Meeting Announcement

Ground-Based Noise Committee

Monday, July 19, 2021
12:00 p.m. – 1:30 p.m.

BY VIDEO CONFERENCE ONLY
Please click the link below to join the webinar:
https://smcgov.zoom.us/j/92052713721
Or Dial-in:
US: +1(669)900-6833 Webinar ID: 920 5271 3721

Note: To arrange an accommodation under the Americans with Disabilities Act to participate in this public meeting, please call (650) 363-4220 at least 2 days before the meeting date.

PUBLIC PARTICIPATION:
Written public comments can be emailed to amontescardenas@smcgov.org, and should include the specific agenda item to which you are commenting. Spoken public comments will also be accepted during the meeting through Zoom on Public Comment on Items Not on the Agenda, and after each Agenda item.

AGENDA

Call to Order

Public Comment on Items NOT on the Agenda

AGENDA ITEMS

1. **Review the Ground Based Noise Report and Direct Staff on Next Steps**
   a. Attachments:
      i. GBN Study
      ii. Staff Recommendations (HMMH Memo attached)
      iii. Hillsborough comments

2. **Discuss and Provide Staff Direction on Ground-Based Noise Impacts:**
   a. Airport policy on use of auxiliary power unit use at gates and taxi operations
   b. Airport and other ground equipment transition from diesel to airport wide electrification
   c. Discussion of environmental mitigation historically implemented by SFO on GBN and mitigation for current and future operations.
   d. Review of noise contours showing low frequency noise.

e. SFO current EIR on expansion plans and impacts to GBN.

3. GBN Glossary

4. Adjourn

__Instructions for Public Comment during Videoconference Meeting__**

During videoconference of the Ground-Based Noise subcommittee meeting, members of the public may address the Roundtable as follows:

Written Comments:
Written public comments may be emailed in advance of the meeting. Please read the following instructions carefully:

1. Your written comment should be emailed to amontescardenas@smcgov.org.
2. Your email should include the specific agenda item on which you are commenting.
3. Members of the public are limited to one comment per agenda item.
4. The length of the emailed comment should be commensurate with two minutes customarily allowed for verbal comments, which is approximately 250-300 words.
5. If your emailed comment is received by 3:00 pm on the day before the meeting, it will be provided to the Roundtable and made publicly available on the agenda website under the specific item to which comment pertains. The Roundtable will make every effort to read emails received after that time but cannot guarantee such emails will be read during the meeting, although such emails will still be included in the administrative record.

Spoken Comments:
Spoken public comments will be accepted during the meeting through Zoom. Please read the following instructions carefully:

1. The July 19, 2021 Ground-Based Noise Subcommittee meeting may be accessed through Zoom online at https://smcgov.zoom.us/j/92052713721. The meeting ID: 920 5271 3721. The meeting may also be accessed via telephone by dialing in +1-669-900-6833, entering meeting ID: 920 5271 3721, then press #.
2. You may download the Zoom client or connect to the meeting using the internet browser. If you are using your browser, make sure you are using current, up-to-date browser: Chrome 30+, Firefox 27+, Microsoft Edge 12+, Safari 7+. Certain functionality may be disabled in older browsers including Internet Explorer.
3. You will be asked to enter an email address and name. We request that you identify yourself by name as this will be visible online and will be used to notify you that it is your turn to speak.
4. When the Roundtable Chairperson calls for the item on which you wish you speak click on “raise-hand” icon. You will then be called on and unmuted to speak.
5. When called, please limit your remarks to the time limit allotted.

San Francisco International Airport

Ground Based Noise Modeling Study

HMMH Report No. 309091.002

January 19, 2021

Prepared for:

San Francisco International Airport/Community Roundtable
455 County Center
2nd Floor
Redwood City, CA 94063

Prepared by

Justin Cook

Timothy Middleton

Mariano Sarrate

Mike Hamilton

HMMH
700 District Avenue, Suite 800
Burlington, MA 01803
T 781.229.0707
F 781.229.7939

Contents

1 Background

Harris Miller Miller & Hanson Inc. (HMMH) currently provides technical support services to the San Francisco International Airport/Community Roundtable (herein Roundtable). To address Ground Based Noise (GBN) concerns from communities adjacent to San Francisco International Airport (SFO), the Roundtable established a GBN ad-hoc subcommittee[1]. The initial meeting for the GBN ad-hoc subcommittee (herein subcommittee) was held on November 1, 2018 at the Millbrae Community Center.

The subcommittee initially worked on a scope of work, which was approved by the Roundtable on December 6, 2018 (**Appendix B**). The approved scope of work established a problem statement, framework for research/collection of data and schedule. As part of the approved scope of work, HMMH was identified to provide additional background information/data on several of the approved scope of work items. In response, HMMH prepared a letter that contained the requested background information/data for all of the items flagged “HMMH” (**Appendix C**). HMMH also prepared and delivered a presentation for the March 19, 2019 subcommittee meeting that summarized the letter (**Appendix D**).

As part of ongoing technical support to the subcommittee, HMMH provided a letter that was a review of previous noise barrier research (**Appendix E**) and a technical memorandum describing vegetation and noise effects (**Appendix F**).

Upon receipt of these documents and further discussion with the subcommittee, HMMH was requested to prepare a proposal to conduct a GBN modeling study (**Appendix G**) and that proposal was ultimately approved by the Roundtable. This GBN Modeling Study is the result of that approved proposal.

1.1 Project Description

Noise is a complex physical quantity. The properties, measurement, and presentation of noise involve specialized terminology that can be difficult to understand. To provide a basic reference on these technical issues, **Appendix A** introduces fundamentals of noise terminology, the effects of noise on human activity, and noise propagation.

The primary purpose of this study is to better understand how ground based noise propagates through the communities adjacent to SFO from aircraft departures. The secondary purpose is to assess vegetation as a means to reducing ground based noise from SFO aircraft departures.

[1] https://sforoundtable.org/gbnsub_20181101/

To determine the effect of ground based noise from aircraft departures on the communities adjacent to SFO, HMMH conducted the following modeling scenarios that were approved as part of the scope of work:

- **Scenario 1:** 2 Aircraft Types Departing Runway 1L at Start of Takeoff Roll – Without and With Vegetation
- **Scenario 2:** 2 Aircraft Types Departing Runway 1R at Start of Takeoff Roll – Without and with Vegetation
- **Scenario 3:** 2 Aircraft Types Departing Runway 1L at Secondary Takeoff Point – Without and With Vegetation
- **Scenario 4:** 2 Aircraft Types Departing Runway 1R at Secondary Takeoff Point – Without and with Vegetation
- **Scenario 5:** 2 Aircraft Types Departing at the Same Time but Staggered on Runways 1L and 1R – Without and With Vegetation
- **Scenario 6:** One Aircraft Type Departing Runway 28L and One Aircraft Type Departing Runway 28R – Without and With Vegetation

The outputs of the noise model are provided in this report for each scenario and are comprised of average spectral noise levels (Leq dB) at multiple receiver locations in tabular form and maximum noise levels (Lmax dB) in noise contour figures.

1.2 SoundPLAN Noise Model

To model the desired effects of ground based noise propagating from aircraft departures at SFO into adjacent communities as well as the potential effects of vegetation, SoundPLAN® was chosen as the preferred noise model.

An industry standard, SoundPLAN[2] was developed to provide estimates of sound levels at distances from specific noise sources taking into account the effects of terrain features including relative elevations of noise sources, receivers, and intervening objects (buildings, hills, trees), and ground effects due to areas of hard ground (pavement, water) and soft ground (grass, field, forest). Unlike the Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT)[3], SoundPLAN accounts for the shielding and reflection effects of buildings, in addition to the effects of ground elevation and ground cover on the propagation of sound.

[2] SoundPLAN 8.1 Noise Simulation Model from SoundPLAN GmbH. https://www.soundplan.eu/en/
[3] https://aedt.faa.gov/

2 Development of Noise Modeling Inputs

SFO is located in San Mateo County, California and is owned and operated by the City and County of San Francisco (herein City), acting by and through the San Francisco Airport Commission (herein Airport Commission). The Airport is located approximately 13.0 miles south of downtown San Francisco and is surrounded by the cities of South San Francisco to the north, San Bruno to the west, and Millbrae to the southwest. SFO has four Runways[4], the number used to designate each runway end reflects, with the addition of a trailing "0", the magnetic heading of the runway to the nearest 10 degrees from the perspective of the pilot. Runway 1L/19R and Runway 1R/19L are parallel and are oriented along approximate magnetic headings of 10° and 190°. Runway 1L/19R is 7,650 feet long by 200 feet wide and Runway 1R/19L is 8,650 feet long by 200 feet wide. Runway 28L/10R and Runway 28R/10L are parallel and are oriented along approximate magnetic headings of 280° and 100°. Runway 28L/10R is 11,381 feet long by 200 feet wide and Runway 28R/10L is 11,870 feet long by 200 feet wide.

Based upon the direction of the subcommittee to focus mainly on aircraft departing Runways 1L and 1R, a project study area was developed to incorporate SFO and areas directly adjacent and to the southwest of Runways 1L and 1R of SFO. The project study area is 9.7 square miles and is 2.8 miles wide by 3.5 miles long encompassing SFO and the cities/towns of San Bruno, Millbrae, Burlingame and Hillsborough. The majority of the project study area contains the City of Millbrae which is the closest adjacent city southwest of SFO. The project study area is shown in **Figure 1**.

2.1 Data Acquisition

To accurately model sound, and the propagation of aircraft departure noise from SFO, a robust data set was developed of geographic information from multiple sources. The sources of geographic data used for the GBN modeling study include the following:

- **San Mateo County:** location and description of local municipal boundaries
- **ESRI:** location of all roadway/highway centerlines
- **Microsoft via GitHub:** three-dimensional building footprints with elevations
- **CalTrans:** roadway/highway right of way boundaries
- **USGS:** three-dimensional digital elevation data; 3-meter resolution
- **SFO:** digital Airport Layout Plan (ALP)
- **NearMap USA:** aerial photography

SFO maintains an aircraft noise monitoring system to keep track of noise levels in communities around the Airport. With permanent monitors located throughout the Bay Area and multiple portable units, the system keeps track of noise levels in communities surrounding SFO. Information produced by the noise monitoring system is central to the operations of the Aircraft Noise Abatement Office (ANAO). The integrated system collects flight, noise reports, noise levels and weather data. In addition, the system provides more technical information for enhanced data analysis and real-time collection of aircraft flight

[4] https://aeronav.faa.gov/d-tpp/2014/00375AD.PDF

track data. This information serves as a basis for the Fly Quiet Program quarterly reports and the Monthly Director's Report, both published by the ANAO. The community and the roundtable are familiar with the locations of the permeant monitors and those that are located within the project study area were included as receptor locations for this GBN modeling study.

At the start of this GBN modeling study, HMMH had multiple discussions with the cities/towns of San Bruno, Millbrae, Burlingame and Hillsborough regarding proposed receptor locations. The cities/towns each provided feedback on HMMH proposed receptor locations within their jurisdictions as well as additional recommendations for receptor locations based upon expertise on their local environment. The City of Millbrae also was able to provide HMMH with current building plans and heights associated for incorporation in the SoundPLAN model.

HMMH utilized proprietary noise measurement data from prior projects to develop the SoundPLAN modeling inputs of the multiple aircraft noise sources. The noise measurements utilized as a base were based on a B757-223 aircraft in one-third octave band sound pressure levels, for frequencies between 12.5 Hertz (Hz) and 20,000 Hz during a single engine run-up at takeoff power, at 10-degree azimuthal increments, relative to the front of the engine (or nose of the aircraft) from 0 degrees to 150 degrees at a radius of 83 feet and a 180-degree measurement at a radius of 120 feet. This base data was then scaled to fit the noise profiles of the modeled aircraft types identified in Section 2.3.

2.2 Receptor Locations

To determine the sound levels at various receptor locations around the communities adjacent to SFO, a total of 28 receptor locations were identified and modeled. The receptor locations are broken in to three categories: "RMT", "R" and "V".

The "RMT" receptor locations were placed at the same location as the permanent noise monitors located around SFO and within the project study area. The "R" locations are receptor points located within the towns/cities in the project study area and that were chosen based on discussions with the subcommittee. The "V" locations are receptors locations directly behind the modeled vegetation. These "V" receptor locations are split in to three sets of three.

Table 1 lists all 28 receptor locations and their latitude, longitude, town/city, and the nearest adjacent roadway (where applicable). **Figure 1** graphically depicts the receptor locations within the project study area. **Figure 1** also contains a zoomed in window view of the vegetation and adjacent "V" receptor locations.

Table 1: Receptor Locations

Receptor Locations	ID	Latitude	Longitude	Town/City	Adjacent Roadway
Vegetation	V1_1	37.605764	-122.386998	Millbrae	
Vegetation	V1_2	37.605712	-122.387054	Millbrae	
Vegetation	V1_3	37.605664	-122.387099	Millbrae	
Vegetation	V2_1	37.605175	-122.386083	Millbrae	
Vegetation	V2_2	37.605122	-122.38614	Millbrae	
Vegetation	V2_3	37.605075	-122.386184	Millbrae	
Vegetation	V3_1	37.604559	-122.385145	Millbrae	
Vegetation	V3_2	37.604507	-122.385201	Millbrae	
Vegetation	V3_3	37.604459	-122.385246	Millbrae	
SFO Permanent RMT8	RMT8	37.601862	-122.386001	Millbrae	
SFO Permanent RMT9	RMT9	37.593591	-122.397279	Millbrae	
SFO Permanent RMT10	RMT10	37.584673	-122.391476	Burlingame	
SFO Permanent RMT11	RMT11	37.588315	-122.378116	Burlingame	
SFO Permanent RMT22	RMT22	37.617358	-122.405299	San Bruno	
R1_Millbrae_CapuchinoDr	R1	37.606958	-122.408678	Millbrae	Capuchino Dr
R2_Millbrae_RichmondDr	R2	37.599987	-122.403321	Millbrae	Richmond Dr
R3_Millbrae_CorteCamellia	R3	37.59367	-122.409438	Millbrae	Corte Camellia
R4_Millbrae_BeverlyAve	R4	37.604678	-122.389578	Millbrae	Beverly Ave
R5_Millbrae_MurchisonDr	R5	37.589188	-122.403096	Millbrae	Murchison Dr
R6_Millbrae_Mills_Estate_Park	R6	37.586651	-122.398804	Millbrae	
R7_Millbrae_HillcrestBlvd	R7	37.600608	-122.393148	Millbrae	Hillcrest Blvd
R8_Millbrae_City_Storage	R8	37.603176	-122.390139	Millbrae	
R9_Millbrae_Central_Park	R9	37.600702	-122.399554	Millbrae	
R10_Millbrae_Spur_Trail	R10	37.595583	-122.399793	Millbrae	
R11_SanBruno_HuntingtonAve	R11	37.621417	-122.406779	San Bruno	Huntington Ave
R12_Millbrae_BayviewAve	R12	37.611853	-122.412897	Millbrae	Bayview Ave
R13_Millbrae_RidgewoodDr	R13	37.605064	-122.415877	Millbrae	Ridgewood Dr
R14_Hillsborough_DelMonteDr	R14	37.574209	-122.382305	Hillsborough	DelMonte Dr
R15_Hillsborough_PumpStation	R15	37.576658	-122.372385	Hillsborough	

Figure 1: Project Study Area

2.3 Aircraft Types

To determine the proper aircraft types for noise modeling, the SFO ANAO ran an annual report of aircraft operations to determine the most frequent aircraft operating on Runways 01L, 01R, 28L and 28R. For Runways 01L and 01R, the Airbus A320 (A320) was the most frequent departing aircraft, the second most frequent departing aircraft was the Embraer E75L (this aircraft was not chosen for this GBN modeling study as it is smaller and newer than other aircraft) and the third most frequent departing aircraft was the Boeing 737-800 type aircraft (B738). All modeled scenarios for the GBN modeling study on Runways 01L and 01R used the Airbus A320 and B738 aircraft types.

For Runways 28L and 28R, the Boeing 777-300ER (B77W) was the most frequent departing aircraft, the second most frequent departing aircraft was the B738. All modeled scenarios for the GBN modeling study on Runways 28L and 28R used the B77W and B738 aircraft types.

Specific measurement data needed for the B77W was not readily available. However, based on an analysis of Sound Exposure Level (SEL) noise contours in the FAA's AEDT noise model, it was determined that the B767-300 would be suitable substitute for a B77W. **Figure 2** shows the AEDT SEL results of a full power takeoff of a B767-300, and **Figure 3** shows the AEDT SEL results of a full power takeoff of a B77W. While the contour shape may look dissimilar, the sound energy disbursement from the rear of the aircraft travels a similar distance and width which is a suitable replacement for this project only.

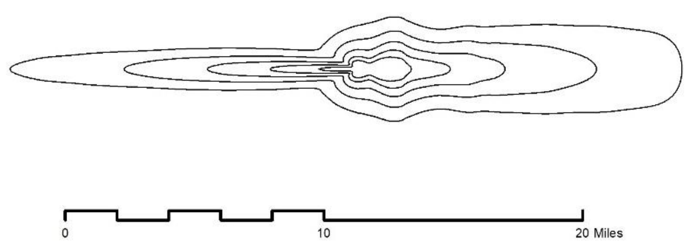

Figure 2: B767-300 SEL Noise Contour

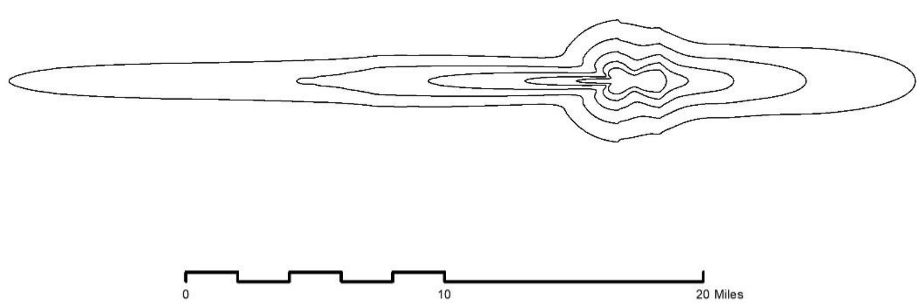

Figure 3: B77W SEL Noise Contour

As stated in Section 2.1, HMMH utilized proprietary noise measurement data from prior projects, that included the frequency spectrum and directivity of a B757-223 aircraft. The B757-223 spectral-class sound levels were then scaled to represent a B738 aircraft, a B767-300 aircraft and an A320 aircraft, based on the spectral-class sound levels of the respective aircrafts in the FAA's AEDT noise model database. **Figures 4-6** show the results of the proprietary spectral noise levels scaling based on the FAA's AEDT noise model using HMMH noise measurements.

Figure 4 shows the spectral data input to the SoundPLAN model for the B767-300 aircraft, for frequencies between 50 Hertz (Hz) and 10,000 Hz. The spectrum has a peak around 125 Hz and 250 Hz. The spectrum's overall sound power level (LW) is 156 dB.

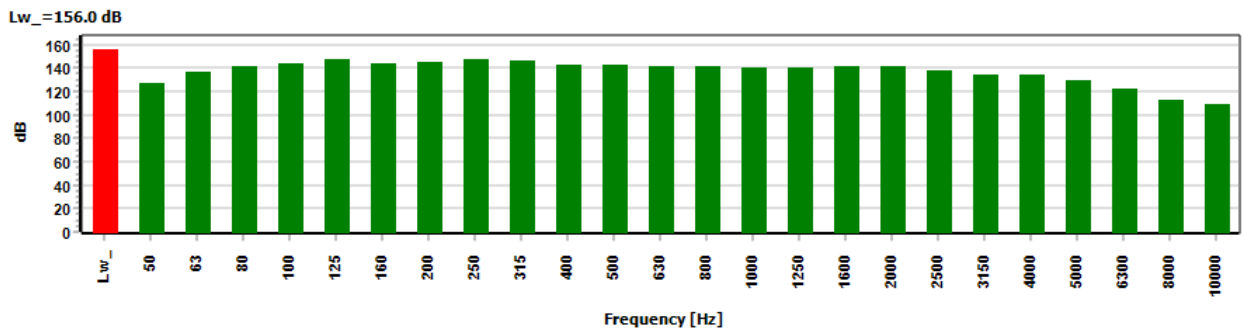

Figure 4: B767-300 Aircraft Noise Spectrum

Figure 5 shows the spectral data input to the SoundPLAN model for the A320 aircraft, for frequencies between 50 Hertz (Hz) and 10,000 Hz. Similar to the B767-300, the A320 spectrum has a peak around 125 Hz and 250 Hz. The spectrum's overall sound power level (LW) is 152.3 dB.

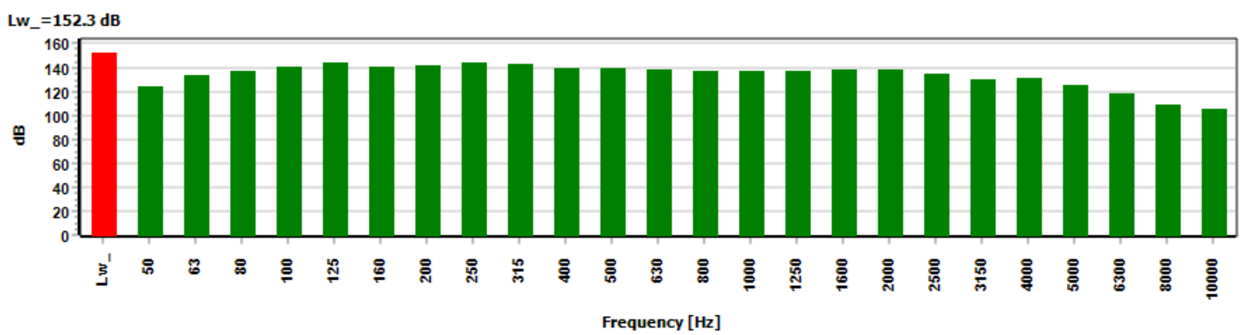

Figure 5: A320 Aircraft Noise Spectrum

Figure 6 shows the spectral data input to the SoundPLAN model for the B738 aircraft, for frequencies between 50 Hertz (Hz) and 10,000 Hz. The spectrum has a peak around 160 Hz and 315 Hz. The spectrum's overall sound power level (LW) is 153.3 dB.

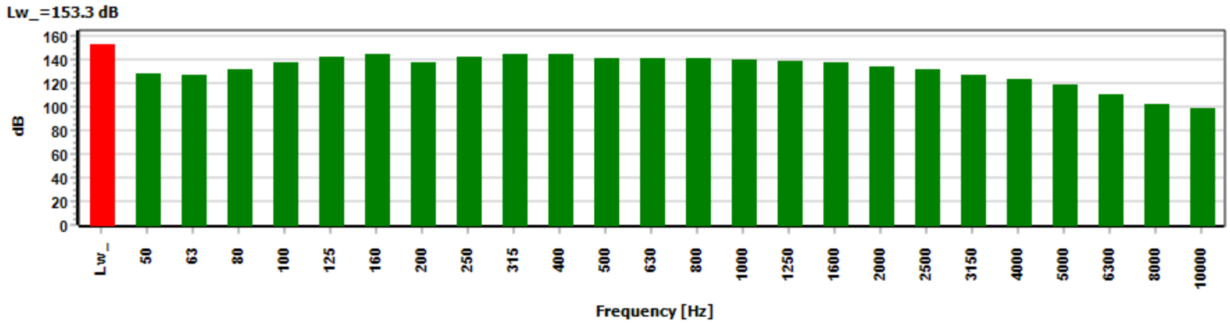

Figure 6: B738 Aircraft Noise Spectrum

Aircraft departure operations were modeled by inputting 2-point sources for each operation and distanced apart based on Boeing and Airbus manufacturer specifications to represent the two engine configurations exhibited for each aircraft type. The aircraft noise sources were modeled approximately 9.8 feet off of the ground to represent the average engine height of the modeled aircraft types. The directivity of the noise sources was rotated to represent the aircraft's orientation for a given runway.

Figure 7 shows unweighted decibels from the noise measurement data. The directivity in the figure is like the cardioid shape expected from jet engines but with narrower "waist" at 90 degrees. 0 degrees represents the front of the aircraft.

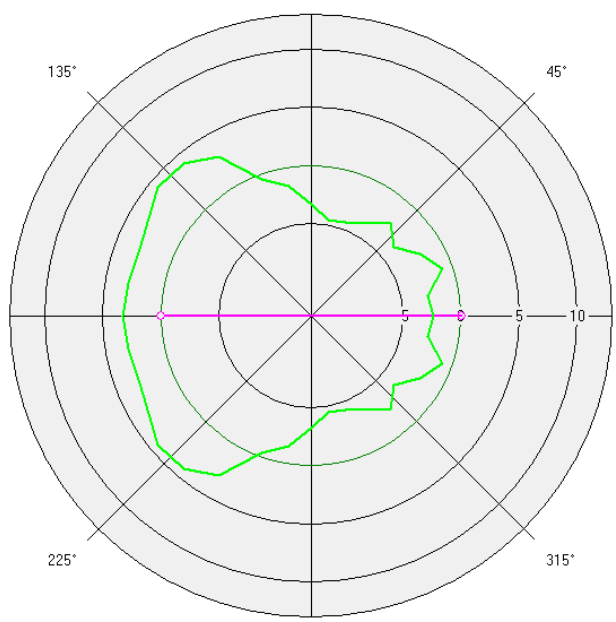

Figure 7: B738, B767-300 and A320 Directivity @ 1000 Hz

The SoundPLAN model computed the noise from the existing aircraft ground noise sources using the model inputs and algorithms that account for the effect of varying ground types, buildings, reflections, and atmospheric conditions on the overall propagation of sound. Default SoundPLAN meteorological values were modeled using a humidity of 70%, temperature of 10 degrees Celsius, and an air pressure of 1013.3 millibars.

2.4 Noise Modeling Scenarios

A total of six modeling scenarios were conducted for this GBN study; results of which are included in **Figures 9-33**. Enlarged versions of each figure are included in **Appendix H**. Each modeling scenario included two cases: with and without vegetation effects. In correspondence with the SFO ANAO, the start of takeoff roll for aircraft on Runways 1L and 1R were identified on a geocoded map. Additionally, the SFO ANAO provided secondary takeoff points for Runways 1L, 1R, 28R, and 28L. These secondary takeoff points were determined by the SFO ANAO to be representative, based on a review of flight track data, of the average point of rotation where a departing aircraft becomes airborne from that given runway.

- **Scenario 1** consisted of two aircraft types, a B738 and an A320 departing Runway 1L, with noise modeled at the start of takeoff roll.
- **Scenario 2** consisted of two aircraft types, a B738 and an A320 Departing Runway 1R, with noise modeled at the start of takeoff roll.
- **Scenario 3** consisted of two aircraft types, a B738 and an A320 departing Runway 1L, with noise modeled at a secondary takeoff point; the point of rotation where a departing aircraft becomes airborne from the runway.
- **Scenario 4** consisted of two aircraft types, a B738 and an A320 departing Runway 1R, with noise modeled at a secondary takeoff point; the point of rotation where a departing aircraft becomes airborne from the runway.
- **Scenario 5** consisted of two aircraft types, a B738 and an A320 departing at the same time but with staggered starting takeoff roll locations on Runway 1L and 1R.
- **Scenario 6** consisted of two aircraft types, a B77W departing Runway 28L and an B738 departing Runway 28R with noise modeled at secondary takeoff points; the point of rotation where a departing aircraft becomes airborne from the runway.

2.5 Vegetation

The international standard used for modeling vegetation is ISO 9613-2[5], originally developed for industrial noise sources, ISO 9613-2 is well-suited for the evaluation of ground based aircraft noise sources under favorable meteorological conditions for sound propagation. ISO 9613-2's methodology for calculating sound propagation includes geometric dispersion from acoustical point sources, atmospheric absorption, the effects of areas of hard and soft ground, screening due to barriers, and reflections.

The attenuation provided by dense foliage varies by octave band and by distance as shown in **Table 2**. For propagation through less than 10 meters (approximately 33 feet) of dense foliage, no attenuation is assumed. For propagation through 10 to 20 meters (approximately 33 to 66 feet) of dense foliage, the total attenuation is shown in the first row. For distances between 20 to 200 meters (approximately 66 to

[5] International Organization for Standardization, Acoustics – Attenuation of sound during propagation outdoors – Part 2: General Method of calculation, International Standard ISO9613-2, Geneva, Switzerland (15 December 1996).

656 feet), the total attenuation is computed by multiplying the distance of propagation through dense foliage by the dB/meter values shown in the second row.

Table 2: Dense Foliage Noise Attenuation

Source: ISO 9613-2, Table A.1

Propagation Distance	Nominal Midband Frequency (Hz)							
	63	125	250	500	1,000	2,000	4,000	8,000
10 to 20 meters (dB/meter attenuation)	0	0	1	1	1	1	2	3
20 to 200 meters (dB/meter attenuation)	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.12

ISO 9613-2 assumes a moderate downwind condition. The equations in the ISO standard also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights. In either case, the sound is refracted downward. The radius of this curved path is assumed to be 5 km. With this curved sound path, only portions of the sound path may travel through the dense foliage, as illustrated by **Figure 8**. Thus, the relative locations of the source and receiver, the dimensions of the volume of dense foliage, and the contours of the intervening terrain are essential to the estimation of the noise attenuation.

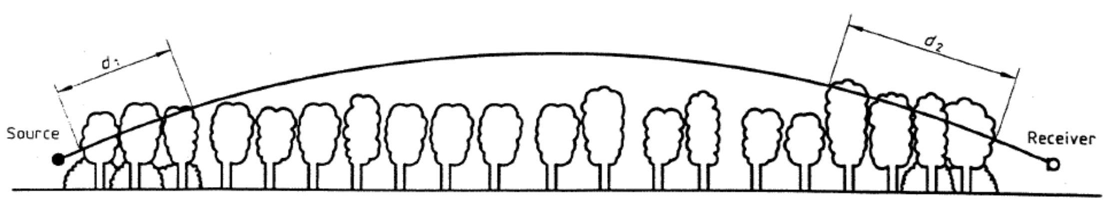

Figure 8: Downward Refracting Sound Path

Source: ISO 9613-2

All cases modeled in this study with vegetation were done so with a 50-foot vegetation thickness, and an average vegetation height of approximately 46 feet. The thickness of the vegetation was based on the approximately thickness of the Caltrans right of way along the 101 Freeway, southwest of SFO. HMMH determined the average vegetation height based upon viewing Google Street View along the 101 Freeway and upon previous ground based noise projects.

The length of the modeled vegetation was approximately 4,511 feet and is depicted on the figures. The location of the vegetation was selected to determine the effects of thickness, height and density of vegetation at a given area and to provide an understanding of effectiveness. Please note that HMMH is not necessarily proposing planting vegetation at this location; the results however show the effectiveness of vegetation at the "V" receptor locations.

3 Noise Modeling Results

As discussed in Section 2, a total of 28 receptor locations were modeled in this GBN modeling study. The GBN modeling study design took in to account direct feedback and guidance from the subcommittee. Although some of the proposed receptor locations from the City of San Bruno and Town of Hillsborough fell outside of the project study area, HMMH placed receptors at the edges of the project study area that would be the best alternative.

All of the modeled scenarios show similar differences between cases without and with vegetation. This result, regardless of the scenario, provides a good indication of the effectiveness that vegetation will have on ground noise propagation in the community. **Figures 9-33** show results for all six modeled scenarios.

The following subsections step through the noise modeling results by scenario.

3.1 Scenario 1

- Noise modeling Scenario 1 consisted of two aircraft types, a B738 and an A320 departing Runway 1L, with noise modeled at the start of takeoff roll.
- Scenario 1.1 is for the B738 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 3**. Noise attenuation in unweighted Leq dB is shown in **Table 4**.
- Scenario 1.2 is for the A320 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 5**. Noise attenuation in unweighted Leq dB is shown in **Table 6**.

Table 3: Results in Lmax dB at Receptor Locations of Scenario 1.1: B738 Departing Runway 1L at Start of Takeoff Roll

Receptor Location	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	90.5	90.0	0.5
Vegetation	V1_2	91.4	90.9	0.5
Vegetation	V1_3	91.3	90.8	0.5
Vegetation	V2_1	90.4	89.9	0.5
Vegetation	V2_2	91.2	90.8	0.4
Vegetation	V2_3	91.1	90.6	0.5
Vegetation	V3_1	90.4	89.9	0.5
Vegetation	V3_2	91.1	90.7	0.4
Vegetation	V3_3	91.0	90.5	0.5
R1_Millbrae_CapuchinoDr	R1	68.2	68.2	0.0
R2_Millbrae_RichmondDr	R2	74.2	74.2	0.0
R3_Millbrae_CorteCamellia	R3	65.9	65.9	0.0
R4_Millbrae_BeverlyAve	R4	85.4	85.4	0.0
R5_Millbrae_MurchisonDr	R5	72.8	72.8	0.0
R6_Millbrae_Mills_Estate_Park	R6	73.6	73.6	0.0

Receptor Location	ID	Without Veg.	With Veg.	Delta
R7_Millbrae_HillcrestBlvd	R7	81.2	81.2	0.0
R8_Millbrae_City_Storage	R8	81.2	81.2	0.0
R9_Millbrae_Central_Park	R9	76.6	76.6	0.0
R10_Millbrae_Spur_Trail	R10	76.0	76.0	0.0
R11_SanBruno_HuntingtonAve	R11	69.2	69.2	0.0
R12_Millbrae_BayviewAve	R12	60.9	60.9	0.0
R13_Millbrae_RidgewoodDr	R13	63.6	63.6	0.0
R14_Hillsborough_DelMonteDr	R14	69.1	69.1	0.0
R15_Hillsborough_PumpStation	R15	67.1	67.1	0.0
SFO Permanent RMT8	RMT8	87.0	87.0	0.0
SFO Permanent RMT9	RMT9	75.8	75.8	0.0
SFO Permanent RMT10	RMT10	74.1	74.1	0.0
SFO Permanent RMT11	RMT11	74.1	74.1	0.0
SFO Permanent RMT22	RMT22	64.5	64.5	0.0

Table 4: Noise Attenuation in Leq dB for Scenario 1.1: B738 Departing Runway 1L at Start of Takeoff Roll

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	86.7	93.1	91.4	90.7	87.6	77.5	59	16.1
		With Veg.	86.7	93.1	90.4	89.7	86.6	76.5	57.2	13.1
		Delta	0	0	1	1	1	1	1.8	3
Vegetation	V1_2	No Veg.	88.4	94.3	91.9	91.3	87.5	75.6	57.1	15
		With Veg.	88.4	94.3	90.9	90.3	86.5	74.6	55.2	12.1
		Delta	0	0	1	1	1	1	1.9	2.9
Vegetation	V1_3	No Veg.	88.2	94	91.8	91.2	88	76.7	58.7	17.8
		With Veg.	88.2	94	90.8	90.2	87	75.7	56.7	14.8
		Delta	0	0	1	1	1	1	2	3
Vegetation	V2_1	No Veg.	86.7	93	91.2	90.6	87.5	77.8	59.4	15.9
		With Veg.	86.7	93	90.2	89.6	86.5	76.8	57.5	12.9
		Delta	0	0	1	1	1	1	1.9	3
Vegetation	V2_2	No Veg.	88.3	94.2	91.8	91.2	87.5	75.8	57.3	15.1
		With Veg.	88.3	94.2	90.8	90.2	86.5	74.8	55.3	12.1
		Delta	0	0	1	1	1	1	2	3
Vegetation	V2_3	No Veg.	87.9	93.8	91.6	91.1	87.8	76.5	58.5	17.4
		With Veg.	87.9	93.8	90.6	90.1	86.8	75.5	56.5	14.4
		Delta	0	0	1	1	1	1	2	3
Vegetation	V3_1	No Veg.	86.7	93	91.1	90.5	87.4	78.3	59.3	15.6
		With Veg.	86.7	93	90.1	89.5	86.4	77.3	57.4	12.6
		Delta	0	0	1	1	1	1	1.9	3
Vegetation	V3_2	No Veg.	88.1	94	91.7	91.1	87.4	77	58.4	15.2
		With Veg.	88.1	94	90.7	90.1	86.4	76	56.5	12.3
		Delta	0	0	1	1	1	1	1.9	2.9

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V3_3	No Veg.	87.2	93.4	91.4	90.8	87.6	76.3	58.4	17.1
		With Veg.	87.2	93.4	90.4	89.8	86.6	75.3	56.4	14.1
		Delta	0	0	1	1	1	1	2	3
R1_Millbrae_CapuchinoDr	R1	No Veg.	62.7	69.8	69.7	69.4	65.6	52.3	8.3	0
		With Veg.	62.7	69.8	69.7	69.4	65.6	52.3	8.3	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	70.8	77	75.5	73.7	69.6	52.5	12.4	0
		With Veg.	70.8	77	75.5	73.7	69.6	52.5	12.4	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	65.2	67.7	61.8	67.1	65.4	43.8	0	0
		With Veg.	65.2	67.7	61.8	67.1	65.4	43.8	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	81.4	87	87.6	85.9	81.7	69	48.1	0
		With Veg.	81.4	87	87.6	85.9	81.7	69	48.1	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	72.1	76.6	72.8	70.7	64.9	46.6	0	0
		With Veg.	72.1	76.6	72.8	70.7	64.9	46.6	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	74	77.1	73.2	71.3	64.9	43.7	0	0
		With Veg.	74	77.1	73.2	71.3	64.9	43.7	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	79.4	84.4	81.6	80.5	76.2	61.6	33.5	0
		With Veg.	79.4	84.4	81.6	80.5	76.2	61.6	33.5	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	80.9	85.1	81	78.6	72.6	57.9	39	0
		With Veg.	80.9	85.1	81	78.6	72.6	57.9	39	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	73.5	79.4	77.7	76.2	72.5	59.3	23.4	0
		With Veg.	73.5	79.4	77.7	76.2	72.5	59.3	23.4	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	75	79.6	76.3	74.6	69.2	50.9	10.5	0
		With Veg.	75	79.6	76.3	74.6	69.2	50.9	10.5	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	61.2	68.9	68.1	70	66.7	50.2	0	0
		With Veg.	61.2	68.9	68.1	70	66.7	50.2	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	55.8	61.9	62.8	62.6	57.1	44.7	0	0
		With Veg.	55.8	61.9	62.8	62.6	57.1	44.7	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	59.7	64.7	65.2	65.2	59.6	43.6	0	0
		With Veg.	59.7	64.7	65.2	65.2	59.6	43.6	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	68.8	73	68.9	66	58.4	33.6	0	0
		With Veg.	68.8	73	68.9	66	58.4	33.6	0	0
		Delta	0	0	0	0	0	0	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
R15_Hillsborough_PumpStation	R15	No Veg.	64.7	70.7	68.3	65.4	59	35.8	0	0
		With Veg.	64.7	70.7	68.3	65.4	59	35.8	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	83.2	88.6	88.5	87.8	84	71	48.6	0
		With Veg.	83.2	88.6	88.5	87.8	84	71	48.6	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	74.6	79.4	76.1	74.4	68.9	50.4	9.6	0
		With Veg.	74.6	79.4	76.1	74.4	68.9	50.4	9.6	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	72.9	76.8	75.2	73.4	67.7	48.8	0	0
		With Veg.	72.9	76.8	75.2	73.4	67.7	48.8	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	70.9	76.5	74.5	73.7	71.7	53.4	11.8	0
		With Veg.	70.9	76.5	74.5	73.7	71.7	53.4	11.8	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	58.3	63.6	66.1	67.3	62.4	50.2	7.3	0
		With Veg.	58.3	63.6	66.1	67.3	62.4	50.2	7.3	0
		Delta	0	0	0	0	0	0	0	0

Table 5: Results in Lmax dB at Receptor Locations of Scenario 1.2: A320 Departing Runway 1L at Start of Takeoff Roll

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	90.4	90.0	0.4
Vegetation	V1_2	91.5	91.2	0.3
Vegetation	V1_3	91.3	91.0	0.3
Vegetation	V2_1	90.4	90.0	0.4
Vegetation	V2_2	91.4	91.0	0.4
Vegetation	V2_3	91.2	90.8	0.4
Vegetation	V3_1	90.5	90.1	0.4
Vegetation	V3_2	91.3	90.9	0.4
Vegetation	V3_3	91.1	90.7	0.4
R1_Millbrae_CapuchinoDr	R1	67.6	67.6	0.0
R2_Millbrae_RichmondDr	R2	74.2	74.2	0.0
R3_Millbrae_CorteCamellia	R3	66.1	66.1	0.0
R4_Millbrae_BeverlyAve	R4	85.4	85.4	0.0
R5_Millbrae_MurchisonDr	R5	73.7	73.7	0.0
R6_Millbrae_Mills_Estate_Park	R6	74.7	74.7	0.0
R7_Millbrae_HillcrestBlvd	R7	81.7	81.7	0.0
R8_Millbrae_City_Storage	R8	82.2	82.2	0.0
R9_Millbrae_Central_Park	R9	76.7	76.7	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R10_Millbrae_Spur_Trail	R10	76.8	76.8	0.0
R11_SanBruno_HuntingtonAve	R11	68.3	68.3	0.0
R12_Millbrae_BayviewAve	R12	60.3	60.3	0.0
R13_Millbrae_RidgewoodDr	R13	63.1	63.1	0.0
R14_Hillsborough_DelMonteDr	R14	70.2	70.2	0.0
R15_Hillsborough_PumpStation	R15	67.6	67.6	0.0
SFO Permanent RMT8	RMT8	86.8	86.8	0.0
SFO Permanent RMT9	RMT9	76.5	76.5	0.0
SFO Permanent RMT10	RMT10	74.7	74.7	0.0
SFO Permanent RMT11	RMT11	74.1	74.1	0.0
SFO Permanent RMT22	RMT22	63.2	63.2	0.0

Table 6: Noise Attenuation in Leq dB for Scenario 1.2: A320 Departing Runway 1L at Start of Takeoff Roll

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	91.1	92.8	92	86.7	83.9	79.3	62.9	23.5
		With Veg.	91.1	92.8	91	85.7	82.9	78.3	61.1	20.5
		Delta	0	0	1	1	1	1	1.8	3
Vegetation	V1_2	No Veg.	92.7	94.1	92.6	87.3	83.8	77.2	61	22.5
		With Veg.	92.7	94.1	91.6	86.3	82.8	76.2	59.2	19.5
		Delta	0	0	1	1	1	1	1.8	3
Vegetation	V1_3	No Veg.	92.5	93.8	92.5	87.2	84.3	78.4	62.7	25.3
		With Veg.	92.5	93.8	91.5	86.2	83.3	77.4	60.7	22.3
		Delta	0	0	1	1	1	1	2	3
Vegetation	V2_1	No Veg.	91	92.7	91.9	86.6	83.8	79.7	63.3	23.3
		With Veg.	91	92.7	90.9	85.6	82.8	78.8	61.4	20.3
		Delta	0	0	1	1	1	0.9	1.9	3
Vegetation	V2_2	No Veg.	92.6	93.9	92.5	87.2	83.7	77.5	61.2	22.5
		With Veg.	92.6	93.9	91.5	86.2	82.7	76.5	59.2	19.5
		Delta	0	0	1	1	1	1	2	3
Vegetation	V2_3	No Veg.	92.2	93.5	92.3	87.1	84.1	78.2	62.5	24.9
		With Veg.	92.2	93.5	91.3	86.1	83.1	77.2	60.5	21.9
		Delta	0	0	1	1	1	1	2	3
Vegetation	V3_1	No Veg.	91	92.6	91.8	86.5	83.6	80	63.2	23
		With Veg.	91	92.6	90.8	85.5	82.6	79.1	61.2	20
		Delta	0	0	1	1	1	0.9	2	3
Vegetation	V3_2	No Veg.	92.5	93.8	92.3	87.1	83.7	78.7	62.3	22.7

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	92.5	93.8	91.3	86.1	82.7	77.7	60.4	19.7
		Delta	0	0	1	1	1	1	1.9	3
Vegetation	V3_3	No Veg.	91.6	93.1	92.1	86.8	83.9	78.1	62.3	24.5
		With Veg.	91.6	93.1	91.1	85.8	82.9	77.1	60.3	21.5
		Delta	0	0	1	1	1	1	2	3
R1_Millbrae_CapuchinoDr	R1	No Veg.	66.9	69.1	70.3	65.4	62	53	11.5	0
		With Veg.	66.9	69.1	70.3	65.4	62	53	11.5	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	75.2	76.6	76.2	69.5	65.8	53.4	15.6	0
		With Veg.	75.2	76.6	76.2	69.5	65.8	53.4	15.6	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	69.3	67.8	63.1	63.8	61.5	44.4	0	0
		With Veg.	69.3	67.8	63.1	63.8	61.5	44.4	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	85.7	86.7	88.3	81.8	77.9	71	51.7	0
		With Veg.	85.7	86.7	88.3	81.8	77.9	71	51.7	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	76.4	76.4	73.7	66.5	61	47.2	0	0
		With Veg.	76.4	76.4	73.7	66.5	61	47.2	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	78.2	77	74.1	67.1	60.9	44.3	0	0
		With Veg.	78.2	77	74.1	67.1	60.9	44.3	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	83.7	84.2	82.4	76.5	72.4	63.2	36.9	0
		With Veg.	83.7	84.2	82.4	76.5	72.4	63.2	36.9	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	85.2	85	82	74.4	68.8	59.5	42.4	0
		With Veg.	85.2	85	82	74.4	68.8	59.5	42.4	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	77.9	79	78.4	72	68.8	60.3	26.7	0
		With Veg.	77.9	79	78.4	72	68.8	60.3	26.7	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	79.3	79.4	77.1	70.5	65.3	51.8	13.7	0
		With Veg.	79.3	79.4	77.1	70.5	65.3	51.8	13.7	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	65.6	68.2	68.8	65.9	62.9	50.7	0.4	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	65.6	68.2	68.8	65.9	62.9	50.7	0.4	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	60.1	61.3	63	58.6	53.5	45.3	0	0
		With Veg.	60.1	61.3	63	58.6	53.5	45.3	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	63.7	64	65.5	61.1	55.8	44.3	0	0
		With Veg.	63.7	64	65.5	61.1	55.8	44.3	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	73.1	73	69.8	61.8	54.4	34.1	0	0
		With Veg.	73.1	73	69.8	61.8	54.4	34.1	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	69.1	70.2	69.1	61	55.1	36.3	0	0
		With Veg.	69.1	70.2	69.1	61	55.1	36.3	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	87.5	88.3	88.8	83.8	80.2	72.7	52.1	0
		With Veg.	87.5	88.3	88.8	83.8	80.2	72.7	52.1	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	78.9	79.2	76.9	70.3	65	51.3	12.8	0
		With Veg.	78.9	79.2	76.9	70.3	65	51.3	12.8	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	77.2	76.6	75.7	69.2	63.9	49.5	2	0
		With Veg.	77.2	76.6	75.7	69.2	63.9	49.5	2	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	75.2	76.1	75.3	69.9	67.9	54.3	15.1	0
		With Veg.	75.2	76.1	75.3	69.9	67.9	54.3	15.1	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	62.5	63.1	65.7	63.3	58.8	50.9	10.6	0
		With Veg.	62.5	63.1	65.7	63.3	58.8	50.9	10.6	0
		Delta	0	0	0	0	0	0	0	0

3.2 Scenario 2

- Noise modeling Scenario 2 consisted of two aircraft types, a B738 and an A320 departing Runway 1R, with noise modeled at the start of takeoff roll.
- Scenario 2.1 is for the B738 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 7**. Noise attenuation in unweighted Leq dB is shown in **Table 8**.

- Scenario 2.2 is for the A320 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 9**. Noise attenuation in unweighted Leq dB is shown in **Table 10**.

Table 7: Results in Lmax dB at Receptor Locations of Scenario 2.1: B738 Departing Runway 1R at Start of Takeoff Roll

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	84.5	83.5	1.0
Vegetation	V1_2	87.5	86.6	0.9
Vegetation	V1_3	90.3	89.8	0.5
Vegetation	V2_1	84.5	83.5	1.0
Vegetation	V2_2	87.4	86.5	0.9
Vegetation	V2_3	90.2	89.7	0.5
Vegetation	V3_1	84.7	83.6	1.1
Vegetation	V3_2	87.4	86.5	0.9
Vegetation	V3_3	90.2	89.6	0.6
R1_Millbrae_CapuchinoDr	R1	66.1	66.1	0.0
R2_Millbrae_RichmondDr	R2	72.7	72.7	0.0
R3_Millbrae_CorteCamellia	R3	70.1	70.1	0.0
R4_Millbrae_BeverlyAve	R4	80.8	80.8	0.0
R5_Millbrae_MurchisonDr	R5	74.8	74.8	0.0
R6_Millbrae_Mills_Estate_Park	R6	73.5	73.5	0.0
R7_Millbrae_HillcrestBlvd	R7	80.0	80.0	0.0
R8_Millbrae_City_Storage	R8	79.5	79.5	0.0
R9_Millbrae_Central_Park	R9	74.9	74.9	0.0
R10_Millbrae_Spur_Trail	R10	75.6	75.6	0.0
R11_SanBruno_HuntingtonAve	R11	67.5	67.5	0.0
R12_Millbrae_BayviewAve	R12	59.9	59.9	0.0
R13_Millbrae_RidgewoodDr	R13	63.1	63.1	0.0
R14_Hillsborough_DelMonteDr	R14	69.8	69.8	0.0
R15_Hillsborough_PumpStation	R15	67.5	67.5	0.0
SFO Permanent RMT8	RMT8	88.6	88.6	0.0
SFO Permanent RMT9	RMT9	76.3	76.3	0.0
SFO Permanent RMT10	RMT10	75.1	75.1	0.0
SFO Permanent RMT11	RMT11	75.4	75.4	0.0
SFO Permanent RMT22	RMT22	63.3	63.3	0.0

Table 8: Noise Attenuation in Leq dB for Scenario 2.1: B738 Departing Runway 1R at Start of Takeoff Roll

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	75.9	84.8	85.3	86	84.7	77.5	58.8	14.7
		With Veg.	75.4	84.1	84.3	84.8	83.3	76.2	57.3	12
		Delta	0.5	0.7	1	1.2	1.4	1.3	1.5	2.7
Vegetation	V1_2	No Veg.	79.8	88.7	88.7	88.1	87.2	77.9	60.1	18.3
		With Veg.	79.4	88	87.9	87	85.9	76.3	58.3	15.8
		Delta	0.4	0.7	0.8	1.1	1.3	1.6	1.8	2.5
Vegetation	V1_3	No Veg.	85.1	92.3	91.5	90.8	88.6	78	60.6	21.2
		With Veg.	85.1	92.3	90.5	89.8	87.6	77	58.6	18.2
		Delta	0	0	1	1	1	1	2	3
Vegetation	V2_1	No Veg.	75.9	84.9	85.3	86	84.7	77.5	58.7	14.2
		With Veg.	75.5	84.2	84.3	84.8	83.3	76	56.7	11.4
		Delta	0.4	0.7	1	1.2	1.4	1.5	2	2.8
Vegetation	V2_2	No Veg.	79.8	88.6	88.6	88	87.1	77.8	60	17.9
		With Veg.	79.4	88	87.8	87	85.9	76.3	58.3	15.5
		Delta	0.4	0.6	0.8	1	1.2	1.5	1.7	2.4
Vegetation	V2_3	No Veg.	85.1	92.3	91.4	90.7	88.4	77.8	60.3	20.6
		With Veg.	85.1	92.3	90.4	89.7	87.4	76.8	58.3	17.6
		Delta	0	0	1	1	1	1	2	3
Vegetation	V3_1	No Veg.	76	84.9	85.3	85.9	85.1	77.7	59.1	13.8
		With Veg.	75.5	84.2	84.4	84.8	83.7	76.1	57.5	11.1
		Delta	0.5	0.7	0.9	1.1	1.4	1.6	1.6	2.7
Vegetation	V3_2	No Veg.	79.9	88.6	88.6	88	87	78.4	59.9	17.6
		With Veg.	79.5	88	87.8	87	85.8	76.9	58.2	15.1
		Delta	0.4	0.6	0.8	1	1.2	1.5	1.7	2.5
Vegetation	V3_3	No Veg.	85.2	92.3	91.3	90.6	88.3	77.6	60.1	20.1
		With Veg.	85.2	92.3	90.3	89.6	87.3	76.6	58.1	17.1
		Delta	0	0	1	1	1	1	2	3
R1_Millbrae_CapuchinoDr	R1	No Veg.	61.4	67.2	68	67.6	62.8	49.5	2.6	0
		With Veg.	61.4	67.2	68	67.6	62.8	49.5	2.6	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	68.3	75.4	74.2	72.4	68.9	52.1	10.9	0
		With Veg.	68.3	75.4	74.2	72.4	68.9	52.1	10.9	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	68.2	73.3	70.4	69.6	65.3	43.6	0	0
		With Veg.	68.2	73.3	70.4	69.6	65.3	43.6	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	73.9	81.3	82.7	81.1	80.8	68.7	44.1	0
		With Veg.	73.9	81.3	82.7	81.1	80.8	68.7	44.1	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	75.8	78.1	73.5	73.3	68.8	48.4	0	0
		With Veg.	75.8	78.1	73.5	73.3	68.8	48.4	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	73.8	77.1	73.3	71.2	64.9	43.9	0	0
		With Veg.	73.8	77.1	73.3	71.2	64.9	43.9	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	76.7	82.7	80.9	79.7	76.9	63.1	34.5	0
		With Veg.	76.7	82.7	80.9	79.7	76.9	63.1	34.5	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	75.7	81.9	79.8	77.4	79.7	70.3	45.1	0
		With Veg.	75.7	81.9	79.8	77.4	79.7	70.3	45.1	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	70.7	77.4	76.3	74.8	71.6	56	22.7	0
		With Veg.	70.7	77.4	76.3	74.8	71.6	56	22.7	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	74.2	79	76	74.4	69.2	51	10.4	0
		With Veg.	74.2	79	76	74.4	69.2	51	10.4	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	60.3	67.8	66.7	70.8	66.4	48.3	0	0
		With Veg.	60.3	67.8	66.7	70.8	66.4	48.3	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	55	60.8	61.7	61.3	57.5	43.1	0	0
		With Veg.	55	60.8	61.7	61.3	57.5	43.1	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	60.5	64.5	64	64.5	60	46.9	0	0
		With Veg.	60.5	64.5	64	64.5	60	46.9	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	69.6	73.8	69.5	66.8	59.4	35.2	0	0
		With Veg.	69.6	73.8	69.5	66.8	59.4	35.2	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	65.7	71.3	68.5	65.4	58.3	39	0	0
		With Veg.	65.7	71.3	68.5	65.4	58.3	39	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	86.2	90.7	87.9	87.3	83.5	70.8	49.7	0
		With Veg.	86.2	90.7	87.9	87.3	83.5	70.8	49.7	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	75.4	79.8	76.4	74.7	69.3	51.1	11.6	0
		With Veg.	75.4	79.8	76.4	74.7	69.3	51.1	11.6	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	73.6	77.3	75.7	74	68.4	49	1	0
		With Veg.	73.6	77.3	75.7	74	68.4	49	1	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	72.8	78.2	75.9	75.2	71.7	54.7	14.7	0
		With Veg.	72.8	78.2	75.9	75.2	71.7	54.7	14.7	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	57.1	62.6	65	66	60.7	47.8	2.8	0
		With Veg.	57.1	62.6	65	66	60.7	47.8	2.8	0
		Delta	0	0	0	0	0	0	0	0

Table 9: Results in Lmax dB at Receptor Locations of Scenario 2.2: A320 Departing Runway 1R at Start of Takeoff Roll

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	83.5	82.5	1.0
Vegetation	V1_2	86.5	85.7	0.8
Vegetation	V1_3	89.9	89.5	0.4
Vegetation	V2_1	83.5	82.5	1.0
Vegetation	V2_2	86.4	85.6	0.8
Vegetation	V2_3	89.9	89.4	0.5
Vegetation	V3_1	83.6	82.6	1.0
Vegetation	V3_2	86.4	85.7	0.7
Vegetation	V3_3	89.8	89.3	0.5
R1_Millbrae_CapuchinoDr	R1	65.6	65.6	0.0
R2_Millbrae_RichmondDr	R2	72.4	72.4	0.0
R3_Millbrae_CorteCamellia	R3	70.5	70.5	0.0
R4_Millbrae_BeverlyAve	R4	79.8	79.8	0.0
R5_Millbrae_MurchisonDr	R5	76.1	76.1	0.0
R6_Millbrae_Mills_Estate_Park	R6	74.7	74.7	0.0
R7_Millbrae_HillcrestBlvd	R7	80.0	80.0	0.0
R8_Millbrae_City_Storage	R8	79.3	79.3	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R9_Millbrae_Central_Park	R9	74.7	74.7	0.0
R10_Millbrae_Spur_Trail	R10	76.2	76.2	0.0
R11_SanBruno_HuntingtonAve	R11	66.1	66.1	0.0
R12_Millbrae_BayviewAve	R12	59.3	59.3	0.0
R13_Millbrae_RidgewoodDr	R13	62.8	62.8	0.0
R14_Hillsborough_DelMonteDr	R14	70.9	70.9	0.0
R15_Hillsborough_PumpStation	R15	68.2	68.2	0.0
SFO Permanent RMT8	RMT8	89.0	89.0	0.0
SFO Permanent RMT9	RMT9	77.1	77.1	0.0
SFO Permanent RMT10	RMT10	75.9	75.9	0.0
SFO Permanent RMT11	RMT11	75.6	75.6	0.0
SFO Permanent RMT22	RMT22	62.1	62.1	0.0

Table 10: Noise Attenuation in Leq dB for Scenario 2.2: A320 Departing Runway 1R at Start of Takeoff Roll

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	80.2	84	85.7	82.1	81.2	79.1	62.6	22.2
		With Veg.	79.8	83.3	84.8	80.9	79.8	77.9	61.1	19.5
		Delta	0.4	0.7	0.9	1.2	1.4	1.2	1.5	2.7
Vegetation	V1_2	No Veg.	84.3	87.6	89	84.1	83.6	79.7	64	25.7
		With Veg.	83.9	87	88.2	83	82.4	78.2	62.2	23.2
		Delta	0.4	0.6	0.8	1.1	1.2	1.5	1.8	2.5
Vegetation	V1_3	No Veg.	89.5	91.9	92.1	86.7	84.9	79.7	64.6	28.6
		With Veg.	89.5	91.9	91.1	85.7	83.9	78.7	62.6	25.6
		Delta	0	0	1	1	1	1	2	3
Vegetation	V2_1	No Veg.	80.3	84	85.8	82	81.2	79	62.4	21.6
		With Veg.	79.8	83.3	84.8	80.9	79.8	77.5	60.5	18.8
		Delta	0.5	0.7	1	1.1	1.4	1.5	1.9	2.8
Vegetation	V2_2	No Veg.	84.3	87.6	89	84	83.5	79.6	63.9	25.3
		With Veg.	83.9	87	88.1	83	82.3	78.1	62.1	22.9
		Delta	0.4	0.6	0.9	1	1.2	1.5	1.8	2.4
Vegetation	V2_3	No Veg.	89.5	91.8	92	86.6	84.7	79.5	64.3	28
		With Veg.	89.5	91.8	91	85.6	83.7	78.5	62.3	25
		Delta	0	0	1	1	1	1	2	3

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V3_1	No Veg.	80.4	84.1	85.8	82	81.7	79.4	62.8	21.3
		With Veg.	79.9	83.4	84.9	80.8	80.3	77.9	61.2	18.6
		Delta	0.5	0.7	0.9	1.2	1.4	1.5	1.6	2.7
Vegetation	V3_2	No Veg.	84.4	87.6	88.9	84	83.4	80	63.8	25
		With Veg.	84	87	88.1	82.9	82.2	78.5	62	22.6
		Delta	0.4	0.6	0.8	1.1	1.2	1.5	1.8	2.4
Vegetation	V3_3	No Veg.	89.6	91.8	91.9	86.5	84.6	79.3	64	27.6
		With Veg.	89.6	91.8	90.9	85.5	83.6	78.3	62	24.6
		Delta	0	0	1	1	1	1	2	3
R1_Millbrae_CapuchinoDr	R1	No Veg.	65.6	66.5	68.4	63.5	59	50.1	5.9	0
		With Veg.	65.6	66.5	68.4	63.5	59	50.1	5.9	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	72.8	74.6	74.7	68.3	65.1	52.9	14.2	0
		With Veg.	72.8	74.6	74.7	68.3	65.1	52.9	14.2	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	72.5	73.1	71.2	65.9	61.4	44.2	0	0
		With Veg.	72.5	73.1	71.2	65.9	61.4	44.2	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	78.3	80.4	82.8	77	77.1	69.9	47.6	0
		With Veg.	78.3	80.4	82.8	77	77.1	69.9	47.6	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	80.1	77.9	74.4	69.2	64.9	49	0.3	0
		With Veg.	80.1	77.9	74.4	69.2	64.9	49	0.3	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	78	77	74.2	67.1	60.9	44.6	0	0
		With Veg.	78	77	74.2	67.1	60.9	44.6	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	81.1	82.3	81.6	75.6	73.2	64.3	37.9	0
		With Veg.	81.1	82.3	81.6	75.6	73.2	64.3	37.9	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	80	81.4	80.6	73.1	76	71.7	48.6	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	80	81.4	80.6	73.1	76	71.7	48.6	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	75.1	76.7	76.9	70.6	67.9	57	26	0
		With Veg.	75.1	76.7	76.9	70.6	67.9	57	26	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	78.5	78.8	76.9	70.2	65.3	51.9	13.7	0
		With Veg.	78.5	78.8	76.9	70.2	65.3	51.9	13.7	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	64.6	67.1	67.4	66.8	62.6	48.8	0	0
		With Veg.	64.6	67.1	67.4	66.8	62.6	48.8	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	59.2	60.2	61.9	57.3	53.8	43.7	0	0
		With Veg.	59.2	60.2	61.9	57.3	53.8	43.7	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	64.4	64	64.3	60.4	56.4	47.4	0	0
		With Veg.	64.4	64	64.3	60.4	56.4	47.4	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	73.9	73.7	70.5	62.6	55.4	35.7	0	0
		With Veg.	73.9	73.7	70.5	62.6	55.4	35.7	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	70.1	70.9	69.4	61	54.3	39.5	0	0
		With Veg.	70.1	70.9	69.4	61	54.3	39.5	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	90.4	90.5	88.6	83.2	79.7	72.4	53.4	4.3
		With Veg.	90.4	90.5	88.6	83.2	79.7	72.4	53.4	4.3
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	79.7	79.7	77.2	70.7	65.4	52.1	14.8	0
		With Veg.	79.7	79.7	77.2	70.7	65.4	52.1	14.8	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	77.8	77.1	76.2	69.9	64.6	49.9	4.3	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	77.8	77.1	76.2	69.9	64.6	49.9	4.3	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	77.1	77.9	76.6	71.3	67.9	55.6	18	0
		With Veg.	77.1	77.9	76.6	71.3	67.9	55.6	18	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	61.4	62	64.6	62	57	48.5	6.1	0
		With Veg.	61.4	62	64.6	62	57	48.5	6.1	0
		Delta	0	0	0	0	0	0	0	0

3.3 Scenario 3

- Noise modeling Scenario 3 consisted of two aircraft types, a B738 and an A320 departing Runway 1L, with noise modeled at a secondary takeoff point, that is the point of rotation where a departing aircraft becomes airborne from the runway.
- Scenario 3.1 is for the B738 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 11**. Noise attenuation in unweighted Leq dB is shown in **Table 12**.
- Scenario 3.2 is for the A320 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 13**. Noise attenuation in unweighted Leq dB is shown in **Table 14**.

Table 11: Results in Lmax dB at Receptor Locations of Scenario 3.1: B738 Departing Runway 1L at Secondary Takeoff Point

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	77.8	77.5	0.3
Vegetation	V1_2	77.1	76.6	0.5
Vegetation	V1_3	76.8	76.4	0.4
Vegetation	V2_1	77.8	77.4	0.4
Vegetation	V2_2	77.0	76.6	0.4
Vegetation	V2_3	76.8	76.4	0.4
Vegetation	V3_1	77.8	77.4	0.4
Vegetation	V3_2	77.0	76.6	0.4
Vegetation	V3_3	76.8	76.4	0.4
R1_Millbrae_CapuchinoDr	R1	69.9	69.9	0.0
R2_Millbrae_RichmondDr	R2	70.9	70.9	0.0
R3_Millbrae_CorteCamellia	R3	65.7	65.7	0.0
R4_Millbrae_BeverlyAve	R4	77.3	77.3	0.0
R5_Millbrae_MurchisonDr	R5	70.1	70.1	0.0
R6_Millbrae_Mills_Estate_Park	R6	69.2	69.2	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R7_Millbrae_HillcrestBlvd	R7	71.6	71.6	0.0
R8_Millbrae_City_Storage	R8	75.2	75.2	0.0
R9_Millbrae_Central_Park	R9	72.2	72.2	0.0
R10_Millbrae_Spur_Trail	R10	71.4	71.4	0.0
R11_SanBruno_HuntingtonAve	R11	67.8	67.8	0.0
R12_Millbrae_BayviewAve	R12	65.0	65.0	0.0
R13_Millbrae_RidgewoodDr	R13	66.5	66.5	0.0
R14_Hillsborough_DelMonteDr	R14	67.0	67.0	0.0
R15_Hillsborough_PumpStation	R15	66.5	66.5	0.0
SFO Permanent RMT8	RMT8	76.4	76.4	0.0
SFO Permanent RMT9	RMT9	70.2	70.2	0.0
SFO Permanent RMT10	RMT10	70.4	70.4	0.0
SFO Permanent RMT11	RMT11	72.4	72.4	0.0
SFO Permanent RMT22	RMT22	66.5	66.5	0.0

Table 12: Noise Attenuation in Leq dB for Scenario 3.1: B738 Departing Runway 1L at Secondary Takeoff Point

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	77.4	81.1	77.9	76.5	71.4	54.7	19.3	0
		With Veg.	77.4	81.1	76.9	75.5	70.4	53.8	18.1	0
		Delta	0	0	1	1	1	0.9	1.2	0
Vegetation	V1_2	No Veg.	75.4	80.4	77.5	76	71.1	53.9	17.6	0
		With Veg.	75.4	80.4	76.5	75	70.1	52.9	16	0
		Delta	0	0	1	1	1	1	1.6	0
Vegetation	V1_3	No Veg.	75.1	80.2	77.4	75.9	71	53.8	17.1	0
		With Veg.	75.1	80.2	76.4	74.9	70	52.8	15.4	0
		Delta	0	0	1	1	1	1	1.7	0
Vegetation	V2_1	No Veg.	77.3	81	77.8	76.4	71.3	54.6	19.3	0
		With Veg.	77.3	81	76.8	75.4	70.3	53.7	18.2	0
		Delta	0	0	1	1	1	0.9	1.1	0
Vegetation	V2_2	No Veg.	75.4	80.4	77.5	76	71.1	53.8	16.8	0
		With Veg.	75.4	80.4	76.5	75	70.1	52.8	14.8	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V2_3	No Veg.	75.1	80.1	77.3	75.8	70.9	53.7	17.8	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	75.1	80.1	76.3	74.8	69.9	52.7	16.5	0
		Delta	0	0	1	1	1	1	1.3	0
Vegetation	V3_1	No Veg.	77.3	81	77.8	76.4	71.3	53.9	17.8	0
		With Veg.	77.3	81	76.8	75.4	70.3	53	16.2	0
		Delta	0	0	1	1	1	0.9	1.6	0
Vegetation	V3_2	No Veg.	75.4	80.3	77.5	75.9	71	53.8	16.6	0
		With Veg.	75.4	80.3	76.5	74.9	70	52.8	14.6	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_3	No Veg.	75.1	80.1	77.3	75.8	70.9	53.6	17.4	0
		With Veg.	75.1	80.1	76.3	74.8	69.9	52.6	16	0
		Delta	0	0	1	1	1	1	1.4	0
R1_Millbrae_CapuchinoDr	R1	No Veg.	69.1	73.2	70.5	68.4	62.4	40.6	0	0
		With Veg.	69.1	73.2	70.5	68.4	62.4	40.6	0	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	70.4	74.8	70.9	68.4	61.6	38.9	0	0
		With Veg.	70.4	74.8	70.9	68.4	61.6	38.9	0	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	66.9	69.7	63.3	62	58.3	31.7	0	0
		With Veg.	66.9	69.7	63.3	62	58.3	31.7	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	75.2	79.6	78.8	77.2	71.8	55.1	17.5	0
		With Veg.	75.2	79.6	78.8	77.2	71.8	55.1	17.5	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	71.8	73.5	68.4	67.4	59.6	33.3	0	0
		With Veg.	71.8	73.5	68.4	67.4	59.6	33.3	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	70.3	73	68.2	65.5	57.2	30.7	0	0
		With Veg.	70.3	73	68.2	65.5	57.2	30.7	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	71.9	75.5	69.9	67.5	67.2	49.6	1.9	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	71.9	75.5	69.9	67.5	67.2	49.6	1.9	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	74.2	78.8	75.4	73.6	68	49	6.2	0
		With Veg.	74.2	78.8	75.4	73.6	68	49	6.2	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	71.7	76	72.1	69.8	63.2	41.3	0	0
		With Veg.	71.7	76	72.1	69.8	63.2	41.3	0	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	72.3	75.2	70.7	68.2	60.9	37.3	0	0
		With Veg.	72.3	75.2	70.7	68.2	60.9	37.3	0	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	64.4	71	68	68.4	62.7	39.6	0	0
		With Veg.	64.4	71	68	68.4	62.7	39.6	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	59.5	64.4	67.1	67.5	61.9	45.6	0	0
		With Veg.	59.5	64.4	67.1	67.5	61.9	45.6	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	63.6	69.7	67.7	65.5	61.4	41.9	0	0
		With Veg.	63.6	69.7	67.7	65.5	61.4	41.9	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	67.1	71.2	65.7	64.6	57	28	0	0
		With Veg.	67.1	71.2	65.7	64.6	57	28	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	67	70.6	65.8	62.4	53.6	25.4	0	0
		With Veg.	67	70.6	65.8	62.4	53.6	25.4	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	73.9	78.7	77.9	76.5	71.2	52.8	11.2	0
		With Veg.	73.9	78.7	77.9	76.5	71.2	52.8	11.2	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	69.8	74.1	70.1	67.5	60.4	38.9	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	69.8	74.1	70.1	67.5	60.4	38.9	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	71.2	73.4	70.3	69	61.2	36.2	0	0
		With Veg.	71.2	73.4	70.3	69	61.2	36.2	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	73.8	75.7	70.8	70.6	64.8	42.2	0	0
		With Veg.	73.8	75.7	70.8	70.6	64.8	42.2	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	61.4	68.3	67.2	66.1	66.7	53.5	4.8	0
		With Veg.	61.4	68.3	67.2	66.1	66.7	53.5	4.8	0
		Delta	0	0	0	0	0	0	0	0

Table 13: Results in Lmax dB at Receptor Locations of Scenario 3.2: A320 Departing Runway 1L at Secondary Takeoff Point

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	78.7	78.4	0.3
Vegetation	V1_2	77.6	77.3	0.3
Vegetation	V1_3	77.4	77.1	0.3
Vegetation	V2_1	78.6	78.4	0.2
Vegetation	V2_2	77.6	77.3	0.3
Vegetation	V2_3	77.4	77.1	0.3
Vegetation	V3_1	78.6	78.4	0.2
Vegetation	V3_2	77.5	77.3	0.2
Vegetation	V3_3	77.3	77.0	0.3
R1_Millbrae_CapuchinoDr	R1	70.6	70.6	0.0
R2_Millbrae_RichmondDr	R2	71.9	71.9	0.0
R3_Millbrae_CorteCamellia	R3	67.3	67.3	0.0
R4_Millbrae_BeverlyAve	R4	77.7	77.7	0.0
R5_Millbrae_MurchisonDr	R5	71.7	71.7	0.0
R6_Millbrae_Mills_Estate_Park	R6	70.7	70.7	0.0
R7_Millbrae_HillcrestBlvd	R7	72.8	72.8	0.0
R8_Millbrae_City_Storage	R8	76.0	76.0	0.0
R9_Millbrae_Central_Park	R9	73.2	73.2	0.0
R10_Millbrae_Spur_Trail	R10	72.8	72.8	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R11_SanBruno_HuntingtonAve	R11	67.7	67.7	0.0
R12_Millbrae_BayviewAve	R12	63.9	63.9	0.0
R13_Millbrae_RidgewoodDr	R13	66.6	66.6	0.0
R14_Hillsborough_DelMonteDr	R14	68.2	68.2	0.0
R15_Hillsborough_PumpStation	R15	67.9	67.9	0.0
SFO Permanent RMT8	RMT8	76.6	76.6	0.0
SFO Permanent RMT9	RMT9	71.2	71.2	0.0
SFO Permanent RMT10	RMT10	71.7	71.7	0.0
SFO Permanent RMT11	RMT11	73.9	73.9	0.0
SFO Permanent RMT22	RMT22	65.9	65.9	0.0

Table 14: Noise Attenuation in Leq dB for Scenario 3.2: A320 Departing Runway 1L at Secondary Takeoff Point

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	81.6	80.9	78.7	72.4	67.5	56.2	22.6	0
		With Veg.	81.6	80.9	77.7	71.4	66.5	55.4	21.4	0
		Delta	0	0	1	1	1	0.8	1.2	0
Vegetation	V1_2	No Veg.	79.7	80.2	78.3	71.9	67.3	54.9	20.9	0
		With Veg.	79.7	80.2	77.3	70.9	66.3	53.9	19.2	0
		Delta	0	0	1	1	1	1	1.7	0
Vegetation	V1_3	No Veg.	79.5	79.9	78.2	71.8	67.1	54.8	20.4	0
		With Veg.	79.5	79.9	77.2	70.8	66.1	53.8	18.7	0
		Delta	0	0	1	1	1	1	1.7	0
Vegetation	V2_1	No Veg.	81.6	80.9	78.6	72.3	67.5	56	22.6	0
		With Veg.	81.6	80.9	77.6	71.3	66.5	55.3	21.5	0
		Delta	0	0	1	1	1	0.7	1.1	0
Vegetation	V2_2	No Veg.	79.7	80.2	78.3	71.9	67.2	54.8	20.1	0
		With Veg.	79.7	80.2	77.3	70.9	66.2	53.8	18.1	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V2_3	No Veg.	79.4	79.9	78.1	71.7	67.1	54.7	21.1	0
		With Veg.	79.4	79.9	77.1	70.7	66.1	53.7	19.8	0
		Delta	0	0	1	1	1	1	1.3	0
Vegetation	V3_1	No Veg.	81.6	80.9	78.6	72.3	67.4	55	21	0
		With Veg.	81.6	80.9	77.6	71.3	66.4	54	19.5	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		Delta	0	0	1	1	1	1	1.5	0
Vegetation	V3_2	No Veg.	79.7	80.1	78.2	71.8	67.1	54.8	19.9	0
		With Veg.	79.7	80.1	77.2	70.8	66.1	53.8	17.9	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_3	No Veg.	79.4	79.9	78.1	71.7	67	54.6	20.7	0
		With Veg.	79.4	79.9	77.1	70.7	66	53.6	19.3	0
		Delta	0	0	1	1	1	1	1.4	0
R1_Millbrae_CapuchinoDr	R1	No Veg.	73.4	72.8	71.3	64	58.5	41.1	0	0
		With Veg.	73.4	72.8	71.3	64	58.5	41.1	0	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	74.8	74.7	71.8	64.3	57.6	39.5	0	0
		With Veg.	74.8	74.7	71.8	64.3	57.6	39.5	0	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	71.1	69.9	64.6	58.6	54.3	32.1	0	0
		With Veg.	71.1	69.9	64.6	58.6	54.3	32.1	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	79.5	79.5	79.7	73.1	68	56.1	20.8	0
		With Veg.	79.5	79.5	79.7	73.1	68	56.1	20.8	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	76	73.5	69.4	63.1	55.6	33.8	0	0
		With Veg.	76	73.5	69.4	63.1	55.6	33.8	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	74.6	73	69.2	61.2	53.2	31.2	0	0
		With Veg.	74.6	73	69.2	61.2	53.2	31.2	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	76.2	75.5	71.1	63.7	63.3	50.4	5.1	0
		With Veg.	76.2	75.5	71.1	63.7	63.3	50.4	5.1	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	78.6	78.6	76.3	69.5	64.1	49.8	9.5	0
		With Veg.	78.6	78.6	76.3	69.5	64.1	49.8	9.5	0
		Delta	0	0	0	0	0	0	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
R9_Millbrae_Central_Park	R9	No Veg.	76	75.9	73	65.7	59.2	42	0	0
		With Veg.	76	75.9	73	65.7	59.2	42	0	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	76.6	75.1	71.7	64	56.9	37.9	0	0
		With Veg.	76.6	75.1	71.7	64	56.9	37.9	0	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	68.8	70.4	68.8	64	58.8	40	0	0
		With Veg.	68.8	70.4	68.8	64	58.8	40	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	63.6	63.7	66.9	63.4	58.2	46.2	0	0
		With Veg.	63.6	63.7	66.9	63.4	58.2	46.2	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	68	68.9	68.3	61.2	57.6	42.4	0	0
		With Veg.	68	68.9	68.3	61.2	57.6	42.4	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	71.5	71.1	66.8	60.5	53	28.4	0	0
		With Veg.	71.5	71.1	66.8	60.5	53	28.4	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	71.3	70.5	66.9	58.1	49.5	25.8	0	0
		With Veg.	71.3	70.5	66.9	58.1	49.5	25.8	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	78.2	78.5	78.3	72.3	67.3	53.7	14.5	0
		With Veg.	78.2	78.5	78.3	72.3	67.3	53.7	14.5	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	74.1	74	71.1	63.3	56.4	39.5	0	0
		With Veg.	74.1	74	71.1	63.3	56.4	39.5	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	75.5	73.3	71	64.7	57.2	36.7	0	0
		With Veg.	75.5	73.3	71	64.7	57.2	36.7	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	78	75.6	71.7	66.8	60.8	42.8	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	78	75.6	71.7	66.8	60.8	42.8	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	65.6	67.7	67.9	61.9	63.1	54.1	8.1	0
		With Veg.	65.6	67.7	67.9	61.9	63.1	54.1	8.1	0
		Delta	0	0	0	0	0	0	0	0

3.4 Scenario 4

- Noise modeling Scenario 4 consisted of two aircraft types, a B738 and an A320 departing Runway 1R, with noise modeled at a secondary takeoff point, that is the point of rotation where a departing aircraft becomes airborne from the runway.
- Scenario 4.1 is for the B738 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 15**. Noise attenuation in unweighted Leq dB is shown in **Table 16**.
- Scenario 4.2 is for the A320 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 17**. Noise attenuation in unweighted Leq dB is shown in **Table 18**.

Table 15: Results in Lmax dB at Receptor Locations of Scenario 4.1: B738 Departing Runway 1R at Secondary Takeoff Point

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	78.1	77.7	0.4
Vegetation	V1_2	77.6	77.2	0.4
Vegetation	V1_3	77.7	77.3	0.4
Vegetation	V2_1	78.1	77.7	0.4
Vegetation	V2_2	77.6	77.2	0.4
Vegetation	V2_3	77.7	77.3	0.4
Vegetation	V3_1	78	77.7	0.3
Vegetation	V3_2	77.5	77.1	0.4
Vegetation	V3_3	77.6	77.3	0.3
R1_Millbrae_CapuchinoDr	R1	68.2	68.2	0.0
R2_Millbrae_RichmondDr	R2	71.3	71.3	0.0
R3_Millbrae_CorteCamellia	R3	64.9	64.9	0.0
R4_Millbrae_BeverlyAve	R4	78.3	78.3	0.0
R5_Millbrae_MurchisonDr	R5	69.0	69.0	0.0
R6_Millbrae_Mills_Estate_Park	R6	69.2	69.2	0.0
R7_Millbrae_HillcrestBlvd	R7	73.9	73.9	0.0
R8_Millbrae_City_Storage	R8	75.6	75.6	0.0
R9_Millbrae_Central_Park	R9	73.7	73.7	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R10_Millbrae_Spur_Trail	R10	71.8	71.8	0.0
R11_SanBruno_HuntingtonAve	R11	67.4	67.4	0.0
R12_Millbrae_BayviewAve	R12	63.8	63.8	0.0
R13_Millbrae_RidgewoodDr	R13	65.1	65.1	0.0
R14_Hillsborough_DelMonteDr	R14	67.2	67.2	0.0
R15_Hillsborough_PumpStation	R15	67.1	67.1	0.0
SFO Permanent RMT8	RMT8	77.0	77.0	0.0
SFO Permanent RMT9	RMT9	70.5	70.5	0.0
SFO Permanent RMT10	RMT10	69.1	69.1	0.0
SFO Permanent RMT11	RMT11	72.9	72.9	0.0
SFO Permanent RMT22	RMT22	63.7	63.7	0.0

Table 16: Noise Attenuation in Leq dB for Scenario 4.1: B738 Departing Runway 1R at Secondary Takeoff Point

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	77.5	81.5	78.1	76.7	71.6	54.4	18.2	0
		With Veg.	77.5	81.5	77.1	75.7	70.6	53.4	16.2	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V1_2	No Veg.	76.2	81	78	76.5	71.5	54.4	19.4	0
		With Veg.	76.2	81	77	75.5	70.5	53.5	18	0
		Delta	0	0	1	1	1	0.9	1.4	0
Vegetation	V1_3	No Veg.	76.6	81	78	76.5	71.6	54.5	18.3	0
		With Veg.	76.6	81	77	75.5	70.6	53.5	16.3	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V2_1	No Veg.	77.5	81.4	78.1	76.7	71.6	54.3	18	0
		With Veg.	77.5	81.4	77.1	75.7	70.6	53.3	16	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V2_2	No Veg.	76.2	81	77.9	76.4	71.5	54.4	19.7	0
		With Veg.	76.2	81	76.9	75.4	70.5	53.4	18.4	0
		Delta	0	0	1	1	1	1	1.3	0
Vegetation	V2_3	No Veg.	76.6	81	77.9	76.5	71.5	54.4	18.1	0
		With Veg.	76.6	81	76.9	75.5	70.5	53.4	16.1	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_1	No Veg.	77.4	81.4	78.1	76.6	71.5	54.2	17.8	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	77.4	81.4	77.1	75.6	70.5	53.2	15.8	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_2	No Veg.	76.1	80.9	77.9	76.4	71.4	54.3	18.8	0
		With Veg.	76.1	80.9	76.9	75.4	70.4	53.3	17.3	0
		Delta	0	0	1	1	1	1	1.5	0
Vegetation	V3_3	No Veg.	76.6	81	77.9	76.5	71.5	54.3	17.9	0
		With Veg.	76.6	81	76.9	75.5	70.5	53.3	15.9	0
		Delta	0	0	1	1	1	1	2	0
R1_Millbrae_CapuchinoDr	R1	No Veg.	66.3	71.6	69.3	66.9	61.4	39.9	0	0
		With Veg.	66.3	71.6	69.3	66.9	61.4	39.9	0	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	70.1	74.8	71.3	70	65.4	43.3	0	0
		With Veg.	70.1	74.8	71.3	70	65.4	43.3	0	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	65.8	68.4	62	63.8	57.9	33.2	0	0
		With Veg.	65.8	68.4	62	63.8	57.9	33.2	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	77.2	80.6	79.3	77.7	72.3	54.1	14.2	0
		With Veg.	77.2	80.6	79.3	77.7	72.3	54.1	14.2	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	68.7	72.9	68.5	66.6	60.8	37.2	0	0
		With Veg.	68.7	72.9	68.5	66.6	60.8	37.2	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	70.3	73	68.3	65.4	57.2	31.1	0	0
		With Veg.	70.3	73	68.3	65.4	57.2	31.1	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	73.5	77.6	73.8	71.9	65.7	45.4	0	0
		With Veg.	73.5	77.6	73.8	71.9	65.7	45.4	0	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	74.8	79.2	75.7	73.9	68.2	51.3	8.9	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	74.8	79.2	75.7	73.9	68.2	51.3	8.9	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	74.7	76.9	72.5	72.3	66.2	45.5	0	0
		With Veg.	74.7	76.9	72.5	72.3	66.2	45.5	0	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	72.6	75.4	70.9	68.4	61.1	37.5	0	0
		With Veg.	72.6	75.4	70.9	68.4	61.1	37.5	0	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	63.9	70.2	67.1	68.8	63.2	40	0	0
		With Veg.	63.9	70.2	67.1	68.8	63.2	40	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	58.4	63.6	65.6	66.3	60.4	43.3	0	0
		With Veg.	58.4	63.6	65.6	66.3	60.4	43.3	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	62	68.2	66.4	64.6	59.1	39.8	0	0
		With Veg.	62	68.2	66.4	64.6	59.1	39.8	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	67.2	71.2	66.1	64.3	58.6	29.4	0	0
		With Veg.	67.2	71.2	66.1	64.3	58.6	29.4	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	67.6	71.2	66.4	63.1	54.5	28.9	0	0
		With Veg.	67.6	71.2	66.4	63.1	54.5	28.9	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	75.3	79.5	77.6	77.1	72.4	56	15.9	0
		With Veg.	75.3	79.5	77.6	77.1	72.4	56	15.9	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	70.3	74.5	70.3	67.8	60.6	37.2	0	0
		With Veg.	70.3	74.5	70.3	67.8	60.6	37.2	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	68	72.3	70.3	67.7	60	35.9	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	68	72.3	70.3	67.7	60	35.9	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	74.3	76.3	71.4	70.6	64.4	43.6	0	0
		With Veg.	74.3	76.3	71.4	70.6	64.4	43.6	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	59.8	65.4	64.7	64	62.5	49.2	0	0
		With Veg.	59.8	65.4	64.7	64	62.5	49.2	0	0
		Delta	0	0	0	0	0	0	0	0

Table 17: Results in Lmax dB at Receptor Locations of Scenario 4.2: A320 Departing Runway 1R at Secondary Takeoff Point

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	78.9	78.7	0.2
Vegetation	V1_2	78.2	77.9	0.3
Vegetation	V1_3	78.4	78.1	0.3
Vegetation	V2_1	78.9	78.7	0.2
Vegetation	V2_2	78.2	77.9	0.3
Vegetation	V2_3	78.4	78.1	0.3
Vegetation	V3_1	78.9	78.6	0.3
Vegetation	V3_2	78.2	77.9	0.3
Vegetation	V3_3	78.4	78.1	0.3
R1_Millbrae_CapuchinoDr	R1	68.6	68.6	0.0
R2_Millbrae_RichmondDr	R2	72.0	72.0	0.0
R3_Millbrae_CorteCamellia	R3	66.1	66.1	0.0
R4_Millbrae_BeverlyAve	R4	79.1	79.1	0.0
R5_Millbrae_MurchisonDr	R5	70.0	70.0	0.0
R6_Millbrae_Mills_Estate_Park	R6	70.7	70.7	0.0
R7_Millbrae_HillcrestBlvd	R7	74.9	74.9	0.0
R8_Millbrae_City_Storage	R8	76.4	76.4	0.0
R9_Millbrae_Central_Park	R9	75.0	75.0	0.0
R10_Millbrae_Spur_Trail	R10	73.2	73.2	0.0
R11_SanBruno_HuntingtonAve	R11	67.1	67.1	0.0
R12_Millbrae_BayviewAve	R12	62.7	62.7	0.0
R13_Millbrae_RidgewoodDr	R13	65.1	65.1	0.0
R14_Hillsborough_DelMonteDr	R14	68.3	68.3	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R15_Hillsborough_PumpStation	R15	68.4	68.4	0.0
SFO Permanent RMT8	RMT8	77.3	77.3	0.0
SFO Permanent RMT9	RMT9	71.6	71.6	0.0
SFO Permanent RMT10	RMT10	69.9	69.9	0.0
SFO Permanent RMT11	RMT11	74.4	74.4	0.0
SFO Permanent RMT22	RMT22	63.4	63.4	0.0

Table 18: Noise Attenuation in Leq dB for Scenario 4.2: A320 Departing Runway 1Rat Secondary Takeoff Point

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	81.8	81.3	78.9	72.7	67.8	55.4	21.5	0
		With Veg.	81.8	81.3	77.9	71.7	66.8	54.4	19.5	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V1_2	No Veg.	80.5	80.8	78.7	72.4	67.7	55.5	22.7	0
		With Veg.	80.5	80.8	77.7	71.4	66.7	54.5	21.3	0
		Delta	0	0	1	1	1	1	1.4	0
Vegetation	V1_3	No Veg.	80.9	80.8	78.8	72.5	67.7	55.5	21.6	0
		With Veg.	80.9	80.8	77.8	71.5	66.7	54.5	19.6	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V2_1	No Veg.	81.8	81.3	78.9	72.6	67.7	55.3	21.3	0
		With Veg.	81.8	81.3	77.9	71.6	66.7	54.3	19.3	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V2_2	No Veg.	80.5	80.8	78.7	72.4	67.6	55.4	23	0
		With Veg.	80.5	80.8	77.7	71.4	66.6	54.4	21.7	0
		Delta	0	0	1	1	1	1	1.3	0
Vegetation	V2_3	No Veg.	81	80.8	78.7	72.4	67.7	55.4	21.4	0
		With Veg.	81	80.8	77.7	71.4	66.7	54.4	19.4	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_1	No Veg.	81.7	81.2	78.9	72.6	67.6	55.3	21.1	0
		With Veg.	81.7	81.2	77.9	71.6	66.6	54.3	19.1	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_2	No Veg.	80.5	80.8	78.7	72.3	67.6	55.3	22.1	0
		With Veg.	80.5	80.8	77.7	71.3	66.6	54.3	20.6	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		Delta	0	0	1	1	1	1	1.5	0
Vegetation	V3_3	No Veg.	80.9	80.8	78.7	72.4	67.6	55.4	21.2	0
		With Veg.	80.9	80.8	77.7	71.4	66.6	54.4	19.2	0
		Delta	0	0	1	1	1	1	2	0
R1_Millbrae_CapuchinoDr	R1	No Veg.	70.6	71	70	62.6	57.5	40.4	0	0
		With Veg.	70.6	71	70	62.6	57.5	40.4	0	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	74.4	74.7	72.2	65.9	61.5	43.9	0	0
		With Veg.	74.4	74.7	72.2	65.9	61.5	43.9	0	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	70	68.6	63.3	59.5	53.9	33.6	0	0
		With Veg.	70	68.6	63.3	59.5	53.9	33.6	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	81.5	80.5	80.1	73.7	68.4	55.1	17.5	0
		With Veg.	81.5	80.5	80.1	73.7	68.4	55.1	17.5	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	73	72.8	69.6	62.5	56.9	37.7	0	0
		With Veg.	73	72.8	69.6	62.5	56.9	37.7	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	74.5	73	69.3	61.1	53.2	31.5	0	0
		With Veg.	74.5	73	69.3	61.1	53.2	31.5	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	77.8	77.5	74.7	67.7	61.8	46.2	1.7	0
		With Veg.	77.8	77.5	74.7	67.7	61.8	46.2	1.7	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	79.1	79	76.5	69.8	64.3	52.3	12.2	0
		With Veg.	79.1	79	76.5	69.8	64.3	52.3	12.2	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	79	76.8	73.5	68.2	62.3	46.1	0	0
		With Veg.	79	76.8	73.5	68.2	62.3	46.1	0	0
		Delta	0	0	0	0	0	0	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
R10_Millbrae_Spur_Trail	R10	No Veg.	76.9	75.4	71.8	64.3	57.1	38.1	0	0
		With Veg.	76.9	75.4	71.8	64.3	57.1	38.1	0	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	68.4	69.6	67.9	64.5	59.2	40.4	0	0
		With Veg.	68.4	69.6	67.9	64.5	59.2	40.4	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	62.5	63	65.3	62.2	56.6	43.9	0	0
		With Veg.	62.5	63	65.3	62.2	56.6	43.9	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	66.3	67.5	67	60.3	55.3	40.2	0	0
		With Veg.	66.3	67.5	67	60.3	55.3	40.2	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	71.6	71.2	67.2	60.2	54.5	29.8	0	0
		With Veg.	71.6	71.2	67.2	60.2	54.5	29.8	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	71.8	71.1	67.5	58.8	50.5	29.4	0	0
		With Veg.	71.8	71.1	67.5	58.8	50.5	29.4	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	79.6	79.3	77.8	73	68.7	57	19.2	0
		With Veg.	79.6	79.3	77.8	73	68.7	57	19.2	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	74.6	74.4	71.3	63.6	56.7	37.8	0	0
		With Veg.	74.6	74.4	71.3	63.6	56.7	37.8	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	72.3	72.2	70.9	63.5	56	36.3	0	0
		With Veg.	72.3	72.2	70.9	63.5	56	36.3	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	78.6	76.2	72.4	66.7	60.4	44.2	0	0
		With Veg.	78.6	76.2	72.4	66.7	60.4	44.2	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	64	64.8	65.3	60.1	58.9	49.8	0.4	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	64	64.8	65.3	60.1	58.9	49.8	0.4	0
		Delta	0	0	0	0	0	0	0	0

3.5 Scenario 5

- Noise modeling Scenario 5 consisted of two aircraft types, a B738 and an A320 departing at the same time but with staggered start of takeoff roll on Runway 1L and 1R.
- Scenario 5.1 is for the B738 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 19**. Noise attenuation in unweighted Leq dB is shown in **Table 20**.
- Scenario 5.2 is for the A320 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 21**. Noise attenuation in unweighted Leq dB is shown in **Table 22**.

Table 19: Results in Lmax dB at Receptor Locations of Scenario 5.1: B738 Departing at the Same Time but with Staggered Start of Takeoff Roll on Runway 1L and Runway 1R

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	90.5	90.0	0.5
Vegetation	V1_2	91.4	90.9	0.5
Vegetation	V1_3	91.3	90.8	0.5
Vegetation	V2_1	90.4	89.9	0.5
Vegetation	V2_2	91.2	90.8	0.4
Vegetation	V2_3	91.1	90.6	0.5
Vegetation	V3_1	90.4	89.9	0.5
Vegetation	V3_2	91.1	90.7	0.4
Vegetation	V3_3	91.0	90.5	0.5
R1_Millbrae_CapuchinoDr	R1	68.2	68.2	0.0
R2_Millbrae_RichmondDr	R2	74.2	74.2	0.0
R3_Millbrae_CorteCamellia	R3	70.1	70.1	0.0
R4_Millbrae_BeverlyAve	R4	85.4	85.4	0.0
R5_Millbrae_MurchisonDr	R5	74.8	74.8	0.0
R6_Millbrae_Mills_Estate_Park	R6	73.6	73.6	0.0
R7_Millbrae_HillcrestBlvd	R7	81.2	81.2	0.0
R8_Millbrae_City_Storage	R8	81.2	81.2	0.0
R9_Millbrae_Central_Park	R9	76.6	76.6	0.0
R10_Millbrae_Spur_Trail	R10	76.0	76.0	0.0
R11_SanBruno_HuntingtonAve	R11	69.2	69.2	0.0
R12_Millbrae_BayviewAve	R12	60.9	60.9	0.0
R13_Millbrae_RidgewoodDr	R13	63.6	63.6	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R14_Hillsborough_DelMonteDr	R14	69.8	69.8	0.0
R15_Hillsborough_PumpStation	R15	67.5	67.5	0.0
SFO Permanent RMT8	RMT8	88.6	88.6	0.0
SFO Permanent RMT9	RMT9	76.3	76.3	0.0
SFO Permanent RMT10	RMT10	75.1	75.1	0.0
SFO Permanent RMT11	RMT11	75.4	75.4	0.0
SFO Permanent RMT22	RMT22	64.5	64.5	0.0

Table 20: Noise Attenuation in Leq dB for Scenario 5.1: B738 Departing at the Same Time but with Staggered Start of Takeoff Roll on Runway 1L and Runway 1R

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	Departure 01L	No Veg.	86.1	92.7	91.1	90.5	87.5	76.8	58.8	15.9
			With Veg.	86.1	92.7	90.1	89.5	86.5	75.9	57	12.9
			Delta	0	0	1	1	1	0.9	1.8	3
		Departure 01R	No Veg.	75.5	84.5	84.9	85.8	84.4	75.9	57.6	13.9
			With Veg.	75	83.7	84	84.6	83	74	55.6	11
			Delta	0.5	0.8	0.9	1.2	1.4	1.9	2	2.9
Vegetation	V1_2	Departure 01L	No Veg.	88.4	94.3	91.9	91.2	87.5	75.7	57.5	14.9
			With Veg.	88.4	94.3	90.9	90.2	86.5	74.7	55.8	11.9
			Delta	0	0	1	1	1	1	1.7	3
		Departure 01R	No Veg.	79.3	88.3	88.3	87.8	86.9	77.8	60.1	17.8
			With Veg.	78.9	87.7	87.5	86.8	85.7	76.2	58.4	15.4
			Delta	0.4	0.6	0.8	1	1.2	1.6	1.7	2.4
Vegetation	V1_3	Departure 01L	No Veg.	88.1	94	91.8	91.2	87.9	76.6	58.7	17.8
			With Veg.	88.1	94	90.8	90.2	86.9	75.6	56.7	14.8
			Delta	0	0	1	1	1	1	2	3
		Departure 01R	No Veg.	84.5	91.9	91.2	90.5	88.5	78	60.5	20.9
			With Veg.	84.5	91.9	90.2	89.5	87.5	77	58.5	17.9
			Delta	0	0	1	1	1	1	2	3
Vegetation	V2_1	Departure 01L	No Veg.	86.1	92.6	91	90.3	87.4	76.8	58.7	15.6

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	86.1	92.6	90	89.3	86.4	75.9	56.9	12.6
			Delta	0	0	1	1	1	0.9	1.8	3
		Departure 01R	No Veg.	75.6	84.5	85	85.8	84.4	77.3	58.3	13.5
			With Veg.	75.1	83.8	84	84.6	83	75.7	56.3	10.6
			Delta	0.5	0.7	1	1.2	1.4	1.6	2	2.9
Vegetation	V2_2	Departure 01L	No Veg.	88.3	94.2	91.8	91.1	87.4	76.9	58.2	15
			With Veg.	88.3	94.2	90.8	90.1	86.4	75.9	56.3	12
			Delta	0	0	1	1	1	1	1.9	3
		Departure 01R	No Veg.	79.4	88.3	88.3	87.7	86.9	77.7	59.8	17.5
			With Veg.	79	87.7	87.5	86.7	85.7	76.1	58	15
			Delta	0.4	0.6	0.8	1	1.2	1.6	1.8	2.5
Vegetation	V2_3	Departure 01L	No Veg.	88	93.9	91.7	91.1	87.8	76.5	58.5	17.4
			With Veg.	88	93.9	90.7	90.1	86.8	75.5	56.5	14.4
			Delta	0	0	1	1	1	1	2	3
		Departure 01R	No Veg.	84.6	91.9	91.1	90.4	88.3	77.8	60.2	20.3
			With Veg.	84.6	91.9	90.1	89.4	87.3	76.8	58.2	17.3
			Delta	0	0	1	1	1	1	2	3
Vegetation	V3_1	Departure 01L	No Veg.	87.2	93.1	91.1	90.5	87.4	78.3	59.3	15.5
			With Veg.	87.2	93.1	90.1	89.5	86.4	77.4	57.5	12.5
			Delta	0	0	1	1	1	0.9	1.8	3
		Departure 01R	No Veg.	75.7	84.6	85	85.7	84.8	77.3	58.1	13
			With Veg.	75.2	83.9	84.1	84.5	83.4	75.5	56.2	10.2
			Delta	0.5	0.7	0.9	1.2	1.4	1.8	1.9	2.8
Vegetation	V3_2	Departure 01L	No Veg.	88.2	94	91.6	91	87.4	76.9	58.3	15
			With Veg.	88.2	94	90.6	90	86.4	75.9	56.4	12
			Delta	0	0	1	1	1	1	1.9	3
		Departure 01R	No Veg.	79.4	88.3	88.3	87.7	86.8	77.6	59.9	17.1

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	79	87.7	87.5	86.7	85.6	76.1	58.2	14.7
			Delta	0.4	0.6	0.8	1	1.2	1.5	1.7	2.4
Vegetation	V3_3	Departure 01L	No Veg.	88	93.8	91.5	91	87.7	76.3	58.5	17
			With Veg.	88	93.8	90.5	90	86.7	75.3	56.6	14
			Delta	0	0	1	1	1	1	1.9	3
		Departure 01R	No Veg.	84.6	91.8	91	90.3	88.2	77.6	60	19.8
			With Veg.	84.6	91.8	90	89.3	87.2	76.6	58	16.8
			Delta	0	0	1	1	1	1	2	3
R1_Millbrae_CapuchinoDr	R1	Departure 01L	No Veg.	62.6	69.7	69.6	69.3	65.5	52.2	8	0
			With Veg.	62.6	69.7	69.6	69.3	65.5	52.2	8	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	61.4	67.1	67.9	67.5	62.7	49.4	2.3	0
			With Veg.	61.4	67.1	67.9	67.5	62.7	49.4	2.3	0
			Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	Departure 01L	No Veg.	70.7	77	75.4	73.7	69.6	52.4	12.3	0
			With Veg.	70.7	77	75.4	73.7	69.6	52.4	12.3	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	68.2	75.3	74.1	72.4	68.8	52.1	13.1	0
			With Veg.	68.2	75.3	74.1	72.4	68.8	52.1	13.1	0
			Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	Departure 01L	No Veg.	65.1	67.7	61.8	67.1	63.6	41.7	0	0
			With Veg.	65.1	67.7	61.8	67.1	63.6	41.7	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	68.1	73.3	70.4	69.6	65.3	43.6	0	0
			With Veg.	68.1	73.3	70.4	69.6	65.3	43.6	0	0
			Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	Departure 01L	No Veg.	81	86.8	87.5	85.8	81.7	69	48	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	81	86.8	87.5	85.8	81.7	69	48	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	73.6	81	82.4	81	80.9	72.1	48.1	0
			With Veg.	73.6	81	82.4	81	80.9	72.1	48.1	0
			Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	Departure 01L	No Veg.	72.1	76.6	72.8	70.7	64.8	46.5	0	0
			With Veg.	72.1	76.6	72.8	70.7	64.8	46.5	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	75.7	78	73.5	73.2	68.5	47.5	0	0
			With Veg.	75.7	78	73.5	73.2	68.5	47.5	0	0
			Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	Departure 01L	No Veg.	73.9	77.1	73.2	71.3	64.9	43.6	0	0
			With Veg.	73.9	77.1	73.2	71.3	64.9	43.6	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	73.8	77.1	73.2	71.2	64.9	43.9	0	0
			With Veg.	73.8	77.1	73.2	71.2	64.9	43.9	0	0
			Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	Departure 01L	No Veg.	79.3	84.3	81.6	80.5	76.2	61.6	33.5	0
			With Veg.	79.3	84.3	81.6	80.5	76.2	61.6	33.5	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	76.5	82.5	80.9	79.6	76.8	63	33.3	0
			With Veg.	76.5	82.5	80.9	79.6	76.8	63	33.3	0
			Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	Departure 01L	No Veg.	80.7	85	81	78.6	72.6	57.9	38.9	0
			With Veg.	80.7	85	81	78.6	72.6	57.9	38.9	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	75.5	81.7	79.7	77.3	79.6	70.3	45	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	75.5	81.7	79.7	77.3	79.6	70.3	45	0
			Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	Departure 01L	No Veg.	73.3	79.3	77.6	76.1	72.4	59.3	23.3	0
			With Veg.	73.3	79.3	77.6	76.1	72.4	59.3	23.3	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	70.5	77.3	76.3	74.7	71.6	56	22.8	0
			With Veg.	70.5	77.3	76.3	74.7	71.6	56	22.8	0
			Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	Departure 01L	No Veg.	74.9	79.5	76.2	74.6	69.2	50.8	10.4	0
			With Veg.	74.9	79.5	76.2	74.6	69.2	50.8	10.4	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	74.1	78.9	76	74.3	69.1	51	10.3	0
			With Veg.	74.1	78.9	76	74.3	69.1	51	10.3	0
			Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	Departure 01L	No Veg.	65.1	69.9	68.1	71.9	68.1	50.1	0	0
			With Veg.	65.1	69.9	68.1	71.9	68.1	50.1	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	60.3	67.8	66.7	70.7	66.3	48.1	0	0
			With Veg.	60.3	67.8	66.7	70.7	66.3	48.1	0	0
			Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	Departure 01L	No Veg.	55.8	61.8	62.7	62.5	57	44.6	0	0
			With Veg.	55.8	61.8	62.7	62.5	57	44.6	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	54.9	60.8	61.6	61.3	57.5	43	0	0
			With Veg.	54.9	60.8	61.6	61.3	57.5	43	0	0
			Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	Departure 01L	No Veg.	59.6	64.6	65.1	65.1	59.5	43.3	0	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	59.6	64.6	65.1	65.1	59.5	43.3	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	60.5	64.5	63.9	64.5	60	46.7	0	0
			With Veg.	60.5	64.5	63.9	64.5	60	46.7	0	0
			Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	Departure 01L	No Veg.	68.8	73.1	68.9	66	58.5	33.7	0	0
			With Veg.	68.8	73.1	68.9	66	58.5	33.7	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	69.7	73.8	69.6	66.8	59.4	35.2	0	0
			With Veg.	69.7	73.8	69.6	66.8	59.4	35.2	0	0
			Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	Departure 01L	No Veg.	64.8	70.7	68.3	65.4	59	35.8	0	0
			With Veg.	64.8	70.7	68.3	65.4	59	35.8	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	65.8	71.3	68.5	65.3	58.2	38.9	0	0
			With Veg.	65.8	71.3	68.5	65.3	58.2	38.9	0	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	Departure 01L	No Veg.	83.1	88.5	88.5	87.8	84	72	50.3	0
			With Veg.	83.1	88.5	88.5	87.8	84	72	50.3	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	87.3	91.7	88.1	88.3	84.5	71.5	50.1	0
			With Veg.	87.3	91.7	88.1	88.3	84.5	71.5	50.1	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	Departure 01L	No Veg.	74.6	79.4	76.1	74.4	68.9	50.4	9.5	0
			With Veg.	74.6	79.4	76.1	74.4	68.9	50.4	9.5	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	75.4	79.8	76.4	74.7	69.2	51.1	11.6	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	75.4	79.8	76.4	74.7	69.2	51.1	11.6	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	Departure 01L	No Veg.	72.9	76.8	75.2	73.4	67.8	48.8	0	0
			With Veg.	72.9	76.8	75.2	73.4	67.8	48.8	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	74.7	77.8	75.9	74.3	68.6	49.1	1.3	0
			With Veg.	74.7	77.8	75.9	74.3	68.6	49.1	1.3	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	Departure 01L	No Veg.	71	76.6	74.6	73.8	72.6	54.1	11.8	0
			With Veg.	71	76.6	74.6	73.8	72.6	54.1	11.8	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	72.9	78.3	75.9	75.2	71.8	54.7	14.8	0
			With Veg.	72.9	78.3	75.9	75.2	71.8	54.7	14.8	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	Departure 01L	No Veg.	58.2	63.5	66.1	67.2	62.4	50.1	7	0
			With Veg.	58.2	63.5	66.1	67.2	62.4	50.1	7	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	57.1	62.5	65	65.9	60.6	47.6	2.5	0
			With Veg.	57.1	62.5	65	65.9	60.6	47.6	2.5	0
			Delta	0	0	0	0	0	0	0	0

Table 21: Results in Lmax dB at Receptor Locations of Scenario 5.2: A320 Departing at the Same Time but with Staggered Start of Takeoff Roll on Runway 1L and Runway 1R

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	90.4	90.0	0.4
Vegetation	V1_2	91.5	91.2	0.3
Vegetation	V1_3	91.3	91.0	0.3
Vegetation	V2_1	90.4	90.0	0.4
Vegetation	V2_2	91.4	91.0	0.4
Vegetation	V2_3	91.2	90.8	0.4

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V3_1	90.5	90.1	0.4
Vegetation	V3_2	91.3	90.9	0.4
Vegetation	V3_3	91.1	90.7	0.4
R1_Millbrae_CapuchinoDr	R1	67.6	67.6	0.0
R2_Millbrae_RichmondDr	R2	74.2	74.2	0.0
R3_Millbrae_CorteCamellia	R3	70.5	70.5	0.0
R4_Millbrae_BeverlyAve	R4	85.4	85.4	0.0
R5_Millbrae_MurchisonDr	R5	76.1	76.1	0.0
R6_Millbrae_Mills_Estate_Park	R6	74.7	74.7	0.0
R7_Millbrae_HillcrestBlvd	R7	81.7	81.7	0.0
R8_Millbrae_City_Storage	R8	82.2	82.2	0.0
R9_Millbrae_Central_Park	R9	76.7	76.7	0.0
R10_Millbrae_Spur_Trail	R10	76.8	76.8	0.0
R11_SanBruno_HuntingtonAve	R11	68.3	68.3	0.0
R12_Millbrae_BayviewAve	R12	60.3	60.3	0.0
R13_Millbrae_RidgewoodDr	R13	63.1	63.1	0.0
R14_Hillsborough_DelMonteDr	R14	70.9	70.9	0.0
R15_Hillsborough_PumpStation	R15	68.2	68.2	0.0
SFO Permanent RMT8	RMT8	89.0	89.0	0.0
SFO Permanent RMT9	RMT9	77.1	77.1	0.0
SFO Permanent RMT10	RMT10	75.9	75.9	0.0
SFO Permanent RMT11	RMT11	75.6	75.6	0.0
SFO Permanent RMT22	RMT22	63.2	63.2	0.0

Table 22: Noise Attenuation in Leq dB for Scenario 5.2: A320 Departing at the Same Time but with Staggered Start of Takeoff Roll on Runway 1L and Runway 1R

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	Departure 01L	No Veg.	90.5	92.3	91.8	86.4	83.8	78.8	62.7	23.3
			With Veg.	90.5	92.3	90.8	85.4	82.8	77.8	60.9	20.4
			Delta	0	0	1	1	1	1	1.8	2.9
		Departure 01R	No Veg.	79.9	83.7	85.4	81.9	81	78.7	62.2	21.4
			With Veg.	79.4	82.9	84.5	80.7	79.5	77.4	60.6	18.7
			Delta	0.5	0.8	0.9	1.2	1.5	1.3	1.6	2.7
Vegetation	V1_2	Departure 01L	No Veg.	92.8	94.1	92.6	87.3	83.7	77.5	61.4	22.3

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	92.8	94.1	91.6	86.3	82.7	76.5	59.7	19.3
			Delta	0	0	1	1	1	1	1.7	3
		Departure 01R	No Veg.	83.8	87.2	88.6	83.8	83.4	79.6	63.9	25.3
			With Veg.	83.4	86.6	87.8	82.8	82.1	78	62.2	22.8
			Delta	0.4	0.6	0.8	1	1.3	1.6	1.7	2.5
Vegetation	V1_3	Departure 01L	No Veg.	92.4	93.7	92.5	87.2	84.2	78.3	62.6	25.2
			With Veg.	92.4	93.7	91.5	86.2	83.2	77.3	60.6	22.2
			Delta	0	0	1	1	1	1	2	3
		Departure 01R	No Veg.	88.9	91.4	91.8	86.5	84.8	79.7	64.5	28.3
			With Veg.	88.9	91.4	90.8	85.5	83.8	78.7	62.5	25.3
			Delta	0	0	1	1	1	1	2	3
Vegetation	V2_1	Departure 01L	No Veg.	90.4	92.2	91.7	86.3	83.7	78.8	62.6	23
			With Veg.	90.4	92.2	90.7	85.3	82.7	77.9	60.8	20
			Delta	0	0	1	1	1	0.9	1.8	3
		Departure 01R	No Veg.	80	83.7	85.5	81.8	80.9	78.8	62	20.9
			With Veg.	79.5	83	84.5	80.6	79.5	77.3	60.1	18
			Delta	0.5	0.7	1	1.2	1.4	1.5	1.9	2.9
Vegetation	V2_2	Departure 01L	No Veg.	92.7	93.9	92.4	87.2	83.7	78.6	62.1	22.5
			With Veg.	92.7	93.9	91.4	86.2	82.7	77.6	60.2	19.5
			Delta	0	0	1	1	1	1	1.9	3
		Departure 01R	No Veg.	83.9	87.2	88.6	83.7	83.3	79.4	63.7	24.9
			With Veg.	83.5	86.6	87.8	82.7	82.1	77.9	61.9	22.4
			Delta	0.4	0.6	0.8	1	1.2	1.5	1.8	2.5
Vegetation	V2_3	Departure 01L	No Veg.	92.4	93.6	92.3	87.1	84.1	78.2	62.5	24.8
			With Veg.	92.4	93.6	91.3	86.1	83.1	77.2	60.5	21.8
			Delta	0	0	1	1	1	1	2	3
		Departure 01R	No Veg.	89	91.4	91.7	86.3	84.7	79.5	64.2	27.7

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	89	91.4	90.7	85.3	83.7	78.5	62.2	24.7
			Delta	0	0	1	1	1	1	2	3
Vegetation	V3_1	Departure 01L	No Veg.	91.5	92.7	91.7	86.4	83.7	80.1	63.2	22.9
			With Veg.	91.5	92.7	90.7	85.4	82.7	79.2	61.3	19.9
			Delta	0	0	1	1	1	0.9	1.9	3
		Departure 01R	No Veg.	80.1	83.8	85.5	81.8	81.4	78.7	62	20.5
			With Veg.	79.6	83.1	84.6	80.6	80	77	60.1	17.7
			Delta	0.5	0.7	0.9	1.2	1.4	1.7	1.9	2.8
Vegetation	V3_2	Departure 01L	No Veg.	92.5	93.8	92.3	87.1	83.6	78.7	62.2	22.5
			With Veg.	92.5	93.8	91.3	86.1	82.6	77.7	60.3	19.5
			Delta	0	0	1	1	1	1	1.9	3
		Departure 01R	No Veg.	83.9	87.2	88.6	83.7	83.2	79.3	63.5	24.5
			With Veg.	83.5	86.6	87.8	82.7	82	77.8	61.7	22.1
			Delta	0.4	0.6	0.8	1	1.2	1.5	1.8	2.4
Vegetation	V3_3	Departure 01L	No Veg.	92.3	93.5	92.2	87	84	78.1	62.5	24.5
			With Veg.	92.3	93.5	91.2	86	83	77.1	60.6	21.5
			Delta	0	0	1	1	1	1	1.9	3
		Departure 01R	No Veg.	89	91.3	91.6	86.3	84.5	79.3	63.9	27.2
			With Veg.	89	91.3	90.6	85.3	83.5	78.3	61.9	24.2
			Delta	0	0	1	1	1	1	2	3
R1_Millbrae_CapuchinoDr	R1	Departure 01L	No Veg.	66.9	69	70.2	65.3	61.9	52.8	11.2	0
			With Veg.	66.9	69	70.2	65.3	61.9	52.8	11.2	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	65.6	66.4	68.3	63.4	58.9	50	5.6	0
			With Veg.	65.6	66.4	68.3	63.4	58.9	50	5.6	0
			Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	Departure 01L	No Veg.	75.1	76.5	76.2	69.5	65.8	53.3	15.5	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	75.1	76.5	76.2	69.5	65.8	53.3	15.5	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	72.7	74.5	74.7	68.2	65	52.9	16.4	0
			With Veg.	72.7	74.5	74.7	68.2	65	52.9	16.4	0
			Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	Departure 01L	No Veg.	69.2	67.8	63	63.8	59.7	42.3	0	0
			With Veg.	69.2	67.8	63	63.8	59.7	42.3	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	72.5	73	71.2	65.9	61.4	44.2	0	0
			With Veg.	72.5	73	71.2	65.9	61.4	44.2	0	0
			Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	Departure 01L	No Veg.	85.3	86.4	88.2	81.7	77.9	71	51.5	0
			With Veg.	85.3	86.4	88.2	81.7	77.9	71	51.5	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	78	80.1	82.6	76.8	77	72.2	50.3	0
			With Veg.	78	80.1	82.6	76.8	77	72.2	50.3	0
			Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	Departure 01L	No Veg.	76.4	76.4	73.7	66.5	61	47.2	0	0
			With Veg.	76.4	76.4	73.7	66.5	61	47.2	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	80	77.9	74.4	69.1	64.6	48.2	0	0
			With Veg.	80	77.9	74.4	69.1	64.6	48.2	0	0
			Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	Departure 01L	No Veg.	78.2	77	74.1	67.1	60.9	44.3	0	0
			With Veg.	78.2	77	74.1	67.1	60.9	44.3	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	78	77	74.1	67.1	60.9	44.6	0	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	78	77	74.1	67.1	60.9	44.6	0	0
			Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	Departure 01L	No Veg.	83.6	84.1	82.3	76.5	72.4	63.1	36.8	0
			With Veg.	83.6	84.1	82.3	76.5	72.4	63.1	36.8	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	80.9	82.1	81.5	75.5	73.2	64.3	36.7	0
			With Veg.	80.9	82.1	81.5	75.5	73.2	64.3	36.7	0
			Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	Departure 01L	No Veg.	85	84.9	81.9	74.4	68.7	59.5	42.3	0
			With Veg.	85	84.9	81.9	74.4	68.7	59.5	42.3	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	79.8	81.2	80.5	73.1	75.9	71.6	48.4	0
			With Veg.	79.8	81.2	80.5	73.1	75.9	71.6	48.4	0
			Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	Departure 01L	No Veg.	77.7	78.9	78.3	71.9	68.7	60.3	26.6	0
			With Veg.	77.7	78.9	78.3	71.9	68.7	60.3	26.6	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	74.9	76.6	76.8	70.6	67.8	56.9	26.1	0
			With Veg.	74.9	76.6	76.8	70.6	67.8	56.9	26.1	0
			Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	Departure 01L	No Veg.	79.2	79.4	77	70.5	65.3	51.7	13.7	0
			With Veg.	79.2	79.4	77	70.5	65.3	51.7	13.7	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	78.4	78.7	76.8	70.2	65.2	51.9	13.6	0
			With Veg.	78.4	78.7	76.8	70.2	65.2	51.9	13.6	0
			Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	Departure 01L	No Veg.	69.7	69.2	68.8	67.8	64.3	50.7	0.2	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	69.7	69.2	68.8	67.8	64.3	50.7	0.2	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	64.6	67	67.3	66.7	62.5	48.6	0	0
			With Veg.	64.6	67	67.3	66.7	62.5	48.6	0	0
			Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	Departure 01L	No Veg.	60.1	61.2	63	58.5	53.4	45.2	0	0
			With Veg.	60.1	61.2	63	58.5	53.4	45.2	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	59.2	60.2	61.9	57.2	53.7	43.6	0	0
			With Veg.	59.2	60.2	61.9	57.2	53.7	43.6	0	0
			Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	Departure 01L	No Veg.	63.7	64	65.4	61	55.8	44	0	0
			With Veg.	63.7	64	65.4	61	55.8	44	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	64.4	64	64.3	60.3	56.4	47.3	0	0
			With Veg.	64.4	64	64.3	60.3	56.4	47.3	0	0
			Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	Departure 01L	No Veg.	73.1	73	69.9	61.8	54.4	34.1	0	0
			With Veg.	73.1	73	69.9	61.8	54.4	34.1	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	74	73.7	70.5	62.6	55.4	35.7	0	0
			With Veg.	74	73.7	70.5	62.6	55.4	35.7	0	0
			Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	Departure 01L	No Veg.	69.1	70.3	69.2	61.1	55.1	36.3	0	0
			With Veg.	69.1	70.3	69.2	61.1	55.1	36.3	0	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	70.1	71	69.4	60.9	54.2	39.4	0	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	70.1	71	69.4	60.9	54.2	39.4	0	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	Departure 01L	No Veg.	87.4	88.3	88.8	83.8	80.2	73.5	53.9	0
			With Veg.	87.4	88.3	88.8	83.8	80.2	73.5	53.9	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	91.6	91.4	88.7	84.2	80.6	73	53.7	4.4
			With Veg.	91.6	91.4	88.7	84.2	80.6	73	53.7	4.4
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	Departure 01L	No Veg.	79	79.2	76.9	70.3	65	51.2	12.8	0
			With Veg.	79	79.2	76.9	70.3	65	51.2	12.8	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	79.7	79.6	77.2	70.6	65.3	52.1	14.9	0
			With Veg.	79.7	79.6	77.2	70.6	65.3	52.1	14.9	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	Departure 01L	No Veg.	77.2	76.6	75.7	69.2	63.9	49.6	2.1	0
			With Veg.	77.2	76.6	75.7	69.2	63.9	49.6	2.1	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	79	77.6	76.4	70.1	64.7	50	4.5	0
			With Veg.	79	77.6	76.4	70.1	64.7	50	4.5	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	Departure 01L	No Veg.	75.4	76.2	75.4	70	68.7	55	15.1	0
			With Veg.	75.4	76.2	75.4	70	68.7	55	15.1	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	77.2	78	76.7	71.4	67.9	55.6	18	0
			With Veg.	77.2	78	76.7	71.4	67.9	55.6	18	0
			Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	Departure 01L	No Veg.	62.5	63	65.7	63.2	58.7	50.7	10.3	0

Receptor Locations	ID		Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
			With Veg.	62.5	63	65.7	63.2	58.7	50.7	10.3	0
			Delta	0	0	0	0	0	0	0	0
		Departure 01R	No Veg.	61.3	62	64.6	61.9	56.9	48.4	5.8	0
			With Veg.	61.3	62	64.6	61.9	56.9	48.4	5.8	0
			Delta	0	0	0	0	0	0	0	0

3.6 Scenario 6

- Noise modeling Scenario 6 consisted of two aircraft types, a B77W departing Runway 28L and an B738 departing Runway 28R with noise modeled at secondary takeoff points, that is the point of rotation where a departing aircraft becomes airborne from the runway.
- Scenario 6.1 is for the B77W and includes results without and with vegetation. Results in Lmax dB are shown in **Table 23**. Noise attenuation in unweighted Leq dB is shown in **Table 24**.
- Scenario 6.2 is for the B738 and includes results without and with vegetation. Results in Lmax dB are shown in **Table 25**. Noise attenuation in unweighted Leq dB is shown in **Table 26**.

Table 23: Results in Lmax dB at Receptor Locations of Scenario 6.1: B77W Departing Runway 28L at Secondary Takeoff Point

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	68.5	67.9	0.6
Vegetation	V1_2	68.5	67.9	0.6
Vegetation	V1_3	68.6	68.0	0.6
Vegetation	V2_1	68.5	67.9	0.6
Vegetation	V2_2	68.4	67.9	0.5
Vegetation	V2_3	68.5	68.0	0.5
Vegetation	V3_1	68.4	67.9	0.5
Vegetation	V3_2	68.4	67.8	0.6
Vegetation	V3_3	68.5	67.9	0.6
R1_Millbrae_CapuchinoDr	R1	62.3	62.3	0.0
R2_Millbrae_RichmondDr	R2	61.3	61.3	0.0
R3_Millbrae_CorteCamellia	R3	54.6	54.6	0.0
R4_Millbrae_BeverlyAve	R4	68.5	68.5	0.0
R5_Millbrae_MurchisonDr	R5	59.3	59.3	0.0
R6_Millbrae_Mills_Estate_Park	R6	60.6	60.6	0.0
R7_Millbrae_HillcrestBlvd	R7	61.8	61.8	0.0
R8_Millbrae_City_Storage	R8	66.0	66.0	0.0
R9_Millbrae_Central_Park	R9	62.0	62.0	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R10_Millbrae_Spur_Trail	R10	61.9	61.9	0.0
R11_SanBruno_HuntingtonAve	R11	60.6	60.6	0.0
R12_Millbrae_BayviewAve	R12	63.1	63.1	0.0
R13_Millbrae_RidgewoodDr	R13	60.5	60.5	0.0
R14_Hillsborough_DelMonteDr	R14	61.3	61.3	0.0
R15_Hillsborough_PumpStation	R15	64.1	64.1	0.0
SFO Permanent RMT8	RMT8	68.2	68.2	0.0
SFO Permanent RMT9	RMT9	61.2	61.2	0.0
SFO Permanent RMT10	RMT10	61.7	61.7	0.0
SFO Permanent RMT11	RMT11	66.9	66.9	0.0
SFO Permanent RMT22	RMT22	62.9	62.9	0.0

Table 24: Noise Attenuation in Leq dB for Scenario 6.1: B77W Departing Runway 28L at Secondary Takeoff Point

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	67.7	68.6	70.8	67	62.6	56.2	22.9	0
		With Veg.	67.7	68.6	69.8	66	61.6	55.4	21.8	0
		Delta	0	0	1	1	1	0.8	1.1	0
Vegetation	V1_2	No Veg.	67.5	68.6	70.8	67.1	62.8	55.2	20.3	0
		With Veg.	67.5	68.6	69.8	66.1	61.8	54.2	18.3	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V1_3	No Veg.	67.9	68.7	70.7	67.2	63.1	55	20.9	0
		With Veg.	67.9	68.7	69.7	66.2	62.1	54	19.4	0
		Delta	0	0	1	1	1	1	1.5	0
Vegetation	V2_1	No Veg.	67.7	68.6	70.8	66.9	62.5	55.3	21.1	0
		With Veg.	67.7	68.6	69.8	65.9	61.5	54.4	19.5	0
		Delta	0	0	1	1	1	0.9	1.6	0
Vegetation	V2_2	No Veg.	67.5	68.6	70.7	67	62.7	55.2	20.1	0
		With Veg.	67.5	68.6	69.7	66	61.7	54.2	18.1	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V2_3	No Veg.	67.9	68.7	70.7	67.1	63	55	20.8	0
		With Veg.	67.9	68.7	69.7	66.1	62	54	19.3	0
		Delta	0	0	1	1	1	1	1.5	0
Vegetation	V3_1	No Veg.	67.7	68.6	70.7	66.9	62.5	55.2	20.2	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	67.7	68.6	69.7	65.9	61.5	54.2	18.2	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_2	No Veg.	67.4	68.6	70.7	67	62.7	55.1	19.9	0
		With Veg.	67.4	68.6	69.7	66	61.7	54.1	17.9	0
		Delta	0	0	1	1	1	1	2	0
Vegetation	V3_3	No Veg.	67.9	68.7	70.6	67.1	62.9	54.9	20.5	0
		With Veg.	67.9	68.7	69.6	66.1	61.9	53.9	19	0
		Delta	0	0	1	1	1	1	1.5	0
R1_Millbrae_CapuchinoDr	R1	No Veg.	62.1	62.9	64.8	59.6	54.6	44.5	0	0
		With Veg.	62.1	62.9	64.8	59.6	54.6	44.5	0	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	60.7	61.6	63.9	59.4	54	44.6	0	0
		With Veg.	60.7	61.6	63.9	59.4	54	44.6	0	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	56.3	55.3	54.8	52.8	48.9	34.2	0	0
		With Veg.	56.3	55.3	54.8	52.8	48.9	34.2	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	66.3	67	71.7	67.8	63.1	56	20.3	0
		With Veg.	66.3	67	71.7	67.8	63.1	56	20.3	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	59.6	60.4	61.5	56.3	49.6	37.1	0	0
		With Veg.	59.6	60.4	61.5	56.3	49.6	37.1	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	62.8	61.6	61.7	56.4	48.6	31.7	0	0
		With Veg.	62.8	61.6	61.7	56.4	48.6	31.7	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	63	63.2	63.1	56.3	55.6	49	4	0
		With Veg.	63	63.2	63.1	56.3	55.6	49	4	0
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	65.4	66.4	68.5	64.3	59.2	50.5	9.6	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	65.4	66.4	68.5	64.3	59.2	50.5	9.6	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	61.7	62.3	64.5	60	54.1	44.1	0	0
		With Veg.	61.7	62.3	64.5	60	54.1	44.1	0	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	63.3	62.6	63.7	58.8	51.9	39.2	0	0
		With Veg.	63.3	62.6	63.7	58.8	51.9	39.2	0	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	59.2	61.1	62.9	59.8	54.9	43.5	0	0
		With Veg.	59.2	61.1	62.9	59.8	54.9	43.5	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	61.4	63	65.1	61.8	60.9	51.6	3.5	0
		With Veg.	61.4	63	65.1	61.8	60.9	51.6	3.5	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	59.9	61.7	62.9	57.3	53.4	45.7	0	0
		With Veg.	59.9	61.7	62.9	57.3	53.4	45.7	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	62.1	62	63.2	58.7	52.6	32.4	0	0
		With Veg.	62.1	62	63.2	58.7	52.6	32.4	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	64.8	66.2	65.6	58.6	51.3	31.9	0	0
		With Veg.	64.8	66.2	65.6	58.6	51.3	31.9	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	67.2	67.5	70.2	67.9	63.5	55.1	15.4	0
		With Veg.	67.2	67.5	70.2	67.9	63.5	55.1	15.4	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	61.5	62.3	63.4	58.3	51.5	38.1	0	0
		With Veg.	61.5	62.3	63.4	58.3	51.5	38.1	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	61.7	62.2	64	59.7	53	36.9	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		With Veg.	61.7	62.2	64	59.7	53	36.9	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	68.2	66.9	68.2	65	60.2	47.6	0	0
		With Veg.	68.2	66.9	68.2	65	60.2	47.6	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	60.8	63.5	64.8	59	60.8	57	8.1	0
		With Veg.	60.8	63.5	64.8	59	60.8	57	8.1	0
		Delta	0	0	0	0	0	0	0	0

Table 25: Results in Lmax dB at Receptor Locations of Scenario 6.2: B738 Departing Runway 28R at Secondary Takeoff Point

Receptor Locations	ID	Without Veg.	With Veg.	Delta
Vegetation	V1_1	64.5	63.8	0.7
Vegetation	V1_2	64.2	63.5	0.7
Vegetation	V1_3	64.2	63.5	0.7
Vegetation	V2_1	64.4	63.8	0.6
Vegetation	V2_2	64.1	63.4	0.7
Vegetation	V2_3	64.2	63.5	0.7
Vegetation	V3_1	64.4	63.7	0.7
Vegetation	V3_2	64.1	63.4	0.7
Vegetation	V3_3	64.1	63.4	0.7
R1_Millbrae_CapuchinoDr	R1	58.9	58.9	0.0
R2_Millbrae_RichmondDr	R2	56.7	56.7	0.0
R3_Millbrae_CorteCamellia	R3	52.1	52.1	0.0
R4_Millbrae_BeverlyAve	R4	64.6	64.6	0.0
R5_Millbrae_MurchisonDr	R5	56.2	56.2	0.0
R6_Millbrae_Mills_Estate_Park	R6	55.8	55.8	0.0
R7_Millbrae_HillcrestBlvd	R7	58.0	58.0	0.0
R8_Millbrae_City_Storage	R8	61.9	61.9	0.0
R9_Millbrae_Central_Park	R9	57.9	57.9	0.0
R10_Millbrae_Spur_Trail	R10	57.8	57.8	0.0
R11_SanBruno_HuntingtonAve	R11	56.9	56.9	0.0
R12_Millbrae_BayviewAve	R12	60.5	60.5	0.0
R13_Millbrae_RidgewoodDr	R13	56.7	56.7	0.0
R14_Hillsborough_DelMonteDr	R14	-	-	0.0

Receptor Locations	ID	Without Veg.	With Veg.	Delta
R15_Hillsborough_PumpStation	R15	59.0	59.0	0.0
SFO Permanent RMT8	RMT8	64.7	64.7	0.0
SFO Permanent RMT9	RMT9	56.8	56.8	0.0
SFO Permanent RMT10	RMT10	59.0	59.0	0.0
SFO Permanent RMT11	RMT11	62.2	62.2	0.0
SFO Permanent RMT22	RMT22	59.6	59.6	0.0

Table 26: Noise Attenuation in Leq dB for Scenario 6.2: B738 Departing Runway 28R at Secondary Takeoff Point

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Vegetation	V1_1	No Veg.	60.5	65	66	66.4	61.5	48.8	9.4	0
		With Veg.	60.5	65	65	65.4	60.5	47.8	7.9	0
		Delta	0	0	1	1	1	1	1.5	0
Vegetation	V1_2	No Veg.	59.1	64.6	65.8	66.2	61.6	48.3	8.4	0
		With Veg.	59.1	64.6	64.8	65.2	60.6	47.3	6.8	0
		Delta	0	0	1	1	1	1	1.6	0
Vegetation	V1_3	No Veg.	59.5	64.6	65.7	66.2	61.7	48	8.3	0
		With Veg.	59.5	64.6	64.7	65.2	60.7	47	6.9	0
		Delta	0	0	1	1	1	1	1.4	0
Vegetation	V2_1	No Veg.	60.5	65	65.9	66.3	61.4	48.7	9.3	0
		With Veg.	60.5	65	64.9	65.3	60.4	47.7	7.9	0
		Delta	0	0	1	1	1	1	1.4	0
Vegetation	V2_2	No Veg.	59.1	64.5	65.7	66.1	61.5	48.2	8.7	0
		With Veg.	59.1	64.5	64.7	65.1	60.5	47.2	7.2	0
		Delta	0	0	1	1	1	1	1.5	0
Vegetation	V2_3	No Veg.	59.5	64.6	65.6	66.2	61.7	47.9	7.6	0
		With Veg.	59.5	64.6	64.6	65.2	60.7	46.9	5.9	0
		Delta	0	0	1	1	1	1	1.7	0
Vegetation	V3_1	No Veg.	60.5	65	65.9	66.3	61.4	48.6	9.3	0
		With Veg.	60.5	65	64.9	65.3	60.4	47.6	8	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		Delta	0	0	1	1	1	1	1.3	0
Vegetation	V3_2	No Veg.	59.1	64.5	65.7	66.1	61.4	48.1	7.9	0
		With Veg.	59.1	64.5	64.7	65.1	60.4	47.1	6.2	0
		Delta	0	0	1	1	1	1	1.7	0
Vegetation	V3_3	No Veg.	59.4	64.5	65.6	66.1	61.6	47.9	8.5	0
		With Veg.	59.4	64.5	64.6	65.1	60.6	46.9	7.2	0
		Delta	0	0	1	1	1	1	1.3	0
R1_Millbrae_CapuchinoDr	R1	No Veg.	55.3	59.5	59.9	61	55.5	40.3	0	0
		With Veg.	55.3	59.5	59.9	61	55.5	40.3	0	0
		Delta	0	0	0	0	0	0	0	0
R2_Millbrae_RichmondDr	R2	No Veg.	52.5	57.8	58.8	58.1	51.6	35.6	0	0
		With Veg.	52.5	57.8	58.8	58.1	51.6	35.6	0	0
		Delta	0	0	0	0	0	0	0	0
R3_Millbrae_CorteCamellia	R3	No Veg.	49.8	53.9	53.1	53.3	47.5	28.9	0	0
		With Veg.	49.8	53.9	53.1	53.3	47.5	28.9	0	0
		Delta	0	0	0	0	0	0	0	0
R4_Millbrae_BeverlyAve	R4	No Veg.	57.6	63.5	67	67.1	61.9	50.7	9.1	0
		With Veg.	57.6	63.5	67	67.1	61.9	50.7	9.1	0
		Delta	0	0	0	0	0	0	0	0
R5_Millbrae_MurchisonDr	R5	No Veg.	54.9	57.9	56.9	57.5	49.2	27.8	0	0
		With Veg.	54.9	57.9	56.9	57.5	49.2	27.8	0	0
		Delta	0	0	0	0	0	0	0	0
R6_Millbrae_Mills_Estate_Park	R6	No Veg.	54.9	57.9	56.9	56.4	48.2	25.9	0	0
		With Veg.	54.9	57.9	56.9	56.4	48.2	25.9	0	0
		Delta	0	0	0	0	0	0	0	0
R7_Millbrae_HillcrestBlvd	R7	No Veg.	54.9	59.8	58.6	57.8	57.4	45.2	0	0
		With Veg.	54.9	59.8	58.6	57.8	57.4	45.2	0	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		Delta	0	0	0	0	0	0	0	0
R8_Millbrae_City_Storage	R8	No Veg.	57.1	62.8	63.7	63.7	58.2	44	0	0
		With Veg.	57.1	62.8	63.7	63.7	58.2	44	0	0
		Delta	0	0	0	0	0	0	0	0
R9_Millbrae_Central_Park	R9	No Veg.	53.5	58.9	59.9	59.4	53.1	37.7	0	0
		With Veg.	53.5	58.9	59.9	59.4	53.1	37.7	0	0
		Delta	0	0	0	0	0	0	0	0
R10_Millbrae_Spur_Trail	R10	No Veg.	55.7	59.5	59.3	58.8	51.3	33.1	0	0
		With Veg.	55.7	59.5	59.3	58.8	51.3	33.1	0	0
		Delta	0	0	0	0	0	0	0	0
R11_SanBruno_HuntingtonAve	R11	No Veg.	50.4	57.5	57.6	59.7	54.3	38	0	0
		With Veg.	50.4	57.5	57.6	59.7	54.3	38	0	0
		Delta	0	0	0	0	0	0	0	0
R12_Millbrae_BayviewAve	R12	No Veg.	53	60.2	61.9	62.2	60.3	47.6	0	0
		With Veg.	53	60.2	61.9	62.2	60.3	47.6	0	0
		Delta	0	0	0	0	0	0	0	0
R13_Millbrae_RidgewoodDr	R13	No Veg.	52.4	58.3	58.7	57.6	52.1	40.8	0	0
		With Veg.	52.4	58.3	58.7	57.6	52.1	40.8	0	0
		Delta	0	0	0	0	0	0	0	0
R14_Hillsborough_DelMonteDr	R14	No Veg.	0	0	0	0	0	0	0	0
		With Veg.	0	0	0	0	0	0	0	0
		Delta	0	0	0	0	0	0	0	0
R15_Hillsborough_PumpStation	R15	No Veg.	56.4	62.4	60.3	58.3	50.3	25.6	0	0
		With Veg.	56.4	62.4	60.3	58.3	50.3	25.6	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT8	RMT8	No Veg.	58.8	63.6	66.6	67.3	62.3	47.5	2.7	0
		With Veg.	58.8	63.6	66.6	67.3	62.3	47.5	2.7	0

Receptor Locations	ID	Case	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT9	RMT9	No Veg.	53.3	58.6	58.7	57.9	50.8	34.1	0	0
		With Veg.	53.3	58.6	58.7	57.9	50.8	34.1	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT10	RMT10	No Veg.	56.8	59.8	59.9	61.1	53.4	32.2	0	0
		With Veg.	56.8	59.8	59.9	61.1	53.4	32.2	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT11	RMT11	No Veg.	59.7	63	63.1	63.9	59	41.3	0	0
		With Veg.	59.7	63	63.1	63.9	59	41.3	0	0
		Delta	0	0	0	0	0	0	0	0
SFO Permanent RMT22	RMT22	No Veg.	52.8	60.4	61	60.2	59.2	50.7	0	0
		With Veg.	52.8	60.4	61	60.2	59.2	50.7	0	0
		Delta	0	0	0	0	0	0	0	0

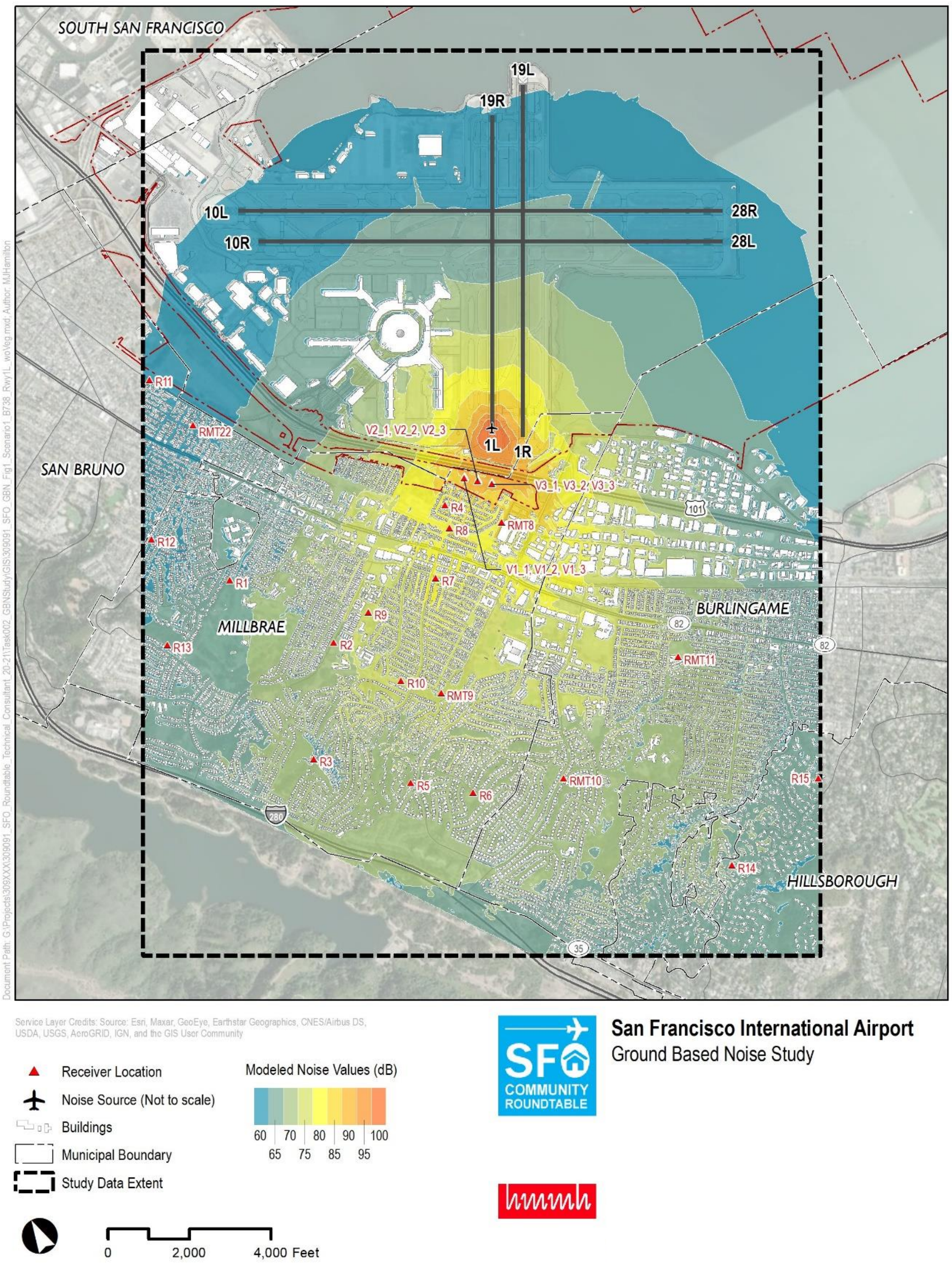

Figure 9: Scenario 1 - B738 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

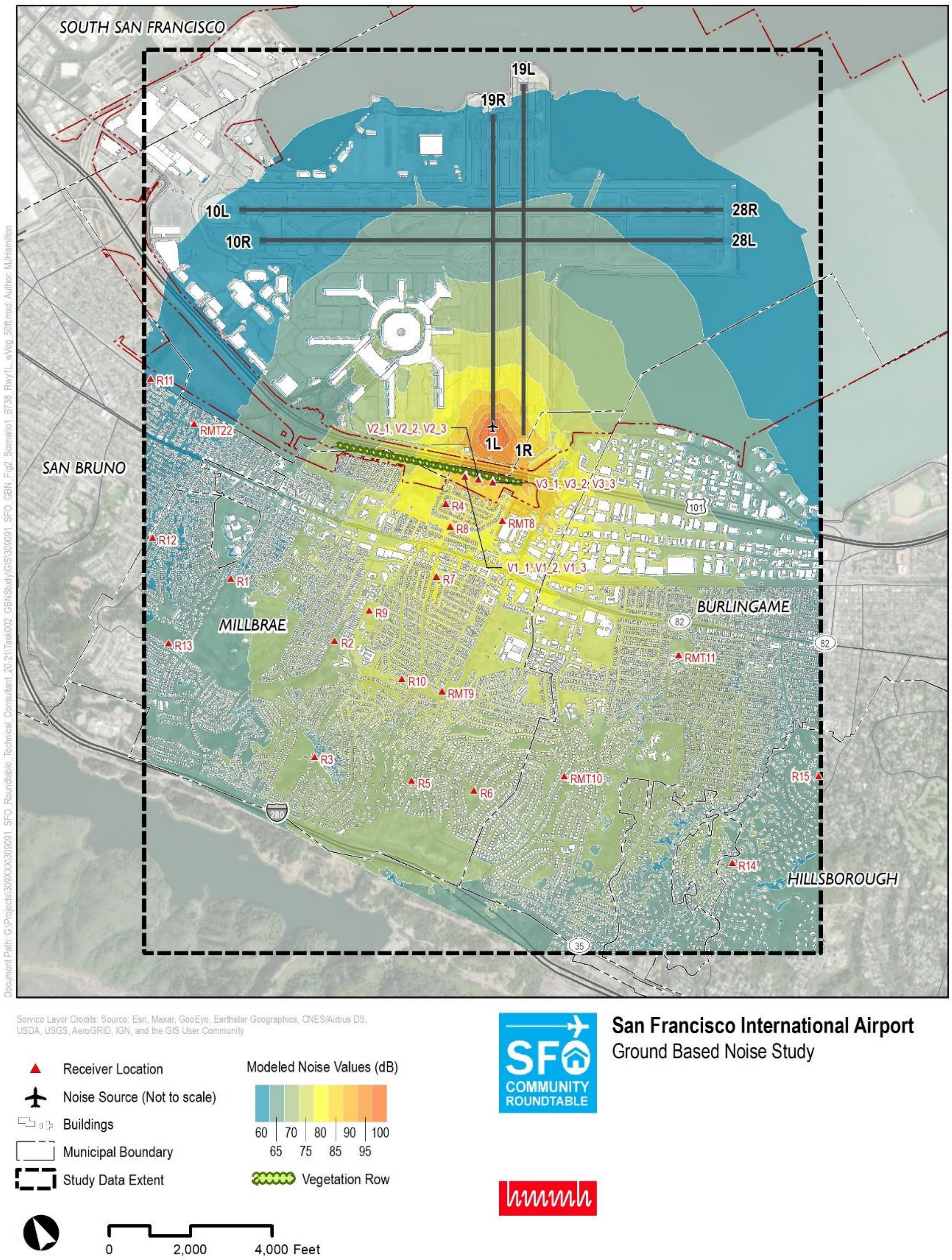

Figure 10: Scenario 1 - B738 Departing Runway 1L at Start of Takeoff Roll - With Vegetation (50 Feet)

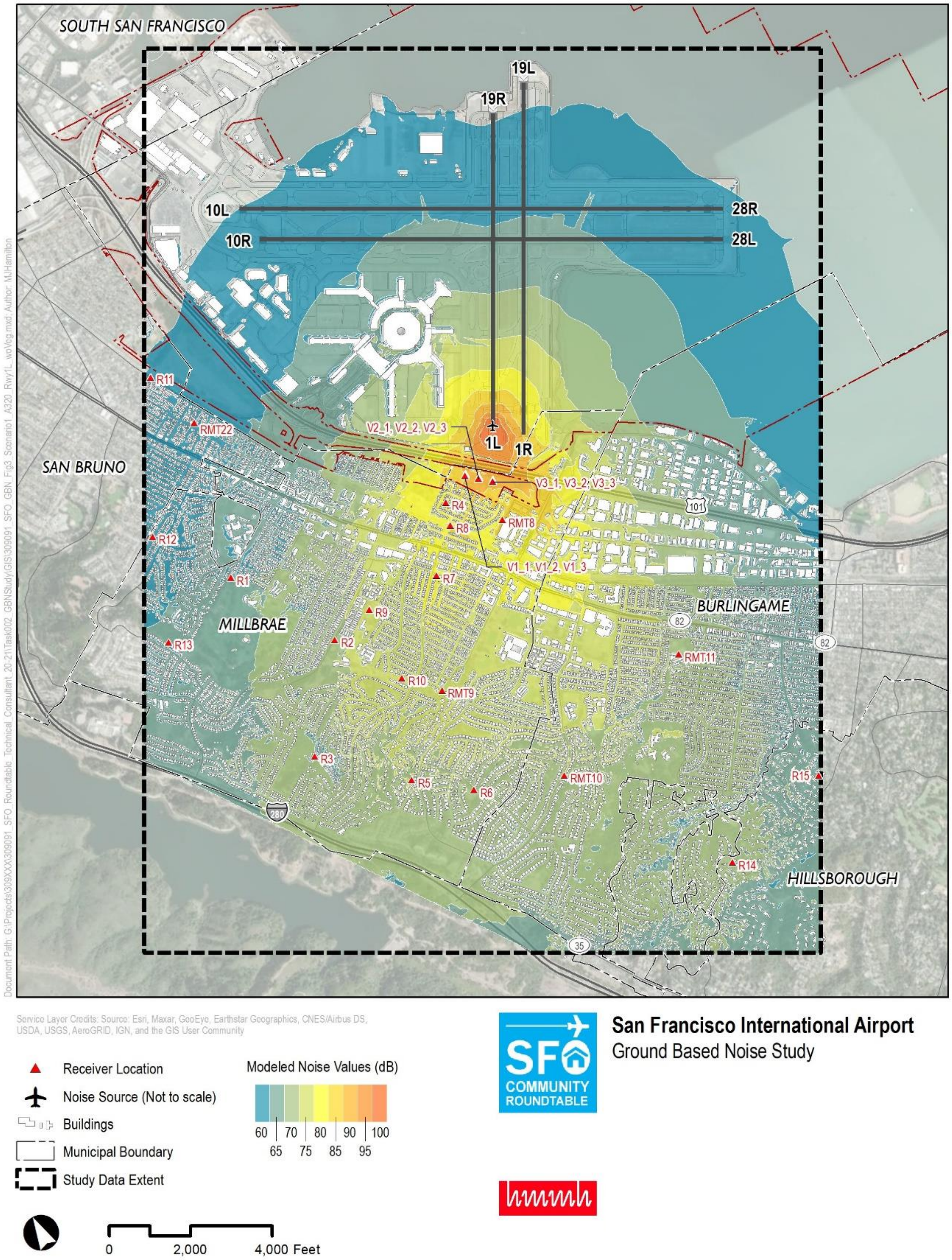

Figure 11: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

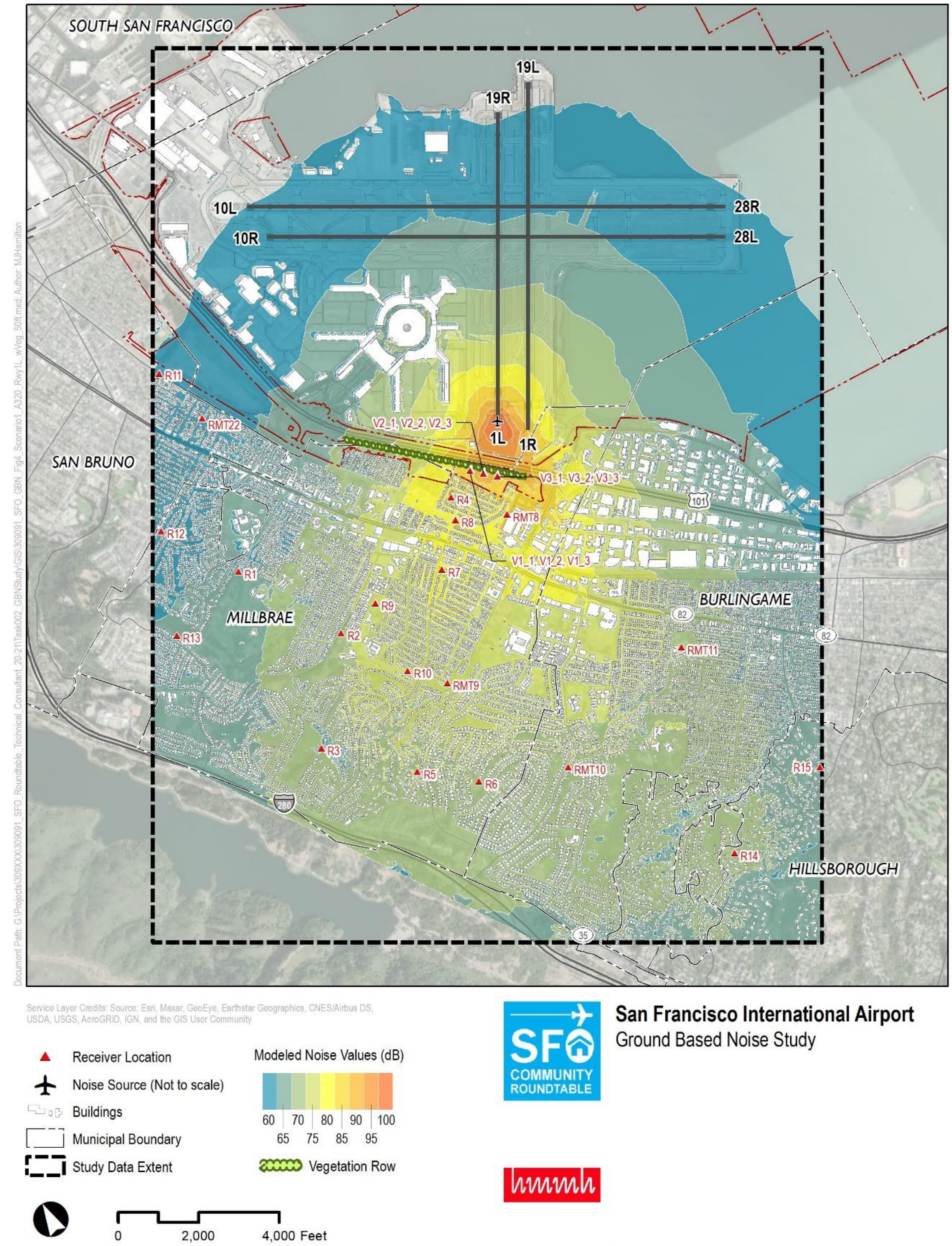

Figure 12: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – With Vegetation (50 Feet)

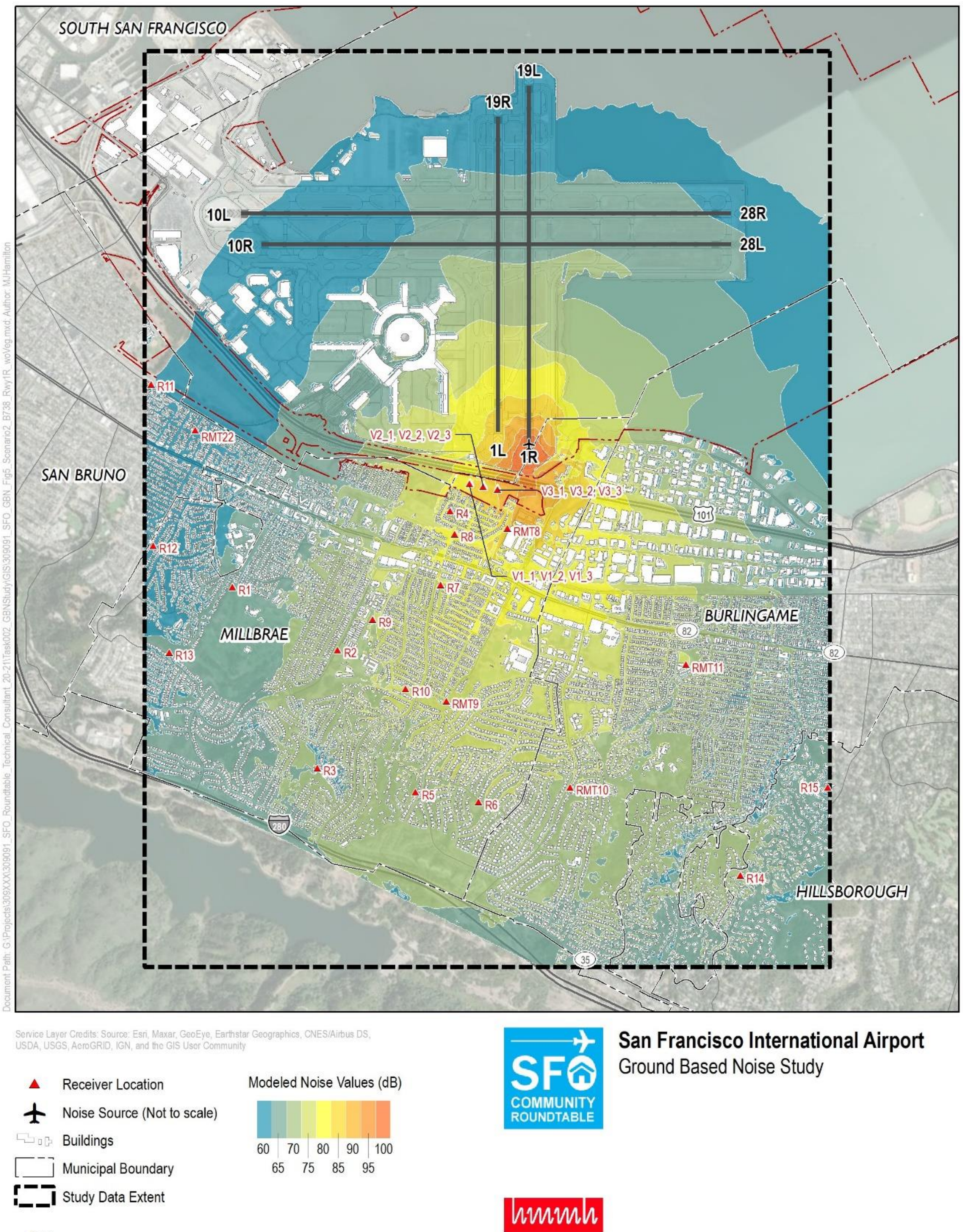

Figure 13: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation

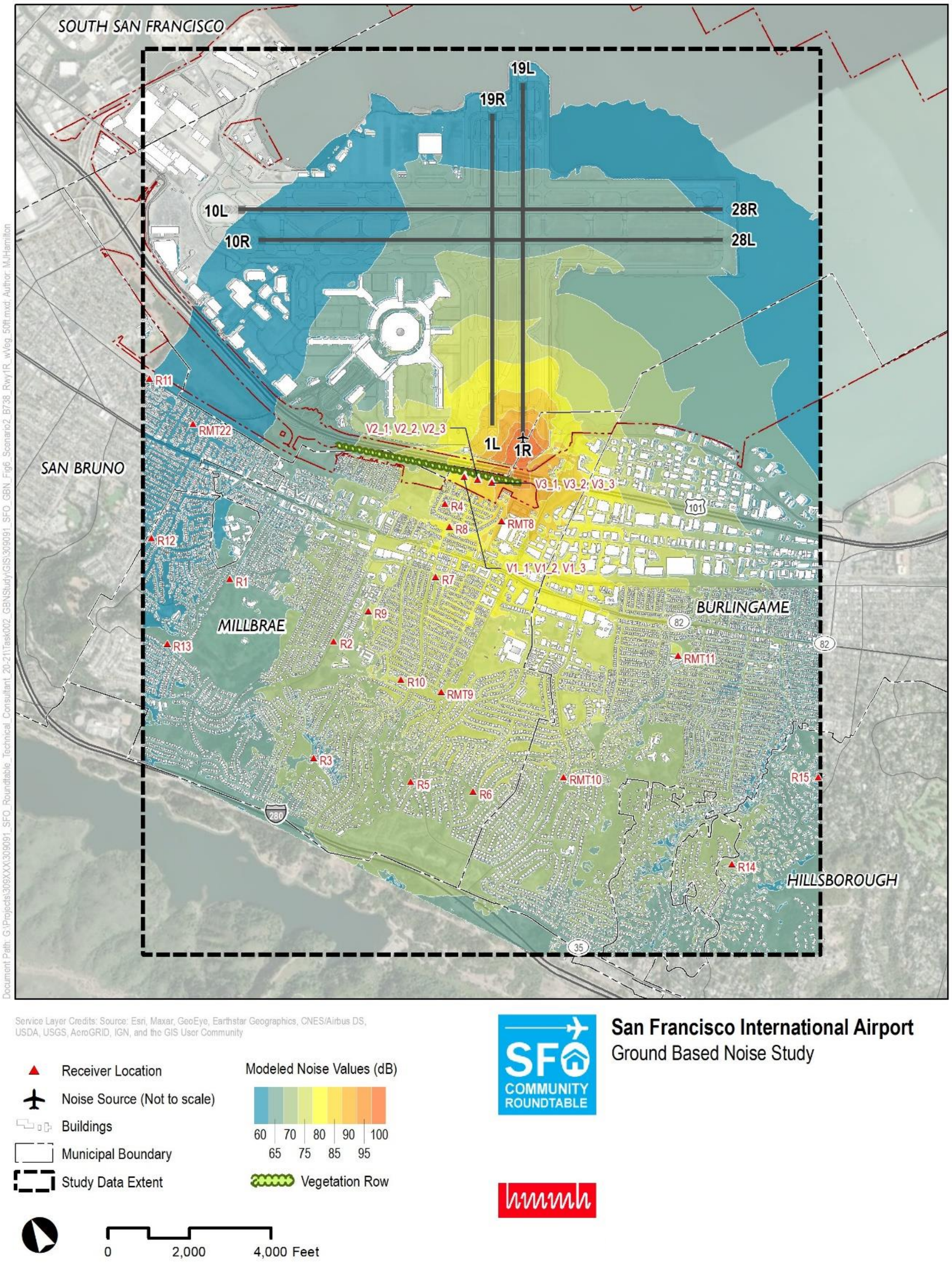

Figure 14: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

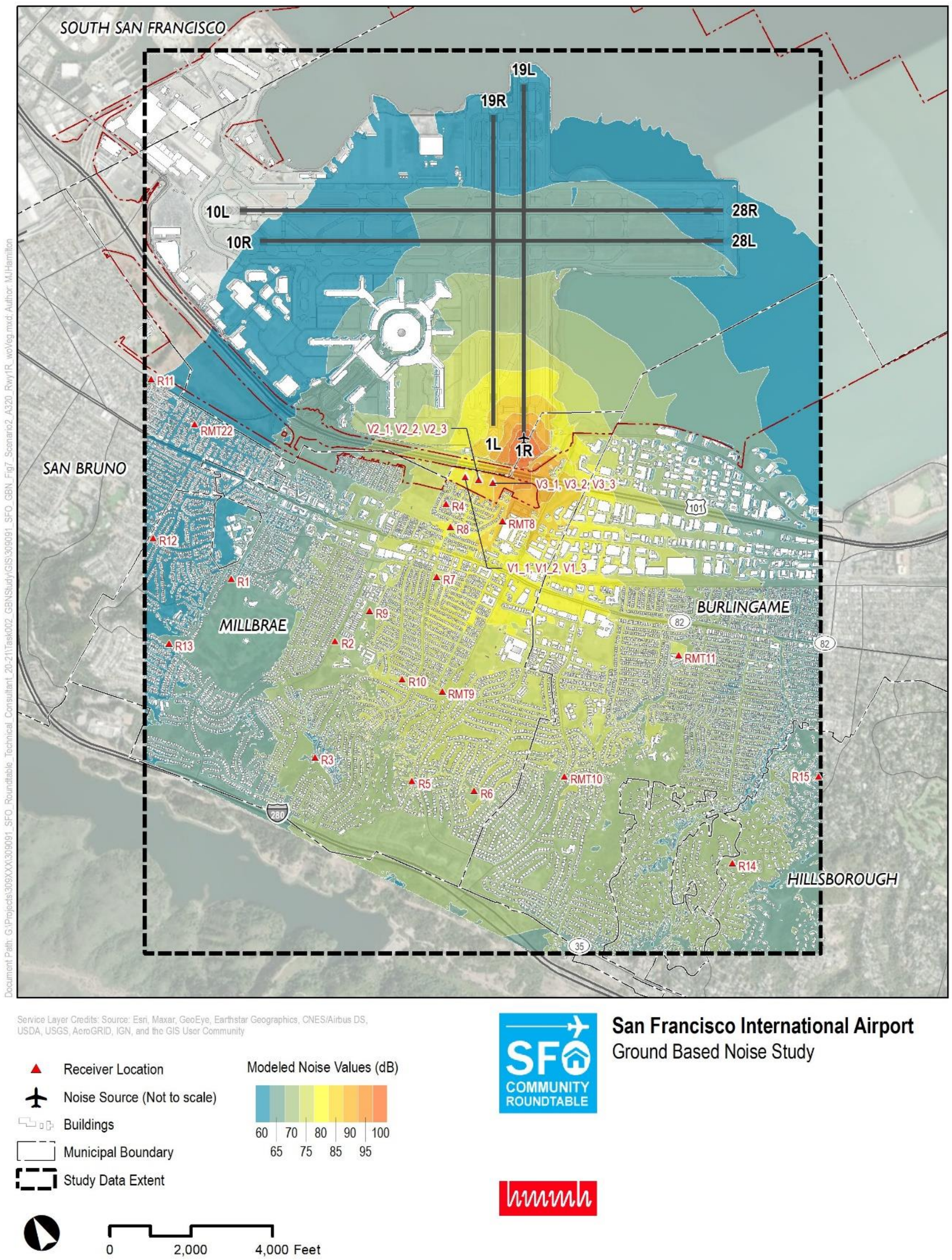

Figure 15: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation

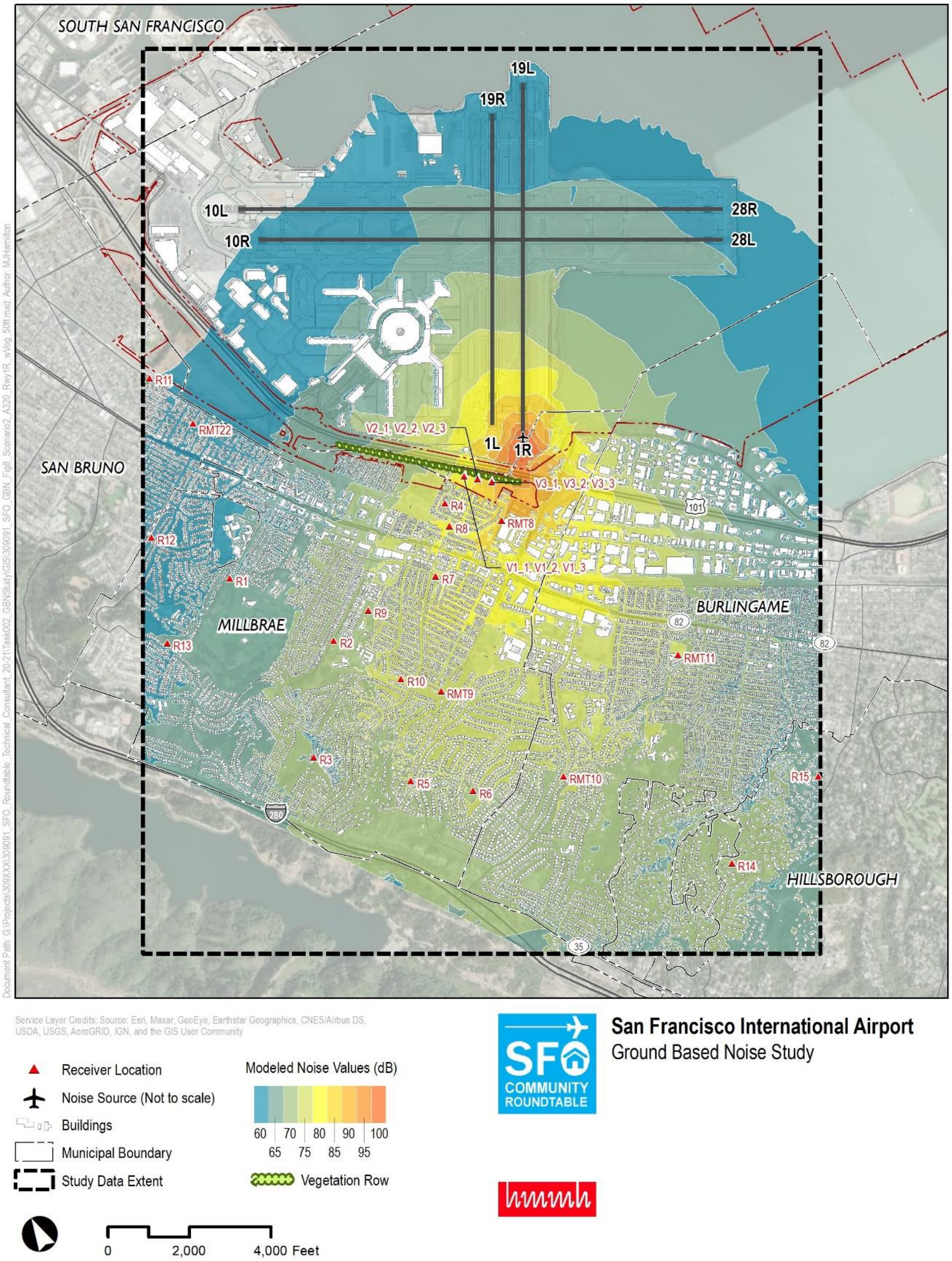

Figure 16: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

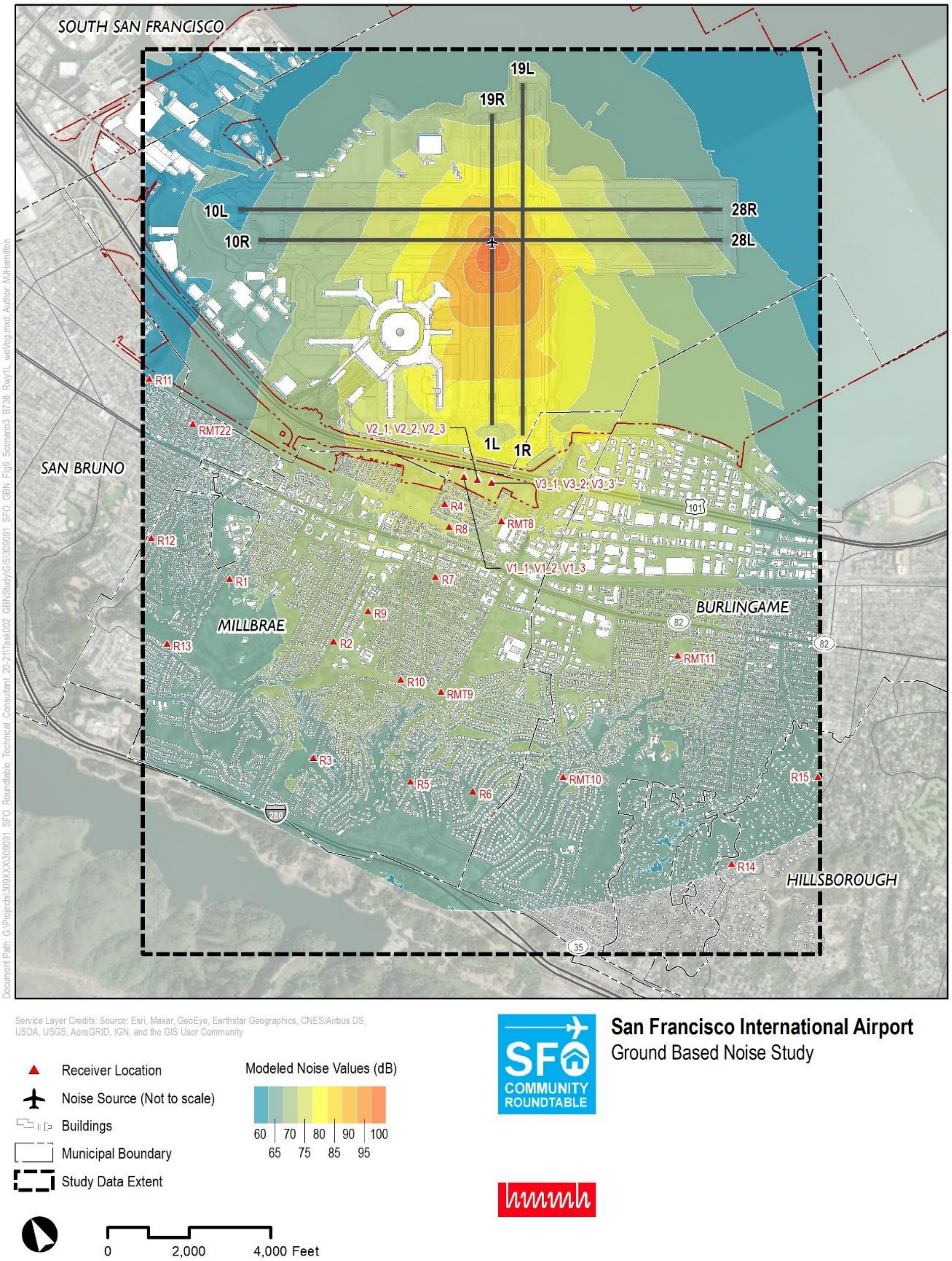

Figure 17: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

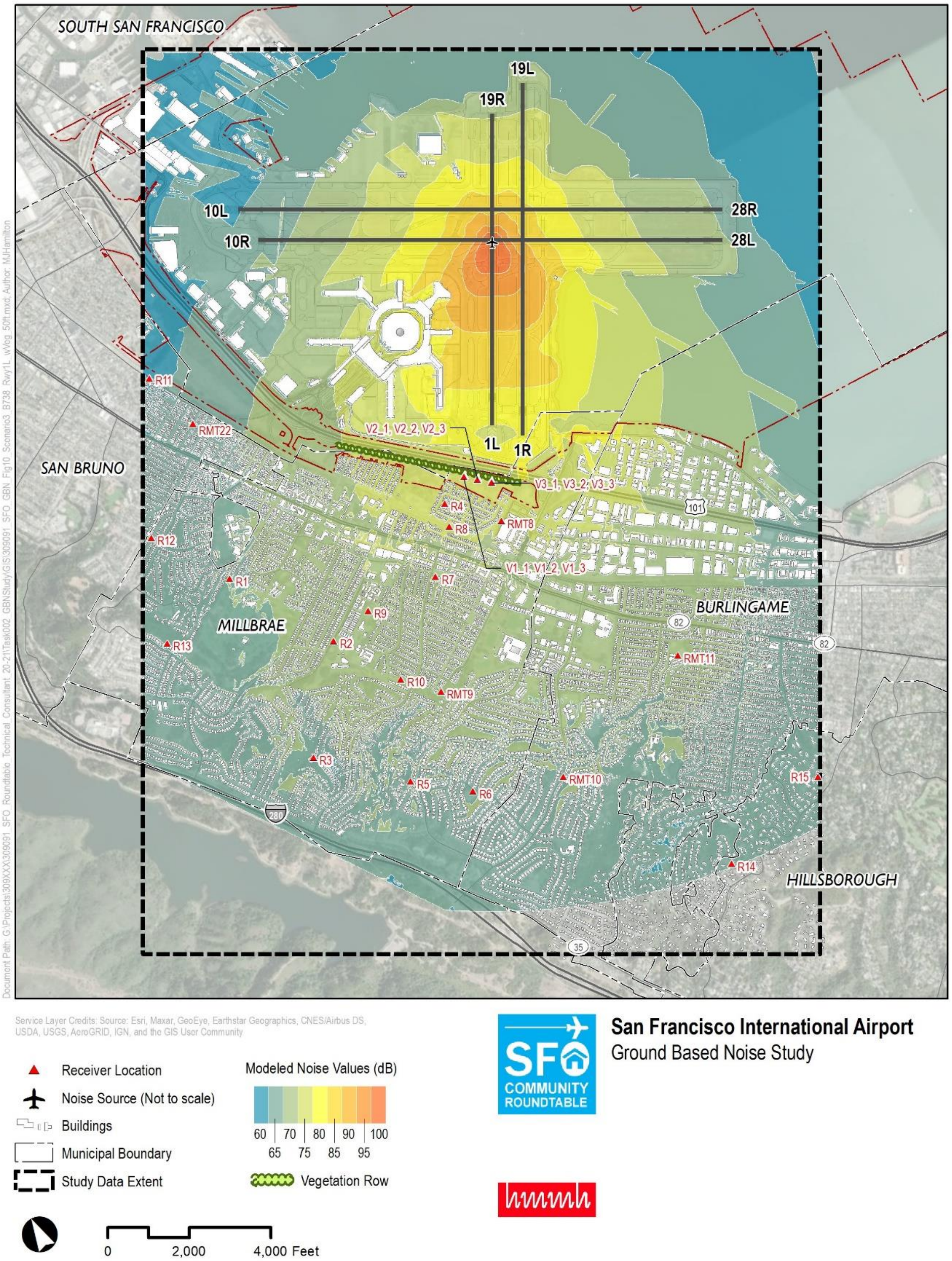

Figure 18: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

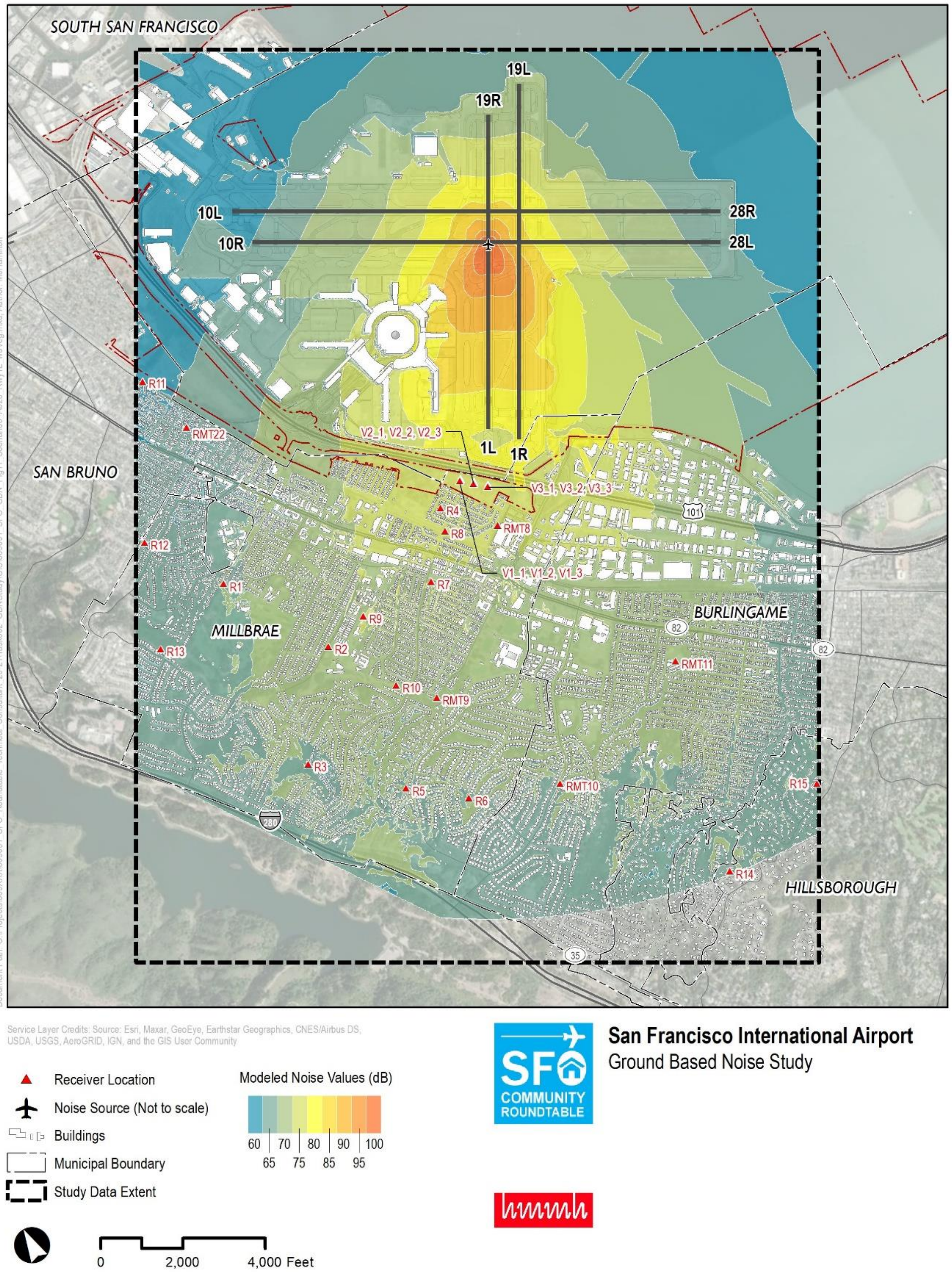

Figure 19: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

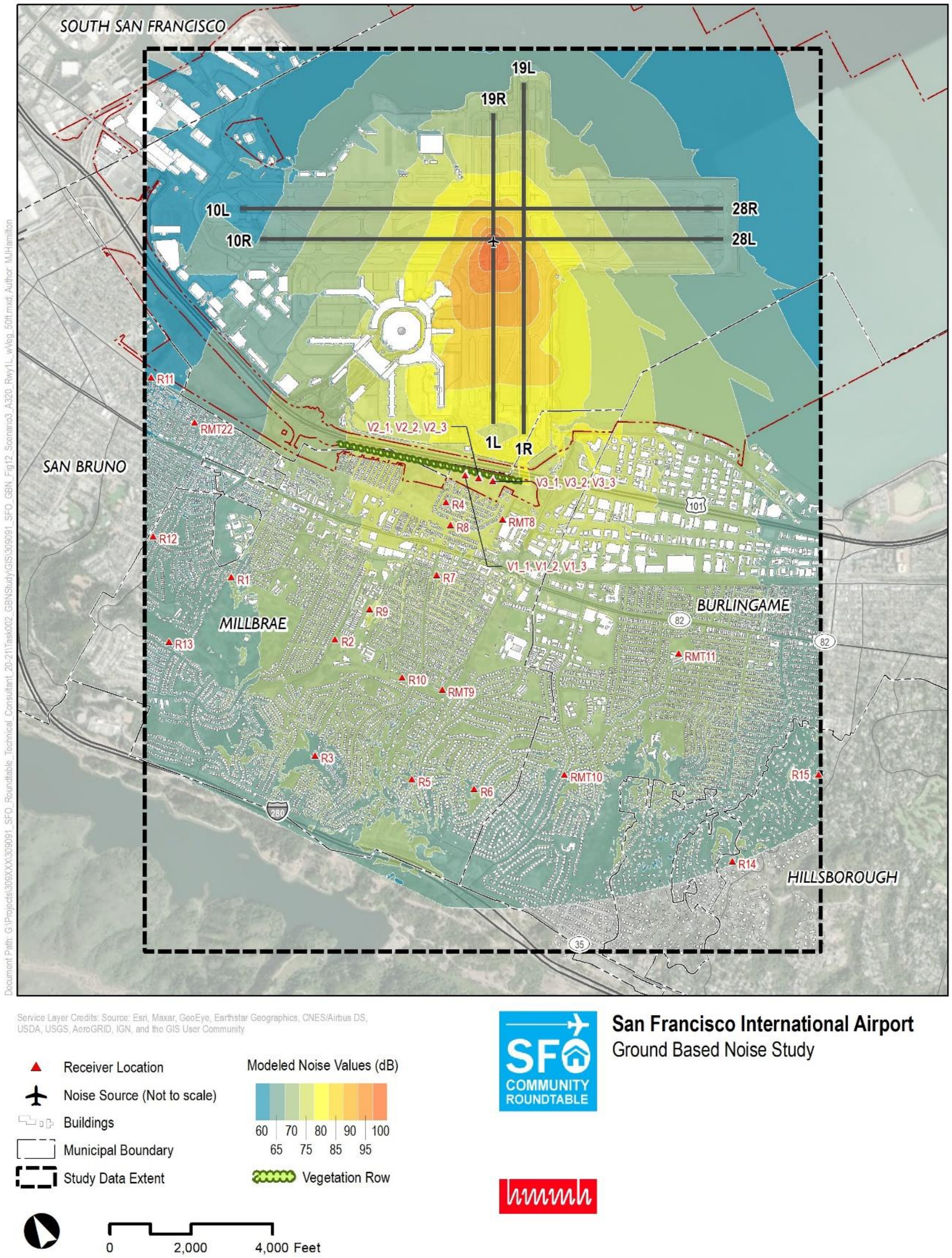

Figure 20: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

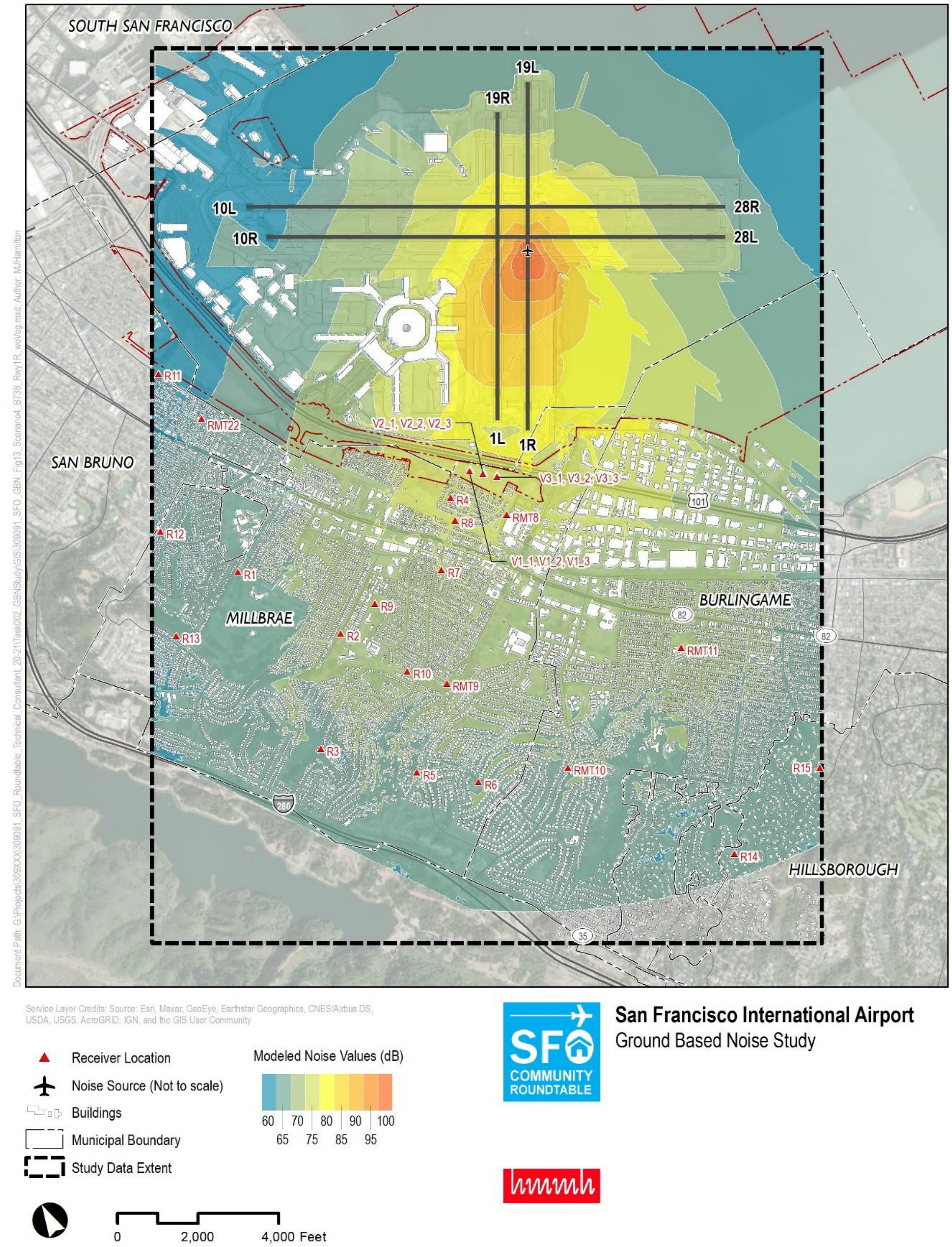

Figure 21: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

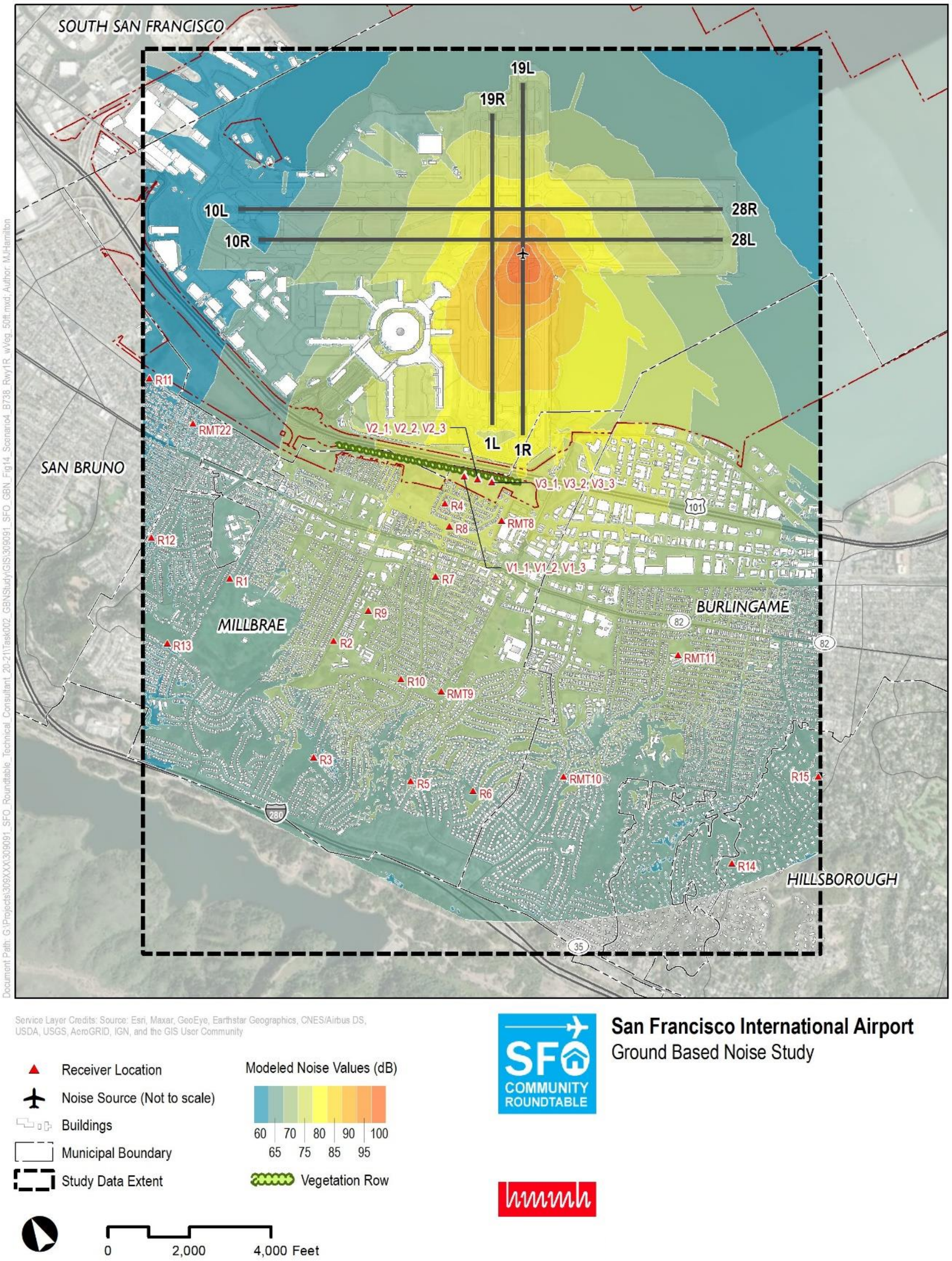

Figure 22: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

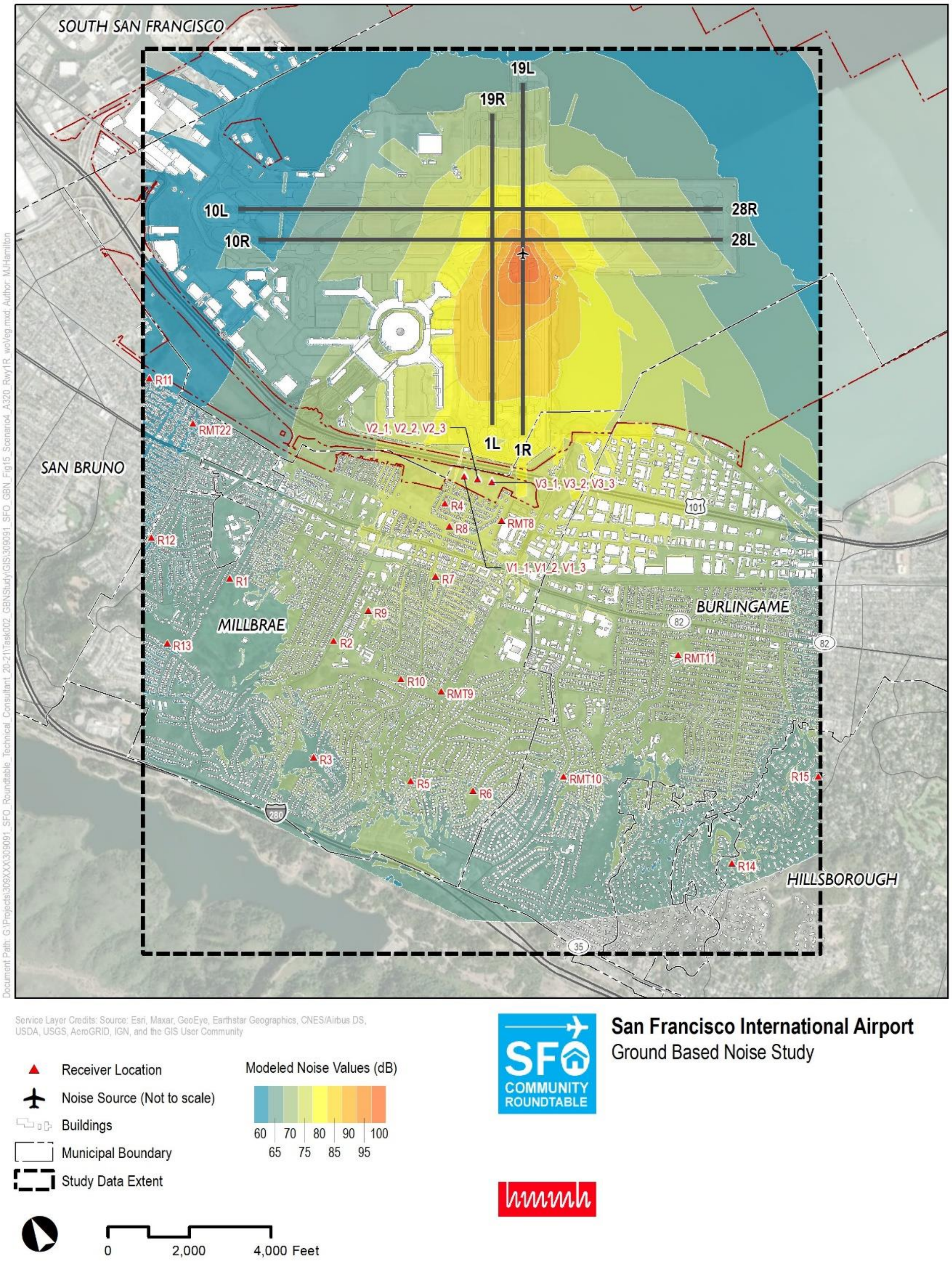

Figure 23: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

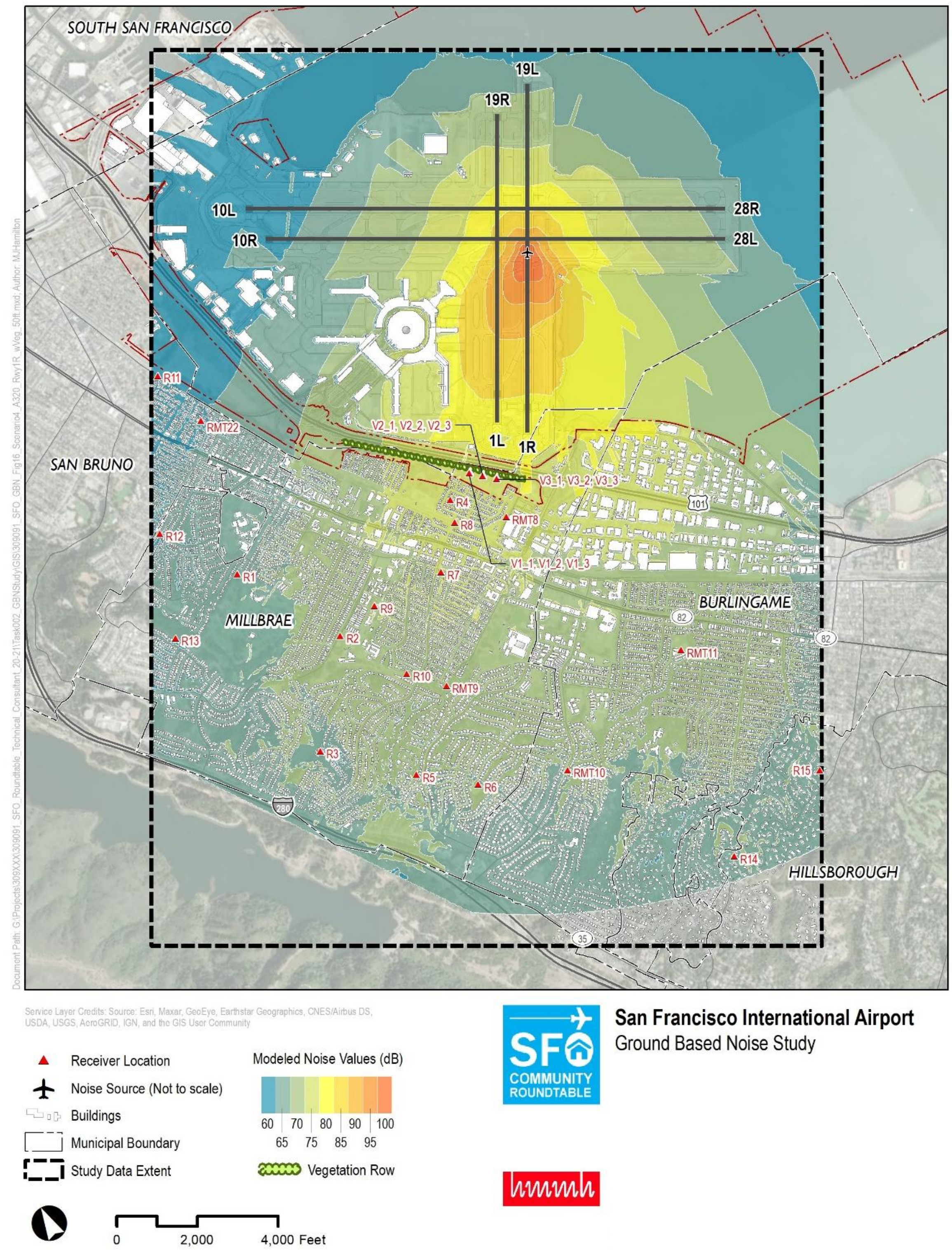

Figure 24: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

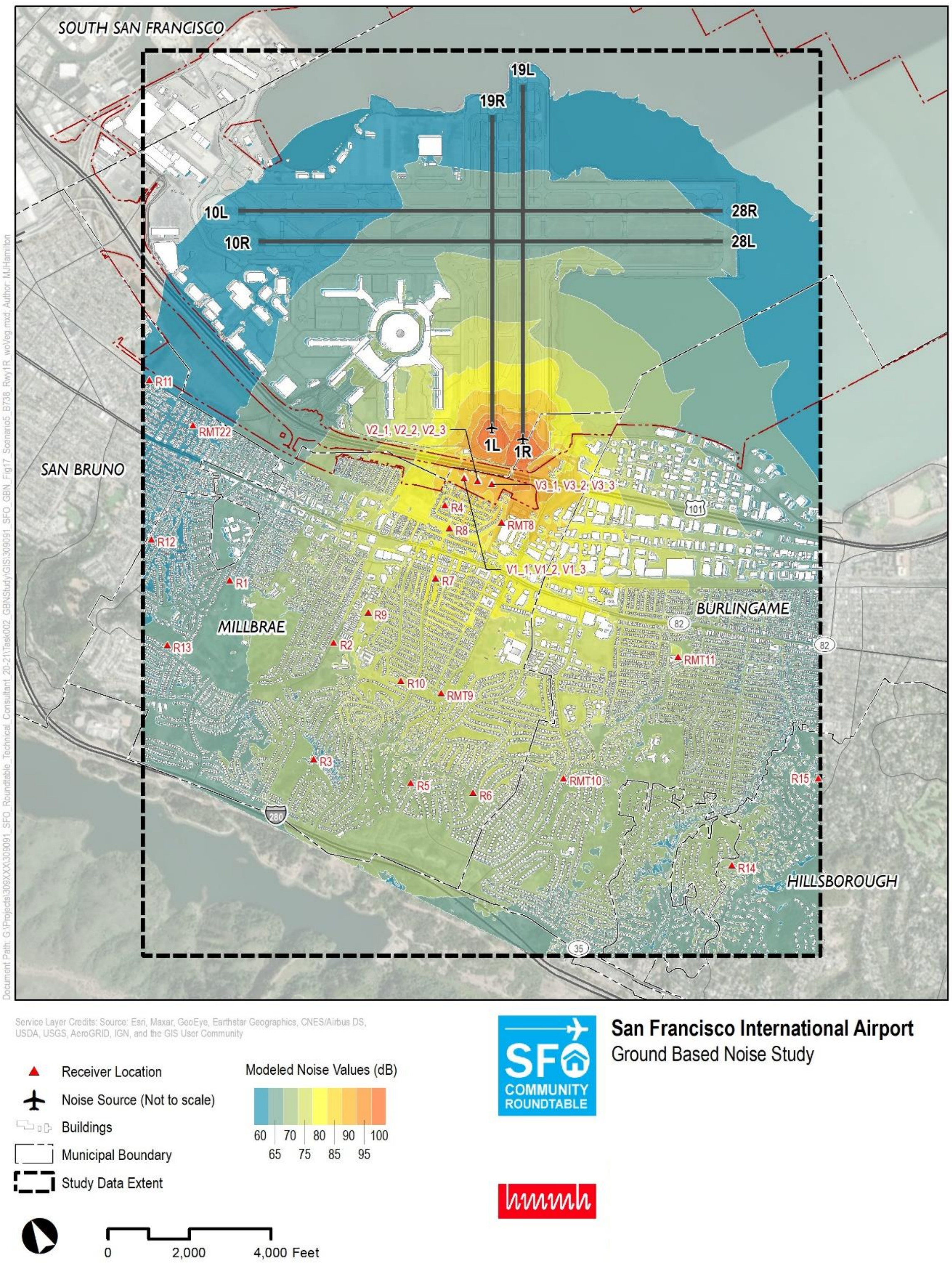

Figure 25: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

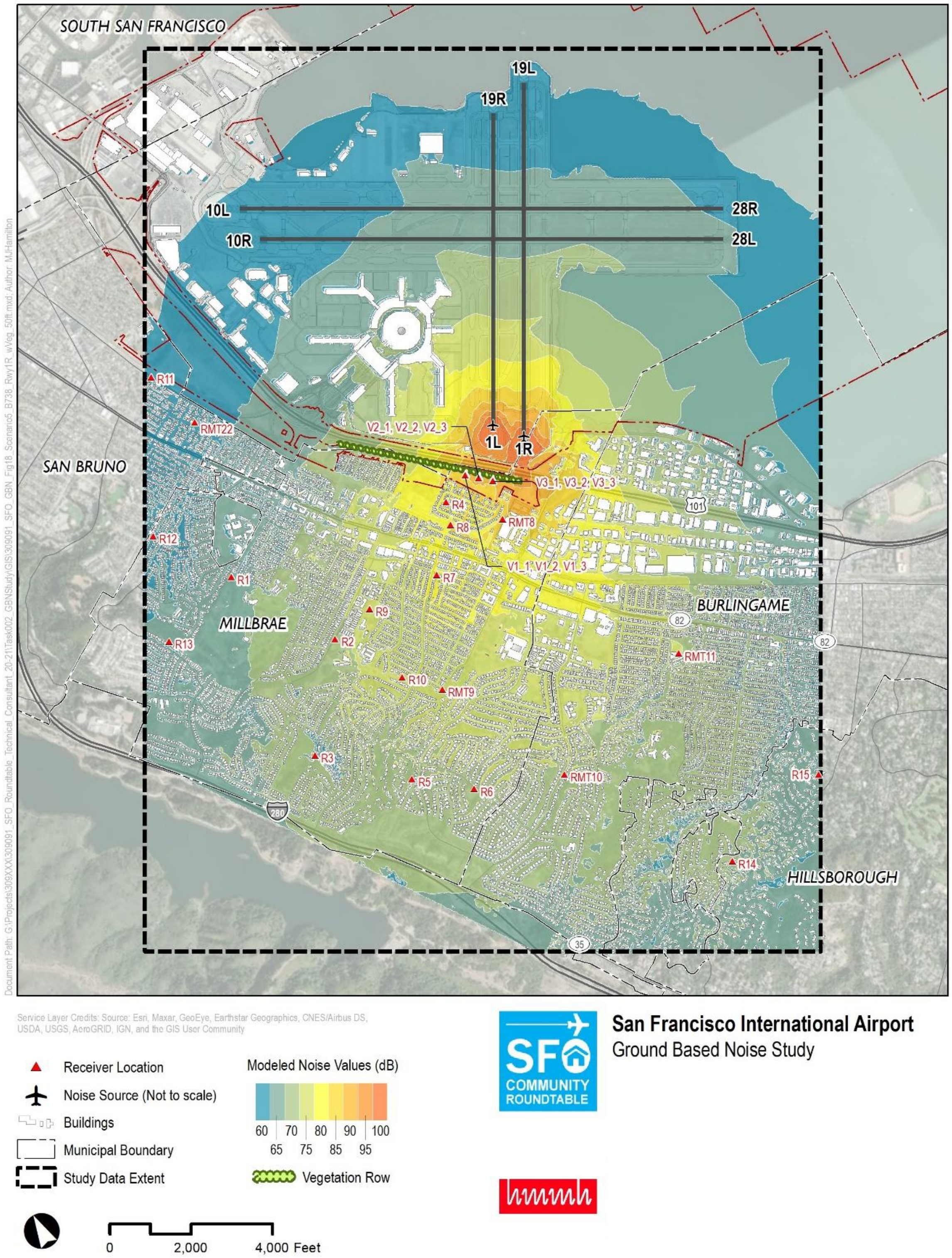

Figure 26: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

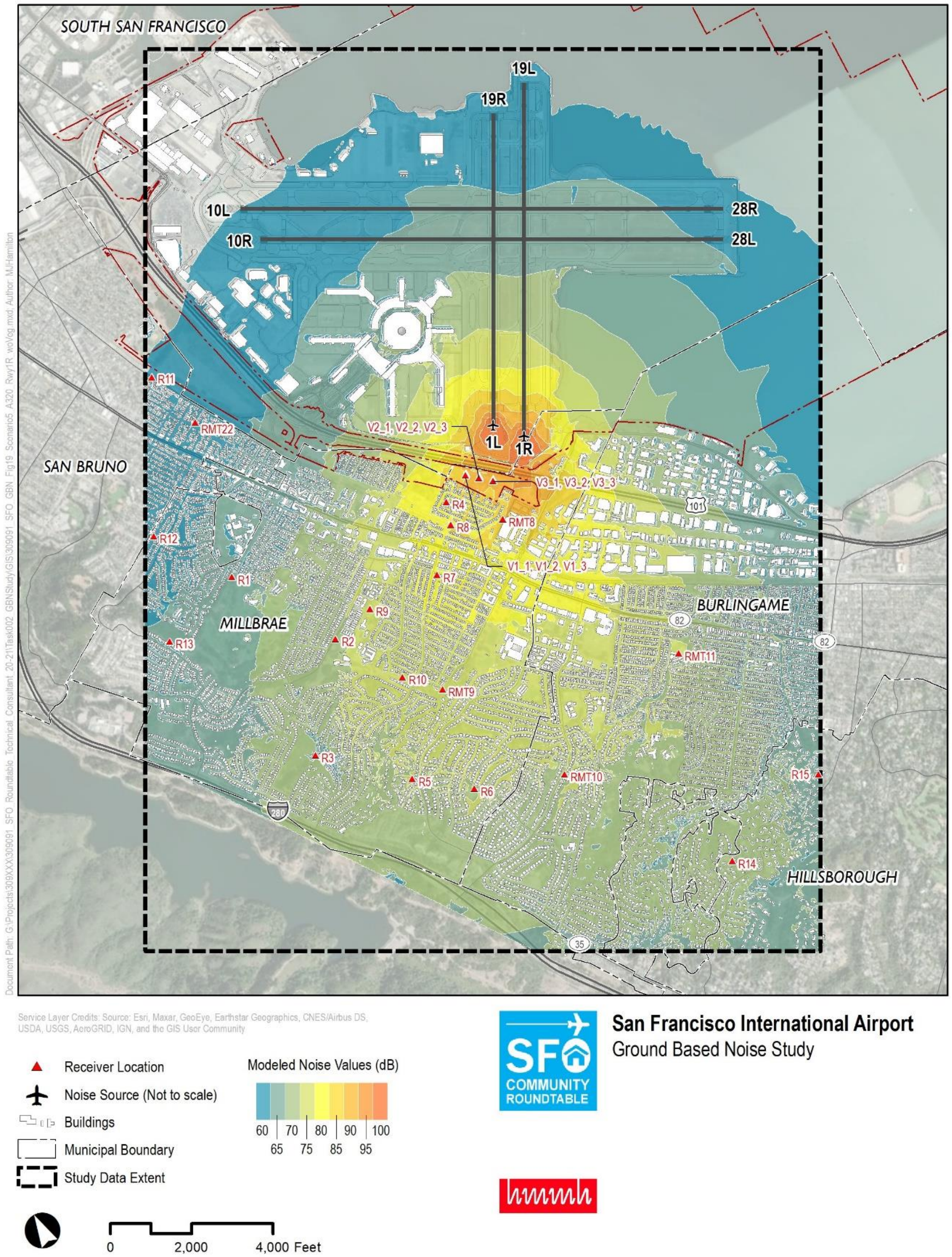

Figure 27: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

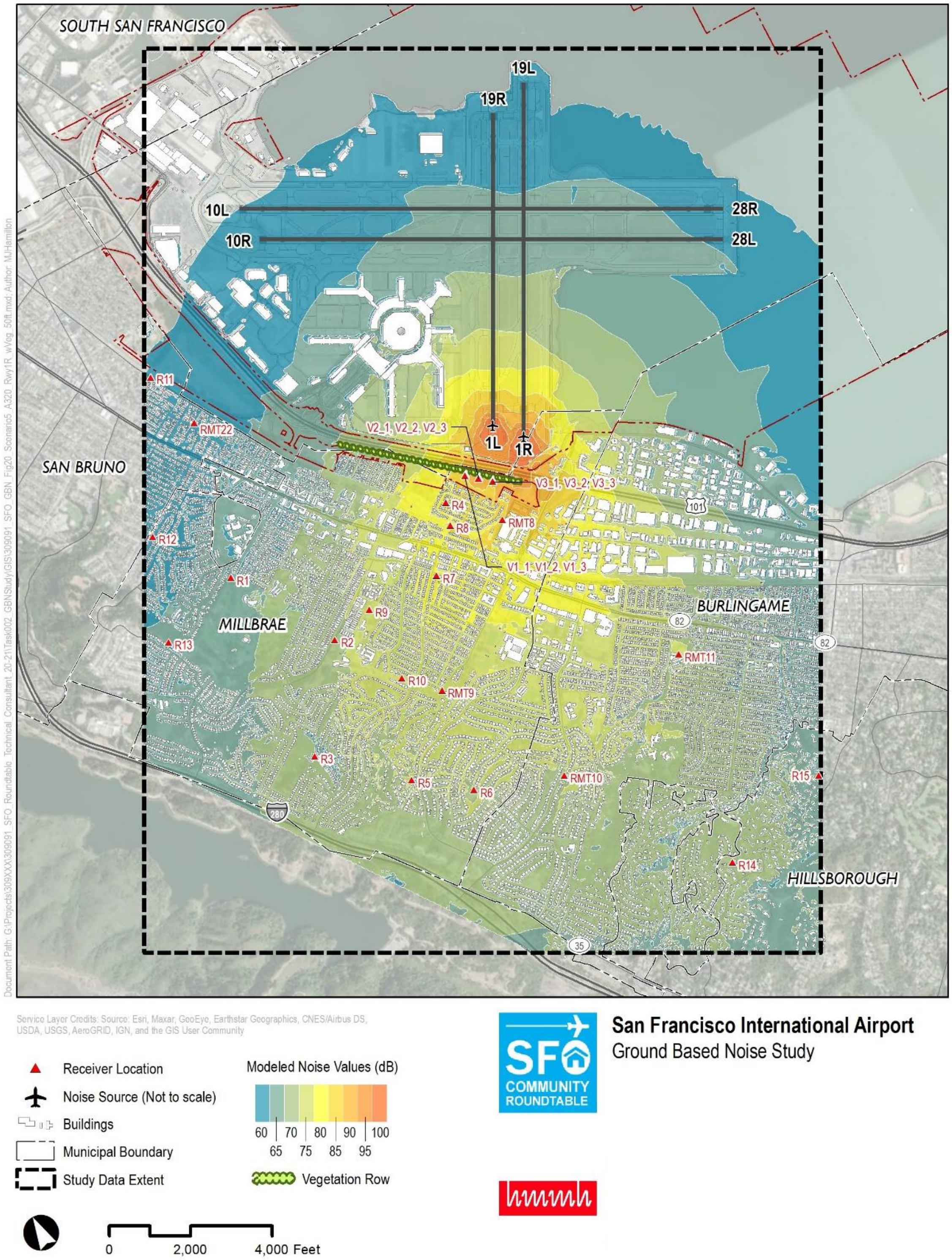

Figure 28: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

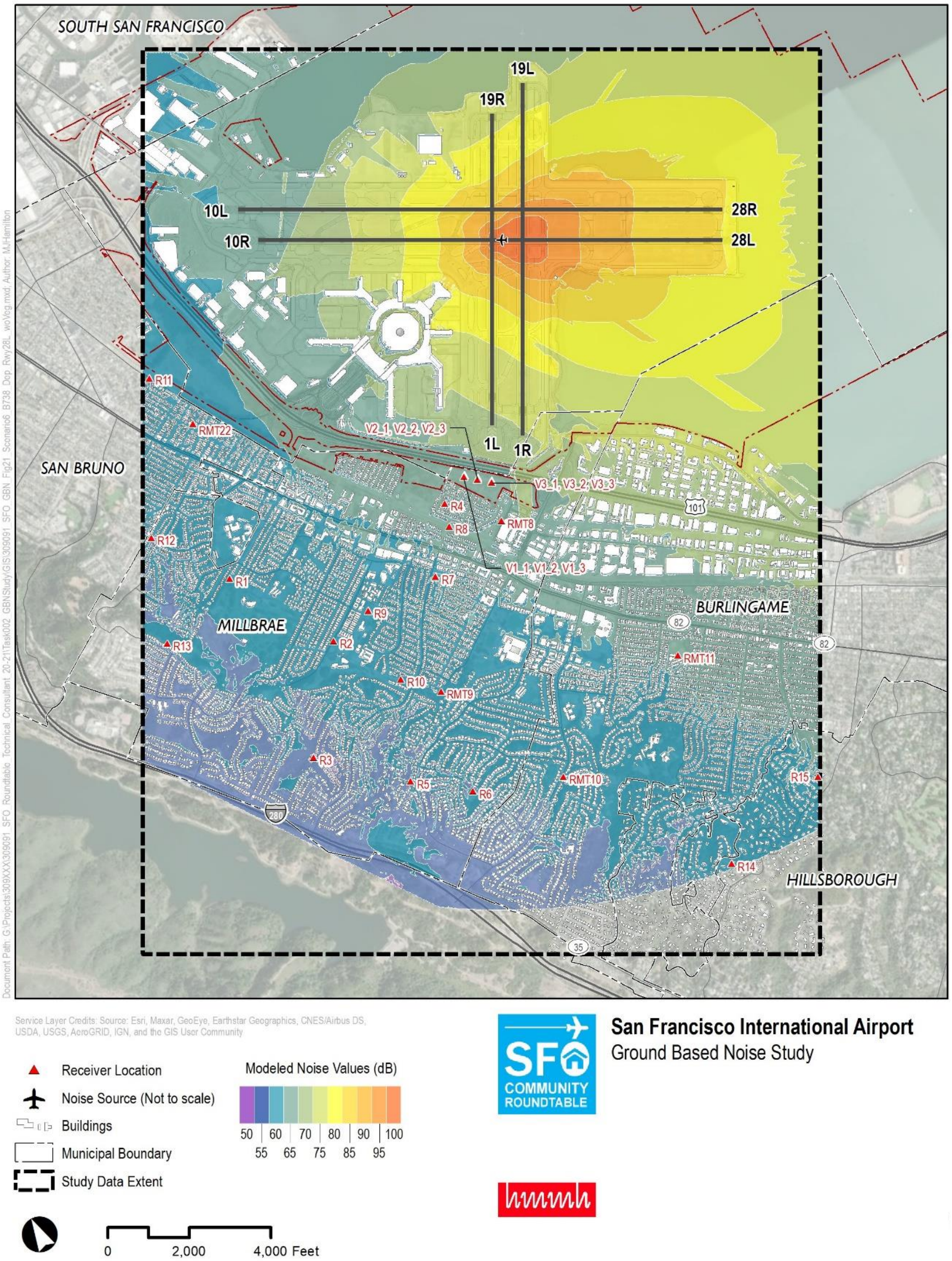

Figure 29: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – Without Vegetation

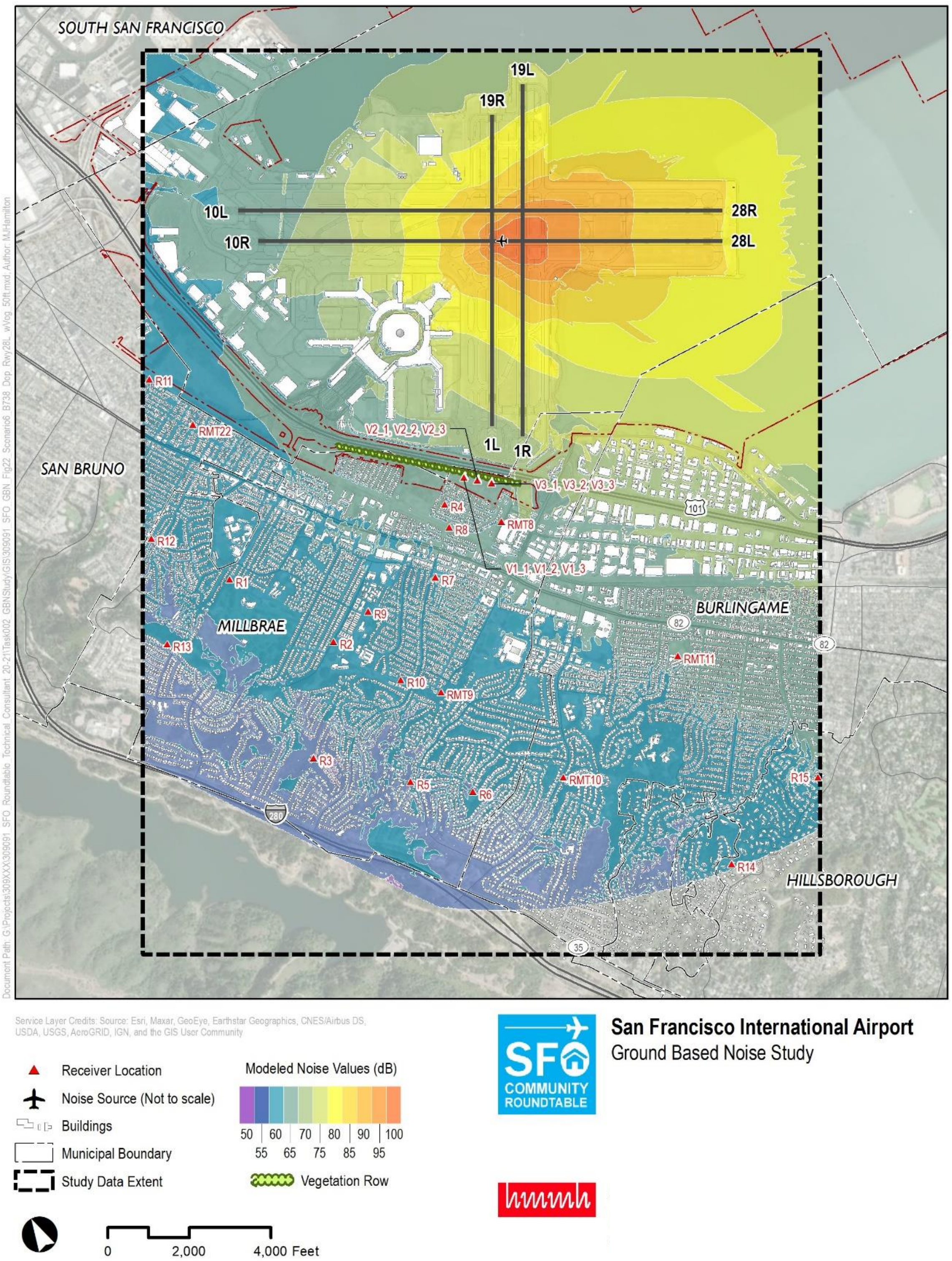

Figure 30: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – With Vegetation (50 Feet)

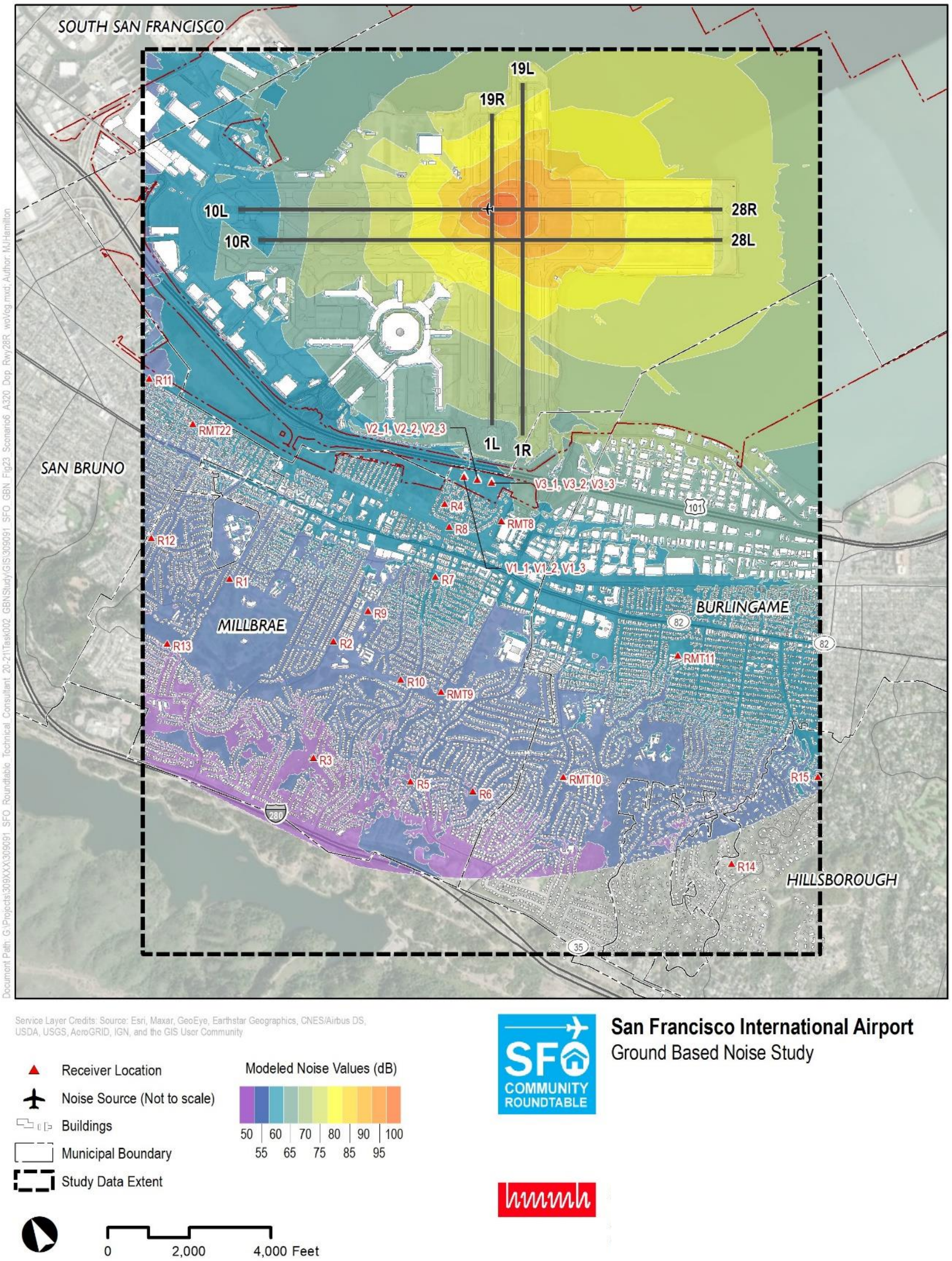

Figure 31: Scenario 6 – B738 Departing Runway 28R at Secondary Takeoff Point – Without Vegetation

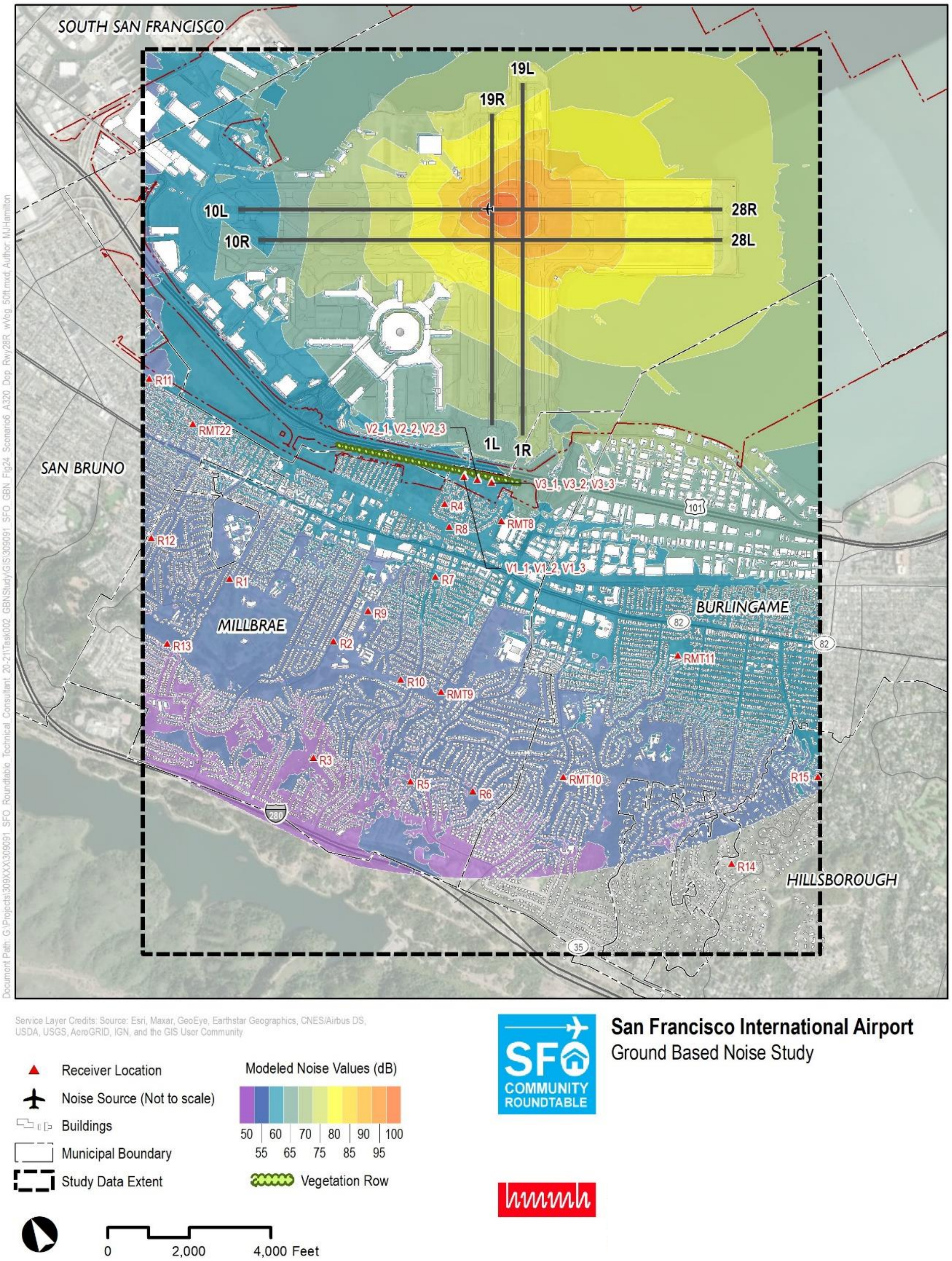

Figure 32: Scenario 6 - B738 Departing Runway 28R at Secondary Takeoff Point – With Vegetation (50 Feet)

3.7 Summary of Results

The following provides some key findings of the results, tables, and figures above:

- Frequencies in the range of 1 kHz and below (lower middle to low frequencies) are likely more noticeable for the communities to the southwest of SFO; with some receptor locations exhibiting highs of 90 dBA in that frequency range.
- Frequencies in the range of 4 kHz and above are not as high at some of the receptor locations due to the high directivity of that frequency range.
- On average, RMT 4 exhibited the highest noise levels of all the “RMT” sites while RMT 22 exhibited the lowest noise levels.
- On average, R4 exhibited the highest noise levels of all the community receptors while R12 exhibited the lowest noise levels.
- On average, the highest delta values in the “V” receptor locations were seen in the 1 kHz and above range; the delta values ranged from 1.0 to 3.0 dB in these frequencies.

The effectiveness of vegetation at reducing noise from aircraft departing SFO was shown as delta changes throughout the results tables. Only receptor locations “V”, which are behind the vegetation, had reductions in noise from vegetation; both in terms of Lmax dB and unweighted spectral Leq dB noise levels.

The Lmax tabular results indicate that for the B738 and A320 aircraft types for Runways 1L and 1R during the start of takeoff roll, vegetation provided 0.3 to 1.1 dB of reduction. For the B738 and A320 aircraft types for Runways 1L and 1R during the secondary takeoff point, vegetation provided 0.2 to 0.5 dB of reduction. For the B77W aircraft type on Runway 28L and the B738 aircraft type on Runway 28R during the secondary takeoff point, vegetation provided 0.5 to 0.7 dB of reduction.

As seen in the noise contour figures (especially the enlarged figures of **Appendix H**), the levels of noise reduction stated above occur when the receptors are directly behind the vegetation. HMMH recommends that if vegetation is planned to be utilized as a mitigation measure, that it be located as close to the noise sensitive receptor as possible.

The vegetation reduction spectral noise values are consistent with what ISO 9613-2 states as attenuation that should be achieved by dense foliage for frequencies between 250 Hz to 2 kHz. Frequencies lower than 250 Hz would have very little to no attenuation. The tabular results show that vegetation is most effective at attenuating the upper middle and high frequencies; vegetation is less effective attenuating lower middle and low frequencies. For frequencies lower than 1 kHz, the maximum noise reduction was 1.2 dB.

The change in noise levels from without and with vegetation vary by frequency but are all well below 3 dB and therefore are likely not discernable by a human ear; a change of 3 dB is a barely perceivable change in noise level. However, if vegetation is to be utilized as a means to provide some ground based noise reduction, it should have a minimum thickness between 33 and 66 feet. It should also have a height that breaks line of sight to the source and be located as close to the noise sensitive receptor as possible.

4 Recommended Next Steps

Within the latest Roundtable Annual Work Plan (adopted December 2, 2020), Goal #2 (Address Airport Operation Noise), it states the following work plan item:

> *The Roundtable Ground Based Noise Subcommittee will complete the Ground Based Noise Study and make a recommendation to the Membership on next steps.*

The following are HMMH's recommended next steps for the subcommittee to consider in their report back to the Roundtable.

4.1 Outreach and Communication with Local Planning Departments

The results of this GBN modeling study provide a baseline and general understanding for how aircraft departure noise propagates through the communities adjacent to SFO. Using industry standard modeling techniques, this GBN modeling study analyzed the effectiveness of vegetation as a means to mitigating the noise emanating from aircraft departures at SFO. From the objective data, we anticipate further discussions are required to share the results with interested stakeholders.

HMMH proposes that outreach be conducted to the planning departments of local municipalities southwest of SFO to:

- Share the results of this GBN study and provide a general level of understanding of how ground based noise propagates through their community, and
- Discuss how they may be able to effectively incorporate noise mitigation principals (such as with vegetation) into the design of new or re-development project.

HMMH proposes that the Roundtable consider the creation of a GBN handout that could be distributed electronically and posted on the Roundtable website[6] that contains the following:

- A summary of the results of this GBN modeling study and specifically how ground based noise propagates
- Possible mitigation measures and associated effectiveness that would aid in project design and ultimately in possible reduction of ground based noise

[6] One of the work plan items of Goal #5 (Address Community Concerns) of the Annual Work Plan (Adopted December 2, 2020) states that the Roundtable will revamp the website to include useful documents and be used to communicate Roundtable successes.

4.2 Ongoing Communication with San Francisco International Airport

HMMH proposes that the Roundtable keep updated on items that could have an effect on how ground based noise propagates such as:

- New terminal and other building construction that may change how noise propagates
- Runway modifications and/or improvements that may change the location of initial and secondary points of takeoff
- Other new construction, such as new sea walls in between the SFO airfield and San Francisco Bay

4.3 Future Modeling Efforts

The SoundPLAN noise model created as part of this GBN modeling study can be utilized as a base for future modeling efforts. Future modeling efforts may include running additional scenarios not included within the approved scope of work of this GBN modeling study. Some of the conditions that may warrant additional modeling efforts include but are not limited to:

- Other possible mitigation measures (not vegetation) such as walls, berms or sound barriers that may include variables such as location, height, construction details, etc.
- Updates to terrain and/or buildings at SFO or within local municipalities to the southwest of SFO based on future building plans or other local input
- Additional vegetation locations, thickness, and heights

Appendix A Aircraft Noise Terminology

Noise is a complex physical quantity. The properties, measurement, and presentation of noise involve specialized terminology that can be difficult to understand. To provide a basic reference on these technical issues, this section introduces fundamentals of noise terminology, the effects of noise on human activity, and noise propagation.

A.1 Introduction to Noise Terminology

Analyses of potential impacts from changes in aircraft noise levels rely largely on a measure of cumulative noise exposure over an entire calendar year, expressed in terms of a metric called the Day-Night Average Sound Level (DNL/Ldn). However, DNL does not provide the only metric for measuring noise. A variety of metrics, which are further described in subsequent sub-sections, are used to describe noise, including:

- Sound Pressure Level, SPL, and the Decibel, dB
- A-Weighted Decibel, dBA
- Maximum A-Weighted Sound Level, L_{max}
- Time Above, TA
- Sound Exposure Level, SEL
- Equivalent A-Weighted Sound Level, L_{eq}
- Day-Night Average Sound Level, DNL/Ldn

A.1.1 Sound Pressure Level, SPL, and the Decibel, dB

All sounds come from a sound source – a musical instrument, a voice speaking, an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source travels through the air in sound waves – tiny, quick oscillations of pressure just above and just below atmospheric pressure. The ear senses these pressure variations and – with much processing in our brain – translates them into “sound.”

Our ears are sensitive to a wide range of sound pressures. The loudest sounds that we can hear without pain contain about one million times more energy than the quietest sounds we can detect. To allow us to perceive sound over this very wide range, our ear/brain “auditory system” compresses our response in a complex manner, represented by a term called sound pressure level (SPL), which we express in units called decibels (dB).

Mathematically, SPL is a logarithmic quantity based on the ratio of two sound pressures, the numerator being the pressure of the sound source of interest (P_{source}), and the denominator being a reference pressure ($P_{reference}$).[7]

$$\textit{Sound Pressure Level (SPL)} = 20 * Log\left(\frac{P_{source}}{P_{reference}}\right) dB$$

The logarithmic conversion of sound pressure to SPL means that the quietest sound that we can hear (the reference pressure) has a sound pressure level of about 0 dB, while the loudest sounds that we hear without pain have sound pressure levels of about 120 dB. Most sounds in our day-to-day environment have sound pressure levels from about 40 to 100 dB[8].

Because decibels are logarithmic quantities, we cannot use common arithmetic to combine them. For example, if two sound sources each produce 100 dB operating individually, when they operate simultaneously, they produce 103 dB -- not the 200 dB we might expect. Increasing to four equal sources operating simultaneously will add another three decibels of noise, resulting in a total SPL of 106 dB. For every doubling of the number of equal sources, the SPL goes up another three decibels.

If one noise source is much louder than another is, the louder source "masks" the quieter one and the two sources together produce virtually the same SPL as the louder source alone. For example, a 100 dB and 80 dB sources produce approximately 100 dB of noise when operating together.

Two useful "rules of thumb" related to SPL are worth noting: (1) humans generally perceive a six to 10 dB increase in SPL to be about a doubling of loudness,[9] and (2) changes in SPL of less than about three decibels for a particular sound are not readily detectable outside of a laboratory environment.

A.1.2 A-Weighted Decibel

An important characteristic of sound is its frequency, or "pitch." This is the per-second oscillation rate of the sound pressure variation at our ear, expressed in units known as Hertz (Hz).

When analyzing the total noise of any source, acousticians often break the noise into frequency components (or bands) to consider the "low," "medium," and "high" frequency components. This breakdown is important for two reasons:

- Our ear is better equipped to hear mid and high frequencies and is least sensitive to lower frequencies. Thus, we find mid- and high-frequency noise more annoying.
- Engineering solutions to noise problems differ with frequency content. Low-frequency noise is generally harder to control.

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[7] The reference pressure is approximately the quietest sound that a healthy young adult can hear.

[8] The logarithmic ratio used in its calculation means that SPL changes relatively quickly at low sound pressures and more slowly at high pressures. This relationship matches human detection of changes in pressure. We are much more sensitive to changes in level when the SPL is low (for example, hearing a baby crying in a distant bedroom), than we are to changes in level when the SPL is high (for example, when listening to highly amplified music).

[9] A "10 dB per doubling" rule of thumb is the most often used approximation.

The normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of about 10,000 to 15,000 Hz. Most people respond to sound most readily when the predominant frequency is in the range of normal conversation – typically around 1,000 to 2,000 Hz. The acoustical community has defined several “filters,” which approximate this sensitivity of our ear and thus, help us to judge the relative loudness of various sounds made up of many different frequencies.

The so-called "A" filter (“A weighting”) generally does the best job of matching human response to most environmental noise sources, including natural sounds and sound from common transportation sources. “A-weighted decibels” are abbreviated “dBA.” Because of the correlation with our hearing, the U. S. Environmental Protection Agency (EPA) and nearly every other federal and state agency have adopted A-weighted decibels as the metric for use in describing environmental and transportation noise. **Figure A-1** depicts A-weighting adjustments to sound from approximately 20 Hz to 10,000 Hz.

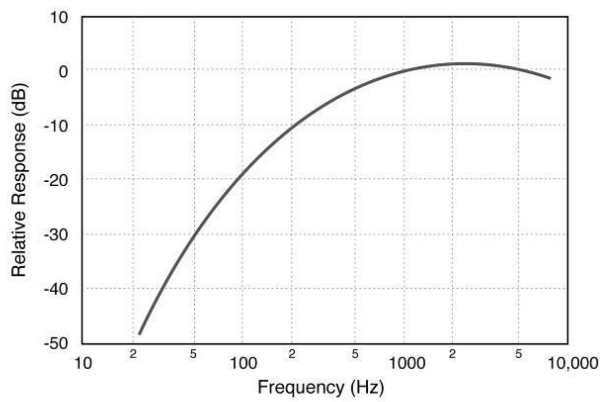


Figure A-1 A-Weighting Frequency Response

Source: Extract from Harris, Cyril M., Editor, “Handbook of Acoustical Measurements and Control,” McGraw-Hill, Inc., 1991, pg. 5.13; HMMH

As the figure shows, A-weighting significantly de-emphasizes noise content at lower and higher frequencies where we do not hear as well, and has little effect, or is nearly "flat,” in for mid-range frequencies between 1,000 and 5,000 Hz. All sound pressure levels presented in this document are A-weighted unless otherwise specified.

Figure A-2 depicts representative A-weighted sound levels for a variety of common sounds.

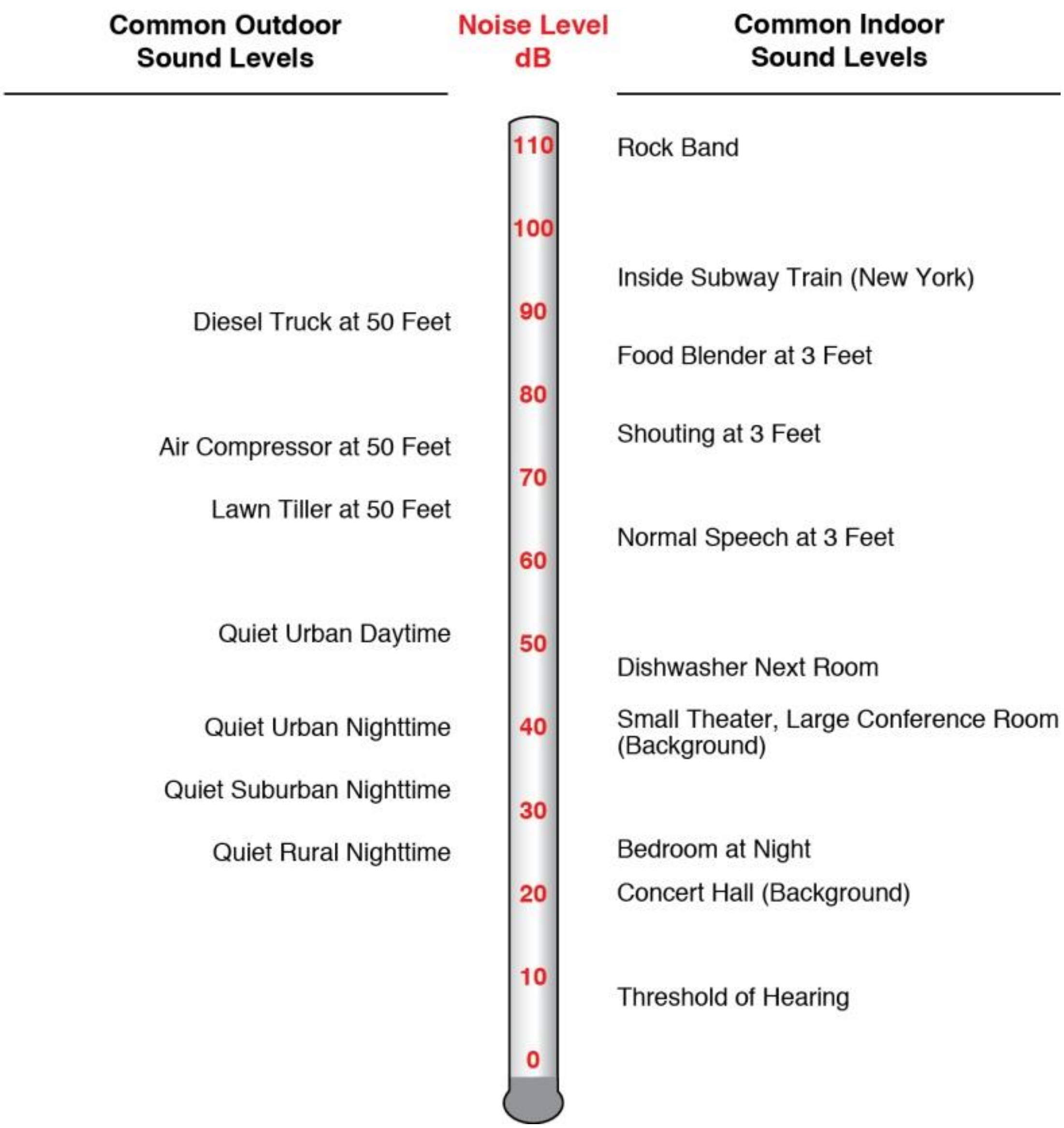


Figure A-2 A-Weighted Sound Levels for Common Sounds

A.1.3 Maximum A-Weighted Sound Level, L_{max}

An additional dimension to environmental noise is that A-weighted levels vary with time. For example, the sound level increases as a car or aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance. The background or “ambient” level continues to vary in the absence of a distinctive source, for example due to birds chirping, insects buzzing, leaves rustling, etc. It is often convenient to describe a particular noise "event" (such as a vehicle passing by, a dog barking, etc.) by its maximum sound level, abbreviated as L_{max}.

Figure A-3 depicts this general concept, for a hypothetical noise event with an L_{max} of approximately 102 dB.

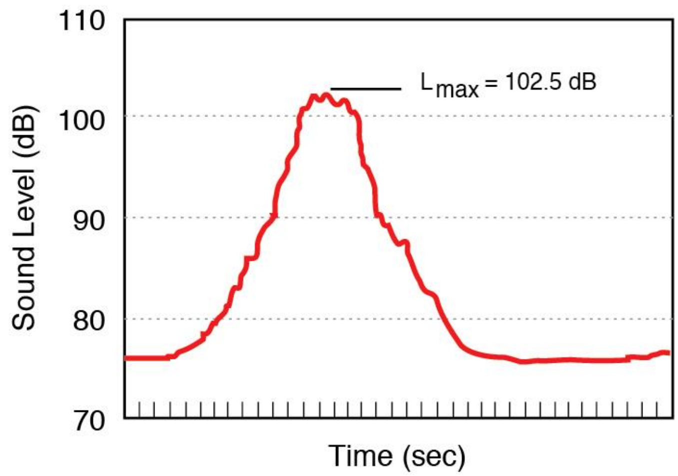


Figure A-3 Variation in A-Weighted Sound Level over Time and Maximum Noise Level

Source: HMMH

While the maximum level is easy to understand, it suffers from a serious drawback when used to describe the relative "noisiness" of an event such as an aircraft flyover; i.e., it describes only one dimension of the event and provides no information on the event's overall, or cumulative, noise exposure. In fact, two events with identical maximum levels may produce very different total exposures. One may be of very short duration, while the other may continue for an extended period and be judged much more annoying. The next section introduces a measure that accounts for this concept of a noise "dose," or the cumulative exposure associated with an individual "noise event" such as an aircraft flyover.

A.1.4 Sound Exposure Level, SEL

The most commonly used measure of cumulative noise exposure for an individual noise event, such as an aircraft flyover, is the Sound Exposure Level, or SEL. SEL is a summation of the A-weighted sound energy over the entire duration of a noise event. SEL expresses the accumulated energy in terms of the one-second-long steady-state sound level that would contain the same amount of energy as the actual time-varying level.

SEL provides a basis for comparing noise events that generally match our impression of their overall "noisiness," including the effects of both duration and level. The higher the SEL, the more annoying a noise event is likely to be. In simple terms, SEL "compresses" the energy for the noise event into a single second. **Figure A-4** depicts this compression, for the same hypothetical event shown in **Figure A-3**. Note that the SEL is higher than the L_{max}.

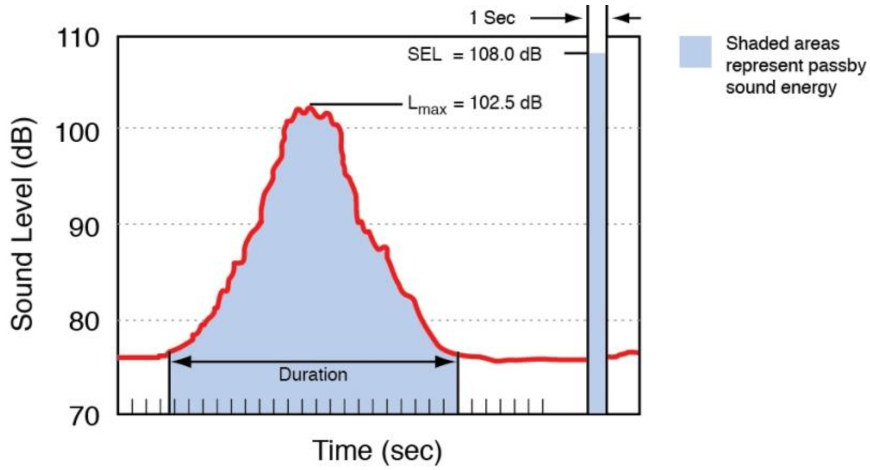


Figure A-4 Graphical Depiction of Sound Exposure Level

Source: HMMH

The "compression" of energy into one second means that a given noise event's SEL will almost always will be a higher value than its L_{max}. For most aircraft flyovers, SEL is roughly five to 12 dB higher than L_{max}. Adjustment for duration means that relatively slow and quiet propeller aircraft can have the same or higher SEL than faster, louder jets, which produce shorter duration events.

A.1.5 Equivalent A-Weighted Sound Level, L_{eq}

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the exposure resulting from the accumulation of sound levels over a particular period of interest; e.g., one hour, an eight-hour school day, nighttime, or a full 24-hour day. L_{eq} plots for consecutive hours can help illustrate how the noise dose rises and falls over a day or how a few loud aircraft significantly affect some hours.

L_{eq} may be thought of as the constant sound level over the period of interest that would contain as much sound energy as the actual varying level. It is a way of assigning a single number to a time-varying sound level. **Figure A-5** illustrates this concept for the same hypothetical event shown in **Figure A-3** and **Figure A-4**. Note that the L_{eq} is lower than either the L_{max} or SEL.

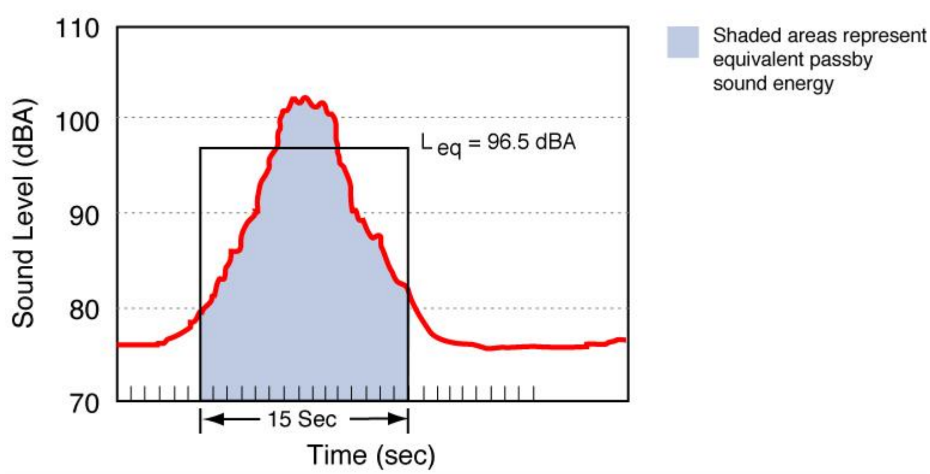


Figure A-5 Example of a 15-Second Equivalent Sound Level

Source: HMMH

A.1.6 Day-Night Average Sound Level, DNL or L_{dn}

The FAA requires that airports use a measure of noise exposure that is slightly more complicated than L_{eq} to describe cumulative noise exposure – the Day-Night Average Sound Level, DNL.

The U.S. Environmental Protection Agency identified DNL as the most appropriate means of evaluating airport noise based on the following considerations[10].

- The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods.
- The measure should correlate well with known effects of the noise environment and on individuals and the public.
- The measure should be simple, practical, and accurate. In principal, it should be useful for planning as well as for enforcement or monitoring purposes.
- The required measurement equipment, with standard characteristics, should be commercially available.
- The measure should be closely related to existing methods currently in use.
- The single measure of noise at a given location should be predictable, within an acceptable tolerance, from knowledge of the physical events producing the noise.
- The measure should lend itself to small, simple monitors, which can be left unattended in public areas for long periods.

Most federal agencies dealing with noise have formally adopted DNL. The Federal Interagency Committee on Noise (FICON) reaffirmed the appropriateness of DNL in 1992. The FICON summary report stated: “There are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric.”

In simple terms, DNL is the 24-hour L_{eq} with one adjustment; all noises occurring at night (defined as 10 p.m. through 7 a.m.) are increased by 10 dB, to reflect the added intrusiveness of nighttime noise events when background noise levels decrease. In calculating aircraft exposure, this 10 dB increase is mathematically identical to counting each nighttime aircraft noise event ten times.

DNL can be measured or estimated. Measurements are practical only for obtaining DNL values for limited numbers of points, and, in the absence of a permanently installed monitoring system, only for relatively short periods. Most airport noise studies use computer-generated DNL estimates depicted as equal-exposure noise contours (much as topographic maps have contours of equal elevation).

The annual DNL is mathematically identical to the DNL for the average annual day; i.e., a day on which the number of operations is equal to the annual total divided by 365 (366 in a leap year). **Figure A-6** graphically depicts the manner in which the nighttime adjustment applies in calculating DNL. **Figure A-7** presents representative outdoor DNL values measured at various U.S. locations.

[10] "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U. S. EPA Report No. 550/9-74-004, March 1974.

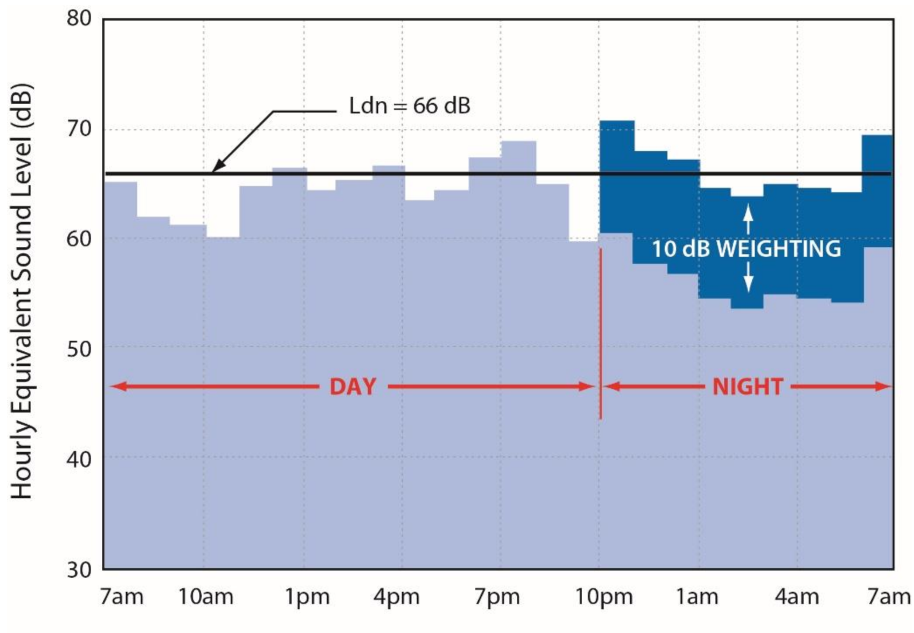


Figure A-6 Example of a Day-Night Average Sound Level Calculation

Source: HMMH

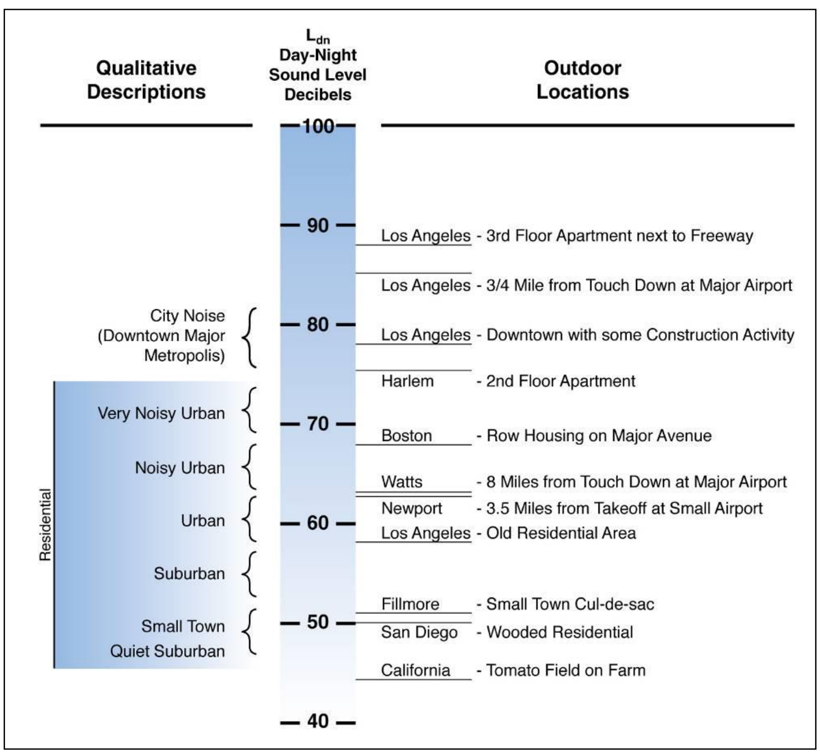


Figure A-7 Examples of Measured Day-Night Average Sound Levels, DNL

Source: U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, p.14.

A.2 Aircraft Noise Effects on Human Activity

Aircraft noise can be an annoyance and a nuisance. It can interfere with conversation and listening to television, disrupt classroom activities in schools, and disrupt sleep. Relating these effects to specific noise metrics helps in the understanding of how and why people react to their environment.

A.2.1 Speech Interference

One potential effect of aircraft noise is its tendency to "mask" speech, making it difficult to carry on a normal conversation. The sound level of speech decreases as the distance between a talker and listener increases. As the background sound level increases, it becomes harder to hear speech.

Figure A-8 presents typical distances between talker and listener for satisfactory outdoor conversations, in the presence of different steady A-weighted background noise levels for raised, normal, and relaxed voice effort. As the background level increases, the talker must raise his/her voice, or the individuals must get closer together to continue talking.

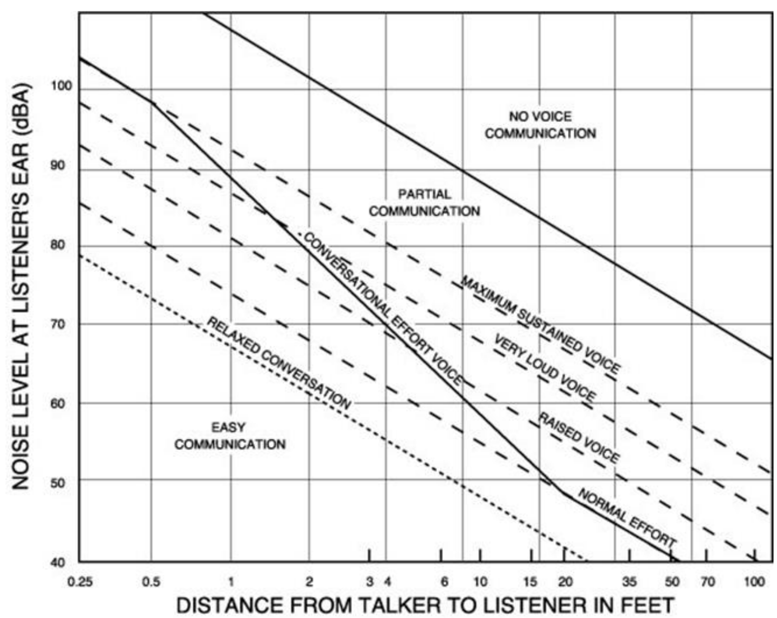


Figure A-8 Outdoor Speech Intelligibility

Source: U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, p.D-5.

Satisfactory conversation does not always require hearing every word; 95% intelligibility is acceptable for many conversations. In relaxed conversation, however, we have higher expectations of hearing speech and generally require closer to 100% intelligibility. Any combination of talker-listener distances and background noise that falls below the bottom line in the figure (which roughly represents the upper boundary of 100% intelligibility) represents an ideal environment for outdoor speech communication. Indoor communication is generally acceptable in this region as well.

One implication of the relationships in **Figure A-8** is that for typical communication distances of three or four feet, acceptable outdoor conversations can be carried on in a normal voice as long as the background noise outdoors is less than about 65 dB. If the noise exceeds this level, as might occur when an aircraft passes overhead, intelligibility would be lost unless vocal effort were increased or communication distance were decreased.

Indoors, typical distances, voice levels, and intelligibility expectations generally require a background level less than 45 dB. With windows partly open, housing generally provides about 10 to 15 dB of interior-to-exterior noise level reduction. Thus, if the outdoor sound level is 60 dB or less, there is a reasonable chance that the resulting indoor sound level will afford acceptable interior conversation. With windows closed, 24 dB of attenuation is typical.

A.2.2 Sleep Interference

Research on sleep disruption from noise has led to widely varying observations. In part, this is because (1) sleep can be disturbed without awakening, (2) the deeper the sleep the more noise it takes to cause arousal, (3) the tendency to awaken increases with age, and other factors. **Figure A-9** shows a summary of findings on the topic.

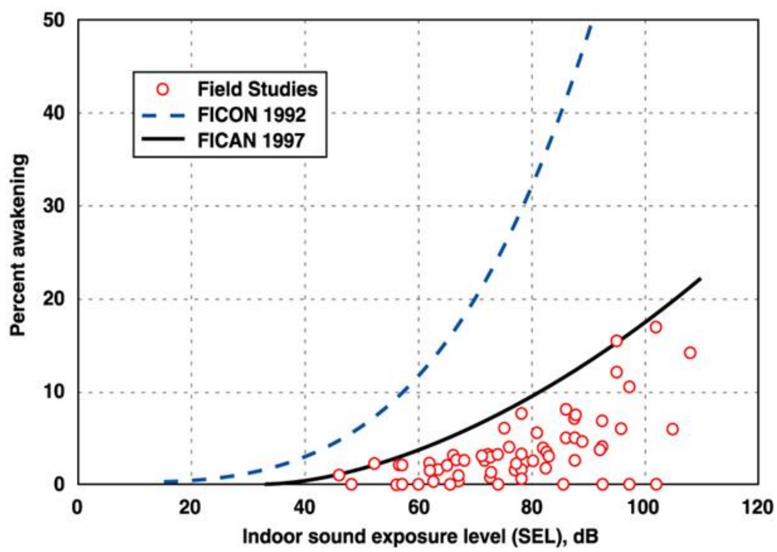


Figure A-9 Sleep Interference

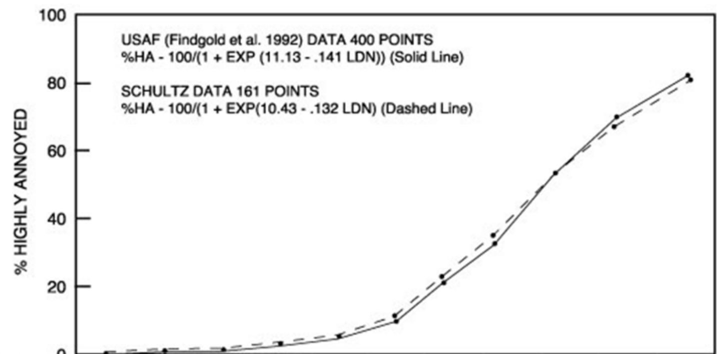
Source: Federal Interagency Committee on Aircraft Noise (FICAN), "Effects of Aviation Noise on Awakenings from Sleep," June 1997, pg. 6

Figure A-9 uses indoor SEL as the measure of noise exposure; current research supports the use of this metric in assessing sleep disruption. An indoor SEL of 80 dBA results in a maximum of 10% awakening.[11]

[11] The awakening data presented in Figure A-9 apply only to individual noise events. The American National Standards Institute (ANSI) has published a standard that provides a method for estimating the number of people awakened at least once from a full night of noise events: ANSI/ASA S12.9-2008 / Part 6, "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." This method can use the information on single events computed by a program such as the FAA's Aviation Environmental Design Tool, to compute awakenings.

A.2.3 Community Annoyance

Numerous psychoacoustic surveys provide substantial evidence that individual reactions to noise vary widely with noise exposure level. Since the early 1970s, researchers have determined (and subsequently confirmed) that aggregate community response is generally predictable and relates reasonably well to cumulative noise exposure such as DNL. COMAR provides methods for the calculation of noise exposure including metrics and measurement methods.[12] **Figure A-10** depicts the widely recognized relationship between environmental noise and the percentage of people "highly annoyed," with annoyance being the key indicator of community response usually cited in this body of research.



Day - Night Average Sound Level in dB		40	45	50	55	60	65	70	75	80	85	100
Calculated %HA Points	USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
	SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

Figure A-10 Percentage of People Highly Annoyed

Source: FICON, "Federal Agency Review of Selected Airport Noise Analysis Issues," September 1992

Separate work by the EPA has shown that overall community reaction to a noise environment is also dependent on DNL. **Figure A-11** depicts this relationship.

[12] COMAR. 11.03.03.02. Methods for Calculation and Measurement of Levels of Cumulative Noise Exposure. http://mdrules.elaws.us/comar/11.03.03.02

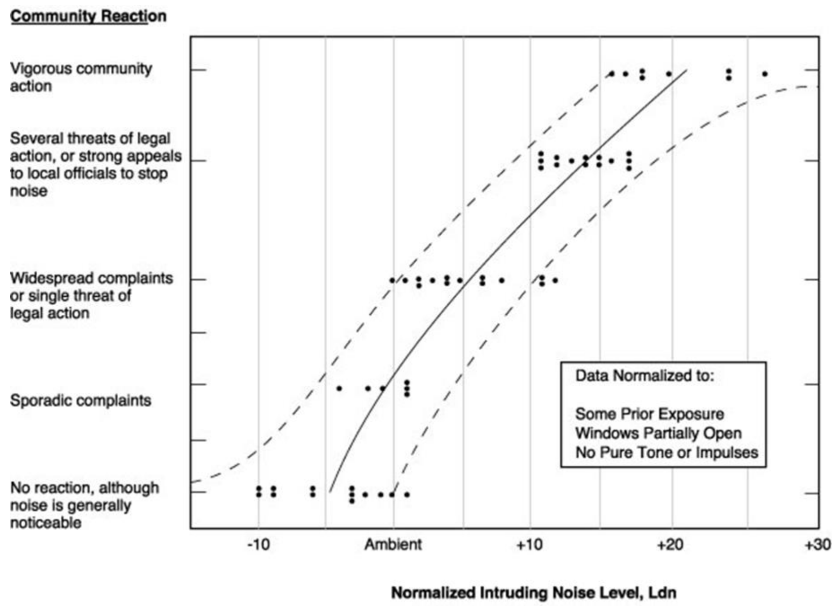


Figure A-11 Community Reaction as a Function of Outdoor DNL

Source: Wyle Laboratories, Community Noise, prepared for the U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C., December 1971, pg. 63

Data summarized in the figure suggest that little reaction would be expected for intrusive noise levels five decibels below the ambient, while widespread complaints can be expected as intruding noise exceeds background levels by about five decibels. Vigorous action is likely when levels exceed the background by 20 dB.

A.3 Noise Propagation

This section presents information sound-propagation effect due to weather, source-to-listener distance, and vegetation.

A.3.1 Weather-Related Effects

Weather (or atmospheric) conditions that can influence the propagation of sound include humidity, precipitation, temperature, wind, and turbulence (or gustiness). The effect of wind – turbulence in particular – is generally more important than the effects of other factors. Under calm-wind conditions, the importance of temperature (in particular vertical “gradients”) can increase, sometimes to very significant levels. Humidity generally has little significance relative to the other effects.

A.3.1.1 Influence of Humidity and Precipitation

Humidity and precipitation rarely effect sound propagation in a significant manner. Humidity can reduce propagation of high-frequency noise under calm-wind conditions. This is called “Atmospheric absorption.” In very cold conditions, listeners often observe that aircraft sound “tinny,” because the dry air increases the propagation of high-frequency sound. Rain, snow, and fog also have little, if any noticeable effect on sound propagation. A substantial body of empirical data supports these conclusions.[13]

A.3.1.2 Influence of Temperature

The velocity of sound in the atmosphere is dependent on the air temperature. [14] As a result, if the temperature varies at different heights above the ground, sound will travel in curved paths rather than straight lines. During the day, temperature normally decreases with increasing height. Under such “temperature lapse" conditions, the atmosphere refracts ("bends") sound waves upwards and an acoustical shadow zone may exist at some distance from the noise source.

Under some weather conditions, an upper level of warmer air may trap a lower layer of cool air. Such a “temperature inversion” is most common in the evening, at night, and early in the morning when heat absorbed by the ground during the day radiates into the atmosphere. [15] The effect of an inversion is just the opposite of lapse conditions. It causes sound propagating through the atmosphere to refract downward.

The downward refraction caused by temperature inversions often allows sound rays with originally upward-sloping paths to bypass obstructions and ground effects, increasing noise levels at greater distances. This type of effect is most prevalent at night, when temperature inversions are most common and when wind levels often are very low, limiting any confounding factors. [16] Under extreme conditions, one study found that noise from ground-borne aircraft might be amplified 15 to 20 dB by a temperature inversion. In a similar study, noise caused by an aircraft on the ground registered a higher level at an observer location 1.8 miles away than at a second observer location only 0.2 miles from the aircraft. [17]

A.3.1.3 Influence of Wind

Wind has a strong directional component that can lead to significant variation in propagation. In general, receivers that are downwind of a source will experience higher sound levels, and those that are upwind will experience lower sound levels. Wind perpendicular to the source-to-receiver path has no significant effect.

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[13] Ingard, Uno. “A Review of the Influence of Meteorological Conditions on Sound Propagation,” *Journal of the Acoustical Society of America*, Vol. 25, No. 3, May 1953, p. 407.

[14] In dry air, the approximate velocity of sound can be obtained from the relationship:
$c = 331 + 0.6T_c$ (c in meters per second, T_c in degrees Celsius). Pierce, Allan D., *Acoustics: An Introduction to its Physical Principles and Applications.* McGraw-Hill. 1981. p. 29.

[15] Embleton, T.F.W., G.J. Thiessen, and J.E. Piercy, “Propagation in an inversion and reflections at the ground,” *Journal of the Acoustical Society of America*, Vol. 59, No. 2, February 1976, p. 278.

[16] Ingard, p. 407.

[17] Dickinson, P.J., “Temperature Inversion Effects on Aircraft Noise Propagation,” (Letters to the Editor) *Journal of Sound and Vibration.* Vol. 47, No. 3, 1976, p. 442.

The refraction caused by wind direction and temperature gradients is additive.[18] One study suggests that for frequencies greater than 500 Hz, the combined effects of these two factors tends towards two extreme values: approximately 0 dB in conditions of downward refraction (temperature inversion or downwind propagation) and -20 dB in upward refraction conditions (temperature lapse or upwind propagation). At lower frequencies, the effects of refraction due to wind and temperature gradients are less pronounced.[19]

Wind turbulence (or “gustiness”) can also affect sound propagation. Sound levels heard at remote receiver locations will fluctuate with gustiness. In addition, gustiness can cause considerable attenuation of sound due to effects of eddies traveling with the wind. Attenuation due to eddies is essentially the same in all directions, with or against the flow of the wind, and can mask the refractive effects discussed above.[20]

A.3.2 Distance-Related Effects

People often ask how distance from an aircraft to a listener affects sound levels. Changes in distance may be associated with varying terrain, offsets to the side of a flight path, or aircraft altitude. The answer is a bit complex, because distance affects the propagation of sound in several ways.

The principal effect results from the fact that any emitted sound expands in a spherical fashion – like a balloon – as the distance from the source increases, resulting in the sound energy being spread out over a larger volume. With each doubling of distance, spherical spreading reduces instantaneous or maximum level by approximately six decibels and SEL by approximately three decibels.

[18] Piercy and Embleton, p. 1412. Note, in addition, that as a result of the scalar nature of temperature and the vector nature of wind, the following is true: under lapse conditions, the refractive effects of wind and temperature add in the upwind direction and cancel each other in the downwind direction. Under inversion conditions, the opposite is true.
[19] Piercy and Embleton, p. 1413.
[20] Ingard, pp. 409-410.

Appendix B SFO Community Roundtable Letter: Ground Based Noise Ad-Hoc Subcommittee Approved Scope of Work

San Francisco International
Airport/Community Roundtable

455 County Center, 2nd Floor
Redwood City, CA 94063
T (650) 363-1853
F (650) 363-4849
www.sforoundtable.org

SFO Roundtable
Ground-Based Noise Ad-Hoc Subcommittee
Approved Scope of Work

Approved by the Roundtable on December 6, 2018

Problem statement
Noise from ground-based operations at San Francisco International Airport (SFO) has a distinct adverse impact on the quality of life for communities adjacent to the airport. As such, ground-based noise (GBN) should be considered a separate and discrete problem from noise created by airborne aircraft, e.g., over-flight/in-flight noise.

There is a perception in the adjacent communities that GBN has increased in recent years, and that such escalation may be a result of factors other than those related to the FAA's implementation of NextGen aircraft procedures including the NorCal Metroplex.

Scope of Work
The SFO Airport/Community Noise Roundtable (SFO RT) GBN Ad-Hoc Subcommittee shall be focused exclusively on GBN noise concerns. GBN sources include, but are not limited to, the following:

- Aircraft application of power on takeoff (also known as "back-blast")
- Aircraft becoming airborne on takeoff (also known as "secondary back-blast")
- Aircraft application of reverse thrust after touch down/arrival
- Aircraft engine run-up/warm up procedures prior to departure
- Aircraft taxiing, queueing and waiting
- Aircraft use of Auxiliary Power Units (APU)
- Vehicular and other noise sources on the airfield

The Subcommittee will initially focus on the collection of data to adequately define the problem, after which it will explore possible solutions and/or mitigations.

Research/Collection of Data
Initial research shall be divided primarily into the following three buckets. *(Organization responsible for providing the information is indicated in parentheses.)*

1. Infrastructure: Conditions and Procedures

    a. Physical conditions at SFO and changes to physical conditions over past 5 years, including the following infrastructural features *(Information to be provided by SFO)*
        - Sound barriers/blast barriers/walls along western perimeter
        - Removal and or addition of structures and features at the south end of runways 1L/1R
        - Access road
        - New construction, including hotel and other structures
        - Fire station

  - Aircraft taxiing path – Installation of Engineering Materials Arrestor System (EMAS): Is aircraft now farther away from barriers? If so, what impact does that have? Did EMAS installation result in any other changes in procedures?

b. Environmental conditions/Terrain (wind, mountains, etc) *(Information to be provided by SFO)*
  - Frequency of west flow conditions that put Runway 01L/R in use
  - Changes in climate/atmospheric conditions that exacerbate noise
  - Other?

c. Operational procedures (existing and prior) *(Information to be provided by SFO)*
  - Did taxiing path change?
  - What type/size/class of aircraft are being used? Do they produce different types of GBN, eg do they use less thrust?
  - Has the number of flights increased over time? And/or are existing flights more loaded with passengers? With heavier loads, does the noise increase?
  - Agreements between SFO and airlines regarding use of APUs
  - When are Noise Abatement Departure Procedures (NADP) used? Does the steeper climb have different GBN impact?

d. Impact of actions by actors others than SFO *(Information to be provided by SFO)*
  - Is there any airline behavior (eg APUs) that impacts ground-based noise?
  - Are there other actors (eg contractors for the hotel or terminal construction) that may have impact?

2. Metrics - Analyze current and historical noise monitor data for <u>the past 5 years</u> to obtain appropriately weighted noise data for ground-based events.

a. Existing data for GBN *(Information to be provided by SFO)*
  - What GBN data has SFO collected in past 5 years?
  - Is there data specific to Burlingame, Millbrae, and Hillsborough?
  - Is noise data correlated to a specific flight track? In cases where the data is not correlated to a specific flight track, is it maintained?
  - Noise level vs duration of noise
  - CalOSHA – does the state agency collect data on noise exposure for employees for worker safety?

b. Existing equipment used to collect such data *(Information to be provided by SFO)*
  - What equipment does SFO currently have in place, and what does it measure (relative to GBN or low-frequency noise)?
  - What new equipment is currently being procured (RFP in progress) and what *will* it measure?

c. Data and Studies on GBN from other airports/communities - what are the most relevant takeaways for SFO? *(Information to be provided by HMMH)*
  - HMMH 1998 study on Baltimore Washington Airport (BWI)
  - MSP 2000
  - FAA 2007 partner study
  - Wyle study on SFO (2001)
  - Any available studies on taxi noise?
  - Any available studies on use of APUs?

d. Equipment/measuring tools that may be needed in future *(Information to be provided by HMMH)*
  - Is there other technology out there that would help us better collect GBN data in the future?

- Where are the ideal locations to site monitors for purposes of measuring GBN?
- Are "accelerometers" necessary?

3. Mitigation Options

   a. What types of mitigation have been used elsewhere? *(Information to be provided by HMMH)*
   b. Mitigation at the home vs mitigation at the airport
      - Alternative designs for blast barrier
      - Analysis of how sound waves bounce off structures and how they may be retrofitted to disperse sound waves.
      - What changes in procedure might help mitigate noise?
      - Does home-based mitigation impact perception of noise?
   c. What further study is required to develop recommendations regarding mitigation?

Sub-Committee Schedule
The Subcommittee shall meet approximately every other month (on the alternating month with regular SFORT meetings), with a tentative schedule as follows:

- January 2019 Subcommittee meeting – SFO and HMMH to present findings from the research/collection of data listed above, particularly regarding infrastructure, procedures and existing metrics

- March 2019 Subcommittee meeting – Discussion and analysis of mitigation options. Discussion of whether further work is needed. Develop recommendation, if possible, to full SFORT regarding next steps.

- April 2019 full SFORT meeting – Present recommendation (if available) to full SFORT regarding next steps

- May 2019 Subcommittee meeting – if needed

Appendix C SFO Community Roundtable Letter from HMMH: Ground Based Noise (GBN) Ad-Hoc Subcommittee – Approved Scope of Work – Items Flagged "HMMH"

San Francisco International
Airport/Community Roundtable

455 County Center, 2nd Floor
Redwood City, CA 94063
T (650) 363-1853
F (650) 363-4849
www.sforoundtable.org

January 21, 2019

TO: Roundtable Members and Interested Parties

FROM: Justin W. Cook – INCE, LEED GA, Principal Consultant
Roundtable Technical Consultant - HMMH

SUBJECT: Ground-Based Noise (GBN) Ad-Hoc Subcommittee – Approved Scope of Work – Items Flagged "HMMH"

At the request of the Ground-Based Noise (GBN) Ad-Hoc Subcommittee of the SFO Roundtable, Harris Miller Miller & Hanson Inc. (HMMH) reviewed the approved scope of work items flagged "HMMH". Below is a high level summary of the findings of that review.

Approved Scope of Work Item #2(c) (Metrics - Data and studies on GBN from other airports/communities – what are the most relevant takeaways for SFO?)

Study #1: Study of Low Frequency Takeoff Noise at BWI Airport (HMMH 1998)

- Objective: quantify the start of takeoff sound levels at a house in the Allwood area adjacent to BWI, quantify a resident's judgement of the start of takeoff sound levels, and measure the propagation rate into the community of the start of takeoff sound levels.
- To help try to correlate the aircraft noise events with human perception of the events. One person rated events while noise monitors acquired sound and vibration data inside and outside that person's residence. The homeowner was instructed to use a scale of 0 to 100 for rating the least to most objectionable events, generally using multiples of 10 in assigning ratings.
- Outdoor C-weighted Lmax was identified as the preferred metric for evaluating takeoff sound levels for correlation with human judgments.
- Low frequency sound energy is important in determining how a person may react to the noise. However if there is enough energy in the higher frequencies, events can also be bothersome.
- As distance increased the average drop-off rate for the measured events was 5.6 dB per doubling of distance which is very close to the theoretical propagation rate of 6.0 dB for every doubling of distance.

Study #2: Status of Low-Frequency Aircraft Noise Research and Mitigation (Wyle 2001)

- Objective: review of backblast noise – how it's generated, how it propagates, how it can be mitigated, and where future study efforts and demonstration projects should be directed.
- Most sound energy generated by backblast noise is below 200 Hz, at these levels noise propagates over longer distances, travels more freely through structures, and can cause structures to vibrate more readily than noise at medium and high frequencies.

- Because of the low-frequencies of the sound caused by backblast noise, the A-weighting network does not adequately represent the noise and should not be used to evaluate its effects or measures to mitigate it.
- Using C-weighting generally works as it is easily measured by most sound level meters and can properly account for the low-frequency noise component of backblast noise.
- High-bypass-ratio (HBPR) engines significantly reduces the low-frequency jet exhaust noise compared with those of a low-by-pass-ratio (LBPR) engine.
- Important to understand the four mechanisms in the propagation of sound over flat ground with no obstacles which are; Geometrical spreading, air absorption, ground absorption, and meteorology.
    - Geometrical spreading: In open air, at distances greater than a few hundred feet, the noise level decreases at the rate of 6 dB per doubling of the distance regardless of the frequency content of the noise. (Inverse-square-law)
    - Air Absorption: At low-frequencies, air absorption is negligible and can be ignored for backblast noise because the maximum attenuation at any reasonable combination of temperature and relative humidity is less than 1 dB per kilometer.
    - Ground absorption: Not a significant factor in low-frequency noise propagation under most conditions.
    - Meteorological effects: Temperature inversions and wind gradients can play a large role in noise increases to backblast noise.
- Communities exposed to backblast noise are downwind of the aircraft and experience increased noise levels.
- As an aircraft departs, there are two noise peaks, first when the thrust is increased to near maximum levels at the start of the takeoff roll and second as the aircraft rotates and climbs from the runway. It is believed that as the jet orientation changes to a vertical direction, there rear lobe of the directivity pattern is pointed more towards the ground which causes a sudden increase in noise level. Total duration for a single departure can be one to two minutes.

<u>Backblast Noise Mitigation</u>

Noise Control at the Source

- Persuading airlines to reduce operations of aircrafts using LBPR engines is a mitigation measure to consider. There is also evidence that low-frequency backblast noise levels of Stage 3 aircraft are on average up to 6 dB lower than for Stage 2 aircraft.
- Because of indications that the second peak of the noise time history may be influenced by the orientation of the aircraft as it climbs from the runway, potentially creating a procedure to lower the climb rate to reduce the noise level of the second peak can be considered, departure turns might also have a similar effect. However it would be necessary to determine if there was any correlation between climb rate or departure track and the low-frequency noise levels in the community.

Barriers and Buildings

- Barriers to reduce backblast noise projected into the community are not a suitable mitigation measure as they would be ineffective.
- Barriers can be effective if they are placed close to the receiver, so they can be a mitigation measure for houses that require protection. To provide even minimal attenuation, the barrier would need to be at least 15 feet tall and located within 50 to 100 feet of the residence.

Trees and Shrubs

- While trees and shrubs provide very minimal reductions to noise levels, it is believed that many people still believe that trees reduce noise, which can be due to the look and feel trees give or that they block the view of the airport.

Sound Insulation

- While residential sound insulation programs are successful in reducing noise levels coming from overflights, sound insulation for backblast noise is generally harder to achieve with low-frequency levels.
- At BWI a pilot program to study the application of low-frequency treatments achieved an average increase in C-weighted noise reduction of 4 dB. However the extent of the treatments were considerable consisting of major wall modifications and windows with an overall thickness of over 12 inches. Cost of the treatment represented a 40% increase over those for the standard acoustical treatment.
- At BOS, in addition to the standard acoustical treatment a home would receive, one room would be designated at the room of preference (ROP) and received special treatment to further reduce transmission of exterior noise. This treatment increases effectiveness of the sound insulation at all frequencies by building the wall in toward the center of the room with additional wall panels and using double-glazed windows 5 to 6 inches thick. The room of preference treatments increase the C-weighted noise reduction by approximately 5 dB in addition to the improvement achieved with the standard treatments which cost between $5,000 to $6,000 per room. Note that some homeowners in Boston declined the ROP plan because of the significant reduction in floor space after the treatment was installed.

Vibration and Rattle

- Two major mitigation concepts applicable to residential buildings; mitigation by reducing low frequency response of building components and mitigation by preventing impact of vibrating objects against their supporting surfaces.
- Potential mitigation measures based on the basic theory of sound transmission into structures at low frequencies include:
    - Changing the wall structure by increasing mass or decreasing stiffness (staggered studs) to lower the modal frequencies and increase mass law transmission loss.
    - Changing the air cavity in conventional double wall systems by adding absorption to damp structural and acoustic resonances, and by adding cavity venting to increase transmission loss at panel-air cavity resonance frequencies.
    - Adding Helmholtz resonators within the wall to reduce wall transmission loss and in the attic to damp lower-older acoustic room modes.
- Techniques like cavity venting and Helmholtz resonators are largely unexplored but promising candidates for future evaluation.
- There are simple and cost-effective solutions to minimize rattle of windows, doors, and other house hold items. Some solutions include using gasket materials to fill the gaps and soften the contact points, vibration-isolation pads and washers added to cushion the impact of vibrating objects which reduce or eliminate rattle noise.
- In the City of Millbrae, additional treatment was applied in attempt to reduce low-frequency vibration in rooms facing the runway. A secondary interior wall was added and higher STC windows were installed. There were no measured data documenting the improvement, but 38 out of 41 homeowners judged the treatments to be very effective.

- In Minneapolis, the majority of homeowners that complained about rattling was due to window rattling. That number dropped by almost 40% after sound insulation treatment which included restoration or replacement of the windows. The standard sound insulation treatment resolves some but not all of the rattling problems.
- Isolation of household articles from tabletops, walls and shelves with felt or rubber pads seems to eliminate the audible rattle.

Noise Cancellation

- Initial demonstrations of active noise control systems to reduce backblast noise from departing aircraft were successful. Noise reductions of up to 10 dB were achieved over the frequency range of importance for vibration and rattle using a 3-speaker system.
- Two possible ways to employ ANC: with the control loudspeaker close to the source of close to the receiver.
- Using a control loudspeaker close to the source is the most appropriate for reducing noise from engine runup operations and provides the widest coverage.
- Placing an ANC system in the community with a detection system so the system would only operate during aircraft departures shows potential.
    - Properly adjusted, the operation of the system would not be apparent to the local community, except that noise levels would be reduced.

Study #3: Findings of the Low-Frequency Noise Expert Panel (MSP 2000)

- Previous Literature review
    - Primary effect of low-frequency aircraft noise on residential areas near runway sidelines is annoyance due to "secondary emissions": rattling noises and vibration of windows, doors, and household paraphernalia.
    - Loudness level contours provide a reliable indication of the loudness, noise rating, and direct annoyance of sounds in the low-frequency range of current interest.
    - Source spectra of departing aircraft contain relatively greater amounts of low-frequency acoustic energy at points closer to the start of takeoff roll than at points further away from the start of takeoff roll.
- Low frequency aircraft noise poses no known risk of adverse public health consequences, nor a risk of structural damage. Under expected circumstances of residential exposure, low-frequency aircraft noise will not interfere with indoor speech, nor is the noise itself likely to awaken people.
- Laboratory study with test subjects judging the annoyance of low-frequency aircraft noise.
    - On an A-weighted sound level scale, low-frequency noise was more annoying than aircraft overflight noise at the same level.
    - The addition of even small amounts of rattle increased its judged annoyance by about 5 dB in this study although the expert panel did not reach a consensus on this.
    - Reductions in the low-frequency content of this noise proportionally decreased the annoyance of non-rattling test sounds.
- The panel identified a range of criteria for acceptability of low-frequency noise in residences in three steps:
    - 1) A-weighted land use compatibility and other interpretations of noise impacts were reviewed.

- 2) the reactions of Minneapolis and other residents to rattle were determined.
- 3) equivalences were established between A-weighted and low-frequency sound levels through associated levels of prevalence of annoyance.

- FICON's adopted relationship of noise exposure to the prevalence of high annoyance, dosage-response curve shows that there is a range of 12% to 37% high annoyance between DNL levels of 65 and 75 dB.
- Field measurements found that the low-frequency noise reduction of acoustically untreated and treated houses were nearly identical, showing that MSP RSIP does not improve the low-frequency noise reduction of residences.
- Low-frequency noise reduction by residences can be increased by modifications to the structures. An improvement of approximately 5 dB can be achieved by adding a heavy layer to the outside or inside (e.g. 1" heavy weight plaster/stucco skin). 10 dB improvement can also be achieved however it would require use of complex structures (e.g. a brick wall with minimal openings toward the noise sources, and/or an insulated cavity wall with separately support interior and exterior cladding and multi-pane windows of limited size).
- Treating rattle in homes affected by high annoyance of low-frequency noise should be a high priority.
- Future mitigation strategies:
  - Evaluate potential barrier effects of existing or planned buildings and evaluate the potential benefits of other barriers.
  - Convert to compatible land use any residential areas where the Low-Frequency Sound Level does is determined to be 87 dB or higher.
  - Develop a program for rattle reduction to be incorporated into RSIP.
- Low-Frequency sound level should be used as the descriptor of low-frequency noise of aircraft single events (e.g. takeoff or landing).
- Social survey conducted via telephone found that more than half of the respondents reported that airplanes made rattling sounds in their homes. Majority of the homes reported rattle were within 3,000 feet of a runway.
- Potential measures capable of increasing the low-frequency noise reduction can be increasing surface mass by adding dense material to exterior and/or interior cladding, adding one or more separated layers to wall to create complex wall structures, and/or incorporation of sound absorbing or vibration isolating provisions into walls.
- Other treatments also include varying number of layers of gypsum wall board and sound deadening board of varying thickness directly to interior walls, and mounting of layers of gypsum wallboard on resilient channels or on a separated metal stud framework.
- Design measures for new construction, such as masonry or complex walls, careful placement and sizing of windows, and vibration isolation for roof and ceiling structures can also probably achieve the desired low-frequency noise reductions. However such designs would be on a case-by-case basis as it is likely to be prohibitively expensive to construct.

Study #5: Low-Frequency Noise Study (PARTNER FAA 2007 Study)

- Low frequencies sounds have the potential for a rapid growth in annoyance with a minimal growth in loudness.
- Past studies:

- SFO (1986 & 1987): Concerned directivity patterns for low-frequency noise and the differences in low-frequency noise exposure between backblast noise experienced by communities located behind aircraft taking off and aircraft overflight noise. Studies showed that communities at an angle of 40 to 50 degrees from the jet exhaust axis experience maximum low-frequency noise levels and that backblast noise had both more low frequency noise and longer duration than overflight noise. Also determined C-weighting scale worked best to describe low-frequency departure noise.
- BWI (1990): Analysis of start of takeoff roll (SOTR) noise was conducted at a home 4,000 feet behind and about 45 degrees to the side of the start of runway 15R. Data analysis showed that there were three significant contributions to the overall Ldn other than SOTR operations: 1) engine maintenance run-ups (59.8 dB), 2) non-airport background noise (55.3 dB), and 3) spurious instrumental readings (59.8 dB). When these levels were subtracted from the overall calculation, the remaining contribution from SOTR operations was 65.9 dB. Study found that models tend to underestimate the noise from Stage 3 aircraft more than Stage 2 aircraft and that modeling ground operations is more challenging than modeling over-flight events due to the greater significance of difficult-to-model conditions such as foliage, barriers, wind, and temperature gradients.
- BWI (1998 & 1997): Reports published based on prior studies at BWI that dealt with insulating existing houses from low-frequency noise. The noise measured in both dBA and dBC were reduced significantly in several instances however the cost to insulate each of the homes from low-frequency noise was in the $40,000 to $50,000 range; which is significantly higher than the cost of tradition sound insulations.
- BOS (1996): Study found that overall community noise levels were significantly decreased after the switch from Stage 2 to Stage 3 aircrafts. There was also a decrease at frequencies below 100 Hz in areas that are normally affected by backblast and sideline noise.
- MSP (1998): Panel found that rattle-related annoyance was an effect of low-frequency aircraft noise for residents living within a mile of runways. They also determined that noise from the reverse thrust during an aircraft's landing was an area needing more research.
- AMS: Study concluded that vibration at homes near runways was due exclusively to airborne noise and that attenuation of 10 dB was desirable, with the frequency range around 31.5 Hz being of the greatest concern. They proposed various mitigation measures that included barriers, ground absorption, modified operations, insulation of residences, active sound cancellations, and wind generation. Barriers would need to be 10-15 meters high to provide a reduction of 6 dB and barriers near runways would affect aircraft safety. Modifying the ground cover with gravel beds or thick vegetation could potentially provide the needed attenuation however gravel bed approach is unproven on that large of a scale. Changes in aircraft operations would require significant regulatory changes and further evaluation on the impact on communities near other runways would need to be examined. Most feasible and effective options seemed to be ground cover modification or airport operations modification.

- In response to the findings issued by the MSP Expert Panel Report (2000) FICAN recommended that further research consider the following:
    1) That measurements be conducted in houses within critical distances from runways identified in previous studies of low-frequency aircraft noise, in particular one conducted at Baltimore-Washington International Airport (BWI). Measurements should include exterior noise and window, wall, and floor vibration with a frequency

range extending down to a few hertz to capture the low-frequency impact. The vibration measurements should be based on the recommendations by the American National Standard Institute (ANSI) Standard S3.29-1983 (R1996). In addition, the measured noise and vibration levels should be compared to thresholds for tactile perception of vibration, known as the "Hubbard criteria," used to establish the extent of the effect of low-frequency noise at BWI.

2) Have panels of subjects rate the annoyance of individual aircraft events in the houses. Conduct statistical analysis to establish what combination of physical measures gave the best prediction of annoyance ratings. Assess the ANSI Standard [S12.9, Part 4] Low-Frequency Level (*LLF*) as a descriptor of low-frequency noise.

3) Study the efficacy of sound insulation in a stepwise fashion, beginning with the most rattle-prone features of houses, the windows and doors. FICAN's idea was to use the same subjects as in Recommendation 2 to assess the impact of insulation.

- IAD conducted a low-frequency noise study in 2004. Measurements along three runways were taken to record sideline noise during start of takeoff roll, acceleration down the runways, and sideline noise during thrust reverser deployment during landings. Noise and vibration measurements were also taken at two residential structures on airport property.
    - Low frequency propagation modeling was modeled using Parabolic-equation models that can account for atmospheric refraction. Because the characteristics of the source change as the aircraft moves down the runway, a range of meteorological conditions (best and worst case) were used to determine the sensitivity of the parabolic-equation noise predictions. Models found that at neutral conditions, propagation from source to receiver obeys spherical spreading. When upwind and downwind conditions were used, levels began to differ by 10 – 20 dB. Differences in meteorological conditions can have significant effect on single-event levels and can affect noise contours.
- The study found that measured vibration levels of windows in houses located within 3,000 ft of runways can exceed the Hubbard threshold criteria. The thresholds were exceeded to a greater degree on rattle-prone windows, whereas vibration levels of secure windows generally fell below the Hubbard thresholds. The Hubbard exterior sound pressure level threshold criteria should be used as a first assessment of the potential for low-frequency noise impacts on residential structures.
    - In resonant systems window rattle will occur over a range of frequencies (rattle band) centered about the resonance of the system if the amplitude of vibration is large enough. Rattle bands can be minimized by using significant preloads. For most typical systems the rattle band is greater than the damping controlled region which indicates that damping is not a significant mitigation strategy for window rattle.
- The Tokita & Nakamura annoyance thresholds were validated as predicators of annoyance due to low-frequency aircraft noise and should be used as indicators for potential annoyance. Lce should be used as a single-number metric for assessing the potential annoyance when high levels of low-frequency aircraft noise are present.
- In general Outdoor/Indoor Transmission Class (OITC) rating is recommended instead of the Sound Transmission Class (STC) rating when identifying the performance of exterior components of homes such as doors and windows. The OITC rating includes frequency content down to 80 Hz thus providing a better single-number metric of low frequency transmission loss performance.

Approved Scope of Work Item #2(d) (Metrics – Equipment/measuring tools that may be needed in future)

Portable noise and vibration monitoring systems that can automatically integrate the data into SFO's Noise and Operations Management System (NOMS) are recommended. These portable systems have wireless communication and can be placed outdoors or indoors for continuous streaming of data. It is recommended that locations are carefully selected to minimize noise from non-airport sources. The sound level meters should be capable of recording unweighted, A, and C weighted one-second noise values. The noise and vibration equipment would not have established thresholds, but would send all one-second data back to the server for post processing. It is recommended that each homeowner be provided with a log where they can record specific concerns at the time that each occurred. As an alternative, there are newly developed buttons or clickers that may be used to assist with instantly issuing a concern that is time stamped. These buttons/clickers are also capable of including a capability that allows for number of clicks to have different meanings. These concerns can be integrated into the existing NOMS. Access to ADSB data would be important as that data will show taxing, queuing, and start of takeoff roll information. The goal would be to utilize equipment and data that will assist in determining the ground based sources that are most concerning to the community. Video camera systems may be another potential for inclusion.

Approved Scope of Work Item #3(a-c) (Mitigation Options)

- Limited means to mitigation at the airport (source):
  - Moving to stage 3 aircraft operating with High-By-Pass ratio engines to lower backblast noise.
  - Potential for barriers near runway ends however they could pose a safety hazard to aircraft and attenuation would be low. Weather could also reduce effectiveness, depending on speed and direction of winds.
    - While a barrier near the runways could provide a slight reduction in Low-Frequency Sound Levels, the barrier would be costly, esthetically undesirable and effective only for the time the aircraft is on the ground.
  - Potential for changes to procedures moving departing aircrafts to runways away from residences.
- More likely to achieve mitigation at residences (receiver):
  - Upgrades to homes to reduce low-frequency noise have limited options and are often very expensive compared to traditional sound isolation upgrades for medium to high frequency noise.
  - Active noise cancellation within the communities itself seems promising; however further study is required for scale.
  - Most complaints come from rattling/vibrations as opposed to the actual low-frequency noise, using affordable products to strap down and dampen objects that move can improve human perception of the annoyance.
  - Fixing older windows/doors can also reduce rattling effects which drive high annoyance levels:
    - Upgrading the edge seals around the window periphery using a tighter seal and more weather-resistant materials.
    - Increasing the window thickness.
    - Using double-pane construction with an airspace between each pane.

Appendix D HMMH Presentation: Ground Based Noise (GBN) Ad-Hoc Subcommittee on March 19, 2019

San Francisco International Airport/Community Noise Roundtable

Ground-Based Noise (GBN) Ad-Hoc Subcommittee

March 19, 2019

Overview

- Reviewed the following approved scope of work items flagged "HMMH"
  - Item #2(c) (Metrics - Data and studies on GBN from other airports/communities – what are the most relevant takeaways for SFO?)
  - Item #2(d) (Metrics – Equipment/measuring tools that may be needed in future)
  - Item #3(a-c) (Mitigation Options)

hmmh

Item #2(c) (Metrics - Data and studies on GBN from other airports/communities – what are the most relevant takeaways for SFO

- Five studies were reviewed and the following is a summary of the research:
  - Objective to quantify resident’s judgement of start of takeoff sound levels and measure propagation rate into community
  - Goal of correlating aircraft noise levels with human perception of events
  - Homeowner instructed to use a scale of 0 to 100 for rating events, generally in multiples of 10
  - Outdoor C-weighted LMax was identified as the preferred metric
  - Low frequency sound energy important in determining how a person may react to the noise

Item #2(c) Continued

- Objective was to review back blast noise – how it's generated, how it propagates, how it can be mitigated, and future study efforts and projects that should be directed
- Most sound energy generated by back blast noise is below 200 Hz and at these levels noise propagates over longer distances, travels more freely through structures, and can cause structures to vibrate
- A-weighting network does not adequately represent the noise; C-weighting works well

Item #2(c) Continued

- Important to understand 4 mechanisms of propagation of sound over flat ground with no obstacles:
  - Geometrical spreading – in open air, at distances greater than a few hundred feet, noise level decreases at a rate of 6 dB per doubling of distance regardless of frequency content
  - Air absorption – at low frequencies, it can be ignored for back blast because maximum attenuation at any reasonable combination is less than 1 dB per kilometer
  - Ground absorption – not significant factor in low frequency propagation under most conditions
  - Meteorological effects – temperature inversions and wind gradients can play a large role in noise increases to back blast noise (HMMH: recently completed study (2018) for LAX)

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Item #2(c) Continued

- As an aircraft departs there are two noise peaks – first when thrust is increased near maximum levels at start of takeoff roll and second when aircraft rotates and climbs from the runway
- As the aircraft orientation changes to vertical direction, the rear lobe of directivity is pointed more towards he ground which causes a sudden increase in noise level

Item #2(c) Continued

- Back blast noise mitigation: noise control at the source, barriers and buildings, trees and shrubs, sound insulation, vibration and rattle, and noise cancellation
- Noise control at source:
  - Persuade airlines for quieter aircraft (HMMH: now would be Stage 4 and 5)
  - Create procedure to lower climb rate to reduce second peak noise (HMMH: consider tradeoffs)
- Barriers and buildings:
  - Barriers effective only if placed close to receiver – minimal attenuation would mean a barrier at least 15 feet tall located within 50 to 100 feet of residence (HMMH: barrier could also create reflections)

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Item #2(c) Continued

- Tress and shrubs:
  - Provide minimal reductions to noise levels
  - Many people believe that it reduces noise, which can be due to the look and feel as they block the view
- Sound insulation:
  - While RSIP are successful for overflight noise, insulation for back blast is harder to achieve because of low frequency penetration
  - BWI pilot program with low frequency treatments achieved average increase in C-weighted noise reduction of 4 dB. Extent of treatments was considerable with major wall modifications and windows with an overall thickness of over 12 inches. Cost of treatment was 40% increase over standard RSIP treatments

Item #2(c) Continued

- Vibration and rattle:
  - There are simple and cost effective solutions to minimize rattle of windows, doors and other household items. Some include using gasket materials to fill in gaps and soften contact points, vibration isolation pads and washer added to cushion impact
  - In Millbrae, additional treatment was applied to reduce low-frequency vibration in rooms facing runway. A secondary interior wall was added and higher STC windows. There was no measured data documenting improvement, but 38 out of 41 homeowners judged the treatments to be effective
  - In Minneapolis, majority of homeowners complained about rattling of windows and number dropped by 40% after standard treatment
  - Isolation of household items from tabletops, walls, and shelves with felt or rubber pads seems to eliminate audible rattle

Item #2(c) Continued

- Noise cancellation:
  - Initial demonstration of active noise control systems to reduce back blast were successful – noise reductions of up to 10 dB were achieved over the frequency range of importance for vibration and rattle

NOTE: HMMH has just submitted a FY2020 ACRP problem statement entitled, “Determining Feasibility of Applying Active Noise Reduction/Cancellation to Jet Aircraft Departures”

Item #2(c) Continued

- Source spectra of departing aircraft contain greater amounts of low-frequency energy at points closer to start of takeoff roll than points further away from start of takeoff roll
- Addition of even small amounts of rattle increased its judged annoyance by 5 dB
- Field measurements found low frequency noise reduction of acoustical treated and untreated residences identical
- Low frequency noise reduction by residences of around 5 dB can be achieved by adding a heavy layer to outside or inside (e.g. 1” heavy weight plaster/stucco/interior wall). Around 10 dB would require complex structures (e.g. brick wall with minimal openings towards sources, and/or insulated cavity wall with separate support interior and exterior cladding)
- Treating rattle/vibration in residences affected by high annoyance of low frequency noise should be highest priority

Item #2(d) (Metrics – Equipment/measuring tools that may be needed in future)

- Portable noise and vibration monitoring systems for short term monitoring that can automatically integrate the data into SFO's Noise and Operations Management System (NOMS) are recommended for any additional study
- These portable systems have wireless communication and can be placed outdoors or indoors for continuous streaming of data
- The sound level meters should be capable of recording unweighted, A, and C weighted one-second noise values
- The noise and vibration equipment would not have established thresholds, but would send all one-second data back to the server for post processing
- It is recommended that each homeowner be provided with a log where they can record specific concerns at the time that each occurred

Item #3(a-c) (Mitigation Options)

- Upgrades to residences to reduce low-frequency noise have limited options and are often very expensive compared to traditional sound isolation upgrades for medium to high frequency noise
- Active noise cancellation within the communities itself seems promising; however further study is required for scale
- Most complaints come from rattling/vibrations as opposed to the actual low-frequency noise, using affordable products to strap down and dampen objects that move can improve human perception of the annoyance (HMMH: Vibrations can occur without audible noise events present or ahead of and after actual noise events. This effect causes longer periods of aggravation
- Fixing older windows/doors can also reduce rattling effects which drive high annoyance levels:
  - Upgrading the edge seals around the window periphery using a tighter seal and more weather-resistant materials
  - Increasing the window thickness
  - Using double-pane construction with an airspace between each pane

Appendix E SFO Community Roundtable Letter from HMMH: Ground Based Noise (GBN) Ad-Hoc Subcommittee Meeting on June 26, 2019 – Noise Barrier Research Review

San Francisco International
Airport/Community Roundtable

455 County Center, 2nd Floor
Redwood City, CA 94063
T (650) 363-1853
F (650) 363-4849
www.sforoundtable.org

August 7, 2019

TO: Roundtable Members and Interested Parties

FROM: Justin W. Cook – INCE, LEED GA, Principal Consultant
Roundtable Technical Consultant - HMMH

SUBJECT: Ground-Based Noise (GBN) Ad-Hoc Subcommittee Meeting on June 26, 2019 – Noise Barrier Research Review

---

During the GBN ad-hoc subcommittee meeting on June 26, 2019, HMMH discussed noise barriers in more detail based on the following five (5) research studies:

1. Study of Low Frequency Takeoff Noise at BWI Airport (HMMH 1998)
2. Status of Low-Frequency Aircraft Noise Research and Mitigation (Wyle 2001)
3. Findings of the Low-Frequency Noise Expert Panel (MSP 2000)
4. Low-Frequency Noise Study (PARTNER FAA 2007 Study)
5. Study of the Levels, Annoyance and Potential Mitigation of Backblast Noise at San Francisco International Airport (BBN Technologies, 2000)

The following bullet points contain information that was summarized at the meeting:

- Most sound energy generated by backblast noise is below 200 Hz, at these levels noise propagates over longer distances, travels more freely through structures, and can cause structures to vibrate more readily than noise at medium and high frequencies.
- In open air, at distances greater than a few hundred feet, the noise level decreases at the rate of 6 dB per doubling of the distance regardless of the frequency content of the noise.
- As an aircraft departs, there are two noise peaks, first when the thrust is increased to near maximum levels at the start of the takeoff roll and second as the aircraft rotates and climbs from the runway. It is believed that as the jet orientation changes to a vertical direction, there rear lobe of the directivity pattern is pointed more towards the ground which causes a sudden increase in noise level. The distance between the source to a potential barrier at the second peak would be too distant for any attenuation.
- Barriers can be effective if they are placed close to the receiver, so they can be a mitigation measure for residences that require protection. To provide even minimal attenuation, the barrier would need to be at least 15 feet tall and located within 50 to 100 feet of the residence.
- Potential for barriers near runway ends, however they could pose a safety hazard to aircraft and attenuation would be low. Weather could also reduce effectiveness, depending on speed and direction of winds.
- Barriers provide attenuation by eliminating the direct line of sight between source and receiver. They don’t work quite as well as might be expected however because the sound diffracts, or

bends, over the top of the barriers, and prorogates into the shadow zone behind it, thereby reducing the attenuation. This is especially the case for low frequency noise.

- Sources close to the barrier are better attenuated than those farther away, and the same goes for receiver distance.
- It is difficult to provide any attenuation from a realistic-sized barrier if the distance between the source and receiver is greater than a few hundred meters.
- Barriers close to the runway are not suitable for reducing backblast noise because it is difficult to place close to the source and it would then be quite distant from the community; attenuation would be low.

Appendix F HMMH Technical Memorandum: Ground Based Noise (GBN) - Vegetation and Noise Effects

HMMH
300 South Harbor Boulevard
Suite 516
Anaheim, California 92805
www.hmmh.com

TECHNICAL MEMORANDUM

To:	James A. Castaneda, AICP San Mateo County 455 County Center, 2nd Floor Redwood City, CA 94063
From:	Heather A. Bruce Justin W. Cook - INCE, LEED GA
Date:	January 3, 2020
Subject:	Ground Based Noise (GBN) - Vegetation and Noise Effects
Reference:	HMMH Project Number 309090.000

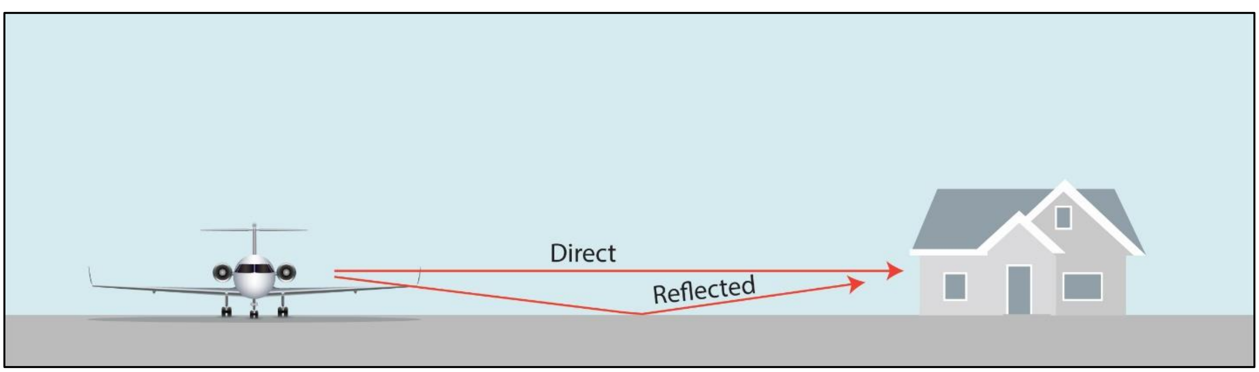
1. Introduction

On the behalf of the San Francisco International Airport/Community Roundtable, Harris Miller Miller & Hanson Inc. (HMMH), conducted a literature search regarding the acoustical attenuation provided by vegetation.

2. Ground Effect

When sound propagates along the surface of the earth from a source to a receiver, it follows two paths. The first is a direct path from the source to the receiver and the second is a path that starts at the source, reflects off the ground, and then travels to the receiver. If the ground is hard, such as pavement or water, the sound reflects off the surface and adds to the sound from the direct path resulting in higher levels than the direct path alone. When sound reflects off of soft ground such freshly-plowed earth, grass, or loose snow, some frequencies of the reflected sound experience a phase reversal, where the areas of high and low pressure become reversed. Adding this phase-reversed sound with the sound from the direct source results in a reduction in the total sound at the receiver. Thus, sound levels are generally higher when the sound propagates over hard ground as compared to soft ground. Figure 1 depicts ground effect.

Figure 1. Ground Effect



Source: HMMH Inc.

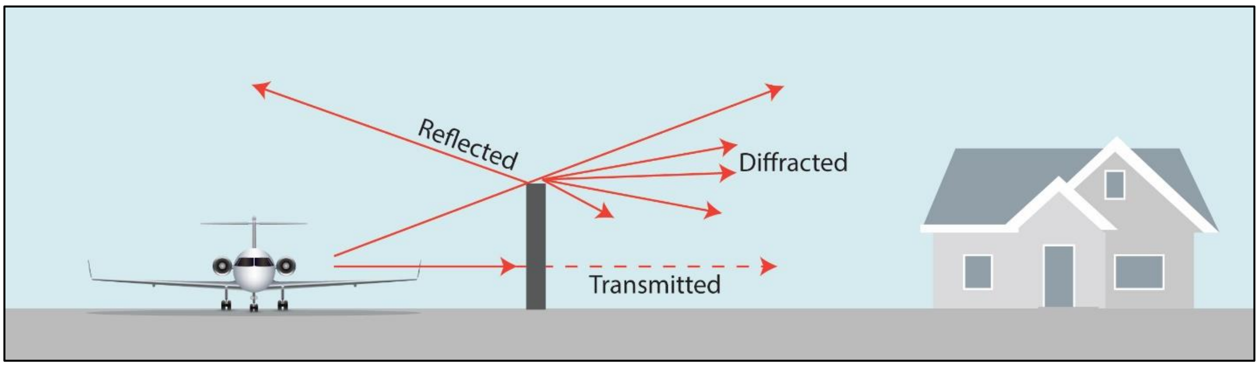
3. Noise Barriers

Noise can be reduced by implementing noise barriers. A noise barrier can be constructed with the specific intent of shielding the community beyond from source noise, or it can be a result of strategically placing buildings (i.e., hangars) or other structures (i.e., retaining walls) blocking the line of sight from the community to the sound source. Objects that are noise barriers include those that are relatively opaque to sound and block the line-of-sight from sound source to receiver, resulting in a sound shadow.

3.1 Barrier Basics

Noise barriers are only effective at reducing noise levels when the barrier blocks the line of sight between the source and receiver and the resulting sound path over the receiver differs significantly from the original sound path. The higher the barrier, the more the line-of-sight is blocked, the greater the path differences (i.e., the difference in distance that the unshielded path and the shielded path of sound has to travel), the greater the sound attenuation (reduction). Aircraft noise can be reflected off, transmitted through, and diffracted from noise barriers. Figure 2 illustrates the sound paths over and through a noise barrier.

Figure 2. Propagation of Noise with Barrier



Source: HMMH

Noise barriers will only perform adequately if they have a minimum surface density of four pounds per square foot, or a Sound Transmission Class (STC) rating of 25 dB or higher. Other than the material used to construct the noise barrier, gaps in noise walls need to be eliminated to the extent possible for a given barrier to be effective. For an adequately constructed noise barrier, the sound transmitted though the barrier is negligible. Masonry and concrete barriers are very common with post and precast panels often being most cost effective. These types of barriers also withstand wide varieties of weather and require little maintenance. Absorptive materials, such as those with metal paneling and incorporating absorptive materials, such as acoustic mineral wool, can be implemented to reduce the amount of sound reflected off a barrier.

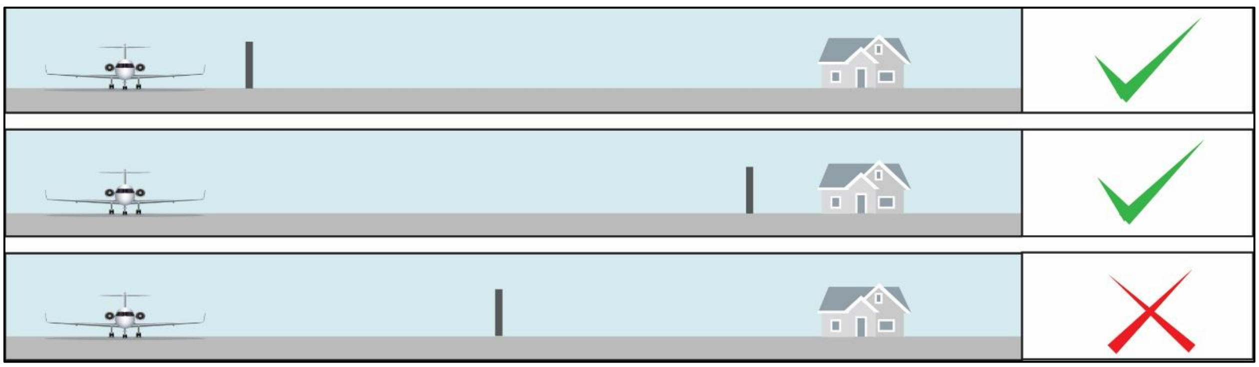
The maintenance free life cycle of a noise barrier as well as the maintenance dependent life-cycle of a noise barrier maintenance depends on several factors, predominantly what the barrier is constructed of and the environmental conditions where it is situated. For example, wooden noise barriers may perform as well initially as a post and panel concrete wall, but are more susceptible to weather damage in certain settings reducing their maintenance free life-cycle.

Over the maintenance dependent life-cycle, access to the noise barrier, availability of replacement parts, landscaping, graffiti, moisture deterioration, snow storage and snow drift are all factors to consider. Providing adequate space for maintenance is important to allow for maintenance crews access, typically 10-15 feet is sufficient. If a noise barrier is a custom-made feature, the availability of replacement parts will be sparse; therefore, it is generally best practice to construct noise barriers of standard materials so that maintenance may be performed. Moisture can result in wall deterioration, such as rust and decomposition of metal and wooden walls, reducing their life and making maintenance more frequent and costly, depending on barrier material. Native vegetation that is relatively maintenance free is often implemented near noise barriers to reduce the amount of time crews will need to keep areas landscaped. Snow being plowed into barriers may cause damage and should be considered in barrier design, both from the snow impacting the barrier during plowing and the resulting pressure of snow pressed up against the barrier. Similarly, snowdrifts may occur with snow accumulating at barriers that may inhibit airfield functions and require crews to remove the snow.

The amount of reduction that a noise barrier provides can be important when it comes to obtaining federal funding for implementation as noise mitigation. For example, FAA Order 5100.38D requires that a noise barrier reduce noise levels by 5 dB at incompatible land uses (e.g., residences within the 65dB DNL contours) in order to be eligible for AIP funding. Note that sound insulated residences are considered a compatible land use.

Careful placement of barriers is critical to their effectiveness. Figure 3 shows locations of noise barriers in relation to the source and receiver, with the green check marks being examples of where barriers can effectively shield noise and an example of where a noise barrier would not provide much shielding due to being far from the source and receiver. In practice, placing the barrier close to the noise source is most effective because it reduces sound levels for many receiver locations. Additionally, the barrier location would generally be on airport property.

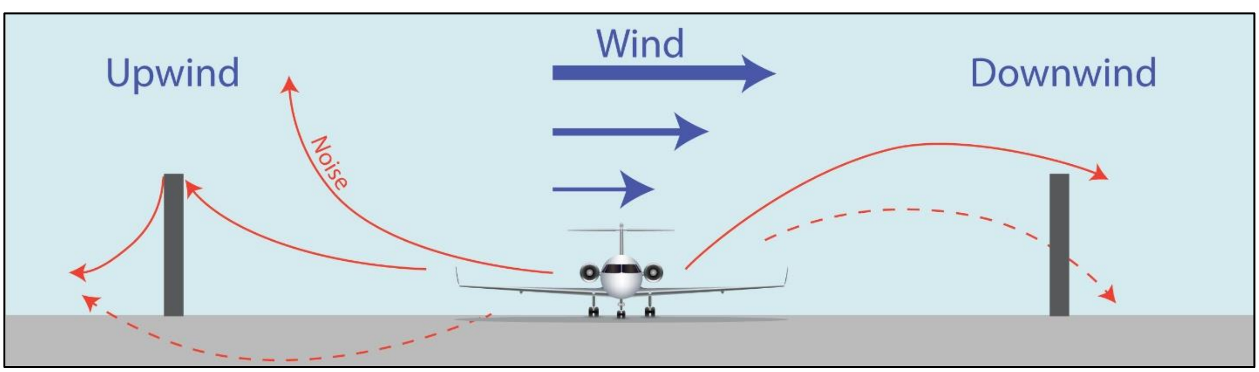
Figure 3. Noise Barrier Placement



Source: HMMH

As discussed in earlier, atmospheric effects of wind and temperature effect sound propagation, especially at distances of about 300 feet or greater from the source. For receptors within about 200 feet of a sound source, temperature and wind effects are less pronounced on barrier performance and the atmospheric conditions can be treated as homogeneous. Figure 4 depicts how wind can increase the effectiveness of barriers in the upwind direction and decrease their effectiveness in the downwind direction. The barrier can remain effective in the downwind direction if it is sufficiently close to the sound source.

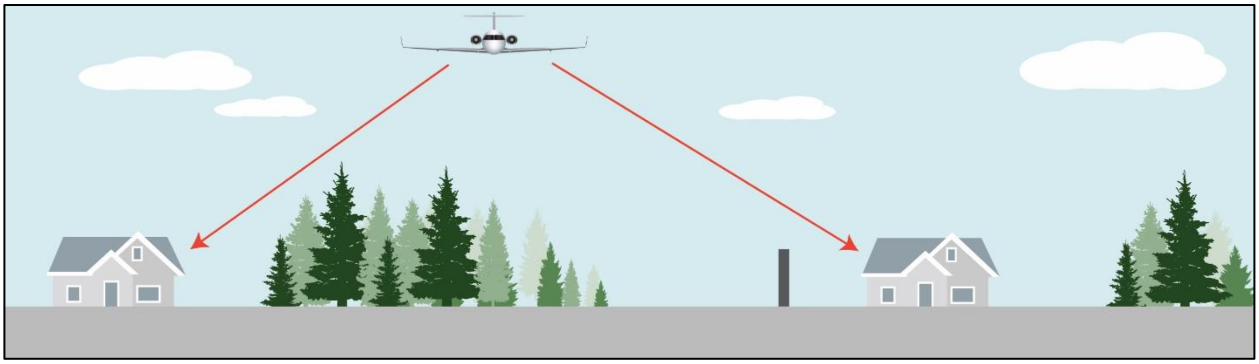
Figure 4. Wind Effects on Noise Barrier Effectiveness



Source: HMMH

Residents near airports commonly inquire about reducing all kinds of airport-related noise using barriers. However, elevated sources of noise, such as aircraft in flight, cannot be mitigated via sound barriers since the line of sight cannot be impeded. Figure 5 provides an illustration of this concept.

Figure 5. Elevated Sound Source

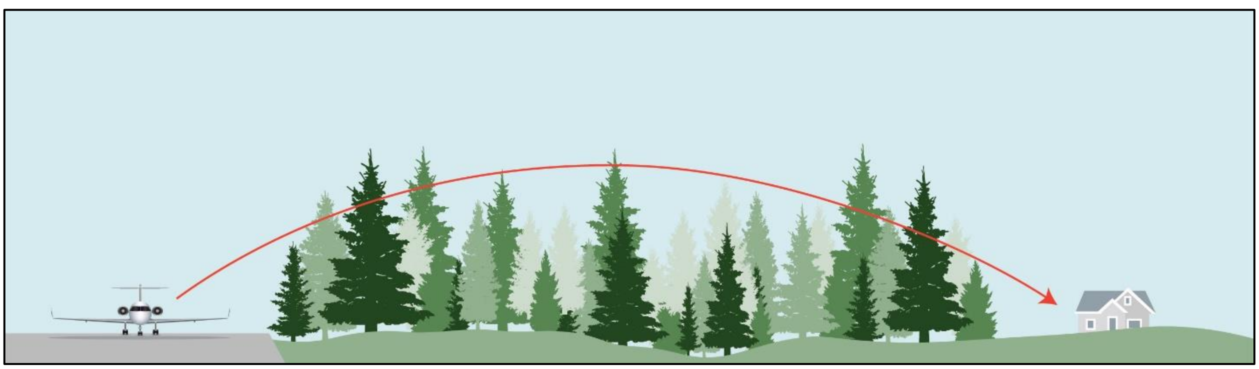


Source: HMMH

3.2 Vegetation as Noise Barrier

Vegetation does not generally meet the qualifications for an adequate sound barrier as outlined above. It may hide the source visually, but not reduce sound levels significantly. The general rule of thumb is that vegetated areas need to be sufficiently dense and cover a significant area (width between the source and receiver) to reduce noise levels. Specifically, it has been found that about 200 feet of continuous densely spaced vegetation is necessary to achieve 5 to 10 dB reductions. For this reason, it is uncommon that implementation of vegetation is feasible for noise reduction purposes. Figure 6 provides an illustration of noise from a taxiing aircraft propagating through a vegetated area. Note that much of the sound path may pass over the vegetation due to downward refraction.

Figure 6. Propagation of Noise through Vegetation



Source: HMMH

4. Applicable Standards

The sections below discuss literature regarding the acoustical attenuation provided by dense vegetation and the methods for computing this attenuation. HMMH looked into three documents, the International Standard ISO 9613-2, the General Prediction Method (GPM) and Leo Baranek's Noise and Vibration Control, Principles and Applications. HMMH judged the ISO Standard predictions of forest reduction to be more consistent with those of other highly-respected sound models such as Nord-2000 and the FHWA's Traffic Noise Model, which derived its calculations from the ISO Standard.

4.1 The International Standard ISO 9613-2

The International Standard ISO 9613-2[1], originally developed for industrial noise sources, ISO 9613-2 is well-suited for the evaluation of ground-based aircraft noise sources under favorable meteorological conditions for sound propagation. ISO 9613-2's methodology for calculating sound propagation includes geometric dispersion from acoustical point sources, atmospheric absorption, the effects of areas of hard and soft ground, screening due to barriers, and reflections. The attenuation provided by dense foliage varies by octave band and by distance as shown in Table 1. For propagation through less than 10 m of dense foliage, no attenuation is assumed. For propagation through 10 m to 20 m of dense foliage, the total attenuation is shown in the first row of Table 1. For distances between 20 m and 200 m, the total attenuation is computed by multiplying the distance of propagation through dense foliage by the db/m values shown in the second row of Table 1.

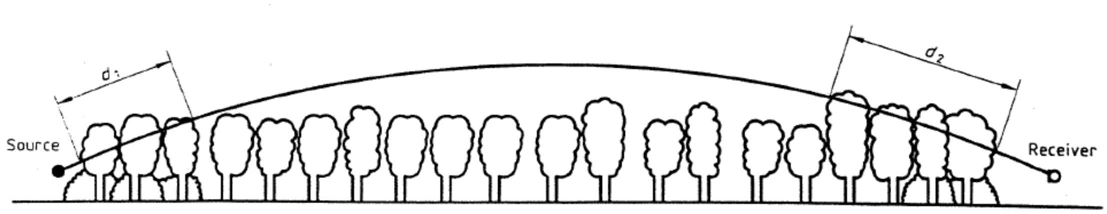
Table 1 Dense Foliage Noise Attenuation

Propagation Distance	Nominal Midband Frequency (Hz)							
	63	125	250	500	1,000	2,000	4,000	8,000
10 m to 20 m (dB/m Attenuation)	0	0	1	1	1	1	2	3
20 m to 200 m (dB/m Attenuation)	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.12

Source: ISO 9613-2, Table A.1

ISO 9613-2 assumes a moderate downwind condition. The equations in the ISO Standard also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights. In either case, the sound is refracted downward. The radius of this curved path is assumed to be 5 km. With this curved sound path, only portions of the sound path may travel through the dense foliage, as illustrated by Figure 7. Thus, the relative locations of the source and receiver, the dimensions of the volume of dense foliage, and the contours of the intervening terrain are essential to the estimation of the noise attenuation.

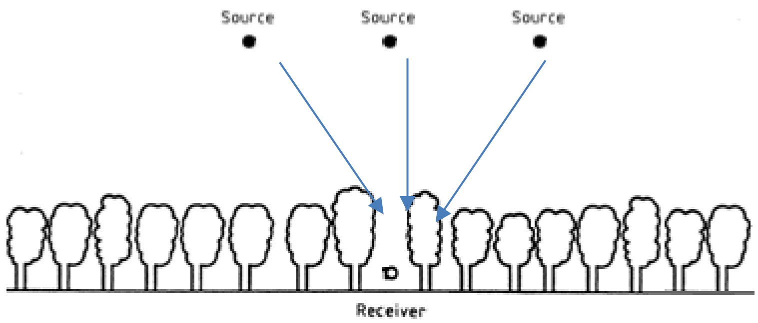
Figure 7 Downward Refracting Sound Path (source: ISO 9613-2)



As illustrated in Figure 7, the foliage only provides attenuation if the sound path passes through the foliage. Additionally, either the noise source or receiver must be near the foliage for it to have an effect. As shown in Figure 8, for aircraft in the air, the sound will pass through little, if any foliage.

[1] International Organization for Standardization, Acoustics – Attenuation of sound during propagation outdoors – Part 2: General Method of calculation, International Standard ISO9613-2, Geneva, Switzerland (15 December 1996).

Figure 8 Air to Ground Sound Propagation through Vegetation



Source: HMMH; adapted from ISO-9613-2

4.2 The General Prediction Method (GPM)

The General Prediction Method (GPM)[2] assumes moderate downwind conditions and a neutral temperature gradient, and also would hold for calm wind with a temperature inversion. Although use of either Standard provides a conservatively high estimate of community sound levels caused by ground-based airport sources, GPM provides an overly conservative estimate of noise reduction provided by a path through a forest, particularly in the presence of a long propagation path over acoustically soft ground.

4.3 Leo Baranek's Noise and Vibration Control, Principles and Applications

Another method found in the literature was a formula referenced in Leo Baranek's Noise and Vibration Control, Principles and Applications[3]. This predicts that the attenuation of heavy woods (must block sight and protrude by more than five meters above the line of sight) is frequency dependent and can have a maximum value of 10 dB. Another method, by C-F Fang, was derived from measurement in thirty-five uniform plantations[4]. The formula predicts attenuation based on visibility through the vegetation. Where visibility is as low as five meters, twenty meters of vegetation may provide 6 dB or more of attenuation. Note that shrubbery which was taller than the source provided the best attenuation. Both of these formulas required calibration to the particular forest and the literature search did not indicate that either had found wide usage.

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[2] ÖAL-Richtline nr 28 Schallabstrahlung und Schallausbreitung. Österreichischer Arbeitstring für Lärmbekämpfung, 1987 (Austrian Acoustical Society Report No. 28, "Sound Radiation and Sound Propagation").
[3] Verein Deutscher Ingenieure, "Schallausbreitung im Freien," (Outdoor Sound Propagation), Repret No. VDI 2714, VDI-Verlag GmbH, Dusseldorf, 1988.
[4] C.-F. Fang, D.-L. Ling, Investigation of the noise reduction provided by tree belts, Landscape and Urban Planning 63 (2003) 187–195.

Appendix G HMMH Letter: Proposal to Provide a Ground-Based Noise (GBN) Modeling Study

HMMH
300 South Harbor Boulevard
Suite 516
Anaheim, California 92805
www.hmmh.com

September 28, 2020

Michele Rodriguez
San Francisco International Airport Community Roundtable Coordinator
County of San Mateo
P: 415.309.1608
MRodriguez2@smcgov.org

Subject: Proposal to Provide a Ground Based Noise (GBN) Modeling Study

Reference: HMMH Proposal Number 20-0152

Dear Ms. Rodriguez:

HMMH is pleased to present this proposal to provide a Ground Based Noise (GBN) modeling study.

Scope of Work:

HMMH proposes to conduct GBN noise modeling of San Francisco International Airport (SFO) utilizing a software program called SoundPLAN[1]. In order to conduct the initial GBN noise modeling, we will need the following GIS data:

- Current Airport Layout Plan (ALP)
  - Should include runway end and taxiway coordinates and elevations, threshold crossing heights and taxiway positions, and displaced thresholds and glideslope for each runway end
  - Should include on airfield surface type identification (i.e. concrete, grass, rubber, etc.)
- On and Off Airport Building Footprints and Heights
- Surrounding Roadway Centerlines

HMMH proposes to conduct the following modeling scenarios. The two (2) aircraft types shall be determined by the SFO Aircraft Noise Abatement Office (ANAO) and should be based on the most frequent and loudest aircraft departing Runway 1L/1R. HMMH will then determine if we have measured and modeled spectral and directivity information for those aircraft. The location, types, heights and thickness of the vegetation will be provided to us by the client.

Scenario 1 – 2 Aircraft Types Departing Runway 1L at Start of Takeoff Roll – Without and With Vegetation

Scenario 2 – 2 Aircraft Types Departing Runway 1R at Start of Takeoff Roll – Without and With Vegetation

Scenario 3 – 2 Aircraft Types Departing Runway 1L at Secondary Takeoff Point – With and Without Vegetation

Scenario 4 – 2 Aircraft Types Departing Runway 1R at Secondary Takeoff Point– With and Without Vegetation

Scenario 5 – 2 Aircraft Types Departing at the Same Time but Staggered on Runway 1L and 1R – With and Without Vegetation

Scenario 6 – 2 Aircraft Types Departing Runway 28L or Runway 28R at Secondary Takeoff Point – With and Without Vegetation

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[1] https://www.soundplan.eu/english/

The model will output the following information:

- Maximum noise Level (Lmax) noise contours
- Unweighted spectral noise values at up to 12 receiver points

Utilizing the noise modeling outputs, HMMH will create Lmax noise contour figures overlaid over a basemap and receiver point tables to be incorporated into the technical memorandum.

HMMH proposes to create a technical memorandum that provides a statement of purpose and details of the noise modeling results. The technical memorandum will general GBN information based on the literature review already prepared for and presented to the GBN subcommittee. Finally, the technical memorandum will make a recommendation to the GBN subcommittee on next steps.

Cost Estimate and Delivery:

HMMH can perform the scope of work described above on a time and materials basis utilizing our previously agreed upon contractual hourly rates and for a Not-To-Exceed (NTE) amount of $50,000.

hmmh

It is estimate that HMMH can complete the noise modeling and technical memorandum within a period of 30-45 business days provided we receive all of the GIS data requested and final determination by the GBN subcommittee of things such as the location, types, heights, and thickness of vegetation.

We will not exceed this amount without your prior written consent. Please note that this proposal is valid for a period of 60 days from the date of this letter.

If this proposal and our Standard Terms & Conditions are acceptable to you, you may accept it by signing below, and then HMMH will return a countersigned copy to you to serve as our contractual agreement. We are prepared to begin work on this project within two (2) weeks of receipt of a signed agreement, or an alternative contracting mechanism.

Thank you for the opportunity to submit a proposal for the subject project. We very much look forward to the opportunity to assist you with this interesting project. Please feel free to contact me if you have any questions or concerns about this proposal.

Sincerely yours,

Harris Miller Miller & Hanson Inc. d/b/a/ HMMH

Justin W. Cook

Justin W. Cook - INCE, LEED GA
Principal Consultant

Note: Once we come to agreement on the terms for these services, Mary Ellen Eagan, President and CEO, will need to sign the contract and/or task order(s) to bind HMMH.

cc: Gene Reindel

Appendix H Enlarged Noise Contour Figures

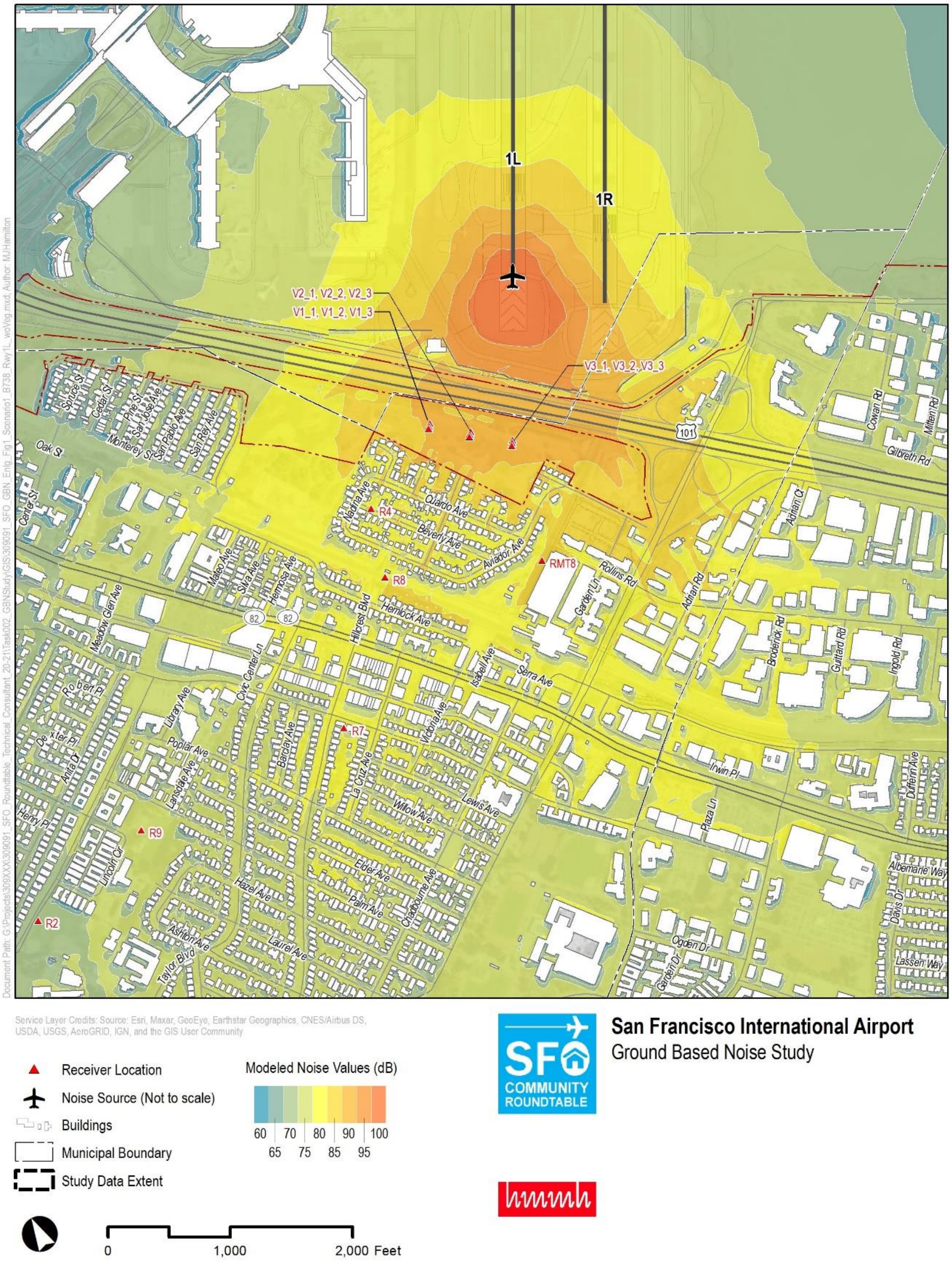


Figure H-1: Scenario 1 – B738 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

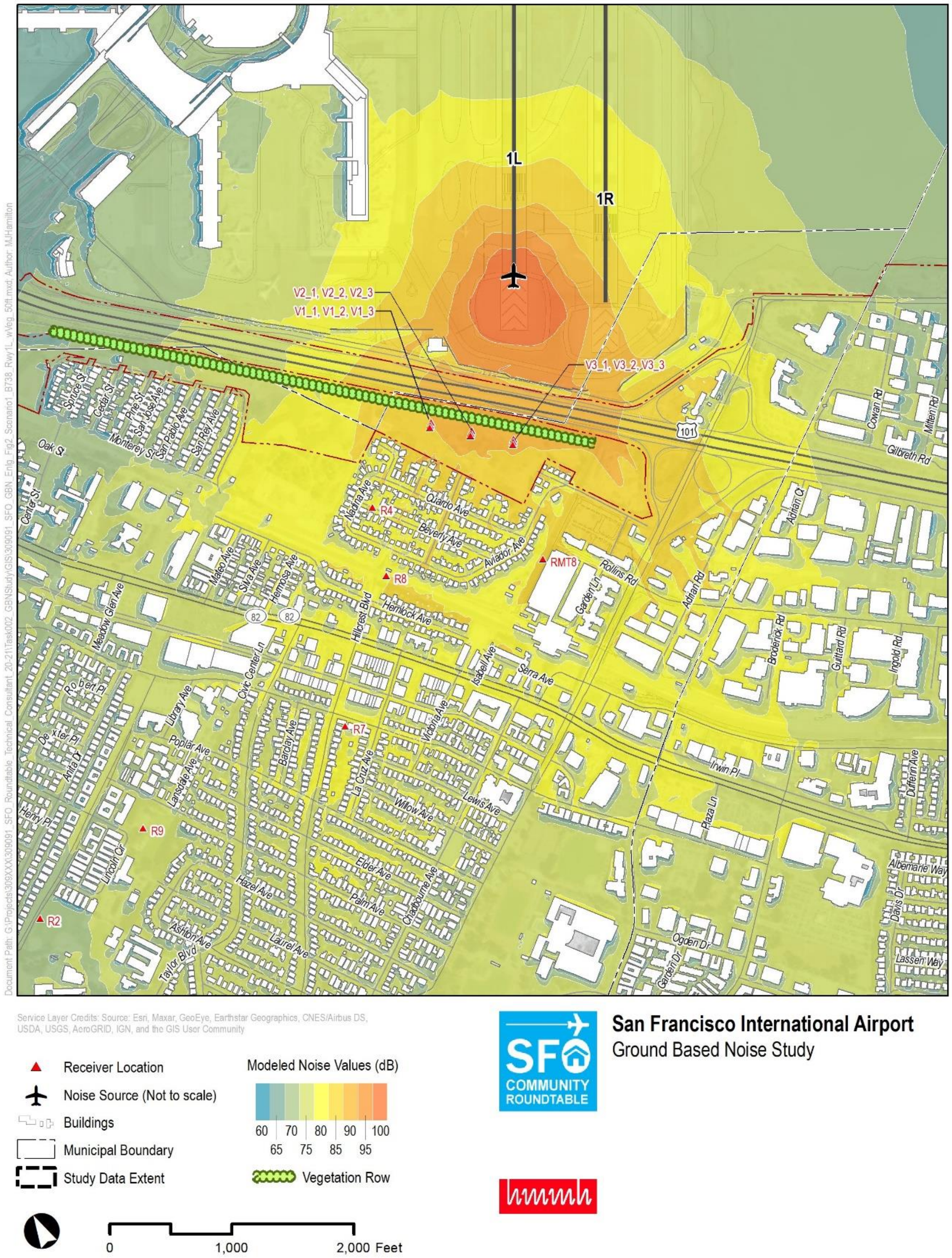


Figure H-2: Scenario 1 – B738 Departing Runway 1L at Start of Takeoff Roll – With Vegetation (50 Feet)

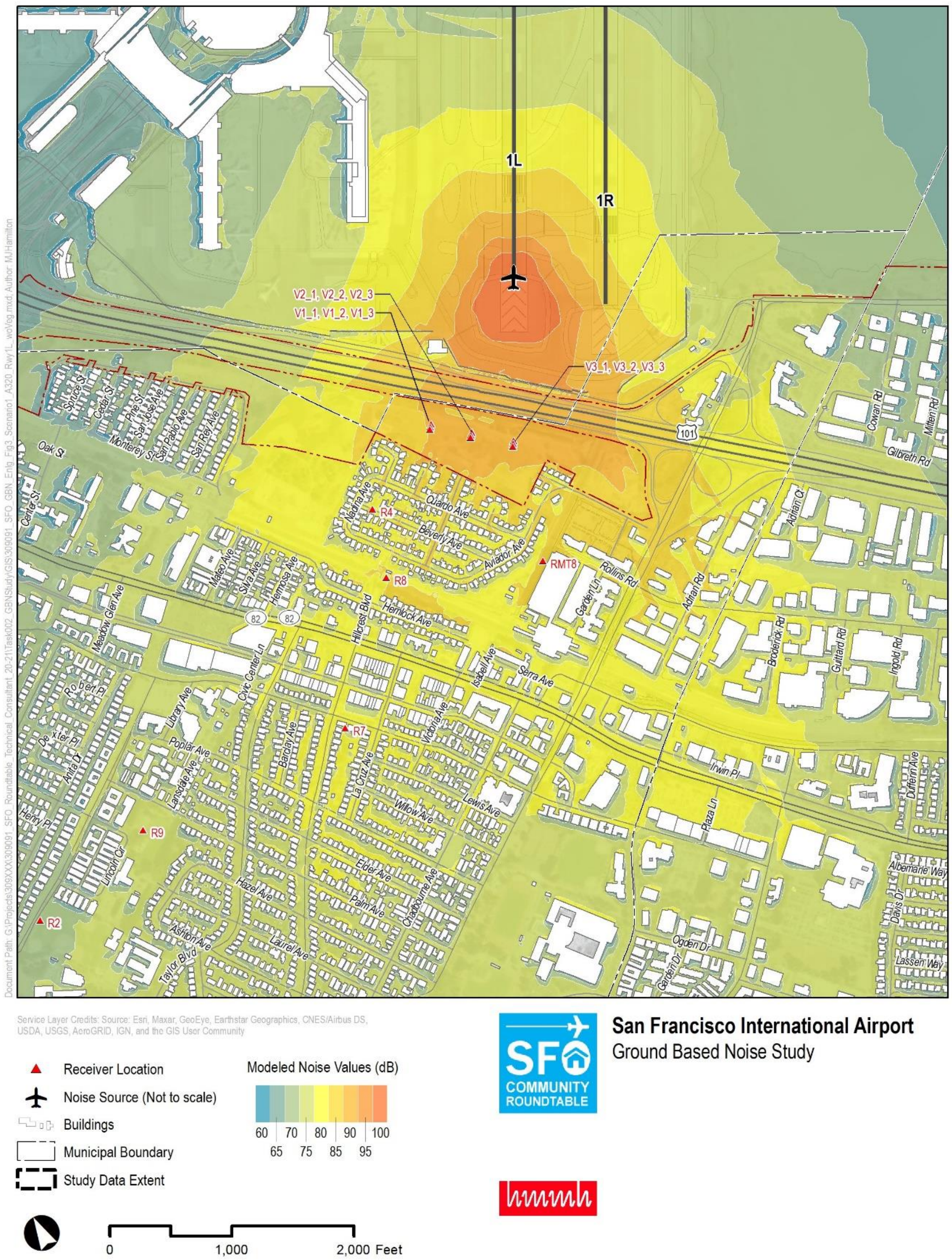


Figure H-3: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

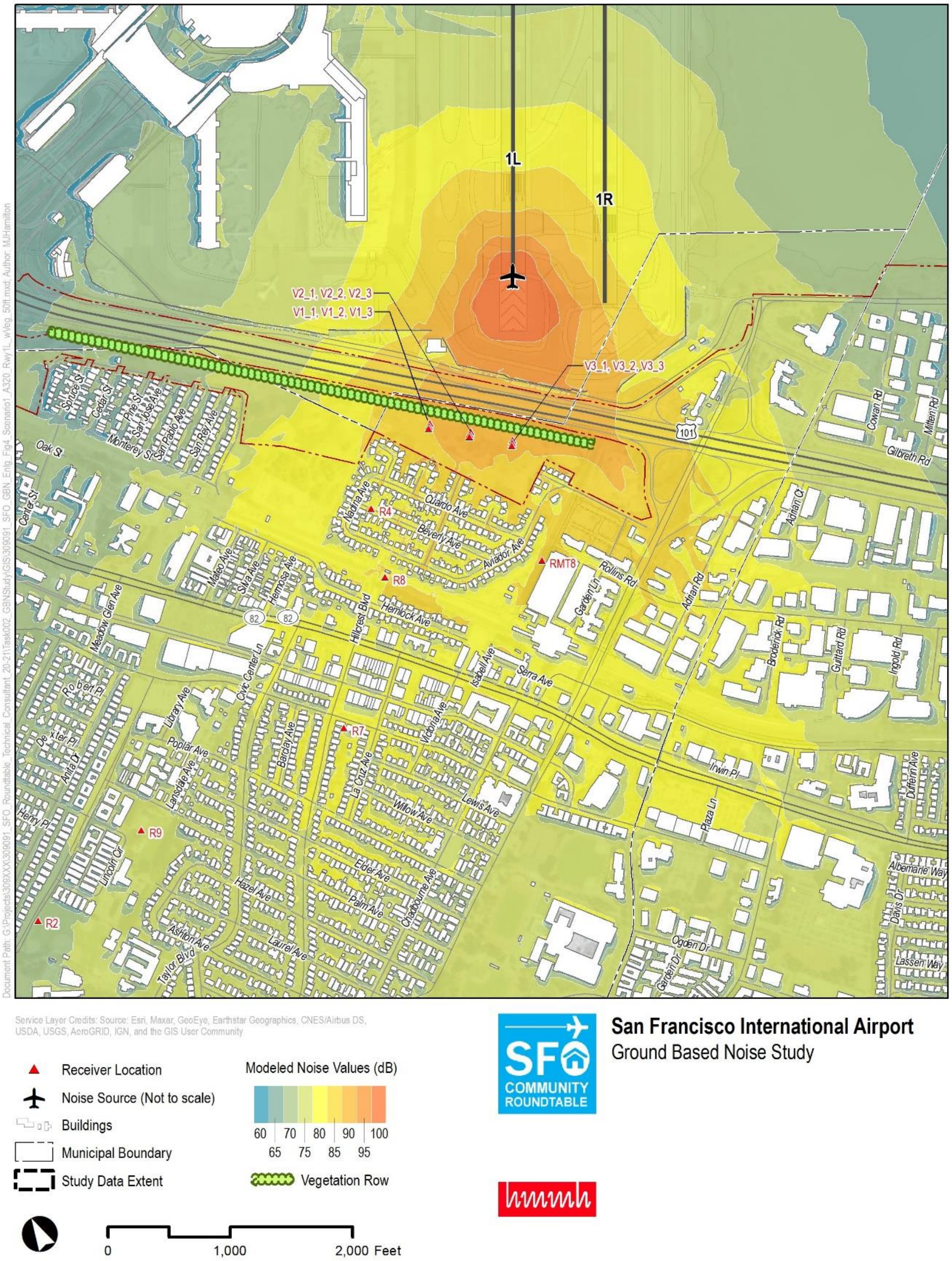


Figure H-4: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – With Vegetation (50 Feet)

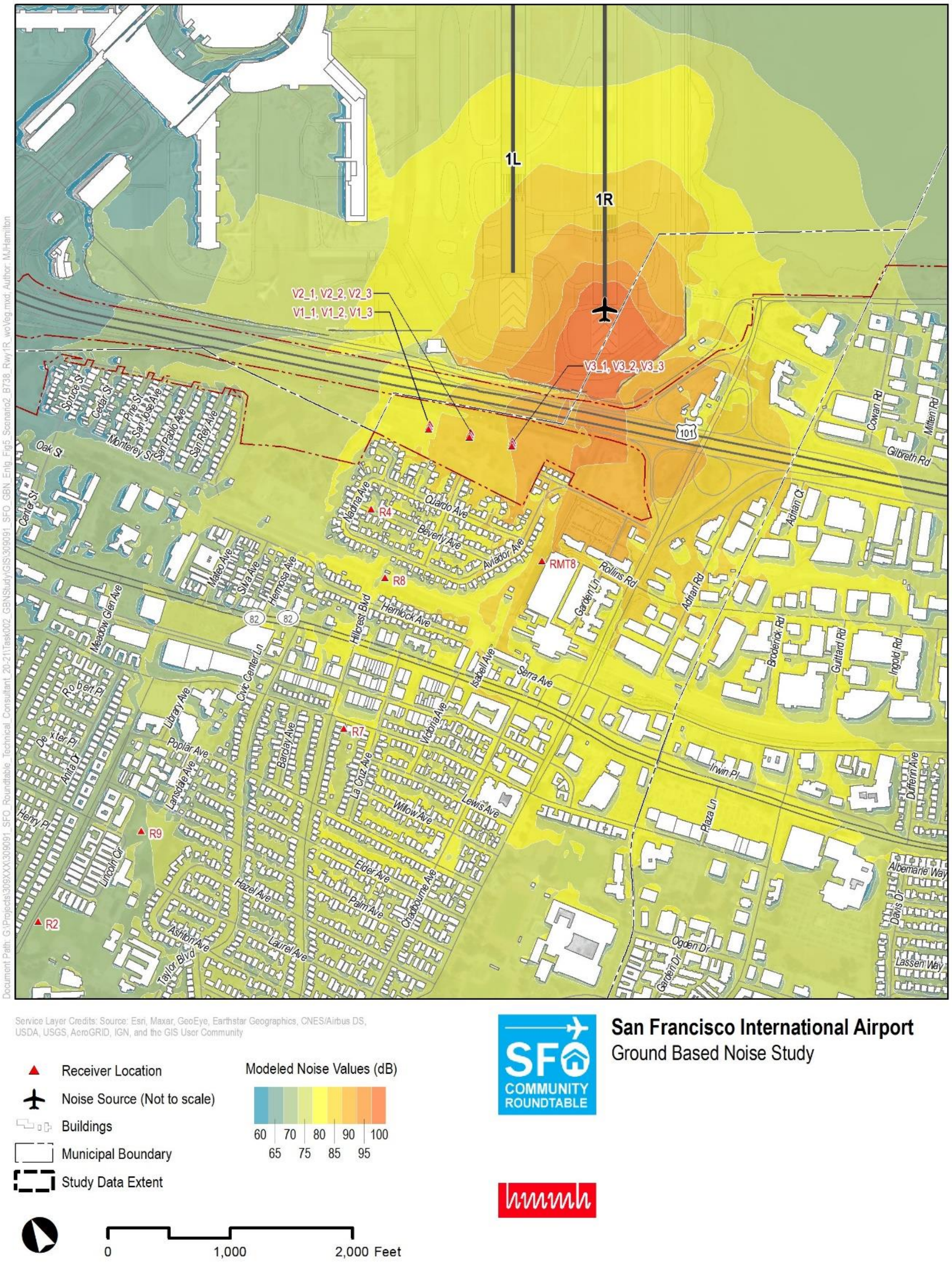


Figure H-5: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation

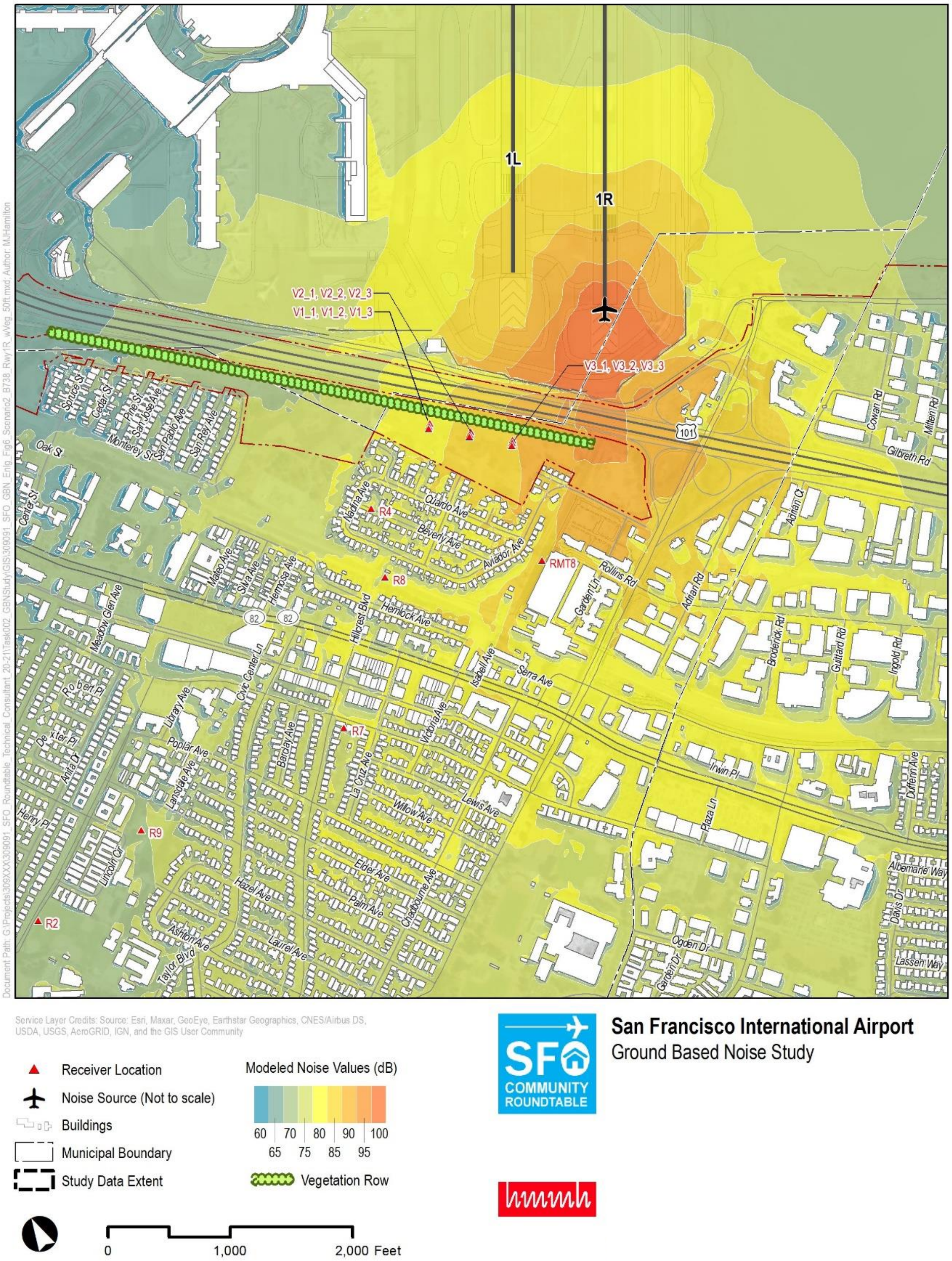


Figure H-6: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

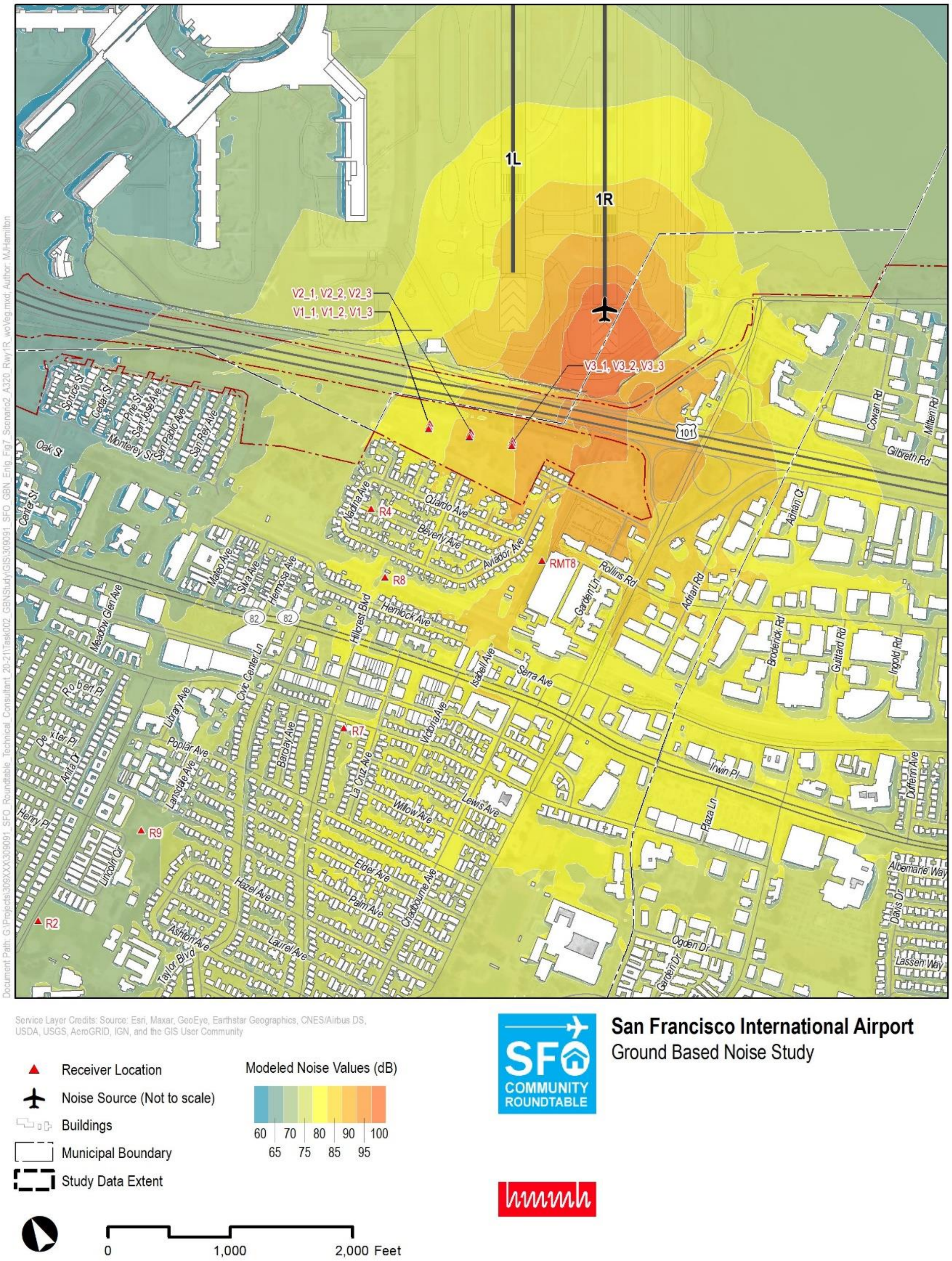
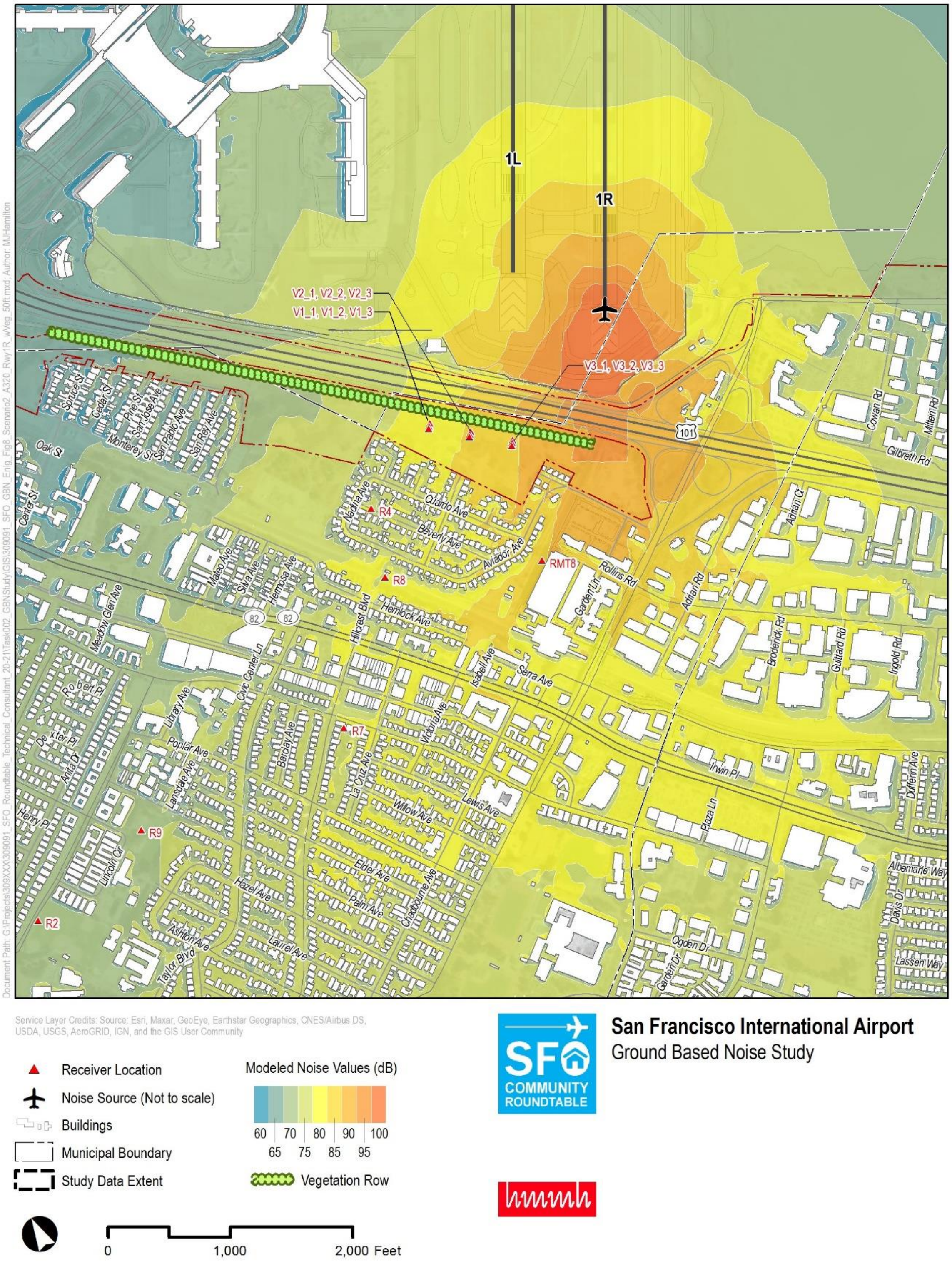


Figure H-7: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation



San Francisco International Airport
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Figure H-8: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

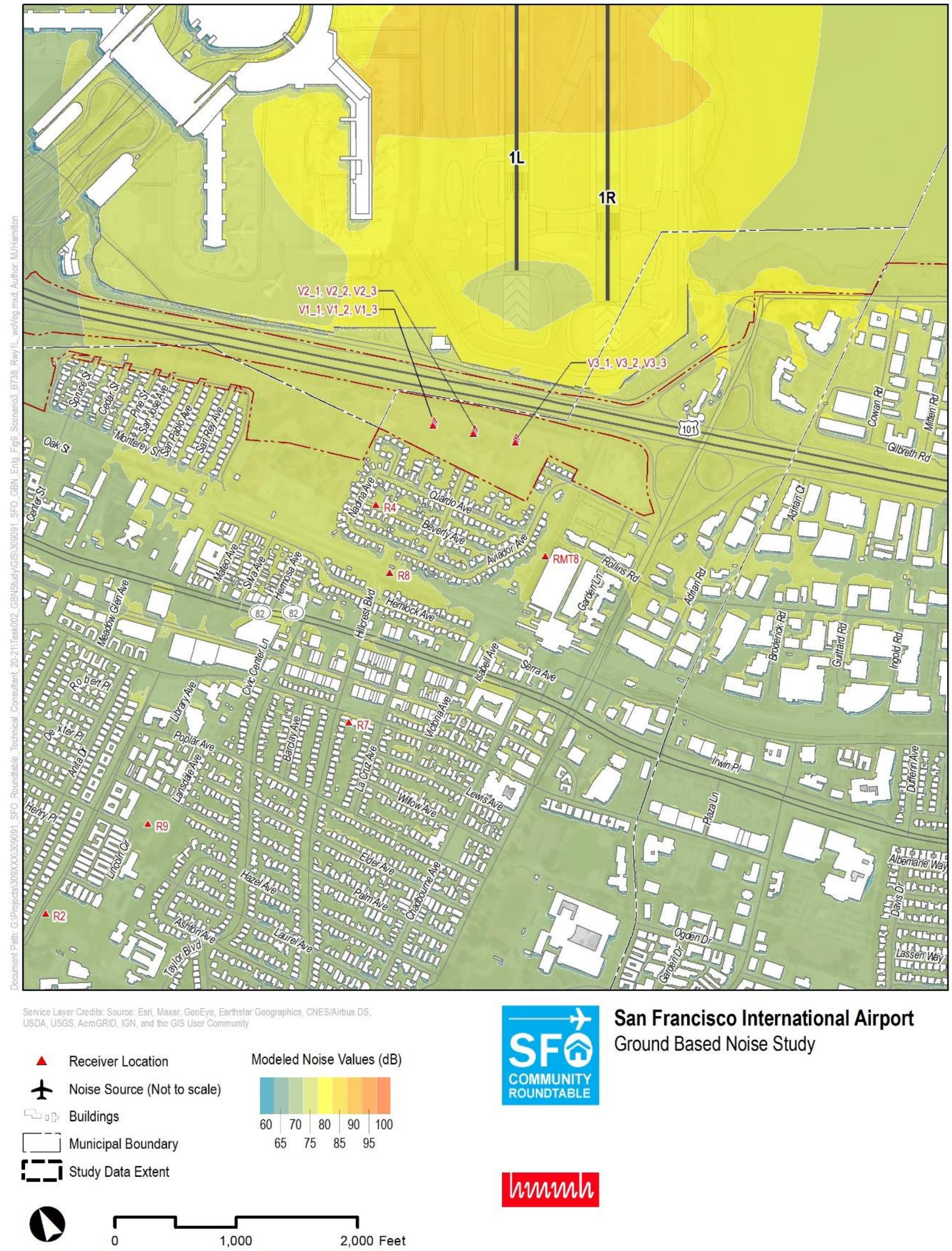

Figure H-9: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

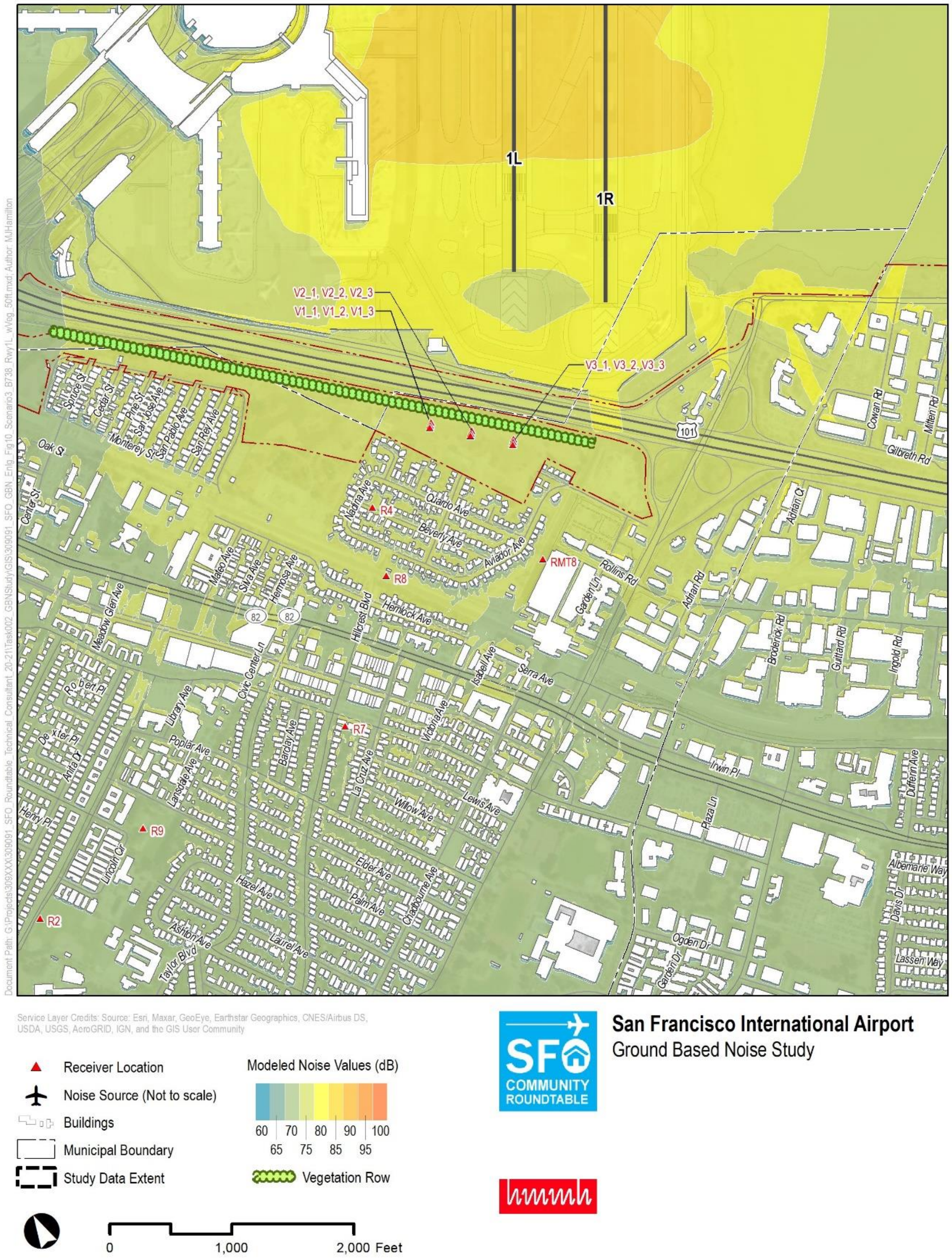

Figure H-10: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

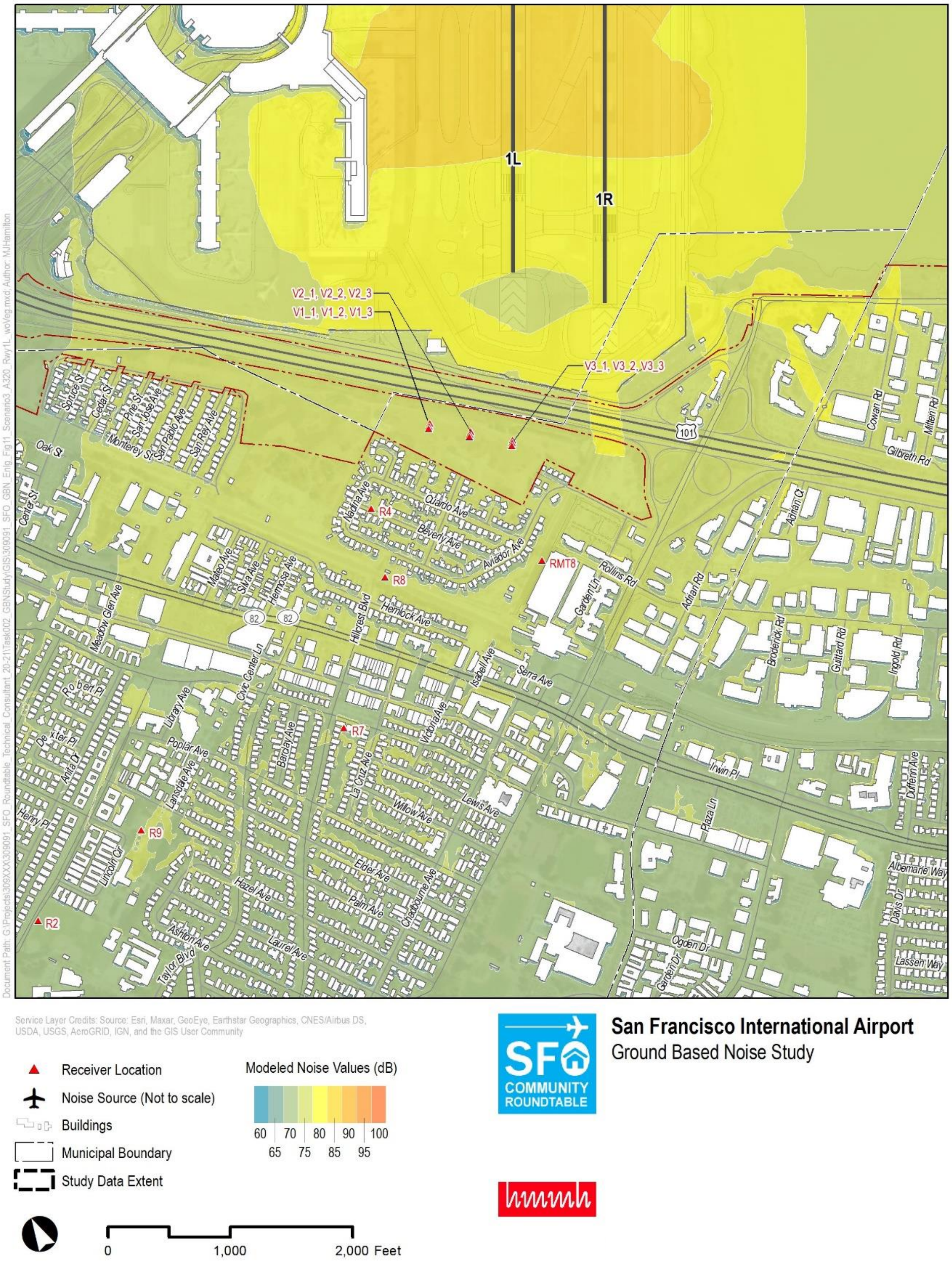

Figure H-11: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

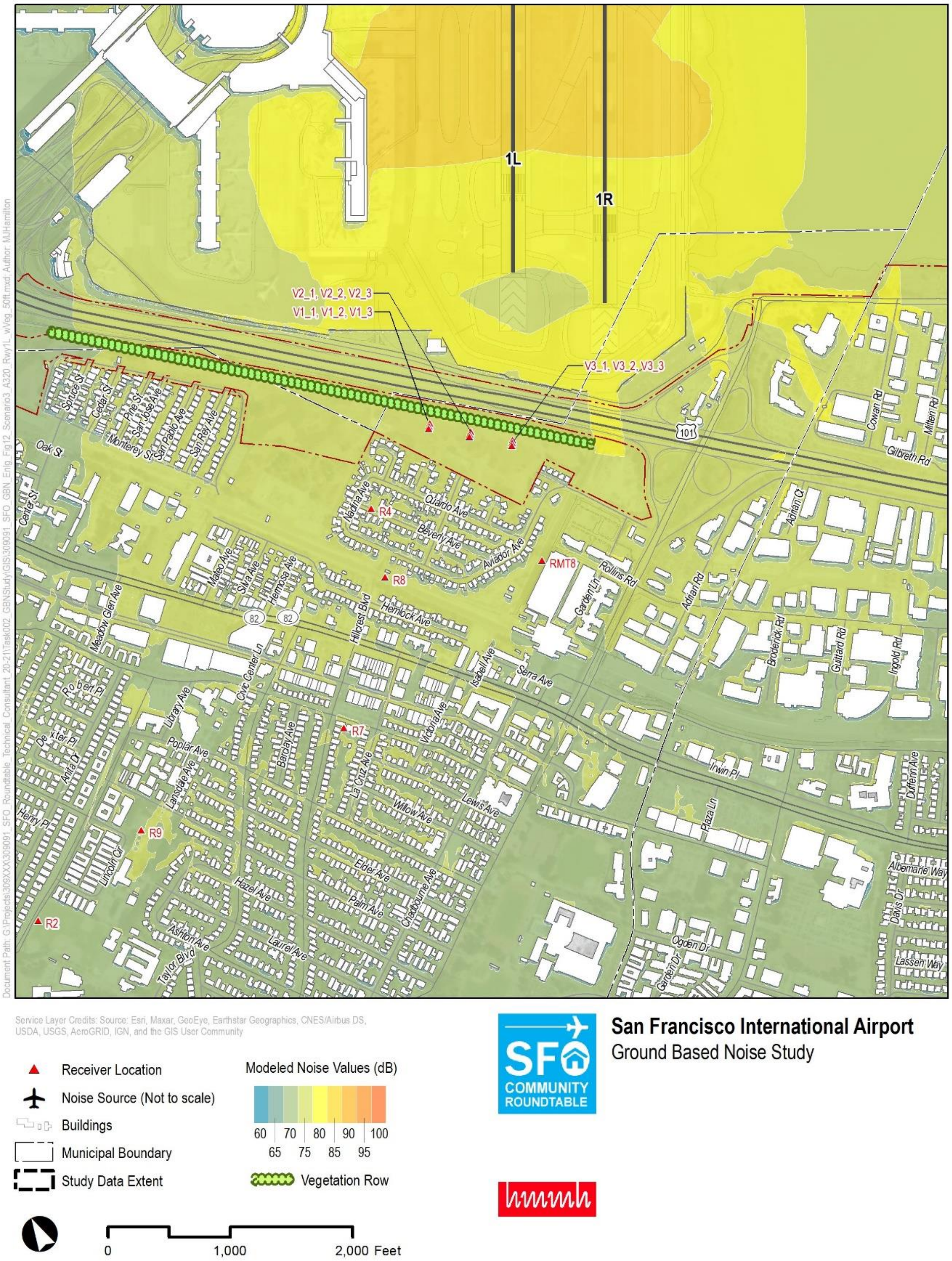

Figure H-12: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

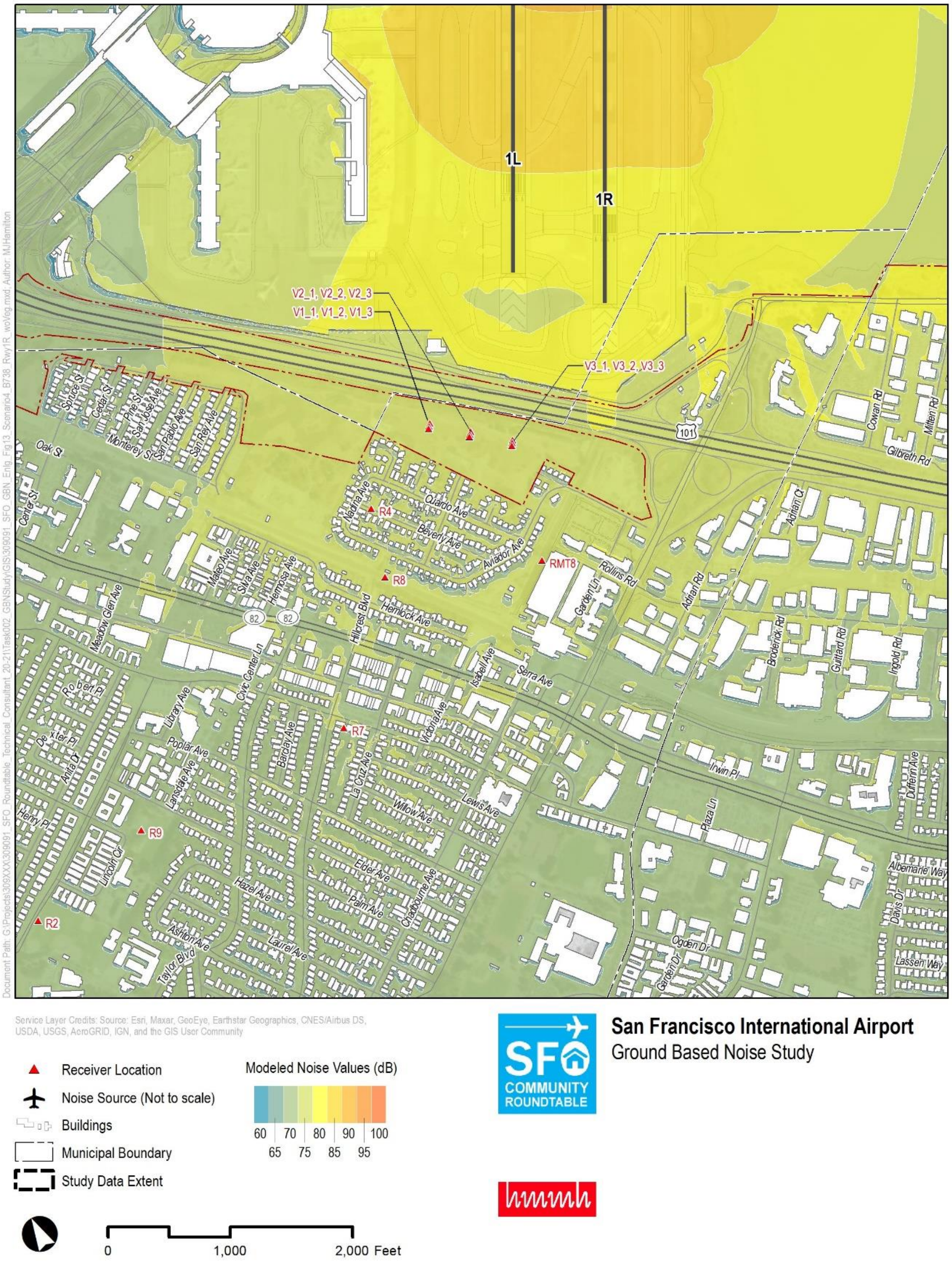

Figure H-13: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

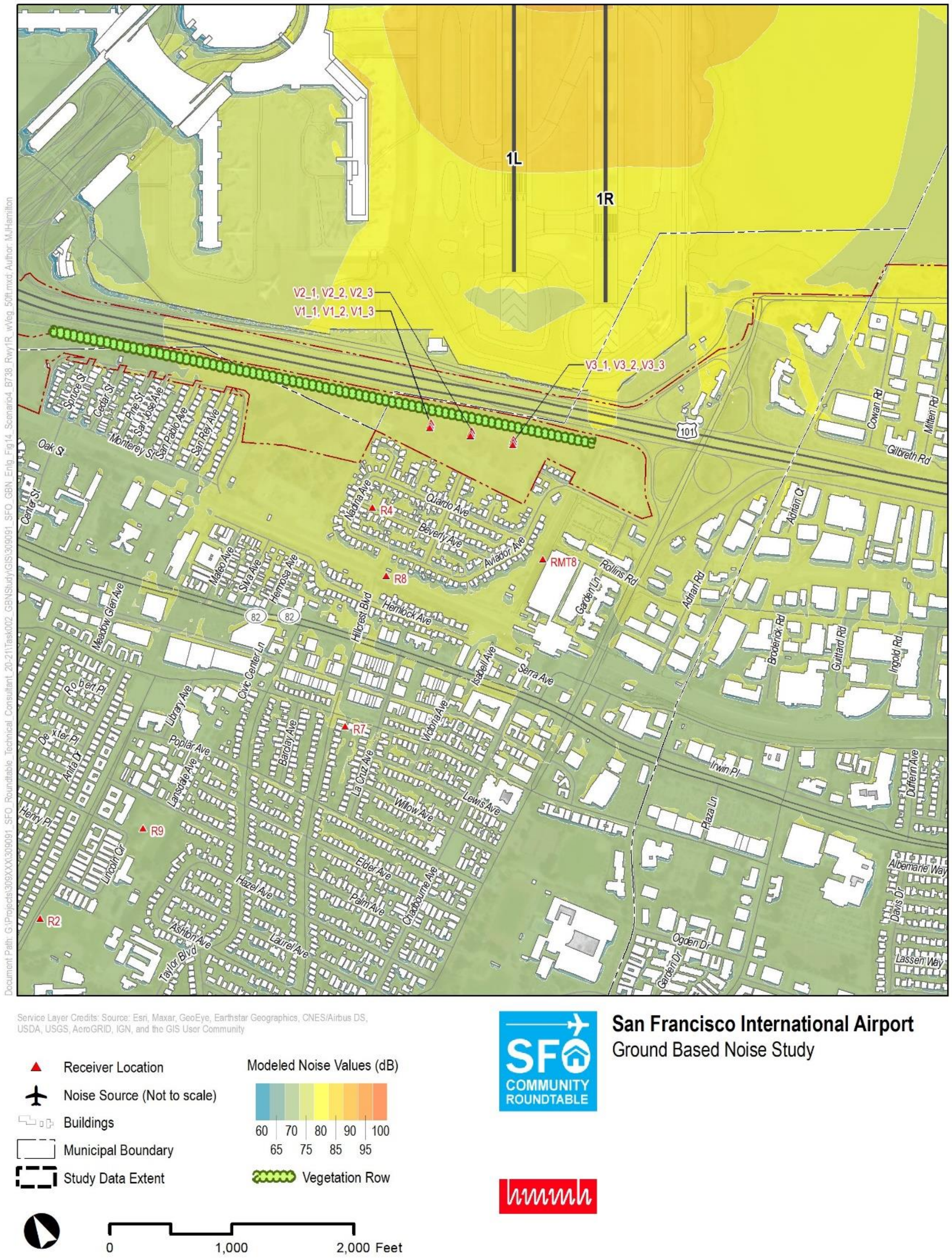

Figure H-14: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

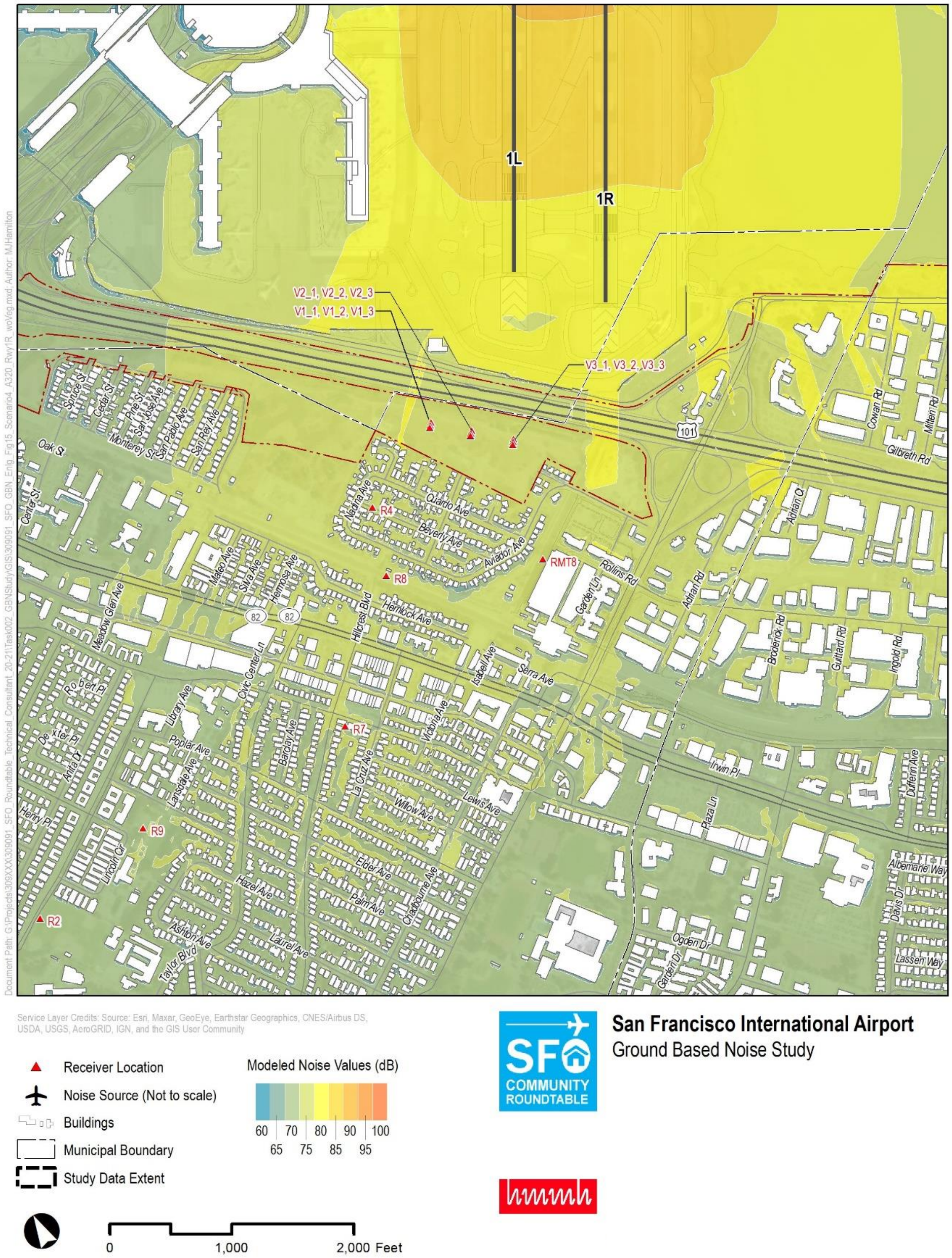

Figure H-15: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

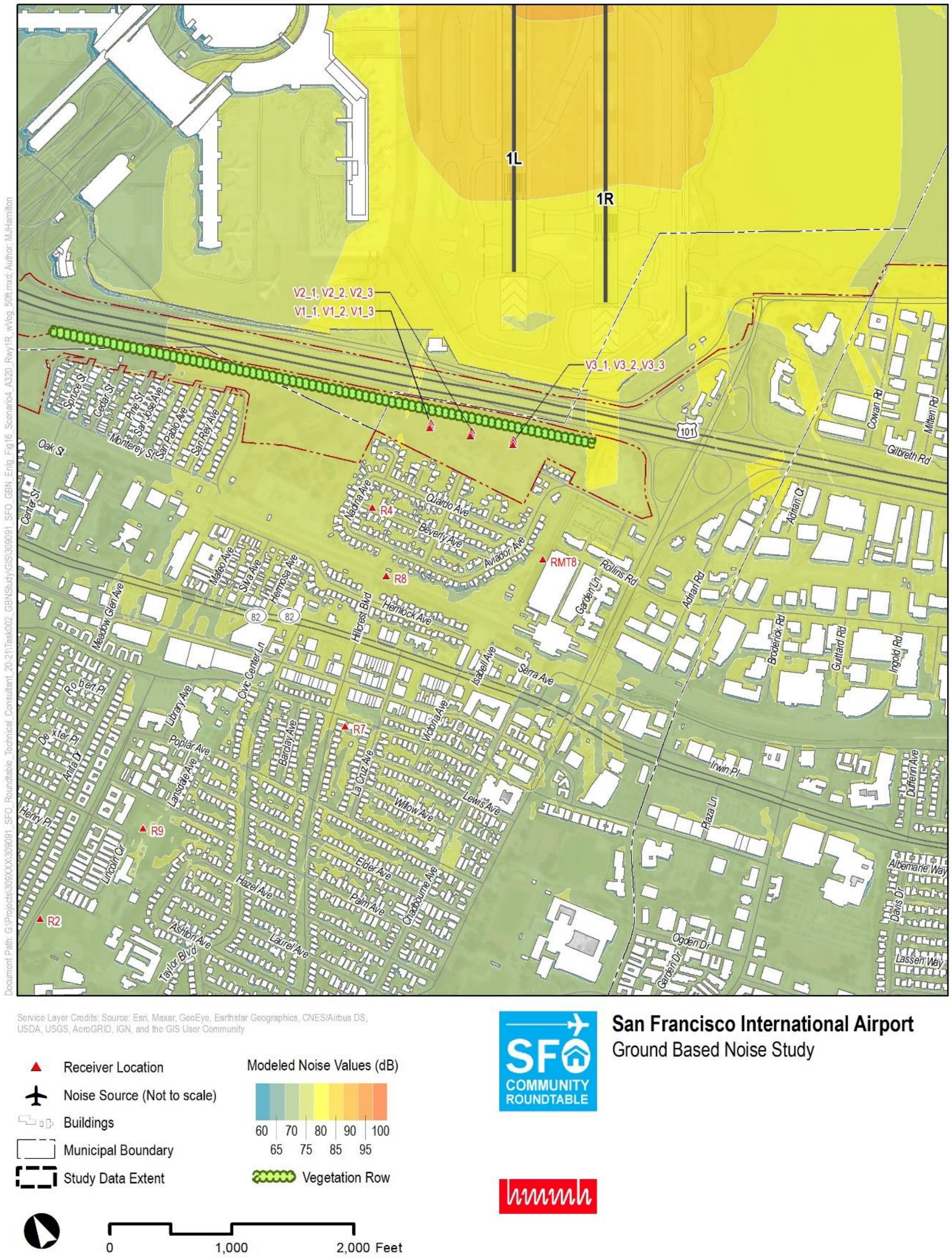

Figure H-16: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

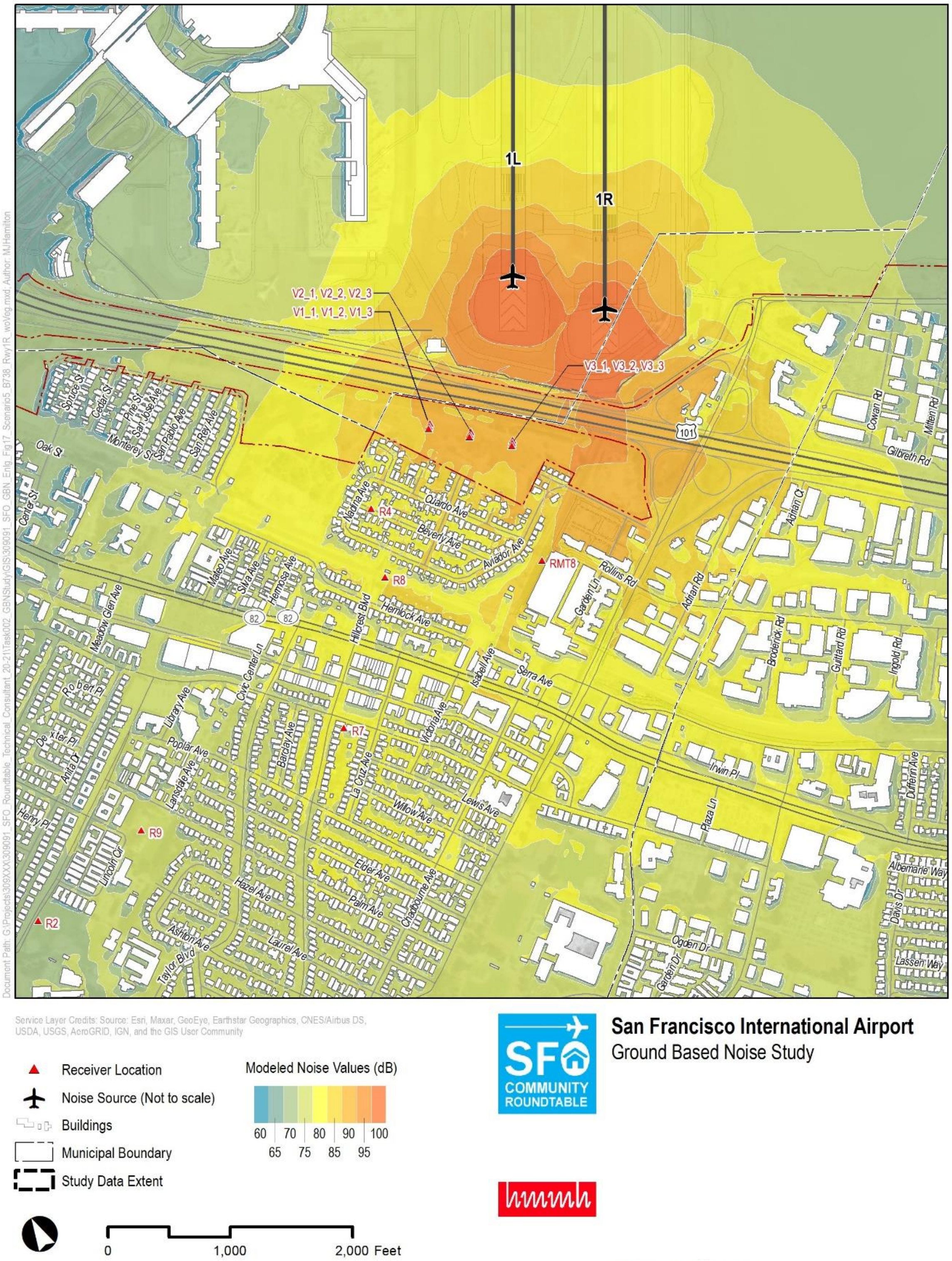

Figure H-17: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

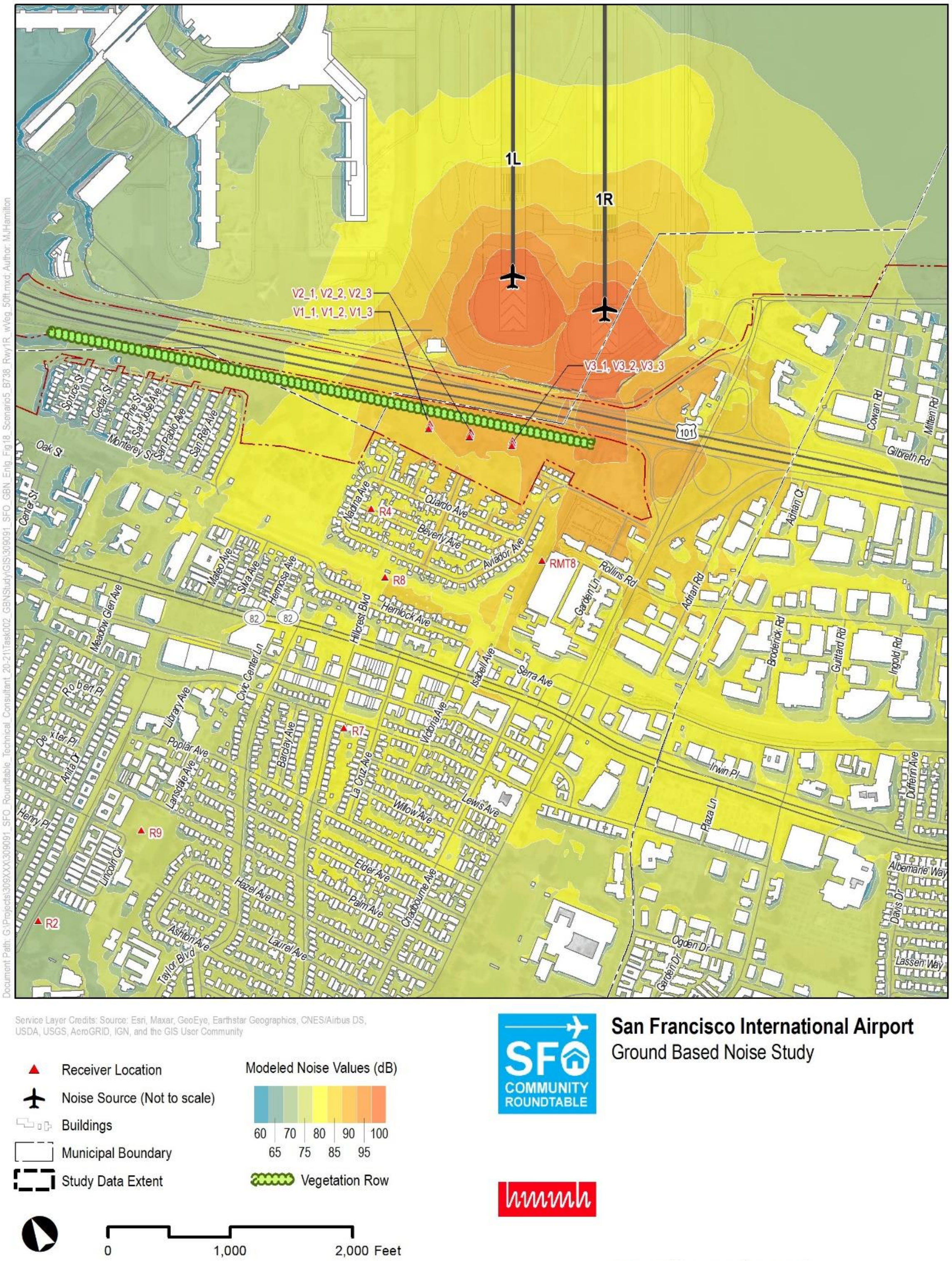

Figure H-18: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

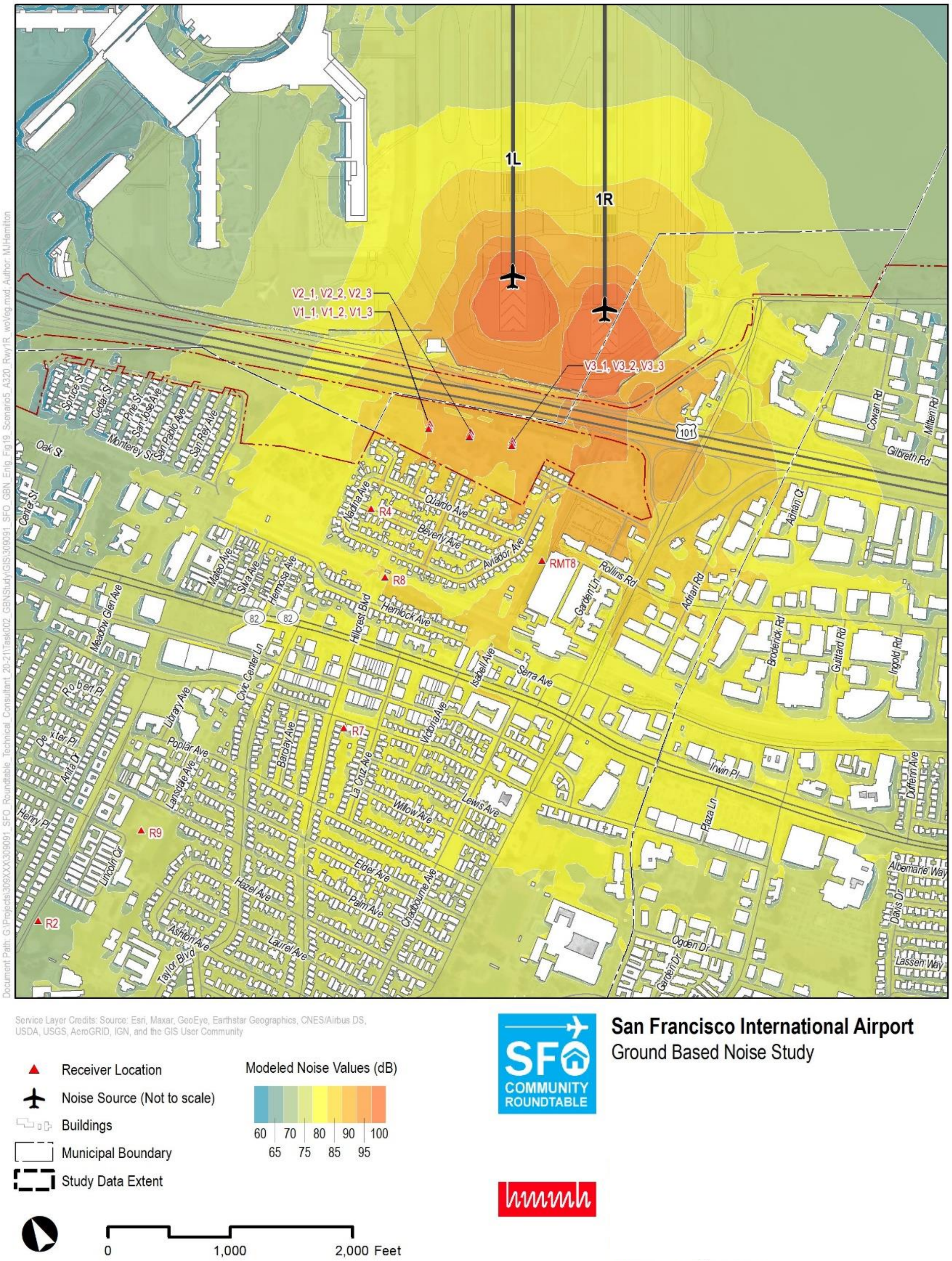

Figure H-19: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

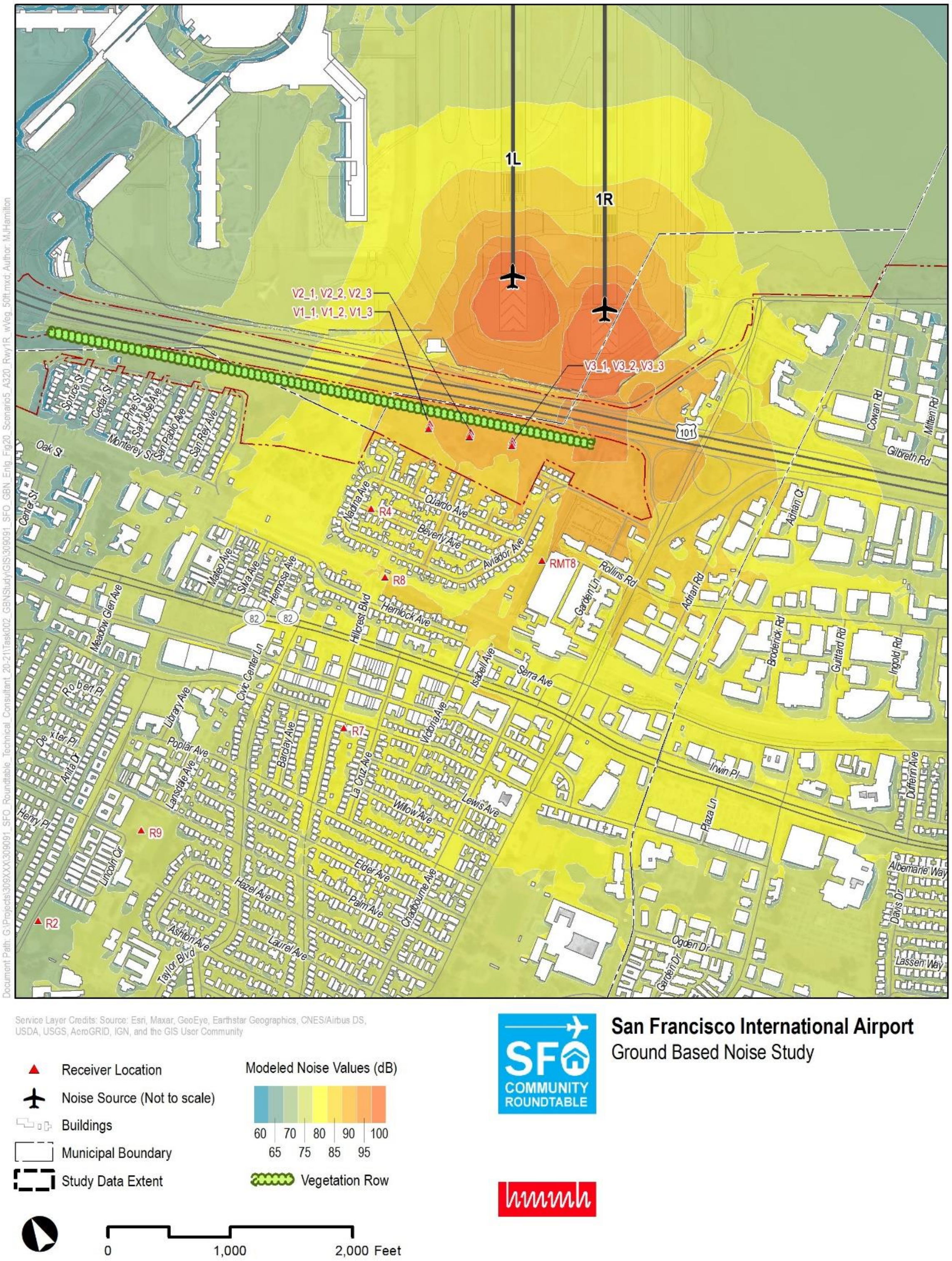

Figure H-20: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

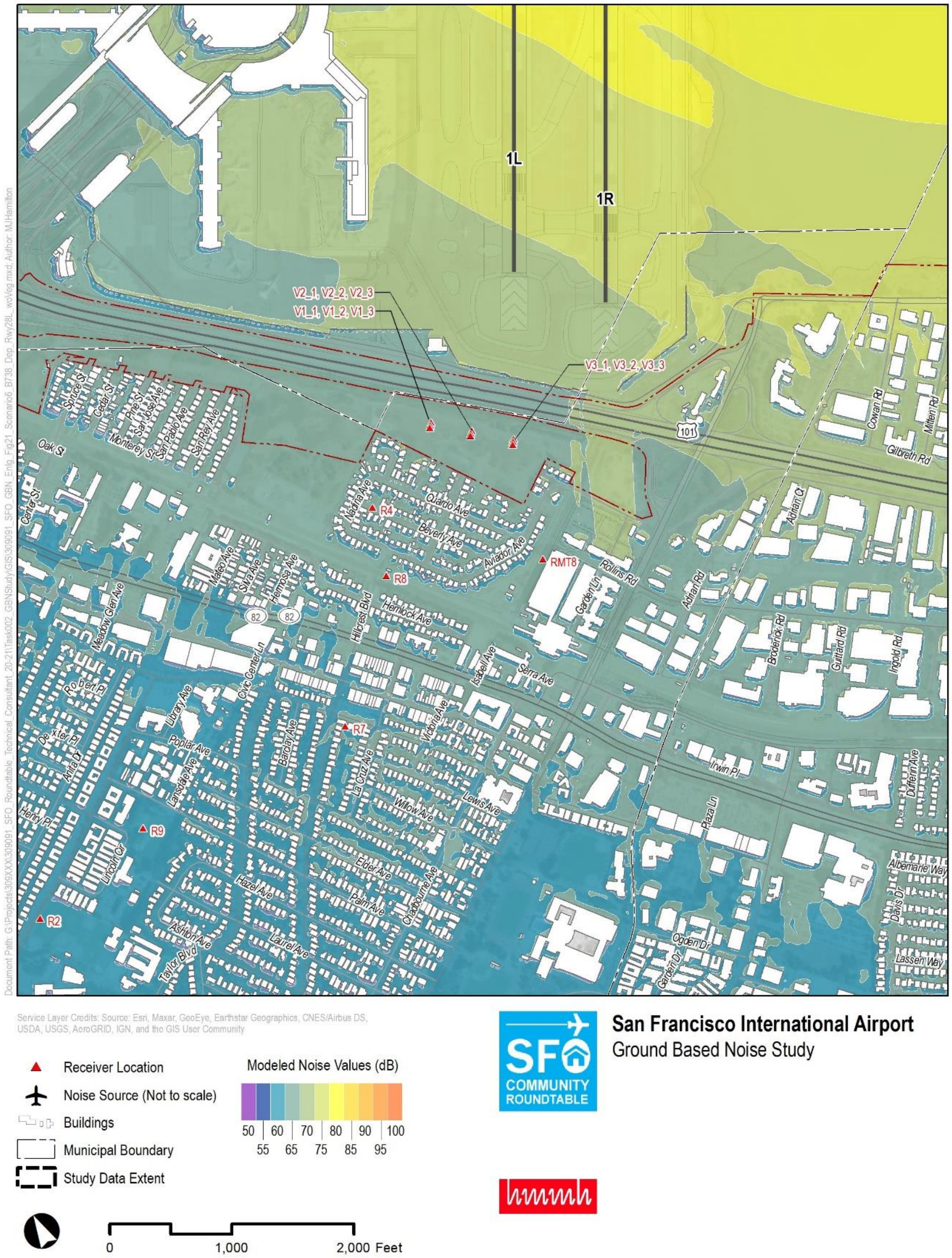

Figure H-21: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – Without Vegetation

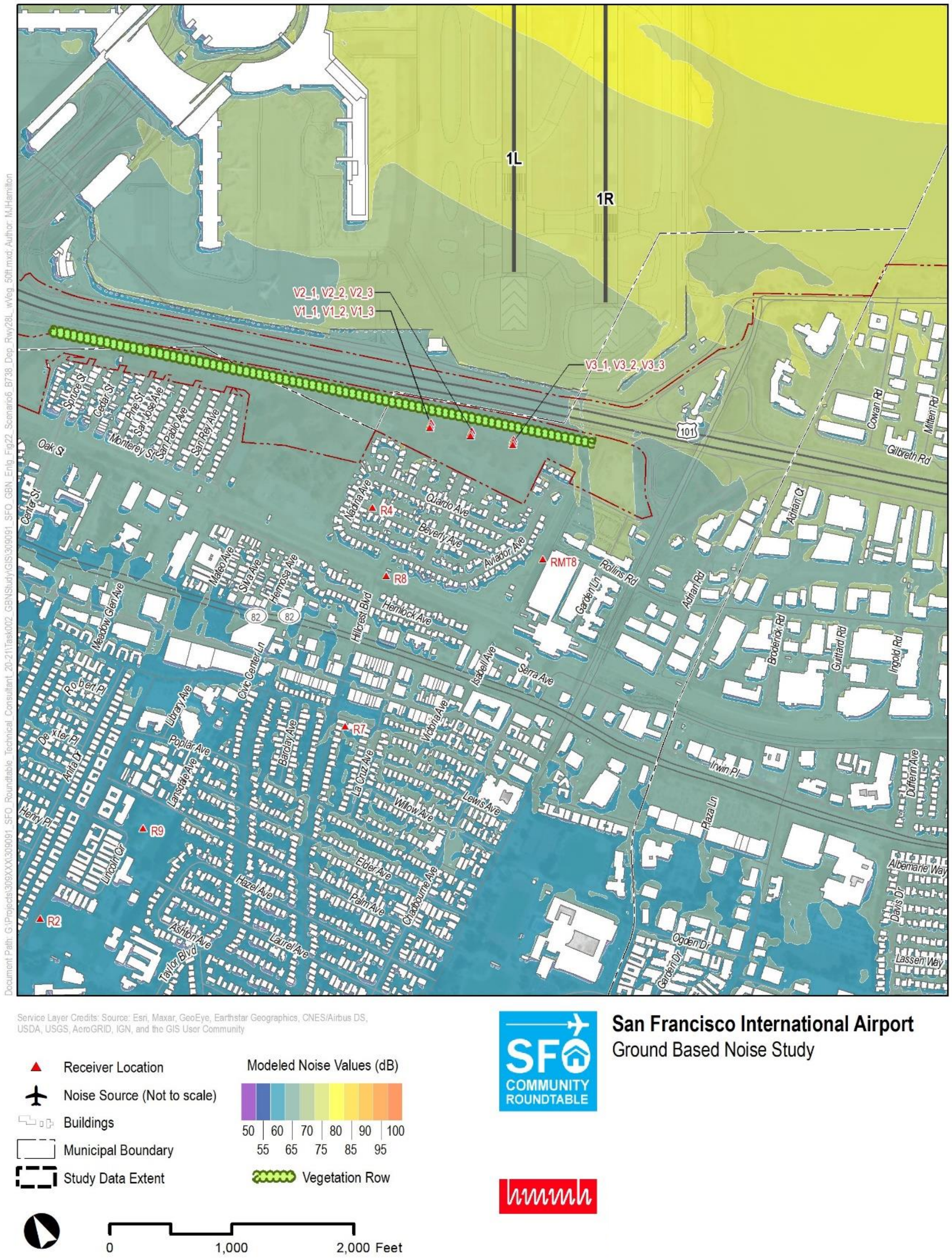

Figure H-22: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – With Vegetation (50 Feet)

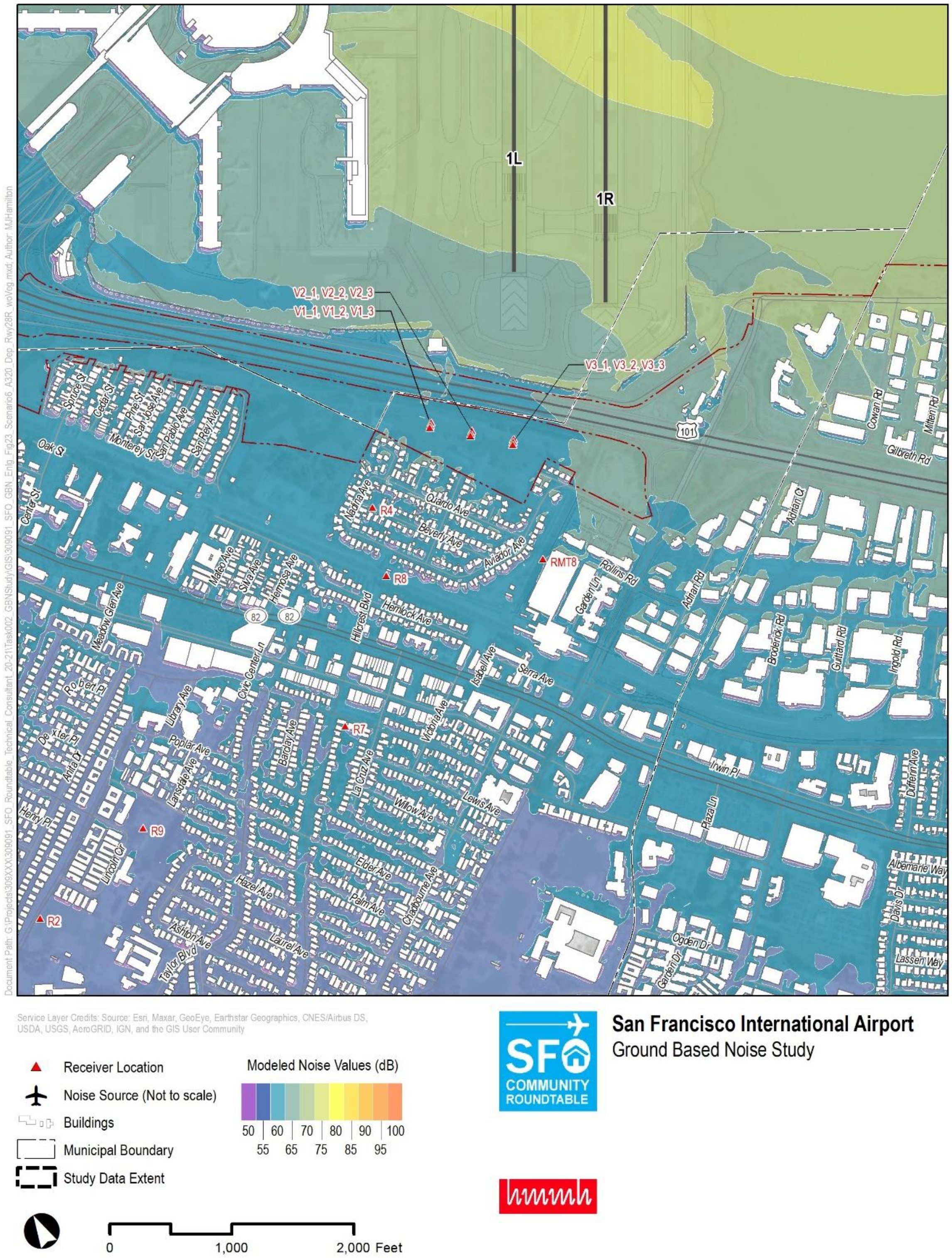

Figure H-23: Scenario 6 – B738 Departing Runway 28R at Secondary Takeoff Point – Without Vegetation

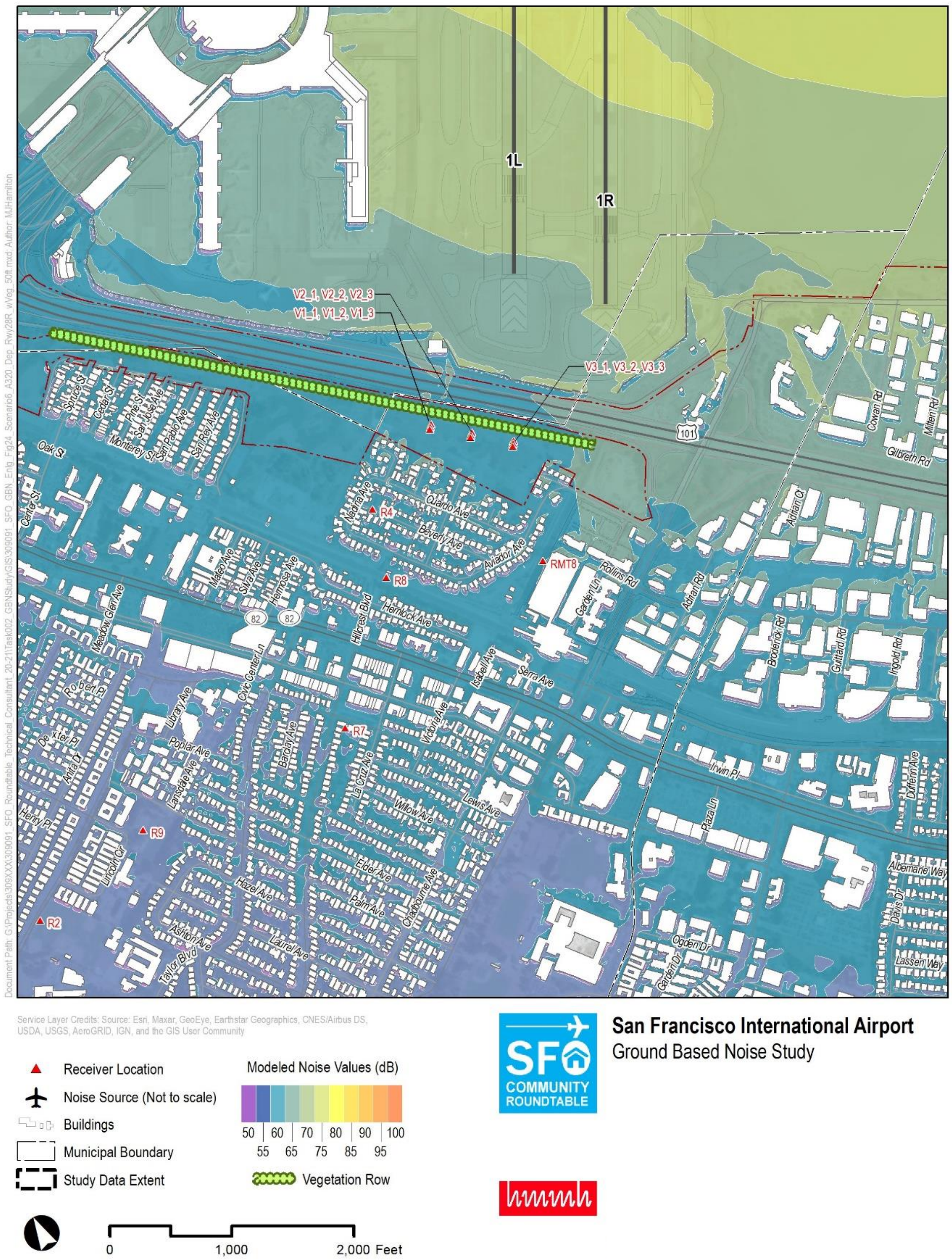

Figure H-24: Scenario 6 – B738 Departing Runway 28R at Secondary Takeoff Point – With Vegetation (50 Feet)

HMMH
300 S. Harbor Boulevard, Suite 516
Anaheim, California 92805
781.229.0707

4/15/2021

Ms. Michele Rodriguez
San Francisco International Airport/Community Roundtable Coordinator
mrodriguez2@smcgov.org
650.241.5180

Re: Response to Comment – HMMH Report #309091.002

Dear Ms. Rodriguez,

This letter provides background and historical information in response to Mr. Mark Shull's e-mail you received on April 6, 2021 regarding concerns with the HMMH Report #309091.002, titled "San Francisco International Airport Ground Based Noise Modeling Study" dated January 19, 2021, specifically the concern over our assessment of the use of vegetation to reduce noise from ground-based sources.

As stated in our report, the Roundtable established a GBN ad-hoc subcommittee[1] to address Ground Based Noise (GBN) concerns from communities adjacent to San Francisco International Airport (SFO). The initial meeting for the GBN ad-hoc subcommittee (herein subcommittee) was held on November 1, 2018 at the Millbrae Community Center. Our recollection of events of the subcommittee are followed.

The subcommittee prepared a scope of work for the ground-based noise study through multiple meetings and discussions in which public comment was accepted. The Roundtable approved the scope of work as proposed by the subcommittee on December 6, 2018 (**Appendix B of our report**). The approved scope of work established a problem statement, framework for research/collection of data and schedule. As part of the approved scope of work, HMMH was identified to provide additional background information/data on several of the approved scope of work items. In response, HMMH prepared a letter that contained the requested background information/data for all of the items flagged "HMMH" (**Appendix C of our report**). HMMH also prepared and delivered a presentation for the March 19, 2019 subcommittee meeting that summarized the data request letter (**Appendix D of our report**).

As part of our technical support to the subcommittee, HMMH provided a letter that reported results from previous noise barrier research (**Appendix E of our report**) and a technical memorandum describing vegetation and noise reduction effects (**Appendix F of our report**). Upon request from the subcommittee, HMMH prepared a proposal (**Appendix G of our report**) to complete a GBN modeling study to support the Roundtable's approved scope of work.

<u>The primary purpose of the noise modeling study was for the subcommittee to better understand how ground-based noise propagates through the communities adjacent to SFO</u>. The secondary purpose was to assess vegetation as a means to reducing ground-based noise from SFO. While prior literature and research results regarding ground-based noise was provided to the subcommittee, it was dated and not specific to the unique terrain and environment that exists near SFO. This noise modeling study included providing the unique local environment understanding utilizing the latest noise modeling technology.

The effectiveness of vegetation at reducing ground-based noise from SFO was shown as delta changes throughout the results tables in the report for a particular location, length, height and density of

[1] https://sforoundtable.org/gbnsub_20181101/

vegetation. Specifically, the report broke down the expected noise level reduction by frequency to help the subcommittee understand the specific effects of vegetation in their environment with the incorporation of terrain, buildings, and other ground effects.

While it is generally understood that the use of vegetation has certain limitation, its overall effectiveness is based on variables such as location, length, height, and density of use. For example, it has been found that about 200 feet of continuous densely spaced vegetation can achieve 5 to 10 dB of noise reduction in certain situations.

At the start of this GBN modeling study, HMMH had multiple discussions in addition to those at the subcommittee meetings with the cities/towns of San Bruno, Millbrae, Burlingame and Hillsborough. These cities/towns were able to provide HMMH with additional feedback, proposed receptor locations, and building plans with height information.

We trust the historical information provided herein is consistent with the subcommittee's recollection of events, and ultimately helps convey why the GBN modeling study included the assessment of vegetation as a noise reducing measure.

Sincerely yours,
Harris Miller Miller & Hanson Inc.

Justin W. Cook

Justin W. Cook – INCE, LEED GA
Director, Emerging Technologies and IT

cc:
enclosures:

(GBN Study Comment from Member Al Royse, City of Hillsborough)

Angela, I have reviewed the GBN Modeling Study. I think it was fairly complete as determined by the scope we provided. I have a few questions/ comments in general:

1 Are there other studies? if so, are these findings consistent with what they found?

2 I would be interested in the author's response to what, if anything, surprised them in the results of the study.

3 Re the 'next steps" (page 91), what are the options for 'noise mitigation principals" re design of new or re-development projects.,

4 From a strictly Hillsborough perspective, I don't see where the vegetation seems to make a big difference; am I reading or understanding the results correctly?

Also what is the effect of the hilly terrain and valleys in Hillsborough? (For example, does the ground base noise increase as it "climbs" a hill? And, if so, is it perceptible?) (see page 67).

5 I note that vegetation closest to the airport seems to have the biggest positive impact (can you confirm); if so, what would be the effect of more vegetation at the airport (I note old airport maps show more land, ground, and vegetation brush AT the airport- is the removal of all this over the course of the construction over the years a cause for increased ground base noise?) ,

Similarly, if significantly more 'vegetation' was planted, how big an impact would be the result? Not sure from study that it would have material or even discernible impact and that doesn't intuitively sound correct to me. Sounds like buildings and structures may be of greater concern or opportunity?

6 I support the next steps, especially as it includes understanding the effects of sound barriers, walls, etc. AND NEW BUILDINGS OR SIMILAR STRUCTURES, and affect of new buildings on the 'bouncing off effects' of these structures and range of the 'bounce'.

7 Minor point, but how recent is the data re the building footprints? Does it include CIP? (pg 3)

8 page 7 We used the most common departing aircraft but were these the ones with the most noise complaints? Assumed they were but wanted to confirm.

9 What are the comments from SFO airport? Do they see any actions they should be considering?

10 Interested in the 'noise annoyance" metrics in the report as compared to the most recent FAA study.

11 Are there technological substitutes for 'vegetation"? Does 'rubber asphalt' streets have an impact. Is there broader application of this, especially at the airport?

12 Very interested in airport construction, runway modifications, and impacts that may have on GBN.

13 What is the impact of all the 'hills and vegetation' that currently exists in Hillsborough? Assume its significant but based on study not sure of impact.

14 What is the impact of the vegetation that currrently exists along El Camino Road- if those trees are removed what will be the impact on GBN?

All the best

Al Royse
Mayor, Town of Hillsborough

Appendix A Aircraft Noise Terminology

Noise is a complex physical quantity. The properties, measurement, and presentation of noise involve specialized terminology that can be difficult to understand. To provide a basic reference on these technical issues, this section introduces fundamentals of noise terminology, the effects of noise on human activity, and noise propagation.

A.1 Introduction to Noise Terminology

Analyses of potential impacts from changes in aircraft noise levels rely largely on a measure of cumulative noise exposure over an entire calendar year, expressed in terms of a metric called the Day-Night Average Sound Level (DNL/Ldn). However, DNL does not provide the only metric for measuring noise. A variety of metrics, which are further described in subsequent sub-sections, are used to describe noise, including:

- Sound Pressure Level, SPL, and the Decibel, dB
- A-Weighted Decibel, dBA
- Maximum A-Weighted Sound Level, L_{max}
- Time Above, TA
- Sound Exposure Level, SEL
- Equivalent A-Weighted Sound Level, L_{eq}
- Day-Night Average Sound Level, DNL/Ldn

A.1.1 Sound Pressure Level, SPL, and the Decibel, dB

All sounds come from a sound source – a musical instrument, a voice speaking, an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source travels through the air in sound waves – tiny, quick oscillations of pressure just above and just below atmospheric pressure. The ear senses these pressure variations and – with much processing in our brain – translates them into “sound.”

Our ears are sensitive to a wide range of sound pressures. The loudest sounds that we can hear without pain contain about one million times more energy than the quietest sounds we can detect. To allow us to perceive sound over this very wide range, our ear/brain “auditory system” compresses our response in a complex manner, represented by a term called sound pressure level (SPL), which we express in units called decibels (dB).

Mathematically, SPL is a logarithmic quantity based on the ratio of two sound pressures, the numerator being the pressure of the sound source of interest (P_{source}), and the denominator being a reference pressure ($P_{reference}$).[1]

$$\textit{Sound Pressure Level (SPL)} = 20 * Log\left(\frac{P_{source}}{P_{reference}}\right) dB$$

The logarithmic conversion of sound pressure to SPL means that the quietest sound that we can hear (the reference pressure) has a sound pressure level of about 0 dB, while the loudest sounds that we hear without pain have sound pressure levels of about 120 dB. Most sounds in our day-to-day environment have sound pressure levels from about 40 to 100 dB[2].

Because decibels are logarithmic quantities, we cannot use common arithmetic to combine them. For example, if two sound sources each produce 100 dB operating individually, when they operate simultaneously, they produce 103 dB -- not the 200 dB we might expect. Increasing to four equal sources operating simultaneously will add another three decibels of noise, resulting in a total SPL of 106 dB. For every doubling of the number of equal sources, the SPL goes up another three decibels.

If one noise source is much louder than another is, the louder source "masks" the quieter one and the two sources together produce virtually the same SPL as the louder source alone. For example, a 100 dB and 80 dB sources produce approximately 100 dB of noise when operating together.

Two useful “rules of thumb” related to SPL are worth noting: (1) humans generally perceive a six to 10 dB increase in SPL to be about a doubling of loudness,[3] and (2) changes in SPL of less than about three decibels for a particular sound are not readily detectable outside of a laboratory environment.

A.1.2 A-Weighted Decibel

An important characteristic of sound is its frequency, or "pitch.” This is the per-second oscillation rate of the sound pressure variation at our ear, expressed in units known as Hertz (Hz).

When analyzing the total noise of any source, acousticians often break the noise into frequency components (or bands) to consider the “low,” “medium,” and “high” frequency components. This breakdown is important for two reasons:

- Our ear is better equipped to hear mid and high frequencies and is least sensitive to lower frequencies. Thus, we find mid- and high-frequency noise more annoying.
- Engineering solutions to noise problems differ with frequency content. Low-frequency noise is generally harder to control.

[1] The reference pressure is approximately the quietest sound that a healthy young adult can hear.
[2] The logarithmic ratio used in its calculation means that SPL changes relatively quickly at low sound pressures and more slowly at high pressures. This relationship matches human detection of changes in pressure. We are much more sensitive to changes in level when the SPL is low (for example, hearing a baby crying in a distant bedroom), than we are to changes in level when the SPL is high (for example, when listening to highly amplified music).
[3] A “10 dB per doubling” rule of thumb is the most often used approximation.

The normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of about 10,000 to 15,000 Hz. Most people respond to sound most readily when the predominant frequency is in the range of normal conversation – typically around 1,000 to 2,000 Hz. The acoustical community has defined several "filters," which approximate this sensitivity of our ear and thus, help us to judge the relative loudness of various sounds made up of many different frequencies.

The so-called "A" filter ("A weighting") generally does the best job of matching human response to most environmental noise sources, including natural sounds and sound from common transportation sources. "A-weighted decibels" are abbreviated "dBA." Because of the correlation with our hearing, the U. S. Environmental Protection Agency (EPA) and nearly every other federal and state agency have adopted A-weighted decibels as the metric for use in describing environmental and transportation noise. **Figure A-1** depicts A-weighting adjustments to sound from approximately 20 Hz to 10,000 Hz.

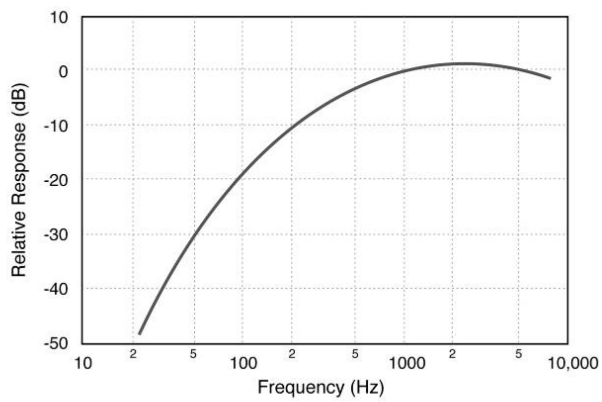

Figure A-1 A-Weighting Frequency Response

Source: Extract from Harris, Cyril M., Editor, "Handbook of Acoustical Measurements and Control," McGraw-Hill, Inc., 1991, pg. 5.13; HMMH

As the figure shows, A-weighting significantly de-emphasizes noise content at lower and higher frequencies where we do not hear as well, and has little effect, or is nearly "flat," in for mid-range frequencies between 1,000 and 5,000 Hz. All sound pressure levels presented in this document are A-weighted unless otherwise specified.

Figure A-2 depicts representative A-weighted sound levels for a variety of common sounds.

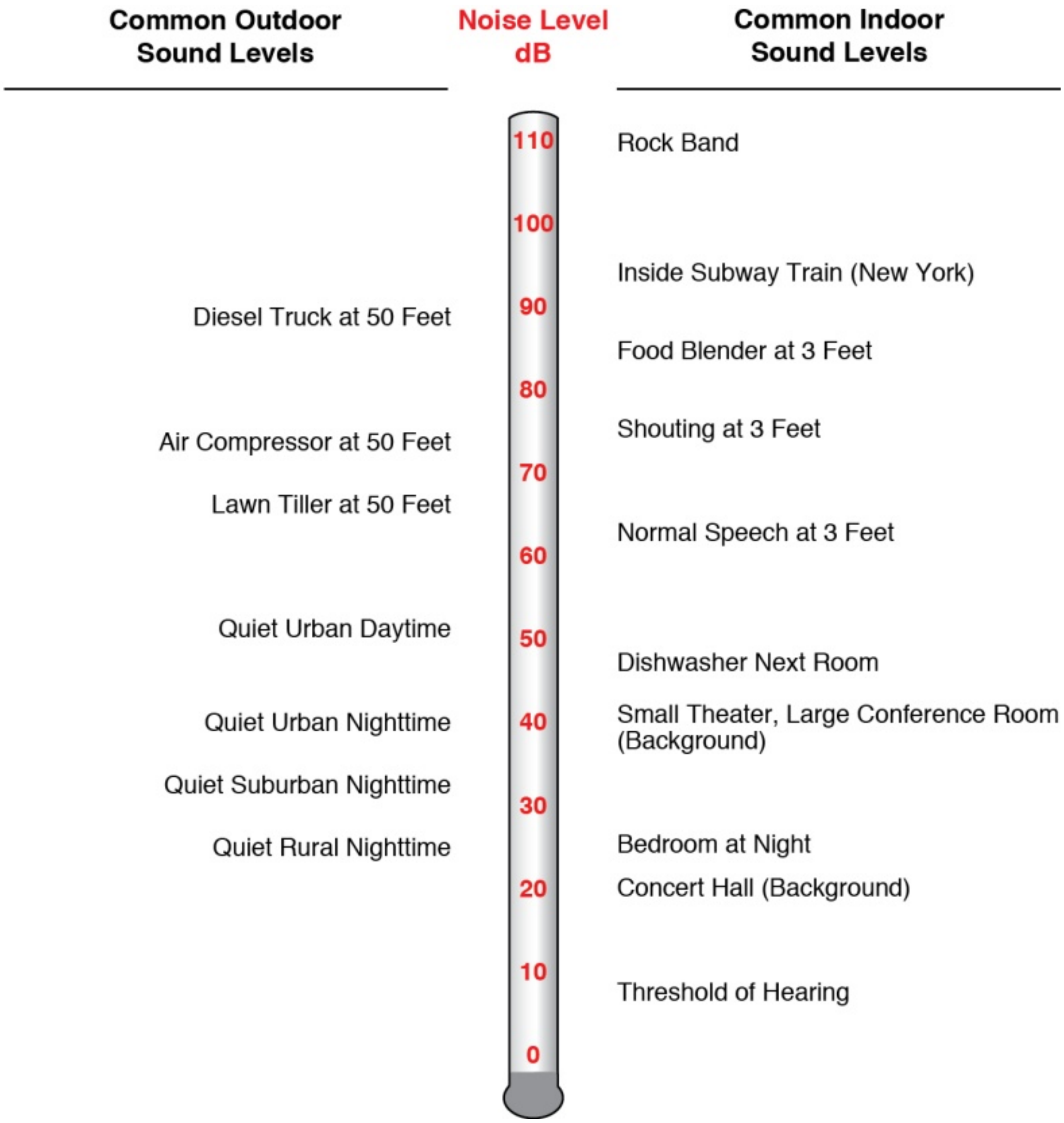

Figure A-2 A-Weighted Sound Levels for Common Sounds

A.1.3 Maximum A-Weighted Sound Level, L_{max}

An additional dimension to environmental noise is that A-weighted levels vary with time. For example, the sound level increases as a car or aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance. The background or “ambient” level continues to vary in the absence of a distinctive source, for example due to birds chirping, insects buzzing, leaves rustling, etc. It is often convenient to describe a particular noise "event" (such as a vehicle passing by, a dog barking, etc.) by its maximum sound level, abbreviated as L_{max}.

Figure A-3 depicts this general concept, for a hypothetical noise event with an L_{max} of approximately 102 dB.

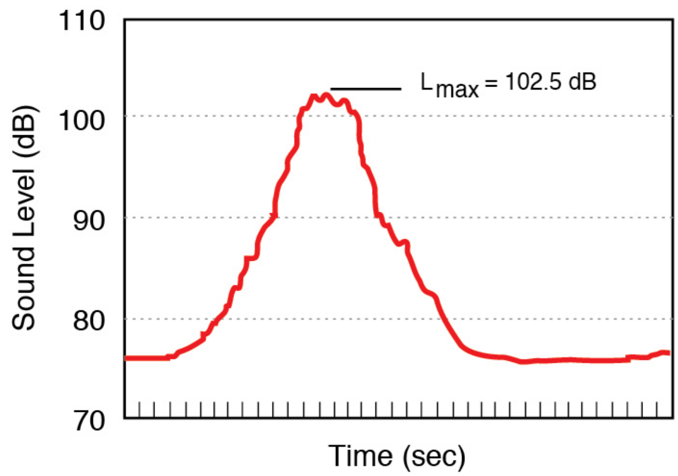

Figure A-3 Variation in A-Weighted Sound Level over Time and Maximum Noise Level

Source: HMMH

While the maximum level is easy to understand, it suffers from a serious drawback when used to describe the relative “noisiness” of an event such as an aircraft flyover; i.e., it describes only one dimension of the event and provides no information on the event’s overall, or cumulative, noise exposure. In fact, two events with identical maximum levels may produce very different total exposures. One may be of very short duration, while the other may continue for an extended period and be judged much more annoying. The next section introduces a measure that accounts for this concept of a noise "dose," or the cumulative exposure associated with an individual “noise event” such as an aircraft flyover.

A.1.4 Sound Exposure Level, SEL

The most commonly used measure of cumulative noise exposure for an individual noise event, such as an aircraft flyover, is the Sound Exposure Level, or SEL. SEL is a summation of the A-weighted sound energy over the entire duration of a noise event. SEL expresses the accumulated energy in terms of the one-second-long steady-state sound level that would contain the same amount of energy as the actual time-varying level.

SEL provides a basis for comparing noise events that generally match our impression of their overall “noisiness,” including the effects of both duration and level. The higher the SEL, the more annoying a noise event is likely to be. In simple terms, SEL “compresses” the energy for the noise event into a single second. **Figure A-4** depicts this compression, for the same hypothetical event shown in **Figure A-3**. Note that the SEL is higher than the L_{max}.

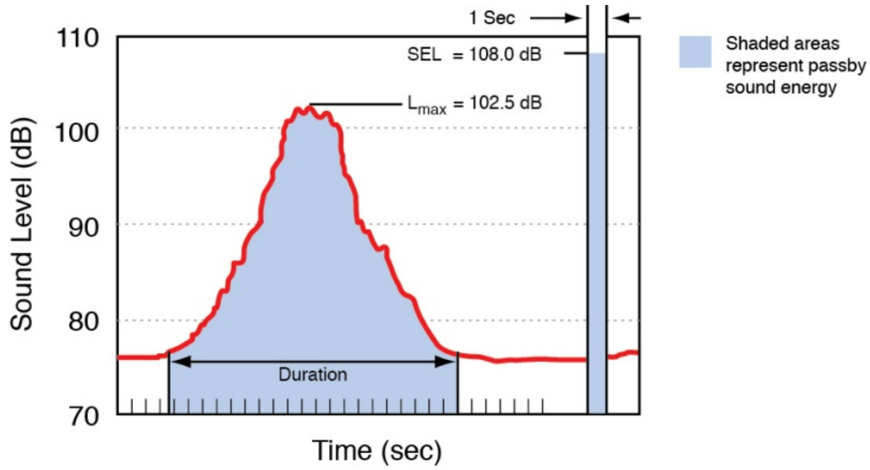

Figure A-4 Graphical Depiction of Sound Exposure Level

Source: HMMH

The "compression" of energy into one second means that a given noise event's SEL will almost always will be a higher value than its L_{max}. For most aircraft flyovers, SEL is roughly five to 12 dB higher than L_{max}. Adjustment for duration means that relatively slow and quiet propeller aircraft can have the same or higher SEL than faster, louder jets, which produce shorter duration events.

A.1.5 Equivalent A-Weighted Sound Level, L_{eq}

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the exposure resulting from the accumulation of sound levels over a particular period of interest; e.g., one hour, an eight-hour school day, nighttime, or a full 24-hour day. L_{eq} plots for consecutive hours can help illustrate how the noise dose rises and falls over a day or how a few loud aircraft significantly affect some hours.

L_{eq} may be thought of as the constant sound level over the period of interest that would contain as much sound energy as the actual varying level. It is a way of assigning a single number to a time-varying sound level. **Figure A-5** illustrates this concept for the same hypothetical event shown in **Figure A-3** and **Figure A-4**. Note that the L_{eq} is lower than either the L_{max} or SEL.

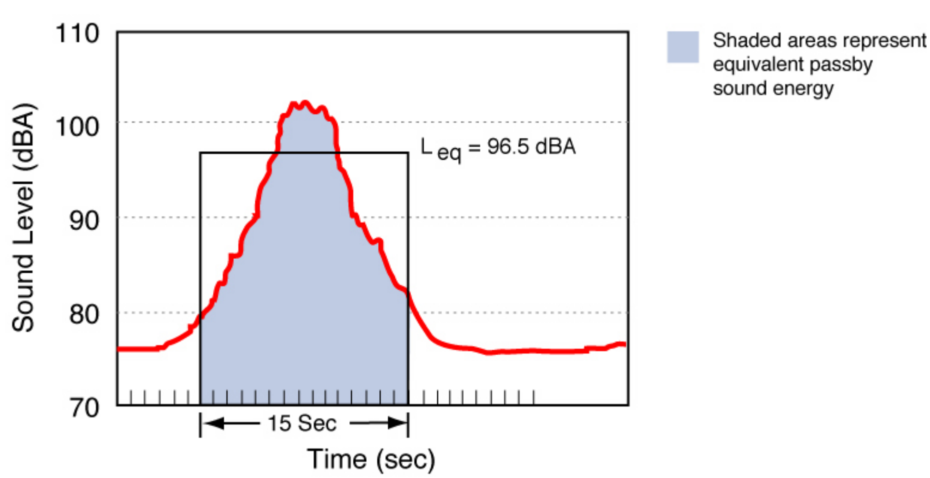

Figure A-5 Example of a 15-Second Equivalent Sound Level

Source: HMMH

A.1.6 Day-Night Average Sound Level, DNL or L_{dn}

The FAA requires that airports use a measure of noise exposure that is slightly more complicated than L_{eq} to describe cumulative noise exposure – the Day-Night Average Sound Level, DNL.

The U.S. Environmental Protection Agency identified DNL as the most appropriate means of evaluating airport noise based on the following considerations[4].

- The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods.
- The measure should correlate well with known effects of the noise environment and on individuals and the public.
- The measure should be simple, practical, and accurate. In principal, it should be useful for planning as well as for enforcement or monitoring purposes.
- The required measurement equipment, with standard characteristics, should be commercially available.
- The measure should be closely related to existing methods currently in use.
- The single measure of noise at a given location should be predictable, within an acceptable tolerance, from knowledge of the physical events producing the noise.
- The measure should lend itself to small, simple monitors, which can be left unattended in public areas for long periods.

Most federal agencies dealing with noise have formally adopted DNL. The Federal Interagency Committee on Noise (FICON) reaffirmed the appropriateness of DNL in 1992. The FICON summary report stated: “There are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric.”

In simple terms, DNL is the 24-hour L_{eq} with one adjustment; all noises occurring at night (defined as 10 p.m. through 7 a.m.) are increased by 10 dB, to reflect the added intrusiveness of nighttime noise events when background noise levels decrease. In calculating aircraft exposure, this 10 dB increase is mathematically identical to counting each nighttime aircraft noise event ten times.

DNL can be measured or estimated. Measurements are practical only for obtaining DNL values for limited numbers of points, and, in the absence of a permanently installed monitoring system, only for relatively short periods. Most airport noise studies use computer-generated DNL estimates depicted as equal-exposure noise contours (much as topographic maps have contours of equal elevation).

The annual DNL is mathematically identical to the DNL for the average annual day; i.e., a day on which the number of operations is equal to the annual total divided by 365 (366 in a leap year). **Figure A-6** graphically depicts the manner in which the nighttime adjustment applies in calculating DNL. **Figure A-7** presents representative outdoor DNL values measured at various U.S. locations.

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[4] "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U. S. EPA Report No. 550/9-74-004, March 1974.

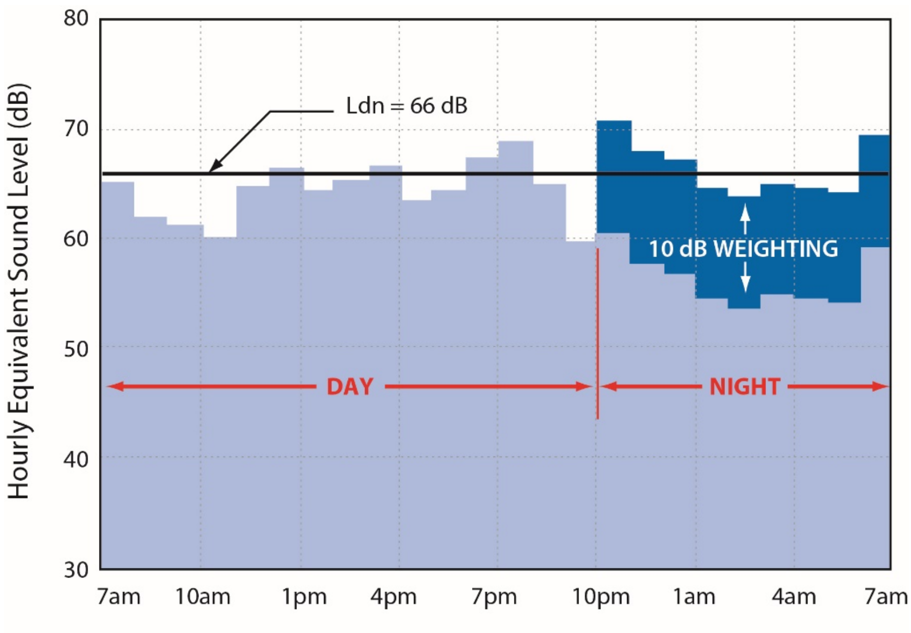


Figure A-6 Example of a Day-Night Average Sound Level Calculation

Source: HMMH

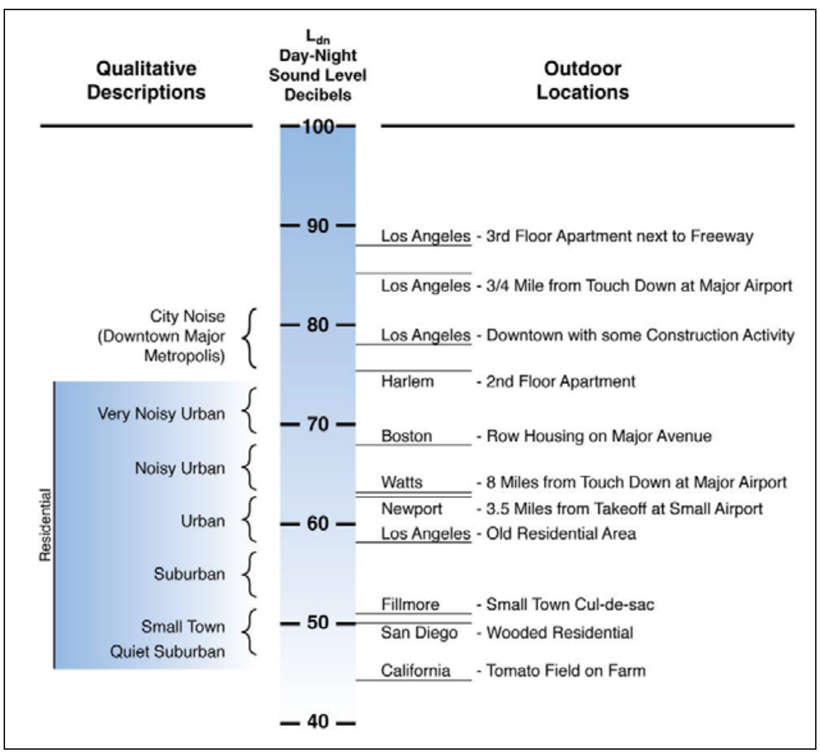


Figure A-7 Examples of Measured Day-Night Average Sound Levels, DNL

Source: U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, p.14.

A.2 Aircraft Noise Effects on Human Activity

Aircraft noise can be an annoyance and a nuisance. It can interfere with conversation and listening to television, disrupt classroom activities in schools, and disrupt sleep. Relating these effects to specific noise metrics helps in the understanding of how and why people react to their environment.

A.2.1 Speech Interference

One potential effect of aircraft noise is its tendency to "mask" speech, making it difficult to carry on a normal conversation. The sound level of speech decreases as the distance between a talker and listener increases. As the background sound level increases, it becomes harder to hear speech.

Figure A-8 presents typical distances between talker and listener for satisfactory outdoor conversations, in the presence of different steady A-weighted background noise levels for raised, normal, and relaxed voice effort. As the background level increases, the talker must raise his/her voice, or the individuals must get closer together to continue talking.

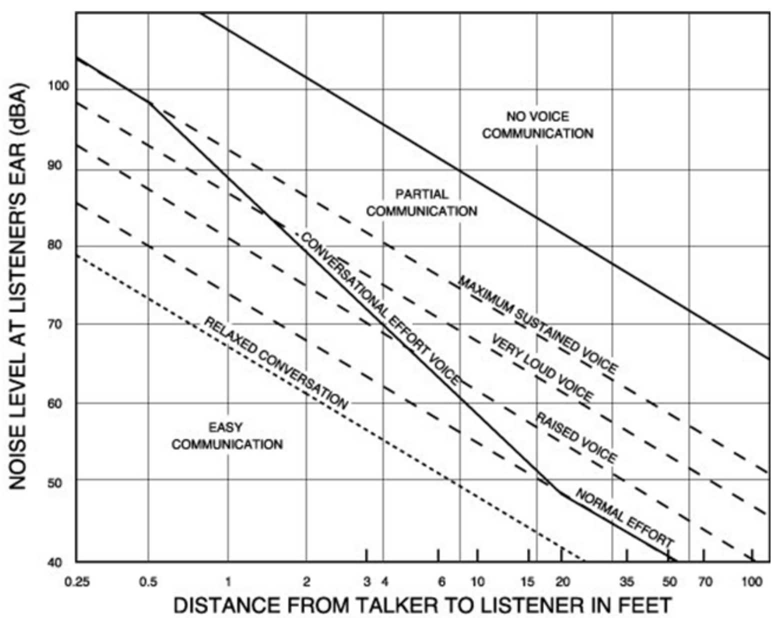


Figure A-8 Outdoor Speech Intelligibility

Source: U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, p.D-5.

Satisfactory conversation does not always require hearing every word; 95% intelligibility is acceptable for many conversations. In relaxed conversation, however, we have higher expectations of hearing speech and generally require closer to 100% intelligibility. Any combination of talker-listener distances and background noise that falls below the bottom line in the figure (which roughly represents the upper boundary of 100% intelligibility) represents an ideal environment for outdoor speech communication. Indoor communication is generally acceptable in this region as well.

One implication of the relationships in **Figure A-8** is that for typical communication distances of three or four feet, acceptable outdoor conversations can be carried on in a normal voice as long as the background noise outdoors is less than about 65 dB. If the noise exceeds this level, as might occur when an aircraft passes overhead, intelligibility would be lost unless vocal effort were increased or communication distance were decreased.

Indoors, typical distances, voice levels, and intelligibility expectations generally require a background level less than 45 dB. With windows partly open, housing generally provides about 10 to 15 dB of interior-to-exterior noise level reduction. Thus, if the outdoor sound level is 60 dB or less, there is a reasonable chance that the resulting indoor sound level will afford acceptable interior conversation. With windows closed, 24 dB of attenuation is typical.

A.2.2 Sleep Interference

Research on sleep disruption from noise has led to widely varying observations. In part, this is because (1) sleep can be disturbed without awakening, (2) the deeper the sleep the more noise it takes to cause arousal, (3) the tendency to awaken increases with age, and other factors. **Figure A-9** shows a summary of findings on the topic.

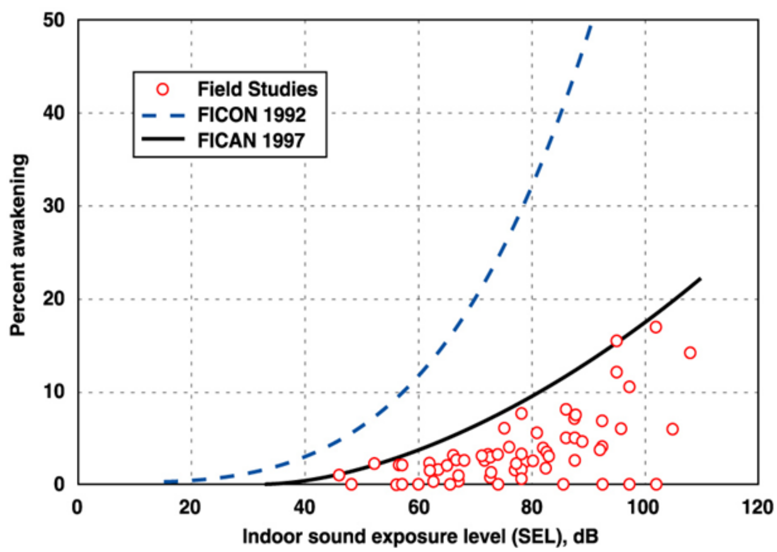


Figure A-9 Sleep Interference

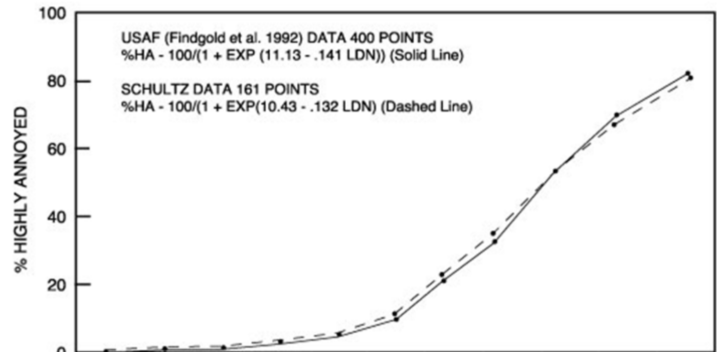
Source: Federal Interagency Committee on Aircraft Noise (FICAN), "Effects of Aviation Noise on Awakenings from Sleep," June 1997, pg. 6

Figure A-9 uses indoor SEL as the measure of noise exposure; current research supports the use of this metric in assessing sleep disruption. An indoor SEL of 80 dBA results in a maximum of 10% awakening.[5]

[5] The awakening data presented in Figure A-9 apply only to individual noise events. The American National Standards Institute (ANSI) has published a standard that provides a method for estimating the number of people awakened at least once from a full night of noise events: ANSI/ASA S12.9-2008 / Part 6, "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." This method can use the information on single events computed by a program such as the FAA's Aviation Environmental Design Tool, to compute awakenings.

A.2.3 Community Annoyance

Numerous psychoacoustic surveys provide substantial evidence that individual reactions to noise vary widely with noise exposure level. Since the early 1970s, researchers have determined (and subsequently confirmed) that aggregate community response is generally predictable and relates reasonably well to cumulative noise exposure such as DNL. COMAR provides methods for the calculation of noise exposure including metrics and measurement methods.[6] **Figure A-10** depicts the widely recognized relationship between environmental noise and the percentage of people "highly annoyed," with annoyance being the key indicator of community response usually cited in this body of research.



	Day - Night Average Sound Level in dB	40	45	50	55	60	65	70	75	80	85	100
Calculated %HA Points	USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
	SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

Figure A-10 Percentage of People Highly Annoyed

Source: FICON, "Federal Agency Review of Selected Airport Noise Analysis Issues," September 1992

Separate work by the EPA has shown that overall community reaction to a noise environment is also dependent on DNL. **Figure A-11** depicts this relationship.

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[6] COMAR. 11.03.03.02. Methods for Calculation and Measurement of Levels of Cumulative Noise Exposure. http://mdrules.elaws.us/comar/11.03.03.02

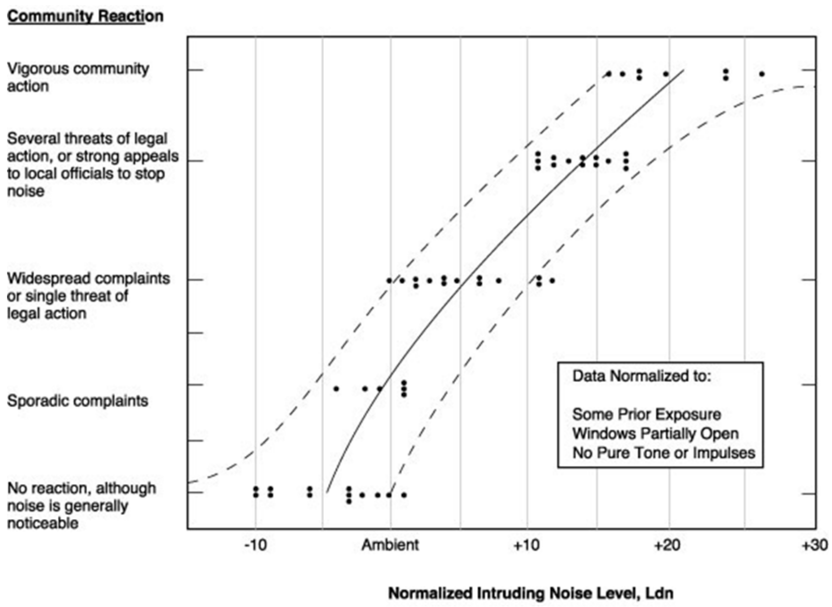

Figure A-11 Community Reaction as a Function of Outdoor DNL

Source: Wyle Laboratories, Community Noise, prepared for the U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C., December 1971, pg. 63

Data summarized in the figure suggest that little reaction would be expected for intrusive noise levels five decibels below the ambient, while widespread complaints can be expected as intruding noise exceeds background levels by about five decibels. Vigorous action is likely when levels exceed the background by 20 dB.

A.3 Noise Propagation

This section presents information sound-propagation effect due to weather, source-to-listener distance, and vegetation.

A.3.1 Weather-Related Effects

Weather (or atmospheric) conditions that can influence the propagation of sound include humidity, precipitation, temperature, wind, and turbulence (or gustiness). The effect of wind – turbulence in particular – is generally more important than the effects of other factors. Under calm-wind conditions, the importance of temperature (in particular vertical “gradients”) can increase, sometimes to very significant levels. Humidity generally has little significance relative to the other effects.

A.3.1.1 Influence of Humidity and Precipitation

Humidity and precipitation rarely effect sound propagation in a significant manner. Humidity can reduce propagation of high-frequency noise under calm-wind conditions. This is called “Atmospheric absorption.” In very cold conditions, listeners often observe that aircraft sound “tinny,” because the dry air increases the propagation of high-frequency sound. Rain, snow, and fog also have little, if any noticeable effect on sound propagation. A substantial body of empirical data supports these conclusions.[7]

A.3.1.2 Influence of Temperature

The velocity of sound in the atmosphere is dependent on the air temperature.[8] As a result, if the temperature varies at different heights above the ground, sound will travel in curved paths rather than straight lines. During the day, temperature normally decreases with increasing height. Under such "temperature lapse" conditions, the atmosphere refracts ("bends") sound waves upwards and an acoustical shadow zone may exist at some distance from the noise source.

Under some weather conditions, an upper level of warmer air may trap a lower layer of cool air. Such a "temperature inversion" is most common in the evening, at night, and early in the morning when heat absorbed by the ground during the day radiates into the atmosphere.[9] The effect of an inversion is just the opposite of lapse conditions. It causes sound propagating through the atmosphere to refract downward.

The downward refraction caused by temperature inversions often allows sound rays with originally upward-sloping paths to bypass obstructions and ground effects, increasing noise levels at greater distances. This type of effect is most prevalent at night, when temperature inversions are most common and when wind levels often are very low, limiting any confounding factors.[10] Under extreme conditions, one study found that noise from ground-borne aircraft might be amplified 15 to 20 dB by a temperature inversion. In a similar study, noise caused by an aircraft on the ground registered a higher level at an observer location 1.8 miles away than at a second observer location only 0.2 miles from the aircraft.[11]

A.3.1.3 Influence of Wind

Wind has a strong directional component that can lead to significant variation in propagation. In general, receivers that are downwind of a source will experience higher sound levels, and those that are upwind will experience lower sound levels. Wind perpendicular to the source-to-receiver path has no significant effect.

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[7] Ingard, Uno. "A Review of the Influence of Meteorological Conditions on Sound Propagation," *Journal of the Acoustical Society of America*, Vol. 25, No. 3, May 1953, p. 407.
[8] In dry air, the approximate velocity of sound can be obtained from the relationship:
$c = 331 + 0.6T_c$ (c in meters per second, T_c in degrees Celsius). Pierce, Allan D., *Acoustics: An Introduction to its Physical Principles and Applications.* McGraw-Hill. 1981. p. 29.
[9] Embleton, T.F.W., G.J. Thiessen, and J.E. Piercy, "Propagation in an inversion and reflections at the ground," *Journal of the Acoustical Society of America*, Vol. 59, No. 2, February 1976, p. 278.
[10] Ingard, p. 407.
[11] Dickinson, P.J., "Temperature Inversion Effects on Aircraft Noise Propagation," (Letters to the Editor) *Journal of Sound and Vibration.* Vol. 47, No. 3, 1976, p. 442.

The refraction caused by wind direction and temperature gradients is additive. [12] One study suggests that for frequencies greater than 500 Hz, the combined effects of these two factors tends towards two extreme values: approximately 0 dB in conditions of downward refraction (temperature inversion or downwind propagation) and -20 dB in upward refraction conditions (temperature lapse or upwind propagation). At lower frequencies, the effects of refraction due to wind and temperature gradients are less pronounced. [13]

Wind turbulence (or "gustiness") can also affect sound propagation. Sound levels heard at remote receiver locations will fluctuate with gustiness. In addition, gustiness can cause considerable attenuation of sound due to effects of eddies traveling with the wind. Attenuation due to eddies is essentially the same in all directions, with or against the flow of the wind, and can mask the refractive effects discussed above. [14]

A.3.2 Distance-Related Effects

People often ask how distance from an aircraft to a listener affects sound levels. Changes in distance may be associated with varying terrain, offsets to the side of a flight path, or aircraft altitude. The answer is a bit complex, because distance affects the propagation of sound in several ways.

The principal effect results from the fact that any emitted sound expands in a spherical fashion – like a balloon – as the distance from the source increases, resulting in the sound energy being spread out over a larger volume. With each doubling of distance, spherical spreading reduces instantaneous or maximum level by approximately six decibels and SEL by approximately three decibels.

[12] Piercy and Embleton, p. 1412. Note, in addition, that as a result of the scalar nature of temperature and the vector nature of wind, the following is true: under lapse conditions, the refractive effects of wind and temperature add in the upwind direction and cancel each other in the downwind direction. Under inversion conditions, the opposite is true.

[13] Piercy and Embleton, p. 1413.

[14] Ingard, pp. 409-410.