

STATE ROUTE 85
NOISE REDUCTION STUDY
FINAL PHASE 1 REPORT



Santa Clara Valley Transportation Authority

September 2016

CSDA | DESIGN
GROUP

**State Route 85
Noise Reduction Study
Final Phase 1 Report**

September 2016

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1.0 Executive Summary

There has been community concern regarding freeway noise along State Route (SR) 85. Various studies and test projects have been conducted to address freeway noise to adjacent sensitive receptors (e.g., residences). During the SR 85 Express Lanes environmental analysis conducted in 2014, certain sensitive receptors were identified as at or above the federal noise threshold; however, per Federal Highway Administration (FHWA)/California Department of Transportation (Caltrans) criteria, it was not feasible and reasonable to construct new sound walls or replace existing sound walls.

This study investigates alternate noise reduction measures for SR 85. Specifically, the following measures were investigated: implementation of acoustically absorptive barrier treatments, addition of barrier “caps” to the top of the existing noise barriers, and incorporation of quieter pavements. These materials/methods are explained and shown in the body of the report.

In order to determine the noise reduction performance of each method, the following was completed:

- 1) Review of applicable scientific research articles (e.g., research reports, journal articles, conference papers).
- 2) Selection of five, noise-impacted sensitive receptors.
- 3) Computer noise modeling of absorptive barriers and barrier caps at selected sensitive receptors located along SR 85.
- 4) Calculation of quieter pavement noise reduction using On-Board Sound Intensity, a measurement method used to quantify the sound level of various pavement types.

It was found that quieter pavements yielded noise reduction ranging from 1.6 to 4.7 dBA (depending on existing pavement type and the type of “quieter” pavement applied to the roadway), barrier caps yielded theoretical reductions of 0.7 to 4.5 dBA, and absorptive barrier treatments yielded a reduction of 0.8 to 0.9 dBA. The project goal was a noise reduction of 5 dBA, which is the Caltrans minimum and considered a readily noticeable improvement. It is recommended that quieter pavement treatment be implemented (at the five selected noise-impacted receptor locations in this report). Even though barrier caps provide similar noise reduction, quieter pavement treatment benefit a greater number of receptors (since barrier caps only benefit those receptors located behind the treated sound wall).

The cost per benefited receptor varied between \$34,000 and \$274,000, depending on the treatment method and analysis location. A cost estimate and exhibits showing treatment areas are included in the report.

2.0 Project Description

2.1 Previous Projects and Studies

Due to community concerns regarding freeway noise along SR 85, the following studies and projects were undertaken by Caltrans and Santa Clara Valley Transportation Authority (VTA):

- 1998: Caltrans completed a study of potential alternatives that could be expected to reduce freeway noise by 3 decibels.
- 2001: VTA completed a study recommending a test project to micro-grind (texture-grind) a portion of the freeway, and conducted noise analyses to determine if an improvement could be achieved.

- 2003: VTA completed a micro-grind (texture-grind) test project with results that indicated while overall freeway noise levels were not significantly reduced, however, the frequency characteristics of the noise was modified resulting in the noise being less noticeable/annoying to the sensitive receptors.
- 2006: VTA completed a noise mitigation project that included textured grinding of about 11 miles of concrete pavement from east of Almaden Expressway to north of Stevens Creek Boulevard.
- 2014: SR 85 Express Lanes Environmental Phase: VTA, in cooperation with Caltrans, completed environmental documentation of SR 85¹ to allow for the implementation of express lanes on the route. The planned implementation of express lanes on SR 85 includes the conversion of the existing carpool lanes in both directions between US 101 in south San Jose and US 101 in Mountain View and the addition of a second express lane in both directions between SR 87 and Interstate 280 (I-280).

During the environmental review period for the project, residents expressed concerns about the existing noise levels along SR 85 and the anticipated increase in noise levels in the proposed express lanes, in particular, the planned double express lanes between SR 87 and I-280 through San Jose, Campbell, Los Gatos, Saratoga and Cupertino.

Environmental Document: The environmental study of SR 85 for express lanes implementation conducted community noise measurements at 149 locations throughout the corridor. The results of the study determined no effect or no more than a 3-decibel increase in noise levels. An increase of 3 decibels is considered barely detectable to the human ear. Under the California Environmental Quality Act (CEQA), changes in traffic noise from the project would not result in a significant impact. Under federal regulation 23 CFR 772, noise abatement was considered because 41 noise receptors along SR 85 and US 101 have existing and future noise levels that approach or exceed federal noise abatement criteria. The noise evaluations identified feasible sound walls; however, none of the sound walls qualified under the Caltrans “reasonableness” criteria for new or replacement sound walls.

Comparison to Previous Noise Studies: VTA compared 12 receptor locations from the 1987 Final Environmental Impact Statement for the construction of SR 85 between I-280 and US 101 in San Jose, and the 1996 environmental document for the construction of High Occupancy Vehicle Lane Widening Project between Dana Street and north of Moffett Boulevard. The noise levels from the SR 85 Express Lanes environmental document and those from the previous studies were found to be equivalent.

Comparison to the 2013 Saratoga Noise Element Update: VTA compared one noise measurement collected along SR 85 for the 2013 City of Saratoga Draft Noise Element Update and the noise analysis from the SR 85 Express Lanes environmental document. It was determined that the SR 85 Express Lanes noise study levels are comparable to the levels documented in the 2013 Saratoga Noise Element Update.

¹ State Route 85 Express Lanes Project: Initial Study with Negative Declaration/Environmental Assessment with Finding of No Significant Impact. Prepared by the State of California Department of Transportation in Cooperation with the Santa Clara Valley Transportation Authority, April 2015.

2.2 Noise Reduction Program

To address existing noise concerns on SR 85, VTA is working with cities along SR 85 and Caltrans to study, test and implement noise reduction treatments through a three-phase process.

The Noise Reduction Program will be implemented in three phases:

- **Phase 1 (this study):** the study phase of the Program. This phase used available noise studies for evaluation of alternative noise reduction measures that could be implemented with Caltrans approval, identification of test locations, selection of five (5) representative test locations, and analysis of feasible noise reduction at each test location.
- **Phase 2:** the pilot testing phase of the Program. This phase involves the pilot testing of the recommended noise reduction measures identified in Phase 1 at the five test locations and evaluation of their efficacy after implementation.
- **Phase 3:** the deployment phase of the Program. This phase involves the implementation of those measures from Phase 2 that show promise in reducing noise at other impacted sensitive receptors along SR 85.

3.0 Acoustical Criteria

Currently, this project is not being funded with federal or state monies; therefore, it is not subject to FHWA or Caltrans noise criteria. However, the following criteria used in this noise reduction study is based on Caltrans/FHWA regulations.

- **Noise Impact Threshold:** The existing noise level at the exterior of residential land uses approaches or exceeds $L_{eq(h)}^2$ 67 dBA.³ This is defined as a noise level of $L_{eq(h)}$ 66 dBA or greater.
- **Minimum Noise Reduction:** To be considered effective, the minimum noise reduction from any noise reduction measure considered should be 5 dBA or greater at impacted residential receptors.
- **Cost per Benefitted Receptor:** The cost per benefitted receptor should not be greater than \$80,000. This is Caltrans' 2016 base allowable cost.⁴

4.0 Existing Freeway Conditions

SR 85 is a freeway that connects the cities of Mountain View and San Jose in California. The freeway, also named the West Valley Freeway, is 23.7 miles in length and is oriented in a southeasterly direction. The freeway begins at its northern terminus with U.S. Route 101 in Mountain View and ends at a junction with U.S. 101 in southern San Jose. SR 85 crosses SR 237, Interstate 280 (I-280), Highway 17 and Highway 87.

² $L_{eq(h)}$, or equivalent hourly sound level: The average sound level over a one hour period.

³ dBA: A-weighted sound pressure (or noise level) represents the noisiness or loudness of a sound by weighting the amplitudes of various acoustical frequencies to correspond more closely with human hearing. A 10-dB (decibel) increase in noise level is perceived to be twice as loud. A-weighting is specified by the U.S. EPA, OSHA, Caltrans, and others for use in noise measurements.

⁴ The 2016 Base Cost Allowance can be found at <http://www.dot.ca.gov/hq/env/noise/index.htm>

SR 85 is primarily used as a passenger car by-pass for U.S. 101, as trucks over 4.5 tons are prohibited between U.S. 101 in South San Jose to Interstate 280 in Cupertino. SR 85 is a six lane highway with three lanes in each direction and a 46-to-50 foot wide center median. There are 10-foot inside and outside shoulders on each side of the traveled lanes.

Along SR 85, between U.S. 101 (in southern San Jose) and west to Highway 87 (Almaden Expressway), the roadway surface is close to original grade. Only a few retaining walls are present and are located mostly at the interchanges. Along SR 85, between Highway 87 and I-280, the roadway is depressed and lined by concrete retaining walls. Further northwesterly along SR 85, from I-280 to U.S. 101, the roadway is positioned on embankment fill, with numerous sound walls near the hinge points. Where present, cut faces vary considerably in height.⁵ All other things equal, community noise levels are lowest for depressed freeways, moderate for freeways on-grade, and potentially loudest on embankment or elevated structures.

Existing noise barrier heights at various locations along SR 85 are described in the table below:

Table 4-1: Noise Barrier Heights at Various Segments of SR 85⁶

Segment Description	Existing Barrier Heights (feet)
US 101 – Oregon Expressway to SR 85 (Palo Alto and Mountain View)	10 to 16
SR 85 – US 101 to Central Expressway (Mountain View)	14
SR 85 – Central Expressway to El Camino Real (Mountain View)	12, 16
SR 85 – El Camino Real to Fremont Avenue (Mountain View, Sunnyvale, and Los Altos)	12, 16
SR 85 – Fremont Avenue to I-280 (Sunnyvale and Cupertino)	12–16
SR 85 – I-280 to South De Anza Boulevard (Cupertino)	12–16
SR 85 – South De Anza Boulevard to Saratoga Avenue (San Jose and Saratoga)	12, 14
SR 85 – Saratoga Avenue to Winchester Boulevard (Saratoga, San Jose, Campbell, and Los Gatos)	6–16
SR 85 – Winchester Boulevard to Union Avenue (Los Gatos, Campbell and San Jose)	10–16
SR 85 – Union Avenue to Camden Avenue (San Jose)	5–14
SR 85 – Camden Avenue to Almaden Expressway (San Jose)	10–14
SR 85 – Almaden Expressway to Blossom Hill Road (San Jose)	6–16
SR 85 – Blossom Hill Road to Cottle Road (San Jose)	12, 14
SR 85 – Cottle Road to South of SR 85/US 101 Interchange (San Jose)	12–16
US 101 – South of SR 85/US 101 Interchange to Bailey Avenue (San Jose)	berms

⁵ Caltrans Storm Water Quality Handbooks, Project Planning and Design Guide, August 2010

⁶ State Route 85 Express Lanes Project: Initial Study with Negative Declaration/Environmental Assessment with Finding of No Significant Impact. Prepared by the State of California Department of Transportation in Cooperation with the Santa Clara Valley Transportation Authority, April 2015.

The current pavement on SR 85 consists of longitudinally tined Portland cement concrete. Figure 4-1 (right) shows a typical section of pavement along SR 85 (For more images of the existing pavement at analysis locations, see Appendix A).



Figure 4-1: Photo of Typical SR 85 Pavement

5.0 Research Review

A comprehensive research review was performed to determine the minimum and maximum noise reduction that could be expected from non-barrier noise reduction measures such as sound wall modification, retrofit and/or treatment of sound walls, and pavement modifications or treatments. The following noise reduction measures were considered:

- Barrier caps: Consisting of various materials and shapes installed at the top of an existing barrier. Typical profiles (shapes) include cylindrical, “mushroom” and T-shaped. Typical materials include steel, aluminum, concrete, and wood.
- Vegetation/absorptive treatment: Vegetation or acoustically absorptive material at the inside face (i.e., at the roadway side) of a barrier to reduce noise reflections from existing noise barriers to residences located on the opposite side of the road as the barrier.
- Quieter pavement: Various rigid and flexible pavement strategies that help reduce tire noise.

These alternatives were considered because research, both through noise modeling and real-world applications, in these areas is recent and readily available. Also, some of the particular methodologies of each alternative appeared to have significant results in the field of noise reduction and warranted further investigation.

The following sections summarize the findings for each noise reduction measure; Appendix B includes the reference information for each report, study, and book reviewed.

5.1 Barrier Caps

Barrier caps increase the noise reduction provided by a barrier through two primary means:

1. *Reduced diffraction:* When noise from vehicular traffic impinges on a barrier, most of the noise is blocked (reflected back) by the barrier; however, some of the noise bends over the top of the barrier and continues to travel to the sensitive receptor located on the shadow (non-road) side of the barrier. (See Figure 5-1). With barrier caps, this “bending” of the sound waves is reduced, thereby increasing the barrier’s noise reduction.
2. *Increased noise path length:* The effectiveness of a noise barrier is primarily determined by the path length difference between the distance sound travels if there is no barrier (i.e., the straight line distance between source and receptor) versus the distance sound must travel when there is a barrier (i.e., the distance from the source to the top of a barrier, plus the distance from the top of the barrier to the receptor). Adding a barrier cap effectively increases the path length, thereby increasing the barrier’s noise reduction. Often the additional path length of a barrier cap is equal to increasing the height of the barrier by one to two feet.

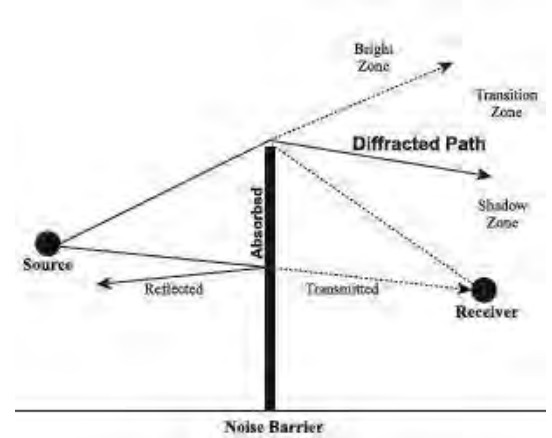


Figure 5-1: Barrier Diffraction Illustration

5.1.1 Barrier Cap Types

There are various barrier cap designs that are acoustically effective. Figure 5-2 shows the most common designs.

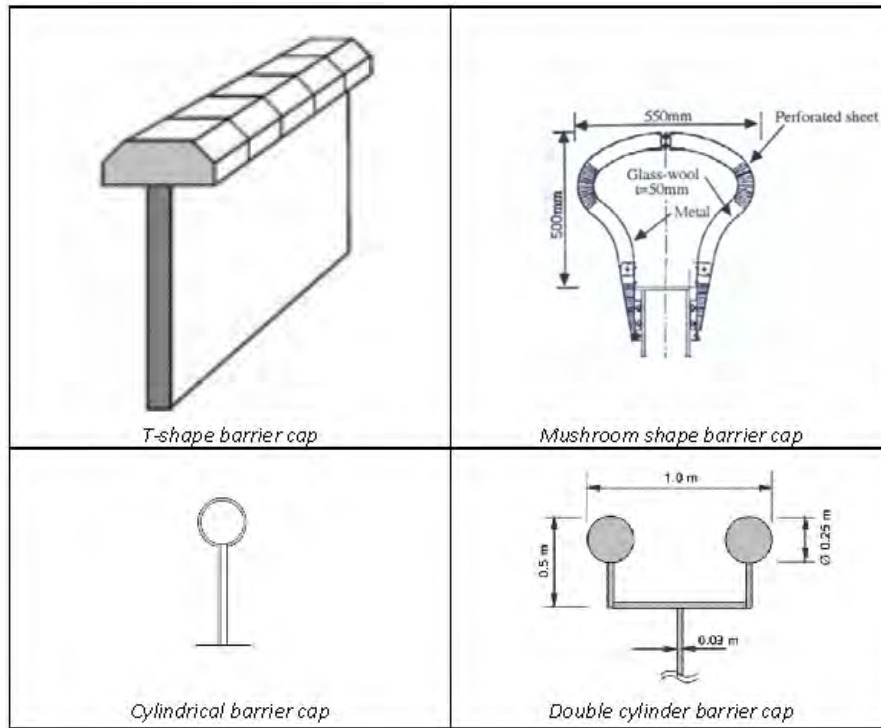


Figure 5-2: Typical Barrier Cap Designs

Barrier caps are generally fabricated from steel, perforated steel, aluminum, concrete, or polycarbonate materials depending upon the style. T-shaped caps can be manufactured in various widths ranging from 3 to 5 feet and made from pre-cast concrete, wood, or metal. Acoustically absorptive materials, typically made from mineral-fiber insulation, are added to obtain a higher level of noise reduction. For example, high density, water resistant absorptive materials may be added to the top of a T-shaped noise barrier (or inside of a mushroom shaped barrier cap) to increase noise reduction. Barrier caps are fabricated in various lengths (10 to 12 feet) to reduce fabrication and installation costs.

The barrier caps fabricated from lighter materials (less weight) are preferred when the caps are to be added to an existing sound wall/barrier, eliminating the need to strengthen the foundation of the existing wall or barrier. Structural angles are attached to the bottom of the barrier cap and “pre-punched” for attachment to the face of the existing barrier. The finished effect, depending on the style of barrier cap, is an added 4 to 20 inches in height to the existing wall.

Installation of the caps from the “freeway” side of the wall may prove to be challenging in areas where the freeway is depressed and the top of the wall can be more than 20-feet above the roadway surface. Temporary easements will be required if the installation needs to occur from the non-freeway side of the wall.

Figure 5-3 below shows field images of installed and “mock-ups” of common barrier caps.

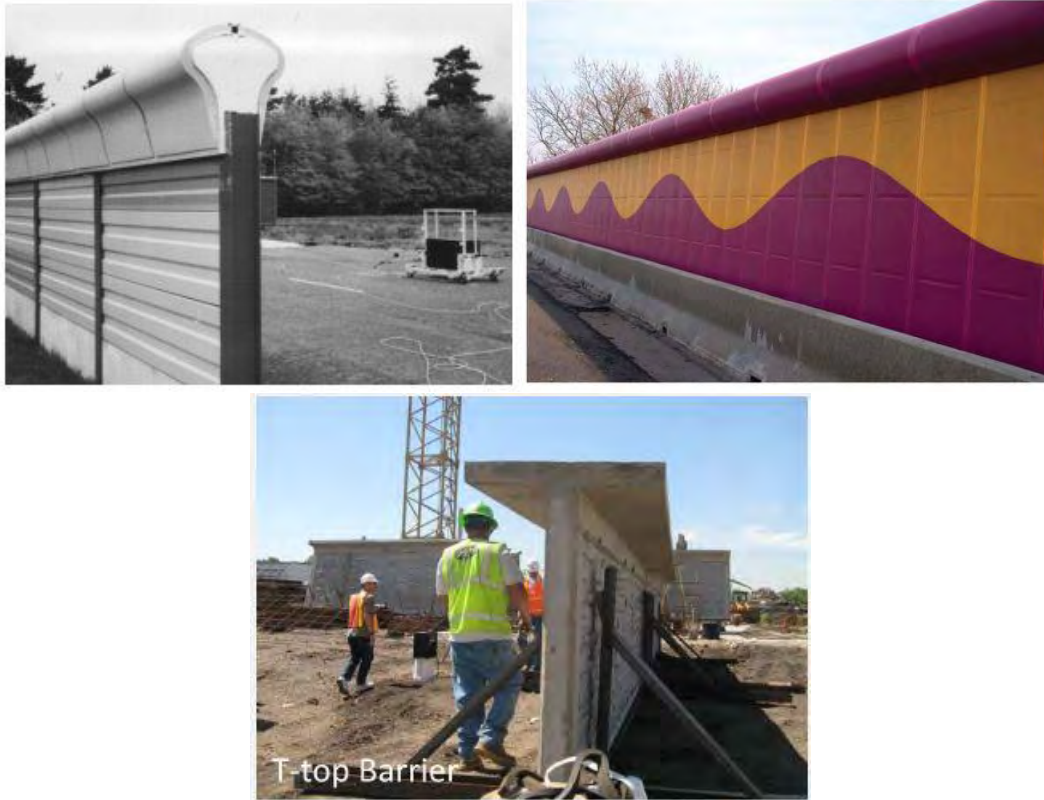


Figure 5-3: Field Images of Common Barrier Caps. Clockwise from Top Left: Mushroom Cap, Cylinder Cap, and T-Shaped Cap

The amount of noise reduction provided by a barrier cap is directly related to the size of the barrier cap (height and width) along with the amount of acoustically absorptive materials contained in the cap. Table 5-1 summarizes typical barrier cap noise reduction obtained from various research papers and books.^{7, 8, 9, 10, 11}

⁷ Morgan, P.A. Review of Japanese Noise Barrier Research. Road and Hydraulic Engineering Division of Rijkswaterstaat (Netherlands), 2004.
⁸ Watts, G.R. Acoustic Performance of New Designs of Traffic Noise Barriers: Full Scale Tests. Journal of Sound and Vibration, Volume 177, 1994.
⁹ Demizieux, P. and Dutilleux, G. Experimental Evaluation of CEN/TS 1793-4 on Two Noise Barriers with Caps. Internoise Conference, Czech Republic, 2004.
¹⁰ Samuels, Stephen and Ancich, Eric. Recent Developments in the Design and Performance of Road Traffic Noise Barriers. Acoustics Australia, Volume 29, No. 2, 2001.
¹¹ Watson, Dustin. Evaluation of Benefits and Opportunities for Innovative Noise Barrier Designs. Final Report 572, Arizona Department of Transportation, 2006.

Table 5-1: Typical Noise Reduction by Barrier Cap Type with and without Absorptive Material

Type of Barrier Cap	Typical Noise Reduction (dBA) without Absorptive Material	Typical Noise Reduction (dBA) with Absorptive Material
T-Shape	1.4 – 3.5	2.0 – 4.5
Mushroom	0.8 – 2.1	2.2 – 2.3
Double Cylinder	(no data available)	5.5
Single Cylinder	0 – 3.0	1.3 – 4.0

Note: There are other, more “exotic” barrier cap profiles that have achieved noise reduction approaching 5 dBA. However, the constructability and long term durability of these profiles is unproven.

5.1.3 Barrier Cap Installation Projects

- T-Shape: Hume Highway, Australia
- Mushroom: I-5 (Santa Ana) Freeway in Commerce, California
- T-Shape: CO 93 in Golden, Colorado
- T-Shape, cylindrical, mushroom, y-shape, etc.: Japan has implemented and tested many different barrier profiles¹²

5.2 Vegetation/Absorptive Treatment

When there are parallel barriers (i.e., barriers on both sides of the freeway), vehicle noise can reflect (bounce) off of the barrier multiple times and cause their noise reduction performance to degrade across the freeway to sensitive receptors located on the opposite side of the reflecting barrier. See Figure 5-4. Absorptive treatments can be applied to the road-side of the barrier on the opposite side of the freeway

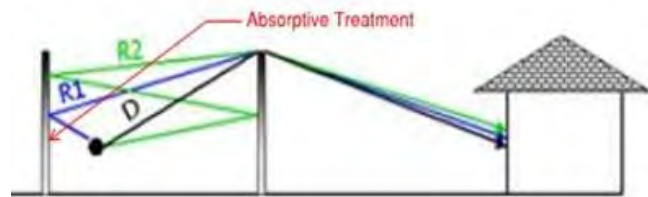


Figure 5-4: Parallel Barrier Reflections

from the receptor (e.g., if the receptor is on the west side of SR 85, absorptive treatment would be added to the barrier on the east side of SR 85). In general, for absorptive treatments to work, the receptor must be at the same or higher elevation than the freeway, and the road width to barrier height ratio is usually 10:1 or less (e.g., road is 100-feet wide and barrier is 10-feet tall).

¹² Morgan, P.A. Review of Japanese Noise Barrier Research. Road and Hydraulic Engineering Division of Rijkswaterstaat (Netherlands), 2004.

5.2.1 *Vegetation/Absorptive Treatment Types*

There are two primary methods to add acoustical absorption to a noise barrier: vegetation and surface-applied materials. Vegetation is a natural, sustainable method to achieve acoustical absorption, yet, like all landscaping, requires space in front of the existing sound wall, water, and maintenance; another benefit of vegetation on barriers is the reduction in graffiti. Surface-applied materials require minimal maintenance, but the upfront costs are higher and repair is required if they are damaged. Both vegetation and surface-applied materials provide similar levels of acoustical absorption.



Figure 5-5: Acoustically Absorptive Barrier Tiles

Figure 5-5 shows an acoustically absorptive barrier¹³ and Figure 5-6 shows a vegetation covered barrier.

Acoustically absorptive panels are often recommended over vegetation as the preferred method of noise reduction due to the maintenance and water requirements of vegetation.



Figure 5-6: Vegetation Covered Barrier

Absorptive treatments are constructed from a variety of materials, whose function is to provide an uneven surface to absorb sound energy or prevent sound reflection. The absorptive panels can be “rough” tiles, such as the barrier tiles depicted in Figure 5-5. The tiles are attached to the face of the sound wall with construction grade adhesive.

Another type of absorptive panel is made from high density insulation sandwiched between non-corrosive aluminum sheets. The outer face of the panel is made from perforated aluminum. The panels are provided in segments, typically 2-foot widths of various heights. A top and bottom mounting channel is attached to the face of the existing barrier and each section/panel is inserted into the mounting track. Since the panels weigh approximately 2 pounds per square foot, the weight of each panel is manageable.

Similar to the barrier caps, access for installation of the panels from the “freeway” side of the wall may prove to be challenging in areas where the freeway is depressed and the top of the wall is more than 20-feet above the roadway surface. Prior to the installation of the panels, the surface of the barriers need to be free of vegetation; however, if vegetation is already present there would be little reason to add panels, since the vegetation likely already provides sufficient acoustical absorption.

¹³ Image courtesy of SoundSorb (www.soundsorb.com)

5.2.2 Vegetation/Absorptive Treatment Noise Reduction

Significant research has been conducted on the performance of acoustically absorptive barrier materials. Researchers have calculated and modeled noise reduction of 3 to 12 dBA^{14, 15}; however, field trials have resulted in 0 to 3 dBA of noise reduction.¹⁶ In general, absorptive materials are more effective for receptors that are located at longer distances (e.g., greater than 50 feet) from the barrier.

5.2.3 Vegetation/Absorptive Treatment Installation Projects

- US 101 in San Rafael, CA
- I-580 in Oakland
- Gene Autry Way in Anaheim, CA
- I-40 in Knoxville, TN
- Highway A2 in Portugal

5.3 Quieter Pavement

At highway speeds, the majority of automobile traffic noise is generated by the tires contacting the pavement; for trucks, it is a mix of tire noise and engine/exhaust noise. Since SR 85 has light truck traffic (less than 2% of the total volume due to trucks being prohibited between the southern boundary with U.S. 101 northwesterly to the intersection with I-280), tire noise is the dominant source. Tire noise levels are dependent on the type of pavement, vehicle speed, and tire type (e.g., off-road tires are significantly louder than road tires).

The level and character of noise generated by the tires contacting pavement is determined by seven mechanisms: impact, adhesion, air displacement, horn effect, acoustical impedance effect, mechanical impedance effect, and tire resonance.¹⁷ The material and texture of a pavement directly influence these seven factors. In general, smooth pavement (minimal surface texture) is quieter than rough pavement, and air space or voids in the pavement surface will often reduce noise levels.

There are basically two types of quieter pavement: flexible and rigid. Flexible pavement is derived from asphalt products that contain mixtures of rubber and other polymer modifiers, allowing the roadway to be less “stiff” than rigid pavement, thus reducing noise from tire impact. Flexible quieter pavement, such as Open Graded Friction Course (OGFC) or Open Grade Asphalt Concrete (OGAC) have air pockets in the roadway surface that captures tire noise.¹⁸

Rigid quieter pavement refers to concrete roadway surfaces that are longitudinally tined in the direction of travel and incorporate specialized grinding methods. Rigid pavement types such as “Grind and Groove” (GnG) or “Conventional Diamond Grinding” (CDG) are smooth concrete surfaces intentionally

¹⁴ Nilsson, et al. Environmental Methods for Transport Noise Reduction. (Results from European HOSANNA Research Project) CRC Press, 2015.

¹⁵ Watts, G.R. Acoustic Performance of Parallel Traffic Noise Barriers. Applied Acoustics, Volume 47, No. 2, 1996.

¹⁶ Watts, G. R. Godfrey, N.S. Effects on Roadside Noise Levels of Sound Absorptive Materials in Noise Barriers. Applied Acoustics, Volume 58, 1999.

¹⁷ Bernhard, Robert, et al. A Study of the Effect of Innovatively Textured Portland Cement Concrete Roadway Surfaces on Tire-Pavement Noise. Purdue University, December 2009.

¹⁸ Rasmussen, et al. The Little Book of Quieter Pavement. FHWA-IF-08-004, July 2007.

cut to create grooves. The grooves produce negative texture which allows air between the tire and roadway surface to escape.¹⁹

5.3.1 *Measuring Tire-Pavement Noise*

One of the techniques for measuring tire-pavement noise is called “on board sound intensity” or OBSI. OBSI is referred to as a *source measurement* because it measures sound near the tire, as opposed to *wayside measurements*, where microphones are set up at specific distances from the side of the road to measure traffic noise.²⁰

OBSI is a measurement procedure used to evaluate tire/pavement noise resulting from the interaction of an ASTM F 2493 Standard Reference Test Tire (SRTT) on a pavement surface. Sound intensity measurements are taken at defined locations near the tire/pavement interface (see Figure 5-7 for an image showing an OBSI measurement). Because of this, noise measured with OBSI will be significantly higher than noise measured where receptors are located (i.e. homes adjacent to the highway).



Figure 5-7: On Board Sound Intensity Measurement

5.3.2 *Range of Existing Pavement Noise*

A range of pavements in California and Arizona were measured using OBSI. Figure 5-8 shows the results of this survey, presented in terms of sound intensity (as discussed above).

In general, concrete pavement is noisier than asphalt surfaces, and all pavement gets noisier as it ages (0.3 to 0.8 decibels per year). As shown in Figure 5-8, Open Grade (OG) Rubberized Asphalt Concrete (RAC) surfaces generally tested between 95.5 to 101.5 dBA. Portland Cement Concrete (PCC) tested between 100.5 and 109 dBA. Dense Grade Asphalt (DGA) pavement tested between 98.5 dBA and 101.5 dBA. The survey shows that pavement noise levels can vary by up to 13 dBA.

The Traffic Noise Model (TNM), as represented by the green oval in Figure 5-8, uses an average pavement noise level regardless of pavement age, type, or measured sound intensity level. The TNM noise level for vehicle traffic similar to SR 85 is 102.7 dBA. The TNM average is significant in that it is an accepted method to calculate noise levels at receptor locations and has been used in the Express Lanes Noise Study for SR-85.

¹⁹ Ibid

²⁰ Ibid

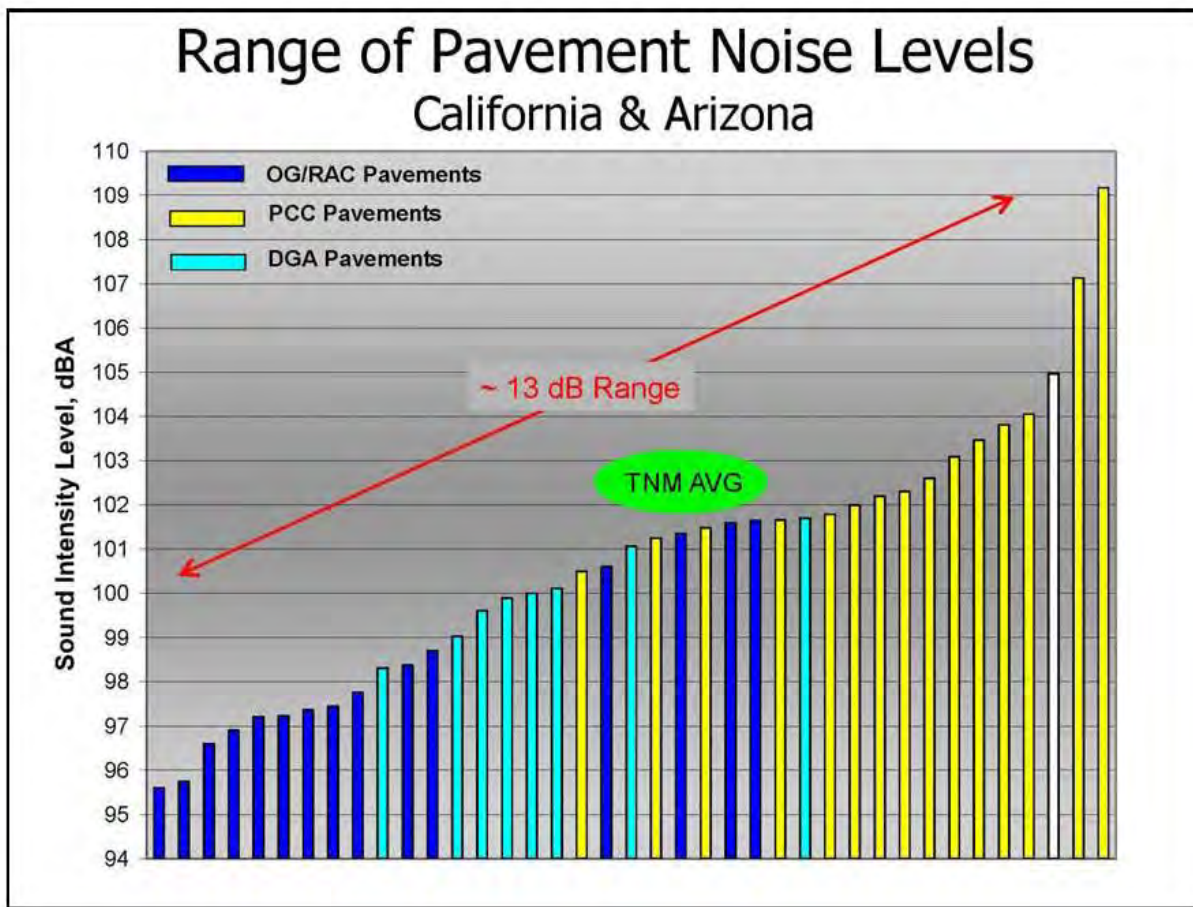


Figure 5-8: Range of Pavement Noise Levels

Notes:

- 1) Chart by: B. Rymer, California Department of Transportation (CalTrans), Division of Environmental Analysis.
- 2) OG/RAC = Open Graded Asphalt
- 3) PCC = Portland Cement Concrete
- 4) DGA = Dense Graded Asphalt
- 5) The white bar on the graph represents "Chip Seal" a unique pavement type to the survey. No similar types were tested and, therefore no sound intensity range is provided.
- 6) TNM Average Noise Level is derived from the following source: National Cooperative Highway Research Program Report 738: Evaluating Pavement Strategies and Barriers for Noise Mitigation, 2013. Page 13.

5.3.3 Quieter Pavement Types

Two types of quieter pavement appear to be especially beneficial: 1) Open Grade Asphalt Concrete (OGAC) or Rubberized Asphalt Concrete Overlay (RAC-O) which is pavement material that consists of regular asphalt concrete mixed with crumb rubber from recycled tires and 2) Grind and Groove or "GnG" pavement, which is characterized by uniform longitudinal grooves in Portland cement concrete roadways. The resultant positive and negative surfaces in GnG pavement is wider than the grooves created when Conventional Diamond Grinding (CDG) is applied to Portland cement roadways. See Figure 5-9 below.



Figure 5-9: Next Generation Concrete Surface (NGCS) Grind and Groove (GnG) pavement.

Implementation of quieter pavement measures will require night work with temporary lane closures.

5.3.4 Quieter Pavement Noise Reduction

Depending on the existing pavement type, condition (age), noise reduction from the implementation of quieter pavement generally is in the range of 1 to 10 dBA.

5.3.5 Quieter Pavement Treatment Installation Projects

Quieter pavement has been implemented in many places nationally and internationally. The following is a list of some representative projects:

- Interstate 5 in Sacramento – Grind and Groove (GnG)
- State Route 101 in Arizona – Asphalt Rubber Friction Course (ARFC)
- U. S. 101 in San Rafael, CA – Open Grade Asphalt Concrete (OGAC)
- I-280 in Woodside, CA – Rubberized Asphalt Concrete Overlay (RAC-O)
- I-80 in Davis, CA - Open Grade Asphalt Concrete (OGAC)

6.0 SR 85 Noise Analysis

6.1 Existing Noise Conditions

This study did not conduct field measurements of traffic noise along SR 85. Instead, this study used measurements of existing noise conditions obtained for the SR 85 Express Lanes Project Initial Study with Negative Declaration/Environmental Assessment with Finding of No Significant Impact (Express Lanes IS/EA) dated April 2015. Appendix C lists the modeled existing noise levels from the Express Lanes IS/EA. Of the locations, 38 noise-sensitive receptors are identified as at or approaching 67 dB, the FHWA level of significance.

6.2 Selection of Analysis Locations

In order to determine the amount of noise reduction that would be provided by each alternative, five analysis locations were selected. These locations were selected by narrowing down the 38 noise-sensitive receptors identified as at or approaching 67 dB in the Express Lanes IS/EA. The following methodologies were employed:

1. **Eliminate receptors adjacent to U.S.101:** Receptors not adjacent to SR 85 are outside of the project scope. This eliminated 10 receptors.
2. **Eliminate non-residential receptors:** Churches, schools, parks, trails, etc. can be considered less sensitive than residences, as people spend less time in these locations, and sleep disturbance is not a concern at non-residential receptors. This eliminated 8 receptors.
3. **Eliminate rural residential receptors:** There are three (3) noise-impacted rural, residential receptors off Malech Road in South San Jose. These receptors were eliminated, as Caltrans' "cost per benefitted receptor" would be greatly exceeded by any potential noise reduction strategy.
4. **Select receptors with potential for at least 3 dB of noise reduction:** An initial screening/modeling of the 17 remaining sensitive receptors were conducted to determine which receptors showed the most potential for noise reduction from the alternative noise reduction measures.

The entire roadside community will benefit from quieter pavements (e.g., Next Generation Concrete Surface (NGCS), grinding, overlays), so the screening was focused on the other two alternatives being studied: barrier caps and absorptive barrier treatments.

5. **Select receptors with varying topography:** Since recommendations from this study will be part of the "pilot" testing phase (Phase 2 of the Program), receptors with varying topography were selected to determine whether greater benefit is received when SR 85 is depressed (below grade of the residence), level (same grade as the residence), or elevated (above the residence). Topography affects how much diffraction a barrier cap will reduce, along with the effectiveness of acoustical absorption at parallel barriers.
6. **Selecting receptors with highest noise level:** The final step is to select receptors with the highest existing noise level.

Based on the methodology above, Table 6-1 below lists the 5 locations that were selected. Appendix D shows these locations on SR-85 and Appendix E reviews each of the recommended analysis locations in detail.

Table 6-1: Summary of Selected Locations

Note: Quieter pavement types will be effective for all receptors in this memo. Receptor Designation codes and existing noise

Location No.	Receptor Designation	Description	Worst Hour Existing Traffic Noise Levels (dBA)	Potential Noise Reduction Measure		
				Barrier Cap?	Absorptive Treatment?	Quieter Pavement?
1	ST - 19	Lubich Drive, Mountain View	69	Yes	Yes	Yes
2	ST - 24	The Dalles Ave. and environs, Sunnyvale	68	Yes	Yes	Yes
3	ST - 40	Tomki Court to Lily Ave., Cupertino	67	Yes	No	Yes
4	ST - 55	Yuba Court, Saratoga	67	Yes	Yes	Yes
5	ST - 107	Glenburry Way, San Jose	66	Yes	No	Yes

levels are from the SR 85 Express Lanes IS/EA.

6.3 Noise Reduction Calculation Methodology

6.3.1 Vegetation as Absorptive Treatments

Noise reduction calculations were not performed for vegetation as an absorptive treatment to existing sound walls as a means to increase noise reduction due to the maintenance and water concerns/costs raised in section 5.2.1.

6.3.2 Barrier Caps and Absorptive Treatments

For state and federal highway projects, the accepted method to calculate noise levels at sensitive receptors is the FHWA’s Traffic Noise Model (TNM) v2.5. This model incorporates the road geometry, barrier configuration, and receptor locations. It is also capable of incorporating the noise reduction from buildings, terrain features (e.g., berms), tree rows, and ground effects. However, the TNM cannot accurately calculate barrier cap noise reduction, and the calculation of noise reduction from absorptive barrier materials has not been fully implemented in the software.²¹

There are a few different acoustical calculation software packages that are able to calculate the effects of barrier caps and absorptive materials. Both SoundPlan²² and CadnaA²³, state-of-the-art noise modeling software, were used to calculate noise reduction from barrier caps and absorptive materials at the five selected analysis locations. Both software packages are able to calculate the noise reduction obtained from barrier caps and absorptive barriers, and both follow the same calculation standards. While this software is not used for federally-funded highway noise studies (due to FHWA mandates), the software is used extensively for other public infrastructure work (e.g., rail/highway construction noise, power plant noise). Both software packages were used to determine whether the results were consistent. In general, the following procedure was followed:

²¹ While the TNM does have some capability to calculate the effect of absorptive barrier treatments, the results are not always accurate or reliable. NCHRP Report 791: Supplemental Guidance on the Application of FHWA’s Traffic Noise Model (TNM) discusses this issue in detail. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_791.pdf

²² <http://www.datakustik.com/en/products/cadnaa>

²³ <http://www.soundplan.eu/english>

- 1) Imported TNM studies used in the Express Lanes noise study (performed by Illingworth & Rodkin) prepared for the Express Lanes IS/EA. The road geometry, barrier locations and heights, and sensitive receptor locations were all imported into SoundPlan and CadnaA. Figure 6-1 below shows a screenshot from the software.

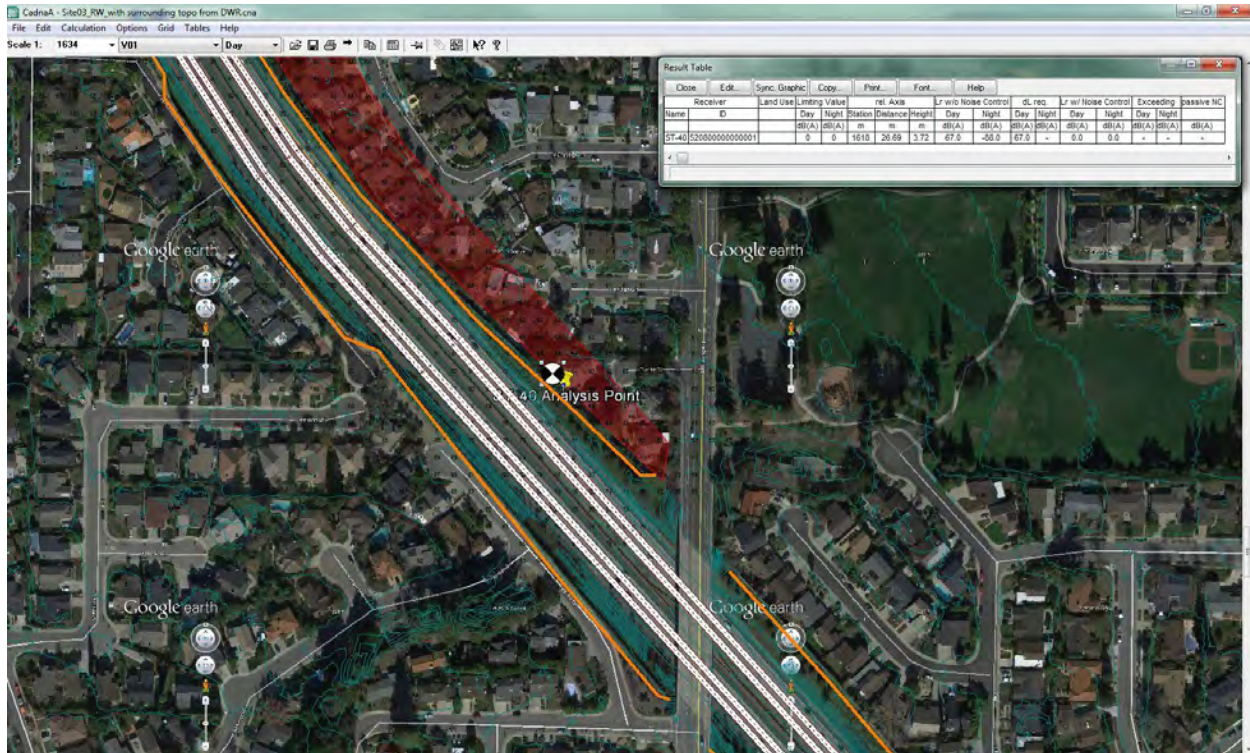


Figure 6-1: Noise Modeling Software Screenshot

- 2) Imported terrain data for the right-of-way from Caltrans Topographic data provided by VTA (Caltrans Radman Aerial Surveys dated 6-30-2010).
- 3) Imported terrain data for areas outside of the right-of-way from the U.S. Geological Survey (USGS) or National Oceanic and Atmospheric Administration (NOAA). Figure 6-2 below shows the topography at one of the analysis locations.

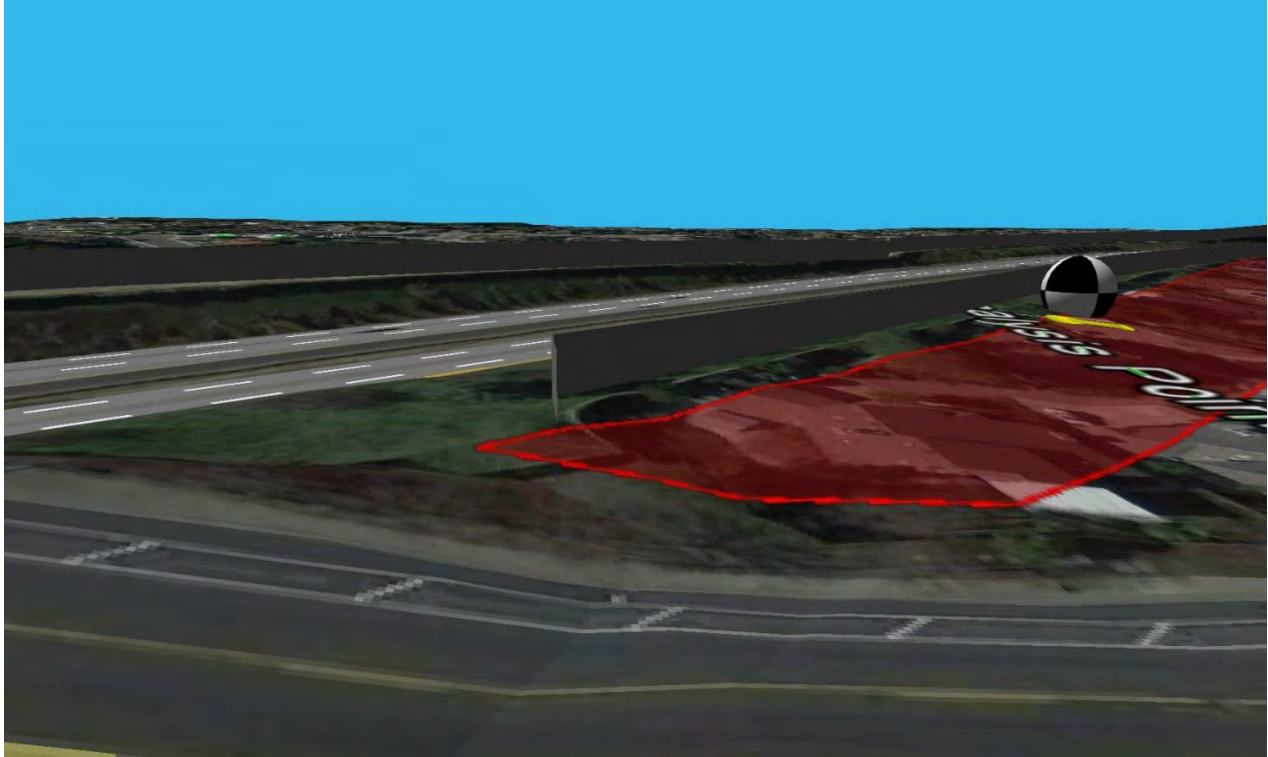


Figure 6-2: 3D View of Local Topography

- 4) Calculated the existing noise level (i.e., no changes made to the TNM study) at each of the five analysis locations; barriers were set as acoustically reflective (NRC²⁴ of 0.2). All other pertinent settings (e.g., temperature, humidity, number of orders of reflection) were made consistent across models.
- 5) Modified the noise model as follows:
 - a. In the case of barrier caps, added cylindrical (three foot diameter) or T-shaped (three and five feet wide) elements; see Figures 6-3 and 6-4.
 - b. For those locations where absorptive materials were being considered, the far barrier (i.e., the barrier on the opposite side of the roadway as the receptor of interest) was modified to be acoustically absorptive (NRC 0.80)

²⁴ Noise Reduction Coefficient (NRC): A measure of the acoustical absorption performance of a material, calculated by averaging its sound absorption coefficients at 250, 500, 1000 and 2000 Hz, expressed to the nearest integral multiple of 0.05.

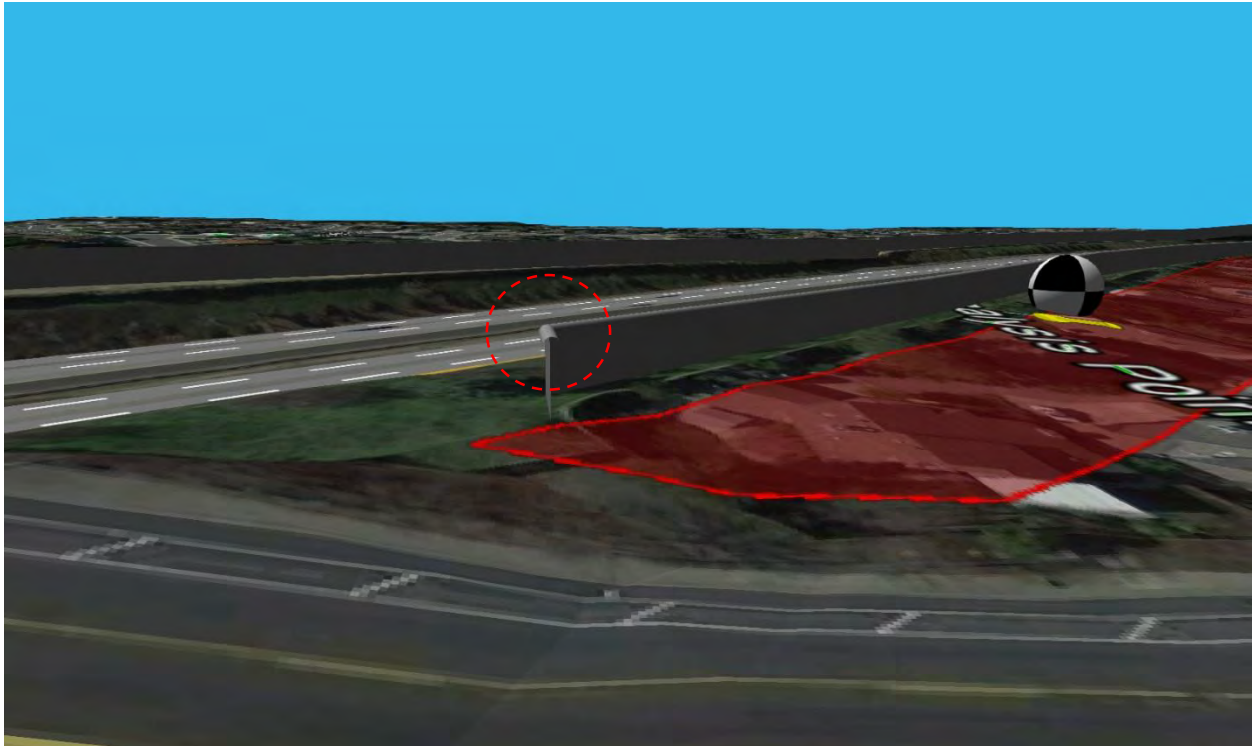


Figure 6-3: Cylindrical Barrier Cap Modeling

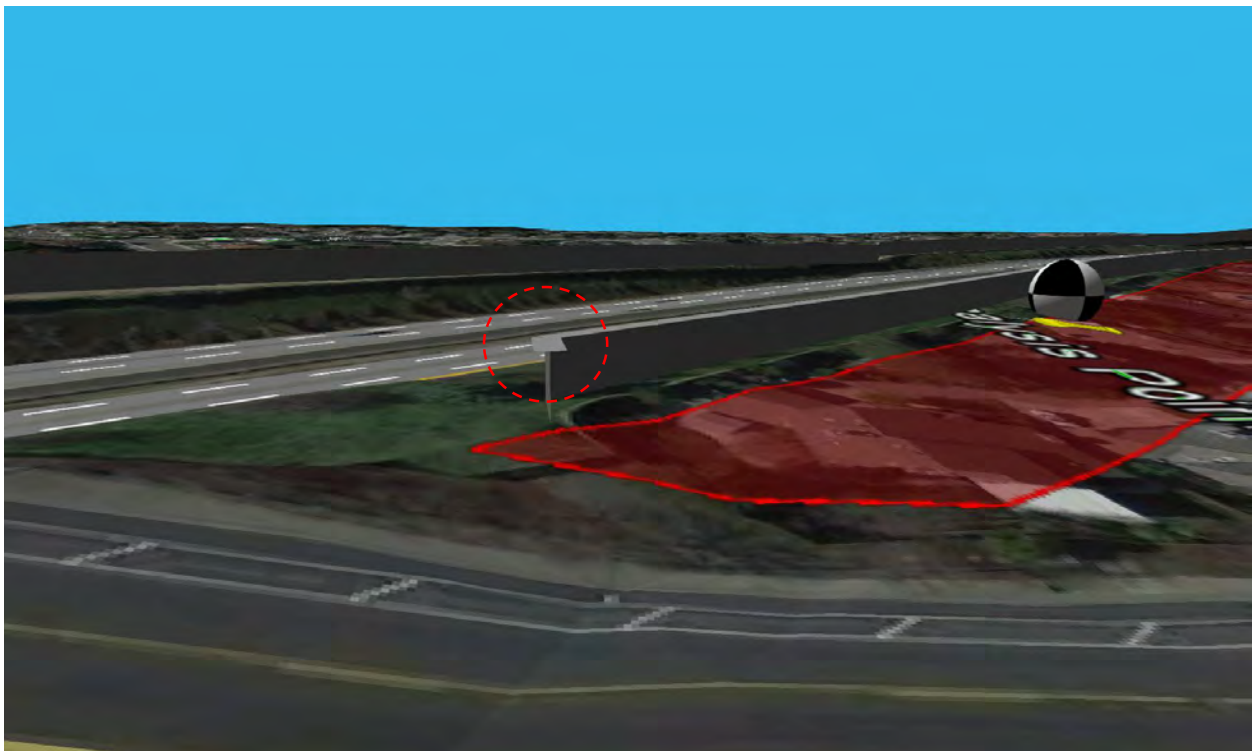


Figure 6-4: T-Shaped Barrier Cap Modeling

- 6) Recalculated the noise levels at the receptors to quantify the difference (i.e., the noise reduction) provided by the barrier cap and/or absorptive treatment

6.3.3 Quieter Pavement Calculation Methodology

The FHWA and the TNM require that noise modeling be conducted using the “average pavement” type. As shown in Figure 5-8, average pavement falls in the middle of the range of tire noise generated by various road surfaces. While both SoundPlan and CadnaA allow other pavement types to be modeled, the options are limited and were not considered as accurate as the method utilized for this study (presented below).

As part of research review, numerous papers and reports concerning quieter pavements were read and summarized. These documents investigated both the overall noise levels of various pavement types, along with the longevity (increase in noise levels over time) of each type. Specifically, the following documents were found to be most useful:

- Quieter Pavement Pilot Program: Progress Report 3, Final Report 577. Arizona Department of Transportation, September 2012.
- Evaluation of Grind and Groove (Next Generation Concrete Surface) Pilot Projects in California. Caltrans/UC Pavement Research Center, November 2012.
- Evaluating Pavement Strategies and Barriers for Noise Mitigation, Report 738. National Highway Cooperative Research Program, 2013

The following procedure was utilized to estimate the noise reduction achieved from quieter pavements:

1. Review the above documents and determine typical On-Board Sound Intensity Levels (OBSI) measured for the various Quieter Pavement types.
2. Calculate the average OBSI noise level for three pavement types of interest:
 - a. Next Generation Concrete Surface
 - b. Rubberized Asphalt Over Concrete (RAC[O])
 - c. Asphalt Rubber Friction Course (ARFC)
3. Calculate the Quieter Pavement noise reduction by subtracting the quieter pavement OBSI from the existing, TNM average pavement OBSI values.

Figure 6-5 shows an excerpt of the quieter pavement calculation worksheet employed to determine noise reduction (NR).

Noise Reduction Based Upon TNM Modeling (Avg. Pavement)

Pavement Type	OBSI	NR
TNM Avg. Pavement - Light Vehicles	102.7	
GNG	101.1	1.6
ARFC (average of new and 9 year)	98.0	4.7
RACO (average of new and 9 year)	98.1	4.6

Notes:

- 1) NR signifies noise reduction, in dBA.
- 2) Since pavement gets noisier as it ages, 0.3 to 0.8 decibels per year, the average OBSI of new and 9 year old pavement is used to determine the noise reduction of ARFC and RACO pavement types.

Figure 6-5: Excerpt from Quieter Pavement Worksheet

6.4 Results

Table 6-2 summarizes findings for each of the analysis points. The two viable noise reduction measures are barrier caps with absorptive material and quieter pavement. The calculated noise reduction is a reduction in noise as compared to the existing noise levels calculated by the TNM during the Express Lanes noise study. Appendix F provides exhibits showing the area of treatment for all three methods.

Table 6-2: Summary of Noise Reduction Calculations

Potential Noise Reduction (dBA)								
			Barrier Cap		Absorptive Treatment	Quieter Pavement		
Location No.	Receptor Designation	Description	Barrier Cap without Absorptive Material	Barrier Cap with Absorptive Material	Absorptive Treatment	GnG Pavement	Asphalt Overlay	Worst Hour Existing Traffic Noise Levels (dBA)
1	ST - 19	Lubich Drive, Mountain View	1.4-2.3	3.4-4.3	0.0*	1.6	4.6-4.7	69
2	ST - 24	The Dalles Ave. and environs, Sunnyvale	1.5-2.4	3.5-4.4	0.9	1.6	4.6-4.7	68
3	ST - 40	Tomki Court to Lily Ave., Cupertino	1.4-2.5	3.4-4.5	n/a	1.6	4.6-4.7	67
4	ST - 55	Yuba Court, Saratoga	1.2-2.1	3.2-4.1	0.8	1.6	4.6-4.7	67
5	ST - 107	Glenburry Way, San Jose	0.7-1.2	2.7-3.2	n/a	1.6	4.6-4.7	66

Notes:

* At Location 1, the opposite sound wall (where the absorptive treatment would be applied), does not run the length of the treatment area. The noise reduction is negligible.

- 1) Regarding barrier caps, the average noise reduction range is for the three types of barrier caps described in Section 6.3.2, step 5 of the modeling procedure; 3-foot diameter cylindrical and 3 and 5-foot T-shaped. There are two ranges of results; one is the range without absorptive material and the other is the range with absorptive material.
- 2) Absorptive Treatment: "n/a" shown in the column indicates that absorptive treatment is not feasible because there is no parallel opposite barrier reflecting noise.
- 3) GnG = Next Generation Concrete Surface or "Grind and Groove", meaning a new concrete grinding process which reduces tire noise over traditional concrete grinding methods.

- 4) Asphalt overlays = Either RAC(O)²⁵ or ARFC²⁶; will need to consult with Caltrans to determine which overlay is feasible for SR 85
- 5) Worst Hour Existing Traffic Noise Levels derived from Express Lanes IS/EA.

6.5 Estimated Costs

Table 6-3 summarizes the estimated costs for the two viable alternatives (barrier cap with absorptive material and quieter pavement).

Table 6-3: Estimated Costs

Locati on No.	Receptor Designation	Number of Receptors Benefited	RAC(O)		Grind and Groove (GnG)		Barrier Cap With Absorptive Material	
			Total Cost	Cost per Receptor	Total Cost	Cost per Receptor	Total Cost	Cost per Receptor
1	ST-19 - Mountain View	11	\$912,000	\$83,000	\$588,000	\$54,000	\$727,000	\$66,000
2	ST-24 - Sunnyvale	24	\$1,543,000	\$64,000	\$958,000	\$40,000	\$1,119,000	\$47,000
3	ST-40 - Cupertino	28	\$1,517,000	\$54,000	\$942,000	\$34,000	\$1,021,000	\$36,000
4	ST-55 - Saratoga	7	\$1,919,000	\$274,000	\$880,000	\$126,000	\$615,000	\$88,000
5	ST-107 – San Jose	16	\$928,000	\$58,000	\$599,000	\$37,000	\$632,000	\$40,000
Totals			\$6,819,000		\$3,967,000		\$3,113,000	

Notes:

- 1) Costs are total project costs including design and construction.
- 2) At Location 4, the length of the area to be paved is 1,202 yards. The length of the sound wall to be fitted with a barrier cap is 500 yards. The difference in the lengths of the treatment areas explains the variation in cost per receptor.

The current Caltrans allowable cost per benefitted receptor is \$80,000.

6.6 Recommendation

As can be seen from Table 6-2, on average the asphalt overlay provides the most noise reduction. Absorptive barrier caps approach the noise reduction provided by the quieter pavement; however, the benefit of quieter pavement extends to more receptors, as a barrier cap only benefits those residences located just behind the sound wall whereas quieter pavement reduces noise for all surrounding receptors. Absorptive barrier treatments provide minimal noise reduction improvement and we do not recommend implementation.

Based on the above, we recommend asphalt overlay as the preferred noise reduction measure.

²⁵ RAC(O): rubberized asphalt concrete overlay

²⁶ ARFC: asphalt rubber friction course

7.0 Implementation Plan

The implementation of Phase 2 is dependent on funding. The Program is funded through Phase 1 (this study) from local sources. The potential funding sources for the project initiation, project approval and environmental document, design, and construction phases of Phase 2 include future sales tax and toll revenue.

After full funding is in place, VTA is projecting the start of construction for Phase 2 to be in the fall of 2018. The Construction phase is assumed to be 9 months.

The implementation of Phase 3 is dependent on the following:

- a. Funding. The potential funding sources for the project initiation, approval and environmental document, design, and construction phases of Phase 3 include future sales tax and toll revenue.
- b. Positive result of noise reduction measure observed several years after Phase 2 construction. The process and timing of the assessment will be determined during the project approval and environmental phase of Phase 2.

Because of the length of the freeway corridor and potential cost of implementation, Phase 3 may have to go through a site selection process to prioritize the locations for a phased implementation.

8.0 Study Limitation and Consideration

- a. Study Limitations. This study and its conclusions are based upon research articles and measurements conducted by others. No on-site measurements were conducted. Acoustical modeling was based upon the TNM noise studies received from VTA/Illingworth & Rodkin and we are not responsible for the veracity of these models. Topography data was obtained from the USGS and NOAA, and we are not responsible for the veracity of this data. As with all acoustical calculations, the margin of error is approximately at least +/- 1 dBA.
- b. Caltrans Process and Approval. Any State highway improvement project to be undertaken follows Caltrans' project development procedures manual (<http://www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm>). The follow on phases (Phase 2 and Phase 3) will go through the policies and procedures outlined in this manual. The typical project development phases include project initiation, project approval and environmental document, design, construction, and project closeout. Further analysis of the recommendation in this study will be undertaken to fully review the benefit of the recommended noise reduction measure against the overall impacts to the facility, including but not limited to constructability, longevity, aesthetics if applicable, structural integrity, service life and maintenance. During these phases, the projected schedule to complete the follow on phases and assessment period after construction of Phase 2 will be fully developed.
- c. Caltrans Quieter Pavement Bulletin. In addition to the project development procedures manual discussed above, Caltrans has a quieter pavement bulletin (http://www.dot.ca.gov/hq/maint/Pavement/Offices/Pavement_Engineering/Quiet_Pavement.html) that establishes policies related to the design, construction and maintenance of quieter pavements. The follow on phases (Phase 2 and Phase 3) will go through the policies and procedures outlined in this bulletin.

9.0 City Involvement

Representatives for the Town of Los Gatos, Cities of Mountain View, Sunnyvale, Cupertino, San Jose, Saratoga, Campbell, Los Altos and Monte Sereno, and Santa Clara County Roads and Airports have been invited and have attended project team meetings with VTA and Caltrans staff. The local representatives have also reviewed and provided comments to the study documentations. Concurrence to the five (5) noise analysis locations were obtained during the January 6, 2016 project team meeting.

Input to the draft report was received from the various cities and Caltrans, and the items were discussed and/or incorporated into this report. On September 9, 2016, a meeting was held with the parties listed above to obtain final concurrence on the report. The attendees (Caltrans, Mountain View, Saratoga, Los Altos) had no additional comments or requested changes. Caltrans stated that the report was technically/acoustically satisfactory.

Appendix A –Existing Pavement at Analysis Locations



Location ST-19, in the proximity of Lubich Drive, Mountain View



Location ST-24, in the proximity of The Dalles, Sunnyvale



Location ST-40, in the proximity of Tomki Court, Cupertino

Appendix A –Existing Pavement at Analysis Locations



Location ST-55 in the proximity of Sea Gull Court, Saratoga



Location ST-107, in the proximity of Glenburry Way, San Jose

Appendix B –Research Article Bibliography

Baulac, Marine, et al. *Optimisation with Genetic Algorithm of the Acoustic Performance of T-shaped Noise Barriers with a Reactive Top Surface*. Applied Acoustics, 2008.

Bernhard, Robert, et al. A Study of the Effect of Innovatively Textured Portland Cement Concrete Roadway Surfaces on Tire-Pavement Noise. Purdue University, December 2009.

Daltrop, Shira, et al. *Field Investigation of the Effects of Vegetation on the Performance of Roadside Noise Barriers*. Noise Control Engineering Journal, March-April 2012.

Defrance, Jerome and Jean, Phillipe. Acoustical Performance of Innovative Vegetated Barriers. Internoise Conference 2013.

Demizieux, P. and Dutilleux, G. Experimental Evaluation of CEN/TS 1793-4 on Two Noise Barriers with Caps. Internoise Conference, Czech Republic, 2004.

Donovan, Pual and Janello, Carrie. Sound Intensity Tire/Pavement Noise Measurement on SCL 85 in Saratoga, CA. July 27, 2011.

Ekici, Inan and Bougdah, Hocine. *A Review of Research on Environmental Noise Barrier*. Building Acoustics, Volume 10, Number 4, 2003.

Evaluating Pavement Strategies and Barriers for Noise Mitigation, Report 738. National Highway Cooperative Research Program, 2013

Evaluation of Grind and Groove (Next Generation Concrete Surface) Pilot Projects in California. Caltrans/UC Pavement Research Center, November 2012.

Harris, R.A. *Vegetative Barriers: An Alternative Highway Noise Abatement Measure*. Noise Control Engineering Journal, July-August 1986.

Hecken, John, et al. *A Framework for Selection of Functional Asphalt Overlays using Tire/Pavement Noise*. Internoise Conference 2015.

Janello, Carrie and Donovan, Paul. *Conclusion of the long-term evaluation of open-grade asphalt for the reduction of traffic noise: Interstate 80 (I-80) Davis Project*. Internoise Conference 2015.

Kragh, Jorgen. *Road Traffic Noise Mitigation - Recent Progress and Trends*. Internoise Conference 2015.

Monazzam, M.R. and Lam, Y.W. *Performance of Profiled Single Noise Barriers Covered with Quadratic Residue Diffusers*. Applied Acoustics, 2005.

Morgan, P.A. Review of Japanese Noise Barrier Research. Road and Hydraulic Engineering Division of Rijkswaterstaat (Netherlands), 2004.

Nilsson, et al. Environmental Methods for Transport Noise Reduction. (Results from European HOSANNA Research Project) CRC Press, 2015.

Ohm, Byung-Sik, et al. *Noise Characteristics between Tire and Surface of Porous Asphalt Pavements*. Internoise Conference 2015.

Quieter Pavement Pilot Program: Progress Report 3, Final Report 577. Arizona Department of Transportation, September 2012.

Radesten-Ekman, Maria, et al. *Case Study Evaluation of a Low and Vegetated Noise Barrier in an Urban Public Space*. Internoise Conference 2011.

Samuels, Stephen and Ancich, Eric. Recent Developments in the Design and Performance of Road Traffic Noise Barriers. *Acoustics Australia*, Volume 29, No. 2, 2001.

Sandberg, Ulf. *Reduction of Noise and Rolling Resistance by Horizontal Grinding of Asphalt Pavements*. Internoise Conference 2015.

Scofield, Larry. Development of Next Generation Low Maintenance Concrete Surface. January 2009.

State Route 85 Express Lanes Project: Initial Study with Negative Declaration/Environmental Assessment with Finding of No Significant Impact. Prepared by the State of California Department of Transportation in Cooperation with the Santa Clara Valley Transportation Authority, April 2015.

Trevino, Manuel. *Thin Overlay Mixes for Highway Noise Mitigation*. Internoise Conference 2015.
Vanchieri, Cori, et al. Cost-Benefit Analysis: Noise Barriers and Quieter Pavements. Institute of Noise Control Engineering of the USA, 2014. Appendix A.4.

Watson, Dustin. Evaluation of Benefits and Opportunities for Innovative Noise Barrier Designs. Final Report 572, Arizona Department of Transportation, 2006.

Watts, G. R. Godfrey, N.S. Effects on Roadside Noise Levels of Sound Absorptive Materials in Noise Barriers. *Applied Acoustics*, Volume 58, 1999.

Watts, G.R. Acoustic Performance of New Designs of Traffic Noise Barriers: Full Scale Tests. *Journal of Sound and Vibration*, Volume 177, 1994.

Watts, G.R. Acoustic Performance of Parallel Traffic Noise Barriers. *Applied Acoustics*, Volume 47, No. 2, 1996.

Appendix C – SR 85 Express Lanes Project, Summary of Long and Short-Term Measurements and Existing Noise Levels

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
LT-1	1	Central Avenue trail entrance to Stevens Creek Trail, Mountain View.	Mountain View	C(67)	64
ST-1	1	Front yard of 751 San Carlos Avenue, Mountain View	Mountain View	B(67)	54
ST-2	1	Rear Yard of 861 San Luppe Drive, Mountain View	Mountain View	B(67)	57
ST-3	1	500 W. Middlefield Road - Willow Creek Apartments, Mountain View	Mountain View	B(67)	59
ST-4	1	Equivalent to pool/common area of 500 W. Middlefield Road - Willow Creek Apartments, Mountain View	Mountain View	B(67)	55
ST-5	1	Alamo Court Park, Mountain View	Mountain View	C(67)	63
ST-6	1	West end of Creekside Park, Mountain View Representative of park and adjacent residential apartments.	Mountain View	B(67)/C(67)	61
ST-7	1	179 B Central Avenue condos.	Mountain View	B(67)	59
ST-8	1	117 Easy Street – Church of Scientology.	Mountain View	C(67)/D(52)	64
LT-2	2	Rear yard of 579 McCarty Avenue, Mountain View.	Mountain View	B(67)	57
ST-9	2	120 Pioneer Way – Jehovah’s Witness Church, Mountain View. No sensitive outdoor uses.	Mountain View	D(52)	71
ST-10	2	Avalon Apartments at Creekside, Mountain View.	Mountain View	B(67)	61

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-11	2	Equivalent to apartments adjoining SR 85 along Alice Avenue.	Mountain View	B(67)	68
LT-3	3	Rear yard of 1105 Remington Court, Sunnyvale.	Sunnyvale	B(67)	64
ST-12	3	150 Kings Row in Sahara Mobile Home Park.	Mountain View	B(67)	64
ST-12a	3	Stevens Creek Trail.	Mountain View	C(67)	71
ST-12b	3	271 Kings Row in Sahara Mobile Home Park.	Mountain View	B(67)	59
ST-13	3	Pool area of Americana Apartments.	Mountain View	B(67)	57
ST-14	3	Park along Franklin Avenue.	Mountain View	C(67)	62
ST-15	3	1240 Dale - Delmonico Apartments.	Mountain View	B(67)	64
ST-16	3	Rear yard of 1317 Brook Place.	Mountain View	B(67)	63
ST-17	3	Rear yard of 877 Heatherstone - Heatherstone Apartments.	Mountain View	B(67)	63
ST-18	3	End of Mockingbird Lane.	Sunnyvale	B(67)	64
ST-19	3	Alta Vista High School at setback of nearest classrooms to SR 85. Equivalent to Lubich Drive residential rear yards.	Mountain View	B(67)/C(67)/D(52)	69
ST-20	3	Rear yard of 1429 Brookmill Road.	Los Altos	B(67)	66
ST-21	3	Bernardo Avenue - Assisted living facility, adjacent to outdoor use area.	Sunnyvale	B(67)	71

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-22	4	Front of 1090 Butte Court.	Sunnyvale	B(67)	65
ST-23	4	Rear yard of 1272 Brookings.	Sunnyvale	B(67)	66
ST-24	4	Equivalent to 1112/1113 The Dalles Ave.	Sunnyvale	B(67)	68
ST-25	4	Rear yard of 1624 Bellmille Way.	Sunnyvale	B(67)/ D(52)	69
ST-26	4	Equivalent to rear yard of 1494 S. Bernardo Avenue.	Sunnyvale	B(67)	62
ST-27	4	10901 Maxine Avenue.	Cupertino	B(67)	64
ST-28	4	Rear yard of 1739 Banff Drive.	Sunnyvale	B(67)	65
ST-29	4	Front yard of 10760 Maxine Avenue.	Cupertino	B(67)	59
ST-30	5	10700 Stokes Avenue - Somerset Park. Receptor outside of study area.	Cupertino	N/A	--
LT-4	5	Rear yard of 10480 Stokes Avenue, Cupertino.	Cupertino	B (67)	62
ST-31	5	Small park next to Casa de Anza Apartments on Mary Avenue.	Cupertino	C(67)	65
ST-32	5	End of Fitzgerald Avenue.	Cupertino	B(67)	63
ST-33	5	Glenbrook Apartments.	Cupertino	B(67)	57
ST-34	5	De Anza College, Campus Drive.	Cupertino	C(67)/ D(52)	69
ST-35	5	Home of Christ Church on Bubba Street. No sensitive outdoor uses.	Cupertino	D(52)	74
ST-36	5	South end of Campus Drive - Child Development Center.	Cupertino	C(67)/ D(52)	74

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-36a1	5		Cupertino	C(67)/D(52)	60
ST-37	5	Rear yard of 826 September Drive.	Cupertino	B(67)	64
ST-38	5	Equivalent to rear yard of 7855 Festival Drive.	Cupertino	B(67)	67
ST-39	5	Park across from 7704 Orogrande Place.	Cupertino	C(67)	68
ST-40	5	Rear yard of 7726 Tomki Court.	Cupertino	B(67)	67
ST-41	5	Rear yard of 1101 Kentwood Avenue.	Cupertino	B(67)	63
ST-42	5	Rear yard of 1114 Scotland Drive.	Cupertino	B(67)	68
ST-44	5	Gardenside Lane at Kingsbury Place. Equivalent to outdoor use areas of residences.	Cupertino	B(67)	66
ST-45	5	Water Lily Way - townhomes.	San Jose	B(67)	64
LT-5	6	Congress Springs Park, Saratoga.	Saratoga	C (67)	65
ST-43	6	7150 Rainbow Drive, Building 1.	Cupertino	B(67)	66
ST-46	6	Rear yard of 20167 Pampas Court.	Saratoga	B(67)	62
ST-47	6	Equivalent to rear yard of 7168 Sharon Drive.	San Jose	B(67)	64
ST-48	6	1507 Eddington Place.	San Jose	B(67)	56
ST-49	6	Prospect Corners Apartments.	San Jose	B(67)	60

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-50	6	Rear yard of 19782 Solana Drive.	Saratoga	B(67)	64
ST-51	6	Rear yard of 20159 Marilla Court.	Saratoga	B(67)	61
ST-52	6	South corner of Kevin Moran Park.	Saratoga	C(67)	63
ST-53	6	Rear yard of 19899 Seagull Way.	Saratoga	B(67)	65
ST-54	6	13149 Anza Court. (Between 13126 and 13148 Anza Drive)	Saratoga	B(67)	61
ST-55	6	Rear yard of 19729 Yuba Court.	Saratoga	B(67)	67
ST-56	6	Front yard of 19201 Vineyard Lane – Vineyards of Saratoga condos.	Saratoga	B(67)	62
ST-57	7	19110 Bonnet Way. Represents both rear yards and front yards.	Saratoga	B(67)	55
ST-58	7	Park across from 18906 Belgrove Circle.	Saratoga	C(67)	62
ST-59	7	Alvarado Court.	Saratoga	B(67)	58
ST-60	7	14035 Abdulla Way.	Saratoga	B(67)	59
ST-61	7	Rear yard of 18581 Lyons Court.	Saratoga	B(67)	51
ST-62	7	5104 Westmont Avenue – Hacienda Quito Apartments.	San Jose	B(67)	58
ST-63	7	Rear yard of 18669 Casa Blanca Lane.	Saratoga	B(67)	59
ST-64	7	Rear yard of 1380 Elwood Drive.	Los Gatos	B(67)	59

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-65	7	5036 Pinetree Terrace – Roundtree Apartments.	Campbell	B(67)	59
ST-66	7	Los Gatos Estates on Pollard Road.	Los Gatos	B(67)	60
ST-67	7	Palmer Drive apartments, swimming pool.	Los Gatos	B(67)	56
ST-68	7	Equivalent to residential yards at end of Mulberry Avenue.	Los Gatos	B(67)	58
ST-69	7	Equivalent to rear yard of 748 Pollard Road.	Los Gatos	B(67)	58
ST-70	7	Elm Wood Court apartments.	Los Gatos	B(67)	60
ST-71	7	End of Del Loma Drive.	Campbell	B(67)	60
ST-72	8	Aventino Apartments, pool/playground.	Los Gatos	B(67)	57
ST-73	8	Bonnie View mobile home park, #58.	Los Gatos	B(67)	56
ST-74	8	Los Gatos Swim and Racquet Club, tennis courts.	Los Gatos	C(67)	65
ST-75	8	Front yard of 106 Pso Laura Court.	Los Gatos	B(67)	54
ST-76	8	Across from 16260 Burton Road.	Los Gatos	B(67)	57
ST-77	8	16160 East Mozart Avenue.	Los Gatos	B(67)	56
ST-78	8	Ashbrook Circle.	San Jose	B(67)	61
ST-79 ²	8	Rear side of Good Samaritan Hospital.	San Jose	D(52)	69

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-80	8	Equivalent to 2313 Clydelle Avenue.	San Jose	B(67)	62
ST-81	8	Equivalent to rear yard of 4643 Marbella Drive.	San Jose	B(67)	59
ST-82	8	Carolyn Norris Park.	San Jose	B(67)	59
LT-6	9	Rear yard of 1860 Little Branham Lane, San Jose	San Jose	B (67)	59
ST-83	9	Front yard of 4840 Anna Drive.	San Jose	B(67)	65
ST-84	9	Standish Drive.	San Jose	B(67)	57
ST-85	9	Equivalent to rear yard of 4794 Sally Drive.	San Jose	B(67)	61
ST-86	9	Rosswood Drive.	San Jose	B(67)	64
LT-7	10	Rear yard of 5071 Las Cruces Court, San Jose.	San Jose	B (67)	66
ST-87	10	Lawson Court, rear patio.	San Jose	B(67)	64
ST-88	10	Rear yard of 1599 Rebel Way	San Jose	B(67)	64
ST-89	10	5055 Dent Avenue.	San Jose	B(67)	59
ST-90	10	Appleseed School field. 5200 Dent Avenue	San Jose	C(67)	58
ST-91	10	Rear yard of 5141 Yucatan Way.	San Jose	B(67)	65
ST-92	10	Rear yard of 1373 Dentwood Drive.	San Jose	B(67)	62
ST-93	10	Rear yard of 5098 Tifton Way.	San Jose	B(67)	54
ST-94	10	5304 Ayrshire, equivalent to Almaden Elementary School playground.	San Jose	C(67)	58

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-95	10	Russo Park. Lansing Avenue	San Jose	C(67)	68
ST-99	10	Rear yard of 1265 Dentwood Drive.	San Jose	B(67)	62
LT-8	11	Rear yard at 5464 Chesbro Avenue, San Jose.	San Jose	B (67)	59
ST-96	11	Sanchez Drive.	San Jose	B(67)	62
ST-97	11	5403-5435 Sanchez Drive – apartments.	San Jose	B(67)	65
ST-98	11	Rear yard of 5283 Fell Avenue.	San Jose	B(67)	65
ST-100	11	5220 Turner Way, setback of Ohlone Court apartments.	San Jose	B(67)	58
ST-101	11	Rear yard of 5371 Glenbury Way	San Jose	B(67)	60
ST-102	11	Gunderson High School, large baseball field.	San Jose	C(67)	64
ST-102a	11	Gunderson High School, small baseball field.	San Jose	B(67)	59
ST-102b	11	Gunderson High School, open field closest SR 85.	San Jose	B(67)	71
ST-102c	11	Gunderson High School, tennis courts.	San Jose	B(67)	64
ST-103	11	In cul-de-sac near 772 Glenbury Way.	San Jose	B(67)	57
ST-104	11	End of Rutherglen Place, rear yard pool.	San Jose	B(67)	61
ST-105	11	Rear yard of 685 Glenbury Way, patio.	San Jose	B(67)	64

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-106	11	Rear yard on Gaundabert Lane.	San Jose	B(67)	62
ST-107	11	Rear yard of 579 Glenbury Way	San Jose	B(67)	66
ST-108	11	Rear yard of 5452 Chesbro Avenue.	San Jose	B(67)	61
ST-109	11	Rear yard of 5536 Chesbro Avenue.	San Jose	B(67)	64
ST-110	11	Front yard of 495 Velasco Drive.	San Jose	B(67)	60
ST-111	11	425 Don Fernando Way - Kinderwood Children's Center.	San Jose	C(67)	55
LT-9	12	Rear yard at 218 Herlong Avenue, San Jose.	San Jose	B (67)	63
ST-112	12	Rear yard of 5614 New Court.	San Jose	B(67)	56
ST-113	12	Rear yard of 5684 Crow Lane.	San Jose	B(67)	64
ST-114	12	Front yard of 5787 Ribchester Court.	San Jose	B(67)	57
ST-115	12	Rear yard of 5733 Hillbright Circle, patio.	San Jose	B(67)	62
ST-116	12	Rear yard of 5834 Bridle Way.	San Jose	B(67)	63
ST-117	12	Rear yard of 5871 Herma Street.	San Jose	B(67)	64
ST-118	12	Rear yard of 5874 Bufkin Court.	San Jose	B(67)	62
ST-119	12	Rear yard of 294 Herlong Avenue.	San Jose	B(67)	63

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-120	12	Rear yard of 5858 Treetop Court.	San Jose	B(67)	63
ST-121	12	End of Pala Mesa Drive.	San Jose	B(67)	62
ST-122	12	Palm Valley townhomes, common use area/pool.	San Jose	B(67)	61
ST-123	13	Kaiser Permanente, picnic area.	San Jose	C(67)	59
ST-124	13	Kaiser Permanente, picnic area.	San Jose	C(67)	63
ST-125	13	End of Holly Gillingham Lane.	San Jose	B(67)	62
ST-126	13	Front of 5983 S. Breeze Court.	San Jose	B(67)	54
ST-127	13	Monterey Grove Apartments.	San Jose	B(67)	62
ST-128	13	Setback of mobile homes nearest US 101 in Monterey Circle.	San Jose	B(67)	62
LT-11	B	Rear yard of 251 Crestridge Court, San Jose	San Jose	B (67)	64
ST-129	B	Swimming pool at 449 Danna Court	San Jose	B(67)	56
ST-130	B	Rear yard of 404 Birkhaven Place	San Jose	B(67)	61
ST-131	B	Rear yard of 7032 Basking Ridge Avenue	San Jose	B(67)	64
ST-132	B	Rear yard of 7406 Basking Ridge Avenue	San Jose	B(67)	60
ST-133	B	Coyote Creek Trail near Metcalf Park	San Jose	C(67)	62

Receptor ID	Segment Number	Location	City	Noise Abatement Criteria Activity Category ¹	Worst- Hour Existing Traffic Noise Level
ST-134	B	Parkway Fishing Lakes	San Jose	C(67)	62
ST-135	B	Parkway Fishing Lakes	San Jose	C(67)	64
ST-136 ²	B	Calibration point for residences on Malech Road	San Jose	G	69
ST-136a	B	Rural residence on Malech Road	San Jose	B(67)	66
ST-136b	B	Rural residence on Malech Road	San Jose	B(67)	67
ST-136c	B	Rural residence on Malech Road	San Jose	B(67)	66
ST-137	B	Rural residence off Coyote Creek Ranch Road	San Jose	B(67)	63

¹ See the Noise Abatement Criteria Activity Category Definitions on the table below.

Noise Abatement Criteria Activity Category Definitions

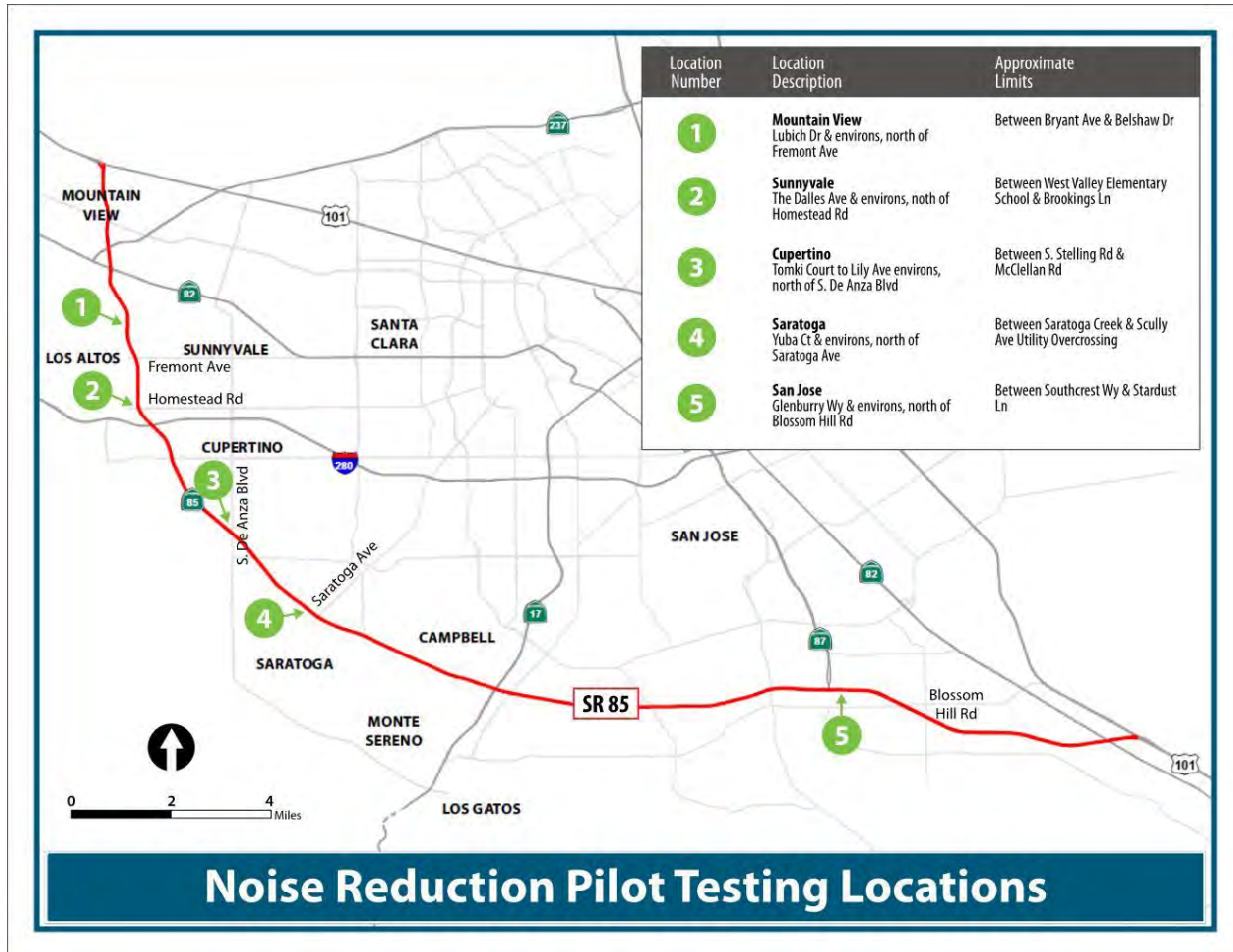
Activity Category	NAC, Hourly A-Weighted Noise Level, L _{eq} (h) ^{1,2}	Description of Activities
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B ¹	67 (Exterior)	Residential.
C ¹	67 (Exterior)	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52 (Interior)	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E	72 (Exterior)	Hotels, motels, offices, restaurants/bars, and other developed lands, properties, or activities not included in A–D or F.
F	No NAC—reporting only	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical, etc.), and warehousing.
G	No NAC—reporting only	Undeveloped lands that are not permitted.

Source: Caltrans 2011d

¹ Includes undeveloped lands permitted for this activity category.

² The L_{eq}(h) activity criteria values are for impact determination only and are not design standards for noise abatement measures. All values are A-weighted decibels (dBA).

Appendix D –Noise Reduction Pilot Testing Locations



Appendix E: Detailed Noise Analysis Location Information

No.	Receptor Designation	City	Description	Noise Level	Topography	Rationale
1	ST-19	Mountain View	Lubich Drive Residences along the west side of SR 85 north of Fremont Avenue.	69 dB	SR 85 below grade of residences	11 receptors affected; barrier cap and/or absorptive treatment may be effective (absorptive treatment will likely only benefit north Lubich Drive residences); note that additional receptors south of Alta Vista High School may also benefit (will be determined during detailed analysis). Roadway width to barrier height ratio is approximately 7.5:1.





Aerial View



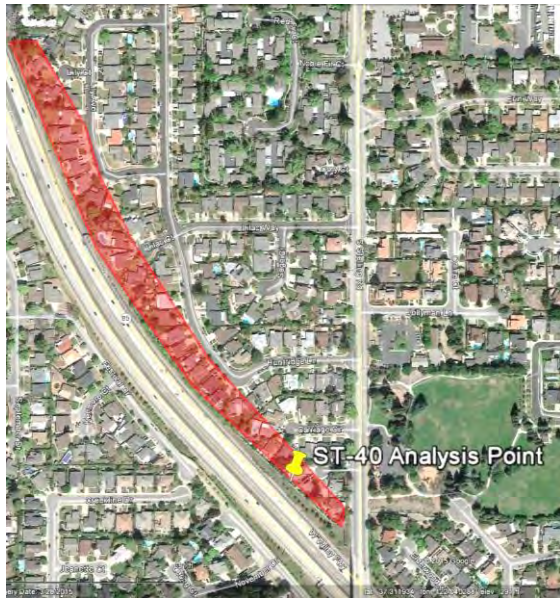
Bird's Eye View Looking West

Appendix E: Detailed Noise Analysis Location Information

No.	Receptor Designation	City	Description	Noise Level	Topography	Rationale
2	ST-24	Sunnyvale	The Dalles Avenue (and residences north and south of The Dalles) along the west side of SR 85 north of Homestead Road.	68 dB	Level ground	24 receptors affected, barrier cap and/or absorptive treatment may be effective. Roadway width to barrier height ratio is approximately 9.5:1.
 <p>Aerial View</p>			 <p>Bird's Eye View Looking West</p>			

Appendix E: Detailed Noise Analysis Location Information

No.	Receptor Designation	City	Description	Noise Level	Topography	Rationale
3	ST-40	Cupertino	Residences from Tomki Court to Lily Avenue, on the east side of SR 85 north of S. De Anza Boulevard	67 dB	SR 85 below grade of residences	28 receptors affected, barrier cap may be effective.



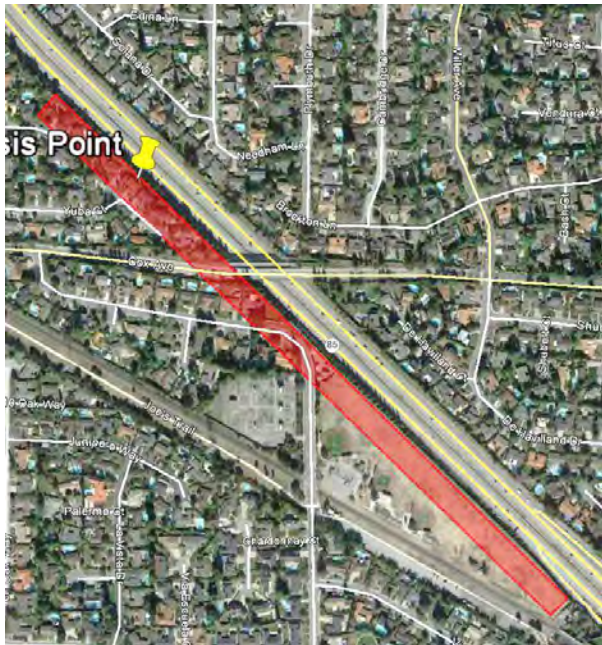
Aerial View



Bird's Eye View Looking East

Appendix E: Detailed Noise Analysis Location Information

No.	Receptor Designation	City	Description	Noise Level	Topography	Rationale
4	ST-55	Saratoga	Yuba and Sea Gull Court residences rear yards along the west side of SR 85, north of Saratoga Avenue.	67 dB	SR 85 below grade of residences	7 receptors affected, barrier cap and/or absorptive treatment may be effective. Roadway width to barrier height ratio is approximately 13:1.



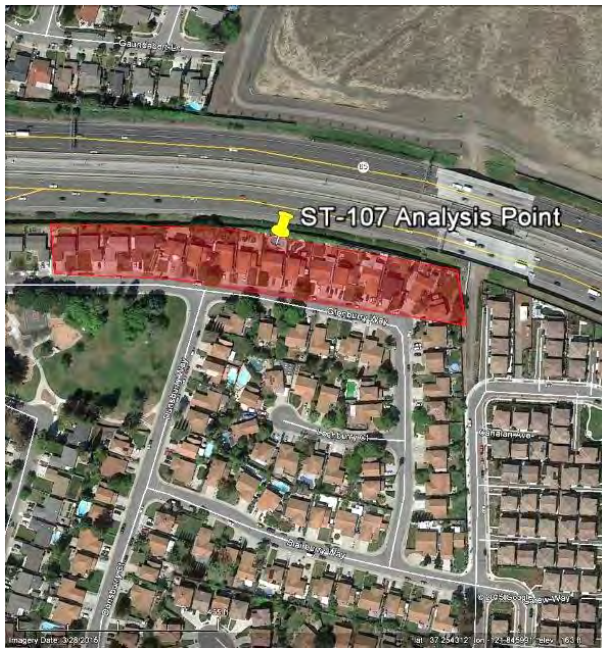
Aerial View



Bird's Eye View Looking West (7 Receptors Shown)

Appendix E: Detailed Noise Analysis Location Information

No.	Receptor Designation	City	Description	Noise Level	Topography	Rationale
5	ST-107	San Jose	Glenburry Way residences along the west side of SR 85, north of Blossom Hill Road.	66 dB	Level	16 residences, barrier cap may be effective.



Aerial View



Bird's Eye View Looking West

Note: Quieter pavement is a potential noise reduction measure at all locations proposed.

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
1	ST-19	Mountain View	Lubich Drive Residences along the west side of SR 85 north of Fremont Avenue.	69 dBA	SR 85 below grade at residences	16-feet	Noise reduction measures include quieter pavement and the addition of barrier caps to the existing sound wall. 11 noise receptors are identified below and will benefit from the noise reduction treatments.



← To West Fremont Avenue

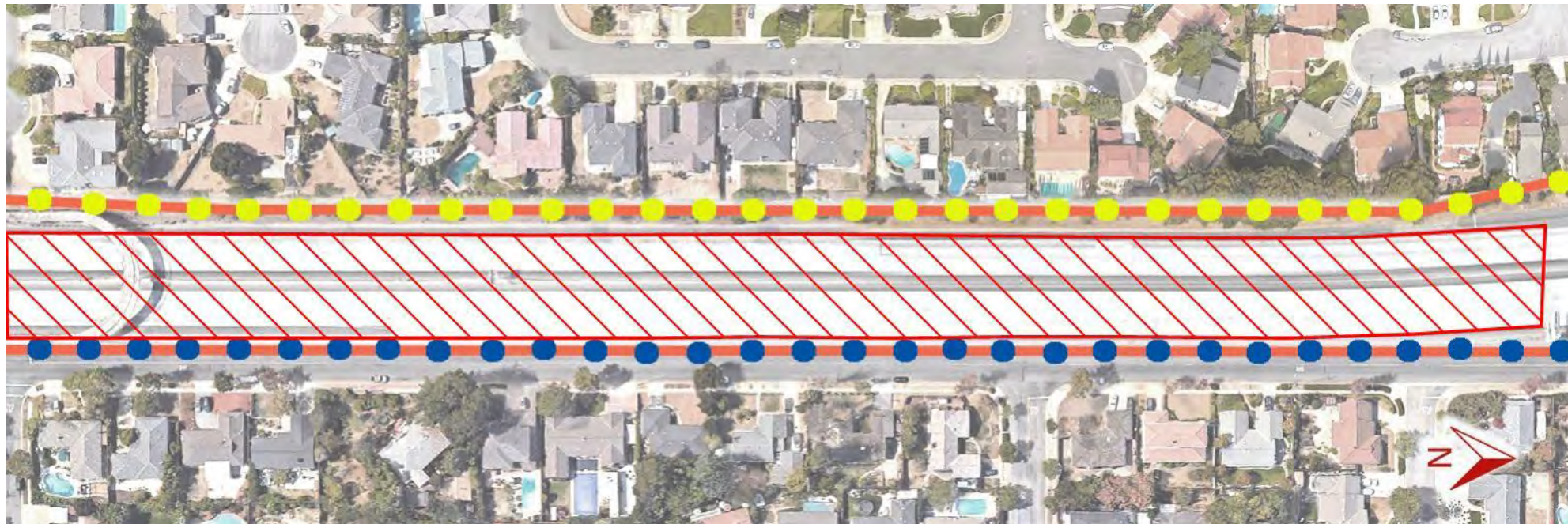
Looking West at the Receptors

To California SR 82 →

Legend					
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap		Quieter Pavement Area	

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
2	ST-24 Northern Segment	Sunnyvale	The Dalles Avenue (and residences north and south of The Dalles) along the west side of SR 85 north of Homestead Road.	68 dBA	Level ground	16-feet	Noise reduction measures include quieter pavement, the addition of barrier caps to the existing sound wall and/or absorptive treatments to the sound wall located on the far side of the freeway from the receptors. 24 noise receptors are identified below and will benefit from the noise reduction treatments. Roadway width to barrier height ratio is approximately 9.5:1.



← To West Homestead Road

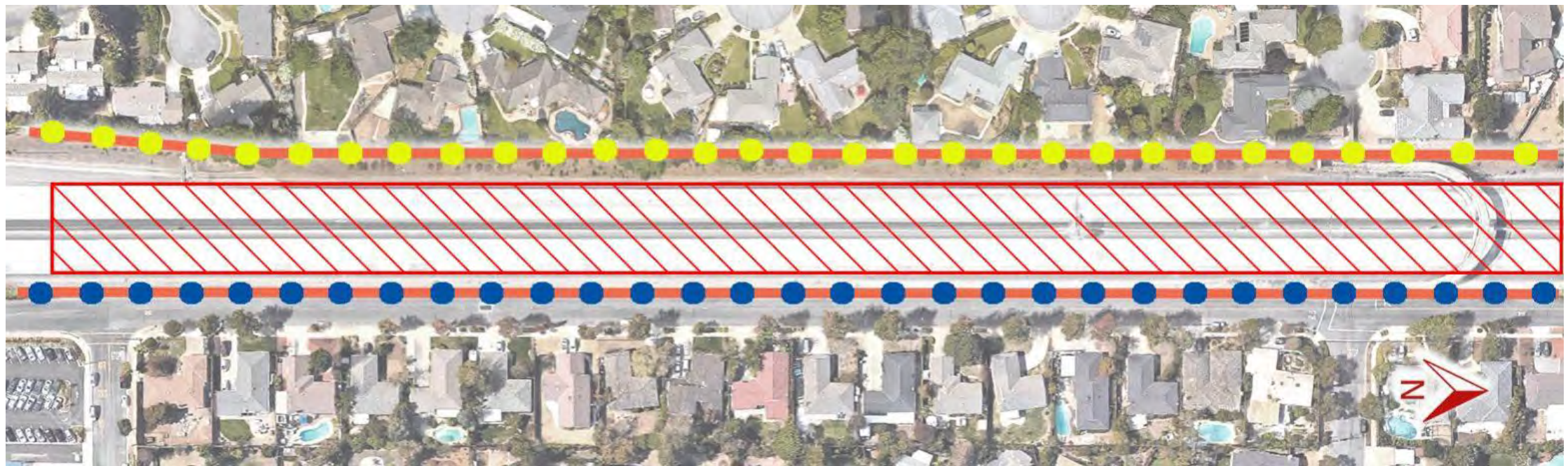
Looking West at the Northern End of ST-24 at the Receptors: Location 2.a

To West Fremont Avenue →

Legend					
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap		Quieter Pavement Area	

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
2	ST-24 Southern Segment	Sunnyvale	The Dalles Avenue (and residences north and south of The Dalles) along the west side of SR 85 north of Homestead Road.	68 dBA	Level ground	16-feet	Noise reduction measures include quieter pavement, the addition of barrier caps to the existing sound wall and/or absorptive treatments to the sound wall located on the far side of the freeway from the receptors. 24 noise receptors are identified below and will benefit from the noise reduction treatments. Roadway width to barrier height ratio is approximately 9.5:1.



Looking West at the Southern End of ST-24 at the Receptors: Location 2.b

← To West Homestead Road

To West Fremont Avenue →

Legend					
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap		Quieter Pavement Area	

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
3	ST-40 Northern Segment	Cupertino	Residences from Tomki Court to Lily Avenue, on the east side of SR 85 north of S. De Anza Boulevard	67 dBA	SR 85 below grade at residences	12-feet	Noise reduction measures include quieter pavement and the addition of barrier caps to the existing sound wall. 28 noise receptors are identified below and will benefit from the noise reduction treatments.



Looking North at the Northern End of ST-40 at the Receptors: Location 3.a



Looking North at the Receptors: Location 3.b

Legend				
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap		Quieter Pavement Area

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
3	ST-40 Southern Segment	Cupertino	Residences from Tomki Court to Lily Avenue, on the east side of SR 85 north of S. De Anza Boulevard	67 dBA	SR 85 below grade at residences	12-feet	Noise reduction measures include quieter pavement and the addition of barrier caps to the existing sound wall. 28 noise receptors are identified below and will benefit from the noise reduction treatments.



Looking North at the Receptors: Location 3.c



Looking North at the Southern End of ST-40 at the Receptors: Location

Legend				
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap		Quieter Pavement Area

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
4	ST-55 Northern Segment	Saratoga	Yuba and Sea Gull Court residences rear yards along the west side of SR 85, north of Saratoga Avenue.	67 dBA	SR 85 below grade at residences	12-feet	Noise reduction measures include quieter pavement, the addition of barrier caps to the existing sound wall and/or absorptive treatments to the sound wall located on the far side of the freeway from the receptors. 7 noise receptors are identified below and will benefit from the noise reduction treatments. Roadway width to barrier height ratio is approximately 13:1.



Looking North at the Northern End of ST-55 at the Receptors: Location



Looking North at the Receptors : Location

Legend			
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap	
		Quieter Pavement Area	

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
4	ST-55 Southern Segment	Saratoga	Yuba and Sea Gull Court residences rear yards along the west side of SR 85, north of Saratoga Avenue.	67 dBA	SR 85 below grade at residences	12-feet	Noise reduction measures include quieter pavement, the addition of barrier caps to the existing sound wall and/or absorptive treatments to the sound wall located on the far side of the freeway from the receptors. 7 noise receptors are identified below and will benefit from the noise reduction treatments. Roadway width to barrier height ratio is approximately 13:1.



Looking North at the Receptors: Location 4.c

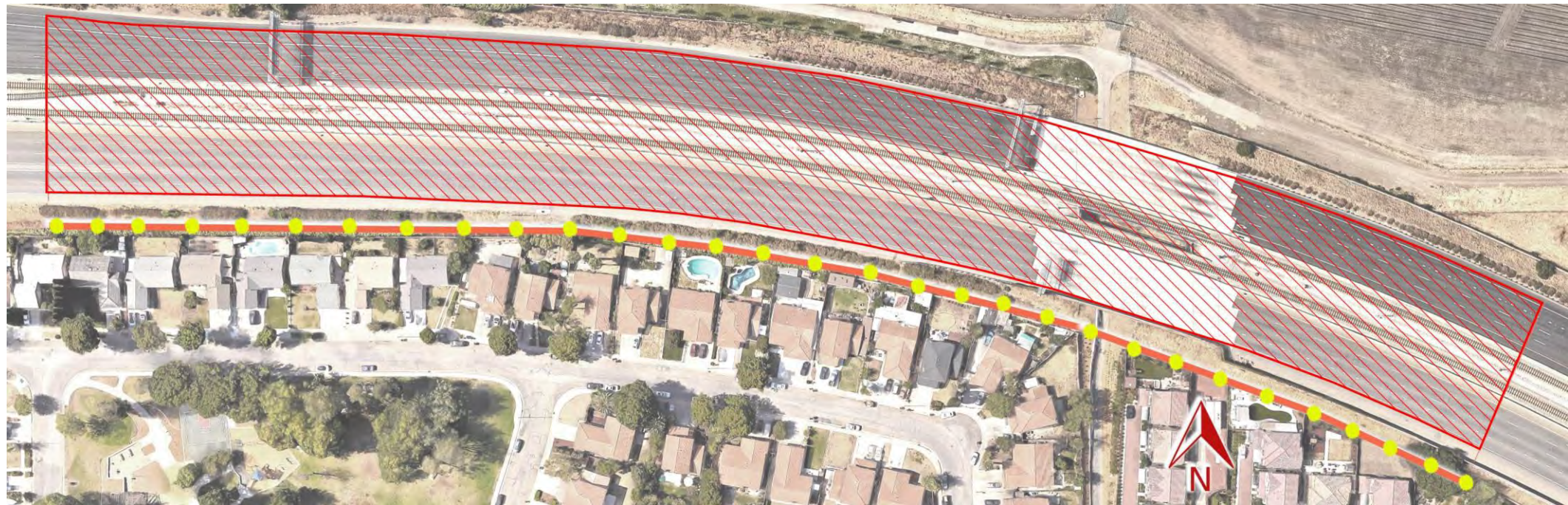


Looking North at the Southern End of ST-55: Location 4.d

Legend			
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap	
		Quieter Pavement Area	

Appendix F: Approximate Treatment Area

No.	Receptor Designation	City	Description	Noise Level	Topography	Existing Sound Wall Height	Treatment Options
5	ST-107	San Jose	Glenburry Way residences along the west side of SR 85, north of Blossom Hill Road.	66 dB	Level ground	12-feet	Noise reduction measures include quieter pavement and the addition of barrier caps to the existing sound wall. 16 noise receptors are identified below and will benefit from the noise reduction treatments.



← To Santa Teresa Boulevard

Looking North at the Receptors

To Blossom Hill Road →

Legend				
Existing Sound Wall w/ Absorptive Treatment		Existing Sound Wall w/ Barrier Cap		Quieter Pavement Area