SFO COMMUNITY ROUNDTABLE

Meeting Announcement

Ground-Based Noise Subcommittee

Thursday, January 13, 2022
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/97466010883
Or Dial-in:
US: +1(669)900-6833 Webinar ID: 974 6601 0883

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 **(5 min)**

CONSENT AGENDA

1. **Brown Act Remote Meetings Resolution** **(2 min)**
   Attachment(s): Memo and Resolution of Approval

AGENDA ITEMS

2. **Ground-Based Noise Report Review and Next Steps** **(20 min)**
   Attachment(s): Ground-Based Noise Modeling Study HMMH Report,
   Study Comment Letter from SFO - 8/25/2021
   Summary of HMMH Airport Ground-Based Noise Study Presentation

3. **FAA Response to Aviation Environment Design Tool (AEDT) Recommendations** **(15 min)**
   Attachment(s): SFORT letter to FAA Director – 8/11/2021
   FAA Response 11/9/2021

4. **Airport Commission Meeting Update** **(15min)**
   Attachment(s): Agenda Oct 19, 2021(*linked*)

Rules and Regulations SFO, Rule 11.0 Noise Abatement Regulation (*linked*)

5. **Noise Metrics Discussion** **(30 min)**

   a. **SFO Noise Monitors: Measurement and Reporting of Ground-Based Noise**
   Attachments: Review of Remote Monitoring Terminal Thresholds – Phase III/II/I & Maps

   b. **Airport Directors Report: Review and Recommend**
   Attachments: Airport Directors Reports Sept-Oct 2021
   GAO Report of 9/28/2021(*linked*)
   Reagan National (DCA) Noise Monitor Program from Public Member Peter Grace 11/24/21
   SFO Noise Office Presentation Dec 2, 2021 slides on ANEEM & Brochure

6. **Future Discussion Items** **(5 min)**
   a. Work Plan 2022-2023
   b. Airport Policy on use of auxiliary power unit at gates and taxi operations.
   c. Airport and other ground equipment transition from diesel to airport wide electrification.
   d. Discussion of environmental mitigation historically implemented by SFO on GBN and mitigation for current and future operations.

Information Only

BBN Report No. 8257 from Public Member Darlene Yaplee

****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 January 13, 2022 Ground-Based Noise Subcommittee meeting may be accessed through Zoom online at https://smcgov.zoom.us/j/97466010883. The meeting ID: 974 6601 0883. The meeting may also be accessed via telephone by dialing in +1-669-900-6833, entering meeting ID: 974 6601 0883, 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/Community Roundtable

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January 7, 2022

TO: Ground-Based Noise Subcommittee

FROM: Angela Montes, Administrative Secretary

SUBJECT: Resolution to make findings allowing continued remote meetings under Brown Act

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RECOMMENDATION:
Adopt a resolution finding that, as a result of the continuing COVID-19 pandemic state of emergency declared by Governor Newsom, meeting in-person would present imminent risks to the health or safety of attendees.

BACKGROUND:
On June 11, 2021, Governor Newsom issued Executive Order N-08-21, which rescinded his prior Executive Order N-29-20 and which waived, through September 30, 2021, certain provisions of the Brown Act relating to teleconferences/remote meetings. The Executive Order waived, among other things, the provisions of the Brown Act that otherwise required the physical presence of members of a local agency or other personnel in a particular location as a condition of participation or as a quorum for a public meeting. These waivers set forth in the Executive Order were to expire on October 1, 2021.

On September 16, 2021, the Governor signed Assembly Bill (AB) 361, a bill that codifies certain teleconference procedures that local agencies have adopted in response to the Governor's Brown Act-related Executive Orders. Specifically, AB 361 allows a local agency to continue to use teleconferencing under the same basic rules as provided in the Executive Orders under certain prescribed circumstances or when certain findings have been made and adopted by the local agency.

In order to continue to hold video and teleconference meetings, the Ground-Based Noise subcommittee (GBN) will need to review and make findings every 30 days or thereafter that the state of emergency continues to directly impact the ability of the members to meet safely in-person and that state or local officials continue to impose or recommend measures to promote social distancing. If the GBN subcommittee does continue to hold video and teleconference meetings, to meet the requirements of AB 361, GBN subcommittee will need to adopt a resolution at every meeting.

The San Mateo County Board of Supervisors has adopted a resolution to continue remote meetings and encouraged other local agencies to make similar findings.

The membership previously found, and it remains the case, that public meetings pose high risks for COVID-19 spread for several reasons. These meetings may bring together people from throughout a geographic region, increasing the opportunity for COVID-19 transmission. Further, the open nature of public meetings makes it is difficult to enforce compliance with vaccination, physical distancing, masking, cough and sneeze etiquette, or other safety measures. Moreover, some of the safety measures used by private businesses to control these risks may be less effective for public agencies.

These factors continue to combine and directly impact the ability of members of the GBN subcommittee to meet safely in person and to make in-person public meetings imminently risky to health and safety.

As noted above, under AB 361, local agency bodies were required to return to in-person meetings on October 1, 2021, unless they chose to continue with fully teleconferenced meetings and made the prescribed findings related to the existing state of emergency. At its meeting of December 1, 2021, the membership adopted a resolution wherein the membership found, among other things, that as a result of the continuing COVID-19 state of emergency, meeting in-person would present imminent risks to the health or safety of attendees.

DISCUSSION:
Because local rates of transmission of COVID-19 are still in the “substantial” tier as measured by the Centers for Disease Control, we recommend that your subcommittee avail itself of the provisions of AB 361 allowing continuation of online meetings by adopting findings to the effect that conducting in-person meetings would present an imminent risk to the health and safety of attendees. A resolution to that effect and directing staff to return each 30 days with the opportunity to renew such findings, is attached hereto.

FISCAL IMPACT:
None

RESOLUTION NO. GBN22-01

RESOLUTION FINDING THAT, AS A RESULT OF THE CONTINUING COVID-19 PANDEMIC STATE OF EMERGENCY DECLARED BY GOVERNOR NEWSOM, MEETING IN PERSON FOR MEETINGS OF THE SAN FRANCISCO INTERNATIONAL AIRPORT/COMMUNITY ROUNDTABLE GROUND-BASED NOISE SUBCOMMITTEE WOULD PRESENT IMMINENT RISKS TO THE HEALTH OR SAFETY OF ATTENDEES

RESOLVED, by the Ground-Based Noise Subcommittee that

WHEREAS, on March 4, 2020, the Governor proclaimed pursuant to his authority under the California Emergency Services Act, California Government Code section 8625, that a state of emergency exists with regard to a novel coronavirus (a disease now known as COVID-19); and

WHEREAS, on June 4, 2021, the Governor clarified that the "reopening" of California on June 15, 2021 did not include any change to the proclaimed state of emergency or the powers exercised thereunder, and as of the date of this Resolution, neither the Governor nor the Legislature have exercised their respective powers pursuant to California Government Code section 8629 to lift the state of emergency either by proclamation or by concurrent resolution in the state Legislature; and

WHEREAS, on March 17, 2020, Governor Newsom issued Executive Order N-29-20 that suspended the teleconferencing rules set forth in the California Open Meeting law, Government Code section 54950 et seq. (the "Brown Act"), provided certain requirements were met and followed; and

WHEREAS, on September 16, 2021, Governor Newsom signed AB 361 that provides that a legislative body subject to the Brown Act may continue to meet without fully complying with the teleconferencing rules in the Brown Act provided the legislative body determines that meeting in person would present imminent risks to the health or safety of attendees, and further requires that certain findings be made by the legislative body every thirty (30) days or when meeting next; and,

WHEREAS, the Ground-Based Noise Subcommittee has an important interest in protecting the health and safety of attendees, and welfare of those who participate in its meetings; and

WHEREAS, at its meeting December 1, 2021, the San Francisco Airport/Community Roundtable adopted, by unanimous vote, a resolution wherein the membership found, *inter alia,* that as a result of the continuing COVID-19 state of emergency, meeting in person would present imminent risks to the health or safety of attendees; and

WHEREAS, The San Francisco Airport/Community Roundtable has not met since its regular meeting in December 1, 2021

WHEREAS, the Ground-Based Noise Subcommittee members have reconsidered the circumstances of the state of emergency and finds that the state of emergency continues to impact the ability of members of the Ground-Based Noise Subcommittee to meet in person because there is a continuing threat of COVID-19 to the community, and because membership meetings have characteristics that give rise to risks to health and safety of meeting participants (such as the increased mixing associated with bringing people together from across the community); and

WHEREAS, in the interest of public health and safety, as affected by the emergency caused by the spread of COVID-19, the membership deems it necessary to find that meeting in-person would present imminent risks to the health an safety of attendees, and thus intends to invoke the provisions of AB 361 related to teleconferencing;

NOW, THEREFORE, IT IS HEREBY DETERMINED AND ORDERED that

1. The recitals set forth above are true and correct.
2. The Ground-Based Noise Subcommittee finds that meeting in person would present imminent risks to the health or safety of attendees.
3. Staff is directed to return no later than thirty (30) days after the adoption of this resolution or at their next regular meeting with an item for the Ground-Based Noise Subcommittee of the Roundtable to consider making the findings required by AB 361 in order to continue meeting under its provisions.
4. Staff is directed to take such other necessary or appropriate actions to implement the intent and purposes of this resolution.

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Adopted at the Ground-Based Noise subcommittee meeting of
________________________.

Ann Schneider
Subcommittee Chairperson n

Date

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
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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.

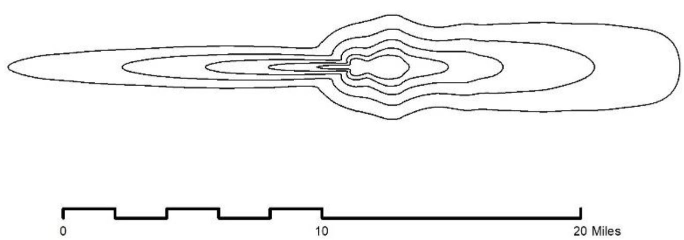


Figure 2: B767-300 SEL Noise Contour

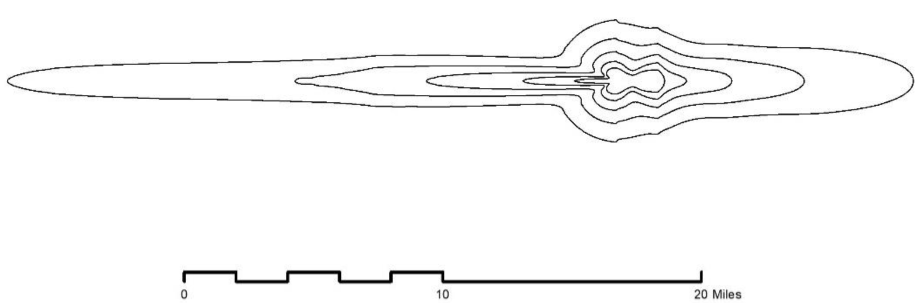


Figure 3: B77W SEL Noise Contour

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.

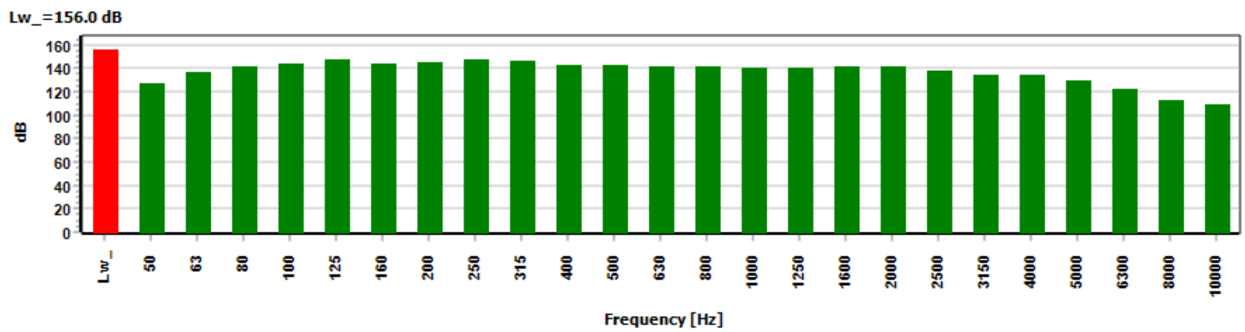


Figure 4: B767-300 Aircraft Noise Spectrum

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.

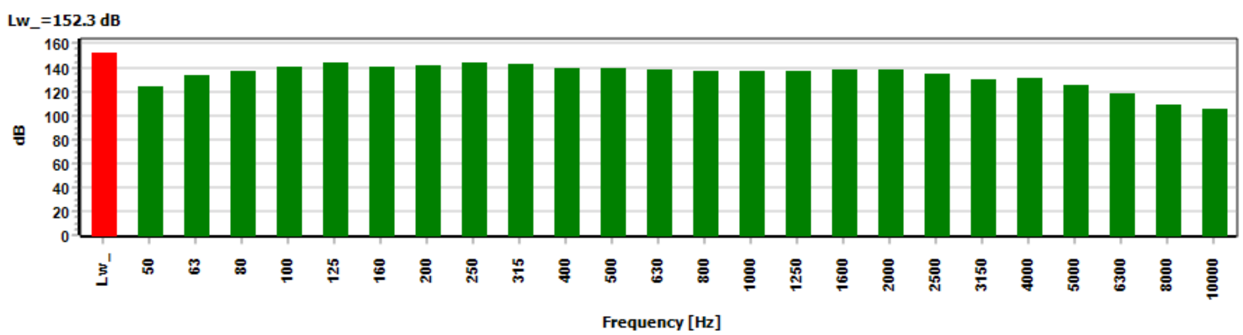


Figure 5: A320 Aircraft Noise Spectrum

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.

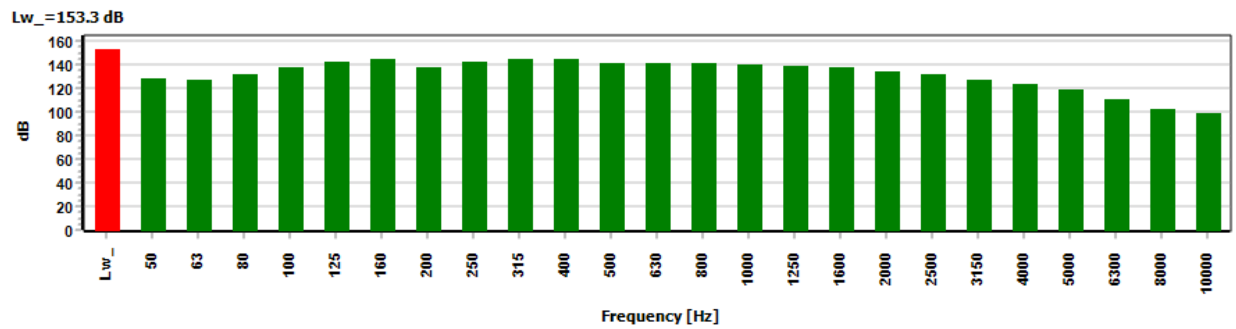


Figure 6: B738 Aircraft Noise Spectrum

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.

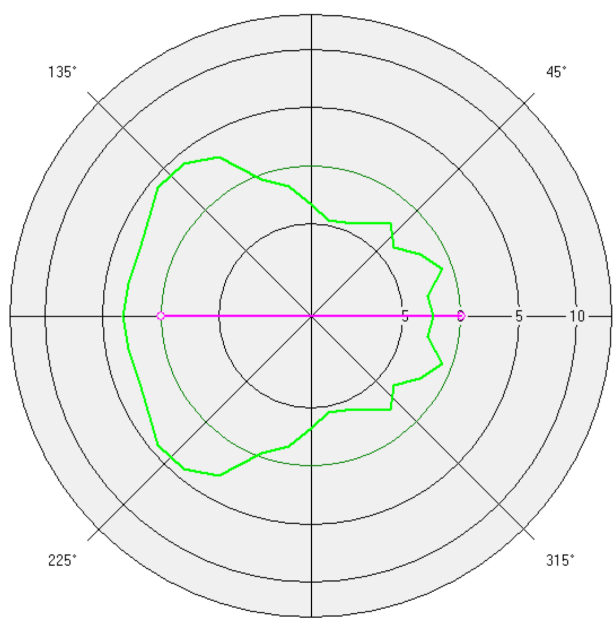


Figure 7: B738, B767-300 and A320 Directivity @ 1000 Hz

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.

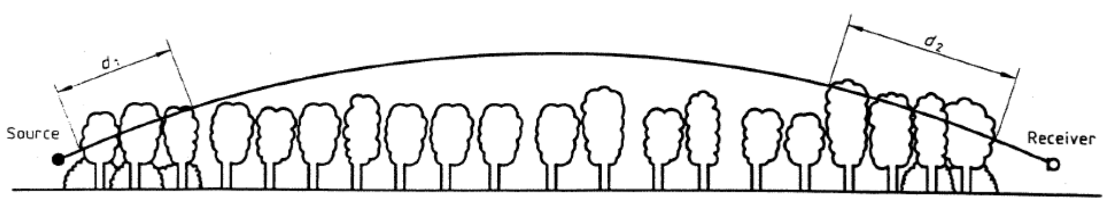


Figure 8: Downward Refracting Sound Path
Source: ISO 9613-2

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

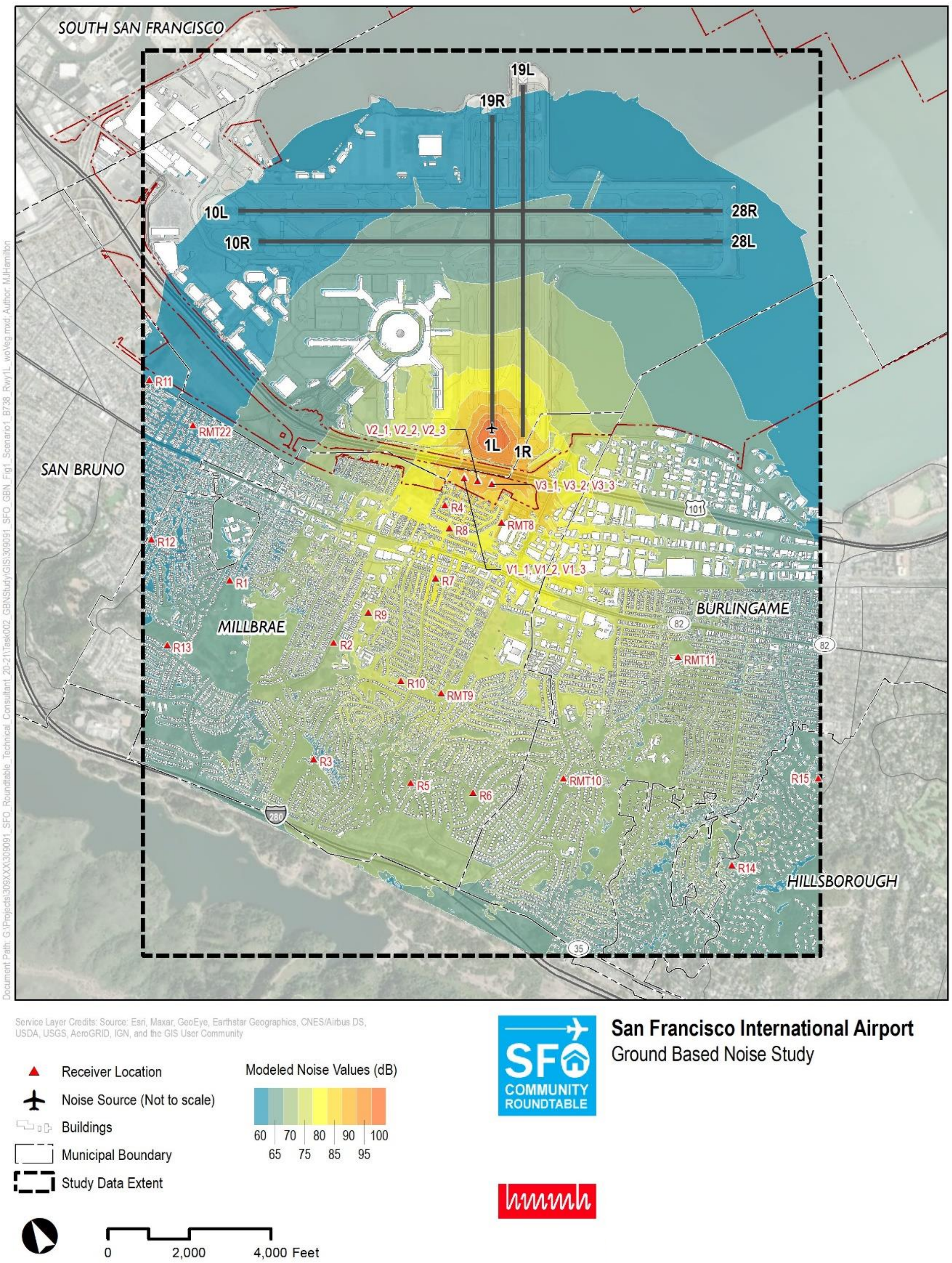


Figure 9: Scenario 1 - B738 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

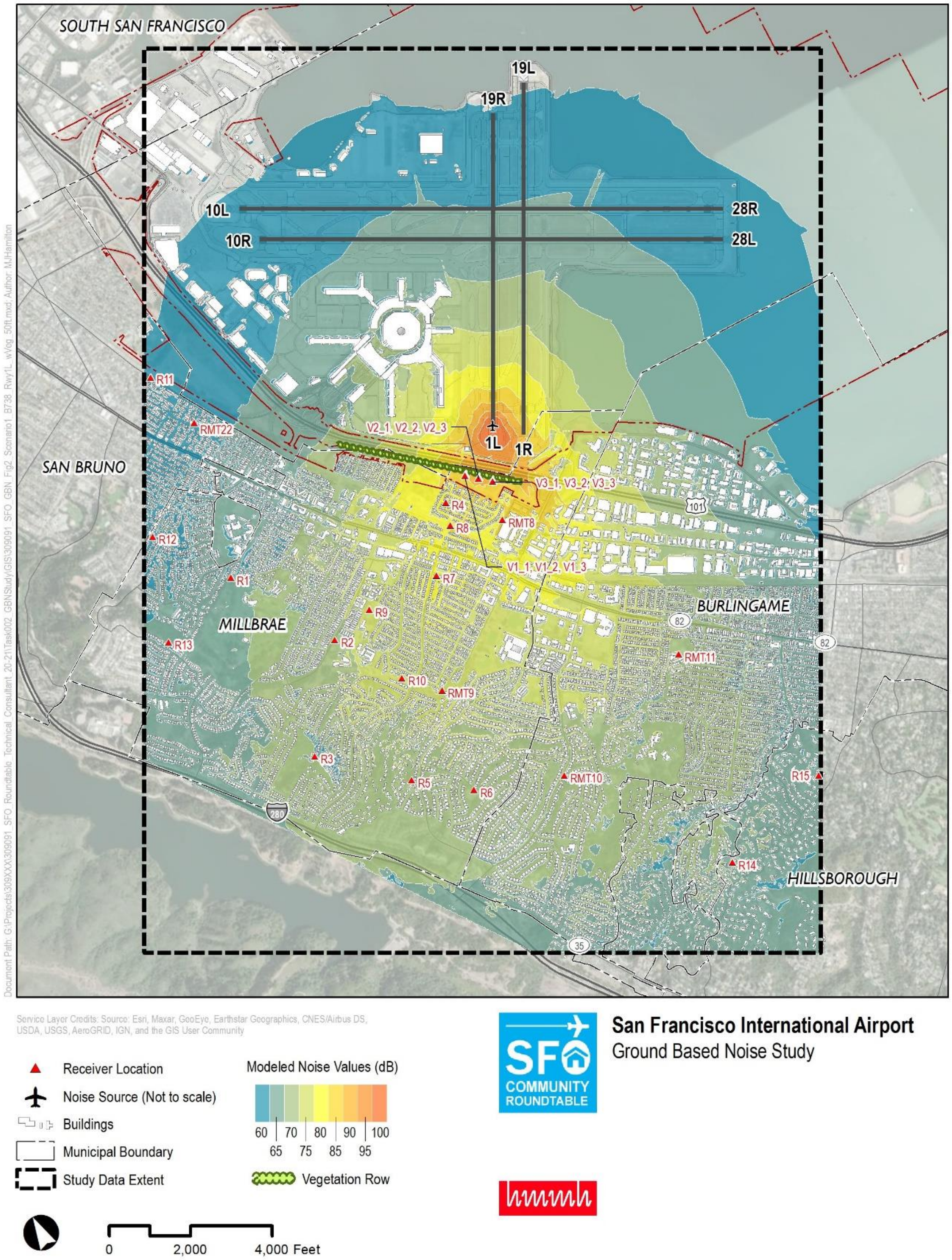


Figure 10: Scenario 1 - B738 Departing Runway 1L at Start of Takeoff Roll - With Vegetation (50 Feet)

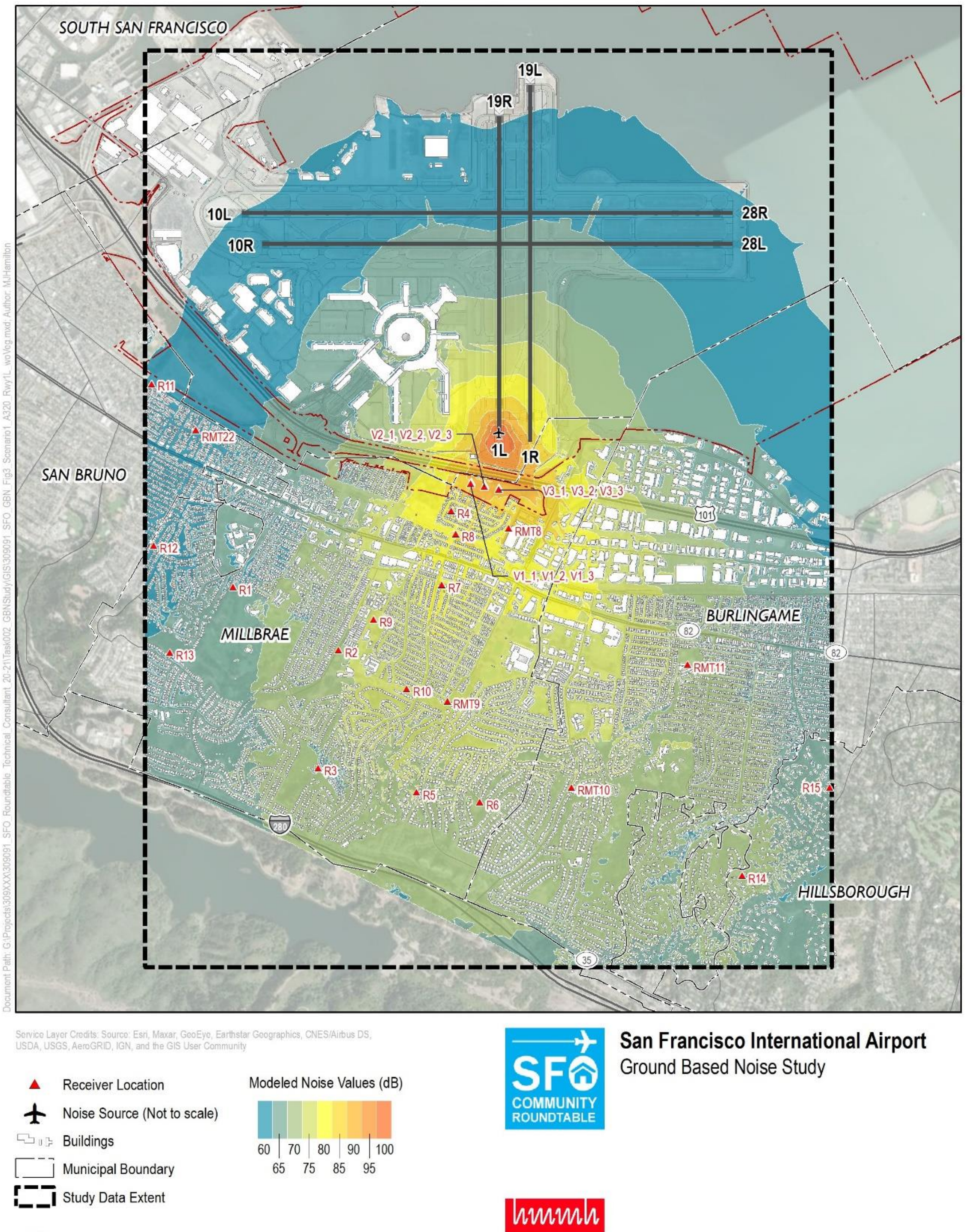


Figure 11: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

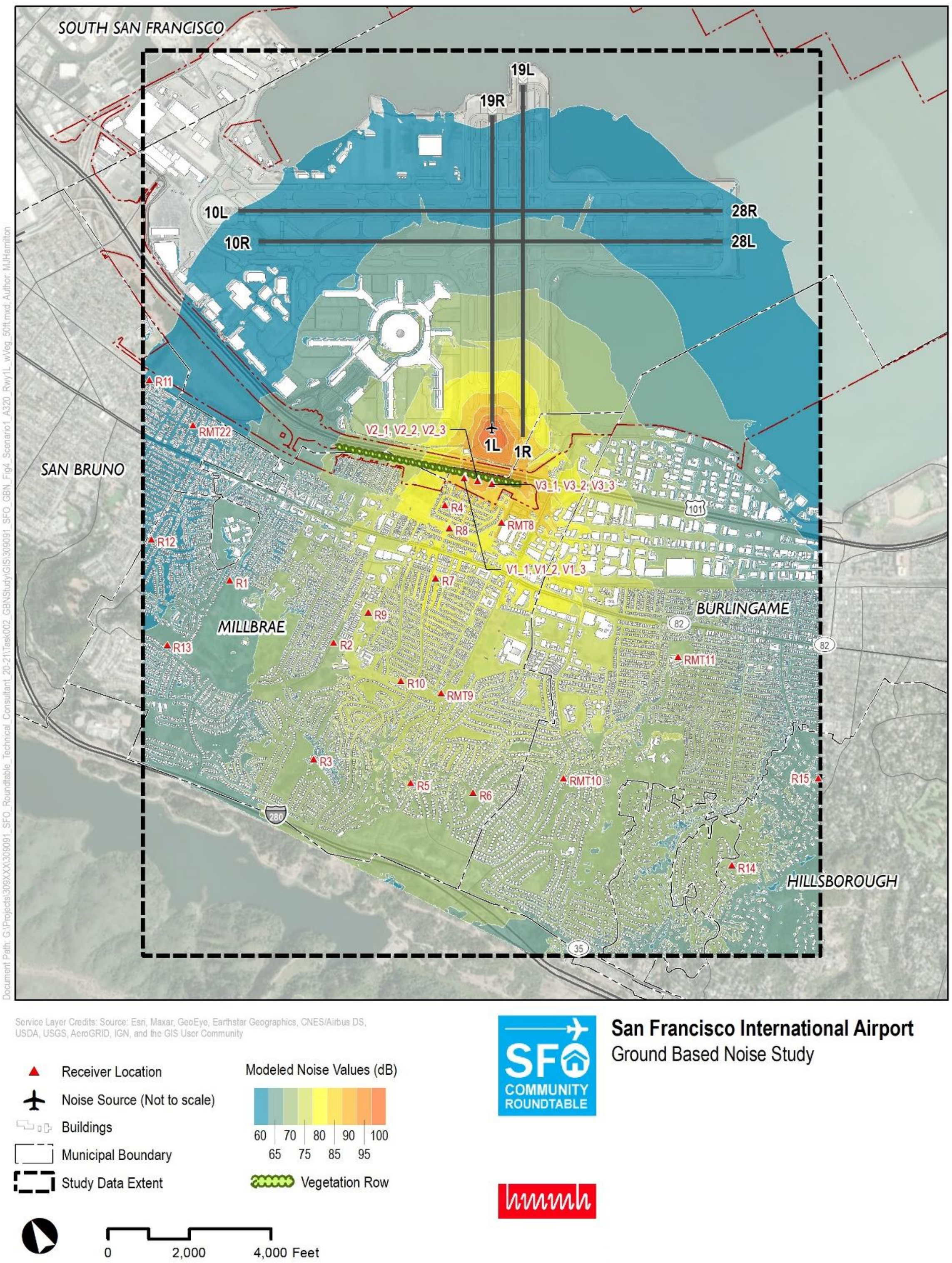


Figure 12: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – With Vegetation (50 Feet)

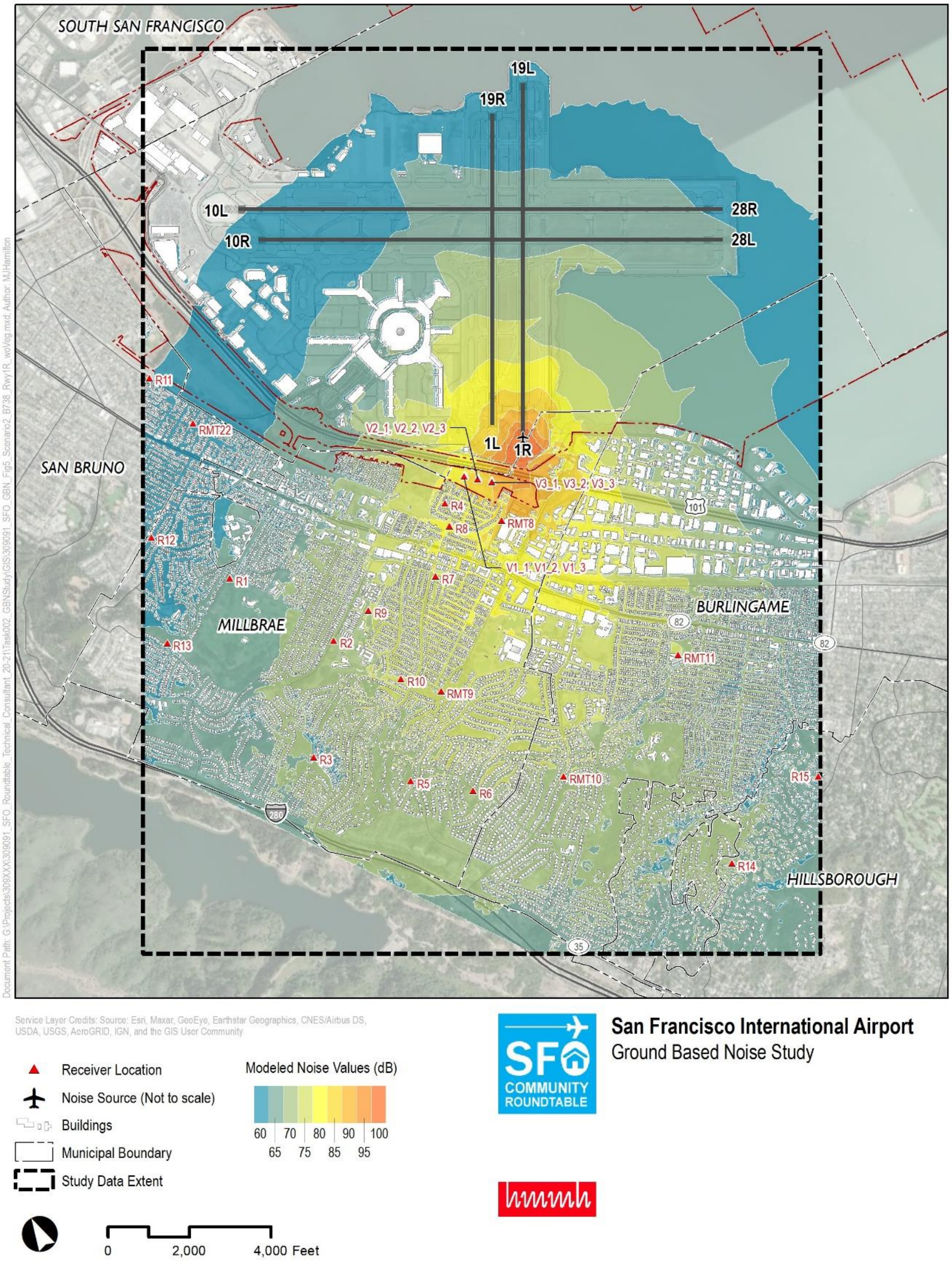


Figure 13: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation

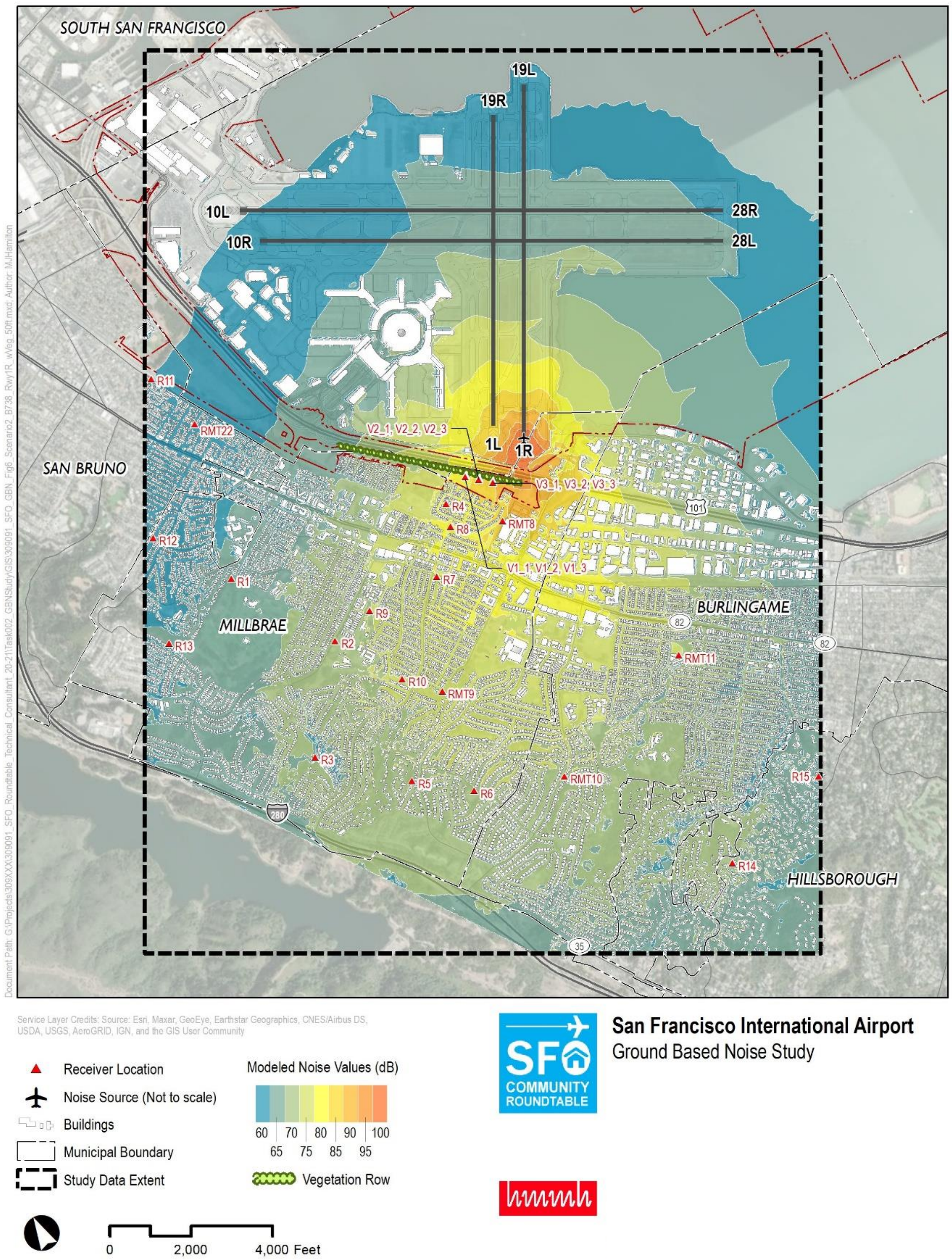


Figure 14: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

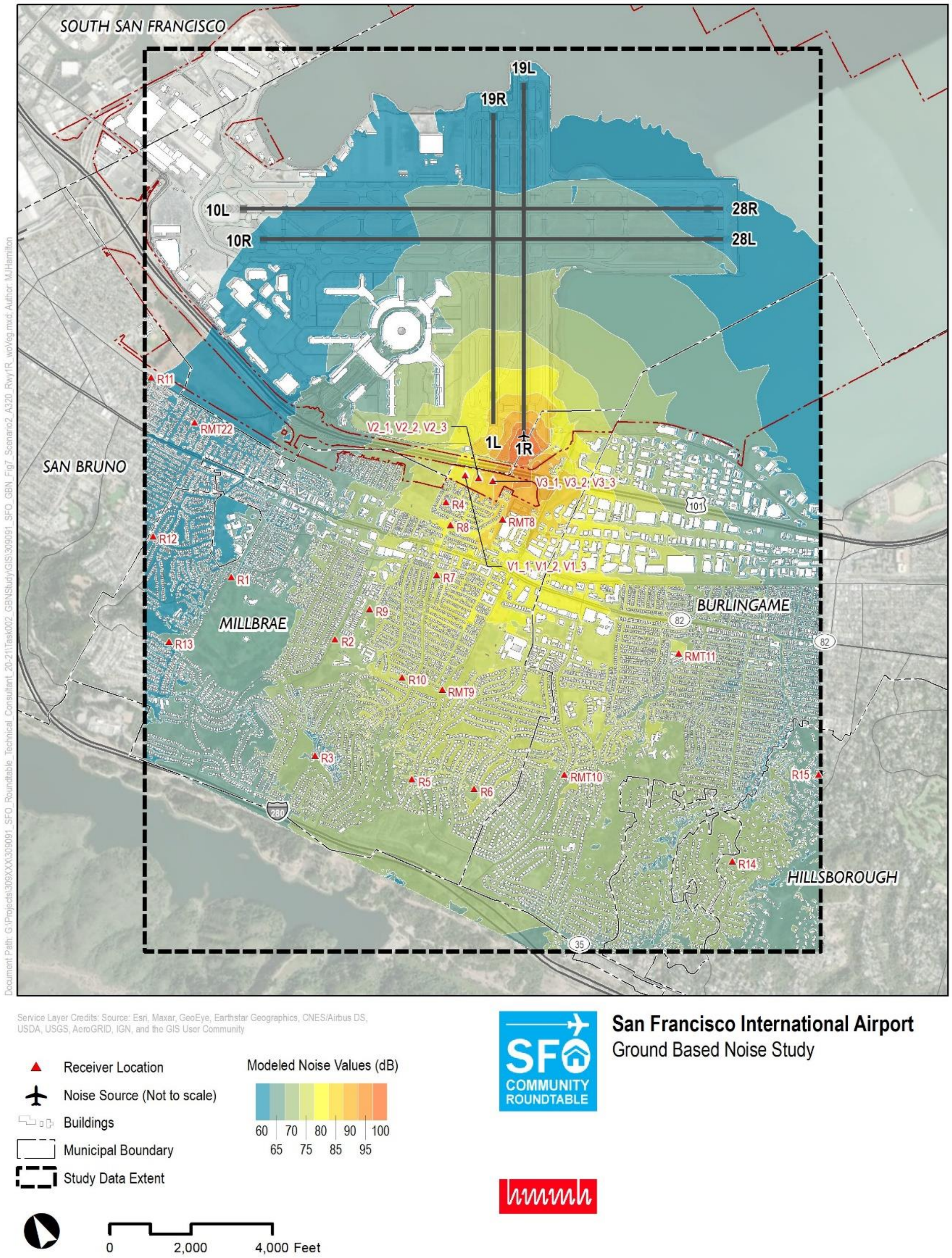


Figure 15: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation

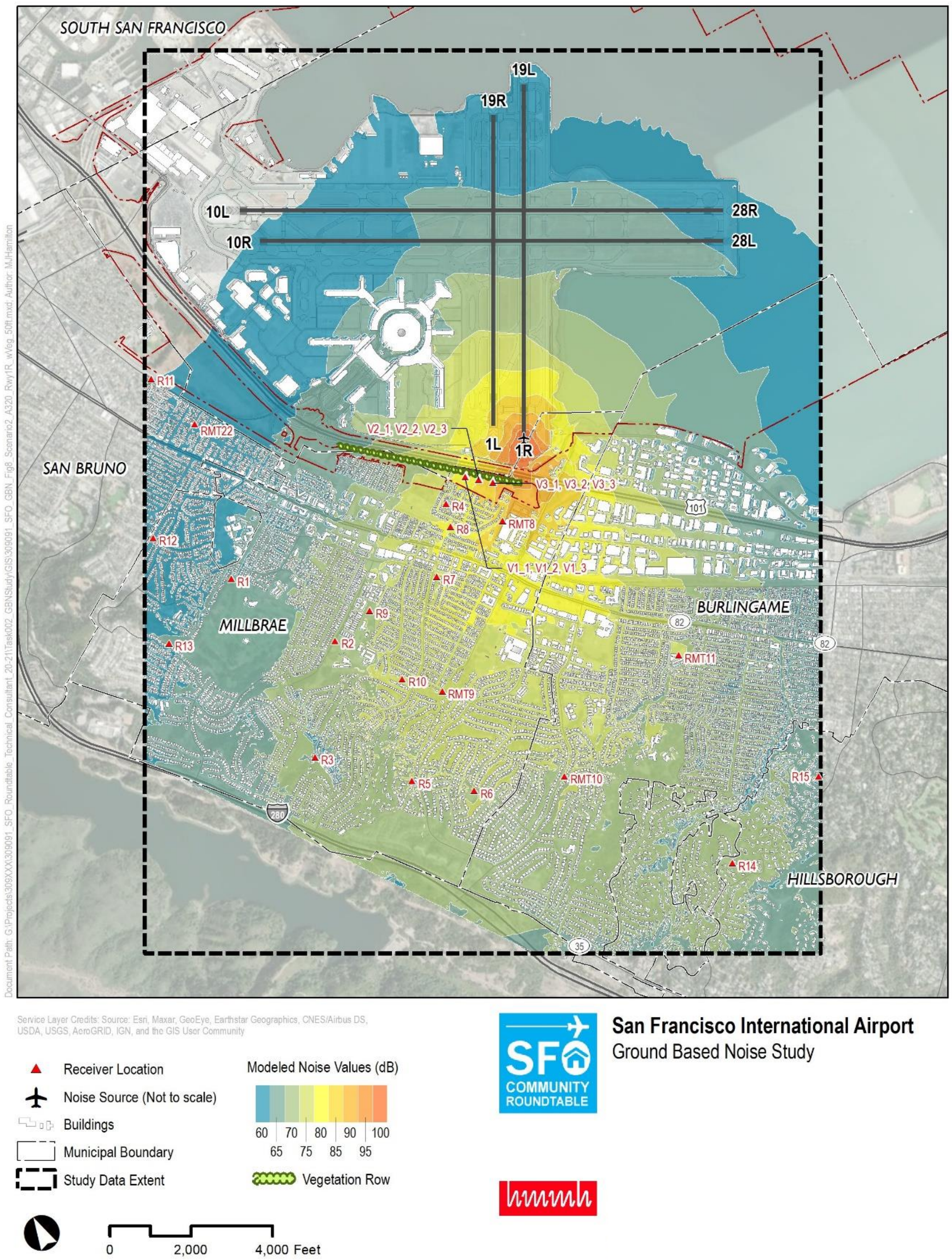


Figure 16: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

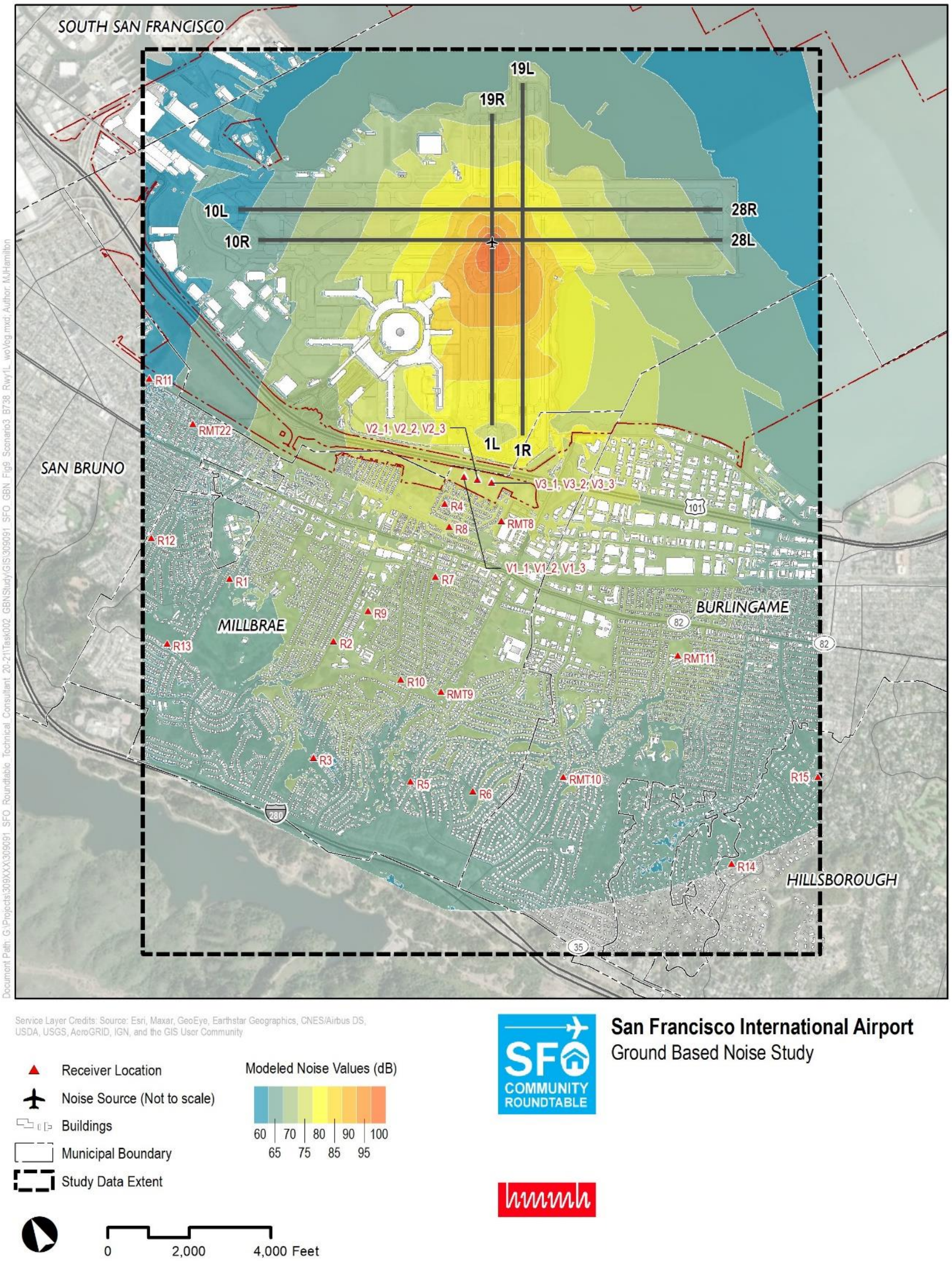


Figure 17: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

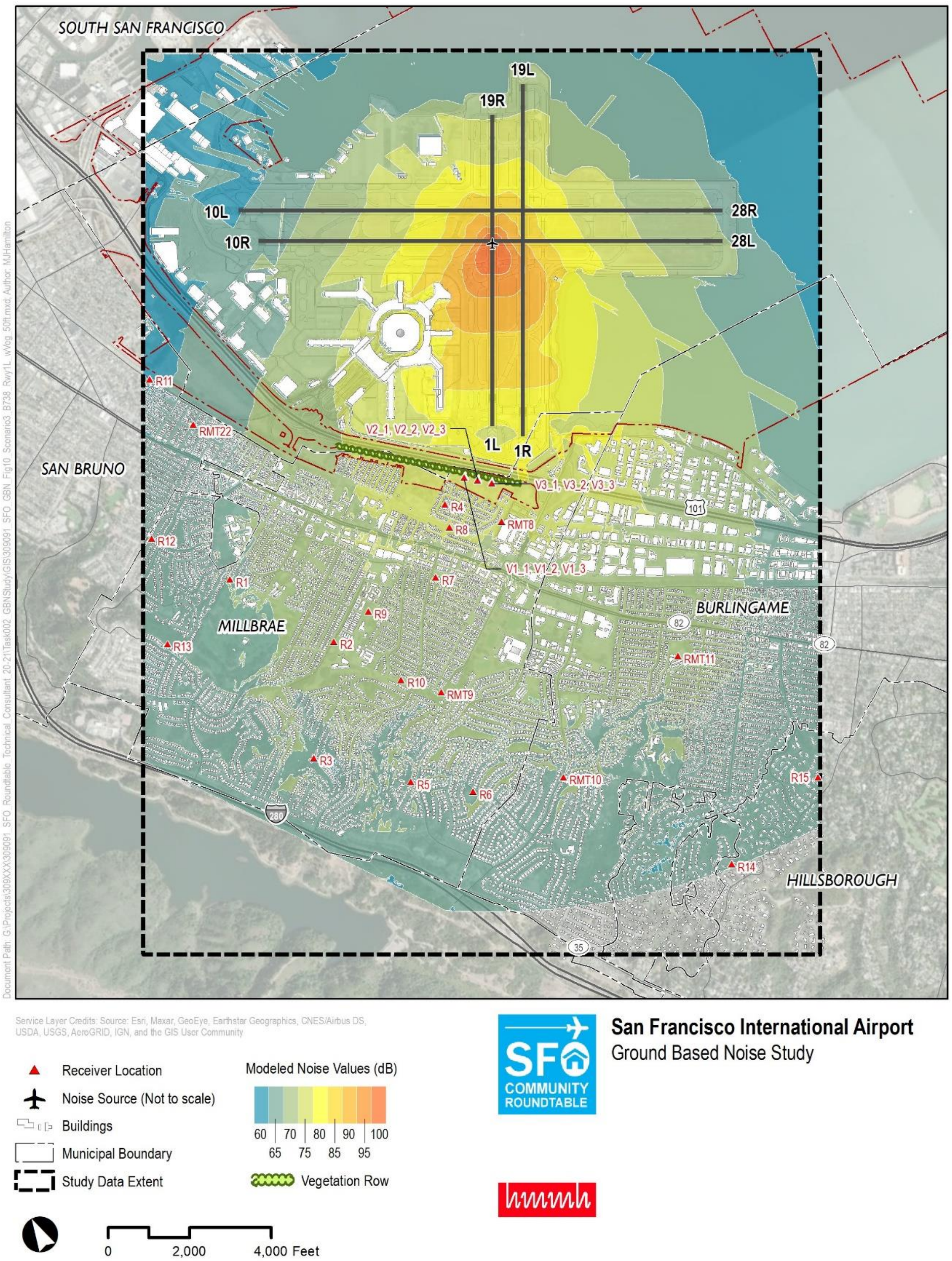


Figure 18: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

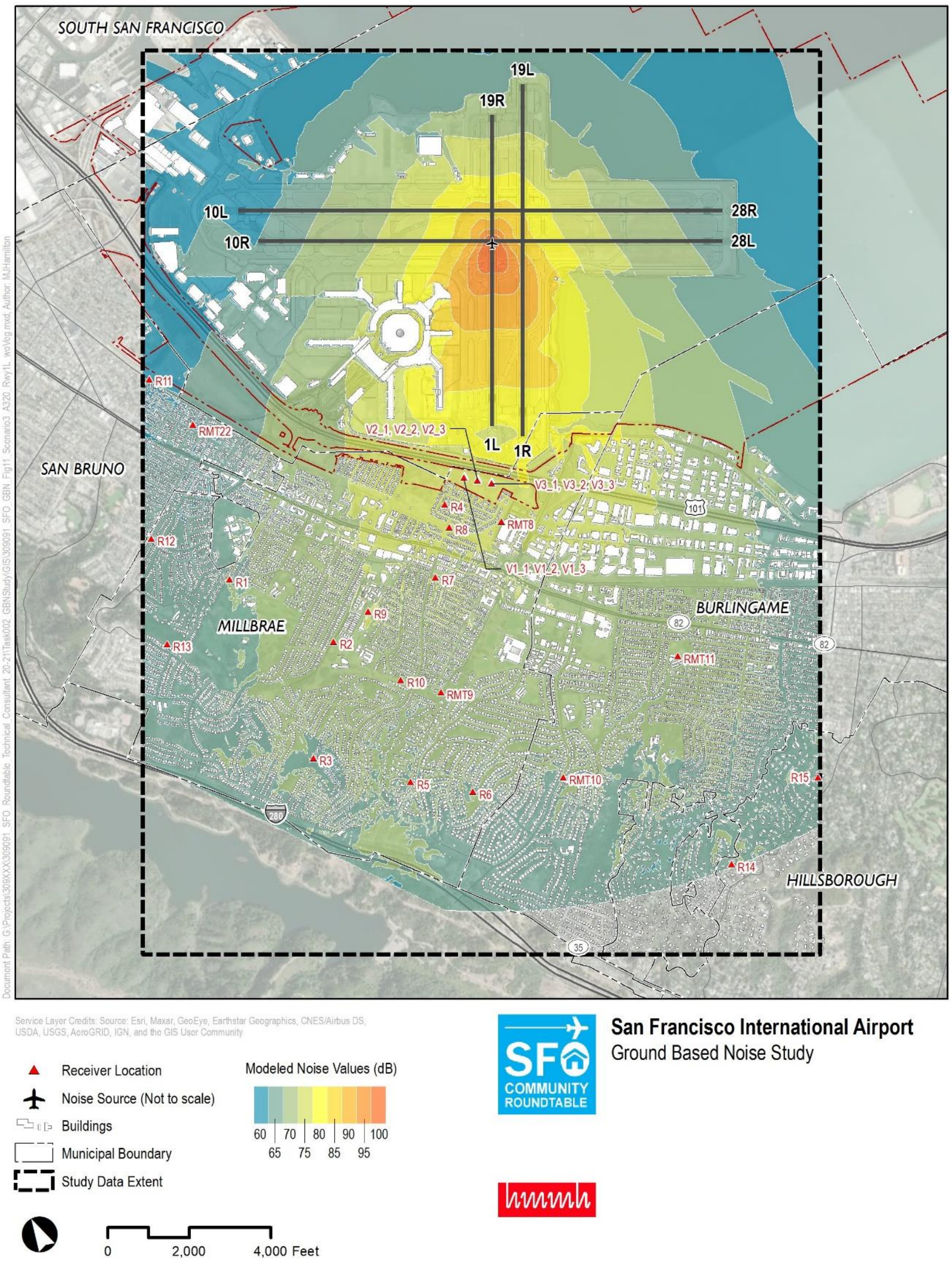


Figure 19: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

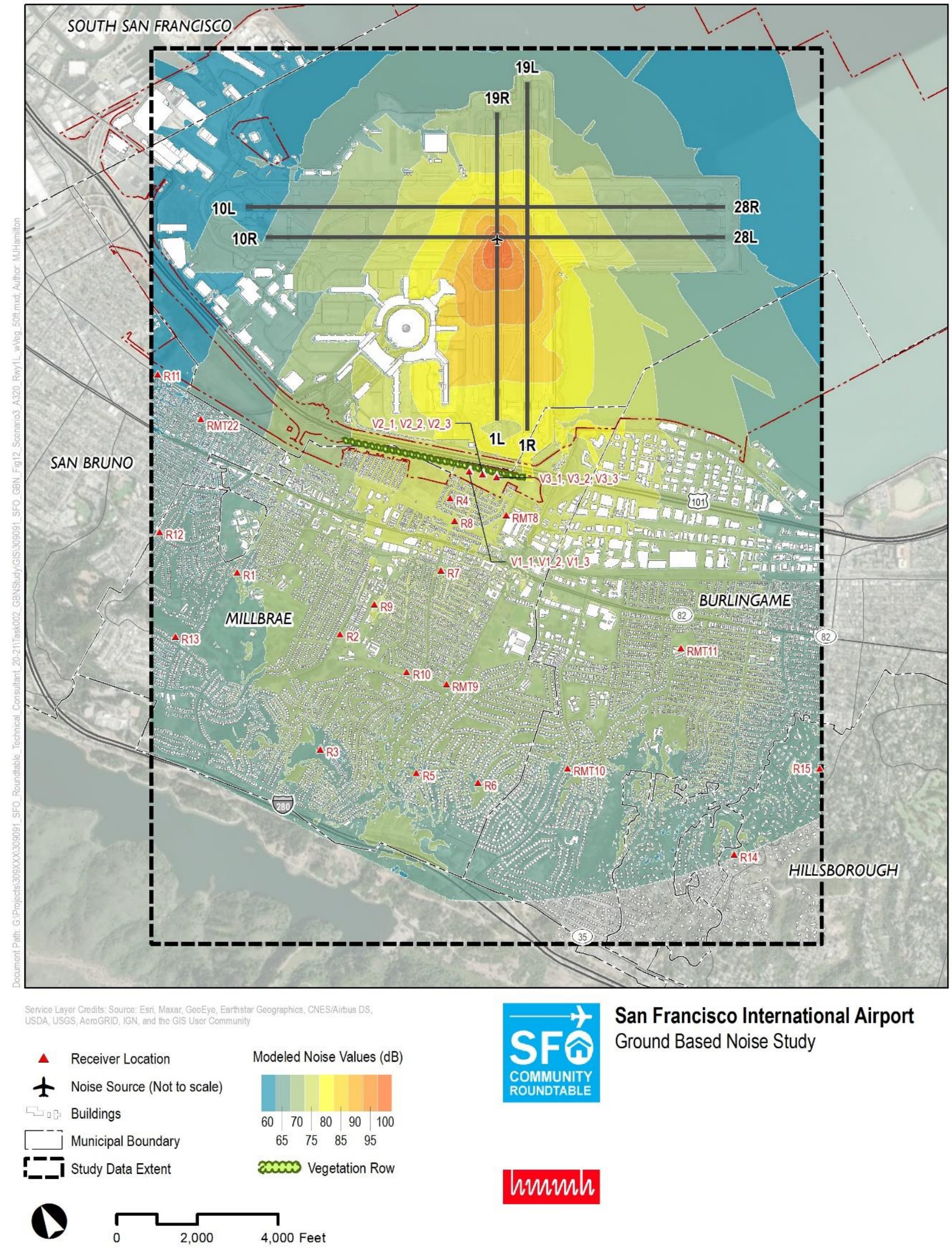


Figure 20: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

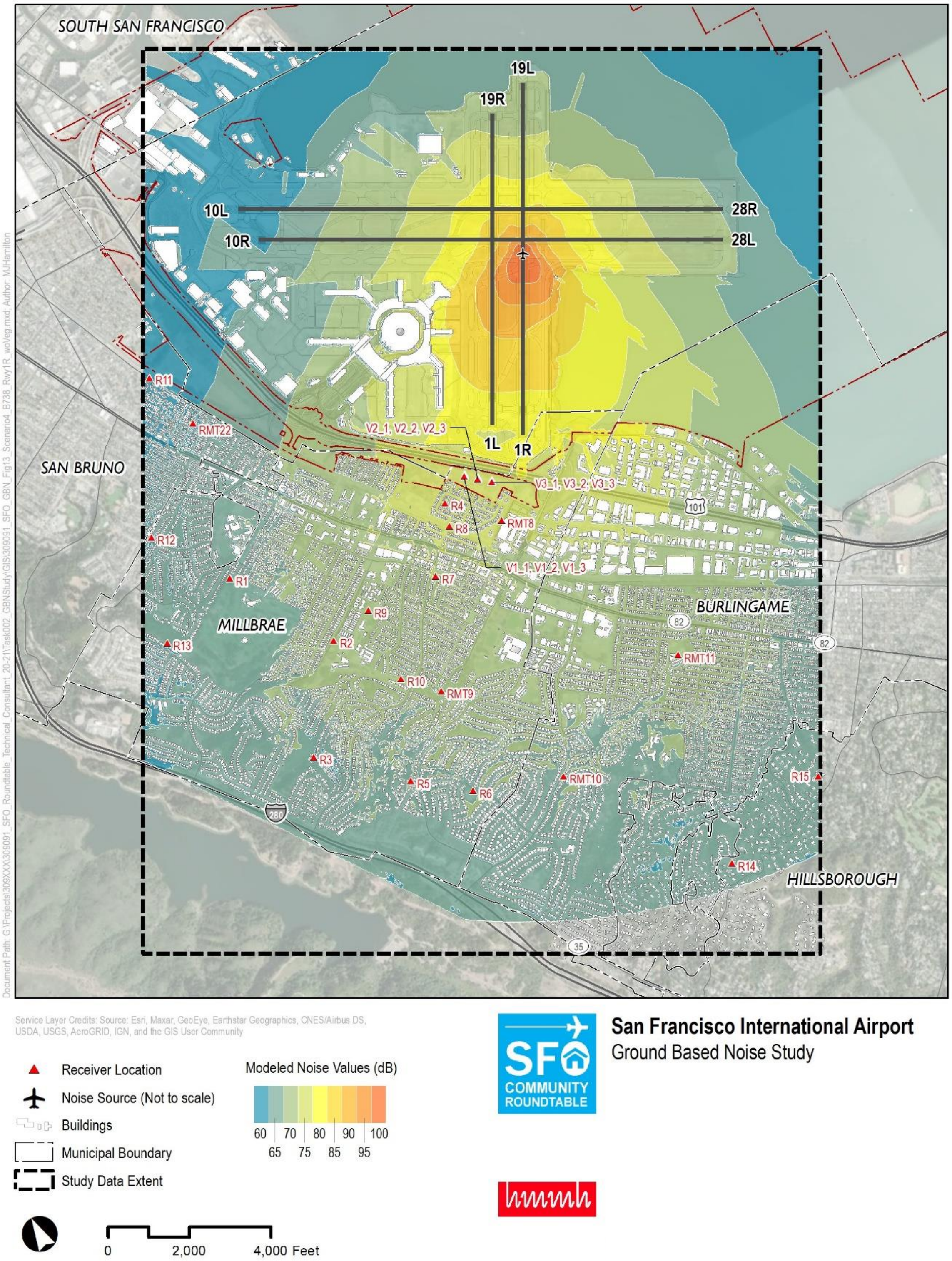


Figure 21: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

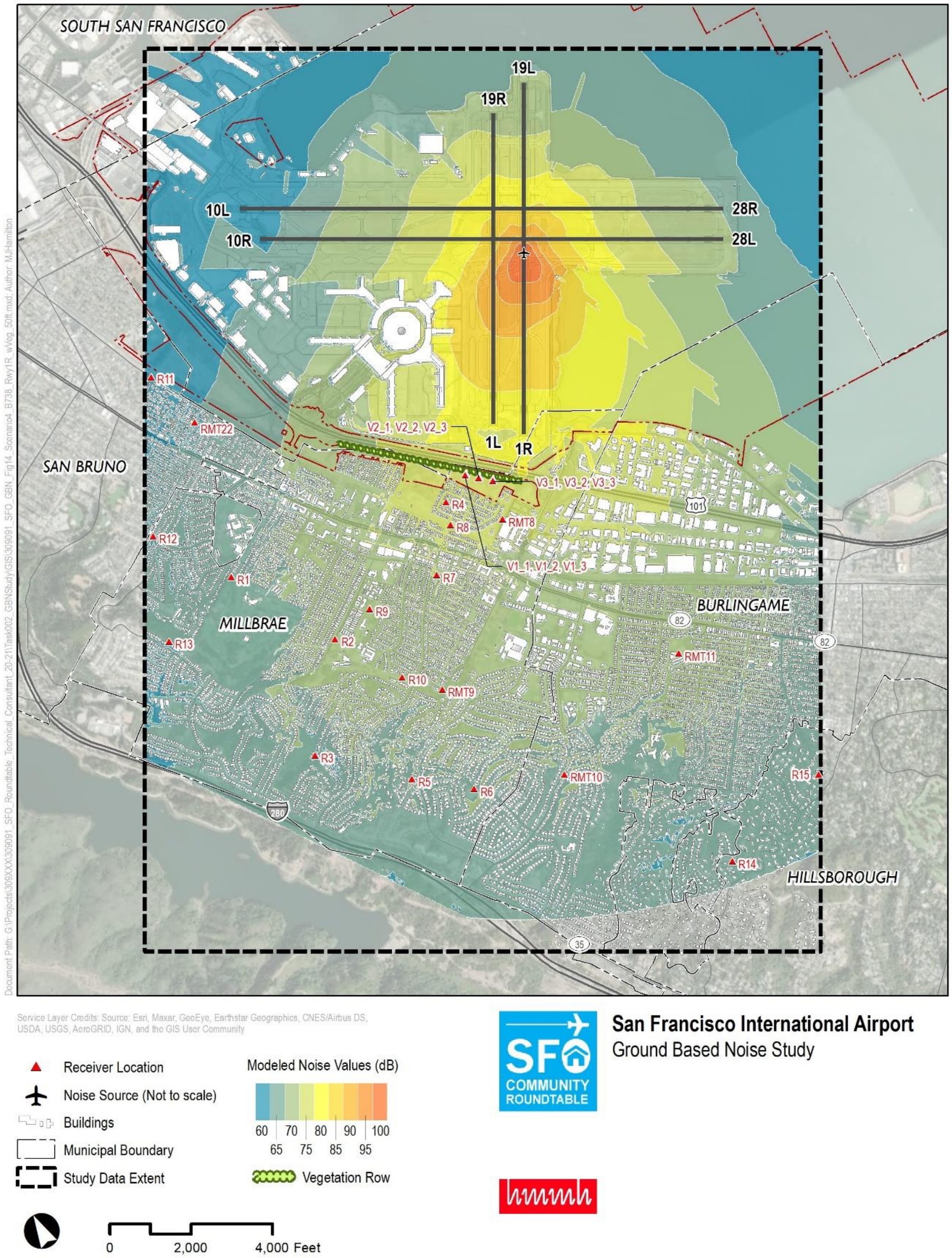


Figure 22: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

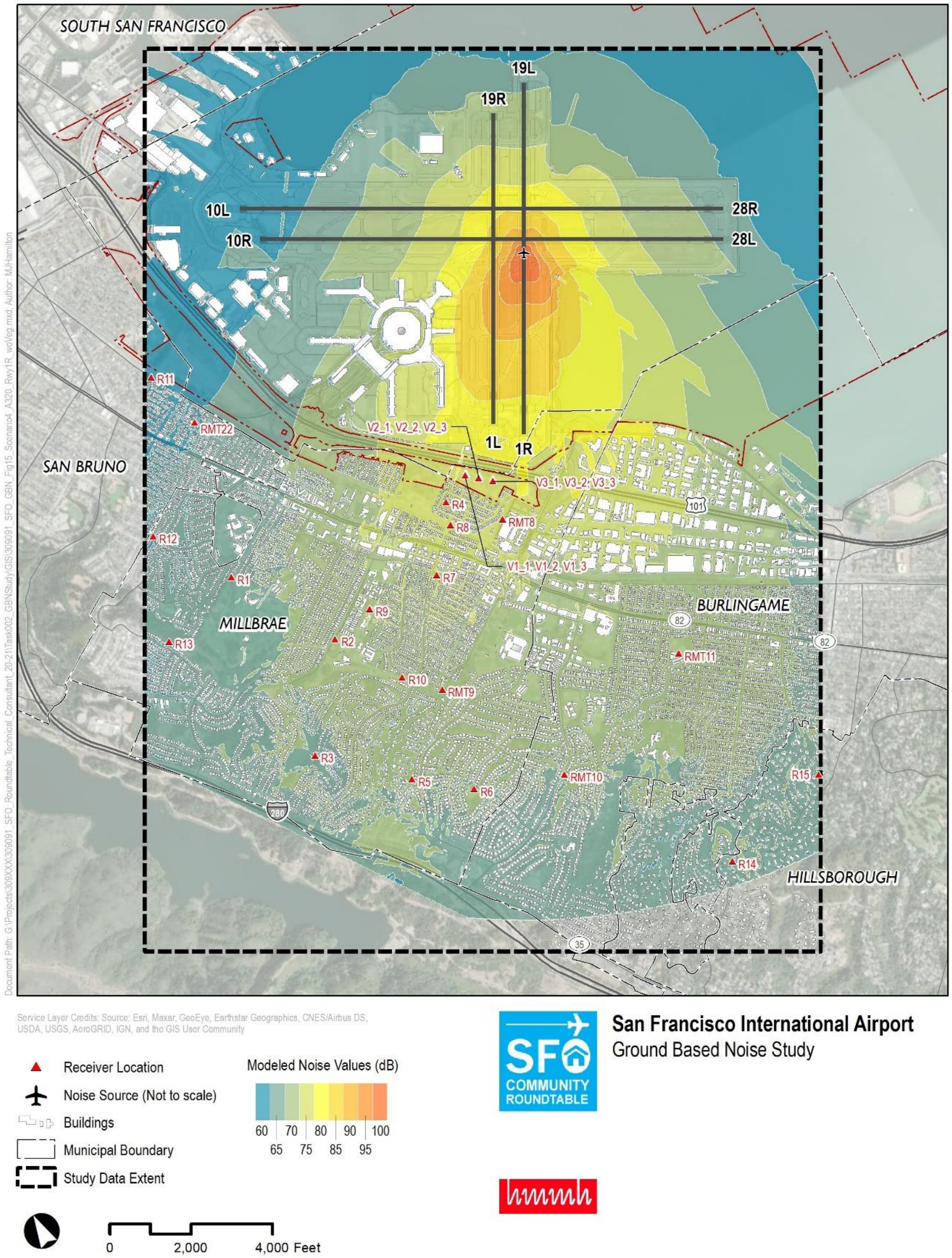


Figure 23: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

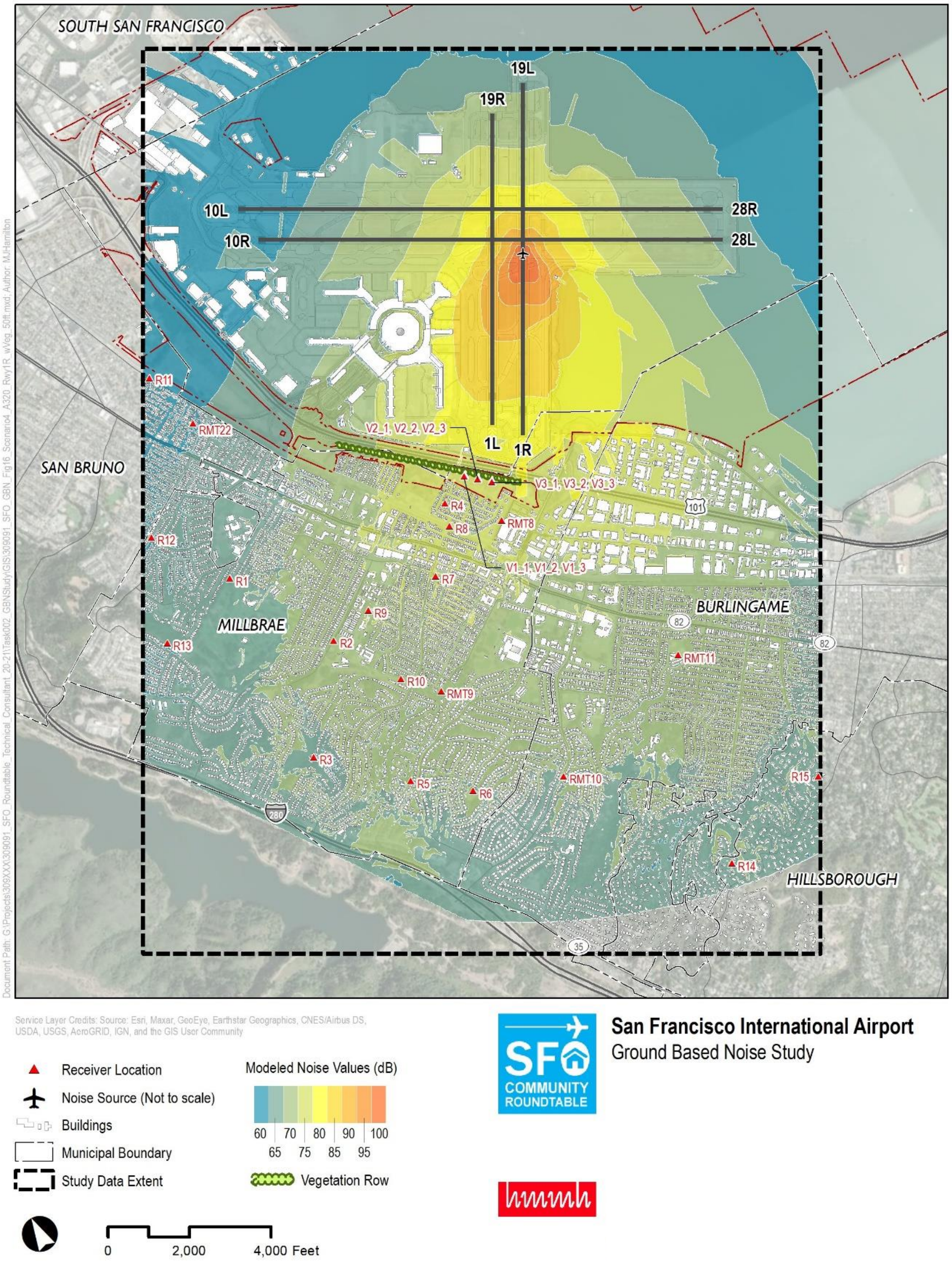


Figure 24: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

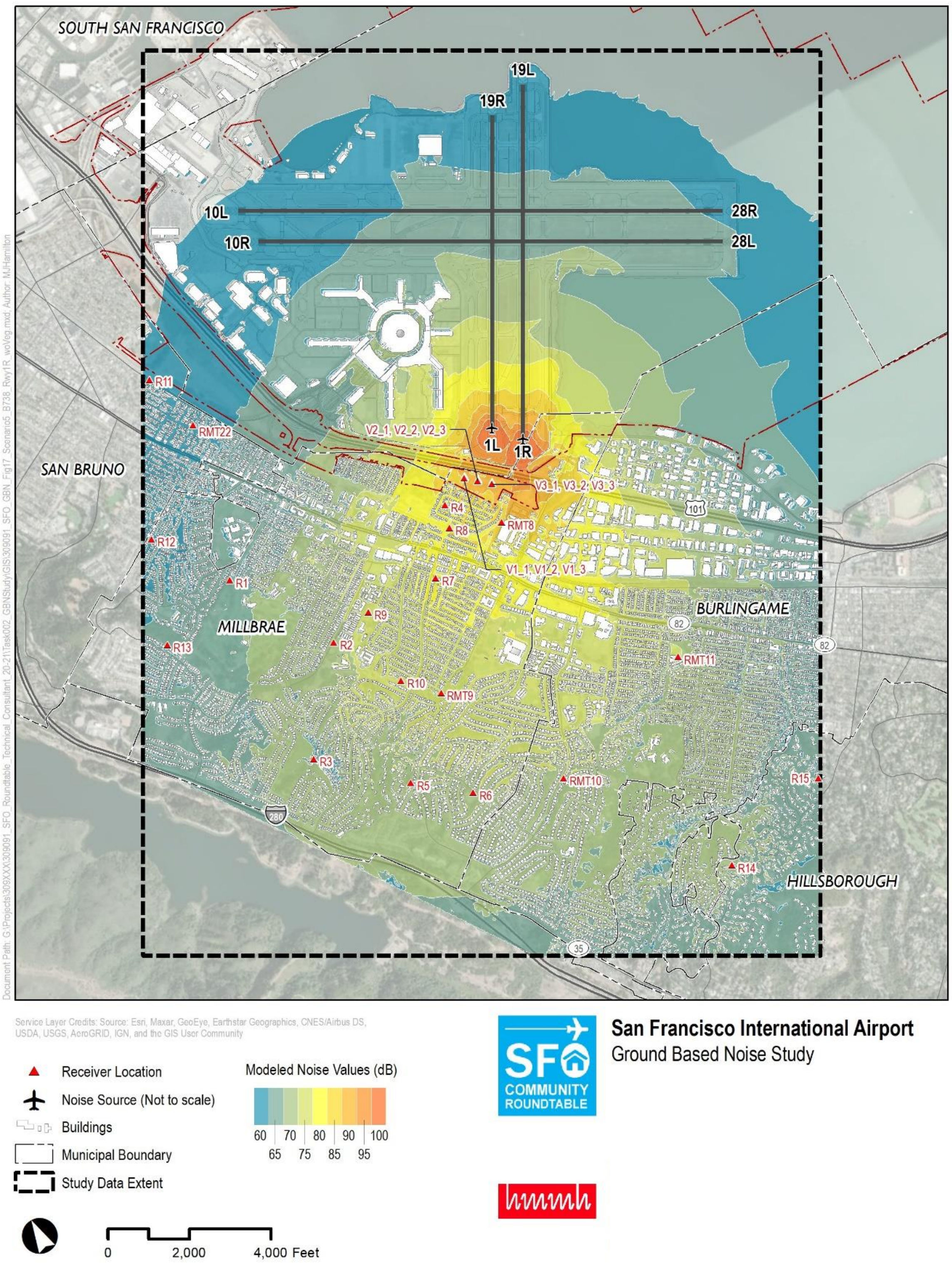


Figure 25: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

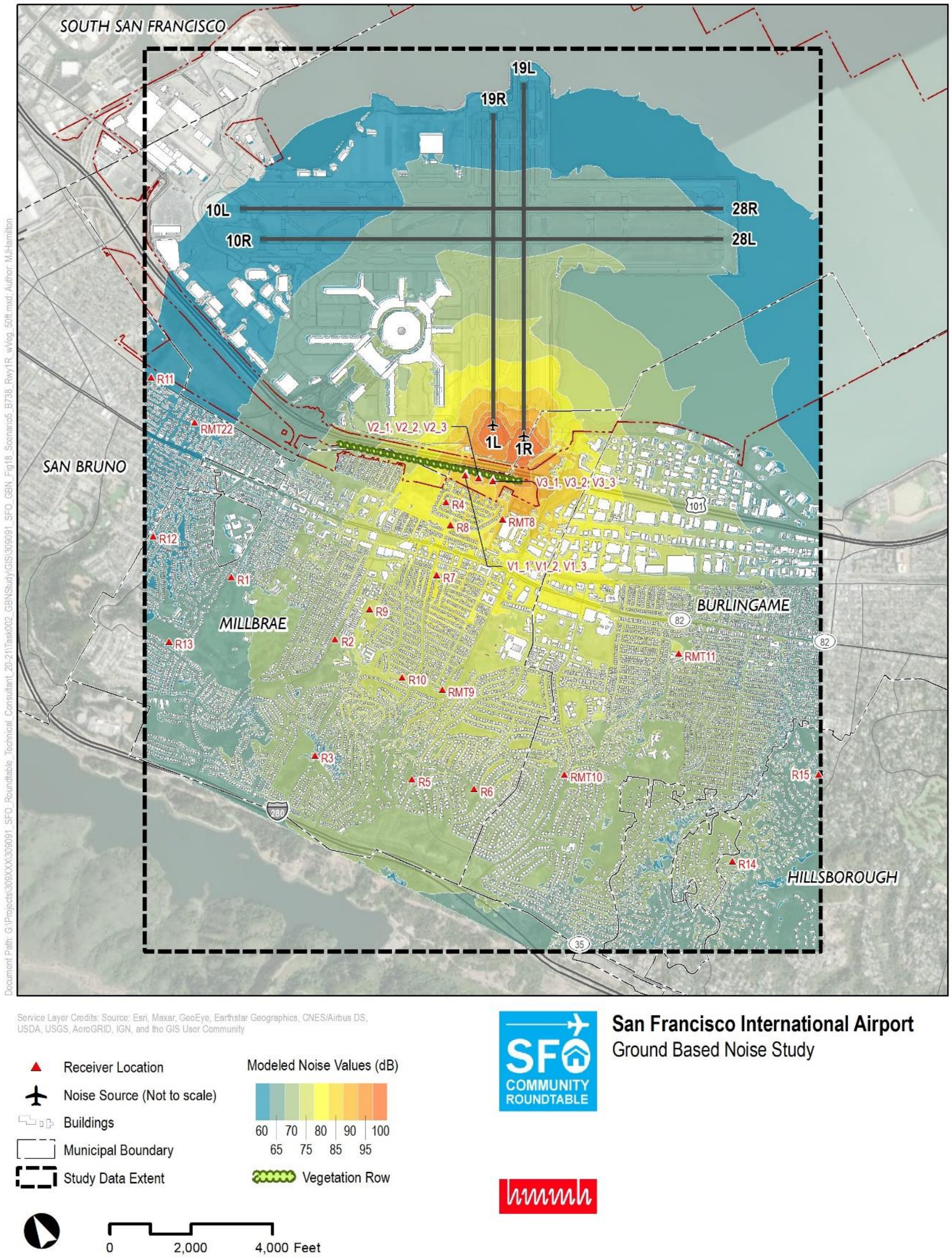


Figure 26: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

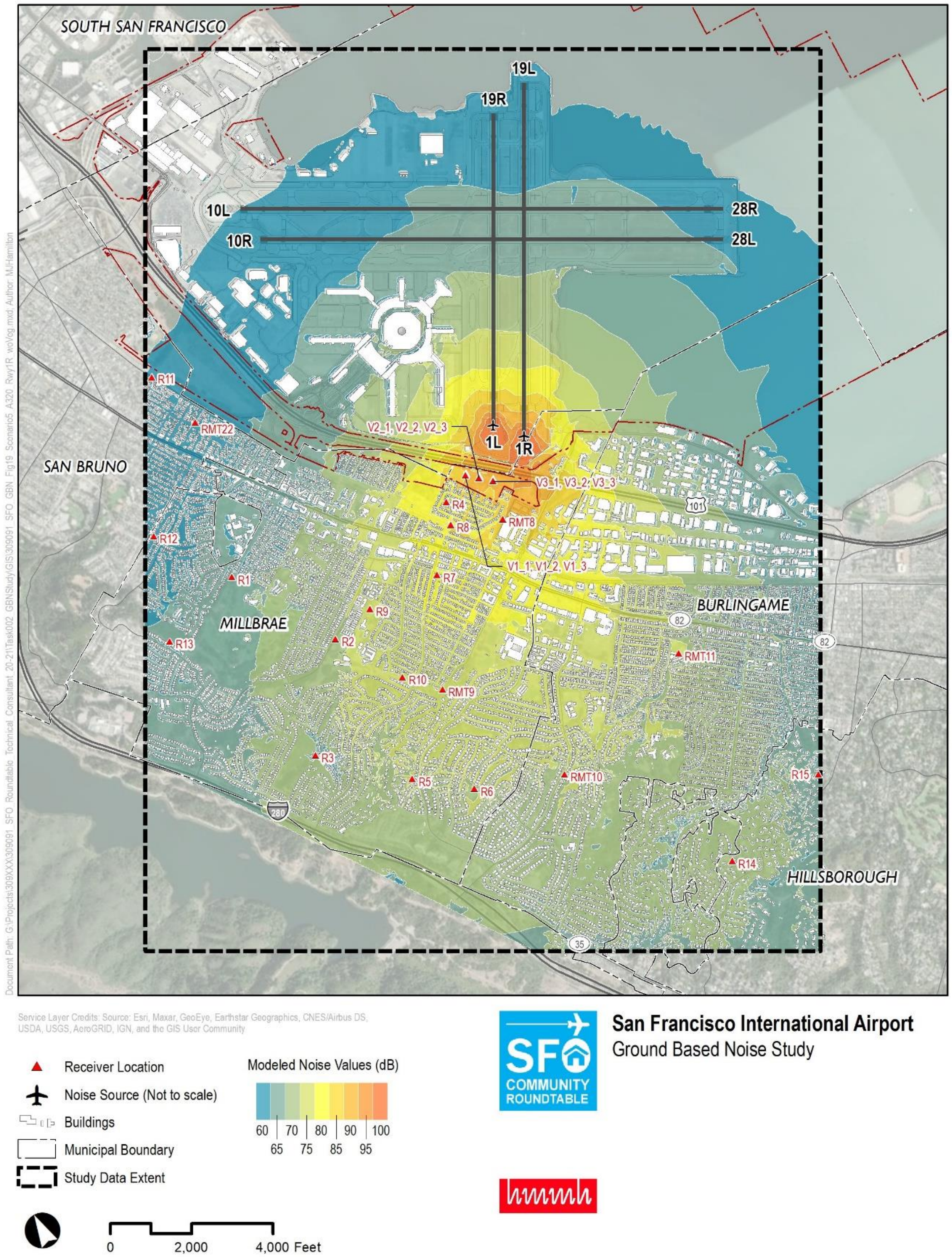


Figure 27: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

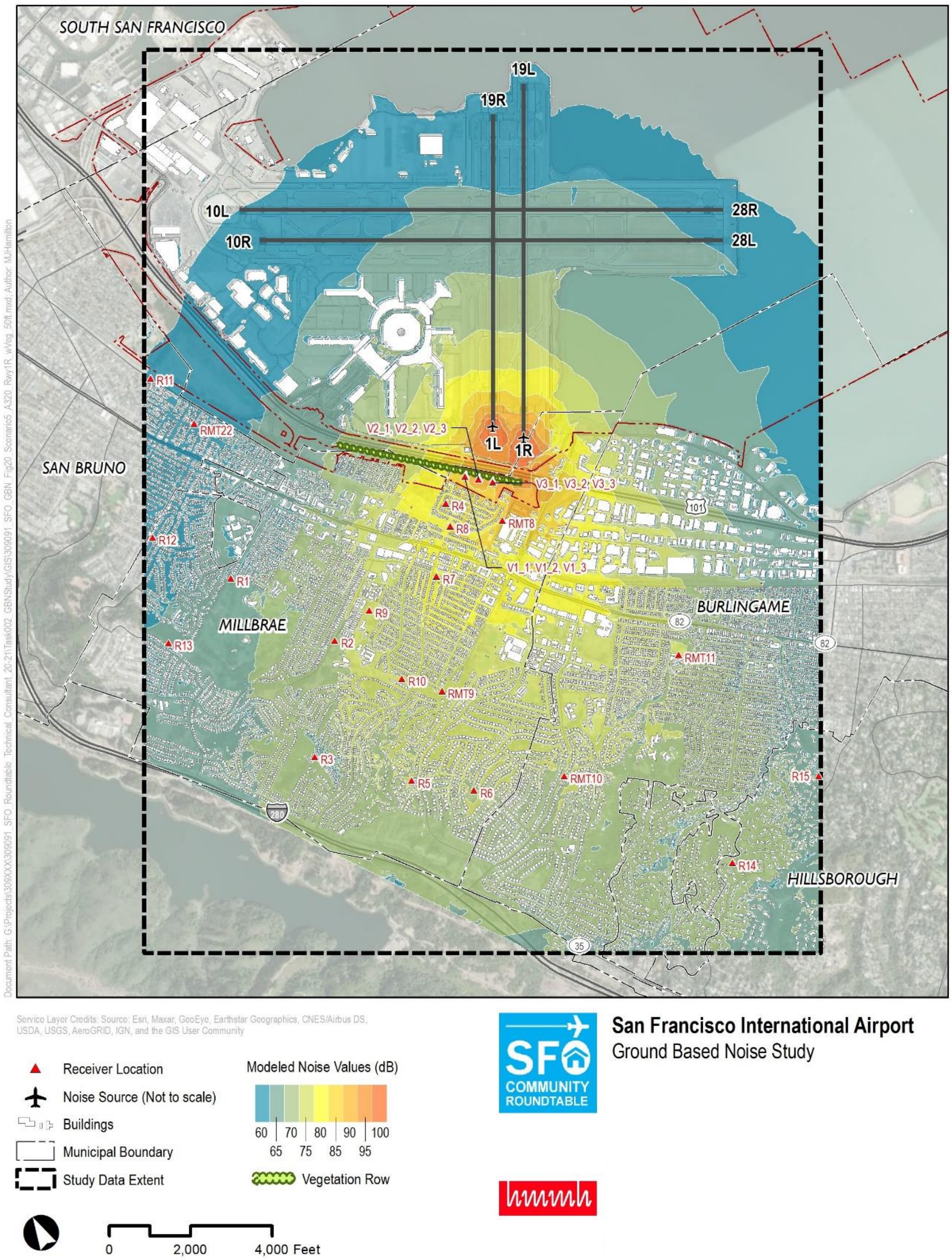


Figure 28: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

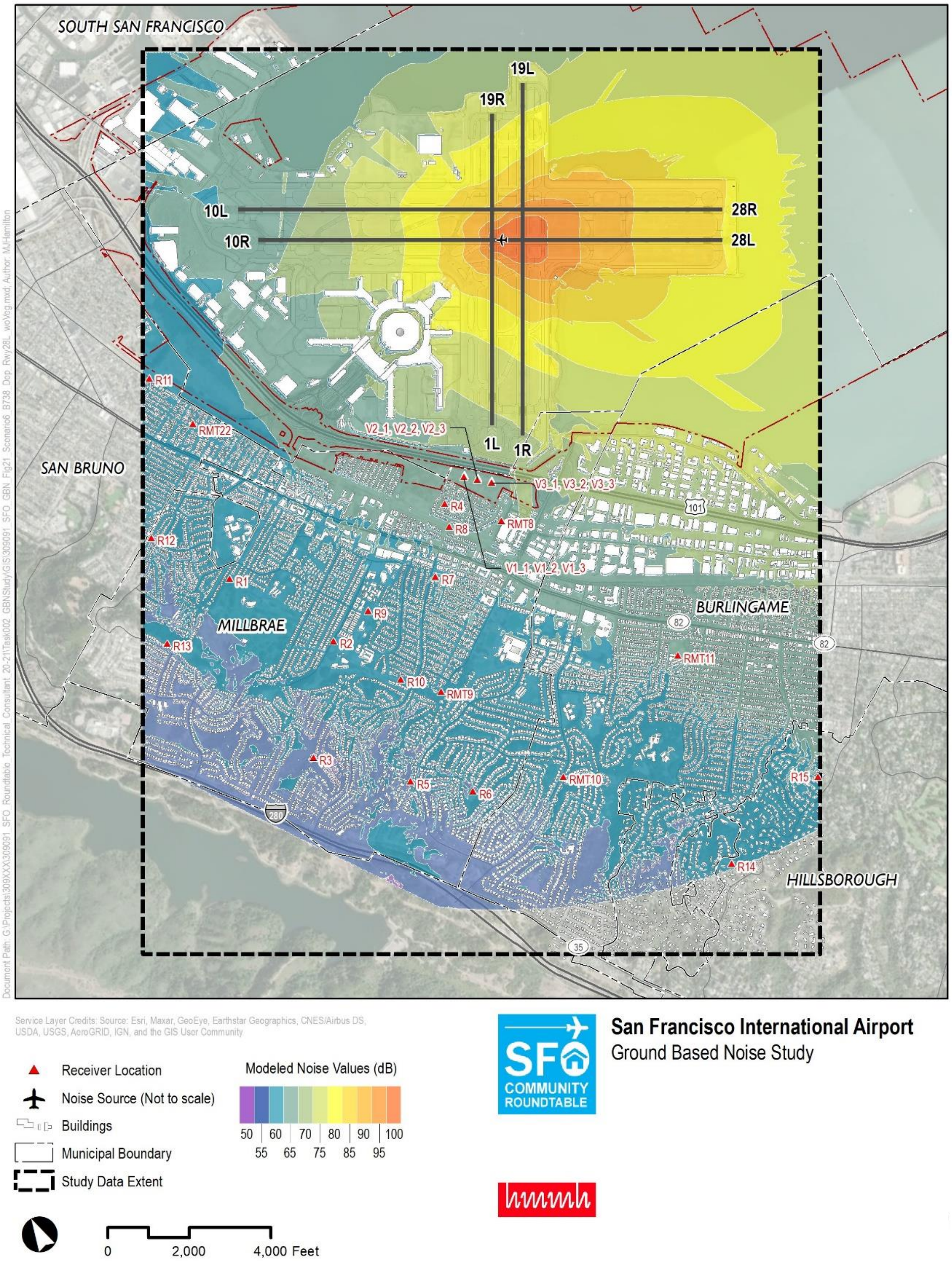


Figure 29: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – Without Vegetation

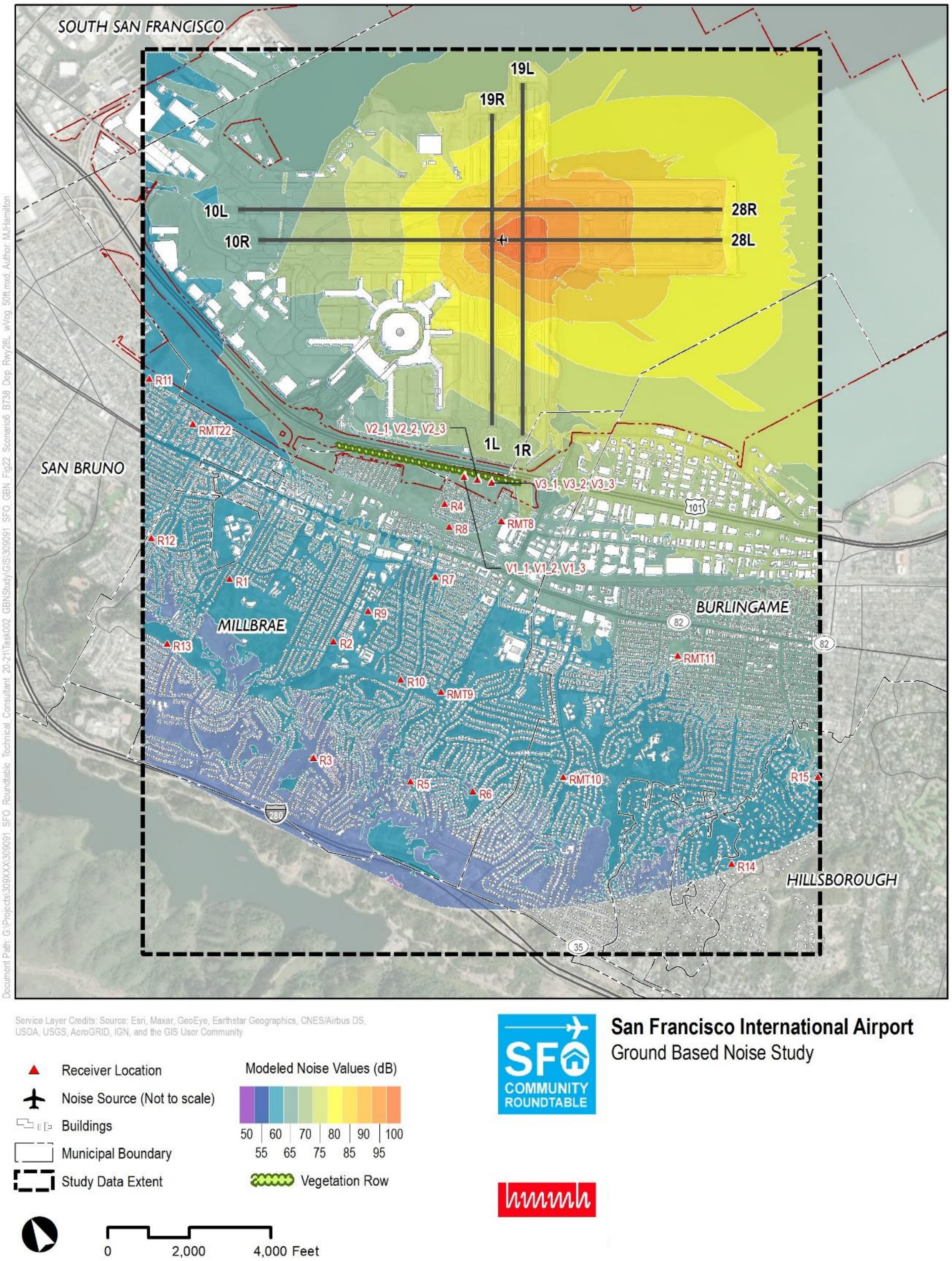


Figure 30: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – With Vegetation (50 Feet)

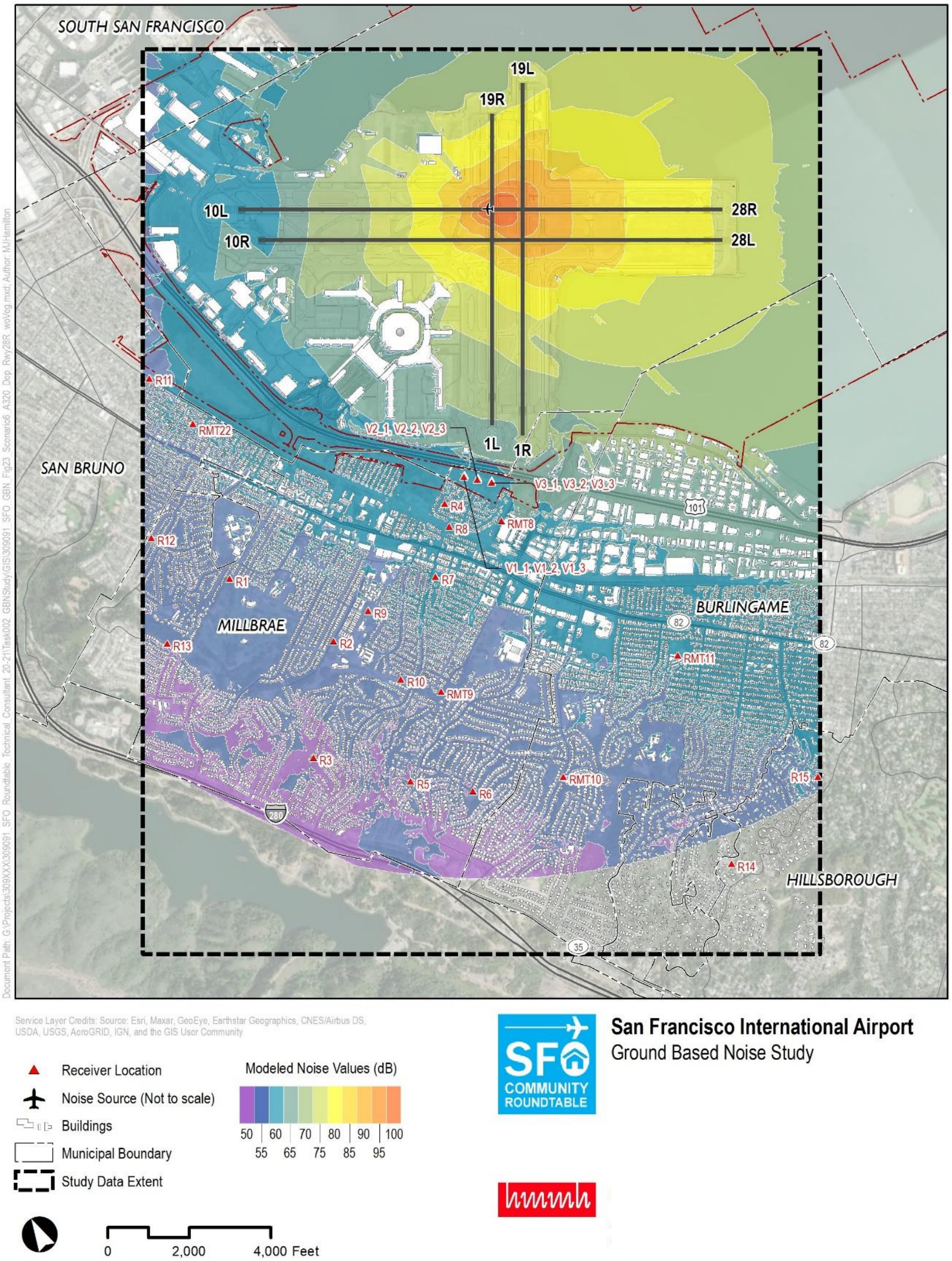


Figure 31: Scenario 6 – B738 Departing Runway 28R at Secondary Takeoff Point – Without Vegetation

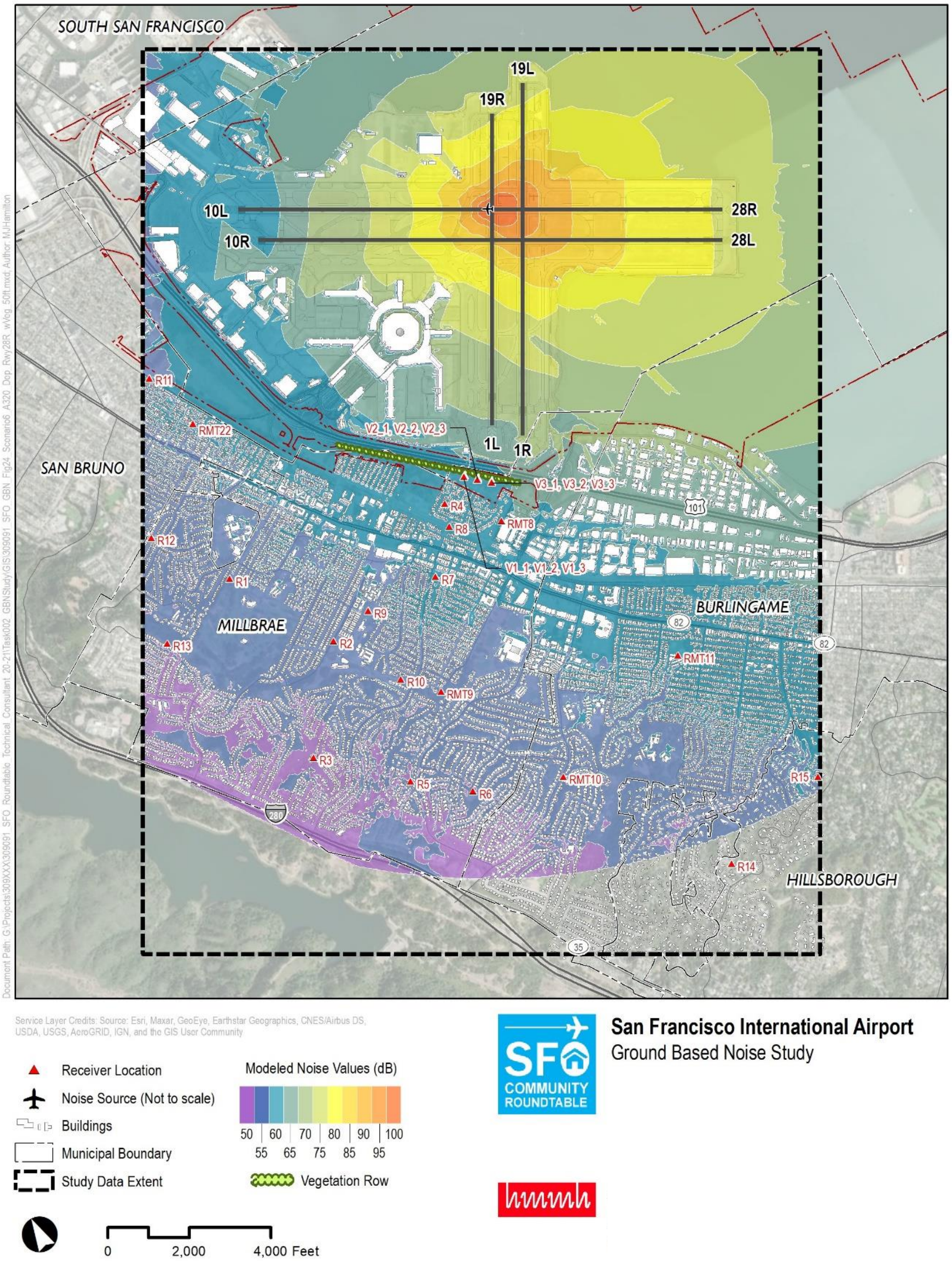


Figure 32: Scenario 6 - B738 Departing Runway 28R at Secondary Takeoff Point – With Vegetation (50 Feet)

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.

[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.

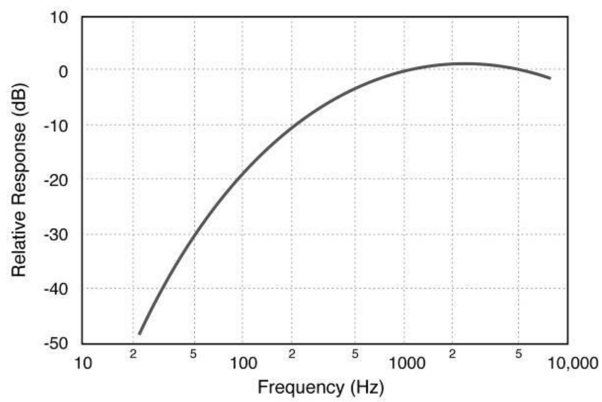


Figure A-1 A-Weighting Frequency Response

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.

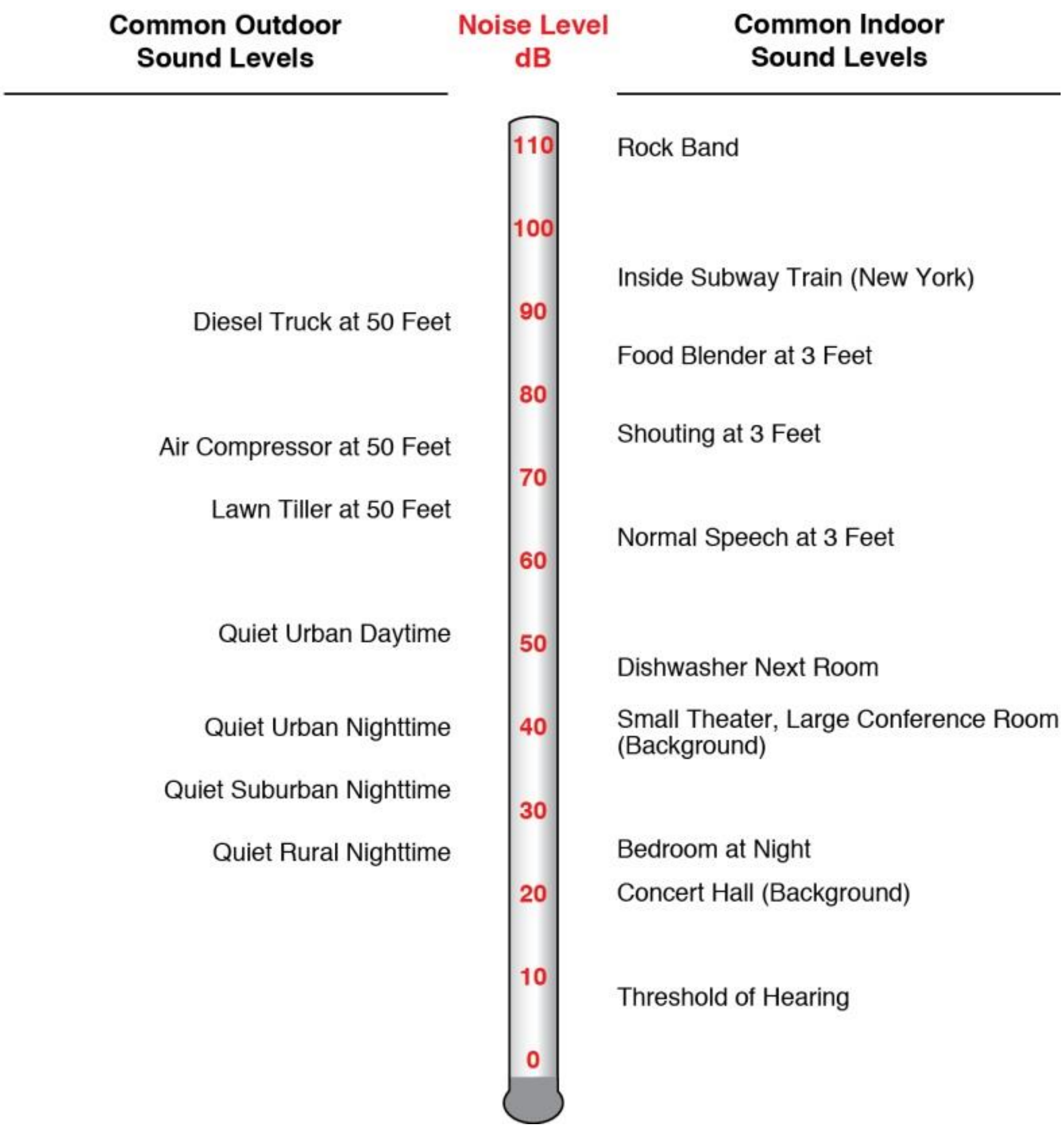


Figure A-2 A-Weighted Sound Levels for Common Sounds

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.

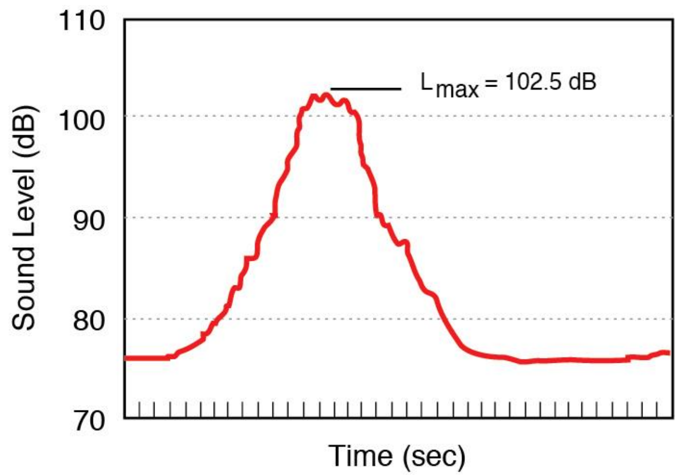


Figure A-3 Variation in A-Weighted Sound Level over Time and Maximum Noise Level

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}.

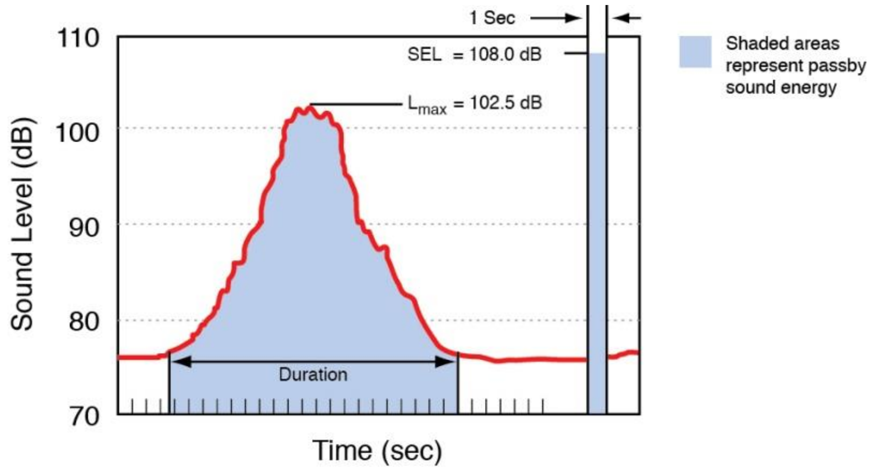


Figure A-4 Graphical Depiction of Sound Exposure Level

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.

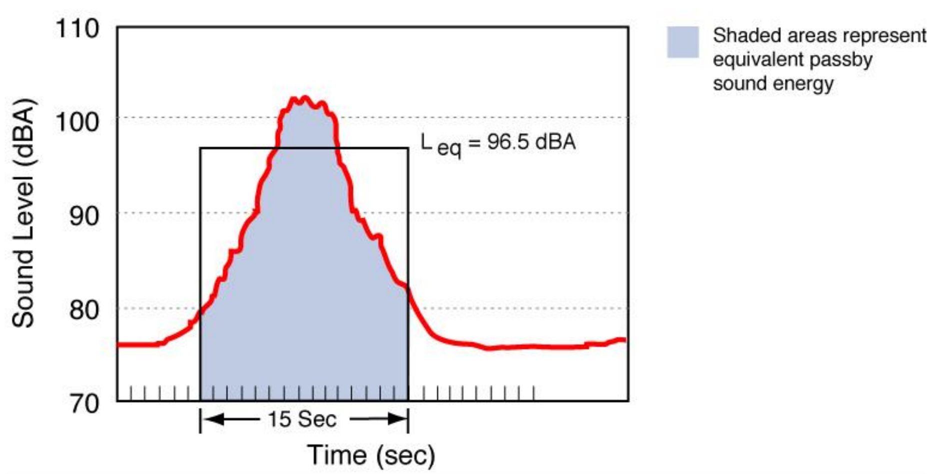


Figure A-5 Example of a 15-Second Equivalent Sound Level

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.

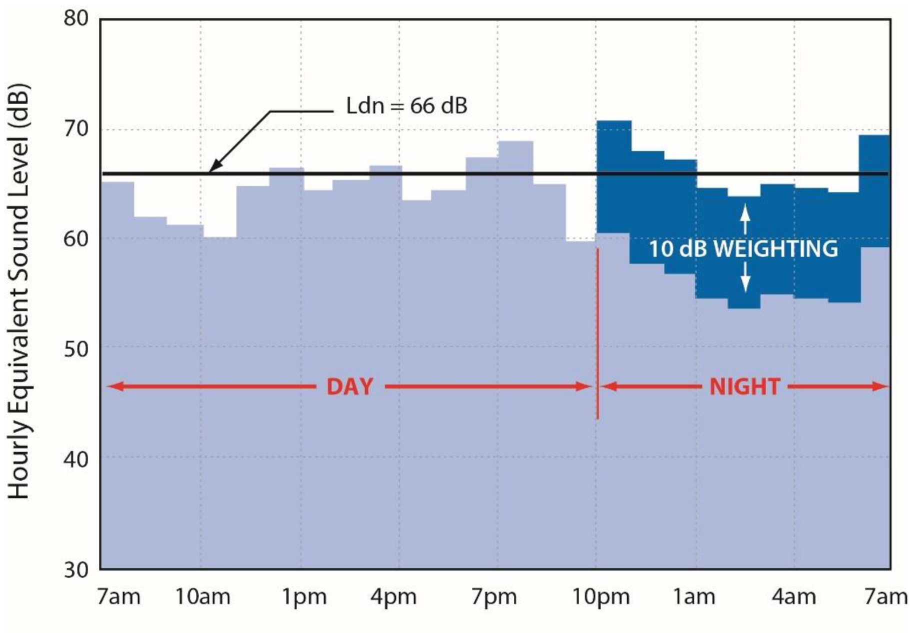


Figure A-6 Example of a Day-Night Average Sound Level Calculation

Source: HMMH

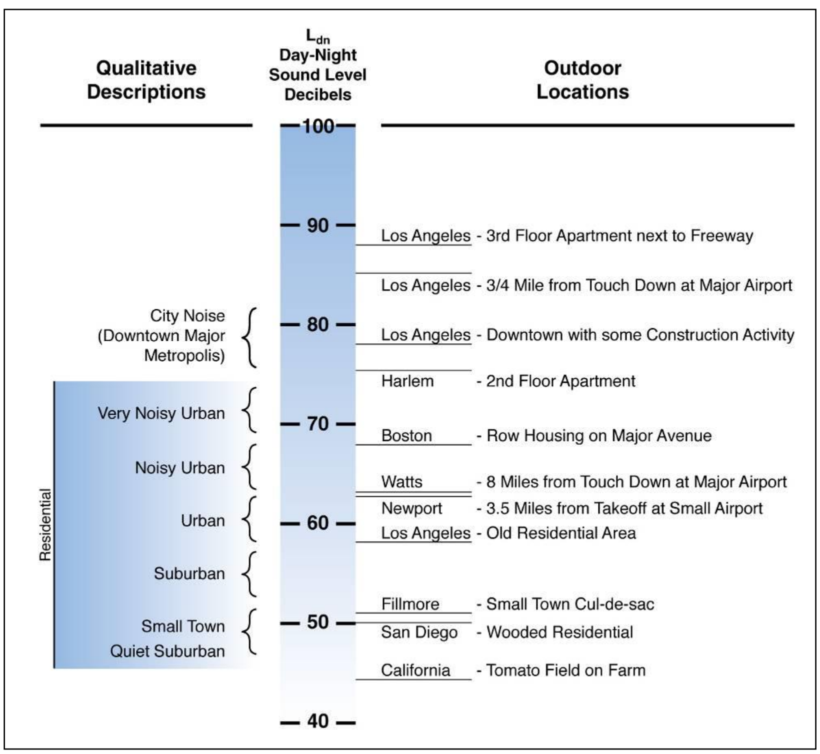


Figure A-7 Examples of Measured Day-Night Average Sound Levels, DNL

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.

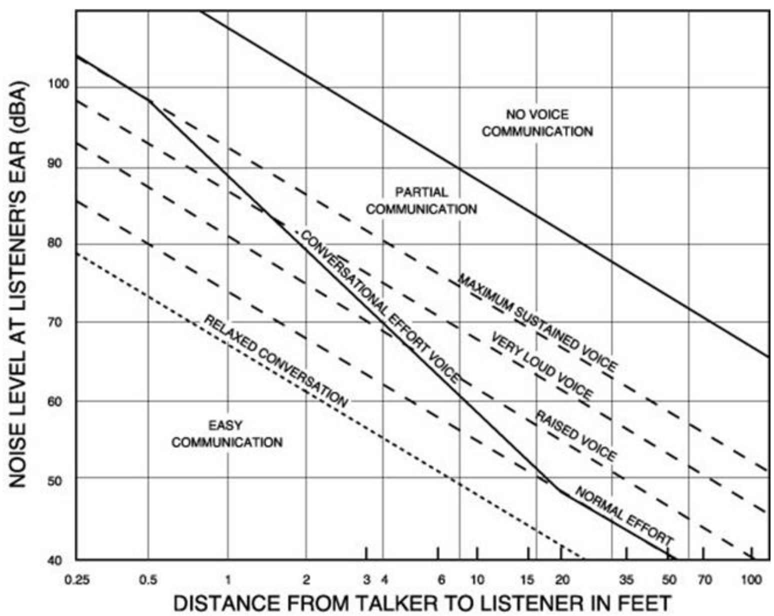


Figure A-8 Outdoor Speech Intelligibility

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.

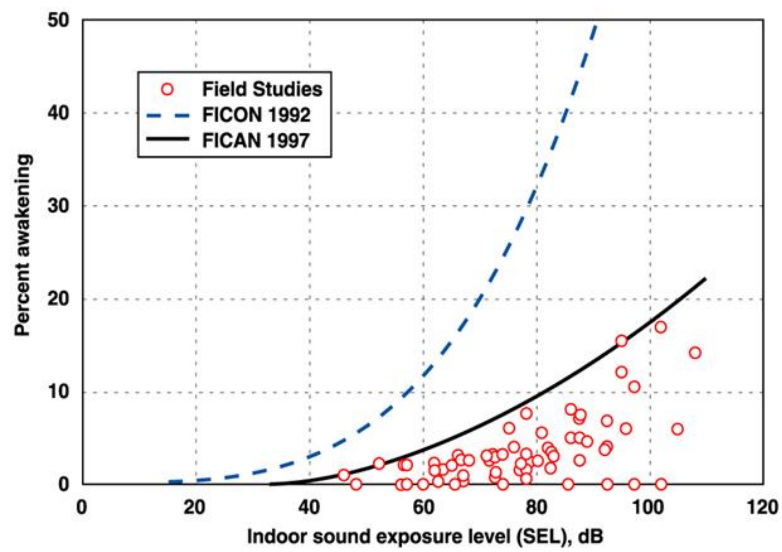


Figure A-9 Sleep Interference

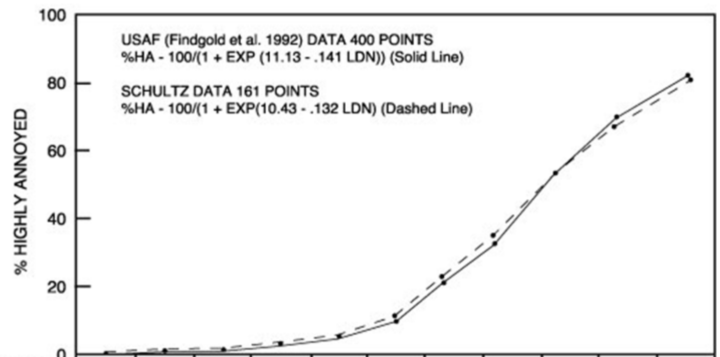
Source: Federal Interagency Committee on Aircraft Noise (FICAN), "Effects of Aviation Noise on Awakenings from Sleep," June 1997, pg. 6

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

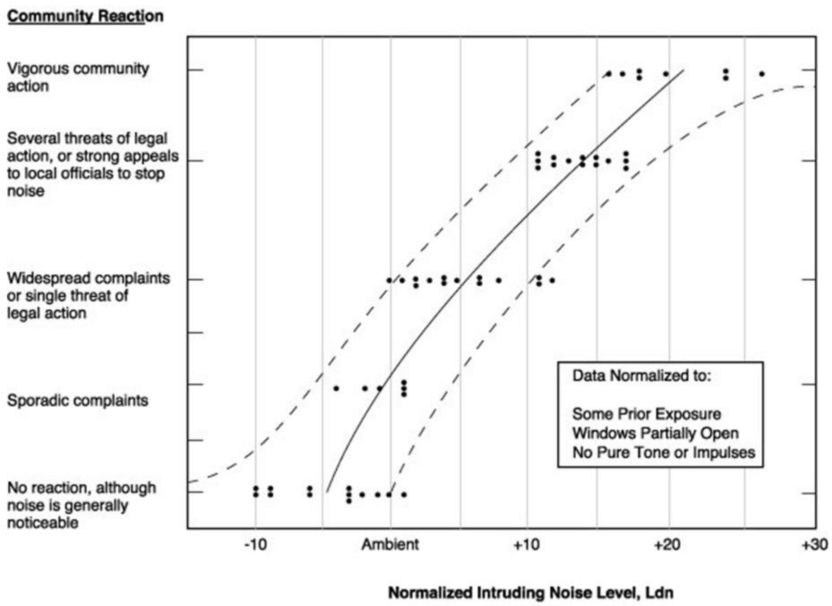


Figure A-11 Community Reaction as a Function of Outdoor DNL

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

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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"

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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)

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

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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)

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

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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"

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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

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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

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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

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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

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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

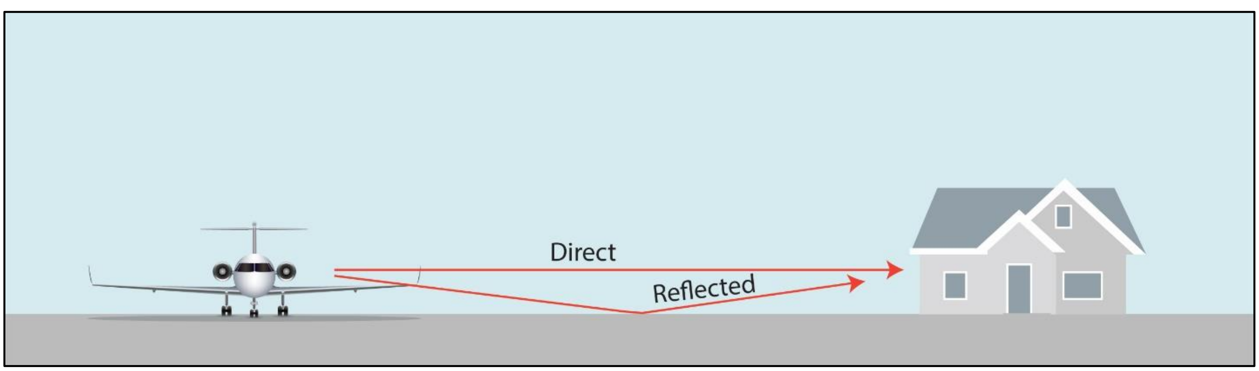
1. Introduction

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.

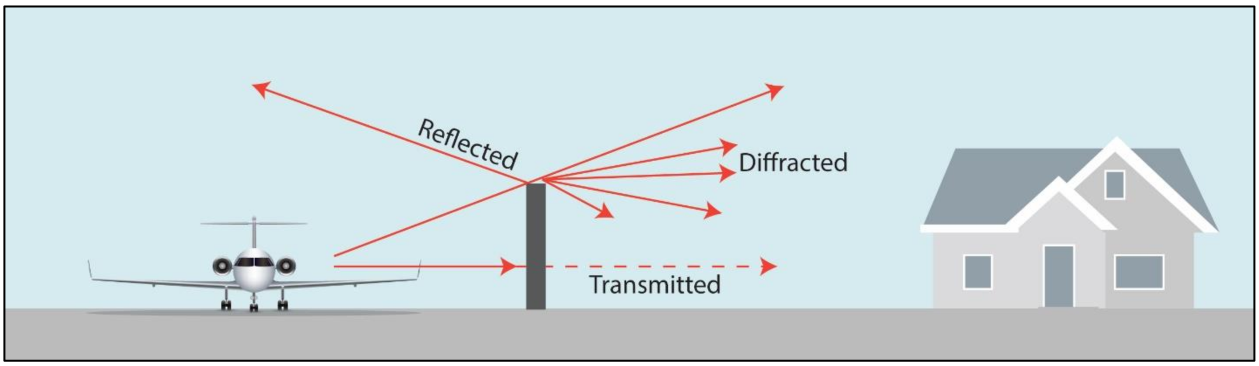
3. Noise Barriers

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.

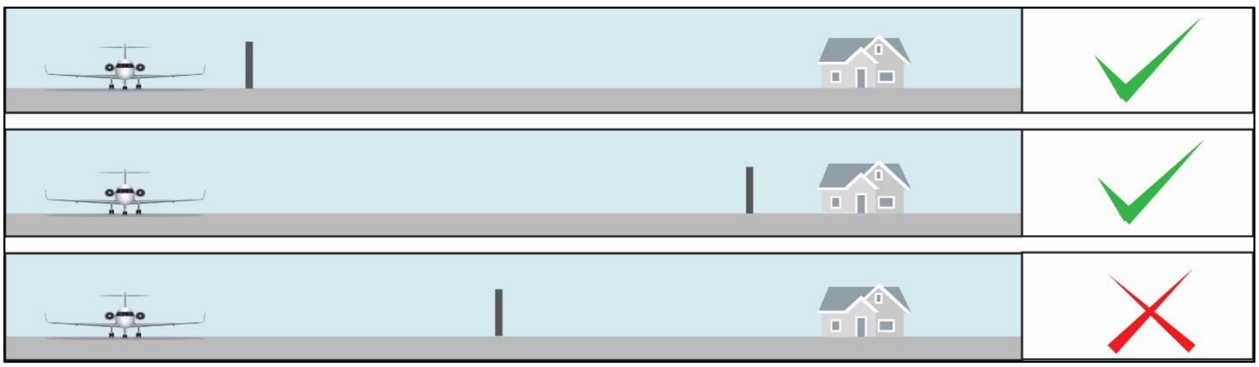
The maintenance free life cycle of a noise barrier as well as the maintenance dependent life-cycle of a noise barrier maintenance depends on several factors, predominantly what the barrier is constructed of and the environmental conditions where it is situated. For example, wooden noise barriers may 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.

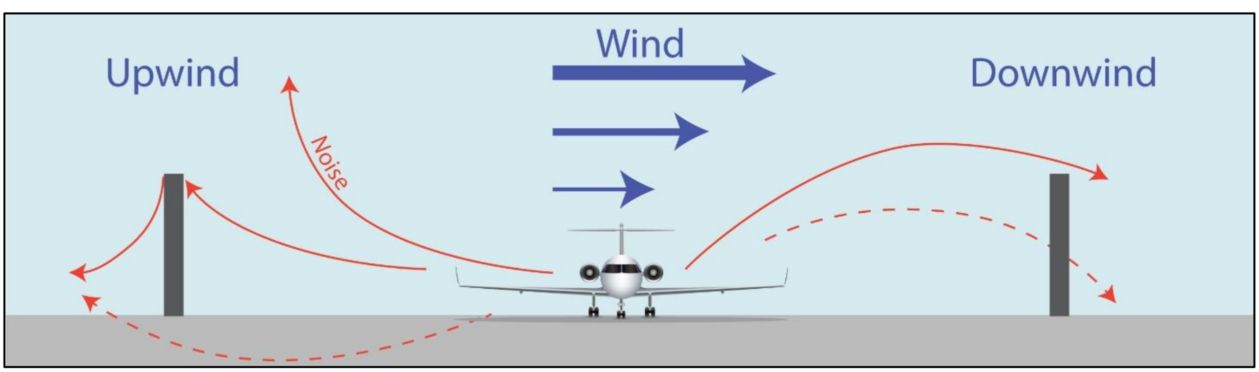
Figure 3. Noise Barrier Placement



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.

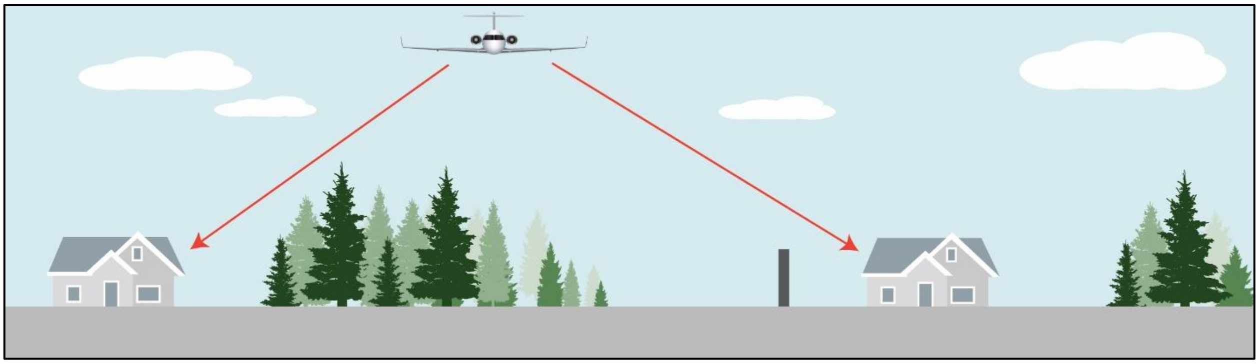
Figure 4. Wind Effects on Noise Barrier Effectiveness



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

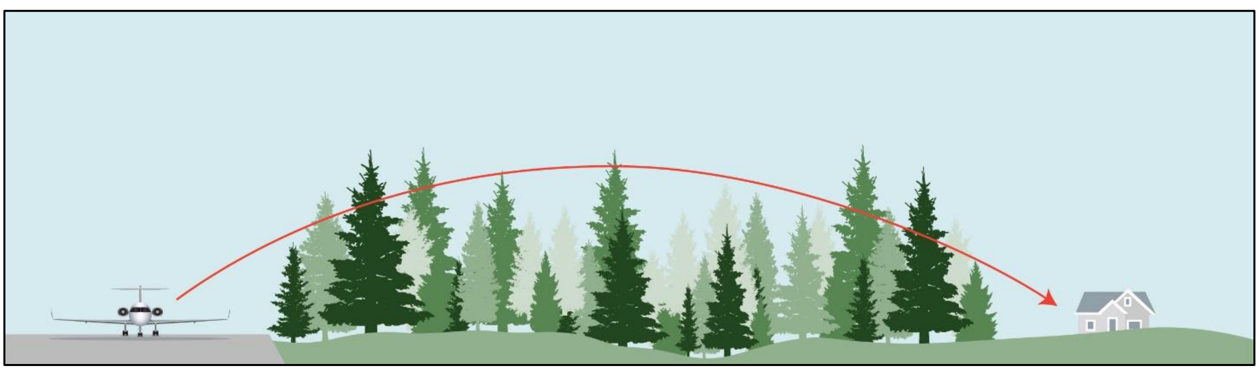


Source: HMMH

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.

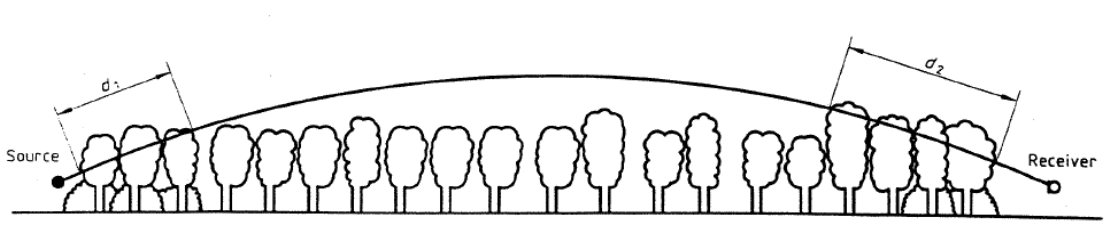
Table 1 Dense Foliage Noise Attenuation

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.

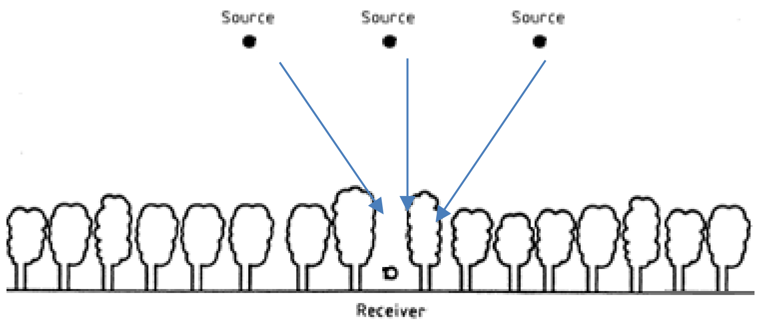
Figure 7 Downward Refracting Sound Path (source: ISO 9613-2)



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

[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.

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

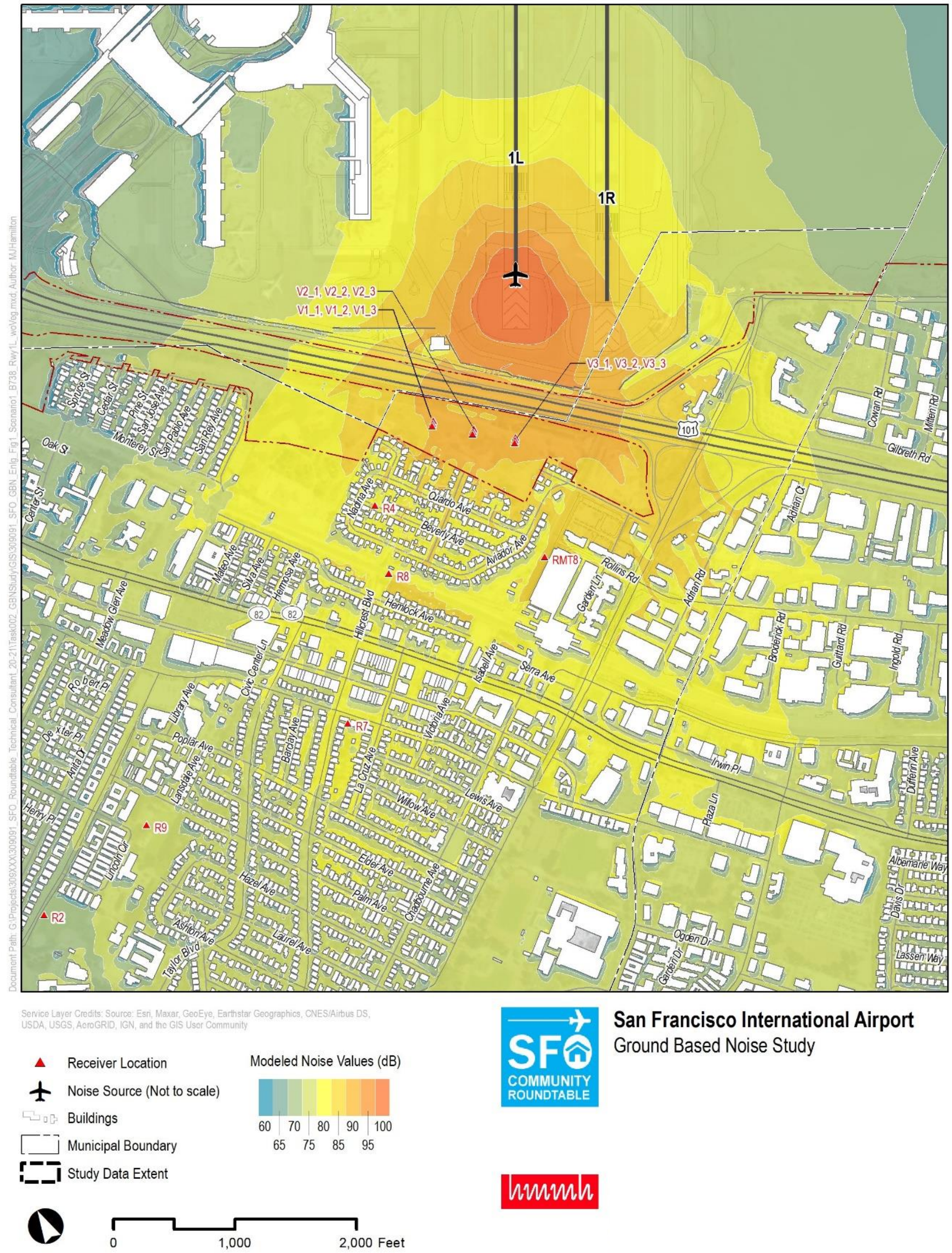

Figure H-1: Scenario 1 – B738 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

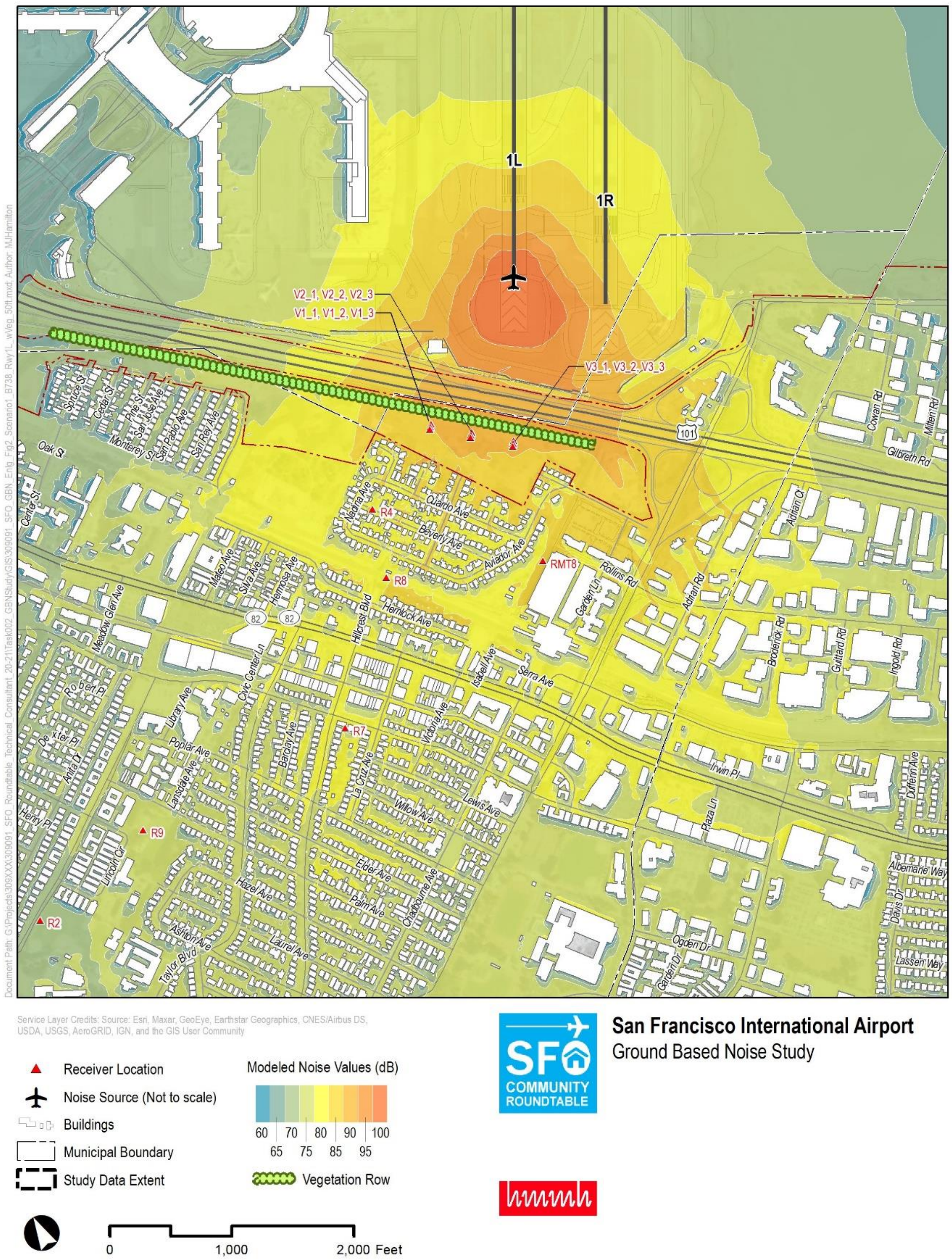

Figure H-2: Scenario 1 – B738 Departing Runway 1L at Start of Takeoff Roll – With Vegetation (50 Feet)

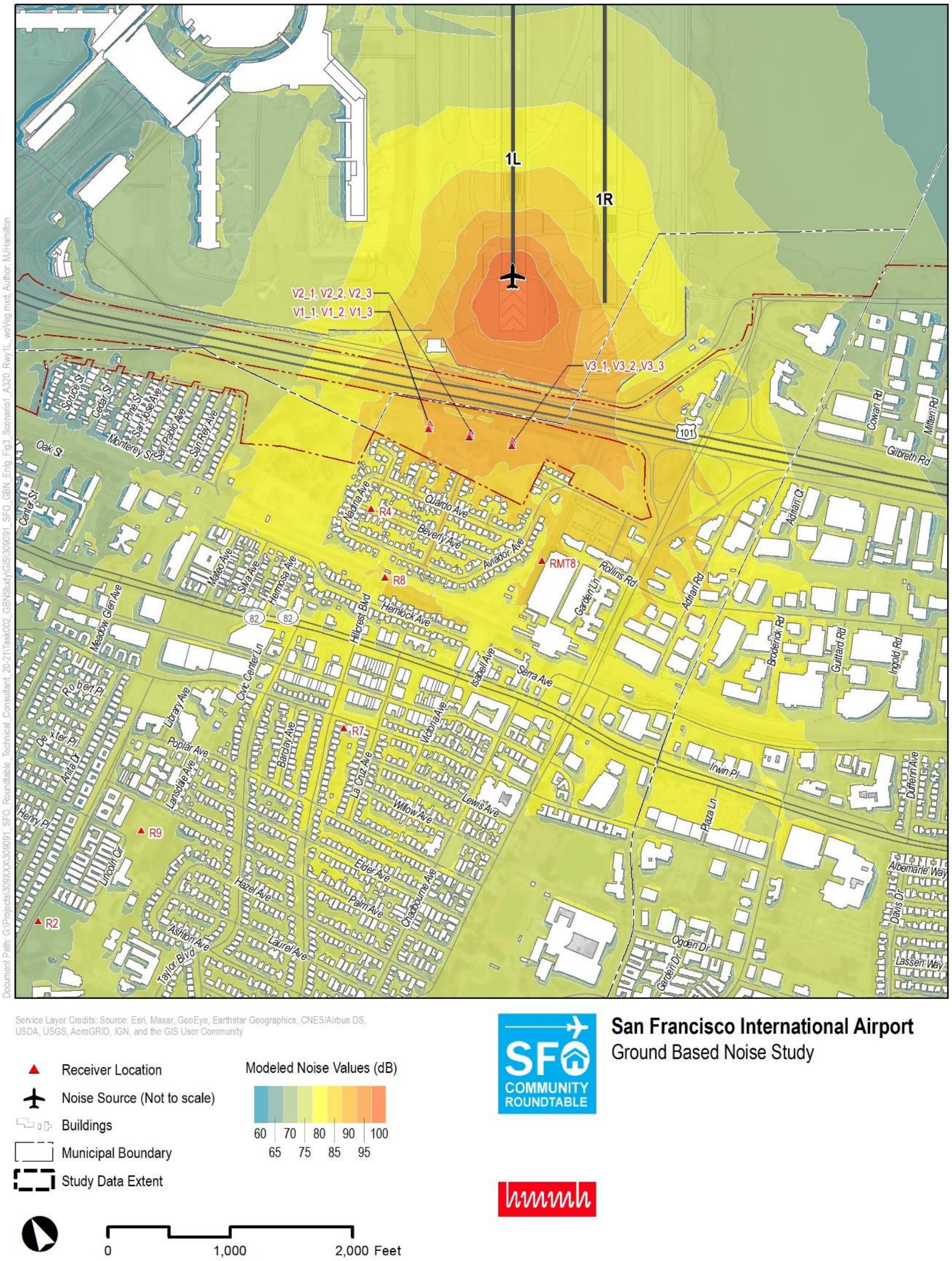

Figure H-3: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – Without Vegetation

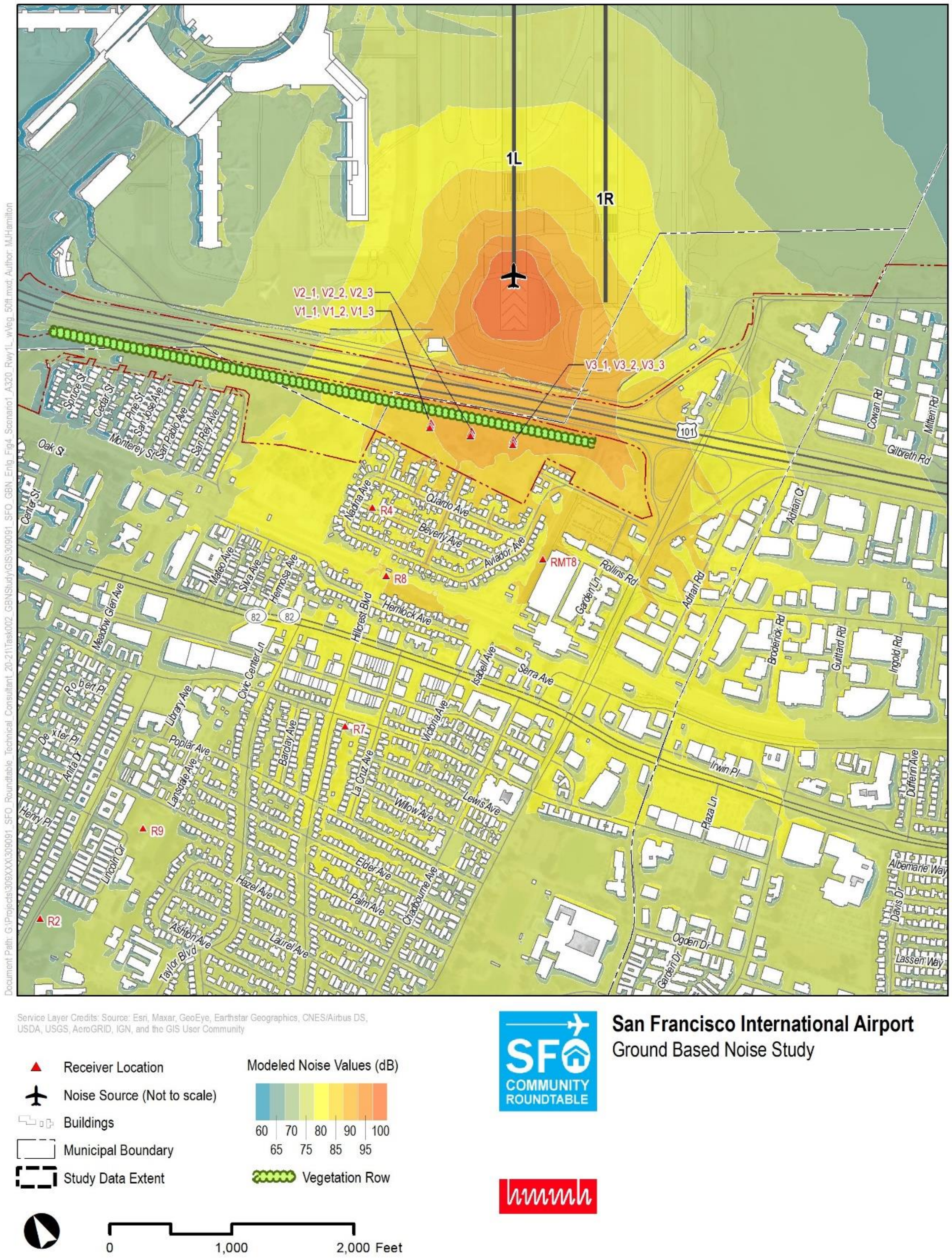

Figure H-4: Scenario 1 – A320 Departing Runway 1L at Start of Takeoff Roll – With Vegetation (50 Feet)

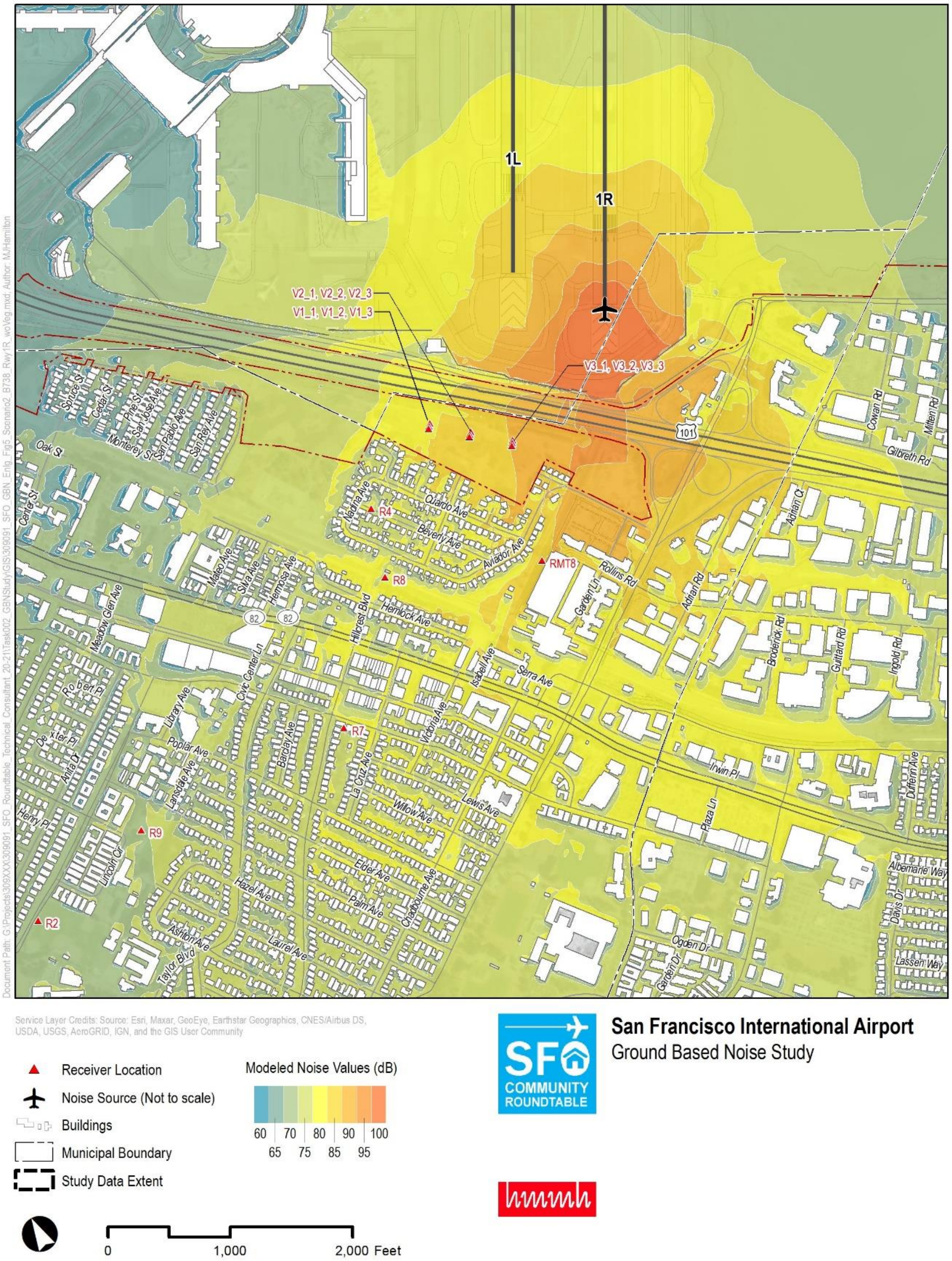

Figure H-5: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation

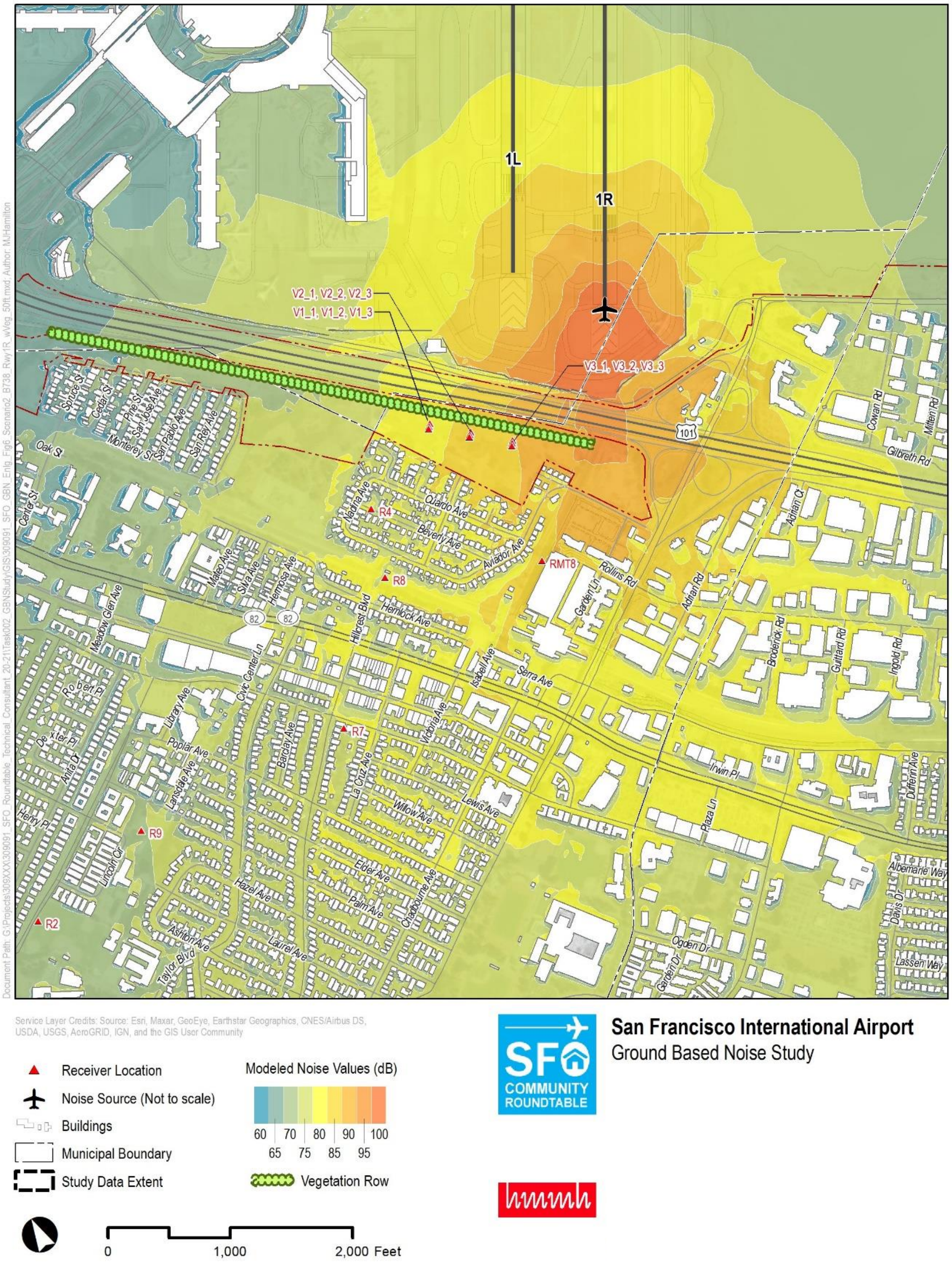

Figure H-6: Scenario 2 – B738 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

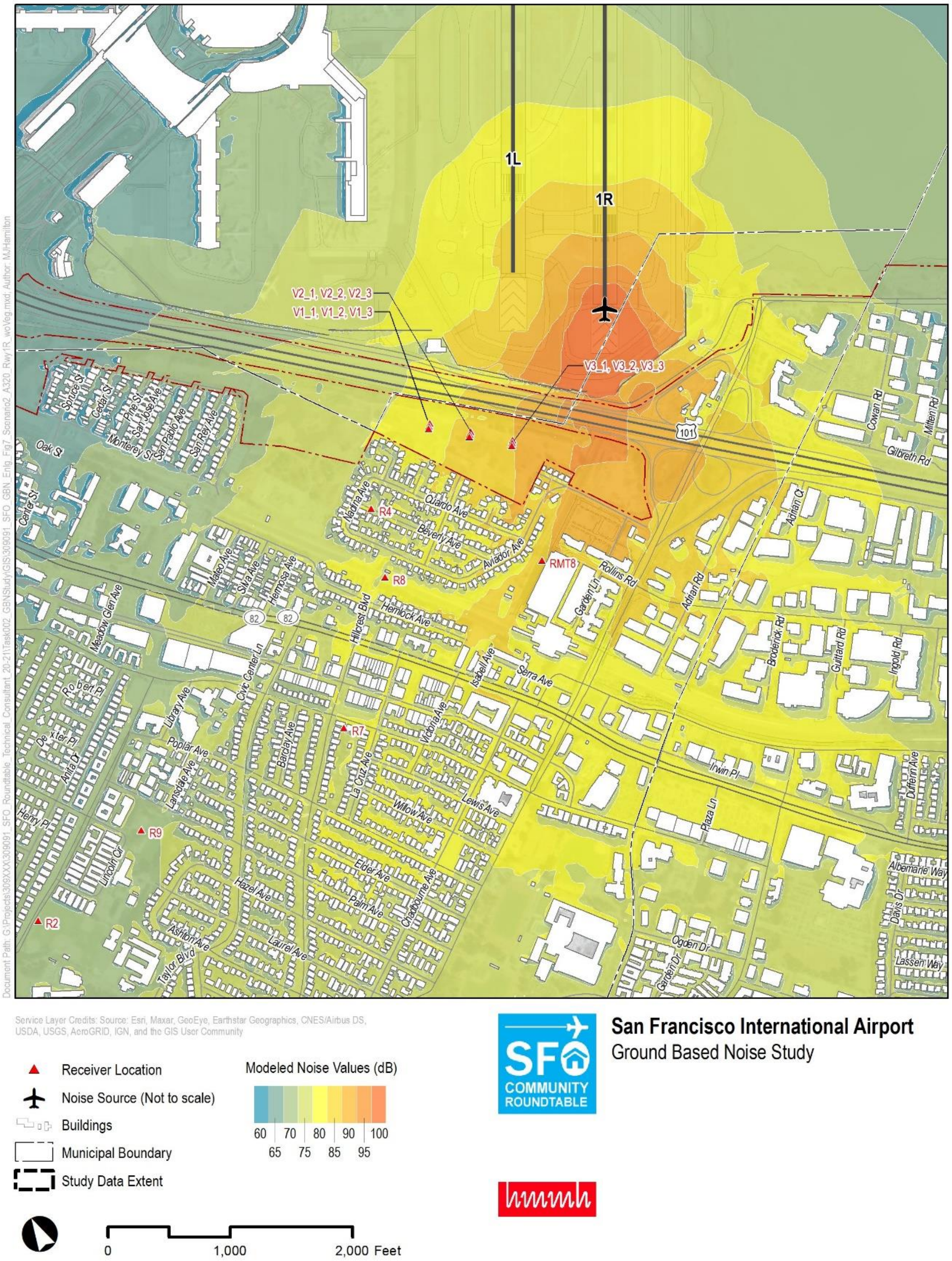

Figure H-7: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – Without Vegetation

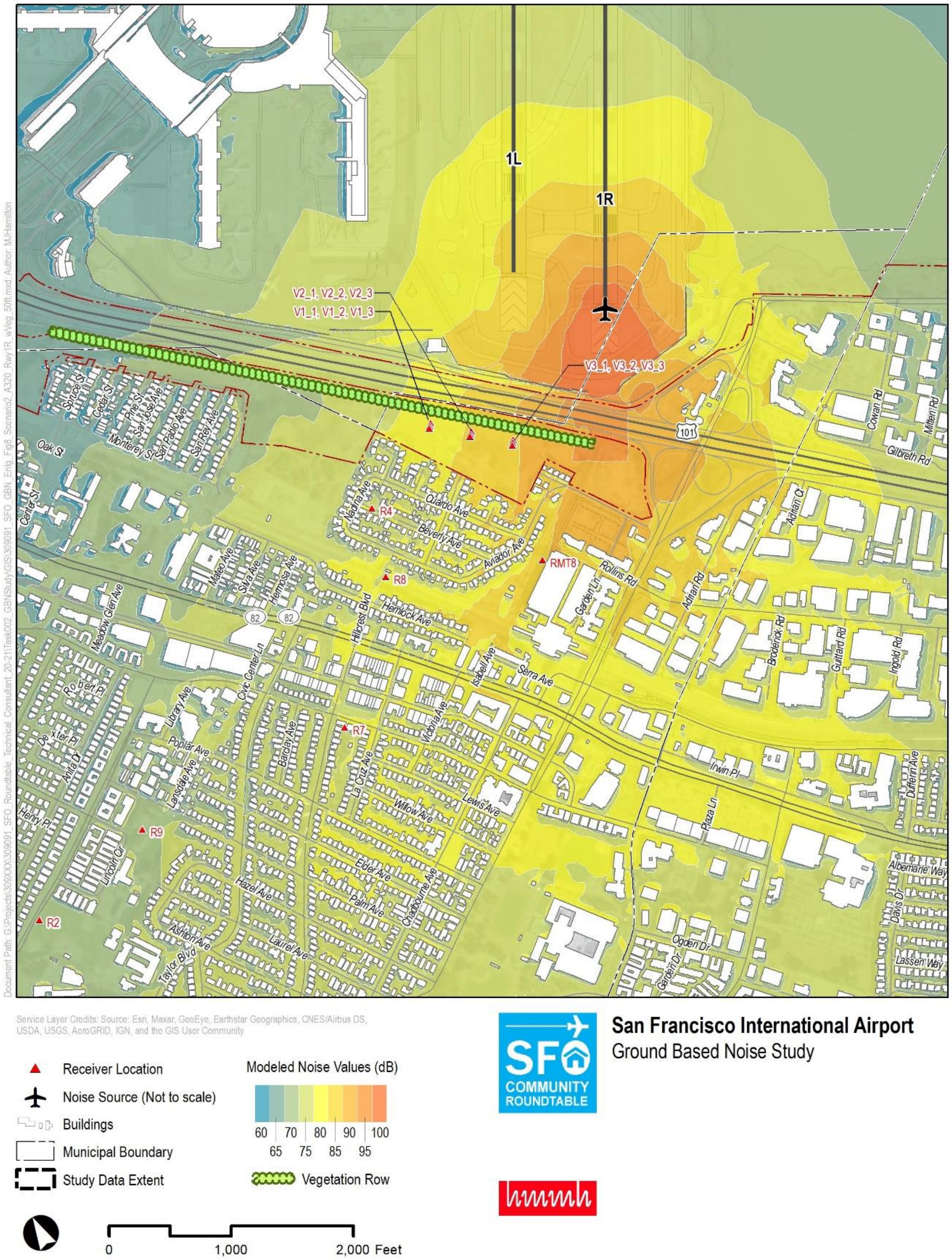

Figure H-8: Scenario 2 – A320 Departing Runway 1R at Start of Takeoff Roll – With Vegetation (50 Feet)

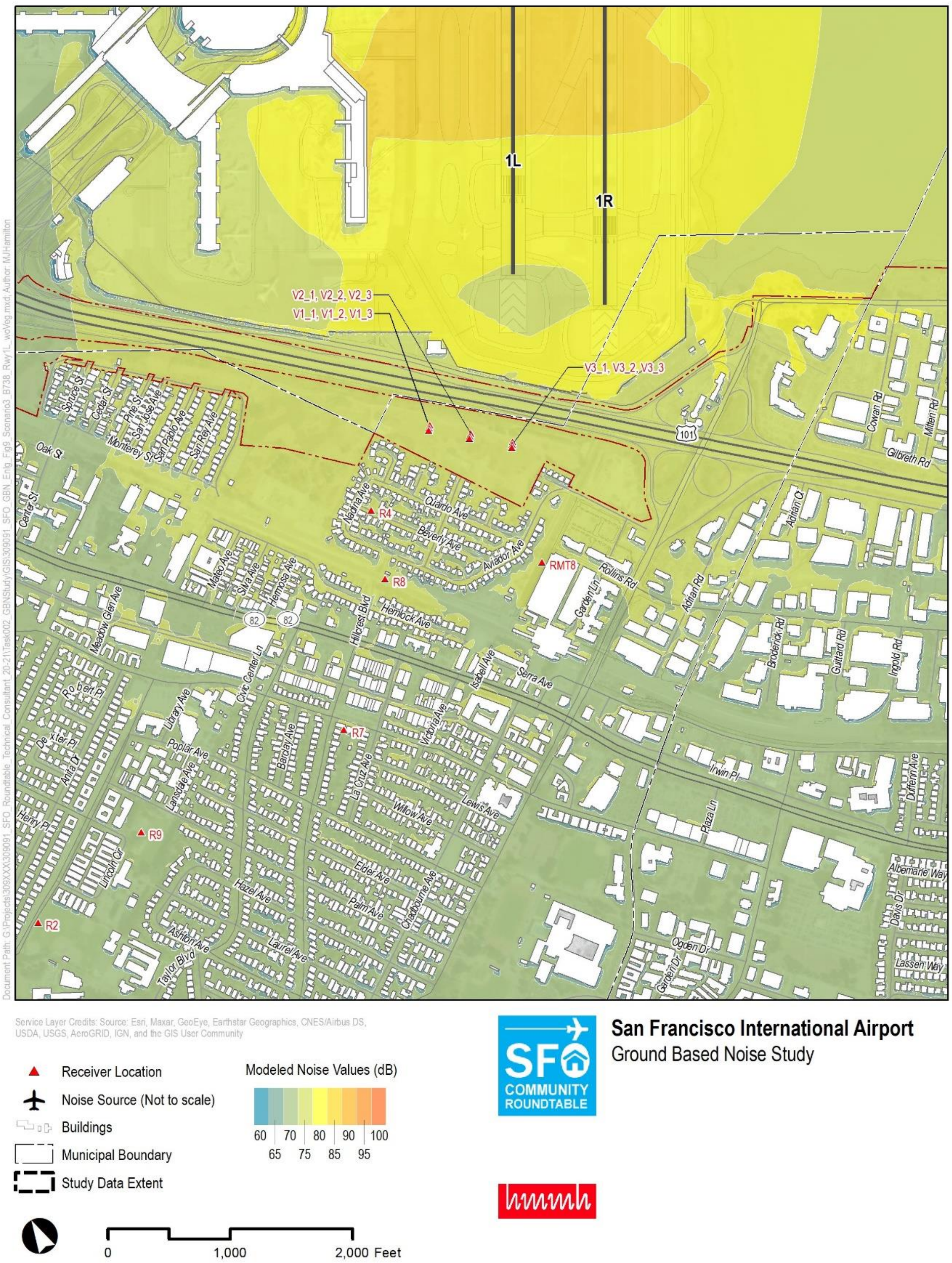

Figure H-9: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

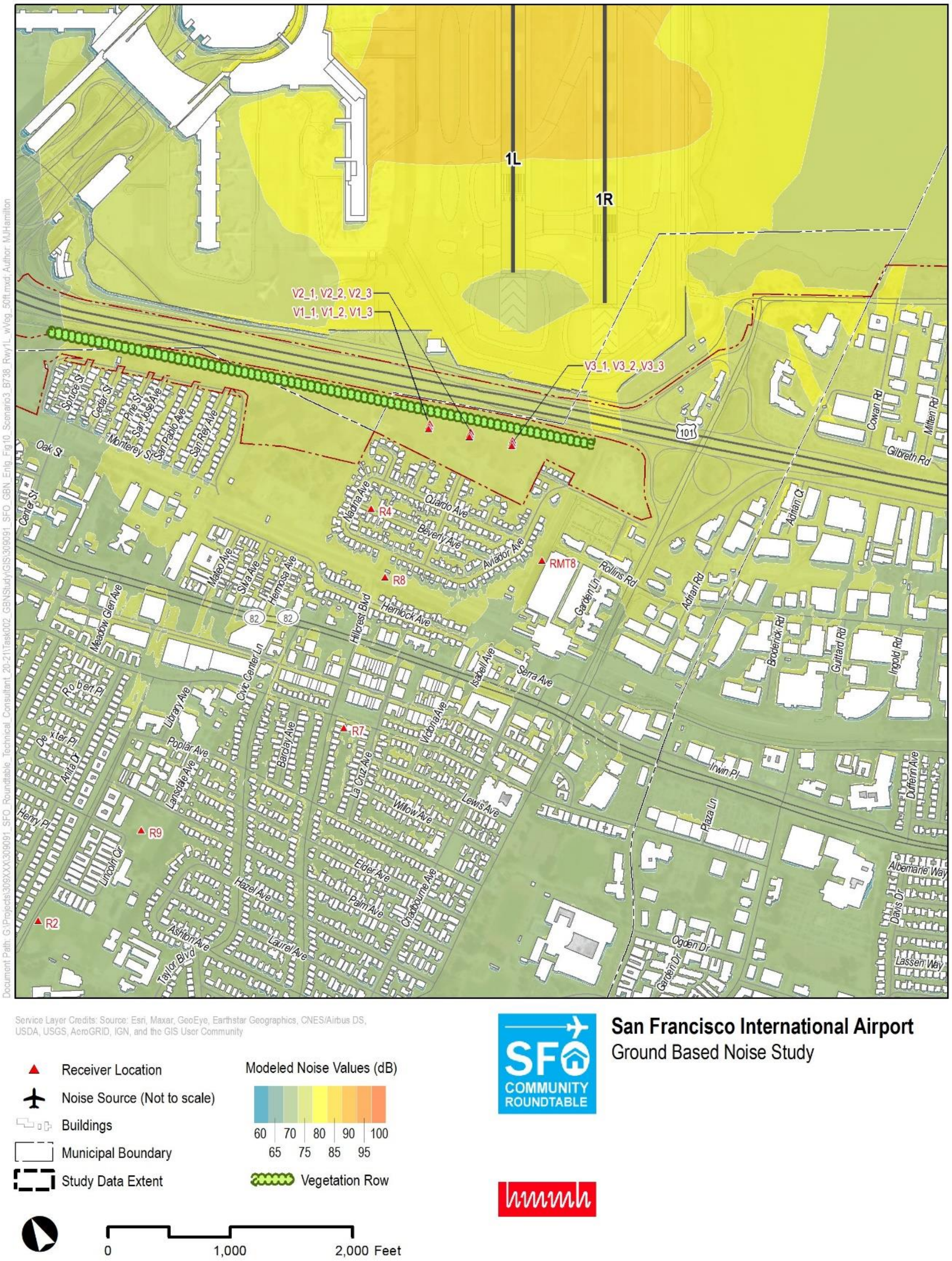

Figure H-10: Scenario 3 – B738 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

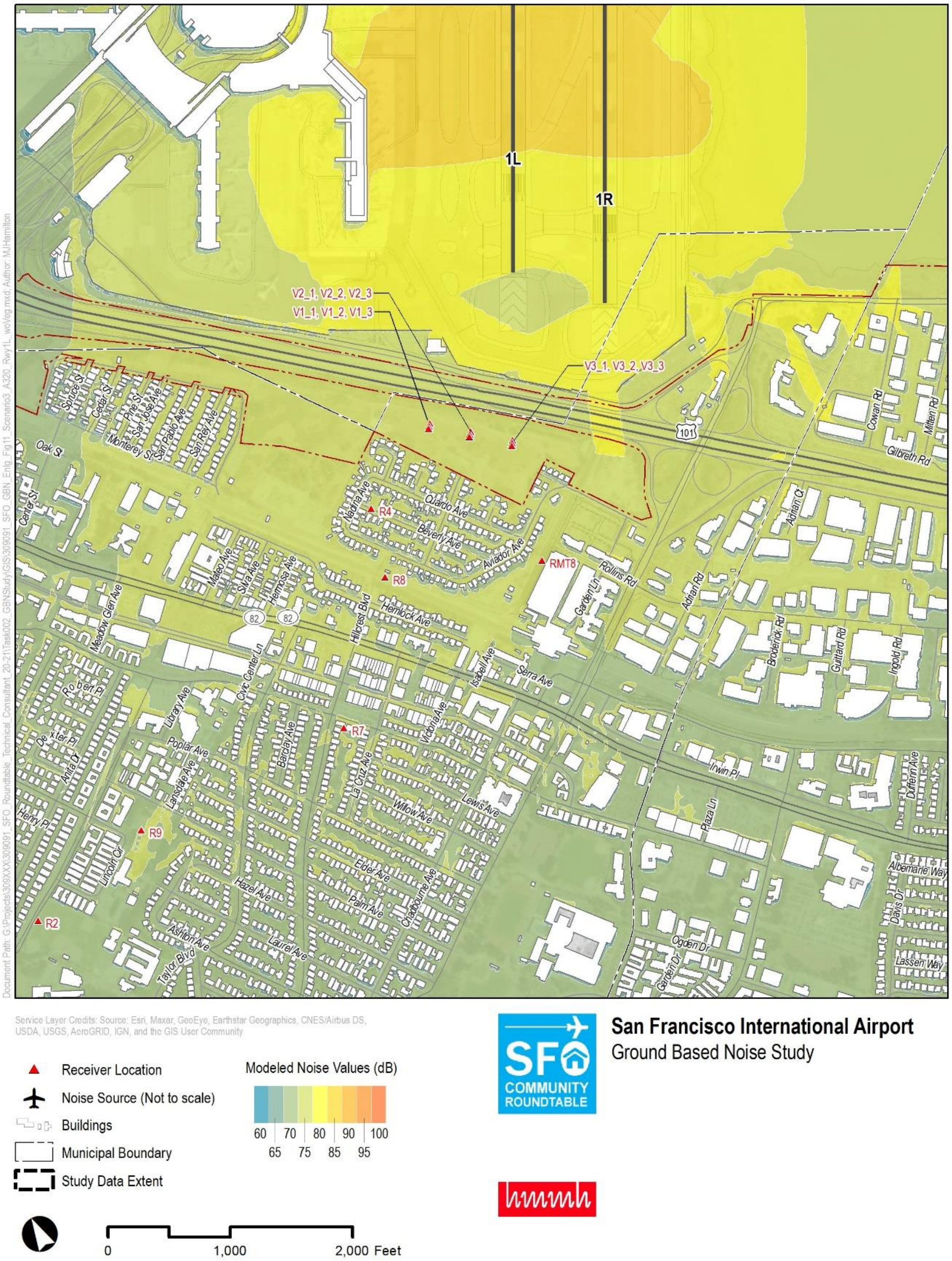

Figure H-11: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – Without Vegetation

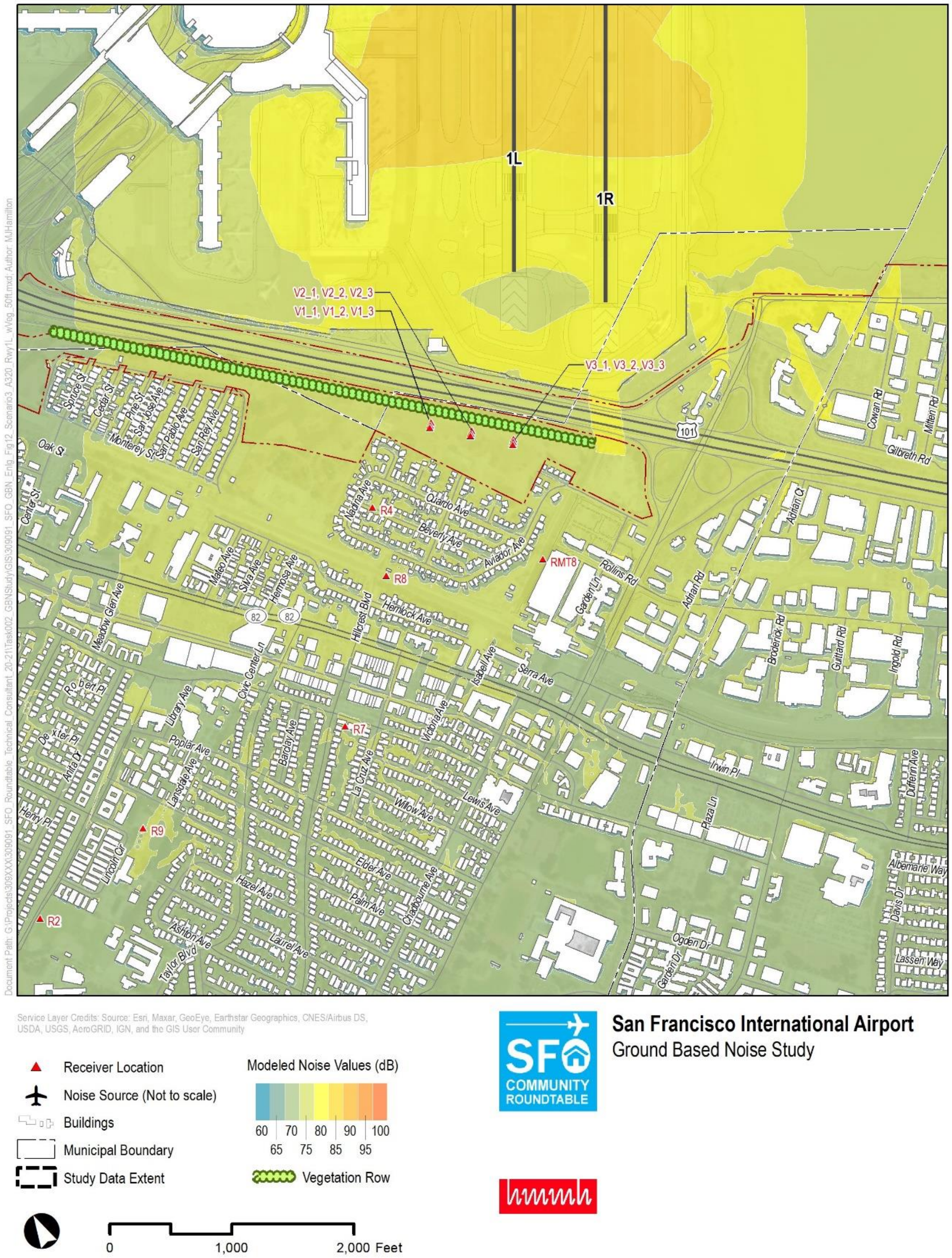

Figure H-12: Scenario 3 – A320 Departing Runway 1L at Secondary Takeoff Point – With Vegetation (50 Feet)

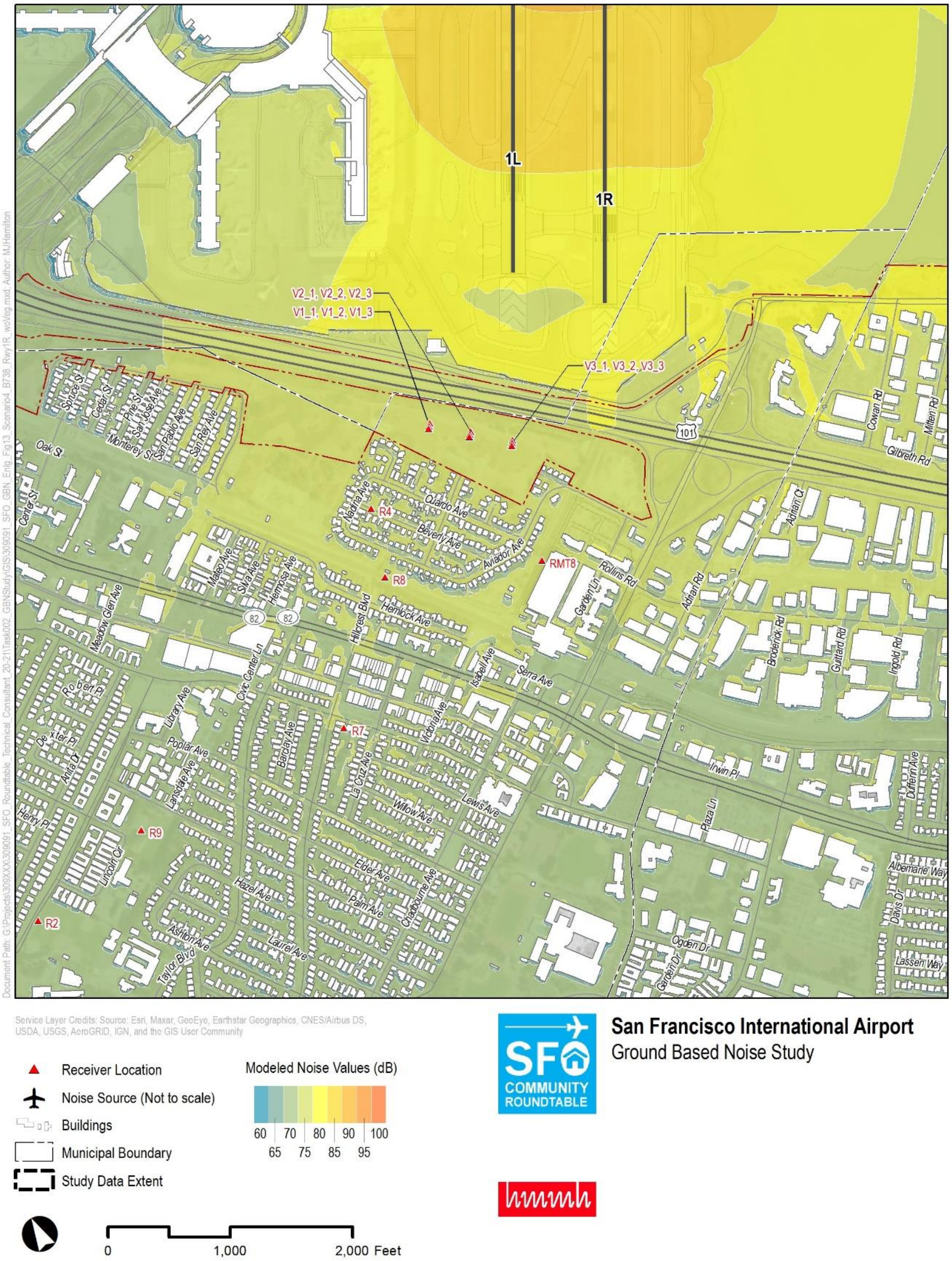

Figure H-13: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

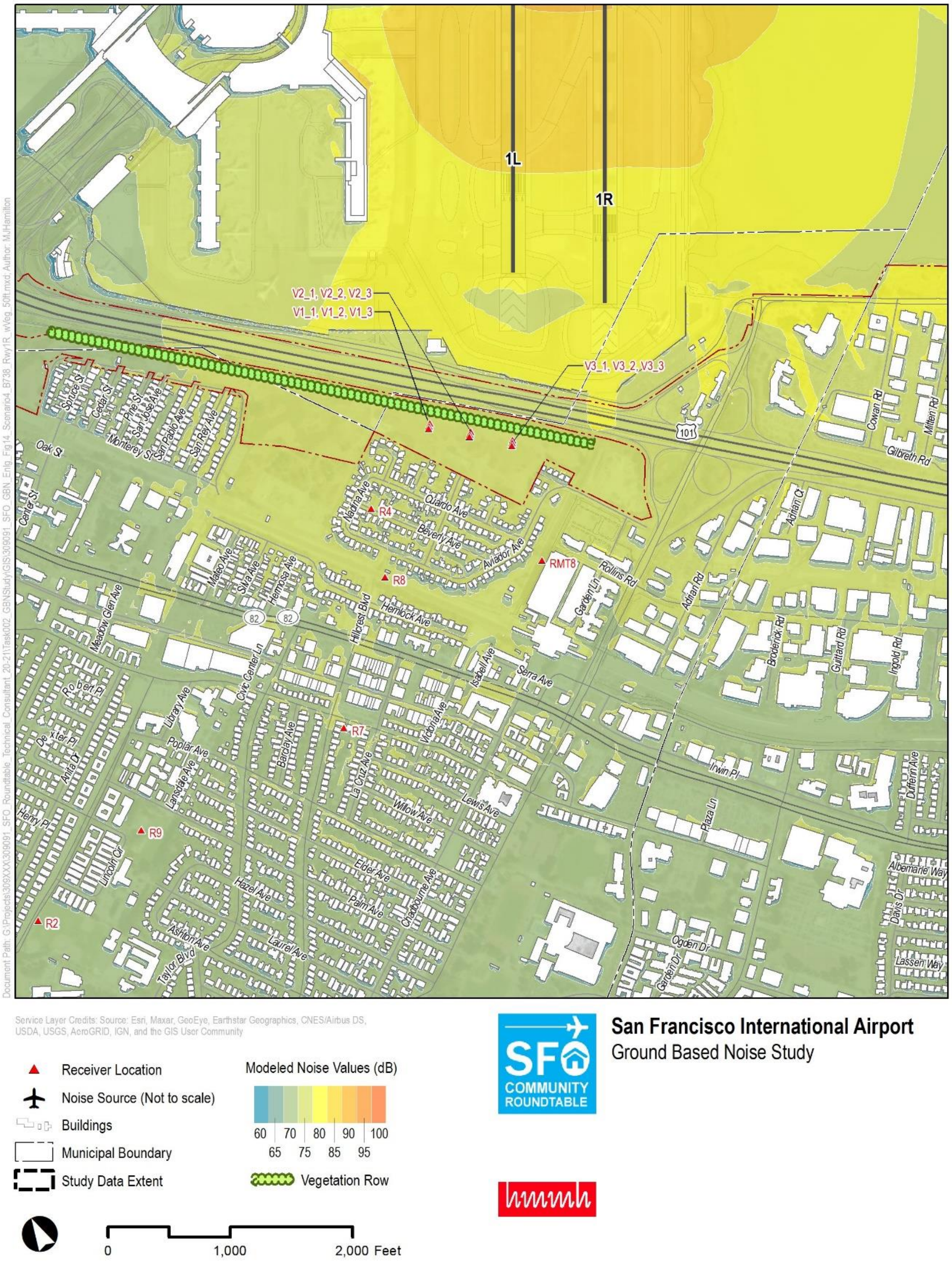

Figure H-14: Scenario 4 – B738 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

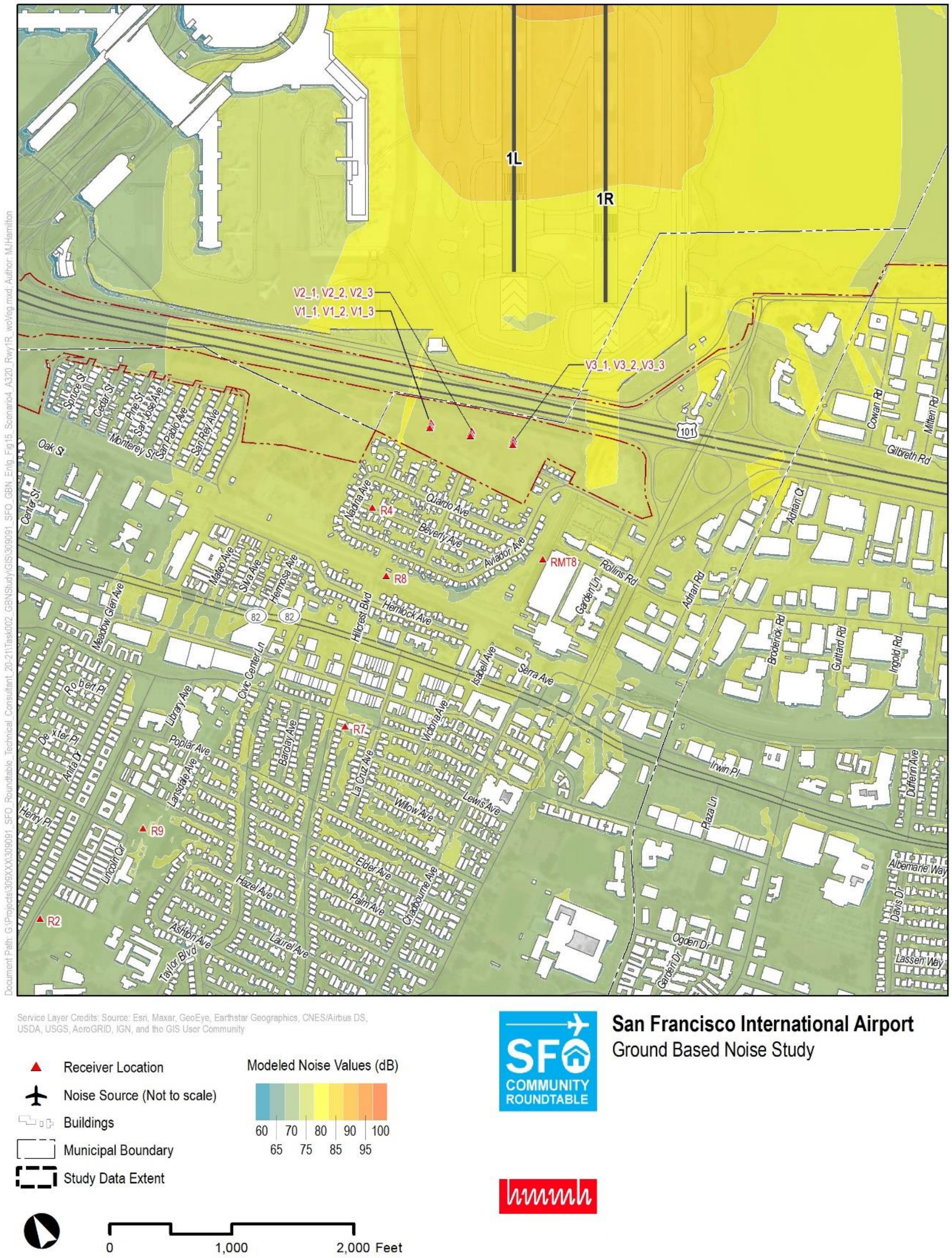

Figure H-15: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – Without Vegetation

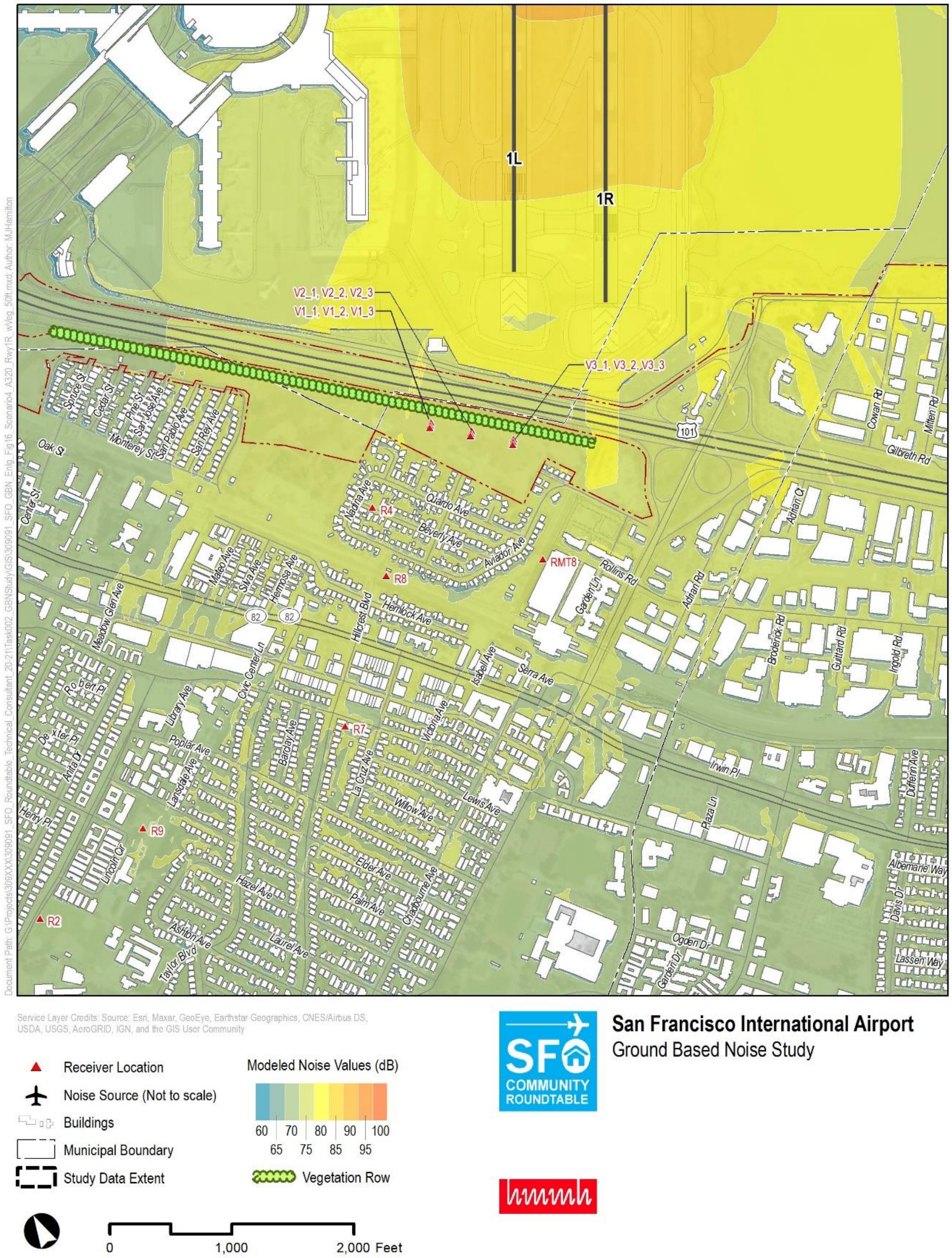

Figure H-16: Scenario 4 – A320 Departing Runway 1R at Secondary Takeoff Point – With Vegetation (50 Feet)

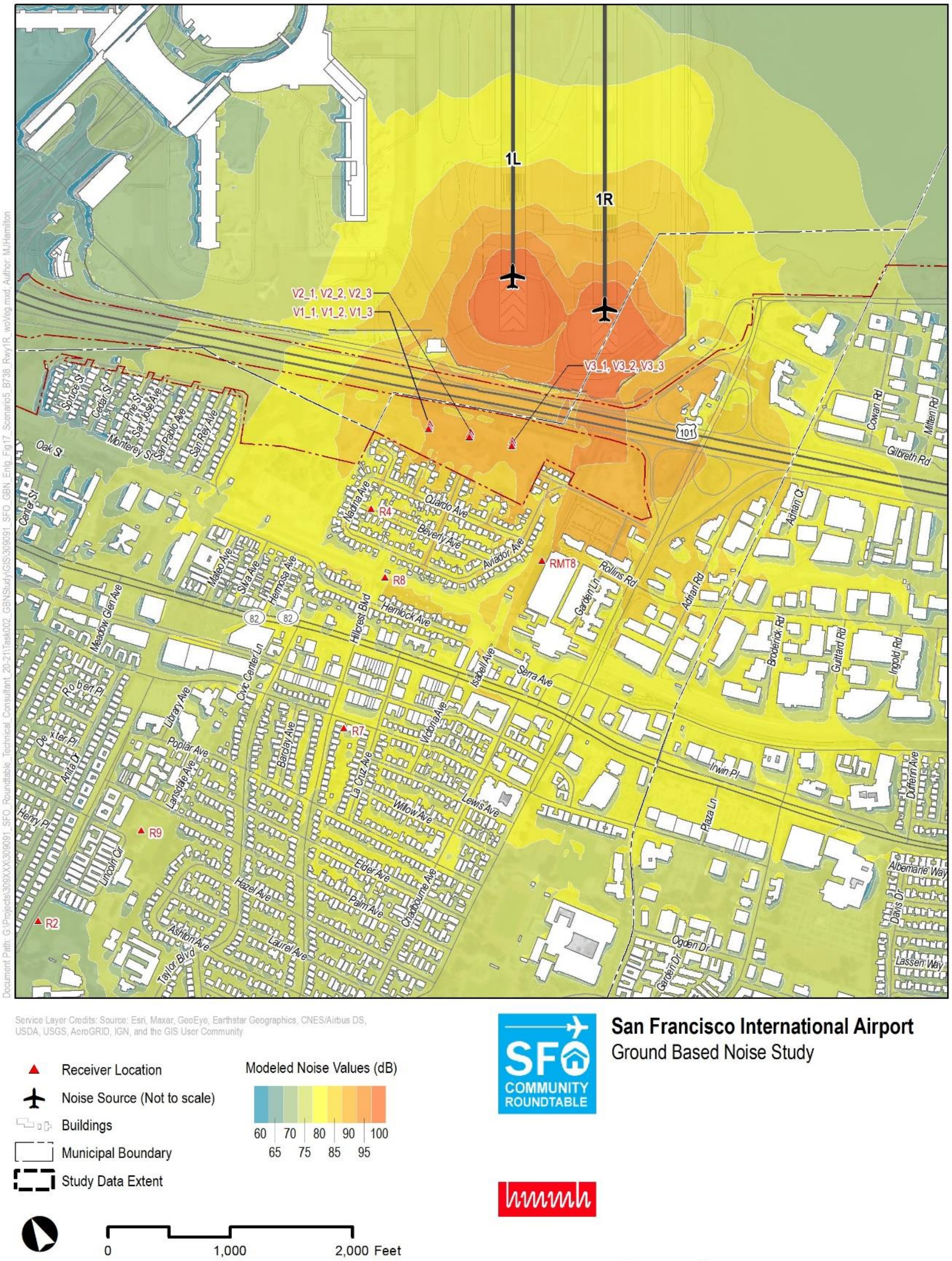

Figure H-17: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

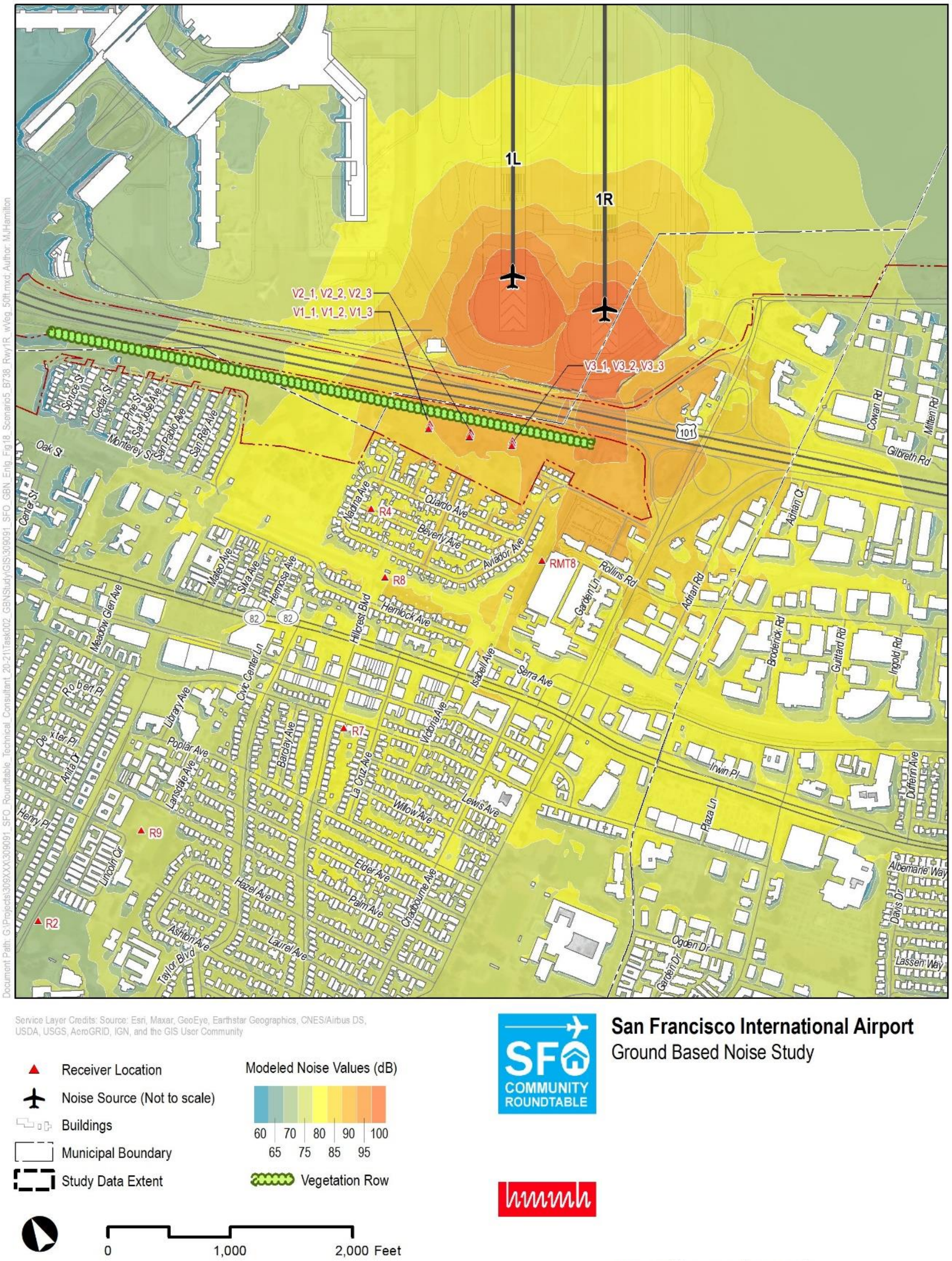

Figure H-18: Scenario 5 – B738 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

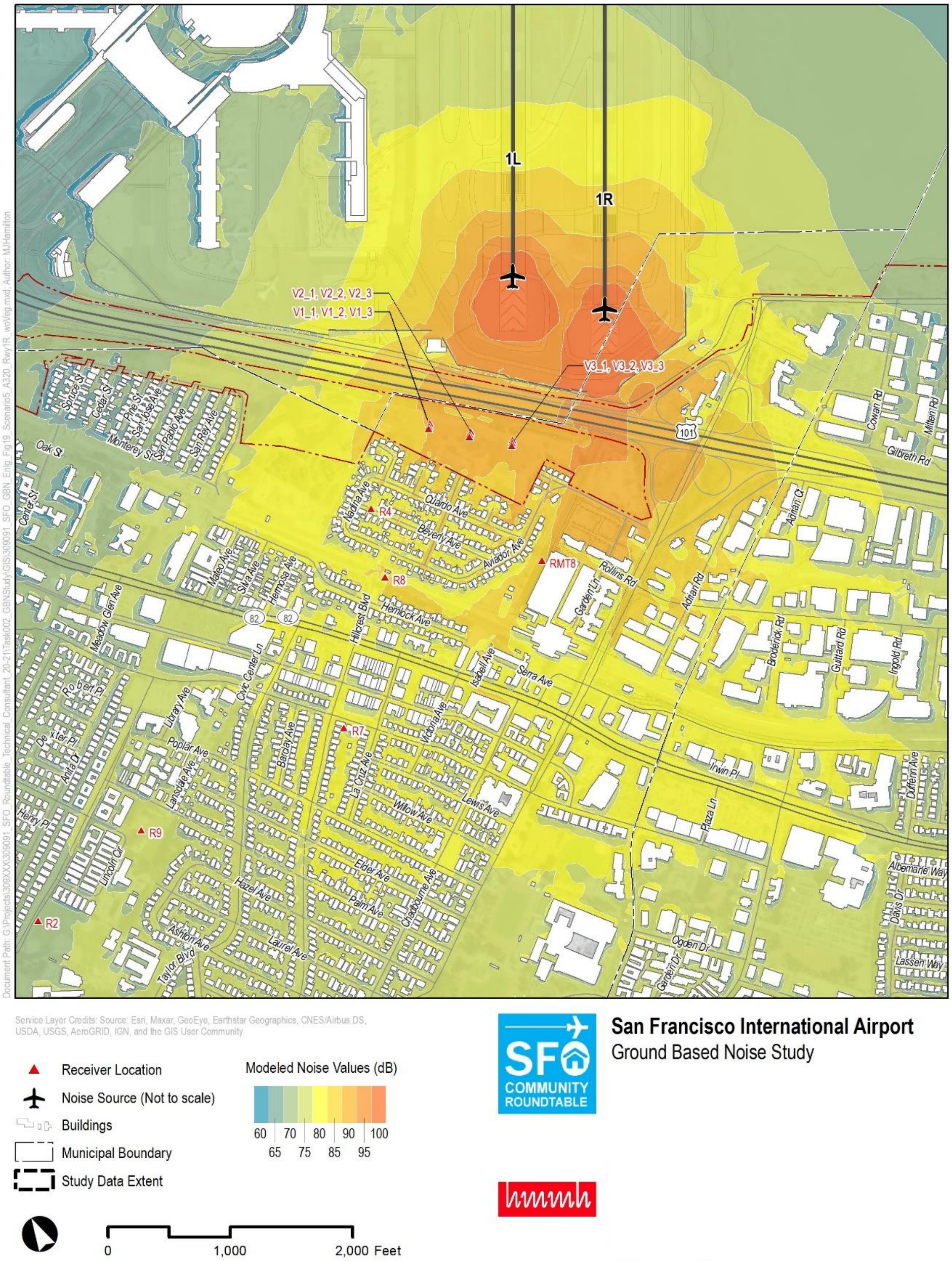

Figure H-19: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R Without Vegetation

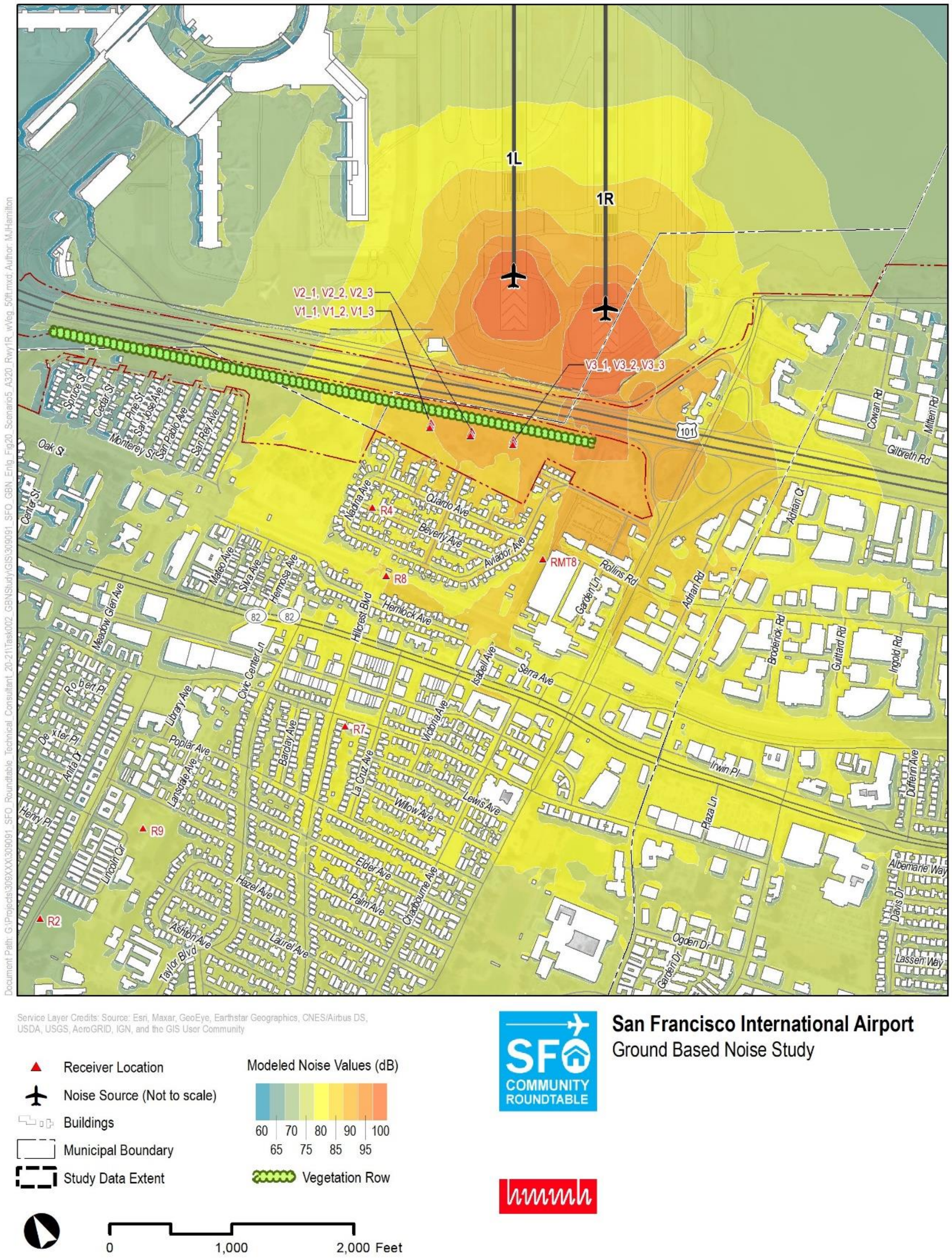

Figure H-20: Scenario 5 – A320 Departing at the Same Time but Staggered on Runway 1L and 1R With Vegetation (50 Feet)

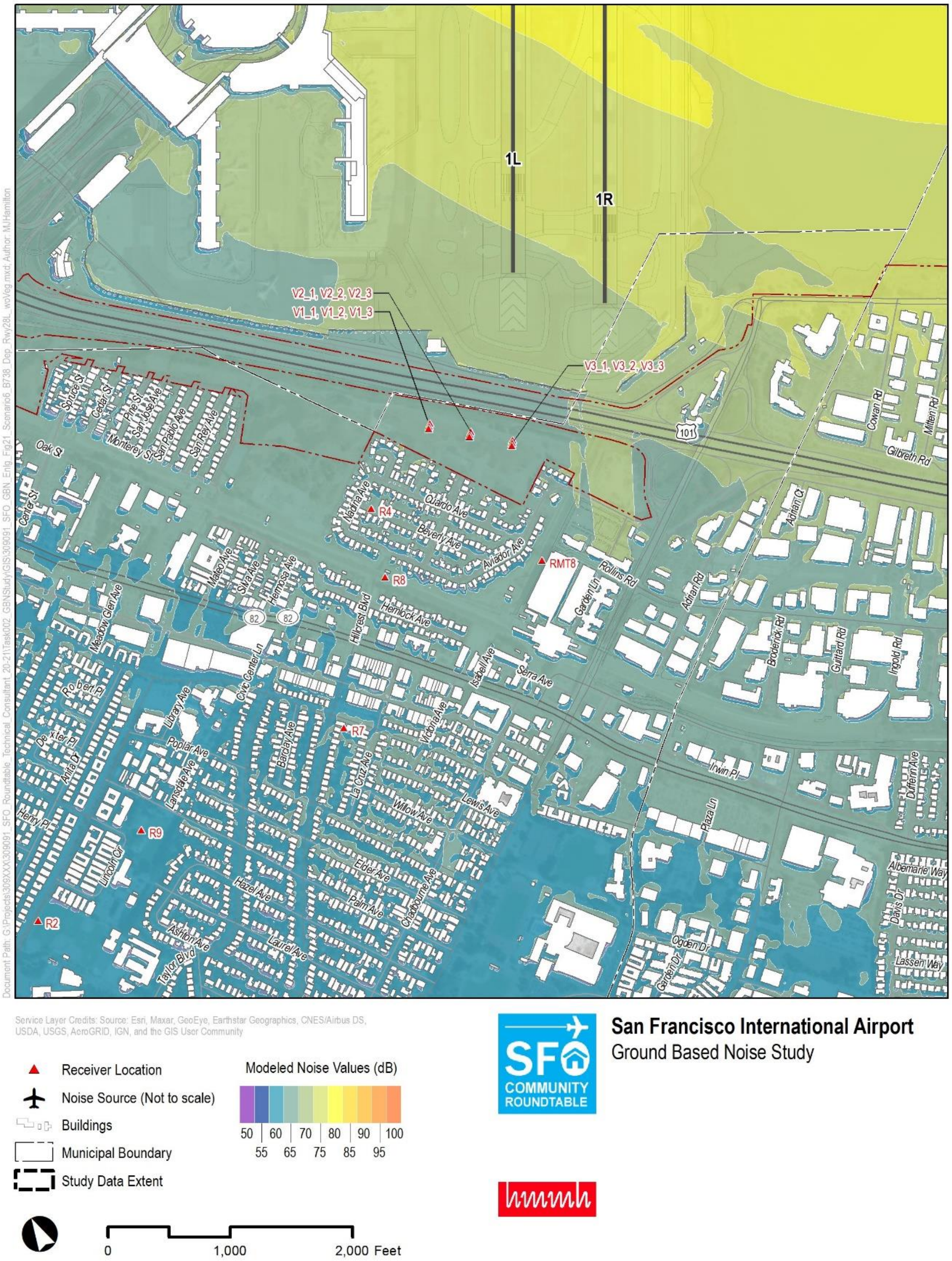

Figure H-21: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – Without Vegetation

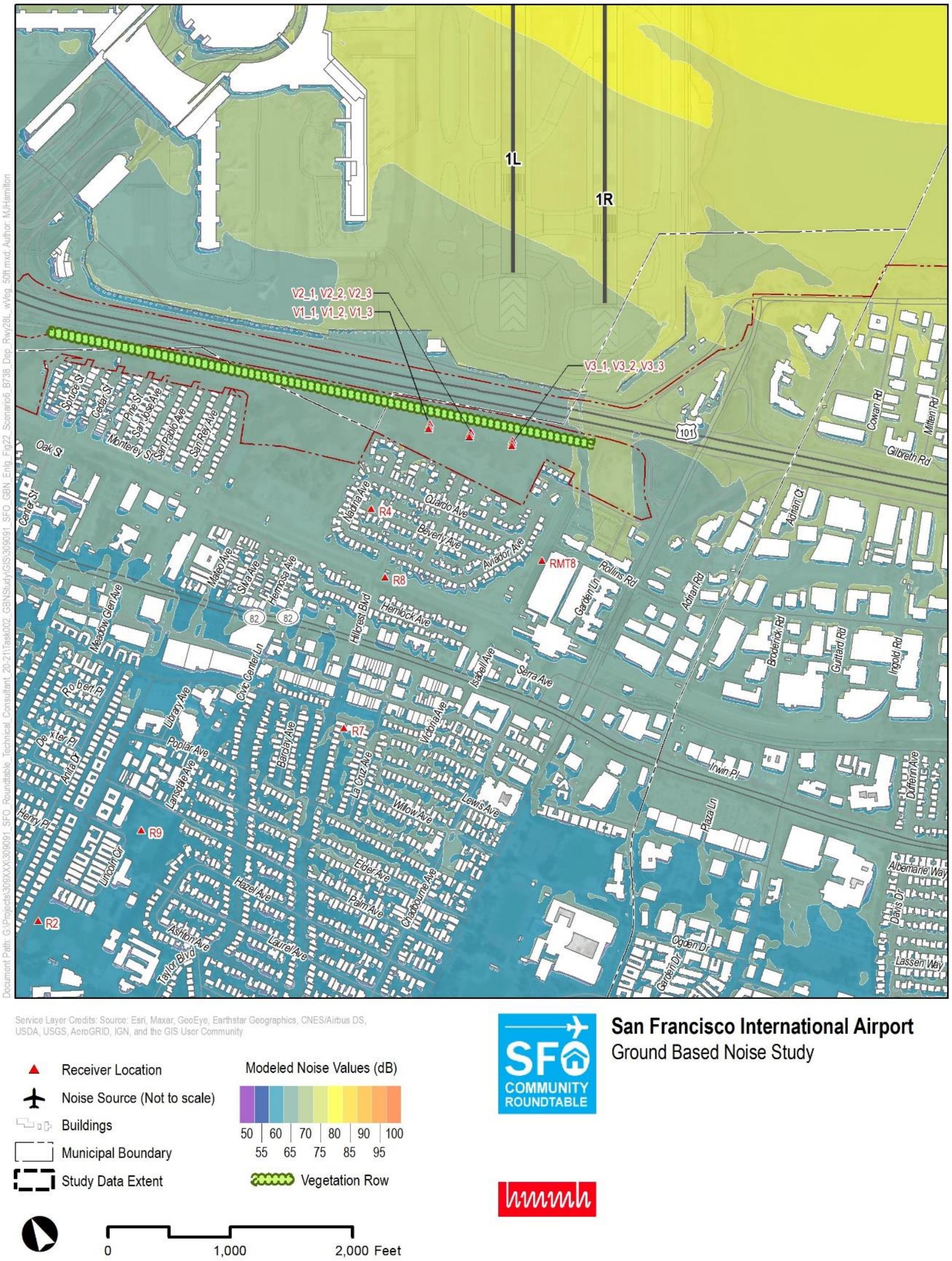

Figure H-22: Scenario 6 – B77W Departing Runway 28L at Secondary Takeoff Point – With Vegetation (50 Feet)

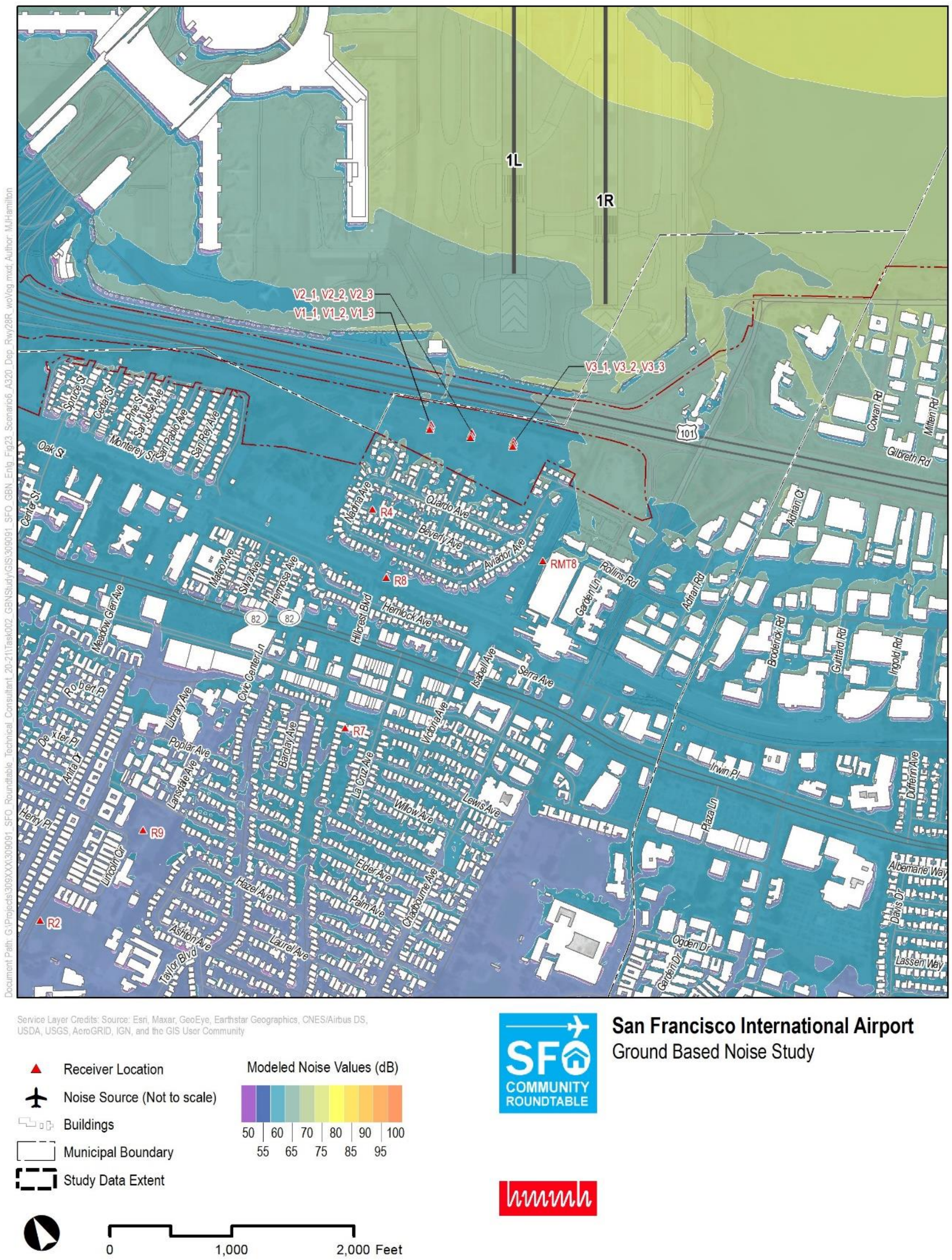

Figure H-23: Scenario 6 – B738 Departing Runway 28R at Secondary Takeoff Point – Without Vegetation

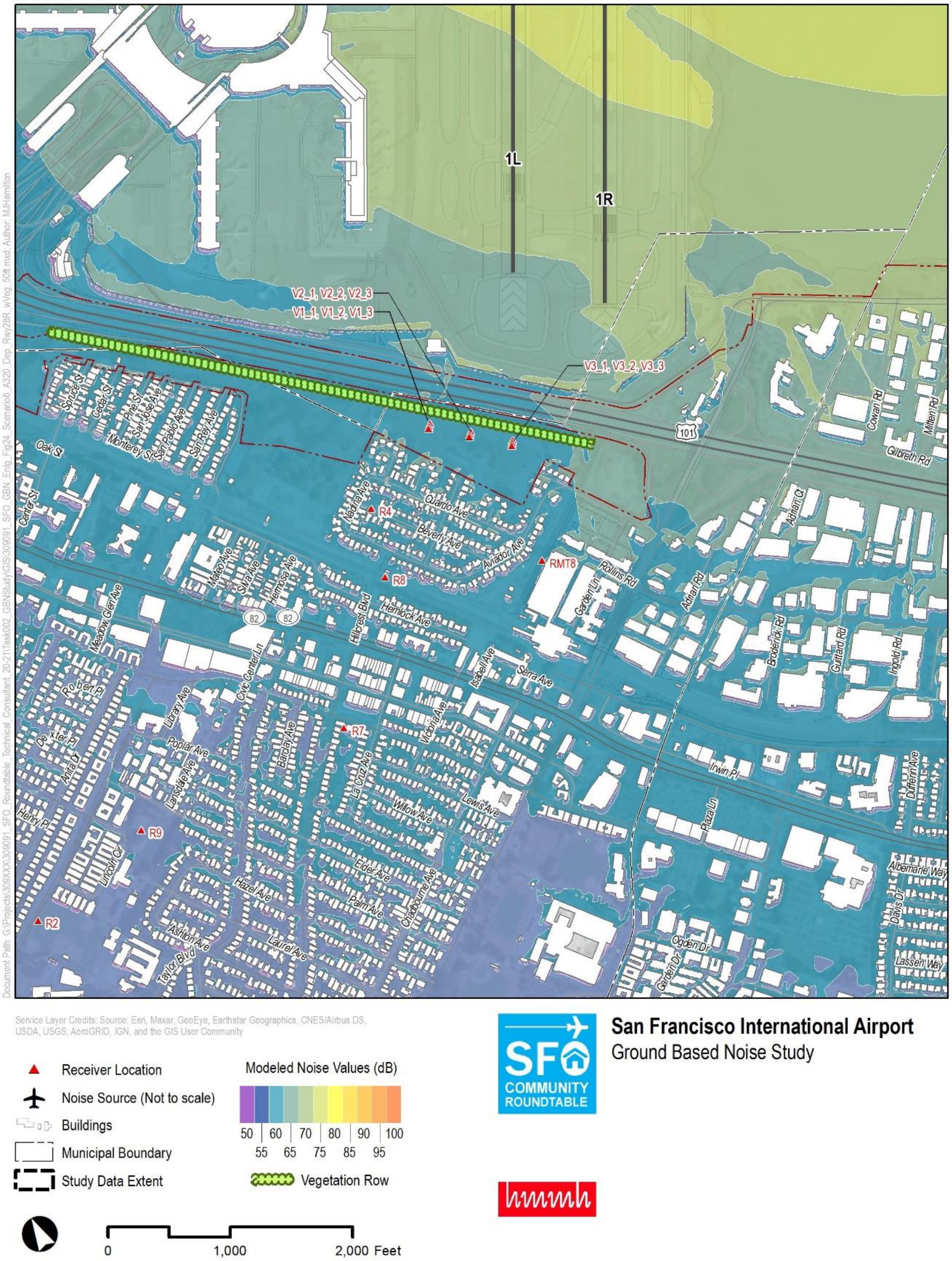

Figure H-24: Scenario 6 – B738 Departing Runway 28R at Secondary Takeoff Point – With Vegetation (50 Feet)

San Francisco International Airport

August 25, 2021

The Honorable Ricardo Ortiz, Chair
San Francisco International Airport/Community Roundtable
c/o **Angela Montes Cardenas**
Administrative Secretary II
County of San Mateo
455 County Center, 2nd Floor
Redwood City, CA 94063

Subject: Ground Based Noise Modeling Study (HMMH Report No. 309091.002, January 19, 2021)

Dear Chair Ortiz:

The following are San Francisco International Airport (SFO) staff comments on the Ground Based Noise Modeling Study, dated January 19, 2021 (the "Study"), prepared by HMMH on behalf of the Airport/Community Roundtable (the "Roundtable"). We appreciate your commitment to the Roundtable, which provides a forum to address difficult airport noise issues, and the work of the Ground Based Noise Subcommittee. In reviewing the Study, we offer the following observations for your consideration:

- SoundPLAN, the model used for the Study, is not approved for use by the Federal Aviation Administration under Title14 of the Code of Federal Regulations Part 150 (14 CFR Part 150). Therefore, the results of the Study cannot be incorporated into federal noise or environmental studies (e.g., Environmental Assessments, Environmental Impact Statements, or 14 CFR Part 150 Studies). In addition, any recommended mitigation measures would not be eligible for federal funding.
- The Study used noise data from a 767 aircraft to represent the noise exposure of a 777 aircraft in SoundPLAN; these aircraft have very different sound profiles. Therefore, the noise exposure in the Study may not be representative of the actual 777 noise exposure levels.
- The Study used the default values for temperature, humidity, and barometric pressure in SoundPLAN, which are not representative of the actual conditions at the SFO. Therefore, the results may not be reflective the actual noise exposure.
- It appears that an incorrect aircraft noise contour was used in either Figure 17 or 18, as both of these contours should be the same. Study, pp. 74, 75. This error should be corrected.
- The Study concludes that the vegetative barriers modeled would have no discernable effects in reducing noise at residences nearest SFO. This is consistent with our understanding based on numerous prior studies, which found that low frequency noise is difficult to attenuate, including with buildings and structures. However, the Study goes on to recommend that vegetation could be used as mitigation, even though this recommendation is not supported by the Study's findings. Study, p. 90, 91. We are concerned that this creates an unrealistic expectation about the effectiveness of vegetative barriers to mitigate noise. Therefore, we request that this recommendation be removed from the Study, so that it is clear the vegetative barriers are not effective and should not be pursued as a mitigation measure.

Post Office Box 8097 San Francisco, California 94128 Tel 650.821.5000 Fax 650.821.5005 www.flysfo.com

- In addition, vegetative barriers may attract hazardous wildlife. Therefore, we oppose the use of vegetative barriers near SFO as we are required by federal regulations to maintain a safe aircraft operating environment.
- Finally, the Study notes that any vegetative barriers should "have a height that breaks line of sight to the source and be located as close to the noise sensitive receptor as possible." Study, p. 90. Behind Runways 1L and 1R, the height needed to disrupt the direct line of sight to houses on the hill would likely violate 14 CFR Part 77 obstruction height limitations. In addition, vegetation continues to grow over time. Therefore, we would not be able to manage the height of off-airport vegetation to maintain compliance with the requirements of 14 CFR Part 77.

Thank you for considering these comments. Please contact me if you would like to discuss our observations.

Sincerely,

Bert Ganoung
Aircraft Noise Office Manager
San Francisco International Airport

Summary of HMMH Airport Ground-Based Noise Study

HMMH Report No. 309091.002

January 19, 2021

Outline

- Project Description
- Noise Model Inputs
- Summary of Results
- Next Steps

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Project Description

Motivation:

Based upon the direction of the subcommittee, 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 encompasses 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.

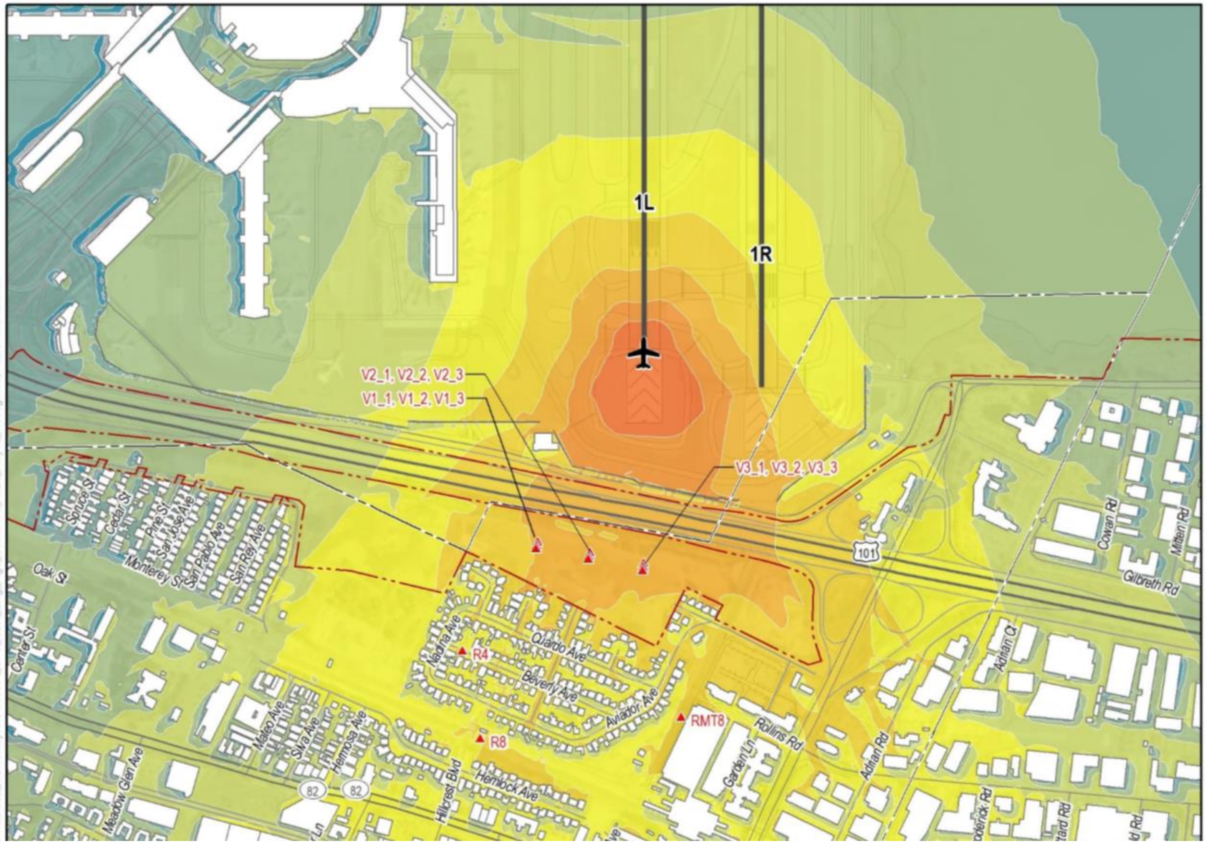
Goals:

1. *To better understand how ground-based noise propagates through the communities adjacent to SFO from aircraft departures*
2. *To assess effectiveness of vegetation to reduce ground-based noise from SFO aircraft departures*

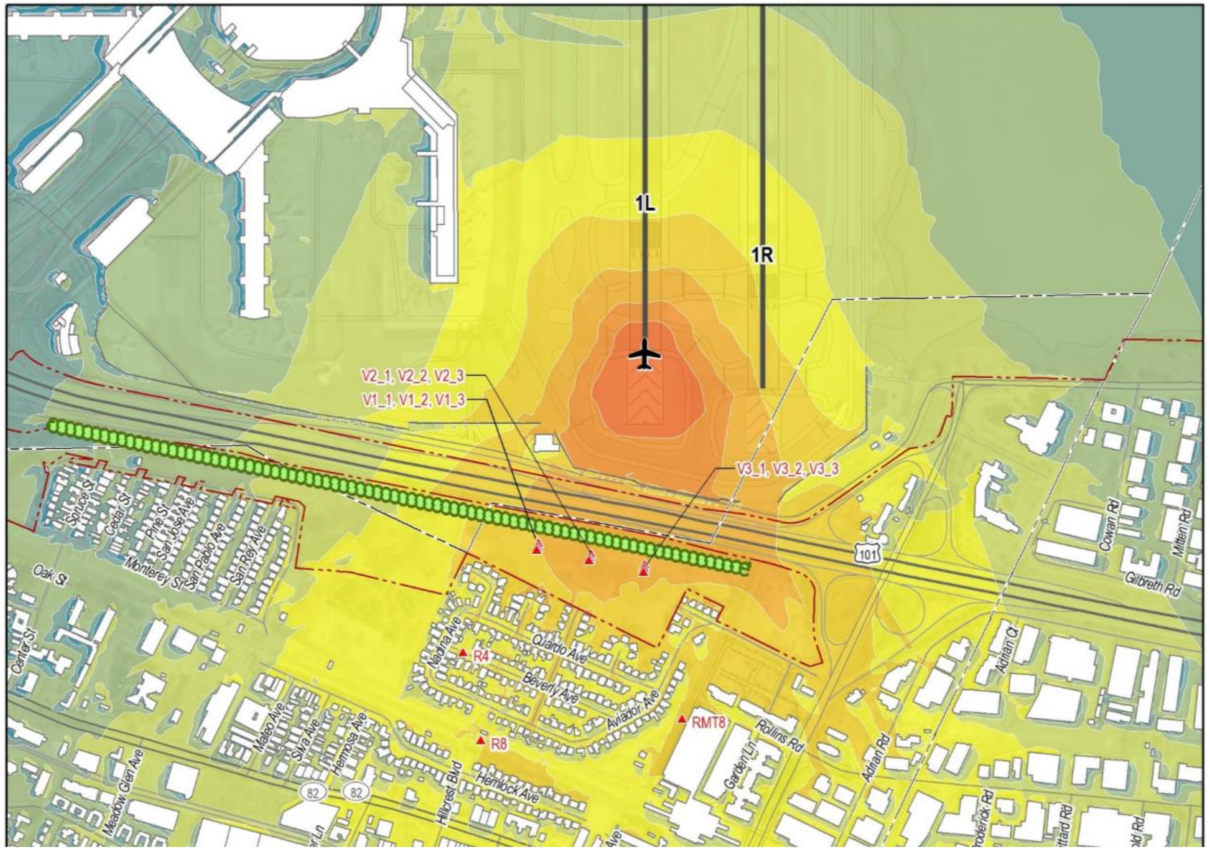
Noise Model Inputs

- Geographic and Land Use Data Sourced From:
  - 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
- 28 Receptor Locations (Increase of 16 from Scope of Work)
- Three Aircraft Types
  - Boeing 737-800
  - Airbus A320
  - Boeing 77W
- Vegetation
  - 50 feet thick
  - Located on CalTrans right of way, 4,511 feet long
  - 46 feet tall

Model Result Example
A320 Departure from Runway 1L



Existing Condition



Added Vegetation (bright green area)

Summary of Results

- Reduction of noise levels from vegetation is expected to be on the order of 1 dB and only for receptors immediately adjacent to the vegetation.
- Changes of less than 3 dB are barely perceptible
- Vegetation area must be greater than 30 feet wide to begin to provide noise reduction

SFO Staff Comments on HMMH Report

- Comment: The noise model used for the study is not approved by the FAA
  - HMMH Response: The FAA's noise model does not currently include ground noise propagation adequately to include barriers, such as buildings, vegetation etc. The FAA has approved noise barrier analysis using noise models, such as SoundPLAN, which we used for this study.
- Comment: Boeing 767 aircraft is not representative of Boeing 777 aircraft in terms of noise exposure levels
  - HMMH Response: HMMH did not have data for the Boeing 777 aircraft in our SoundPLAN database, so we used the Boeing 767 data, which as shown in the report has difference sound levels.
- Comment: The model default meteorological values are not representative of conditions at SFO
  - HMMH Response: HMMH concurs, but the meteorological conditions in the model have only limited effect on sound propagation, as opposed to wind and temperature inversions, so the difference should be minimal, particularly in comparison of the change in noise level.

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SFO Staff Comments on HMMH Report

- Comment: Figures 17 and 18 should have the same contours and do not.
  - HMMH Response: Figure 17 shows condition with no vegetation and Figure 18 shows the same condition with vegetation and should have slightly different results as shown in the figures.
- Comment: Remove the recommendation to use vegetation for noise mitigation as the HMMH report findings do not support such a recommendation.
  - HMMH Response: Generally, HMMH concurs that vegetation does not provide perceptible noise level reduction. However, communities seemed interested in trying to find areas to plant thick vegetation.
- Vegetative barriers may attract hazardous wildlife and therefore oppose the use of vegetative barriers near SFO.
  - HMMH Response: HMMH concurs and further research would be required to determine types of vegetation that may not attract hazardous wildlife if such a barrier would be recommended near the Airport.
- Barriers at the height required to break the line of sight to the noise source would likely violate FAA regulations on height limitations near airports and vegetation requires management to maintain the height limitations.
  - HMMH Response: HMMH concurs.

hmmh

Next Steps

- According to the Roundtable Annual Work Plan
  - The Roundtable Ground Based Noise Subcomittee will:
    - ✓ Complete the GBN study
    - ❑ Recommend next steps to Roundtable membership

Thank you

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 24, 2021

Steve Dickson, Administrator
Federal Aviation Administration (FAA)
500 Independence Avenue, S.W.
Washington, DC 20591

Re: Ground-Based Noise Recommendations

Dear Mr. Dickson,

The San Francisco Airport/Community Roundtable (SFORT) is in its 40th year of providing community noise reduction recommendations related to aircraft and airport operations from the San Francisco International Airport (SFO) to airport management, FAA staff, and airline representatives. The Roundtable Membership consists of 22 appointed and elected officials from the City and County of San Francisco, the County of San Mateo, and most cities in San Mateo County representing more than 2,000,000 people.

The Ground-Based Noise (GBN) Subcommittee, a subcommittee of the SFORT, investigates the sources of ground-based noise impacts from SFO. Recently a Ground-Based Noise Study was completed documenting the environs around the airport, the cause and effect of hills on noise, modeled ground-based noise levels, and noise mitigation. At its July 19, 2021 GBN subcommittee meeting, the subcommittee members voted to provide the following recommendations regarding ground-based noise for your consideration:

1. The FAA's Aviation Environment Design Tool (AEDT) should be updated to incorporate aircraft noise reflection and diffraction from terrain and manmade structures. This is crucial when generating noise contours for understanding how ground-based noise propagates.

2. The FAA should establish a framework for adopting FAA policy related to ground-based noise including an appropriate noise metric, weighting (such as "C-weighting") to adequately address community perception and airplane noise annoyance.

3. Requiring FAA to use C-weighting noise in the creation of noise contours.

When does the FAA expect the next update to AEDT? The Roundtable is interested in a pilot program to test ground-based noise relief measures at the airport. We would be happy to discuss the findings of the Ground-Based Noise Study, or the recommendations in the letter. Subcommittee Chair Ann Schneider and Roundtable Chairperson Ricardo Ortiz are available to discuss these recommendations in more detail at your convenience. Please direct your response to Angela Montes, SFO Airport/Community Roundtable Administrative Secretary, at amontescardenas@smcgov.org.

Regards,

Ricardo Ortiz

Working together for quieter skies

Roundtable Chairperson

CC: Shannetta Griffin, Associate Administrator for the Office of Airports
Raquel Girvin, Regional Administrator – Western Pacific Region
Faviola Garcia, Supervisory Senior Advisor

U.S. Department
of Transportation
**Federal Aviation
Administration**

November 9, 2021

Ricardo Ortiz
Chairperson
San Francisco Airport Community Roundtable
455 County Center, 2nd Floor
Redwood City, CA 94063

Dear Chairman Ortiz:

Thank you for your August 24 letter submitting the recommendations of the San Francisco Airport Community Roundtable (SFORT) related to the Aviation Environmental Design Tool (AEDT), suggesting the Federal Aviation Administration (FAA) establish a noise policy framework to address community perception and airplane noise annoyance, and recommending a requirement for C-weighting noise data when creating noise contours.

The FAA developed AEDT to model the environmental impacts of aircraft fuel consumption, emissions, noise, and air quality. A model of environmental impacts strives to depict accurately the projected effects over broad geographical areas based on the most up-to-date data and methodologies. As scientific understanding, data, and methodologies advance and expand, the FAA works to improve AEDT by developing new features, refining algorithms, and integrating mature data and methodologies. AEDT quantifies accurately aircraft noise resulting from all phases of an aircraft's operation, including ground takeoff roll.

The most recent version of the tool (AEDT 3d) was released in March 2021, with additional updates planned for 2022. The next major release of AEDT will be the 4 series, planned for introduction in 2023. The AEDT 4 series will offer enhancements to the noise model, including processing land cover data, calculating attenuation due to ground type and terrain, and accounting for man-made structures. The FAA's release of each new feature is the culmination of extensive testing and policy analysis to determine suitability for regulatory applications, with the goal of improving its capabilities to model noise and emissions from aircraft. Some of these features may initially only be available for research purposes while the FAA verifies the utility and accuracy of each feature.

As you may already be aware, in May 2021, the FAA announced its intent to conduct a review of its existing noise policies. Administrator Dickson notified the Congressional Quiet Skies Caucus that the FAA will engage in a robust, evidence-based review of our national noise policies. We have selected the Federal Mediation and Conciliation Service to help us develop a policy review framework and to facilitate collaborative dialogue between the FAA and stakeholders. The FAA will consider this feedback in developing any noise policy updates that the FAA determines are needed to better address aircraft noise. This review will be data driven and informed by the results of the Neighborhood Environmental Survey and other applicable research findings on aircraft noise. See 86 FR 2722 (January 13, 2021) describing our civil aviation noise research program.

Consistent with your recommendation and the agency's existing authority, the FAA intends to review the continued use of the Day-Night Average Sound Level as our primary noise metric for assessing cumulative aircraft noise exposure during our policy review. We will also explore whether, and under what circumstances, supplemental or alternative noise metrics are appropriate to inform research and policy considerations. As detailed in the FAA's 2019 report to Congress on supplemental noise metrics, the FAA understands all metrics have limitations. During the noise policy review, the FAA will work to ensure that any proposed metrics can both quantify the potential for impacts and be applied equitably.

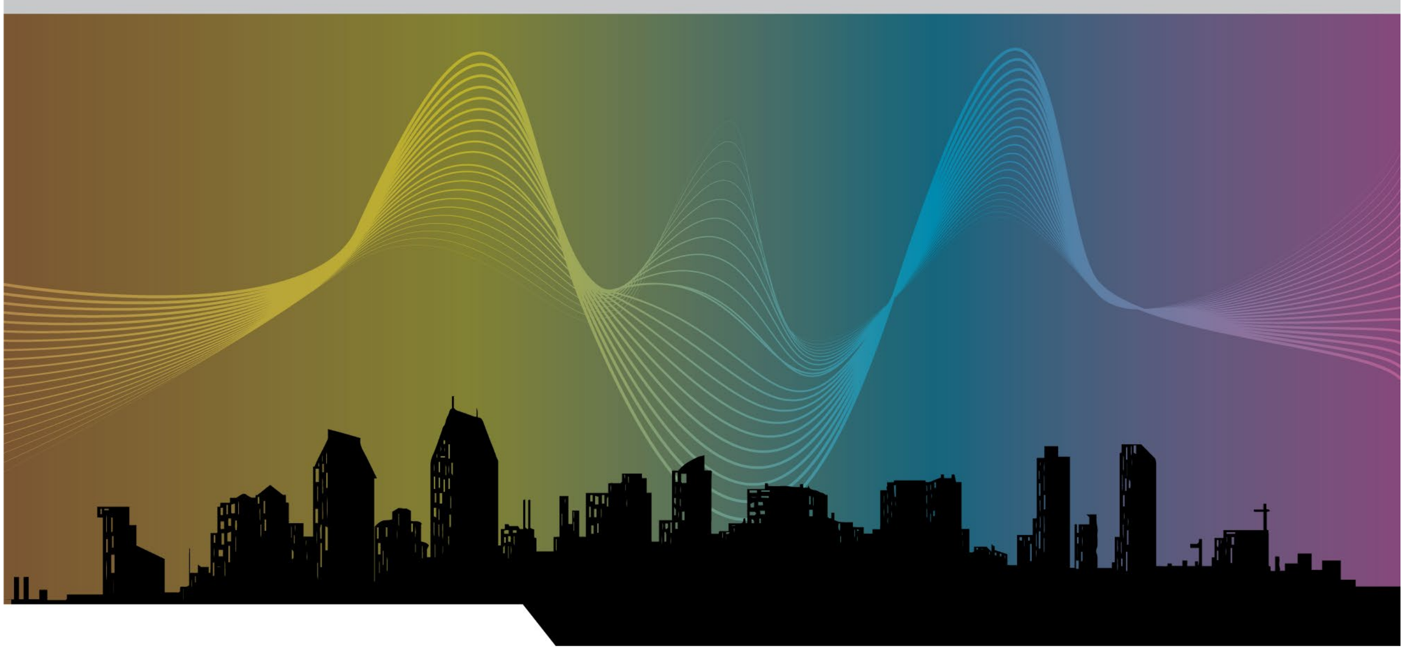
I thank you and the members of the SFORT for your ongoing collaboration with the FAA's Western Pacific Regional Office team and for your commitment to community noise reduction. We share SFORT's commitment. If the FAA can be of further assistance, please contact the Office of Government and Industry Affairs at (202) 267-3277 or the Regional Administrator's office at (424) 405-7000.

Sincerely,

Laurence Wildgoose
Assistant Administrator for Policy,
International Affairs, and Environment

cc: Shannetta Griffin, Associate Administrator for the Office of Airports
Raquel Girvin, Regional Administrator – Western Pacific Region
Faviola Garcia, Supervisory Senior Advisor

November 18, 2021



Review of Remote Monitoring Terminal Thresholds-Phase 3

Prepared for:
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Prepared by:
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Contents

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Appendix

1. Background

BridgeNet International was contracted by the San Francisco International Airport's (SFO) Noise Office to review aircraft noise event thresholds and noise monitoring settings for all the Remote Noise Monitoring Terminals (NMTs). This review is the third of three phases that analyzed aircraft noise events, including conducting an analysis of measured noise levels and recommending noise thresholds and durations that should be used in the future. The first phase analyzed five (5) NMTs, 12, 15, 18, 19 and potential applications of a new threshold to NMT 8. The second phase reviewed Sites 1, 4, 5, 6, 14, 16, and17 which are all located along the GAP departure corridor. This third phase will review the final 17 NMTs, including: 2, 3, 7, 9, 10, 11, 13, 20, 21, 22, 23, 24, 25, 26, 27, 28 and 29.

In the fall of 2019, SFO installed a new noise system, the Envirosuite (EVS) Airport Noise and Operations Monitoring System (ANOMS), to replace the airport's existing ANOMS that was installed in 2006. The system underwent various hardware and software upgrades, but the basic noise event detection process per Title 21 has remained essentially the same. The software upgrade did not include changes to how noise events are calculated and correlated to aircraft. Historically, SFO operated with a variance to its state operating certificate due to the airport's status as a "noise problem airport" because there were incompatible land uses[1] within the 65 dBA CNEL noise contour. In 2002, the airport no longer needed to operate with a variance because it no longer had incompatible land uses within the 65 dBA CNEL contour, which meant that all sensitive land uses within the 65 dBA CNEL contour were either sound insulated or had granted an avigation easement to the airport. While the airport has operated without a variance for 18 years, it still abides by the standards in Title 21 for a noise problem airport, including the requirement in Section 5033 of Title 21 requiring noise monitoring systems to be submitted and approved by the state as part of an airport's Noise Monitoring Plan.

Per Section 5001 of Title 21, the thresholds of the NMTs should be 10 dB below the appropriate CNEL value; for the purposes of this analysis, the appropriate CNEL value is 65 CNEL as described in Section 5012 of Title 21. Should an airport need a waiver to the 10 dB value, per Section 5070 of Title 21, an airport can apply for a waiver that demonstrates an airport will still maintain the required accuracy of 1.5 CNEL using a different threshold value. Since 2011, SFO has operated with a waiver for noise thresholds at certain NMTs. For this NMT Phase 3 analysis, there are no NMTs currently within the 65 CNEL. This report will describe the background, or ambient noise levels, and aircraft noise levels at each of the monitors and the supporting analysis for continuing to use a threshold different than 55 dBA and identify an optimum threshold specific to the conditions at each of the above locations.

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[1] As defined in Section 5014 of Title 21: https://govt.westlaw.com/calregs/Document/ICD7B5DE0D45011DEB97CF67CD0B99467?originationContext=document&transitionType=StatuteNavigator&needToInjectTeNMT=False&viewType=FullText&contextData=%28sc.Default%29

Given the airport operational changes associated with COVID-19, this is also an opportune time to evaluate the current NMT threshold settings to reflect a post COVID-19 environment. This global pandemic accelerated the retirement of older aircraft that are not as efficient as newer aircraft in use or about to be introduced into service. Much of the remaining existing aircraft fleet and the newest generation of aircraft entering service on average generate lower peak noise levels that the pre COVID-19 time frame. Being able to capture the noise from the new generation, quieter aircraft is becoming more important as the fleet become quieter. Thus, this report will review potential threshold changes to better capture lower peak noise levels from aircraft that is expected to be more common in the future.

2. Definition of Terms

Characteristics of Sound

Sound can be described technically in terms of amplitude (loudness), frequency (pitch), or duration (time). Frequency (or pitch) is measured in hertz (Hz). The standard unit of measurement for the loudness of sound is the decibel (dB). Decibels are based on a logarithmic scale. The logarithmic scale compresses the wide range in sound pressure levels to a more usable range of numbers (in a manner similar to the Richter scale used to measure earthquakes).

Human hearing is not equally sensitive to sound at all frequencies. Sound waves below 16 Hz are not heard at all and are "felt" more as a vibration. Similarly, while people with extremely sensitive hearing can hear sounds as high as 20,000 Hz, most people cannot hear above 15,000 Hz. In all cases, hearing acuity falls off rapidly above about 10,000 Hz and below about 200 Hz. Since the human ear is not equally sensitive to sound at all frequencies, a special frequency-dependent rating scale has been devised to measure loudness in a way that reflects how the human ear actually perceives sound. Community noise levels are measured in terms of this A-weighted decibel scale (or dBA), which is widely used in industrial and environmental noise-management contexts.

Propagation of Noise

Outdoor sound levels decrease as a result of several factors, including increased distance from the sound source, atmospheric absorption (characteristics in the atmosphere that absorb sound), and ground attenuation (characteristics on the ground that absorb sound). If sound radiates from a source in a homogeneous and undisturbed manner, the sound travels in spherical waves. As the sound wave travels away from the source, the sound energy is spread over a greater area dispersing the power of the sound wave.

Atmospheric temperature and humidity also influence the sound levels received by the observer. How much sound is absorbed by the atmosphere depends on the frequency of the sound as well as the humidity and air temperature. For example, when the air is cold and humid, and therefore denser, atmospheric absorption is lowest and sound travels farther. Higher frequencies are more readily absorbed than the lower frequencies. The fluctuations in sound levels created by atmospheric conditions increase with distance and become particularly important at distances greater than 1,000 feet. Over large distances, lower frequency sounds become dominant as the higher frequencies are attenuated. Noise propagation is one of the reasons that aircraft noise will be higher one day than other days even when the same aircraft are flying the same path and altitude.

Noise Metrics

The description, analysis, and reporting of noise levels around communities is made difficult by the complexity of human response to noise and the variety of metrics that have been developed for describing noise impacts. Each of these metrics attempts to quantify noise levels with respect to community impact.

Noise metrics can be divided into two categories: single event and cumulative. Single event metrics describe the noise levels from an individual event such as an aircraft flyover. Cumulative metrics average the total noise over a specific time period, typically from one to 24 hours. This study presents single event measurement results.

- **Maximum Noise Level,** or Lmax, is the maximum or peak sound level during an aircraft noise event. The metric accounts only for the peak intensity of the sound and not for the duration of the event. As an aircraft passes by an observer, the sound level increases to a maximum level and then decreases. Typical single event noise levels range from over 90 dBA close to the airport to the low 50s dBA at more distant locations.
- **Single Event Noise Exposure Level (SEL)** - The duration of a noise event, or an aircraft flyover, is an important factor in assessing annoyance and is measured most typically as SEL. The effective duration of a sound starts when a sound rises above the background sound level and ends when it drops back below the background level. An SEL is calculated by summing the dB level at each second during a noise event and compressing that noise into one second. It is the level the noise would be if it all occurred in one second. The SEL value is the integration of all the acoustic energy contained within the event. This metric takes into account the maximum noise level of the event and the duration of the event. For aircraft flyovers, the SEL value is numerically about 10 dBA higher than the maximum noise level.
- **Community Noise Equivalent Level (CNEL)** is an average noise over twenty-four hours; it applies a weighting factor that penalizes noise events occurring during the evening and night hours (when humans are typically more sensitive to noise and sleep disturbance is a concern). More specifically, noises occurring during the evening (from 7 PM to 10 PM) are penalized by 5 dB, while noises occurring during the night (10 PM to 7 AM) are penalized by 10 dBA. CNEL noise levels near airports range from 70 CNEL directly next to an airport to less than 45 CNEL at more distant locations.

  CNEL is influenced most by the loudest aircraft operating at an airport, which at SFO is typically a wide-body passenger or cargo jet traveling long distances (such as to Europe or Asia). At SFO the aircraft that most influence the CNEL contour are the Boeing 777, other large jets like the Boeing 787, and historically the Boeing 747 which recently stopped being used for passenger service but is still used by cargo carriers. The CNEL contours are influenced to a lesser extent by operations conducted by smaller aircraft; these aircraft influence the contour due to the larger number of operations (for example, narrow-body jets on domestic routes). The CNEL noise levels at locations along the peninsula (i.e., departure procedures along The Gap) are especially dominated by the larger jet aircraft in that many of these operations also occur during the evening and night penalty period of 5 dB and 10 dB, respectively.

Note that measuring CNEL at levels below 55 CNEL becomes less precise because the noise from aircraft events can be close to existing ambient noise, and it is not always technically possible to separate the two. CNEL differs from the Lmax values which are numerically higher than CNEL values because the CNEL represents an average that includes both peak sounds (like the Lmax) and lower values when aircraft noise is not present.

3. Purpose

The purpose of this Phase 3 NMT analysis is to support SFO's acceptance of the new ANOMS that was installed in the fall of 2019; in particular, the accuracy of identifying and correlating measured noise to flights at SFO. This system was submitted for review and acceptance to the State of California in 2020. The goal of this analysis is to determine the most effective and accurate thresholds and NMT settings to be used to identify the noise levels due to aircraft flights while in compliance with Title 21 standards at additional monitoring sites beyond the 65 CNEL.

Additionally, this analysis supports Section 5032 of Title 21 that validates the noise impact boundary, which reviews locations of the NMTs relative to the outer-most points of the 65 CNEL contour. Per Section 5032, "The locations shall be selected to facilitate locating the maximum extent (closure points) of the noise impact boundary when the contour extremities encompass incompatible land uses." The NMT sites in Phase 3 are not near the closure points of the contour, and the majority of the NMTs have historically been outside of the 65 CNEL.

4. Methodology

4.1 Remote Monitoring Terminal Locations

Figure 1 shows a map of the NMTs; Phase 3 NMTs are shown with red circles; at the time of this report, all sites except NMT 1 are located outside of the 65 CNEL. It also shows the existing noise thresholds at these NMTs; these values were approved by the State of California in December 2011 and is not inclusive of all the NMTs with threshold waivers[2]. **Table 1** shows the current NMT Thresholds and general location of the monitor and the type of aircraft noise that is captured.

[2] In December 2011 the State of California approved a threshold waiver for the following NMTs: 1,4,5,6,12,14,15,16,17,18, and 19.

Most sites are exposed to predominately either arrival or departure noise; NMTs that are located further from the airport can record arrival and departure noise. These are labeled “distant site.”

Table 1 – Current NMT Threshold Values

NMT	City	Location	NMT Threshold, dBA
2	San Bruno	Gap departure along centerline	65
3	South San Francisco	SSTIK Departure	63
7	Brisbane	SSTIK Departure	65
9	Millbrae	Runway 01 Departure Roll	64
10	Burlingame	Runway 01 Departure Roll	64
11	Burlingame	Runway 01 Departure Roll	65
13	Hillsborough	Distant Site	64
20	Daly City	Gap departure along centerline	63
21	San Francisco (Glen Park)	Distant Site	62
22	San Bruno	Gap departure along sideline	65
23	San Francisco (Visitacion Valley)	SSTIK Departure	64
24	San Francisco (Excelsior)	Distant Site	64
25	San Francisco (Balboa Terrace)	Distant Site	57
26	San Francisco (Forest Hill)	Distant Site	62
27	San Francisco (Pacific Heights)	Distant Site	62
28	Redwood City	Runway 28 arrivals	62
29	San Mateo	Distant Sites	65

Source: San Francisco International Airport Noise Office, 2021

The NMT thresholds shown in Table 1 are fixed, meaning the noise threshold is an A-weighted decibel shown as dBA and was determined as described in Section 1. The farther away an NMT is from an airport, it becomes more difficult to discern aircraft noise from other sources of noise within the community. For the NMTs used at the closure points of the 65 CNEL, per Title 21, a fixed noise threshold must be used. For monitors not used to verify the 65 CNEL, it is possible to use alternative thresholds such as variable or floating for the ANEEM process. EVS, the proprietor of SFO’s ANOMS, created a system called Aircraft Noise Event Extraction Methodology (ANEEM). The ANEEM system was put in place subsequent to SFO’s ANOMS upgrade in 2019. The airport can potentially use ANEEM to better identify and correlate aircraft noise with flight events at these more distance sites. ANEEM automatically considers the prevailing noise environment at the time aircraft are near the monitor and the available information about the aircraft; unlike a “floating threshold” that moves up and down based on noise recorded at an NMT, ANEEM is more agile and quicker to identify spikes in noise.

The sites in Phase 3 are locations that are further from SFO than the sites in Phase 1 and Phase 2, not near the 65 CNEL noise contour, therefore are not used for Title 21 requirements. Many of distant NMTs are not under regular flight patterns. Thus, the correlated noise events are more indiscriminate, not showing the usual pattern of higher noise for the larger category of aircraft. A lower threshold would be expected to improve the measurement of lower-level events.

While NMTs should ideally be located in areas with ambient noise levels less than 55 dBA (i.e., away from noisy sources such as freeways, railroad tracks, etc.) many of the NMTs at SFO are in urban areas with ambient levels higher than 55 dBA. This analysis will determine suggested thresholds based upon the type of operations a site is exposed to, the level of noise from aircraft events and the background noise environment.

4.2. Evaluation Criteria

The evaluation criteria used in Phase 3 was the same as Phase 2; this information can be found in the Phase 2 report, which includes: threshold calculation at various alternative levels, background noise level, and single event noise levels. The analysis used information on the background noise level at the site, predicted ANOMS CNEL noise levels based upon various reduced thresholds, and the number of current and predicted long duration 120 second events. The data on measured SEL noise levels was used to evaluate the quality of the current noise correlations.

4.3. Evaluation Data

The evaluation of each site is presented in the Appendix, **Figures A-2** through **A-18, Parts A-B** for each NMT. A full description of each of the five parts is in the Phase 2 NMT report.

5. NMT Sites

This section describes the physical attributes of each NMT, a brief history of the threshold level and the recommendation for a daytime and nighttime threshold level. Additional data for each NMT is show in **Appendix A**.

5.1 NMT Site 2

NMT Site 2 is west of the airport under the San Bruno Gap departure flight path. It is located near the intersection of Fleetwood Dr. and Rollingwood Dr. The dominant, non-aircraft noise source is from residential land uses; the L50 is 53 dBA with a two times standard deviation of 63 dBA. The default threshold for this NMT is 55 dBA, however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dBA. Data for this site is presented in the Appendix in **Figure A-2 (Part A, B).**

The dominant aircraft noise is from long-haul aircraft departing on Runways 28L/R flying through the San Bruno Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 71 dBA and are fully captured with the current settings. The quieter regional jets are reflective of several of the new generation aircraft anticipated to operate at the airport in the future, generating an average

Lmax of 73 dBA which are captured under the current settings. The threshold cannot be lowered more because there starts to become a larger and larger number of 120 second events that limit the ability of the system to accurately measure noise events during those time periods. The recommendation is to lower the threshold to 63 dBA for daytime and 60 dBA for nighttime.

5.2 NMT Site 3

NMT Site 3 is located to the north of the Gap departure flight path. It is south of the intersection of Park Way and Walnut Ave. The default threshold for this NMT is 55 dBA, however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 63 dBA. Data for this site is presented in the Appendix in **Figure A-3 (Part A, B)**.

The dominant aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 68 dBA and are fully captured with the current settings. The quieter regional jets are reflective of several of the new generation aircraft anticipated to operate at the airport in the future, generating an average Lmax of 70 dBA which are captured under the current settings. Lower the threshold will capture a greater number of these aircraft.

While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 49 dBA with a two times standard deviation of 60 dBA.

Based upon a review of the evaluation data, the recommended optimum setting is 61 dBA for daytime and nighttime.

5.3 NMT Site 7

This NMT is located in Brisbane, at the top of Alexander Road near the water tower. Data for this site is presented in the Appendix in **Figure A-4 (Part A, B)**. Surrounding land uses include residential to the north and open space on all other sides. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 48 dBA with a two times standard deviation of 55 dBA. The default threshold for this NMT is 55 dBA, however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dBA.

The dominant aircraft noise is from departures on Runways 01L/R flying over the peninsula for destinations to the west and south; these are typically narrow body aircraft such as the Airbus A320 or Boeing 737 series. The secondary source of aircraft noise are departures on Runways 28 L/R going out the Gap but turning on the shoreline. Narrow body aircraft flying over this NMT generate an average Lmax of 70 dBA and are fully captured with the current settings. The quieter regional jets reflective of several of the new generation aircraft operating at the airport in the future generate an average Lmax of 72 dBA.

Based the evaluation data, the recommended optimum setting is to lower the threshold to 60 dBA for daytime and nighttime. Given the background noise, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

Lowering the threshold will improve the site's ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft but the quieter aircraft that are going to be more common in the future.

5.4 NMT Site 9

This NMT is located in Millbrae on the east side of Josephine Waugh-Soroptomist Park near the intersection of Hillcrest Blvd. and El Paseo. Data for this site is presented in the Appendix in **Figure A-5 (Part A, B)**. The site is surrounded by residential land uses and the park to the west. The primary non-aircraft noise source is from park activities and residential land uses, including vehicle traffic; the L50 is 47 dBA with a two times standard deviation of 56 dBA. Historically, the site is outside of the 65 CNEL noise contour. The default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R when they're on the departure roll before lifting off the ground. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. Most of the aircraft are not currently measured at this site with the current threshold because the threshold was not low enough.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 58 dBA for daytime and nighttime to better measure the ground roll activities at this location. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.5 NMT Site 10

This NMT is located in Millbrae, south of Trousdale Drive near the intersection of Granada Dr. and Arguello Dr. Data for this site is presented in the Appendix in **Figure A-6 (Part A, B)**. The site is surrounded by residential on all sides. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 47 dBA with a two times standard deviation of 56 dBA. The site is historically and currently located outside of the 65 CNEL noise contour; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R when they're on the departure roll before lifting off the ground. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. Most of the aircraft are not currently measured at this site with the current threshold because the threshold was not low enough. Lowering the threshold will capture a greater number of these quieter aircraft.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 58 dBA for daytime and nighttime to better measure lower noise events.

5.6 NMT Site 11

This NMT is located in Burlingame on Devereaux Dr. east of Bernal Ave. Data for this site is presented in the Appendix in **Figure A-7 (Parts A, B)**. The site is surrounded by residential land uses and Lincoln Elementary School. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 46 dBA with a two times standard deviation of 54 dBA. The site is historically and currently located outside of the 65 CNEL noise contour. the default threshold for this NMT is 55 dBA CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R when they're on the departure roll before lifting off the ground. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. Most of the aircraft are not currently measured at this site with the current threshold because the threshold was not low enough. Lowering the threshold will capture a greater number of these aircraft.

Based upon a review of the evaluation data, the recommended optimum setting is to lower the threshold to 58 dBA.

5.7 NMT Site 13

This NMT is located in Hillsborough east of the intersection of Skyline Dr. and Fir Ct. Data for this site is presented in the Appendix in **Figure A-8 (Part A, B)**. The site is surrounded residential land uses on large lots. The primary non-aircraft noise source is from residential activities, including vehicle traffic and the average ambient noise level L50 is 45 dBA with a two times standard deviation of 55 dBA. The default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The NMT is located to the south of the airport. The dominant aircraft noise is from departing aircraft on Runways 01L/R; the secondary noise is from aircraft arriving on Runways 28L/R. Aircraft departing on Runways 01L/R generate an average Lmax of 69 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 70 dBA.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 58 dBA for daytime and nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.8 NMT Site 20

This NMT is located in Daly City northwest of the Airport at the intersection of Post St. and Bellevue Ave. Data for this site is presented in the Appendix in **Figure A-9 (Part A, B)**. The site is surrounded by residential land uses to the north, east and west, and Mission Hills Park directly to the south. The primary non-aircraft noise source is from residential activities, including vehicle traffic and the average ambient noise level L50 is 47 dBA with a two times standard deviation of 56 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 63 dBA.

The dominant aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 70 dBA and are fully captured with the current settings. The secondary aircraft noise source is from aircraft departing Runways 01L/R and turning over the peninsula for destinations to the south. The quieter regional jets are reflective of a number of the new generation aircraft anticipated to operate at the airport in the future; a lower the threshold will capture a greater number of these aircraft.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 58 dBA for daytime and nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.9 NMT Site 21

This NMT is located in the Glen Park area of San Francisco east of Fire Station No. 26 on Digby St. Data for this site is presented in the Appendix in **Figure A-10 (Part A, B)**. The site is surrounded residential land uses to the east and south, a fire station followed by a neighborhood park to the north and west. The primary non-aircraft noise source is from residential and park activities, including vehicle traffic and the average ambient noise level L50 is 50 dBA with a two times standard deviation of 57 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 62 dBA.

The dominant aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 68 dBA and are fully captured with the current settings. The secondary aircraft noise source is from aircraft departing Runways 01L/R and turning over the peninsula for destinations to the south. The quieter regional jets are reflective of a number of the new generation aircraft anticipated to operate at the airport in the future, generating an average Lmax of 68 dBA; lowering the threshold will capture a greater number of these aircraft.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 58 dBA for daytime and nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.10 NMT Site 22

This NMT is located in San Bruno, west of the departure end of Runways 10L/R near the intersection of San Anselmo Ave. S and Santa Domingo Ave. Data for this site is presented in the Appendix in **Figure A-11 (Part A, B)**. The site is surrounded residential land uses on all sides. The primary non-aircraft noise source is from residential activities, including vehicle traffic and the average ambient noise level L50 is 50 dBA with a two times standard deviation of 62 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dBA.

The dominant aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 71 dBA and are fully captured with the current settings. The secondary aircraft noise source is from aircraft departing Runways 01L/R and turning over the peninsula for destinations to the south.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is lowering the threshold to 63 dBA to better capture the lower noise events. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.11 NMT Site 23

This NMT is located in the Visitacion Valley area of San Francisco, north of the Airport near the intersection of Lathrop Ave. and Tocaloma Ave. Data for this site is presented in the Appendix in **Figure A-12 (Part A, B)**. The site is surrounded residential land uses on all sides. The primary non-aircraft noise source is from residential activities, including vehicle traffic and the average ambient noise level L50 is 52 dBA with a two times standard deviation of 60 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R from aircraft turning back over the peninsula for destinations to the south and west. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. The narrow body aircraft generate an average Lmax of 78 dBA and are fully captured with the current settings. The quieter regional jets reflective of several of the new generation aircraft operating at the airport in the future generate an average Lmax of 68 dBA.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 62 dBA for daytime and nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.12 NMT Site 24

This NMT is located in the Excelsior area of San Francisco, north of the Airport near the intersection of Bacon St and Bowdoin St. Data for this site is presented in the Appendix in **Figure A-13 (Part A, B)**. The site is surrounded residential land uses to the east and south and a maintenance yard to the north and west. The primary non-aircraft noise source is from residential activities, including vehicle traffic and the average ambient noise level L50 is 50 dBA with a two times standard deviation of 58 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R from aircraft turning back over the peninsula for destinations to the south and west. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. The narrow body aircraft generate an average Lmax of 77 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 67 dBA.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 60 dBA for daytime and 58 dBA for nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.13 NMT Site 25

This NMT is located in the Balboa Terrace area of San Francisco, north of the Airport on the eastern edge of Aptos Park. Data for this site is presented in the Appendix in **Figure A-14 (Part A, B)**. The site is surrounded residential land uses to the east and south and Aptos Park and Aptos Middle School to the north and west. The primary non-aircraft noise source is from residential and park activities, including vehicle traffic and the average ambient noise level L50 is 45 dBA with a two times standard deviation of 54 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 57 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R from aircraft turning back over land for destinations to the south and west. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. The narrow body aircraft generate an average Lmax of 64 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 63 dBA.

Based upon a review of the evaluation data, the recommended optimum setting is to maintain the current threshold of 57 dBA for daytime and nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.13 NMT Site 26

This NMT is located in the Forest Hill area of San Francisco, north of the Airport at the top of Mendosa Ave. co-located with the water tower. Data for this site is presented in the Appendix in **Figure A-15 (Part A, B)**. The site is surrounded residential land uses on all sides; it is located inside a small municipal yard. The primary non-aircraft noise source is from residential activities, including vehicle traffic and the average ambient noise level L50 is 48 dBA with a two times standard deviation of 57 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 62 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R from aircraft turning back over land for destinations to the south and west. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. The narrow body aircraft generate an average Lmax of 67 dBA and are fully captured with the current settings. The quieter regional jets reflective of several of the new generation aircraft operating at the airport in the future generate an average Lmax of 67 dBA.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 60 dBA for daytime and 58 dBA nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.14 NMT Site 27

This NMT is located in the Pacific Heights area of San Francisco, in Alta Plaza Park near Jackson St. and Steiner St. Data for this site is presented in the Appendix in **Figure A-16 (Part A, B)**. The site is surrounded residential land uses on all sides. The primary non-aircraft noise source is from residential and park activities, including vehicle traffic and the average ambient noise level L50 is 48 dBA with a two times standard deviation of 57 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 62 dBA.

The dominant aircraft noise is from departing aircraft on Runways 01L/R from aircraft turning back over land for destinations to the south and west. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. The narrow body aircraft generate an average Lmax of 68 dBA and are fully captured with the current settings. The quieter regional jets reflective of several of the new generation aircraft operating at the airport in the future generate an average Lmax of 70 dBA.

Based upon a review of the evaluation data, the recommended optimum setting is to decrease the threshold to 60 dBA for daytime and 58 dBA nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.15 NMT Site 28

This NMT is located in Redwood City, at the John Gill Elementary School. Data for this site is presented in the Appendix in **Figure A-17 (Part A, B)**. The site is surrounded by residential land uses on all sides. The primary non-aircraft noise source is from residential and school activities, including vehicle traffic and the average ambient noise level L50 is 41 dBA with a two times standard deviation of 50 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 62 dBA.

The NMT is located approximately 10 miles to the south of the airport. The dominant aircraft noise is from aircraft arriving on Runways 28L/R. Aircraft generate an average Lmax of 67 dBA and are fully captured with the current settings.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is to decrease the threshold to 58 dBA for daytime and nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.16 NMT Site 29

This NMT is located in San Mateo, at Harborview Park, southeast of Coyote Point. Data for this site is presented in the Appendix in **Figure A-18 (Part A, B)**. The site is surrounded residential land uses to the south, bayfront to the north and east, and park to the west. The primary non-aircraft noise source is from residential and park activities, including vehicle traffic and the average ambient noise level L50 is 46 dBA with a two times standard deviation of 54 dBA. The site is historically and currently located outside of the 65 CNEL; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dBA.

The NMT is located approximately 2.7 miles to the southwest of the airport. The dominant aircraft noise is from aircraft arriving on Runways 28L/R. Aircraft generate an average Lmax of 71 dBA and are fully captured with the current settings.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is to decrease the threshold to 58 dBA for daytime and nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

5.17 Global Settings

There are a number of additional setting other than the thresholds that were reviewed for potential changes, which would be applied to all the NMTs. These settings and any recommendations are described below.

Minimum Duration: At each of the NMTs, the settings include a "minimum duration" which is the time, in seconds, an event must last before it is recorded in the NMT as an event. This current time is 6 to 8 seconds, which is typical of noise monitoring system settings, and it is recommended to keep the current settings. Aircraft noise events are typically longer duration than community events because the noise source (aircraft) is further away and takes longer to rise and drop off. Lowering this setting generally results in the generation of more short duration community events that can be incorrectly associated with an aircraft.

Maximum Duration: The maximum duration setting is the maximum time, in seconds, an event can last before it is stopped, and an event is created. Currently that time is 120 seconds at all the NMTs; it is recommended to reduce that time duration to 60 seconds because the majority of aircraft events are 20 to 40 seconds in duration. The long duration events occur when the ambient noise exceeds the threshold and a continuous event is generated.

6. Summary and Recommendations

Based on the analysis presented in Section 5, **Table 2** shows the recommended NMT thresholds and event detection for the NMTs in Phase 3. As shown in Table 2, most of the thresholds are recommended to be lowered to improve the site's ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft but the quieter aircraft that are going to be more common in the future. The maximum noise level from the events is trending downward; an example of this is shown in **Figure A-9** for Site 20, representing the Lmax at that NMT. Lowering the threshold will help capture more of these quieter events both now and in the future.

As discussed in Section 4.1, the San Francisco Airport ANOMS is now capable of using ANEEM technology to better correlate and measure aircraft noise events in locations further from the airport. While this report recommends the NMT thresholds in Table 2, they could also be used to inform use of ANEEM and as a checks and balance should ANEEM replace the fixed threshold at

NMTs beyond the closure points of the 65 CNEL. Additionally, use of ANEEM at the distant sites could reduce the time staff spends reviewing the noise and radar data to ensure events are properly correlated.

Table 2 – Recommended NMT Thresholds and Duration

NMT	City	Location	Current NMT Threshold, dBA	Recommended NMT Threshold, CNEL DAY	Recommended NMT Threshold, CNEL NIGHT
2	San Bruno	Gap departure along centerline	65	63	60
3	South San Francisco	SSTIK Departure	63	61	61
7	Brisbane	SSTIK Departure	65	60	60
9	Millbrae	Runway 01 Departure Roll	64	58	58
10	Burlingame	Runway 01 Departure Roll	64	58	58
11	Burlingame	Runway 01 Departure Roll	65	58	58
13	Hillsborough	Distant Site	64	58	58
20	Daly City	Gap departure along centerline	63	58	58
21	San Francisco (Glen Park)	Distant Site	62	58	58
22	San Bruno	Gap departure along sideline	65	63	63
23	San Francisco (Visitacion Valley)	SSTIK Departure	64	62	62
24	San Francisco (Excelsior)	Distant Sites	64	60	58
25	San Francisco (Balboa Terrace)	Distant Sites	57	57	57
26	San Francisco (Forest Hill)	Distant Sites	62	60	58
27	San Francisco (Pacific Heights)	Distant Sites	62	60	58
28	Redwood City	Runway 28 arrivals	62	58	58
29	San Mateo	Distant Sites	65	58	58

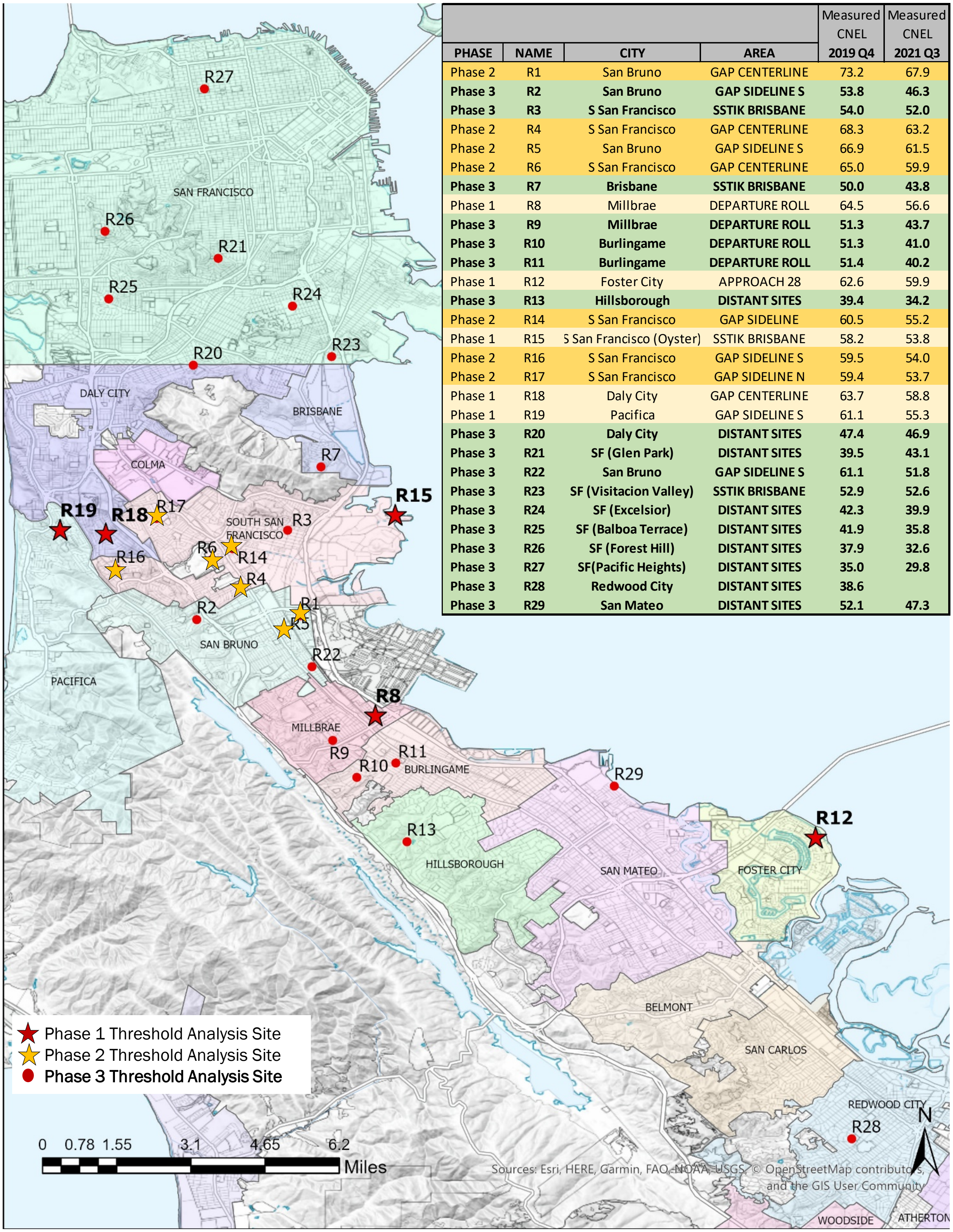
Source: BridgeNet International, 2021

APPENDIX

Report Figures

Figure A-1
Noise Monitor Terminals Site Map

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

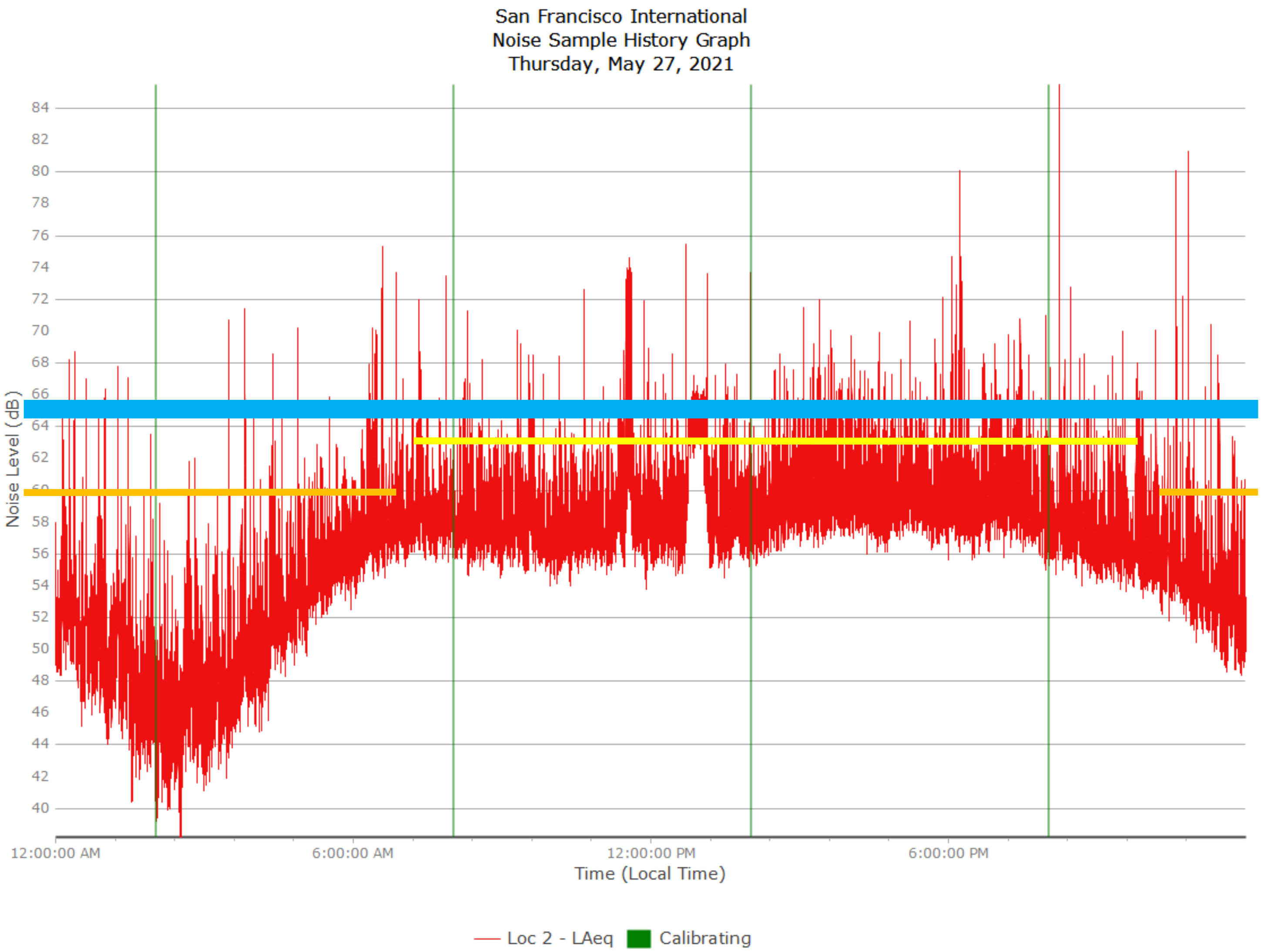


PHASE	NAME	CITY	AREA	Measured CNEL 2019 Q4	Measured CNEL 2021 Q3
Phase 2	R1	San Bruno	GAP CENTERLINE	73.2	67.9
Phase 3	R2	San Bruno	GAP SIDELINE S	53.8	46.3
Phase 3	R3	S San Francisco	SSTIK BRISBANE	54.0	52.0
Phase 2	R4	S San Francisco	GAP CENTERLINE	68.3	63.2
Phase 2	R5	San Bruno	GAP SIDELINE S	66.9	61.5
Phase 2	R6	S San Francisco	GAP CENTERLINE	65.0	59.9
Phase 3	R7	Brisbane	SSTIK BRISBANE	50.0	43.8
Phase 1	R8	Millbrae	DEPARTURE ROLL	64.5	56.6
Phase 3	R9	Millbrae	DEPARTURE ROLL	51.3	43.7
Phase 3	R10	Burlingame	DEPARTURE ROLL	51.3	41.0
Phase 3	R11	Burlingame	DEPARTURE ROLL	51.4	40.2
Phase 1	R12	Foster City	APPROACH 28	62.6	59.9
Phase 3	R13	Hillsborough	DISTANT SITES	39.4	34.2
Phase 2	R14	S San Francisco	GAP SIDELINE	60.5	55.2
Phase 1	R15	S San Francisco (Oyster)	SSTIK BRISBANE	58.2	53.8
Phase 2	R16	S San Francisco	GAP SIDELINE S	59.5	54.0
Phase 2	R17	S San Francisco	GAP SIDELINE N	59.4	53.7
Phase 1	R18	Daly City	GAP CENTERLINE	63.7	58.8
Phase 1	R19	Pacifica	GAP SIDELINE S	61.1	55.3
Phase 3	R20	Daly City	DISTANT SITES	47.4	46.9
Phase 3	R21	SF (Glen Park)	DISTANT SITES	39.5	43.1
Phase 3	R22	San Bruno	GAP SIDELINE S	61.1	51.8
Phase 3	R23	SF (Visitacion Valley)	SSTIK BRISBANE	52.9	52.6
Phase 3	R24	SF (Excelsior)	DISTANT SITES	42.3	39.9
Phase 3	R25	SF (Balboa Terrace)	DISTANT SITES	41.9	35.8
Phase 3	R26	SF (Forest Hill)	DISTANT SITES	37.9	32.6
Phase 3	R27	SF(Pacific Heights)	DISTANT SITES	35.0	29.8
Phase 3	R28	Redwood City	DISTANT SITES	38.6	
Phase 3	R29	San Mateo	DISTANT SITES	52.1	47.3

Source: BridgeNet International 2021

Figure A-2 Part A
Sample Time History Plot (Site 2 – San Bruno)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current	(blue)	65
Proposed Day	(yellow)	63
Proposed Night	(orange)	60



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-2 Part B

Supporting Measured Analytical Data (Site 2 - San Bruno)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	59	60	61	62	63	64	65	66	67
2	Number of events	4956	5059	4843	3480	2059	1099	678	454	333
2	Duration 120 sec	2025	1170	399	100	14	2	0	0	0
2	Correlated events	1439	1394	1315	1075	821	620	485	359	277
2	CNEL	56.5	55.9	55.2	54.4	53.6	52.9	52.2	51.4	50.4
2	Model CNEL	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	
2	Uncorrelated dB	1.24	1.21	1.16	1.21	1.37	1.66	2.14	2.77	3.71

Measured Single Event Noise Levels

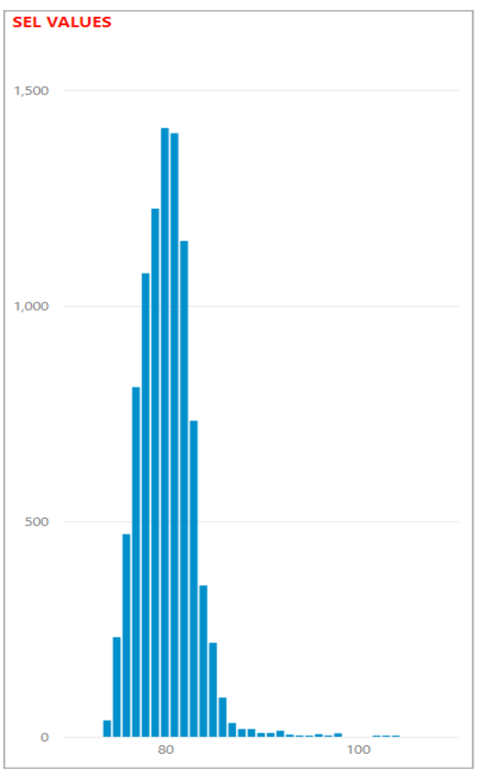
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

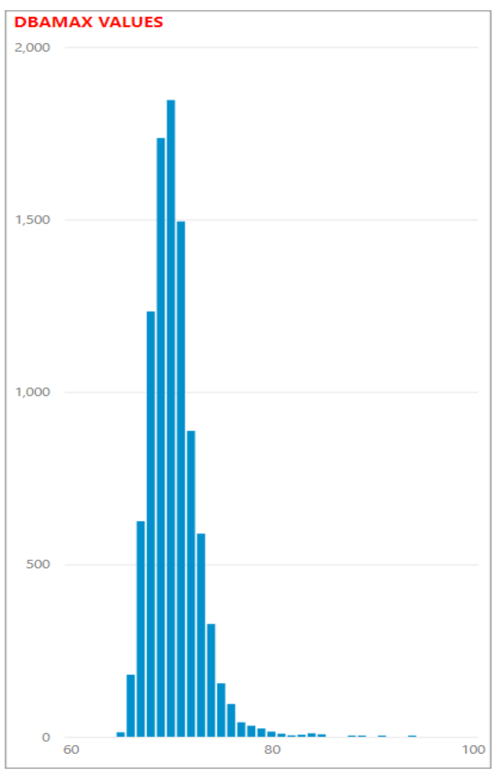
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	5,607	70.9	81.0	81.9	
Narrow	2,165	69.9	79.4	81.4	
Wide	1,267	70.6	80.4	82.2	
Regional	198	72.9	81.6	85.3	
Business	98	72.1	80.8	84.0	
Total	**9,335**	**70.7**	**80.6**	**82.0**	**82.0**

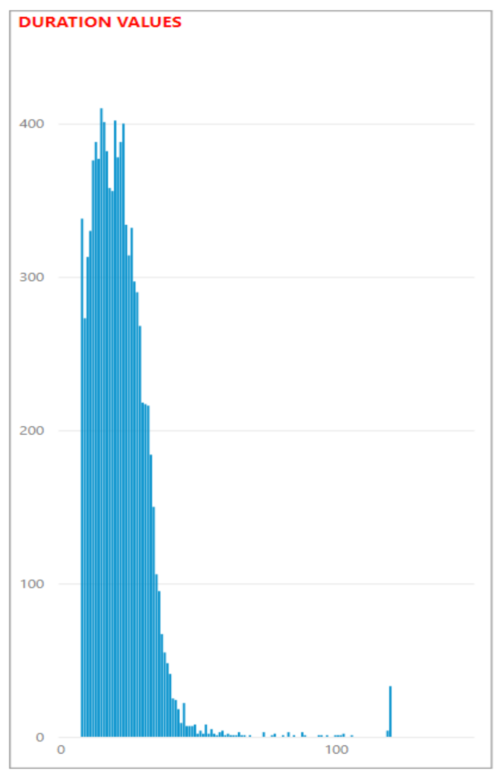
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
2	All Hours	Average	53	53	52
	Day only	Average	55	55	54
	Night Only	Average	49	48	47
	All Hours	Std Dev	4.9	4.2	4.5
	Day only	Std Dev	3.5	3.6	3.9
	Night Only	Std Dev	4.7	4.9	5.3
	All Hours	2x Std Dev	63	67	66
	Day only	2x Std Dev	62	62	62
	Night Only	2x Std Dev	59	58	57
			2019	2020	2021
	All Hours	Average L50	56	53	54
	All Hours	Average L90	55	52	53







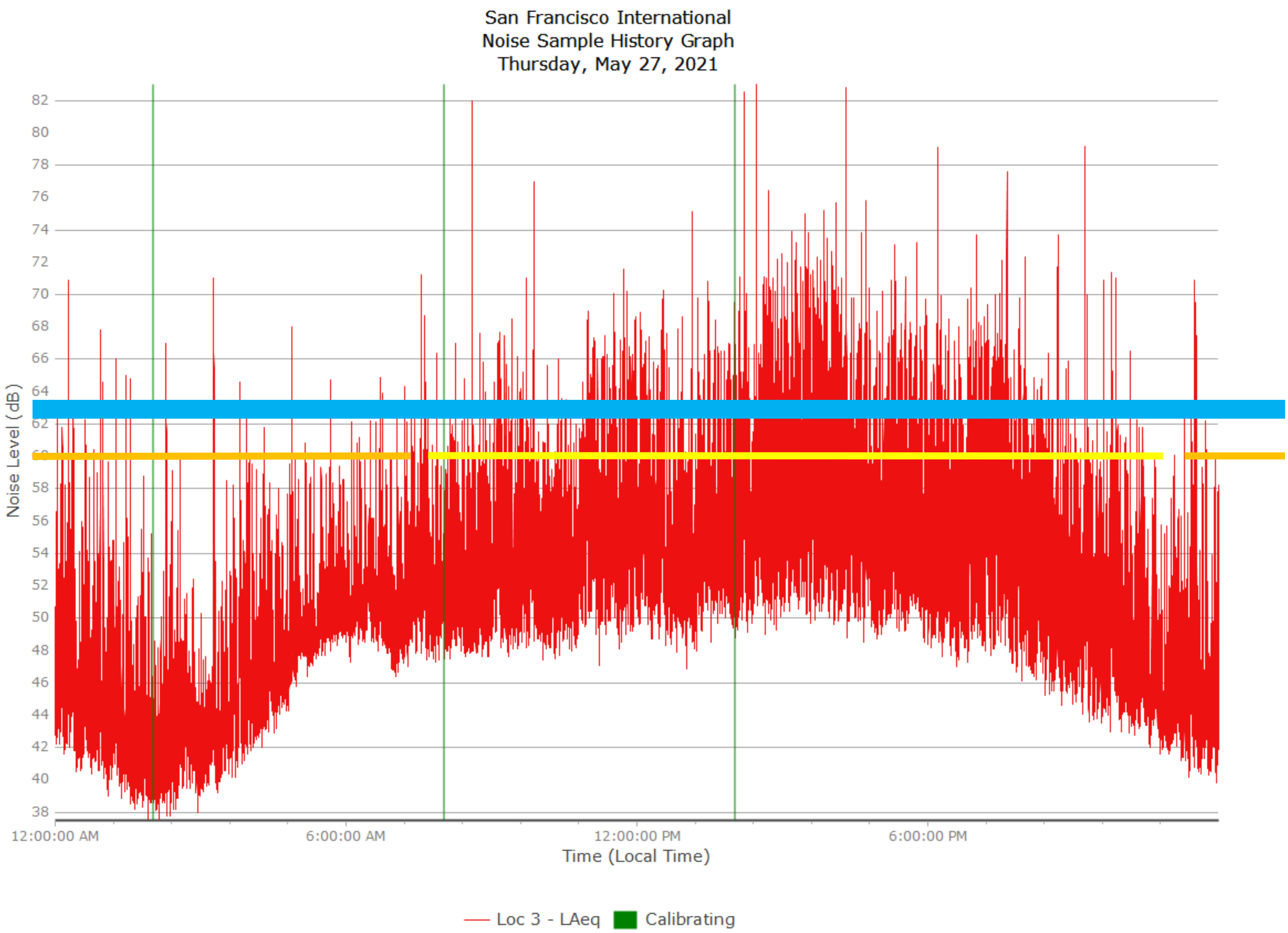
Source: BridgeNet International 2021

Figure A-3 Part A

Sample Time History Plot (Site 3 – South San Francisco)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current		63
Proposed Day		61
Proposed Night		61



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-3 Part B
Supporting Measured Analytical Data (Site 3 - South San Francisco)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

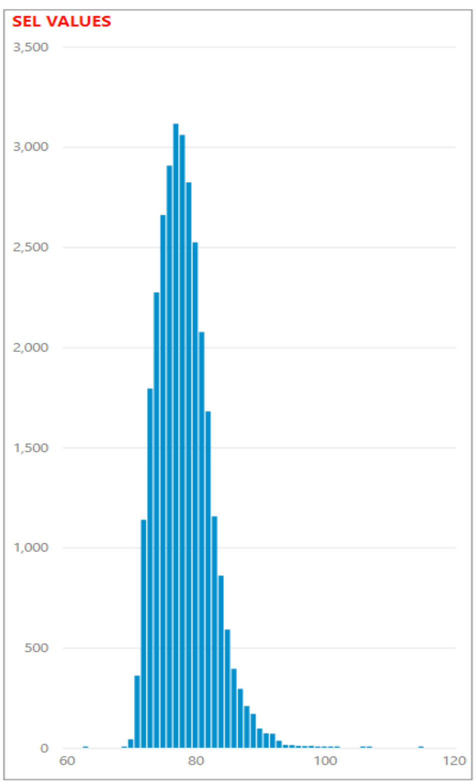
Monitor	Metric	57	58	59	60	61	62	63	64	65
3	Number of events	9380	8317	7036	5487	3946	2644	1684	985	593
3	Duration 120 sec	2751	1872	1142	566	255	92	19	4	3
3	Correlated events	3293	3050	2716	2282	1825	1403	1000	647	401
3	CNEL	59	58.7	58.1	57.3	56.4	55.4	54.1	53	52
3	Model CNEL	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	
3	Uncorrelated dB	1.44	1.36	1.44	1.51	1.84	2.34	2.93	3.77	4.79

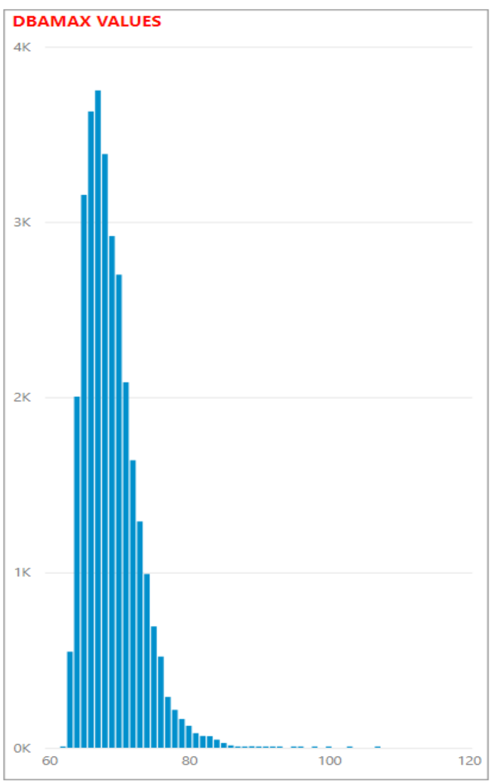
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	14,559	69.4	78.9	81.9	
Long Haul	9,513	68.3	77.9	80.7	
Wide	2,425	70.6	79.6	83.0	
Regional	2,312	69.9	78.4	80.9	
Business	1,644	70.8	79.4	81.6	
Total	**30,453**	**69.3**	**78.6**	**81.6**	**81.6**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
3	All Hours	Average	49	48	47
	Day only	Average	50	49	48
	Night Only	Average	47	46	45
	All Hours	Std Dev	5.4	5.4	5.4
	Day only	Std Dev	4.3	4.4	4.5
	Night Only	Std Dev	6.5	6.5	6.5
	All Hours	2x Std Dev	60	59	58
	Day only	2x Std Dev	59	58	57
	Night Only	2x Std Dev	60	59	58
			2019	**2020**	**2021**
	All Hours	Average L50	50	48	48
	All Hours	Average L90	50	47	48





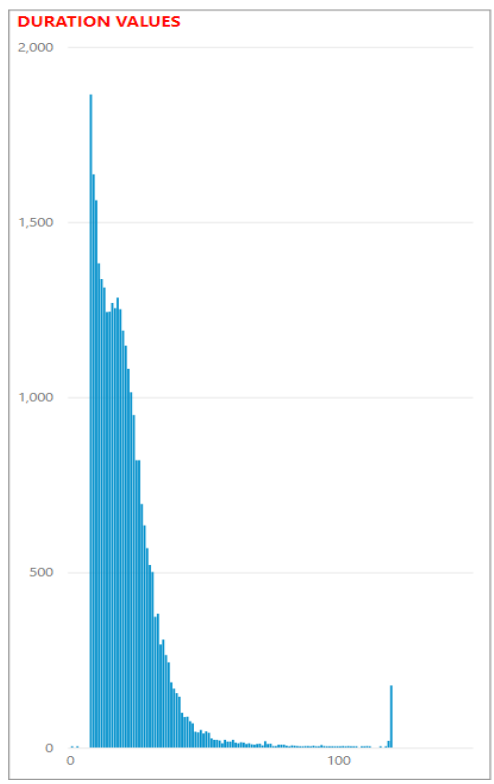
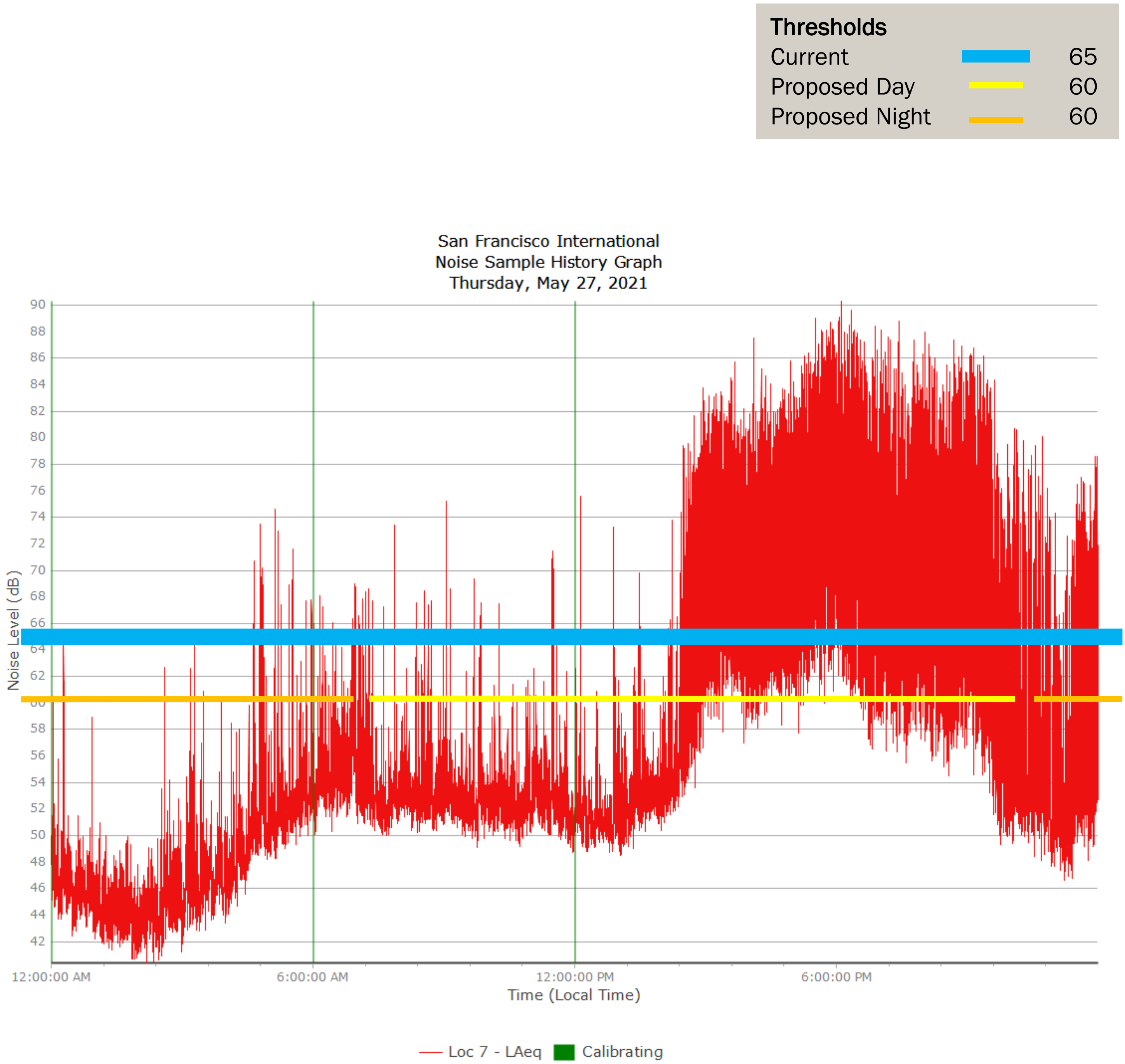


Figure A-4 Part A

Sample Time History Plot (Site 7 - Brisbane)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)



Note anormal date with night noise activity.

Time History Plot from ANOMS that auto scales the vertical range

Figure A-4 Part B
Supporting Measured Analytical Data (Site 7 - Brisbane)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	59	60	61	62	63	64	65	66	67
7	Number of events	877	701	567	451	388	330	282	233	190
7	Duration 120 sec	0	0	0	0	0	0	0	0	0
7	Correlated events	732	615	519	422	365	311	267	224	184
7	CNEL	52	51.8	51.6	51.3	51.1	50.8	50.5	50.1	49.8
7	Model CNEL	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	
7	Uncorrelated dB	1.17	1.42	1.65	2	2.22	2.51	2.87	3.26	3.87

Measured Single Event Noise Levels

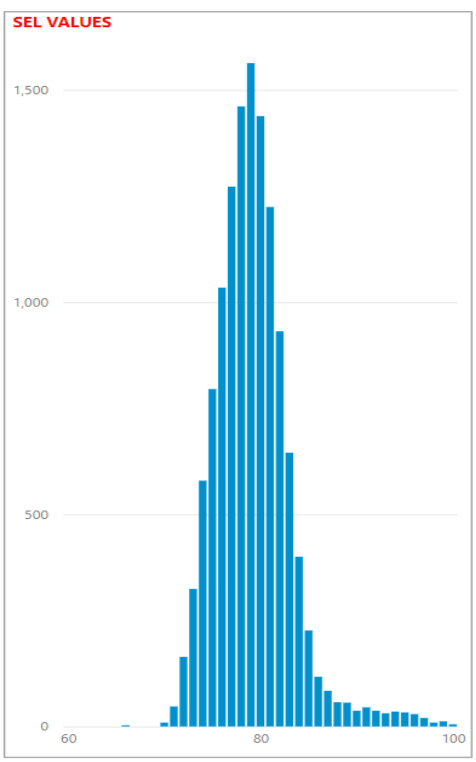
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

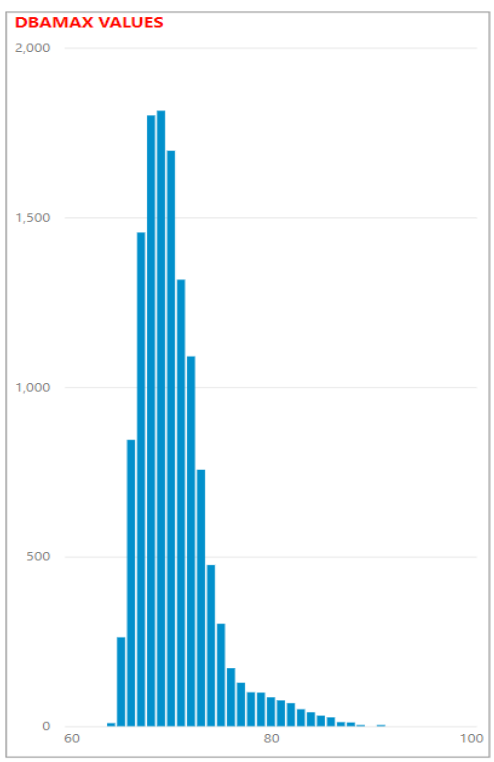
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Business	218	73.3	81.4	87.3	
Long Haul	263	73.8	83.1	86.2	
Regional	1,625	71.7	79.9	85.3	
Wide	624	72.7	81.3	83.7	
Narrow	9,990	70.3	79.4	81.5	
Total	**12,720**	**70.7**	**79.7**	**82.7**	**82.7**

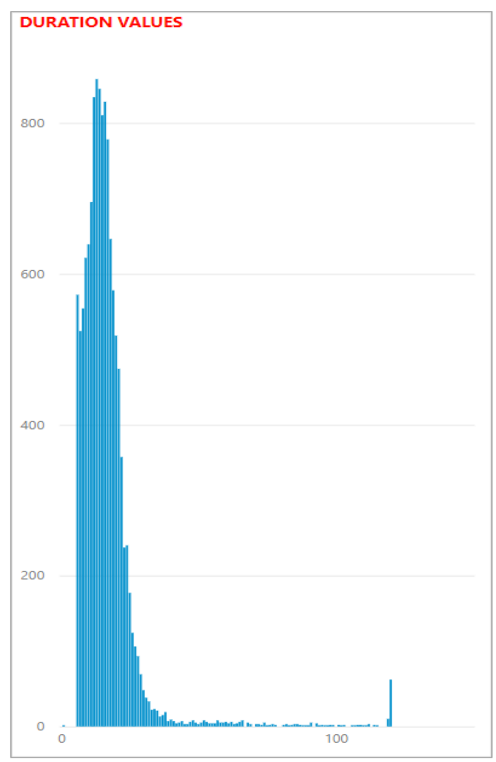
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
7	All Hours	Average	48	48	47
	Day only	Average	49	49	48
	Night Only	Average	46	45	44
	All Hours	Std Dev	3.7	3.7	3.8
	Day only	Std Dev	3.1	3.1	3.1
	Night Only	Std Dev	3.8	3.8	3.9
	All Hours	2x Std Dev	55	55	54
	Day only	2x Std Dev	55	55	54
	Night Only	2x Std Dev	54	53	52
			2019	**2020**	**2021**
	All Hours	Average L50	49	47	48
	All Hours	Average L90	48	47	48







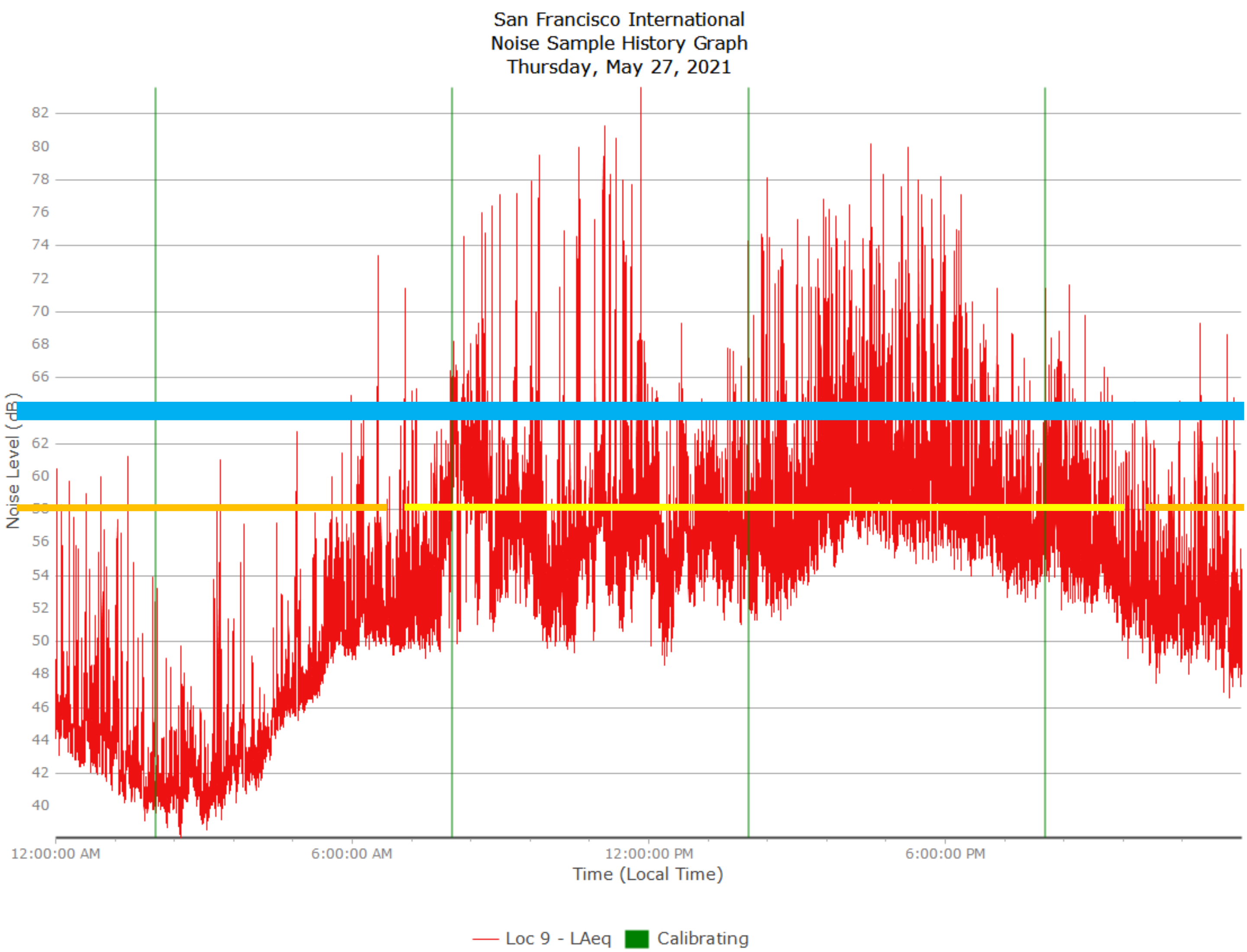
Source: BridgeNet International 2021

Figure A-5 Part A

Sample Time History Plot (Site 9 - Millbrae)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds	
Current	64
Proposed Day	58
Proposed Night	58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-5 Part B
Supporting Measured Analytical Data (Site 9 - Millbrae)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

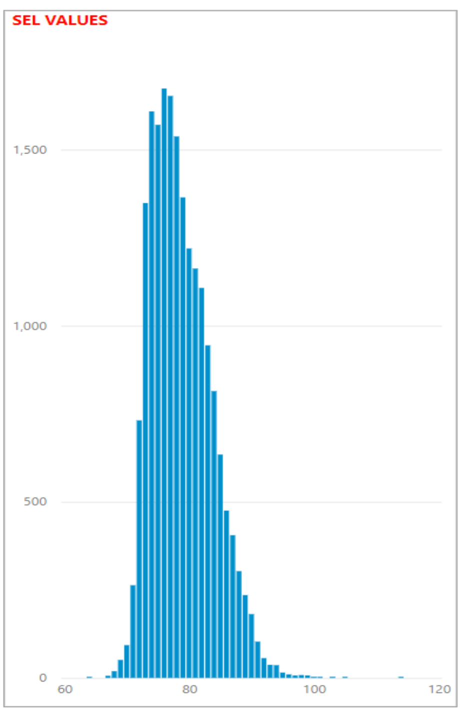
Monitor	Metric	58	59	60	61	62	63	64	65	66
9	Number of events	3711	2469	1662	1156	777	525	367	256	189
9	Duration 120 sec	37	13	8	5	3	2	1	0	0
9	Correlated events	1773	1201	842	582	378	265	192	129	90
9	CNEL	51.8	50.9	50.2	49.2	48.4	47.8	47.1	46.2	45.4
9	Model CNEL	61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	
9	Uncorrelated dB	7.47	8.6	9.75	10.83	12.26	13.27	14.13	15.36	16.66

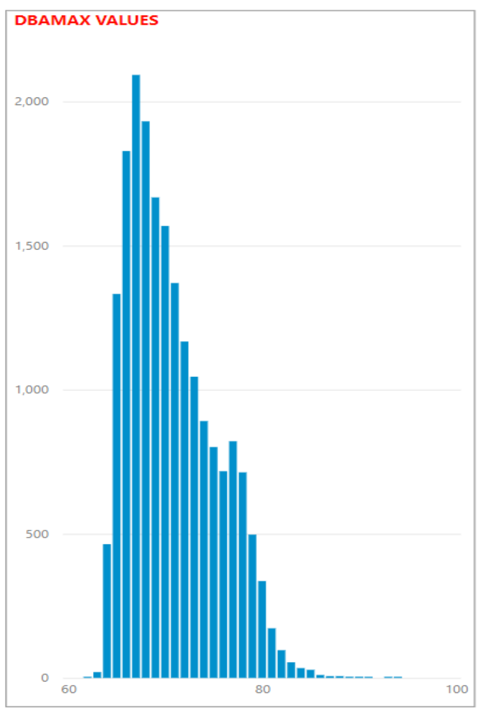
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

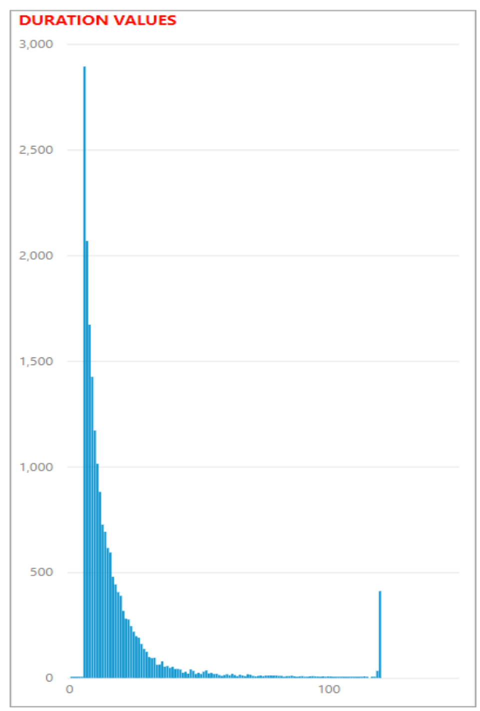
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	11,919	71.0	79.1	82.4	
Regional	4,526	71.6	79.5	84.0	
Long Haul	1,350	70.8	78.7	82.1	
Wide	1,062	71.6	79.6	82.9	
Business	824	71.4	79.3	82.7	
Total	**19,681**	**71.2**	**79.2**	**82.9**	**82.9**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
9	All Hours	Average	47	46	45
	Day only	Average	48	48	46
	Night Only	Average	43	43	42
	All Hours	Std Dev	4.7	4.7	4.6
	Day only	Std Dev	3.6	3.6	3.6
	Night Only	Std Dev	4.9	4.9	4.9
	All Hours	2x Std Dev	56	55	54
	Day only	2x Std Dev	55	55	54
	Night Only	2x Std Dev	53	53	52
			2019	2020	2021
	All Hours	Average L50	48	46	46
	All Hours	Average L90	47	45	46



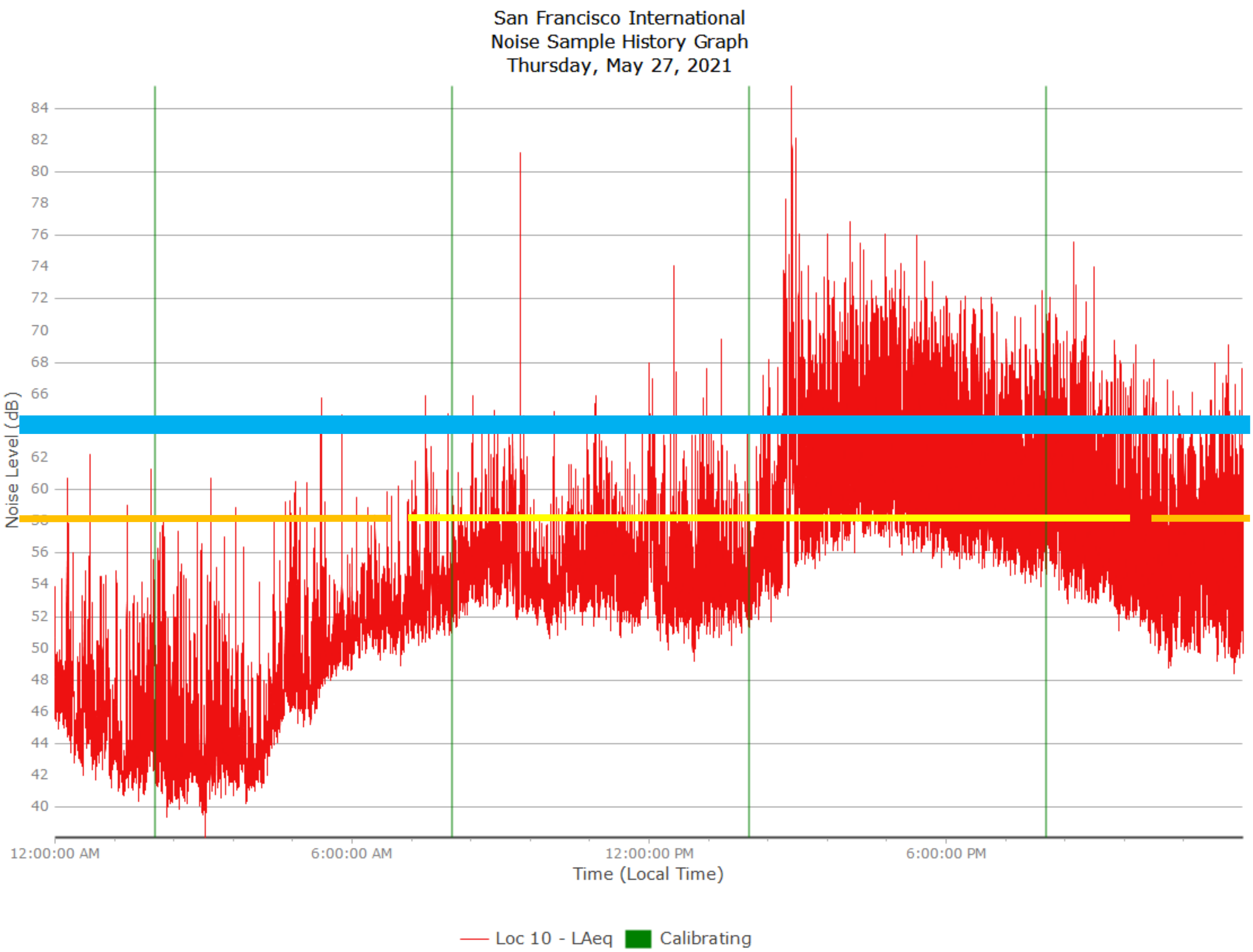




Source: BridgeNet International 2021

Figure A-6 Part A
Sample Time History Plot (Site 10 - Burlingame)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds	
Current	64
Proposed Day	58
Proposed Night	58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-6 Part B
Supporting Measured Analytical Data (Site 10 - Burlingame)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

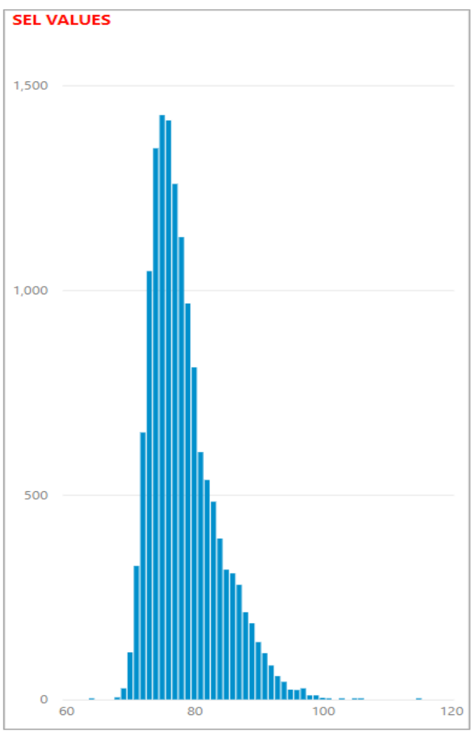
Monitor	Metric	58	59	60	61	62	63	64	65	66
10	Number of events	2001	1392	945	657	466	328	248	192	159
10	Duration 120 sec	31	22	19	17	12	11	7	6	2
10	Correlated events	688	486	344	236	166	104	79	60	50
10	CNEL	47.2	46.4	45.5	44.8	44.9	44	43.6	43.3	41.7
10	Model CNEL	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	
10	Uncorrelated dB	10.61	11.71	12.76	13.82	15.09	17.1	17.62	17.41	17.23

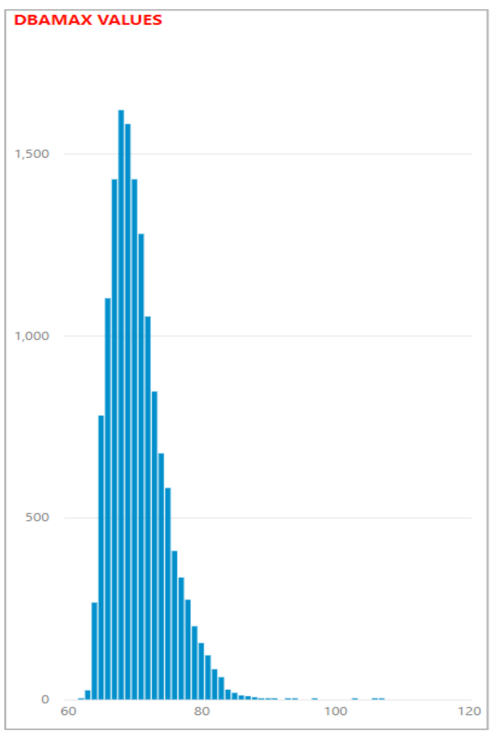
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	8,436	71.0	78.7	83.2	
Regional	3,296	70.9	78.7	82.8	
Long Haul	1,250	70.8	78.5	83.1	
Wide	916	71.4	79.3	87.9	
Business	488	70.7	78.4	82.9	
Total	**14,386**	**70.9**	**78.7**	**83.6**	**83.6**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
10	All Hours	Average	47	46	46
	Day only	Average	49	48	47
	Night Only	Average	43	43	42
	All Hours	Std Dev	4.6	4.6	4.5
	Day only	Std Dev	3.6	3.6	3.7
	Night Only	Std Dev	4.1	4.1	4.1
	All Hours	2x Std Dev	56	56	55
	Day only	2x Std Dev	56	56	55
	Night Only	2x Std Dev	52	51	50
			2019	2020	2021
	All Hours	Average L50	48	46	47
	All Hours	Average L90	48	45	46





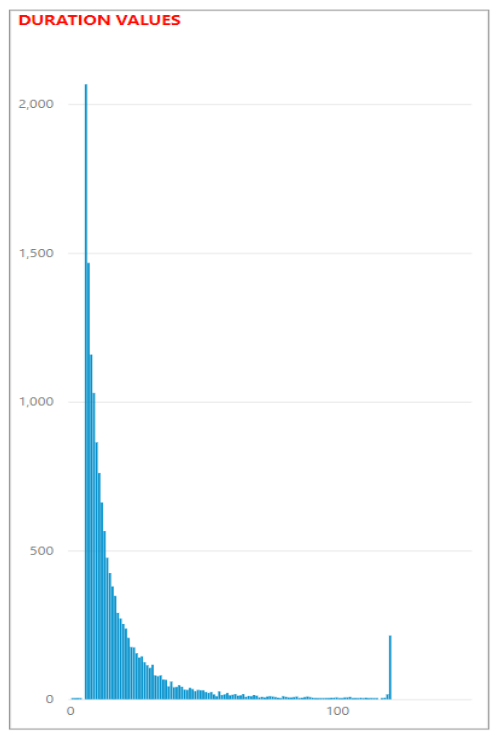
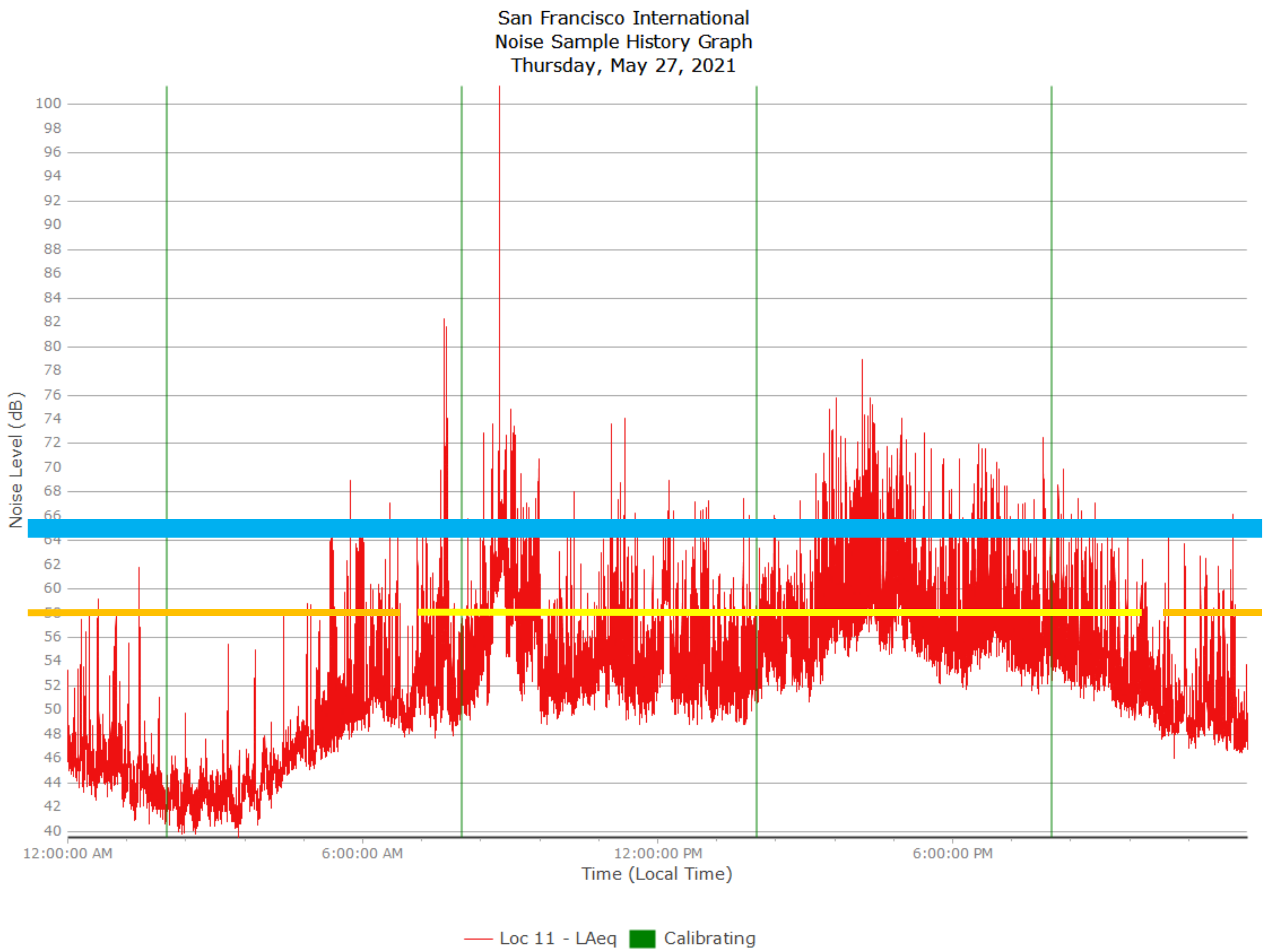


Figure A-7 Part A
Sample Time History Plot (Site 11 - Burlingame)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current		65
Proposed Day		58
Proposed Night		58



Time History Plot from ANOMS that auto scales the vertical range

Figure A-7 Part B
Supporting Measured Analytical Data (Site 11 - Burlingame)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

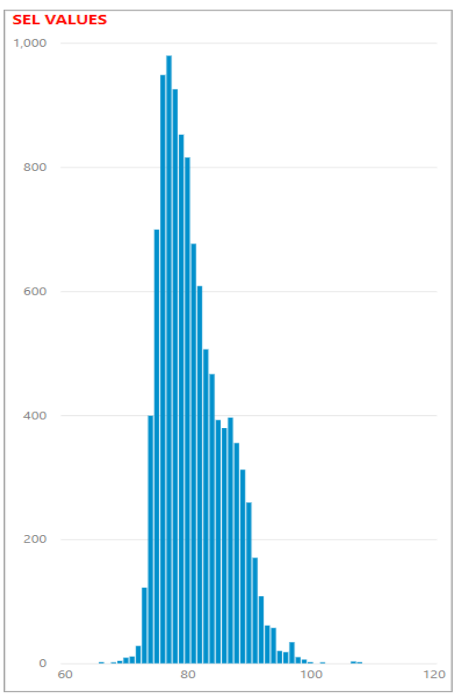
Data not available

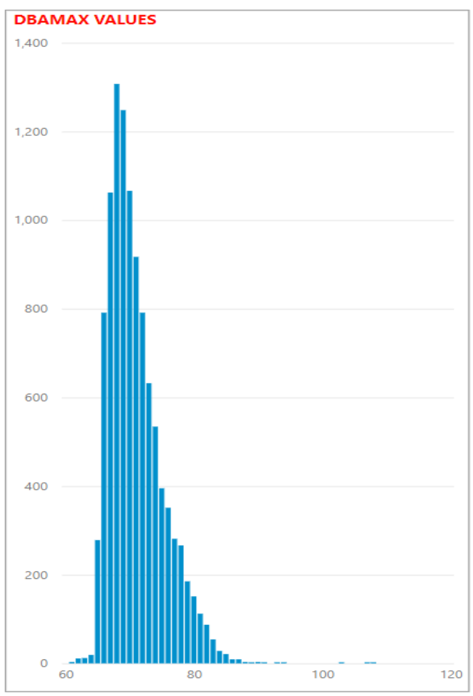
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

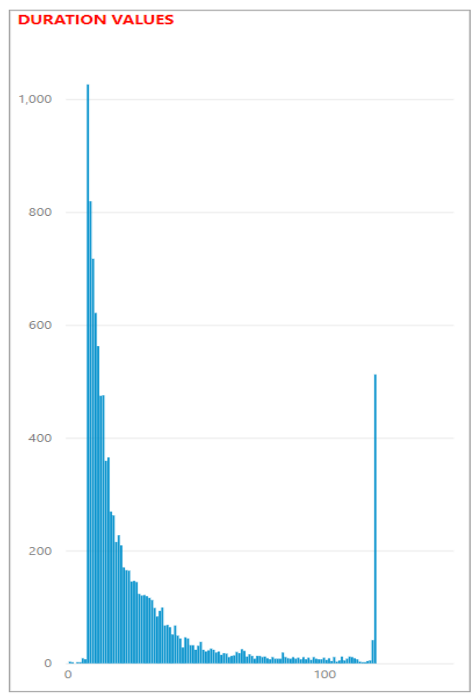
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	6,735	71.4	81.2	85.2	
Regional	2,298	71.6	82.0	85.9	
Long Haul	731	70.6	80.7	84.8	
Wide	453	71.4	81.7	85.3	
Business	418	72.0	82.7	86.8	
Total	**10,635**	**71.4**	**81.4**	**85.4**	**85.4**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
11	All Hours	Average	46	49	49
	Day only	Average	47	50	50
	Night Only	Average	44	47	46
	All Hours	Std Dev	4.5	4.2	4.2
	Day only	Std Dev	3.9	3.8	3.7
	Night Only	Std Dev	4.8	4.3	4.3
	All Hours	2x Std Dev	54	58	57
	Day only	2x Std Dev	54	58	57
	Night Only	2x Std Dev	53	56	55
			2019	**2020**	**2021**
	All Hours	Average L50	47	49	50
	All Hours	Average L90	47	49	50







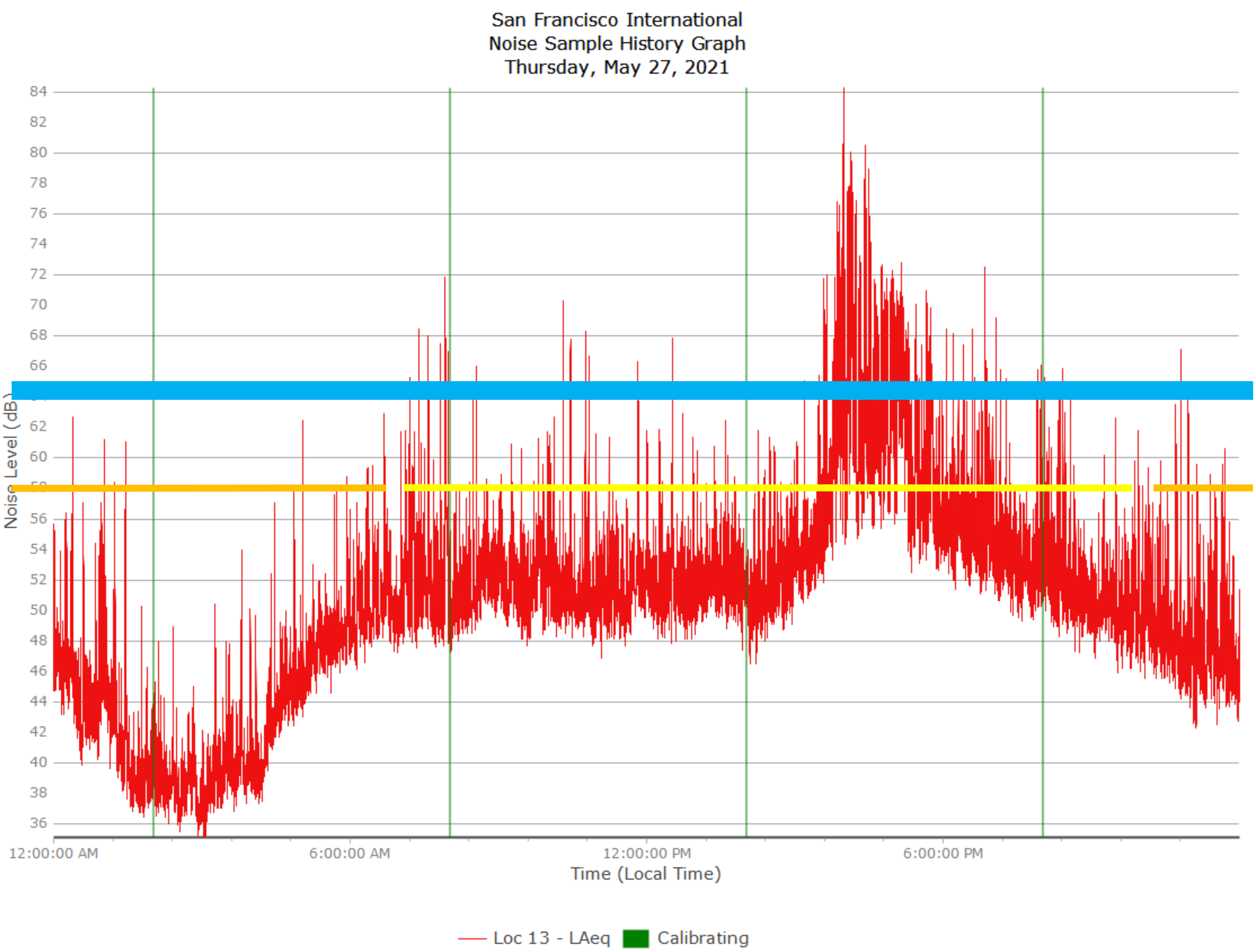
Source: BridgeNet International 2021

Figure A-8 Part A

Sample Time History Plot (Site 13 - Hillsborough)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds	
Current	64
Proposed Day	58
Proposed Night	58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-8 Part B
Supporting Measured Analytical Data (Site 13 - Hillsborough)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	58	59	60	61	62	63	64	65	66
13	Number of events	887	636	455	344	258	200	154	129	89
13	Duration 120 sec	31	27	22	16	14	12	9	8	6
13	Correlated events	127	99	66	52	37	30	23	20	13
13	CNEL	39.6	39.1	38.4	38.2	38.2	37.9	36.7	36.4	35.8
13	Model CNEL	42	42	42	42	42	42	42	42	
13	Uncorrelated dB	6.93	8.27	9.03	9.44	9.44	9.96	10.08	10.16	9.43

Measured Single Event Noise Levels

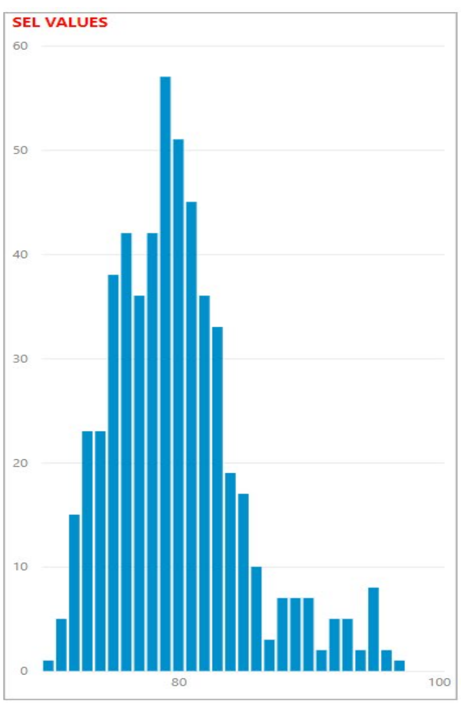
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

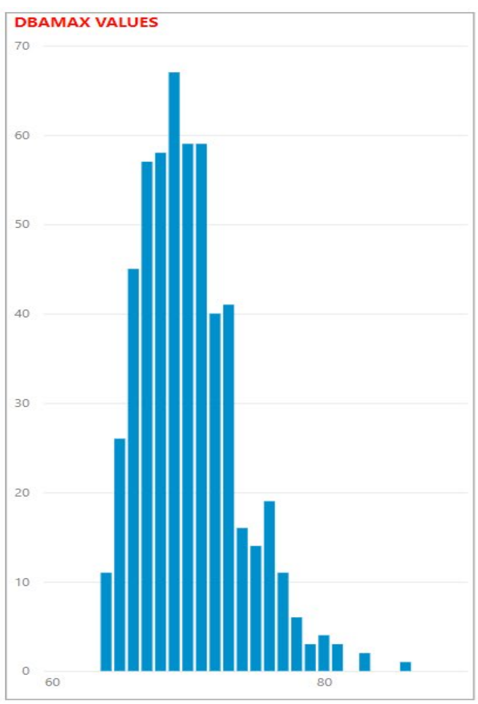
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	11,497	68.4	77.6	80.8	
Regional	2,899	69.8	78.4	81.8	
Wide	688	70.2	79.7	81.5	
Long Haul	224	70.4	79.6	82.1	
Business	121	71.7	79.9	82.6	
Total	**15,429**	**68.8**	**77.9**	**81.1**	**81.1**

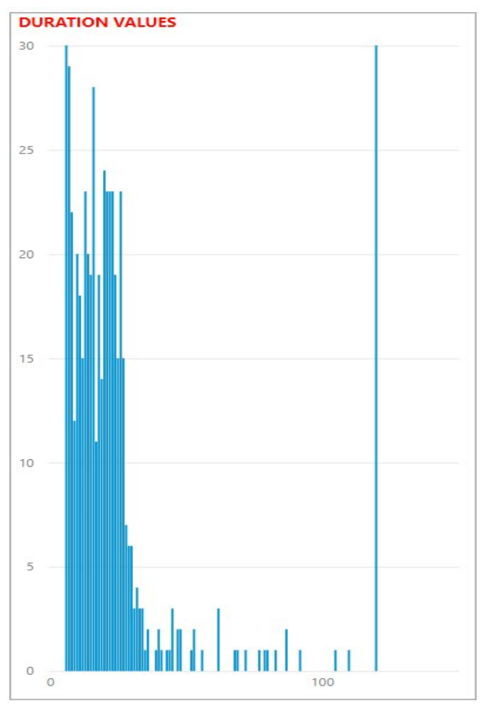
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
13	All Hours	Average	45	45	44
	Day only	Average	46	46	45
	Night Only	Average	43	43	42
	All Hours	Std Dev	4.8	4.8	4.8
	Day only	Std Dev	4.4	4.5	4.5
	Night Only	Std Dev	4.8	4.8	5.0
	All Hours	2x Std Dev	55	54	54
	Day only	2x Std Dev	55	54	54
	Night Only	2x Std Dev	53	52	52
			2019	2020	2021
	All Hours	Average L50	47	44	45
	All Hours	Average L90	46	43	45







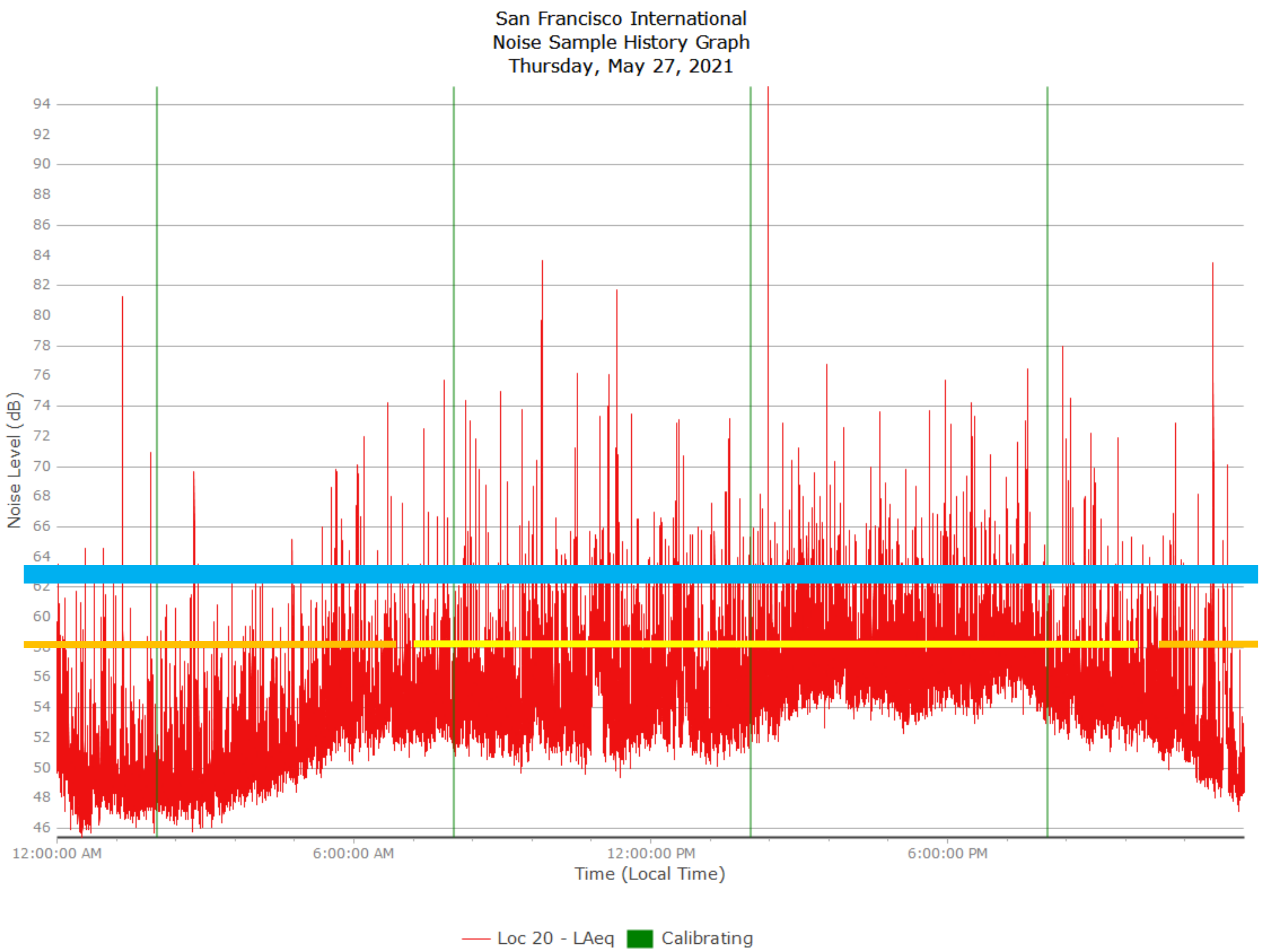
Source: BridgeNet International 2021

Figure A-9 Part A

Sample Time History Plot (Site 20 – Daly City)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current		63
Proposed Day		58
Proposed Night		58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-9 Part B
Supporting Measured Analytical Data (Site 20 – Daly City)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

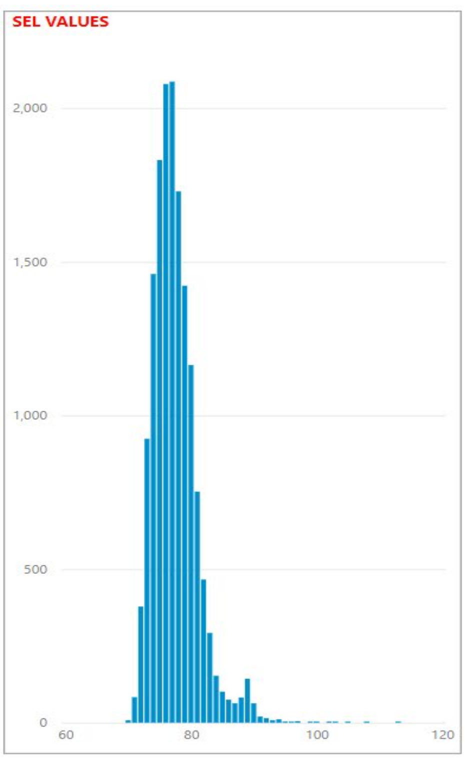
Monitor	Metric	57	58	59	60	61	62	63	64	65
20	Number of events	4743	3756	3016	2450	2015	1659	1337	1037	754
20	Duration 120 sec	16	4	1	0	0	0	0	0	0
20	Correlated events	1793	1595	1384	1181	984	793	620	454	310
20	CNEL	52.9	52.6	52.3	51.9	51.4	50.9	50.2	49.5	48.6
20	Model CNEL	52.2	52.2	52.2	52.2	52.2	52.2	52.2	52.2	
20	Uncorrelated dB	0.89	0.99	1.17	1.45	1.85	2.31	2.95	3.84	5

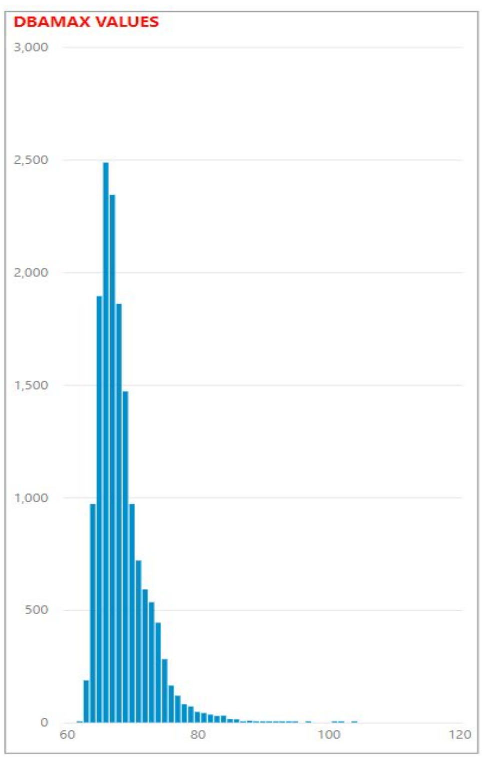
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	11,497	68.4	77.6	80.8	
Regional	2,899	69.8	78.4	81.8	
Wide	688	70.2	79.7	81.5	
Long Haul	224	70.4	79.6	82.1	
Business	121	71.7	79.9	82.6	
Total	**15,429**	**68.8**	**77.9**	**81.1**	**81.1**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
20	All Hours	Average	47	47	46
	Day only	Average	49	48	47
	Night Only	Average	44	44	43
	All Hours	Std Dev	4.3	4.3	4.4
	Day only	Std Dev	3.7	3.8	3.9
	Night Only	Std Dev	3.9	4.0	4.0
	All Hours	2x Std Dev	56	55	55
	Day only	2x Std Dev	56	56	55
	Night Only	2x Std Dev	52	52	51
			2019	**2020**	**2021**
	All Hours	Average L50	48	47	48
	All Hours	Average L90	47	46	47





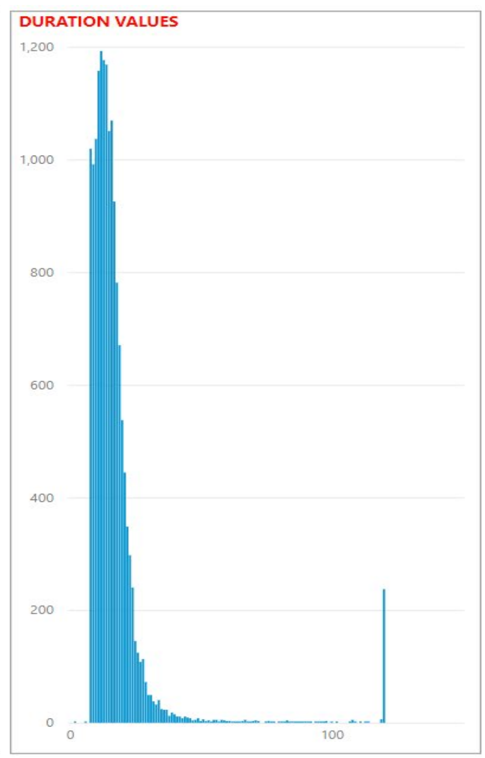
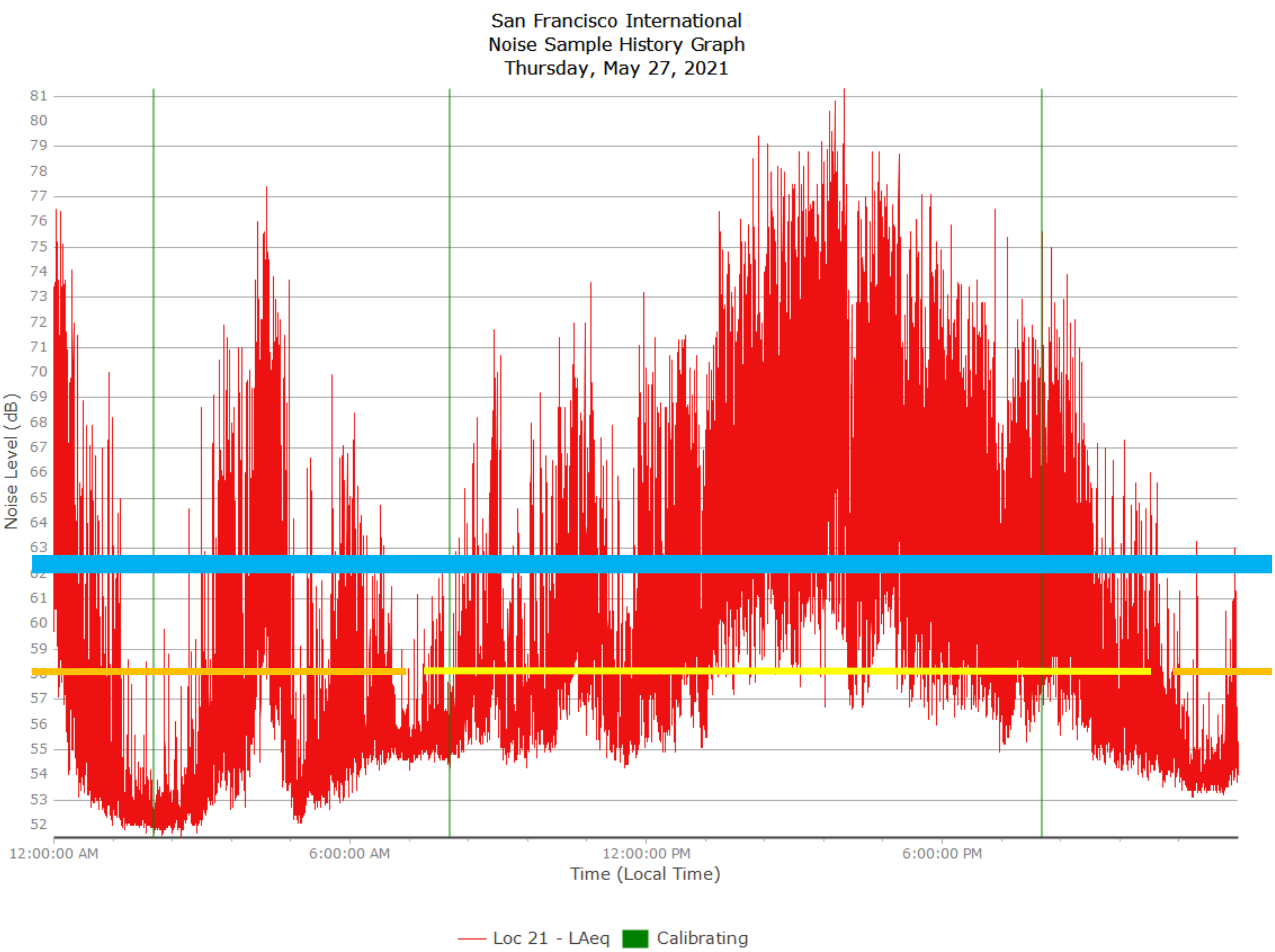


Figure A-10 Part A

Sample Time History Plot (Site 21 – San Francisco Glen Park)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current	(blue)	62
Proposed Day	(yellow)	58
Proposed Night	(orange)	58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-10 Part B
Supporting Measured Analytical Data (Site 21 – San Francisco Glen Park)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

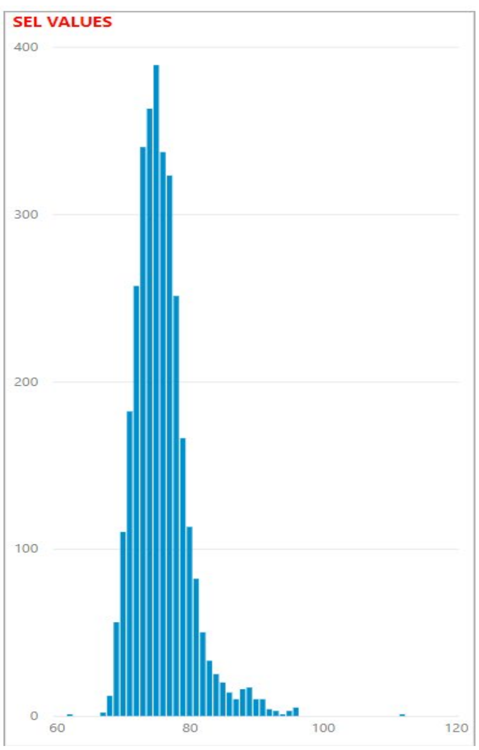
Monitor	Metric	56	57	58	59	60	61	62	63	64
21	Number of events	2437	1763	1338	1000	799	614	475	370	291
21	Duration 120 sec	80	57	34	25	19	13	10	5	4
21	Correlated events	904	729	557	420	302	216	143	97	71
21	CNEL	44.7	44	43.2	42.4	41.5	40.5	39.2	38	36.8
21	Model CNEL	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	
21	Uncorrelated dB	1.28	1.55	1.96	2.43	3.12	3.87	4.49	5.37	6.15

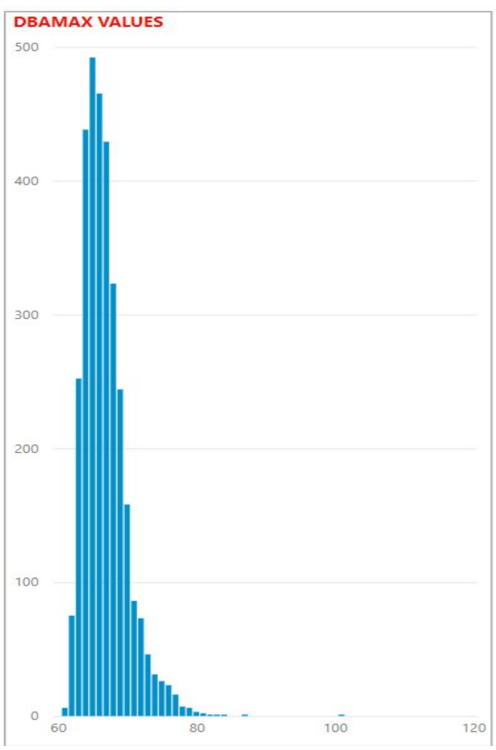
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

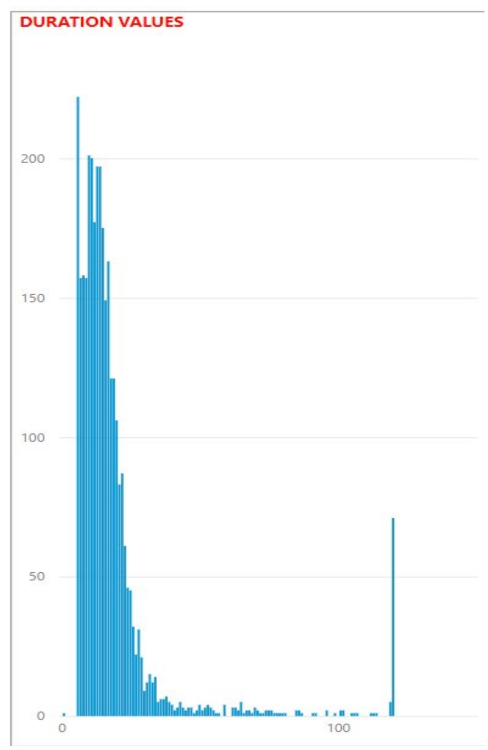
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	1,894	66.7	75.6	78.2	
Regional	684	68.0	76.9	86.2	
Wide	449	67.8	77.5	78.8	
Long Haul	145	67.4	76.6	79.1	
Business	34	68.8	76.9	79.2	
Total	**3,206**	**67.2**	**76.2**	**81.6**	**81.6**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
21	All Hours	Average	50	50	49
	Day only	Average	51	50	50
	Night Only	Average	48	48	47
	All Hours	Std Dev	3.5	3.4	3.3
	Day only	Std Dev	3.1	3.0	3.0
	Night Only	Std Dev	3.4	3.4	3.3
	All Hours	2x Std Dev	57	56	56
	Day only	2x Std Dev	57	56	56
	Night Only	2x Std Dev	55	55	54
			2019	**2020**	**2021**
	All Hours	Average L50	49	49	54
	All Hours	Average L90	49	48	54



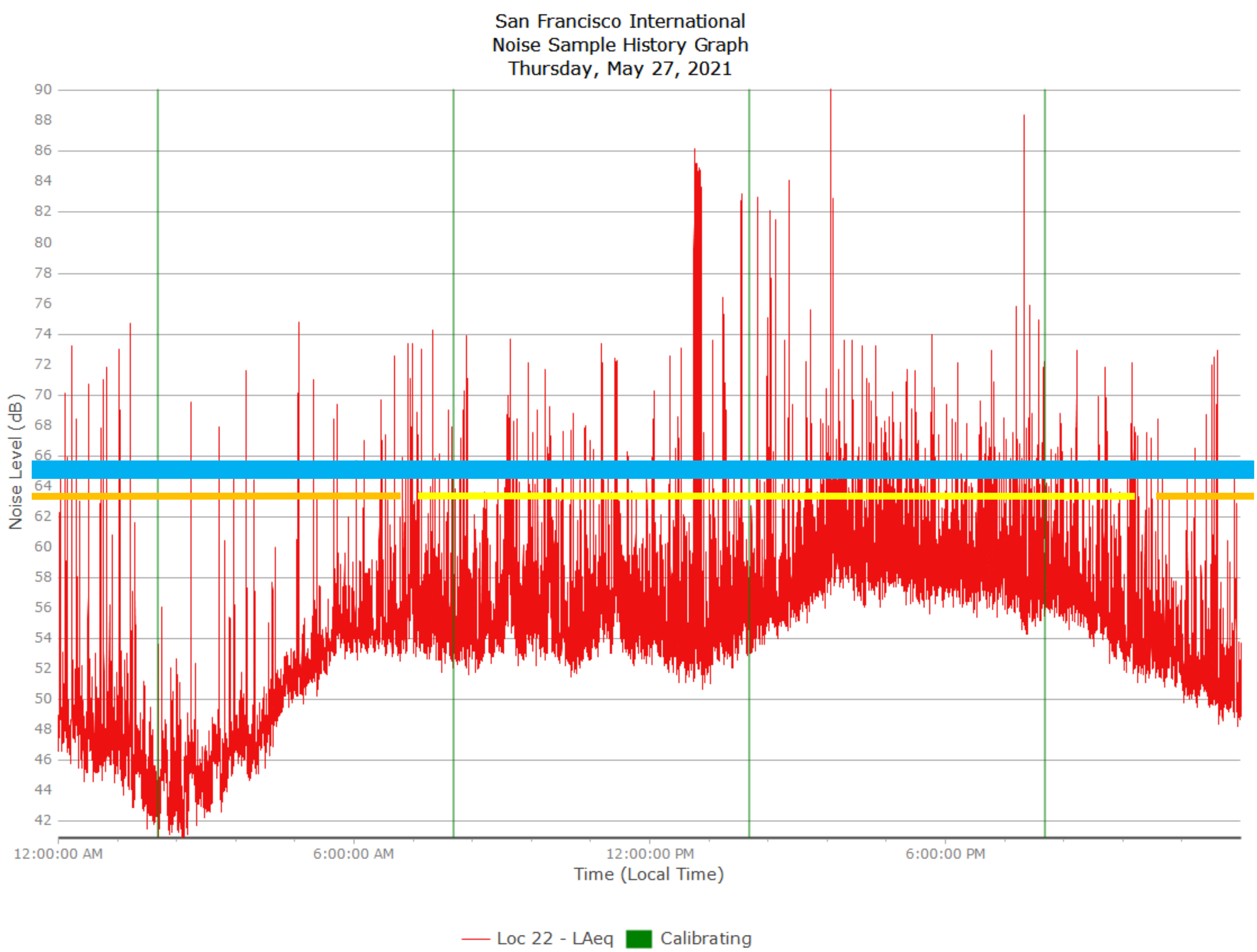




Source: BridgeNet International 2021

Figure A-11 Part A
Sample Time History Plot (Site 22 – San Bruno)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current	(blue)	65
Proposed Day	(yellow)	63
Proposed Night	(orange)	63



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-11 Part B
Supporting Measured Analytical Data (Site 22 – San Bruno)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	59	60	61	62	63	64	65	66	67
22	Number of events	9303	8075	6928	5930	4949	3866	3028	2243	1489
22	Duration 120 sec	2622	1939	1399	949	562	305	103	18	1
22	Correlated events	6305	5556	4812	4180	3538	2900	2306	1729	1196
22	CNEL	64.8	64.5	64.1	63.5	62.8	61.8	60.6	59.3	57.9
22	Model CNEL	65.2	65.2	65.2	65.2	65.2	65.2	65.2	65.2	
22	Uncorrelated dB	4.25	4.61	4.89	5.16	5.56	5.87	6.34	7.06	8.11

Measured Single Event Noise Levels

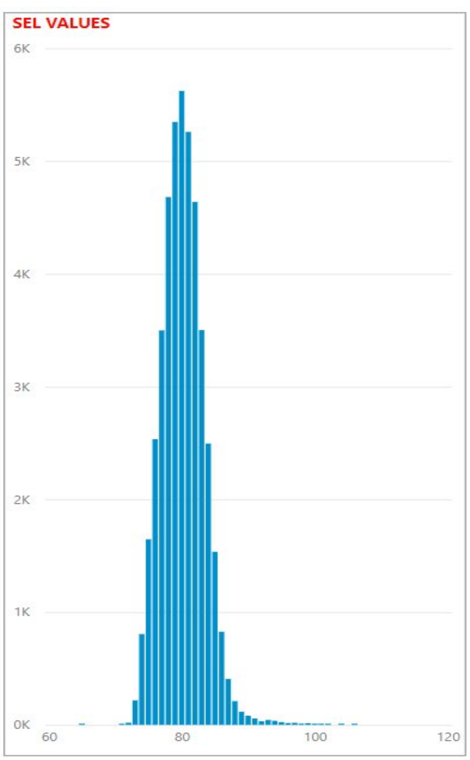
Dept 28L/R Jan 1st, 2019 – Nov 6th, 2021

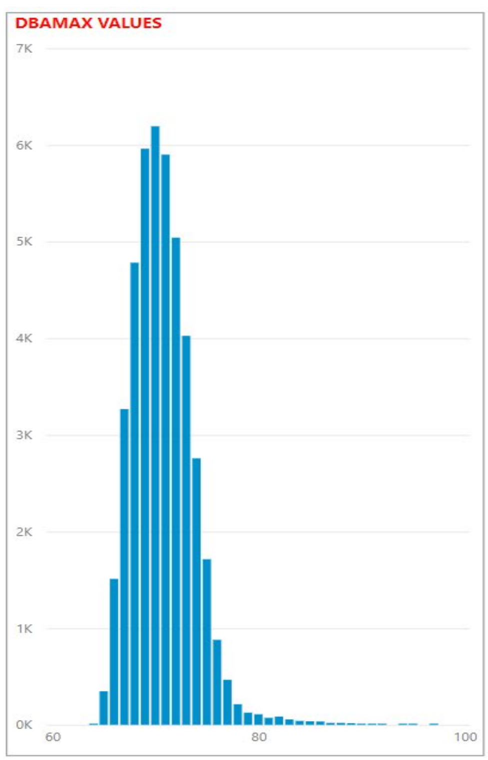
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	20,879	71.9	81.5	82.6	
Narrow	14,323	70.5	79.6	81.2	
Wide	5,791	71.1	80.6	82.8	
Regional	1,771	69.8	78.7	81.3	
Business	924	70.9	80.2	84.8	
Total	**43,688**	**71.2**	**80.6**	**82.2**	**82.2**

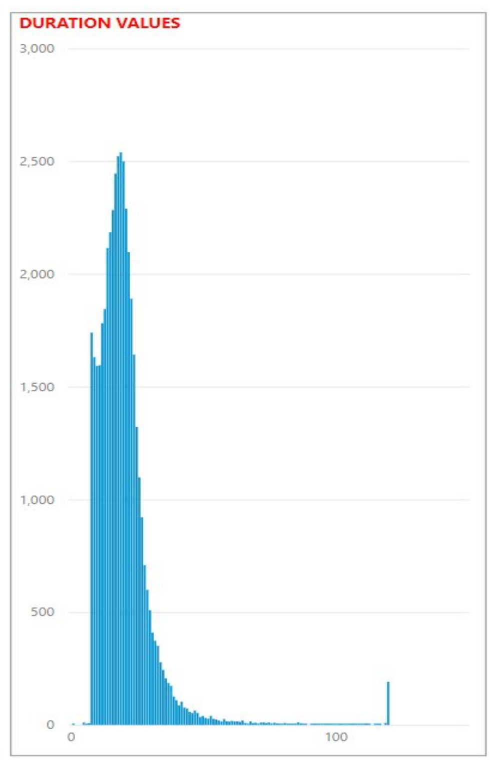
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
22	All Hours	Average	50	50	49
	Day only	Average	53	53	52
	Night Only	Average	51	50	49
	All Hours	Std Dev	4.5	4.6	4.7
	Day only	Std Dev	3.7	3.7	3.7
	Night Only	Std Dev	5.6	5.6	5.7
	All Hours	2x Std Dev	62	61	60
	Day only	2x Std Dev	61	60	60
	Night Only	2x Std Dev	62	61	61
			2019	2020	2021
	All Hours	Average L50	54	51	52
	All Hours	Average L90	54	51	51







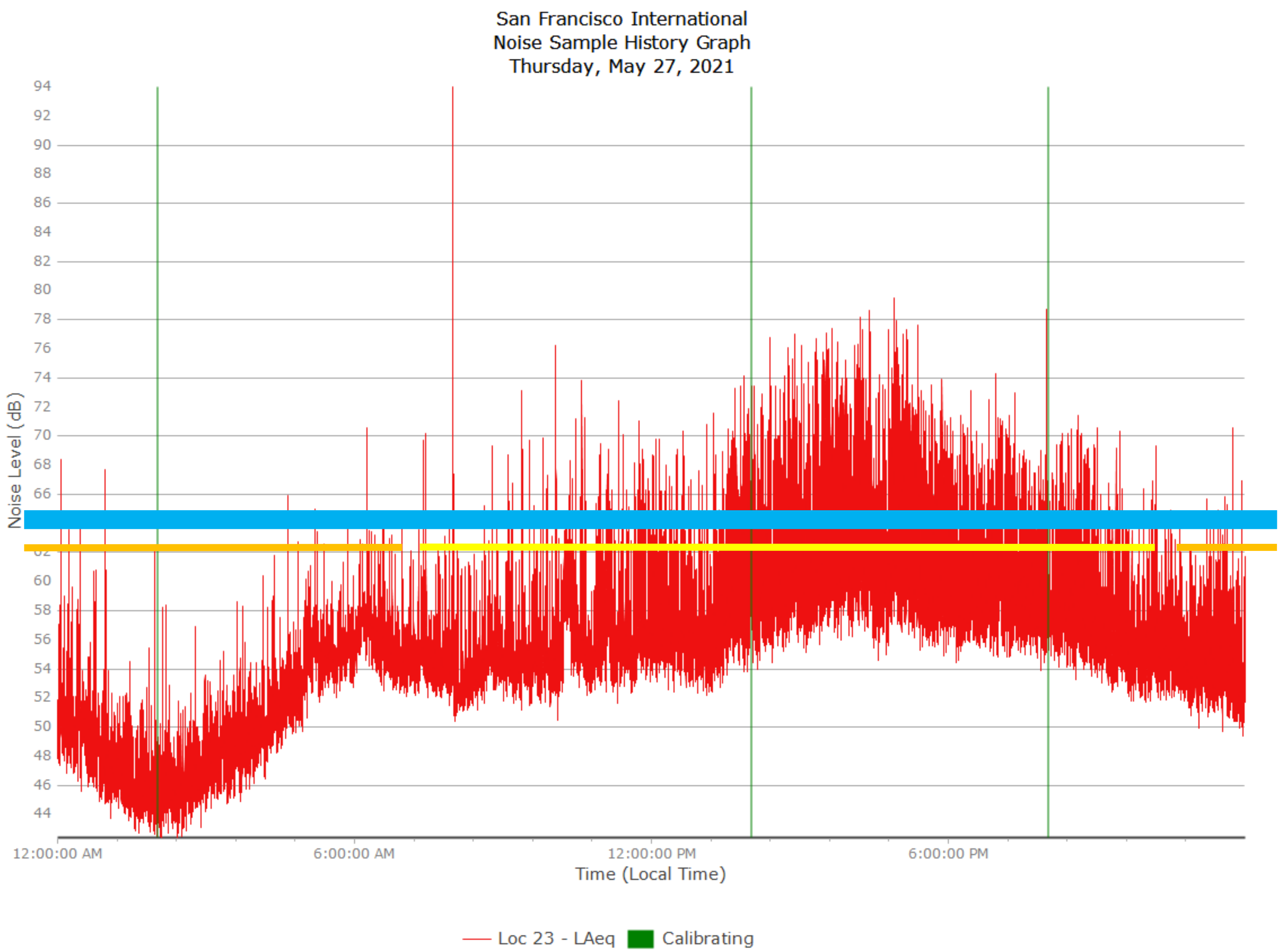
Source: BridgeNet International 2021

Figure A-12 Part A

Sample Time History Plot (Site 23 – San Francisco – Visitacion Valley)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current	(blue)	64
Proposed Day	(yellow)	62
Proposed Night	(orange)	62



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-12 Part B
Supporting Measured Analytical Data (Site 23 – San Francisco – Visitacion Valley)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	58	59	60	61	62	63	64	65	66
23	Number of events	10567	9905	8699	6421	4439	3180	2306	1644	1154
23	Duration 120 sec	3528	2260	1194	659	349	168	66	13	1
23	Correlated events	2606	2532	2352	2048	1755	1486	1225	1012	821
23	CNEL	58.4	57.9	57.3	56.6	55.9	55.3	54.6	53.9	53.2
23	Model CNEL	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	
23	Uncorrelated dB	0.52	0.49	0.56	0.65	0.81	1.07	1.4	1.79	2.24

Measured Single Event Noise Levels

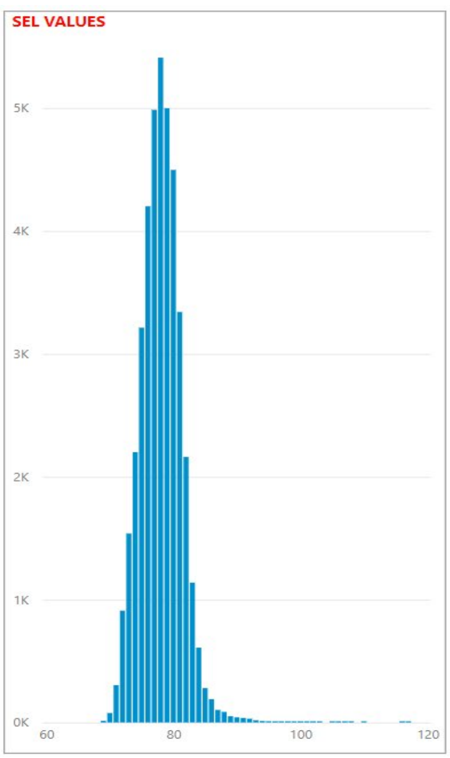
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

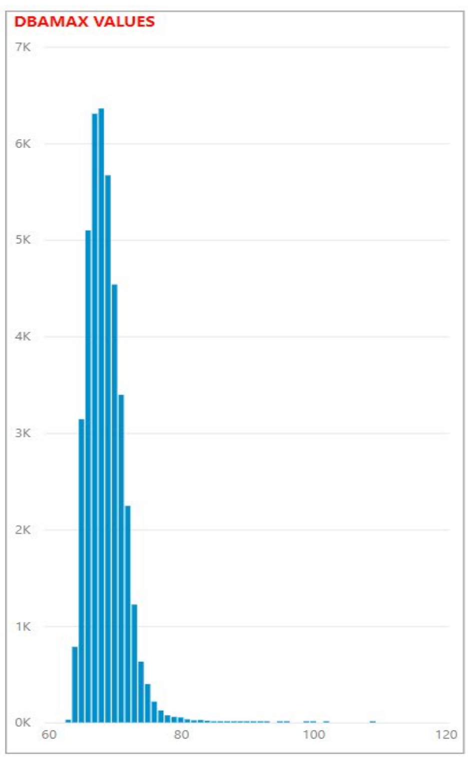
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	31,785	69.1	78.7	80.3	
Regional	7,255	68.7	77.5	83.7	
Wide	980	70.9	80.9	82.3	
Long Haul	331	69.5	79.8	80.9	
Business	132	69.5	77.5	80.5	
Total	**40,483**	**69.1**	**78.5**	**81.2**	**81.2**

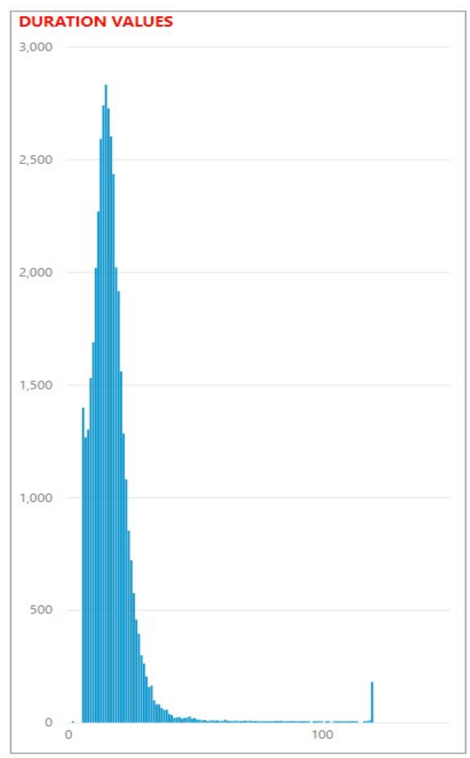
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
23	All Hours	Average	52	52	51
	Day only	Average	53	53	52
	Night Only	Average	50	49	48
	All Hours	Std Dev	3.9	3.9	4.0
	Day only	Std Dev	3.3	3.3	3.3
	Night Only	Std Dev	4.1	4.1	4.2
	All Hours	2x Std Dev	60	60	59
	Day only	2x Std Dev	60	59	59
	Night Only	2x Std Dev	58	58	57
			2019	2020	2021
	All Hours	Average L50	53	51	52
	All Hours	Average L90	53	51	52





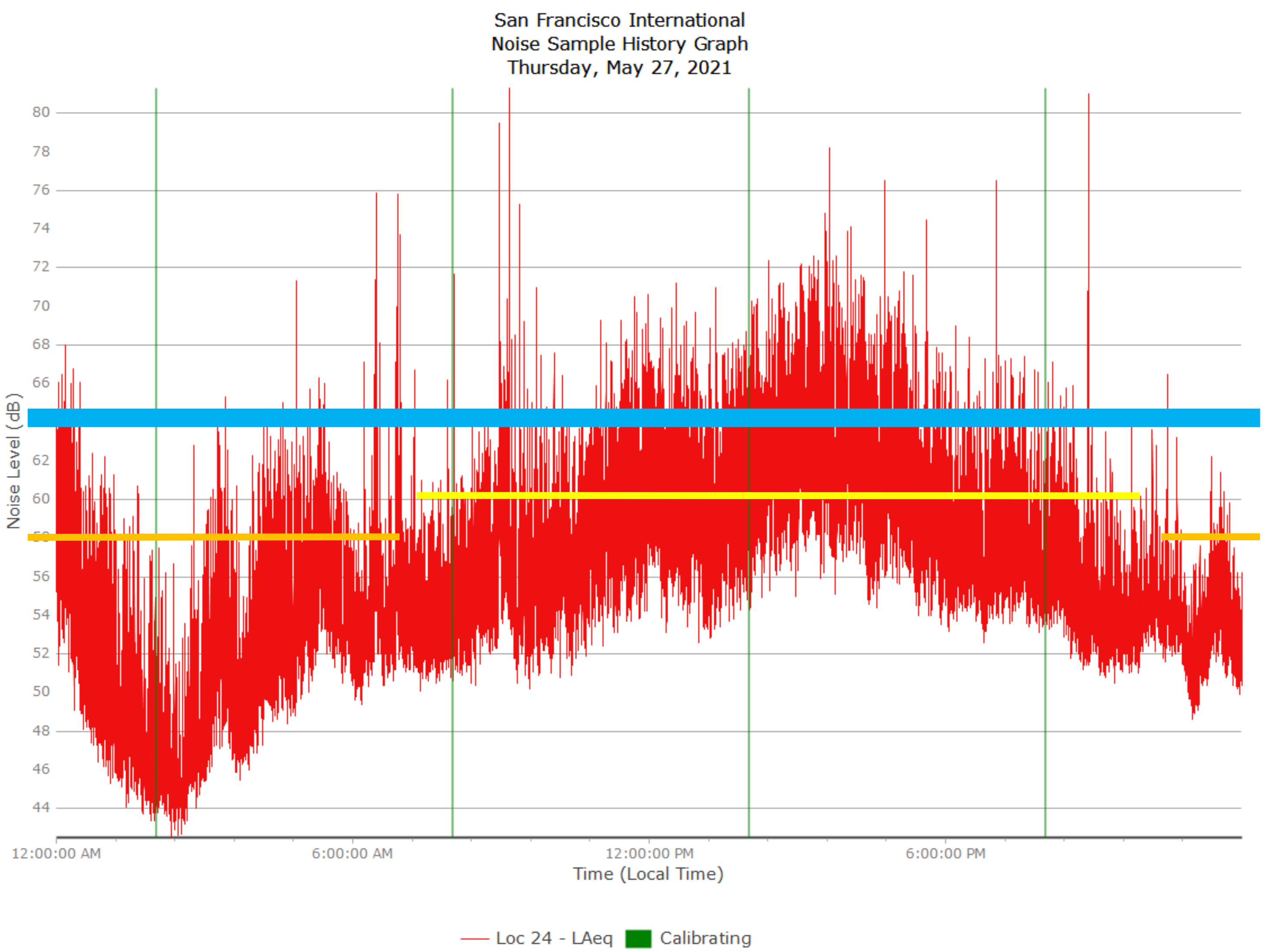


Source: BridgeNet International 2021

Figure A-13 Part A
Sample Time History Plot (Site 24 – San Francisco - Excelsior)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Thresholds	
Current	64
Proposed Day	60
Proposed Night	58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-13 Part B
Supporting Measured Analytical Data (Site 24 – San Francisco - Excelsior)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

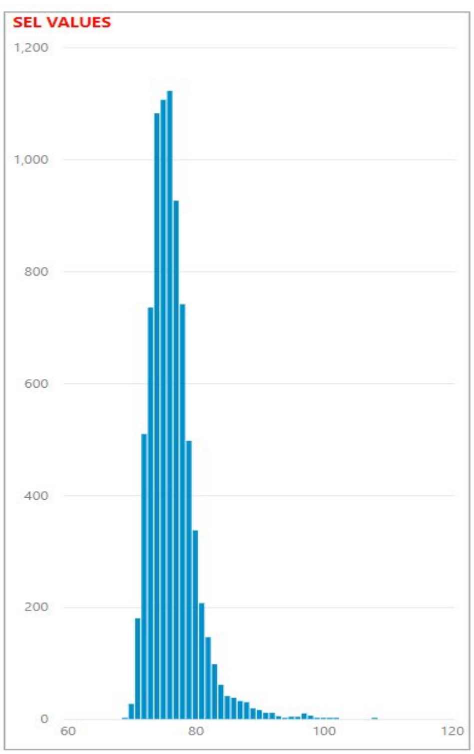
Monitor	Metric	58	59	60	61	62	63	64	65	66
24	Number of events	4983	3376	2324	1654	1202	852	599	391	244
24	Duration 120 sec	152	45	23	20	18	14	4	3	3
24	Correlated events	1757	1518	1271	1004	773	560	376	248	151
24	CNEL	52.2	51.3	50.5	49.7	48.9	47.9	46.8	45.5	44.2
24	Model CNEL	52	52	52	52	52	52	52	52	
24	Uncorrelated dB	0.69	0.91	1.2	1.66	2.22	2.97	3.99	5.16	6.39

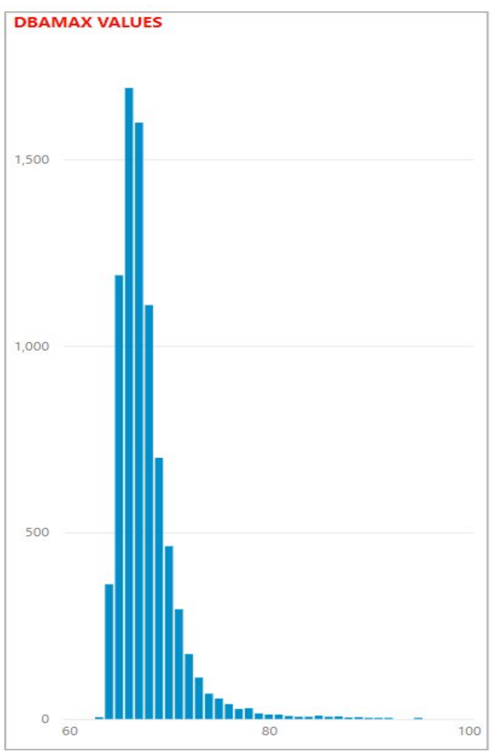
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

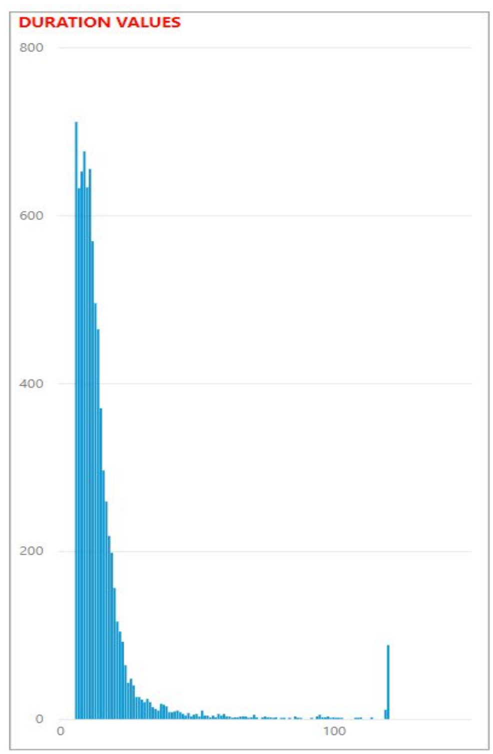
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	5,505	67.7	76.4	78.8	
Regional	1,798	68.7	77.3	83.0	
Wide	585	69.4	79.0	80.2	
Long Haul	63	68.7	77.9	79.4	
Business	61	70.3	79.0	83.9	
Total	**8,012**	**68.1**	**76.8**	**80.3**	**80.3**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
24	All Hours	Average	50	49	49
	Day only	Average	51	50	50
	Night Only	Average	48	47	46
	All Hours	Std Dev	4.3	4.2	4.2
	Day only	Std Dev	3.8	3.8	3.7
	Night Only	Std Dev	4.3	4.3	4.3
	All Hours	2x Std Dev	58	58	57
	Day only	2x Std Dev	59	58	57
	Night Only	2x Std Dev	56	56	55
			2019	**2020**	**2021**
	All Hours	Average L50	50	49	50
	All Hours	Average L90	50	49	50







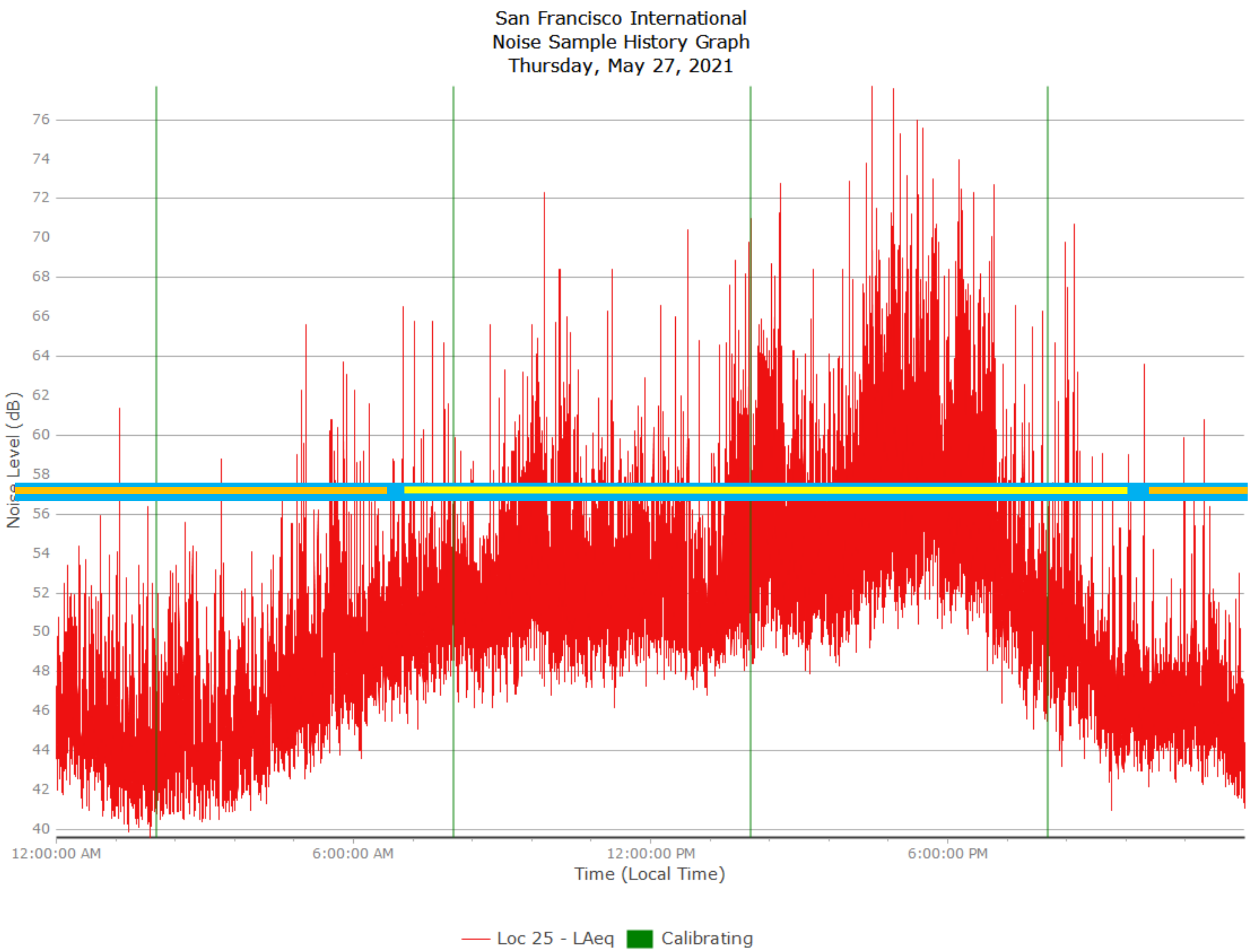
Source: BridgeNet International 2021

Figure A-14 Part A

Sample Time History Plot (Site 25 – San Francisco – Balboa Terrace)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current		57
Proposed Day		57
Proposed Night		57



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-14 Part B
Supporting Measured Analytical Data (Site 25 – San Francisco – Balboa Terrace)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	51	52	53	54	55	56	57	58	59
25	Number of events	9250	8125	6853	5512	4373	3427	2784	2326	1804
25	Duration 120 sec	1221	879	685	597	521	452	308	163	86
25	Correlated events	1187	1112	1014	869	741	630	532	455	368
25	CNEL	47.1	46.8	46.5	46.1	45.7	45.2	44.8	44.2	43.5
25	Model CNEL	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	
25	Uncorrelated dB	1.22	1.27	1.02	1.02	1.31	1.46	1.56	1.8	2.09

Measured Single Event Noise Levels

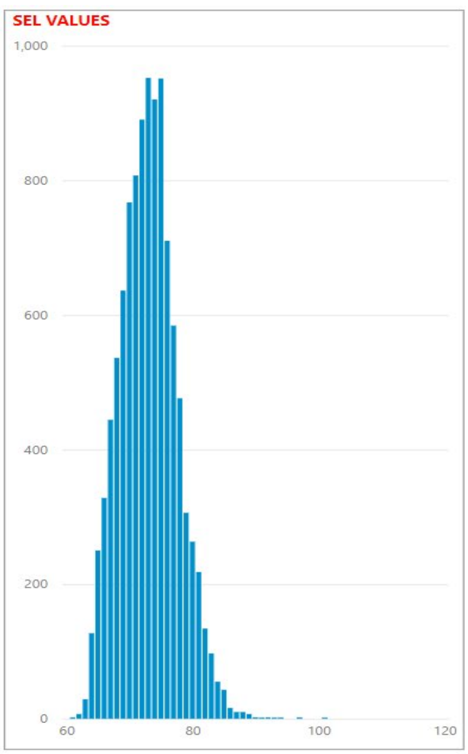
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

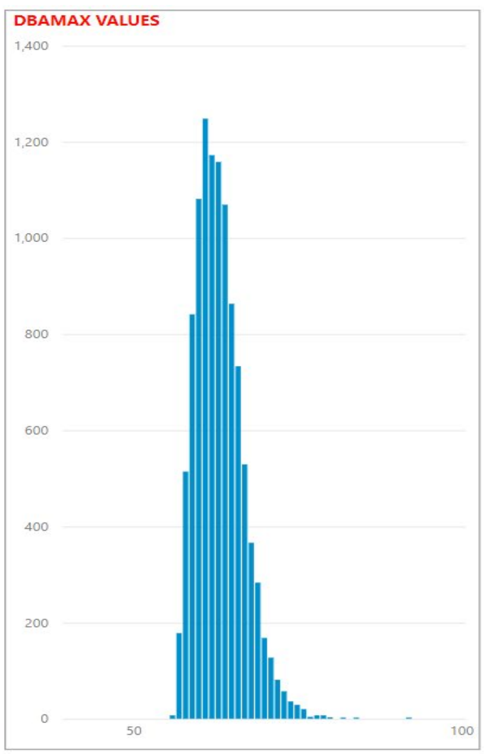
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	6,321	63.6	73.7	76.0	
Regional	2,463	63.1	72.6	75.8	
Wide	1,059	64.6	75.0	77.8	
Long Haul	586	63.5	73.4	77.9	
Business	156	63.7	72.3	75.6	
Total	**10,585**	**63.6**	**73.5**	**76.3**	**76.3**

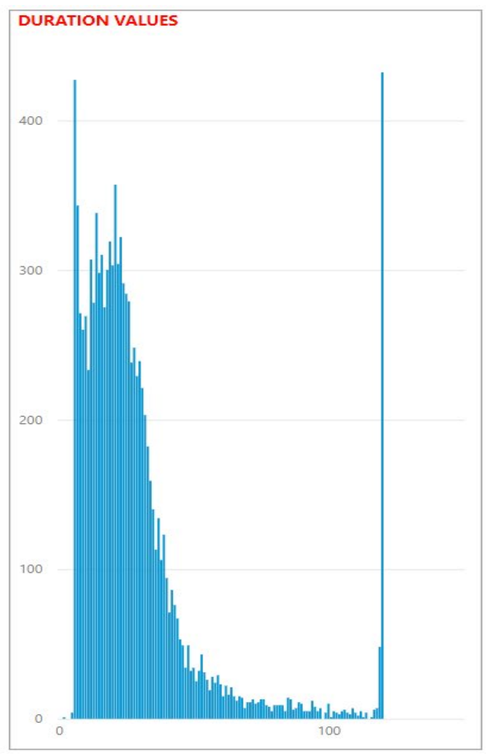
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
25	All Hours	Average	45	45	44
	Day only	Average	47	47	45
	Night Only	Average	41	41	40
	All Hours	Std Dev	4.5	4.5	4.3
	Day only	Std Dev	3.8	3.8	3.7
	Night Only	Std Dev	3.3	3.2	3.1
	All Hours	2x Std Dev	54	54	52
	Day only	2x Std Dev	55	54	53
	Night Only	2x Std Dev	48	47	47
			2019	**2020**	**2021**
	All Hours	Average L50	46	45	45
	All Hours	Average L90	45	44	45



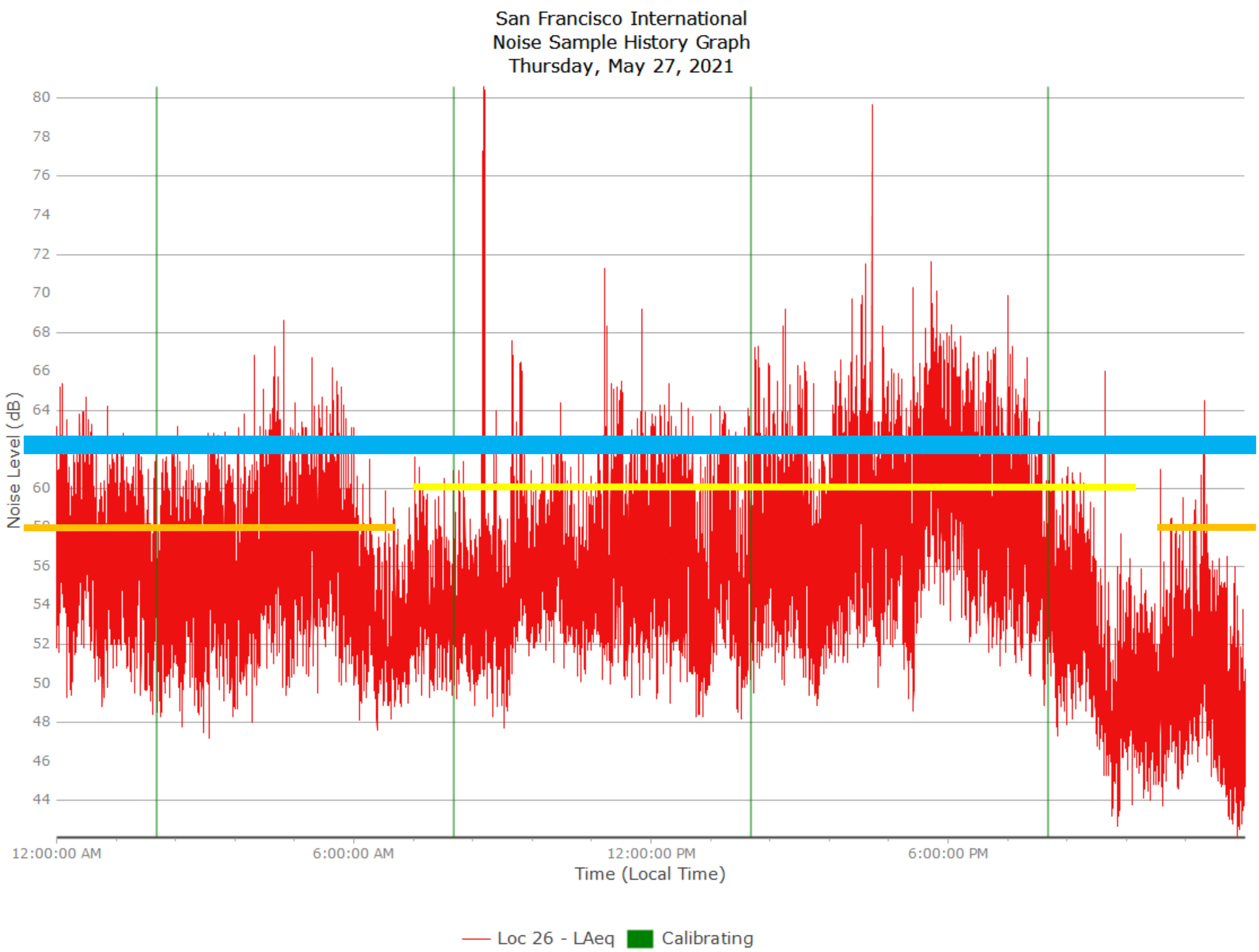




Source: BridgeNet International 2021

Figure A-15 Part A
Sample Time History Plot (Site 26 – San Francisco - Forest Hill)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current	(blue)	62
Proposed Day	(yellow)	60
Proposed Night	(orange)	58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-15 Part B
Supporting Measured Analytical Data (Site 26 – San Francisco - Forest Hill)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	56	57	58	59	60	61	62	63	64
26	Number of events	2843	2213	1796	1527	1277	1081	929	794	676
26	Duration 120 sec	137	100	70	54	45	33	25	23	21
26	Correlated events	424	348	264	206	152	106	75	47	30
26	CNEL	45.3	44.7	44.3	44.2	43.8	42.9	42.5	41.7	40.8
26	Model CNEL	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	
26	Uncorrelated dB	1.25	1.61	2.26	2.85	3.47	4.12	5.21	6.35	7.52

Measured Single Event Noise Levels

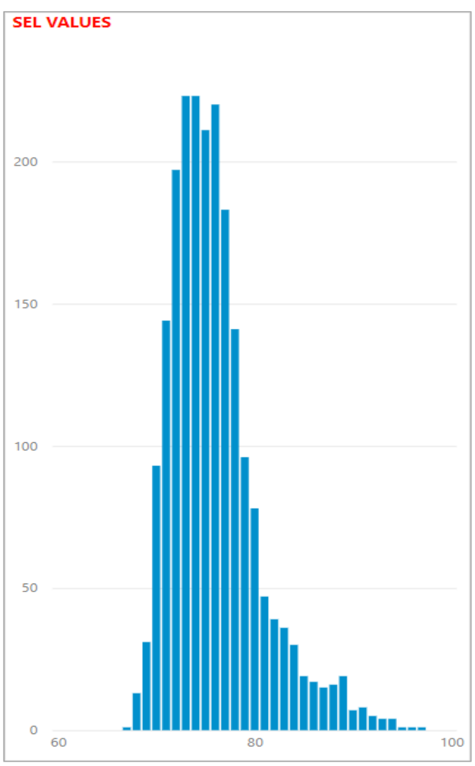
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

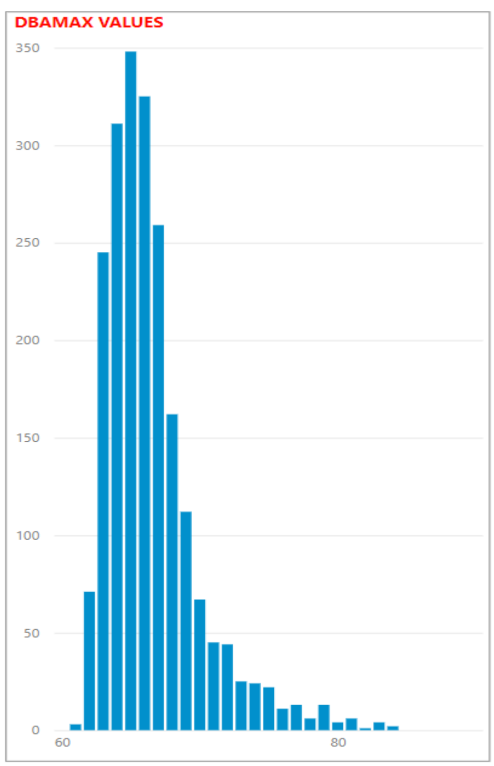
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	1,059	66.6	75.7	79.0	
Wide	404	67.3	77.2	80.9	
Long Haul	317	67.0	76.6	80.0	
Regional	311	67.4	77.1	81.7	
Business	32	67.6	75.9	78.8	
Total	**2,123**	**66.9**	**76.3**	**80.0**	**80.0**

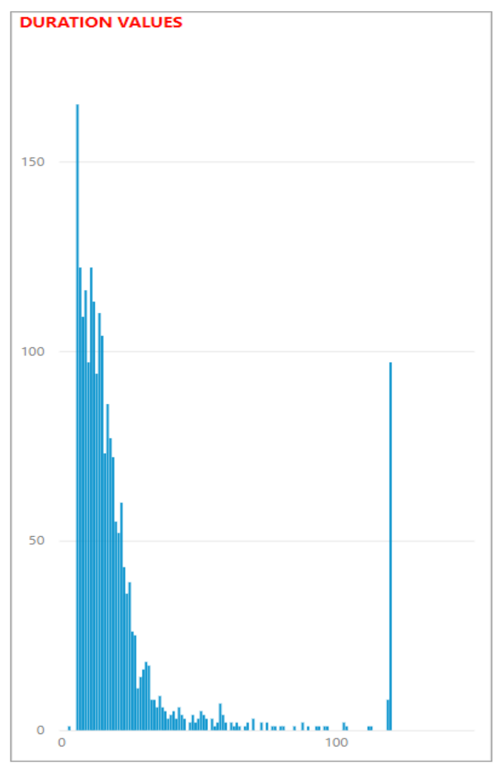
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
26	All Hours	Average	48	47	46
	Day only	Average	49	49	48
	Night Only	Average	45	44	43
	All Hours	Std Dev	4.4	4.3	4.1
	Day only	Std Dev	3.8	3.7	3.5
	Night Only	Std Dev	4.1	3.9	3.6
	All Hours	2x Std Dev	57	56	54
	Day only	2x Std Dev	57	56	55
	Night Only	2x Std Dev	53	52	51
			2019	**2020**	**2021**
	All Hours	Average L50	49	47	48
	All Hours	Average L90	48	47	47





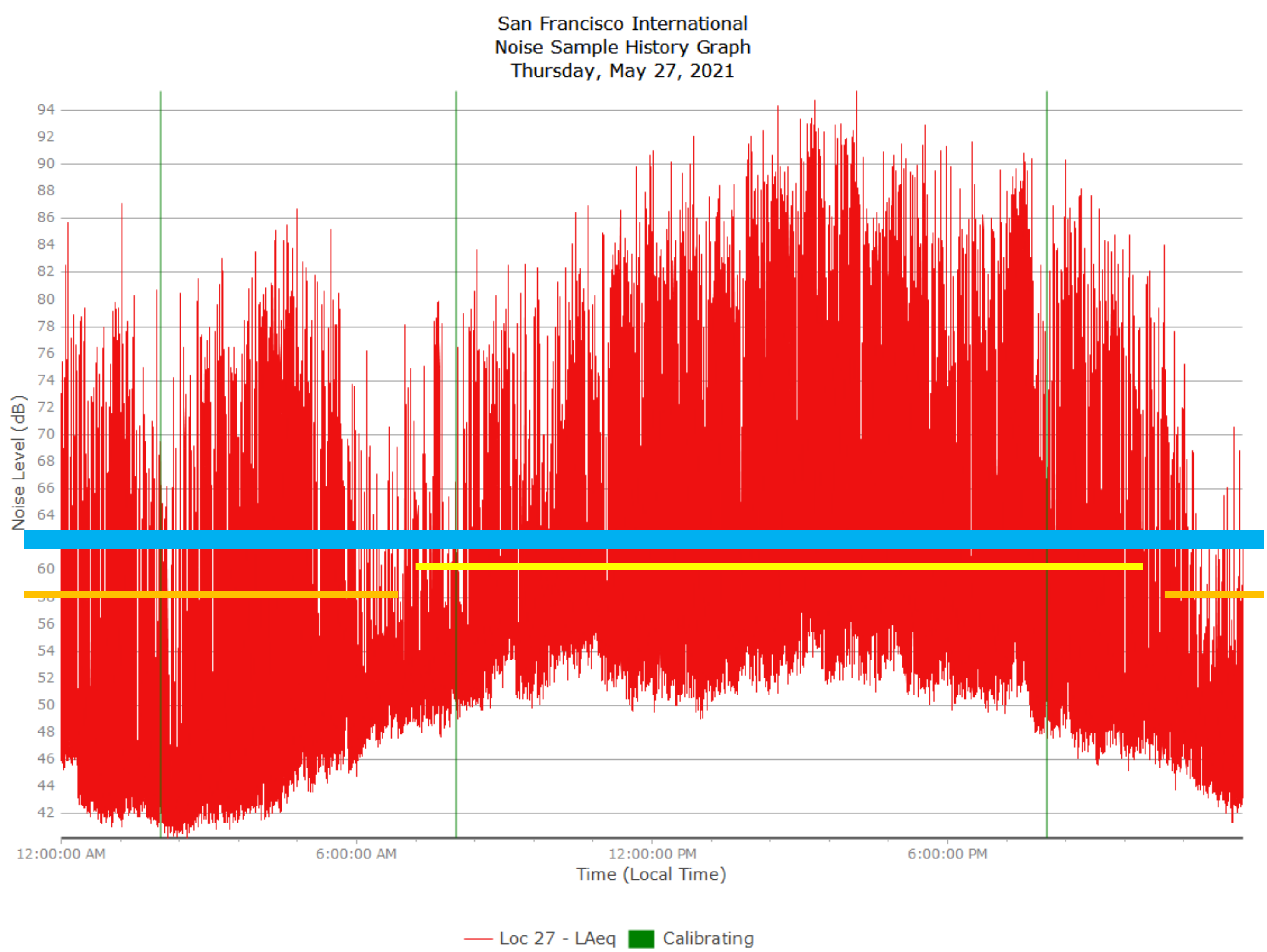


Source: BridgeNet International 2021

Figure A-16 Part A
Sample Time History Plot (Site 27 – San Francisco – Pacific Heights)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Thresholds	
Current	62
Proposed Day	60
Proposed Night	58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-16 Part B
Supporting Measured Analytical Data (Site 27 – San Francisco – Pacific Heights)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

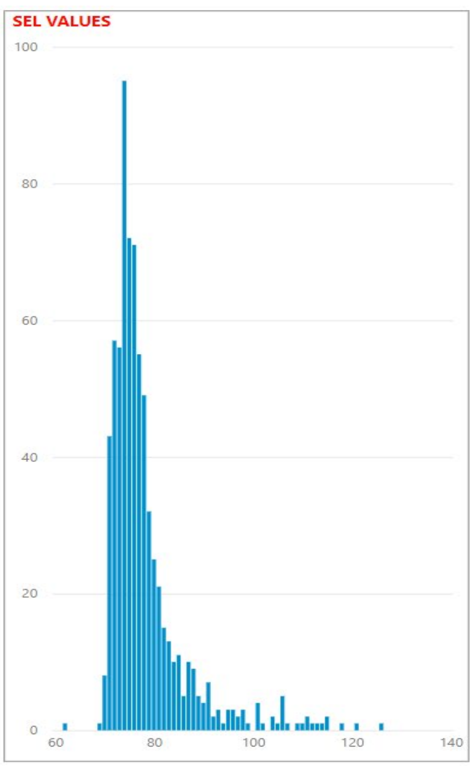
Monitor	Metric	56	57	58	59	60	61	62	63	64
27	Number of events	5875	5143	4506	3950	3479	3048	2637	2357	2200
27	Duration 120 sec	1349	1185	1031	903	821	751	696	659	614
27	Correlated events	689	563	473	405	345	295	246	223	189
27	CNEL	75.5	75.5	73.6	73.5	73.6	73.6	75.9	76.1	75.9
27	Model CNEL	45.1	45.1	45.1	45.1	45.1	45.1	45.1	45.1	
27	Uncorrelated dB	1.45	1.73	1.92	2.27	2.56	3.08	3.6	4.37	5.39

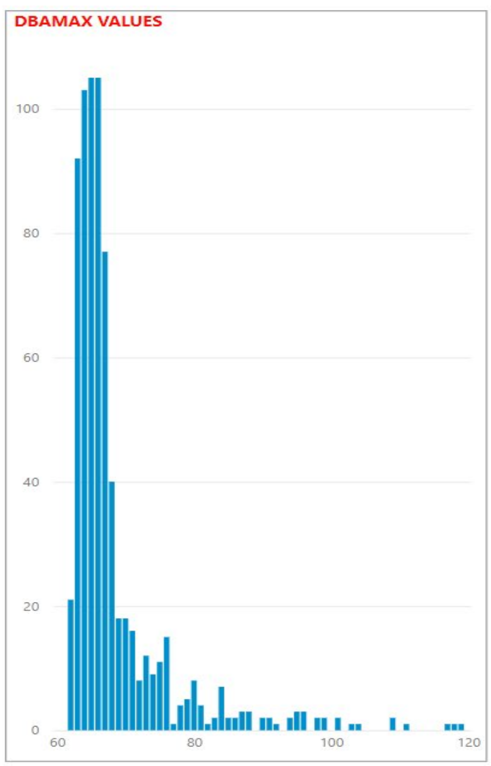
Measured Single Event Noise Levels
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

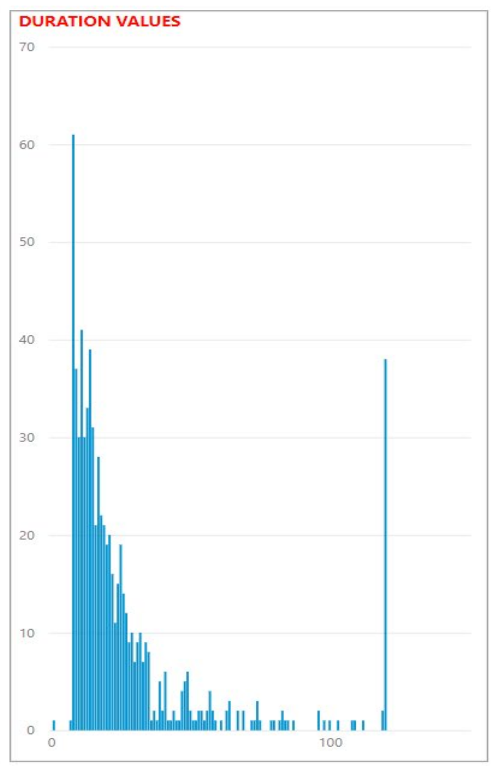
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	283	67.9	77.7	97.2	
Long Haul	210	68.8	78.5	95.8	
Regional	102	69.7	79.8	107.2	
Wide	102	70.6	80.2	102.4	
Business	22	70.5	79.9	83.4	
Total	**719**	**68.9**	**78.6**	**101.2**	**101.2**

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
27	All Hours	Average	48	47	47
	Day only	Average	50	49	49
	Night Only	Average	44	44	43
	All Hours	Std Dev	4.4	4.3	4.2
	Day only	Std Dev	3.6	3.5	3.4
	Night Only	Std Dev	3.3	3.2	3.1
	All Hours	2x Std Dev	57	56	55
	Day only	2x Std Dev	57	56	55
	Night Only	2x Std Dev	51	50	49
			2019	2020	2021
	All Hours	Average L50	49	47	48
	All Hours	Average L90	49	47	47





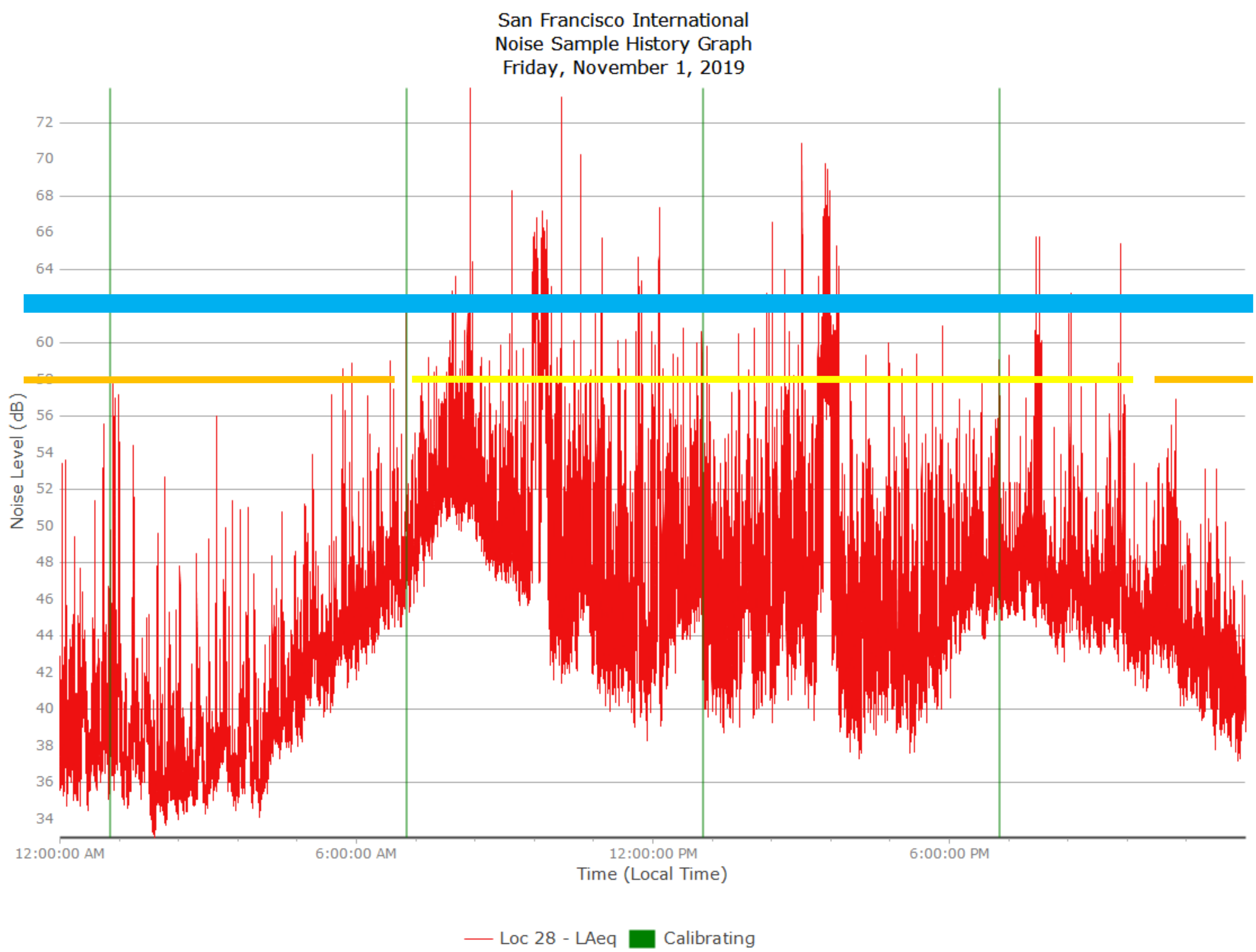


Source: BridgeNet International 2021

Figure A-17 Part A
Sample Time History Plot (Site 28 – Redwood City)
(24-hour plot of 1 measured one-second noise data – November 1, 2019)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Thresholds		
Current		62
Proposed Day		58
Proposed Night		58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-17 Part B
Supporting Measured Analytical Data (Site 28 – Redwood City)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	56	57	58	59	60	61	62	63	64
28	Number of events	1003	750	573	423	310	248	188	143	113
28	Duration 120 sec	34	30	29	26	23	18	16	14	8
28	Correlated events	323	268	212	168	129	101	68	50	37
28	CNEL	43.3	42.9	42.4	41.9	41.3	40.6	39.7	39	37.8
28	Model CNEL	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	
28	Uncorrelated dB	1.28	1.57	1.89	2.3	3.14	3.75	4.91	6.59	7.41

Measured Single Event Noise Levels

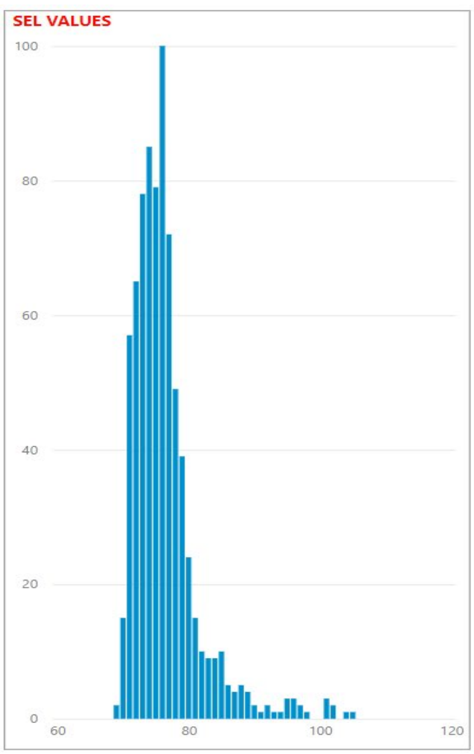
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

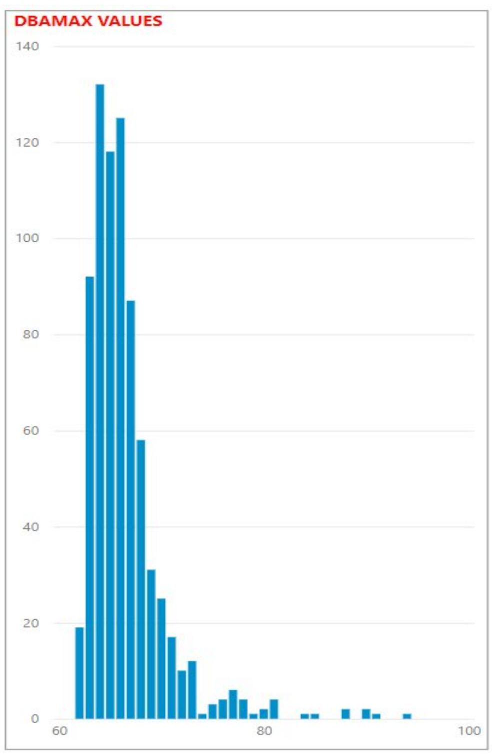
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	324	66.7	76.7	80.1	
Narrow	254	66.7	76.3	85.0	
Wide	113	66.7	76.7	86.5	
Regional	53	69.3	80.4	91.1	
Business	15	67.7	76.9	86.2	
Total	**759**	**66.9**	**76.8**	**85.0**	**85.0**

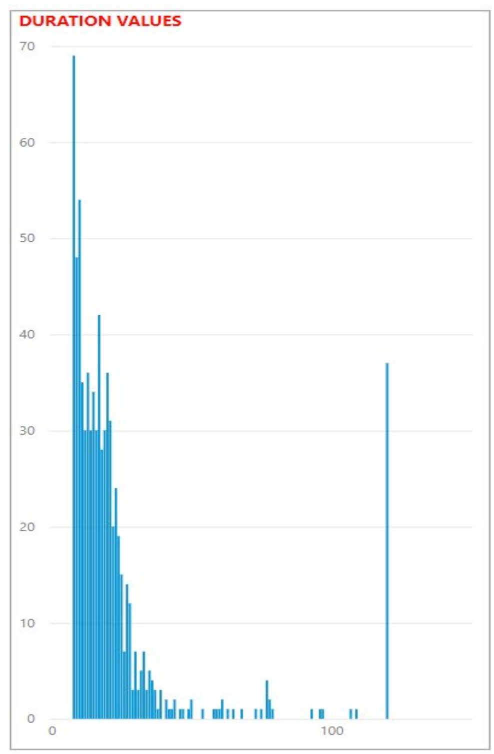
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
28	All Hours	Average	41	40	39
	Day only	Average	42	42	41
	Night Only	Average	37	37	36
	All Hours	Std Dev	4.9	4.8	4.7
	Day only	Std Dev	4.1	4.1	4.0
	Night Only	Std Dev	4.3	4.3	4.3
	All Hours	2x Std Dev	50	50	49
	Day only	2x Std Dev	51	50	49
	Night Only	2x Std Dev	46	45	44
			2019	**2020**	**2021**
	All Hours	Average L50	41	39	--
	All Hours	Average L90	41	39	--





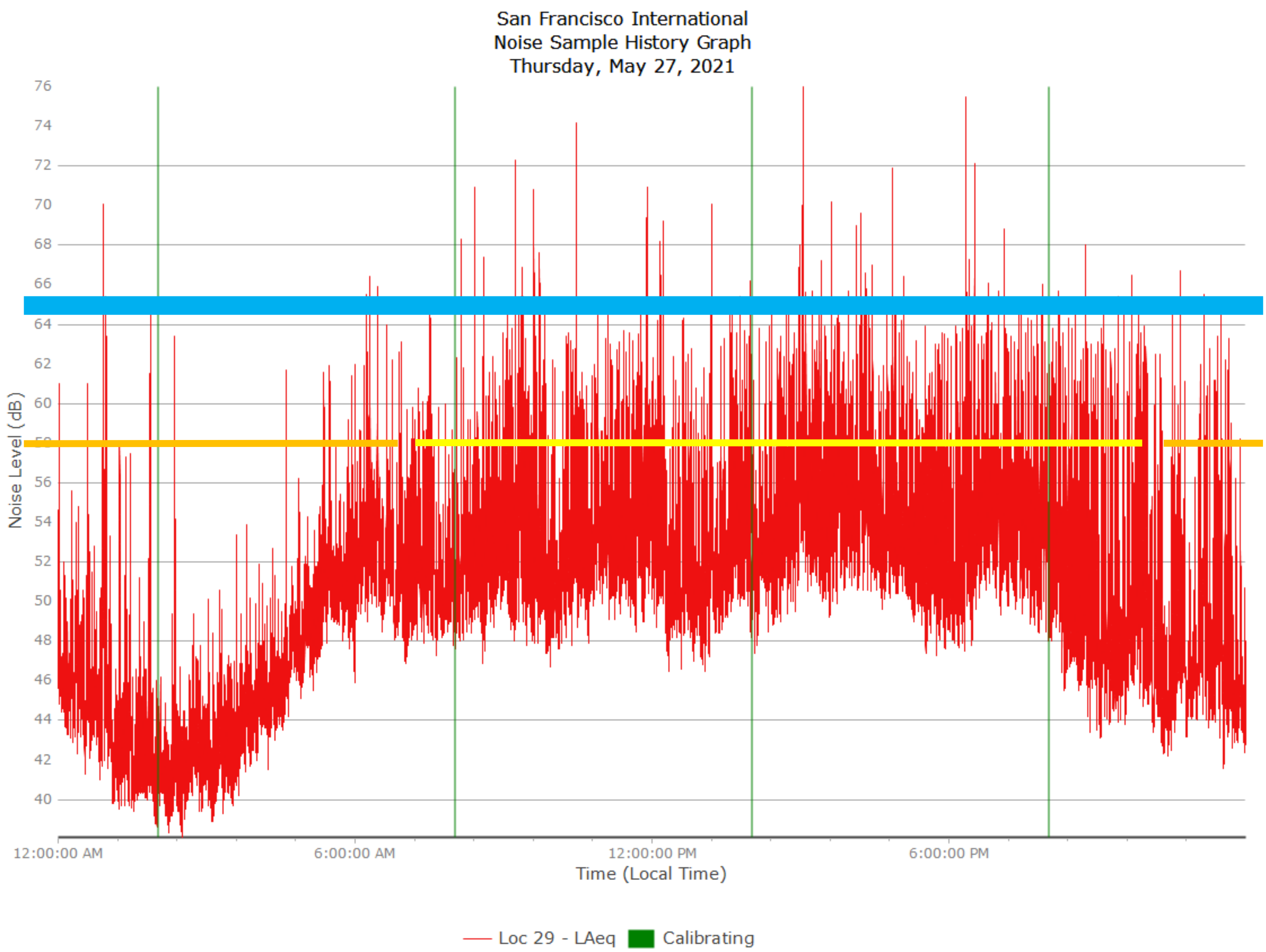


Source: BridgeNet International 2021

Figure A-18 Part A
Sample Time History Plot (Site 29 – San Mateo)
(24-hour plot of 1 measured one-second noise data – May 27, 2021)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Thresholds		
Current		65
Proposed Day		58
Proposed Night		58



Time History Plot from ANOMS that auto scales the vertical range

Source: BridgeNet International 2021

Figure A-18 Part B

Supporting Measured Analytical Data (Site 29 – San Mateo)

SAN FRANCISCO INTERNATIONAL – NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	59	60	61	62	63	64	65	66	67
29	Number of events	4057	2992	2198	1742	1460	1273	1103	947	762
29	Duration 120 sec	107	80	62	44	26	16	8	7	5
29	Correlated events	3332	2488	1836	1469	1236	1091	957	820	663
29	CNEL	58.1	57.8	57.5	57.2	56.9	56.6	56.2	55.6	54.8
29	Model CNEL	58.2	58.2	58.2	58.2	58.2	58.2	58.2	58.2	
29	Uncorrelated dB	1.77	2.25	2.65	2.95	3.07	3.32	3.38	3.69	3.75

Measured Single Event Noise Levels

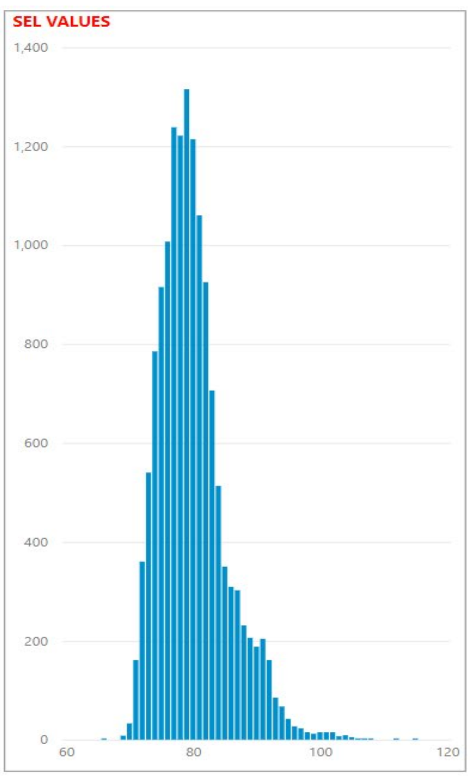
All Correlated Events Jan 1st, 2019 – Nov 6th, 2021

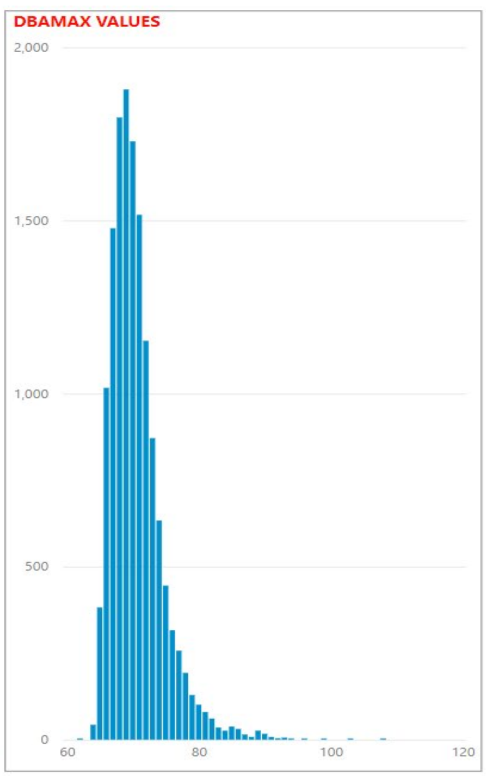
Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Narrow	8,966	70.8	80.1	85.7	
Regional	2,269	72.1	81.7	87.5	
Long Haul	1,730	70.5	79.8	84.9	
Wide	919	71.3	80.5	84.7	
Business	413	71.6	80.6	87.6	
Total	**14,297**	**71.0**	**80.4**	**86.0**	**86.0**

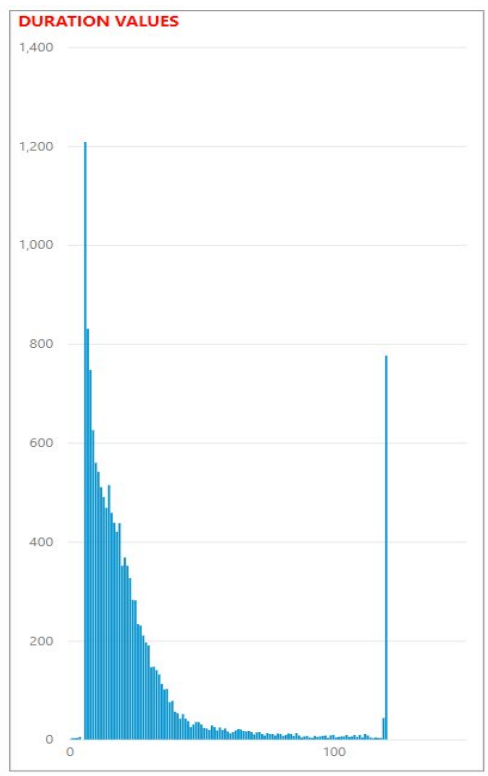
Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
29	All Hours	Average	46	45	45
	Day only	Average	47	47	46
	Night Only	Average	44	43	42
	All Hours	Std Dev	3.9	3.9	3.9
	Day only	Std Dev	3.4	3.4	3.4
	Night Only	Std Dev	3.9	3.9	4.0
	All Hours	2x Std Dev	54	53	52
	Day only	2x Std Dev	54	53	52
	Night Only	2x Std Dev	52	51	50
			2019	2020	2021
	All Hours	Average L50	48	45	46
	All Hours	Average L90	47	44	45

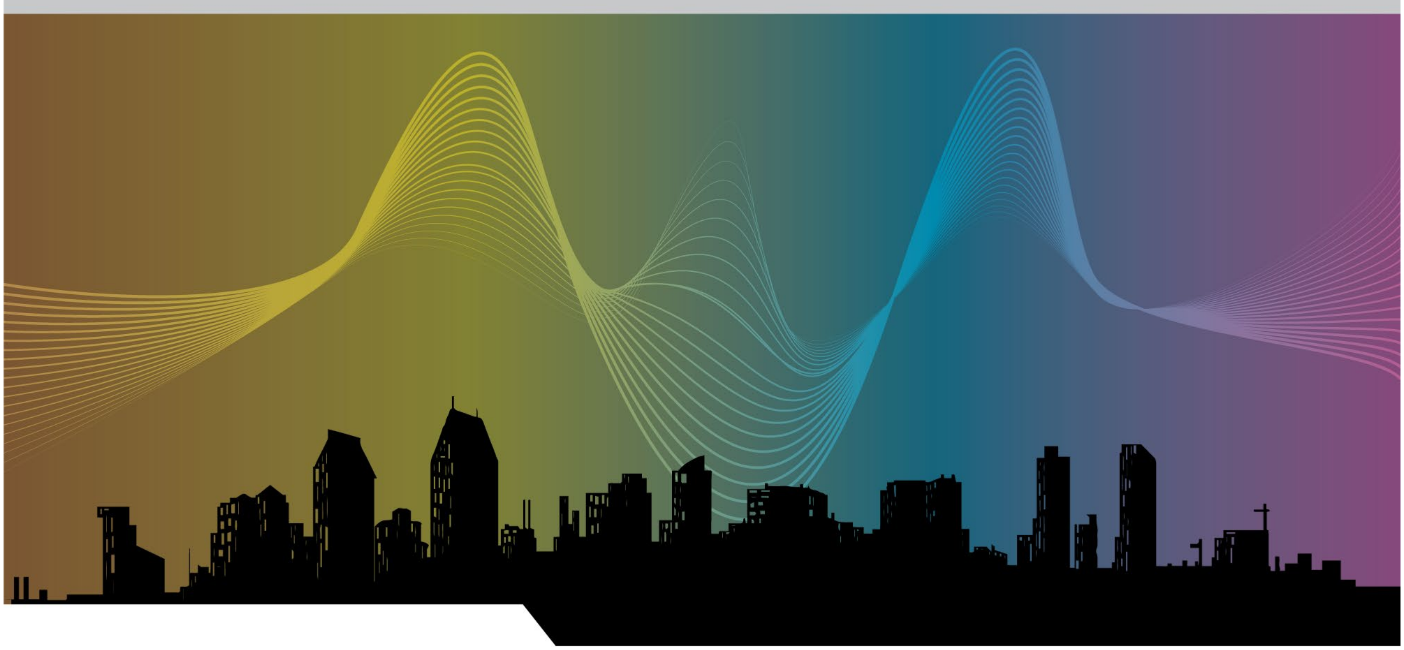






Source: BridgeNet International 2021

June 21, 2021



Review of Remote Monitoring Terminal Thresholds-Phase 2

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Contents

Tables

Appendix

1. Background

BridgeNet International was contracted by the San Francisco International Airport's (SFO) Noise Office to review aircraft noise event thresholds and noise monitoring settings at seven (7) Remote Noise Monitoring Terminals (NMTs). This review is the second of two phases that analyzed aircraft noise events, including conducting an analysis of measured noise levels and recommending noise thresholds and durations that should be used in the future. The first phase analyzed five (5) NMTs, 12, 15, 18, 19 and potential applications of a new threshold to NMT 8. This report reviews Sites 1, 4, 5, 6, 14, 16, and17 which are all located along the GAP departure corridor.

In the fall of 2019, SFO installed a new noise system, the Envirosuite (EVS) Airport Noise and Operations Monitoring System (ANOMS), to replace the airport's existing ANOMS that was installed in 2006. The system underwent various hardware and software upgrades, but the basic noise event detection process per Title 21 has remained essentially the same. The software upgrade did not include changes to how noise events are calculated and correlated to aircraft. Historically, SFO operated with a variance to its state operating certificate due to the airport's status as a "noise problem airport" because there were incompatible land uses[1] within the 65 CNEL. In 2002, the airport no longer needed to operate with a variance because it no longer had incompatible land uses within the 65 CNEL noise contour, which meant that all sensitive land uses within the 65 CNEL were either sound insulated or had granted an avigation easement to the airport. While the airport has operated without a variance for 18 years, it still abides by the standards in Title 21 for a noise problem airport, including the requirement in Section 5033 of Title 21 requiring noise monitoring systems to be submitted and approved by the state as part of an airport's Noise Monitoring Plan.

Per Section 5001 of Title 21, the thresholds of the NMTs should be 10 dB below the appropriate CNEL value; for the purposes of this analysis, the appropriate CNEL value is 65 CNEL as described in Section 5012 of Title 21. Should an airport need a waiver to the 10 dB value, per Section 5070 of Title 21, an airport can apply for a waiver that demonstrates an airport will still maintain the required accuracy of 1.5 CNEL using a different threshold value. Since 2011, SFO has operated with a waiver for noise thresholds at certain NMTs. This analysis will review these noise threshold values to determine their continued applicability at NMTs 1, 4, 5, 6, 14, 16, and 17. For this analysis, the only NMT currently within the 65 CNEL is Site 1; historically prior to Covid-19 NMT Sites 4, 5 and 6 were exposed to 65 CNEL or greater. This report will describe the background, or ambient noise levels, and aircraft noise levels at each of the monitors and the supporting analysis for continuing to use a threshold different than 55 dB and identify an optimum threshold specific to the conditions at each of the above locations.

[1] As defined in Section 5014 of Title 21: https://govt.westlaw.com/calregs/Document/ICD7B5DE0D45011DEB97CF67CD0B99467?originationContext=document&transitionType=StatuteNavigator&needToInjectTeNMT=False&viewType=FullText&contextData=%28sc.Default%29

Given the airport operational changes associated with Covid-19, this is also an opportune time to evaluate the current NMT threshold settings to reflect a post Covid-19 environment. This global pandemic accelerated the retirement of older aircraft that are not as efficient as newer aircraft in use or about to be introduced into service. The majority of the remaining existing aircraft fleet and the newest generation of aircraft entering service on average generate lower peak noise levels that the pre Covid-19 time frame. This shift is most pronounced with the long haul, widebody aircraft that dominate noise along the GAP route, historically referred to as "the Gap." This means that the peak sound generated by these aircraft is lower, and they will not dominate the overall GAP noise as much as they have in the past.

The CNEL noise levels at the noise monitoring sites along the GAP route were very much dominated by large aircraft such as the Boeing 747-400 and Boeing 777; and, these aircraft often make up a large percentage of nighttime operations. With the current thresholds, many of the smaller, quieter aircraft generated peak noise levels below these thresholds; thus, they were not always captured as a noise event. These aircraft more commonly operate in the daytime. Because these aircraft contributed little to the overall CNEL, this was not an issue in measuring a valid CNEL to meet the requirements of the Title 21 process. Being able to capture the noise from the new generation, quieter aircraft is becoming more important as the fleet become quieter. Thus, this report will review potential threshold changes to better capture lower peak noise levels from aircraft that is expected to be more common in the future.

2. Definition of Terms

Characteristics of Sound

Sound can be described technically in terms of amplitude (loudness), frequency (pitch), or duration (time). Frequency (or pitch) is measured in hertz (Hz). The standard unit of measurement for the loudness of sound is the decibel (dB). Decibels are based on a logarithmic scale. The logarithmic scale compresses the wide range in sound pressure levels to a more usable range of numbers (in a manner similar to the Richter scale used to measure earthquakes).

Human hearing is not equally sensitive to sound at all frequencies. Sound waves below 16 Hz are not heard at all and are "felt" more as a vibration. Similarly, while people with extremely sensitive hearing can hear sounds as high as 20,000 Hz, most people cannot hear above 15,000 Hz. In all cases, hearing acuity falls off rapidly above about 10,000 Hz and below about 200 Hz. Since the human ear is not equally sensitive to sound at all frequencies, a special frequency-dependent rating scale has been devised to measure loudness in a way that reflects how the human ear actually perceives sound. Community noise levels are measured in terms of this A-weighted decibel scale (or dBA), which is widely used in industrial and environmental noise-management contexts.

Propagation of Noise

Outdoor sound levels decrease as a result of several factors, including increased distance from the sound source, atmospheric absorption (characteristics in the atmosphere that absorb sound), and ground attenuation (characteristics on the ground that absorb sound). If sound radiates from a source in a homogeneous and undisturbed manner, the sound travels in spherical waves. As the sound wave travels away from the source, the sound energy is spread over a greater area dispersing the power of the sound wave.

Atmospheric temperature and humidity also influence the sound levels received by the observer. How much sound is absorbed by the atmosphere depends on the frequency of the sound as well as the humidity and air temperature. For example, when the air is cold and humid, and therefore denser, atmospheric absorption is lowest and sound travels farther. Higher frequencies are more readily absorbed than the lower frequencies. The fluctuations in sound levels created by atmospheric conditions increase with distance and become particularly important at distances greater than 1,000 feet. Over large distances, lower frequency sounds become dominant as the higher frequencies are attenuated. Noise propagation is one of the reasons that aircraft noise will be higher one day than other days even when the same aircraft are flying the same path and altitude.

Noise Metrics

The description, analysis, and reporting of noise levels around communities is made difficult by the complexity of human response to noise and the variety of metrics that have been developed for describing noise impacts. Each of these metrics attempts to quantify noise levels with respect to community impact.

Noise metrics can be divided into two categories: single event and cumulative. Single event metrics describe the noise levels from an individual event such as an aircraft flyover. Cumulative metrics average the total noise over a specific time period, typically from one to 24 hours. This study presents single event measurement results.

- **Maximum Noise Level,** or Lmax, is the maximum or peak sound level during an aircraft noise event. The metric accounts only for the peak intensity of the sound and not for the duration of the event. As an aircraft passes by an observer, the sound level increases to a maximum level and then decreases. Typical single event noise levels range from over 90 dBA close to the airport to the low 50s dBA at more distant locations.
- **Single Event Noise Exposure Level (SEL) -** The duration of a noise event, or an aircraft flyover, is an important factor in assessing annoyance and is measured most typically as SEL. The effective duration of a sound starts when a sound rises above the background sound level and ends when it drops back below the background level. An SEL is calculated by summing the dB level at each second during a noise event and compressing that noise into one second. It is the level the noise would be if it all occurred in one second. The SEL value is the integration of all the acoustic energy contained within the event. This metric takes into account the maximum noise level of the event and the duration of the event. For aircraft flyovers, the SEL value is numerically about 10 dBA higher than the maximum noise level.
- **Community Noise Equivalent Level (CNEL)** is an average noise over twenty-four hours; it applies a weighting factor that penalizes noise events occurring during the evening and

night hours (when humans are typically more sensitive to noise and sleep disturbance is a concern). More specifically, noises occurring during the evening (from 7 PM to 10 PM) are penalized by 5 dB, while noises occurring during the night (10 PM to 7 AM) are penalized by 10 dBA. CNEL noise levels near airports range from 70 CNEL directly next to an airport to less than 45 CNEL at more distant locations.

CNEL is influenced most by the loudest aircraft operating at an airport, which at SFO is typically a wide-body passenger or cargo jet traveling long distances (such as to Europe or Asia). At SFO the aircraft that most influence the CNEL contour are the Boeing 777, other large jets like the Boeing 787, and historically the Boeing 747 which recently stopped being used for passenger service but is still used by cargo carriers. The CNEL contours are influenced to a lesser extent by operations conducted by smaller aircraft; these aircraft influence the contour due to the larger number of operations (for example, narrow-body jets on domestic routes). The CNEL noise levels at locations along the peninsula (i.e. departure procedures along The Gap) are especially dominated by the larger jet aircraft in that many of these operations also occur during the evening and night penalty period of 5 dB and 10 dB, respectively.

Note that measuring CNEL at levels below 55 CNEL becomes less precise because the noise from aircraft events can be close to existing ambient noise, and it is not always technically possible to separate the two. CNEL differs from the Lmax values which are numerically higher than CNEL values because the CNEL represents an average that includes both peak sounds (like the Lmax) and lower values when aircraft noise is not present.

3. Purpose

The purpose of this Phase 2 NMT analysis is to support SFO's acceptance of the new ANOMS that was installed in the fall of 2019; in particular, the accuracy of identifying and correlating measured noise to flights at SFO. This system was submitted for review and acceptance to the State of California in 2020. The goal of this analysis is to determine the most effective and accurate thresholds and NMT settings to be used to identify the noise levels due to aircraft flights while in compliance with Title 21 standards at additional monitoring sites beyond the 65 CNEL.

Additionally, this analysis supports Section 5032 of Title 21 that validates the noise impact boundary, which reviews locations of the NMTs relative to the outer-most points of the 65 CNEL contour. Per Section 5032, "The locations shall be selected to facilitate locating the maximum extent (closure points) of the noise impact boundary when the contour extremities encompass incompatible land uses."

4. Methodology

4.1 Remote Monitoring Terminal Locations

The seven NMTs chosen are shown in **Figure 1;** at the time of this report, all sites except NMT 1 are located outside of the 65 CNEL; these locations were chosen for their positions relative to departure noise. It should be noted that these sites primarily measure departure noise from Runway 28L/R. **Table 1** shows the existing noise thresholds at these NMTs; these values were approved by the State of California in December 2011 and is not inclusive of all the NMTs with threshold waivers[2].

Table 1 – Current NMT Threshold Values

NMT	City	Location	Latitude	Longitude	NMT Threshold, dBA
1	San Bruno	Gap departure along centerline	37.632328	-122.408416	65
4	South San Francisco	Gap departure along centerline	37.64092	-122.42652	64
5	San Bruno	Gap departure left of centerline	37.62816	-122.413408	64
6	South San Francisco	Gap departure along centerline	37.649267	-122.435134	64
14	South San Francisco	Gap departure right of centerline	37.6526	-122.42902	64
16	South San Francisco	Gap departure right of centerline	37.64646	-122.46408	63
17	South San Francisco	Gap departure along centerline	37.661712	-122.45188	63

Source: San Francisco International Airport Noise Office, 2021

This analysis will correlate noise events to a nearby flight using Title 21 guidelines to determine an appropriate threshold for the seven NMTs in Table 1. This analysis, as guided by Section 5032 of Title 21, will determine the delta of measured and modeled noise to be within 1.5 dB annual CNEL. While NMTs should ideally be located in areas with ambient noise levels less than 55 dB (i.e. away from noisy sources such as freeways, railroad tracks, etc) many of the NMTs at SFO are in urban areas with ambient levels higher than 55 dB. This analysis will determine suggested thresholds based upon the type of operations a site is exposed to, the level of noise from aircraft events and the background noise environment.

[2] In December 2011 the State of California approved a threshold waiver for the following NMTs: 1,4,5,6,12,14,15,16,17,18, and 19.

4.2. Evaluation Criteria

The following evaluation criteria was used to identify the optimum threshold settings.

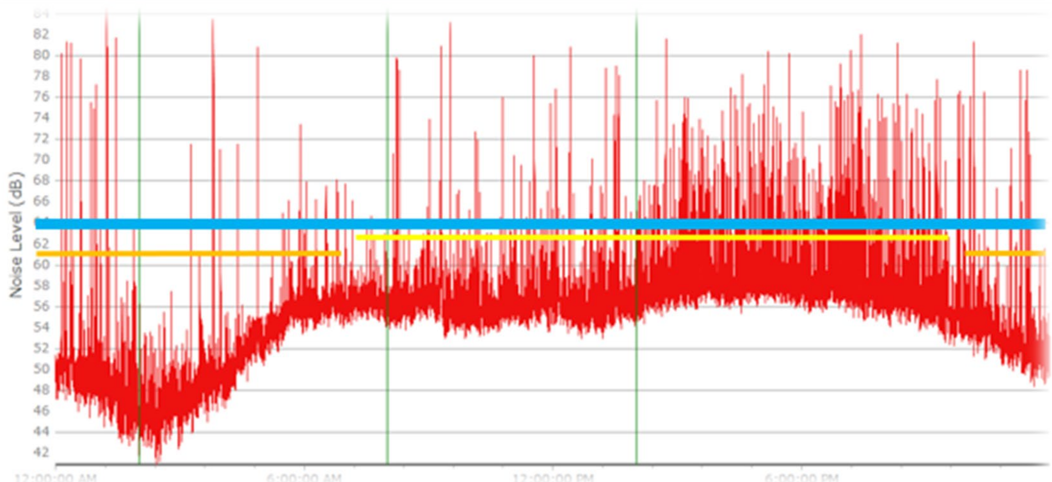
1. Threshold Calculation at Various Alternative Levels. EVS calculated the CNEL noise levels based upon various alternatives thresholds. The goal of the evaluation is to measure aircraft noise within 0.5 CNEL of the theoretical level; this measurement does not include significant events that are incorrectly associated with an aircraft overflight. The total number of long duration events (120 seconds) should be minimal.
2. Background Noise Level. The background, or ambient noise levels, limits how low the threshold can be lowered. If the threshold is lowered to near the background noise level, then continuous noise events occur, and it is not possible to generate a noise event that can be accurately associated with a flight. Because the background levels vary throughout the day and year, there is no one set value. The optimum threshold should be greater than the higher range of ambient conditions a site experiences throughout the year.
3. Single Event Noise Levels. The single event noise levels are expected to lessen in the post Covid-19 environment. This analysis is to evaluate the ability of the system to not only capture the noise from the louder operations, but also from the noise generated by smaller, quieter aircraft operations.

4.3. Evaluation Data

The evaluation of each site is presented in the Appendix, **Figures A-2** through **A-8, Parts A-C** for each NMT. There are five parts as described below. This section presents an example figure for each of the five parts; the Appendix contains this specific information for each of the NMTs.

1. Time History Noise Graphic. This example table (**Table 2**) shows a typical 24-hour time history of the measured 1-second noise levels. The red lines are all the noise levels including background and peak levels. In addition, it also includes peak events that are usually aircraft events. The time history on the bottom of the graphics shows that background noise is typically quieter at night. The blue line represents the current NMT threshold; the yellow and orange lines show the recommended day and nighttime thresholds, respectively. The recommended thresholds are also presented tabularly in the top of Part A of the figures. Generally, the threshold should be close to, but above, the background and be 10 dBA or greater below the peaks of the events. Note that this is one day for example purposes and that there is variability in the day-to-day noise levels. The threshold must account for the fact that the ambient noise varies and should be set at a level that can detect events during periods of higher background noise, not just the lower background periods.

Table 2 – Time History Noise Graphic Example



Source: BridgeNet International, 2021

2. <u>EVS Threshold Calculations.</u> Shown below in **Table 3**, EVS has a process to test the consequence of lowering or raising the threshold to determine its change to the measured aircraft CNEL; this is shown on the top of Part B in the appendix figures. The threshold calculations used in this report are based on a two-week period in December 2019. The different threshold values are shown in gold with the current setting in yellow. For each threshold level, the calculations determined:

    a. Total number of events that were generated including those not correlated to an aircraft.

    b. Number of events of 120 seconds or greater in duration. Too many events over 120 seconds is an indication that the threshold setting is too close the background noise.

    c. The number of events correlated to an aircraft, or correlated events. This could include valid correlations as well as incorrect correlations where an aircraft happens to fly over at the same time a non-aircraft event is generated. A threshold too low tends to increase the probability that an incorrect correlation has occurred.

    d. CNEL is the measured CNEL based upon the correlated events calculated at that threshold. If there is little change measured when the threshold is lowered (less than 0.5 CNEL), this means that the majority of the aircraft noise at the site has already been measured.

    e. The Model CNEL is a guide for the noise level at a site, not an absolute level. This is the CNEL level EVS predicts using an internal noise predictor. It is based upon all aircraft that flew near a site and is independent of a noise event being measured. It is not intended be an accurate representation of the actual total aircraft noise if all events were measured but is used by EVS in evaluating if a measured noise event is consistent with an expected value.

f. Uncorrelated dB is the level that would increase if the uncorrelated events were added to the CNEL value. It is optimum when this delta is small and does not increase when the threshold is lowered. It does not determine if the correlated events are valid or not.

Table 3 – Threshold Calculations

Monitor	Metric	58	59	60	61	62	63	64	65	66
4	Number of events	4776	3810	3070	2580	2237	2079	1947	1821	1718
4	Duration 120 sec	188	65	23	10	9	6	5	5	3
4	Correlated events	2592	2367	2176	2007	1870	1791	1721	1654	1601
4	CNEL	67.8	67.8	67.8	67.7	67.7	67.7	67.7	67.7	67.6
4	Model CNEL	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	
4	Uncorrelated dB	0.21	0.21	0.21	0.21	0.22	0.23	0.24	0.26	0.28

Source: EVS, 2021

3. Ambient Noise Levels. On the middle right of Part B of the site figures, the ambient noise level assessment is shown; an example is show below in **Table 4**. For a near three-year period (2019, 2020 and January through May 2021) the hourly ambient noise levels as determined by ANOMS were evaluated. The data below shows the average L50 and L90 for: all hours of the day, the daytime (7am to 10pm), and the nighttime (10pm to 7am) hourly periods. The L50 represents the average, or mean noise level, during that hour. The L90 represents the residual noise level, or the level for which 90% of the noise in that hour exceeds the level. While both metrics are often used to define the background or ambient level, the L50 will be used as the ambient noise level.

   In addition to the average values, the standard deviation was also determined. This is important in that the ambient noise levels vary throughout the day and year. The threshold should be higher than the highest ambient noise periods, otherwise the noise events will not be accurately calculated during those higher background noise periods. For the purposes of this study, the high ambient is defined as 2 standard deviations over the average value. This means that 97.5 percent of the time, the hourly ambient level will be at or below that value.

   The hourly noise level for the past three years was also determined in order to identify the change that may have occurred as a result of Covid-19. The data shows the ambient was highest in 2019, lower in 2020 and starting to return to 2019 levels in 2021. For this study the average of all three years was used.

Table 4 – Ambient Noise Level Example

Site	Period	Statistics	L50	L90	L99
4	All Hours	Average	49.4	48.9	48.1
4	Day Only	Average	51.3	50.8	50.0
4	Night Only	Average	46.9	46.4	45.5
4	All Hours	Std Dev	4.2	4.2	4.3
4	Day Only	Std Dev	2.6	2.6	2.6
4	Night Only	Std Dev	4.6	4.6	4.7
4	All Hours	2x Std Dev	57.7	57.3	56.7
4	Day Only	2x Std Dev	56.4	56.0	55.3
4	Night Only	2x Std Dev	56.0	55.6	54.9
			2019	**2020**	**2021**
4	All Hours	Average L50	50.7	48.6	48.9
4	All Hours	Average L90	50.2	48.1	48.4

Source: SFO ANOMS as reported by BridgeNet, 2021

4. Measured Single Event Noise Levels. The ideal goal of setting the threshold is for it to be at least 10 dBA below the peak noise levels of aircraft events. The measured noise events for each of the sites was determined from the period of January 1st, 2019 through June 7th, 2021 for departures on Runways 28L/R which is the dominate operational mode affecting these sites. An example is shown in **Table 5** below. The data displayed on the top table shows the total number of measured events, the average Lmax, the average SEL and energy average SEL of the events for each category of jet aircraft. The long-haul aircraft category is the dominate category of aircraft, which includes wide-body aircraft typically traveling to Asia or Europe. As shown in the example below, the average Lmax is 82 dBA, so with a threshold of 65 dBA, most of these flights should result in a measurable noise event. Lowering the threshold further would have little change in measuring these events.

   In identifying the optimum threshold, it should capture not only the dominate aircraft events by heavy, large aircraft but also the newer generation quieter aircraft that are becoming more prominent. As an example, regional jets generate a lower noise level; the sample below shows an average peak noise level of 73 Lmax for this category of aircraft. The different types of regional jets are shown in the middle figure with the quieter regional jet, the CRJ2, that generates an average noise level of 70 Lmax. New generation jets like the Airbus A220 (BCS1) generate similar noise levels. Ideally, the threshold would be at least 10 dBA below the level of this aircraft, but this will not always be possible given that these aircraft are much quieter than the current dominate aircraft. The bottom part of the figure shows the total number of flights, the number of flights that cause a noise event, and the percent measured with the current threshold. The current thresholds do a good job measuring the dominate aircraft source but less so with the quieter aircraft.

Table 5 – Measured Single Event Noise Levels Example

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	24,841	82.4	91.7	93.2	
Wide	13,513	79.4	88.6	89.7	
Narrow	20,226	77.9	87.5	88.4	
Regional	6,036	73.0	82.3	83.7	
Business	9,748	72.2	80.8	82.5	
Total	**74,364**	**78.5**	**87.8**	**90.4**	**90.4**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
CRJ9	Regional	55	75.6	85.0	85.7	
E75L	Regional	4,073	74.3	83.9	84.7	
CRJ7	Regional	265	71.6	81.0	81.7	
BCS3	Regional	2	71.2	80.0	80.1	
BCS1	Regional	64	70.2	79.2	79.8	
CRJ2	Regional	1,577	69.9	78.6	79.4	
Total		**6,036**	**73.0**	**82.3**	**83.7**	**83.7**

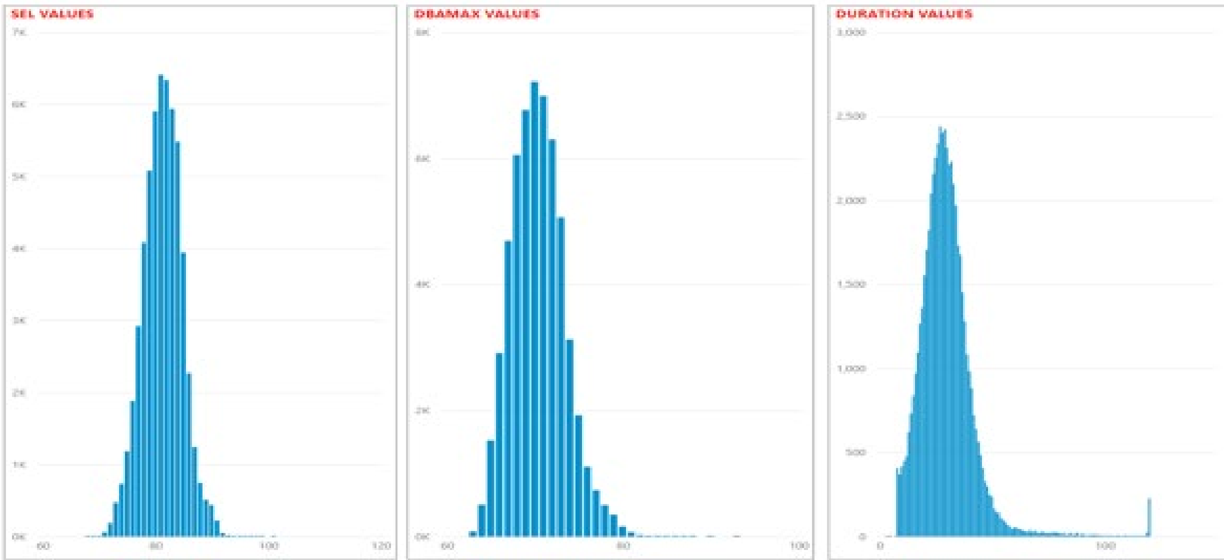
Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
4	Long Haul	24,463	24,841	100%
4	Regional Jets	7,254	6,936	96%
4	CRJ2 (Quiet RJ)	2,158	1,577	73%

Source: BridgeNet International, 2021

5. Noise Event Distribution. Part C of the figures in the Appendix shows the distribution of the measured noise events at each site for the period of January 1st, 2019 and June 7th, 2021, as shown in **Table 6** example. This data shows the measured SEL, Maximum Noise Level (dBA MAX) and Duration in seconds. This data shows events from departures on Runways 28L/R, which are the dominate source at these sites and for all correlated events.

   A number of different parameters can be determined from these graphs to help determine the optimum threshold setting. This includes if the threshold setting is cutting off events, long duration events and the optimum setting for other measurement parameters.

Table 6 – Noise Event Distribution Example



Source: BridgeNet International, 2021

5. NMT Sites

This section describes the physical attributes of each NMT, a brief history of the threshold level and the recommendation for a daytime and nighttime threshold level. Additional data for each NMT is show in **Appendix A**.

5.1 NMT Site 1

NMT Site 1 is west of the airport under the Gap departure flight path, located less than a mile from the end of Runway 10R. It is located near the intersection of 4th Ave and Walnut Ave. The dominant, non-aircraft noise source is from the nearby freeways; the L50 is 59 dBA with a two times standard deviation of 66 dBA. The site is located inside of the most recent 65 CNEL noise contour (1Q21); the default threshold for this NMT is 55 dBA, however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dBA. The recommendation is the leave the threshold at 65 dBA. Data for this site is presented in the Appendix in **Figure A-2 (Part A, B, C).**

The dominate aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 89 dBA and are fully captured with the current settings. The quieter regional jets are reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 73 dBA which are captured under the current settings. The threshold cannot be lowered more because there starts to become a larger and larger number of 120 second events that limit the ability of the system to accurately measure noise events during those time periods.

Given the high background noise at this site, it could not be lowered to 55 dBA or other lower levels and still accurately measure the aircraft CNEL noise levels.

Given it is not recommended to change the threshold, the site would report the same CNEL level and still measure within the 1.5 CNEL Title 21 measurement accuracy of the estimated aircraft noise CNEL (The 1.5 CNEL accuracy tested is based on the difference between the EVS measured CNEL at the recommended threshold and the EVS measured CNEL at the lowest threshold). The threshold setting for this site is recommended to remain the same because of the high background noise that exists at this location makes lowering the threshold not feasible.

5.2 NMT Site 4

NMT Site 4 is west of the airport under the Gap departure flight path, located approximately 1.8 miles from the end of Runway 10R. Data for this site is presented in the Appendix in **Figure A-3 (Part A, B, C)**. It is southwest of El Camino Real, near the intersection of Pinehurst Way and Brentwood Drive. Historically the site is within the 65 CNEL noise contour, but is currently outside of the most recent (1Q21) quarterly contour. The default threshold for this NMT is 55 dBA, however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The dominate aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 82 dBA and are fully captured with the current settings. The quieter regional jets that will be reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 70 dBA. Lower the threshold will capture a greater number of these aircraft.

While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 49 dBA with a two times standard deviation of 58 dBA.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum settings are: 62 dBA for daytime and 60 dBA for nighttime. Based on EVS estimates the site would report the same CNEL level and still measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL (The 1.5 CNEL accuracy tested is based on the difference between the EVS measured CNEL at the recommended threshold and the EVS measured CNEL at the lowest threshold). Optimally, lowering the threshold will improve the sites ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft, but the quieter aircraft that are going to be more common in the future.

5.3 NMT Site 5

This NMT is located in San Bruno, west of San Mateo Avenue near the intersection of Easton Avenue and Kains Avenue. Data for this site is presented in the Appendix in **Figure A-4 (Part A, B, C)**. Surrounding land uses include residential on all sides. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 52 dBA with a two times standard deviation of 61 dBA. Historically, the site is within the 65 CNEL noise contour but is currently outside of the recent (1Q21) quarterly contour. The default threshold for this NMT is 55 dBA, however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The dominate aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 81 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 69 dBA. Lowering the threshold will capture a greater number of these aircraft. The recommended threshold is only lowered slightly because the site has a higher ambient noise where lowering the threshold too much there becomes a larger number of 120 second events that limit the ability of the system to accurately measure noise events during those time periods.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is to lower the threshold to 63 dBA for daytime and 61 dBA for nighttime. Given the background noise, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

Based on EVS estimates, the site may potentially report approximately 0.1 to 0.5 dBA higher, but still measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL (The 1.5 CNEL accuracy tested is based on the difference between the EVS measured CNEL at the recommended threshold and the EVS measured CNEL at the lowest threshold). Lowering the threshold will improve the sites ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft but the quieter aircraft that are going to be more common in the future.

5.4 NMT Site 6

This NMT is located in South San Francisco on Hill Ave, between Southwood Drive and Fairway Drive. Data for this site is presented in the Appendix in **Figure A-5 (Part A, B, C)**. The site is surrounded by residential land uses and the Baden High School athletic field to the south. The primary non-aircraft noise source is from residential land uses, including vehicle traffic; the L50 is 47 dBA with a two times standard deviation of 56 dBA. Historically, the site is within the 65 CNEL noise contour, but is currently outside of the most recent (1Q21) quarterly contour. The default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The dominate aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 78 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 68 dBA. Lowering the threshold will capture a greater number of these quieter aircraft. The recommended threshold is a balance of a lower threshold to capture more quieter events while still minimizing the number of community noise events that would then be incorrectly correlated to an aircraft that happened to be nearby the site at the time of the community event.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is to lower the threshold to 62 dBA for daytime and 60 dBA for nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to. Given the anticipated noise levels of GAP aircraft that over, the 60 dBA is appropriate; using a lower threshold could potentially result in more false events. This is shown in the EVS data where the number of correlated events exceeds the number of GAP flights duration that time period.

Based on EVS estimates, the site may potentially report approximately 0.1 dBA higher, but still measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL (The 1.5 CNEL accuracy tested is based on the difference between the EVS measured CNEL at the recommended threshold and the EVS measured CNEL at the lowest threshold). Lowering the threshold will improve the sites ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft but the quieter aircraft that are going to be more common in the future.

5.5 NMT Site 14

This NMT is located in South San Francisco in a parking lot for Orange Memorial Park between W. Orange Avenue and 2nd Street. Data for this site is presented in the Appendix in **Figure A-6 (Part A, B, C)**. The site is surrounded by parkland to the north and residential land uses on all other sides. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 48 dBA with a two times standard deviation of 58 dBA. The site is historically and currently located outside of the 65 CNEL noise contour, located to the north edge of the contour; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA.

The NMT is located on the north of the extended runway centerline for Runway 28R. The dominate aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 78 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 68 dBA. Lowering the threshold will capture a greater number of these quieter aircraft. The recommend threshold is a balance of a lower threshold to capture more quieter events while still minimize the number of community noise events that would then be in correctly correlated to an aircraft that happened to be nearby the site at the time of the community event.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is to lower the threshold to 62 dBA for daytime and 60 dBA for nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions at the site.

Based on EVS estimates, the site may potentially report approximately 0.2 to 0.4 dBA higher, but still measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL (The 1.5 CNEL accuracy tested is based on the difference between the EVS measured CNEL at the recommended threshold and the EVS measured CNEL at the lowest threshold). Lowering the threshold will improve the sites ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft but the quieter aircraft that are going to be more common in the future.

5.6 NMT Site 16

This NMT is located in South San Francisco on the roof of St. Augustine Catholic Church complex. Data for this site is presented in the Appendix in **Figure A-7 (Parts A, B, C)**. The site is surrounded by residential land uses and a church. The primary non-aircraft noise source is from residential land uses, including vehicle traffic and the average ambient noise level L50 is 46 dBA with a two times standard deviation of 56 dBA. The site is historically and currently located outside of the 65 CNEL noise contour located to the south edge of the contour; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 63 dBA.

The NMT is located on the south side of the extended runway centerline for Runway 28L. The dominate aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the Gap. These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 73 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 67 dBA. Lowering the threshold will capture a greater number of these quieter aircraft. The recommend threshold is a balance of a lower threshold to capture more quieter events while still minimizing the number of community noise events that would then be incorrectly correlated to an aircraft that happened to be nearby the site at the time of the community event,

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is to lower the threshold to 62 dBA for daytime and 60 dBA for nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

Based on EVS estimates, the site may potentially report approximately 0.2 to 0.4 dBA higher, but still measure within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL (The 1.5 CNEL accuracy tested is based on the difference between the EVS measured CNEL at the recommended threshold and the EVS measured CNEL at the lowest threshold). Lowering the threshold will improve the site's ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft but the quieter aircraft that are going to be more common in the future.

5.7 NMT Site 17

This NMT is located in South San Francisco on the grounds of Grace Covenant Church at the intersection of Del Monte Ave and El Rancho Dr. Data for this site is presented in the Appendix in **Figure A-8 (Part A, B, C)**. The site is surrounded by Alta Loma Middle School to the northeast and residential land uses on all other sides. The primary non-aircraft noise source is from the church and residential activities, including vehicle traffic and the average ambient noise level L50 is 48 dBA with a two times standard deviation of 58 dBA. The site is historically and currently located outside of the 65 CNEL noise contour located to the north edge of the contour; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 63 dBA.

The NMT is located to the north of the extended runway centerline for Runway 28R. The dominate aircraft noise is from long haul aircraft departing on Runways 28L/R flying through the GAP.

These aircraft are typically the largest and loudest that operate at SFO, often at night, flying to destinations in Asia and Europe. They generate an average Lmax of 72 dBA and are fully captured with the current settings. The quieter regional jets reflective of a number of the new generation aircraft operating at the airport in the future generate an average Lmax of 69 dBA. Lowering the threshold will capture a greater number of these quieter aircraft. The recommended threshold is a balance of a lower threshold to capture more quieter events while still minimize the number of community noise events that would then be in correctly correlated to an aircraft that happened to be nearby the site at the time of the community event.

Based upon a review of the evaluation data in Section 4.3, the recommended optimum setting is to lower the threshold to 62 dBA for daytime and 60 dBA for nighttime. While the background noise at this site is relatively low, the threshold could not be lowered down to 55 dBA and still accurately measure the aircraft CNEL noise levels under the range of acoustic conditions the site is exposed to.

Based on EVS estimates, the site may potentially report approximately 0.2 to 0.5 dBA higher, but still measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL (The 1.5 CNEL accuracy tested is based on the difference between the EVS measured CNEL at the recommended threshold and the EVS measured CNEL at the lowest threshold). Lowering the threshold will improve the site's ability to correctly measure and correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft but the quieter aircraft that are going to be more common in the future.

5.8 Global Settings

There are a number of additional setting other than the threshold that were reviewed for potential changes, which would be applied to all the NMTs. These settings and any recommendations are described below.

Minimum Duration: At each of the NMTs, the settings include a "minimum duration" which is the time, in seconds, an event must last before it is recorded in the NMT as an event. This current time is 6 to 8 seconds, which is typical of noise monitoring system settings and it is recommended to keep the current settings. Aircraft noise events are typically longer duration than community events because the noise source (aircraft) is further away and takes longer to rise and drop off. Lowering this setting generally results in the generation of more short duration community events that can be incorrectly associated with an aircraft.

Maximum Duration: The maximum duration setting is the maximum time, in seconds, an event can last before it is stopped, and an event is created. Currently that time is 120 seconds at all the NMTs; it is recommended to reduce that time duration to 60 seconds because the vast majority of aircraft events are 20 to 40 seconds in duration. The long duration events occur when the ambient noise exceeds the threshold and a continuous event is generated.

End Duration: The end duration setting is the minimum time between events when the event drops below the threshold and then rises back up. If it is 5 seconds or less, those events are merged as the system assumes it is the same aircraft. If it is greater than 5 seconds, they are considered separate events. It is recommended to keep this setting the same. As aircraft fly past the monitor, these noise events can drop off with variability in the duration and time. This setting allows for the full noise of the event to be captured.

6. Summary and Recommendations

Based on the analysis presented in Section 5, **Table 7** shows the recommended NMT thresholds and event detection for NMTs 1, 4, 5, 6, 14, 16, and 17. All NMTs studied in this report are recommended to continue to be used for Title 21 threshold correlation of aircraft noise that meet the requirements of Title 21, Section 5070 (i.e., measure aircraft noise within an accuracy of 1.5 CNEL. The recommended thresholds in this report are predicted to result in some small changes to the measured CNEL and will more accurately correlate aircraft events to the associated noise of lower noise level events. These recommendations will ensure the NMTs are capturing more of the quieter aircraft events; the NMTs will continue to capture the louder events, which contribute more greatly to the shape and size of the noise contours. The maximum noise level from the events is trending downward; an example of this is shown in **Figure A-9** for Site 1, representing the Lmax at that NMT. Lowering the threshold will help capture more of these quieter events both now and in the future.

Table 7 – Recommended NMT Thresholds and Duration

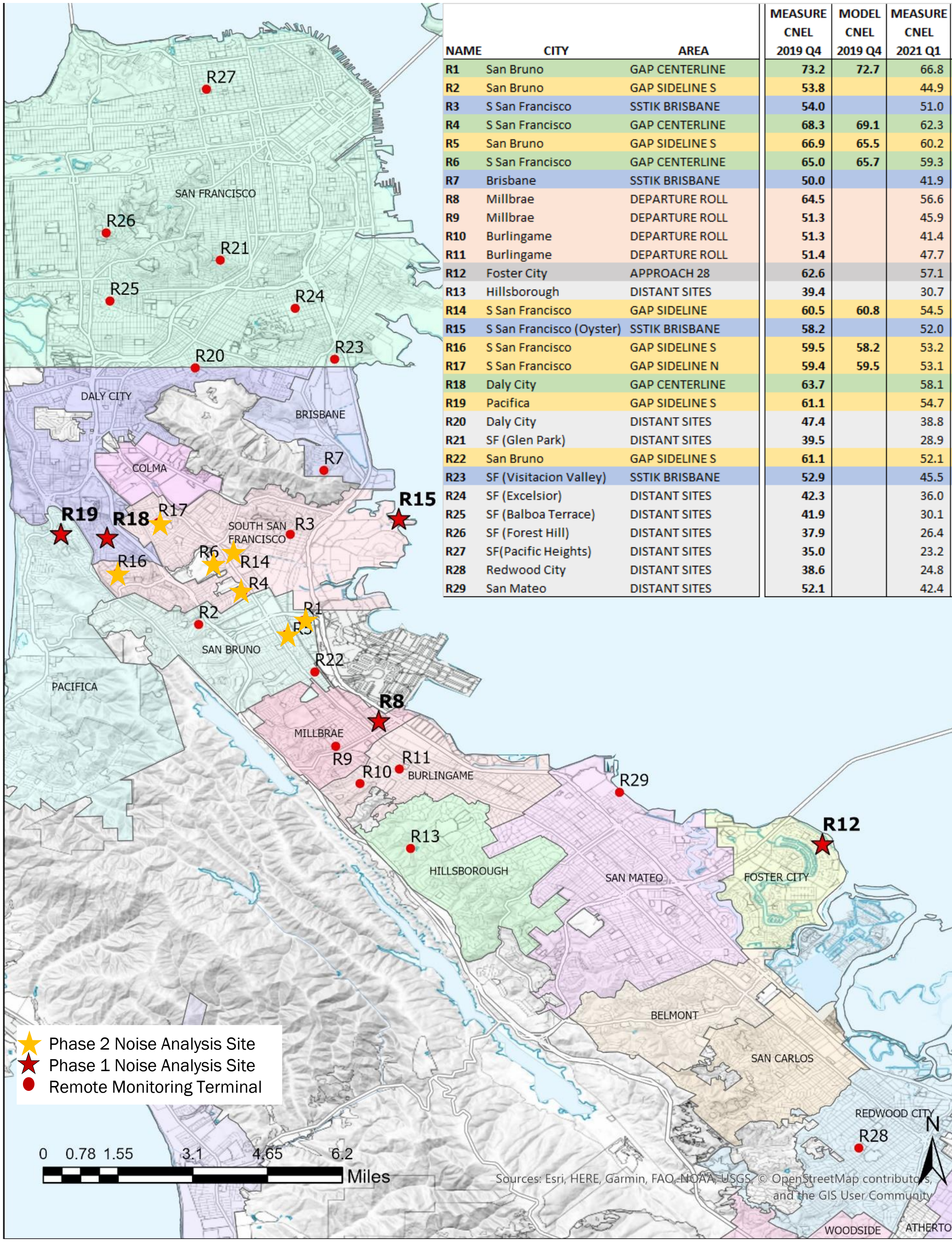
NMT	City	Location	Current NMT Threshold, CNEL	Recommended NMT Threshold, CNEL DAY	Recommended NMT Threshold, CNEL NIGHT	Recommended NMT Maximum Duration, Seconds
1	San Bruno	Gap departure along centerline	65	65	65	60
4	South San Francisco	Gap departure along centerline	64	62	60	60
5	San Bruno	Gap departure left of centerline	64	63	61	60
6	South San Francisco	Gap departure along centerline	64	62	60	60
14	South San Francisco	Gap departure right of centerline	64	62	60	60
16	South San Francisco	Gap departure right of centerline	63	62	60	60
17	South San Francisco	Gap departure along centerline	63	62	60	60

Source: BridgeNet International, 2021

APPENDIX
Report Figures

Figure A-1
Noise Monitor Terminals Site Map

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS



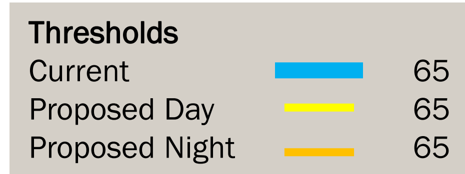
NAME	CITY	AREA	MEASURE CNEL 2019 Q4	MODEL CNEL 2019 Q4	MEASURE CNEL 2021 Q1	Threshold Study
R1	San Bruno	GAP CENTERLINE	73.2	72.7	66.8	Phase 2
R2	San Bruno	GAP SIDELINE S	53.8		44.9	
R3	S San Francisco	SSTIK BRISBANE	54.0		51.0	
R4	S San Francisco	GAP CENTERLINE	68.3	69.1	62.3	Phase 2
R5	San Bruno	GAP SIDELINE S	66.9	65.5	60.2	Phase 2
R6	S San Francisco	GAP CENTERLINE	65.0	65.7	59.3	Phase 2
R7	Brisbane	SSTIK BRISBANE	50.0		41.9	
R8	Millbrae	DEPARTURE ROLL	64.5		56.6	Phase 1
R9	Millbrae	DEPARTURE ROLL	51.3		45.9	
R10	Burlingame	DEPARTURE ROLL	51.3		41.4	
R11	Burlingame	DEPARTURE ROLL	51.4		47.7	
R12	Foster City	APPROACH 28	62.6		57.1	Phase 1
R13	Hillsborough	DISTANT SITES	39.4		30.7	
R14	S San Francisco	GAP SIDELINE	60.5	60.8	54.5	Phase 2
R15	S San Francisco (Oyster)	SSTIK BRISBANE	58.2		52.0	Phase 1
R16	S San Francisco	GAP SIDELINE S	59.5	58.2	53.2	Phase 2
R17	S San Francisco	GAP SIDELINE N	59.4	59.5	53.1	Phase 2
R18	Daly City	GAP CENTERLINE	63.7		58.1	Phase 1
R19	Pacifica	GAP SIDELINE S	61.1		54.7	Phase 1
R20	Daly City	DISTANT SITES	47.4		38.8	
R21	SF (Glen Park)	DISTANT SITES	39.5		28.9	
R22	San Bruno	GAP SIDELINE S	61.1		52.1	
R23	SF (Visitacion Valley)	SSTIK BRISBANE	52.9		45.5	
R24	SF (Excelsior)	DISTANT SITES	42.3		36.0	
R25	SF (Balboa Terrace)	DISTANT SITES	41.9		30.1	
R26	SF (Forest Hill)	DISTANT SITES	37.9		26.4	
R27	SF(Pacific Heights)	DISTANT SITES	35.0		23.2	
R28	Redwood City	DISTANT SITES	38.6		24.8	
R29	San Mateo	DISTANT SITES	52.1		42.4	

Source: BridgeNet International 2021

Figure A-2 Part A

Sample Time History Plot (Site 1 - San Bruno)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)



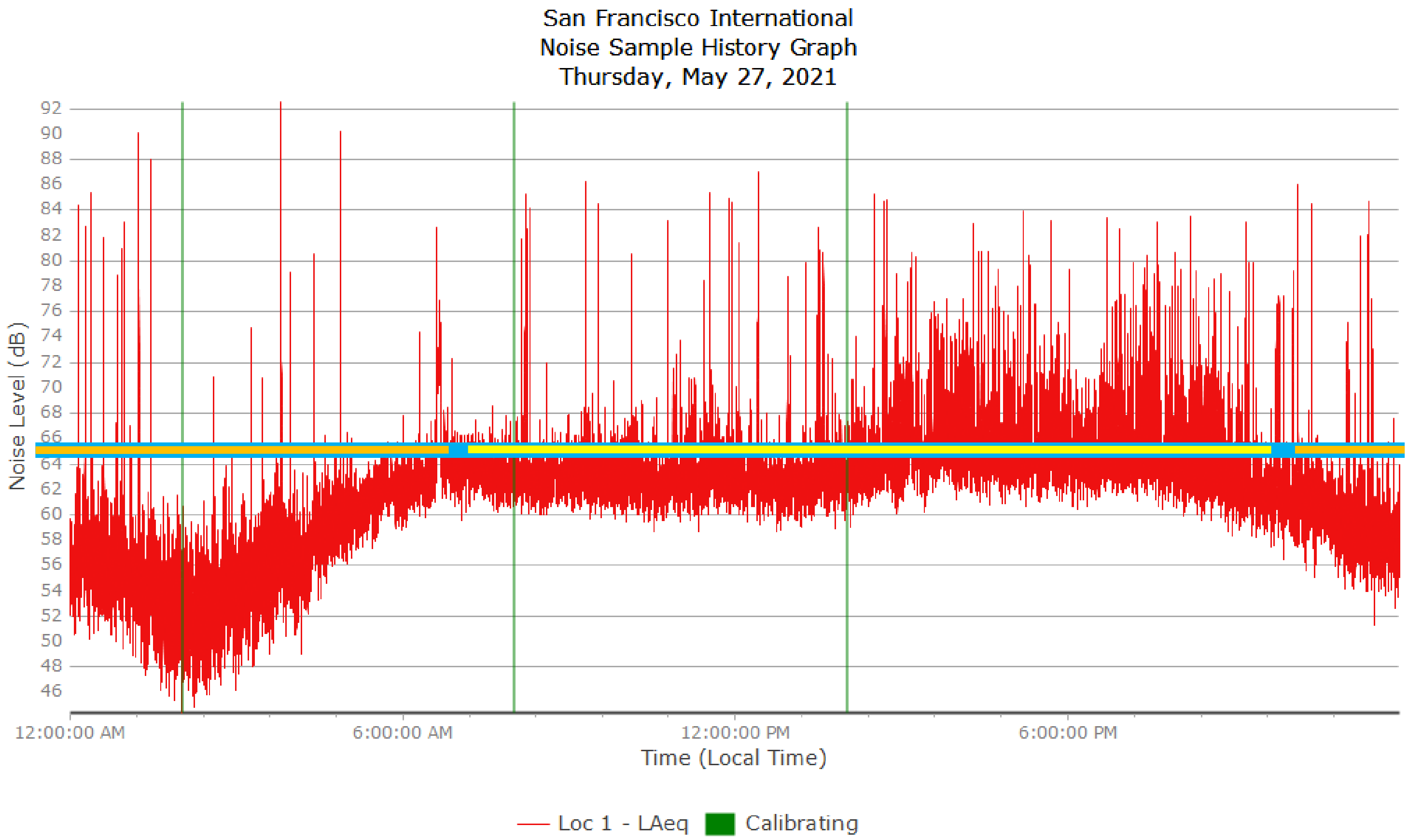


Figure A-2 Part B
Supporting Measured Analytical Data (Site 1 - San Bruno)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	59	60	61	62	63	64	65	66	67
1	Number of events	10231	10201	10180	10037	9724	7985	5388	3568	2640
1	Duration 120 sec	8331	7647	6567	5030	3116	1547	732	343	112
1	Correlated events	7122	7066	7097	6952	6548	5176	3552	2557	2076
1	CNEL	73.7	73.6	73.6	73.5	73.4	73.2	73	72.9	72.8
1	Uncorrelated dB	0.83	0.8	0.77	0.75	0.74	0.77	0.79	0.86	0.89

Measured Single Event Noise Levels

Departures 28L/28R Jan 1st, 2019 – Jun 7th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	24,854	89.3	96.6	97.9	
Wide	14,027	85.4	92.8	94.1	
Narrow	22,079	82.3	90.9	92.1	
Business	11,999	77.3	85.9	87.2	
Regional	7,179	76.1	85.6	87.1	
Total	**80,138**	**83.7**	**91.8**	**94.6**	**94.6**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
CRJ9	Regional	64	78.5	87.8	88.8	
E75L	Regional	4,820	77.4	86.9	88.0	
CRJ7	Regional	365	75.3	85.0	86.0	
BCS1	Regional	97	73.3	82.9	83.7	
CRJ2	Regional	1,821	73.0	82.6	83.5	
BCS3	Regional	12	71.7	82.3	83.3	
Total		**7,179**	**76.1**	**85.6**	**87.1**	**87.1**

Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
1	Long Haul	24,464	24,854	100%
1	Regional Jets	9,049	7,179	79%
1	CRJ2 (Quiet RJ)	2,801	1,821	65%

Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

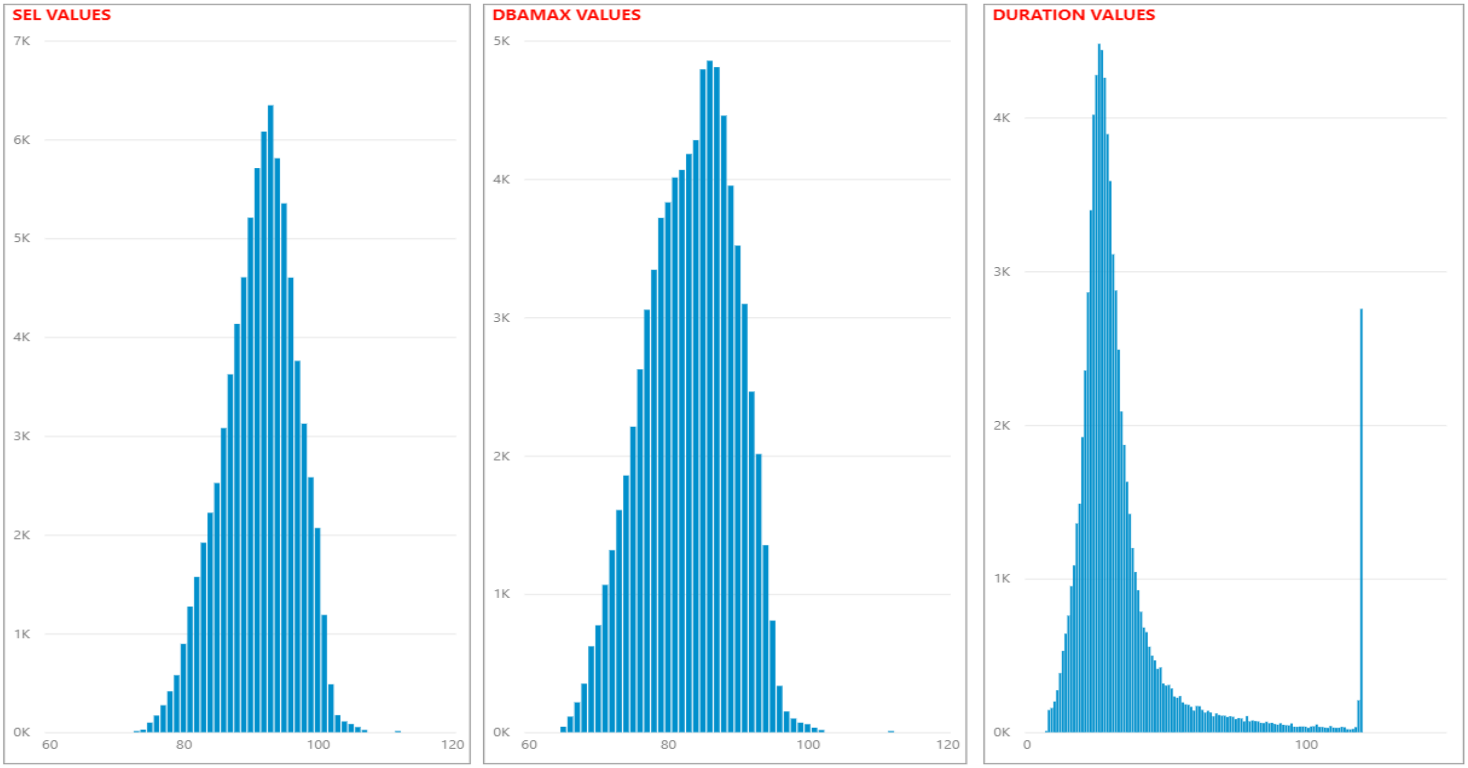
Site	Period	Statistics	L50	L90	L99
1	All Hours	Average	58.7	58.2	57.3
1	Day Only	Average	60.5	60.1	59.4
1	Night Only	Average	56.2	55.6	54.4
1	All Hours	Std Dev	4.0	4.2	4.5
1	Day Only	Std Dev	2.1	2.2	2.3
1	Night Only	Std Dev	4.6	4.8	5.2
1	All Hours	2x Std Dev	66.7	66.6	66.3
1	Day Only	2x Std Dev	64.8	64.4	63.9
1	Night Only	2x Std Dev	65.5	65.2	64.8
			2019	**2020**	**2021**
1	All Hours	Average L50	59.9	57.9	58.4
1	All Hours	Average L90	59.4	57.4	57.8

Source: BridgeNet International 2021

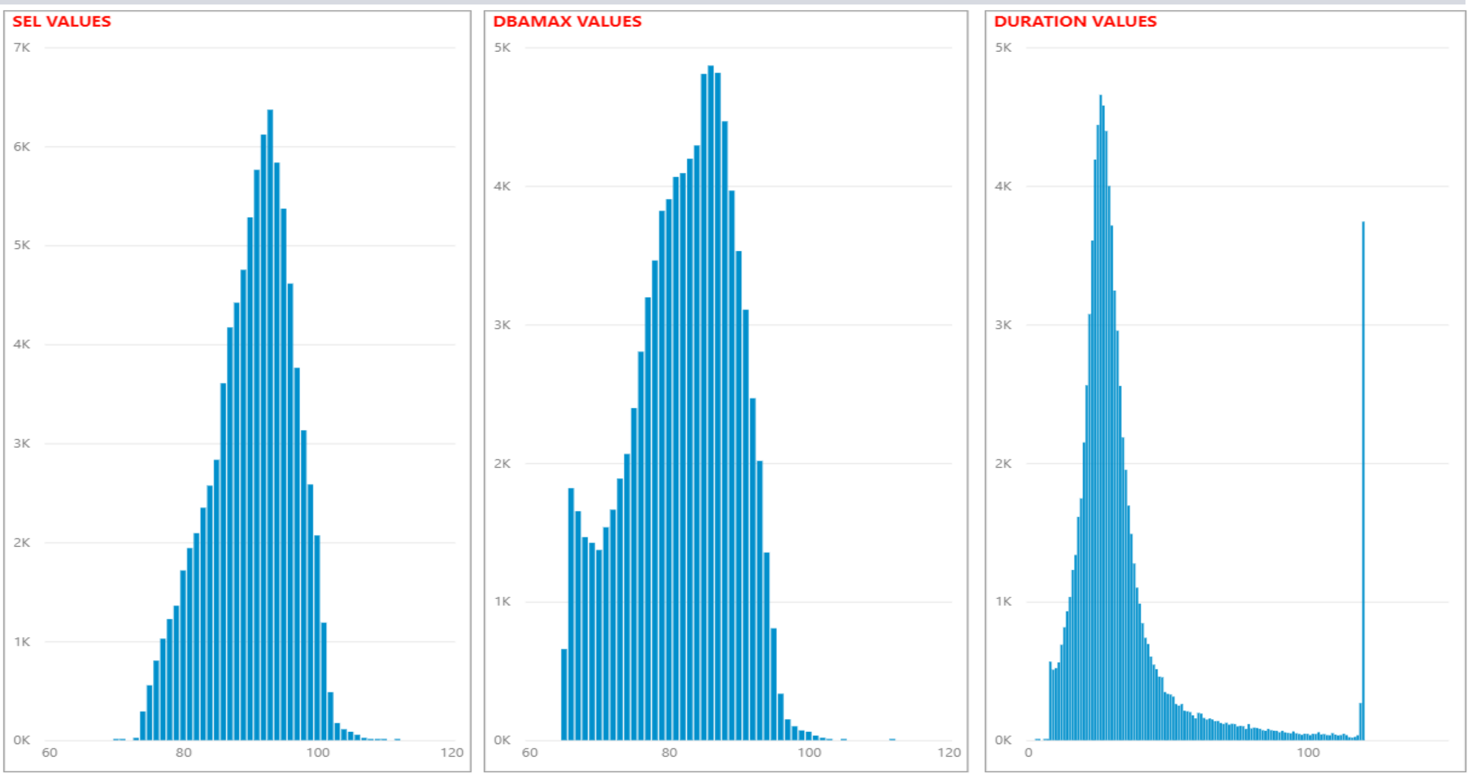
Figure A-2 Part C
Supporting Measured Analytical Data (Site 1 – San Bruno)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Measured Single Event Noise Levels *Departures 28L/28R* *Jan 1st, 2019 – Jun 7th, 2021*



Measured Single Event Noise Levels *ALL OPERATIONS* *Jan 1st, 2019 – Jun 7th, 2021*



Source: BridgeNet International 2021

Figure A-3 Part A

Sample Time History Plot (Site 4 – So. San Francisco)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current		64
Proposed Day		62
Proposed Night		60

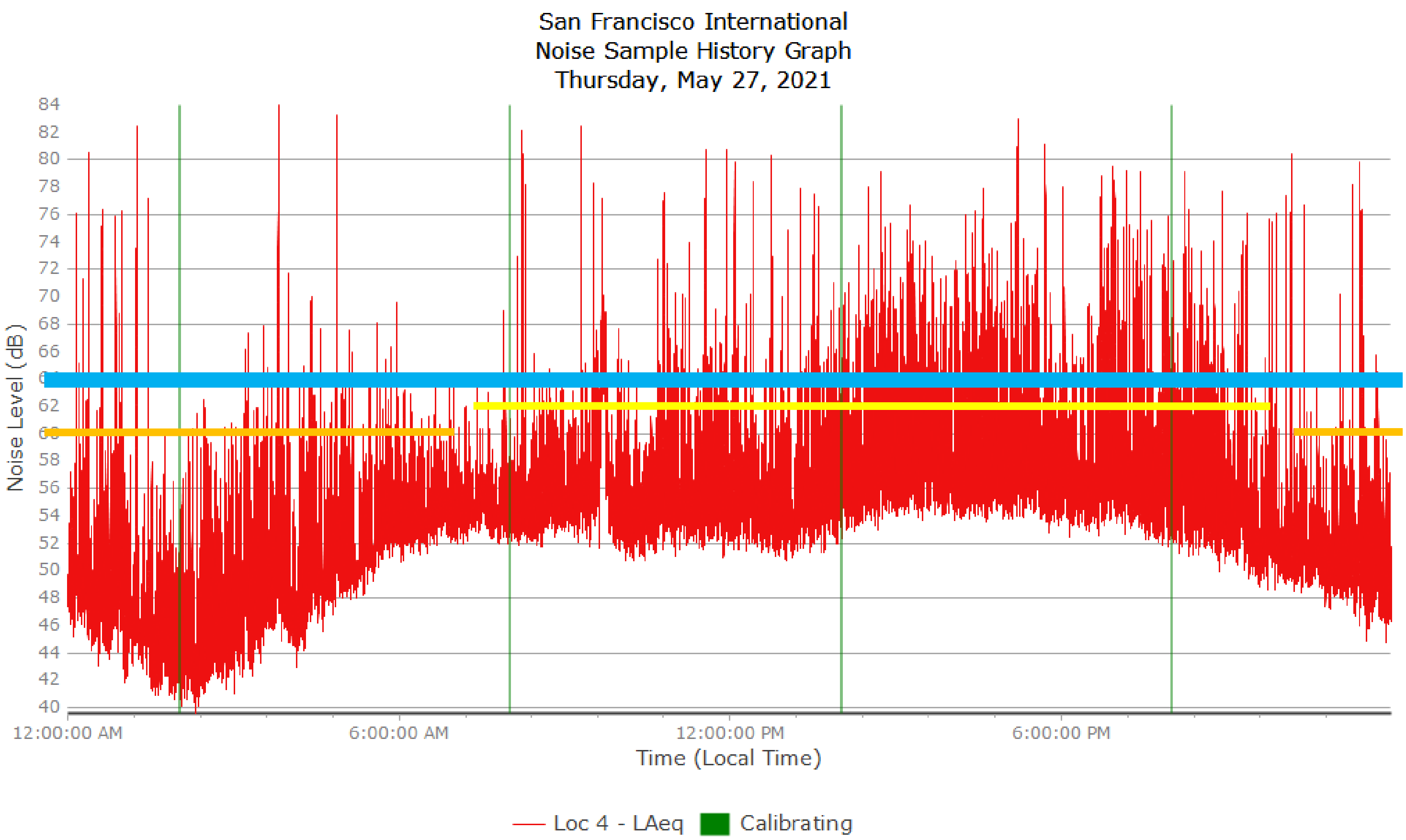


Figure A-3 Part B
Supporting Measured Analytical Data (Site 4 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	58	59	60	61	62	63	64	65	66
4	Number of events	4776	3810	3070	2580	2237	2079	1947	1821	1718
4	Duration 120 sec	188	65	23	10	9	6	5	5	3
4	Correlated events	2592	2367	2176	2007	1870	1791	1721	1654	1601
4	CNEL	67.8	67.8	67.8	67.7	67.7	67.7	67.7	67.7	67.6
4	Uncorrelated dB	0.21	0.21	0.21	0.21	0.22	0.23	0.24	0.26	0.28

Measured Single Event Noise Levels

Departures 28L/28R Jan 1st, 2019 – Jun 7th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	24,841	82.4	91.7	93.2	
Wide	13,513	79.4	88.6	89.7	
Narrow	20,226	77.9	87.5	88.4	
Regional	6,036	73.0	82.3	83.7	
Business	9,748	72.2	80.8	82.5	
Total	**74,364**	**78.5**	**87.8**	**90.4**	**90.4**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
CRJ9	Regional	55	75.6	85.0	85.7	
E75L	Regional	4,073	74.3	83.9	84.7	
CRJ7	Regional	265	71.6	81.0	81.7	
BCS3	Regional	2	71.2	80.0	80.1	
BCS1	Regional	64	70.2	79.2	79.8	
CRJ2	Regional	1,577	69.9	78.6	79.4	
Total		**6,036**	**73.0**	**82.3**	**83.7**	**83.7**

Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
4	Long Haul	24,463	24,841	100%
4	Regional Jets	7,254	6,936	96%
4	CRJ2 (Quiet RJ)	2,158	1,577	73%

Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

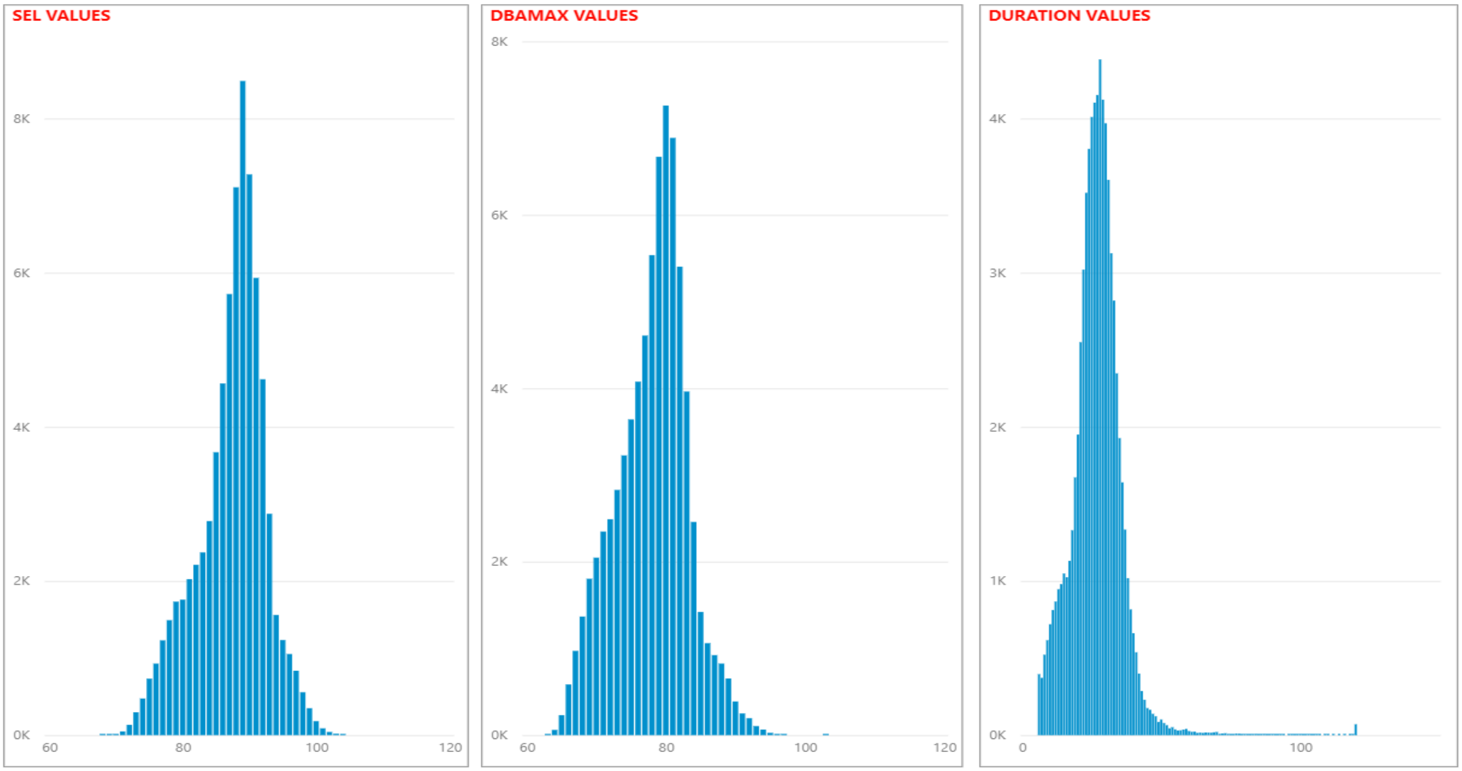
Site	Period	Statistics	L50	L90	L99
4	All Hours	Average	49.4	48.9	48.1
4	Day Only	Average	51.3	50.8	50.0
4	Night Only	Average	46.9	46.4	45.5
4	All Hours	Std Dev	4.2	4.2	4.3
4	Day Only	Std Dev	2.6	2.6	2.6
4	Night Only	Std Dev	4.6	4.6	4.7
4	All Hours	2x Std Dev	57.7	57.3	56.7
4	Day Only	2x Std Dev	56.4	56.0	55.3
4	Night Only	2x Std Dev	56.0	55.6	54.9
			2019	**2020**	**2021**
4	All Hours	Average L50	50.7	48.6	48.9
4	All Hours	Average L90	50.2	48.1	48.4

Source: BridgeNet International 2021

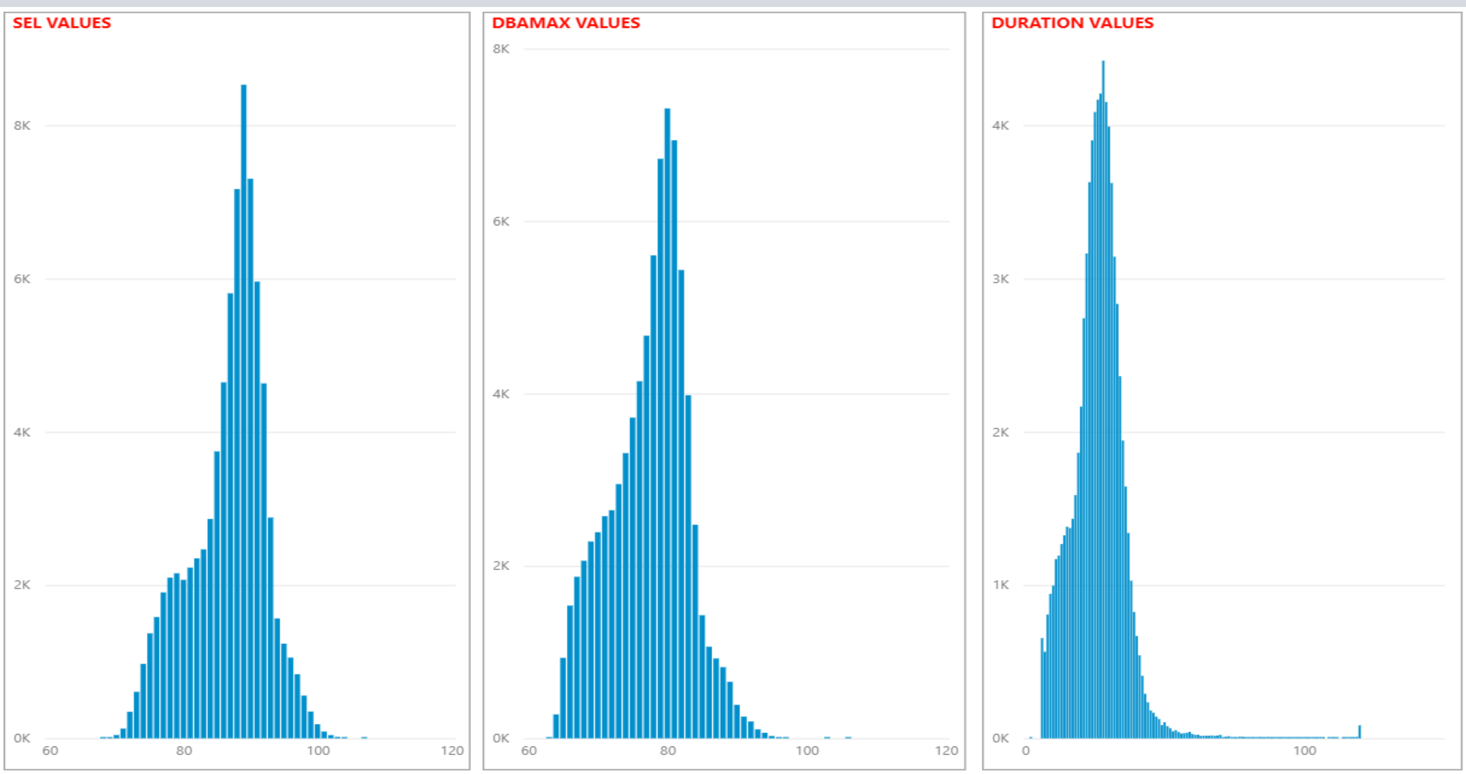
Figure A-3 Part C
Supporting Measured Analytical Data (Site 4 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Measured Single Event Noise Levels *Departures 28L/28R* *Jan 1st, 2019 – Jun 7th, 2021*



Measured Single Event Noise Levels *ALL OPERATIONS* *Jan 1st, 2019 – Jun 7th, 2021*



Source: BridgeNet International 2021

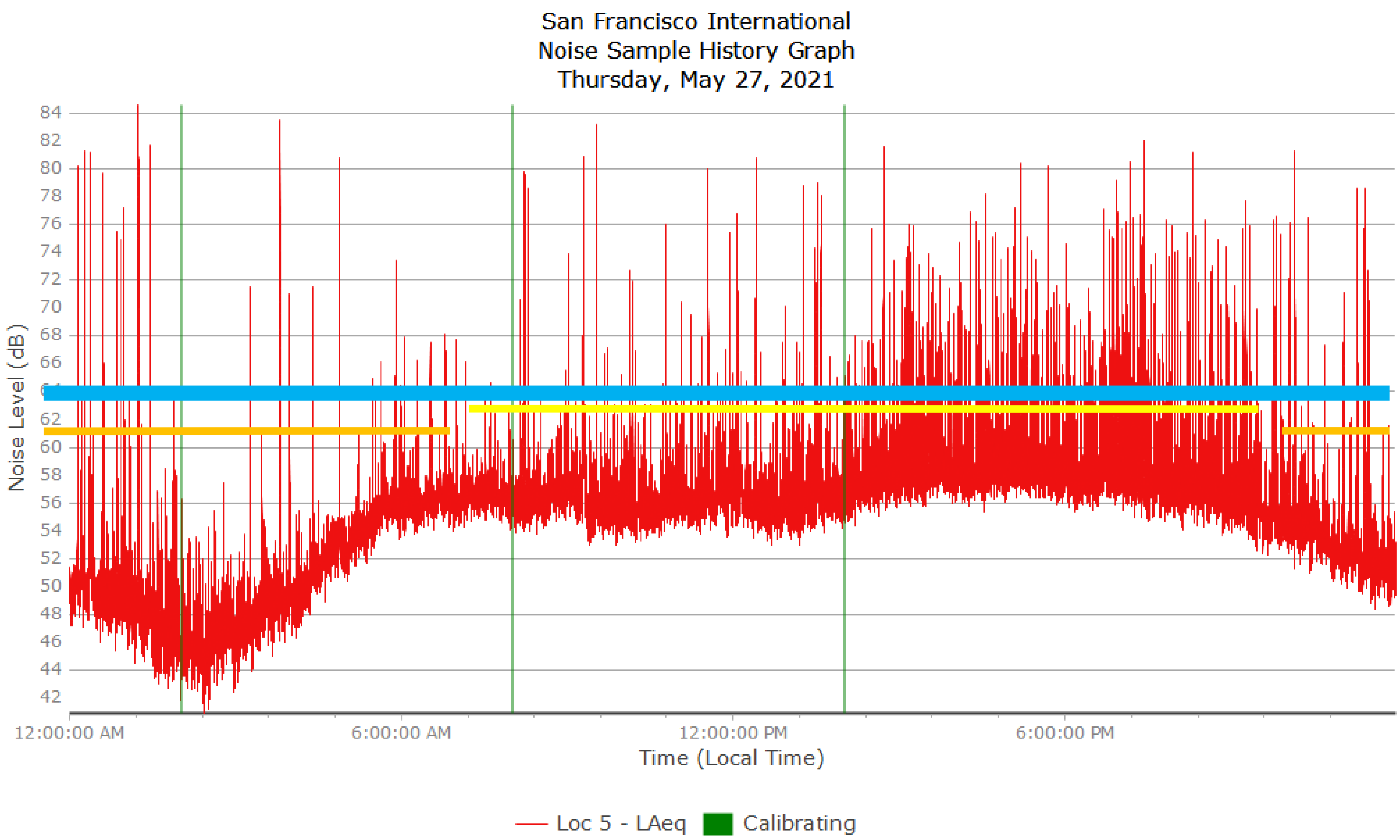
Figure A-4 Part A

Sample Time History Plot (Site 5 - San Bruno)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Thresholds		
Current		64
Proposed Day		63
Proposed Night		61



Source: BridgeNet International 2021

Figure A-4 Part B
Supporting Measured Analytical Data (Site 5 – San Bruno)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

Monitor	Metric	58	59	60	61	62	63	64	65	66
5	Number of events	8243	7081	5945	4887	4018	3322	2721	2205	1782
5	Duration 120 sec	2388	1642	1065	693	431	225	75	18	3
5	Correlated events	5063	4521	3899	3319	2841	2418	2052	1763	1543
5	CNEL	67.8	67.7	67.5	67.4	67.2	67	66.9	66.8	66.7
5	Uncorrelated dB	1.24	1.28	1.41	1.54	1.67	1.81	1.92	2	2.12

Measured Single Event Noise Levels
Departures 28L/28R Jan 1st, 2019 – Jun 7th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	24,915	81.2	90.5	91.5	
Wide	14,073	76.9	86.4	87.7	
Narrow	24,259	76.2	85.7	86.7	
Regional	5,661	73.2	82.4	83.6	
Business	8,104	70.5	79.0	80.3	
Total	**77,012**	**77.1**	**86.4**	**88.7**	**88.7**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
E75L	Regional	4,258	74.5	83.9	84.5	
BCS3	Regional	3	71.7	80.5	80.6	
CRJ7	Regional	285	71.6	80.5	81.3	
CRJ9	Regional	106	71.2	80.2	81.3	
BCS1	Regional	71	70.4	79.0	79.4	
CRJ2	Regional	938	68.5	76.9	77.9	
Total		**5,661**	**73.2**	**82.4**	**83.6**	**83.6**

Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
5	Long Haul	24,464	24,915	100%
5	Regional Jets	9,005	5,661	63%
5	CRJ2 (Quiet RJ)	2,788	938	34%

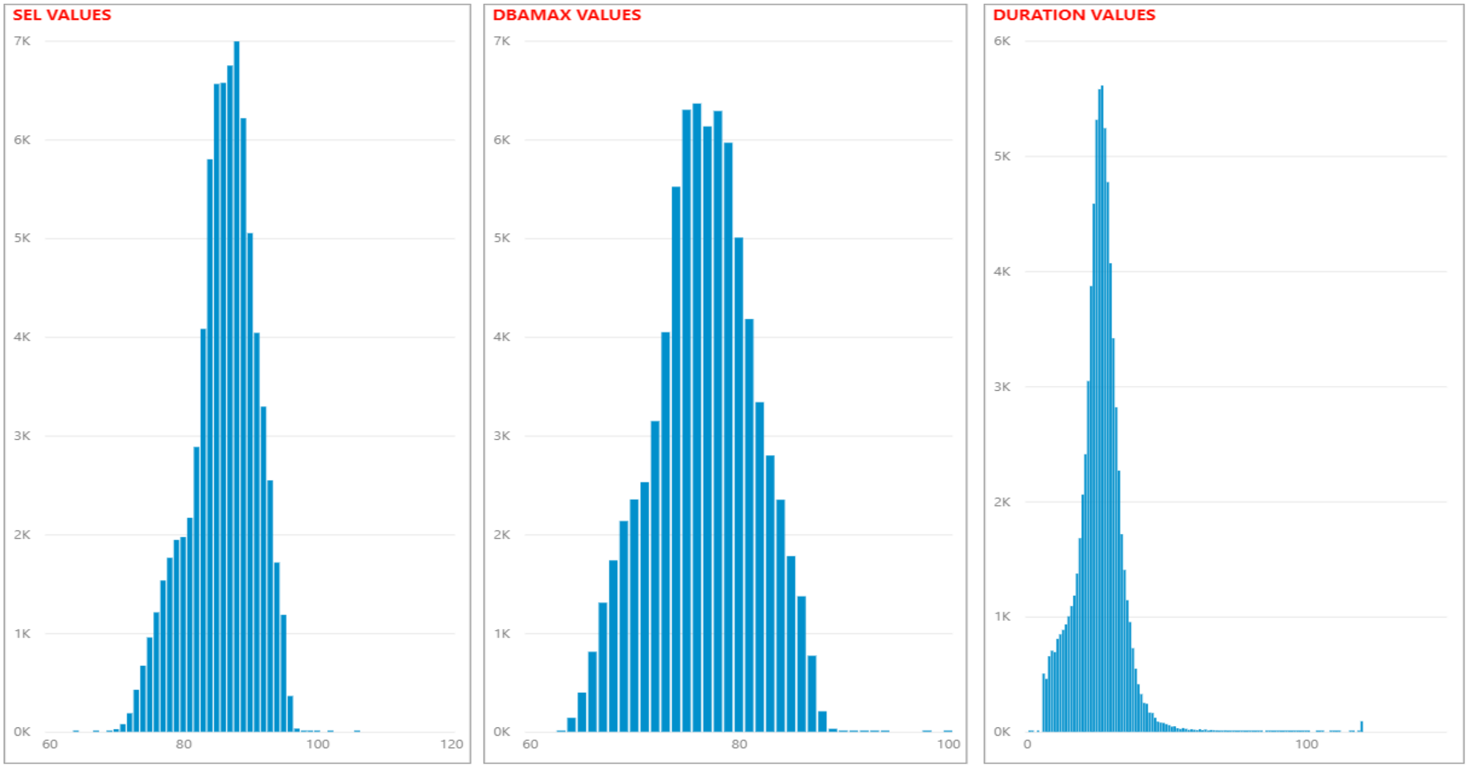
Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

Site	Period	Statistics	L50	L90	L99
5	All Hours	Average	51.8	51.4	50.6
5	Day Only	Average	53.2	52.8	52.1
5	Night Only	Average	49.8	49.3	48.4
5	All Hours	Std Dev	4.3	4.4	4.5
5	Day Only	Std Dev	2.8	2.9	2.9
5	Night Only	Std Dev	5.2	5.3	5.3
5	All Hours	2x Std Dev	60.5	60.2	59.6
5	Day Only	2x Std Dev	58.9	58.5	58.0
5	Night Only	2x Std Dev	60.3	59.9	59.1
			2019	**2020**	**2021**
5	All Hours	Average L50	53.0	51.0	51.4
5	All Hours	Average L90	52.5	50.5	51.0

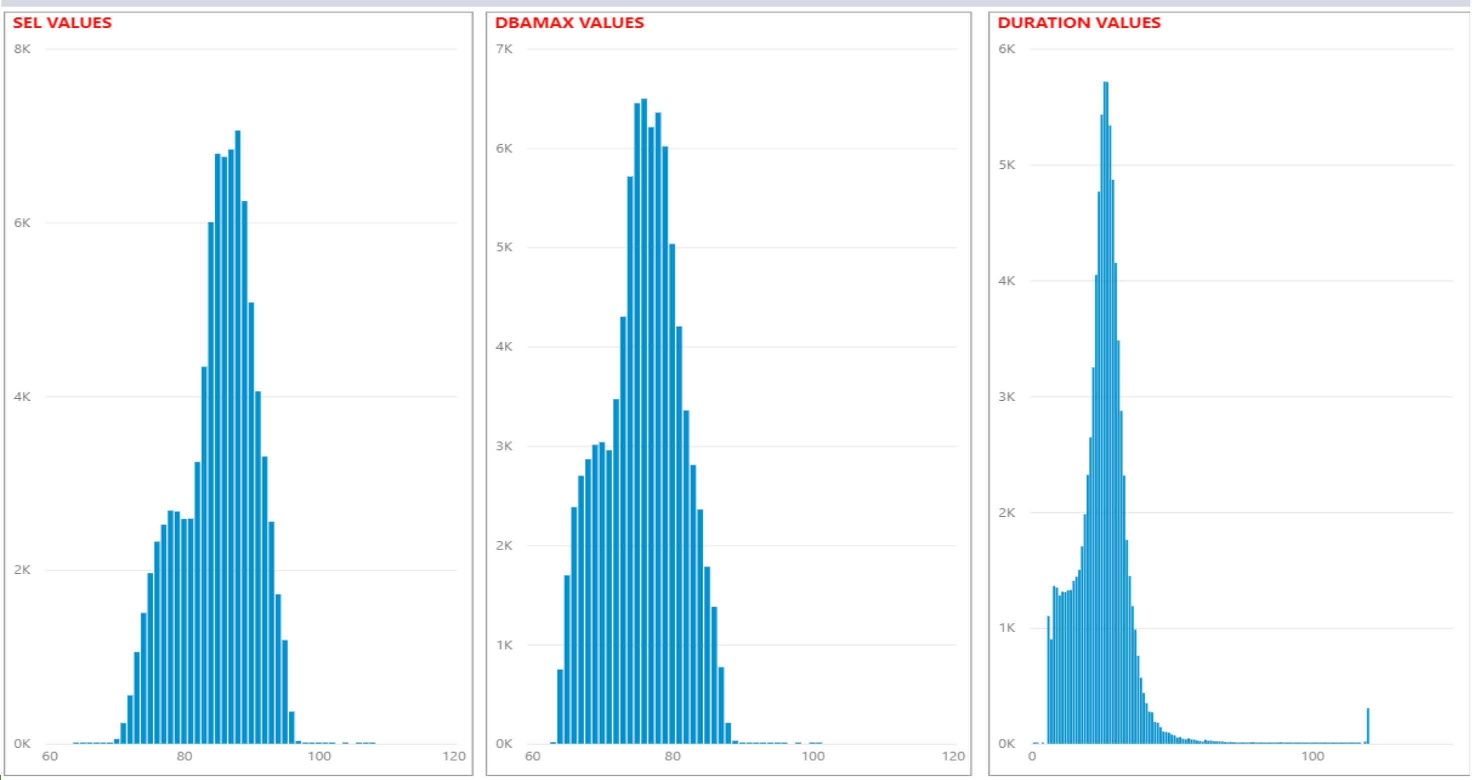
Figure A-4 Part C
Supporting Measured Analytical Data (Site 5 – San Bruno)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Measured Single Event Noise Levels *Departures 28L/28R* *Jan 1st, 2019 – Jun 7th, 2021*



Measured Single Event Noise Levels *ALL OPERATIONS* *Jan 1st, 2019 – Jun 7th, 2021*



Source: BridgeNet International 2021

Figure A-5 Part A

Sample Time History Plot (Site 6 – So. San Francisco)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds	
Current	64
Proposed Day	62
Proposed Night	60

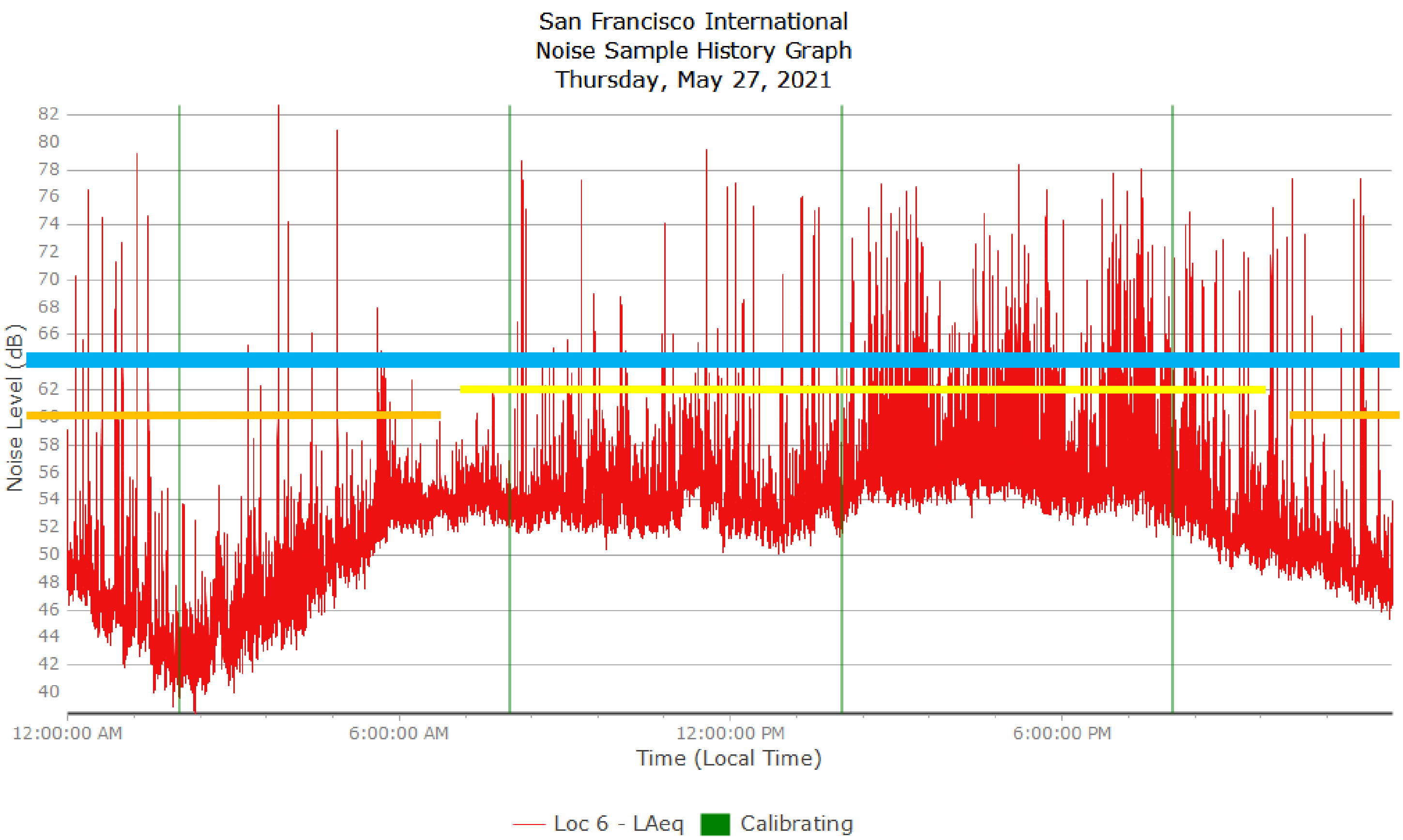


Figure A-5 Part B
Supporting Measured Analytical Data (Site 6 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

Monitor	Metric	58	59	60	61	62	63	64	65	66
6	Number of events	3045	2746	2446	2216	2032	1883	1738	1611	1517
6	Duration 120 sec	19	8	3	1	0	0	0	0	0
6	Correlated events	2348	2209	2059	1930	1825	1736	1639	1555	1486
6	CNEL	65	64.9	64.9	64.9	64.9	64.8	64.8	64.8	64.7
6	Uncorrelated dB	0.18	0.19	0.21	0.22	0.24	0.26	0.29	0.34	0.38

Measured Single Event Noise Levels
Departures 28L/28R Jan 1st, 2019 – Jun 7th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	24,483	78.7	88.8	90.1	
Wide	13,022	75.7	85.6	86.6	
Narrow	18,922	75.7	85.7	86.4	
Regional	4,679	71.9	81.0	82.4	
Business	6,724	70.5	79.2	80.8	
Total	**67,830**	**76.0**	**85.8**	**87.8**	**87.8**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
E75L	Regional	3,657	72.8	82.2	83.1	
CRJ9	Regional	48	72.5	81.8	82.5	
CRJ7	Regional	172	69.1	77.8	78.3	
BCS3	Regional	1	68.2	77.4	77.4	
BCS1	Regional	37	68.5	76.7	77.2	
CRJ2	Regional	764	67.9	76.2	77.1	
Total		**4,679**	**71.9**	**81.0**	**82.4**	**82.4**

Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
6	Long Haul	24,436	24,483	100%
6	Regional Jets	6,215	4,679	75%
6	CRJ2 (Quiet RJ)	1,833	764	42%

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

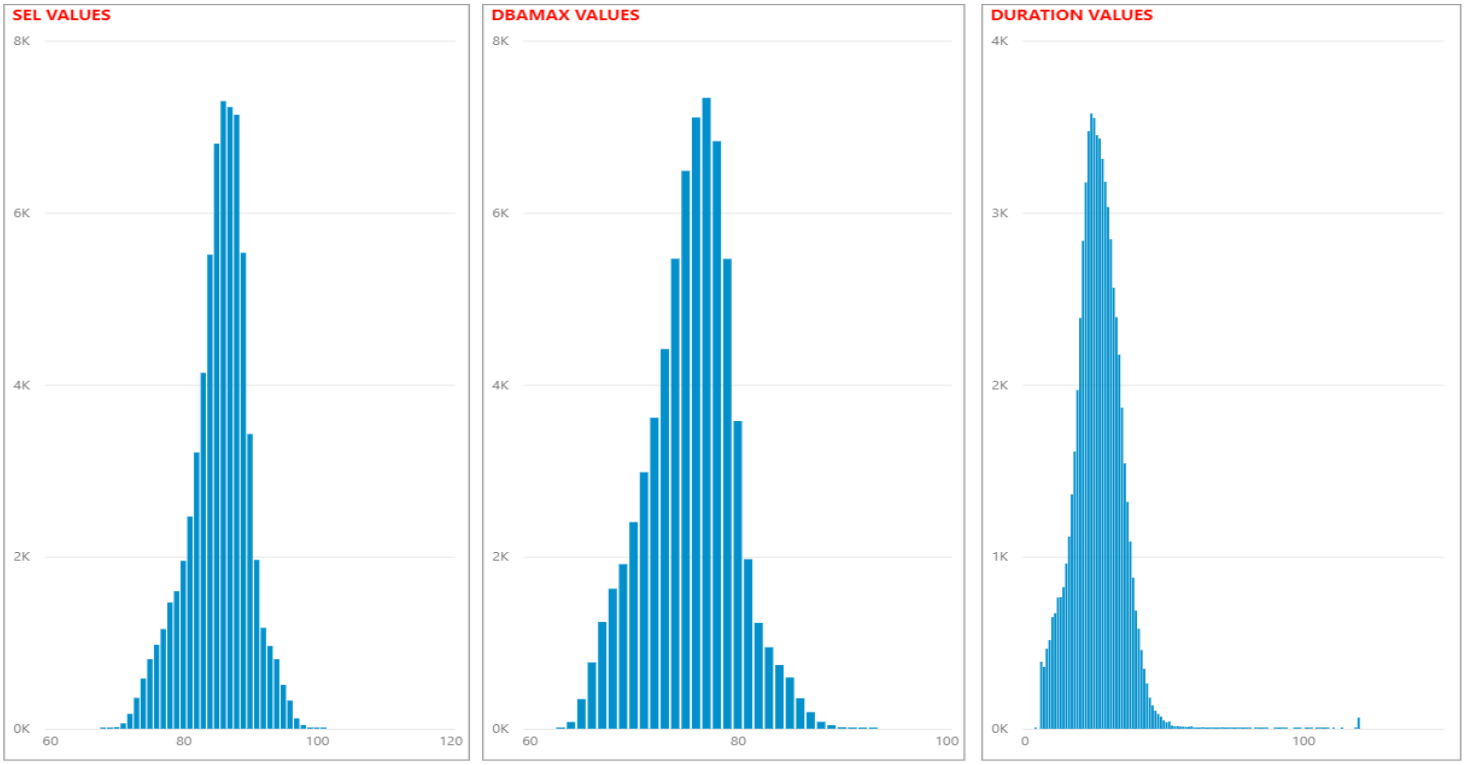
Site	Period	Statistics	L50	L90	L99
6	All Hours	Average	46.7	46.2	45.5
6	Day Only	Average	48.7	48.2	47.5
6	Night Only	Average	43.9	43.4	42.6
6	All Hours	Std Dev	4.5	4.6	4.7
6	Day Only	Std Dev	3.5	3.6	3.6
6	Night Only	Std Dev	4.4	4.4	4.5
6	All Hours	2x Std Dev	55.8	55.4	54.9
6	Day Only	2x Std Dev	55.7	55.3	54.8
6	Night Only	2x Std Dev	52.7	52.3	51.6
			2019	2020	2021
6	All Hours	Average L50	47.6	46.0	46.7
6	All Hours	Average L90	47.2	45.5	46.2

Source: BridgeNet International 2021

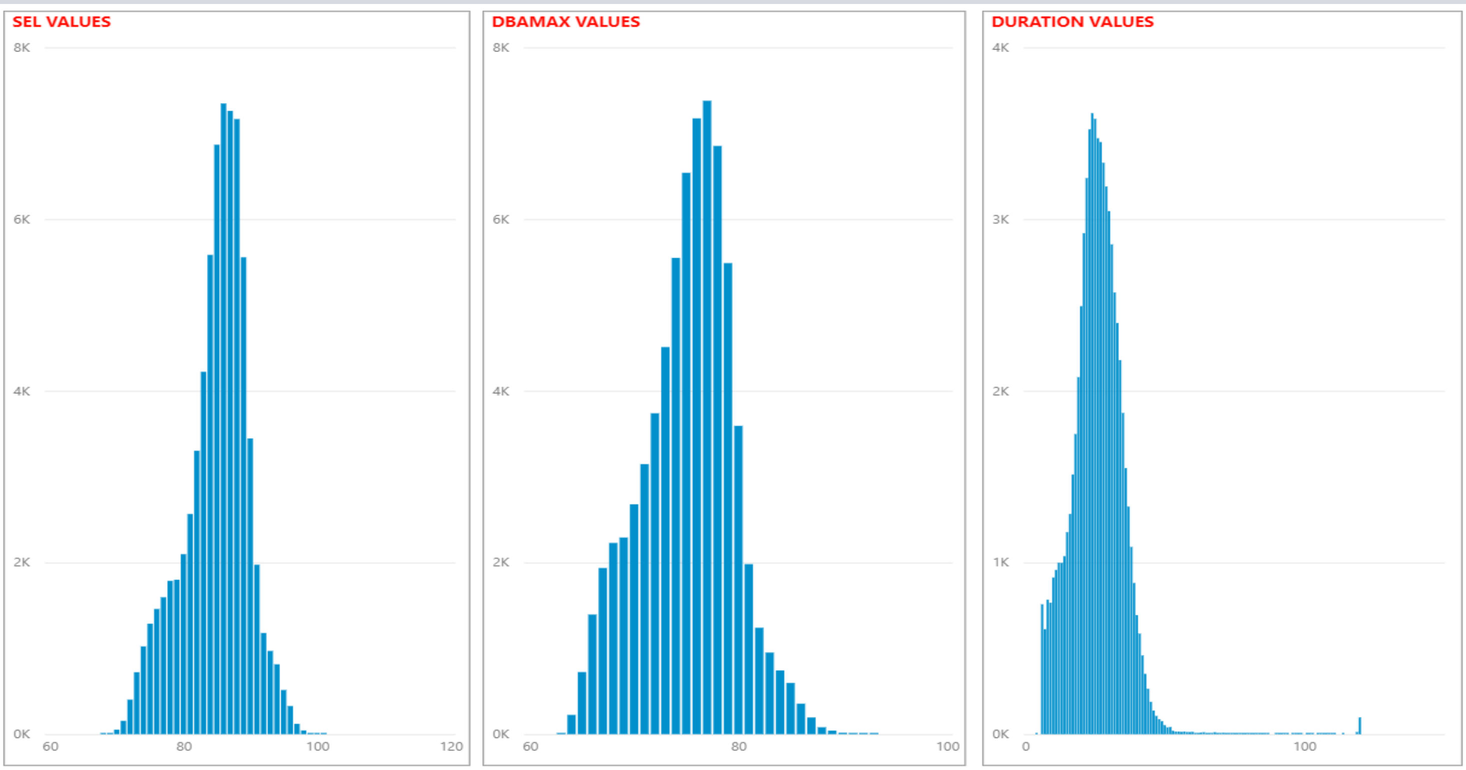
Figure A-5 Part C
Supporting Measured Analytical Data (Site 6 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Measured Single Event Noise Levels *Departures 28L/28R* *Jan 1st, 2019 – Jun 7th, 2021*



Measured Single Event Noise Levels *ALL OPERATIONS* *Jan 1st, 2019 – Jun 7th, 2021*

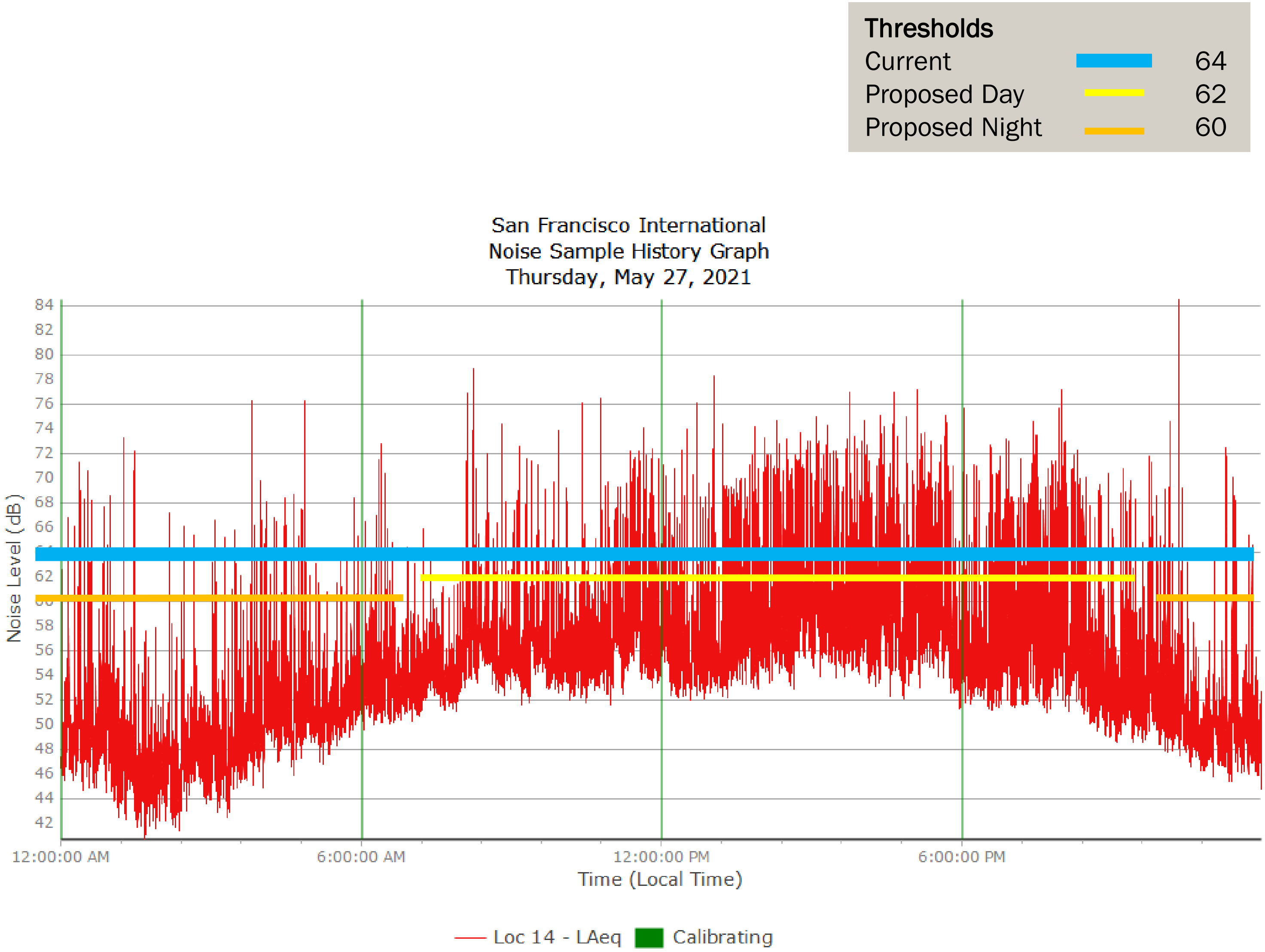


Source: BridgeNet International 2021

Figure A-6 Part A

Sample Time History Plot (Site 14 - So. San Francisco)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)



Source: BridgeNet International 2021

Figure A-6 Part B
Supporting Measured Analytical Data (Site 14 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations
Dec 16th – Dec 29th, 2019

Monitor	Metric	58	59	60	61	62	63	64	65	66
14	Number of events	5056	4260	3506	2943	2492	2148	1848	1644	1490
14	Duration 120 sec	35	9	5	1	1	0	0	0	0
14	Correlated events	2583	2366	2145	1942	1765	1619	1488	1377	1281
14	CNEL	60.7	60.6	60.5	60.4	60.3	60.2	60.1	59.9	59.7
14	Uncorrelated dB	0.42	0.45	0.5	0.58	0.66	0.74	0.81	0.9	0.97

Measured Single Event Noise Levels
Departures 28L/28R Jan 1st, 2019 – Jun 7th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	23,798	73.6	84.6	85.7	
Narrow	18,304	71.4	81.8	82.7	
Wide	12,076	70.8	80.9	82.1	
Regional	3,313	69.7	79.1	80.2	
Business	3,573	69.3	77.9	79.9	
Total	**61,064**	**71.9**	**82.3**	**83.9**	**83.9**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
E75L	Regional	2,968	69.8	79.4	80.3	
CRJ9	Regional	33	68.4	77.2	78.3	
CRJ7	Regional	66	68.5	77.0	78.7	
CRJ2	Regional	235	69.1	76.8	79.5	
BCS1	Regional	11	67.6	76.1	81.8	
Total		**3,313**	**69.7**	**79.1**	**80.2**	**80.2**

Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
14	Long Haul	24,458	23,798	97%
14	Regional Jets	6,628	3,313	50%
14	CRJ2 (Quiet RJ)	1,955	235	12%

Ambient Noise Levels
Jan 1st, 2019 – May 31st, 2021

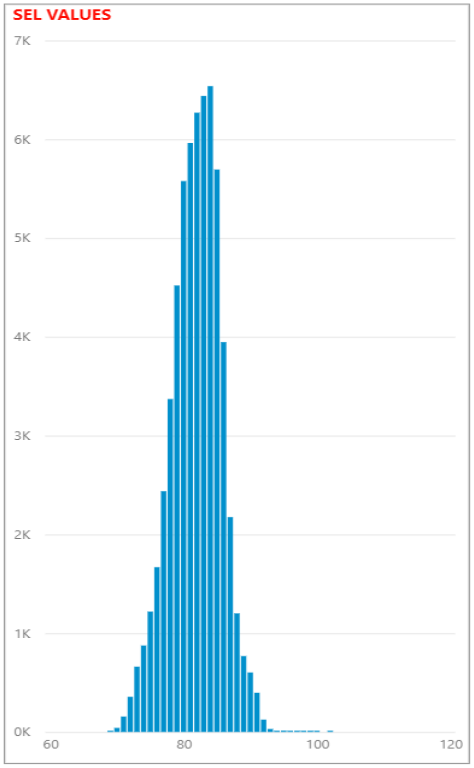
Site	Period	Statistics	L50	L90	L99
14	All Hours	Average	48.4	47.8	47.0
14	Day Only	Average	50.6	50.0	49.2
14	Night Only	Average	45.3	44.7	43.9
14	All Hours	Std Dev	4.6	4.6	4.6
14	Day Only	Std Dev	3.2	3.2	3.2
14	Night Only	Std Dev	4.5	4.5	4.5
14	All Hours	2x Std Dev	57.6	57.0	56.2
14	Day Only	2x Std Dev	56.9	56.4	55.5
14	Night Only	2x Std Dev	54.3	53.8	53.0
			2019	**2020**	**2021**
14	All Hours	Average L50	49.5	47.6	48.0
14	All Hours	Average L90	48.9	47.1	47.4

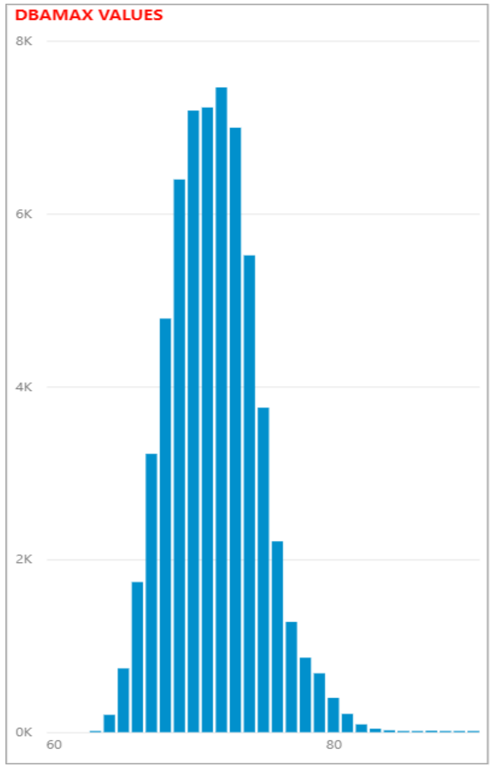
Source: BridgeNet International 2021

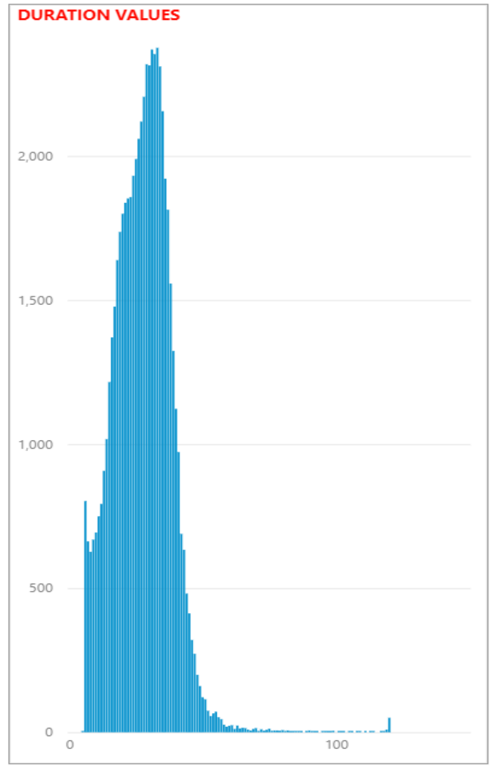
Figure A-6 Part C
Supporting Measured Analytical Data (Site 14 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

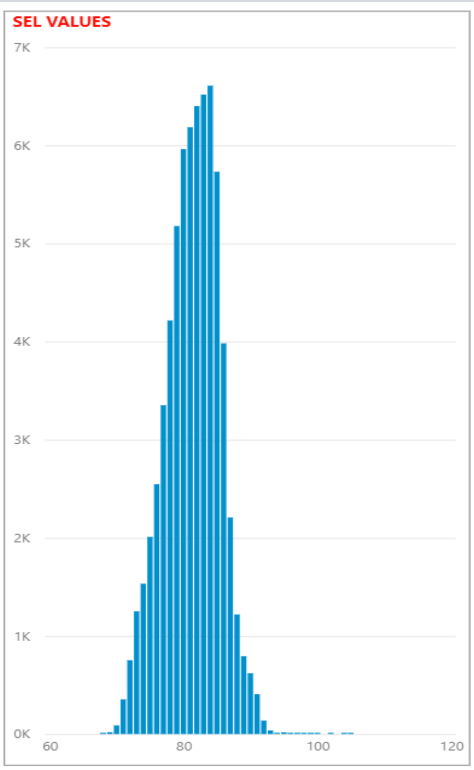
Measured Single Event Noise Levels *Departures 28L/28R* *Jan 1st, 2019 – Jun 7th, 2021*

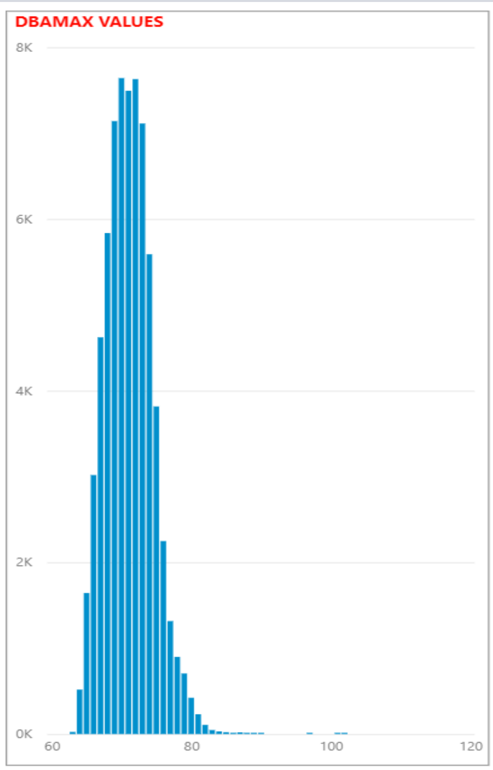


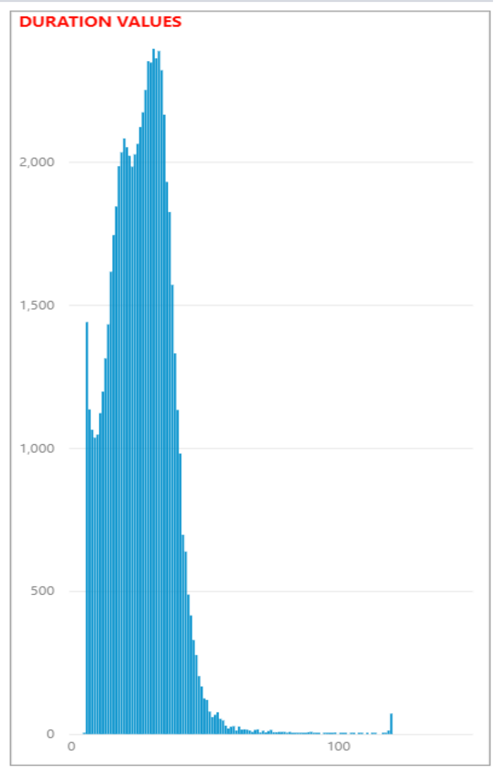




Measured Single Event Noise Levels *ALL OPERATIONS* *Jan 1st, 2019 – Jun 7th, 2021*







Source: BridgeNet International 2021

Figure A-7 Part A

Sample Time History Plot (Site 16 - So. San Francisco)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Thresholds	
Current	63
Proposed Day	62
Proposed Night	60

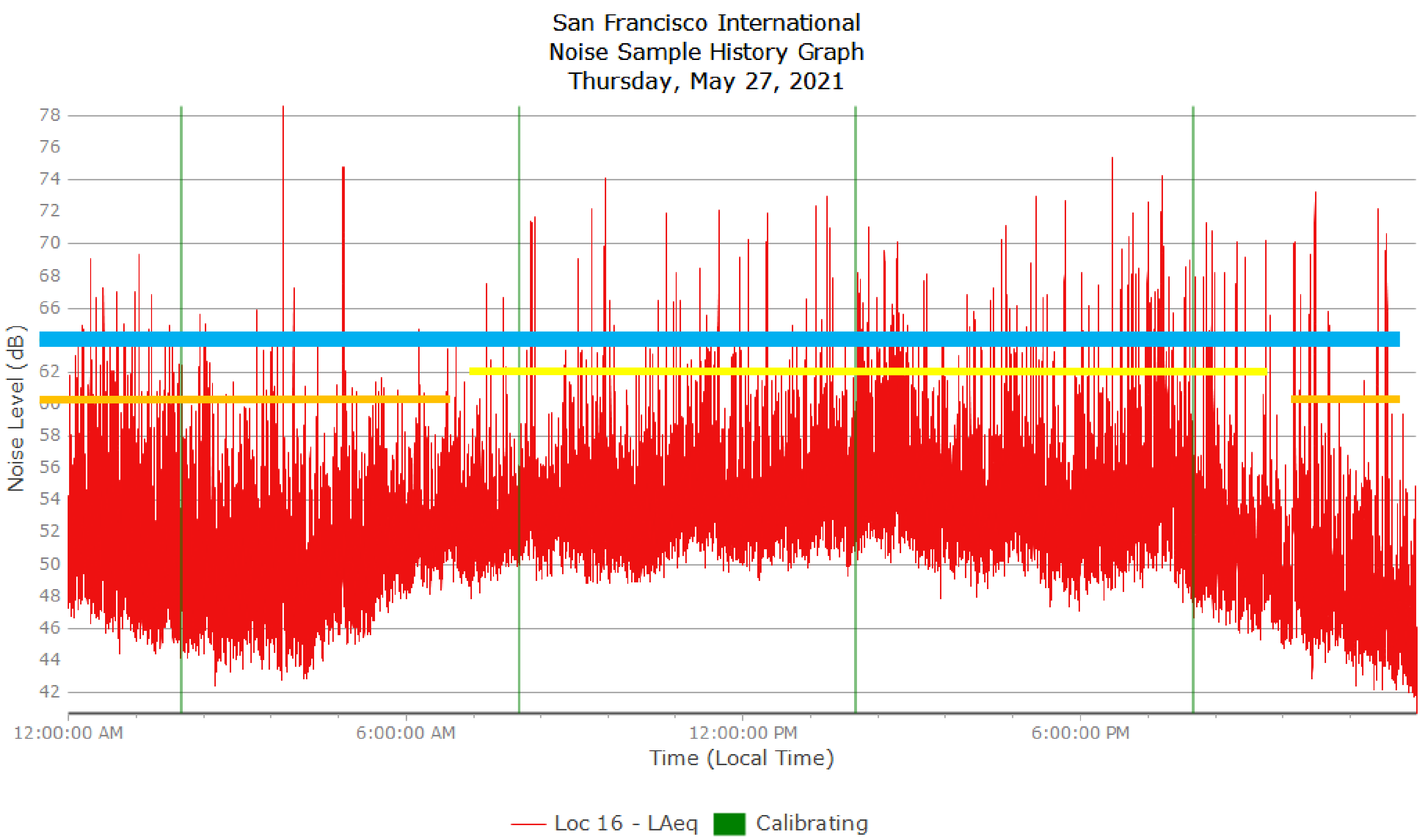


Figure A-7 Part B
Supporting Measured Analytical Data (Site 16 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	58	59	60	61	62	63	64	65	66
16	Number of events	3529	3013	2575	2219	1881	1642	1464	1342	1247
16	Duration 120 sec	67	43	21	12	2	2	2	2	2
16	Correlated events	2441	2213	1984	1781	1591	1452	1337	1249	1180
16	CNEL	59.6	59.5	59.4	59.3	59.2	59.1	59	58.9	58.7
16	Uncorrelated dB	0.29	0.33	0.39	0.46	0.55	0.62	0.71	0.79	0.88

Measured Single Event Noise Levels

Departures 28L/28R Jan 1st, 2019 – Jun 7th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	23,809	73.2	83.9	84.7	
Wide	11,896	70.5	80.8	81.8	
Narrow	17,487	70.8	81.0	81.8	
Regional	2,684	69.1	78.7	79.4	
Business	1,983	68.4	77.3	79.0	
Total	**57,859**	**71.6**	**81.9**	**83.1**	**83.1**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
E75L	Regional	2,569	69.2	78.8	79.5	
CRJ9	Regional	23	66.2	75.6	76.0	
CRJ2	Regional	68	67.1	75.6	79.8	
CRJ7	Regional	22	66.6	75.3	78.0	
BCS1	Regional	2	65.3	74.7	74.7	
Total		**2,684**	**69.1**	**78.7**	**79.4**	**79.4**

Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
16	Long Haul	24,283	23,809	98%
16	Regional Jets	6,089	2,684	44%
16	CRJ2 (Quiet RJ)	1,800	68	4%

Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

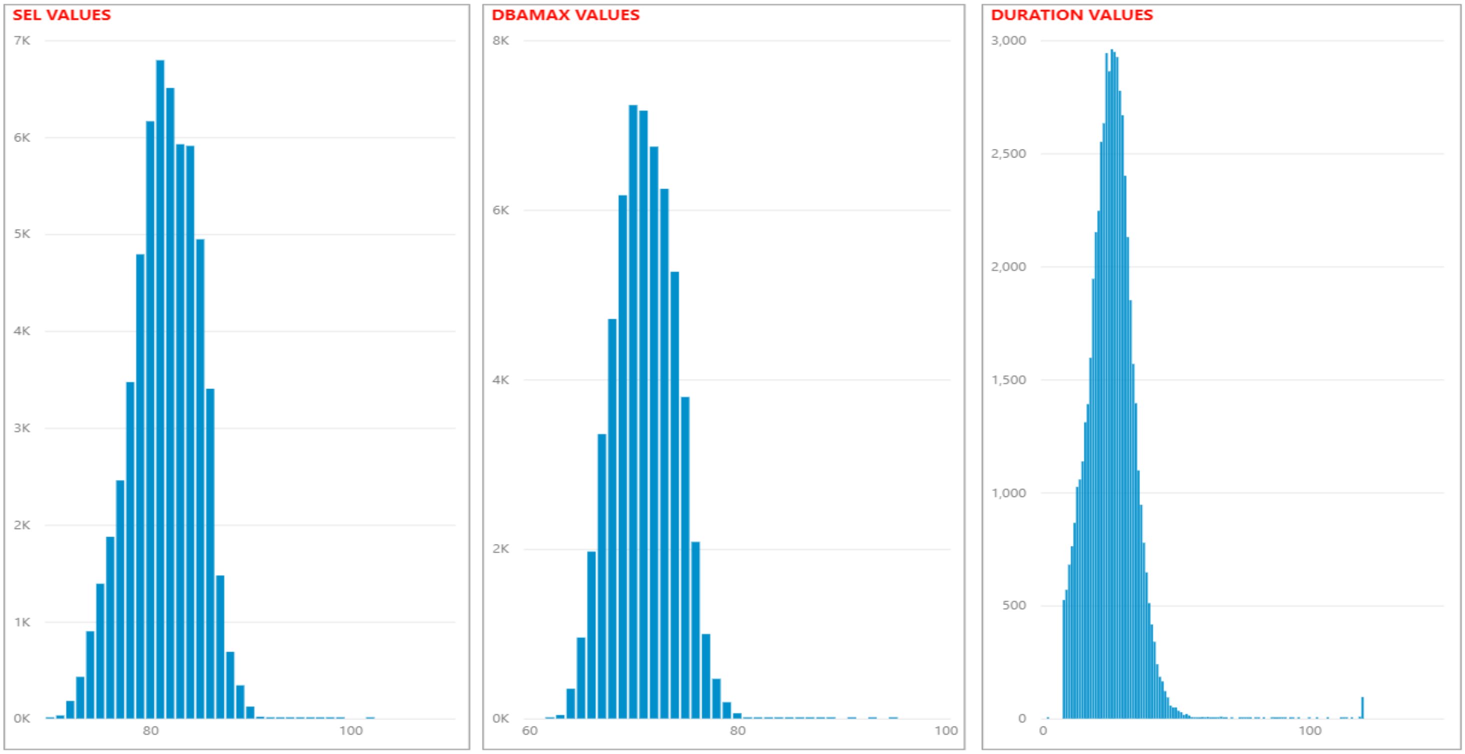
Site	Period	Statistics	L50	L90	L99
16	All Hours	Average	45.8	45.2	44.1
16	Day Only	Average	48.3	47.6	46.6
16	Night Only	Average	42.3	41.7	40.6
16	All Hours	Std Dev	4.9	4.9	5.0
16	Day Only	Std Dev	3.1	3.1	3.3
16	Night Only	Std Dev	4.9	4.9	4.9
16	All Hours	2x Std Dev	55.6	55.0	54.1
16	Day Only	2x Std Dev	54.4	53.9	53.2
16	Night Only	2x Std Dev	52.1	51.4	50.4
			2019	**2020**	**2021**
16	All Hours	Average L50	47.0	44.9	45.5
16	All Hours	Average L90	46.4	44.2	44.9

Source: BridgeNet International 2021

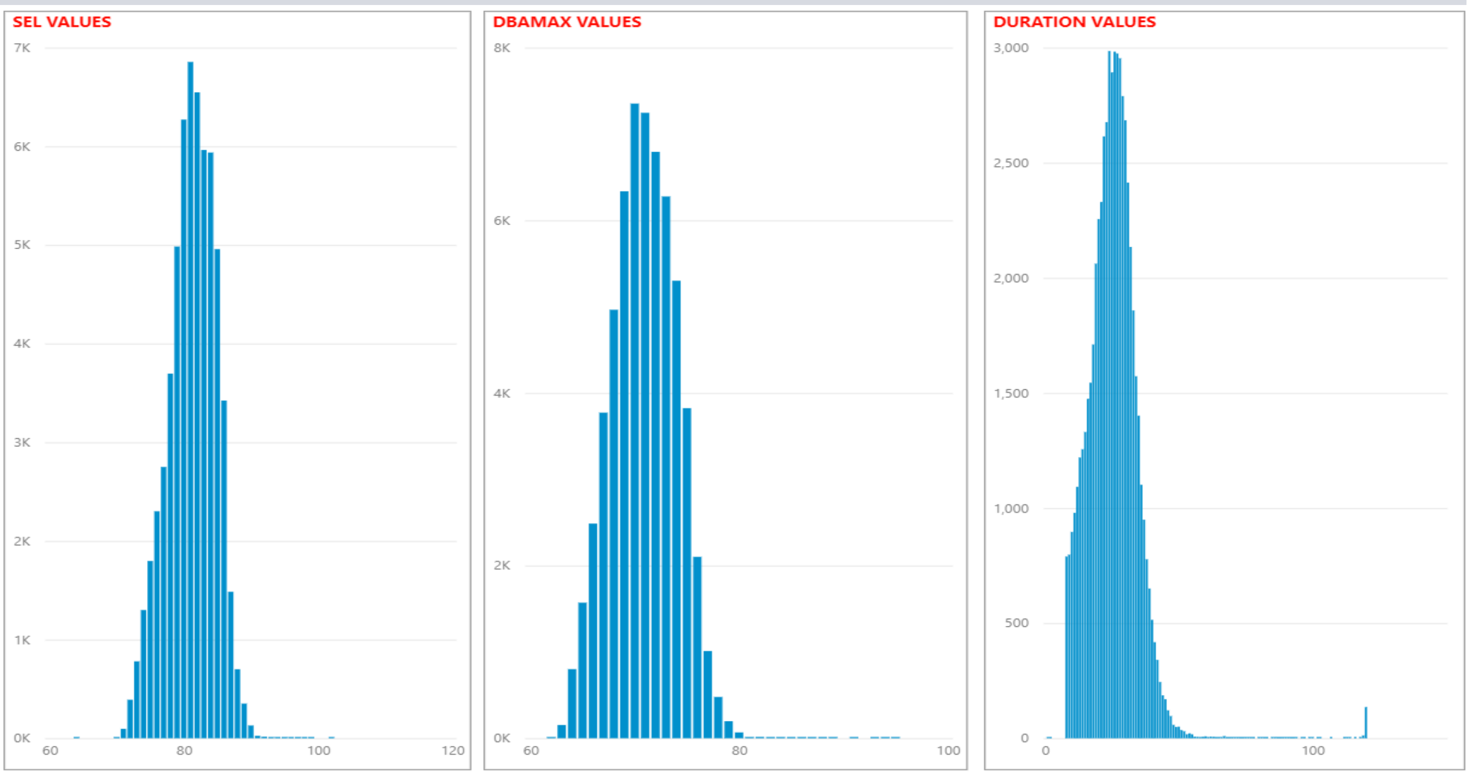
Figure A-7 Part C
Supporting Measured Analytical Data (Site 16 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

Measured Single Event Noise Levels *Departures 28L/28R* *Jan 1st, 2019 – Jun 7th, 2021*



Measured Single Event Noise Levels *ALL OPERATIONS* *Jan 1st, 2019 – Jun 7th, 2021*



Source: BridgeNet International 2021

Figure A-8 Part A

Sample Time History Plot (Site 17 - So. San Francisco)

(24-hour plot of 1 measured one-second noise data – May 27, 2021)

Thresholds		
Current		63
Proposed Day		62
Proposed Night		60

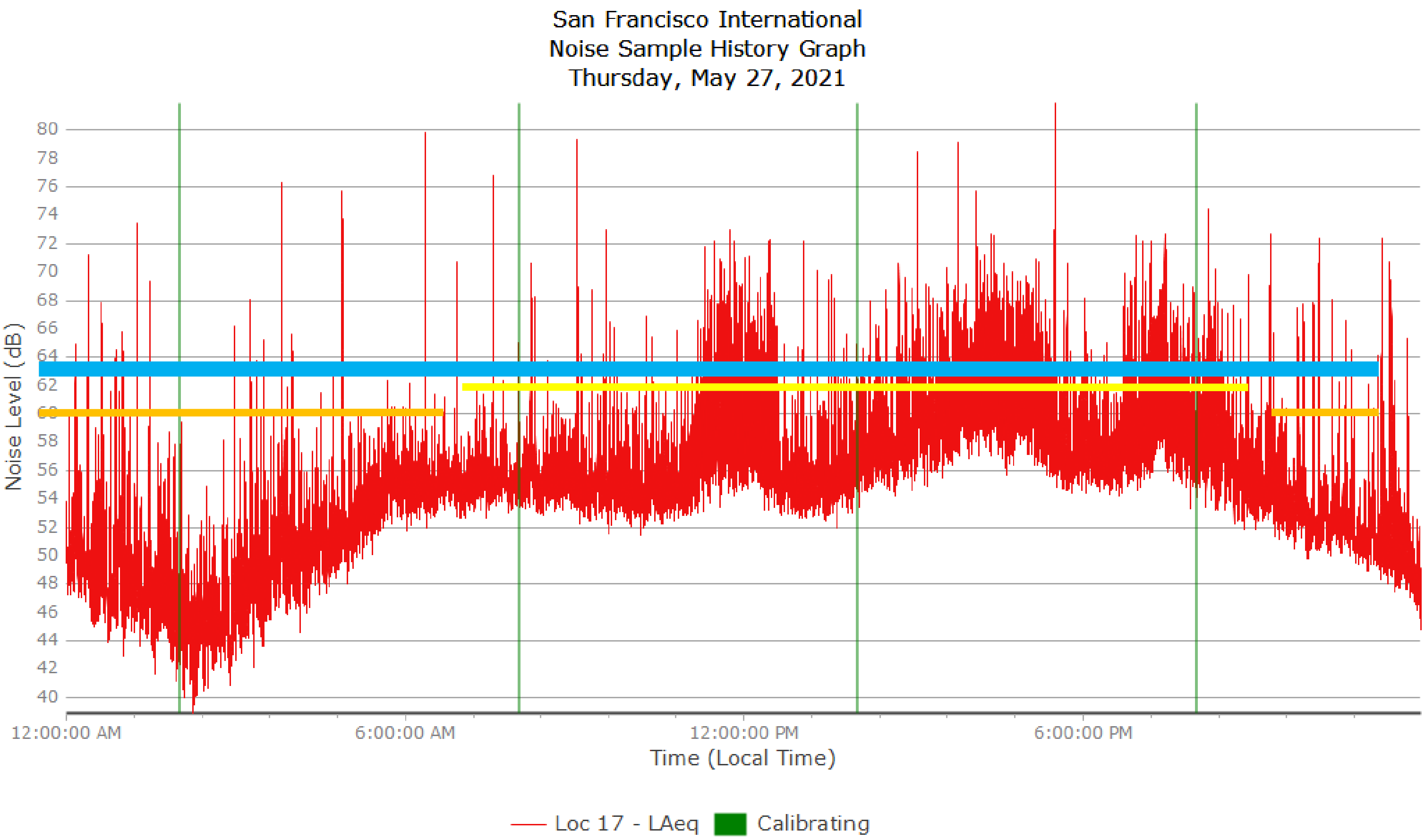


Figure A-8 Part B
Supporting Measured Analytical Data (Site 17 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

EVS Threshold Calculations

Dec 16th – Dec 29th, 2019

Monitor	Metric	57	58	59	60	61	62	63	64	65
17	Number of events	3937	3389	2982	2651	2379	2123	1893	1674	1500
17	Duration 120 sec	156	111	78	53	31	19	14	5	2
17	Correlated events	2727	2543	2338	2129	1931	1740	1565	1405	1280
17	CNEL	59.7	59.6	59.5	59.4	59.2	59.1	58.9	58.7	58.5
17	Uncorrelated dB	0.33	0.36	0.41	0.48	0.56	0.66	0.76	0.89	1.03

Measured Single Event Noise Levels

Departures 28L/28R Jan 1st, 2019 – Jun 7th, 2021

Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	SEL (E Avg)
Long Haul	22,921	72.3	83.6	84.7	
Narrow	16,949	70.3	81.2	82.0	
Wide	10,847	69.7	80.5	81.7	
Regional	2,886	68.9	79.1	80.8	
Business	2,475	68.8	78.2	80.1	
Total	**56,078**	**70.9**	**81.8**	**83.2**	**83.2**

ACTYPE	Group	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
E75L	Regional	2,528	68.9	79.2	80.7	
CRJ2	Regional	277	69.6	78.7	81.8	
CRJ7	Regional	44	67.6	77.2	79.7	
CRJ9	Regional	27	67.4	77.0	77.6	
BCS1	Regional	10	67.8	75.9	77.1	
Total		**2,886**	**68.9**	**79.1**	**80.8**	**80.8**

Site	Aircraft Category	Flights 8000' Radius	Measured Flights	Percent Measured
17	Long Haul	24,289	22,921	94%
17	Regional Jets	6,091	2,886	47%
17	CRJ2 (Quiet RJ)	1,799	277	15%

Ambient Noise Levels

Jan 1st, 2019 – May 31st, 2021

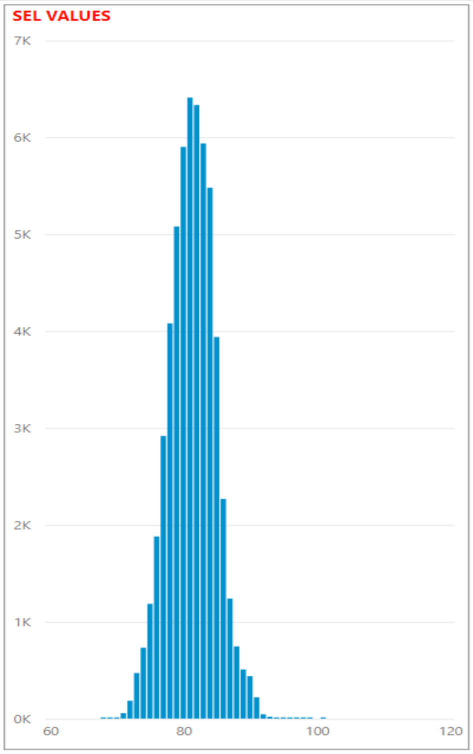
Site	Period	Statistics	L50	L90	L99
17	All Hours	Average	48.2	47.8	47.0
17	Day Only	Average	50.9	50.5	49.7
17	Night Only	Average	44.5	44.0	43.1
17	All Hours	Std Dev	4.9	4.9	4.9
17	Day Only	Std Dev	3.1	3.1	3.1
17	Night Only	Std Dev	4.4	4.4	4.4
17	All Hours	2x Std Dev	58.0	57.5	56.8
17	Day Only	2x Std Dev	57.1	56.6	55.9
17	Night Only	2x Std Dev	53.2	52.7	51.9
			2019	**2020**	**2021**
17	All Hours	Average L50	49.3	47.4	48.2
17	All Hours	Average L90	48.8	46.9	47.7

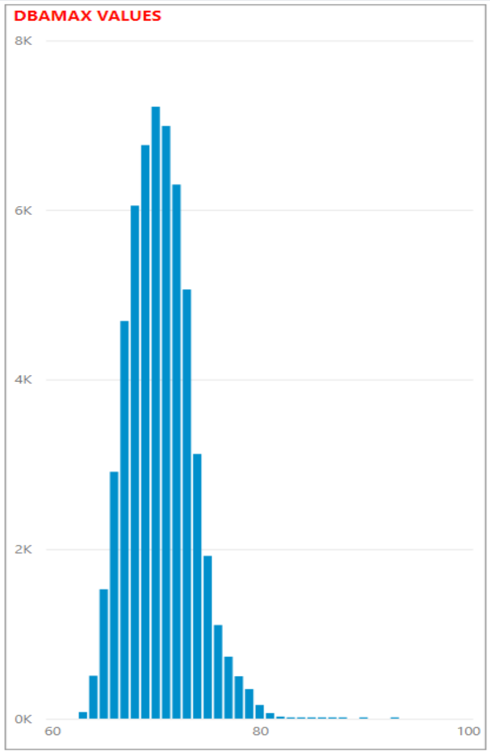
Source: BridgeNet International 2021

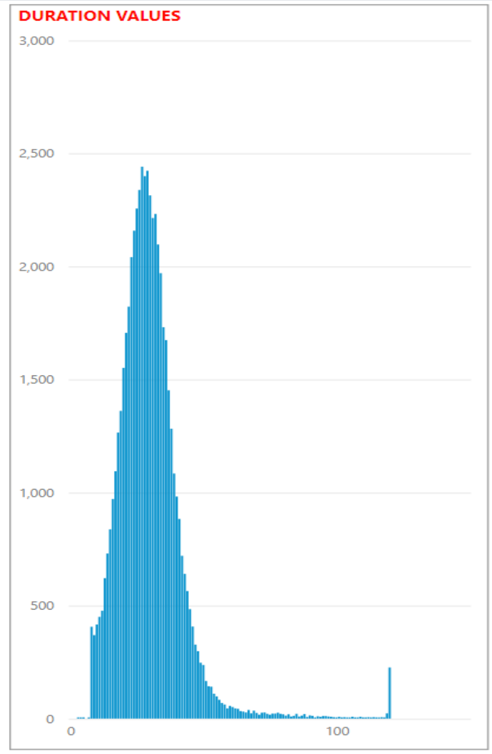
Figure A-8 Part C
Supporting Measured Analytical Data (Site 17 – So. San Francisco)

SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

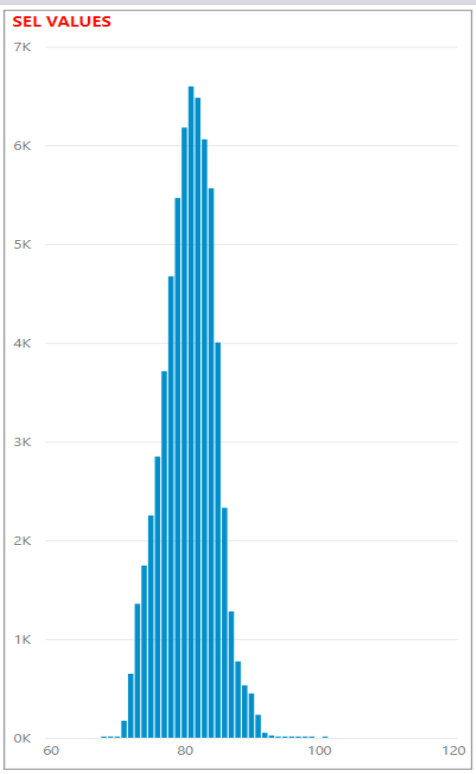
Measured Single Event Noise Levels *Departures 28L/28R* *Jan 1st, 2019 – Jun 7th, 2021*

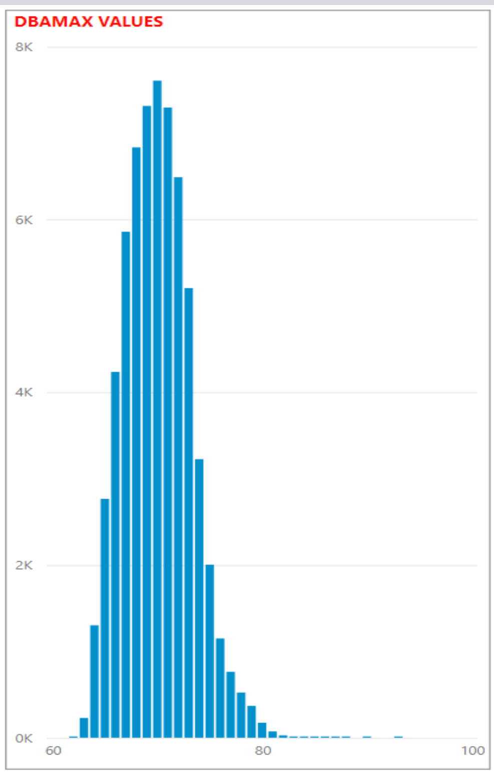


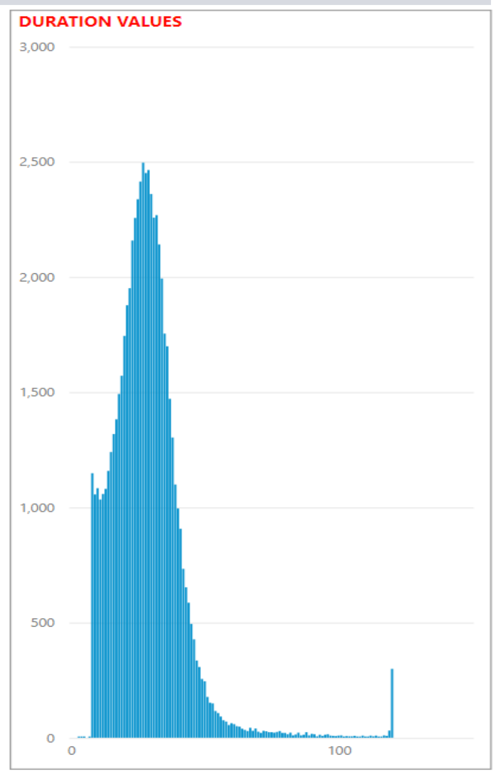




Measured Single Event Noise Levels *ALL OPERATIONS* *Jan 1st, 2019 – Jun 7th, 2021*







Source: BridgeNet International 2021

Figure A-9
Change in Measured Single Event Noise Levels over Time (Site 1)

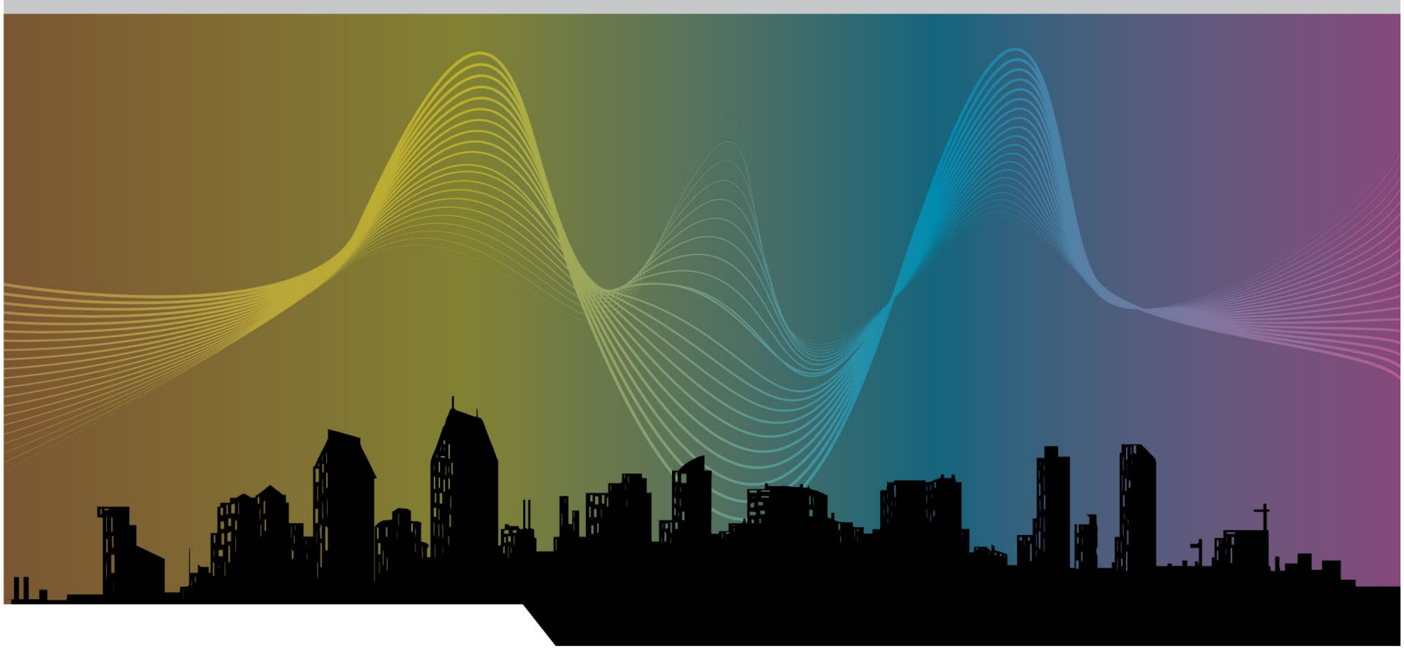
SAN FRANCISCO INTERNATIONAL –NOISE MONITOR TERMINAL THRESHOLD ANALYSIS

MONTH	Total Evts	Lmax (Avg)	SEL (Avg)	SEL (E Avg)	Scale
January 2019	3,419	85.6	93.5	96.0	
February 2019	3,535	83.7	92.2	94.8	
March 2019	3,591	85.4	93.4	95.7	
April 2019	4,418	84.8	93.0	95.4	
May 2019	4,707	84.7	92.8	95.3	
June 2019	3,719	86.3	94.0	96.5	
July 2019	4,243	85.1	93.2	95.7	
August 2019	3,913	85.7	93.5	95.7	
September 2019	3,291	85.3	93.4	95.2	
October 2019	3,693	84.8	92.3	94.8	
November 2019	3,053	86.3	93.8	96.2	
December 2019	2,608	86.9	94.3	96.3	
January 2020	3,139	85.9	93.5	95.7	
February 2020	3,461	82.9	91.2	94.0	
March 2020	3,125	82.4	90.4	93.3	
April 2020	948	80.7	89.0	92.4	
May 2020	1,503	80.2	88.5	91.9	
June 2020	1,926	79.2	87.8	91.2	
July 2020	1,495	81.0	89.1	92.3	
August 2020	1,176	82.2	90.1	92.9	
September 2020	1,479	82.2	90.0	93.1	
October 2020	1,405	83.6	91.0	93.8	
November 2020	2,036	81.4	89.6	92.4	
December 2020	1,899	83.1	90.9	93.5	
January 2021	1,588	82.1	90.4	93.1	
February 2021	1,702	81.4	89.8	92.3	
March 2021	2,934	80.1	88.9	91.3	
April 2021	2,883	79.9	88.5	91.5	
May 2021	2,510	80.2	89.3	91.9	
June 2021	739	80.1	89.2	91.9	
Total	**80,138**	**83.7**	**91.8**	**94.6**	**94.6**

Source: BridgeNet International 2021

Report #2020-007

December 30, 2020



Review of Remote Monitoring Terminal Thresholds

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Contents

Appendix

1. Background

BridgeNet International was contracted by the San Francisco International Airport's (SFO) Noise Office to review aircraft noise event thresholds at five (5) Remote Noise Monitoring Terminals (NMTs). This review of aircraft noise events includes conducting an analysis of measured noise levels and recommending noise thresholds and durations that should be used in the future.

In the fall of 2019, SFO installed a new noise system, the Envirosuite (EVS) Airport Noise and Operations Monitoring System (ANOMS), to replace the airport's existing ANOMS that was installed in 2006. The system underwent various hardware and software upgrades, but the basic noise event detection process has remained essentially the same. The software upgrade did not include changes to how noise events are calculated and correlated to aircraft. Historically, SFO operated with a variance to its state operating certificate due to the airport's status as a "noise problem airport" because there were incompatible land uses[1] within the 65 CNEL. In 2002, the airport no longer needed to operate with a variance because it no longer had incompatible land uses within the 65 CNEL noise contour, which meant that all sensitive land uses within the 65 CNEL were either sound insulated or had granted an avigation easement to the airport. While the airport has operated without a variance for 18 years, it still abides by the standards in Title 21 for a noise problem airport, including the requirement in Section 5033 of Title 21 requiring noise monitoring systems to be submitted and approved by the state as part of an airport's Noise Monitoring Plan.

Per Section 5001 of Title 21, the thresholds of the NMTs should be 10 dB below the appropriate CNEL value; for the purposes of this analysis, the appropriate CNEL value is 65 CNEL as described in Section 5012 of Title 21. Should an airport need a waiver to the 10 dB value, per Section 5070 of Title 21, an airport can apply for a waiver that demonstrates an airport will still maintain the required accuracy of 1.5 CNEL using a different threshold value. Since 2011, SFO has operated with a waiver for noise thresholds at certain NMTs. This analysis will review these noise threshold values to determine their continued applicability at NMTs 12, 15, 18 and 19 and for any potential application for NMT 8. This report will describe the background, or ambient noise levels, and aircraft noise levels at each of the monitors and the supporting analysis for continuing to use a threshold different than 55 dB and identify an optimum threshold specific to the conditions at each of the above locations.

[1] As defined in Section 5014 of Title 21: https://govt.westlaw.com/calregs/Document/ICD7B5DE0D45011DEB97CF67CD0B99467?originationContext=document&transitionType=StatuteNavigator&needToInjectTeNMT=False&viewType=FullText&contextData=%28sc.Default%29

2. Definition of Terms

Characteristics of Sound

Sound can be described technically in terms of amplitude (loudness), frequency (pitch), or duration (time). Frequency (or pitch) is measured in hertz (Hz). The standard unit of measurement for the loudness of sound is the decibel (dB). Decibels are based on a logarithmic scale. The logarithmic scale compresses the wide range in sound pressure levels to a more usable range of numbers (in a manner similar to the Richter scale used to measure earthquakes).

Human hearing is not equally sensitive to sound at all frequencies. Sound waves below 16 Hz are not heard at all and are "felt" more as a vibration. Similarly, while people with extremely sensitive hearing can hear sounds as high as 20,000 Hz, most people cannot hear above 15,000 Hz. In all cases, hearing acuity falls off rapidly above about 10,000 Hz and below about 200 Hz. Since the human ear is not equally sensitive to sound at all frequencies, a special frequency-dependent rating scale has been devised to measure loudness in a way that reflects how the human ear actually perceives sound. Community noise levels are measured in terms of this A-weighted decibel scale (or dBA), which is widely used in industrial and environmental noise-management contexts.

Propagation of Noise

Outdoor sound levels decrease as a result of several factors, including increased distance from the sound source, atmospheric absorption (characteristics in the atmosphere that absorb sound), and ground attenuation (characteristics on the ground that absorb sound). If sound radiates from a source in a homogeneous and undisturbed manner, the sound travels in spherical waves. As the sound wave travels away from the source, the sound energy is spread over a greater area dispersing the power of the sound wave.

Atmospheric temperature and humidity also influence the sound levels received by the observer. How much sound is absorbed by the atmosphere depends on the frequency of the sound as well as the humidity and air temperature. For example, when the air is cold and humid, and therefore denser, atmospheric absorption is lowest and sound travels farther. Higher frequencies are more readily absorbed than the lower frequencies. The fluctuations in sound levels created by atmospheric conditions increase with distance and become particularly important at distances greater than 1,000 feet. Over large distances, lower frequency sounds become dominant as the higher frequencies are attenuated. Noise propagation is one of the reasons that aircraft noise will be higher one day than other days even when the same aircraft are flying the same path and altitude.

Noise Metrics

The description, analysis, and reporting of noise levels around communities is made difficult by the complexity of human response to noise and the variety of metrics that have been developed for describing noise impacts. Each of these metrics attempts to quantify noise levels with respect to community impact.

Noise metrics can be divided into two categories: single event and cumulative. Single event metrics describe the noise levels from an individual event such as an aircraft flyover. Cumulative metrics average the total noise over a specific time period, typically from one to 24 hours. This study presents single event measurement results.

- **Maximum Noise Level,** or Lmax, is the maximum or peak sound level during an aircraft noise event. The metric accounts only for the peak intensity of the sound and not for the duration of the event. As an aircraft passes by an observer, the sound level increases to a maximum level and then decreases. Typical single event noise levels range from over 90 dBA close to the airport to the low 50s dBA at more distant locations.
- **Single Event Noise Exposure Level (SEL)** - The duration of a noise event, or an aircraft flyover, is an important factor in assessing annoyance and is measured most typically as SEL. The effective duration of a sound starts when a sound rises above the background sound level and ends when it drops back below the background level. An SEL is calculated by summing the dB level at each second during a noise event and compressing that noise into one second. It is the level the noise would be if it all occurred in one second. The SEL value is the integration of all the acoustic energy contained within the event. This metric takes into account the maximum noise level of the event and the duration of the event. For aircraft flyovers, the SEL value is numerically about 10 dBA higher than the maximum noise level.
- **Community Noise Equivalent Level (CNEL)** is an average noise over twenty-four hours; it applies a weighting factor that penalizes noise events occurring during the evening and night hours (when humans are typically more sensitive to noise and sleep disturbance is a concern). More specifically, noises occurring during the evening (from 7 PM to 10 PM) are penalized by 5 dB, while noises occurring during the night (10 PM to 7 AM) are penalized by 10 dB. CNEL noise levels near airports range from 70 CNEL directly next to an airport to less than 45 CNEL at more distant locations.

  CNEL is influenced most by the loudest aircraft operating at an airport, which at SFO is typically a wide-body passenger or cargo jet traveling long distances (such as to Europe or Asia). At SFO the aircraft that most influence the CNEL contour are the Boeing 777, other large jets like the Boeing 787, and historically the Boeing 747 which recently stopped being used for passenger service, but is still used by cargo carriers. The CNEL contours are influenced to a lesser extent by operations conducted by smaller aircraft; these aircraft influence the contour due to the larger number of operations (for example, narrow-body jets on domestic routes). The CNEL noise levels at locations along the peninsula (i.e. departure procedures along the gap) are especially dominated by the larger jet aircraft in that many of these operations also occur during the evening and night penalty period of 5 dB and 10 dB, respectively.

  Note that measuring CNEL at levels below 55 CNEL becomes less precise because the noise from aircraft events can be close to existing ambient noise, and it is not always technically possible to separate the two. CNEL differs from the Lmax values which are numerically higher than CNEL values because the CNEL represents an average that includes both peak sounds (like the Lmax) and lower values when aircraft noise is not present.

3. Purpose

The purpose of this analysis is to support SFO's acceptance of the new ANOMS that was installed in the fall of 2019; in particular, the accuracy of identifying and correlating measured noise to flights at SFO. This system was submitted for review and acceptance to the State of California in 2020. The goal of this analysis is to determine the most effective and accurate thresholds and NMT settings to be used to identify the noise levels due to aircraft flights while in compliance with Title 21 standards.

Additionally, this analysis supports Section 5032 of Title 21 that validates the noise impact boundary, which reviews locations of the NMTs relative to the outer-most points of the 65 CNEL contour. Per Section 5032, "The locations shall be selected to facilitate locating the maximum extent (closure points) of the noise impact boundary when the contour extremities encompass incompatible land uses."

4. Methodology

4.1 Remote Monitoring Terminal Locations

The five NMTs chosen are shown in **Figure 1** and are located in or close to the 65 CNEL; these locations were chosen for their positions relative to departure and arrival noise. It should be noted that Site 12 is between the 60 and 65 CNEL, and is one of two sites that measures noise from the primary arrival path to Runways 28L/R. **Table 1** shows the existing noise thresholds at these NMTs; these values were approved by the State of California in December 2011 and is not inclusive of all the NMTs with threshold waivers[2].

[2] In December 2011 the State of California approved a threshold waiver for the following NMTs: 1,4,5,6,12,14,15,16,17,18, and 19.

Table 1 – Current NMT Threshold Values

NMT	City	Location	Latitude	Longitude	NMT Threshold, dBA
8*	Millbrae	Behind departure roll for Runways 1L/1R	37.6022	-122.385728	65
12	Foster City	Approach path to Runways 28L/28R	37.565328	-122.252728	65
15	South San Francisco (Oyster)	SSTIK departures over Brisbane	37.662811	-122.379716	64
18	Daly City	Gap departure along centerline	37.65722	-122.46716	63
19	Pacifica	Gap departure at the left of centerline	37.65833	-122.48106	65

*NMT 8 was not approved for a different threshold by the State of California in 2011.
Source: San Francisco International Airport Noise Office

This analysis will correlate noise events to a nearby flight using Title 21 guidelines to determine an appropriate threshold for the five NMTs in Table 1. This analysis, as guided by Section 5032 of Title 21, will determine the delta of measured and modeled noise to be within 1.5 dB annual CNEL. While NMTs should ideally be located in areas with ambient noise levels less than 55 dB (i.e. away from noisy sources such as freeways, railroad tracks, etc) many of the NMTs at SFO are in urban areas with ambient levels higher than 55 dB. This analysis will determine suggested thresholds based upon the type of operations a site is exposed to, the level of noise from aircraft events and the background noise environment.

4.2 Data Requirements

The following steps were taken to gather noise information from the five NMTs:

1. Extracted 10 days of ANOMS noise and radar data from November and December 2019 to determine existing NMT thresholds for:
    a. Ambient noise. Ambient background noise represents the typical residual noise that exists in the area independent of the aircraft noise. The results are presented in terms of the L% statistical noise levels. The L% is the percent of time that the noise is above that level. The L50 or mean noise level, which is defined as the point at which half the time the noise is above that value and half below that value.
    b. Minimum noise event duration (note: this value has been determined to be eight (8) seconds for each NMT),
    c. Maximum noise event duration. The current duration of 120 seconds was used; this is the maximum duration allowable in ANOMS. Durations that are too long can produce false positives of assigning an aircraft event to a non-aircraft noise event; these false positives are manually adjusted. Conversely, if the duration is set to a

shorter time, the NMT may not capture the full extent of an aircraft event. In this case, the NMT will assign one aircraft event to multiple shorter noise events.
   d. Correlation of noise events to aircraft flights using the point of closest approach (PCA). Note this correlation is a BridgeNet process and may not exactly match ANOMS process.
   e. Noise event thresholds, in dBA and
   f. One-second Leq time history.
2. Run a bulk analysis with different thresholds, starting as high as 70 dBA and working down to as low as 56 dBA in 1 dBA increment or when the background noise interfered with the results. The multiple thresholds were chosen to determine the point at which the most aircraft events were captured at each of the five NMTs or the threshold approached the ambient where continuous events were created. If a threshold is too low, it can create false positives, or incorrectly assign an aircraft even to a noise event that was from a different source. If a threshold is too high, it will not capture aircraft events and report a lower number of events. However, it is important to note that even though not all events are captured, they are the lower noise level events and have a smaller, or negligible, contribution to the overall CNEL. This is especially evident for the two NMTs, NMT 18 and 19 in "the Gap" where large, wide-body aircraft events contribute the most noise; lowering the NMT threshold value may result in capturing more aircraft events, but will not result in a change to the CNEL because these NMTs are already recording and correlating the loudest aircraft events. As determined in 2011 by the airport and approved by Caltrans, the threshold of 55 dBA is too low of a threshold at the NMTs referenced in this report, due to the location of the NMTs in areas with higher ambient noise levels.
   a. Durations settings were used to determine the minimum and maximum duration,
   b. Range setting to determine how far away an aircraft could be and still be considered to be a candidate source, and
   c. At each threshold, correlate aircraft overflight with a noise event to determine correlation rates and false positives.
   d. The recommended NMT threshold should be as low as feasible without resulting in significant long duration events (these events occur when the ambient is at or above the threshold generating false events) and the predicted aircraft CNEL value is within 1.5 dBA of the potential lowest threshold. Since CNEL is a noise energy-based metric, the higher noise level events contribute the most to the overall aircraft CNEL. The lower noise level events have a smaller contribution. When lowering the threshold to capture more lower noise level events, and the potential aircraft CNEL has a minimal change in noise (i.e., 0.2 CNEL or less), that is also an indicator that the threshold setting is capturing the aircraft CNEL noise at that location.

Table 2 shows the 13 dates used for the data analysis; these days were chosen because they represented a typical operational configuration at SFO, which is aircraft arriving from the east on Runways 28 L/R and departing to the north on Runways 01 L/R commonly referred to as "West Flow."

Table 2 – Runway Use and Operation Counts

Date	Total Daily Flights at SFO	Flow
Nov. 1, 2019	1,265	West
Nov. 2, 2019	1,081	West
Nov. 3, 2019	1,285	West
Nov. 4, 2019	1,274	West
Nov. 5, 2019	1,189	West
Nov. 6, 2019	1,248	West
Dec. 9, 2019	1,188	West
Dec. 10, 2019	1,169	West
Dec. 11, 2019	1,200	West
Dec. 12, 2019	1,227	West
Dec. 13, 2019	1,228	West
Dec. 14, 2019	1,073	West
Dec. 15, 2019	1,210	West

Source: LT6 File Export from SFO ANOMS, 2019

An automated process was used to calculate noise events and when possible, correlated to an aircraft that generated the noise event. **Figures 2 – 4** show radar tracks from the date range for the analysis.

5. Ambient Noise Measurement Results

Ambient background noise represents the typical residual noise that exists in the background. These results are presented in **Table 3,** below. These levels include all noise sources, including aircraft and can be used as a guide to determine the residual noise that an aircraft event will need to produce that raises it above ambient to be measurable by an automated noise monitoring system. The L50 or mean noise level, which is defined as the point at which half the time the noise is above that value and half below that value. Other values of interest are the L90 and L10. The L90 is the background level that is exceeded 90% of the time. It generally reflects quiet periods. The L10 is the level that is exceed 10% of the time. It reflects the high noise level periods.

Ambient noise varies throughout the day; typically, ambient noise is reduced at night, therefore is lower than the daytime levels. When ambient noise is low, the sound of an aircraft may be distinct and measurable, while when ambient noise is higher the same aircraft emitting the same noise may be not audible or measurable above the background. The data in Table 3 show the ambient noise for a 24-hour period. The ambient noise levels at night are roughly 5 dBA quieter than in the daytime hours. Note that the ambient at Site 8 was consistently higher than other sites; NMT 12, 15, 18, and 19 are all between 48-51 dBA while the ambient noise at Site 8 is 62 dBA.

Table 3 – Ambient Noise Measurement Results

Noise Monitoring Terminal	Statistical Noise Levels (dBA)								
	Max	L1	L5	L10	**L50**	L90	L95	L99	Min
NMT 8	84	71	67	66	**62**	58	56	55	50
NMT 12	81	72	67	63	**51**	42	41	39	36
NMT 15	82	69	64	61	**51**	44	43	41	39
NMT 18	86	72	59	56	**50**	45	44	42	39
NMT 19	82	70	58	54	**48**	41	39	37	34

Source: BridgeNet International, 2020

The results show that Sites 12, 15, 18 and 19 have generally quieter background noise levels than other more urban locations with an L50 level in the low 50s dBA. However, in order to set an NMT threshold to 55 dBA per Title 21 Section 5012, the ambient levels should be in the order of 45 dBA; all of the NMTs in this report have ambient levels above 45 dBA. This means that more noise events can be measured when the signal-to-noise ratio between the aircraft noise and the background sound is roughly 10 dBA. Therefore, typically NMT thresholds are recommended to be approximately 10 dBA above the ambient to best record aircraft noise without false positives that correlate noise to other non-aircraft events. While Sites 18 and 19 are quieter almost all the time represented by the L10 levels, Sites 12 and 15 have periods of time that the background noise is higher. This is likely from wind noise and would limit how low the threshold could be lowered at these sites without the background exceeding the ambient. As noted in the previous section, NMT 18 and 19 capture noise from large aircraft typically flying the furthest distances from SFO; lowering the NMT threshold at these monitors to be within 10 dBA of the ambient threshold could result in additional, non-aircraft events being captured and falsely correlated to an aircraft event.

6. NMT Sites

The data presented in this section shows information using logarithmic and arithmetic mean. As noted in Section 3, logarithmic results are those that have been summed and are shown as an energy average. Arithmetic mean is the addition of each numerical value, divided by the number in the set. Additional data for each NMT is show in **Appendix A**. Each NMT section contains a table with data for each of the monitor thresholds, including:

- Number of events – the number of aircraft and non-aircraft events measured by the NMT for the time period.

- Number correlated events – the number of noise events assigned to a flight within the Point of Closest Approach. The PCA is a cylinder centered around the noise monitor that is two miles wide.
- Number nearby flights – all aircraft activity (arrivals or departures) overhead that were captured within the PCA.

6.1 NMT Site 8

NMT Site 8 is located behind Runways 01L/R. The primary source of aircraft noise are departures from Runways 01L/R, with Runway 01R generating higher noise events in that it is closer to the site. These runways are utilized by the majority of departures at SFO, mainly narrow body and regional jets and to a lesser extent, wide body jets. Over time, the aircraft fleet has changed, and aircraft generate less noise to the rear of the aircraft during take-off than in the past with older generation aircraft such as Stage 2 and older Stage 3. Thus, the peak sounds of the events are lower and harder to separate from background noise at this site with the current generation of aircraft. The site is also located near taxiway and hold pad locations that generate ground noise that is a more constant, and less event based like an aircraft flyover.

The ambient background noise levels at Site 8 are much higher than the other sites. This site is also exposed to freeway noise and airport ground activities. The 101 freeway is 1,000 feet to the east, where there is no sound barrier and areas of open space where the NMT has line of sight view to a portion of the freeway. Aircraft ground movements also contribute to the background noise. This includes aircraft idling, taxiing, queuing, and position prior to takeoff from Runways 01L/R at the runway end, and from aircraft taxiing to Runway 28L/R from the south International Terminal. The site is also exposed to other noise sources such as electric power transmission lines to the east, railroad tracks used for cargo and passengers to the west, BART tracks, parking structure and lot for cars using Caltrans and BART to the south, and residential uses to the north. The site can have near constant noise in the 58 to 67 dBA range that may potentially be from each of these sources; the average ambient noise at this site is 62 dBA. This limits the ability of an NMT to measure lower-level aircraft noise events because these aircraft events are near the ambient level, and the noise event threshold must be greater than the ambient background.

This NMT is generally on the edge of the 65 CNEL noise contour. The current threshold for this NMT is 65 dBA. The site has measured both below and above 65 CNEL over the course of the last five years. Since it is located near sources of noise that can be louder than aircraft events, it has historically been difficult to correlate aircraft flights with noise events. This is due to its location behind the departure roll, which produces noise events that are not as loud as flyover events, low frequency vibratory noise that can be difficult to monitor, and as described above is near other noise sources that is at or near the noise from the aircraft flyover events. Also, the site is under two procedures, the BDEGA (arrival) and SSTIK (departure); while these flights do not generate loud events, they can be confusing to the ANOMS correlating process. Aircraft on the BDEGA arrival path fly over the top of SFO on approach to Runways 28L/R. SSTIK departures from Runways 01L/R also fly over or near NMT 8. With the current ANOMS system, it will often incorrectly correlate noise from other sources to an aircraft from these operations that fly over the site.

Table 4 shows the different thresholds and aircraft correlation based on these thresholds. These flights were correlated to noise events at NMT 8 at thresholds from 70 to 60 dBA. Because of the high ambient noise, noted in Section 5 of this report as 62 dBA, it was not possible to have a lower threshold.

Table 4 – NMT 8 Thresholds and Durations

Metric	Thresholds 60	61	62	63	64	65	B&K ANOMS 65	66	67	68	69
Number of Events	12,214	11,196	9,817	8,550	6,921	4,862		3,197	2,077	1,391	825
Number of Correlated Events	9,081	8,504	7,683	6,851	5,545	3,950	3,985	2,610	1,677	1,112	660
Duration (arithmetic mean)	29.4	28.7	28.1	27.1	25.5	23.5	45.7	23.1	23	20.8	19.4
Start to Peak (arithmetic mean)	12.5	12.4	11.9	11.5	11.0	10.0		9.8	10.1	9.1	8.2
dBA Max (logarithmic average)	69.2	69.4	69.7	70.1	70.6	71.5	71.8	72.6	74	74.8	76.1
SEL (logarithmic average)	80.7	80.9	81.2	81.5	82.0	82.7	84.7	83.7	84.8	85.6	87.0
Ground Distance (ft) (arithmetic mean)	5,179	5,209	5,189	5,148	5,167	5,053		4,934	4,850	4,768	4,591
Slant Range Distance (arithmetic mean)	5,688	5,689	5,681	5,630	5,642	5,542		5,440	5,350	5,183	5,071
Altitude (arithmetic mean)	855	808	829	810	792	821		847	826	699	786
CNEL Aircraft (logarithmic average)	66.84	66.82	66.59	66.22	65.96	65.23	**66.15**	64.19	63.45	62.43	60.79
CNEL Community (logarithmic average)	67.78	67.80	67.98	68.22	68.38	68.75		69.14	69.35	69.58	69.84
CNEL Total (logarithmic average)	70.35	70.35	70.35	70.35	70.35	70.35		70.35	70.35	70.35	70.35

Source: BridgeNet International, 2020

Based on the information in **Table 4,** the recommended threshold is 67 dBA; this is 2 dBA higher than the current threshold of 65 dBA. The recommended event duration minimum is eight (8) seconds and maximum is 120 seconds. This threshold will capture less events, but there will also be less occurrences of ambient noise being mistaken for aircraft. Because of the high ambient levels and how ANOMS works, NMT 8 is consistently measuring 120 second events because the ambient noise level (62 dBA) exceeded the threshold.

While the primary aircraft flight noise captured at NMT 8 is from departures on Runways 01L/R, it will also capture departure roll noise from aircraft on Runways 28L/R. In order to capture noise from the Runway 28L/R departure roll, the range should also be set to 10,000 feet. This range setting should reduce correlations to high-altitude aircraft flying over the site. The BDEGA arrival path is right at 10,000 feet MSL (mean sea level) over the airport, so some aircraft will still potentially be captured. For the SSTIK departures, the aircraft are generally greater than 10,000 feet MSL.

The range is the distance, vertically and laterally, from the NMT to a candidate aircraft flight. An aircraft must be within that specified distance to be considered correlated to the aircraft noise event. An aircraft beyond that distance is not considered. When the range is too large, there is a greater potential for a poor correlation of a noise event an aircraft that likely did not cause the event. Too low of a range, the aircraft could be not correlated that did cause the event.

As previously stated, the site is continuously exposed to noise from the highway and from aircraft taxi/idle/positioning at the end of Runways 01L/R and end around taxiing. These sources of noise contribute to the overall noise at this site; however, the noise system currently does not correlate noise to airport ground activities. These activities are more characterized by long near continuous noise, but at a lower magnitude. Raising of the threshold to 67 dBA will improve the measurements by reducing the number of false correlated noise events, however, measuring within 1.5 CNEL will still be difficult to accomplish when using a threshold based monitoring system.

Due to NMT 8's location to the airfield, adjacent land uses and high ambient noise levels, this noise monitor is not recommended for use in correlating aircraft noise events for Title 21 purposes. This NMT is unable to meet Title 21 requirements as noted in Section 4.1 of this report; however, it is still useful to capture noise and use the data for other analysis beyond Title 21.

6.2 NMT Site 12

This NMT is located on the approach path in Foster City, near the corner of Gull and Crane Avenues, outside of the 65 CNEL noise contour; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dBA. The NMT is surrounded by residential land use and the primary noise source is from the residential land uses, including passing cars which contributes to the average ambient noise level of 51 dBA. The primary aircraft noise is from arriving aircraft on Runways 28L and 28R. These arrivals include aircraft that fly a straight-in approach as well as those that are on the offset approach to Runway 28R. **Table 5** shows the 58 – 67 dBA thresholds and aircraft correlation; the current threshold is shown in red.

Table 5 – NMT 12 Thresholds and Durations

Metric	Thresholds										
	58	59	60	61	62	63	64	65	EVS ANOMS 65	66	67
Number of Events	7,265	6,763	6,368	6,114	5,874	5,632	5,351	4,960		4,478	3,880
Number of Correlated Events	6,229	5,989	5,781	5,630	5,458	5,257	5,004	4,650	**4,587**	4,221	3,675
Total Number of Nearby Flights	7,739	7,739	7,739	7,739	7,739	7,739	7,739	7,739		7,739	7,739
Number of Correlated Events with duration > 60 seconds	102	60	48	30	25	19	10	10	**18**	5	0
dBA Max (logarithmic average)	71.0	71.2	71.3	71.4	71.5	71.6	71.8	72.0	**72.0**	72.2	72.6
CNEL Aircraft (logarithmic average)	63.64	63.56	63.47	63.37	63.25	63.10	62.89	62.63	**62.0**	62.25	61.71
CNEL Community (logarithmic average)	56.52	56.91	57.30	57.70	58.13	58.59	59.11	59.68	**59.3**	60.35	61.07
CNEL Total (logarithmic average)	64.41	64.41	64.41	64.41	64.41	64.41	64.41	64.41	**63.9**	64.41	64.41

Source: BridgeNet International, 2020

Based on the information in **Table 5**, the recommended threshold is 62 dBA which is approximately 10 dBA above the ambient; this is three decibels lower than the current threshold of 65 dBA. The site may potentially report approximately 0.5 dBA higher, but still below 65 CNEL and measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL. Lowering the threshold is possible due to the monitor being able to correctly correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft as noted in

Section 2 of this report. The recommended event duration minimum is eight (8) seconds and maximum is 120 seconds. This threshold and event duration will capture more events, correlating the highest number of flight events in the PCA to noise events. While it is recommended to lower the threshold, the current threshold does capture the majority of the acoustic energy and this change should only result in minor changes to the measured aircraft CNEL. The events should be continued to be analyzed to determine if there is an increase in 120 second events. If so, the threshold should be raised in 1 dBA increments and the data reprocessed.

To reduce false correlations to aircraft overflights, it is suggested that the range be reduced to 15,000 feet. The offset approach to Runway 28R is roughly 5,000 feet from NMT 12. Occasionally, NMT 12 will capture arrival noise from Runways 10L/R operations. These operations are higher and fly a wider path than those on approach to Runways 28L/R; decreasing the range should limit most correlations to aircraft on Runways 10L/R.

6.3 NMT Site 15

This NMT is located in Oyster Point in South San Francisco, in the parking lot of the marina. Surrounding land uses include the marina to the north, and the associated vehicle parking lot to the south, east and west. It is located outside of the 65 CNEL noise contour; the default threshold for this NMT is 55 dBA, however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 64 dBA. The primary noise source is from the marina. The average ambient noise level is 51 dBA. The primary aircraft noise is from aircraft departing on Runway 01L using the SSTIK procedure and arrivals from the northwest that are headed to Runway 28R for landing. In December 2019, the monitor was moved approximately 1,300 feet to the west, on the western edge of the marina. The noise sources remain the same for aircraft and non-aircraft events and does not change the 1.5 CNEL measurement accuracy. The site is predicted to measure potentially 1 dBA CNEL higher with the lower threshold, but still below 65 CNEL. This is due to the monitor being able to correctly correlate aircraft noise events generated by aircraft that are not the dominant noise aircraft as noted in Section 2 of this report.

Table 6 shows the different thresholds and aircraft correlation based on these thresholds.

Table 6 – NMT 15 Thresholds and Durations

	Thresholds										
Metric	57	58	59	60	61	62	63	64	EVS ANOMS 64	65	66
Number of Events	5,636	4,682	3,845	3,284	2,863	2,559	2,309	2,055		1,735	1,370
Number of Correlated Events	3,340	3,044	2,786	2,592	2,428	2,292	2,152	1,943	**1,909**	1,641	808
Total Number of Nearby Flights	9,605	9,605	9,605	9,605	9,605	9,605	9,605	9,605		9,605	9,605
Number of Correlated Events with duration <60 seconds	514	283	150	21	21	11	5	2	**9**	0	0
dBA Max (logarithmic average)	69.3	69.6	69.9	70.2	70.4	70.6	70.7	71.0	**70.9**	71.3	72.1
CNEL Aircraft (logarithmic average)	61.01	60.62	60.43	60.24	60.04	59.81	59.50	59.09	**58.23**	58.56	57.87
CNEL Community (logarithmic average)	56.69	57.59	57.95	58.27	58.57	58.87	59.23	59.62	**59.63**	60.05	60.47
CNEL Total (logarithmic average)	62.37	62.37	62.37	62.37	62.37	62.37	62.37	62.37	**62.00**	62.37	62.37

Source: BridgeNet International, 2020

Based on the information in **Table 6**, the recommended threshold is 60 dBA; this is four (4) dBA lower than the current threshold of 64 dBA and is approximately 0.24 dBA lower than the CNEL measured noise level, measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL. The recommended minimum duration is eight (8) seconds and the maximum duration remains at 60 seconds. This threshold and duration recommendation will ensure that long events are not falsely captured. While a lower threshold is recommended, the current threshold captures the majority of the acoustic energy and this change should only result in minor changes to the measured aircraft CNEL. The events should be continued to be analyzed to determine if there is an increase in 120 second events. If so, the threshold should be raised in 1 dBA increments and the data reprocessed.

6.4 NMT Site 18

This NMT is located in Daly City on Margate Street, between Shipley Avenue and Gellert Blvd. The site is surrounded by residential land uses on all sides and is located outside of the 65 CNEL noise contour; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 63 dB. The primary noise source is from residential land uses, including vehicle traffic and the average ambient noise level is 50 dBA. The primary aircraft noise is from wide body aircraft departing on Runways 28L/R using the GNNRR procedure and some aircraft using the GAP procedure. These aircraft are typically the largest and loudest that operate at SFO, flying to destinations in Asia and Europe. Since this monitor already captures noise events by these aircraft that are the dominate contributors to the CNEL contour, it does not change the 1.5 CNEL measurement accuracy. No change in the predicted measured CNEL noise level would occur with the lower threshold. However, more lower-level noise events would be detected and potential correlated.

Table 7 shows the different thresholds and aircraft correlation based on these thresholds.

Table 7 - NMT 18 Thresholds and Durations

Metric	Thresholds 56	57	58	59	60	61	62	63	EVS ANOMS 63	64	65
Number of Events	6,460	5,092	4,126	3,614	3,054	2,764	2,584	2,428	NA	2,334	2,264
Number of Correlated Events	2,169	1,993	1,806	1,634	1,461	1,352	1,270	1,198	**1,192**	1,157	1,124
Total Number of Nearby Flights	7,857	7,857	7,857	7,857	7,857	7,857	7,857	7,857		7,857	7,857
Number of Correlated Events with duration > 60 seconds	92	41	10	3	0	0	0	0	**0**	0	0
dBA Max (logarithmic average)	75.5	75.9	76.4	76.8	77.3	77.6	77.9	78.1	**78.2**	78.3	78.4
SEL (logarithmic average)	85.0	85.4	85.9	86.3	86.8	87.1	87.3	87.5	**87.5**	87.6	87.7
CNEL Aircraft (logarithmic average)	64.08	64.04	64.00	63.96	63.92	63.89	63.85	63.82	**63.5**	63.78	63.73
CNEL Community (logarithmic average)	56.54	56.78	57.00	57.19	57.36	57.50	57.66	57.81	**57.4**	57.96	58.12
CNEL Total (logarithmic average)	64.79	64.79	64.79	64.79	64.79	64.79	64.79	64.79	**64.4**	64.79	64.79

Source: BridgeNet International, 2020

Based on the information in **Table 7**, the recommended threshold is 63 dBA; this is the same as the current threshold and is approximately 0.5 CNEL lower than the measured noise level while still below 65 CNEL and measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL. The recommended minimum duration is eight (8) seconds and the maximum duration is 60 seconds. This threshold and duration recommendation will continue to correlate aircraft flight events to noise. Lowering the threshold would potentially result in a higher number of false long-duration 120 second events.

6.5 NMT Site 19

This NMT is located in Pacifica in Fairmont Park, between Highway 1 and Hickey Blvd. The site is surrounded by parkland on all sides, followed by residential land uses and is located outside of the 65 CNEL noise contour; the default threshold for this NMT is 55 CNEL; however, the threshold waiver was approved by Caltrans in 2011 for it to be raised to 65 dB. The primary noise source is from activities at the park and residential land uses, include vehicle traffic; the average ambient noise level is 48 dBA. The primary aircraft noise is from wide body aircraft departing on Runways 28L/R using the GNNRR and GAP procedures. These aircraft are typically the largest and loudest that operate at SFO, flying to destinations in Asia and Europe. As with NMT Site 18, this monitor already captures noise events by these aircraft that are the dominate contributors to the CNEL contour and does not change the 1.5 CNEL measurement accuracy. With lowering the threshold by 1 dBA, the predicted CNEL noise level would be approximately 0.1 CNEL higher. However, more lower level noise events would be detected and potentially correlated.

Table 8 shows the different thresholds and aircraft correlation based on these thresholds.

Table 8 - NMT 19 Thresholds and Durations

Metric	Thresholds 58	59	60	61	62	63	64	65	EVS ANOMS 65	66	67
Number of Events	1,585	1,455	1,351	1,268	1,219	1,189	1,146	1,102		1,050	981
Number of Correlated Events	1,398	1,307	1,227	1,169	1,126	1,104	1,072	1,035	**1,037**	990	927
Total Number of Nearby Flights	1,688	1,688	1,688	1,688	1,688	1,688	1,688	1,688		1,688	1,688
Number of Correlated Events with duration > 60 seconds	5	4	3	3	3	3	3	2	**1**	2	2
dBA Max (logarithmic average)	73.9	74.2	74.5	74.6	74.7	74.8	74.9	75.0	**75.0**	75.2	75.4
SEL (logarithmic average)	84.1	84.3	84.5	84.7	84.8	84.8	84.9	84.9	**84.8**	85.0	85.0
CNEL Aircraft (logarithmic average)	61.26	61.23	61.19	61.15	61.10	61.04	60.97	60.87	**60.3**	60.74	60.55
CNEL Community (logarithmic average)	54.43	54.60	54.77	54.95	55.15	55.36	55.62	55.94	**56.2**	56.32	56.80
CNEL Total (logarithmic average)	62.08	62.08	62.08	62.08	62.08	62.08	62.08	62.08	**61.8**	62.08	62.08

Source: BridgeNet International, 2020

Based on the information in **Table 8**, the recommended threshold is 64 dBA; this is one (1) dBA lower than the current threshold. The recommended minimum duration is eight (8) seconds and the maximum duration is 60 seconds, which is 60 seconds lower. This threshold and duration recommendation will continue to correlate aircraft flight events to noise. While it is recommended that it is possible to lower the threshold, the current threshold does capture the majority of the acoustic energy and this change should only result in minor changes to the measured aircraft CNEL. The events should be followed to determine if there is an increase in 120 second events. If so, the threshold should be raised in 1 dBA increments and the data reprocessed. The site may potentially report approximately 0.1 dBA higher, but still below 65 CNEL and measures within the 1.5 dBA Title 21 measurement accuracy of the estimated aircraft noise CNEL.

7. Summary and Recommendations

Based on the analysis presented in Section 6, **Table 9** shows the recommended NMT thresholds and event detection for NMTs 8, 12, 15, 18 and 19. As noted in Section 6.1, NMT 8 is not recommended to be used for Title 21 purposes. All other NMTs studied in this report are recommended to continue to be used for Title 21 threshold correlation of aircraft noise that meet the requirements of Title 21, Section 5070 (i.e., measure aircraft noise within an accuracy of 1.5 CNEL. The recommended thresholds in this report are predicted to result in some small changes to the measured CNEL, and will more accurately correlate aircraft events to the associated noise of lower noise level events. These recommendations will ensure the NMTs are capturing more of the quieter aircraft events; the NMTs will continue to capture the louder events, which contribute more greatly to the shape and size of the noise contours.

Table 9 – Recommended NMT Thresholds and Duration

NMT	City	Location	Current NMT Threshold, CNEL	Recommended NMT Threshold, CNEL	Recommended NMT Minimum Duration	Recommended NMT Maximum Duration
8	Millbrae	Behind departure roll for Runways 1L/1R	65	67	8	60
12	Foster City	Approach path to Runways 28L/28R	65	62	8	60
15	South San Francisco (Oyster)	SSTIK departures over Brisbane	64	60	8	60
18	Daly City	Gap departure along centerline	63	63	8	60
19	Pacifica	Gap departure at the left of centerline	65	64	8	60

Source: BridgeNet International, July 2020

APPENDIX

Report Figures

Airport Director's Report

Presented at the December 1, 2021
Airport/Community Roundtable Meeting

Aircraft Noise Office
September 2021

SFO San Francisco International Airport

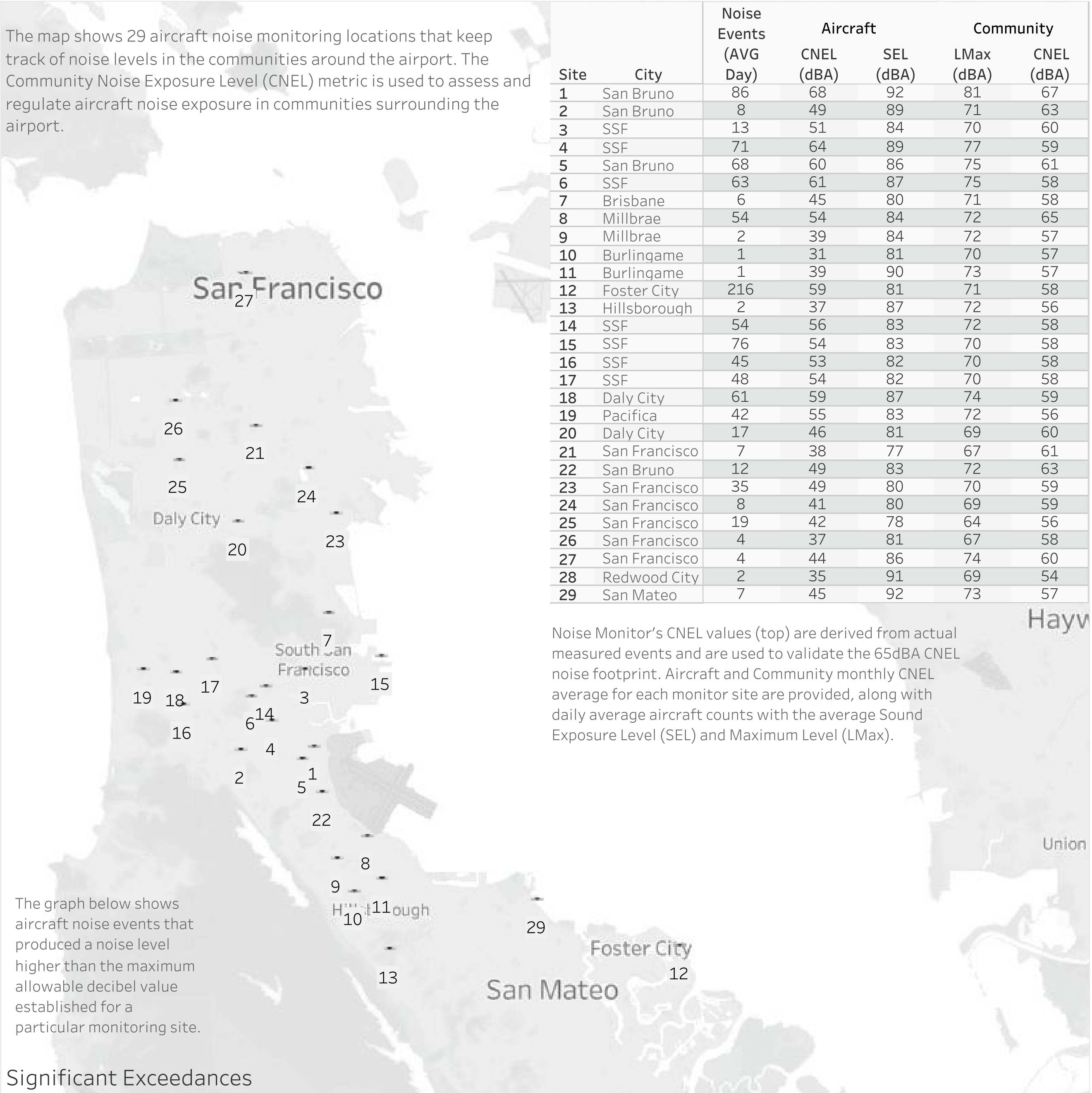
Aircraft Noise Levels

September 2021

The map shows 29 aircraft noise monitoring locations that keep track of noise levels in the communities around the airport. The Community Noise Exposure Level (CNEL) metric is used to assess and regulate aircraft noise exposure in communities surrounding the airport.

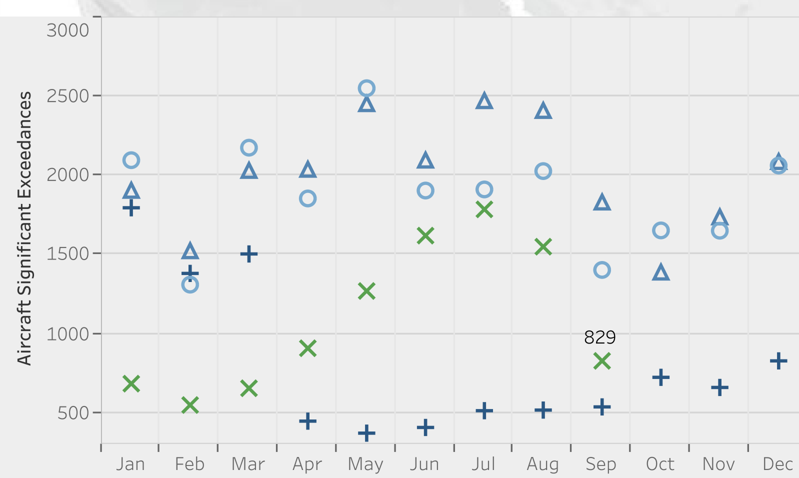
Site	City	Noise Events (AVG Day)	Aircraft CNEL (dBA)	Aircraft SEL (dBA)	Community LMax (dBA)	Community CNEL (dBA)
1	San Bruno	86	68	92	81	67
2	San Bruno	8	49	89	71	63
3	SSF	13	51	84	70	60
4	SSF	71	64	89	77	59
5	San Bruno	68	60	86	75	61
6	SSF	63	61	87	75	58
7	Brisbane	6	45	80	71	58
8	Millbrae	54	54	84	72	65
9	Millbrae	2	39	84	72	57
10	Burlingame	1	31	81	70	57
11	Burlingame	1	39	90	73	57
12	Foster City	216	59	81	71	58
13	Hillsborough	2	37	87	72	56
14	SSF	54	56	83	72	58
15	SSF	76	54	83	70	58
16	SSF	45	53	82	70	58
17	SSF	48	54	82	70	58
18	Daly City	61	59	87	74	59
19	Pacifica	42	55	83	72	56
20	Daly City	17	46	81	69	60
21	San Francisco	7	38	77	67	61
22	San Bruno	12	49	83	72	63
23	San Francisco	35	49	80	70	59
24	San Francisco	8	41	80	69	59
25	San Francisco	19	42	78	64	56
26	San Francisco	4	37	81	67	58
27	San Francisco	4	44	86	74	60
28	Redwood City	2	35	91	69	54
29	San Mateo	7	45	92	73	57

Noise Monitor's CNEL values (top) are derived from actual measured events and are used to validate the 65dBA CNEL noise footprint. Aircraft and Community monthly CNEL average for each monitor site are provided, along with daily average aircraft counts with the average Sound Exposure Level (SEL) and Maximum Level (LMax).



The graph below shows aircraft noise events that produced a noise level higher than the maximum allowable decibel value established for a particular monitoring site.

Significant Exceedances

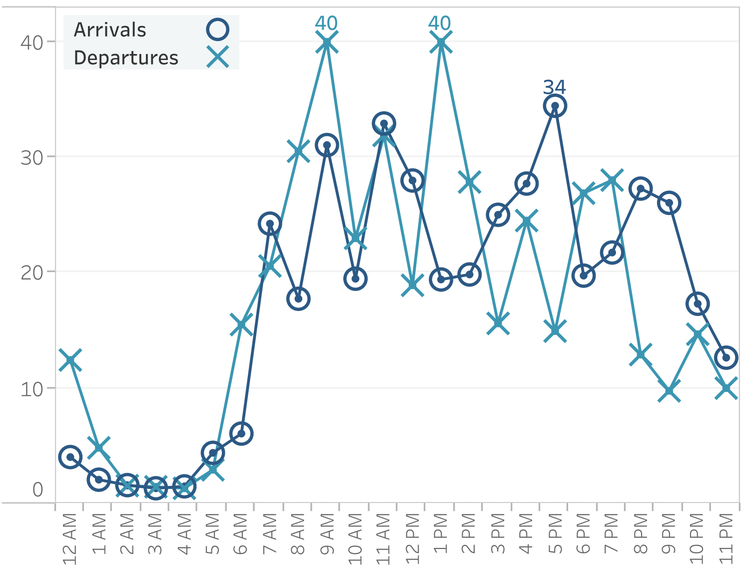


Operations

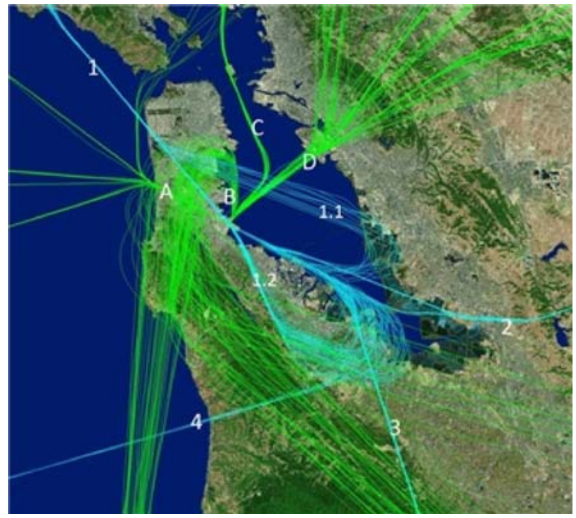
September 2021

Monthly Ops	AVG Daily Ops	12 Month AVG	YOY Growth
25,558	852	19,365	38%

September 2021 Average Day (Hourly)



Major Arrival and Departure Routes (West Flow)



West Flow is depicted in the above image and is a predominate flow at SFO.

West Flow
100%

Top Destinations

Los Angeles	Seattle	San Diego
8%	4%	4%

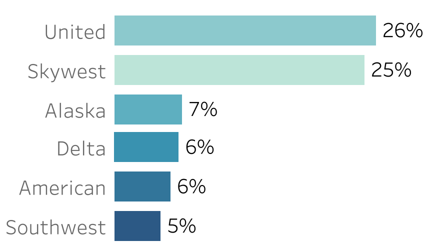
Down the Bay vs Peninsula

1.1 Down the Bay Visual	35%
1.2 BDEGA Arrival	65%

Arrival Route	
1. BDEGA	29%
2. DYAMD	36%
3. SERFR	29%
4. PIRAT	6%

Departure Route	
A. GAP	17%
B. SSTIK	31%
C. NIITE	8%
D. TRUKN RWY 01	43%
D. TRUKN RWY 28	2%

Airlines with the Most Operations



Non Airline

9%

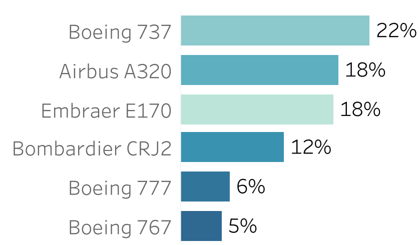
Narrow Body

74%

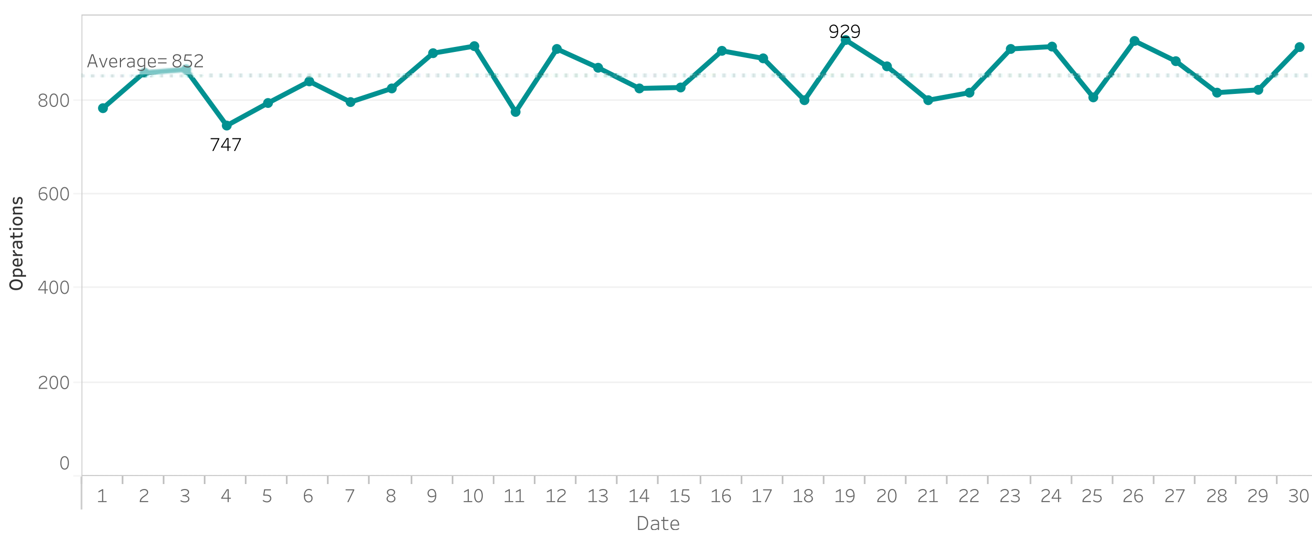
Wide Body

17%

Most Utilized Aircraft Types



Daily Aircraft Operations



Runway Usage and Nighttime Operations

Leftmost Runway Utilization table shows percent of runway usage for arrivals and departures by runway based on air carrier operations using jet, regional jet, and turboprop aircraft. Late Night Preferential Runway Use table depicts departure runway usage between 1am - 6am for jet aircraft for the whole month (top) and during nighttime hours only (bottom). Percentages [%] are rounded to the nearest whole number.

Runway Utilization

	Arrivals	Departures
01 L/R		84% 9,885
10 L/R	0% 1	0% 2
28 L/R	100% 11,746	16% 1,863

Late Night Preferential Runway Use (1 am - 6 am)

	Departures
10 L/R	1% 2
01 L/R	40% 106
28 L/R	60% 160

Runway Utilization

Arrivals

	28L	28R
	37%	63%
Night (10pm-7am)		
	13%	87%

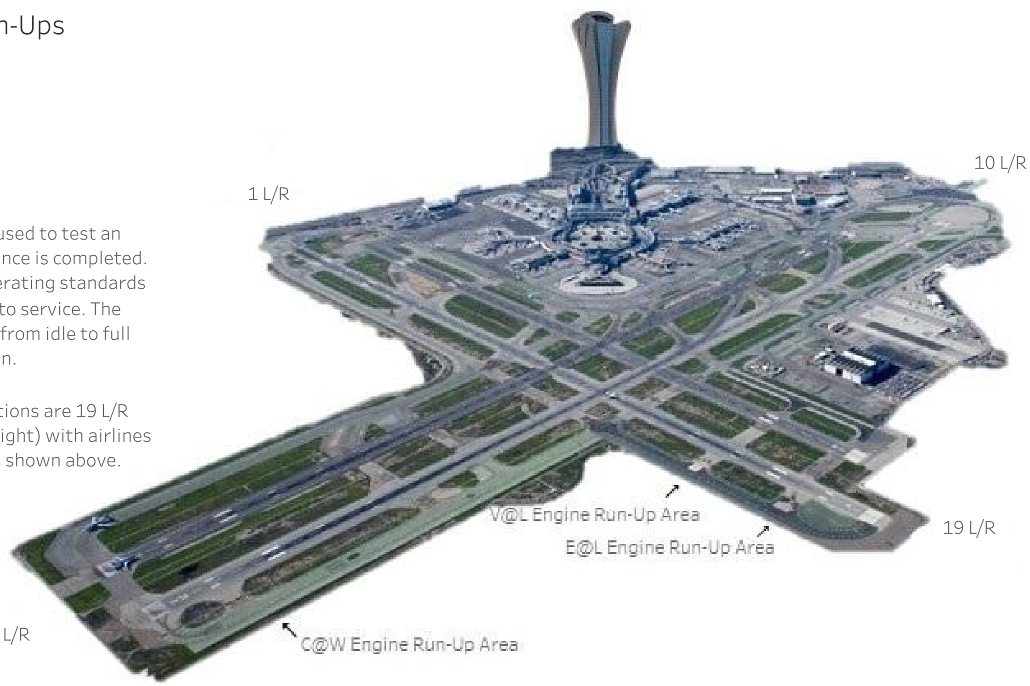
Nighttime Power Run-Ups

10pm-7am

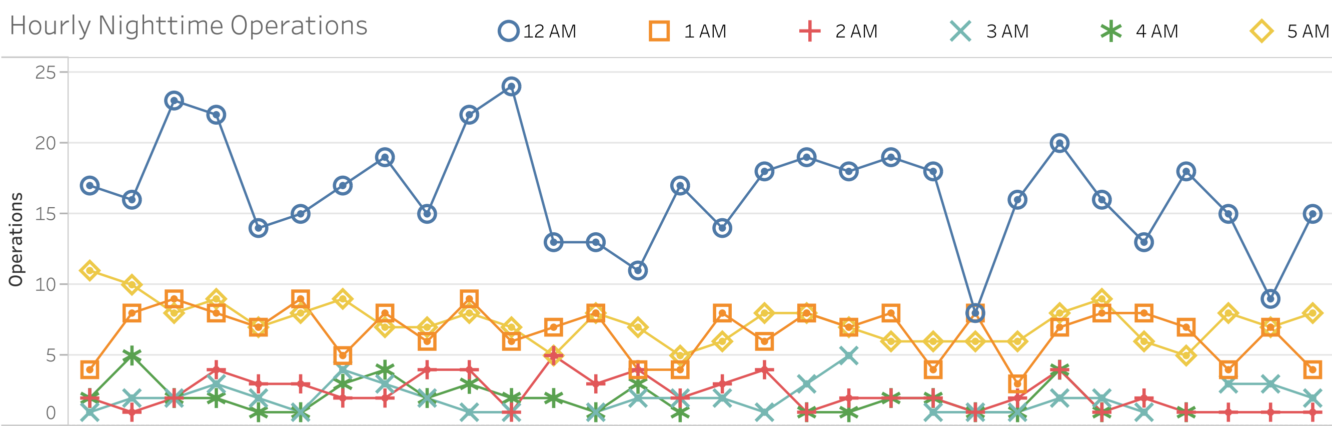
Alaska Airlines	2
American Airlines	2
Jetblue Airways	1
United Airlines	2

A power runup is a procedure used to test an aircraft engine after maintenance is completed. This is done to ensure safe operating standards prior to returning the aircraft to service. The Aircraft power settings range from idle to full power and may vary in duration.

Designated Power Runup locations are 19 L/R depicted on the airfield map (right) with airlines nighttime power runup counts shown above.



Hourly Nighttime Operations



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
12 AM	17	16	23	22	14	15	17	19	15	22	24	13	13	11	17	14	18	19	18	19	18	8	16	20	16	13	18	15	9	15
1 AM	4	8	9	8	7	9	5	8	6	9	6	7	8	4	4	8	6	8	7	8	4	8	3	7	8	8	7	4	7	4
2 AM	2	1	2	4	3	3	2	2	4	4	1	5	3	4	2	3	4	1	2	2	2	1	2	4	1	2	1	1	1	1
3 AM	1	2	2	3	2	1	4	3	2	1	1		1	2	2	2	1	3	5		1	1	1	2	2	1		3	3	2
4 AM	2	5	2	2	1	1	3	4	2	3	2	2	1	3	1			1	1	2	2	1	1	4	1		1			
5 AM	11	10	8	9	7	8	9	7	7	8	7	5	8	7	5	6	8	8	7	6	6	6	6	8	9	6	5	8	7	8

Noise Reports

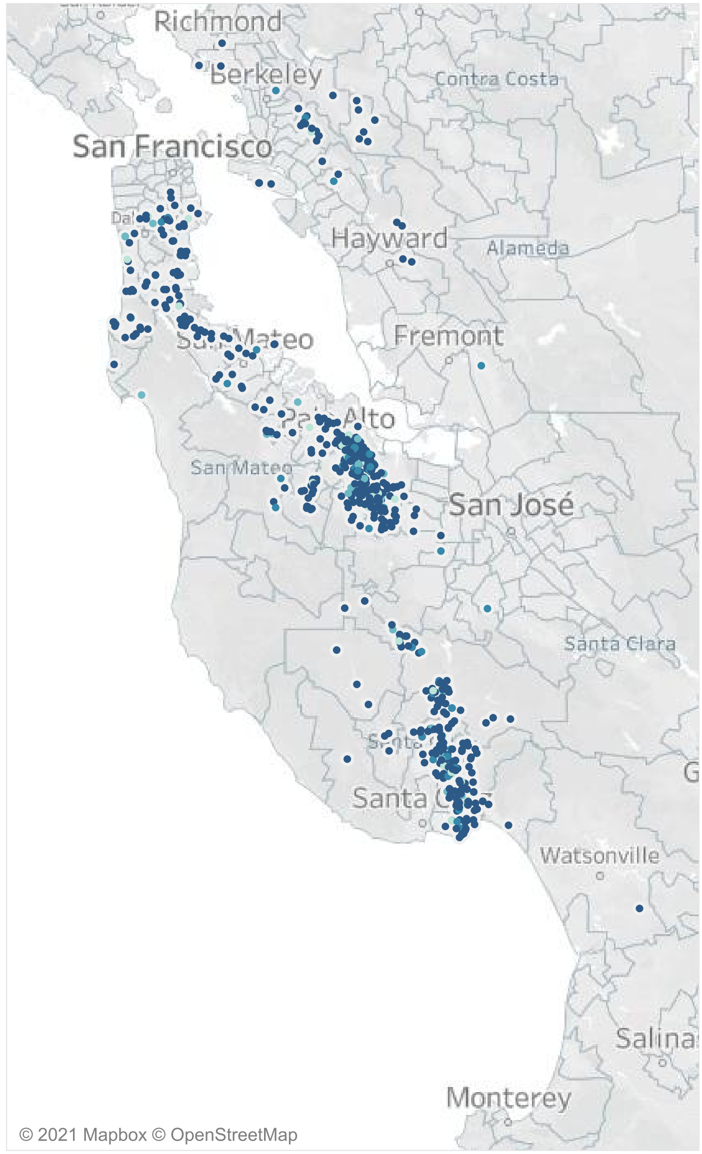
	City	Noise Reporters	Noise Reports
Roundtable	Atherton	5	218
	Belmont	2	45
	Brisbane	15	335
	Burlingame	7	28
	Daly City	7	1,617
	El Granada	1	640
	Foster City	2	17
	Hillsborough	1	2
	Menlo Park	14	1,461
	Millbrae	9	70
	Montara	1	107
	Pacifica	18	888
	Portola Valley	22	17,589
	Redwood City	6	1,396
	San Bruno	10	982
	San Carlos	3	24
	San Francisco	22	3,789
	San Mateo	12	798
	South San Francisco	11	154
	Woodside	5	1,350
Other	Alameda	3	162
	Aptos	2	19
	Ben Lomond	2	7
	Berkeley	2	361
	Boulder Creek	3	17
	Capitola	7	360
	Carmel Valley	1	1
	Castro Valley	2	22
	Cupertino	1	346
	East Palo Alto	1	245
	Emerald Hills	4	457
	Felton	3	109
	Fremont	1	342
	Hayward	2	9
	Los Altos	73	12,679
	Los Altos Hills	16	1,670
	Los Gatos	54	8,184
	Moraga	6	178
	Mountain View	25	2,810
	Oakland	13	2,948
	Orinda	1	15
	Palo Alto	134	26,767
	Richmond	3	267
	Santa Clara	1	1
	Santa Cruz	68	12,843
	Scotts Valley	46	5,695
	Soquel	39	5,073
	Stanford	4	246
	Sunnyvale	3	50
	Watsonville	1	109
	Grand Total	**694**	**113,502**

Notes: Address validation Relies on USPS-provided ZIP Code look up table and USPS-specified default city values.

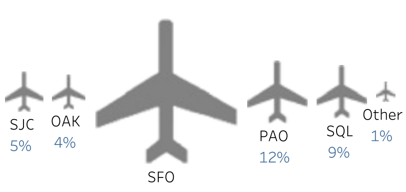
Reporters Annual AVG	672
Reports Annual AVG	102,435
New Reporters	44
New Reporters Top City	Burlingame
Furthest Report	85 miles
Reports per SFO Operation	4
Top Aircraft Types	B737 A320 E75L
Top Flight Numbers	KAL214 JBU636 AMX664

Noise Reporters Location Map

September 2021

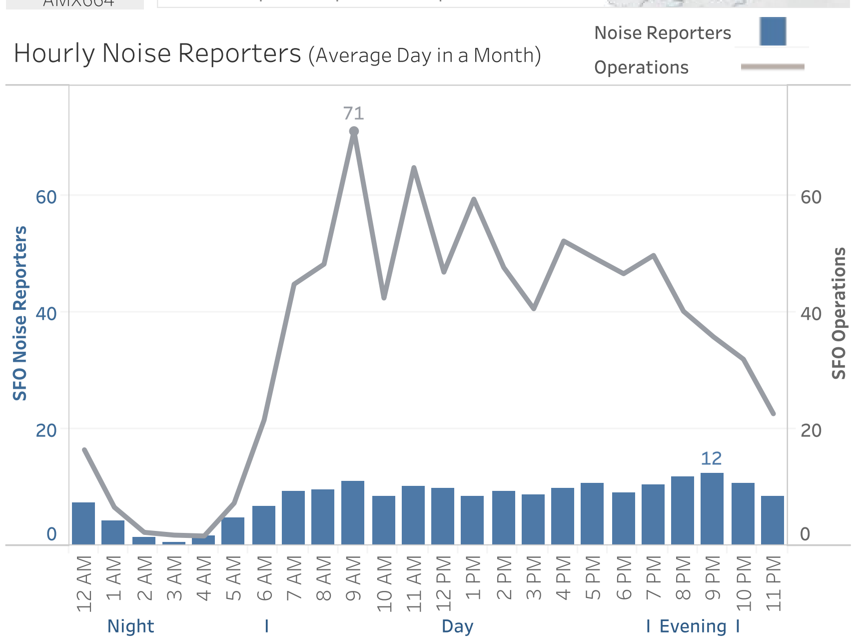


Noise Reports by Airport



99% of noise reports correlate to a flight origin/destination airport.

Hourly Noise Reporters (Average Day in a Month)



Source: SFO Intl Airport Noise Monitoring System

Airport Director's Report

Presented at the December 1, 2021
Airport/Community Roundtable Meeting

Aircraft Noise Office
October 2021

SFO San Francisco International Airport

Aircraft Noise Levels

October 2021

The map shows 29 aircraft noise monitoring locations that keep track of noise levels in the communities around the airport. The Community Noise Exposure Level (CNEL) metric is used to assess and regulate aircraft noise exposure in communities surrounding the airport.

Site	City	Noise Events (AVG Day)	Aircraft CNEL (dBA)	Aircraft SEL (dBA)	Community LMax (dBA)	Community CNEL (dBA)
1	San Bruno	139	69	92	81	66
2	San Bruno	19	48	81	70	63
3	SSF	35	54	84	72	61
4	SSF	110	64	88	77	59
5	San Bruno	118	63	87	75	61
6	SSF	95	62	86	75	57
7	Brisbane	11	46	81	71	58
8	Millbrae	43	59	89	73	65
9	Millbrae	10	47	85	73	58
10	Burlingame	6	45	87	74	57
11	Burlingame	20	50	88	77	57
12	Foster City	236	60	82	71	59
13	Hillsborough	21	43	83	70	56
14	SSF	87	57	83	71	58
15	SSF	98	56	82	71	59
16	SSF	75	56	82	71	58
17	SSF	73	56	82	70	58
18	Daly City	88	60	85	74	59
19	Pacifica	69	57	83	72	58
20	Daly City	19	48	82	70	60
21	San Francisco	7	45	85	68	61
22	San Bruno	28	51	82	72	62
23	San Francisco	40	51	81	70	60
24	San Francisco	8	41	79	69	59
25	San Francisco	19	43	79	65	57
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27	San Francisco	3	56	101	76	65
28	Redwood City	2	36	82	68	55
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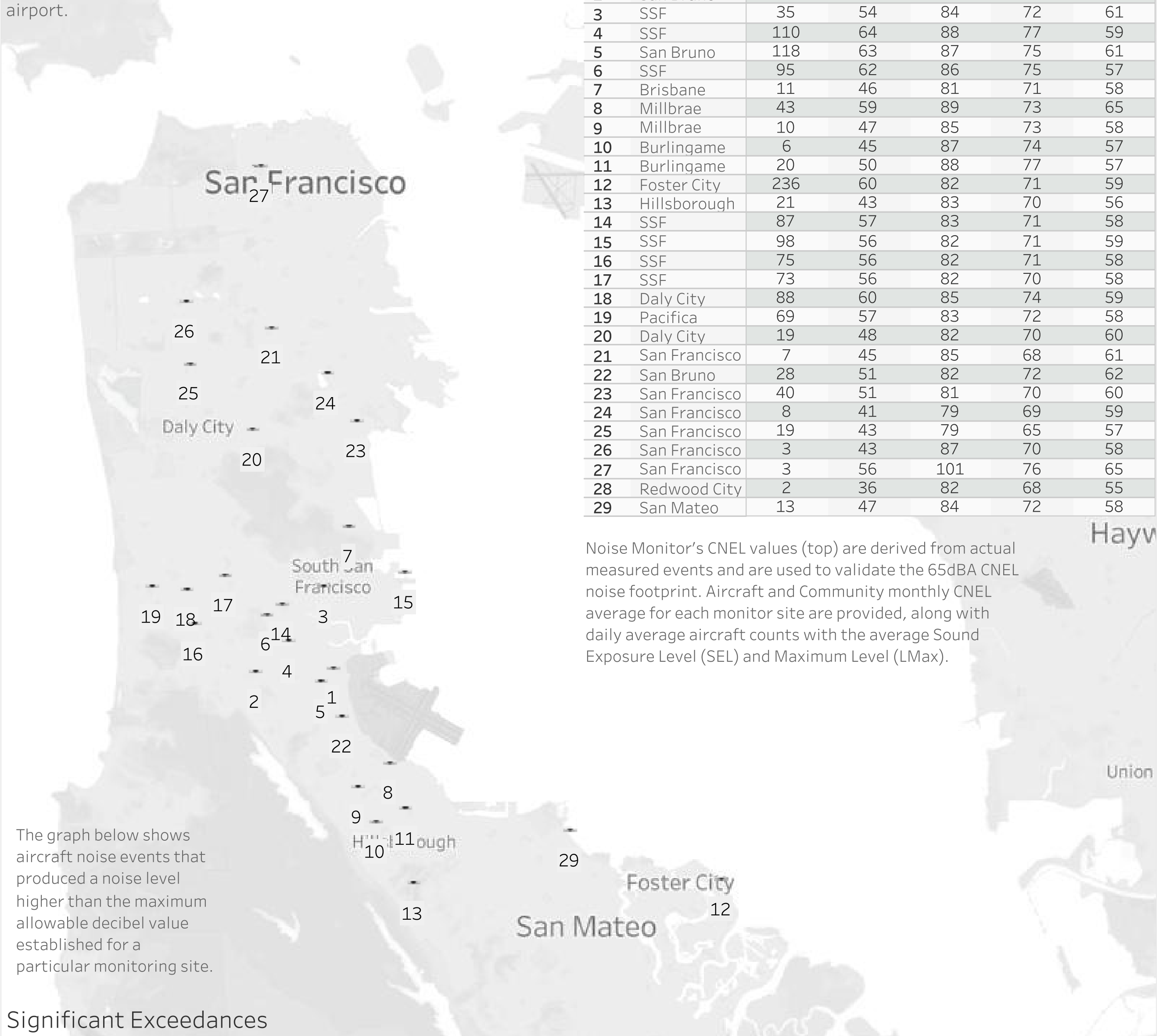
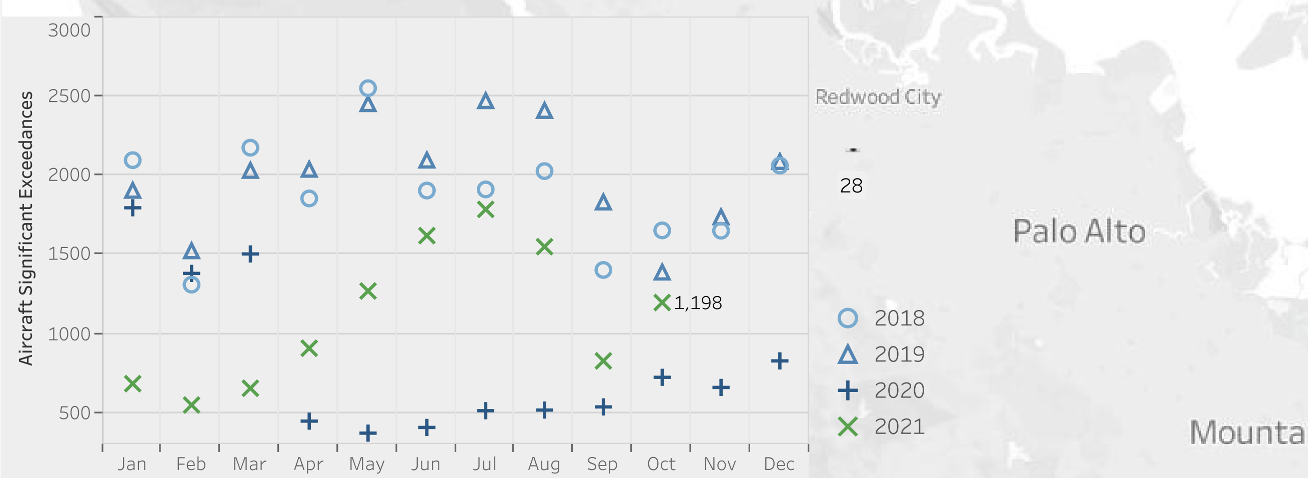
Noise Monitor's CNEL values (top) are derived from actual measured events and are used to validate the 65dBA CNEL noise footprint. Aircraft and Community monthly CNEL average for each monitor site are provided, along with daily average aircraft counts with the average Sound Exposure Level (SEL) and Maximum Level (LMax).



The graph below shows aircraft noise events that produced a noise level higher than the maximum allowable decibel value established for a particular monitoring site.

Significant Exceedances

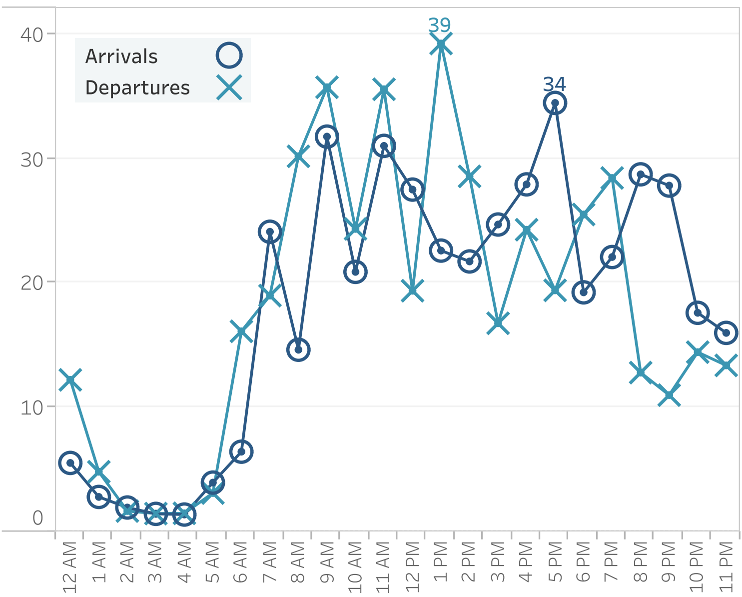


Operations

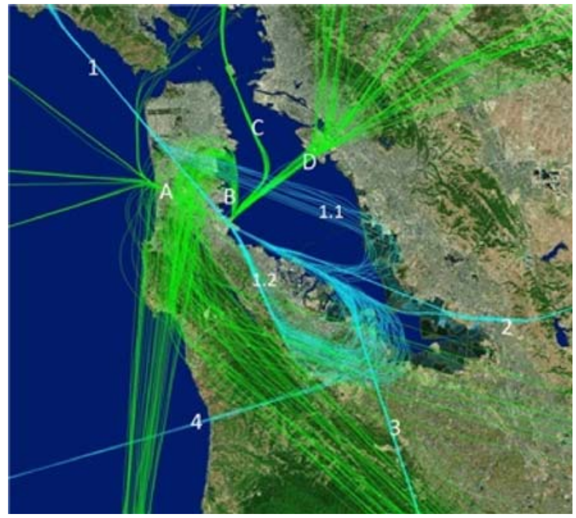
October 2021

Monthly Ops	AVG Daily Ops	12 Month AVG	YOY Growth
27,030	872	20,199	37%

October 2021 Average Day (Hourly)



Major Arrival and Departure Routes (West Flow)



West Flow is depicted in the above image and is a predominate flow at SFO.

West Flow
93%

Arrival Route	
1. BDEGA	29%
2. DYAMD	35%
3. SERFR	30%
4. PIRAT	5%

Departure Route	
A. GAP	25%
B. SSTIK	27%
C. NIITE	7%
D. TRUKN RWY 01	32%
D. TRUKN RWY 28	8%

Top Destinations

Los Angeles	Seattle	Las Vegas
8%	4%	3%

Down the Bay vs Peninsula

1.1 Down the Bay Visual	29%
1.2 BDEGA Arrival	71%

Airlines with the Most Operations

United	27%
Skywest	24%
Alaska	7%
Delta	7%
American	6%
Southwest	4%

Non Airline

10%

Narrow Body

75%

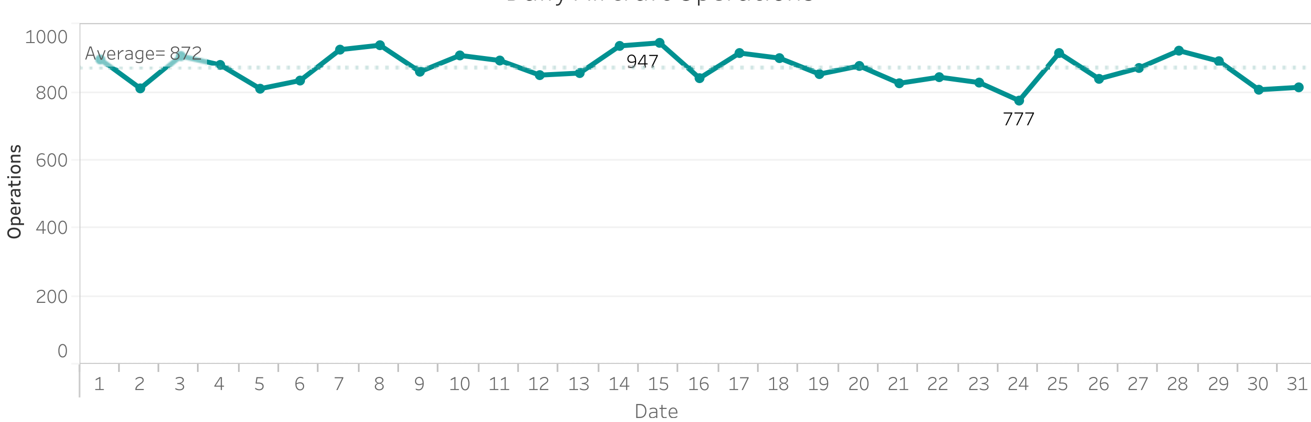
Wide Body

15%

Most Utilized Aircraft Types

Boeing 737	24%
Airbus A320	19%
Embraer E170	16%
Bombardier CRJ2	10%
Boeing 777	6%
Boeing 787	5%

Daily Aircraft Operations



Runway Usage and Nighttime Operations

Leftmost Runway Utilization table shows percent of runway usage for arrivals and departures by runway based on air carrier operations using jet, regional jet, and turboprop aircraft. Late Night Preferential Runway Use table depicts departure runway usage between 1am - 6am for jet aircraft for the whole month (top) and during nighttime hours only (bottom). Percentages [%] are rounded to the nearest whole number.

Runway Utilization

	Arrivals	Departures
01 L/R		65% 7,972
10 L/R		6% 699
19 L/R	7% 875	2% 200
28 L/R	93% 11,454	28% 3,470

Late Night Preferential Runway Use (1 am - 6 am)

	Departures
10 L/R	11% 34
01 L/R	33% 102
28 L/R	54% 165
19 L/R	1% 4

Runway Utilization

	Arrivals	
	28L	28R
	45%	55%
Night (10pm-7am)		
	29%	71%

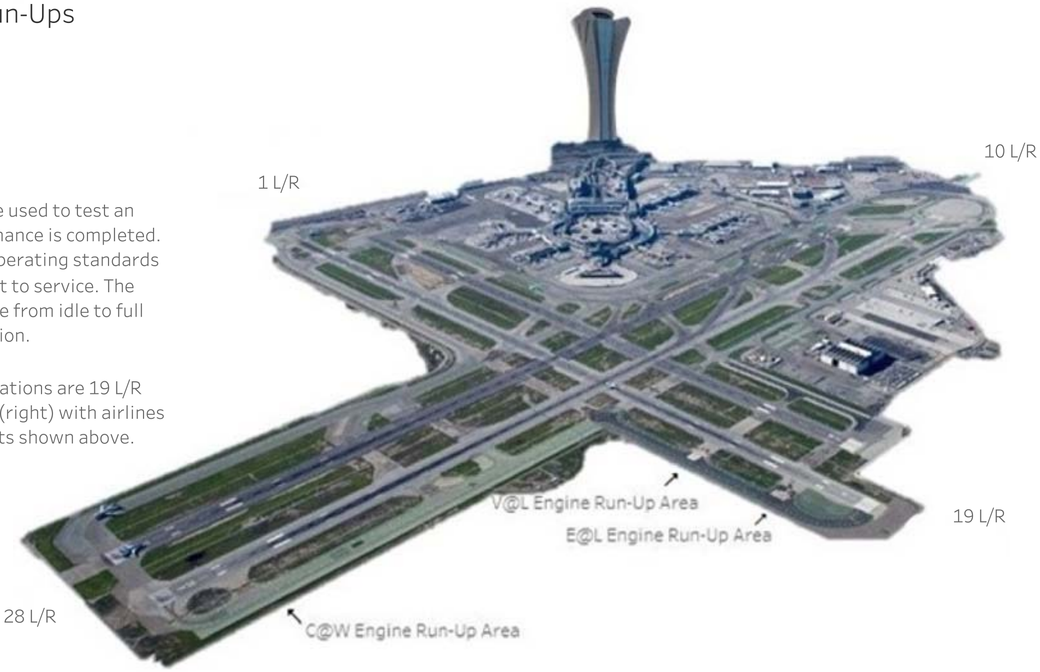
Nighttime Power Run-Ups

10pm-7am

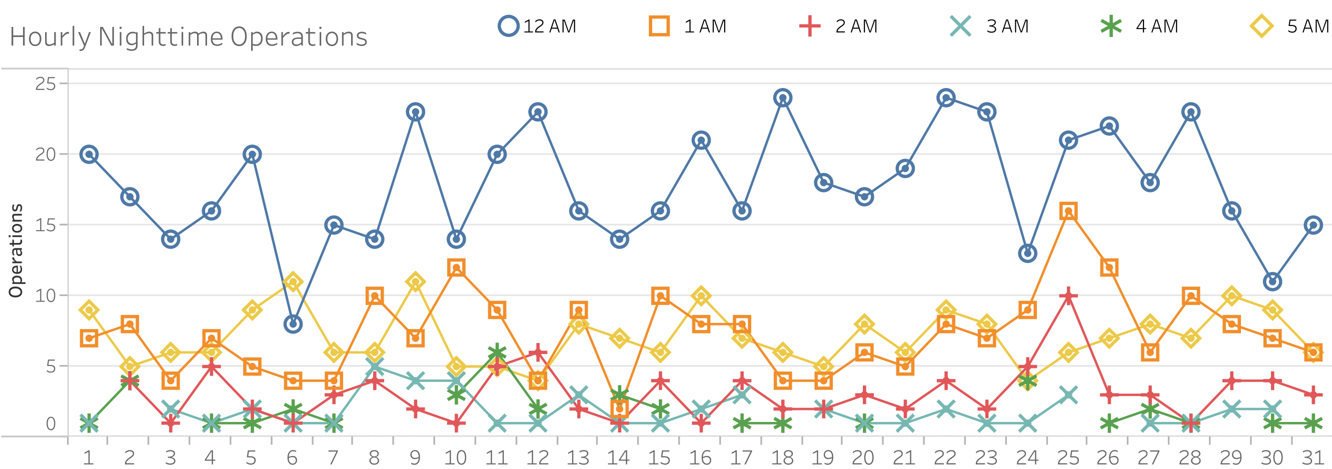
Alaska Airlines	2
American Airlines	4
United Airlines	3

A power runup is a procedure used to test an aircraft engine after maintenance is completed. This is done to ensure safe operating standards prior to returning the aircraft to service. The Aircraft power settings range from idle to full power and may vary in duration.

Designated Power Runup locations are 19 L/R depicted on the airfield map (right) with airlines nighttime power runup counts shown above.



Hourly Nighttime Operations



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
12 AM	20	17	14	16	20	8	15	14	23	14	20	23	16	14	16	21
1 AM	7	8	4	7	5	4	4	10	7	12	9	4	9	2	10	8
2 AM		4	1	5	2	1	3	4	2	1	5	6	2	1	4	1
3 AM	1		2	1	2	1	1	5	4	4	1	1	3	1	1	2
4 AM	1	4		1	1	2	1			3	6	2		3	2	
5 AM	9	5	6	6	9	11	6	6	11	5	5	4	8	7	6	10

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
12 AM	16	24	18	17	19	24	23	13	21	22	18	23	16	11	15
1 AM	8	4	4	6	5	8	7	9	16	12	6	10	8	7	6
2 AM	4	2	2	3	2	4	2	5	10	3	3	1	4	4	3
3 AM	3		2	1	1	2	1	1	3		1	1	2	2	
4 AM	1	1		1				4		1	2	1		1	1
5 AM	7	6	5	8	6	9	8	4	6	7	8	7	10	9	6

Noise Reports

October 2021

	City	Noise Reporters	Noise Reports
Roundtable	Atherton	5	420
	Belmont	2	172
	Brisbane	12	493
	Burlingame	6	41
	Daly City	7	2,175
	El Granada	1	828
	Foster City	8	40
	Hillsborough	2	3
	Menlo Park	15	1,816
	Millbrae	10	65
	Montara	1	953
	Pacifica	17	1,159
	Portola Valley	20	18,023
	Redwood City	9	1,888
	San Bruno	12	1,222
	San Carlos	3	48
	San Francisco	22	2,776
	San Mateo	11	946
	South San Francisco	16	173
	Woodside	5	1,966
Other	Alameda	7	86
	Aptos	2	35
	Ben Lomond	2	5
	Berkeley	2	552
	Boulder Creek	2	63
	Capitola	8	391
	Carmel Valley	1	9
	Castro Valley	2	44
	Cupertino	1	593
	East Palo Alto	1	12
	Emerald Hills	5	1,129
	Felton	3	70
	Fremont	1	339
	Hayward	1	5
	Los Altos	68	13,222
	Los Altos Hills	15	1,728
	Los Gatos	49	8,605
	Moraga	6	420
	Mountain View	26	3,350
	Oakland	16	4,020
	Orinda	1	70
	Palo Alto	132	29,724
	Richmond	3	566
	San Jose	1	4
	Santa Cruz	67	15,249
	Scotts Valley	45	6,559
	Soquel	42	7,524
	Stanford	5	628
	Sunnyvale	1	91
	Watsonville	1	103
	Grand Total	**700**	**130,403**

Notes: Address validation Relies on USPS-provided ZIP Code look up table and USPS-specified default city values.

Reporters Annual AVG
673

Reports Annual AVG
105,789

New Reporters
26

New Reporters Top City
South San Francisco

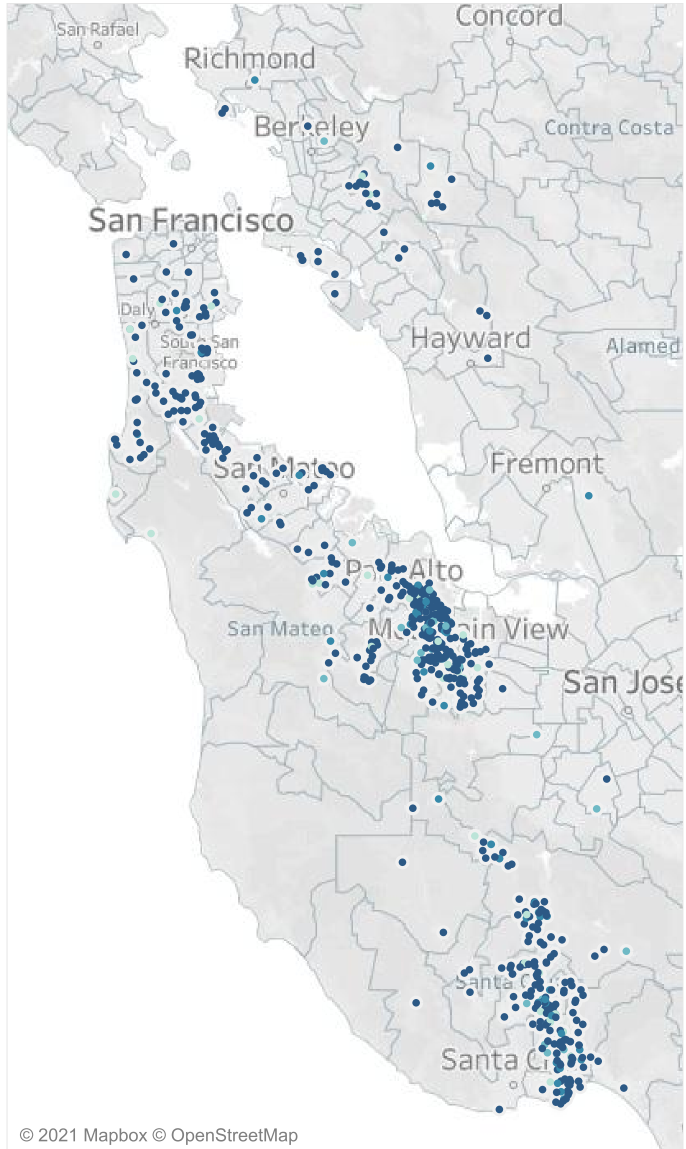
Furthest Report
85 miles

Reports per SFO Operation
5

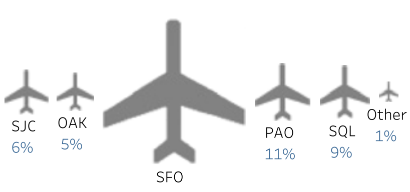
Top Aircraft Types
B737
A320
E75L

Top Flight Numbers
JBU636
ASA1273
UAL1761
AMX608

Noise Reporters Location Map

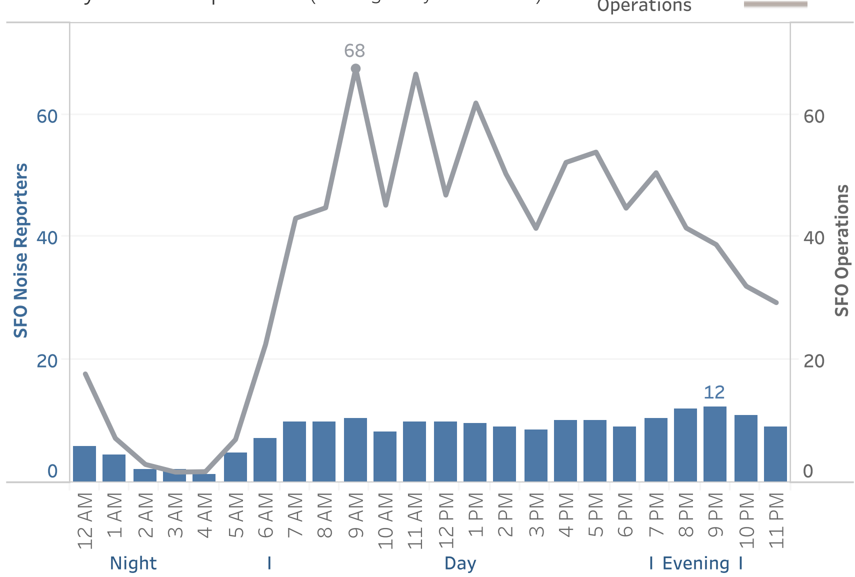


Noise Reports by Airport



99% of noise reports correlate to a flight origin/destination airport.

Hourly Noise Reporters (Average Day in a Month)



Source: SFO Intl Airport Noise Monitoring System

From:	vessacks@gmail.com
To:	Angela Montes
Cc:	"Marie-Jo Fremont"; "Darlene Yaplee"; "Greg Leyh"; "Jim"; "Patrick Tainter"; "Kathleen Wentworth"; "Ann Schneider"; terryoconnell@brisbaneca.org; rortiz@burlingame.org
Subject:	RT 10/6/21 Agenda item 1, Director"s Report
Date:	Tuesday, October 5, 2021 11:17:54 AM
Attachments:	final_2020_annual_noise_report 2020 Threshold and Duration method Page 17b.pdf

Angela:

Could you have the following and attachment included in the written record for Wednesday's RT meeting under item 1. Airport Director's Report July-August 2021?

Many thanks
Peter Grace

Comment:

Dear RT members

1. The traditional Threshold and Duration method, which is used by SFO, is neither as accurate as the Aircraft Noise Event Extraction Methodology (ANEEM) nor state of the art.
- Reagan and Dulles airports have used ANEEM since 2015 --see attached report and in particular the comparison of the 2 methods in the screenshot below

Noise Monitors and Noise Event Detection Criteria:

Traditional Noise Event Detection Methodology: Prior to 2015, the Airports Authority's noise monitors
detected a noise event when the noise level exceeded a noise threshold for a minimum duration.
During noise data post-processing, only detected noise events were correlated against aircraft position data. The traditional methodology had technological challenges:

- Quieter aircraft commonly generated noise levels that did not satisfy the noise event threshold criteria.
- Aircraft noise events could easily be contaminated by community noise sources (traffic,
sirens, lawn mowers, construction, community activities, nature – weather, animals).
- Lowering the noise event detection threshold did not account for increased background
noise levels.

ANEEM - Aircraft Noise Event Extraction Methodology: As of 2015, the Airports Authority became the
first U.S. airport system to upgrade its noise monitoring software using a new noise event

detection
methodology called ANEEM (Aircraft Noise Event Extraction Methodology), provided by
EMS Bruel &
Kjaer.

ANEEM does not solely rely on the noise monitor to detect a noise event. During noise data postprocessing,
ANEEM cross-references databases to identify aircraft in the vicinity of the noise monitor when the noise level rises above the background level. It identifies and correlates aircraft-dominated
noise events by comparing aircraft position data with predicted noise levels for that aircraft, using
FAA noise certification data. ANEEM provides a more accurate detection methodology for distinguishing aircraft noise from other noise sources experienced in neighboring communities.

It is very important to clarify that the "total noise" experienced at a noise monitor is unaffected by the
choice of a noise event detection methodology.
ANEEM only improves the accuracy of the noise source classification process. ANEEM noise event counts
will be higher because ANEEM accounts for quieter aircraft and higher background noise levels.
However, the "total noise" experienced at the noise monitor is consistent with legacy software.

- from
  -

https://www.flydulles.com/sites/flydulles.com/files/legacyfiles/final_2020_annual_noise_report.pdf
- The Threshold and Duration method will continue to undercount SFO aircraft noise events even if you lower the thresholds slightly.

2. Why is SFO continuing to use a methodology that is not as accurate as another proven methodology that has been in use since 2015 at Reagan and Dulles airports?
- Residents and elected officials should be given accurate data
- SFO uses the same Noise Monitor provider as Reagan and Dulles.
- SFO needs to explain why they are not willing to use ANEEMS to report Noise Events in the Director's Report. This question has been raised before but remains unanswered.

Thank you
Peter Grace
Brisbane Resident

Reagan National (DCA)
Noise Monitor Program

The Airports Authority operates a network of noise monitors around Regan National and Dulles International. The first noise monitors were installed around Reagan National in 1978 when the FAA operated the airport. At Reagan National, a key strategy for limiting aircraft noise exposure has been to maximize aircraft movements over water and minimize movements over densely populated communities. After consultation with the Metropolitan Washington Council of Governments, many of the noise monitors have been sited along the flight corridors near the Potomac and Anacostia Rivers to track historical noise trends. In accordance with FAA regulations, noise monitor data may not be used for regulatory or enforcement purposes.

The Airports Authority continues to voluntarily upgrade and maintain the noise monitors around Reagan National without any external funding. The noise monitors provide aircraft and community noise levels near Reagan National as a public resource for general information only.

Federal law prohibits the use of noise monitor data to audit, investigate or enforce the DCA Nighttime Noise Rule, or any other rule or regulation.

Noise Monitors and Noise Event Detection Criteria:

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SFO Noise Office Update

December 1, 2021

Airport/Community Roundtable Meeting

SFO

SFO implementing ANEEM

Where to expect changes **Airport Director's** report?
Starting 2022, reports will reflect the changes this method brings in the numbers on this table.

This will change the process of matching noise events to flights. There are three methods to match noise events to flights:

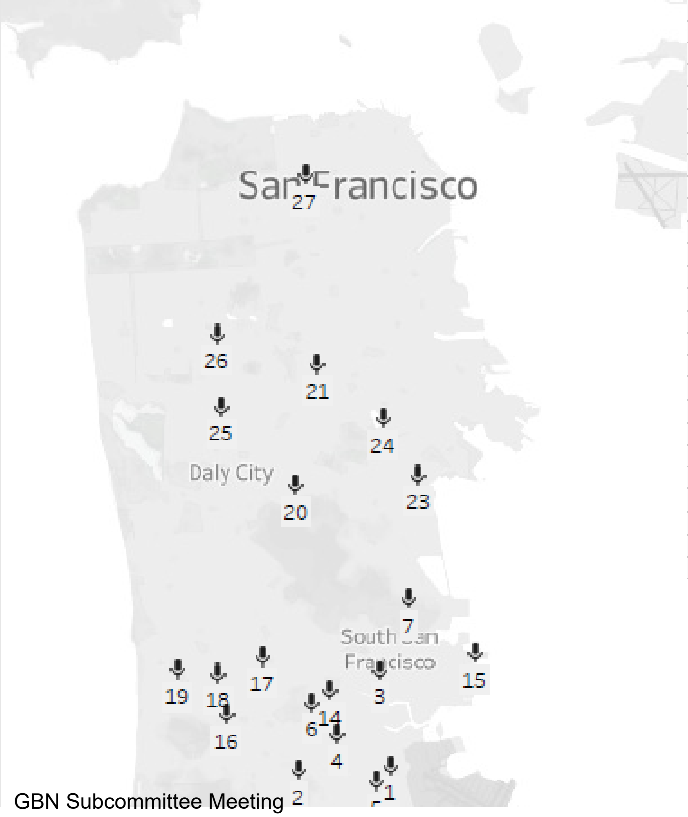
1. Noise to track (N2T2)
2. Noise Power Distance (NPD)
3. Aircraft Noise Event Extraction Methodology (ANEEM)

Please check out SFO noise system vendor's website for more information on ANEEM:
https://envirosuite.com/platforms/aviation/aneem

Aircraft Noise Levels

October 2021

The map shows 29 aircraft noise monitoring locations that keep track of noise levels in the communities around the airport. The Community Noise Exposure Level (CNEL) metric is used to assess and regulate aircraft noise exposure in communities surrounding the airport.



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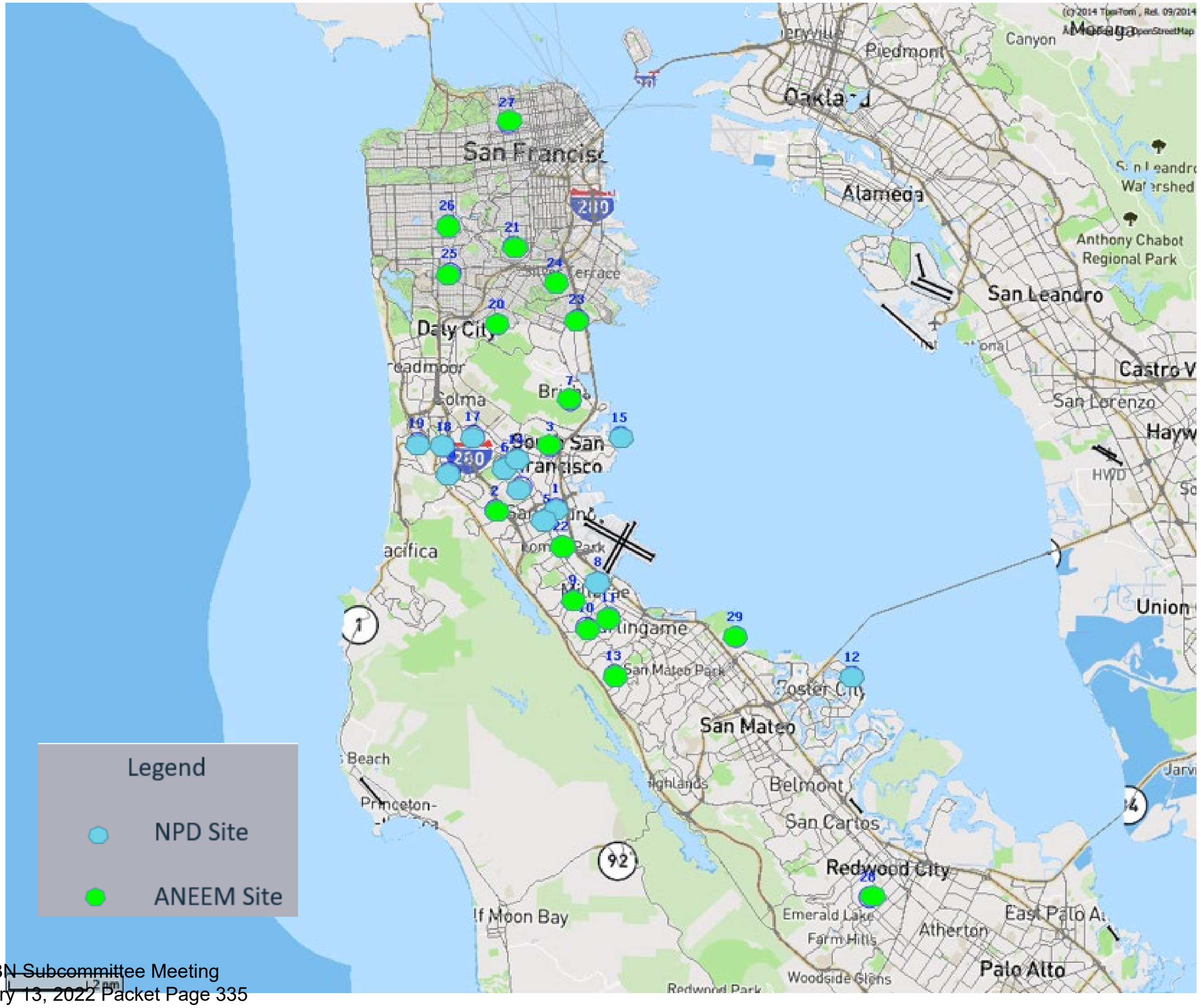
SFO implementing ANEEM

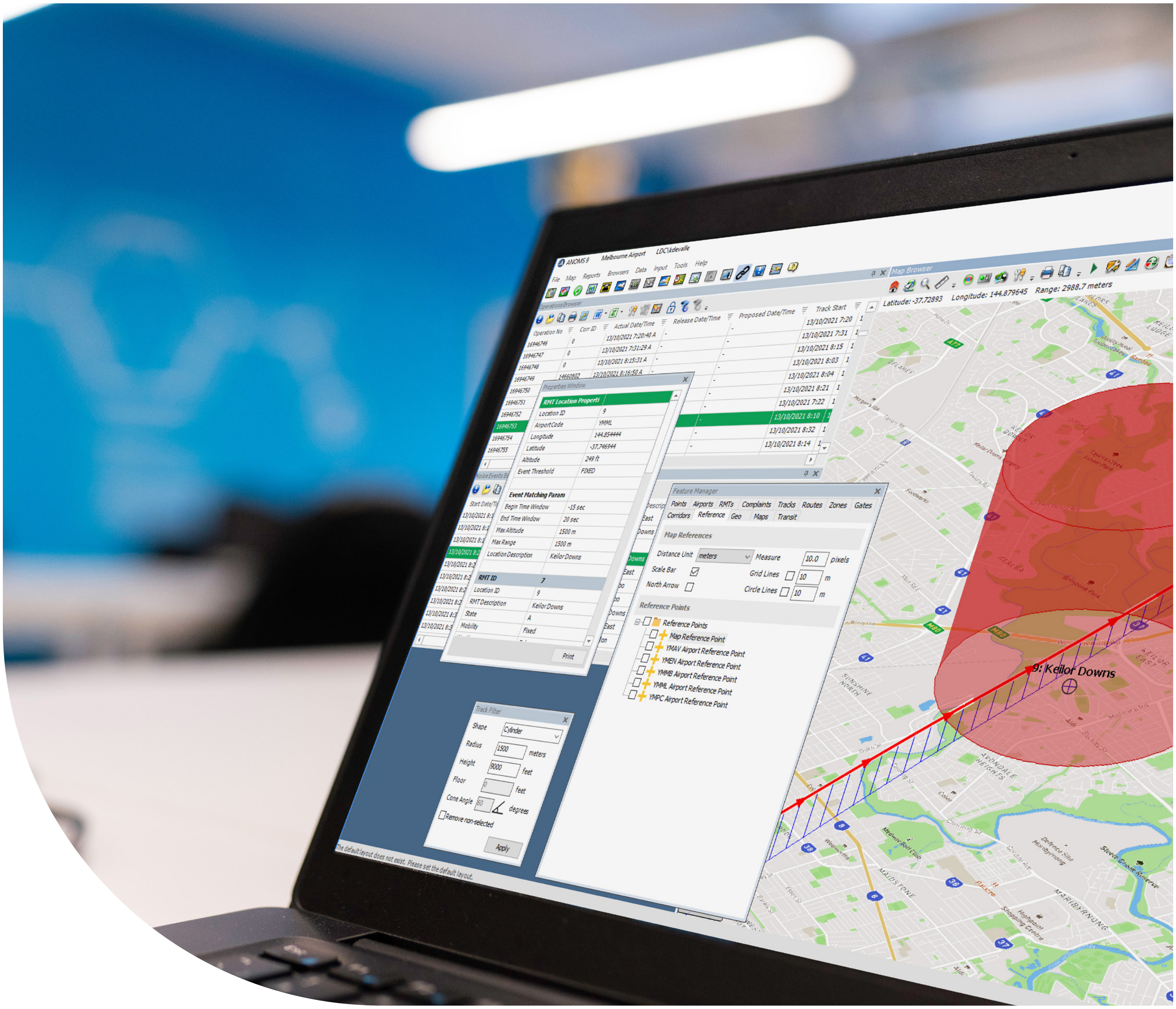
- Starting January 2022 SFO will start using the ANEEM method at 17 permanent monitoring sites. The remaining 12 sites will continue to use NPD method to meet Title 21 regulations.

- Starting January 2022 SFO will start using the ANEEM method for all portable monitoring sites.



evs
aviation
ANEEM

Accurately measure aircraft noise exposure in **airport communities** and determine contribution



ANEEM detects more aircraft **noise events** by eliminating events from other sources

Standard approaches to noise detection are not effective when the aircraft noise levels are close to the background level. The fixed threshold method either misses the events completely being set too high or too low.

ANOMS ANEEM solves this challenge providing an accurate measure of the contribution of aircraft to the noise communities experience.

Identify aircraft noise exposure

Airport communities need confidence that aircraft noise exposure is fairly captured by monitoring systems.

ANOMS ANEEM provides higher quality data for environmental noise reporting compared to traditional noise threshold-based methods. Our product can determine whether an aircraft is the dominant source or a contributing source of a noise event, or whether the event is dominated by other noise sources.

- ✓ **Differentiate other sources from aircraft noise exposure**

  Isolate aircraft noise from irregular background community noise levels to measure contribution to noise in the community with more accuracy.

- ✓ **Adapt to changing conditions**

  ANEEM continually adjusts settings to ensure aircraft noise is measured as accurately as possible in all conditions.

- ✓ **Support airport noise mitigation strategies**

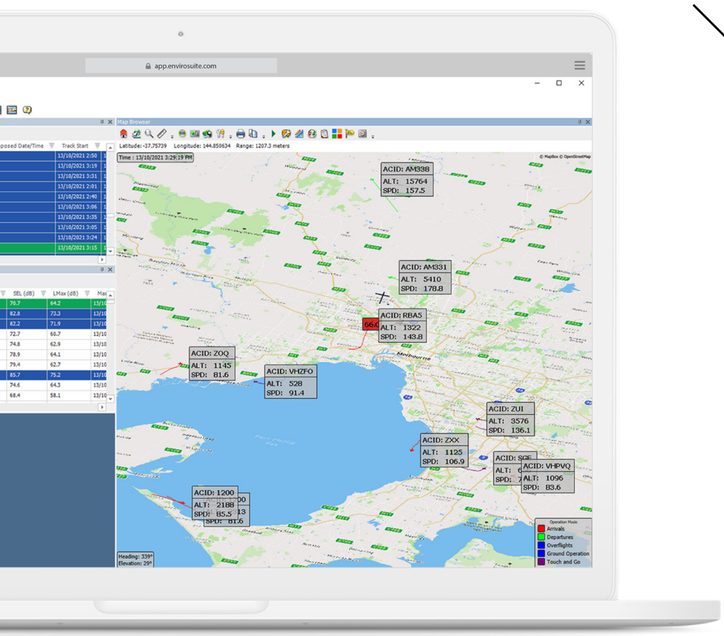
  More accurate data from ANEEM reduces effort in checking and grooming event data, allowing noise offices to focus on other business activities.

- ✓ **High quality data to support noise monitoring activities**

  Deploy noise monitoring equipment in areas with varying background noise or areas where aircraft noise is close to background levels.

Support airport noise mitigation strategies with **detailed data** on community noise exposure

The ANEEM algorithm can identify aircraft noise in challenging noise environments in communities.



Measure contribution to community noise exposure

ANOMS ANEEM automatically considers the prevailing noise environment at the time aircraft are near the monitor and the available information about the aircraft.

Support airport noise mitigation strategies by focusing efforts in the right place

Determine if aircraft noise was the dominant source or a contributing source of a noise event.

Integrates with ANOMS airport noise monitoring and operations system

ANOMS embeds proven expertise in noise monitoring, stakeholder engagement, flight tracking and aircraft noise abatement procedure performance, and airport optimisation and expansion planning.

Adopt industry **best-practice**

ANEEM is the culmination of decades of industry best practice and emerging research at the world's most environmentally conscious airports.

Airports can use ANEEM for all sites except for monitors that are used to report under CALTRANS Title21 program.

FAQs

Q How is ANEEM different from floating threshold?

A

Using a floating threshold is a step up from fixed thresholds as it effectively varies the detection threshold based on continuously assessing background noise levels. It still requires the customer to correctly set a threshold which ANEEM doesn't. If background levels have been high in the recent past, then a floating threshold takes time to lower the threshold level so may miss quieter aircraft noise levels. Similarly, if background levels suddenly increase, a floating threshold can take time to adapt and assigning other noise as aircraft noise. ANEEM detects when an aircraft may be causing noise and then looks to see whether it can see a peak in the noise levels that could have been generated by the aircraft. A floating threshold can also float down to very low levels that result in continuous generation of events. Effectively, meaning that whenever an aircraft is anywhere near the NMT, it can be correlated. It doesn't offer the additional validation that ANEEM does to confirm that the noise level recorded was typical of the specific aircraft under the conditions of measurement. Where aircraft noise levels are approaching background noise levels this can lead to incorrect noise levels being assigned to aircraft movements.

Q Does ISO20906 mandate how events are generated and classified?

A

No, ISO20906 does not mandate how events are generated and classified.

ISO20906 has requirements for what is included in an event. ANEEM provides the required information.

ISO20906 suggests using a threshold, minimum and maximum durations and staying below the detection level for a minimum fall time. ANEEM applies the threshold-based technique described by the standard to delineate candidate events that are evaluated.

The event delineation process is not run continuously. It is only run when aircraft are near the monitoring location. A set of candidate events are cycling through a series of threshold levels. ANEEM evaluates the candidates to determine the best fit, if any, for an aircraft event. No event is generated unless ANEEM has found a plausible aircraft event.

Q Does ANEEM generate community noise events?

A

No, ANEEM only generates events for aircraft activity. The energy from other noise sources will be contained in the background noise measurements.

Q Will ANEEM change historically reported aircraft noise levels and how can this be mitigated?

A

ANEEM is designed to improve the accuracy of the aircraft noise assessment. So, yes, it will change the results. The level of change will depend on how much manual grooming was being done previously and how good a monitoring location is. Depending on the environment that the monitoring is done in ANEEM may result in higher or lower levels of aircraft noise. But whichever way the data changes, aircraft noise levels will be more accurately reported with less manual grooming.

When monitoring has been done using other techniques, you may want to explain to the community why they should have more trust in the data from ANEEM. Appropriate strategies will depend on the sensitivity of the noise measurements at a location. The following engagement processes have been used:

- Use of ANEEM only at new portable monitoring locations, thus avoiding any apparent change in reported aircraft noise.

- Presenting the advantages of ANEEM versus standard event detection with examples of the improvements made. The Noise Event Workbench makes it easy to review the data for examples.

- Envirosuite has prepared comparisons at a few locations to show the advantages of ANEEM and characterise the improvements.

- External third-party report on the effectiveness of ANEEM.

- ANEEM does not produce community noise events. The community noise will be contained in the background noise levels.

Q **Does ANEEM work without radar or flight plan data?**

A

The type of aircraft and what it is doing are key inputs into ANEEM. ANEEM will not function without track data. Of course, complete loss of radar data is rare. Furthermore, it should be noted that ANOMS is designed to adapt reporting to missing data. In the event of radar loss, all that is required is to flag periods that should be excluded. Envirosuite also recommends adding a suitable comment.

ANEEM will function without knowledge of the aircraft type. However, it will need to assume an aircraft type and performance will be degraded. While long periods of lost radar data are also rare, the airport may also choose to remove such periods from reporting to avoid distorting data.

Q **Can ANEEM detect aircraft ground noise?**

A

ANEEM is designed for monitoring the noise levels from overflying aircraft only. It is not suitable for detecting noise from aircraft on the ground. Envirosuite has specialist algorithms that are designed for these potentially complex monitoring situations.

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BBN Report No. 8257

STUDY OF THE LEVELS, ANNOYANCE AND POTENTIAL MITIGATION OF BACKBLAST NOISE AT SAN FRANCISCO INTERNATIONAL AIRPORT

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The authors are grateful to the staff of SFO's Noise Abatement Office, and to the staff of the Airport/Community Roundtable for providing background information; to Mr. Mark Hinds for permission to include in this report information developed under the sponsorship of the City of Richfield, MN; to Mss. Mary Westheimer and Elizabeth Fujimoto for assistance in data collection; to Mr. Daniel Flynn for making his house available for data recordings; and to the test subjects for their diligent participation in the annoyance judgment study.

1 INTRODUCTION AND SUMMARY OF FINDINGS

This report describes the initial phase of a study of the levels, annoyance and potential mitigation of aircraft departure ("backblast") noise at San Francisco International Airport (SFO). The effort reported here was intended to quantify low-frequency aircraft noise levels and complaint densities in specific neighborhoods, and to determine the relative annoyance of backblast and overflight noise. Information of this sort is needed to develop recommendations for potential treatments of residences to mitigate low-frequency aircraft noise impacts.

This report contains information derived from (1) an analysis of noise complaints from residential areas behind Runways 01 L/R; (2) field measurements of low-frequency aircraft noise; and (3) a laboratory study of the annoyance of low-frequency aircraft noise. These findings are expected to help define design measures for a subsequent low-frequency noise mitigation demonstration.

The major conclusions that may be drawn from this study include the following:

- Backblast noise is a readily measurable concentration of low-frequency noise created by individual aircraft departures in areas behind Runways 01L/R at SFO.
- The density of aircraft noise complaints in residential areas to the southwest of Runways 01L/R is greatest in two areas of Millbrae, Burlingame, and Hillsborough located roughly two miles from the start of takeoff roll.
- Although these two areas lie well outside of SFO's 65 dB CNEL contour, their locations are consistent with high noise levels associated with the directivity of jet engine exhaust noise.
- Meteorological conditions may be responsible for inducing considerable variability (at least ± 5 dB) in low-frequency aircraft departure noise level and duration in areas of Millbrae, Burlingame, and Hillsborough. Therefore, reliable prediction of times of day and seasons of the year when backblast noise is likely to be particularly high in level requires very detailed information about atmospheric conditions.
- C-weighted sound levels of individual aircraft departures measured in these two areas often exceed 80 dB, and can occasionally reach levels in the high 90 dB range, depending on aircraft type and other factors.

- Low-frequency sound levels corresponding to these C-weighted levels vary from about 70 to 90 dB in the one-third octave bands from 25 to 80 Hz.

- Instances of backblast noise associated with individual departures can be of unusually long duration with respect to typical aircraft overflight noise.

- When judged equally annoying, longer-duration, backblast-like sounds are lower in level than shorter-duration sounds by 3 dB per doubling of duration throughout the range of durations from 15-120 seconds. This finding confirms the need to keep in mind a 10 log (duration) correction in planning measures intended to mitigate the annoyance of backblast noise.

- The annoyance of backblast is heightened by its duration and potentially by the production of rattle in homes.

- When judged equally annoying, the maximum A-weighted sound levels of backblast noises lasting two minutes or more are 5 to 7 dB lower than those of typical aircraft overflights.

2 BACKGROUND AND LITERATURE REVIEW

2.1 REVIEW OF STUDIES OF BACKBLAST NOISE AT SFO

SFO and the cities of Burlingame, Hillsborough, and Millbrae have longstanding concerns with low-frequency noise created by aircraft departures from Runways 01 L/R at SFO. Prior studies of low-frequency aircraft noise at SFO have focused on physical measurements of A- and C-weighted noise levels behind Runways 01 L/R (Caltrans, 1984; Connor, 1986; Kesterson, Vondemkamp, and Connor, 1987), and on secondary analyses and interpretations of these measurements (HMMH, 1996b). According to Gilfillan (1999), formal concern about low-frequency aircraft noise in communities near SFO can be traced to the 1970s. Chapter V of a Joint Action Plan developed under a 1980 Joint Land Use Study contained a list of unresolved issues, of which one was "What alternatives to the A-weighted decibel scale could be used to measure the effects of low-frequency noise events?"

A set of low-frequency noise measurements was an initial step taken by Caltrans to address this issue in 1984 (Caltrans, 1984). This data set, presented to the Airport/Community Roundtable in four volumes without evaluation, narrative of findings, or conclusions, was reviewed by the Roundtable's consultant in 1985. Nighttime B-727 operations on Runways 01 L/R were identified as a prominent source of low-frequency aircraft noise in the community. As part of a 1986 settlement agreement arising from noise nuisance litigation, SFO agreed to conduct and report a set of "full spectrum" (including low-frequency) aircraft noise measurements in neighborhoods behind Runways 01L/R.

Measurements made by Tracor at several of SFO's permanent noise monitoring stations in 1986 and 1987 (Connor, 1986; Kesterson, Vondemkamp, and Connor, 1987) were analyzed to assess how the low-frequency content of aircraft departure noise affected the accuracy of aircraft noise measurements behind Runways 01L/R, and the appropriateness of A-weighted (as opposed to C-weighted) measurements for characterizing aircraft departure noise. Tracor concluded that "The sound of some aircraft departures from Runways 1L and 1R has a character distinct from that of ordinary aircraft noise in that it has relatively more low-frequency content and longer duration." Tracor also noted that B-727 and B-737 departures were the predominant source of aircraft noise in areas behind Runways 01L/R, and that CNEL values in the area behind Runways 01L/R were adequately measured.

A Memorandum of Understanding concerning aircraft noise mitigation, based on the Environmental Impact Report of SFO's 1992 Airport Master Plan, was adopted in 1993. One item identified in the Joint Work Plan (Item C.3.(c)) of this document addressed the reduction of backblast noise. When Caltrans included the Roundtable Work Plan as a condition of SFO's 1993 noise variance, conduct of a demonstration house project became one condition of this variance.

SFO and the Roundtable commissioned another review of the 1986/87 Tracor information. Completed in 1996 (HMMH, 1996b), this review identified a C-weighted single-event noise descriptor (a maximum C-weighted sound level of 80 dB) as a reasonable criterion for identifying aircraft departure noise with vibration-producing potential. Arrangements for the conduct of the current project began in 1996, when SFO issued a Request for Proposals to establish the location of a demonstration house and plans for empirical study of low-frequency noise mitigation measures.

2.2 RECENT STUDIES OF LOW-FREQUENCY AIRCRAFT NOISE EFFECTS ELSEWHERE

Recent studies of the effects of low-frequency aircraft noise (not necessarily associated with start of takeoff roll noise) in the United States have been conducted near airports in Baltimore, Boston, and Minneapolis.

2.2.1 Study of Low-Frequency Takeoff Noise at Baltimore-Washington International Airport (BWI)

Miller, Reindel, Senzig, and Horonjeff (1998) report measurements of aircraft departure sound levels in single family detached housing located about half a mile from the end of a busy departure runway at BWI. The homes in question were within BWI's 65 dB DNL aircraft noise contour. They also report an analysis of a single resident's annoyance ratings of a limited number of aircraft departures. Shade (1997) conducted analyses of low-frequency noise reduction improvements in two houses exposed to start of takeoff roll noise on BWI's Runway 28 that were treated to increase C-weighted noise reduction. These measurements and analyses, complemented by an "Engineer's Report" for residential sound insulation, provided the documentary basis for a decision by FAA to participate in funding sound insulation treatments beyond those required to produce a 5 dB A-weighted improvement in noise reduction.

2.2.2 Measurements of Low-Frequency Noise Emissions of Stage II and Stage III Aircraft at Logan International Airport (BOS)

Horonjeff and Thompson (1996) describe a study focused on measurement and analysis of "low-frequency rumble produced by jet aircraft operations at Boston's Logan International Airport." Their analyses indicate (*inter alia*) little difference in the very low-frequency (below 40 Hz) noise emissions of Stage II and Stage III aircraft, and no reduction in thrust reverser noise for a Stage III aircraft fleet *vs*. a Stage II fleet. Horonjeff and Thompson also noted that even unusually thorough acoustic treatments of homes (*i.e.*, super-insulation of a single room-within-a-room) failed to yield an increase in noise reduction of more than 8 to 9 decibels at frequencies below 100 Hz.

2.2.3 Study of Annoyance of Low-Frequency Noise near Los Angeles International Airport

Fidell, Silvati, Pearsons, Lind, and Howe (1999) describe a social survey of the annoyance of rattle and vibration associated with runway sideline noise.[1] Interviews were completed with 644 respondents living in households with LFSL[2] values between 60 and 95 dB in a neighborhood immediately south of Los Angeles International Airport.

Figures 1 through 3 summarize major findings of this study. Figure 1 shows how often respondents noticed rattle produced by aircraft operations. Figure 2 identifies the sources of rattling sounds in the respondents' homes. Figure 3 compares the percentage of respondents who noticed rattle, were annoyed in any degree by rattle, and were highly annoyed by rattle, as a function of outdoor low-frequency sound levels.

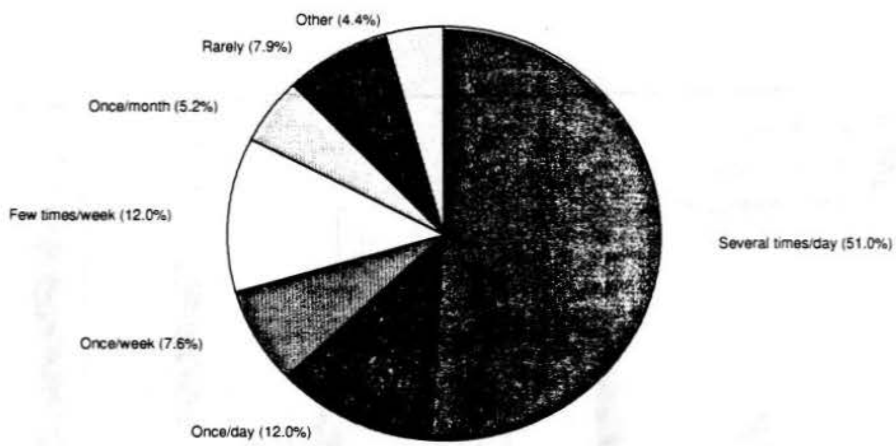


Figure 1 Frequency of notice of rattling sounds in respondents' homes.

[1] Noise created along runway sidelines has proportionally more low-frequency content than noise produced by overflights, but differs in character from backblast noise in ways discussed in Section 3.

[2] LFSL is the abbreviation for Low-Frequency Sound Level, a descriptor of low-frequency aircraft noise described by Fidell, Silvati, Pearsons Lind and Howe (1999). LFSL is a single-event noise metric that sums the maximum one-third octave band sound levels from 25 to 80 Hz, inclusive, that occur during the course of an individual aircraft passby.

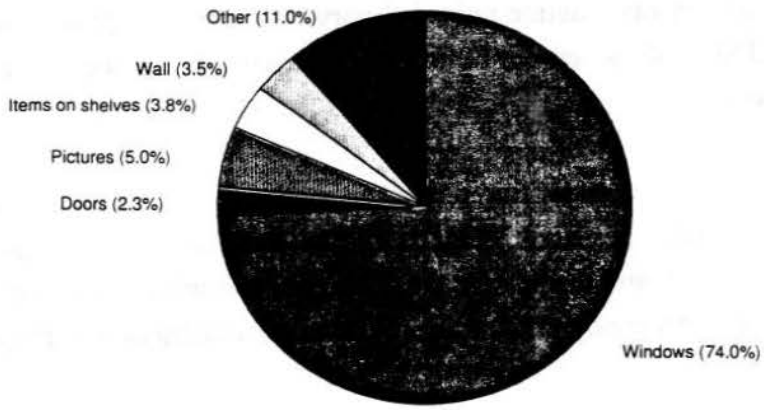


Figure 2 Identification of sources of rattling noises in respondents' homes.

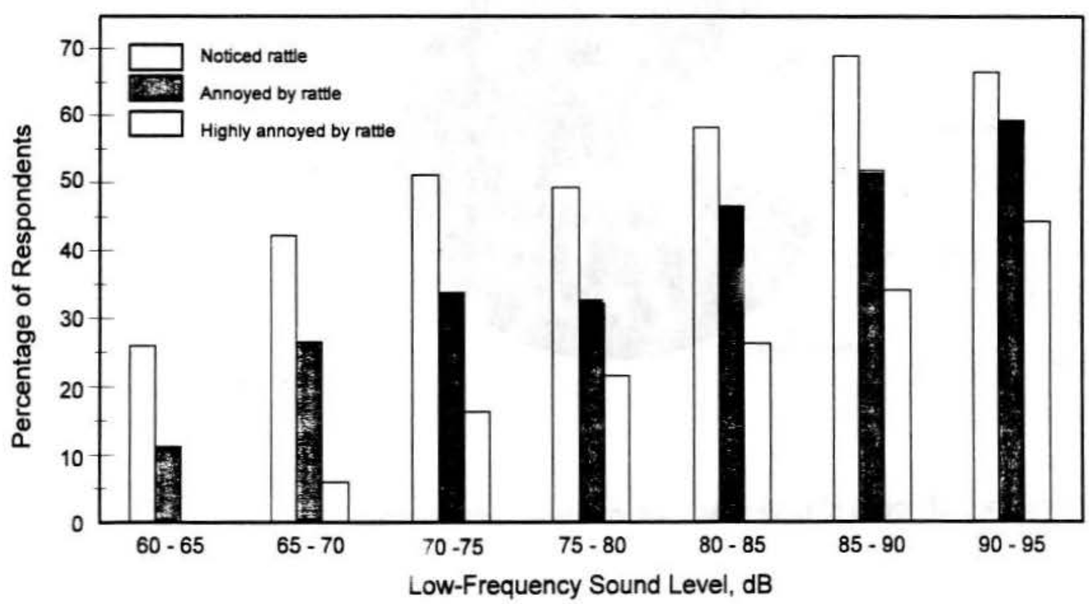


Figure 3 Comparison of percentages of respondents noticing rattle, annoyed in any degree by rattle, and highly annoyed by rattle associated with low-frequency noise

2.2.4 Study of Annoyance of Low-Frequency Noise near Wold-Chamberlain Field in Minneapolis (MSP)

Fidell, Silvati, and Pearsons (1999) have recently completed a social survey of the annoyance of rattle and vibration due to low-frequency aircraft noise in the vicinity of MSP.[3] The major goal of the study was to document the prevalence of annoyance due to aircraft noise-induced rattle among residents exposed to runway sideline noise at MSP. It was found that the prevalence of annoyance due to aircraft noise-induced rattle was similar to that described above at LAX for similar low-frequency sound levels; that similar objects were cited as sources of rattle in the two studies; and that the frequencies of occurrence of rattle were comparable among respondents to the MSP and LAX surveys. Figure 4 displays the prevalence of annoyance among respondents living in households with similar LFSL values at both LAX and MSP.

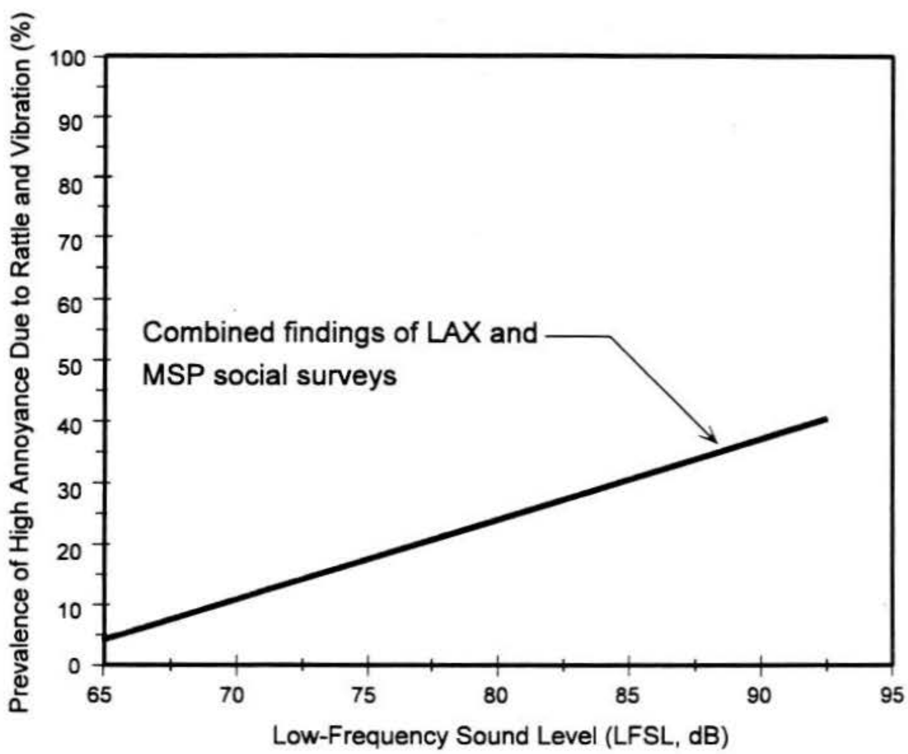


Figure 4 Relationship between LFSL values and the prevalence of a consequential degree of annoyance in combined findings of LAX and MSP social surveys.

[3] This study was conducted as part of an extensive set of measurements and analyses stemming from an agreement between the City of Richfield, MN and the Metropolitan Airports Commission. The findings of the study described here are not those of the entire process.

3 TECHNICAL DISCUSSION

This section contains a general discussion of the nature of low-frequency aircraft noise. The reader's attention is directed to the Glossary for definitions of terms.

3.1 GENERAL CHARACTERISTICS OF AIRCRAFT NOISE AS HEARD NEAR AIRPORTS

The character of aircraft noise heard in communities near airports varies considerably with location relative to runways in sound level, frequency content, onset and decay rates, duration, and distinctiveness. Table 1 summarizes the general characteristics of overflight, sideline, and departure noise. Figure 5 illustrates the areas in which these types of aircraft noise predominate. In addition to differences between the noise emissions of different aircraft types, factors that affect the character of aircraft noise as heard in different locations include the flight regime and directivity of aircraft noise emissions, the geometry of the aircraft's flight path with respect to an observer, the slant range between the aircraft and the observer, and the path(s) by which aircraft noise reaches the observer.

Table 1 Summary of general characteristics of overflight, sideline, and departure noise. (Specific location with respect to runway influences all characteristics.)

	TYPE OF AIRCRAFT NOISE		
Factor	**Overflight**	**Sideline**	**Departure**
Frequency content	Broadband, dominated by mid frequencies	Greater low-frequency content than overflights	Little or no high-frequency content
Duration	15 - 30 seconds	30 - 60 seconds	60 - 120 seconds
Onset rate	5- 15 dB/second	5 - 15 dB/second	Relatively slow
Decay rate	5 - 15 dB/second	Strong function of distance	Very slow decay rate
Time history	Roughly symmetric "haystack", usually with clear 10 dB-down points	Often skewed toward greater duration after peak	Multiple peaks common; 10 dB-down points may be difficult to discern
Maximum level	Generally greatest	Intermediate	Generally lowest

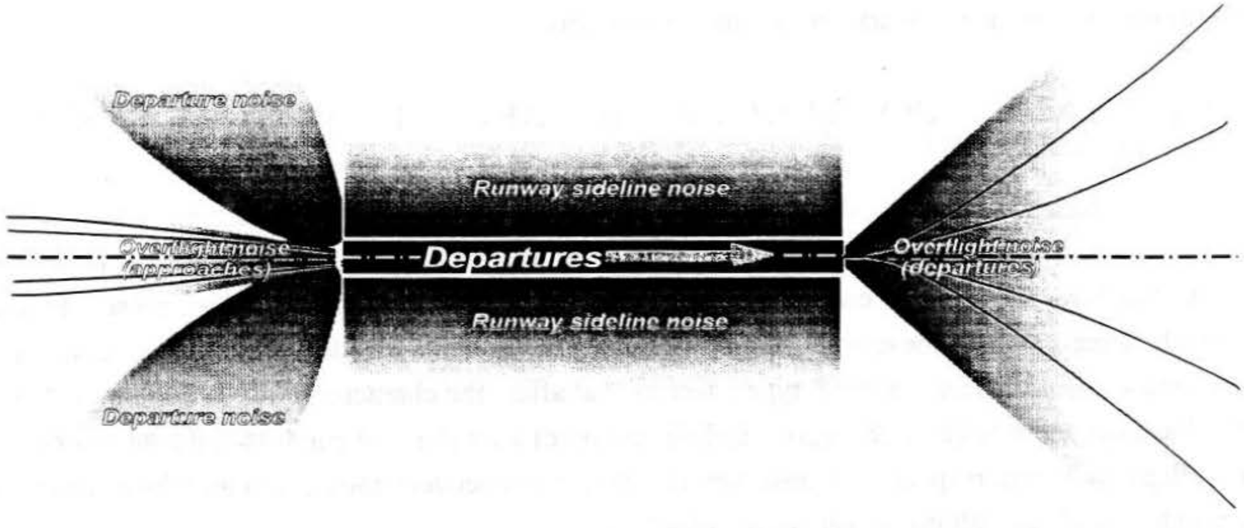


Figure 5 Identification of areas near runways in which sideline, departure, and overflight noise predominate.

3.2 CHARACTERISTICS OF AIRCRAFT DEPARTURE NOISE

Figure 6 shows the time history of an aircraft departure from Runway 01R at SFO of the sort that produces prominent low-frequency noise, as measured at a point 1.5 km behind the start of takeoff roll. The passage of time is represented from left to right on the horizontal axis, while A- and C-weighted sound levels are shown on the vertical axis. As the aircraft begins its takeoff roll, its sound level rises from the ambient noise level (roughly 50 dB A-weighted/62 dB C-weighted) to an initial maximum value (about 75 dB A-weighted/nearly 90 dB C-weighted) after about 20 seconds. As the aircraft's takeoff roll continues, its level slowly declines until about a minute after the start of takeoff roll. After the aircraft becomes airborne, its sound level gradually increases in level to a second peak at about a minute and forty five seconds after the start of takeoff roll, after which it gradually reverts to the ambient level.

Figure 7 illustrates the distribution in frequency of the acoustic energy of the overflight on the same time scale as Figure 6. Rather than expressing sound levels in A-weighted or C-weighted units as in Figure 6, the vertical axis of Figure 7 shows sound levels in individual one-third octave bands. Reds, oranges and yellows represent higher sound levels, while blues and greens represent lower sound levels. Thus, the brightest red and yellow colors, marking the highest sound levels at frequencies in bands from about 63 to 200 Hz, occur both at the time of the initial and second peaks in Figure 6.

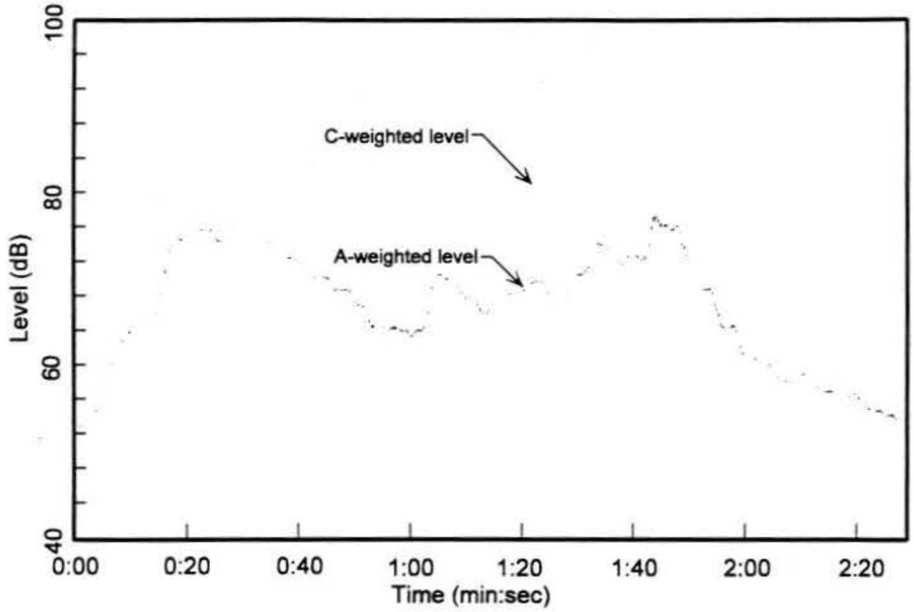


Figure 6 A- and C-weighted time histories of aircraft departure as heard approximately 1.5 km behind SFO Runway 01R.

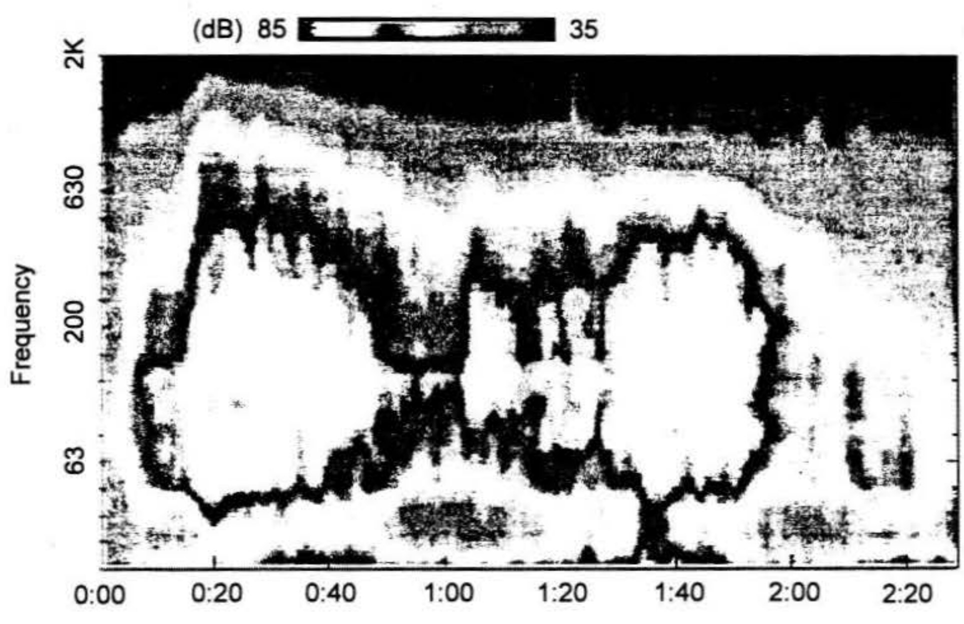


Figure 7 Spectrogram of aircraft departure at a point approximately 1.5 km behind San Francisco International Airport Runway 01R.

4 COMPLAINT ANALYSIS

Digital files containing information about telephone calls received by SFO's noise complaint telephone service for the years 1992 through 1998 were made available by SFO for analysis. These files were processed to yield monthly statistics for numbers of complainants and numbers of complaints per complainant. The latitude and longitude of each complainant's street address were also established. Figure 8 is a summary of geographic complaint patterns for Millbrae, Burlingame and Hillsborough. The figure was prepared from combined monthly numbers of complaints and of complainants. Data for each month of the year were aggregated over the entire time period (1992-1998), as shown in Table 2.

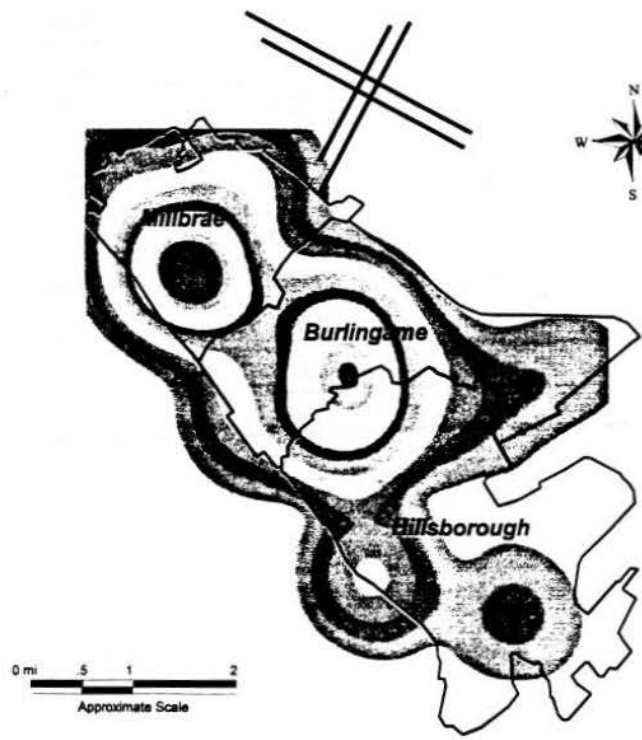


Figure 8 Aircraft noise complaint density for the Millbrae/Burlingame/Hillsborough areas, 1992-1998.

The color coding in Figure 8 represents complaint densities over the entire time period. The yellow, orange, and red areas encompass values from a low of 896 complaints to a high of 1,344 complaints per square mile. The greens and lighter blues represent a low of 448 complaints to a high of less than 896 complaints per square mile. The darker blue and magenta represent areas with ranges of complaints from 2 through 448 complaints per square mile.

Two concentrations of complaints are readily apparent, located approximately 45° to the side of the extended centerline of Runways 01L/R. These locations correspond closely to the lobes of the directivity pattern of jet engine exhaust noise of aircraft departing on Runways 01 L/R. Although the relative numbers of complaints in each lobe vary somewhat from month to month, the gross geographic pattern of complaints remains consistent in Millbrae, Burlingame and Hillsborough through all seasons of the year.

Table 2 Summary of aggregated complaint data.

MONTH	NUMBER OF YEARS	NUMBER OF COMPLAINTS	NUMBER OF COMPLAINANTS
January	6	2,436	804
February	6	2,629	803
March	6	2,695	814
April	6	2,106	639
May	6	2,609	776
June	5	2,004	721
July	5	1,897	637
August	6	2,361	854
September	7	2,782	906
October	7	3,005	971
November	6	1,944	605
December	6	2,278	789

5 FIELD MEASUREMENTS OF BACKBLAST NOISE

This section describes field measurements made by Wyle Laboratories.

5.1 SCHEDULE OF FIELD MEASUREMENTS

Two sets of acoustic measurements were made in an area southwest of SFO. The first set of measurements was made between 8 and 11 June, 1999, while the second set was made from 23 to 27 August, 1999. A- and C-weighted sound level event data and hourly interval noise level measurements were collected at six measurement sites during the two periods. Broadband noise levels were recorded at four of the sites.

The field instrumentation included Larson·Davis LD820, LD 870, and LD700 integrating sound level meters, and Tascam and Sony digital audio tape recorders. The sound level meters met the requirements for Type I sound level meters as defined in ANSI S1.4, 1983 except for three Type II LD700 instruments used during the first measurements to monitor C-weighted sound level event data and hourly noise levels.

5.2 MEASUREMENT SITES

Two primary sites were selected near the centroid of areas where large numbers of complaints had been received by the airport. These two sites were designated as sites 3A and 3B. Other sites were chosen along a line between the primary sites and the south end of Runway 01. Two of these locations were selected near the runway, while the other two sites were selected near the midpoint of the line between the runway and the primary site. The locations are identified on the map of Figure 9 as sites 1A, 1B, 2A, 2B, 3A, and 3B. The site locations are also listed in Table 3. The locations of sites 1B and 3A were moved a short distance during the second measurement period, as homeowners at sites 1B and 3A were not available during the second period.

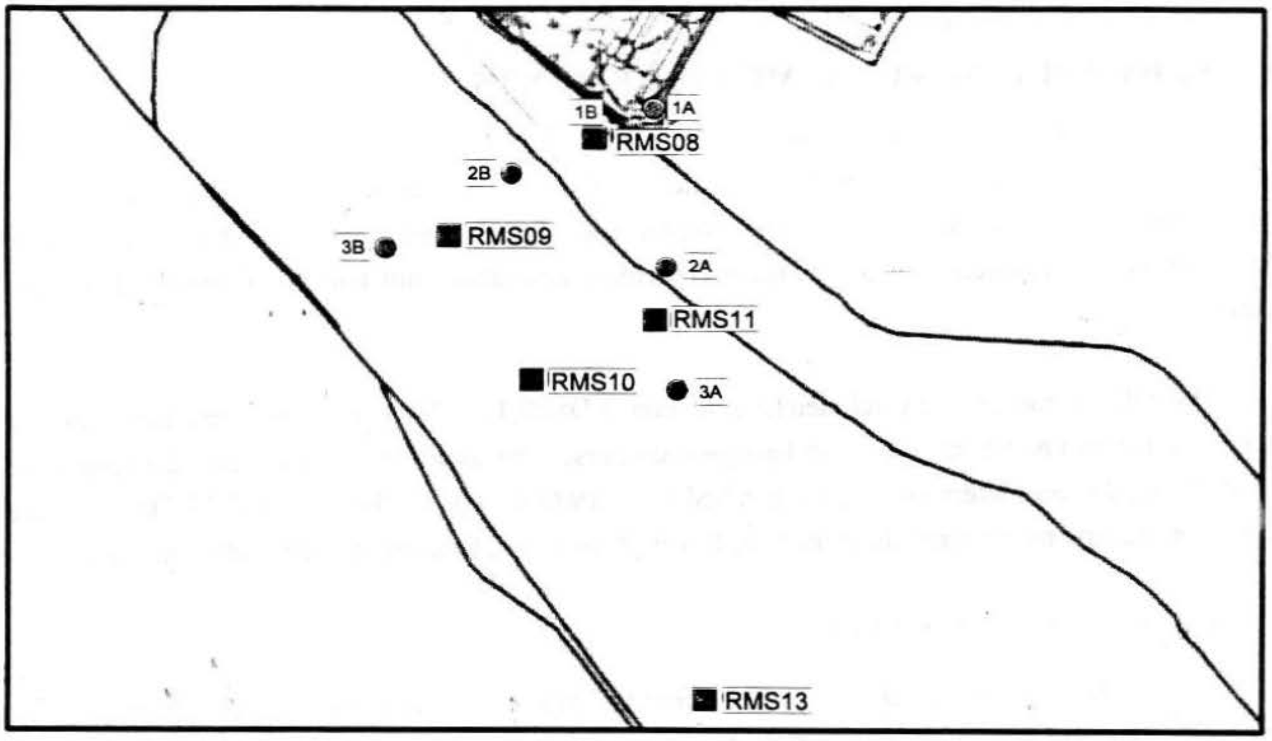


Figure 9 Locations of sites at which measurements were made from 8-11 June and from 23-27 August 1999, and of SFO's nearby remote noise monitoring sites.

Table 3 Addresses of measurement sites.

SITE	ADDRESS	LATITUDE	LONGITUDE
1A	San Francisco International Airport	37° 38.729' N	122° 22.767' W
1B	191 Aviador, Millbrae (first measurement period) 307 Roblar, Millbrae (second measurement period)	37° 36.163' N 37° 36.186' N	122° 23.073' W 122° 23.096' W
2A	1128 Hamilton, Burlingame	37° 35.527' N	122° 22.527' W
2B	254 La Cruz, Millbrae	37° 35.996' N	122° 23.617' W
3A	2116 Hillside, Burlingame (first measurement period) 2114 Hillside, Burlingame (second measurement period)	37° 34.995' N 37° 34.970' N	122° 22.560' W 122° 22.560' W
3B	1177 Hillcrest, Millbrae	37° 35.627' N	122° 24.294' W

5.3 MEASUREMENT PROCEDURES

Microphones with windscreens were mounted on tripods at a height of 4 feet. Associated instrumentation was placed in nearby environmental enclosures. Microphones were positioned more than 6 feet from building facades, and in most cases at distances greater than 10 feet. Noise level thresholds for event data were set approximately 5 dB above ambient levels.

A signal splitter placed at the output of the microphone preamplifier routed the signal to the integrating sound level meter and to the input of the digital audio tape recorder, as shown in Figure 10. The sound level meter was calibrated and the 114 dB calibrator signal was recorded at the beginning of the digital tape. The recorded calibration signal was used during the analysis to provide the spectrum analyzer with a reference for normalizing the recorded data to the proper sensitivity and to yield absolute sound levels. All of the instrumentation systems were battery powered except at the primary measurement sites (3A and 3B), where electrical power was available from the residences.

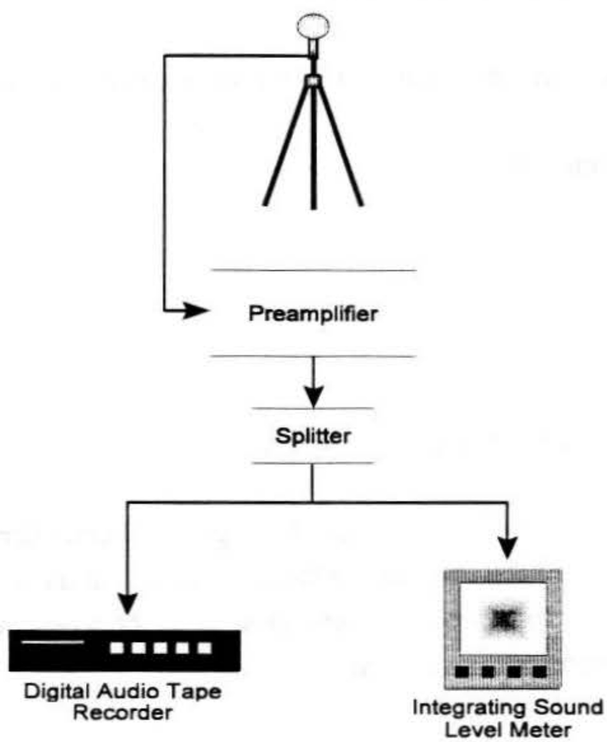


Figure 10 Schematic of field measurement instrumentation.

5.4 NATURE OF MEASUREMENTS MADE

5.4.1 Sound Level Measurements

One of the sound level meters at each site was configured to store A-weighted sound level events and hourly interval data, while another meter stored C-weighted sound level events and hourly interval data. The noise level measurements were compared to background noise levels and to aircraft noise levels obtained from analysis of the recorded data and information collected by airport noise monitoring stations.

The event information collected included the following:

- Date and time
- Maximum level
- Sound Exposure Level (SEL)
- Duration (for time above the threshold)

The following parameters were stored and analyzed for each of the hourly interval data:

- Date and hour of the day
- Hourly L_{eq}
- Maximum level
- Statistical levels (L_1, L_{10}, L_{33}, L_{50}, L_{90}, and L_{99})

The noise event data collected at various sites for a given aircraft departure operation were not precisely synchronized, since most of the instruments store the time that the sound level of an event first crosses the noise level threshold. Differences of several seconds between the time of the same event recorded at different sites were therefore anticipated.

5.4.2 Broadband Recordings

Broadband recordings were made at sites 1A, 1B, 3A, and 3B on one Sony TCD-D100 and three Tascam DA-P1 digital audio tape (DAT) recorders. The recordings were approximately 2 hours in duration. The tape recorders located at the four sites were started as close as possible to the same time to acquire simultaneous data.

5.5 SUPPLEMENTARY INFORMATION

The intent of the measurement program was to estimate spectral levels of aircraft operations at the primary measurement sites. Supplementary information from the airport noise monitoring system and complaint data were used to help identify aircraft events for analysis and to permit comparisons with A-weighted aircraft noise levels. The times and locations of complaints were used to review measured data for possible events. Upper air soundings from the National Weather Service in Oakland were also collected.

5.5.1 San Francisco International Airport Noise Monitoring System and Complaint Data

SFO's airport noise monitoring system includes five remote monitoring sites (RMS) near the current measurement locations: RMS-8, 9, 10, 11 and 13. Aircraft noise data measured at each RMS were associated with airport operations and complaint data to aid in verifying the sources of noise events. The airport operations data for the August visit may be found in Table 6 of this report.

5.5.2 Weather Information

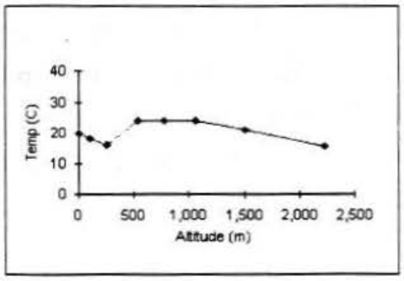
A temperature profile for the first 2,000 m of the atmosphere at a location in Oakland was plotted for two times of each day of the study. It is not clear how closely these profiles predict temperature gradients between the western threshold of Runways 01L/R and the measurement sites. The Oakland data nonetheless illustrate a wide range of temperature profile conditions, as shown for the August measurements in Figure 11. During some time periods, temperature decreased with altitude in the usual manner. At other times, temperature increased with altitude (a temperature "inversion"). Temperature (as well as wind) gradients can dramatically influence long-range sound propagation, since sound refracted back to the earth can produce increased sound levels at extended distances from the source.

5.6 DATA ANALYSIS

The field measurements were analyzed to determine the levels of selected (unambiguously identifiable, relatively high level) aircraft noise events. Most of the analysis was conducted on the data obtained at the primary sites, 3A and 3B.

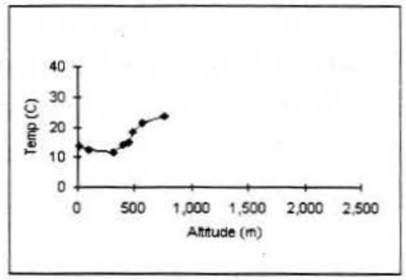
August 23, 1999
1700

Alt. (m)	T (C)
5	20.0
99	18.4
254	16.0
531	24.4
773	24.4
1,061	24.4
1,510	21.2
2,224	15.6



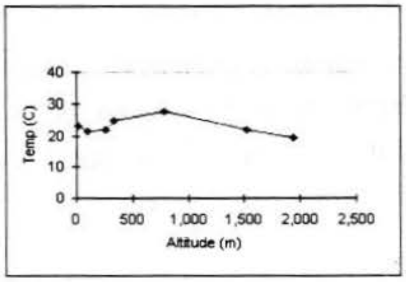
August 24, 1999
0500

Alt. (m)	T (C)
7	14.0
99	12.8
320	11.6
398	14.2
442	15.2
486	18.6
568	21.6
763	23.8



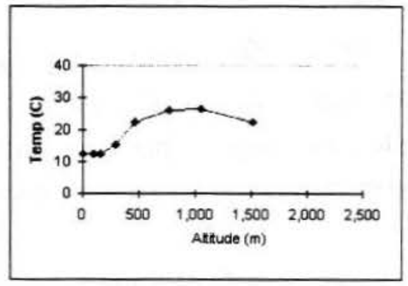
August 24, 1999
1700

Alt. (m)	T (C)
8	23.2
94	21.4
261	22.0
332	25.0
779	27.8
1,519	21.8
1,934	19.2



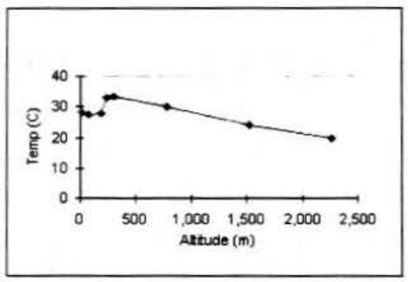
August 25, 1999
0500

Alt. (m)	T (C)
4	12.4
96	12.4
164	12.4
292	15.6
461	22.4
768	26.2
1,048	26.6
1,508	22.4



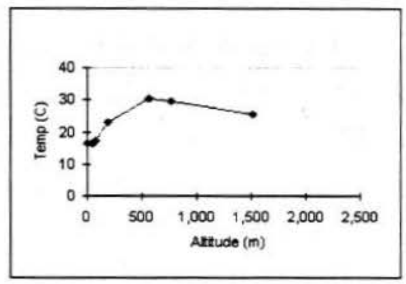
August 25, 1999
1700

Alt. (m)	T (C)
7	28.6
77	27.6
184	28.0
238	33.0
294	33.6
775	30.2
1,520	24.0
2,263	19.6



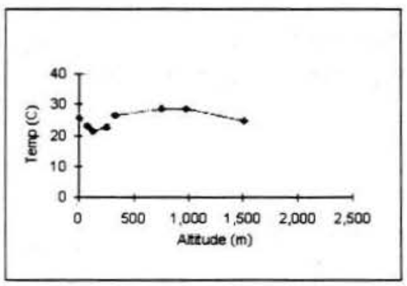
August 26, 1999
0500

Alt. (m)	T (C)
3	16.4
54	16.6
71	17.4
184	23.0
559	30.6
759	29.6
1,508	25.6



August 26, 1999
1700

Alt. (m)	T (C)
3	25.6
72	23.4
124	21.6
257	22.6
329	26.8
759	28.8
982	28.8
1,506	25.0



August 27, 1999
0500

Alt. (m)	T (C)
2	19.4
79	19.2
167	25.0
256	26.4
764	23.8
888	24.6
1,501	20.6

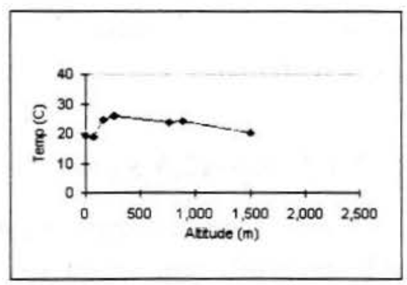


Figure 11 Atmospheric temperature profiles observed in Oakland during the 23-27 August, 1999 measurement period.

5.6.1 Sound Level Measurements

A- and C-weighted noise event levels stored in each sound level meter were downloaded in the field to laptop computers. These data, which provided nearly continuous 24-hour monitoring of noise events, were used to verify noise event levels recorded on digital audio tape.

Some of the sound level meters were additionally set to record A-weighted interval data. These interval data were analyzed to estimate daily CNEL values for sites 3A and 3B during the second measurement period, as shown in Table 4. The data measured at RMS 9 and 11 are shown in the table for comparison.

Table 4 24 hour A-weighted CNEL values during the August measurement period.

SITE	24 AUGUST 1999	25 AUGUST 1999
3A	57.9 dB	58.2 dB
3B	54.0	59.5
RMS 9	58.5	63.2
RMS 11	57.3	62.7

A subset of the C-weighted sound level meter data was analyzed to estimate the distributions of high level aircraft noise events at the various sites. The measurements were made synchronously at all sites between 16:30 and 21:16 on 25 August, 1999. Figures 12, 13 and 14 show cumulative distributions of these noise levels. Each point represents the cumulative percentage of measurements (shown on the ordinate) that reached the corresponding sound level (on the abscissa) in excess of thresholds set at 90 dB at sites 1A and 1B, 75 dB at site 2B, and 70 dB at sites 2A, 3A and 3B. These cumulative distributions of C-weighted maximum aircraft event levels are included to illustrate the distribution of the maximum event levels in August. Each of the figures illustrates typical distribution curves, while Figure 12 indicates the expected decay in level as sound propagates from site 1A to site 3A. In Figure 13, the curve for site 2B crosses over the curve for site 3B, possibly due to some shielding at site 2B. Figure 14 compares this distribution for sites 3A and 3B, showing greater sound levels at site 3B, possibly due to a higher elevation.

Note that the median (50^{th} centile) C-weighted sound levels of aircraft departure noise at the more remote sites 2A and 3A were in the high 70 dB range. In other words, roughly half of the aircraft departures during this four hour period produced C-weighted sound levels in excess of 78 dB. About ten percent of the aircraft departures in the same time period produced C-weighted sound levels in the high 80 dB range at these sites, and a small percentage of departures produced noise levels on the order of 90 dB.

Figures 13 and 14 show a very similar pattern of findings for sites 1B, 2B, 3A and 3B.

5.6.2 Broadband Recordings

Field recordings were reduced to time history strip charts as a visual indication of times of occurrence of unambiguous aircraft noise events. Figure 15 shows one example of such a chart for noise events at sites 3A and 3B between 21:25 and 21:40 on 24 August, 1999. Selected noise events were auditioned to verify that they were due to aircraft noise, and analyzed on a Larson·Davis 2900 spectrum analyzer to determine the frequency spectra of the event. One-third octave band levels were obtained at half second intervals over a 30-second time period that encompassed the maximum sound level. These spectra were imported into spreadsheets, from which A- and C-weighted levels were computed. These data were compared to the event data measured by the sound level meters and airport noise monitoring system.

The unambiguous high level aircraft events recorded during the surveys are summarized in Tables 5 and 6. The events shown in the tables were selected because each was appreciably greater in level than the ambient noise level, and because the events could be associated with events registered by sound level meters and the airport noise monitoring system. The tables combine the measurements made by the sound level meters, the broadband data analysis, and the supplementary airport noise monitoring system data.

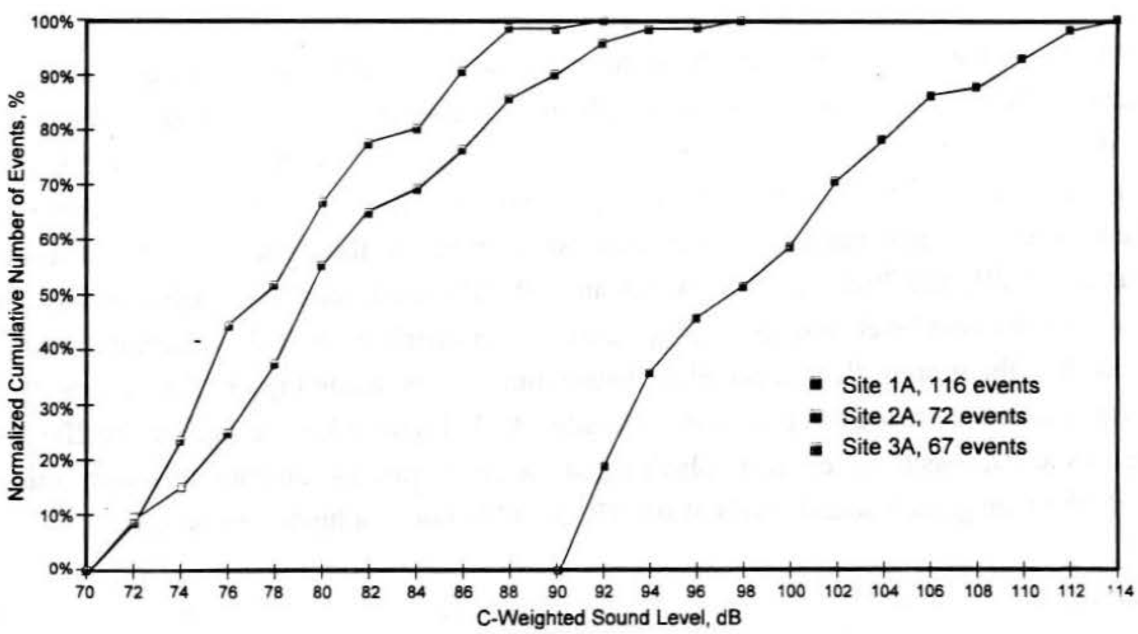


Figure 12 Cumulative distribution of greatest aircraft noise levels measured on 25 August, 1999, 16:30 to 21:16, sites 1A, 2A and 3A.

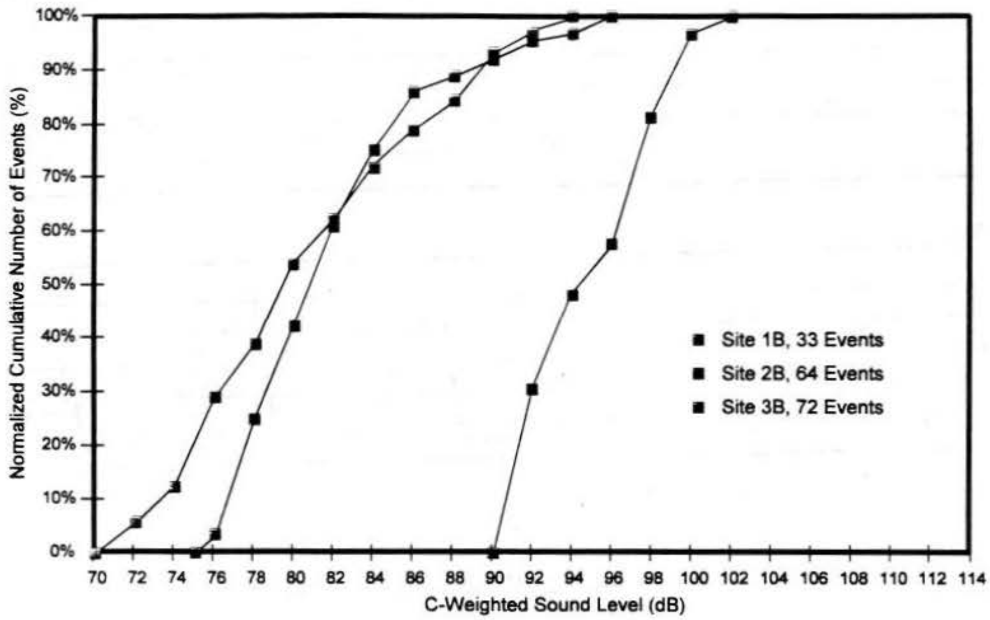


Figure 13 Cumulative distribution of maximum event levels on 25 August, 1999, 16:30 to 21:16, sites 1B, 2B and 3B.

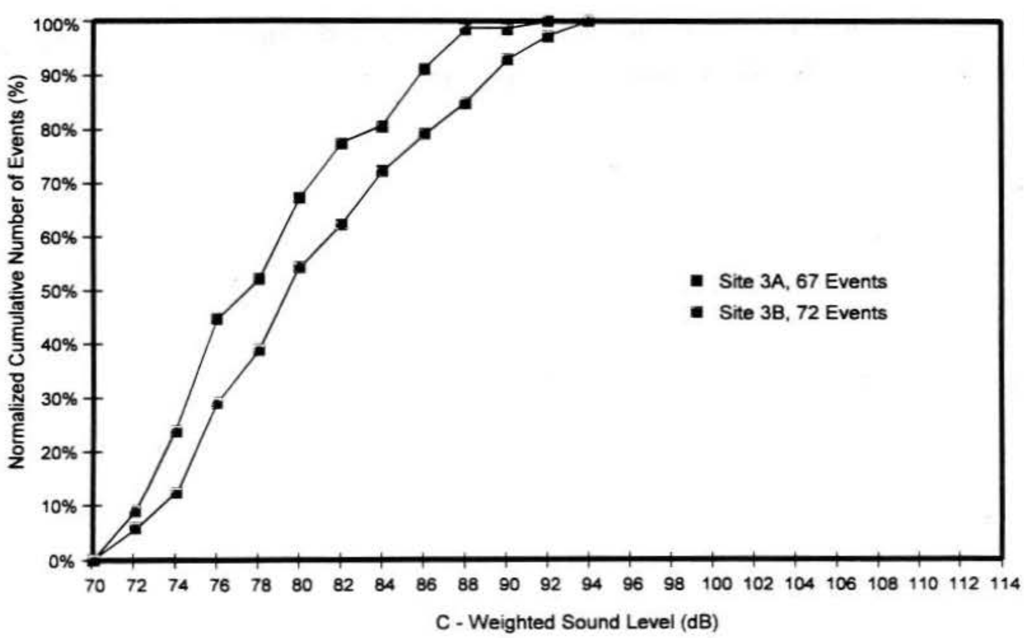


Figure 14 Cumulative distribution of maximum event levels on 25 August, 1999, 16:30 to 21:16, sites 3A and 3B.

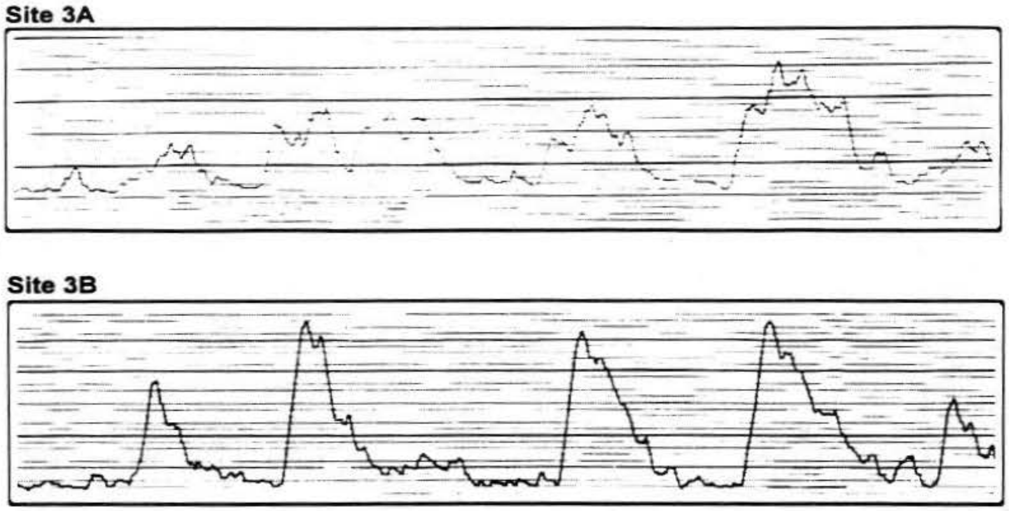


Figure 15 Time history strip chart for 24 August, 1999, 21:25 to 21:40.

Tables 5 and 6 show that measured aircraft noise levels were characteristically higher in level at site 3B than at site 3A, and that the higher levels were measured during the second set of measurements. The latter measurements are similar to those made earlier for purposes of collecting samples of backblast sounds for use in the laboratory study described in the following section.

The three August aircraft noise events plotted in Figures 16 through 21 show the range of one-third octave band levels measured during the second measurement period.

Table 5 Summary of measured aircraft noise levels, from 8 through 10 June, 1999.

	Site 1A		Site 2A		Site 3A		Site 1B		Site 2B		Site 3B		RMS 08	RMS 09	RMS 10	RMS 11	Aircraft Operation			
	L_{max}		L_{max}		L_{max}		L_{max}		L_{max}		L_{max}		L_{max}	L_{max}	L_{max}	L_{max}				
Time	C-Wtd	A-Wtd	C-Wtd	A-Wtd	C-Wtd	A-Wtd	C-Wtd	A-Wtd	C-Wtd	A-Wtd	C-Wtd	A-Wtd	A-Wtd	A-Wtd	A-Wtd	A-Wtd	Oper	Rwy.	Airline	A/C Type
8 June 1999																				
2126	113.3	99.5	NA	65	75.6	NA	89.1	72	NA	NA	84.1	NA	66.2	NA	NA		D	01R	UAL2458	B733
2138	112.3	93		60.5	82.3		88.8			58.5	88.5		76.5				D	01L	SKW5303	E120
Average	112.8	96.3	NA	62.8	79.0	NA	89.0	72.0	NA	58.5	86.3	NA								
9 June 1999																				
1910	101.1		76.9	60	76.2		86	73.5			75.8		75.4	70.3	70.6				ROA2735	MD83
2127	110	97.5	74.2	59.5	72.2		89.9			59.5	87		61.8			63.1			ASA387	MD80
2138	110.1	97	84	68	77		87.1			54.5	82.2		63.3						UAL1286	DC10
2151	110.2	91.5	76.7		72.8		85.5			53	80		66.2						COA150	B752
2200	105.1	88	73.1		73.7		81.9			62	77.4					64.1			UAL2272	B735
2209	108.8	93.5	76.3		73.1		85.1			58	77.3								UAL2071	B735
2223	107.1	89.5	73.1	61.5	77.1		85.9			56.5	81.5		66.6						USA72	B752
2233	108.5	99.5	73.6	60	74.8		87.1			56.5	81.5		69.3			61.4			COA9920	MD80
2257	110.7	91.5	73	58.5	72.9		88.6			65	74.8		63.1						USA96	B752
Average	108.0	93.5	75.7	61.3	74.4	NA	86.3	73.5	NA	58.1	79.7	NA								
10 June 1999																				
1108		101.5	79.4	71	68.6			73.5			84								UAL1694	B722
1155		93.5	74.1	63	74.6			95			85.2								AWE804	B732
1205		90.5	79.8	63.5	72						82								ROA2729	MD83
Average	NA	95.2	77.8	65.8	71.7	NA	NA	84.3	NA	NA	83.7	NA								
Two day Average	108.8	94.3	76.2	62.8	74.5	NA	86.8	78.5	NA	58.2	81.5	NA								

Table 6 Summary of measured aircraft noise levels, 24-25 August, 1999.

	Site 3A			Site 3B			RMS 08	RMS 09	RMS 11	Aircraft Operation			
	L_{max}			L_{max}			L_{max}	L_{max}	L_{max}				
Time	C-Wtd	A-Wtd	C - A	C-Wtd	A-Wtd	C - A	A-Wtd	A-Wtd	A-Wtd	Oper	Rwy.	Airline	A/C Type
24 Aug 1999													
2113	NA	NA		90.6	76.3	14.3		88.2	82.2	D	01L	CC1312	B722
2123	81.8	70.0	11.8	99.0	80.0	19.0			61.8	D	28R	DAL1985	B763
2128	77.8	65.9	11.9	99.3	80.6	18.7		75.1		D	01R	ASA387	MD80
2135	82.5	64.4	18.1	96.9	77.3	19.6	71.9	77.2		D	01L	SWR109	MD11
2157	80.0	NA		90.5	71.5	19.0	64.8		61.0	A	28L	UAL2137	B733
2205	78.0	60.1	17.9	86.5	68.9	17.6	68.1			D	01R	DAL212	B763
2213	79.5	NA		88.8	69.9	18.9		66.9		D	01R	USA72	B752
2226	75.0	NA		85.4	64.1	21.3			61.8	A	28R	COA1543	B752
2228	76.0	NA		84.1	65.8	18.3			61.9	A	28L	UAL8105	B752
2231	75.5	NA		83.0	66.5	16.5	70.4		57.7	D	01R	AAL18	B752
Average	78.5	65.1	14.9	80.4	72.1	18.3							
25 Aug 1999													
1126	78.6	63.9	14.7	85.4	68.9	16.5			58.2	D	01L	UAL1972	B735
1136	80.6	64.3	16.3	86.5	71.0	15.5			58.2	A	U/K	UAL288	B752
1210	74.1	59.0	15.1	80.5	63.4	17.1			66.1	D	01L	MEP921	MD80
1613	75.9	58.1	17.8	80.9	61.2	19.7			60.0	D	01L	ROA2777	MD90
1615	87.8	68.3	19.5	92.3	83.5	8.8			67.7	D	U/K	N911HB	DA50
1630	86.5	66.8	19.7	88.5	70.1	18.4		67.5	73.4	D	01R	AZA625	B763
1635	85.5	67.9	17.6	93.4	73.1	20.3		73.5	69.3	D	01L	SKW5039	E120
1655	88.2	71.9	16.3	94.2	77.5	16.7		83.9		D	01L	UAL1458	B722
1703	80.6	64.1	16.5	92.8	73.4	19.4	77.0		63.6	D	U/K	SKW5452	E120
1717	85.0	66.5	18.5	92.2	70.7	21.5		73.1	74.2	D	01L	ROA2745	MD83
1719	91.6	76.7	14.9	90.8	77.9	12.9		78.9	81.6	D	01L	CDN514	B732
1743	77.0	60.3	16.7	85.5	62.7	23.1	78.5	64.1		D	01L	AAL492	MD80
Average	82.6	65.7	17.0	88.6	71.1	17.5							
Two-day average	80.7	65.5	16.5	89.5	71.6	17.9							

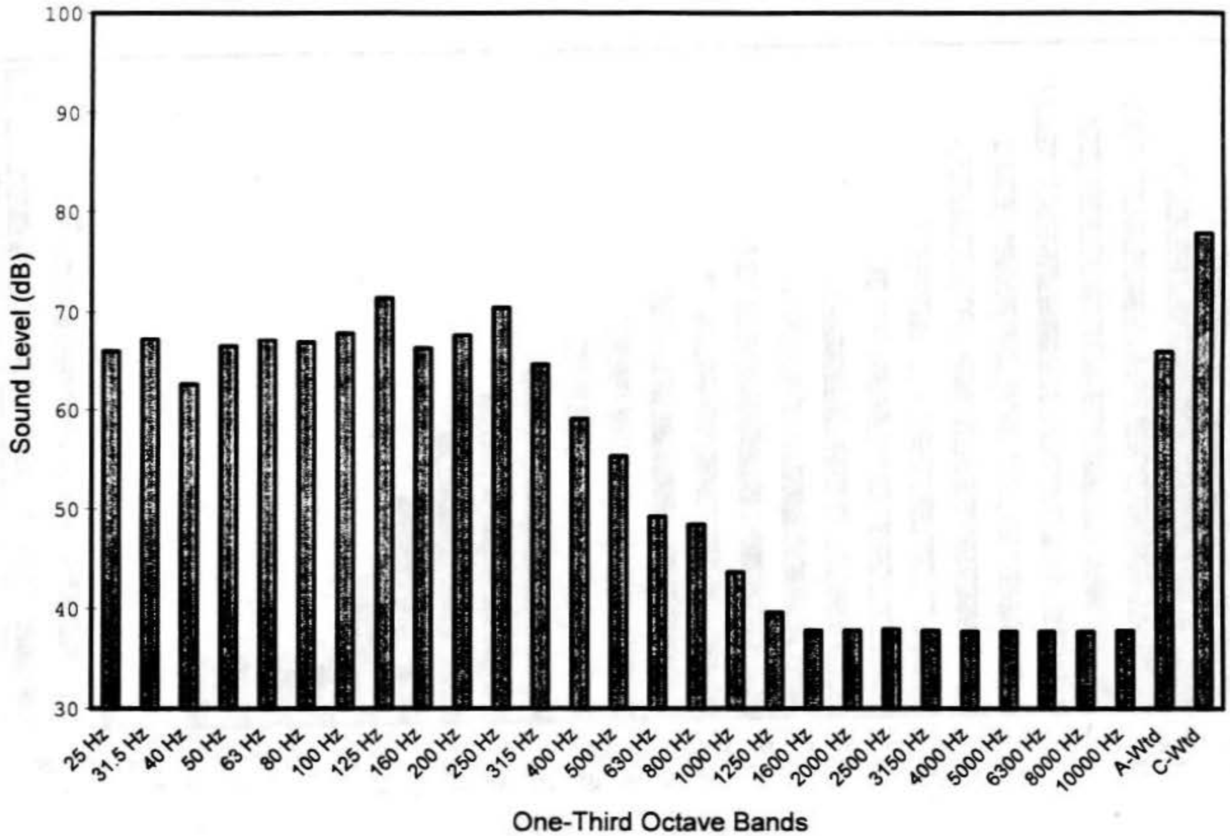


Figure 16 Maximum aircraft noise spectrum of MD-80 measured at Site 3A, 24 August, 1999, at 21:28.

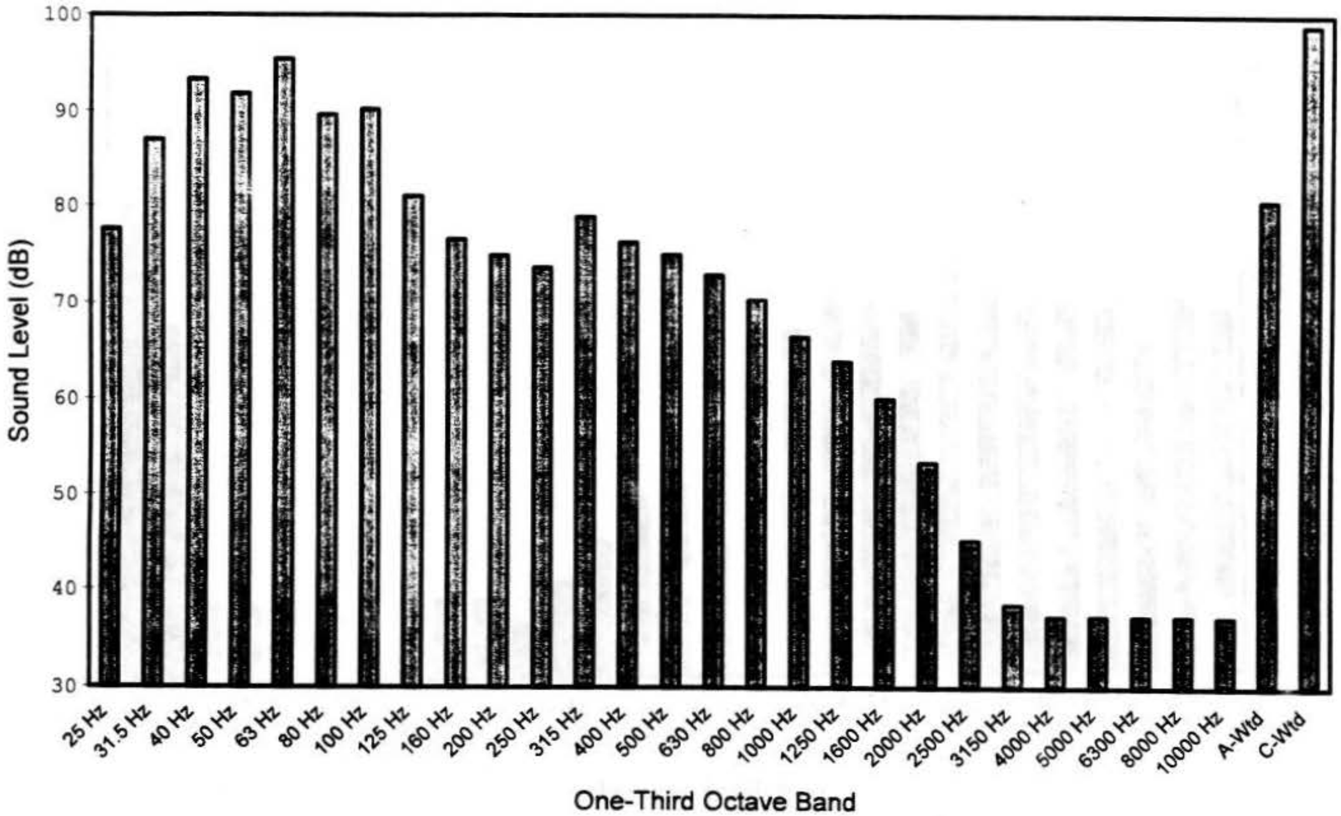


Figure 17 Maximum aircraft noise spectrum of MD-80 measured at Site 3B, 24 August, 1999, at 21:28.

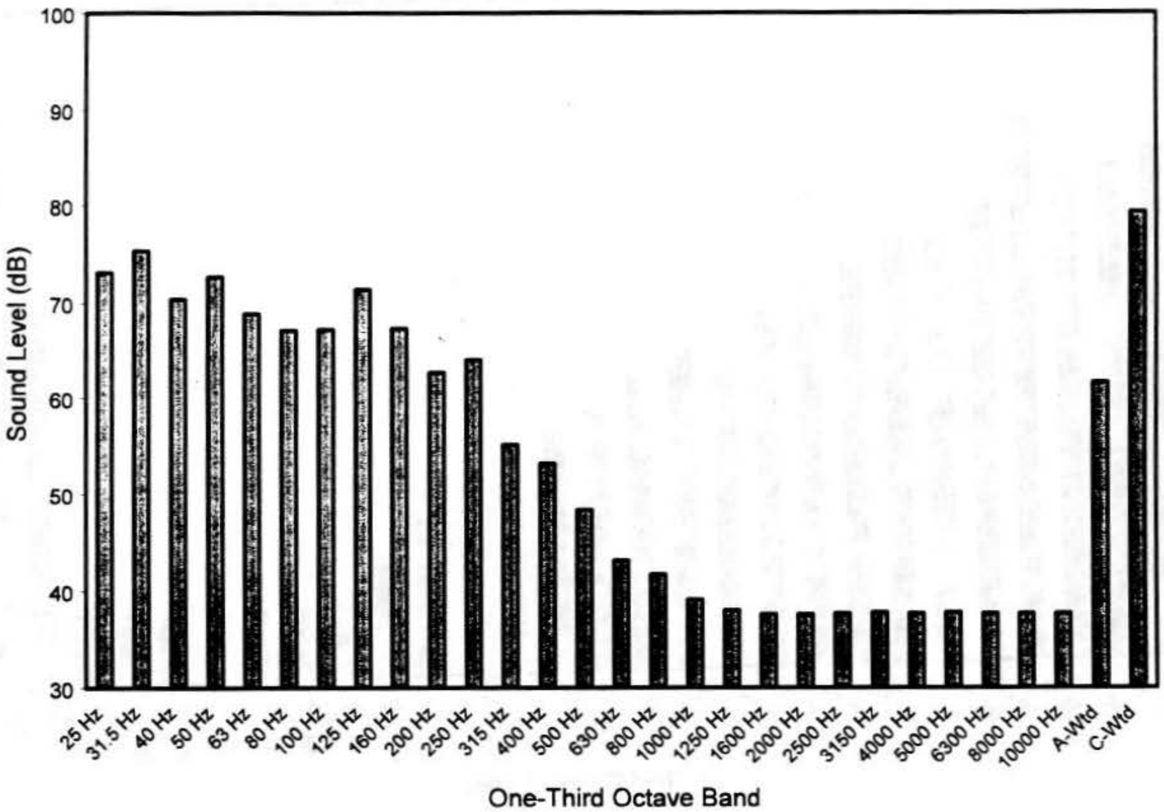


Figure 18 Maximum aircraft noise spectrum of B-757-200 measured at Site 3A, 24 August, 1999, at 22:13.

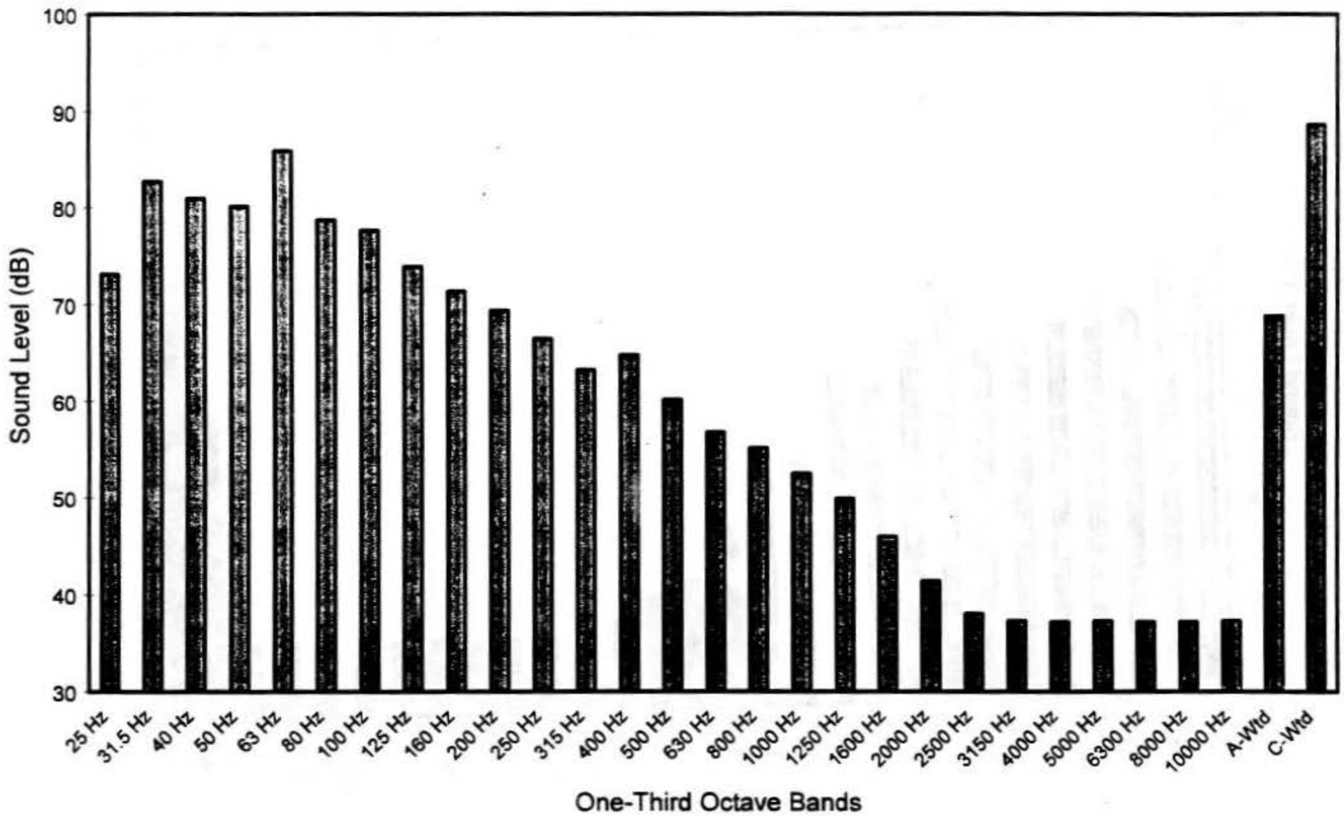


Figure 19 Maximum aircraft noise spectrum of B-757-200 measured at Site 3B, 24 August, 1999, at 22:13.

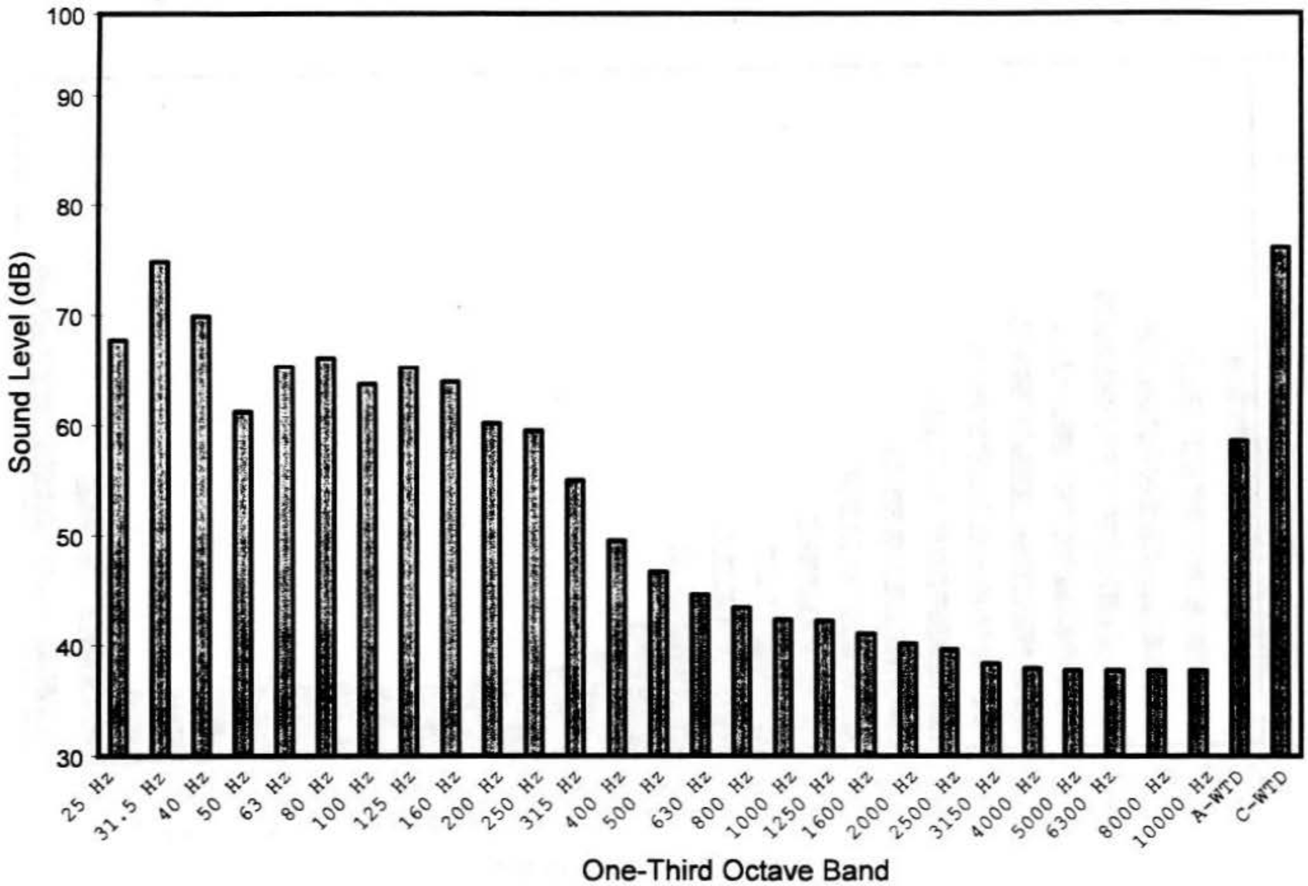


Figure 20 Maximum aircraft noise spectrum of MD-90 measured at Site 3A, 25 August, 1999, at 16:13.

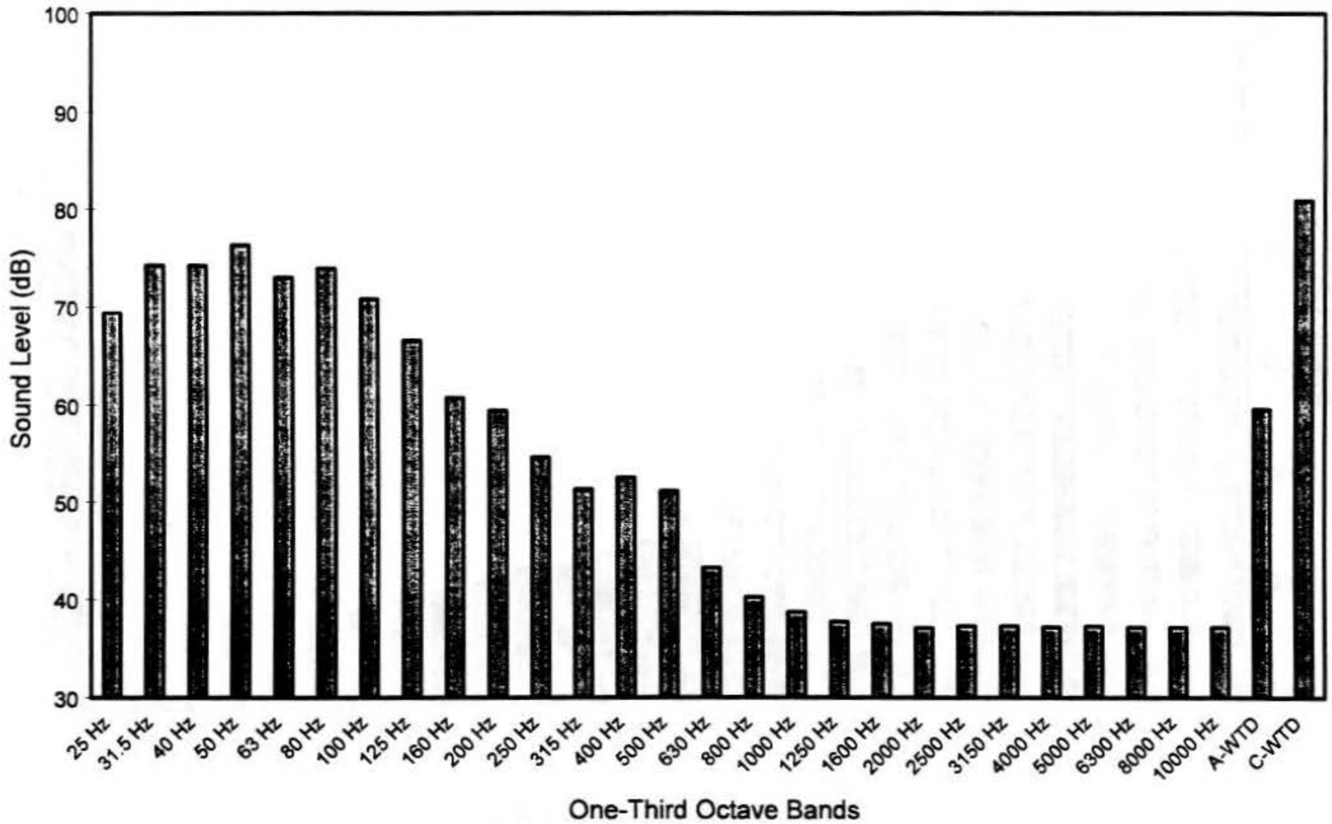


Figure 21 Maximum aircraft noise spectrum of MD-90 measured at Site 3B, 25 August, 1999, at 16:13.

5.7 DISCUSSION OF FIELD MEASUREMENTS

5.7.1 Effect of Atmospheric and Terrain Conditions

While much is known of near-ground sound propagation, it is impossible to effectively account for all the different conditions that prevail at any given time period. The usual approach to modeling aircraft noise levels in the community is to assume an annual average temperature and relative humidity, flat terrain with ground attenuation of sound at the ground plane, and a generalized model of lateral attenuation for angles of sound propagation referenced to the ground plane between 0° and 45°. The most recent release of FAA's aircraft noise modeling computer program (INM) takes account of some (but not all) of the effects of elevation changes due to hills and valleys.

However, other propagation effects can cause common aircraft operations at the airport to produce unusually high noise levels elsewhere. These unusual noise conditions may sometimes be due to temperature inversion conditions. They can combine with local terrain and wind effects to cause apparent amplification and/or focusing of noise in specific geographical areas. Figure 22 illustrates the effect of downward refraction (bending) of sound waves that would otherwise propagate away from the ground. Such downward refraction can increase noise levels at locations where they would otherwise occur at lower levels, giving a false impression of unusual aircraft operations.

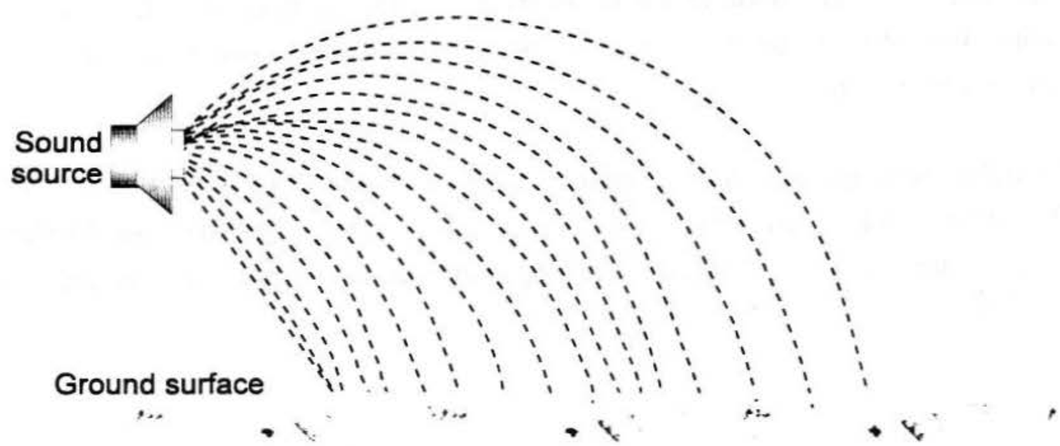


Figure 22 Illustration of downward refraction (bending) of sound waves caused by unusual temperature or wind gradients in the local atmosphere.

The seasonal distribution of complaints, and the noise measurements made during June and August 1999, suggest that such atmospheric conditions might effect low-frequency noise levels to the southwest of Runways 01 L/R. The prevalence of complaints in winter and spring months is consistent with the likelihood of temperature inversion conditions. The occurrence and magnitude of downward refractive atmospheric conditions are difficult to predict, however, without continuous knowledge of wind and temperature gradients in the direction of noise propagation.

5.7.2 Differences in Maximum Noise Event Levels During Two Measurement Periods

The June measurements show some distinctive differences in the maximum level of noise events at sites that are approximately the same distance from the airport. The average difference between maximum C-weighted event levels at sites 3A and 3B is approximately 6 dB. Site 3B is at an elevation of approximately 375 feet whereas site 3A is at an elevation of approximately 75 feet.

The average noise levels measured on 10 June at site 3B were higher than those measured on 9 June. Although this difference could be due to a stronger temperature inversion on the 10th of June, which might have focused sound at the more elevated site 3B, such an effect cannot be calculated from the limited weather data available.

The aircraft noise levels measured during the second measurement period generally exceeded those measured during the first survey. The highest level C-weighted event recorded during the first visit was 88.5 dB. The maximum levels of the aircraft noise events measured at site 3B during the second survey varied from 72.5 to 99.3 dB (C-weighted) and 55.7 to 80.6 dB (A-weighted). The higher level events occurred during the late afternoon and early evening, the time period when the strongest temperature inversion conditions often occur. C-weighted noise levels exceeded A-weighted noise levels by as much as 20 dB for the same event.

The highest level noise events occurring between 16:30 and 18:00 on 25 August, 1999 were Stage II aircraft. The distribution of aircraft types is summarized in Table 7. Of the Stage III aircraft operations listed in Table 7, the MD-80 aircraft type departing from Runway 01 produced the highest noise levels at sites 3A and 3B.

Table 7 Aircraft types identified on 25 August, 1999 between 16:30 and 18:00.

AIRCRAFT TYPE	NUMBER OF EVENTS
B-727	3
B-737	11
B-747	1
B-757	1
B-767	4
A320	1
MD-80	4

It appears from Table 6 and Figures 16 through 21 that the low-frequency content of the aircraft noise at site 3B is higher than that at site 3A. Comparison of similar data on 24 and 25 August shows the average C-weighted levels for site 3B to be higher than those at site 3A by 1.9 dB and 6.0 dB, respectively, while the A-weighted level differences for the two days are 7.0 and 5.4 dB. The weather inversion data do not indicate a significant difference for these days. The overall average C-weighted difference is 8.8 dB while the A-weighted difference is 6.1 dB. Calculating the value of the C-weighted level minus the A-weighted level ("C minus A") gives a rough indication of the low-frequency content of the noise. The C minus A level for the two days measured 16.5 dB at site 3A and 17.9 dB at site 3B, indicating strong low-frequency content of the noise.

5.8 SUMMARY OF FIELD MEASUREMENTS

High levels of C-weighted aircraft noise levels are present in each of the areas of complaints. Higher level aircraft noise events generally occurred in the late afternoon and early evening. These levels can vary over the course of the year by as much as 10 dB. The highest C-weighted noise levels measured in the high complaint areas during the measurement periods were within the range of 95 to 100 dB. The C-weighted noise levels of some noise events were about 20 dB higher than their A-weighted equivalents. The average difference between A- and C-weighted levels of the significant events over the two-day period in August was 16.5 dB and 17.9 dB for sites 3A and 3B, respectively. These differences do not necessarily affect long-term CNEL values.

Occasional occurrences of unusually high levels of low-frequency aircraft noise may be due to specific atmospheric conditions, such as temperature inversions, rather than to changes in aircraft type or operating conditions. The specific areas affected by low-frequency aircraft noise may therefore vary in an unpredictable manner.

6 LABORATORY STUDY OF ANNOYANCE

This section describes judgments of the annoyance of recorded aircraft departure and related sounds made under highly controlled conditions.

6.1 METHOD

An empirical study of the effects of varying duration and low-frequency content of aircraft noise on annoyance was conducted in a laboratory setting. Sounds heard by test participants were selected to test hypotheses about the relative annoyance of aircraft overflight and backblast noise of varying duration and low-frequency content.

6.1.1 Description of Test Environment and Procedures

All annoyance judgments were made in a low-frequency test facility that permitted controlled generation of signals at sound pressure levels as great as 136 dB at infrasonic frequencies. Figure 23 is a schematic representation of the test facility. Figure 24 is an interior view of the drive modules that created the test signals. Figure 25 is a photograph of the area in which subjects were seated.

Subjects entered the low-frequency facility with the experimenter prior to the start of testing on their first day of participation to familiarize themselves with the environment and listen to typical signals. They were encouraged to discuss the nature of their participation and to seek clarification of any matters that they might not have fully understood prior to granting written informed consent for participation in the study.

One subject at a time was seated in a chair inside the test facility facing a curtain hung in front of a full-scale plaster wall, behind which the low-frequency drive modules were mounted. These drive modules produced the low-frequency (below 100 Hz) portion of the signals. Two high-quality loudspeakers installed just behind the curtain reproduced the high-frequency (above 100 Hz) portion of the signals. An intercom and a video camera permitted an experimenter located in a nearby control room to communicate with and view subjects at all times. Four test sessions lasting approximately 25 minutes each were conducted daily.[4] Subjects were required to leave the test facility between testing sessions. A subject's participation spanned three days. Instructions to subjects may be found in Appendix A.

[4] Since subjects were not forced to respond within a fixed duration response interval, the pace of data collection varied slightly from session to session.

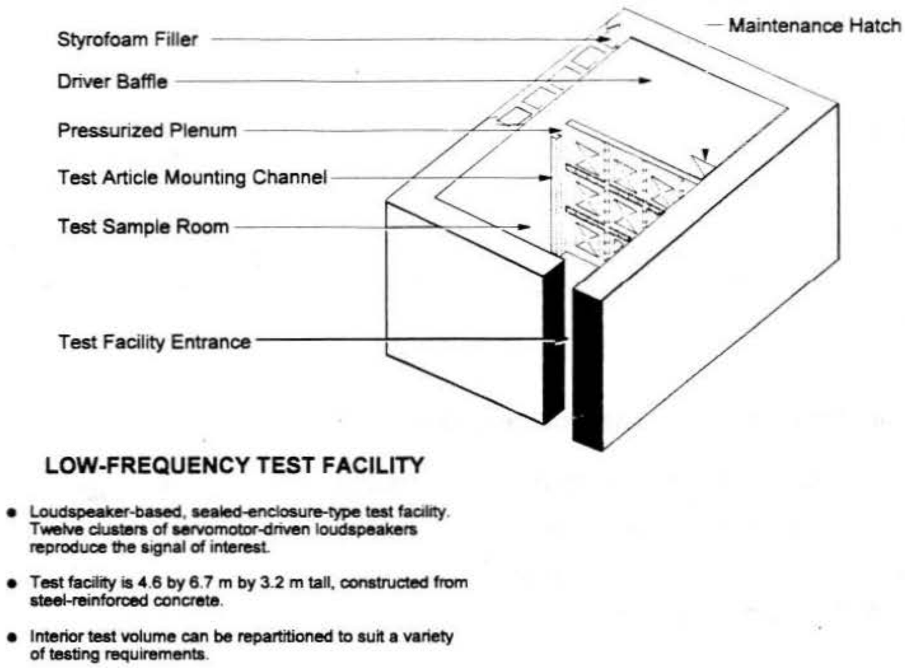


Figure 23 Schematic representation of low-frequency test facility.

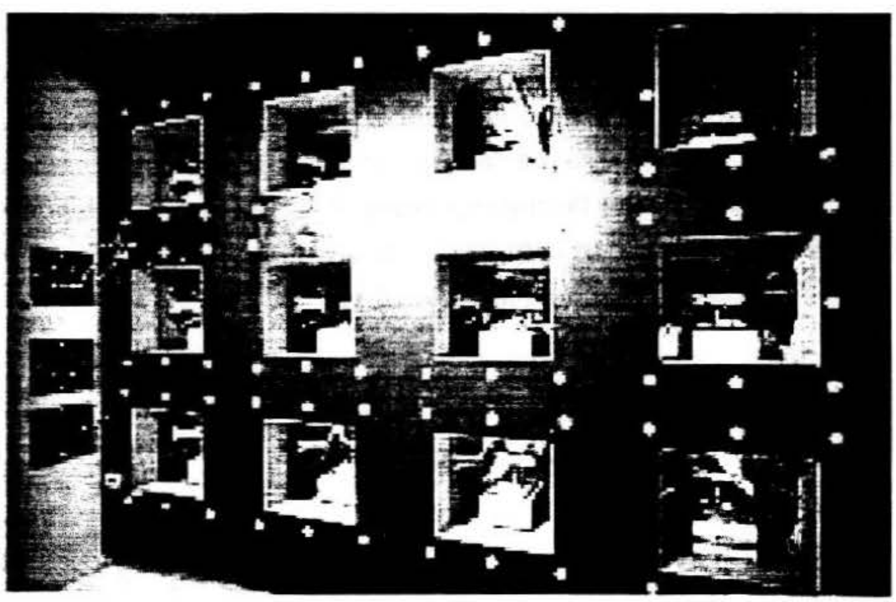


Figure 24 Interior view of low-frequency test facility.

Figure 25 Interior view of low-frequency test facility test subject chamber, showing seated test participant holding response box used to record subjective judgments.

6.1.2 Solicitation of Annoyance Judgments

Direct judgments of the relative annoyance of pairs of test signals were solicited in an adaptive paired comparison experimental design. Subjects were instructed to judge whether the first or second signal presentation of each trial was the more annoying. Ten such trials were presented for each signal pair. The durations of the signal presentation intervals were determined by the durations of the signals themselves. The duration of the response interval was determined by a subject's response latency.

Signal generation and presentation, as well as all other aspects of data collection, were under real-time computer control. Figure 26 diagrams the signal generation and presentation hardware. A maximum likelihood estimation algorithm described by Green (1990, 1995) and by Zhou and Green (1995) adaptively controlled signal presentation levels in real time, on the basis of test participants' ongoing decisions. The underlying psychometric function was assumed to be a cumulative Gaussian with a standard deviation of 10 dB. The value of the estimated point on the psychometric function was 50%. This is the point of subjective equality of annoyance, at which individual subjects rated the comparison (variable level signal) more annoying 50% of the time and the standard (fixed level) signal more annoying 50% of the time.

The point of subjective equality of annoyance was approached by a binary search algorithm. Step sizes between trials ranged from a maximum of 40 dB to a minimum of 2.5 dB. The maximum permissible signal presentation level was approximately 110 dB. The spectra of the presented noises are shown in Figures 27 and 28. Ten trials were administered for each determination of the relative annoyance of signal pairs, sufficient to yield a standard deviation of the threshold estimate of approximately 4 dB. The order of presentation of the fixed and variable signals was randomized on a trialwise basis. The order of presentation of signal pairs was independently randomized and fully interleaved, so that subjects were unable to predict which signal pair would be heard next.

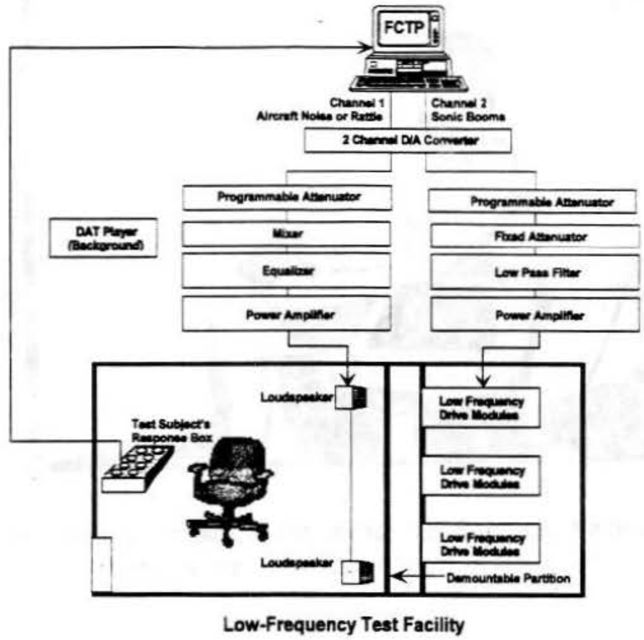


Figure 26 Illustration of instrumentation controlling administration of test conditions in the low-frequency test facility.

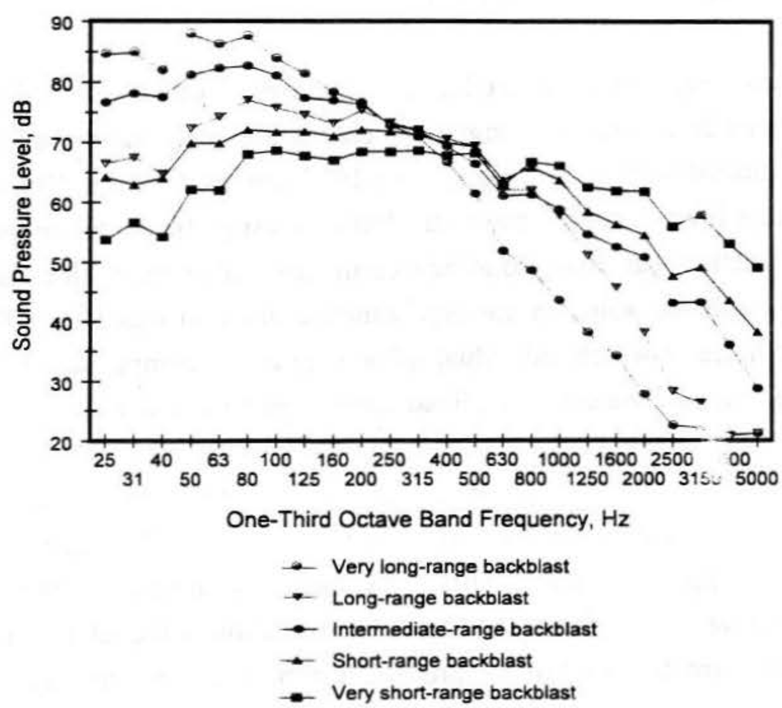


Figure 27 Spectral plots of the synthetic signals included in the low-frequency study.

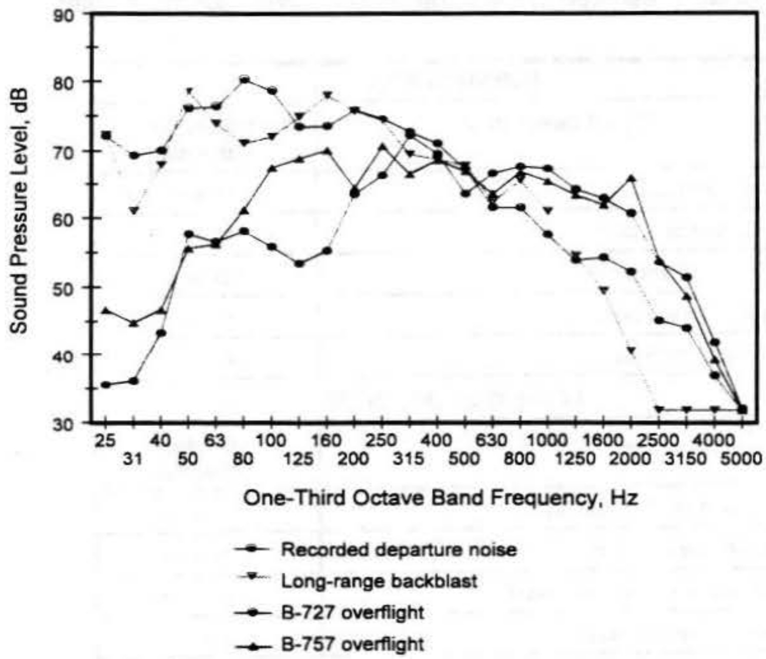


Figure 28 Spectral plots of the recorded signals used in the low-frequency study.

A long-duration digital recording of shaped Gaussian noise was reproduced at all times that subjects were present in the test facility. The A-level of the background noise at the subject's head position was approximately 41 dB.

6.1.3 Description of Test Signals and Presentation Levels

The experiment was conducted in two parts. The first part of the study examined the effects of varying durations of test signals on annoyance, while the second part examined the effects of varying low-frequency content of test signals on annoyance. Table 8 summarizes the fixed and variable level signals presented in the two parts of the experiment. Prior to the start of data collection, SFO-area residents auditioned samples of backblast noise recorded at several sites near their homes in the test chamber.

Table 9 summarizes the eight signal pairs presented in the duration study. Fixed level signals were always presented at the levels shown in the table. Table 10 summarizes the 12 signals pairs presented in the low-frequency portion of the experiment.

Table 8 Summary of signals presented in the duration and low-frequency studies.

DURATION STUDY	
Signal Description	**A-Weighted Signal Duration**
Simulated backblast	15 sec
Simulated backblast	40 sec
Simulated backblast	120 sec
Recorded backblast	15 sec
Recorded backblast	40 sec
LOW-FREQUENCY STUDY	
Signal Description	**Simulated/ Recorded**
Very long-range backblast	Simulated
Long-range backblast	Simulated
Intermediate-range backblast	Simulated
Short-range backblast	Simulated
Runway threshold noise	Simulated
Departure noise	Recorded
Long-range backblast	Recorded
B-727 overflight	Recorded
B-757 overflight	Recorded

Table 9 Summary of fixed and variable level signals presented in the duration study.

Fixed Level Signal	A-Weighted Presentation Level (dB)	Variable Level Signal
15 seconds of recorded backblast	75	15 seconds of recorded backblast
		40 seconds of recorded backblast
15 seconds of simulated backblast	75	15 seconds of simulated backblast
		40 seconds of simulated backblast
		120 seconds of simulated backblast
		40 seconds of recorded backblast
40 seconds of simulated backblast	70	40 second of recorded backblast
		120 seconds of simulated backblast

Table 10 Summary of signal pairs presented in low-frequency study.

SIGNAL PAIR ID	FIXED LEVEL SIGNALS		VARIABLE LEVEL SIGNALS
	Description	Level	Description
1	Simulated Intermediate-range backblast	75	Simulated very long-range backblast
2	Simulated Intermediate-range backblast	75	Simulated long-range backblast
3	Simulated Intermediate-range backblast	75	Simulated long-range backblast
4	Simulated Intermediate-range backblast	75	Simulated intermediate-range backblast
5	Simulated Intermediate-range backblast	75	Simulated short-range backblast
6	Simulated Intermediate-range backblast	75	Simulated runway threshold noise
7	Recorded departure noise	75	Simulated intermediate-range backblast
8	Intermediate-range backblast	75	Recorded long-range backblast
9	Intermediate-range backblast	75	Recorded B-727 overflight
10	Intermediate-range backblast	75	Recorded B-757 overflight
11	Simulated short-range backblast	75	Simulated long-range backblast
12	Simulated runway threshold noise	75	Simulated very long-range backblast

6.1.4 Subjects

Subjects were audiometrically screened to within 20 dB of normal hearing (audiometric zero) over the frequency range of 100 to 6,000 Hz prior to testing. All subjects were retested at the end of their third day. No substantive changes in hearing were observed upon completion of the judgment tests.

A total of twenty-nine test subjects judged the relative annoyance of the test signals. Twenty-eight of the participants completed all three days of planned testing, while one (a woman) completed the duration study only. Thirteen of the test participants who participated in the study were women ranging in age from 18 to 47, while sixteen were men ranging in age from 18 to 50. The average age of female participants was 26 years, while the average age of male participants was 25 years.

6.2 RESULTS

This section summarizes data collection, reliability analyses, and analyses of paired comparison judgments. The basic unit of analysis was the sound level of a variable level signal on the final signal pair presentation (assumed to be equal in annoyance to a fixed level signal.

6.2.1 Data Collection and Processing

The eight signal pairs presented ten times to each of 29 subjects yielded a total of 2,320 paired comparison judgments in the duration study. These eight determinations of subjective equality of the signal pairs produced 232 data points.

The twelve signal pairs presented ten times to each of 28 subjects yielded a total of 3,360 paired comparison judgments in the low-frequency study. These twelve determinations of subjective equality between the signal pairs produced 336 data points.

6.2.2 Reliability of Adjusted Signal Levels

6.2.2.1 Comparisons of signal versus itself

One paired comparison was administered for initial screening purposes, and to quantify the reliability of annoyance judgments. Subjects unable to judge the variable level signal to be equal in annoyance to that of the same signal presented 7 dB or more higher or lower in level were not permitted to participate in the study. Only two potential test subjects were unable to do so. Figure 29 shows the levels of the variable level signal when judged to be equal in annoyance to itself signal for each test subject. The level of the fixed signal was always 75 dB, whereas the mean level of the variable level signal at the point of subjective

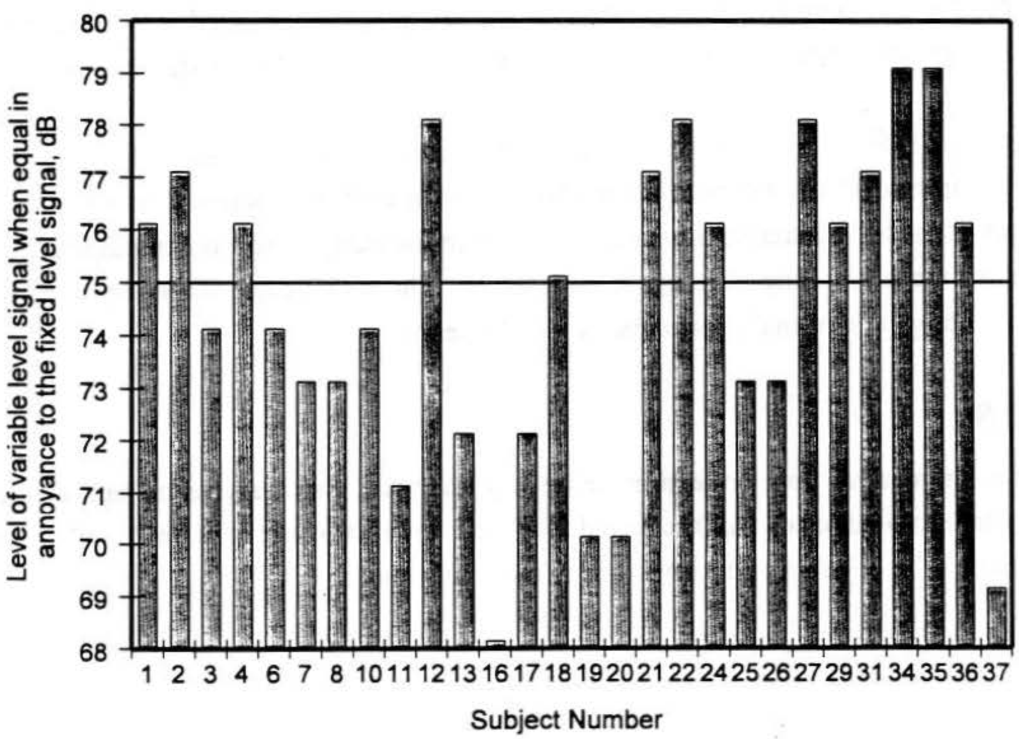


Figure 29 Levels of variable level signal when judged to be equally annoying to the fixed level signal for 28 test subjects.

equality was 74.5 dB. Most subjects were able to judge the variable level signal to be equally annoying when it was within 4 dB of the same signal in this initial paired comparison.

6.2.2.2 Test-Retest Reliability

For reliability purposes, the long-range backblast signal was compared to the intermediate-range backblast signal twice in the low-frequency study. Figure 30 shows the levels of the long-range backblast signal when judged to be equal in annoyance to the intermediate-range backblast signal for all test subjects. Although the spread of the resulting levels is slightly greater in the second comparison, the overall means do not differ.

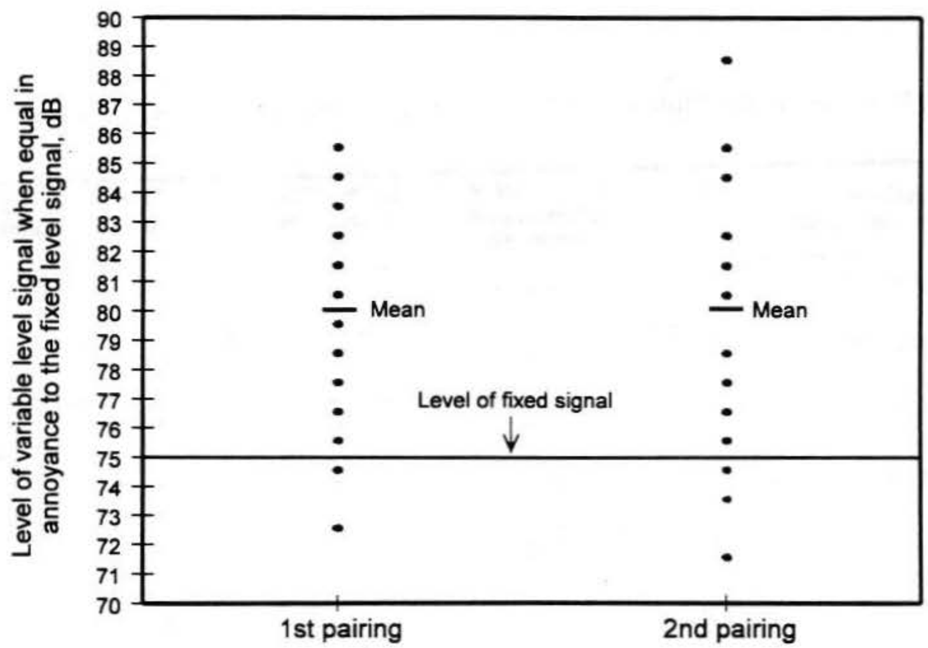


Figure 30 Level of long-range backblast signal when judged to be equally annoying to the intermediate-range backblast signal in repeated pairings.

6.2.3 Results of Duration Study

Table 11 contains summary statistics (of maximum A-weighted levels) of eight paired comparisons tested in the duration study. The second column contains the number of subjects whose resulting variable signal levels were within three standard deviations of the mean for each comparison and hence included in further analyses. The third column of the table contains the average level of the variable level signal when judged to be equal in annoyance to the fixed level signals. The fourth column contains the levels of the fixed level signals in each comparison. The fifth column contains the average differences between the variable and fixed level signals when judged to be equally annoying. The sixth column, which contains 10 times the log of the ratios of durations (variable duration/fixed duration) of the signal pairs, shows predicted decibel differences in noise levels of the variable and fixed level signals, in accordance with the "equal energy" theory. Table 12 presents summary statistics in sound exposure level (SEL) for the same comparisons.

Table 11 Summary statistics (of maximum A-weighted levels) of eight paired comparisons in duration study.

Description of Comparison (Variable Level *vs* Fixed Level Signal)	N	Mean Level of Variable Level Signal, dB	Level of Fixed Level Signal, dB	Mean Difference	10 Log Ratio of Durations, dB
15 sec simulated *vs* 15 sec simulated backblast *	27	74.5	75	-0.5	0
40 sec simulated *vs* 15 sec simulated backblast *	27	68.7	75	-6.3	-4.3
120 sec simulated *vs* 15 sec simulated backblast *	27	66.8	75	-8.2	-9.0
40 sec recorded *vs* 15 sec simulated backblast	28	67.7	75	-7.3	-4.3
120 sec simulated *vs* 40 sec simulated backblast	28	68.2	70	-1.8	-4.8
40 sec recorded *vs* 40 sec simulated backblast	28	66.4	70	-3.6	0
15 sec recorded *vs* 15 sec recorded backblast	28	76.1	75	1.1	0
40 sec recorded *vs* 15 sec recorded backblast	28	66.6	75	-8.4	-4.3

* Indicates that comparison was included in analysis of variance

Table 12 Summary statistics (of SEL) of eight paired comparisons in duration study.

Description of Comparison (Variable Level *vs* Fixed Level Signal)	N	Mean Level of Variable Level Signal, dB	Level of Fixed Level Signal, dB	Mean Difference
15 sec simulated *vs* 15 sec simulated backblast	27	82.5	82.1	0.4
40 sec simulated *vs* 15 sec simulated backblast	27	82.4	82.1	0.3
120 sec simulated *vs* 15 sec simulated backblast	27	83.7	82.1	1.6
40 sec recorded *vs* 15 sec simulated backblast	28	79.9	82.1	-2.2
120 sec simulated *vs* 40 sec simulated backblast	28	85.2	83.3	1.9
40 sec recorded *vs* 40 sec simulated backblast	28	78.9	83.3	-4.4
15 sec recorded *vs* 15 sec recorded backblast	28	82.5	81.6	0.9
40 sec recorded *vs* 15 sec recorded backblast	28	79.0	81.6	-2.6

Figure 31 displays the A-weighted sound levels of the variable level signals when judged to be equal in annoyance to the fixed level signals for all eight comparisons in the duration study. (Many overlapping judgments are obscured by the plotting symbols.) The heavy horizontal lines mark the levels of the fixed signals, while the solid triangles indicate the mean levels of the variable signals for each comparison. If the mean of the variable level signal is lower than the fixed level signal, then the fixed signal would be more annoying at equal levels. If the mean of the variable signal is higher than that of the fixed signal, then the variable level signal would be more annoying at equal levels.

Three comparisons (marked with asterisks in Table 11) were subjected to a repeated measures analysis of variance (ANOVA) to investigate the effects of varying signal duration on subjects' judgments of annoyance. The durations of the variable level signals for these three comparisons were 15 seconds, 40 seconds, and 2 minutes, whereas the duration of the fixed level signal was always 15 seconds. The signals were identical in their spectral contents and differed only in duration. Data from two subjects were dropped from this analysis since their resultant annoyance judgments were more than three standard deviations from the mean in at least one of the three comparisons. Hence, data from 27 subjects were included in this analysis.

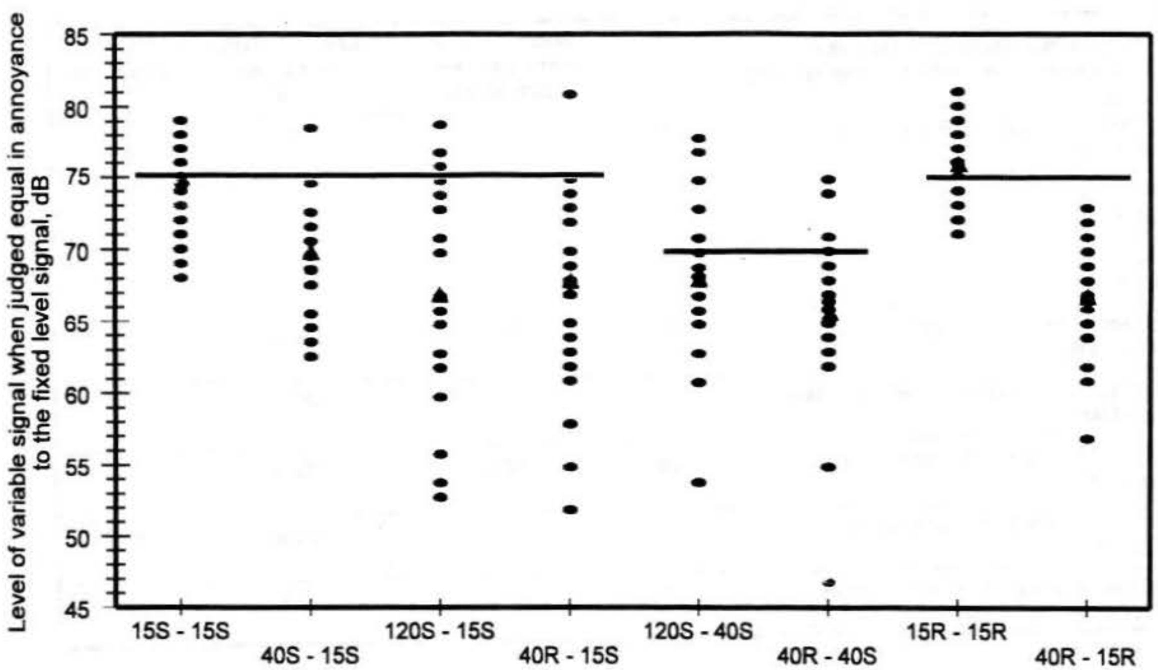


Figure 31 Level of variable level signal when judged to be equally annoying to the fixed level signals for all comparisons in the duration study. Mean values of the variable level signal are plotted as solid red triangles. Dark horizontal lines indicate fixed signal levels.

Table 13 shows the results of the ANOVA. A statistically significant effect of duration was found (with $F_{(2,52)} = 20.8$, $p < .001$). Mean levels of the three variable signals at the points of equal annoyance are shown in Figure 32. Increasing the duration of the variable level signal from 15 to 40 seconds produced an increase of 5.8 dB in the level of the variable signal at the point of subjective equality. A further increase in the duration of the variable signal to 120 seconds yielded an increase of 7.7 dB in the level of the variable signal at the point of subjective equality.

Table 13 Summary of analysis of variance results for effects of duration on annoyance.

SOURCE	SS	df	MS	F	p
Duration	863.5	2	431.8	20.8	<.001
Error	1,079.3	52	20.8		

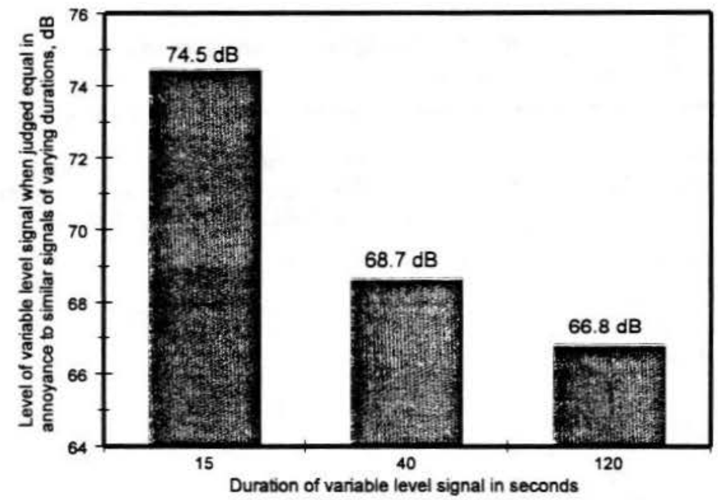


Figure 32 Mean levels of variable signals of varying durations when judged equally annoying to a similar fixed level signal of 15 seconds in duration.

6.2.4 Results of Low-Frequency Study

Table 14 summarizes the results of twelve paired comparisons tested in the low-frequency study in A-weighted levels. The second column contains the number of subjects whose resulting variable signal levels were within three standard deviations of the mean for each comparison and hence included in further analyses. The third column of the table contains the average level of the variable level signal when judged to be equal in annoyance to the fixed level signals. The fourth column contains the levels of the fixed level signals in each comparison. The fifth column contains the average differences between the variable and fixed level signals at the point of subjective equality.

Figure 33 shows the levels of the variable level signals when judged equal in annoyance to the intermediate-range backblast signal. The red bar indicates the level of the fixed level signal. The center comparison (of the blue shaded bars) is the intermediate-range signal versus itself (with a mean of 74.7 dB). The level of the very long-range backblast signal as well as the level of the runway threshold noise signal were within 1 dB of the level of the intermediate-range backblast signal at the point of equal annoyance. The level of the intermediate-range backblast signal was 5 dB lower than the long-range backblast signal at the point of equal annoyance. The level of the intermediate-range backblast signal was 3 dB lower than the short-range backblast signal at the point of equal annoyance.

Table 14 Summary statistics (of maximum A-weighted levels) of annoyance judgments for 12 paired comparisons in low-frequency study.

DESCRIPTION OF COMPARISON (VARIABLE LEVEL *vs* FIXED LEVEL SIGNAL)	N	MEAN LEVEL OF VARIABLE LEVEL SIGNAL, dB	LEVEL OF FIXED LEVEL SIGNAL, dB	DIFFERENCE
simulated very long-range backblast *vs* simulated intermediate-range backblast	28	74.1	75	-0.9
simulated long-range backblast *vs* simulated intermediate-range backblast	28	80.1	75	5.1
simulated long-range backblast *vs* simulated intermediate-range backblast	28	80.0	75	5.0
simulated intermediate-range backblast *vs* simulated intermediate-range backblast	28	74.7	75	-0.3
simulated short-range backblast *vs* simulated intermediate-range backblast	28	78.0	75	3.0
simulated runway threshold noise *vs* simulated intermediate-range backblast	28	75.4	75	0.4
simulated long-range backblast *vs* simulated short-range backblast	27	78.5	75	3.5
simulated very long-range backblast *vs* runway threshold noise	28	75.5	75	0.5
recorded long-range backblast *vs* simulated intermediate-range backblast	28	75.6	75	0.6
recorded B727 overflight *vs* simulated intermediate-range backblast	28	72.7	75	-2.3
recorded B757 overflight *vs* simulated intermediate-range backblast	27	71.7	75	-3.3
simulated intermediate-range backblast *vs* recorded departure noise	28	70.3	75	-4.7

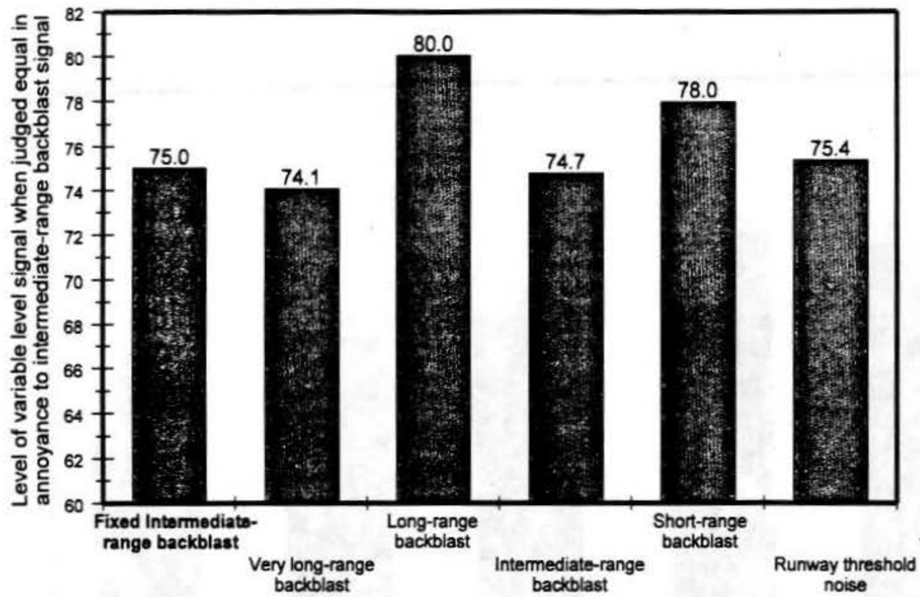


Figure 33 Mean levels of five signals with varying spectral content when judged to be equal in annoyance to the intermediate-range backblast signal. The red bar indicates the level of the fixed level signal.

Figure 34 compares the annoyance of simulated intermediate-range backblast noise and recorded flyover and backblast noise at short and long ranges. In all but the long-range backblast noise case, the recorded signals were lower in maximum A-level than the simulated signals at the point of equal annoyance. Aircraft flyover noise recordings were 2-3 dB lower and the short-range backblast signal was 5 dB lower than the simulated medium-range backblast signal at judged equal annoyance. The maximum A-level of the recorded long-range backblast signal was comparable (0.5 dB higher) than the simulated intermediate-range backblast signal. However, as shown in Figure 33, the simulated long-range backblast signal was 5 dB higher than the simulated intermediate-range backblast at the point of subjective equality. Thus the recorded long-range backblast signal would be about 4. 5 dB lower in level than the simulated backblast signal when judged to be equal in annoyance. In general, recorded signals are lower in maximum A-level than simulated backblast signals.

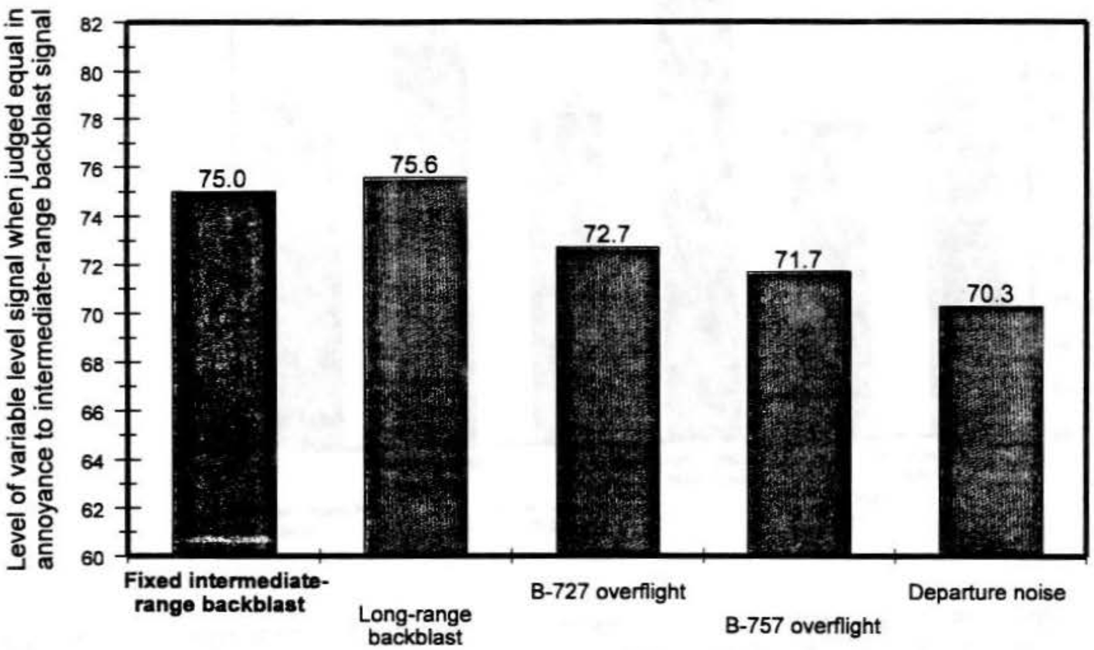


Figure 34 Mean level of recorded long-range backblast, B727, B757, and departure noise signals when judged equal in annoyance to the intermediate-range backblast signal. The red bar indicates the level of the fixed level signal.

6.3 DISCUSSION OF FINDINGS OF DURATION STUDY

The data show that sounds of longer duration must be lower in level to be judged equal in annoyance to sounds of shorter duration. Figure 35 suggests that the amount of increase is related to the amount of energy in the signal, at a rate of 3 dB for every doubling of duration. The red regression line through the data points and the blue line representing 3 dB per doubling are in close agreement.

Figure 36 illustrates a similar conclusion with a nearly horizontal regression line through the data points using SEL as a metric. (SEL takes account of duration of the signal as well as its maximum level.) It was noted when field recordings were made of the signals for the judgment tests that durations of two minutes were not uncommon for backblast noise. This was further confirmed by field measurements of duration associated with noise levels tabulated at locations 3A and 3B in Table 5 on Page 25. If durations of 15 seconds are assumed for typical aircraft flyover noises under the departure flight path near an airport, then all other things being equal, the backblast noise would have to be 9 dB lower than the shorter-duration flyover signal to be judged equally annoying.

Correcting for duration differences by expressing paired comparison judgments in units of SEL, recorded backblast sounds were judged between 2.2 and 4.4 dB more annoying than synthesized backblast sounds.

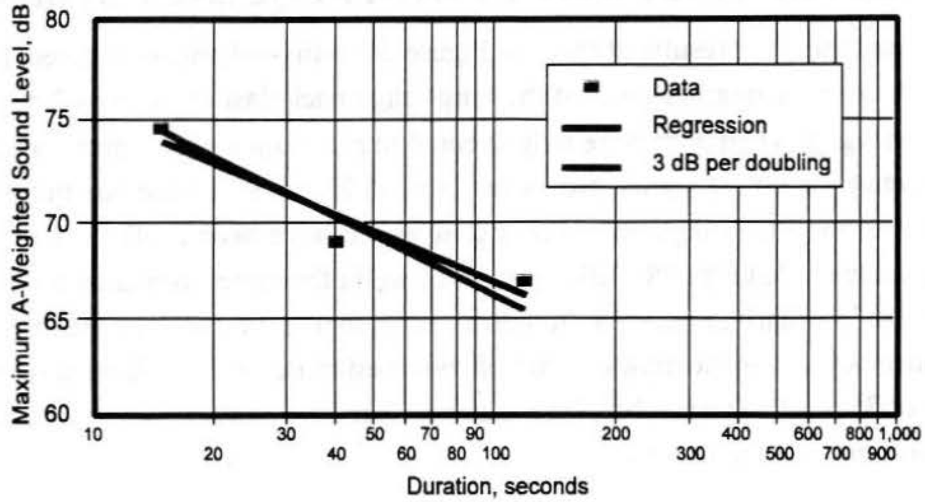


Figure 35 Signal level at judged equal annoyance, maximum A-weighted sound level *vs.* log duration.

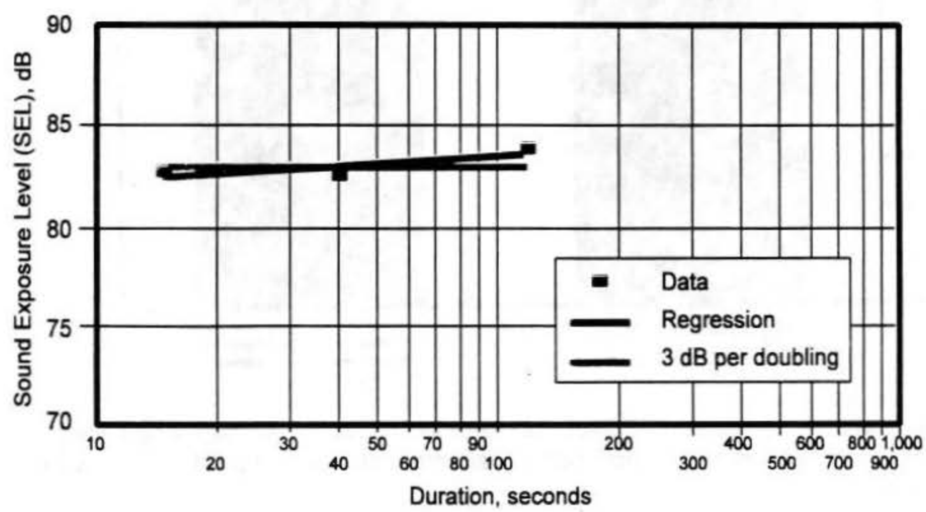


Figure 36 Signal level at judged equal annoyance, SEL *vs.* log duration.

6.4 DISCUSSION OF FINDINGS OF LOW-FREQUENCY STUDY

Figure 38 combines the results shown in Figure 37 with judgments derived from Figure 33. Figure 33 shows that the maximum A-level of the long-range backblast signal was 2 dB higher than the short-range backblast signal when both were judged equal in annoyance to the intermediate-range signal. Thus, if the short-range backblast signal had been fixed at 75 dB (the case for the results shown in Figure 37), the level of the long-range backblast signal would have been 2 dB higher (77 dB) at equal annoyance. This is comparable to the 78.5 dB result obtained for the direct comparison shown in Figure 37 (replotted in Figure 38). Similarly, Figure 38 shows the results for the level of the very long-range backblast signal when equal in annoyance to the runway threshold noise estimated at 73.7 dB do not differ greatly from the observed value of 75.5 dB. The results of these comparisons are another indication of the consistency and reliability of the annoyance judgments.

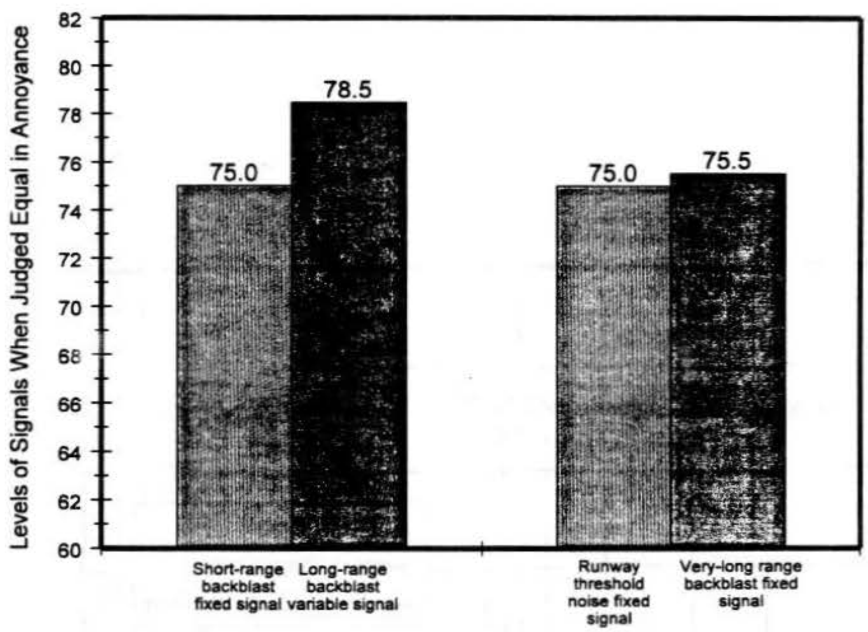


Figure 37 Mean levels of long-range and very long-range backblast signals when judged to be equal in annoyance to the fixed level short-range backblast signal and the fixed runway threshold noise, respectively.

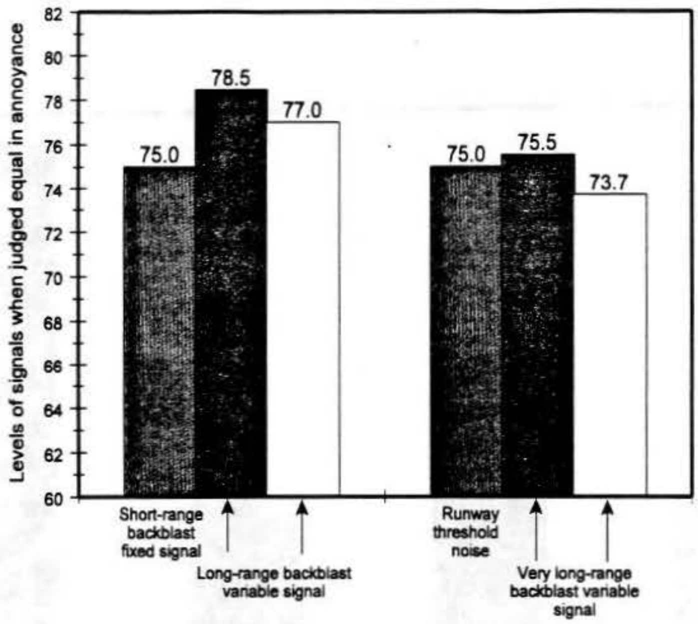


Figure 38 Mean levels of long-range and very long-range backblast signals when judged to be equal in annoyance to the fixed level short-range backblast signal and the fixed runway threshold noise, respectively. (Data represented by yellow bars were derived from data in Figure 33.)

6.4.1 Findings of Related Laboratory Study of Annoyance of Low-Frequency Noise and Rattle

A similar study (Pearsons, Fidell, Silvati, and Howe, 1999) employing identical trial procedures and some of the same test sounds documented the effect of rattle on the annoyance of low-frequency aircraft noise. The same backblast signal as compared to sideline noise was presented for annoyance judgments to 28 subjects, with and without rattle sounds. Figure 39 shows that the addition of minor amounts of rattling sounds notably increased the annoyance of the backblast signal.

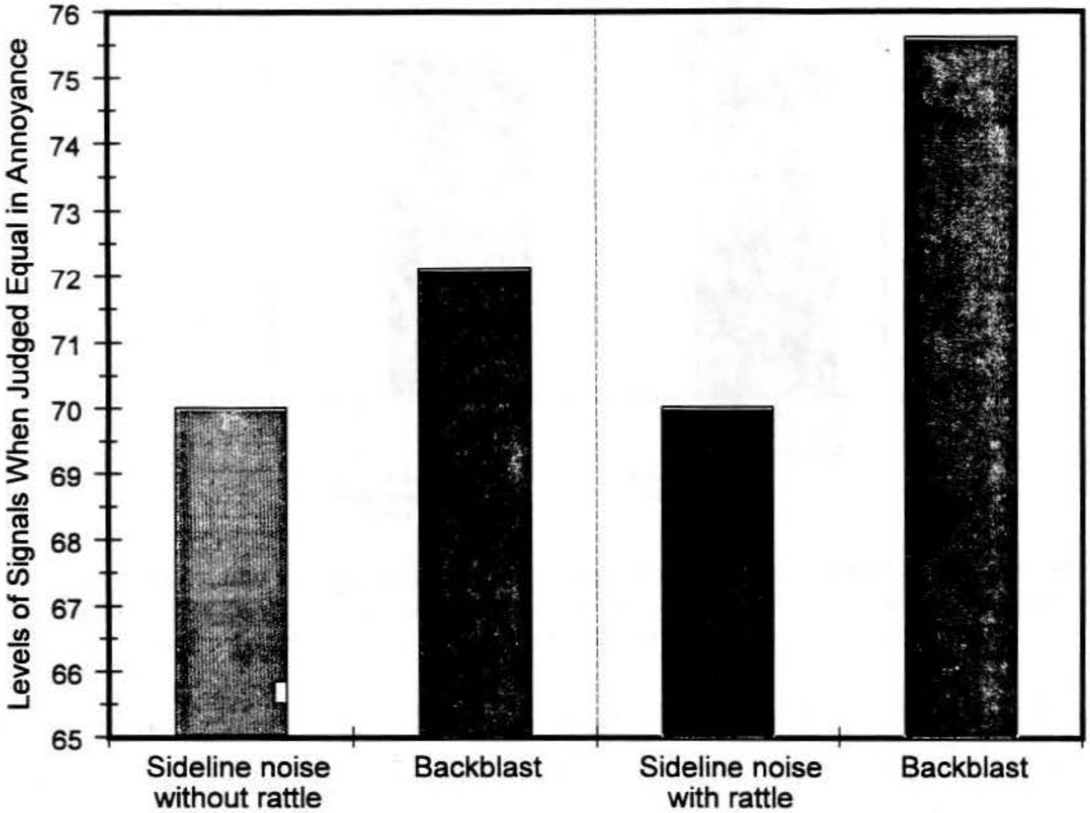


Figure 39 Effect of rattle on annoyance judgment of sideline noise.

7 CONCLUSIONS

The major conclusions that may be drawn from this study include the following:

- Backblast noise is a readily measurable concentration of low-frequency noise created by individual aircraft departures in areas behind Runways 01L/R at SFO.

- The density of aircraft noise complaints in residential areas to the southwest of Runways 01L/R is greatest in two areas of Millbrae, Burlingame, and Hillsborough located roughly two miles from the start of takeoff roll.

- Although these two areas lie well outside of SFO's 65 dB CNEL contour, their locations are consistent with high noise levels associated with the directivity of jet engine exhaust noise.

- Meteorological conditions may be responsible for inducing considerable variability (at least ± 5 dB) in low-frequency aircraft departure noise level and duration in areas of Millbrae, Burlingame, and Hillsborough. Therefore, reliable prediction of times of day and seasons of the year when backblast noise is likely to be particularly high in level requires very detailed information about atmospheric conditions.

- C-weighted sound levels of individual aircraft departures measured in these two areas often exceed 80 dB, and can occasionally reach levels in the high 90 dB range, depending on aircraft type and other factors.

- Low-frequency sound levels corresponding to these C-weighted levels vary from about 70 to 90 dB in the one-third octave bands from 25 to 80 Hz.

- Instances of backblast noise associated with individual departures can be of unusually long duration with respect to typical aircraft overflight noise.

- When judged equally annoying, longer-duration, backblast-like sounds are lower in level than shorter-duration sounds by 3 dB per doubling of duration throughout the range of durations from 15-120 seconds. This finding confirms the need to keep in mind a 10 log (duration) correction in planning measures intended to mitigate the annoyance of backblast noise.

- The annoyance of backblast is heightened by its duration and potentially by the production of rattle in homes.

- When judged equally annoying, the maximum A-weighted sound levels of backblast noises lasting two minutes or more are 5 to 7 dB lower than those of typical aircraft overflights.

8 REFERENCES

Berglund, B., Hassmén, P., and Job, R.F.S. (1996). "Sources and effects of low-frequency noise," *J. Acoust. Soc. Am.*, *99*(5), 2985-3002.

Blazier, W. (1991) "Noise Control Criteria for Heating, Ventilating, and Air-Conditioning Systems," Chapter 43 of Harris, C. (ed.), Third Edition, Handbook of Acoustical Measurements and Noise Control, McGraw-Hill, Inc., New York.

Broner, N. (1978). "The effects of low-frequency noise on people — a review," *J. Sound and Vib.*, *58*(4), 483-500.

Brown, D., and Sutherland, L.C. (1992), "Evaluation of Outdoor-to-Indoor Response to Minimized Sonic Booms," NASA Contractor Report 189643, Langley Research Center, Hampton, VA.

Caltrans Division of Aeronautics (1984). "Monitoring data, aircraft noise frequency analysis, San Francisco International Airport."

Connor, W. (1986). "Investigation of aircraft departure noise in community areas behind runways 1L and 1R at San Francisco International Airport," Tracor Applied Sciences Document T86-01-9521U, Austin, TX.

FAA Engineer's Report (1998) "Residential Sound Insulation at Baltimore/Washington International Airport," AIP 3-24-0005-39.

Federal Interagency Committee on Noise (FICON) (1992). Final Report: Airport Noise Assessment Methodologies and Metrics, Washington, D.C.

Fidell, S., Silvati, L., Pearsons, K., Lind, S., and Howe, R. (1999). "Field study of the annoyance of low-frequency runway sideline noise," *J. Acoust. Soc. Am.*, in press.

Fidell, S., Silvati, L., Pearsons, K., (1999). "Field study of the annoyance of aircraft noise-induced rattle and vibration at MSP," *J. Acoust. Soc. Am.*, in press.

Gilfillan, W. (1999). "Fast Track Item III.B — Backblast noise insulation pilot project; Initial findings," Memorandum prepared for 7 April 1999 meeting of Airport/Community Roundtable.

Green, D. M. (1990). "Stimulus selection in adaptive psychophysical procedures," *J. Acoust. Soc. Am.*, *87*(6), pp. 2662-2674.

Green, D. M. (1995). "Maximum likelihood procedures and the inattentive observer," *J. Acoust. Soc. Am.*, *97*(6), pp. 3749-3760.

Horonjeff, R.D. and Thompson (1996). "Logan Low-Frequency Noise Study," HMMH Report 293810.04.

Harris Miller Miller & Hanson (1996b). "Development of Single Event Noise Metrics for Use in Identifying Aircraft Operations for Possible Mitigation," HMMH Report 294090.

Hubbard, H. (1982). "Noise Induced House Vibrations and Human Perception," *Noise Control Engineering Journal*, *19*(2), pp. 49-55.

Kesterson, J., Vondemkamp, M., and Connor, W. (1987). "Investigation of low-frequency noise from departures on runways 1L and 1R at San Francisco International Airport," Tracor Project 076-439(-01), Austin, TX.

Lind, S., Pearsons, K., and Fidell, S. (1997). "An Analysis of Anticipated Low-Frequency Aircraft Noise in Richfield Due to Operation of a Proposed North-South Runway at MSP," BBN Report 8196.

Miller, Reindel, Senzig and Horonjeff (1998). "Study of Low-Frequency Takeoff Noise at Baltimore-Washington International Airport," HMMH Report 294730.300/293100.09.

Passchier-Vermeer, W. (1998). "Vibrations in the living environment: Factors related to vibration perception and annoyance," TNO Prevention and Health Report 98.022, Leiden, The Netherlands.

Passchier-Vermeer, W., and Zeichart, K. (1998). "Vibrations in the living environment: Relationships between vibration annoyance and vibration metrics," TNO Prevention and Health Report 98.022, Leiden, The Netherlands.

Pearsons, K., Fidell, S., Silvati, L., and Howe, R. (1999). BBN Contribution to Richfield-MAC Low Frequency Noise Expert Panel.

Shade, N. T. (1997). "Final Report: BWI Low-Frequency Noise Analysis for Allwood Neighborhood," Acoustical Design Collaborative Project 96.01, Falls Church, VA.

Sutherland, L. (1982) "Low-frequency response of structures," Wyle Research Report WR 22-18.

Sutherland, L., Sharp, B., and Mantey, R., (1983). "Preliminary evaluation of low-frequency noise and vibration reduction retrofit concepts for woodframe structures," Wyle Research Report WR 83-26.

Zhou, B., and Green, D. M. (1995). "Reliability of pure-tone thresholds at high frequencies," *J. Acoust. Soc. Am.*, *98*(2:1), pp. 828-836.

Zwicker, E. (1977). "Procedure for calculating loudness of temporally variable sounds," *J. Acoust. Soc. Am.*, *62*, pp. 675-682.

9 GLOSSARY

Definitions of formal acoustic quantities correspond to those of *American National Standard S1.1-1994 Acoustical Terminology*. Other terms, abbreviations, and symbols are defined in the sense in which they are used in this report.

A-weighted sound level: A single number index of a broadband sound that has been subjected to the A-weighting network (*q.v.*).

A-weighting network: A frequency-equalizing function intended to approximate the sensitivity of the human hearing to sounds of moderate sound pressure level.

C-weighted sound exposure level: Sound exposure level, as defined below, where C-weighted sound pressure is used instead of A-weighted sound pressure. Unit, decibel; abbreviation, CSEL; symbol, L_{CE}.

day average sound level: Time-average sound level between 0700 and 2200 hours. Unit, decibel (dB); abbreviation, DL; symbol, L_d. Note: Day average sound level in decibels is related to the corresponding day sound exposure level, L_{Ed}, according to:

$$L_d = L_{Ed} - 10 \log(54000/1)$$

where 54,000 is the number of seconds in a 15-hour day.

day-night average sound level: Twenty-four hour average sound level for a given day, after addition of 10 decibels to levels from 0000 to 0700 hours and from 2200 (10 p.m.) to 2400 hours. Unit, decibel (dB); abbreviation, DNL; symbol, L_{dn}. Note: Day-night average sound level in decibels is related to the corresponding day-night sound exposure level, L_{Edn}, according to:

$$L_{dn} = L_{Edn} - 10 \log(86400/1)$$

where 86,400 is the number of seconds in a 24-hour day. A-frequency weighting is understood, unless another frequency weighting is specified explicitly.

departure noise: A general descriptive term for noise created by aircraft operations on a departure runway.

energy average. Colloquial term for time-mean-square average of a series of sound signals.

energy summation. Colloquial term loosely used to indicate addition of non-coherent sound signals by the sum of the squares of their sound pressures or sound exposures.

instantaneous sound pressure: Total instantaneous pressure at a point in a medium minus the static pressure at that point. Unit, pascal (Pa); symbol, p.

maximum sound level; maximum frequency-weighted sound pressure level: Greatest fast (125 ms) A-weighted sound level within a stated time interval. Alternatively, slow (1000 ms) time-weighting and C-frequency-weighting may be specified. Unit, decibel (dB); abbreviation, MXFA; symbol, L_{AFmx} (or C and S).

night average sound level: Time-average sound level between 0000 and 0700 hours and 2200 and 2400 hours. Unit, decibel (dB); abbreviation, NL; symbol, L_n. Note: Night average sound level in decibels is related to the corresponding night sound exposure level, L_{En}, according to:

$$L_n = L_{En} - 10 \log(32400/1)$$

where 32,400 is the number of seconds in a 9-hour night.

one-hour average sound level: Time-average sound level during a time period of one hour. Unit, decibel (dB); abbreviation, 1HL; symbol, L_{1h}. Note: One-hour average sound level in decibels is related to the corresponding one-hour sound exposure level, L_{E1h}, according to:

$$L_{1h} = L_{E1h} - 10 \log(3600/1)$$

where 3600 is the number of seconds in one hour, 1 s is the reference duration for sound exposure, and sound exposure E is in pascal-squared seconds.

NOTE – Procedures for computing perceived noise level are stated in Federal Aviation Regulation Part 36, *Noise Standards: Aircraft Type and Airworthiness Certification*, Appendix B, and in International Civil Aviation Organization Annex 16, Volume 1, *Aircraft Noise*, Third Edition, July 1993.

sound exposure: Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second; symbol, E. Note: If frequency weighting is not specified, A-frequency weighting is understood. If other than A-frequency weighting is used, such as C-frequency weighting, an appropriate subscript should be added to the symbol; e.g., E_C.

Duration of integration is implicitly included in the time integral and need not be reported explicitly. For the sound exposure measured over a specified time interval such as one hour, a 15-hour day, or a 9-hour night, the duration should be indicated by the abbreviation or letter symbol, for example, one-hour sound exposure (1HSE or E_{1h}) for a particular hour; day sound exposure (DSE or E_d) from 0700 to 2200 hours; and night sound exposure (NSE or E_n) from 0000 to 0700 hours plus from 2200 to 2400 hours.

Day-night sound exposure (DNSE or E_{dn}) for a 24-hour day is the sum of the day sound exposure and 10 times the night sound exposure. Unless otherwise stated, the normal unit for sound exposure is the pascal-squared second.

sound level; weighted sound pressure level: Ten times the logarithm to the base ten of the ratio of A-weighted squared sound pressure to the squared reference sound pressure of 20 μPa, thc squared sound pressure being obtained with fast (F) (125 ms) exponentially weighted time-averaging. Alternatively, slow (S) (1000 ms) exponentially weighted time-averaging may be specified; also C-frequency weighting. Unit, decibel (dB); symbol L_A, L_C. Note: In symbols, A-weighted sound level $L_{A\tau}(t)$ at running time t is:

$$L_{A\tau}(t) = 10 \log \left\{ \left[(1/\tau) \int_{-\infty}^{t} p_A^2(\xi)\, e^{-(t-\xi)/\tau}\, d\xi \right] / p_0^2 \right\}$$

where τ is the exponential time constant in seconds, ξ is a dummy variable of integration, $p_A^2(\xi)$ is the squared, instantaneous, time-varying, A-weighted sound pressure in pascals, and p_0 is the reference sound pressure of 20 μPa. Division by time constant τ yields the running time average of the exponential-time-weighted, squared sound-pressure signal. Initiation of the running time average from some time in the past is indicated by $-\infty$ for the beginning of the integral. ANSI S1.4-1983, *American National Standard Specification for Sound Level Meters*, gives standard frequency weightings A and C and standard exponential time weightings fast (F) and slow (S).

sound pressure; effective sound pressure: Root-mean-square instantaneous sound pressure at a point, during a given time interval. Unit, pascal (Pa). Note: In the case of periodic sound pressures, the interval is an integral number of periods or an interval that is long compared with a period. In the case of nonperiodic sound pressures, the interval should be long enough to make the measured sound pressure essentially independent of small changes in the duration of the interval.

sound pressure level: Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20 μPa. Unit, decibel (dB); abbreviation, SPL; symbol, L_p.

time-average sound level; time-interval equivalent continuous sound level; time-interval equivalent continuous A-weighted sound pressure level; equivalent continuous sound level: Ten times the logarithm to the base ten of the ratio of time-mean-square instantaneous A-weighted sound pressure, during a stated time interval T, to the square of the standard reference sound pressure. Unit, decibel (dB); respective abbreviations, TAV and TEQ; respective symbols, L_{AT} and L_{aeqT}. Note: A frequency weighting other than the standard A-weighting may be employed if specified explicitly. The frequency weighting that is essentially constant between limits specified by a manufacturer is called flat.

In symbols, time-average (time-interval equivalent continuous) A-weighted sound level in decibels is:

$$L_{AT} = 10 \log\left\{\left[(1/T)\int_o^T p_A^2(t)\,dt\right]/p_0^2\right\}$$
$$= L_{AeqT}$$

where p_A^2 is the squared instantaneous A-weighted sound pressure signal, a function of elapsed time t; in gases reference sound pressure $p_0 = 20\ \mu$Pa; T is a stated time interval. In principle, the sound pressure signal is not exponentially time-weighted, either before or after squaring.

APPENDIX A INSTRUCTIONS TO TEST SUBJECTS

What you will hear during a listening session

You will hear many pairs of sounds during the course of three listening sessions. Your job will always be the same: to listen carefully to each sound of a pair of sounds, and then to push either the first or the second button on the response box to tell us which of the two sounds was more annoying.

In making your decision about which of the pair of sounds was more annoying, you should assume that each sound occurs 20 to 30 times a day in your home. Think about which of the two sounds you would not want to hear in your home 20 to 30 times a day and select that sound.

When to Make Your Judgment

You must wait until the second sound of each pair ends before you decide which of the pair of sounds was more annoying. During the first session, some of the sounds will last much longer than others, and you may be comparing the annoyance of relatively short sounds and longer sounds. When deciding which of a pair of sounds is more annoying, you must be patient, and take into consideration your overall annoyance throughout the entire sound, not just how loud the two sounds were at one time or another.

Remember: The computer will not let you judge the annoyance of a pair of sounds until you have heard both sounds completely. Please be patient, listen carefully to all of both sounds, and wait until the second sound ends before responding.

Trial Sequence

The experimenter will show you into the room where the experiment will take place. You should sit down and pick up the response box. You will be using this box to record your answers during the study.

1. When you first start a listening session, the display on the response box will ask if you are ready to begin. The left button on the display will indicate "Yes" and the right button will indicate "No." Press the "Yes" button when you are ready to begin.

2. Next, the display will indicate "Experiment in Progress" and "Listen now for noise [1]." You will then see the lefthand light and hear the first noise.

3. Then the display will indicate "Listen now for noise [2]" and you will see the right-hand light and hear the second noise.

4. Once the second noise has finished playing the screen will say "Which noise was more annoying?" and you will see on the display, "Interval 1" with an arrow pointing to the left button and "Interval 2" with an arrow pointing to the right button. Push the button corresponding to the noise that you think was more annoying. Once you have done that, the next pair of sounds will be presented.

5. ***Your judgments of annoyance for each pair of sounds should be based only on the current pair of sounds and not on any pair heard previously***. You will hear many pairs of sounds in an unpredictable order, so you must judge the relative annoyance of only the two sounds that you have just heard.

Each listening session will last about two hours, but there will be opportunities to take a five minute break every thirty minutes or so. Each listening session consists of four or more experiments. When an experiment has been completed, the display on the black box will say "You have finished Experiment [number]." An OK button will be displayed with this message. You should click the OK button to begin the next experiment.

On your first day, the experimenter will show you how the study works and will sit with you in the testing room while you hear some of the test sounds. The sound levels that you will hear during the listening session will never be louder than the sounds that you hear during this initial training session. Once the actual experiment begins, the experimenter will not be in the testing room with you, but will be able to see and hear you on a TV monitor.

Just talk at any time you have a question or want to contact the experimenter. If you feel uncomfortable at any time in the testing room and you do not wish to continue, just stop pressing the buttons on the black box and the sounds will stop. You may then leave the room, or tell the experimenter that you want to stop, and the experimenter will open the door of the testing room so that you can leave.

7 CONCLUSIONS

The major conclusions that may be drawn from this study include the following:

- Backblast noise is a readily measurable concentration of low-frequency noise created by individual aircraft departures in areas behind Runways 01L/R at SFO.

- The density of aircraft noise complaints in residential areas to the southwest of Runways 01L/R is greatest in two areas of Millbrae, Burlingame, and Hillsborough located roughly two miles from the start of takeoff roll.

- Although these two areas lie well outside of SFO's 65 dB CNEL contour, their locations are consistent with high noise levels associated with the directivity of jet engine exhaust noise.

- Meteorological conditions may be responsible for inducing considerable variability (at least ± 5 dB) in low-frequency aircraft departure noise level and duration in areas of Millbrae, Burlingame, and Hillsborough. Therefore, reliable prediction of times of day and seasons of the year when backblast noise is likely to be particularly high in level requires very detailed information about atmospheric conditions.

- C-weighted sound levels of individual aircraft departures measured in these two areas often exceed 80 dB, and can occasionally reach levels in the high 90 dB range, depending on aircraft type and other factors.

- Low-frequency sound levels corresponding to these C-weighted levels vary from about 70 to 90 dB in the one-third octave bands from 25 to 80 Hz.

- Instances of backblast noise associated with individual departures can be of unusually long duration with respect to typical aircraft overflight noise.

- When judged equally annoying, longer-duration, backblast-like sounds are lower in level than shorter-duration sounds by 3 dB per doubling of duration throughout the range of durations from 15-120 seconds. This finding confirms the need to keep in mind a 10 log (duration) correction in planning measures intended to mitigate the annoyance of backblast noise.

- The annoyance of backblast is heightened by its duration and potentially by the production of rattle in homes.

- When judged equally annoying, the maximum A-weighted sound levels of backblast noises lasting two minutes or more are 5 to 7 dB lower than those of typical aircraft overflights.