 would have between 0 and 2.6 (and an average of 1) additional annual average nighttime awakening per 100 flights, compared to existing conditions. The greatest change in NAWR, regardless of windows being opened or closed, would occur at the block group centroids southeast of the approach end of Runway 30. These block group centroids would be near the predominant arrival paths of commercial jets arriving onto Runway 30. There would be an increase in commercial jet operations in future year 2028 relative to existing conditions based on the projected market-based passenger demand, which would occur with or without implementation of the Proposed Project.

2.3 Future Year 2038

Figures 2-7 and **2-8** show the NAWR results for future year 2038, for windows open and windows closed, respectively. **Table 2-3** lists the statistics for nighttime awakenings for future year 2038 and the differences in NAWR for the future year 2038 relative to existing conditions. NAWR would range from less than 0.005 to 1.76 for windows closed and up to 3.14 for windows open. Block group centroids with higher NAWR would be near the ends of Runways 12 and 10L/10R and southeast of the end of Runway 30. The block group centroid with the highest NAWR would be near the predominant arrival paths for commercial jets arriving on Runway 30. The average NAWR across all block group centroids would range from 0.08 to 0.37. Or stated differently, the average NAWR would range between 8 and 37 annual average nighttime awakenings per 100 flights, depending on the windows being open or closed.

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Figure 2-5
Difference in NAWR between Future Year 2028 and Existing Conditions, Windows Open

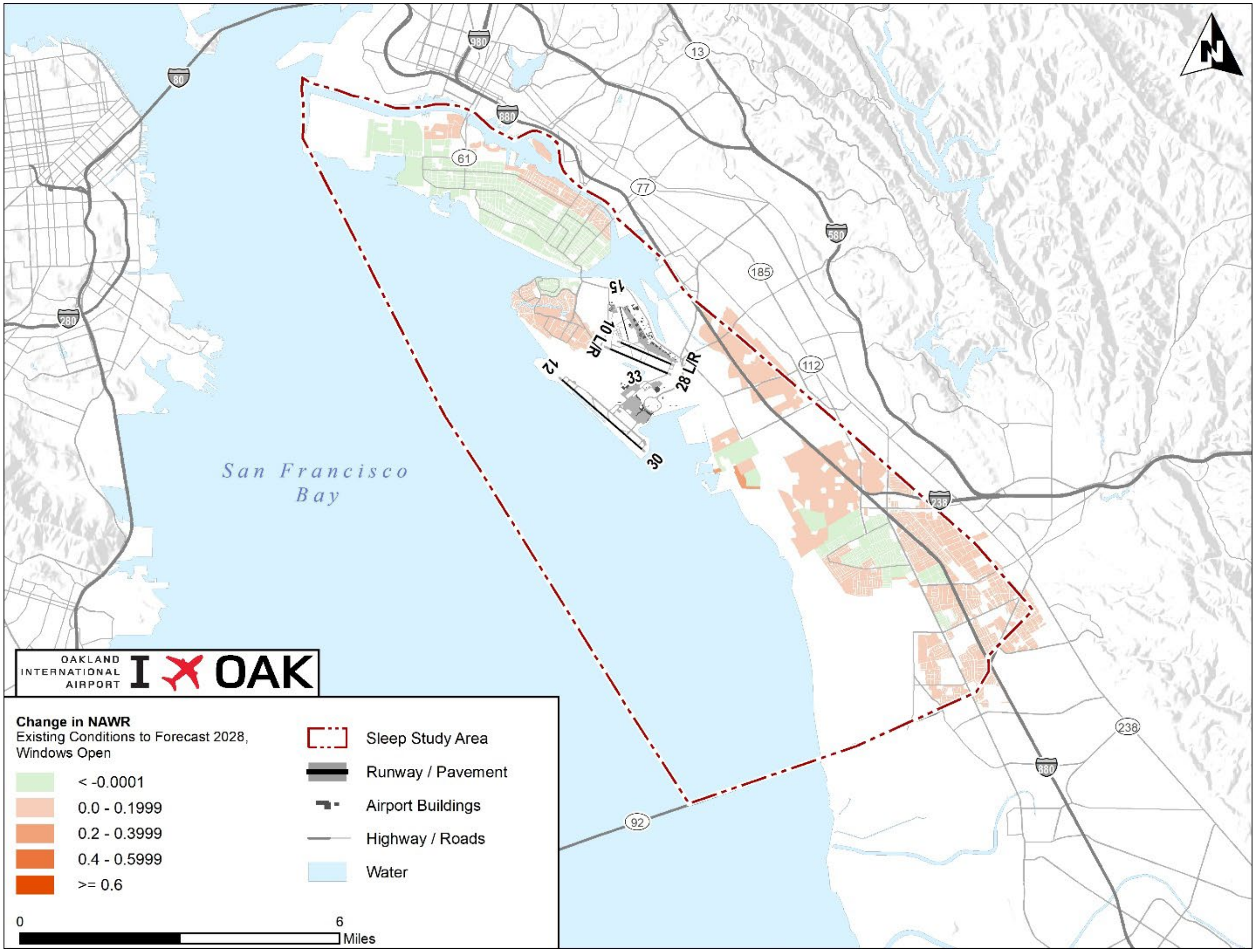

Figure 2-6
Difference in NAWR between Future Year 2028 and Existing Conditions, Windows Closed

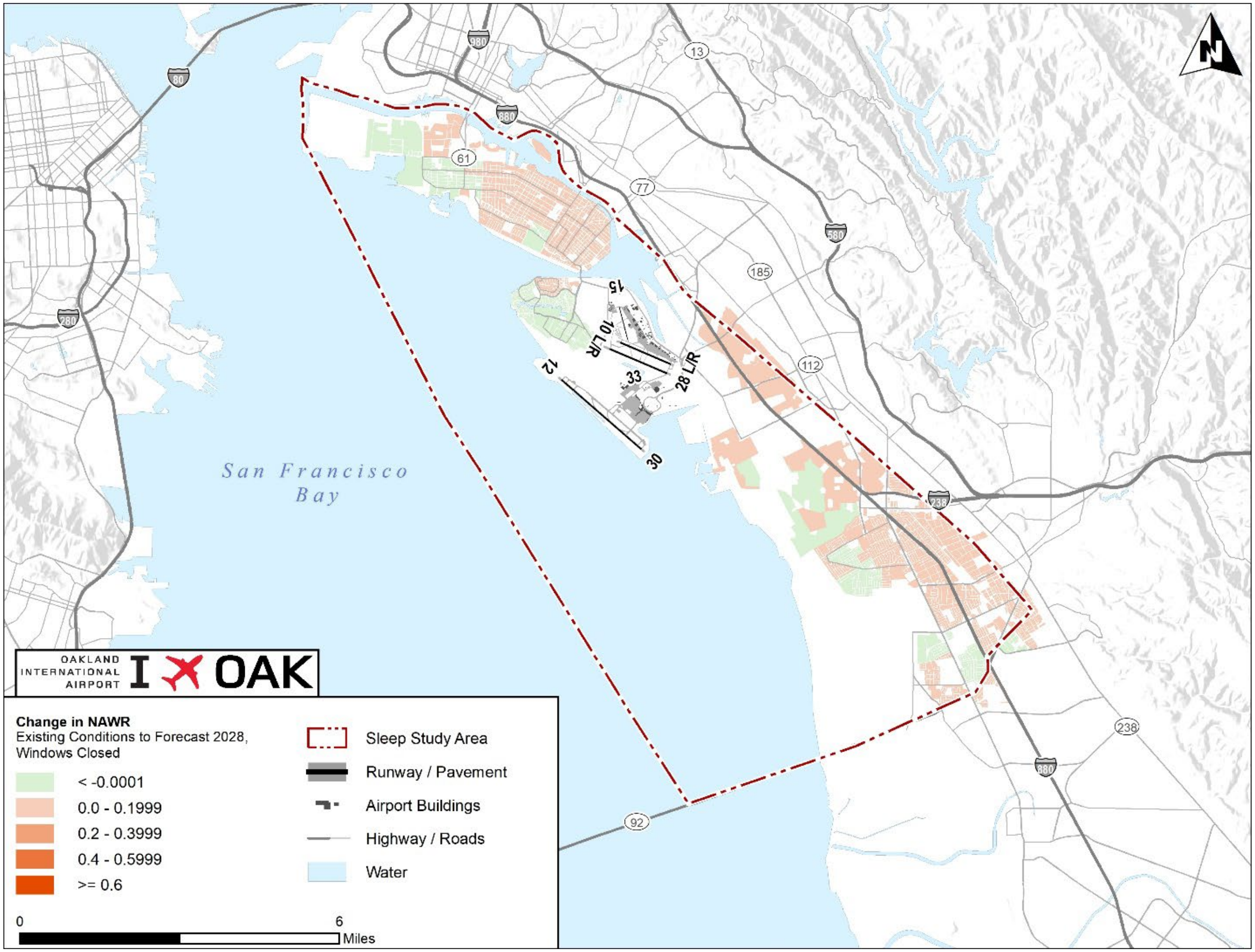

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Figure 2-7
NAWR for Future Year 2038, Windows Open

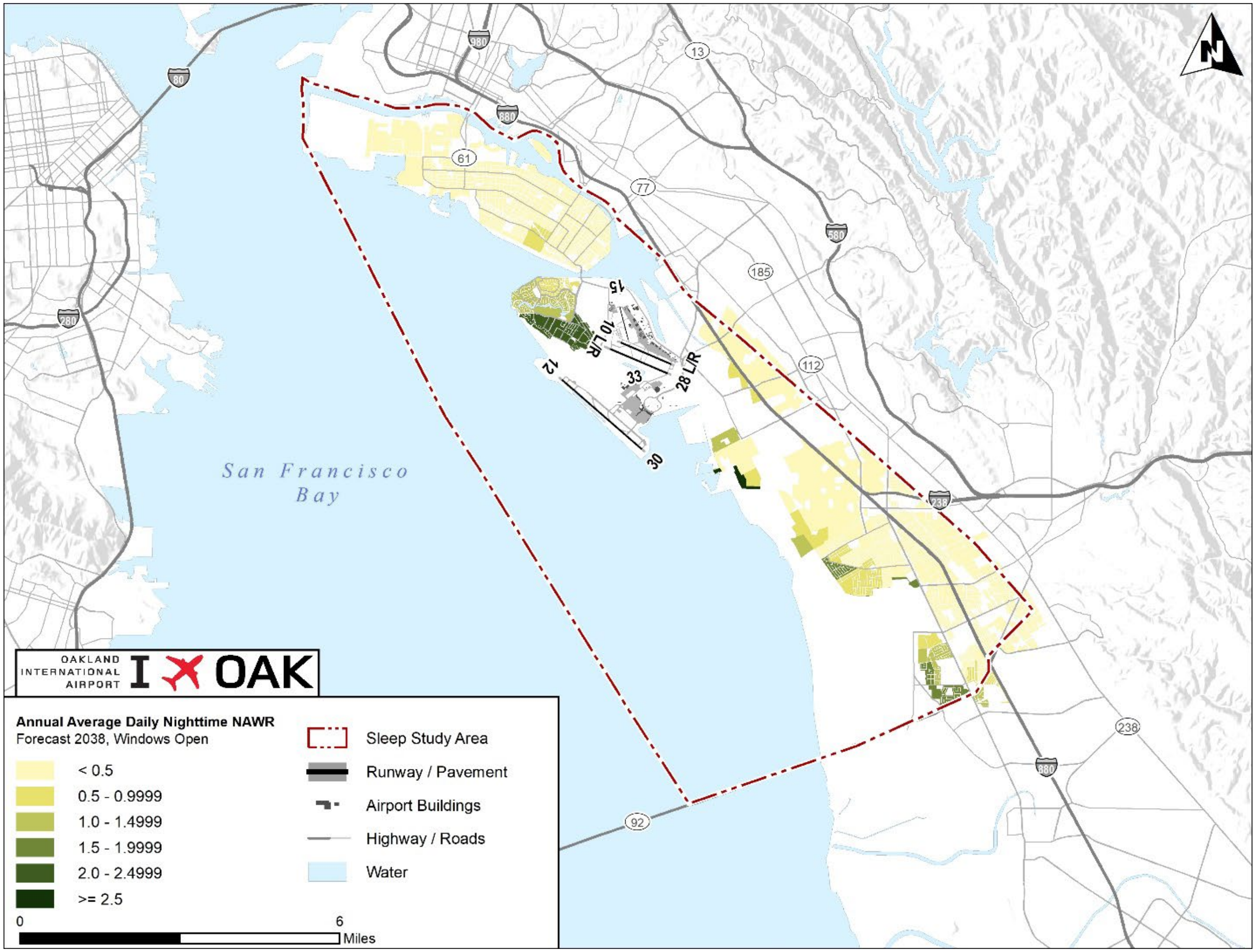

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Figure 2-8
NAWR for Future Year 2038, Windows Closed

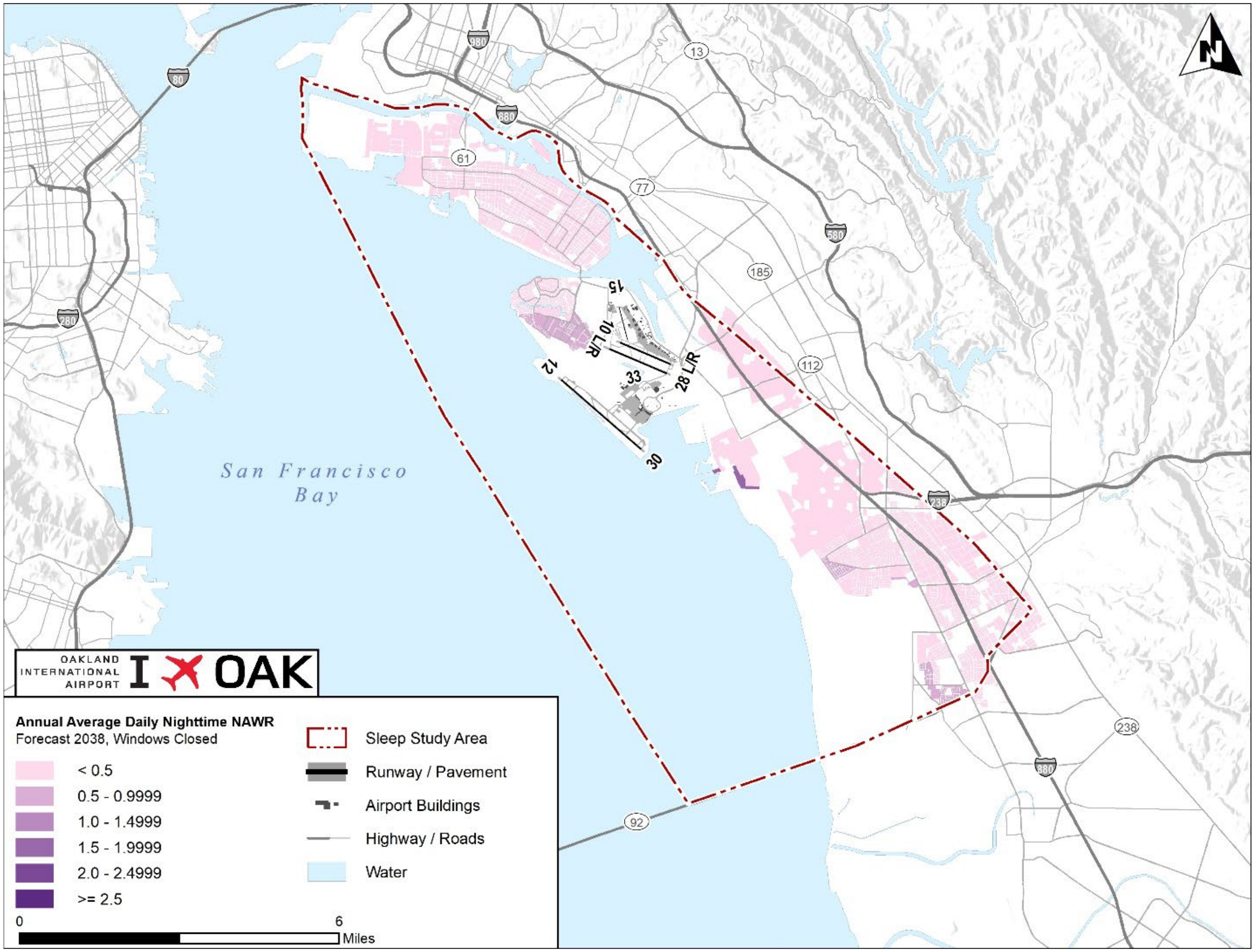

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Table 2-3
NAWR for Future Year 2038 Across All Modeled Block Group Centroids Compared with Existing Conditions

Scenario	Windows	Minimum	Average	Maximum
Existing Conditions	Open	0.02	0.34	2.48
	Closed	<0.005	0.08	1.41
Future Year 2038	Open	0.03	0.37	3.14
	Closed	<0.005	0.08	1.76
Change from Existing Conditions	Open	0.01	0.03	0.66
	Closed	-	-	0.35

NAWR: aircraft noise-induced indoor awakenings

Unlike existing conditions and future year 2028 condition, in future year 2038 most residential areas' NAWR values would be primarily affected by two-engine wide-body jets, such as the Boeing 767/777/787 series of aircraft or Airbus A300/A330 series of aircraft. The second highest contribution would be from two-engine narrow-body jets, such as the Boeing 737 and Airbus A319/A320/A321 series of aircraft.

Figures 2-9 and **2-10** show the difference in NAWR for each block group centroid, between future year 2038 and existing conditions, for windows open and closed, respectively. Residential areas in future year 2038 would have between 0 and 6.6 (and an average of 3) additional annual average nighttime awakening per 100 flights, compared to existing conditions. Like NAWR in 2028, the greatest change in NAWR in 2038, regardless of windows being open or closed, would occur at the block group centroids southeast of the approach end of Runway 30. These block group centroids would be near the predominant arrival paths of commercial jets arriving onto Runway 30. There would be an increase in commercial jet operations in future year 2038 relative to existing conditions based on projected market-based passenger demand, which would occur with or without implementation of the Proposed Project.

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Figure 2-9
Difference between NAWR for Future Year 2038 and Existing Conditions, Windows Open

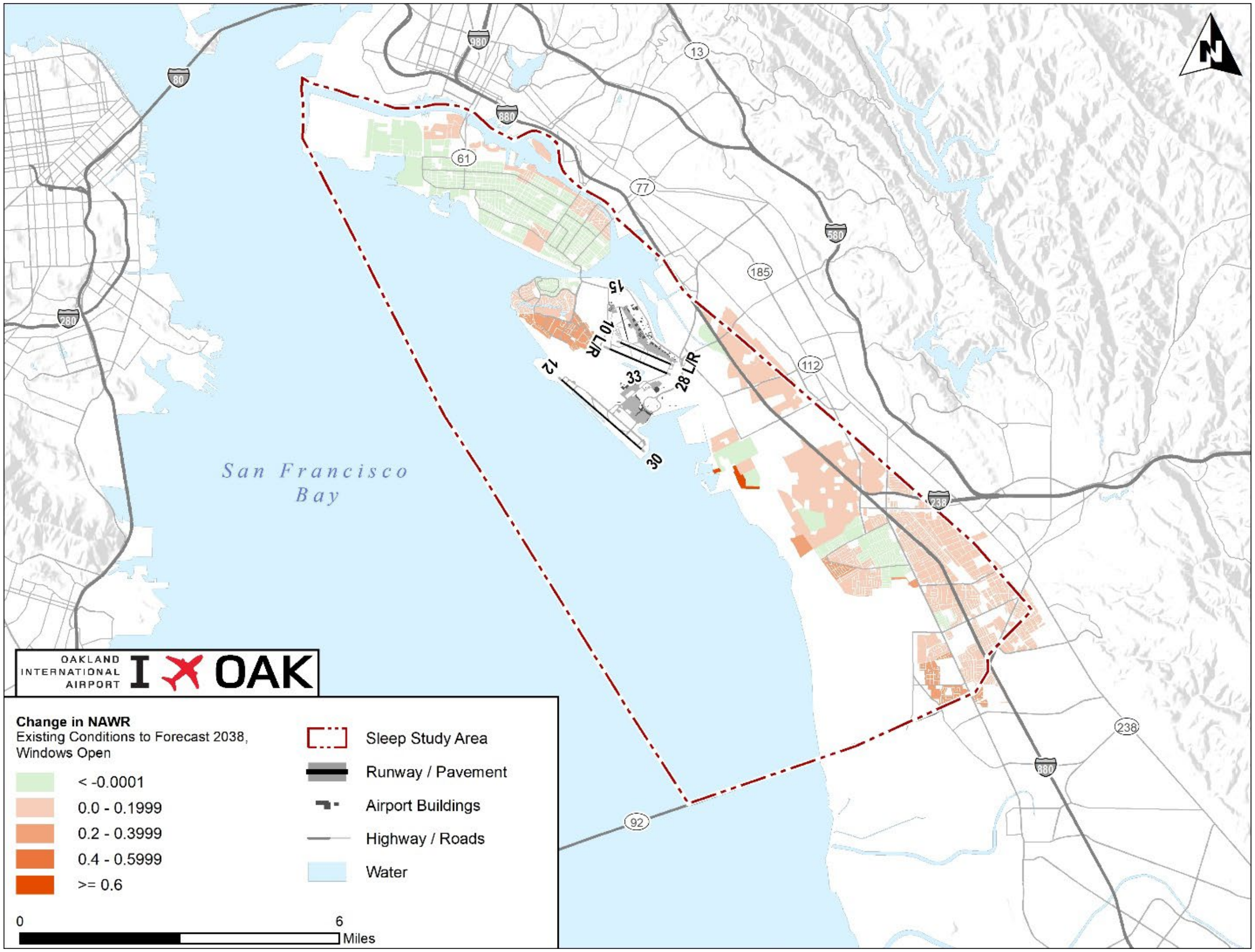

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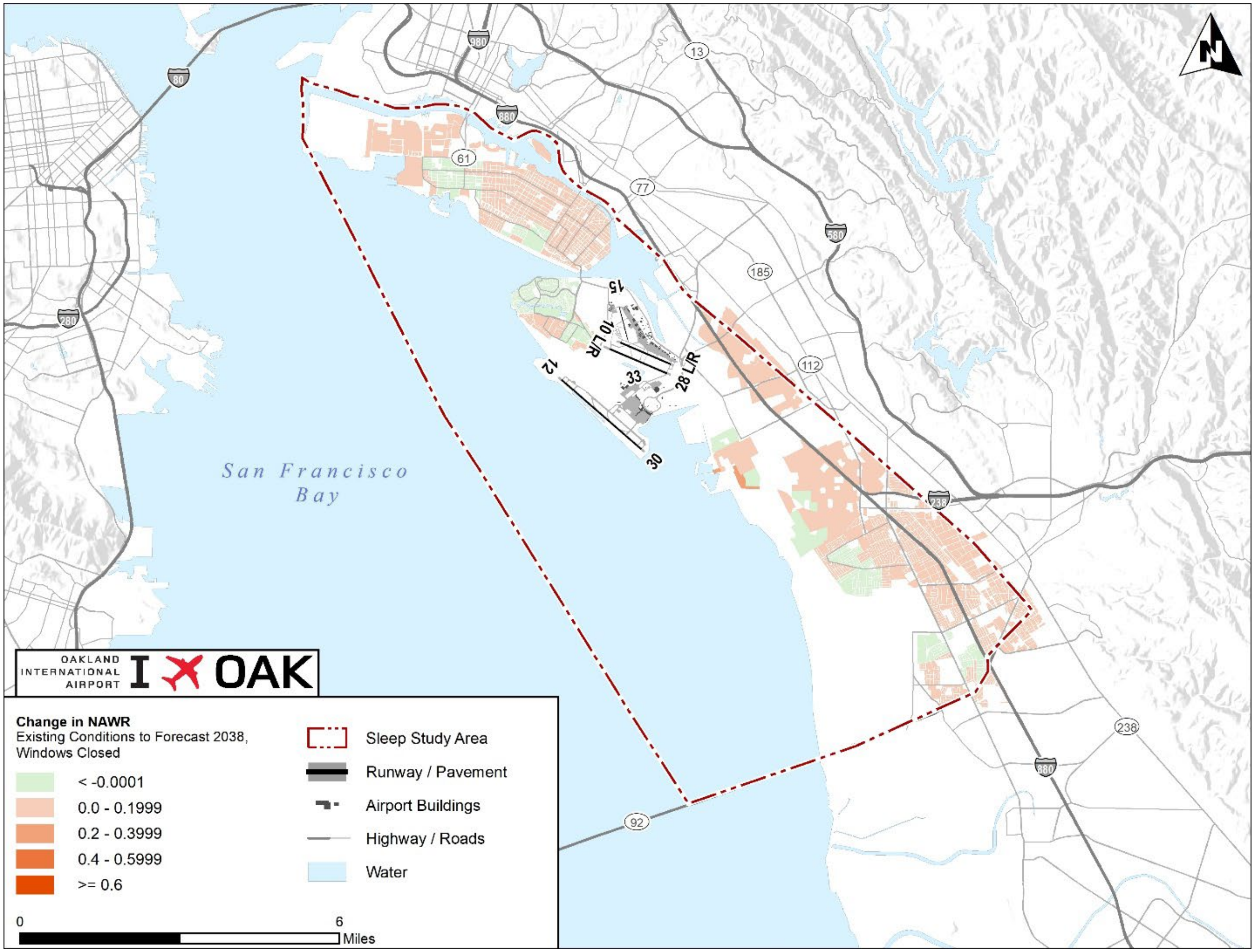
Figure 2-10
Difference between NAWR for Future Year 2038 and Existing Conditions, Windows Closed



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Attachment 1 – Sleep Study Methodology Technical Memorandum

To:	Dave Full, RS&H 311 California Street, Suite 720 San Francisco, CA 94104
From:	Rhea Hanrahan, Principal Consultant Joe Czech, Principal Consultant
Date:	December 21, 2022
Subject:	Oakland International Airport Terminal Modernization and Development Project - Environmental Impact Report Methodology for Evaluation of the Potential for Sleep Disturbance
Reference:	HMMH Project Number 311530.000

This memo presents the proposed methodology for the evaluation of the potential for sleep disturbance for the Oakland International Airport's (OAK) Terminal Modernization and Development Project (Proposed Project). While a sleep disturbance study is not required under the National Environmental Policy Act (NEPA) or the California Environmental Quality Act (CEQA), it will be included with the NEPA and CEQA documentation for informational purposes only. There is not an established threshold of significance that can be used to evaluate the results.

Section 1 documents a brief literature review that provides background for the methodology. Section 2 presents the methodology proposed to be used. Section 3 describes how it will be implemented.

1.0 Background/Literature Review

There is limited application of sleep disturbance analysis for airports. The 2003 OAK Airport Development Program (ADP) Supplemental Environmental Impact Report (SEIR)[1] used the methodology promulgated by the Federal Interagency Committee on Aviation Noise (FICAN) in 1997. [2] The FICAN method resulted in maximum percent awakenings by residential adults, as an exponential function of indoor Sound Exposure Level (SEL). In July 2008, the American National Standards Institute published ANSI/ASA S12.9-2008/Part 6: *Methods for Estimation of Awakenings with Outdoor Noise Events Heard in Homes*, which provided a method to estimate the percent of the exposed population that would be awakened by multiple aircraft noise events based on statistical assumptions about the probability of

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1 Oakland International Airport, Airport Development Program (ADP), Draft Supplemental Environmental Impact Report, SCH No. 1994113039, Environmental Science Associates, September 2023.

2 "Effects of Aviation Noise on Awakenings from Sleep", Federal Interagency Committee on Aviation Noise, 1997.

awakening (or not awakening).[3] The ANSI/ASA standard was also based on indoor SEL but with a different exponential function than FICAN. The standard was withdrawn by the ASA/ANSI in the 2017 timeframe.[4] The 2019 Draft Environmental Impact Report (DEIR) for San Diego International Airport (SAN) showed outdoor Number of Events (at or) Above (NA) an A-weighted SEL of 80 dB (NA80SEL) and NA90SEL contours of 5 and 10 events.[5] It mentions the 2008 ANSI standard for probability of awakenings (PA) but does not show any PA analyses.

The Federal Aviation Administration (FAA) is conducting a National Sleep Study (NSS) with the goal of developing a dose-response relationship between noise, likely in terms of single-event (A-weighted) Maximum Sound Level (L_{Amax}), and sleep disturbance. The NSS is being led by the University of Pennsylvania's Mathias Basner, PhD. HMMH is a subcontractor on the NSS. Dr. Basner is a world-renowned expert in sleep disturbance Dr. Basner recommends evaluating the potential for sleep disturbance with L_{Amax}, instead of SEL, as described in the 2006 paper for which he was the lead author.[6] In lieu of any other industry standard, the method from Basner et al. (2006) is recommended for the Proposed Project and is described in the following section.

2.0 Methodology

The 2006 Basner et al. method estimates the average number of aircraft noise-induced awakenings (NAWR) at a location in the vicinity of the airport as a function of indoor L_{Amax} and Sound Pressure Level (SPL) classes of a certain width, as given by the paper's Equation 3b, interpreted here as Equation 1:

$$N_{AWR} = \sum_i f(L_{Amax}) \times SPL\ class \qquad (1)$$

The function of L_{Amax}, i.e., f(L_{Amax}), is given by the paper's Equation 4, replicated here as Equation 2:

$$f(L_{Amax}) = \max\left(1.894 \times 10^{-5} \times {L_{Amax}}^2 + 4.008 \times 10^{-4} \times L_{Amax} - 3.3243 \times 10^{-2}; 0\right) \qquad (2)$$

SPL class is chosen to be 1 dB wide. Equation 1 was developed over a range of indoor L_{Amax} from 33 dB to 73 dB. The authors of the 2006 paper do not anticipate problems with using Equation 1 beyond (lower or higher) that range.

Outdoor L_{Amax} will be estimated by the FAA's Aviation Environmental Design Tool (AEDT), Version 3e. Outdoor L_{Amax} will be converted to indoor levels using the national average Noise

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3 American National Standards Institute (ANSI)-Accredited Standards Committee S12, *Quantities and Procedures for Description and Measurement of Environmental Sound – Part 6: Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes* (Melville, NY: Acoustical Society of America, ANSI, 2008).

4 ANSI-Accredited Standards Committee S12, Rationale for Withholding ANSI/ASA S12.0-2008/Part 6 (Melville, NY: Acoustical Society of America, ANSI, July 22, 2018).

5 San Diego International Airport, *Airport Development Plan*, Recirculated Draft EIR (September 2019), Sec. 3.12.

6 Mathias Basner, Alexander Samel, and Ullrich Isermann, *Aircraft noise effects on sleep: Application for the results of a large polysomnographic field study* (Acoustical Society of America, February 11, 2006).

Level Reduction (NLR) values for residential structures given by the Federal Interagency Committee on Noise (FICON) of 15 dB for open windows and 25 dB for closed windows,[7] which, in turn, references the US Environmental Protection Agency's "Levels" document.[8] For example, indoor L_{Amax} for closed windows will be determined by subtracting 25 dB from the estimated outdoor L_{Amax}.

3.0 Implementation and Example

The goal is to report the average number of aircraft noise-induced nighttime awakenings, or NAWR, at select points within the project's general study area for each modeled scenario. We foresee presenting the resulting range of NAWR via color-coded maps in addition to tabulating the differences in NAWR between the proposed scenarios and the Baseline/existing conditions. A range of NAWR is needed to be presented because the NAWR will be fewer with closed windows than with open windows.

Equation 1 will be applied to the centroids of 2020 US Census blocks containing low-, medium- or high-density residential land use, or mixed use, within the Proposed Project's general study area, shown in **Figure 3-1**. The land use is based on data gathered from the jurisdictions within the general study area and used for the Land Use analysis in the Draft EIR.

Table 3-1 provides an example set-up for the NAWR calculation, for closed windows, for outdoor L_{Amax} between 58 dB and 98 dB, the range of outdoor L_{Amax} corresponding to the range over which Equation 1 was developed. For each modeled aircraft type in each scenario, the AEDT will identify the L_{Amax} at each of the centroids. Numbers of CNEL nighttime (10 p.m. to 7 a.m.) events from the CNEL modeling for each aircraft type will be binned in 1-decibel increments of L_{Amax}. The product of $f(L_{Amax})$ and the numbers of events will be computed for each L_{Amax} bin and the products will be summed to compute the overall NAWR for that centroid. The process would be repeated for open windows, and then again for each centroid and each scenario. Differences in NAWR can be obtained by subtracting one NAWR set from another.

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[7] Federal Interagency Committee on Noise (FICON), *Federal Agency Review of Selected Airport Noise Analysis Issues* (FICON, August 1992).

[8] U.S. Environmental Protection Agency (EPA), *Information Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety* (Washington, D.C.: EPA, 1974).

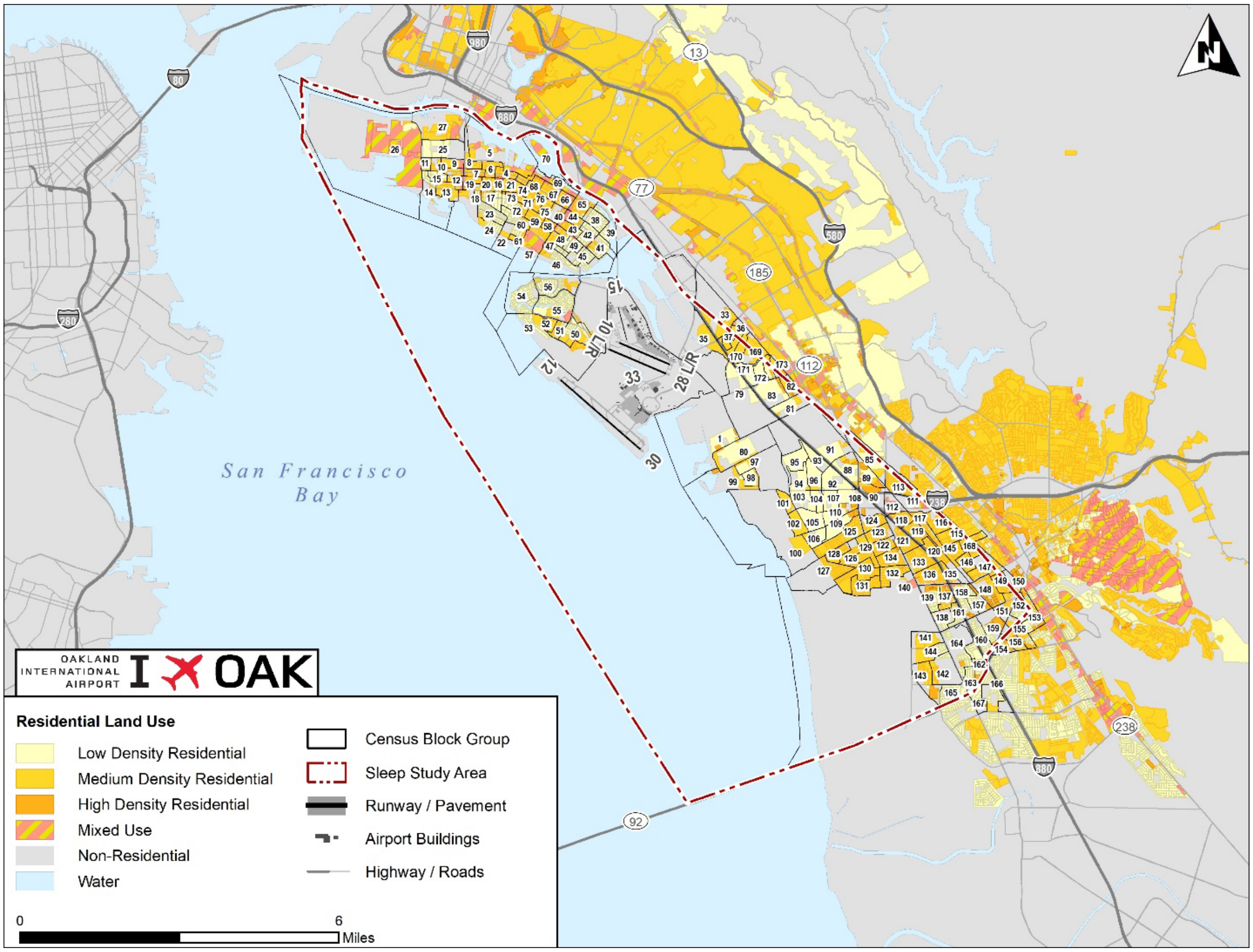

Figure 3-1
Residential Land Use Within the General Study Area and Census Block Group Centroids

Table 3-1
Computational Set-up for NAWR for Closed Windows

Outdoor L_{Amax} (dB)	Indoor L_{Amax} /a/ (dB)	$f(L_{Amax})$ given by Equation 2	Nighttime Events, n, for $Aircraft_1$	Nighttime Events, n, for $Aircraft_2$	…	Nighttime Events, n, for $Aircraft_N$	Total Number of Events	Product of $f(L_{Amax})$ x n
98	**73**	0.096947						
97	72	0.09380						
96	71	0.09069						
.	.	.						
.	.	.						
88	63	0.06718						
.	.	.						
.	.	.						
.	.	.						
58	**33**	0.000609						
							NAWR=	Sum of products

NAWR: aircraft noise-induced awakenings
dB: decibel
LA_{max}: A-weighted Maximum Sound Level
/a/assumes an (outdoor to indoor) Noise Level Reduction of 25 dB for closed windows

To further the example, say for a Baseline/existing conditions there are only 100 nighttime events (N98) producing an outdoor L_{Amax} of 98 dB. The closed-windows indoor L_{Amax} would be (98-25=) 73 dB. Equation 2 would result in an $f(L_{Amax})$ of 0.096947. The product of $f(L_{Amax})$ and N98 would be (0.096947 × 100 =) 9.7. Thus, with no other events to consider, the NAWR for Baseline/existing conditions would be 9.7, or approximately 10 sleep-disturbing events per night, on average, with closed windows.

Then consider a (fictitious) Proposed Action. Suppose it has the same 100 nighttime events from Baseline/existing conditions (N_{98}) plus 10 nighttime events producing an L_{Amax} of 96 dB (N96). Equation 2 for the 96 dB events would result in an $f(L_{Amax})$ of 0.09069. The product of $f(L_{Amax})$ and N96 would be (0.09069 × 10 =) 0.9069. The sum of the products across all events, i.e., the NAWR, would be (9.7 + 0.9069 =) 10.6 sleep-disturbing events per night, on average, with closed windows. Thus, the Proposed Action, in this fictitious example, would increase the closed-windows NAWR, relative to the Baseline/existing conditions, by approximately 1 event per night, on average.

This exercise would be repeated for open windows to inform a range of NAWR for each modeled scenario.

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