Addendum Vibration Report

South Coast 101 High Occupancy Vehicle (HOV) Lanes

In Santa Barbara County between 0.22 miles south of the Bailard Avenue overcrossing in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara

05-SB-101-PM 1.4/12.3

05-0N7000

Prepared by the

State of California Department of Transportation

July 2014

Caltrans

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The environmental review, certification and any other action required in accordance with applicable federal laws for this project is being, or has been, carried out by Caltrans under its assumption of responsibility pursuant to 23 U.S.C. 327

Executive Summary

This April 2013 Supplemental Vibration Report augments studies previously presented in the June 2011 Vibration Report for the South Coast 101 High Occupancy Vehicle (HOV) Lanes Project in Santa Barbara County between 0.22 miles south of the Bailard Avenue overcrossing in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara, 05-SB-101-PM 1.4/12.3, 05-0N7000 (Mikel 2011). Additional sound walls or sound wall extensions have recently been proposed at eight locations in the project corridor. This Supplemental Report has been prepared to assess the potential for vibration impacts to built-environment resources located on adjacent parcels and to identify the areas where alternate sound wall construction methods will be employed to avoid potential vibration impacts. The proposed additional sound wall locations (S374, S464, S498, S519, S520, and S549) are depicted on maps located in Appendix C of this report, maps are intended to show additional parcels only.

This Supplemental Vibration Report concludes that, without modification, the proposed construction of one sound wall extension (Sound wall S519) and one new sound wall (Sound wall S549) would have the potential to cause vibration impacts to built-environment resources located on six adjacent parcels (See Appendix B). Sound wall design will therefore be modified to incorporate low-vibration footing design and construction methods at these locations.

Highway construction projects generate vibration in varying amounts, depending on the type of construction equipment and methods used, the intensity and duration of construction activities, distance from construction activities, and underlying soil types. In urban areas where homes and businesses are often adjacent to highways, there is a need for early identification and assessment of potential vibration impacts to built-environment resources.

The purpose of this report is to document potential vibration impacts from the proposed South Coast 101 High Occupancy Vehicle (HOV) Lanes project. The South Coast 101 High Occupancy Vehicle (HOV) Lanes Project proposes to widen State Route 101 to three lanes in each direction between 0.22 miles south of the Bailard Avenue overcrossing in the

City of Carpinteria and Sycamore Creek in the City of Santa Barbara, California [post mile (PM) 1.4 and 12.3. The current study is based on an extensive review of previous vibration monitoring and reports produced by Caltrans, and on standard procedures outlined in the Caltrans Transportation and Construction-Induced Vibration Guidance Manual (2004). Caltrans' protocol has been further substantiated by an independent study released in September 2012, *Final Report: Current Practices to Address Construction Vibration and Potential Effects to Historic Buildings Adjacent to Transportation Projects,* prepared under contract for the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on the Environment, with funding provided through the National Cooperative Highway Research Program Project 25-25.

The Caltrans vibration studies prepared for the South Coast 101 HOV Lanes project place emphasis on informing the public about construction-related vibrations, and establishing minimization measures that will protect residences and businesses near the highway, to the extent possible, from vibration impacts.

The assessment of vibration impacts also depends on the age and nature of the resource affected. Historic properties, for example, have a lower threshold for construction-related vibration impacts than recently constructed residences have. The area of potential effects for vibration impacts is therefore delineated to take these differing thresholds into account. For the June 2011 Vibration Report, fifteen properties that had previously been determined eligible for listing in the National Register of Historic Places, or that had been determined eligible pending the concurrence of the California State Historic Preservation Officer, were specifically evaluated for potential impacts from pile driving or construction activities occurring in close proximity by conducting site specific vibration analysis. For the current April 2013 Addendum Vibration Report, three historic properties were specifically evaluated. Two of these properties (the Ortega-Masini Adobe and Acacia Lodge) are listed on the National Register of Historic Places, and one property (Wylbron Lodge) has been determined eligible for listing on the National Register.

Appendix A of this report presents the Historic Property Vibration Induced Analysis – the results of the vibration risk assessment, based on conservative estimates of distance to the construction activity, intervening soil class, and the maximum energy rating for

the pile driver hammer used. Based on this “worst-case scenario” evaluation of potential vibration impacts to these properties, the analysis concluded that it does not appear that these historic properties would be affected due to construction activities. Appendix C of this report provides mapping for these properties.

Due to the length and urbanized character of much of the Highway 101 corridor in the project area, there are multiple locations where older (i.e., constructed in 1969 or earlier) but not historically significant buildings and residential dwelling units are in close proximity to proposed construction activities. For properties built prior to 1969, an empirical analysis was conducted and a buffer of 64 feet was used as the threshold for potential damage due to construction activities. The June 2011 Vibration Report identified a total of 57 parcels that had older buildings and residences within 64 feet of proposed pile driving activities, for example where sound walls, overpass structures and retaining walls will be constructed. Of these 57 parcels, 38 are residential structures and 19 are located within mobile home parks. The current Addendum Vibration Report identified five parcels occupied by older residences within 64 feet of proposed sound wall construction. Special provisions would be provided in the construction contract to avoid, minimize or mitigate these impacts. (Refer to Appendix A, B and C for a listing and maps of these properties).

The same methodology was used to evaluate buildings or structures that were considered newer or modern construction (1970 to present). Because these structures are generally built with more stringent seismic codes and construction practices and materials, they are more resistant to earth-borne movements such as vibration caused by pile-driving. Using the "safe distance" methodology discussed in Section 8 of this report, a safe distance of 34 feet was used as the threshold for potential damages due to construction activities. In other words, parcels with buildings within 34 feet of proposed pile driving (for sound walls, structures and retaining walls) were identified and evaluated individually. The June 2011 Vibration Report identified a total of 33 parcels as being located within this zone. The current April 2013 Addendum Vibration Report identified one parcel with a structure within 34 feet of sound wall construction, These properties have all been determined to have a small potential for architectural damages and/or human annoyance. (Refer to Appendix B and C for a listing and maps of these properties).

Based on the vibration analysis conducted in this report, low-vibration footing design and construction methodology will be employed within the identified 64-foot and 34-

foot buffers to ensure that these properties are not impacted or affected by activities associated with this project (Refer to Appendix C mapping). Other areas of the project where either no structures exist or structures are located farther than 64 foot will have standard special provisions provided in the construction contract to minimize or mitigate potential claims.

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1. Purpose of Vibration Study Report

The California Department of Transportation (Caltrans) proposes to make operational improvements to Route 101 in Santa Barbara County. The purpose of this project is to reduce congestion and improve travel time on Route 101 within the project limits. To achieve this purpose, the project proposes to construct an additional lane on Route 101 in both the northbound and southbound directions to be used as High Occupancy Vehicle (HOV) lanes. Adding capacity to the corridor will reduce peak hour congestion and improve freeway operations within the project limits.

As proposed, the project entails construction activities that have the potential to result in vibration impacts to sensitive receptors at particular locations. These activities include the construction of multiple soundwalls and sound wall extensions (with foundation types as yet unknown) throughout the corridor; the demolition of several hydraulic bridge structures and the construction of replacements; the removal of culvert parapets, wingwalls, and other hydraulic components to widen over-crossing structures; and, depending on the project alternative selected, the possible demolition and reconstruction of overpasses at Sheffield Drive and Cabrillo Boulevard.

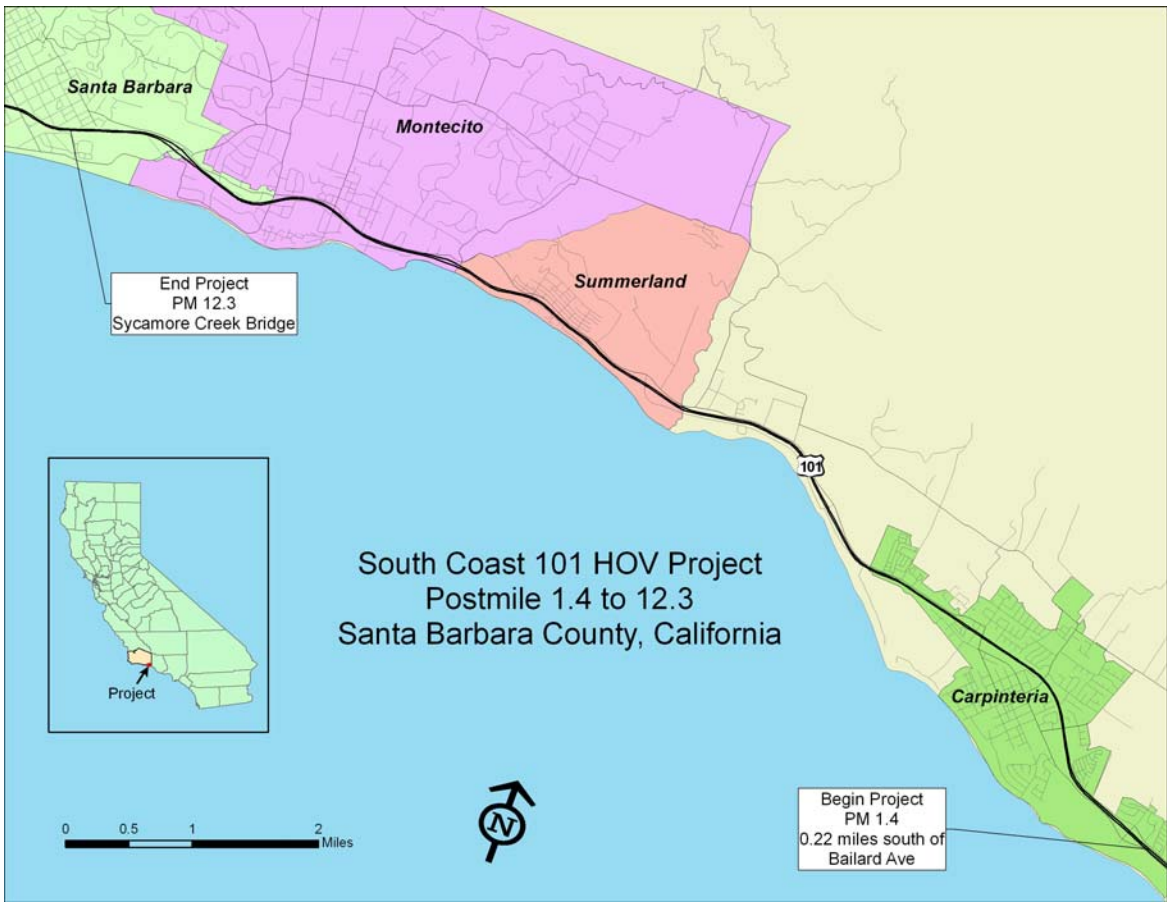
The purpose of this report is to identify the sources and characteristics of potential project-related vibration impacts. This vibration study is based on an extensive review of pertinent literature and on standard procedures provided in the Caltrans *Transportation and Construction-Induced Vibration Guidance Manual* (2004). Caltrans' protocol has been further substantiated by an independent study released in September 2012, *Final Report: Current Practices to Address Construction Vibration and Potential Effects to Historic Buildings Adjacent to Transportation Projects,* prepared under contract for the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on the Environment, with funding provided through the National Cooperative Highway Research Program Project 25-25.

The June 2011 Vibration Report and the April 2013 Addendum Vibration Report emphasize the importance of informing the project development team and the general public about identified potential construction-related vibrations, and of establishing avoidance and minimization measures that will protect residences and businesses near the highway, to the extent possible, from vibration impacts.

2. Project Description

The proposed project would add one High Occupancy Vehicle (HOV) lane in each direction to Highway 101 in Santa Barbara County between one-half mile south of Carpinteria Creek in Carpinteria, and Sycamore Creek in the City of Santa Barbara. The proposed widening would occur within the existing right-of-way, with the new HOV lanes being added either to the inside or outside of the existing edge of the roadway, or else in a combination of inside and outside widening to preserve median landscaping where possible. The purpose of the proposed new lanes is to relieve existing and projected future congestion on the highway in the project area (Figure 1).

Figure 1 Project Location/Vicinity Map



Purpose and Need

The existing capacity of Route 101 within the project limits and throughout much of the Santa Barbara south coast is congested during peak periods and weekends. During these times, the facility operates at Level of Service (LOS) F, congested flow conditions for two

to four hours daily in each direction (SBCAG *Congestion Management Program,* 2007). Without capacity improvements, LOS F conditions on Route101within the project limits are forecast to exceed nine hours a day in each direction by 2040 (SBCAG's 101 in Motion July 2006). The forecast rise in congestion and delay is a result of several factors, including increased long distance commuting from Ventura County; internal population growth, which is forecast to expand by ten percent by 2020 in Santa Barbara County (SBCAG *Regional Growth Forecast,* 2007); and interregional traffic growth, including goods movement. This project represents one component of a larger Route 101 corridor improvement strategy in northern Ventura County and southern Santa Barbara County.

Alternatives Description

The South Coast 101 High Occupancy Vehicle (HOV) Lanes Project proposes to widen State Route 101 to three lanes in each direction between 0.22 miles south of the Bailard Avenue overcrossing in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara, California [post mile (PM) 1.4 and 12.3. Caltrans proposes to widen State Route 101 between 0.44 miles south of Carpinteria Creek in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara. Three build alternatives and a no-build alternative is proposed for this project. Each build alternative would add a single High Occupancy Vehicle (HOV) lane in both the northbound and southbound directions and reconstruct interchanges at Sheffield Drive and Cabrillo Boulevard.

Three build alternatives – Alternatives 1, 2, and 3 – and a No-Build Alternative are proposed for this project. All build alternatives provide add an additional lane in each direction to provide for a part time High Occupancy Vehicle (HOV) facility within the project limits. Alternative 1 proposes to balance competing resource interests such as scenic views, wetlands, and median/outside landscaping. Alternative 2 proposes to maximize landscaping in the median. Alternative 3 proposes to construct all new paved lanes within the existing available median and maximizes the retention of outside planting. All build alternative improvements would be constructed primarily within the existing public right of way.

Water quality impacts are considered to be equivalent for the various project alternatives due to the similar size, scope, and nature of the proposed project features.

Common Design Features of the Build Alternatives

Alternatives 1, 2 and 3 would include the following:

Basic Common Design Features

- Add an additional lane in each direction on Route 101 to provide for a part time, continuous access High Occupancy Vehicle (HOV) facility within the project limits.
- Replace bridge structures at: Arroyo Paredon (Parida), Toro Canyon, Romero (Picay), Oak, and San Ysidro Creeks.
- Widen bridge structures at Franklin and Santa Monica creeks.
- Widen traffic undercrossing structures at South Padaro Lane and Evans Avenue.
- Reconstruct the northbound off ramp and on ramp at Salinas Street.
- Convert the existing northbound auxiliary lane to a through lane between the northbound on ramp at Cabrillo Boulevard and Salinas Street off ramp.
- Construct a southbound auxiliary lane between the Sheffield Drive on ramp and the Evans Avenue off ramp.
- Reconstruct the interchanges at Sheffield Drive and Cabrillo Boulevard.
- Consideration, as design options, seven mutually exclusive Cabrillo Blvd. interchange configurations (F, H, I, J, L, M, and Q). Interchange configurations under consideration include:

F) SB 1/2 DIAMOND – Close both median off ramps at Cabrillo Blvd.; improve the northbound Hermosillo Drive off ramp and the northbound Cabrillo Blvd. on ramp. Construct new on and off ramps to intersect at Cabrillo Blvd., northbound and southbound, immediately adjacent and to the right of the freeway lane.

H) TIGHT DIAMOND – Close all existing off ramps, including the Los Patos Way and Hermosillo Drive ramps. Construct new on and off ramps to intersect at Cabrillo Blvd., northbound and southbound, immediately adjacent and to the right of the freeway lanes.

I) EXISTING MAINLINES / IMPROVE LOS PATOS – Close both median off ramps at Cabrillo Blvd.; improve the northbound Hermosillo Drive off ramp, the southbound Los Patos Way off ramp, and the northbound Cabrillo Blvd. on ramp.

J) EXISTING MAINLINES / IMPROVE LOS PATOS – Identical to Configuration “I” with the addition of a southbound Los Patos Way on ramp.

L) NB 1/2 DIAMOND / IMPROVE LOS PATOS – Close northbound and southbound median off ramps at Cabrillo Blvd. and close the northbound Hermosillo Drive off ramp; add a southbound Cabrillo Blvd. off ramp; improve the southbound Los Patos Way off ramp and the northbound Cabrillo Blvd. on ramps.

M) NB 1/2 DIAMOND / IMPROVE LOS PATOS – Identical to Configuration “L” with the addition of a southbound Los Patos Way onramp.

Q) HALF SINGLE POINT – Close the Los Patos southbound off ramp, the northbound and southbound median off ramps at Cabrillo Blvd, and the northbound on ramp at Cabrillo; construct a new Cabrillo Blvd southbound right side off ramp that will undercross three southbound freeway lanes and a new northbound right side on ramp that will undercross three northbound freeway lanes – both will join at the existing median ramp intersections at Cabrilllo Blvd.; also improve the northbound Hermosillo Drive off ramp.

Additional Common Design Features

- Construct retaining walls at two locations: On the southbound outside shoulder at the right of way line along the southbound off ramp at Sheffield Drive (430 feet in length) and on the outside shoulder of the proposed southbound auxiliary lane from Sheffield Drive to Evans Avenue (1550 feet in length).
- Provide median landscaping in the first 0.2 mile at the southern limits of the project, and the last 0.5 mile of the project.
- Install replacement planting.
- Construct sound walls for noise abatement where appropriate.
- Provide noise attenuating pavement surface on all travel lanes.
- Relocate underground and aboveground utilities as needed.
- Lengthen cross culverts to accommodate additional pavement width.
- Construct maintenance vehicle pullout areas.
- Construct stormwater treatment facilities within the project limits and on publicly owned property near the Bailard Interchange (PM 1.6).

Unique Design Features of the Build Alternatives

Alternative 1: Balanced Resources

- This alternative proposes to balance competing resource interests such as scenic views, wetlands, and median/outside landscaping.
- Provide median landscaping, where appropriate, at several additional locations: from 0.2 mile from the southern limits of the project to Linden Avenue; the South Padaro Lane Interchange; and at the North Padaro Lane Interchange.
- The freeway outside edge of pavement requires widening in all locations where additional median landscaping is proposed.

Alternative 2: Maximize Median Planting

- This alternative proposes to maximize landscaping in the median, and recognizes that some identified scenic resources may be partially blocked and some wetland areas impacted.
- Provide median landscaping, where appropriate, at several additional locations: from 0.2 mile from the southern limits of the project to Reynolds Avenue; and from Santa Monica Road to the Evans Avenue Interchange.
- The freeway outside edge of pavement requires widening in all locations where additional median landscaping is proposed.
- Construct additional southbound auxiliary lanes between 1) the Santa Claus Lane on ramp and the Carpinteria Avenue off ramp and 2) the Reynolds Avenue on ramp and the Linden Avenue off ramp.
- Construct 3 additional retaining walls. One on the southbound shoulder at the right of way line ending at the Santa Claus Lane southbound on ramp (500 feet in length), one on the northbound shoulder near Greenwell Creek (700 feet in length) and one on the northbound shoulder near the northbound offramp to Summerland (300 feet in length.)

Alternative 3: Maximize Outside Planting

- This alternative proposes to construct all new paved lanes within the existing available median and maximizes the retention of outside planting.
- A single concrete barrier separating the two inside paved shoulders will be provided in the median between Carpinteria Creek and Olive Mill Road, which largely retains the existing outside edge of pavement within these areas.

No-Build Alternative

The No-Build Alternative would add no additional lanes to the highway, and would not relieve existing and future congestion.

3. Construction-Related Vibrations

Construction activities result in varying degrees and types of ground vibration, depending on the equipment and construction methods employed, the intensity and duration of the specific construction activity, and underlying soil types. Vibrations are also perceived in different ways, depending on the sensitivity of the receptor, and result in different kinds of physical impacts, depending on the age and condition of adjacent resources.

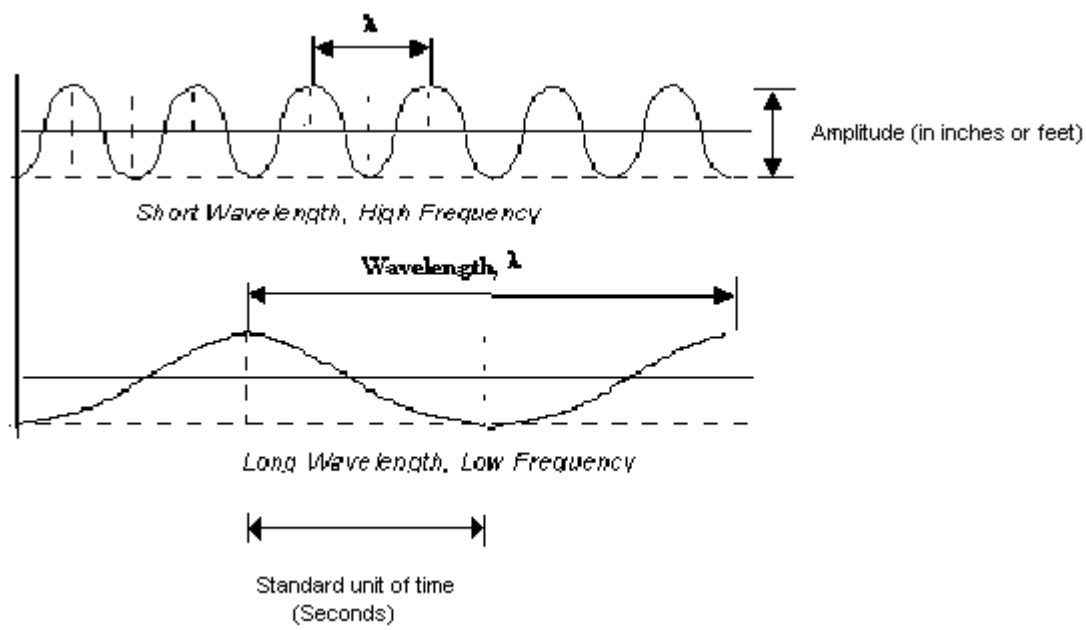
In most cases, vibration induced by typical construction equipment does not result in adverse effects on people or structures. Noise, rather than vibration, is generally perceived

as more noticeable and objectionable. In some instances, however, construction-related vibration has the potential to cause impacts.

Operation of construction equipment such as excavators, road graders, vibratory rollers, and paving machinery causes sustained ground vibrations that spread through the ground and diminish in strength with distance. Buildings founded on the soil in the vicinity of the construction site respond to these vibrations with varying results, ranging from no perceptible effects (low vibration levels), to perceptible vibrations (moderate vibration levels), to slight architectural damage (high vibration levels).

Construction activities such as demolition and blasting generate ground vibration characterized by sudden, intense energy waves. If the energy wave amplitude is high enough (Figure 2), the ground vibration has the potential to cause cosmetic damage (*e.g.,* crack plaster), or disrupt the operation of vibration sensitive equipment. Ground vibration and ground-borne noise can also be a source of annoyance to individuals who live or work close to vibration-generating activities.

Figure 2: Illustration of Wavelength, Frequency, and Amplitude



Equipment or activities typical of continuous vibration include: excavation equipment, static compaction equipment, tracked vehicles, traffic on a highway, vibratory pile drivers, pile-extraction equipment, and vibratory compaction equipment.

Equipment or activities typical of single-impact (transient) or low-rate repeated impact vibration include: impact pile drivers, blasting, drop balls, "pogo stick" compactors, and crack-and-seat equipment.

4. Vibration Standards

There are no Federal Highway Administration (FHWA) or State standards for vibration impacts. The traditional view has been that highway traffic and most construction vibrations pose no threat to buildings and structures, and that annoyance to people is similar to typical noise issues experienced from living near highways.

Caltrans, however, has conducted research and developed a *Transportation and Construction-Induced Vibration Guidance Manual* (CTVM) to assess the potential for construction-related vibration impacts. The type of assessment – qualitative or quantitative – and the level of analysis are determined by the scale of the project and by the sensitivity of surrounding land uses. A quantitative analysis is conducted in cases where construction vibration may result in prolonged annoyance or building damage.

5. Transportation Related Vibration

Most Caltrans projects are concerned with three types of transportation-related earth-borne vibration sources: normal highway traffic, light and heavy rail operations, and construction equipment and operations. Of the three transportation vibration sources listed above, construction vibrations are of greatest concern because of the nature of the sound waves produced and the potential for greater impacts. Construction equipment and operations on large jobs such as this one usually entail pile driving, pavement breaking, excavation, blasting, paving operations, and demolition of structures, which generate the highest construction vibrations.

Even so, ground vibrations from construction activities do not often reach the levels that can damage structures, but they can achieve the audible and perceptible (*i.e.,* "feelable") ranges in buildings very close to the site. A possible exception is the case of fragile buildings, many of them old, where special care must be taken to avoid damage. The construction vibration criteria include special consideration for such buildings. Pile driving, pavement breaking, blasting, and demolition of structures have potential impacts to buildings at distances of less than 100 feet from the vibration source.

6. Quantitative Construction Vibration Assessment Methods

Construction vibration should be assessed quantitatively in cases where there is significant potential for impact from construction activities (*e.g.*, blasting, pile-driving, vibratory compaction, demolition, and drilling or excavation in close proximity to sensitive structures). Earth-borne vibrations may be described by amplitude and frequency. Referring to earth-borne vibrations, amplitude is described by the local movement of soil particles. The formula for propagation of the energy wave is:

frequency (f) = wave velocity (c) / wavelength.
or
wave velocity (c) = $2\Pi f * D$ *(displacement)*

The resultant of this formula is the peak particle velocity (PPV), expressed in inches per second or millimeters per second. The recommended procedure for estimating vibration impacts from construction activities is as follows:

Damage Assessment (Equipment)

Select the equipment and associated vibration source levels at a reference distance of 25 feet from Table 18 (CTVM). Make the propagation adjustment according to the following formula (this formula is based on point sources with normal propagation conditions):

$PPV_{equip} = PPV_{ref} \times (25/D)^n$ (in/sec) where:

PPV (equip) is the peak particle velocity in in/sec of the equipment adjusted for distance.
PPV (ref) is the reference vibration level in in/sec at 25 feet from Table 18 (CTVM).
n is the soil type calibration factor from Table 17 (CTVM).
D is the distance from the equipment to the receiver.

For pile driving the equation becomes:

$PPV_{pile\ driver} = PPV_{ref} \times (25/D)^n \times (E_{equip}/E_{ref})^{0.5}$ (in/sec) where:

PPV (pile driver) is the peak particle velocity in in/sec for the hammer adjusted for distance.
PPV (ref) is equal to 0.65 in/sec at 25 feet for a reference pile driver.
n is the soil type calibration factor from Table 17 (CTVM).
D is the distance from the pile driver to the receiver.
E_{equip} is rated energy of impact pile driver in ft-lbs.
E_{ref} is 36,000 ft-lb (rated energy of reference pile driver)

Once the PPV is calculated, one would then apply the vibration damage criteria (Table 1, below, from TAV-04-01-R0201). The table correlates the potential human reaction to the potential damaging effect on buildings. It should be noted that there is a considerable variation in reported ground vibration levels from construction and pile driving activities. The data provide a reasonable estimate for a wide range of soil conditions.

A considerable amount of research has been done to correlate vibrations from single events such as dynamite blasts with architectural and structural damage. The U.S. Bureau of Mines has set a "safe blasting limit" of 2 in/sec. Below this level there is virtually no risk of building damage from a single event.

Safe levels for continuous vibrations from sources such as traffic are not as well defined. The Transport and Road Research Laboratory in England has researched continuous vibrations to some extent and developed a summary of vibration levels and reactions of people and the effects on buildings (Table 1, below). These are the criteria used by Caltrans to evaluate the severity of vibration problems. Traffic, train, and most construction equipment-produced vibrations (with the exception of pile driving, blasting, and some types of demolition) are considered continuous**.**

Table 1: Vibration Source Levels For Construction Equipment

Equipment		**PPV (in/sec) at 25 ft**	**Approximate Lv† at 25 ft.**
Pile Driver (impact)	Upper range	1.518	112
	Typical	0.644	104
Pavement Breaker		2.4*	110
Pile Driver (sonic)	Upper range	0.734	105
	Typical	0.170	93
Vibratory Roller		0.60	103
Clam shovel drop (slurry wall)		0.202	94
Hydro-mill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

Source: ntl.bts.gov/data/rail05/ch12.pdf .
† RMS (Root mean square) velocity in decibels (VdB) re 1 micro-inch/second. Comparable to decibels used in noise measurement.
*Caltrans studies conducted in 2000 on crack-and-seat operations along US 101 in Santa Maria indicate a more conservative value of 2.4 PPV (in/sec) at 25 feet should be used, rather than the earlier value of 1.25 PPV (in/sec) at 25 feet.

The numbers in the first 2 columns on the left are based on the peak particle velocity in the vertical direction (Rayleigh waves). Where human reactions are concerned, the value is at the point at which the person is situated (no set distance from the source). For buildings, the value refers to the ground motion but no allowance is included for the amplifying effect of structural components.

The "architectural damage risk level" for continuous vibrations (peak vertical particle velocity of 5 mm/sec or 0.2 in/sec) shown on Table 1 is one tenth of the maximum safe level of 50 mm/sec (2 in/sec) for single events.

All damage criteria for buildings are in terms of ground motion at the buildings' foundations. No allowance is included in Table 1 for the amplifying effects of structural components. Obviously, the way a building is constructed and the condition it is in determines how much vibration it can withstand before damage occurs. Table 1 shows a recommended upper level of 0.08 in/sec for continuous vibrations to which "ruins and ancient monuments" should be subjected. This criterion level may also be used for fragile historical buildings, or buildings that are in very poor condition.

Limited information is available concerning the damaging effects of pile driving. Although technically a series of single events, pile driver blows occurring often enough in a confined area could cause damage at a lower level than the single event criterion of 2 in/sec. Pile driving levels can exceed 0.2 in/sec at distances of 50 feet, and 0.5 in/sec at 25 feet. However, pile driving has been done frequently at these distances (50 feet and 25 feet) without structural damage to buildings.

Caltrans' general experience has been that almost never are traffic-generated vibrations damaging to structures near the highway. Construction generated vibrations, however, can exceed the point of architectural damage. Tables 1 and 2 illustrate this point—compare the peak particle velocity from pile drivers and pavement breakers at 25 feet (Table 2) to the effect on buildings (Table 1).

Table 2: Vibration Source Levels For Construction Equipment

Equipment		PPV (in/sec) at 25 ft	Approximate Lv† at 25 ft.
Pile Driver (impact)	Upper range	1.518	112
	Typical	0.644	104
Pavement Breaker		1.25	~110
Pile Driver (sonic)	Upper range	0.734	105
	Typical	0.170	93
Vibratory Roller		0.60	103

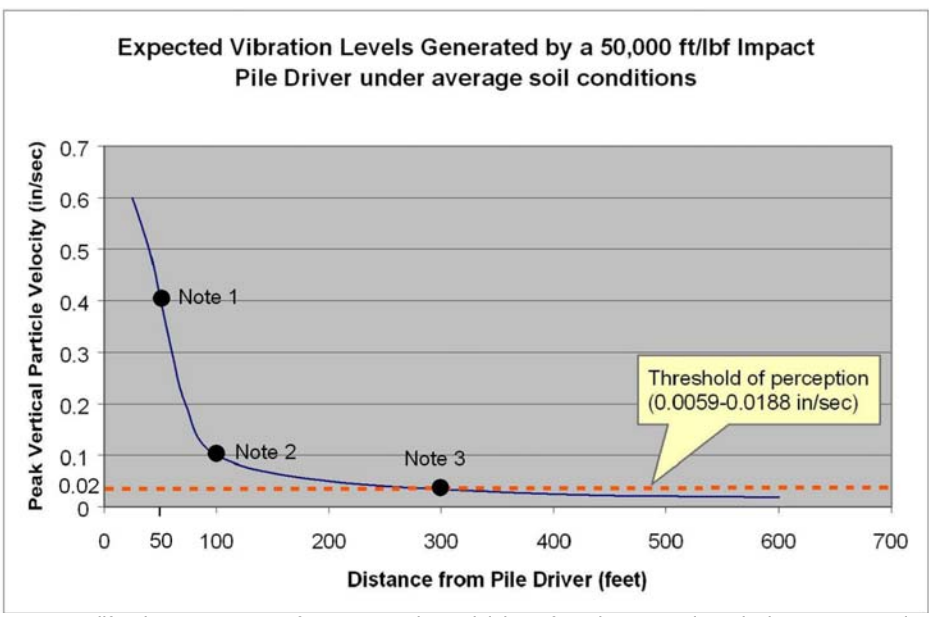
Equipment		PPV (in/sec) at 25 ft	Approximate Lv† at 25 ft.
Clam shovel drop (slurry wall)		0.202	94
Hydro-mill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

Source: ntl.bts.gov/data/rail05/ch12.pdf

† RMS (Root mean square) velocity in decibels (VdB) re 1 micro-inch/second. Comparable to decibels used in noise measurement.

Figure 3 shows how typical pile driving vibrations decrease with distance, for a 50,000 ft.-lb.[1] energy impact pile driver in average soil conditions. Clay soils provide more resistance to advancing piles and therefore generate higher vibration levels near the source than those in sandy soils. Vibrations in clay soils, however, tend to drop off more rapidly with distance than those in sandy soils.

Figure 3: Pile Driver Vibration Attenuation with Distance



Source: California Department of Transportation, Division of Environmental Analysis. Transportation Related Earth-borne Vibrations. 2004.

[1] One foot-pound is the amount of energy expended when a force of one pound acts through a distance of one foot along the direction of the force.

Note 1—vibrations may cause architectural damage (0.4-inches/second ppv—Table 2)
Note 2—continuous vibrations begin to annoy people (0.1-inches/second ppv—Table 2)
Note 3—vibrations may be perceived (~0.02-inches/second ppv—Table 2)

The above indicates that in any situation the probability of exceeding architectural damage risk levels for continuous vibrations from construction is very low. However, if pavement breaking or extensive pile driving is involved, then damage to nearby buildings or non-reinforced structures is a remote possibility. This may also be true if these operations occur within 50-100 feet of historical buildings (unless in excellent condition), buildings in poor condition, or buildings previously damaged in earthquakes.

The outer limits for architectural damage to historical buildings from pile driving, and perhaps from pavement-breaking operations as well, is 50 feet to 100 feet, while the limit for structural damage to at risk buildings is within 25 feet of the vibration source. Project features such as sound wall locations, retaining structures, drainage systems, new lane construction, etc., all have the potential to cause vibration impacts to adjacent receptor locations.

Buildings that are outside the limits for architectural and structural damage may still be close enough to pile driving sites that the annoyance level from vibrations may be exceeded. Partial demolition of bridge structures may occur at night, when noise and vibration impacts may disrupt local residents' sleep.

7. Proposed Construction Activities

Construction activities resulting from the proposed improvements have the potential to generate noise that can be perceived by residents up to 300 feet from the highway, and vibrations than can annoy and cause architectural and structural damage to residences and buildings adjacent to the work zone. Those activities include but are not limited to:

1) Demolition of Highway Structures: Demolition is typically conducted with a hoe ram mounted on a backhoe. Impacts from the hoe ram are similar to those of a pavement breaker, and would very likely generate similar vibrations. Structure demolition is proposed at multiple hydraulic structures. The project would additionally be removing parapets, wing walls, etc., to widen over-crossing structures. One traffic bearing structure at Sheffield Drive and two traffic bearing structures at Cabrillo Boulevard might be demolished, depending on the alternative selected.

2) Pavement Breaking: Also referred to as "cracking and seating," breaking up the concrete pavement with a large impact hammer is not proposed for this project.

3) Pile-driving: For bridges that will be reconstructed or widened, pile-driving would occur during daylight or nighttime hours, and would last for about eight hours per day. Pile-driving may also occur during the construction of retaining and sound walls throughout the corridor. Final details on footing types will come after the completion of geotechnical studies. Once local soil types have been classified for any structure construction, foundation types would be determined at that time, and the need for pile driving in areas of weak soils would be explored. Piles would only be utilized if necessary, otherwise standard foundations would be constructed.

8. Potential Impacts from Construction

This report documents the impacts of proposed construction activities as currently designed. Because of its greater potential to cause construction-related vibration damage or annoyance, pile driving has been selected as the hypothetical construction activity for the purpose of calculating project impacts. Options with the potential for fewer impacts will be evaluated once the geotechnical studies are complete and during the Plans, Specifications and Estimates (PS&E) phase of the project when Caltrans Structures Design will determine the feasibility of foundations for the retaining walls and sound walls that do not require driven piles. One example of these is Mechanically Stabilized Earth (MSE) retaining walls. Structures Design will also explore the feasibility of micro-pile foundations, which are less vibration intensive than the currently planned driven piles for sound wall foundations. The development of alternative foundation types would help minimize potential vibration impacts to residents near the construction project. Additionally, as depicted on the mapping contained in Appendix C (sheets 11-20), properties that fall within or adjacent to established buffer zones will have site specific low vibration construction methods employed to ensure there are no impacts due to construction induced vibration.

Depending on the duration, intensity and timing of the proposed construction activities, structure demolition, pavement breaking, and pile driving may affect residents and structures adjacent to the proposed construction activity. The effects of activities like pile driving and pavement breaking lessen with distance from the vibration source as the energy from the impacts is absorbed by the sub-surface. In general, three zones of lessening intensity are established within the CTVM to classify the expected impacts from proposed construction activities. These zones of influence are general in nature and are defined in the CTVM as follows:

Perception: A 300-foot radius zone is shown in Figure 3 where the expected vibration level crosses the (dotted) threshold of perception line (0.02 inches per second peak particle velocity). Residents will begin to perceive vibrations at this distance.

Annoyance: A 100-foot radius zone is shown in Figure 3 where continuous vibrations begin to annoy people (0.10-inches per second peak particle velocity). Figure 3 shows that this level occurs at about 100 feet from the source.

Damage: The CTVM established a generalized 60-foot radius, shown in Table 2, where continuous vibrations may cause architectural damage (0.4-inches per second peak particle velocity assuming a 50,000 foot – pound energy impact pile driver in average soil conditions). This radius does not take into account more fragile, historic structures. For this project, site specific vibration analysis was conducted to help better assess potential impacts from potential pile driving activities specifically related to various types of structures. Encountered soil conditions and a more realistic maximum credible energy rating for pile driving equipment were used to calculate project specific radii to predict whether continuous vibrations could cause architectural damage.

For determining project specific "damage" radii, project specific piles and pile driver maximum energy ratings must be known. Because these have not yet been specified for this project, a conservative estimate must be prepared assuming that the largest piles will be used, consequently requiring the highest credible pile driver energy rating.

To determine the maximum energy rating for a pile driver, the input energy must not exceed that which would cause failure to the pile during driving. The assumption should be a pre-cast reinforced concrete displacement pile as this type requires the highest hammer energy as compared to other pile types.

Caltrans utilizes three standard classes of pre-cast reinforced concrete piles: Class 90, Class 140 and Class 200, with the class numbers representing the nominal axial strength (ultimate capacity) of the pile in tons. For Caltrans applications, assuming standard plan piles, the largest credible driven pre-cast pile to be specified for a sound wall or retaining wall installation is the Class 140 pile, and the largest for a traffic structure is the Class 200 pile. These three pile classes are all specified at 15" diameters with additional strength being supplied by reinforcing steel. There are other types available, but these pre-cast reinforced

concrete displacement piles require the highest hammer energy as compared to other pile types.

Both AASHTO and FHWA recommend that for determining pile failure loads, the Davisson approach should be used for small (*i.e.,* less than 24") diameter reinforced concrete piles. Davisson developed the elastic offset approach to define pile failure or ultimate capacity. Davisson's offset limit load criterion defines ultimate load as the point at which the displacement of the pile head meets a limit that is offset to the elastic compression line of the pile. Bengt H. Fellenius (PCI Journal Jan-Feb 1977) states that Davisson's work limits the hammer to a maximum rated energy, Emax (in ft-lbs) as follows:

Emax = 60 * A* (B^0.5),

where A is the pile cross sectional area in square inches and B is the pile diameter in inches. Based on this equation, the maximum rated energy of a hammer for a standard plan pile at 15" diameter should be limited to 42,000 ft-lbs.

After determining the maximum energy rating for the driving hammer based on pile size, potential risk of damage distances and peak particle velocity can be determined assuming the default coefficients for unknown soil types. For example: if one uses a hammer of 42,000 ft-lbs with a .5 $PPV_{pile\ driver}$ with n = 1.1 (unknown soil type) in the following equation: $PPV_{pile\ driver} = PPV_{ref} \times (25/D)^n \times (E_{equip}/E_{ref})^{0.5}$ (in/sec); you get a "minimum safe from damage distance" of 34 feet for newer or modern construction. Using the lowest PPV of 0.08 and n = 1.1 you get a "minimum safe from damage distance" of 179 feet for historic, extremely fragile structures. The minimum safe distance results based on the above methodology is as follows:

a)	historic, extremely fragile structures	179 feet	(PPV less than 0.08 in/sec)
b)	historic, fragile structures	147 feet	(PPV less than 0.10 in/sec)
c)	historic old structures	64 feet	(PPV less than 0.25 in/sec)
d)	old structures	54 feet	(PPV less than 0.30in/sec)
e)	new or modern construction	34 feet	(PPV less than 0.50 in/sec)

After determining that the project contained only one historic, fragile structure, the balance of the structures were conservatively categorized as either historic/old or new at safe distances of 64 feet and 34 feet respectively. The above approximate safe distances have been used as a screening tool to check specifically for any structures that fall within the

relevant limit for potential architectural damage impacts. The "safe distance" simply means that structures located farther than this distance from the source of vibration have virtually no risk of damage during pile driving or construction operations. Once the safe distance line has been established, properties that fall within the various limits of potential damage can be evaluated more thoroughly for potential damage utilizing specific soil types for each particular location.

9. Site Specific Project Analysis

Using the screening analysis methodology discussed in the previous section, specific properties and structure types that are located within or adjacent to the established safe distance zones were further evaluated to determine their risk of structural damage or annoyance to people.

Historic Property Analysis

Several properties along the project corridor have been listed in, or determined eligible for listing in, the National Register of Historic Places. These properties have been individually evaluated for potential impacts from pile driving activities. The Ortega-Masini Adobe is the only historic, extremely fragile structure in the project corridor, requiring a buffer of 179 feet from vibration-inducing construction activities. The other historic properties were evaluated as historic, old structures, requiring a buffer of 64 feet from vibration-inducing construction activities.

Appendix A provides the results of the vibration risk assessments based on conservative estimates of distance to the construction activity, soil class, and the maximum energy rating for the pile driver hammer.

Using the methodology outlined in the CTVM, Table 3 indicates that, based on the analysis conducted specifically for this project, there are no historic structures on this project located near enough to pile driving activities that would be expected to be damaged.

Older, Non-Historic Property Analysis

Historic-period properties (*i.e.,* constructed in 1969 or earlier) that were determined ineligible for the National Register were nonetheless evaluated for vibration impacts because of their age, using the "safe distance" methodology discussed above in Section 8. For these properties, a safe distance of 64 feet was used as the threshold for potential damages due to construction activities. In other words, parcels with historic-period buildings within 64 feet of proposed pile driving (for sound walls, structures and retaining walls) were

identified and evaluated individually. A total of 38 residential parcels were identified in the June 2011 Vibration Report, and an additional five residential parcels were identified in the April 2013 Addendum Vibration Report, for a total of 43 parcels. These properties have all been determined to have an increased potential for human annoyance. Special provisions will be provided in the construction contract to minimize or mitigate potential impacts. Additionally, as depicted on the mapping contained in Appendix C, properties that fall within or adjacent to established buffer zones will have site specific low vibration construction methods employed to ensure there are no impacts due to construction induced vibration. (Refer to Appendix B and C for a listing and maps of these properties).

Newer Property Analysis

The same methodology was used to evaluate buildings or structures that were considered newer or modern construction (1970 to present). Because these structures are generally built with more stringent seismic codes and construction practices, they are more resistant to earth-borne movements such as vibration caused by pile-driving. Using the "safe distance" methodology discussed in Section 8, a safe distance of 34 feet was used as the threshold for potential architectural damages due to construction activities. In other words, parcels with buildings within 34 feet of proposed pile driving (for sound walls, structures and retaining walls) were identified and evaluated individually.

A total of 33 parcels were identified as being located within this zone in the June 2011 Vibration Report, and one additional parcel was identified in the April 2013 Addendum Vibration Report, for a total of 34 parcels. These properties have all been determined to have an increased potential for architectural damages and/or human annoyance. Special provisions will be provided in the construction contract to minimize or mitigate potential impacts. Additionally, as depicted on the mapping contained in Appendix C, properties that fall within or adjacent to established buffer zones will have site specific low vibration construction methods employed to ensure there are no impacts due to construction induced vibration. (Refer to Appendix B for a listing and maps of these properties and Appendix C for mapping).

Mobile Home Analysis

Nineteen parcels located within several mobile home parks were identified within a safe distance limit of 64 feet. Due to the foundation type for these structures, these properties do not have rigid foundations and are built to withstand the type of vibration typical of sound wall construction and do not have great potential for vibration related impacts. (Refer to Appendix B and C for a listing and maps of these properties).

10. Vibration Reduction Strategies

As with construction noise, in many cases the information available during the preliminary engineering phase will not be sufficient to define specific construction vibration mitigation measures. In such cases, it is appropriate to describe and commit to a Vibration Reduction and Minimization Plan (VRMP) that will be developed and implemented during the final design and construction phases of the project. The VRMP will be produced by Design with input from the Environmental division, Construction, and other functional units as appropriate. The objective of the VRMP should be to avoid construction vibration damage using all reasonable and feasible means available. The VRMP should provide a procedure for establishing thresholds and limiting vibration values for structures with a potential to be adversely affected, based on an assessment of each structure's ability to withstand the loads and displacements due to construction vibrations. The VRMP should also include the development of a vibration monitoring strategy during final design and the implementation of compliance and where needed building monitoring program including pre and post photo survey during construction as feasible.

A few alternatives to standard driven piles are discussed below. The list is not meant to be inclusive or to suggest that these measures are mandatory for use, rather the listed measures merely represent the types of techniques that could be employed. Unlike with noise, there is no easy way to mitigate earth-borne vibrations. There are however, a limited number of options available to reduce their impact. Once detailed geotechnical data is available, the options discussed below will be evaluated in further detail in the aforementioned VRMP developed specifically for the project.

Alternative Foundation Types: The easiest way to eliminate the potential for structural damage or human annoyance is simply to avoid driving piles in the first place. Standard plan spread footings should be used in all instances where their use is permitted. Typically piles must be driven in wet or unfavorable soil conditions. Standard spread footings are a much cheaper foundation type and would be predominately used on this project.

Jetting: Jetting is a pile driving aid in which a mixture of air and water is pumped through high-pressure nozzles to erode the soil adjacent to the pile to facilitate placement of the pile. Jetting can be used to bypass shallow, hard layers of soil that would generate high levels of vibration at or near the surface if an impact pile driver were used.

Pre-drilling: Pre-drilling a hole for a pile can be used to place the pile at or near its ultimate depth, thereby eliminating most or all impact driving.

Cast-in-place or auger cast piles: Using cast-in-place or auger cast piles eliminates impact driving and limits vibration generation to the small amount caused by drilling, which is negligible.

Non-displacement piles: Use of non-displacement piles such as H piles may reduce vibration from impact pile driving because this type of pile achieves its capacity from end bearing rather than from large friction transfer along the pile shaft.

Pile cushioning: With pile cushioning, a resilient material is placed between the driving hammer and the pile to increase the period of time over which the energy from the driver is imparted to the pile. Keeping fresh, resilient cushions in the system can reduce the vibration generated by as much as a factor of 2.

Scheduling: Limiting construction activities to specific times can minimize disturbance at nearby vibration-sensitive sites: Adverse effects can be avoided if pile driving is not scheduled for times at which vibration could disturb equipment or people. For example, if pile driving near a residential area can be scheduled during business hours on weekdays, many people will be at work and will therefore not be affected.

Using alternative non-impact drivers: Several types of proprietary pile driving systems have been designed specifically to reduce impact-induced vibration by using torque and down-pressure or hydraulic static loading. These methods would be expected to significantly reduce adverse vibration effects from pile placement. The applicability of these methods depends in part on the type of soil. The following information is provided for informational purposes only. This discussion is not intended to favor any commercial product; inclusion of information on these products does not constitute endorsement or approval by Caltrans.

11. Standard Avoidance, Minimization, and/or Mitigation Measures

Avoiding the adverse vibration effects caused by planned construction activities and subsequent highway operations involves informing the public of the potential for these effects and using physical methods to reduce vibration impacts. Information disseminated to the public about the kinds of equipment, expected noise levels and durations will help to forewarn potentially affected neighbors about the temporary inconvenience. In these cases, a general description of the variation of noise levels during a typical construction day may be helpful.

In general, literature on the subject shows that only blasting, pile driving, and pavement breaking have documented examples of potential damage to buildings (American Association of State Highway and Transportation Officials [AASHTO] 1990). For pile driving and pavement breaking, the potential for damage from vibration is at locations in relatively close proximity to the activity. However, because the threshold of perception for vibration is much lower than the threshold for damage, claims of damage often arise because of perceptible vibration and not because of actual damage.

Standard Special Provisions (SSPs) have been developed that the contractor must implement to accommodate these types of potential issues. Typically these SSPs include performance based mitigation measures such as before-and-after structural evaluations of the subject property by a licensed structural engineer including photo/video surveys. The SSPs state that, since Caltrans does not control the means and methods of construction, the contractor is liable if damage is done to any structure due to their activities.

Every attempt should be made to mitigate the adverse vibration effects from construction activities through the use of modern techniques, procedures, and products. It is equally important to develop a process to avoid and, if necessary, address problems identified by the public that can arise from construction activities, even when the levels of vibration are well below the levels at which damage to structures or excessive annoyance to humans are expected to occur. The following steps will be taken in development of the location-specific vibration reduction plan:

- Identify potential problem areas surrounding the localized project work area,
- Determine conditions that exist before construction begins,
- Notify nearby residents and property owners that vibration-generating activity is imminent,
- Inform the public about the project and potential vibration-related consequences,
- Schedule work to reduce adverse effects,
- Design construction activities to reduce vibration,
- Monitor and record vibration from the activity if necessary;
- Respond to and investigate complaints.

To reduce the effects of construction vibration from pile driving, structure demolition and pavement breaking for Vibration Sensitivity zones at 100-foot and 300-foot intervals, the following measures are recommended to be included in a Vibration Reduction Plan:

1) Notify residents within 300 feet of areas where construction activities and pavement breaking will take place at least two weeks in advance of the proposed activity through the local news media and by mail. Residents may wish to secure fragile items that could be damaged by shaking. See Figure 3 for the attenuation of vibration with distance from a pile driving or pavement breaking activity.

2) When especially egregious activities are expected to be conducted at night, arrange motel rooms for residents living adjacent to the proposed activity when protracted vibrations approaching 0.20 inches/second are expected at their residences.

3) Monitor and record peak particle velocities near sensitive receptors identified while the highest vibration producing activities are taking place (Refer to Appendix A for maps and a listing of these properties)

4) Use rubber tired instead of tracked vehicles near vibration sensitive areas.

5) For paving operations and bridge work, assure that night joints and bridge conforms are as smooth as possible, especially where there is heavy truck traffic near residences.

6) Perform activities most likely to propagate objectionable vibrations during the day, or at least before most residents retire for the night.

7) Restrict pavement breaking to daylight hours.

8) As much as possible, conduct pile driving during daylight hours.

9) Phase demolition, earth-moving and ground-impacting operations so as not to occur in the same time period. Unlike noise, the total vibration level produced could be significantly less when each vibration source operates separately.

10) Use of Standard Plan cast in drill hole (CIDH) piles, trench footings, or spread footings are the preferred foundations for locations requiring designs utilizing low intensity vibration construction as follows (PPV not to exceed):

Carpinteria

NB - PM 3.31to 3.46 <0.25 in/sec at buildings
NB - PM 3.66 to 3.73 <0.50 in/sec at buildings
NB - PM 3.73 to 3.76 <0.25 in/sec at buildings
NB - PM 3.76 to 3.79 <0.50 in/sec at buildings

SB - PM 3.68 to 3.72 <0.25 in/sec at buildings
SB - PM 3.72 to 3.74 <0.50 in/sec at buildings
SB - PM 3.74 to 3.78 <0.25 in/sec at buildings
SB - PM 3.90 to 3.95 <0.25 in/sec at buildings
SB - PM 3.95 to 4.05 <0.50 in/sec at buildings

Summerland

NB - PM 7.84 to 7.89 <0.25 in/sec at buildings
NB - PM 7.89 to 7.94 <0.25 in/sec at buildings
NB - PM 8.05 to 8.18 <0.25 in/sec at buildings
NB - PM 8.20 to 8.24 <0.25 in/sec at buildings
NB - PM 8.41 to 8.44 <0.50 in/sec at buildings
NB - PM 8.47 to 8.53 <0.50 in/sec at buildings

Sheffield

NB - PM 9.09 to 9.14 <0.25 in/sec at buildings
NB - PM 9.19 to 9.23 <0.25 in/sec at buildings

Montecito/Santa Barbara

SB - PM 9.56 to 9.59 <0.25 in/sec at buildings
NB - PM 9.67 to 9.72 <0.25 in/sec at buildings
NB - PM 10.18 to 10.20 <0.25 in/sec at buildings
SB - PM 10.12 to 10.44 <0.25 in/sec at buildings
SB - PM 10.59 to 10.64 <0.50 in/sec at buildings

12. References

American Association of State Highway and Transportation Officials (AASHTO)

2012 Final Report: Current Practices to Address Construction Vibration and Potential Effects to Historic Buildings Adjacent to Transportation Projects, prepared under contract for the American Association of State Highway and Transportation Officials Standing Committee on the Environment, with funding provided through the National Cooperative Highway Research Program Project 25-25, Task 72

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2011 Vibration Report, South Coast 101 High Occupancy Vehicle (HOV) Lanes in Santa Barbara County between 0.22 miles south of the Bailard Avenue overcrossing in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara, 05-SB-101-PM 1.4/12.3, 05-0N7000, February 2011

Appendix A Historic Property Vibration Induced Analysis List

APPENDIX A

APN	Address	City/Area	Structure Type	Resource	Map Sheet No.	Soil Class (n)	Proposed Foundation Feature	Maximum Credible Pile Class	Maximum Hammer Energy	Distance from Proposed Piles (ft)	Allowable Minimum Distance from Proposed Piles (ft)	Calculated Vibration Amplitude (in/sec)	Maximum Amplitude With No Damage (in/sec)
007-350-020	129 Sheffield	Montecito	Historic, old, extremely fragile	Ortega-Masini Adobe (c1820s)	17A	1.1	Soundwall	140	42000	230	179	0.0061	0.08
009-263-006	109 Miramar	Montecito	Historic, old	Acacia Lodge (c1917)	19A	1.1	Soundwall	140	42000	70	64	0.226	0.25
009-263-007	100 San Ysidro	Montecito	Historic, old	Wylbron Lodge (c1909)	19A	1.1	Soundwall	140	42000	120	64	0.125	0.25

Appendix B Non-Historic Property Vibration Induced Analysis List

APPENDIX B

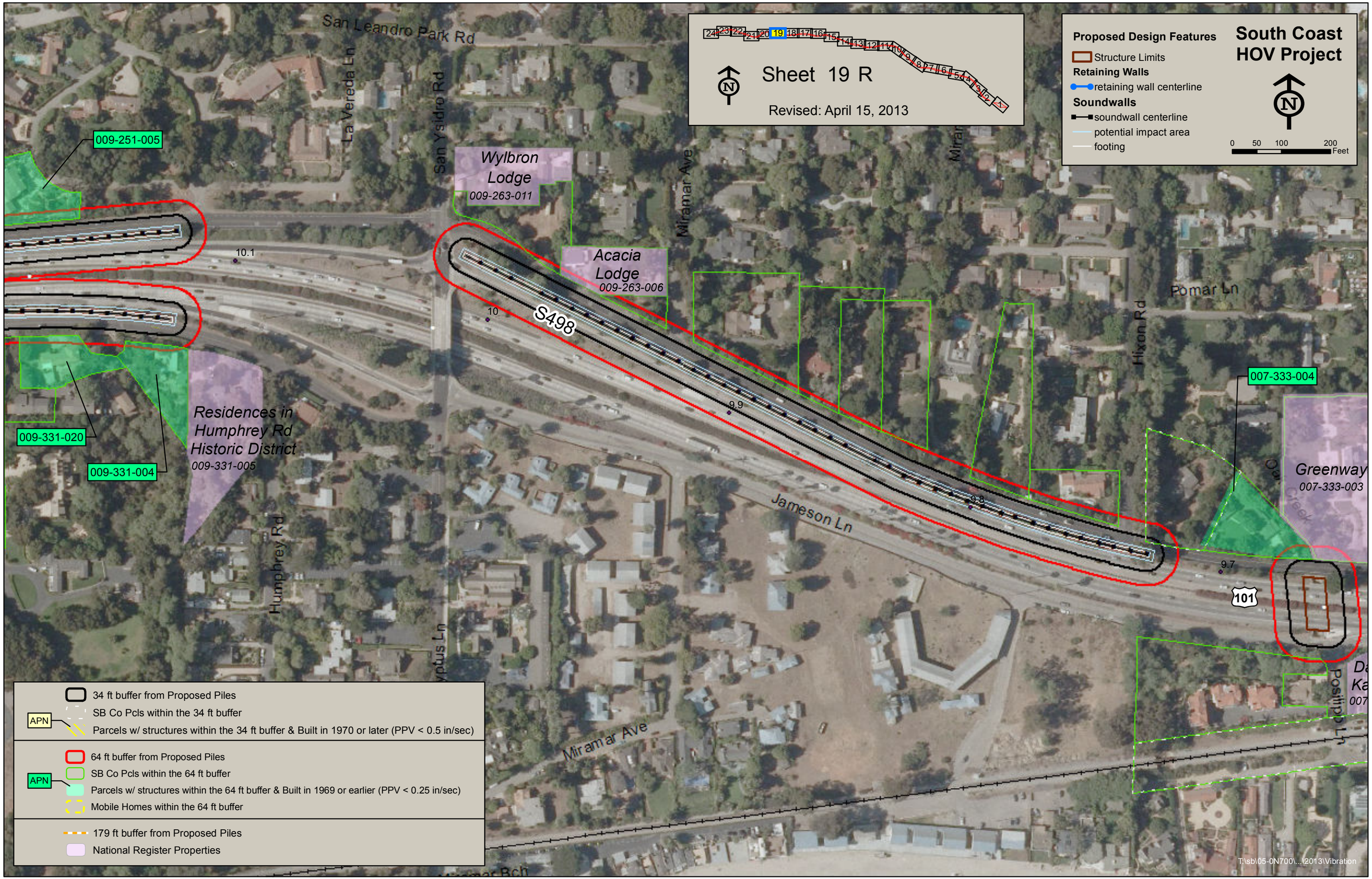
APN	Owner	Address	City/Area	Year Built	Land Use
009-301-008	Loebman	1360 Virginia Road	Montecito	1937	Single-family residence
009-301-009	Farr	1350 Virginia Road	Montecito	1940	Single-family residence
009-301-010	S2C LLC	1346 Virginia Road	Montecito	1941	Single-family residence
009-301-011	Spiva	1342 Virginia Road	Montecito	1962	Single-family residence
009-301-012	Weaver	1332 Virginia Road	Montecito	1959	Single-family residence

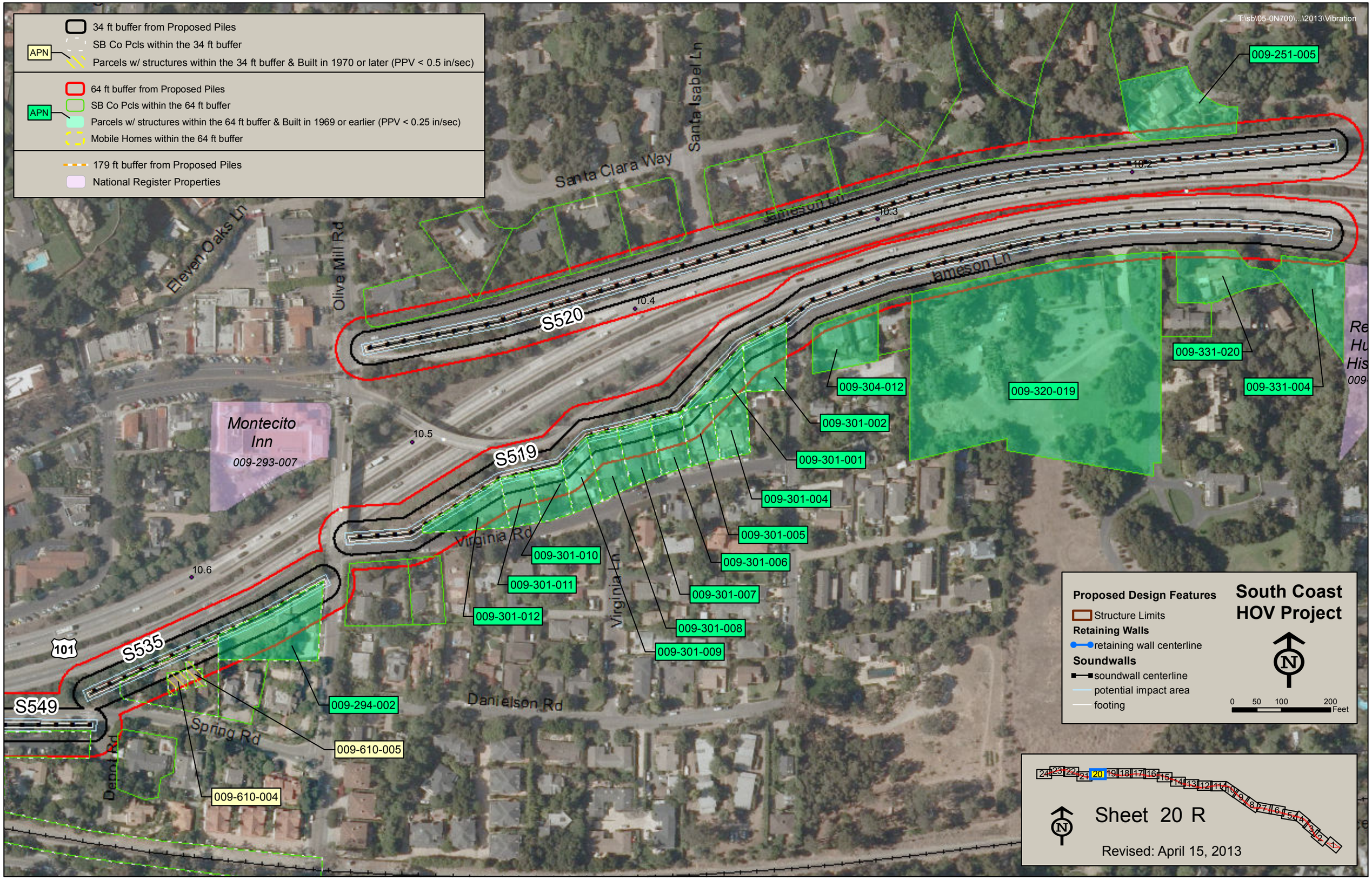
Properties with A 34-ft buffer (Built after 1969)

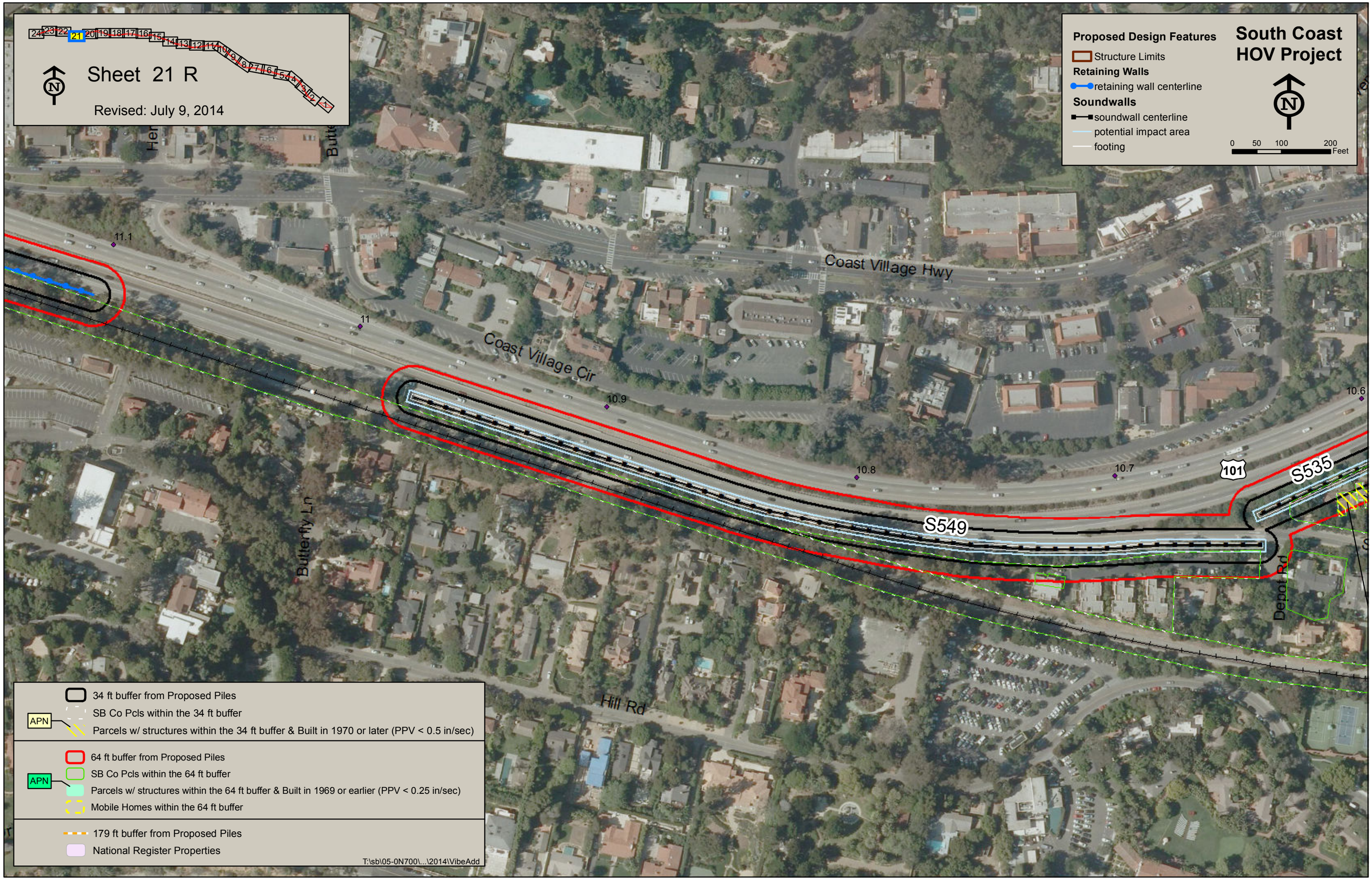
APN	Owner	Address	City/Area	Year Built	Land Use
009-650-007	Quackenbush	93 Depot Road	Montecito	1990	Condominium

Appendix C Vibration Induced Analysis Mapping

Sheet 17 R
Revised: April 15, 2013
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet
San Leandro
Arroqui Rd
Loureyro Rd
N Jameson Ln
Sheffield Dr
Ortega Hill
Ortega-Masini Adobe
007-350-010
S464
101
9.2
9.1
9
8.9
8.8
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
APN
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
APN
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
179 ft buffer from Proposed Piles
National Register Properties
T:\sb\05-0N700\...\2013\Vibration


Sheet 19 R
Revised: April 15, 2013
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet
San Leandro Park Rd
La Vereda Ln
San Ysidro Rd
Wylbron Lodge
009-263-011
Acacia Lodge
009-263-006
Miramar Ave
Pomar Ln
Hixon Rd
009-251-005
009-331-020
009-331-004
Residences in Humphrey Rd Historic District
009-331-005
S498
10.1
10
9.9
9.8
9.7
Jameson Ln
Humphrey Rd
007-333-004
Greenway
007-333-003
Oak Creek
101
Postlip Ln
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
APN
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
APN
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
179 ft buffer from Proposed Piles
National Register Properties
T:\sb\05-0N700\...\2013\Vibration


T:\sb\05-0N700\...\2013\Vibration
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
APN
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
APN
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
179 ft buffer from Proposed Piles
National Register Properties
Santa Clara Way
Santa Isabel Ln
Jameson Ln
Eleven Oaks Ln
Olive Mill Rd
S520
S519
S535
S549
101
Montecito Inn
009-293-007
Virginia Rd
Virginia Ln
Danielson Rd
Spring Rd
Dean Rd
10.2
10.3
10.4
10.5
10.6
009-251-005
009-331-020
009-331-004
009-320-019
009-304-012
009-301-002
009-301-001
009-301-004
009-301-005
009-301-006
009-301-007
009-301-008
009-301-009
009-301-010
009-301-011
009-301-012
009-294-002
009-610-005
009-610-004
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
N
0 50 100 200 Feet
Sheet 20 R
Revised: April 15, 2013


Sheet 21 R
Revised: July 9, 2014
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet
Coast Village Hwy
Coast Village Cir
Butterfly Ln
Hill Rd
Depot Rd
101
S549
S535
11.1
11
10.9
10.8
10.7
10.6
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
APN
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
APN
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
179 ft buffer from Proposed Piles
National Register Properties
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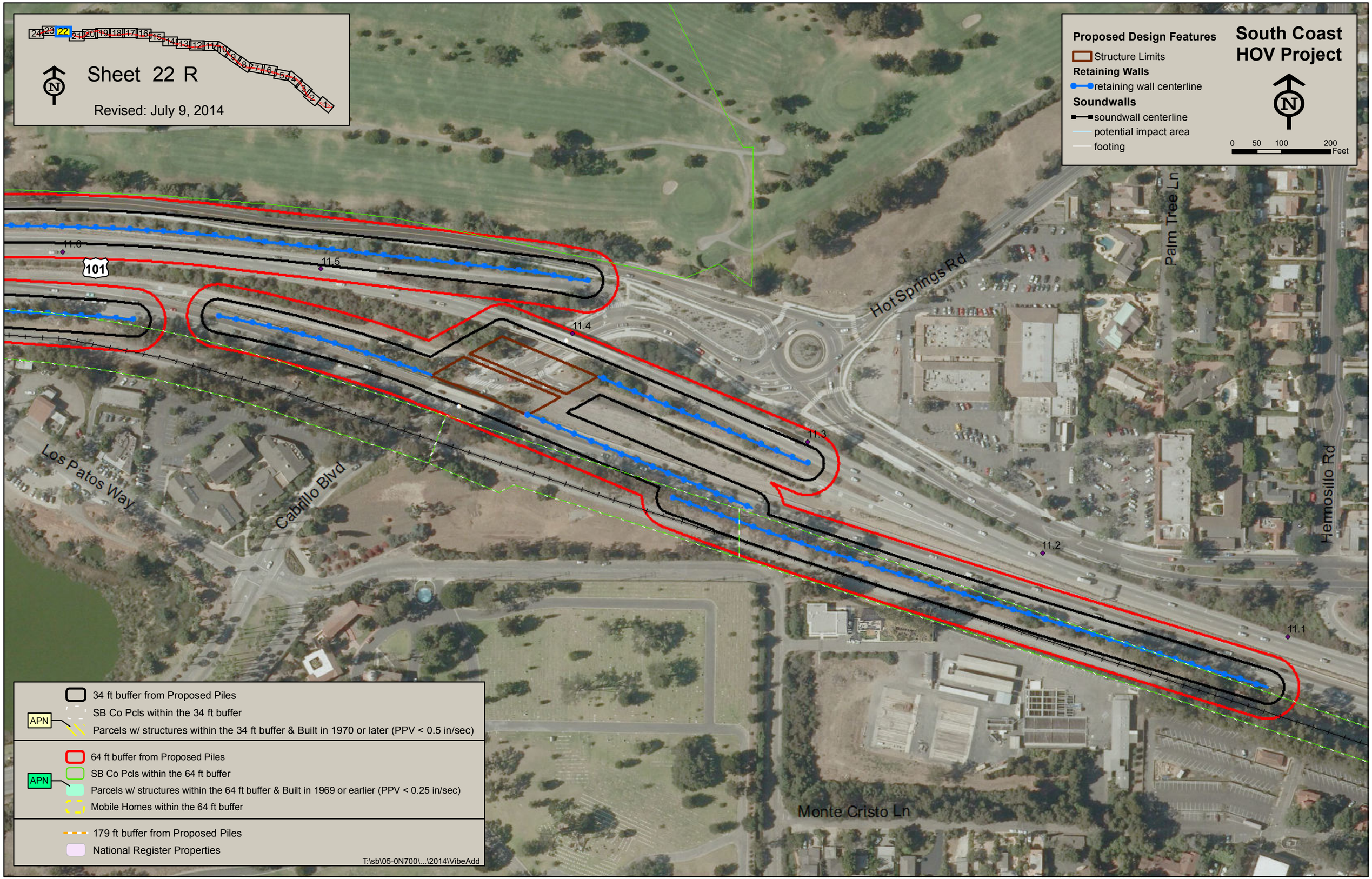
Sheet 22 R
Revised: July 9, 2014
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet
101
11.6
11.5
11.4
11.3
11.2
11.1
Hot Springs Rd
Palm Tree Ln
Hermosillo Rd
Los Patos Way
Cabrillo Blvd
Monte Cristo Ln
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
APN
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
APN
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
179 ft buffer from Proposed Piles
National Register Properties
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Vibration Report

South Coast 101 High Occupancy Vehicle (HOV) Lanes

In Santa Barbara County between 0.22 miles south of the Bailard Avenue overcrossing in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara

05-SB-101-PM 1.4/12.3

05-0N7000

Prepared by the

State of California Department of Transportation

June 2011

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June 2011

Prepared By: Karl Mikel **Date:** 6-30-2011

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Approved By: Valerie Levulett **Date:** 6-30-2011

Valerie Levulett, Senior Environmental Planner

Phone Number: 805-549-3669
Office Name: Central Coast Technical Studies Branch
District/Region: District 5, Central Region

The environmental review, certification and any other action required in accordance with applicable federal laws for this project is being, or has been, carried out by Caltrans under its assumption of responsibility pursuant to 23 U.S.C. 327

Executive Summary

Highway construction projects generate vibration in varying amounts, depending on the type of construction equipment and methods used, the intensity and duration of construction activities, distance from construction activities, and underlying soil types. In urban areas where homes and businesses are often adjacent to highways, there is a need for early identification and assessment of potential vibration impacts to built-environment resources.

The purpose of this report is to document potential vibration impacts from the proposed South Coast 101 High Occupancy Vehicle (HOV) Lanes project. The South Coast 101 High Occupancy Vehicle (HOV) Lanes Project proposes to widen State Route 101 to three lanes in each direction between 0.22 miles south of the Bailard Avenue overcrossing in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara, California [post mile (PM) 1.4 and 12.3. The current study is based on an extensive review of previous vibration monitoring and reports produced by Caltrans, and on standard procedures outlined in the Caltrans Transportation and Construction-Induced Vibration Guidance Manual (2004). This study places emphasis on informing the public about construction-related vibrations, and establishing minimization measures that will protect residences and businesses near the highway, to the extent possible, from vibration impacts.

The assessment of vibration impacts also depends on the age and nature of the resource affected. Historic properties, for example, have a lower threshold for construction-related vibration impacts than recently constructed residences have. The area of potential effects for vibration impacts is therefore delineated to take these differing thresholds into account. Fifteen properties that have previously been determined eligible for listing in the National Register of Historic Places, or that have been determined eligible pending the concurrence of the California State Historic Preservation Officer, were specifically evaluated for potential impacts from pile driving or construction activities occurring in close proximity by conducting site specific vibration analysis. Appendix A of this report presents the results of the vibration risk assessment, based on conservative estimates of distance to the construction activity, intervening soil class, and the maximum energy rating for the pile driver hammer used. Based on this “worst-case scenario” evaluation of potential vibration impacts to these properties, the analysis concluded that it does not appear that these historic properties would be affected due to construction activities.

Due to the length and urbanized character of much of the Highway 101 corridor in the project area, there are multiple locations where older (i.e., constructed in 1969 or earlier) but not historically significant buildings and residential dwelling units are in close proximity to proposed construction activities. For properties built prior to 1969, an empirical analysis was conducted and a buffer of 64 feet was used as the threshold for potential damage due to construction activities. A total of 57 parcels were identified that had older buildings and residences within 64 feet of proposed pile driving activities, for example where sound walls, overpass structures and retaining walls will be constructed (Refer to Appendix A). Of these 57 parcels, 38 are residential structures and 19 are located within mobile home parks. Special provisions would be provided in the construction contract to avoid, minimize or mitigate these impacts. (Refer to Appendix B and C for a listing and maps of these properties).

The same methodology was used to evaluate buildings or structures that were considered newer or modern construction (1970 to present). Because these structures are generally built with more stringent seismic codes and construction practices and materials, they are more resistant to earth-borne movements such as vibration caused by pile-driving. Using the "safe distance" methodology discussed in Section 8 of this report, a safe distance of 34 feet was used as the threshold for potential damages due to construction activities. In other words, parcels with buildings within 34 feet of proposed pile driving (for sound walls, structures and retaining walls) were identified and evaluated individually. A total of 33 parcels were identified as being located within this zone. These properties have all been determined to have a small potential for architectural damages and/or human annoyance. (Refer to Appendix B and C for a listing and maps of these properties).

Based on the vibration analysis conducted in this report, low-vibration footing design and construction methodology will be employed within the identified 64-foot and 34-foot buffers to ensure that these properties are not impacted or affected by activities associated with this project (Refer to Appendix C Mapping). Other areas of the project where either no structures exist or structures are located farther than 64 foot will have standard special provisions provided in the construction contract to minimize or mitigate potential claims.

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1. Purpose of Vibration Study Report

The California Department of Transportation (Caltrans) proposes to make operational improvements to Route 101 in Santa Barbara County. The purpose of this project is to reduce congestion and improve travel time on Route 101 within the project limits. To achieve this purpose, the project proposes to construct an additional lane on Route 101 in both the northbound and southbound directions to be used as High Occupancy Vehicle (HOV) lanes. Adding capacity to the corridor will reduce peak hour congestion and improve freeway operations within the project limits.

As proposed, the project entails construction activities that have the potential to result in vibration impacts to sensitive receptors at particular locations. These activities include the construction of multiple sound walls (with foundation types as yet unknown) throughout the corridor; the demolition of several hydraulic bridge structures and the construction of replacements; the removal of culvert parapets, wingwalls, and other hydraulic components to widen over-crossing structures; and, depending on the project alternative selected, the possible demolition and reconstruction of overpasses at Sheffield Drive and Cabrillo Boulevard.

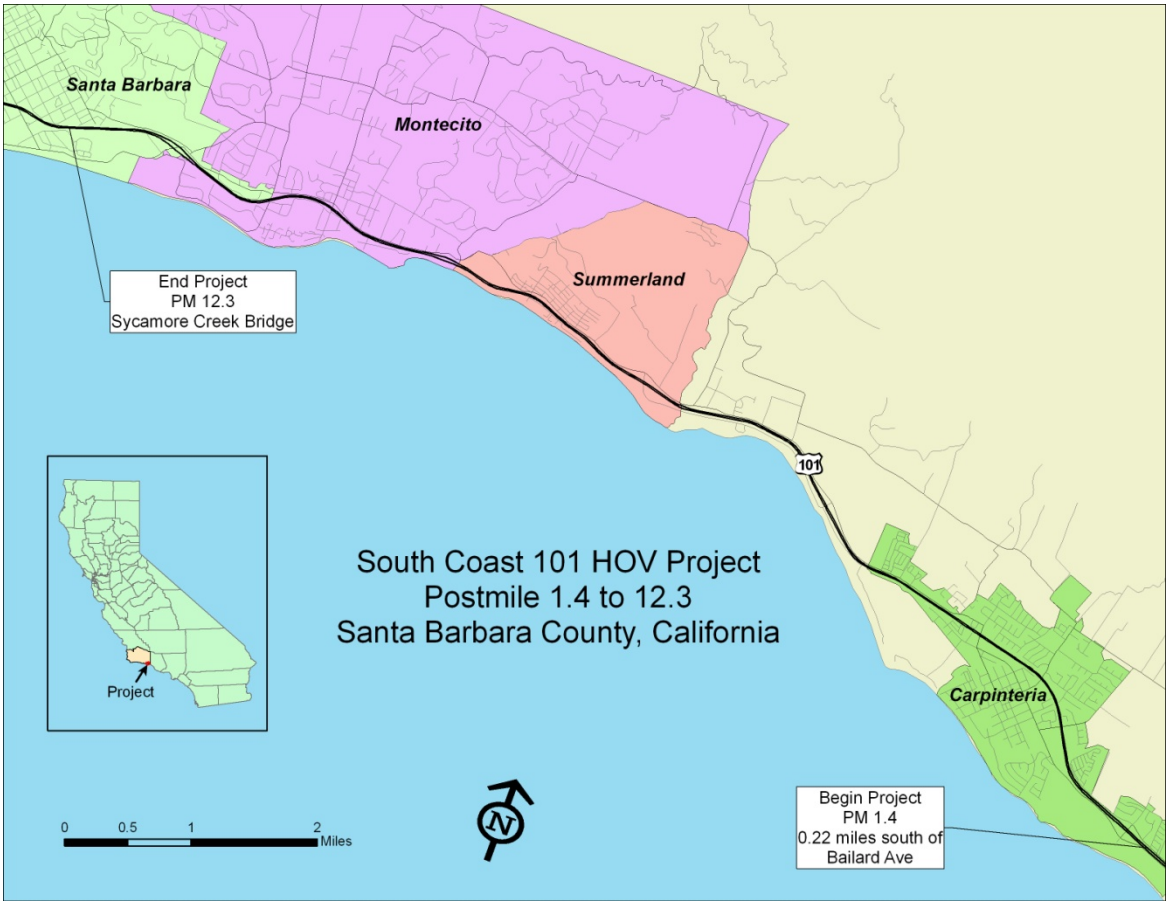
The purpose of this report is to identify the sources and characteristics of potential project-related vibration impacts. This vibration study is based on an extensive review of pertinent literature and on standard procedures provided in the Caltrans *Transportation and Construction-Induced Vibration Guidance Manual* (2004). The study emphasizes the importance of informing the project development team and the general public about identified potential construction-related vibrations, and of establishing avoidance and minimization measures that will protect residences and businesses near the highway, to the extent possible, from vibration impacts.

2. Project Description

The proposed project would add one High Occupancy Vehicle (HOV) lane in each direction to Highway 101 in Santa Barbara County between one-half mile south of Carpinteria Creek in Carpinteria, and Sycamore Creek in the City of Santa Barbara. The proposed widening would occur within the existing right-of-way, with the new HOV lanes being added either to the inside or outside of the existing edge of the roadway, or else in a combination of inside and outside widening to preserve median landscaping where possible. The purpose of the

proposed new lanes is to relieve existing and projected future congestion on the highway in the project area (Figure 1).

Figure 1 Project Location/Vicinity Map



Purpose and Need

The existing capacity of Route 101 within the project limits and throughout much of the Santa Barbara south coast is congested during peak periods and weekends. During these times, the facility operates at Level of Service (LOS) F, congested flow conditions for two to four hours daily in each direction (SBCAG *Congestion Management Program*, 2007). Without capacity improvements, LOS F conditions on Route101within the project limits are forecast to exceed nine hours a day in each direction by 2040 (SBCAG's 101 in Motion July 2006). The forecast rise in congestion and delay is a result of several factors, including increased long distance commuting from Ventura County; internal population growth, which is forecast to expand by ten percent by 2020 in Santa Barbara County (SBCAG *Regional Growth Forecast*, 2007); and interregional traffic growth, including goods movement. This project represents one component of a larger Route 101 corridor improvement strategy in northern Ventura County and southern Santa Barbara County.

Alternatives Description

The South Coast 101 High Occupancy Vehicle (HOV) Lanes Project proposes to widen State Route 101 to three lanes in each direction between 0.22 miles south of the Bailard Avenue overcrossing in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara, California [post mile (PM) 1.4 and 12.3. Caltrans proposes to widen State Route 101 between 0.44 miles south of Carpinteria Creek in the City of Carpinteria and Sycamore Creek in the City of Santa Barbara. Three build alternatives and a no-build alternative is proposed for this project. Each build alternative would add a single High Occupancy Vehicle (HOV) lane in both the northbound and southbound directions and reconstruct interchanges at Sheffield Drive and Cabrillo Boulevard.

Three build alternatives -- Alternatives 1, 2, and 3 -- and a No-Build Alternative are proposed for this project. All build alternatives provide add an additional lane in each direction to provide for a part time High Occupancy Vehicle (HOV) facility within the project limits. Alternative 1 proposes to balance competing resource interests such as scenic views, wetlands, and median/outside landscaping. Alternative 2 proposes to maximize landscaping in the median. Alternative 3 proposes to construct all new paved lanes within the existing available median and maximizes the retention of outside planting. All build alternative improvements would be constructed primarily within the existing public right of way.

Water quality impacts are considered to be equivalent for the various project alternatives due to the similar size, scope, and nature of the proposed project features.

Common Design Features of the Build Alternatives

Alternatives 1, 2 and 3 would include the following:

Basic Common Design Features

- Add an additional lane in each direction on Route 101 to provide for a part time, continuous access High Occupancy Vehicle (HOV) facility within the project limits.
- Replace bridge structures at: Arroyo Paredon (Parida), Toro Canyon, Romero (Picay), Oak, and San Ysidro Creeks.
- Widen bridge structures at Franklin and Santa Monica creeks.
- Widen traffic undercrossing structures at South Padaro Lane and Evans Avenue.
- Reconstruct the northbound off ramp and on ramp at Salinas Street.
- Convert the existing northbound auxiliary lane to a through lane between the northbound on ramp at Cabrillo Boulevard and Salinas Street off ramp.

- Construct a southbound auxiliary lane between the Sheffield Drive on ramp and the Evans Avenue off ramp.
- Reconstruct the interchanges at Sheffield Drive and Cabrillo Boulevard.
- Consideration, as design options, seven mutually exclusive Cabrillo Blvd. interchange configurations (F, H, I, J, L, M, and Q). Interchange configurations under consideration include:

F) SB 1/2 DIAMOND -Close both median off ramps at Cabrillo Blvd.; improve the northbound Hermosillo Drive off ramp and the northbound Cabrillo Blvd. on ramp. Construct new on and off ramps to intersect at Cabrillo Blvd., northbound and southbound, immediately adjacent and to the right of the freeway lane.

H) TIGHT DIAMOND- Close all existing off ramps, including the Los Patos Way and Hermosillo Drive ramps. Construct new on and off ramps to intersect at Cabrillo Blvd., northbound and southbound, immediately adjacent and to the right of the freeway lanes.

I) EXISTING MAINLINES / IMPROVE LOS PATOS - Close both median off ramps at Cabrillo Blvd.; improve the northbound Hermosillo Drive off ramp, the southbound Los Patos Way off ramp, and the northbound Cabrillo Blvd. on ramp.

J) EXISTING MAINLINES / IMPROVE LOS PATOS - Identical to Configuration "I" with the addition of a southbound Los Patos Way on ramp.

L) NB 1/2 DIAMOND / IMPROVE LOS PATOS -Close northbound and southbound median off ramps at Cabrillo Blvd. and close the northbound Hermosillo Drive off ramp; add a southbound Cabrillo Blvd. off ramp; improve the southbound Los Patos Way off ramp and the northbound Cabrillo Blvd. on ramps.

M) NB 1/2 DIAMOND / IMPROVE LOS PATOS -Identical to Configuration "L" with the addition of a southbound Los Patos Way onramp.

Q) HALF SINGLE POINT -Close the Los Patos southbound off ramp, the northbound and southbound median off ramps at Cabrillo Blvd, and the northbound on ramp at Cabrillo; construct a new Cabrillo Blvd southbound right side off ramp that will undercross three southbound freeway lanes and a new northbound right side on ramp that will undercross three northbound freeway lanes - both will join at the existing median ramp intersections at Cabrilllo Blvd.; also improve the northbound Hermosillo Drive off ramp.

Additional Common Design Features

- Construct retaining walls at two locations: On the southbound outside shoulder at the right of way line along the southbound off ramp at Sheffield Drive (430 feet in length) and on the outside shoulder of the proposed southbound auxiliary lane from Sheffield Drive to Evans Avenue (1550 feet in length).
- Provide median landscaping in the first 0.2 mile at the southern limits of the project, and the last 0.5 mile of the project.
- Install replacement planting.
- Construct soundwalls for noise abatement where appropriate.
- Provide noise attenuating pavement surface on all travel lanes.
- Relocate underground and aboveground utilities as needed.
- Lengthen cross culverts to accommodate additional pavement width.
- Construct maintenance vehicle pullout areas.
- Construct stormwater treatment facilities within the project limits and on publicly owned property near the Bailard Interchange (PM 1.6).

Unique Design Features of the Build Alternatives

Alternative 1: Balanced Resources

- This alternative proposes to balance competing resource interests such as scenic views, wetlands, and median/outside landscaping.
- Provide median landscaping, where appropriate, at several additional locations: from 0.2 mile from the southern limits of the project to Linden Avenue; the South Padaro Lane Interchange; and at the North Padaro Lane Interchange.
- The freeway outside edge of pavement requires widening in all locations where additional median landscaping is proposed.

Alternative 2: Maximize Median Planting

- This alternative proposes to maximize landscaping in the median, and recognizes that some identified scenic resources may be partially blocked and some wetland areas impacted.
- Provide median landscaping, where appropriate, at several additional locations: from 0.2 mile from the southern limits of the project to Reynolds Avenue; and from Santa Monica Road to the Evans Avenue Interchange.
- The freeway outside edge of pavement requires widening in all locations where additional median landscaping is proposed.

- Construct additional southbound auxiliary lanes between 1) the Santa Claus Lane on ramp and the Carpinteria Avenue off ramp and 2) the Reynolds Avenue on ramp and the Linden Avenue off ramp.
- Construct 3 additional retaining walls. One on the southbound shoulder at the right of way line ending at the Santa Claus Lane southbound on ramp (500 feet in length), one on the northbound shoulder near Greenwell Creek (700 feet in length) and one on the northbound shoulder near the northbound offramp to Summerland (300 feet in length.)

Alternative 3: Maximize Outside Planting

- This alternative proposes to construct all new paved lanes within the existing available median and maximizes the retention of outside planting.
- A single concrete barrier separating the two inside paved shoulders will be provided in the median between Carpinteria Creek and Olive Mill Road, which largely retains the existing outside edge of pavement within these areas.

No-Build Alternative

The No-Build Alternative would add no additional lanes to the highway, and would not relieve existing and future congestion.

3. Construction-Related Vibrations

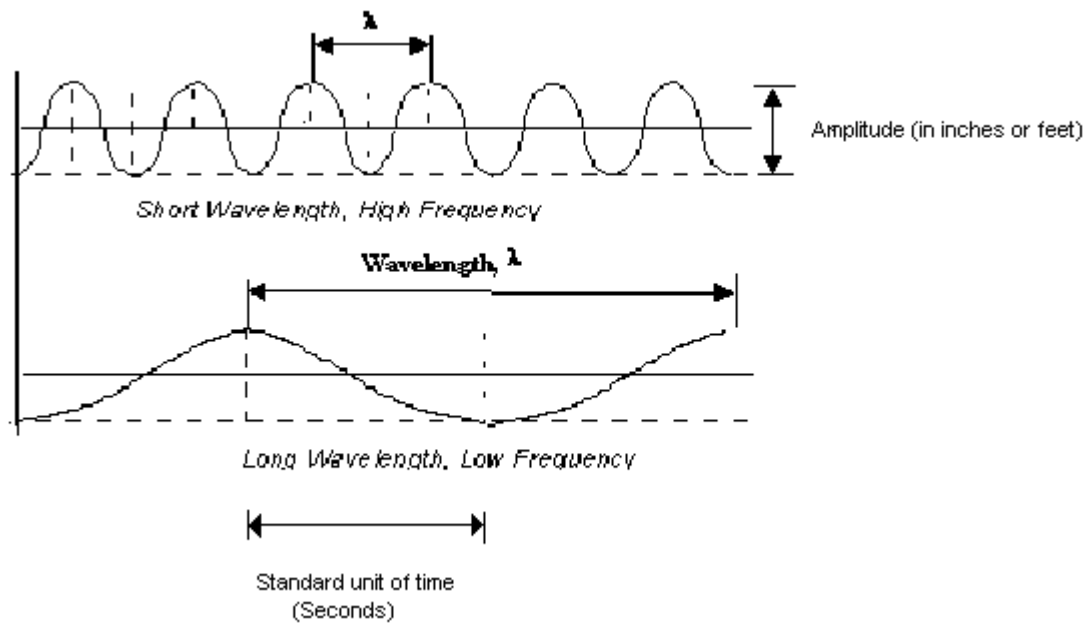
Construction activities result in varying degrees and types of ground vibration, depending on the equipment and construction methods employed, the intensity and duration of the specific construction activity, and underlying soil types. Vibrations are also perceived in different ways, depending on the sensitivity of the receptor, and result in different kinds of physical impacts, depending on the age and condition of adjacent resources.

In most cases, vibration induced by typical construction equipment does not result in adverse effects on people or structures. Noise, rather than vibration, is generally perceived as more noticeable and objectionable. In some instances, however, construction-related vibration has the potential to cause impacts.

Operation of construction equipment such as excavators, road graders, vibratory rollers, and paving machinery causes sustained ground vibrations that spread through the ground and diminish in strength with distance. Buildings founded on the soil in the vicinity of the construction site respond to these vibrations with varying results, ranging from no perceptible effects (low vibration levels), to perceptible vibrations (moderate vibration levels), to slight architectural damage (high vibration levels).

Construction activities such as demolition and blasting generate ground vibration characterized by sudden, intense energy waves. If the energy wave amplitude is high enough (Figure 2), the ground vibration has the potential to cause cosmetic damage (*e.g.*, crack plaster), or disrupt the operation of vibration sensitive equipment. Ground vibration and ground-borne noise can also be a source of annoyance to individuals who live or work close to vibration-generating activities.

Figure 2: Illustration of Wavelength, Frequency, and Amplitude



Equipment or activities typical of continuous vibration include: excavation equipment, static compaction equipment, tracked vehicles, traffic on a highway, vibratory pile drivers, pile-extraction equipment, and vibratory compaction equipment.

Equipment or activities typical of single-impact (transient) or low-rate repeated impact vibration include: impact pile drivers, blasting, drop balls, “pogo stick” compactors, and crack-and-seat equipment.

4. Vibration Standards

There are no Federal Highway Administration (FHWA) or State standards for vibration impacts. The traditional view has been that highway traffic and most construction vibrations pose no threat to buildings and structures, and that annoyance to people is similar to typical noise issues experienced from living near highways.

Caltrans, however, has conducted research and developed a *Transportation and Construction-Induced Vibration Guidance Manual* (CTVM) to assess the potential for construction-related vibration impacts. The type of assessment – qualitative or quantitative – and the level of analysis are determined by the scale of the project and by the sensitivity of surrounding land uses. A quantitative analysis is conducted in cases where construction vibration may result in prolonged annoyance or building damage.

5. Transportation Related Vibration

Most Caltrans projects are concerned with three types of transportation-related earth-borne vibration sources: normal highway traffic, light and heavy rail operations, and construction equipment and operations. Of the three transportation vibration sources listed above, construction vibrations are of greatest concern because of the nature of the sound waves produced and the potential for greater impacts. Construction equipment and operations on large jobs such as this one usually entail pile driving, pavement breaking, excavation, blasting, paving operations, and demolition of structures, which generate the highest construction vibrations.

Even so, ground vibrations from construction activities do not often reach the levels that can damage structures, but they can achieve the audible and perceptible (*i.e.*, "feelable") ranges in buildings very close to the site. A possible exception is the case of fragile buildings, many of them old, where special care must be taken to avoid damage. The construction vibration criteria include special consideration for such buildings. Pile driving, pavement breaking, blasting, and demolition of structures have potential impacts to buildings at distances of less than 100 feet from the vibration source.

6. Quantitative Construction Vibration Assessment Methods

Construction vibration should be assessed quantitatively in cases where there is significant potential for impact from construction activities (*e.g.*, blasting, pile-driving, vibratory compaction, demolition, and drilling or excavation in close proximity to sensitive structures). Earth-borne vibrations may be described by amplitude and frequency. Referring to earth-borne vibrations, amplitude is described by the local movement of soil particles. The formula for propagation of the energy wave is:

$$\textit{frequency } (f) = \textit{wave velocity } (c) \,/\, \textit{wavelength}$$

or

$$\text{wave velocity } (c) = 2\Pi f * D \textit{ (displacement)}$$

The resultant of this formula is the peak particle velocity (PPV), expressed in inches per second or millimeters per second. The recommended procedure for estimating vibration impacts from construction activities is as follows:

Damage Assessment (Equipment)
Select the equipment and associated vibration source levels at a reference distance of 25 feet from Table 18 (CTVM). Make the propagation adjustment according to the following formula (this formula is based on point sources with normal propagation conditions):
$PPV_{equip} = PPV_{ref} \times (25/D)^n$ (in/sec) where:

PPV (equip) is the peak particle velocity in in/sec of the equipment adjusted for distance.
PPV (ref) is the reference vibration level in in/sec at 25 feet from Table 18 (CTVM).
n is the soil type calibration factor from Table 17 (CTVM).
D is the distance from the equipment to the receiver.

For pile driving the equation becomes:
$PPV_{pile\ driver} = PPV_{ref} \times (25/D)^n \times (E_{equip}/E_{ref})^{0.5}$ (in/sec) where:

PPV (pile driver) is the peak particle velocity in in/sec for the hammer adjusted for distance.
PPV (ref) is equal to 0.65 in/sec at 25 feet for a reference pile driver.
n is the soil type calibration factor from Table 17 (CTVM).
D is the distance from the pile driver to the receiver.
E_{equip} is rated energy of impact pile driver in ft-lbs.
E_{ref} is 36,000 ft-lb (rated energy of reference pile driver)

Once the PPV is calculated, one would then apply the vibration damage criteria (Table 1, below, from TAV-04-01-R0201). The table correlates the potential human reaction to the potential damaging effect on buildings. It should be noted that there is a considerable variation in reported ground vibration levels from construction and pile driving activities. The data provide a reasonable estimate for a wide range of soil conditions.

A considerable amount of research has been done to correlate vibrations from *single events* such as dynamite blasts with architectural and structural damage. The U.S. Bureau of Mines has set a “safe blasting limit” of 2 in/sec. Below this level there is virtually no risk of building damage from a single event.

Safe levels for *continuous* vibrations from sources such as traffic are not as well defined. The Transport and Road Research Laboratory in England has researched continuous vibrations to some extent and developed a summary of vibration levels and reactions of people and the effects on buildings (Table 1, below). These are the criteria used by Caltrans to evaluate the severity of vibration problems. Traffic, train, and most construction equipment-produced vibrations (with the exception of pile driving, blasting, and some types of demolition) are considered continuous.

Table 1: Vibration Level and Intensity

Vibration Level			
Peak Particle Velocity mm/sec	**Peak Particle Velocity in/sec**	**Human Reaction**	**Effect on Buildings**
0.15 to 0.3	.006 to .019	Threshold of perception – possibility of intrusion	Vibrations unlikely to cause damage of any type
2.0	0.08	Vibrations Readily Perceptible	Recommended upper level of the vibration to which ruins and ancient monuments should be subjected
2.5	0.10	Level at which continuous vibrations begin to annoy people	Virtually no risk of "architectural" damage to normal buildings
5	0.20	Vibrations annoying to people in buildings (this agrees with the levels established for people standing on bridges and subjected to relatively short periods of vibrations)	Threshold at which there is a risk of "architectural" damage to normal dwelling – houses with plastered walls and ceilings Special types of finish such as lining of walls, flexible ceiling treatment, etc., would minimize "architectural" damage
10 to 15	0.4 to 0.6	Vibrations considered unpleasant by people subjected to continuous vibrations and unacceptable to some people walking on bridges	Vibrations at a greater level than normally expected from traffic, but would cause "architectural" damage and possibly minor structural damage

Source: A Survey of Traffic-Induced Vibrations by Whiffen, A.C. England, 1971

Annoyance levels in this table are subjective and can vary depending on the activity level of the observer. Annoyance can occur at lower peak particle velocities for more sedentary observers.

The numbers in the first 2 columns on the left are based on the peak particle velocity in the vertical direction (Rayleigh waves). Where human reactions are concerned, the value is at the point at which the person is situated (no set distance from the source). For buildings, the value refers to the ground motion but no allowance is included for the amplifying effect of structural components.

The "architectural damage risk level" for continuous vibrations (peak vertical particle velocity of 5 mm/sec or 0.2 in/sec) shown on Table 1 is one tenth of the maximum safe level of 50 mm/sec (2 in/sec) for single events.

All damage criteria for buildings are in terms of ground motion at the buildings' foundations. No allowance is included in Table 1 for the amplifying effects of structural components. Obviously, the way a building is constructed and the condition it is in determines how much vibration it can withstand before damage occurs. Table 1 shows a

recommended upper level of 0.08 in/sec for continuous vibrations to which "ruins and ancient monuments" should be subjected. This criterion level may also be used for fragile historical buildings, or buildings that are in very poor condition.

Limited information is available concerning the damaging effects of pile driving. Although technically a series of single events, pile driver blows occurring often enough in a confined area could cause damage at a lower level than the single event criterion of 2 in/sec. Pile driving levels can exceed 0.2 in/sec at distances of 50 feet, and 0.5 in/sec at 25 feet. However, pile driving has been done frequently at these distances (50 feet and 25 feet) without structural damage to buildings.

Caltrans' general experience has been that almost never are traffic-generated vibrations damaging to structures near the highway. Construction generated vibrations, however, can exceed the point of architectural damage. Tables 1 and 2 illustrate this point—compare the peak particle velocity from pile drivers and pavement breakers at 25 feet (Table 2) to the effect on buildings (Table 1).

Table 2: Vibration Source Levels For Construction Equipment

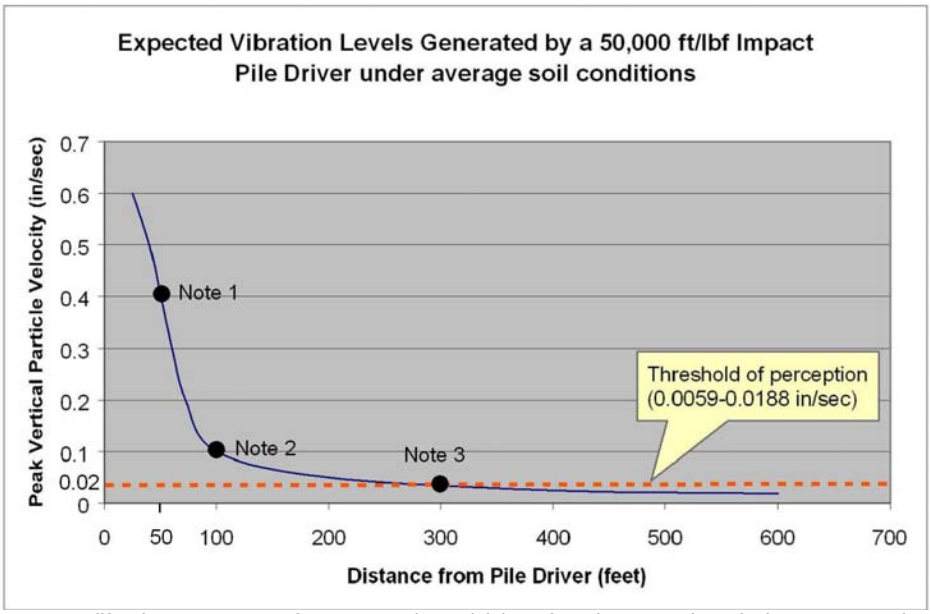
Equipment		PPV (in/sec) at 25 ft	Approximate Lv† at 25 ft.
Pile Driver (impact)	Upper range	1.518	112
	Typical	0.644	104
Pavement Breaker		1.25	~110
Pile Driver (sonic)	Upper range	0.734	105
	Typical	0.170	93
Vibratory Roller		0.60	103
Clam shovel drop (slurry wall)		0.202	94
Hydro-mill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

Source: ntl.bts.gov/data/rail05/ch12.pdf

† RMS (Root mean square) velocity in decibels (VdB) re 1 micro-inch/second. Comparable to decibels used in noise measurement.

Figure 3 shows how typical pile driving vibrations decrease with distance, for a 50,000 ft.-lb.[1] energy impact pile driver in average soil conditions. Clay soils provide more resistance to advancing piles and therefore generate higher vibration levels near the source than those in sandy soils. Vibrations in clay soils, however, tend to drop off more rapidly with distance than those in sandy soils.

Figure 3: Pile Driver Vibration Attenuation with Distance



Source: California Department of Transportation, Division of Environmental Analysis. Transportation Related Earth-borne Vibrations. 2004.

Note 1—vibrations may cause architectural damage (0.4-inches/second ppv—Table 2)
Note 2—continuous vibrations begin to annoy people (0.1-inches/second ppv—Table 2)
Note 3—vibrations may be perceived (~0.02-inches/second ppv—Table 2)

The above indicates that in any situation the probability of exceeding architectural damage risk levels for continuous vibrations from construction is very low. However, if pavement breaking or extensive pile driving is involved, then damage to nearby buildings or non-reinforced structures is a remote possibility. This may also be true if these operations occur within 50-100 feet of historical buildings (unless in excellent condition), buildings in poor condition, or buildings previously damaged in earthquakes.

The outer limits for architectural damage to historical buildings from pile driving, and perhaps from pavement-breaking operations as well, is 50 feet to 100 feet, while the limit for structural damage to at risk buildings is within 25 feet of the vibration source. Project

[1] One foot-pound is the amount of energy expended when a force of one pound acts through a distance of one foot along the direction of the force.

features such as sound wall locations, retaining structures, drainage systems, new lane construction, etc., all have the potential to cause vibration impacts to adjacent receptor locations.

Buildings that are outside the limits for architectural and structural damage may still be close enough to pile driving sites that the annoyance level from vibrations may be exceeded. Partial demolition of bridge structures may occur at night, when noise and vibration impacts may disrupt local residents' sleep.

7. Proposed Construction Activities

Construction activities resulting from the proposed improvements have the potential to generate noise that can be perceived by residents up to 300 feet from the highway, and vibrations than can annoy and cause architectural and structural damage to residences and buildings adjacent to the work zone. Those activities include but are not limited to:

1) Demolition of Highway Structures: Demolition is typically conducted with a hoe ram mounted on a backhoe. Impacts from the hoe ram are similar to those of a pavement breaker, and would very likely generate similar vibrations. Structure demolition is proposed at multiple hydraulic structures. The project would additionally be removing parapets, wing walls, etc., to widen over-crossing structures. One traffic bearing structure at Sheffield Drive and two traffic bearing structures at Cabrillo Boulevard might be demolished, depending on the alternative selected.

2) Pavement Breaking: Also referred to as "cracking and seating," breaking up the concrete pavement with a large impact hammer may occur on Highway 101 in both directions of travel.

3) Pile-driving: For bridges that will be reconstructed or widened, pile-driving would occur during daylight or nighttime hours, and would last for about eight hours per day. Pile-driving may also occur during the construction of retaining and sound walls throughout the corridor. Final details on footing types will come after the completion of geotechnical studies. Once local soil types have been classified for any structure construction, foundation types would be determined at that time, and the need for pile driving in areas of weak soils would be explored. Piles would only be utilized if necessary, otherwise standard foundations would be constructed.

8. Potential Impacts from Construction

This report documents the impacts of proposed construction activities as currently designed. Because of its greater potential to cause construction-related vibration damage or annoyance, pile driving has been selected as the hypothetical construction activity for the purpose of calculating project impacts. Options with the potential for fewer impacts will be evaluated once the geotechnical studies are complete and during the Plans, Specifications and Estimates (PS&E) phase of the project when Caltrans Structures Design will determine the feasibility of foundations for the retaining walls and sound walls that do not require driven piles. One example of these is Mechanically Stabilized Earth (MSE) retaining walls. Structures Design will also explore the feasibility of micro-pile foundations, which are less vibration intensive than the currently planned driven piles for sound wall foundations. The development of alternative foundation types would help minimize potential vibration impacts to residents near the construction project. Additionally, as depicted on the mapping contained in Appendix C (sheets 11-20), properties that fall within or adjacent to established buffer zones will have site specific low vibration construction methods employed to ensure there are no impacts due to construction induced vibration.

Depending on the duration, intensity and timing of the proposed construction activities, structure demolition, pavement breaking, and pile driving may affect residents and structures adjacent to the proposed construction activity. The effects of activities like pile driving and pavement breaking lessen with distance from the vibration source as the energy from the impacts is absorbed by the sub-surface. In general, three zones of lessening intensity are established within the CTVM to classify the expected impacts from proposed construction activities. These zones of influence are general in nature and are defined in the CTVM as follows:

Perception: A 300-foot radius zone is shown in Figure 3 where the expected vibration level crosses the (dotted) threshold of perception line (0.02 inches per second peak particle velocity). Residents will begin to perceive vibrations at this distance.

Annoyance: A 100-foot radius zone is shown in Figure 3 where continuous vibrations begin to annoy people (0.10-inches per second peak particle velocity). Figure 3 shows that this level occurs at about 100 feet from the source.

Damage: The CTVM established a generalized 60-foot radius, shown in Table 2, where continuous vibrations may cause architectural damage (0.4-inches per second peak particle velocity assuming a 50,000 foot – pound energy impact pile driver in average soil

conditions). This radius does not take into account more fragile, historic structures. For this project, site specific vibration analysis was conducted to help better assess potential impacts from potential pile driving activities specifically related to various types of structures. Encountered soil conditions and a more realistic maximum credible energy rating for pile driving equipment were used to calculate project specific radii to predict whether continuous vibrations could cause architectural damage.

For determining project specific "damage" radii, project specific piles and pile driver maximum energy ratings must be known. Because these have not yet been specified for this project, a conservative estimate must be prepared assuming that the largest piles will be used, consequently requiring the highest credible pile driver energy rating.

To determine the maximum energy rating for a pile driver, the input energy must not exceed that which would cause failure to the pile during driving. The assumption should be a pre-cast reinforced concrete displacement pile as this type requires the highest hammer energy as compared to other pile types.

Caltrans utilizes three standard classes of pre-cast reinforced concrete piles: Class 90, Class 140 and Class 200, with the class numbers representing the nominal axial strength (ultimate capacity) of the pile in tons. For Caltrans applications, assuming standard plan piles, the largest credible driven pre-cast pile to be specified for a sound wall or retaining wall installation is the Class 140 pile, and the largest for a traffic structure is the Class 200 pile. These three pile classes are all specified at 15" diameters with additional strength being supplied by reinforcing steel. There are other types available, but these pre-cast reinforced concrete displacement piles require the highest hammer energy as compared to other pile types.

Both AASHTO and FHWA recommend that for determining pile failure loads, the Davisson approach should be used for small (*i.e.*, less than 24”) diameter reinforced concrete piles. Davisson developed the elastic offset approach to define pile failure or ultimate capacity. Davisson's offset limit load criterion defines ultimate load as the point at which the displacement of the pile head meets a limit that is offset to the elastic compression line of the pile. Bengt H. Fellenius (PCI Journal Jan-Feb 1977) states that Davisson's work limits the hammer to a maximum rated energy, Emax (in ft-lbs) as follows:

Emax = 60 * A* (B^0.5),

where A is the pile cross sectional area in square inches and B is the pile diameter in inches. Based on this equation, the maximum rated energy of a hammer for a standard plan pile at 15" diameter should be limited to 42,000 ft-lbs.

After determining the maximum energy rating for the driving hammer based on pile size, potential risk of damage distances and peak particle velocity can be determined assuming the default coefficients for unknown soil types. For example: if one uses a hammer of 42,000 ft-lbs with a .5 $PPV_{pile\ driver}$ with n = 1.1 (unknown soil type) in the following equation: $PPV_{pile\ driver} = PPV_{ref} \times (25/D)^n \times (E_{equip}/E_{ref})^{0.5}$ (in/sec); you get a "minimum safe from damage distance" of 34 feet for newer or modern construction. Using the lowest PPV of 0.08 and n = 1.1 you get a "minimum safe from damage distance" of 179 feet for historic, extremely fragile structures. The minimum safe distance results based on the above methodology is as follows:

historic, extremely fragile structures	179 feet	(PPV less than 0.08 in/sec)
historic, fragile structures	147 feet	(PPV less than 0.10 in/sec)
historic old structures	64 feet	(PPV less than 0.25 in/sec)
old structures	54 feet	(PPV less than 0.30in/sec)
new or modern construction	34 feet	(PPV less than 0.50 in/sec)

After determining that the project contained only one historic, fragile structure, the balance of the structures were conservatively categorized as either historic/old or new at safe distances of 64 feet and 34 feet respectively. The above approximate safe distances have been used as a screening tool to check specifically for any structures that fall within the relevant limit for potential architectural damage impacts. The "safe distance" simply means that structures located farther than this distance from the source of vibration have virtually no risk of damage during pile driving or construction operations. Once the safe distance line has been established, properties that fall within the various limits of potential damage can be evaluated more thoroughly for potential damage utilizing specific soil types for each particular location.

9. Site Specific Project Analysis

Using the screening analysis methodology discussed in the previous section, specific properties and structure types that are located within or adjacent to the established safe distance zones were further evaluated to determine their risk of structural damage or annoyance to people.

Historic Property Analysis

Several properties along the project corridor have been determined eligible for listing in the National Register of Historic Places. These properties have been individually evaluated for potential impacts from pile driving activities. Appendix A provides the results of the vibration risk assessments based on conservative estimates of distance to the construction activity, soil class, and the maximum energy rating for the pile driver hammer.

Using the methodology outlined in the CTVM, Table 3 indicates that, based on the analysis conducted specifically for this project, there are no historic structures on this project located near enough to pile driving activities that would be expected to be damaged.

Older, Non-Historic Property Analysis

Historic-period properties (*i.e.,* constructed in 1969 or earlier) that were determined ineligible for the National Register were nonetheless evaluated for vibration impacts because of their age, using the "safe distance" methodology discussed above in Section 8. For these properties, a safe distance of 64 feet was used as the threshold for potential damages due to construction activities. In other words, parcels with historic-period buildings within 64 feet of proposed pile driving (for sound walls, structures and retaining walls) were identified and evaluated individually. A total of 38 residential parcels were identified. These properties have all been determined to have an increased potential for human annoyance. Special provisions will be provided in the construction contract to minimize or mitigate potential impacts. Additionally, as depicted on the mapping contained in Appendix C, properties that fall within or adjacent to established buffer zones will have site specific low vibration construction methods employed to ensure there are no impacts due to construction induced vibration. (Refer to Appendix B and C for a listing and maps of these properties).

Newer Property Analysis

The same methodology was used to evaluate buildings or structures that were considered newer or modern construction (1970 to present). Because these structures are generally built with more stringent seismic codes and construction practices, they are more resistant to earth-borne movements such as vibration caused by pile-driving. Using the "safe distance" methodology discussed in Section 8, a safe distance of 34 feet was used as the threshold for potential architectural damages due to construction activities. In other words, parcels with buildings within 34 feet of proposed pile driving (for sound walls, structures and retaining walls) were identified and evaluated individually.

Table 3: Vibration Evaluation for Historic Properties

JRP No.	Scott No.	Structure type	Soil class (n)	Proposed foundation feature	Max credible pile class	Max hammer Energy (ft-lb)	Distance from prop piles (ft)	Allowable min distance from prop piles (ft)	Calculated vibration amplitude (in/sec)	Maximum amplitude/ no damage	Comments
22	S-2	historic, old	1.3	soundwall	140	42000	64	42	0.107	0.25	1889 2-story Summerland
			1.3	bridge-Evans	200	42000	2170	55	0.002	0.25	
24	S-4	historic, old	1.3	soundwall	140	42000	73	42	0.082	0.25	1889 1-story Summerland
			1.3	bridge-Evans	200	42000	2005	55	0.002	0.25	
36	S-18	historic, old	1.1	soundwall	140	42000	256	64	0.054	0.25	McIntyre House
			1.1	bridge-Evans	200	42000	315	64	0.043	0.25	
40	n/a	historic, old	1.1	soundwall	140	42000	218	64	0.065	0.25	Darling House
			1.1	bridge-Evans	200	42000	200	64	0.071	0.25	
42	S-19	historic, old	1.1	soundwall	140	42000	84	64	0.185	0.25	Becker House
			1.1	bridge-Evans	200	42000	300	64	0.046	0.25	
43	M-1	historic,	1.1	soundwall	140	42000	210	179	0.068	0.08	Ortega-Masine Adobe
		extremely fragile	1.1	bridge-Sheffield	200	42000	300	179	0.046	0.08	
51	M-38	historic, old	1.1	soundwall	140	42000	100	64	0.153	0.25	Danielson-Katenkamp House
			1.1	bridge-Oak	200	42000	105	64	0.145	0.25	
n/a	M-7	historic, old	1.1	soundwall	140	42000	163	64	0.089	0.25	Greenways homesite
			1.1	bridge-Oak	200	42000	140	64	0.106	0.25	
n/a	M-36	historic, old	1.1	soundwall	140	42000	152	64	0.096	0.25	99 Humphrey Road
			1.1	bridge-Oak	200	42000	2120	64	0.005	0.25	
n/a	M-12A	historic, old	1.1	soundwall	140	42000	166	64	0.087	0.25	Acacia Lodge
			1.1	bridge-Oak	200	42000	1400	64	0.008	0.25	
n/a	M-5	new or reconst	1.3	soundwall	140	42000	60	54	0.225	0.50	Eisenberg House (completely reconstructed)
			1.3	bridge-Romero	200	42000	100	54	0.116	0.50	
n/a	025	historic, old	1.3	soundwall	140	42000	70	64	0.184	0.25	unnamed LaVuelta
			1.3	bridge-Romero	200	42000	310	64	0.027	0.25	

A total of 33 parcels were identified as being located within this zone. These properties have all been determined to have an increased potential for architectural damages and/or human annoyance. Special provisions will be provided in the construction contract to minimize or mitigate potential impacts. Additionally, as depicted on the mapping contained in Appendix C, properties that fall within or adjacent to established buffer zones will have site specific low vibration construction methods employed to ensure there are no impacts due to construction induced vibration. (Refer to Appendix B for a listing and maps of these properties and Appendix C for mapping).

Mobile Home Analysis

Nineteen parcels located within several mobile home parks were identified within a safe distance limit of 64 feet. Due to the foundation type for these structures, these properties do not have rigid foundations and are built to withstand the type of vibration typical of sound wall construction and do not have great potential for vibration related impacts. (Refer to Appendix B and C for a listing and maps of these properties).

10. Vibration Reduction Strategies

As with construction noise, in many cases the information available during the preliminary engineering phase will not be sufficient to define specific construction vibration mitigation measures. In such cases, it is appropriate to describe and commit to a Vibration Reduction and Minimization Plan (VRMP) that will be developed and implemented during the final design and construction phases of the project. The VRMP will be produced by Design with input from the Environmental division, Construction, and other functional units as appropriate. The objective of the VRMP should be to avoid construction vibration damage using all reasonable and feasible means available. The VRMP should provide a procedure for establishing thresholds and limiting vibration values for structures with a potential to be adversely affected, based on an assessment of each structure's ability to withstand the loads and displacements due to construction vibrations. The VRMP should also include the development of a vibration monitoring strategy during final design and the implementation of compliance and where needed building monitoring program including pre and post photo survey during construction as feasible.

A few alternatives to standard driven piles are discussed below. The list is not meant to be inclusive or to suggest that these measures are mandatory for use, rather the listed measures merely represent the types of techniques that could be employed. Unlike with noise, there is no easy way to mitigate earth-borne vibrations. There are however, a limited number of options available to reduce their impact. Once detailed geotechnical data is available, the

options discussed below will be evaluated in further detail in the aforementioned VRMP developed specifically for the project.

Alternative Foundation Types: The easiest way to eliminate the potential for structural damage or human annoyance is simply to avoid driving piles in the first place. Standard plan spread footings should be used in all instances where their use is permitted. Typically piles must be driven in wet or unfavorable soil conditions. Standard spread footings are a much cheaper foundation type and would be predominately used on this project.

Jetting: Jetting is a pile driving aid in which a mixture of air and water is pumped through high-pressure nozzles to erode the soil adjacent to the pile to facilitate placement of the pile. Jetting can be used to bypass shallow, hard layers of soil that would generate high levels of vibration at or near the surface if an impact pile driver were used.

Pre-drilling: Pre-drilling a hole for a pile can be used to place the pile at or near its ultimate depth, thereby eliminating most or all impact driving.

Cast-in-place or auger cast piles: Using cast-in-place or auger cast piles eliminates impact driving and limits vibration generation to the small amount caused by drilling, which is negligible.

Non-displacement piles: Use of non-displacement piles such as H piles may reduce vibration from impact pile driving because this type of pile achieves its capacity from end bearing rather than from large friction transfer along the pile shaft.

Pile cushioning: With pile cushioning, a resilient material is placed between the driving hammer and the pile to increase the period of time over which the energy from the driver is imparted to the pile. Keeping fresh, resilient cushions in the system can reduce the vibration generated by as much as a factor of 2.

Scheduling: Limiting construction activities to specific times can minimize disturbance at nearby vibration-sensitive sites: Adverse effects can be avoided if pile driving is not scheduled for times at which vibration could disturb equipment or people. For example, if pile driving near a residential area can be scheduled during business hours on weekdays, many people will be at work and will therefore not be affected.

Using alternative non-impact drivers: Several types of proprietary pile driving systems have been designed specifically to reduce impact-induced vibration by using torque and down-pressure or hydraulic static loading. These methods would be expected to significantly reduce adverse vibration effects from pile placement. The applicability of these methods depends in part on the type of soil. The following information is provided for informational purposes only. This discussion is not intended to favor any commercial product; inclusion of information on these products does not constitute endorsement or approval by Caltrans.

11. Standard Avoidance, Minimization, and/or Mitigation Measures

Avoiding the adverse vibration effects caused by planned construction activities and subsequent highway operations involves informing the public of the potential for these effects and using physical methods to reduce vibration impacts. Information disseminated to the public about the kinds of equipment, expected noise levels and durations will help to forewarn potentially affected neighbors about the temporary inconvenience. In these cases, a general description of the variation of noise levels during a typical construction day may be helpful.

In general, literature on the subject shows that only blasting, pile driving, and pavement breaking have documented examples of potential damage to buildings (American Association of State Highway and Transportation Officials [AASHTO] 1990). For pile driving and pavement breaking, the potential for damage from vibration is at locations in relatively close proximity to the activity. However, because the threshold of perception for vibration is much lower than the threshold for damage, claims of damage often arise because of perceptible vibration and not because of actual damage.

Standard Special Provisions (SSPs) have been developed that the contractor must implement to accommodate these types of potential issues. Typically these SSPs include performance based mitigation measures such as before-and-after structural evaluations of the subject property by a licensed structural engineer including photo/video surveys. The SSPs state that, since Caltrans does not control the means and methods of construction, the contractor is liable if damage is done to any structure due to their activities.

Every attempt should be made to mitigate the adverse vibration effects from construction activities through the use of modern techniques, procedures, and products. It is equally important to develop a process to avoid and, if necessary, address problems identified by the public that can arise from construction activities, even when the levels of vibration are well below the levels at which damage to structures or excessive annoyance to humans are

expected to occur. The following steps will be taken in development of the location-specific vibration reduction plan:

- Identify potential problem areas surrounding the localized project work area,
- Determine conditions that exist before construction begins,
- Notify nearby residents and property owners that vibration-generating activity is imminent,
- Inform the public about the project and potential vibration-related consequences,
- Schedule work to reduce adverse effects,
- Design construction activities to reduce vibration,
- Monitor and record vibration from the activity if necessary;
- Respond to and investigate complaints.

To reduce the effects of construction vibration from pile driving, structure demolition and pavement breaking for Vibration Sensitivity zones at 100-foot and 300-foot intervals, the following measures are recommended to be included in a Vibration Reduction Plan:

1) Notify residents within 300 feet of areas where construction activities and pavement breaking will take place at least two weeks in advance of the proposed activity through the local news media and by mail. Residents may wish to secure fragile items that could be damaged by shaking. See Figure 3 for the attenuation of vibration with distance from a pile driving or pavement breaking activity.
2) When especially egregious activities are expected to be conducted at night, arrange motel rooms for residents living adjacent to the proposed activity when protracted vibrations approaching 0.20 inches/second are expected at their residences.
3) Monitor and record peak particle velocities near sensitive receptors identified while the highest vibration producing activities are taking place (Refer to Appendix A for maps and a listing of these properties)
4) Use rubber tired instead of tracked vehicles near vibration sensitive areas.
5) For paving operations and bridge work, assure that night joints and bridge conforms are as smooth as possible, especially where there is heavy truck traffic near residences.
6) Perform activities most likely to propagate objectionable vibrations during the day, or at least before most residents retire for the night.
7) Restrict pavement breaking to daylight hours.

8) As much as possible, conduct pile driving during daylight hours.

9) Phase demolition, earth-moving and ground-impacting operations so as not to occur in the same time period. Unlike noise, the total vibration level produced could be significantly less when each vibration source operates separately.

10) Use of Standard Plan cast in drill hole (CIDH) piles, trench footings, or spread footings are the preferred sound wall foundations. In areas when these foundations are not feasible, low intensity pile driving techniques would be employed when soil and other conditions are favorable, with peak particle velocity (PPV) not to exceed:

Carpinteria

NB - PM 3.31to 3.46 <0.25 in/sec at buildings
NB - PM 3.66 to 3.73 <0.50 in/sec at buildings
NB - PM 3.73 to 3.76 <0.25 in/sec at buildings
NB - PM 3.76 to 3.79 <0.50 in/sec at buildings

SB - PM 3.68 to 3.72 <0.25 in/sec at buildings
SB - PM 3.72 to 3.74 <0.50 in/sec at buildings
SB - PM 3.74 to 3.78 <0.25 in/sec at buildings
SB - PM 3.90 to 3.95 <0.25 in/sec at buildings
SB - PM 3.95 to 4.05 <0.50 in/sec at buildings

Summerland

NB - PM 7.84 to 7.89 <0.25 in/sec at buildings
NB - PM 7.89 to 7.94 <0.25 in/sec at buildings
NB - PM 8.05 to 8.18 <0.25 in/sec at buildings
NB - PM 8.20 to 8.24 <0.25 in/sec at buildings
NB - PM 8.41 to 8.44 <0.50 in/sec at buildings
NB - PM 8.47 to 8.53 <0.50 in/sec at buildings

Sheffield

NB - PM 9.09 to 9.14 <0.25 in/sec at buildings
NB - PM 9.19 to 9.23 <0.25 in/sec at buildings

Montecito

SB - PM 9.56 to 9.59 <0.25 in/sec at buildings
NB - PM 9.67 to 9.72 <0.25 in/sec at buildings
NB - PM 10.18 to 10.20 <0.25 in/sec at buildings
SB - PM 10.12 to 10.44 <0.25 in/sec at buildings
SB - PM 10.55 to 10.59 <0.25 in/sec at buildings
SB - PM 10.59 to 10.64 <0.50 in/sec at buildings

Santa Barbara

SB - PM 11.60 to 11.64 <0.25 in/sec at buildings
SB - PM 12.08 to 12.10 <0.25 in/sec at buildings

12. References

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Appendix A Historic Property Vibration Induced Analysis List

APN	Address	City/Area	Structure Type	Resource	Map Sheet No.	Soil Class (n)	Proposed Foundation Feature	Maximum Credible Pile Class	Maximum Hammer Energy	Distance from Proposed Piles (ft)	Allowable Minimum Distance from Proposed Piles (ft)	Calculated Vibration Amplitude (in/sec)	Maximum Amplitude With No Damage (in/sec)
005-194-006	2492 Lillie	Summerland	Historic, old	2-story residence (1889)	15	1.3	Soundwall	140	42000	64	42	0.107	0.25
							Bridge – Evans	200	42000	2170	55	0.002	0.25
005-194-004	2480 Lillie	Summerland	Historic, old	1-story residence (1889)	15	1.3	Soundwall	140	42000	73	42	0.082	0.25
							Bridge – Evans	200	42000	2005	55	0.002	0.25
005-175-003	2274 Lillie	Summerland	Historic, old	McIntyre House	15	1.1	Soundwall	140	42000	256	64	0.054	0.25
							Bridge – Evans	200	42000	315	64	0.043	0.25
005-172-003	2225 Lillie	Summerland	Historic, old	Darling House	16	1.1	Soundwall	140	42000	218	64	0.065	0.25
							Bridge – Evans	200	42000	200	64	0.071	0.25
005-173-001	108 Pierpont	Summerland	Historic, old	Becker House	16	1.1	Soundwall	140	42000	85	64	0.181	0.25
							Bridge – Evans	200	42000	300	64	0.046	0.25
007-350-020	129 Sheffield	Montecito	Historic, old, extremely fragile	Ortega-Masini Adobe (c1820s)	17	1.1	Soundwall	140	42000	210	179	0.068	0.08
							Bridge - Sheffield	2-00	42000	300	179	0.046	0.08
007-373-001	1637 Posilipo	Montecito	Historic, old	Danielson-Katenkamp House	18	1.1	Soundwall	140	42000	164	64	0.089	0.25
							Bridge – Oak	200	42000	105	64	0.145	0.25
005-210-026, 005-210-028, 005-210-032	2950 Via Real	Carpinteria	Historic, old	CD Hubbard Ranch house (c1858)	12	1.1	Soundwall	140	42000	1588	64	0.0007	0.25
							Structure or bridge	200	42000	121	64	0.124	0.25
005-270-042	3375 Foothill	Carpinteria	Historic, old	Fleischmann Polo Field (no structure)	11	1.1	Soundwall	140	42000	526	64	0.025	0.25
							Structure or bridge	200	4200	1082	64	0.011	0.25
007-333-003	1630 N Jameson	Montecito	Historic, old	Greenways Estate (c1916) The estate is officially listed in the NRHP	18	1.1	Soundwall	140	42000	168	64	0.086	0.25
							Structure or bridge	200	42000	164	64	0.089	0.25
007-340-010	135 La Vuelta	Montecito	Historic, old (now new construction)	Eisenberg House Determined eligible for the NRHP in 1992; replaced with new construction in 2010	18	1.1	Soundwall	140	42000	61	34	0.263	0.50
							Structure or bridge	200	42000	152	34	0.50	
009-263-006	109 Miramar	Montecito	Historic, old	Acacia Lodge (c1917)	19	1.1	Soundwall	140	42000	166	64	0.087	0.25
							Bridge – Oak	200	42000	1400	64	0.008	0.25

APN	Address	City/Area	Structure Type	Resource	Map Sheet No.	Soil Class (n)	Proposed Foundation Feature	Maximum Credible Pile Class	Maximum Hammer Energy	Distance from Proposed Piles (ft)	Allowable Minimum Distance from Proposed Piles (ft)	Calculated Vibration Amplitude (in/sec)	Maximum Amplitude With No Damage (in/sec)
009-263-007	100 San Ysidro	Montecito	Historic, old	Wylbron Lodge (c1909)	19	1.1	Soundwall	140	42000	609	64	0.021	0.25
							Soundwall	140	42000	432	64	0.031	0.25
009-293-007	1295 Coast Village	Montecito	Historic, old	Montecito Inn (c1928)	20	1.1	Soundwall	140	42000	246	64	0.057	0.25
							Soundwall	140	42000	537	64	0.024	0.25
009-331-005	1469-1471 S Jameson, and 93, 95, 99 Humphrey	Montecito	Historic, old	Humphrey Road Historic District (c1890-1910s)	19	1.1	Soundwall	140	42000	155	64	0.094	0.25
							Soundwall	140	42000	302	64	0.045	0.25

Appendix B Non-Historic Property Vibration Induced Analysis List

Properties with A 64-foot Buffer (Non-Historic)

APN	Owner	Address	City/Area	Year Built	Land Use	Map Ref No.
003-103-008 and 003-103-011	Cisneros	1373 Cramer St	Carpinteria	1935	SFR on 2 parcels	JRP: 15
003-210-001	Espinoza	1043 Plum St	Carpinteria	1960	SFR	JRP: 18
003-542-015	Scott/Cooper	1314 Sterling Ave	Carpinteria	1962	SFR	JRP: 1
003-542-016	Castro Trust	1313 Sterling Ave	Carpinteria	1962	SFR	JRP: 2
003-552-028	Westmore	1312 Post Ave	Carpinteria	1964	SFR	JRP: 7
003-552-037	Marquez	1313 June Ave	Carpinteria	1964	SFR	JRP: 6
003-552-038	Rodriguez	1314 June Ave	Carpinteria	1964	SFR	JRP: 5
007-333-004	Butler Family Trust	1620 N Jameson Ln	Montecito	1958	SFR	PJC: 97
007-350-019	Lewis	111 Arroqui St	Montecito	1920	SFR	PJC: 105
007-373-004	Blaser Trust	1645 Posilipo Ln	Montecito	1951	SFR	JRP: 48
009-251-005	Zaki	1424 La Vereda Ln	Montecito	1922	SFR	PJC: 96
009-294-002	Garner	75 Olive Mill Rd	Montecito	1925	SFR	JRP: 64
009-301-001	Corona	1394 Danielson Rd	Montecito	1946	SFR	JRP: 54
009-301-002	Sage	1396 Danielson Rd	Montecito	1920	SFR	PJC: 99
009-301-004	McAllister	1390 Virginia Rd	Montecito	1942	SFR	PJC: 98
009-301-005	Robinson	1380 Virginia Rd	Montecito	1938	SFR	JRP: 55
009-301-007	IDB Investments	1368 Virginia Rd	Montecito	1947	Residential rentals	JRP: 57
009-301-009	Schneider	1350 Virginia Rd	Montecito	1940	SFR	JRP: 59
009-304-012	Prenatt	1403 S Jameson Ln	Montecito	1900	SFR	PJC: 100
009-331-004	Akers	1465 S Jameson Ln	Montecito	1930	SFR	PJC: 103
003-210-002	Requejo	1041 Plum St	Carpinteria	1955	SFR	PJC: 94
004-036-004	Olivas Family Trust	4484 Carpinteria Ave	Carpinteria	1963	Residential rentals	JRP: 16
004-036-022	Goena	1094 Cramer Rd	Carpinteria	1930	Residential rentals	JRP: 13
005-177-005	Robertson Trust	2285 Lillie Ave	Summerland	1963	Service stations	JRP: 35
005-183-008	Azar	2325 Lillie Ave	Summerland	1925	Retail stores	JRP: 34
005-183-009	Azar	2329 Lillie Ave	Summerland	1890	Retail stores	JRP: 33

005-184-004*	Carpinteria Union HS	2375 Lillie Ave	Summerland	1918	WWI Monument	JRP: 31
005-184-005*	Carpinteria-Summerland Fire District	2375 Lillie Avenue	Summerland	1953	Public buildings	JRP: 32
009-301-006	Wright	1376 Virginia Rd	Montecito	1935	Residential rentals	JRP: 56
009-301-008	Loebman	1360 Virginia Rd	Montecito	1937	Residential rentals	JRP: 58
009-331-020	Hogan	1447 S Jameson Ln	Montecito	1922	Residential rentals	PJC: 102
017-391-001	Porter	50 Los Patos Way	Santa Barbara	1872	Retail stores	PJC: 104
009-320-019	Hammond Estate	1433 S Jameson Ln	Montecito	1900 and later	SFR	PJC: 101
005-192-006	Platinum Fitness	2448 Lillie Ave	Summerland	1964	Commercial Service	JRP: 27
005-192-005	Jarchow	2440 Lillie Ave	Summerland	1952	SFR	JRP: 28
005-192-004	McLeod	2430 Lillie Ave	Summerland	1930	SFR	JRP: 29
005-192-001	Presbyterian Church	2400 Lillie Ave	Summerland	1895	Religious institution	JRP: 30
007-350-011	Clearly	126 Loureyro Rd	Montecito	1940	SFR	JRP: 45

*** Information on the resources located on these two parcels is reversed in the Santa Barbara County Assessor records. A field check verified that Assessor Parcel Number (APN) 005-184-005, located west of APN 005-184-004, is actually occupied by the Summerland World War I Monument; APN 005-184-004 is occupied by the Carpinteria-Summerland Fire Department.**

Properties with A 34-ft buffer (Built 1970 or newer)

APN	Owner	Address	City/Area	Year Built	Land Use	Map Sheet No.
003-102-020	UNKNOWN	UNKNOWN	CA	1984	Single Family Residence	
003-102-021	ORTIZ	1364 CRAMER CIR	CARPINTERIA,	1984	Single Family Residence	5
003-104-005	FERGUSON	1240 CRAMER CIR	CARPINTERIA	1995	Single Family Residence	5
003-104-014	NARANG ACQUISITION	1234 CRAMER CIR	CARPINTERIA,	2007	Single Family Residence	5
003-200-001	ROBITAILLE	4228 CARPINTERIA AVE 5	CARPINTERIA	1989	Condo	6
003-200-002	MOROPOULOS	4228 CARPINTERIA AVE 4	CARPINTERIA,	1989	Condo	6
003-200-026	RICH	4264 CARPINTERIA AVE 4	CARPINTERIA	1989	Condo	6
003-200-027	SANDOVAL	4264 CARPINTERIA AVE 5	CARPINTERIA,	1989	Condo	6
003-200-028	VEGA	4252 CARPINTERIA AVE 3	CARPINTERIA	1989	Condo	6
003-200-031	ORTEGA	4240 CARPINTERIA AVE 1	CARPINTERIA,	1989	Condo	6
003-200-032	TORRES	4240 CARPINTERIA AVE 2	CARPINTERIA	1989	Condo	6
003-200-033	HERNANDEZ	4240 CARPINTERIA AVE 3	CARPINTERIA,	1989	Condo	6
004-036-005	GUTIERREZ	1097 CRAMER RD	CARPINTERIA	2010	Single Family Residence	5
009-610-004	HESTRIN	1278 SPRING RD	SANTA BARBARA	1992	Condo	20
009-610-005	HESTRIN	1280 SPRING RD	SANTA BARBARA	1992	Condo	20
503-210-028	MANUEL	4400 CARPINTERIA AVE 28	CARPINTERIA	1989	Sited inside M/H Park	
503-210-032	GAGGERO	4400 CARPINTERIA AVE 32	CARPINTERIA	1987	Double Wide New Const	
503-210-070	HERTLEIN	4400 CARPINTERIA AVE 70	CARPINTERIA	2004	Sited inside M/H Park	
005-121-005	LEVINE	2165 ORTEGA HILL RD	SUMMERLAND	1990	warehouse	16

005-121-006	NORMAN	2173 ORTEGA HILL RD	SUMMERLAND	1980	office buildings	16
005-194-003	KIMSEY FAMILY TRUST	2476 LILLIE AVE	SUMMERLAND	1970	Store & Office	
017-500-001	UNKNOWN	1407 Park Place	SANTA BARBARA,	1977	Apartment Complex	

*** Information on the resources located on these two parcels is reversed in the Santa Barbara County Assessor records.**

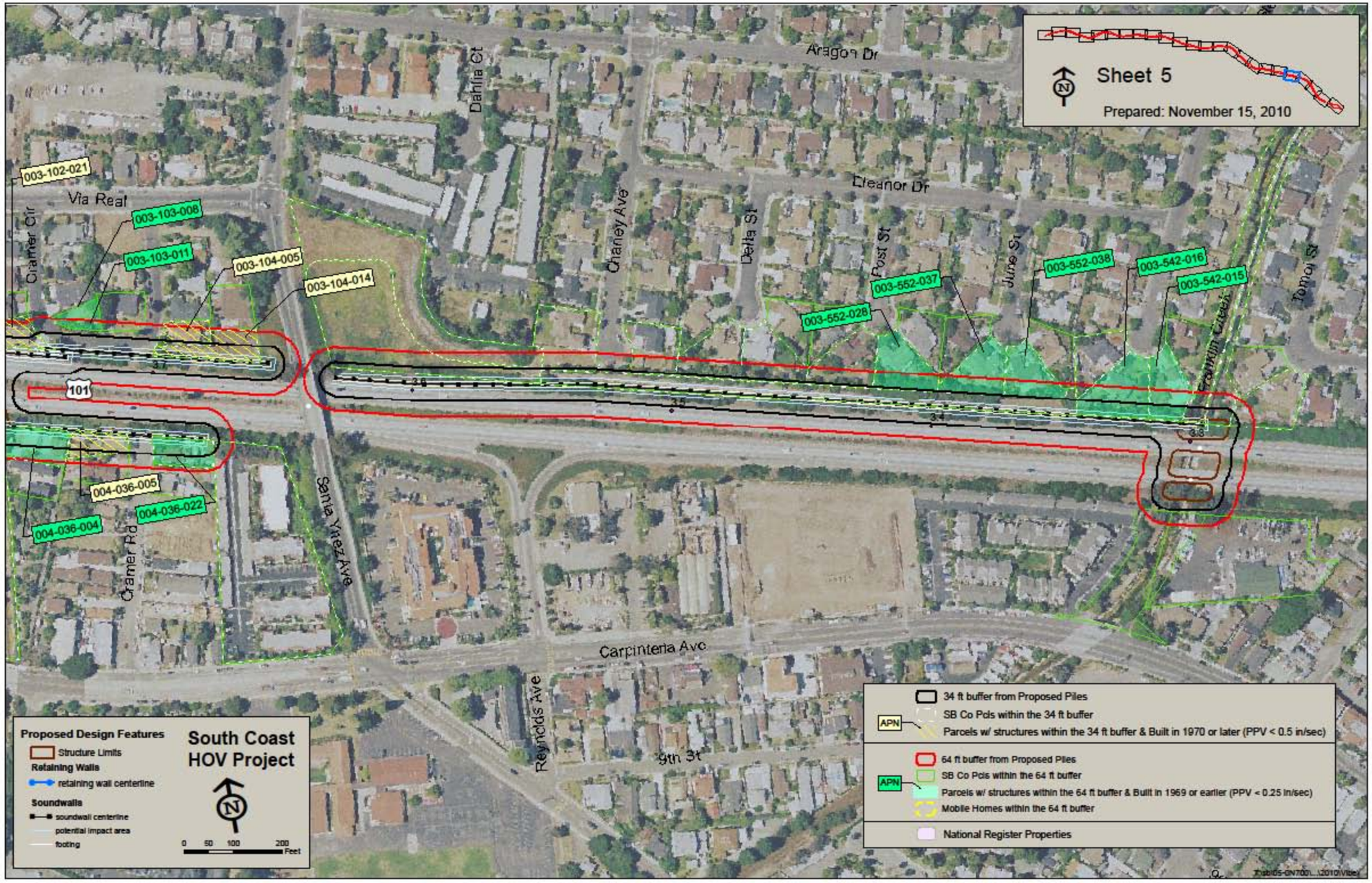
Properties with A 64-ft buffer (Mobile Homes)

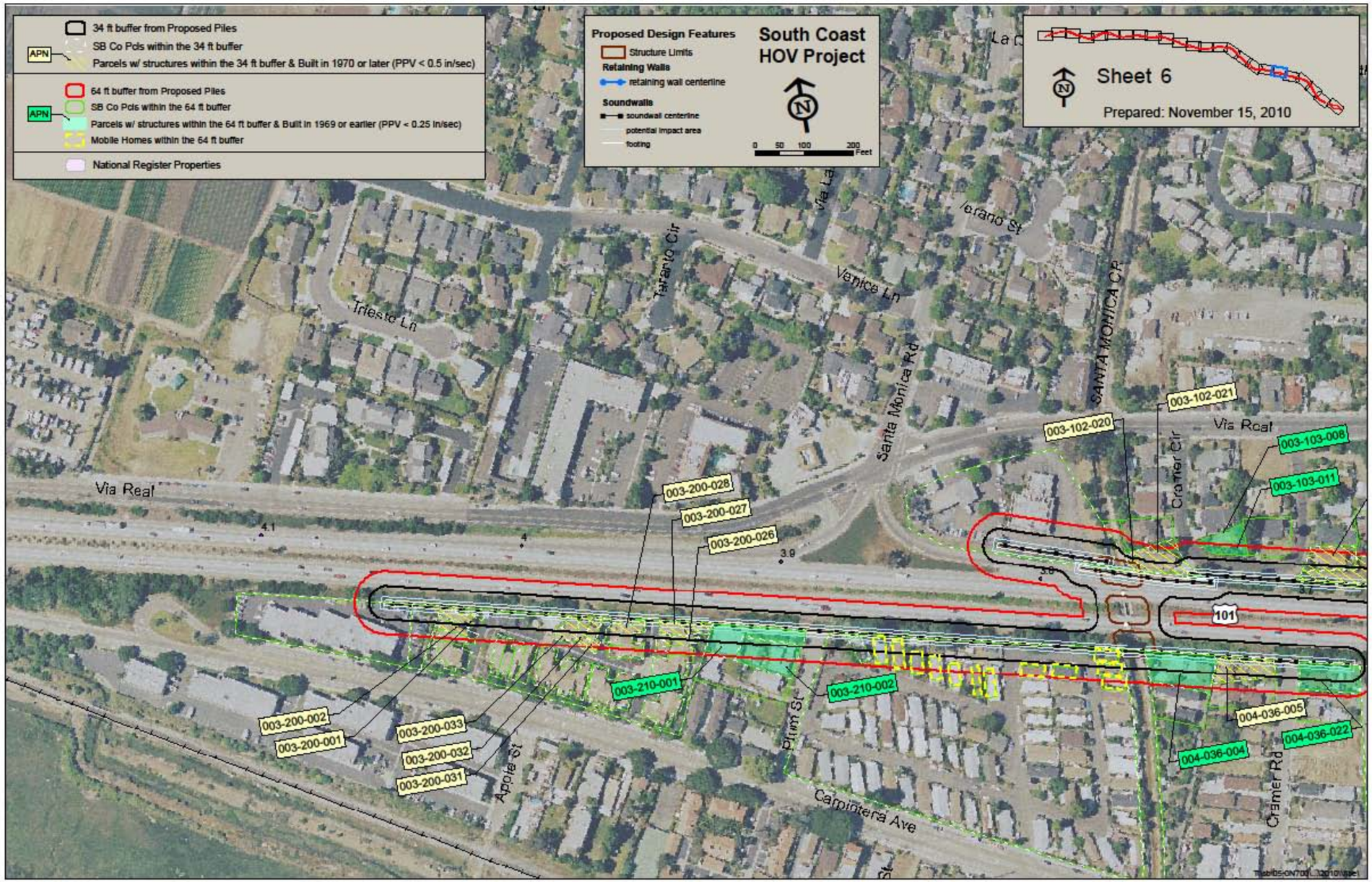
APN	Owner	Address	City/Area	Year Built	Land Use	Map Ref No.
501-073-001	WASILKO	5750 VIA REAL 311	CARPINTERIA	unknown	Sited inside M/H Park	
501-073-002	WISEMAN	5750 VIA REAL 312	CARPINTERIA	unknown	Sited inside M/H Park	
501-073-006	MCLAIN	5750 VIA REAL 200	CARPINTERIA	unknown	Sited inside M/H Park	
505-432-076	REYES	3950 VIA REAL 276	CARPINTERIA	unknown	Sited inside M/H Park	
505-432-077	COWEN	3950 VIA REAL 277	CARPINTERIA	unknown	Sited inside M/H Park	
505-432-078	HARRIGAN	3950 VIA REAL 278	CARPINTERIA	unknown	Sited inside M/H Park	
505-432-079	PENDERGRAFT	3950 VIA REAL 279	CARPINTERIA	unknown	Sited inside M/H Park	
505-432-080	MORA	3950 VIA REAL 280	CARPINTERIA	unknown	Sited inside M/H Park	
505-432-081	KENLY	3950 VIA REAL 281	CARPINTERIA	unknown	Sited inside M/H Park	
503-210-026	GALVEZ	4400 CARPINTERIA AVE 26	CARPINTERIA	1958	Sited inside M/H Park	
503-210-030	MARTINEZ	4400 CARPINTERIA AVE 30	CARPINTERIA	1958	Sited inside M/H Park	
503-210-034	TREJO	4400 CARPINTERIA AVE 34	CARPINTERIA	1958	Sited inside M/H Park	
503-210-036	HERRERA	4400 CARPINTERIA AVE 36	CARPINTERIA	1958	Sited inside M/H Park	
503-210-038	DELGADO	4400 CARPINTERIA AVE 38	CARPINTERIA	1958	Sited inside M/H Park	
503-210-039	MENDOZA	4400 CARPINTERIA AVE 39	CARPINTERIA	1958	Sited inside M/H Park	
503-210-040	WADLEY	4400 CARPINTERIA AVE 40	CARPINTERIA	1958	Sited inside M/H Park	
503-210-041	RAMIREZ	4400 CARPINTERIA AVE 41	CARPINTERIA	1958	Sited inside M/H Park	
503-210-069	VILLEGAS	4400 CARPINTERIA AVE 69	CARPINTERIA	1958	Double Wide New Const	
503-210-071	GARCIA	4400 CARPINTERIA AVE 71	CARPINTERIA	1958	Single Wide New Const	

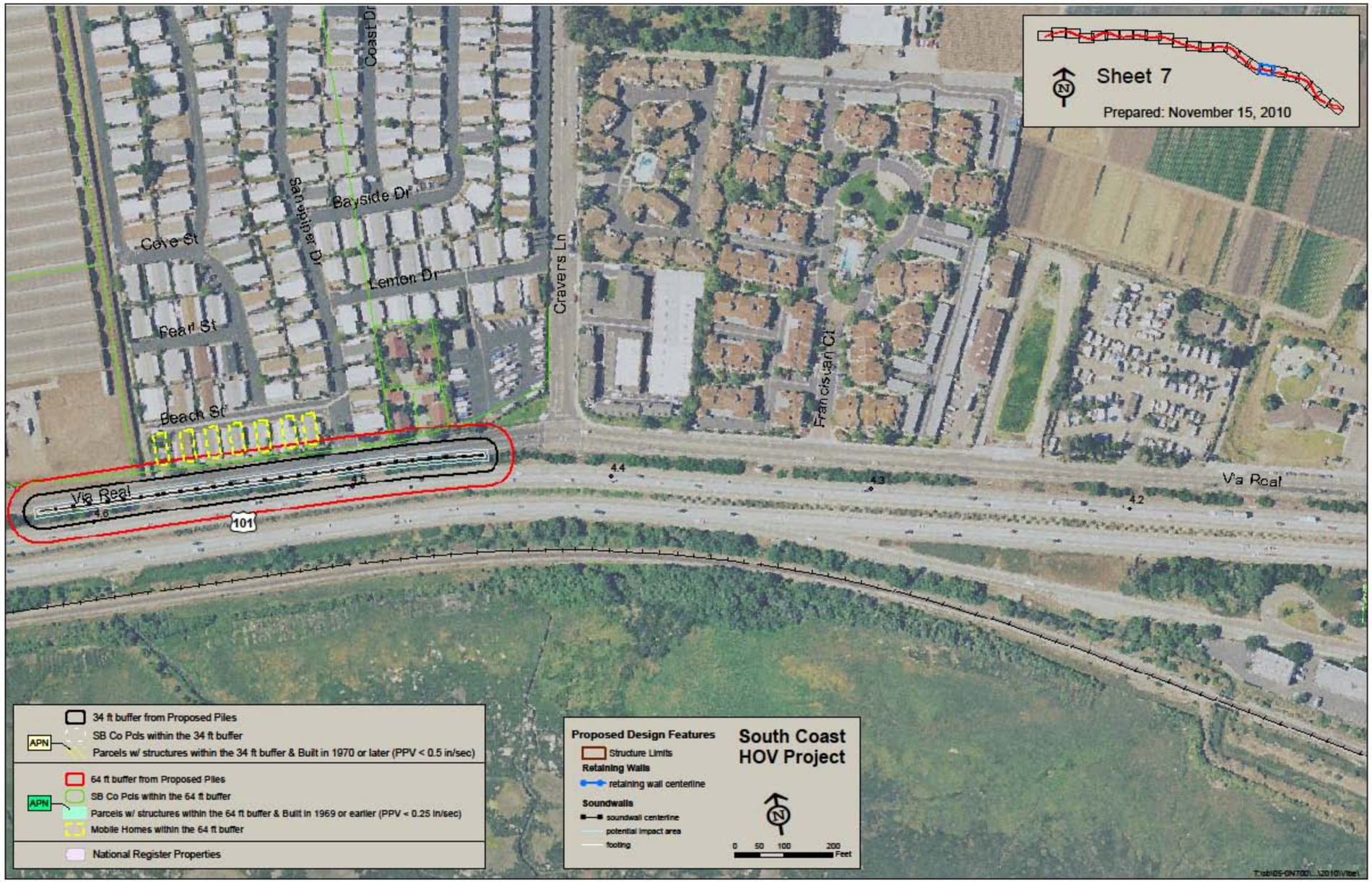
*** Information on the resources located on these two parcels is reversed in the Santa Barbara County Assessor records.**

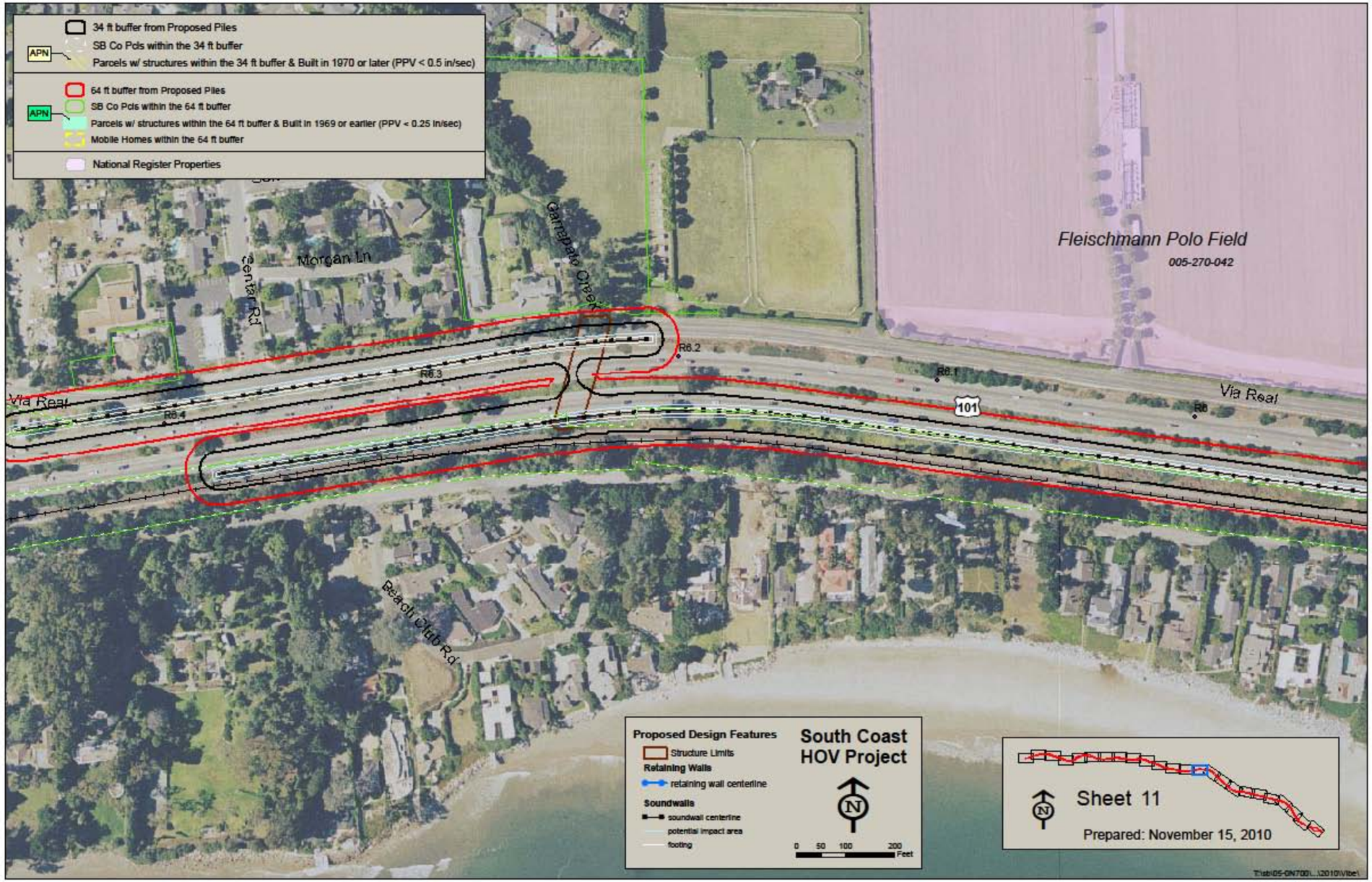
Appendix C Vibration Induced Mapping

Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
0 50 100 200 Feet
South Coast HOV Project
Sheet 2
Prepared: November 15, 2010
Via Elena
Via Picaro
Via El Rincon
Oakwood Dr
Via Maria
Lemonwood Dr
Via Linda
Rogue Dr
Via Real
101
Carpinteria Ave
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
APN
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
APN
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
National Register Properties


Sheet 5
Prepared: November 15, 2010
Aragon Dr
Dahlia Ct
Eleanor Dr
Via Real
Cramer Cir
Chaney Ave
Delta St
Post St
June St
Tomoi St
Franklin Creek
Santa Ynez Ave
Cramer Rd
Carpinteria Ave
Reynolds Ave
9th St
101
003-102-021
003-103-008
003-103-011
003-104-005
003-104-014
003-552-028
003-552-037
003-552-038
003-542-016
003-542-015
004-036-005
004-036-022
004-036-004
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
APN
National Register Properties

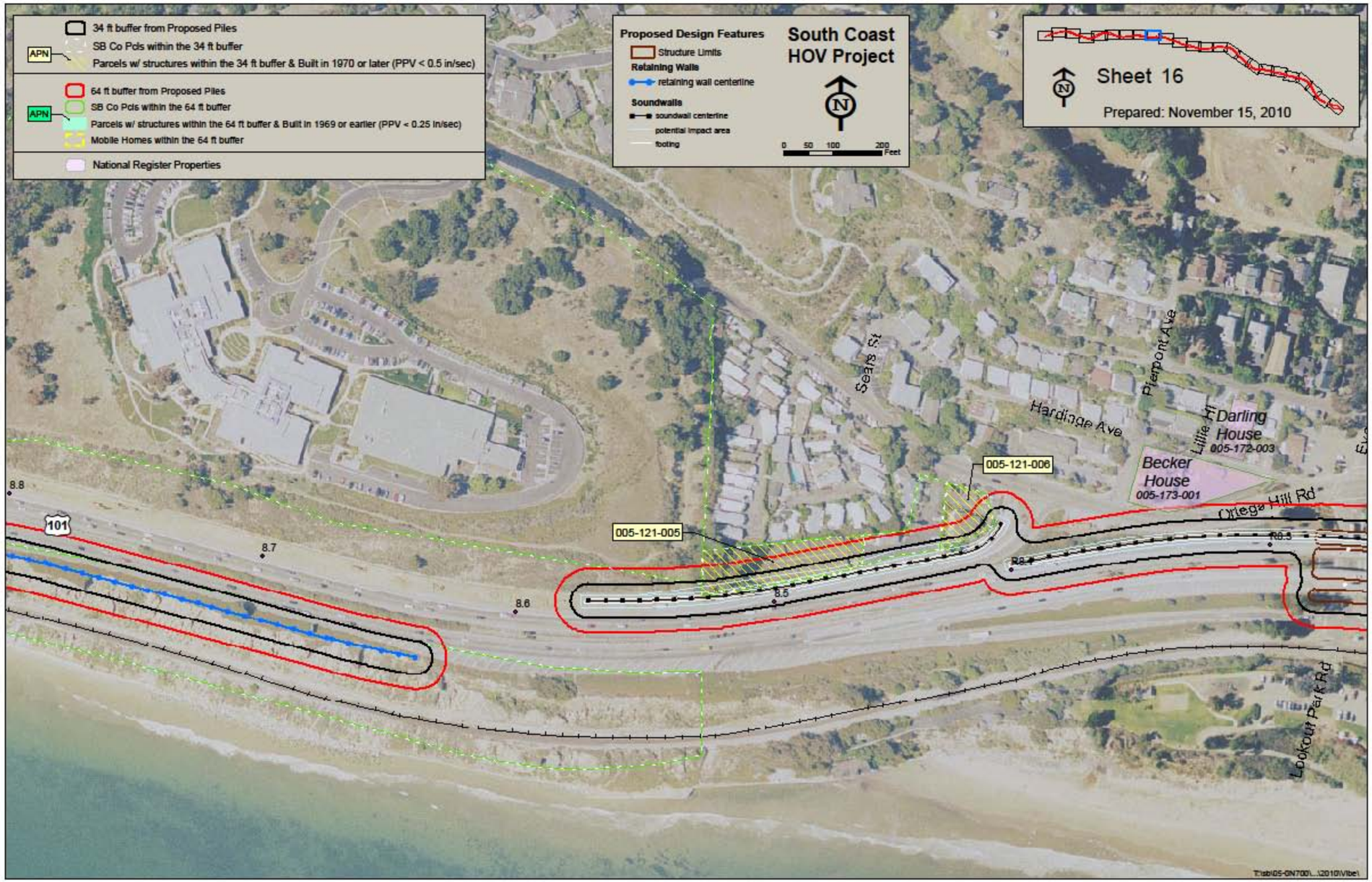

34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
APN
National Register Properties
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet
Sheet 6
Prepared: November 15, 2010
Via Real
Triesta Ln
Taranto Cir
Venice Ln
Santa Monica Rd
SANTA MONICA CR
Cramer Cir
Cramer Rd
Campiotera Ave
Pitm St
Apple St
101
003-200-028
003-200-027
003-200-026
003-200-002
003-200-001
003-200-033
003-200-032
003-200-031
003-210-001
003-210-002
003-102-020
003-102-021
003-103-008
003-103-011
004-036-005
004-036-004
004-036-022

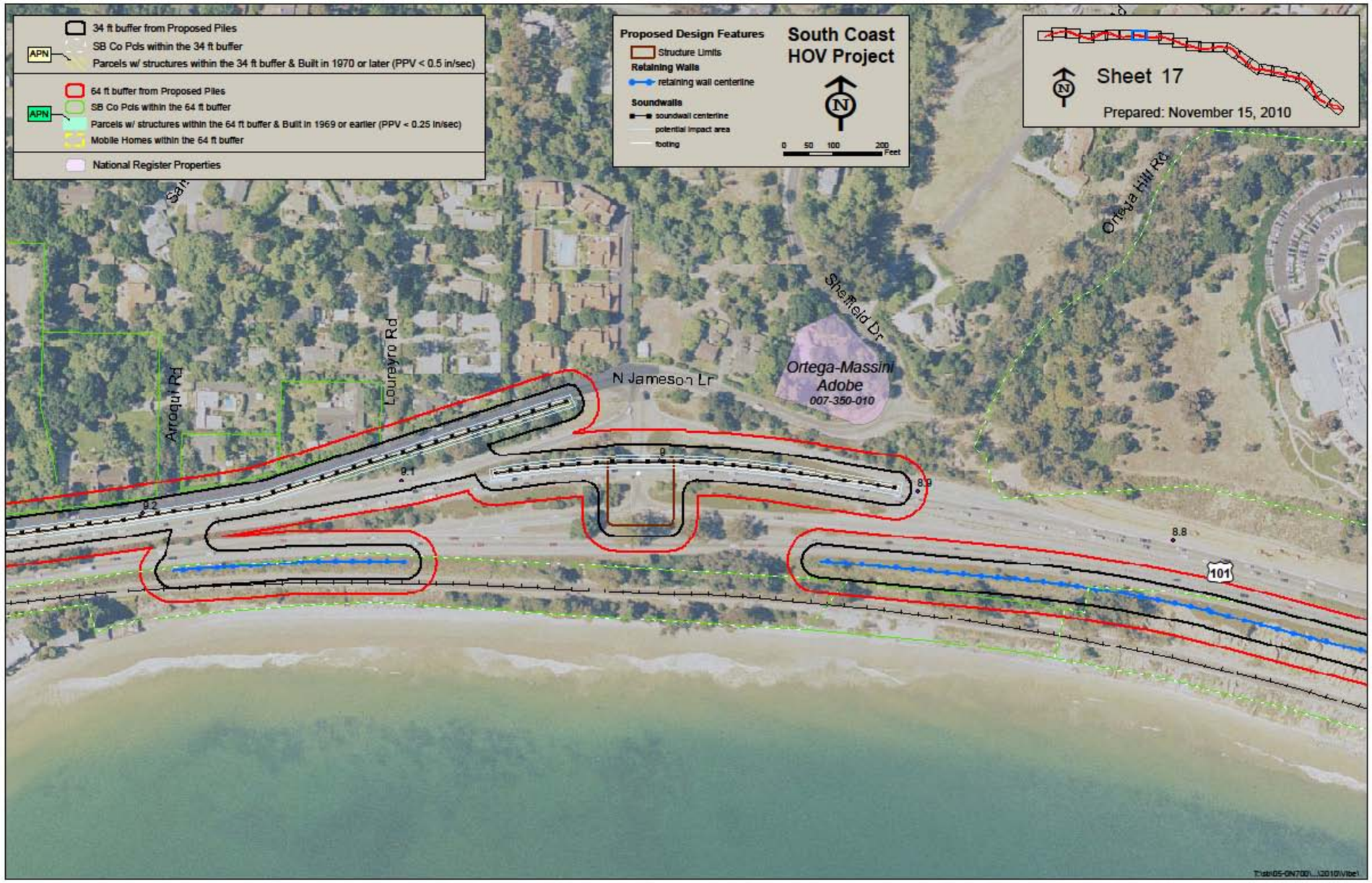

Sheet 7
Prepared: November 15, 2010
Coast Dr
Bayside Dr
Sandpiper Dr
Cove St
Lemon Dr
Pearl St
Beach St
Cravers Ln
Franciscan Ct
Via Real
101
4.4
4.3
4.2
4.5
4.6
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
National Register Properties
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet


34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
APN
National Register Properties
Fleischmann Polo Field
005-270-042
Morgan Ln
Santa Rd
Carpinteria Creek
Via Real
Via Real
Via Real
101
R6.1
R6.2
R6.3
R6.4
R6
Beach Club Rd
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast
HOV Project
N
0 50 100 200
Feet
N
Sheet 11
Prepared: November 15, 2010

Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
N
0 50 100 200 Feet
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
APN
National Register Properties
Serena Ave
C.D. Hubbard Ranch House
005-210-026
Toro Canyon Rd
Toro Canyon
Via Real
R6.9
101
R6.8
R6.7
R6.6
R6.5
R6.4
Padaro Ln
Sheet 12
Prepared: November 15, 2010

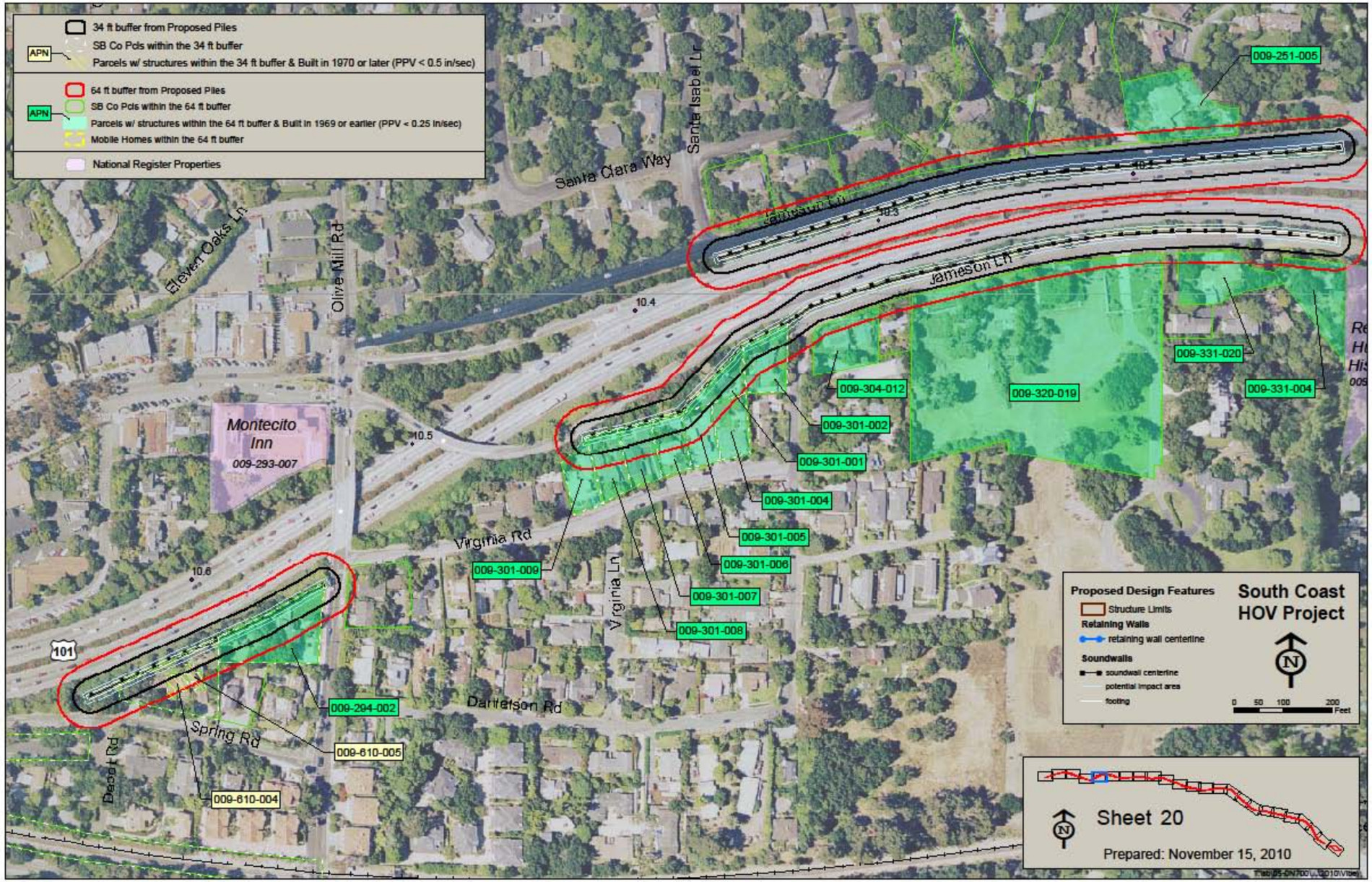
Sheet 15
Prepared: November 15, 2010
Darling House
005-172-003
McIntyre House
005-175-003
Lillie Hf
Evans Ave
Lillie Ave
Ortega Hill Rd
Valley St
Banner Ave
Golden Gate Ave
Shelby St
Sotville St
Valencia Rd
Olive St
Temple St
005-177-005
005-183-008
005-183-009
005-186-005
005-186-004
Lillis-Sloan Residence
005-194-004
Hickey Residence
005-194-006
Lookout Park Rd
Wallace Ave
Finney St
Via Real
101
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
National Register Properties
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet


34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
APN
National Register Properties
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast
HOV Project
0 50 100 200
Feet
Sheet 16
Prepared: November 15, 2010
Sears St
Hardinge Ave
Pierpont Ave
Little Hill
Darling
House
005-172-003
Becker
House
005-173-001
005-121-006
005-121-005
Ortega Hill Rd
Lookout Park Rd
101
8.8
8.7
8.6
8.5
R8.4
R8.3


34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
National Register Properties
APN
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
0 50 100 200 Feet
South Coast HOV Project
Sheet 17
Prepared: November 15, 2010
Ortega Hill Rd
Sheffield Dr
Ortega-Massini Adobe
007-350-010
N Jameson Ln
Loureyro Rd
Arroqui Rd
9
9.1
9.2
8.9
8.8
101

34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
National Register Properties
APN
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet
Sheet 18
Prepared: November 15, 2010
007-333-004
Greenways
007-333-003
San Ysidro Creek
La Vuelta Rd
Romero Creek
Arroyo Rd
Eisenberg House
007-340-010
101
Danielson-Katenkamp
007-373-001
Postrip Ln
Ferrari Point Ln
007-373-004

Sheet 19
Prepared: November 15, 2010
San Leandro Park Rd
La Vereda Ln
San Ysidro Rd
Wylbron Lodge
009-263-011
Miramar Ave
Miramar Ln
Acacia Lodge
009-263-006
Fomar Ln
Hixon Rd
009-251-005
10.1
10
9.9
9.8
9.7
007-333-004
Greenway
007-333-003
Creek
Residences in Humphrey Rd Historic District
009-331-005
009-331-020
009-331-004
Jameson Ln
Humphrey Rd
Eucalyptus Ln
Miramar Ave
Postrio Ln
101
34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
National Register Properties
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
0 50 100 200 Feet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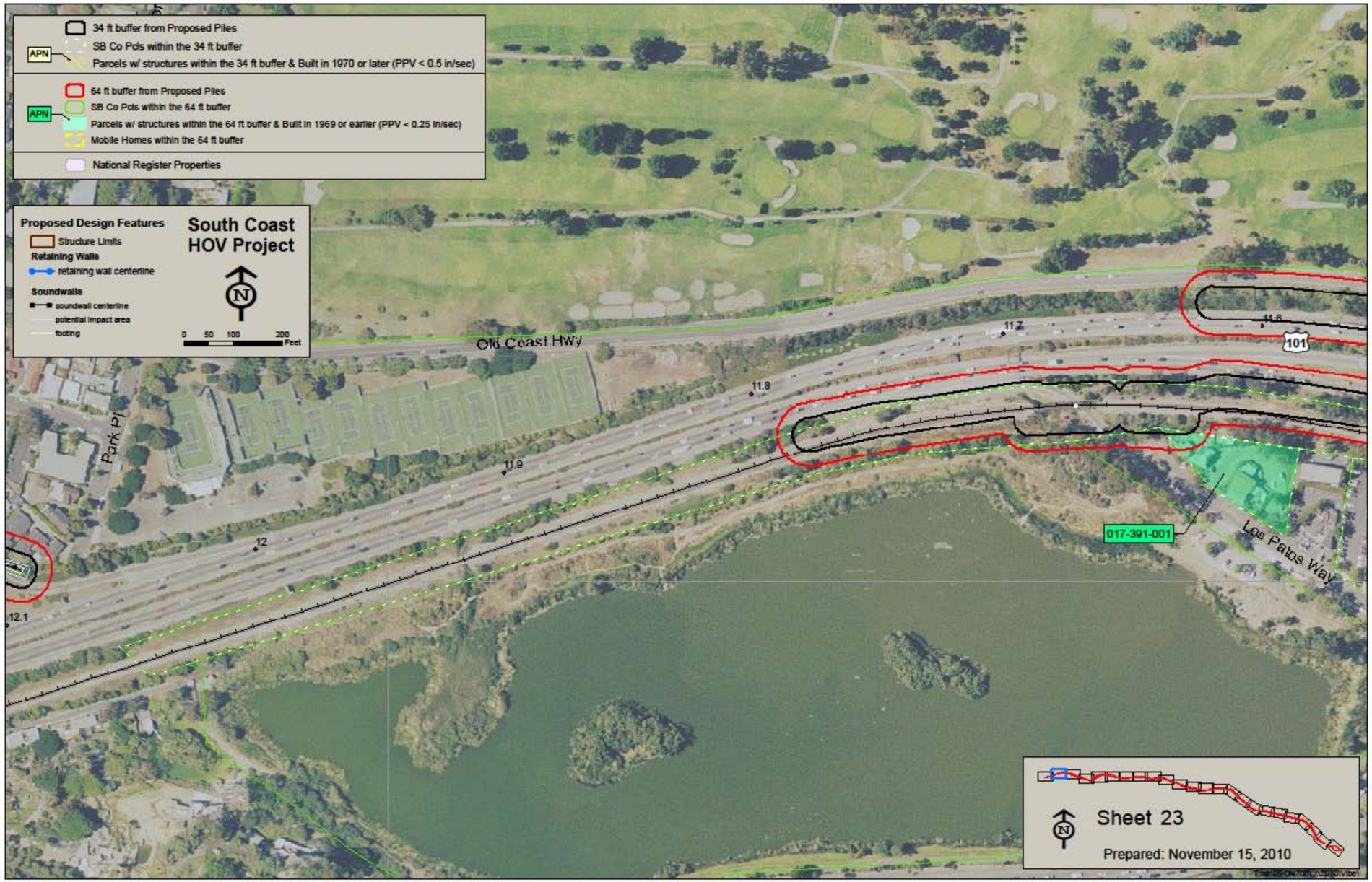
SB Co Pcls within the 34 ft buffer
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
APN
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
APN
National Register Properties
Santa Clara Way
Santa Isabel Ln
Jameson Ln
Eleven Oaks Ln
Olive Mill Rd
Montecito Inn
009-293-007
Virginia Rd
Virginia Ln
Darlielson Rd
Spring Rd
Depot Rd
101
009-251-005
009-331-020
009-331-004
009-320-019
009-304-012
009-301-002
009-301-001
009-301-004
009-301-005
009-301-006
009-301-007
009-301-008
009-301-009
009-294-002
009-610-005
009-610-004
10.3
10.4
10.5
10.6
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast HOV Project
N
0 50 100 200 Feet
Sheet 20
Prepared: November 15, 2010


34 ft buffer from Proposed Piles
SB Co Pcls within the 34 ft buffer
APN
Parcels w/ structures within the 34 ft buffer & Built in 1970 or later (PPV < 0.5 in/sec)
64 ft buffer from Proposed Piles
SB Co Pcls within the 64 ft buffer
APN
Parcels w/ structures within the 64 ft buffer & Built in 1969 or earlier (PPV < 0.25 in/sec)
Mobile Homes within the 64 ft buffer
National Register Properties
Proposed Design Features
Structure Limits
Retaining Walls
retaining wall centerline
Soundwalls
soundwall centerline
potential impact area
footing
South Coast
HOV Project
N
0 50 100 200
Feet
Old Coast Hwy
Park Pl
11.7
11.8
11.9
12
12.1
101
017-391-001
Los Patos Way
Sheet 23
Prepared: November 15, 2010