Exhibit K

Acoustics Report

January 16, 2025
45dB Project 24039

Project and Address:	**Architect:**	**Client to be Invoiced:**
Multi-Family Housing 1 Hot Springs Rd. Santa Barbara, CA 93108	**DesignARC** Attn: Jaeson Greer, AIA jgreer@designarc.net Attn: Melisa Cinarli Turner mcturner@designarc.net	1HSR GP, LLC Attn: Brian Holland bcraig.holland@gmail.com

Summary

45dB Acoustics ("**45dB**") has reviewed local regulatory requirements for the proposed multifamily housing project at the above address. The 24-hour CNEL level at/near the site has been measured and evaluated according to the City of Santa Barbara's Noise Element. Expected exterior noise levels at all elevations were determined using SoundPLAN® 3D noise-modeling software and calibrated with field tests of the existing noise environment for a more detailed exterior noise study of the project's elevations.

Acoustical 3D modeling calculates the exterior CNEL/L_{dn}[1] (Day-Night Level) to range from CNEL/L_{dn} 50 dBA at the south elevations up to CNEL/ L_{dn} 75 dBA at the north elevations closest to U.S. Highway 101.

Per the Noise Element, outdoor areas for residences should remain below 65 dBA whenever possible and residences in locations of exterior noise levels greater than CNEL of 60 dBA are to be designed such that interior habitable spaces do not exceed CNEL of 45 dBA. Based on our analysis, mitigation is required for habitable spaces on the north, east, and west elevations. Mitigation is to be provided by the noise barrier wall along the northern property boundary as drawn and modeled, along with mitigating walls and windows for all habitable rooms (i.e., kitchens, living, dining and bed rooms). Exterior wall assemblies of the north, east, and west elevations of the 2nd and 3rd floors of Units #14 – 22 (Buildings #4 – 7) must have the interior layer of drywall isolated from the framing with RSIC clips (minimum STC 63 / OITC 46) and all glazing assemblies must have a minimum STC 36 / OITC 29. All other ground floor habitable spaces, south-facing elevations, and Units #1-13 (Buildings #1 – 3) will not require additional mitigation; typical exterior wall assemblies and glazing may be used. This assumes no more than 15% of square footage for glazing/windows on all habitable room walls on west, north, and east elevations.

[1] L_{dn}, DNL, and CNEL typically agree within 1 dB and are considered approximately equivalent in this study.

Sound levels at the specified private outdoor living spaces for each unit must not exceed CNEL 65 dBA to comply with the Noise Element. Assuming all terrace guardrail walls and roof parapets are a minimum of 42-inches tall, all outdoor spaces do not require mitigation and will comply with the Noise Element.

All recommendations are dependent upon floor plans and exterior details. When detailed floorplans, finish floor level heights, and exterior wall and glazing dimensions are defined, **45dB** can re-analyze and provide more specific mitigation measures for the exteriors in order to meet Code.

Because windows must be closed in order to maintain the interior noise level below CNEL 45 dBA, mechanical ventilation must be provided to all habitable rooms. We assume that PTAC units will not be utilized in this project—PTAC units generally do not provide sufficient mitigation and, if they are included in exterior wall assemblies, higher STC specifications for all glazing and potentially walls would be needed. Vents and other openings in the exterior walls should face the south or run up to the roof, or else must have Z- or “dead” vents to minimize noise leakage into the buildings.

Future noise levels, assuming a 1% increase per year in traffic counts, may increase by as much as 1 dB and, as such, our recommendations are also compliant for a 20-year buildout to year 2044 for all residential units.

for 45dB Acoustics, LLC:

Sarah Taubitz, Mem.INCE, ASA

Erin L. Dugan, INCE Bd. Cert.

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1 Introduction

This report is intended to determine the potential noise impact associated with the proposed Project and to provide recommended mitigation if required. The following topics are presented in this report in response to the requirements for compliance with the California Noise Insulation Standards and the Noise Element of the City of Santa Barbara General Plan. The following factors are considered:

- The topographical relationship of noise source(s) and the dwelling/occupied site(s) to be developed
- Identification of noise sources and their sound level(s) at the exterior of the proposed dwellings, considering present and future land usage and terrain
- Basis for the sound level prediction (i.e., acoustically modeled from published data), and an analysis of the noise propagation considering the physical layout of the built environment
- Specification of level of noise insulation required and analysis of the noise insulation effectiveness showing that the prescribed interior noise level requirements are met
- Information on fundamentals of noise and vibration to aid in interpreting this report (located in the Appendix)

The proposed Project, a multi-family housing development, is to be located at 1 Hot Springs Road in Santa Barbara, California. The Project's location is shown in Figure 1 and the site plan, provided by the Client, is shown in Figure 2. The development will consist of 2- and 3-story townhomes with terraces and rooftop decks throughout. 2^{nd} and 3^{rd} floor plans are shown in Figure 3 and Figure 4. A 6-ft tall solid masonry wall (relative to existing grade) is planned along the north boundary of the project site to shield noise from US Highway 101.

2 Regulatory Setting

Noise regulations are addressed by Federal, State, and local government agencies, as discussed below. In general, local policies are adaptations of Federal and State guidelines, adjusted to prevailing local conditions.

2.1 Federal Regulation

The adverse impact of noise was officially recognized by the federal government in the Noise Control Act of 1972, which serves three purposes:

a) Promulgating noise emission standards for interstate commerce.
b) Assisting state and local abatement efforts.
c) Promoting noise education and research.

The Department of Transportation (DOT) assumed a significant role in noise control. The Federal Aviation Administration (FAA) regulates noise of aircraft and airports. Surface transportation system noise is regulated by the Federal Transit Administration (FTA). Freeways that are part of the interstate highway system are regulated by the Federal Highway

Administration (FHWA). The Federal Railway Administration (FRA) regulates train traffic and subsequently train noise.

For this Project, the nearest airport (Santa Barbara Airport) is approximately 10 miles to the west and does not contribute to the noise levels above those already established by the local road and rail noise. The nearest railroad line is directly north of the Project and is included as a noise source in this analysis.

2.2 State Regulation

Title 24, Part 2, Section 1206 of the California Building Code (California Noise Insulation Standards)[2] requires noise insulation inside new apartment homes to provide an annual average noise level of no more than 45 dBA CNEL/DNL due to exterior sources. When such structures are located within a 60 dBA CNEL/DNL (or greater) noise contour, an acoustical analysis is required to ensure that interior levels do not exceed the 45 dBA CNEL/DNL annual threshold.

2.3 Local Regulation

California State Code Section 65302[3] mandates that the legislative body of each county and city in California adopt a noise element as part of its comprehensive general plan. The local noise element must recognize the land use compatibility guidelines published by the State Department of Health Services. The guidelines rank noise land use compatibility in terms of normally acceptable, conditionally acceptable, normally unacceptable, and clearly unacceptable.

The Noise Element within the Environmental Resources Element of the City of Santa Barbara General Plan[4] provides the conclusions, recommendations, and strategies necessary to ensure an appropriately quiet and pleasurable interior environment for the residents of the proposed project. Since the regulation of transportation noise sources such as roadway and aircraft primarily fall under either State or Federal jurisdiction, the local jurisdiction generally uses land use and planning decisions to limit locations or volumes of such transportation noise sources, to avoid development within noise impact zones, or to shield impacted receivers or sensitive receptors.

An outdoor L_{dn} level between 60 and 75 dBA is "Normally Unacceptable" for new multi-family residence developments without a detailed analysis (Figure 5).

3 Noise Propagation Model

We have utilized SoundPLAN® to create a 3D noise model of the site and project. SoundPLAN has implemented the FHWA's Traffic Noise Model 3.0 (TNM) for road traffic noise modeling, and ISO 9613-13 for other noise sources. See the Appendix for more information on this software and calculation methods. Traffic counts for nearby roads and railway noise levels are

[2] California Building Code, Title 24, Part 2, Section 1206 Sound Transmission, 2022. https://codes.iccsafe.org/content/CABC2022P2/chapter-12-interior-environment#CABC2022P2_Ch12_Sec1206

[3] California State Code, Title 7, Division 1, Chapter 3, Article 5. *Authority for and Scope of General Plans.* https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=GOV&sectionNum=65302

[4] The City of Santa Barbara General Plan, Environmental Resources Element, *Noise Element*. https://santabarbaraca.gov/government/priorities-policies/general-plan/general-plan-elements-appendices

input to the model to establish an ambient existing noise environment and compared to measured existing sound levels. All sound levels in this report are presented as CNEL (Community Noise Equivalent Level) values in units of A-weighted decibels, dBA.

3.1 Traffic Noise

The noise propagation software SoundPLAN® utilizes traffic counts from Caltrans[5] and the City's Traffic Data database[6] (see Table 1) to model/predict the noise levels from roads. These values are utilized to formulate traffic counts for the streets surrounding the project. A conservatively high, 1% per year, increase in AADT is utilized to determine the 2024 traffic counts.

Table 1: Traffic Count Data and 2024 Projections

Road	Speed Limit (mph)	Published AADT	Year	Years to Project	2024 AADT Projection with 1% Annual Growth	% Heavy Trucks
US Highway 101 – N of Hwy 225	60	90,000	2022	2	91,809	1.9%
US Highway 101 – S of Hwy 225	60	76,000	2022	2	77,528	1.9%
Cabrillo Blvd (Hwy 225) – W of Channel Dr	35	6565	2019	5	6900	

Buses were also included on Cabrillo Blvd as part of the traffic mix, based on the published schedules for MTD[7] routes 14 and 20, which included a total of 60 buses between the hours of 7am and 7pm, six (6) buses between 7pm and 10pm, and nine (9) buses between 10pm and 7am.

3.2 Railway Noise

Passenger trains primarily use the railroad tracks to the north of the property. Based on the Amtrak Coast Starlight[8] and Pacific Surfliner[9] schedules as well as our knowledge of this area, we estimated that 10 passenger trains and 2 freight trains pass by during daytime hours and 1 passenger train passes by during evening and nighttime hours. No railroad grade crossings are nearby and warning horns are not expected to be audible at the site.

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[5] Caltrans Traffic Census Database. https://dot.ca.gov/programs/traffic-operations/census
[6] City of Santa Barbara, Traffic Engineering. (Accessed June 2024) https://santabarbaraca.gov/government/departments/public-works/streets-operations-infrastructure-management/traffic
[7] Santa Barbara MTD. https://sbmtd.gov/
[8] https://www.amtrak.com/coast-starlight-train
[9] https://www.amtrak.com/pacific-surfliner-train

4 Existing Ambient Sound Levels

4.1 Measured Existing Sound Levels

Twenty-four-hour A-weighted sound levels (CNEL, Leq, Lmax, Lmin, etc.) were measured by **45dB** on May 26-28, 2024, at the project site to establish existing ambient sound levels. An ANSI Type/Class 2 calibrated sound level meter and a Type 1 field calibrator were utilized. Calculation of the CNEL, $L_{eq,d}$ (daytime hourly), $L_{eq,e}$ (evening hourly), and $L_{eq,n}$ (nighttime hourly) sound levels are based on 1-sec Leq measurement data. Figure 6 shows the location (S1) where the 24-hour measurement was taken.

The time series of the measured 24-hour sound levels for the measurement location is shown in Figure 7. The existing ambient level at this location was CNEL 66 dBA.

Weather in Santa Barbara[10] on May 26-28, 2024, (Figure 8) was clear without precipitation, with temperatures ranging from 59 to 77 degrees Fahrenheit. Wind speeds were calm, ranging up to 12 mph.

4.2 Modeled Existing Sound Levels

Terrain/elevation data is imported from Google Maps and traffic and railway data are input into the SoundPLAN model. The resulting existing CNEL noise contours are shown in Figure 9 in plan view at typical ground receiver height (5 feet above grade) around the project site. The receiver point for the measurement location, S1, is also shown. The measured and modeled sound levels at location F1 agreed well (see Table 2).

Table 2: Comparison of Measured and Modeled Sound Levels at Location F1

Sound Level	CNEL (dBA)	Leq,d (dBA)	Leq,e (dBA)	Leq,n (dBA)
Measured	66.1	63.5	62.9	57.7
Modeled	65.8	64.0	60.7	57.4

[10] Weather Underground, Santa Barbara Municipal Airport Weather History, Weather Station KSBA, May 26 - 28, 2024. https://www.wunderground.com/history/daily/us/ca/goleta/KSBA/date/2024-8-26

5 Modeled Exterior Noise Levels with Project

A 3D view of the acoustic model's geometry with the project in place (represented by the buildings with orange roofs) is shown in Figure 10.

Figure 11 shows the resulting typical CNEL noise contours, in plan view, at typical ground receiver height (5-ft) around the project. Receiver points help to show the expected sound levels at the exterior locations around the proposed project, as indicated in the figure.

The expected exterior levels at selected residential units at the ground floor are provided below in Table 3. The north elevations of the units closest to Highway 101, facing the railroad tracks, are expected to reach up to CNEL 69 dBA at the ground floor level. Levels at the exteriors of the 2nd and 3rd floors, which do not benefit from the 6-ft-high min. wall along the property line (above existing grade), are expected to have exterior noise levels up to 75 dBA.

Table 3: Selected Exterior Receiver Point Levels

Building	Unit Number	Direction/ Elevation	1st Floor CNEL dB(A)
1	1	N	60
2	9	W	63
3	11	NW	67
4	12	NW	69
5	15	N	68
6	17	N	68
7	22	N	68

6 Project Compliance Evaluation and Recommended Mitigation

6.1 Residential Habitable Spaces

The State Building Code requires that residential habitable spaces, specifically where the exterior CNEL/DNL is 65 dBA or higher, be designed so that the interior noise level attributable to exterior sources does not exceed 45 dBA CNEL/DNL when doors and windows are closed.

The worst-case exterior noise level for the residential units on this project, CNEL 75 dBA at the north elevations closest to the highway, falls into the Normally Unacceptable range for Residential Multi-Family projects within the City's Land Use Compatibility Guidelines (see Figure 5), thereby requiring a detailed analysis.

6.1.1 Interior Levels

Using the exterior noise level CNEL 75 dBA for units at the north elevations exposed to noise from Highway 101 and the railway, we can calculate the frequency band-specific Outdoor-to-Indoor Transmission Class (OITC) of the exterior wall and glazing. Since STC values apply to interior partitions, and the STC and OITC only weakly correlate with one another, the OITC value is the more appropriate specification for walls (and glazing) and is used to evaluate the resulting interior noise level of any exterior wall assembly. Both values (STC and OITC) are stated within this report for all recommended glazing and wall assemblies.

With typical wall assemblies and windows (assumed to be typical glazing having a minimum STC 28 / OITC 26), this project is **not** expected to comply with the California Noise Insulation Standards requirement of 45 dBA CNEL or less for habitable spaces. Recommended mitigation measures that may bring the project into compliance are described in the following section.

6.1.2 Recommended Mitigation

All north, east, and west-facing elevations of buildings 3 - 7 will require mitigation in order to maintain the interior noise levels of no more than CNEL 45 dBA.

Exterior wall assemblies of the north, east, and west elevations of the 2nd and 3rd floors of Units # 14-22 (Buildings # 4 – 7) must have the interior layer of drywall isolated from the framing with RSIC clips (minimum STC 63 / OITC 46) and glazing must have a minimum STC 36 / OITC 29. See Figure 12 for a typical compliant wall assembly.

Recommendations are based on floor plans provided and assume glazing does not comprise more than 15% of the exterior wall area. Once floorplans, finish floor level heights, and exterior wall and glazing dimensions are defined, **45dB** can analyze and provide more specific mitigation measures for the exteriors in order to meet Code.

All other ground floor habitable spaces, south-facing elevations, and Units #1-13 (Buildings #1 – 3) will not require additional mitigation; typical exterior wall assemblies and glazing may be used.

The mitigations specified are preliminary and subject to final designs; room/wall/glazing dimensions and wall design are all factors which affect the mitigation solution set provided. The above recommendations for the north and east elevations include a 5-point margin on STC for as-built construction that we recommend in order to account for the expected reduction in real-life performance typically seen in as-built construction.

All recommendations assume acoustically-rated window assemblies tested in an accredited laboratory.

Because interior allowable noise levels are met by requiring that windows be closed, the design for the structure must also specify the means that will be employed for ventilation to provide a habitable interior environment. Air-conditioning or air-handling units in these residences must be provided such that the interior noise level requirement can be met—i.e., the residences must not rely on natural ventilation through the windows. **We assume that PTAC units will not be utilized in this project—PTAC units generally do not provide sufficient mitigation and, if they are included in exterior wall assemblies, <u>higher</u> STC specifications for all glazing and potentially walls would be needed.**

6.2 Outdoor Activity Areas

As shown in the floor plans, some units have more than one outdoor activity area such as a rooftop deck or terrace, however each unit has one dedicated private outdoor living space (P.O.L.S.) on the 1st or 2nd floor, shown highlighted in green in Figure 2 or Figure 3, that must comply with the Noise Element requirement of CNEL 65 dBA or less for outdoor spaces. Levels at all specified outdoor living spaces are well-shielded from highway noise and will comply, assuming all terrace guardrail walls and parapets are a minimum of 42" tall. All guardrails/parapet walls must be of solid construction to maintain efficacy as noise barriers and comply with the Noise Element.

6.2.1 Eastern Corner Area (Option)

The Client is considering an additional outdoor activity area at the eastern corner of the property. Although the current schematic architectural plans do not show this, the Architect has provided a landscape design concept--Figure 13 shows the area highlighted in green, with a proposed noise barrier wall in red. Exterior noise levels in this area are CNEL 70-72 dBA. A solidly constructed noise barrier wall (again, without gaps) of 8 feet minimum will provide approximately 6-8 dB of mitigation for the green area, and as such would be sufficient mitigation for the proposed outdoor activity area.

6.3 Future Noise Levels with Project

The future CNEL/DNL sound pressure level (year 2044) across the site in all the previous scenarios may increase approximately 1 dB above existing sound levels modeled here, assuming that continued future combustion-engine traffic growth of approximately one percent per year for these roads shall continue. All residential units are expected to comply with a 20-year buildout.

7 Conclusions and Recommendations

Per the Noise Element, outdoor areas for residences should remain below 65 dBA whenever possible and residences in locations of exterior noise levels greater than CNEL of 60 dBA are to be designed such that interior habitable spaces do not exceed CNEL of 45 dBA. Based on our analysis, mitigation is required for habitable spaces on the north, east, and west elevations.

Exterior wall assemblies of the north, east, and west elevations of the 2nd and 3rd floors of Units #14 – 22 (Buildings #4 – 7) must have the interior layer of drywall isolated from the framing with RSIC clips (minimum STC 63 / OITC 46) and glazing must have a minimum STC 36 / OITC 29. All other ground floor habitable spaces, south-facing elevations, and Units #1-13 (Buildings #1 – 3) will not require additional mitigation; typical exterior wall assemblies and glazing may be used.

Sound levels at the specified private outdoor living spaces for each unit must not exceed CNEL 65 dBA to comply with the Noise Element. Assuming all terrace guardrail walls and roof parapets are a minimum of 42-inches tall, all outdoor spaces do not require mitigation and will comply with the Noise Element.

All recommendations are dependent upon floor plans and exterior details. When floorplans, finish floor level heights, and exterior wall and glazing dimensions are defined, **45dB** can analyze and provide more specific mitigation measures for the exteriors in order to meet Code. We assume that PTAC units will not be utilized in this project—PTAC units generally do not provide sufficient mitigation and, if they are included in exterior wall assemblies, higher STC specifications for all glazing and potentially walls would be needed.

The conclusions and recommendations of this acoustical analysis are based upon the information known to 45dB Acoustics, LLC ("**45dB**") at the time the analysis was prepared concerning the proposed site plans, traffic volumes, and public transit schedules. Any significant changes to these factors will require a reevaluation of the findings of this report. Additionally, any significant future changes in site plan, noise regulations, or other factors beyond **45dB**'s control may result in long-term noise results that differ from those described by this analysis.

8 Figures

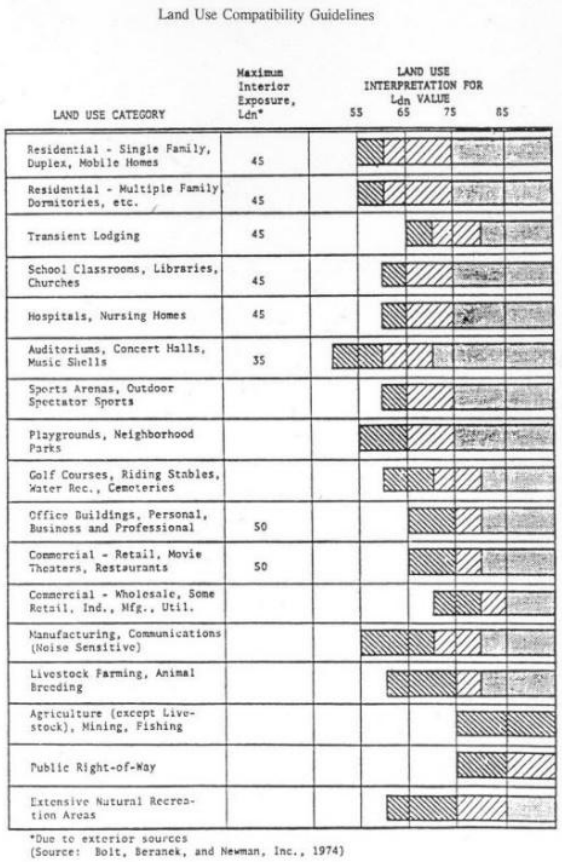
Figure 1: Site View

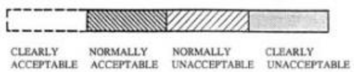
Figure 2: Project Site Plan, 1st Floor Plan (reprinted from client drawings)

Figure 3: 2nd Floor Plan (reprinted from client drawings)

Figure 4: 3rd Floor Plan (reprinted from client drawings)

Figure 5: City of Santa Barbara Land Use Compatibility for Community Noise





CLEARLY ACCEPTABLE The noise exposure is such that the activities associated with the land use may be carried out with essentially no interference. (Residential areas: both indoor and outdoor noise environments are pleasant.)

NORMALLY ACCEPTABLE The noise exposure is great enough to be of some concern, but common constructions will make the indoor environment acceptable, even for sleeping quarters. (Residential areas: the outdoor environment will be reasonably pleasant for recreation and play at the quiet end and will be tolerable at the noisy end.)

NORMALLY UNACCEPTABLE The noise exposure is significantly more severe so that unusual and costly building constructions are necessary to ensure adequate performance of activities. (Residential areas: barriers must be erected between the site and prominent noise sources to make the outdoor environment tolerable.)

CLEARLY UNACCEPTABLE The noise exposure at the site is so severe that construction costs to make the indoor environment acceptable for performance of activities would be prohibitive. (Residential areas: the outdoor environment would be intolerable for normal residential use.)

SUMMARY LAND USE
COMPATIBILITY STANDARDS

Land Use Category	Normally Acceptable Exterior Noise Exposure, L_{dn} dBA[1]
Residential-Single Family, Duplex, Mobile Homes, Multiple Family, Dormitories, etc.	60
Transient Lodging	70
School Classrooms, Libraries, Churches	65
Hospitals, Nursing Homes	65
Auditoriums, Concert Halls, Music Shells	60
Sports Arenas, Outdoor Spectator Sports	65
Playgrounds, Neighborhood Parks	65
Golf Courses, Riding Stables, Water Recreation, Cemeteries	70
Office Buildings, Personal, Business, and Professional	75
Commercial-Retail, Movie Theaters, Restaurants	75
Commercial-Wholesale, Some Retail Industry, Manufacturing, Utilities	80
Manufacturing-Communications (Noise sensitive)	70
Livestock Farming, Animal Breeding	75
Agriculture (except Livestock), Mining, Fishing	95
Public Right-of-Way	85
Extensive Natural Recreation Areas	75

[1] These noise exposure levels represent the upper limit of the range of "normally acceptable" noise levels. "Normally acceptable" is defined as being an exposure that is great enough to be of some concern, but common building constructions will make the indoor environment acceptable, even for sleeping quarters. Above these levels, unusual and costly building constructions are necessary to ensure adequate performance of activities.

Figure 6: Existing Ambient Sound Level Measurement Location

Figure 7: 24-Hour Measured Sound Levels at Project Site on May 26-28, 2024

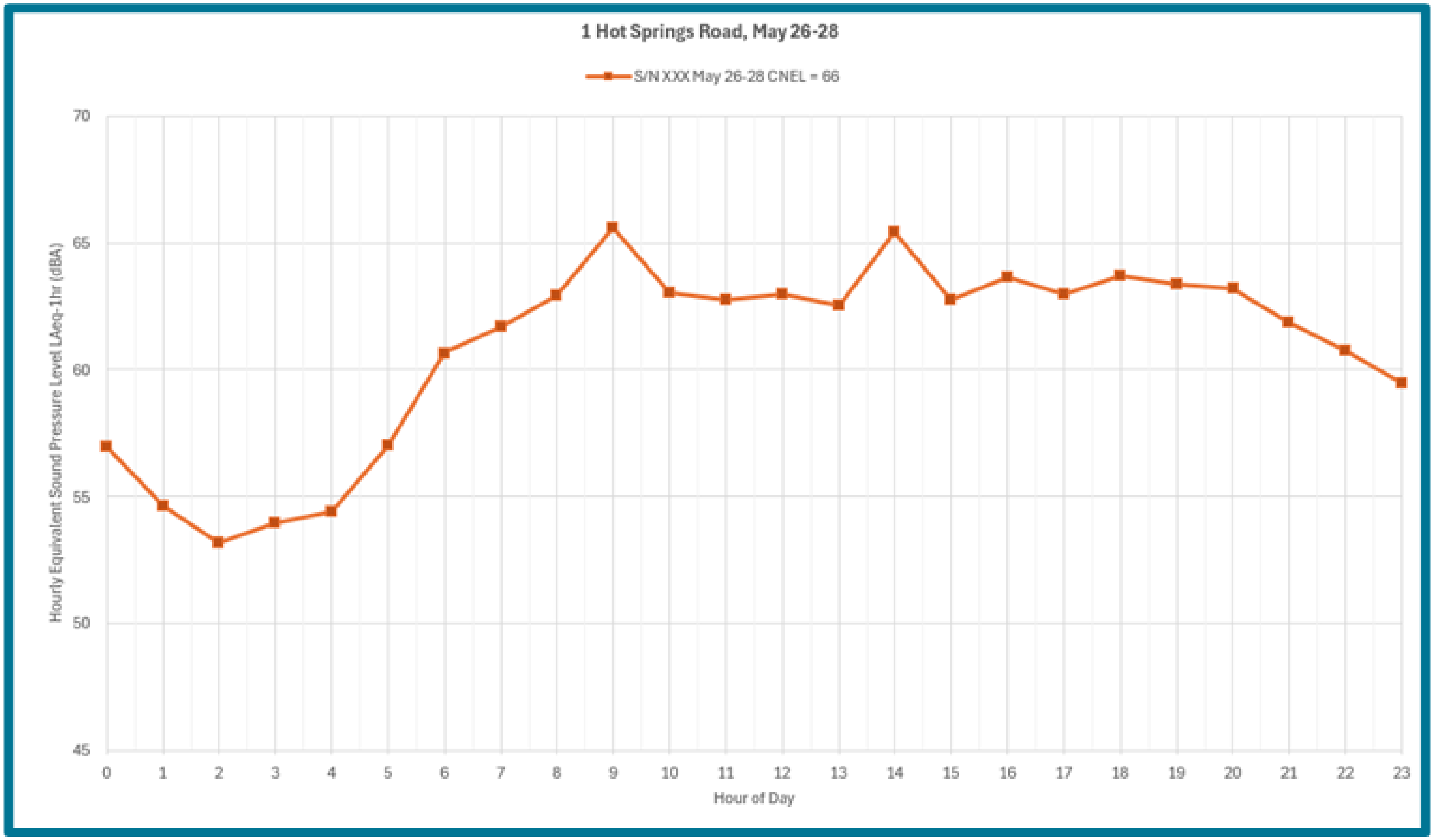


Figure 8: Weather Data at Bakersfield Weather Station KCABAKER214, Dec 28-29, 2023

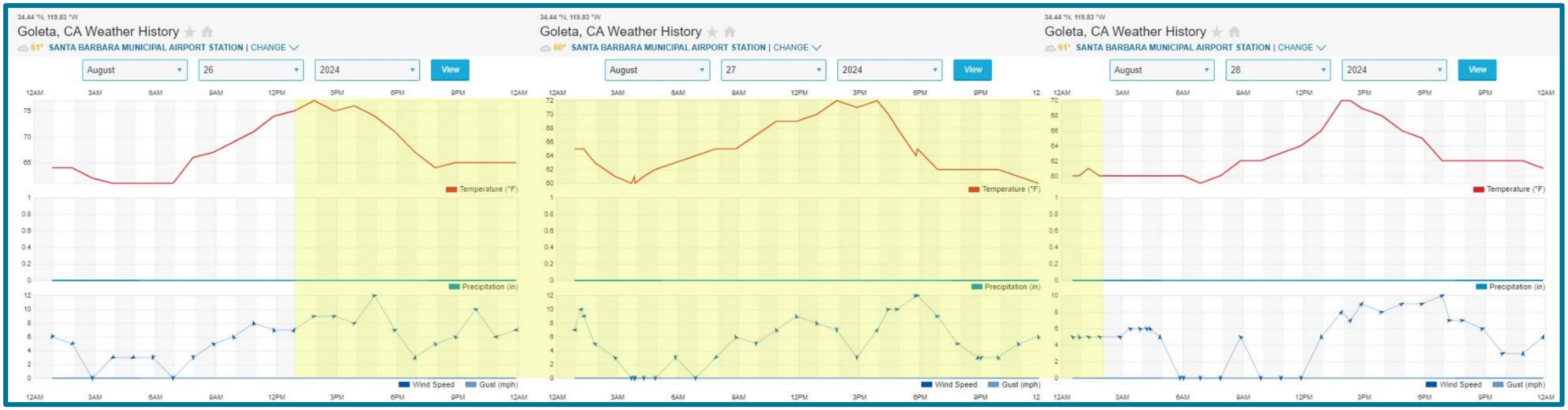


Figure 9: Existing Ambient 24-Hour (CNEL) Sound Level Contours, Plan View

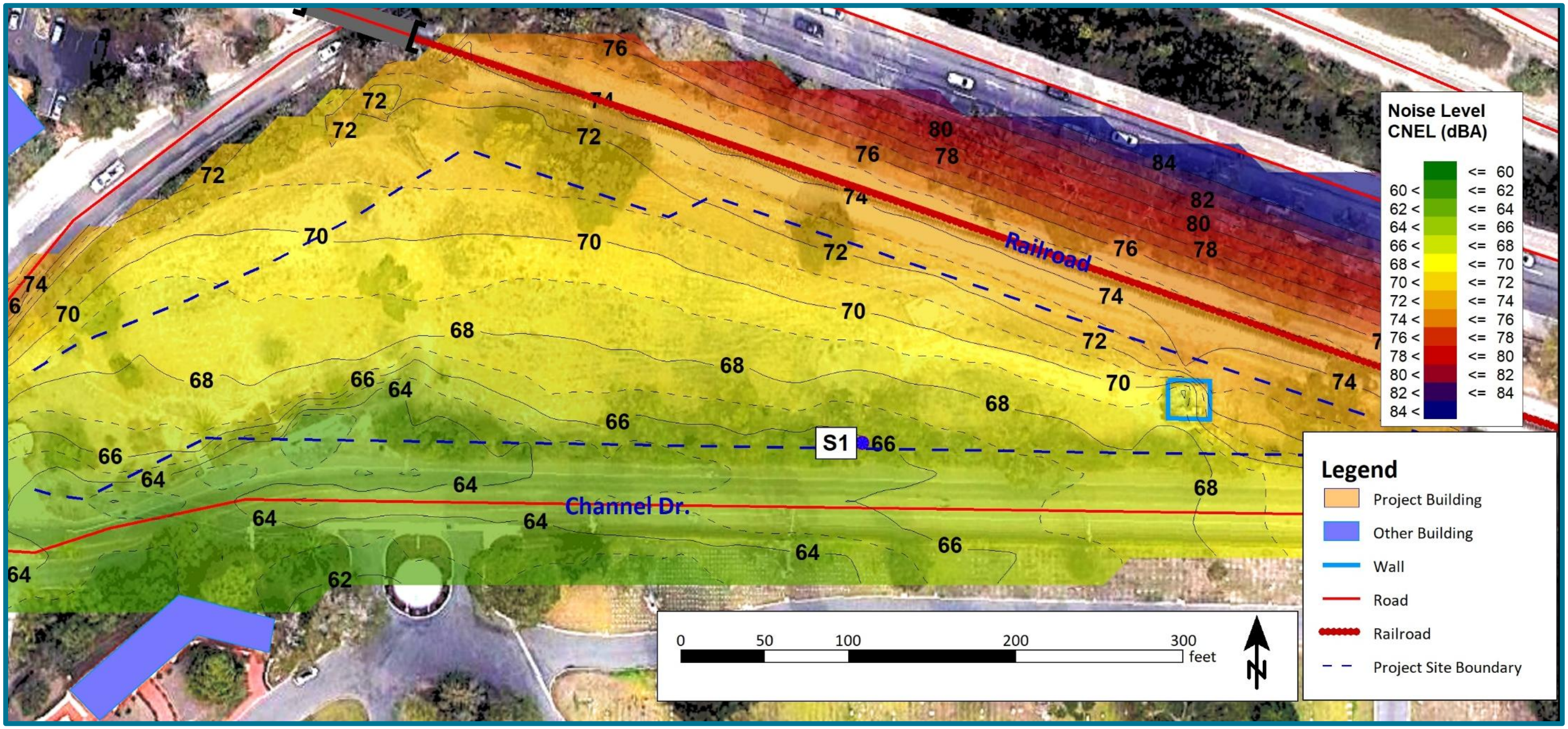


Figure 10: 3D Perspective of Acoustic Model Geometry with Project in Place

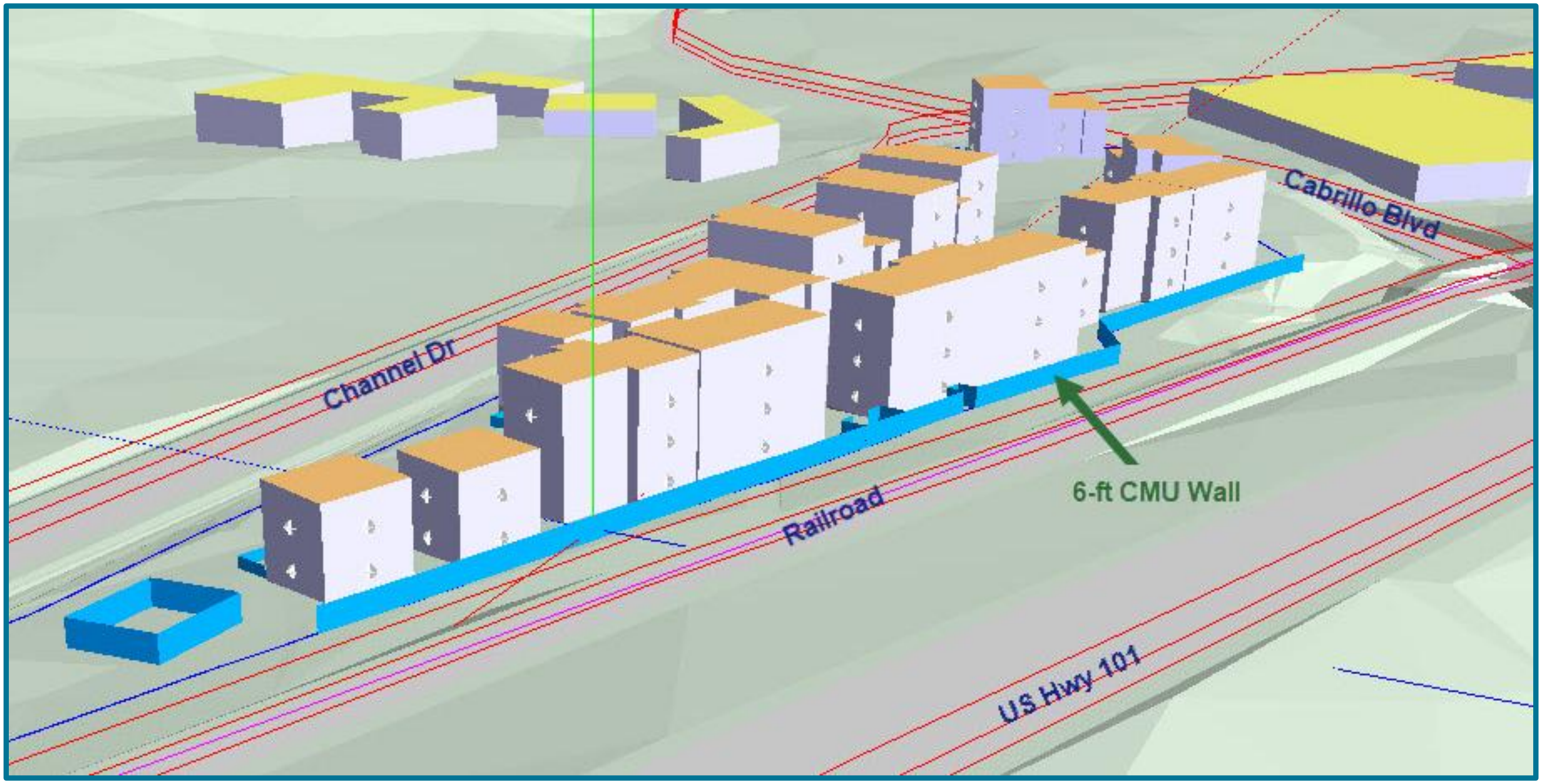


Figure 11: 24-Hour (CNEL) Sound Level Contours with Project, Plan View

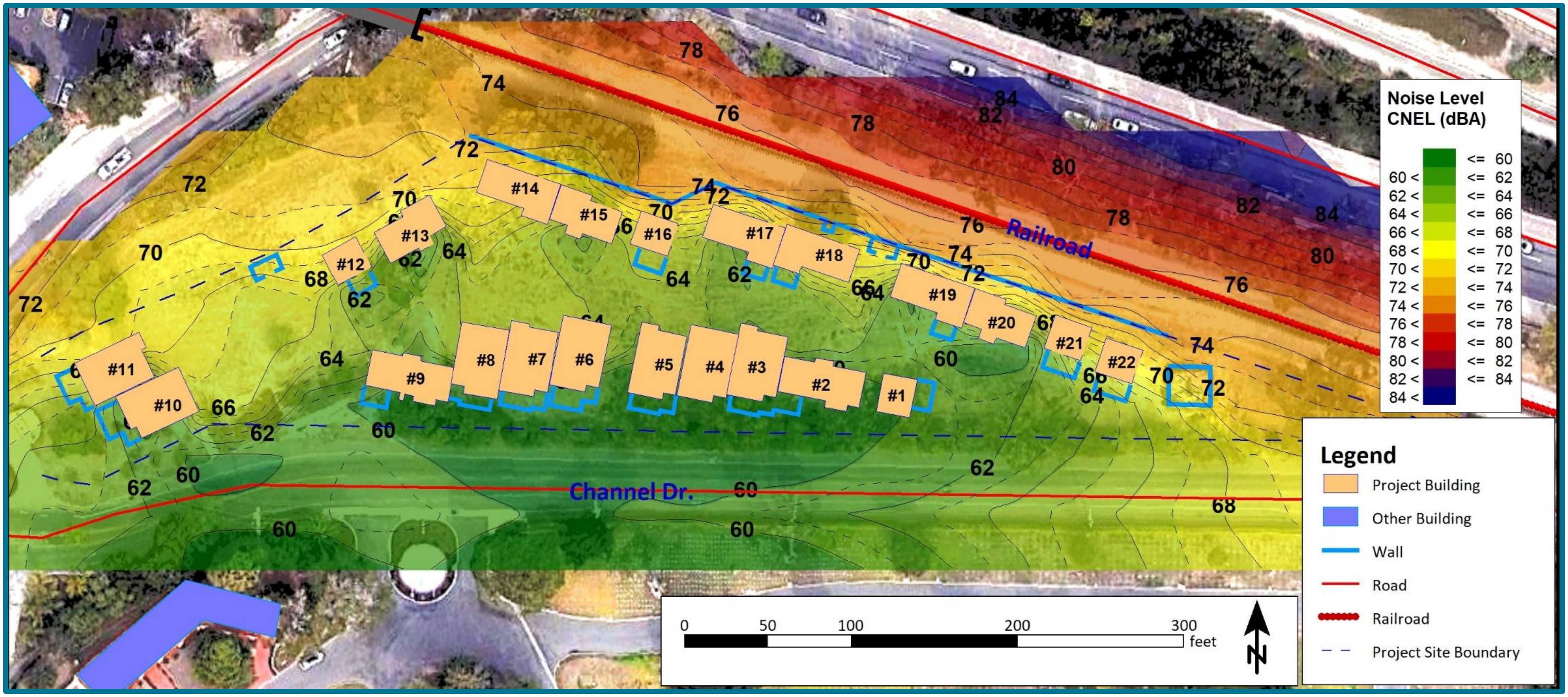
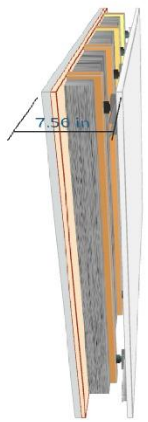


Figure 12: Transmission Loss Characteristics for Recommended Wall Design

Sound Insulation Prediction (v9.0.24)

Program copyright Marshall Day Acoustics 2017
Margin of error is generally within STC ±3 dB
45dB Acoustics LLC - Key No. 4856
Job Name:1 Hot Springs Rd
Job No.: 24039 Initials:eld
Date:8/29/2024
File Name:Typ Ext Wall - STC44-OITC37.ixl

Notes:



STC 63
OITC 46

Mass-air-mass resonant frequency = =47 Hz

Panel Size = 8.9 ft x 13.1 ft

Partition surface mass = 11.9 lb/ft2

System description

Panel 1 : 1 x 0.866 in Stucco + 1 x 0.5 in Plywood

Frame: Rubber isolation clip on Timber stud (3.7 in x 1.8 in), Stud spacing 16 in ; Cavity Width 5.57 in , 1 x fiberglass (0.6 lb/ft3) Thickness 3.0 in
Panel 2 : 1 x 0.626 in Type X Gypsum Board

freq.(Hz)	TL(dB)	TL(dB)
50	17	
63	22	20
80	29	
100	35	
125	41	39
160	46	
200	50	
250	54	53
315	57	
400	60	
500	63	62
630	65	
800	66	
1000	67	67
1250	66	
1600	64	
2000	68	65
2500	64	
3150	67	
4000	72	70
5000	76	

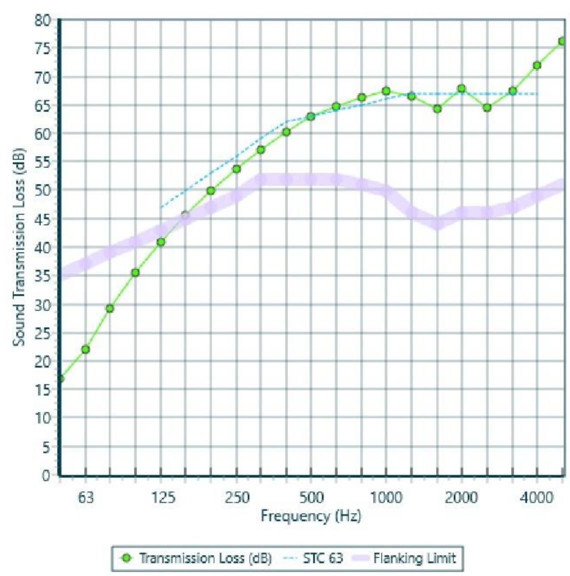
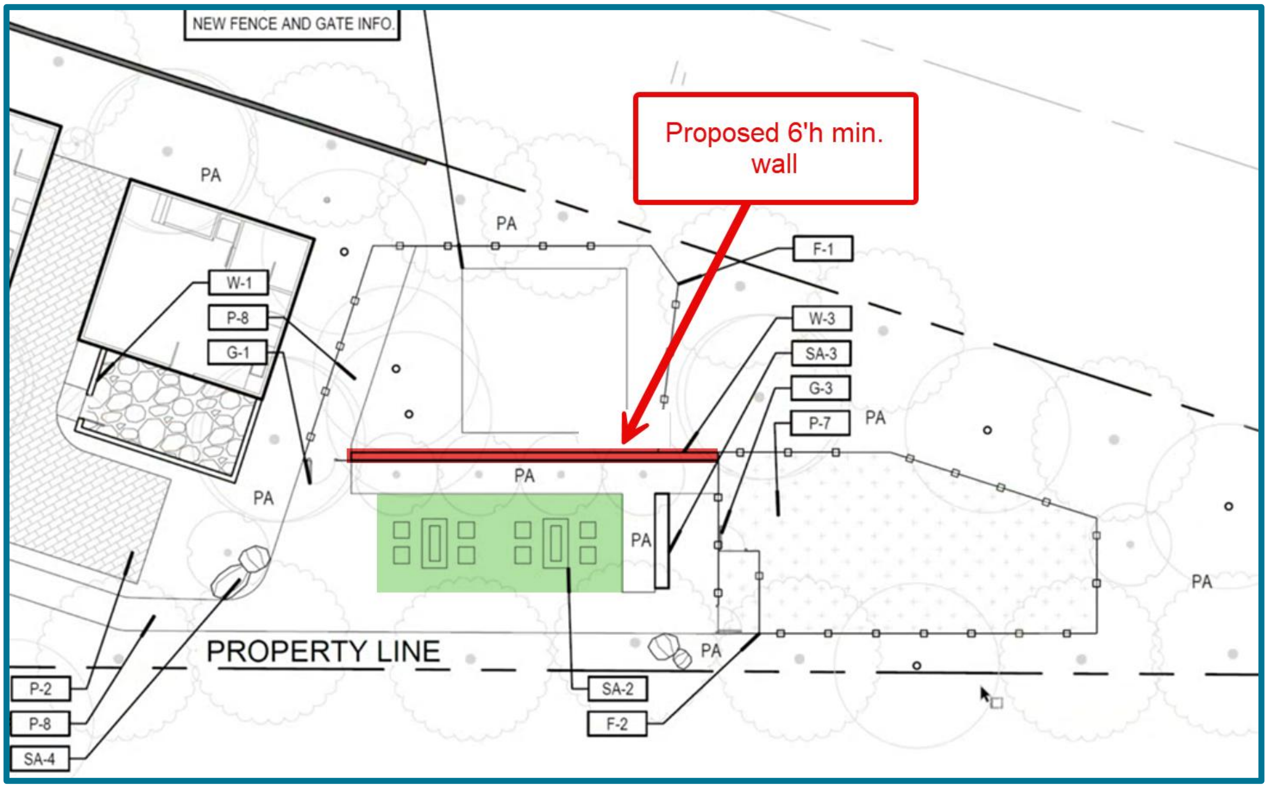


Figure 13: Landscape sketch of eastern outdoor area (green) with proposed noise barrier wall (red)



9 Appendix

9.1 Characteristics of Sound

When an object vibrates, it radiates part of its energy as acoustical pressure in the form of a sound wave. Sound can be described in terms of amplitude (loudness), frequency (pitch), or duration (time). The human hearing system is not equally sensitive to sound at all frequencies. Therefore, to approximate this human, frequency-dependent response, the A-weighted filter system is used to adjust measured sound levels. The normal range of human hearing extends from approximately 0 to 140 dBA. Unlike linear units such as inches or pounds, decibels are measured on a logarithmic scale, representing points on a sharply rising curve. Because of the physical characteristics of noise transmission and of noise perception, the relative loudness of sound does not closely match the actual amounts of sound energy. Table 4 below presents the subjective effect of changes in sound pressure levels.

Table 4: Sound Level Change Relative Loudness/Acoustic Energy Loss[11]

Change in Level	Relative Loudness	Acoustic Energy Loss
0 dB	Reference	0%
- 3 dB	Just Perceptible Change	50%
- 5 dB	Readily Perceptible Change	67%
- 10 dB	Half as Loud	90%
- 20 dB	¼ as Loud	99%
- 30 dB	1/8 as Loud	99.9%

Sound levels are generated from a source and their decibel level decreases as the distance from that source increases. Sound dissipates exponentially with distance from the noise source. This phenomenon is known as spreading loss. Generally, sound levels from a point source will decrease by 6 dBA for each doubling of distance. Sound levels for a highway line source vary differently with distance because sound pressure waves propagate along the line and overlap at the point of measurement. A closely spaced, continuous line of vehicles along a roadway becomes a line source and produces a 3 dBA decrease in sound level for each doubling of distance. However, experimental evidence has shown that where sound from a highway propagates close to “soft” ground (e.g., plowed farmland, grass, crops, etc.), a more suitable drop-off rate to use is not 3.0 dBA but rather 4.5 dBA per distance doubling (FHWA 2010).

When sound is measured for distinct time intervals, the statistical distribution of the overall sound level during that period can be obtained. The L_{eq} is the most common parameter associated with such measurements. The L_{eq} metric is a single-number noise descriptor that represents the average sound level over a given period of time. For example, the L50 noise level is the level that is exceeded 50 percent of the time. This level is also the level that is exceeded 30 minutes in an hour. Similarly, the L02, L08 and L25 values are the noise levels that are exceeded 2, 8, and

[11] Highway Traffic Noise Analysis and Abatement Policy and Guidance, U.S. Department of Transportation, Federal Highway Administration, Office of Environment and Planning, Noise and Air Quality Branch, June 1995.

25 percent of the time or 1, 5, and 15 minutes per hour. Other values typically noted during a noise survey are the L_{min} and L_{max}. These values represent the minimum and maximum root-mean-square noise levels obtained over the measurement period.

Because community receptors are more sensitive to unwanted noise intrusion during the evening and at night, State law requires that, for planning purposes, an artificial dB increment be added to quiet-time noise levels in a 24-hour noise descriptor called the CNEL or L_{dn}. This increment is incorporated in the calculation of CNEL or L_{dn}, described earlier.

9.2 Terminology/Glossary

A-Weighted Sound Level (dBA)
The sound pressure level in decibels as measured on a sound level meter using the internationally standardized A-weighting filter or as computed from sound spectral data to which A-weighting adjustments have been made. A-weighting de-emphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

Air-borne Sound
Sound that travels through the air, differentiated from structure-borne sound.

Ambient Sound Level
The prevailing general sound level existing at a location or in a space, which usually consists of a composite of sounds from many sources near and far. The ambient level is typically defined by the L_{eq} level.

Background Sound Level
The underlying, ever-present lower-level noise that remains in the absence of intrusive or intermittent sounds. Distant sources, such as Traffic, typically make up the background. The background level is generally defined by the L90 percentile noise level.

Community Noise Equivalent Level (CNEL)
The L_{eq} of the A-weighted noise level over a 24-hour period with a 5-dB penalty applied to noise levels between 7 p.m. and 10 p.m. and a 10-dB penalty applied to noise levels between 10 p.m. and 7 a.m. CNEL is similar to L_{dn}.

Day-Night Sound Level (DNL or L_{dn})
The L_{eq} of the A-weighted noise level over a 24-hour period with a 10-dB penalty applied to noise levels between 10 p.m. and 7 a.m. L_{dn} is similar to CNEL.

Decibel (dB)
The decibel is a measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power, sound intensity) with respect to a reference quantity.

DBA or dB(A)
A-weighted sound level. The ear does not respond equally to all frequencies, and is less sensitive at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound level of a noise containing a wide range of frequencies in a manner representative of the ear's response, it is necessary to reduce the effects of the low and high frequencies with respect to the medium frequencies. The resultant sound level is said to be A-weighted, and the units are dBA. The A-weighted sound level is also called the noise level.

Energy Equivalent Level (L_{eq})
Because sound levels can vary markedly in intensity over a short period of time, some method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, one describes ambient sounds in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This energy-equivalent sound/noise descriptor is called L_{eq} . In this report, an hourly period is used.

Field Sound Transmission Class (FSTC)
A single number rating similar to STC, except that the transmission loss values used to derive the FSTC are measured in the field. All sound transmitted from the source room to the receiving room is assumed to be through the separating wall or floor-ceiling assembly.

Noise Reduction (NR)
Noise reduction is the difference between outdoor sound level and indoor sound level. It is not identical to Sound Transmission Class.

Outdoor-Indoor Transmission Class (OITC)
A single number classification, specified by the American Society for Testing and Materials (ASTM E 1332 issued 1994), that establishes the A-weighted sound level reduction provided by building façade components (walls, doors, windows, and combinations thereof), based upon a reference sound spectrum that is an average of typical air, road, and rail transportation sources. The OITC is the preferred rating when exterior façade components are exposed to a noise environment dominated by transportation sources. Once built, as much as a 5-point reduction in Apparent Outside-Inside Transmission Class (OITC) from the original, as-designed OITC may be expected.

Percentile Sound Level, Ln
The noise level exceeded during *n* percent of the measurement period, where *n* is a number between 0 and 100 (e.g., L10 or L90)

Sound Transmission Class (STC)
STC is a single number rating, specified by the American Society for Testing and Materials, which can be used to measure the sound insulation properties for comparing the sound transmission capability, in decibels, of interior building partitions for noise sources such as speech, radio, and television. It is used extensively for rating sound insulation characteristics of building materials and products.

Structure-Borne Sound
Sound propagating through building structure. Rapidly fluctuating elastic waves in gypsum board, joists, studs, etc.

Sound Exposure Level (SEL)
SEL is the sound exposure level, defined as a single number rating indicating the total energy of a discrete noise-generating event (e.g., an aircraft flyover) compressed into a 1-second time duration. This level is handy as a consistent rating method that may be combined with other SEL and L_{eq} readings to provide a complete noise scenario for measurements and predictions. However, care must be taken in the use of these values since they may be misleading because their numeric value is higher than any sound level which existed during the measurement period.

Subjective Loudness Level
In addition to precision measurement of sound level changes, there is a subjective characteristic which describes how most people respond to sound:

- A change in sound level of 3 dBA is *barely perceptible* by most listeners.
- A change in level of 6 dBA is *clearly perceptible*.
- A change of 10 dBA is perceived by most people as being *twice* (or *half*) as loud.

9.3 SoundPLAN® Acoustics Software

SoundPLAN®, the software used for this acoustic analysis, is an acoustic ray-tracing program dedicated to the prediction of noise in the environment. Noise emitted by various sources propagates and disperses over a given terrain in accordance with the laws of physics. The software calculates sound attenuation of environmental noise, even over complex terrain, uneven ground conditions, and with complex obstacles. Up to three reflections for each noise source are taken into account to closely and accurately predict real-world acoustics. Worldwide, governments and engineering associations have created algorithms to calculate acoustical phenomena to standardize the assessment of physical scenarios. Accuracy has been validated in published studies to be + / - 2.7 dBA with an 85% confidence level, for a wide variety of large-scale models and situations.

9.4 ISO 9613-2

For industrial and other noise sources besides road traffic, SoundPLAN calculates the sound field in accordance with ISO 9613-2 “Acoustics - Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation.” The standard states that “this part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors, in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.” Uncertainty of calculations with this method are +/-1 dB for sources less than 10m in height and within 1000m of the receiver.

9.5 Traffic Noise Model (TNM)

The Federal Highway Administration Traffic Noise Model (TNM), implemented into the SoundPLAN® software, was used for the road traffic sound level modeling in this study. TNM contains the following components:

1. Modeling of five standard vehicle types, including automobiles, medium trucks, heavy trucks, buses, and motorcycles, as well as user-defined vehicles.
2. Modeling both constant- and interrupted-flow traffic using a field-measured data base.
3. Modeling effects of different pavement types, as well as the effects of graded roadways.
4. Sound level computations based on a one-third octave-band data base and algorithms.
5. Graphically-interactive noise barrier design and optimization.
6. Attenuation over/through rows of buildings and dense vegetation.
7. Multiple diffraction analysis.
8. Parallel barrier analysis.

9. Contour analysis, including sound level contours, barrier insertion loss contours, and sound-level difference contours.

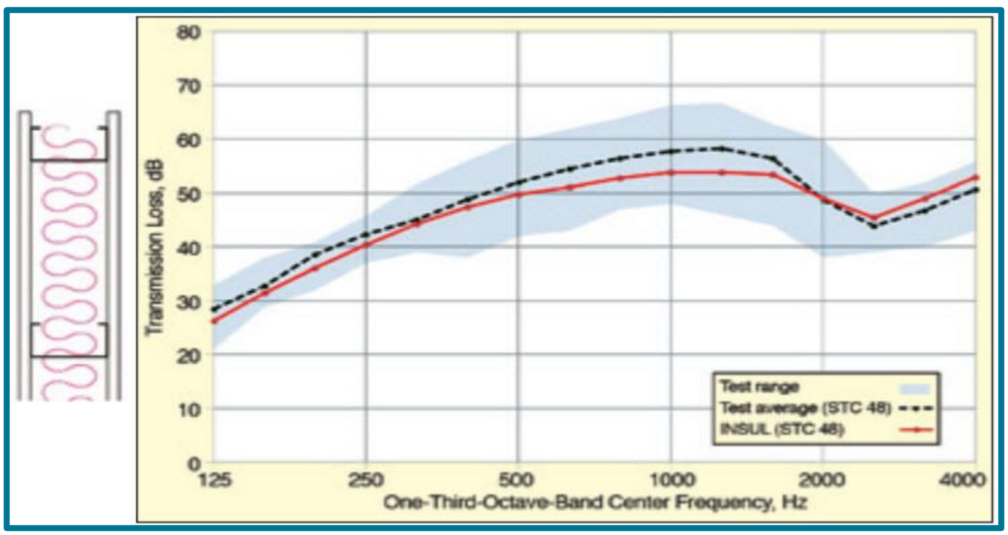
These components are supported by a scientifically founded and experimentally calibrated acoustic computation methodology, as well as a flexible data base, made up of over 6000 individual pass-by events measured at forty sites across the country.

9.6 Computer Modeling of Transmission Class (STC)

The use of computer modeling to estimate sound transmission class (STC) and outdoor-to-indoor transmission class (OITC) ratings has become increasingly common. There are several factors to consider when using software to estimate the sound insulation of architectural elements and assemblies. One of the most important factors is the question of real-world accuracy. Others include the use of analytical vs. empirical models, the complexity of assemblies that can be modeled and the level of user experience and knowledge necessary to yield valid or useful results.

Computational results using INSUL software yield octave or third octave-band transmission loss values as well as providing an estimated single-number STC rating. Modeled results are compared to published laboratory test data for several representative assemblies in Figure 14.

Figure 14: Comparison of INSUL and Laboratory Testing



9.7 Resilient Channel vs. Isolation Clips on Hat Channel

STC and IIC performance may be significantly compromised by incorrect installation of resilient channel. Resilient channels ("RC") are notoriously easy to improperly specify and install and are easily rendered ineffective; an independent study found that all RC except for Clark Dietrich's RC Deluxe underperformed by an average of 8 points on STC, and as much as 13 points below their clams! [12]. Rubber isolation clips (RSIC) on hat channel are much less prone to these problems and always outperform resilient channel—RC is **not** an equivalent for RSIC. As is the case with any drywall isolation product, care must be taken not to mechanically short out the isolation and render it ineffective. Please see this white paper from Pliteq describing the drawbacks of the various RC-Deluxe competitors and how installation is critical for the products to perform correctly[13].

In any case, if RC must be used, Clark Dietrich RC-Deluxe is the superior and the only product we can support. Refer to the Clark Dietrich RC Installation Guidelines and consider using PAC-International RC-1 Boost to prevent incorrect installation and improve performance.

We **highly** recommend replacing the resilient channel with rubber isolation clips on hat channel to improve performance and minimize installation problems. Consider these three options for rubber isolation clips having equivalent performance:

- PAC-International RSIC-1
- Pliteq GenieClip® RST
- REGUPOL SonusClips

[12] Dong, LoVerde: *Quantitative Comparisons of Resilient Cannel Designs in Walls and Ceilings.* NoiseCon 2022.

[13] Golden: Resilient Channels: *Guaranteed to Fail*. 2017. Available here: https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://pliteq.com/wp-content/uploads/Resilient-Channels-White-Paper.pdf