Final Report

ORANGE COUNTY RAIL-HIGHWAY GRADE CROSSING SAFETY ENHANCEMENT PROGRAM

SAN CLEMENTE AUDIBLE WARNING SYSTEM STUDY

TECHNICAL MEMORANDUM

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1.0 Executive Summary

The development of the San Clemente Beach Trail (SCBT) as a safety enhancing feature is, with one exception, considered a resounding success. The City of San Clemente (City) estimates that every year more than 2.5 million pedestrians cross the railroad tracks to get to and from the beach; this adds up to millions of crossings of the railroad tracks annually. Before development of the SCBT with its fencing, signage, and designated at-grade crossings equipped with warning bells, flashing lights and automatic gates, these public beach goers crossed the railroad tracks at will and at any location they chose. While the improvement in safety is unquestionable, the several successive soundings of the train horns at each of the crossings throughout the day and night has resulted in a community noise problem for the many residents who live adjacent to the approximately 2.3 miles of railroad track and SCBT.

Federal Railroad Administration (FRA) Train Horn rule (Rule) requires that locomotive horns be sounded at most public highway-rail intersections (grade crossings) in the United States(49 CFR Part 222). This is due to the incontrovertible evidence showing that horns are an effective safety device preventing collisions at crossings. However, because the blowing of railroad train horns has an adverse effect on the acoustical environment of adjacent noise-sensitive use, especially at night, the Rule typically provides an opportunity for a community to establish a “quiet zone” in which the locomotive horn would not be sounded at crossings provided supplementary safety measures (SSMs) fully compensate for the absence of the warning provided by the locomotive horn. Unfortunately, based on interpretation of the Rule, the nature of the San Clemente Beach Trail (SCBT) pedestrian-bicycle only crossings and their locations with respect to municipal boundaries appear to preclude the implementation of an FRA-defined quiet zone.

An alternative solution to the community noise issue at railroad/highway crossings allowed by the FRA is a “Wayside Horn” (WH); this is a stationary acoustic source (typically a horn loudspeaker) located at the crossing. The WH is sounded in place of the locomotive’s compressed air-driven warning horn (train horn) when a train approaches. Oriented differently than the train horn, the WH is positioned to direct the sound generally along the intersection roadways rather than along the track where the train horn is directed. The directional WH can therefore operate at a slightly lower sound level than a locomotive horn, while maintaining the effectiveness of an audible warning for safety purposes. The major acoustical benefit of a WH is that it is fixed in position and concentrates its sound at the crossing where it is needed, rather than toward adjacent residential use where its warning is unnecessary. A shortcoming of the WH approach in San Clemente along the SCBT is that the sound level produced by a WH was designed to warn the driver inside a moving motor vehicle of an approaching train. Thus a WH sound is also quite loud and disturbing to adjacent noise-sensitive uses including residents who do not require warning of an approaching train. This study finds that the relatively loud warning sound from a train horn or a WH is not necessary to provide the SCBT Users (walkers, joggers, and bicyclists) an equivalently effective and safe audible warning of an approaching train.

The objective of this study was to evaluate the characteristics of an Audible Warning System (AWS) that could function as a “WH for pedestrians and bicyclists”, who are the only user group authorized to travel on the SCBT. The SCBT Users are moving much slower than a motor vehicle; they are outdoors and not inside a closed vehicle; and they are engaged in simple tasks with minimal distractions or need to make complex decisions regarding train avoidance. Thus an audible warning from the AWS at a substantially reduced sound level, delivered to the SCBT User's ear as they approach a pedestrian-bicycle/railroad crossing, can be just as effective as a WH warning is for a driver in a vehicle.

Safety was the premier concern in this study as it has been during each phase of the SCBT development process. For example, numerous features to enhance safety were incorporated into the SCBT as a result of a settlement agreement with the California Public Utilities Commission.

A safety-biased conservative approach was taken by the study team for each calculation, comparison, analysis and recommendation. Based on analysis contained in this report, the baseline sound level required from the AWS at the SCBT User's uncovered ear is 70 decibels. A ten decibel margin of safety was added to account for miscellaneous audible distractions and for SCBT Users who wear earbuds. Thus, an **AWS sound level of 80 decibels is required at the SCBT User's ear (external to earbuds, if worn), delivered when the User is twenty feet before the crossing gate arm(s) in the horizontal position**. Based on a likely configuration of the AWS, with the loudspeaker located at the side of the 10-feet-wide SCBT near crossings, this would require the AWS to nominally produce 80 dBA at a distance of 10 feet from the AWS loudspeaker.

Where the Users' speeds were required for calculations, this study utilized the 85th percentile of measured speeds, including the small number of bicyclists who travel twice as fast as walkers and joggers. Time calculations used conservative assumptions as well. The minimum required duration of an AWS signal of less than three seconds was doubled to six seconds in the interest of safety. The recommended location of an AWS loudspeaker is 10 to 20 feet before each crossing gate which places the loudspeaker closer to the SCBT Users who need the train-horn-sound warning. Because of the typical coverage pattern and orientation provided by a suitable loudspeaker, the 20-feet-before-the-gate location can provide the AWS warning sound at the necessary decibel level 30 feet before the gate. Thus, depending on final design, the initial, conservative warning zone of20 feet before the gate may be increased by up to 150 percent without causing increased noise in the adjacent community. Conversely, an AWS loudspeaker located 10 feet from the gate can provide a more robust and noticeable AWS warning signal in the presence of the potentially interfering sound of the gate bells, also without causing increased noise in the adjacent community. A beneficial feature of the AWS is flexibility without compromising safety. The substantially lower, but safe, sound level required to be produced by the AWS benefits the adjacent community by substantially reducing noise pollution where the warning signal is not needed.

An extensive discussion regarding the development of the federal train horn Rule and WH sound level requirements was provided by staff of the U.S. Department of Transportation, Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center (Volpe), who also conducted a review and evaluation of this AWS study's Agency Review Draft Technical Memorandum. The Volpe review found, in part that "All material helps to support the Orange County Transportation Authority's draft technical memo on the San Clemente Audible Warning System Study [Parsons Brinckerhoff 2011]; the methodology to determine signal detection is similar and both are applicable and the choice of using a wayside warning device emitting a train horn recording is validated by studies showing its effectiveness.” The Volpe review continues “It was found that example calculations using the methodology to develop the FRA 2005 Locomotive Horn rule applied to the SCBT show that the sound level of a wayside horn required to alert pedestrians and bicyclists is approximately 68 dBA, not accounting for ear bud insertion loss or music playing, both of which would raise the required sound level. The example showing 68 dBA also supports the 80 dBA recommendation (with ear buds/music), assuming the 10 dB increase addresses ear bud insertion loss and music playing, which seems to be a reasonable assumption. Also consistent with the Parsons Brinckerhoff 2011 Draft Memo, the example calculations in this [Volpe] memo show a substantial sound level reduction from the current requirement of 92 dBA at 100 ft (112 dBA at 10 ft) for wayside horns; with a reduction of 44 dB (without ear buds/music), a 95% likelihood of signal detection is maintained (the reduction is approximated to be 34 dB with a 10-dB adjustment assigned to account for use of ear buds/music).

Implementing the AWS and discontinuing the routine sounding of the train horn now used for audible warnings is recommended as the preferred solution for SCBT pedestrian-bicycle/railroad crossings.

A Glossary of technical terms used in this report is provided in Section 17.0. Acronyms used in the report are defined at their first occurrence.

2.0 Background and Reason for this Study

2.1 Background

The Southern California Regional Rail Authority (SCRRA) operates Southern California's 5-county rail system known as Metrolink. Metrolink is a joint powers Authority with five member agencies representing the counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The three lines servicing Orange County provide a total of 44 trains daily serving ten Orange County stations; total ridership is approximately 13,000 riders per day. The right-of way owned by the Orange County Transportation Authority (OCTA) extends from the Orange County/ San Diego boundary to 0.5 mile before the Fullerton Station and through the City of Orange to Placentia in northern Orange County. In 2005, the Metrolink Service Expansion was authorized for 36 more trains in Orange County, including service every 30 minutes between Laguna Niguel/Mission Viejo and Fullerton. The tracks adjacent to the SCBT are also used by Amtrak passenger trains and by Burlington Northern Santa Fe (BNSF) freight trains throughout the day and night. As part of the expansion, the OCTA initiated the Orange County Rail-Highway Grade Crossing Safety Enhancement Program. This AWS study is part of that effort, with a focus on the approximately 2.3-mile-long portion of the rail system located within the City that is immediately adjacent to the SCBT. The SCBT is a pedestrian-and-bicycle-only recreational facility that by design also acts as a safety improvement to reduce trespass over the tracks through channelization and identification of designated pedestrian crossings for general beach goers who previously scampered willy-nilly across the tracks at random locations.

The newly developed main SCBT, including its short branches that accommodate beach access as required by the California Coastal Commission, results in several locations where active railroads cross pedestrian-bicycle pathways in the coastal area of the City, as may be seen in Figure 2-1 below.

There are two crossings of the SCBT that are eligible for FRA approval as Quiet Zones (Senda De la Playa and Metrolink Pedestrian Crossing) plus seven non-motorized-vehicle (i.e., pedestrian-bicycle) at-grade crossings of the railroad tracks along the SCBT in San Clemente where the train horns are sounded. This section of the railroad line carries 38 to 40 trains per day during the week and about 8 to 10 fewer trains on weekend days.

Pursuant to a Settlement Agreement adopted by the California Public Utilities Commission (CPUC) the City incorporated several specified improvements into the SCBT project (CPUC 2003). The improvements included fencing to channelize pedestrians to safe crossing locations. Trail surface and drainage improvements were included, thus providing a very pleasant and preferable place to travel, as compared to traversing the railroad rip rap and the tracks. These surface improvements further encourage pedestrians to walk in safe areas and not trespass on the tracks, which is where pedestrians randomly ventured prior to the construction of the SCBT. Finally, the pedestrian crossings were required to be uniformly treated with a standard (typically CPUC #9) grade crossing safety package with signage plus automatic gate arms, flashing lights, and ringing bells.

In addition to the train horn and signs, activation of the crossing bells and automatic gate arms equipped with flashing lights, plus dual alternating flashing lights at these crossings provide audible and visual warning to persons approaching the crossing when a train is expected. As discussed below, the degree of annoyance expressed by the adjacent residents regarding the nearly continuous sounding of each train’s warning horn sequence as the trains travels the length of the SCBT area has increased due to the recent promulgation and interpretation of the Federal Railroad Administration (FRA) Final Train Horn Rule (Rule). This dissatisfaction will grow with the anticipated increase in the number of trains operating on the portion of the railroad line adjacent to the SCBT.

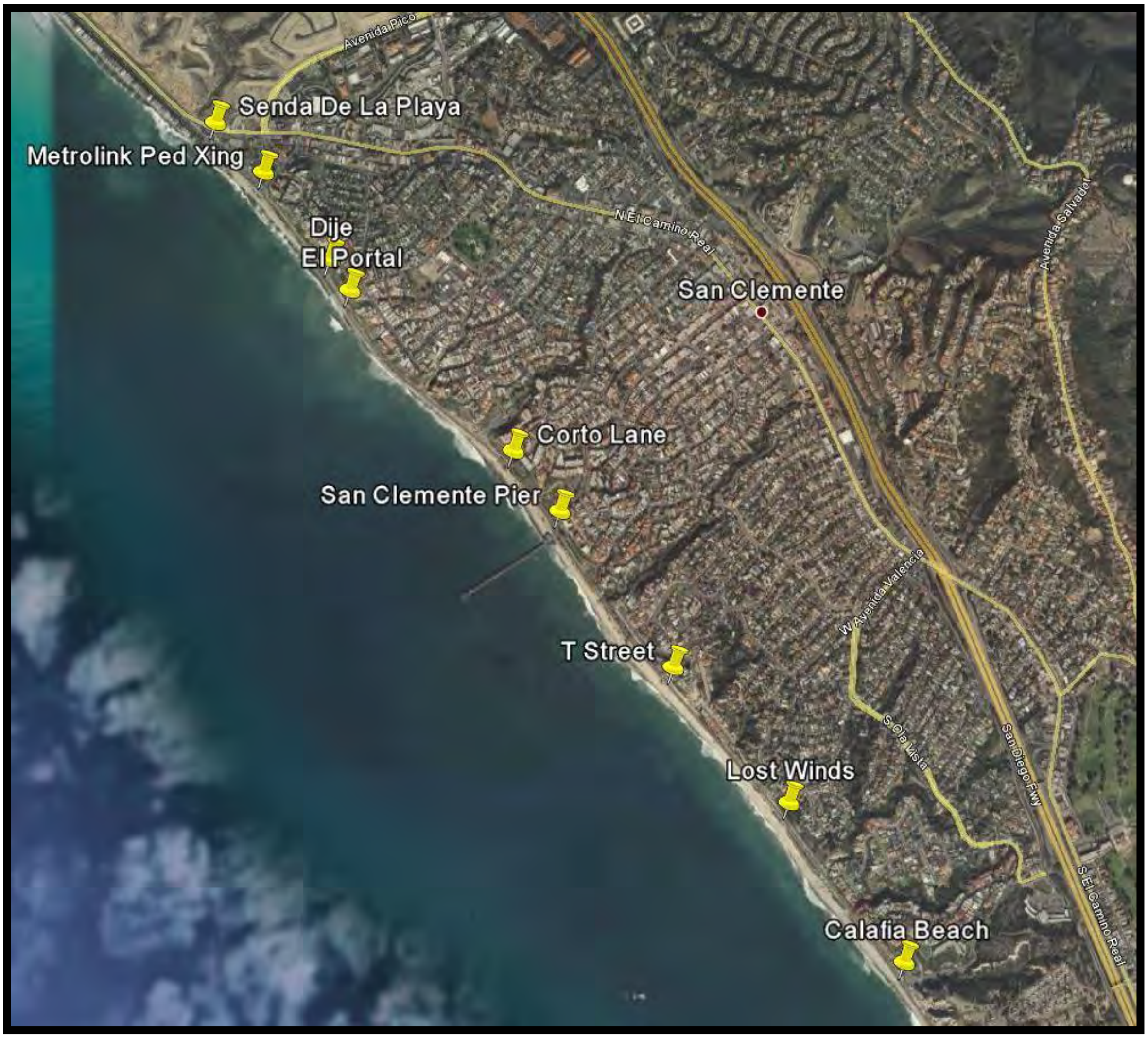

Figure 2—1. The Seven SCBT Pedestrian-Bicycle Crossings of Railroad Tracks in San Clemente

The SCBT and railroad track are located at the toe of steep coastal bluffs that support substantial residential development along the bluff tops, with at-grade development in the vicinity of the San Clemente Pier. Thus, noise-sensitive use is located close to the SCBT/railroad crossing locations. An example is seen below in Photo 2-1, which shows the main SCBT parallel to the railroad and one of the beach access “branch” trails that crosses the railroad tracks; the beach and ocean are directly behind the photographer.

Photo 2—1. Residential Use on Bluff Top Above SCBT/Railroad Crossing at Dije Court.

The current federal requirements for the WH variant of the Quiet Zone, contained in the Federal Train Horn Rule (49 CFR Part 222, Appendix E), specify that the WH produce a minimum exterior audible warning sound level of 92 dBA at a distance of 100 feet from the rail centerline for highway/rail at-grade crossings. This criterion was developed based on initial and supplemental data and analyses similar to that used to develop the criterion for locomotive train horns to warn motorists inside a moving vehicle of an approaching train (Rapoza and Fleming 2002). Thus, the City suggested and discussed with the California Public Utilities Commission (CPUC) the possibility of a safety-equivalent audible warning with a lower sound level suitable for providing an effective warning of an approaching railroad train at exclusively pedestrian-bicycle crossings of the railroad tracks by the SCBT.

2.2 Rationale for this Study

In response to its residents' complaints regarding train horn noise, and mindful of the importance of safety of all persons using at-grade crossings of railroad tracks, the City, OCTA, and other stakeholders initiated investigations into an alternative, and perhaps less audible to the adjacent community, method of providing a safe warning of an approaching train at the seven pedestrian-bicycle/railroad at-grade crossings along the SCBT.

These investigations led initially to evaluation of implementing a Quiet Zone for the SCBT area or using a Wayside Horn (WH) system as defined in the Final Train Horn Rule (Appendix E to Title 49 CFR Part 222). However, from an opinion issued by FRA counsel it appears that federal regulations do not apply to the SCBT's non-highway (i.e., pedestrian-bicycle) crossings of the railroad tracks (Werner 2010). The FRA letter recommended that unless State law provides otherwise, the warning sound level prescribed in the Rule should be used "unless data analysis has determined that a variation does not reduce safety."

This current study (2011 June) of a potentially different Audible Warning System (AWS)[1] resulted from previous studies of WH, including a demonstration completed by the City on September 3, 2009 and the most recent demonstrations conducted in December, 2009 and February, 2010. The last two studies were documented in a Technical Memorandum that includes a more extensive discussion of the events and issues leading to the preparation of these studies (Greene 2010). Further, part of the CPUC response to the City inquiries was to identify additional technical information that CPUC believed would be beneficial in determining an appropriate sound level for an audible warning to pedestrian-bicycle SCBT Users. This additional information included a discussion of the development of the FRA specified decibel levels for train and wayside horns, differences in acoustic perception between vehicle drivers and pedestrians and bicyclists, differences in velocities between cars and pedestrians-bicycles when approaching a railroad crossing, and the ambient noise environment along the SCBT (Gilbert 2010).

Based on community reaction to the previous demonstrations, community acceptance of audible warnings at each crossing is not likely unless the warning sound levels are significantly lower than the WH's specified 92dB at 100 feet. As noted, both the FRA and the CPUC believed that additional data and analysis were necessary if a lower sound level but equivalently effective AWS could be implemented at the SCBT pedestrian-bicycle crossings.

The previous demonstrations and technical studies represent an effort to resolve San Clemente residents' concerns about the annoyance from railroad train warning horn soundings and the residents' perception that the train horns are now sounded more frequently.

It appears that train horns are being blown more frequently and this is the result of three factors:

1. Generally, there has been an increase in railroad activity since resurgence of railroad use during the past two decades; there is more freight and passenger service demand for limited rail capacity, thus more trains overall and more freight train activity during nighttime hours to accommodate the higher speed passenger rail activity during the day. This increase in rail activity has been a somewhat slowly evolving situation; it is typical in many areas of the United States and does not generally precipitate strong community reaction. By 2015 the weekday railroad train activity along the SCBT area tracks is expected to increase to about 42 trains per day.

[1] The term AWS is used in this Technical Memorandum to identify an audible warning system that has different characteristics, including a lower sound level, than those required for a Wayside Horn system.

2. Specific to the study area are development and opening of the new SCBT with its seven pedestrian-bicycle/railroad crossings.
3. A recently promulgated Federal Final Train Horn Rule coupled with train operator interpretation is resulting in multiple soundings of each train's warning horn along the SCBT.

As a result of these factors the environmental noise conditions for residents living along the SCBT have changed and all stakeholders are seeking a safe and more environmentally friendly technical alternative to the present situation. The collection and analysis of additional technical data is the primary reason for this AWS study, which endeavors to provide an acceptable technical solution to the safety and noise concerns of all stakeholders.

3.0 Study Approach

While annoyance and community response to man-made environmental noise is essentially a subjective phenomenon, the relationship between environmental sound level and annoyance/political action has been objectively quantified to a substantial degree by highly respected researchers and documented in several published studies, the benchmark of which is Schultz (Schultz 1978). Individual factors such as the sound levels and repetitiveness of intrusive sounds (however necessary) that result in speech, sleep, or activity interference have been identified as the major issues in these studies. This AWS study draws upon the published results of these previous researchers, and the experience, expertise, and relevant publications by this study's authors and reviewers.

The initial actions in this study were to adopt a set of "Guiding Principles" and "Major Assumptions" to frame the investigation. Primary Guiding Principles for the conduct of this study, in order of importance, are to:

1. Maintain or improve safety at SCBT crossings of railroad tracks, and
2. Improve the existing community noise environment by sounding a quieter audible warning system (AWS) instead of the much louder and intrusive train horns.

Thus, in addition to the awareness of safety first, this study's primary focus is on a broad range of acoustic issues. This includes the acoustic environment of SCBT Users compared to the acoustic environment inside a moving motor-vehicle; the sound level and related characteristics of traditional railroad-related audible warning signals and their exterior environments compared to the acoustic environment of the SCBT; and the sound level and related characteristics of a safety-equivalent AWS suitable for use specifically at SCBT pedestrian-bicycle at-grade crossings of the railroad tracks.

The Major Assumptions used in this study include the following:

1. The acoustic effectiveness of the WH system sound level as prescribed by the federal Train Horn Rule (Appendix E to Title 49 CFR Part 222) was accepted, *prima facie*, as the safety benchmark (in acoustical terms) for its delivery to motor vehicle operators approaching an at-grade highway/railroad crossing an audible warning of an approaching railroad train.
2. The important WH criteria and assumptions are believed to be:
    - a required sound level of 92 A-weighted decibels,

- a reference distance of 100 feet from the centerline of the railroad track;
- the ambient acoustical environment was the interior of a moving automobile traveling 30 miles per hour;
- inside a moving motor vehicle, in the presence of attention requiring activities such as driving, the WH is as effective as a train horn, where "effectiveness" was defined as the 95 percent likelihood that the horn would be detected by the motorist.
- "detection" was defined using the "noticeability" criterion of d'*L*=17 plus an additional margin of 6; and,
- the auditory warning effectiveness of a train horn was considered in light of the overall ambient sound in the moving vehicle, including masking sound such as engine, road, and wind noise. Other distractions or sound from air conditioning/heating systems, radio and music systems, passengers, stormy weather, etc., for which no data was available, were not considered.

An additional assumption of this AWS investigation is that the general population characteristics considered for the SCBT Users are essentially equivalent to what is believed was assumed for the federal WH regulatory requirements, including factors such age, gender, hearing acuity, mental state, familiarity with rules governing safe behavior near railroad tracks and trains, awareness of the need to responsibly monitor children, possession of common sense, etc. However, comments received by Volpe during their review of this AWS study indicate that other than normal hearing, no specific population characteristics were assumed during development of the Rule (Volpe 2011).

The authors believe equivalent safety of an AWS for Users of the SCBT where the trail intersects with at-grade crossings of the active railroad may be established by providing an acoustic warning signal equal in warning <u>effectiveness</u> for pedestrian and bicycle SCBT Users as is the benchmark warning provided by a train horn or WH for motor vehicle operators approaching a highway/railroad at-grade crossing under lawful reference conditions.

A major premise of this study is that the values of acoustic and related factors considered to establish effectiveness of a train horn or the WH as a "one-size-fits-all" safety solution are distinctly different for the SCBT environment and its Users.

This study will:

- Compare the values of similar factors for an AWS solution to a WH approach.
- Discuss components of the historic/traditional audible warning that signals the approach of a train toward a highway-railroad at-grade crossing with respect to the specifics of the SCBT physical configuration.
- Evaluate typical (or worst-case) acoustic ambient conditions along the SCBT.
- Contrast travel speeds of the SCBT Users compared to motor-vehicles.
- Evaluate the acoustic attenuation characteristics of earbuds worn by some SCBT Users. Earbud sound attenuation is the analogue of the acoustic attenuation from the motor-vehicle body "shell" that reduces WH sound level inside a vehicle.

- Evaluate the effects of attentiveness and decision requirements of motor vehicle operators that do not apply to SCBT Users.
- Evaluate audible masking (e.g., road and wind noise) and other acoustic “distractions” (e.g., speech, music).
- Consider other relevant factors.
- Evaluate typical acoustic warning signal delivery systems for applicability to the SCBT crossings.
- Provide an objective safety evaluation.
- Provide recommendations for implementing an AWS at the SCBT pedestrian-bicycle crossing locations.

A brief summary comparing salient characteristics of a WH and AWS is presented in Table 3-1, below.

Table 3—1. Comparable Factors Between Wayside Horn and Audible Warning System

WH Factor	AWS Factor	Difference Metric	Estimated/Assumed Difference Amount	AWS required versus WH for same effectiveness
Warning to motorist in a moving vehicle	Warning to pedestrian/bicyclist	Acoustical	25-35 dBA	Substantially lower sound level*
Vehicle body	Earbuds*	Acoustical	5 dB for earbuds compared to 20 dB minimum for vehicle*	+5 dB adjustment for AWS*
Speed 30 mph	Speed <10 mph	Velocity	One third	Less warning time
Automotive interior noise (engine, road, wind)	Moderately quiet SCBT environment	Acoustical	10 dBA	Lower sound level
Includes interior noise (engine, road, wind)	No comparable noise for nearly all SCBT Users*	Acoustical	10 dBA	Lower sound level*
Distractions operating a motor-vehicle as the primary task; (other distractions such as passenger activity, conversation, music/radio, stormy weather, etc. were not specifically considered)	Distractions walking, jogging, riding a bicycle as the primary task (other distractions considered were conversation, listening to music/talk radio*)	Attentiveness	SCBT Users have a less demanding primary task and somewhat lower level of distractions and need to make complex decisions resulting in faster recognition of and reaction time to an audible warning	Possibly Lower sound level Possibly Less warning time required
	Music/talk radio through Earbuds*	Acoustical	Average is 5 dBA*	+5 dB adjustment for AWS*
Sound Level for effective safety warning is 92 dBA at 100 feet from centerline of track (exterior to vehicle)	Sound Level for effective safety warning is 70 – 80* dBA at SCBT User (exterior to ear) per this study, Section 12.	Acoustical	112 dBA at 10 feet (WH) difference from 80 dBA at 10 feet (AWS) is 32 dBA	Much lower sound level
Audible warning provided to motorists up to 400 feet from crossing	Audible warning provided to User approximately10 feet from AWS loudspeaker and 20 feet before crossing gate	Distance	Substantial	Ample sound level at User with much lower noise in community

*Indicates special consideration to accommodate SCBT Users who wear earbuds; Required AWS level is increased by 10 dB from 70 dBA to 80 dBA, see Section 12 of this study.

4.0 Study Team

Multiple disciplines are represented by the study team members, with well over 100 combined years of expertise and experience addressing the study issues. These include physical acoustics, sound generation and propagation; auditory physiology; perception of sound, including audibility, noticeability, detectability, interference, masking, signal-to-noise ratio, critical bandwidth; warning signal characteristics (sound level/tonality/frequency content/temporal pattern); electro-acoustics (loudspeakers, directionality, sensitivity, etc.); select human behavior, primary task attention, expectation/distractions, reaction time (mental and physical); and physical safety issues, including active (lights, bells, AWS, motorized gates) and passive (signs/kiosks/barriers, and fencing) visual, audible, and educational methods. The qualifications of the principal members of the team are provided in Appendix 21.1

5.0 San Clemente Beach Trail

5.1 Physical Description and Brief History

The SCBT is an engineered and developed recreational facility that was designed for exclusive use by pedestrians, including walkers, joggers, and others using people-powered wheeled vehicles including wheelchairs and bicycles. Except for extremely limited use by the City Lifeguard's small ATV response vehicles, motor-vehicles are prohibited and are not physically accommodated on the SCBT. The SCBT, by design, also acts as a safety improvement to reduce trespass over the tracks through channelization and identification of designated pedestrian crossings for general beach goers and SCBT Users alike. The improvement in safe access to the beach was a pre-eminent City goal for the development of the SCBT.

The SCBT is 2.3 miles long, connecting North Beach to Calafia Beach portions of the City's picturesque coastline. The SCBT is about ten feet wide and is constructed of stabilized decomposed granite except for occasional concrete steps near the actual crossings of the railroad tracks. Although most of the SCBT is sandwiched between railroad tracks and residential development perched atop steep bluffs, the SCBT is very natural in ambience and appearance as shown in Photo 5-1, below, looking northerly from the Calafia Beach trail head.

Photo 5—1. View of SCBT Approximately 265 feet Northerly of the Calafia Beach Crossing (during surf noise measurement).

Although the railroad tracks were first constructed in the 1880's, the Railroad Corridor Pedestrian Beach Trail project, as it was first called, began serious planning in the 1990's. The project went through an extended tumultuous period including initial design, citizen protests, redesign, an extensive governmental permitting process, plus final design and construction to arrive at a dedication of the facility in late 2006. Project cost was estimated at $15,000,000.

Based on the observations by the study team during several visits to the SCBT, comments by City officials, observations by one of the study team members who lived in San Clemente, plus newsletter and newspaper articles, the SCBT is very popular and well used by a wide range of persons from within and outside of the City. More than 2.7 million people visited San Clemente city beaches in 2006 and San Clemente State Beach had nearly a million visitors in 2008. It is estimated that the SCBT channels about 300,000 pedestrians-bicycles annually to signalized crossings along the trail. The SCBT hours of operation are set in two segments: Between North Beach and South T Street Restrooms: 4:00 am - Midnight; and between South T Street Restrooms and Calafia Beach: 6:00 am - 10:00 pm.

This study addresses seven at-grade pedestrian-bicycle crossings of the railroad tracks along the SCBT. These crossings are at Dije Court, El Portal, Corto Lane, the San Clemente Pier, South T-Street, Lost Winds, and Calafia Beach. Each of these crossings is equipped with signs, automated mechanical gate arms, electronic bells (ding, ding, ding…), and flashing lights as may be seen in Photo 13-2.

An aerial view of the SCBT was provided above in Section 1.0. The References section contains links to additional sources of specific information about the SCBT.

6.0 History of Federal Final Train Horn Rule

On April 27, 2005, the Federal Railroad Administration (FRA), which enforces rail safety regulations, published the final Train Horn rule (Rule) on the use of locomotive horns at highway-rail grade crossings (49 CFR Part 222). Effective June 24, 2005, the Rule requires that locomotive horns be sounded at all public railroad/highway grade crossings at least 15 seconds, but not more than 20 seconds before entering a crossing. This rule applies when the train speed is below 45 mph (70 km/h). The trains operating adjacent to the SCBT are moving at 40 mph, except in the immediate vicinity of a station.

The pattern for blowing the horn remains two long, one short, and one long horn sound. This is to be repeated as necessary until the lead locomotive fully occupies the crossing. Locomotive engineers retain the authority to vary this pattern as necessary for crossings in close proximity, and are allowed to sound the horn in emergency situations no matter where the location.

The new federal Rule was developed in response to many state and local jurisdictions limiting or banning the sounding of locomotive train horns within their zones of authority. A ban on sounding locomotive horns in Florida and other states was ordered removed by the FRA after it was shown that the accident rate increased substantially during the ban. The new Rule preempts any state or local laws regarding the use of the train horn at public railroad/highway grade crossings. The Rule also provides public authorities the option to maintain and/or establish quiet zones provided certain supplemental or alternative safety measures (including Wayside Horns) are in place, and the crossing accident rate meets government standards. The entire Rule may be found at:

http://www.fra.dot.gov/downloads/safety/trainhorn_2005/amended_final_rule_081706.pdf

The sound levels established in the Rule were based in part on technical studies conducted by the Volpe National Transportation Systems Center for the Federal Railroad Administration Office of Research and Development, 1120 Vermont Avenue NW-Mail Stop 20, Washington, DC 20590 [contact: Thomas Raslear]. This work is summarized in “Research Results”, Report RR07-06 February 2007, entitled Railroad Horn Systems. A copy of federal report and a more comprehensive discussion of the Train Horn Rule are provided in Appendix 21.2.

7.0 Wayside Horn Alternative

7.1 Purpose and Signal characteristics

One solution for reducing the overall impact on a community of traditional train horn noise is to place a loudspeaker on a pole at the highway/railroad at-grade crossing and direct it toward oncoming traffic. Instead of blowing the train horn, the stationary, wayside, pole-mounted loudspeaker is activated when the train approaches the grade crossing, thus electronically reproducing the sound of a train horn from the WH fixed position. For a typical application in which traffic approaches from two opposing directions, two loudspeakers would be located at the grade crossing, one facing oncoming traffic in each direction.

As part of the development of the Rule, the Volpe investigators measured traditional train horns and earlier versions of "automated horns" that evolved into the current WH, the sound level of which is defined by the present federal Rule. A typical early version experimental horn is pictured below in Photo 7-1 from the FRA Research Results document. At peak sound levels, a typical automated horn at the same distance was approximately 13 dB quieter than the locomotive-mounted train horn. The lower sound level of the automated horn compared to the train horn was a significant factor in explaining why the automated horn was perceived as less annoying than the train horn during testing and observations. Unlike the actual train horn, the automated horn did not meet the minimum sound level required of train horns by the Rule. For WH systems in operation, and the newer WH systems tested, the frequency distribution of the wayside horn signal was similar but not identical to the train horns measured in the study. For the 14 sites where sound measurements were collected, the WH had a negative community impact only during nighttime hours (Multer Rapoza 1998).

Photo 7—1. Early Version of Automated Horn

The train horns tested contained a broader band of acoustic signal (i.e., more frequencies) that is more difficult to mask than the signal produced by the early automated horns. Rapoza and Rickley (1995), using acoustical data, determined that an automated horn with a single tone and a maximum sound level of 87 dBA would be less detectable inside a moving motor vehicle than the Nathan 5 chime and Leslie 3 chime train horns that predominate on most locomotives today. The motorists could detect the audible warning up to 400 feet from the grade crossing when the car was stopped and idling. However, in a moving car in which the background noise level was in the 55-65 dBA range, the motorist would fail to detect the automated horn in time to stop before arriving at the grade crossing.

Typical five-chime and three-chime horns that are mounted on the locomotive or lead car of heavy-rail trains may be seen in Photos 7-2, 7-3 and 7-4, below. Photo 7-5 shows a typical stand-alone pole-mounted WH with control box. Sometimes the WH is incorporated on other crossing-related structures.

Photo 7—2. Leslie S5T Five-Chime Train Horn

Photo 7—3. Nathan K3L Three-Chime Train Horn

Photo 7—4. Leslie RS3L Three-Chime Train Horn

Photo 7—5. A Typical WH from Railroad Controls, Limited

Saurenman and Robert, during a 1995 study, in which this study's principal investigator Greene also participated, evaluated whether the automated fixed-location horn would serve as an effective warning for pedestrians and bicyclists. They asked a focus group to rate the effectiveness of a custom built automated horn compared to the transit vehicle's train horn used on a rail transit system in Los Angeles. Their results suggest that the automated wayside-located, pole-mounted loudspeaker horn approach would be effective in alerting pedestrians and bicyclists to the presence of an approaching train.

7.2 Wayside Horn Assumptions

The following information is from a study by the Acoustics Facility of the Volpe National Transportation Systems Center in support of the Federal Railroad Administration titled *Analysis of Railroad Horn Detectability* conducted by Amanda Rapoza and Thomas Raslear (2001):

Three sets of data were collected in an effort to evaluate the probability of detecting railroad horn systems used to deliver audible warnings to motorists at highway-railroad grade crossings. The data and assumptions were used to determine the ratio of exterior warning-signal-level to the noise level inside the motor vehicle at the minimum distance that would give the motorist sufficient time to reach the crossing but avoid a collision. Additional conditions/assumptions included:

- Windows closed, ventilation systems off, and stereo off.
- Vehicle speed of 30 miles per hour (mph). (No appreciable acoustic difference from 35 mph vehicle speed.)
- Measured vehicle body attenuation of 25 to 35 dB (comparable to Fidell 2007 used in this AWS study, and to Brach and Brach 2009).
- Driving a motor vehicle requires mental attention and drivers who were not expecting to hear a train horn had more difficulty in doing so. This was reflected in reaction time to a train horn.
- Acoustic and other distractions evaluated were road and wind noise, air conditioner blower noise, and radio/stereo operation. Open vehicle windows will increase interior noise levels by 2 to 3 dB at low frequencies (<1,000 Hz) and by 5 to 10 dB at high frequencies. Air conditioning systems operating at medium or high will increase interior noise levels by 2 to 5 dB at low frequencies (<1,000 Hz) and 5 to 10 dB at high frequencies. Radio operation at a "normal volume" will increase interior noise levels by upward of 10 dB. Overall interior noise levels were found to be approximately 55 to 65 dBA in the several vehicles tested.

The Volpe study did not mention additional distractions that might include passengers (especially children) in the vehicle. Because the Volpe study predated prevalent cell phone and texting activities, these distractions were not addressed. In any case, these distractions are either of lesser magnitude or not relevant to SCBT Users based on observations by the study team. An additional assumption for this present study (believed to be the same for the studies performed by others) is that the general characteristics of the drivers reflect a normally distributed population in all relevant categories including a normal range of hearing sensitivity.

7.3 Defined Wayside Horn Signal and Sound Level Characteristics

In consideration of all the studies, testimony, and comments that resulted from the 8+ year process of Train Horn Rule development and deliberations, the interim final Rule required the WH to generate a train horn sound and propagate that warning signal to a motor vehicle approaching a crossing at the same SPL as that required of the train horn at the reference distance. After reviewing comments and evidence received from several entities, the Volpe Center conducted a supplemental evaluation, including an analysis of the newly available data on WH sound level and frequency content, together with previously obtained data on automotive insertion loss, interior noise, and on-board railroad horn sound levels. The Volpe Center evaluation confirmed the findings of the Mundelein study (Thunder 2003), and concluded that the wayside horn, set to a level of 92 dBA at 100 ft from the centerline of the track, would be at least as loud as the locomotive horn at the critical decision point. The Volpe Center then recommended (and it is in the Rule) that the WH must deliver a minimum warning sound level of 92 dBA, measured at a distance of 100 feet from the centerline of the railroad track in front of the WH loudspeaker. All comparisons in this study of an AWS to a WH are based on this defined acoustic performance required of the WH.

8.0 SCBT Ambient Acoustics and Users Surveys

With the discussion of background issues completed, it is appropriate to focus on the SCBT acoustic conditions and relevant characteristics of the SCBT Users.

8.1 Ambient Acoustics

The Parsons Brinckerhoff (PB) field team conducted sound level and spectrum measurements, and observations of SCBT Users on Saturday, October 2, 2010. The weather was warm; with little to no cloud cover, sunny skies and negligible wind (calm to slight breeze), plus high surf throughout the day. Thus, the conditions were good for beach activity, SCBT activity, and for acoustic measurements. A summary of the measured sound level data is provided for each measurement in Appendix 21.3. Sound levels were measured simultaneously on both sides (within approximately 100 feet) of each SCBT/railroad crossing, with sound spectra also measured at one side of each crossing. Except for the sound level during the immediate railroad train pass-by, ten of the remaining twelve ambient sound levels, including the high surf, were mostly in the low to mid 50's dBA Leq, with only two measurements at mid 60's dBA Leq. Note that the measured ambient sound levels along the SCBT are generally lower than the in-car noise levels from road noise, air conditioning and radio reported by Rapoza and Raslear (Rapoza 2001) and by Fidell (Fidell 2007).

The observers also noted that the sandy beach areas adjacent to the SCBT were being used by a variety of people involved in various activities, including children playing and beach volleyball games. However, the sounds of these activities were barely audible along the SCBT and at the crossing locations. The dominant ambient sound was from the surf along the shoreline. Also noteworthy is that surf noise is very cyclical with maximum levels of one to three seconds duration connected by periods of relative quiet (40's and 50's dBA L_{90}), compared to the mostly continuous interior noise in moving vehicles of 55 to 65 dBA as measured by Volpe (Rapoza and Raslear 2001).

The actual time duration of potential interference or acoustic masking by surf noise of a longer duration and louder AWS is minimal.

The collected ambient environmental noise data well describes a representative sample of the SCBT acoustic environment during active surf conditions. The area would be quieter during calm surf conditions. Digitally recorded samples of the collected surf noise spectral data were used during the detectability/audibility analyses discussed in Section 12.0.

8.2 Users' Velocities and Earbud Usage

In addition to the acoustic measurements of the SCBT environment, the PB field team also conducted measurements and observations of SCBT Users of this popular recreational facility on Saturday, October 2, 2010. The weather conditions were the same as for the acoustic measurements and ideal for a SCBT User activity survey. There was little to no cloud cover, clear, sunny blue skies with a high temperature of 81 degrees F and no precipitation during the observations. The first observation started at 8:30 am and the last primary observation ended at 12:45 pm. In total, three User surveys were conducted by the primary observer within that time frame. A secondary observer collected information at two crossings during the same period, plus the Calafia Beach crossing for a period extending slightly later into the afternoon.

The PB field team noted over one thousand two hundred (1,200+) SCBT Users consisting of walkers, joggers, and bicyclists of all genders and ages during the measurement/observation periods at multiple SCBT/RR crossing locations. Statistics were gathered regarding the number of pedestrians, number of bicyclists, and overall number of SCBT Users wearing earbuds. The team obtained more than 750 speed (velocity) measurements of SCBT Users. The speeds of seven passenger trains were also measured. The collected data well describes a very robust and representative sample of SCBT Users. The methodology used for the SCBT User surveys and additional results are presented in Appendices 21.3 and 21.4.

8.2.1 Results for Velocity Surveys

For the extended surveys, a total of 731 people were counted. The percentages for each User group are found in the following table.

Table 8—1. Combined Speed Data for All Three Survey Locations

User Group	Count	Percentage	Average Speed (mph)
Walker	490	67	3.3
Jogger	215	29	6.2
Bicyclist	26	4	7.6
Total	731	100	

As a very conservative approach, the 85th percentile speeds were also calculated to provide the velocity in feet per second (fps) and miles per hour (mph). The 85th percentile results, calculated for all locations, are as follows:

- Walkers - 4 mph (5.9 fps)
- Joggers - 7.2 mph (10.6 fps)
- Bicyclists - 9.63 mph (14.1 fps).

The official posted speed limit on the SCBT is 10 mph (14.7 fps).

8.2.2 Results for Earbud Use

Another purpose of the survey was to determine the percentage of Users wearing earbuds while on the SCBT. Of the total noted population, 22 percent (164 Users) were wearing earbuds, which does not differentiate among the user groups. Almost half of the joggers using the SCBT were wearing earbuds. The percentage of Users wearing earbuds is appreciable and was the rationale for conducting the acoustic testing of typical earbuds believed likely to be worn by Users of the SCBT.

Table 8—2. Earbud Data from All Three Extended Surveys

	Count with Earbuds	Percentage
Walker	59	12
Jogger	102	47
Bicyclist	3	12

8.3 SCBT User Survey General Observations

In addition to counts and measurements discussed above, several general observations were noted during the survey periods. Unlike the counts and measured data, these general observations are anecdotal and should be used for informational purposes only; they cannot be summarized with a statistical significance at this time. In general, the SCBT Users were observed to be walking and jogging in pairs or solo. There were occasional groups of three, and very few groups of four or more people using the SCBT during the survey period. The ages of the SCBT Users varied from small children to senior citizens with the majority of Users estimated to be over the age of 25. Many individuals walked with dogs, and a small portion of Users were pushing baby strollers. A common theme on the trail was fitness versus a leisurely stroll, as many of the Users were wearing workout clothes and athletic shoes versus jeans and sandals. For the bicyclists, at times it appeared to be difficult for them to maneuver around the pedestrian groups, especially at the crossing locations. While this appeared to restrain their speeds to some degree, nearly all the observed cyclists appeared to be more leisurely or recreationally inclined as opposed to fitness or speed focused. This is consistent with the segments of the SCBT that can be ridden without stopping and with the posted speed limit of 10 mph. Also, several of the observed bicyclists were children under the age of ten. Typical SCBT Users are seen in Photo 8-1 below. The bright orange paint line under the User wearing blue shorts marks one end of the timed, 50-feet-long section used to cross check the radar measurements of Users' velocities.

Photo 8—1. SCBT Users on the Main Trail and Branch Trail at Dije.

9.0 Attenuation from Wearing Ear Buds

9.1 Background

Because an appreciable percentage of SCBT Users, especially in the "jogger" classification, wear earbuds while using the SCBT it was considered important to quantify the attenuation provided by earbud use to enable comparison to the typical attenuation reported for an automobile "shell".[2] In determining the appropriate sound level for WH, one factor considered by FRA was the acoustical attenuation provided by the "shell" or body of the typical motor-vehicle that reduces the sound level of the WH as experienced by the driver. For most SCBT Users this attenuation element does not exist, thus an AWS signal is not typically subject to this extra ("excess") attenuation. However, because they wear earbud style headphones, a small but appreciable percentage (22%) of the SCBT User population wears an acoustical attenuating element corresponding to the car body for motorists.

Based on formal observations by PB investigators of more than 1200 SCBT Users conducted on Saturday, October 2, 2010, plus informal observations of and anecdotal conversations with earbud wearers during three other visits to various portions of the SCBT, the earbuds most often seen are the ubiquitous white original equipment devices (concha, flat-front style) and, in multiple colors,

[2] SCBT Users are generally classified in this Report as *walker*, *jogger*, or *bicyclist*.

various brands of aftermarket replacement devices (concha and insert styles). The earbud study included measurement of the typical noise reduction (attenuation or *Insertion Loss*) provided by flat-faced micro-speakers that occlude the opening to the ear canal described as concha style because they rest in that portion of the outer ear, and by intra-aural (inserted into the ear canal) type of audio headphones, both commonly called ear buds or earbuds.

A characteristic of any material or device that is placed in front of the opening to or into the ear canal is the attenuation of the level (or intensity) of sound that would otherwise enter the ear unabated. Of concern to this study is the degree to which the perception of a potential audible warning sound might be reduced for persons wearing earbud style headphones. As noted elsewhere in this report, it is important to understand that earbuds are not earplugs and most earbuds worn on the SCBT barely affect the level of exterior sounds that enter the ear.

Detailed information about the earbud testing protocol, results, and findings is provided in Appendix 21.7. A summary of the acoustic evaluation process is provided below.

9.2 Approach to Earbud Evaluation

A methodology was developed to objectively quantify the earbud's acoustic property of attenuating external sound by measuring the *Insertion Loss* of a diverse sample of earbuds.

Based on previous experience testing and reviewing results of insert hearing protectors, as well as consultation with the independent testing facility's owner[3], it was decided to purchase, primarily from available off-the-shelf stock of national retailers, an assortment of earbuds representative of the range of earbuds likely to be worn by those Users of the SCBT who chose to wear earbuds. The three factors considered significant in selecting the earbuds to be tested were availability, range of cost, and diversity of manufacturers.

9.2.1 Range of cost

The retail price of a pair of stereo earbuds ranges from $1.99 to over $450.00. The earbuds that cost $75 to $100.00 are approaching "audiophile" or high quality and are only occasionally considered for recreational use. Earbuds that cost over $100.00 are generally considered "audiophile" or very- high-end quality and would rarely, if at all, be considered for recreational use such as jogging due to potential damage from perspiration, dropping, dirt, etc. Thus, a range of earbuds was selected for testing that cost between $2.50 and $100.00. Photo 9-1, below, shows many of the earbuds that were obtained for testing.

[3] W. Gary Sokolich, Ph. D., Custom Sound Systems, Newport Beach, CA.

Photo 9—1. Identical Pairs of Earbud Samples Marked and Ready for Delivery to Test Facility

9.2.2 Diversity of manufacturers and retailers

The manufacturers of the sample earbuds include Apple™, Vibe Sound™/DGL Group, 2XL™, Gummy/JVC®, Sony®, Ink'd/Skullcandy™, Memorex™, PLUGZ Ear Pollution/ifrogz™, Maxell Corporation of America®, Auvio™, IMIXID™, Panasonic®, Ultimate Ears™, and Sennheiser™ electronic GmbH.

The sample earbuds were purchased by the principal study investigator at local facilities of national retailers Best Buy, Fry's Electronics, Radio Shack, Micro Center, the Apple Store, Borders, Big Lots, and Walmart. Similar products were found at Target, Sears, Sav-on/Osco, and Walgreens stores. One brand was purchased at a local hi-end specialty store. The list of models tested, source, price, and type is provided in Appendix 21.7.2.3.

9.2.3 Test Methodology

The prescribed methodology is essentially a step-by-step process for ensuring valid, repeatable measurement results with a satisfactory degree of statistical significance.

Factory packaged earbuds were purchased, pre-marked, and delivered to the testing facility. Photo 9-2 shows testing of an insert style earbud in an ear simulator. Photo 9-3 shows the KEMAR® device used to test the most common earbud, the flat-faced mini speaker that sits in the ear's concha. In the photograph the KEMAR® is shown with an ear*plug* inserted as a test control. Additional testing was conducted using a mannequin (pictured in Appendix 21.7.7).

The test consisted of blasting random noise containing many frequencies from a loudspeaker toward the test fixture. Sound levels were measured and noted without and with an earbud present to determine the sound attenuation performance of each earbud under test.

Photo 9—2. Earbud Inserted into Ear Simulator In Front of Excitation Source

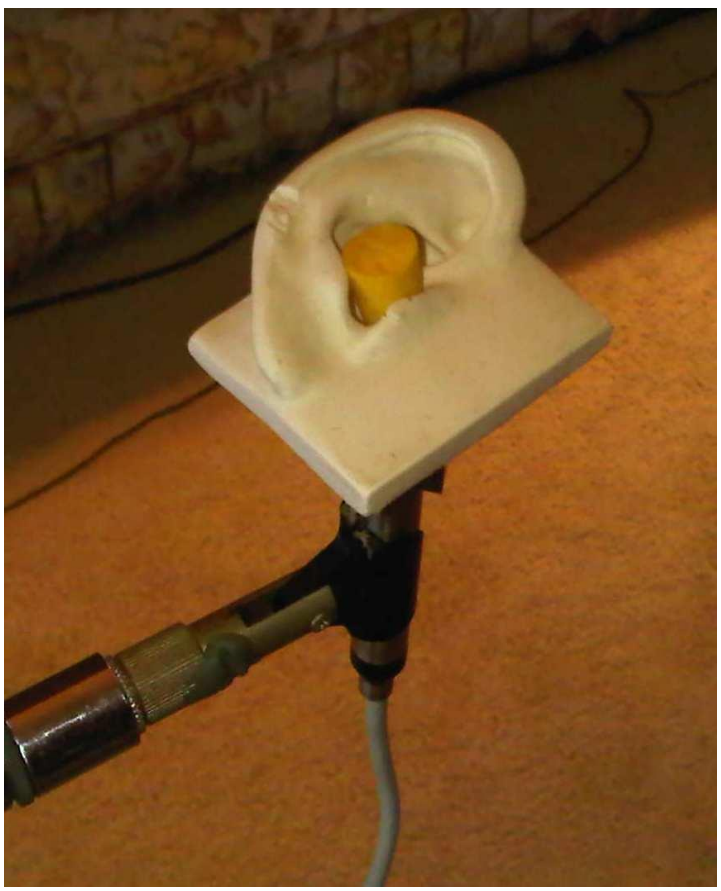

Photo 9—3. Close up of KEMAR Rubber Pinna Used for Testing the Loose Fit, Flat-faced Concha Type Earbuds. Shown with EAR® Insert Hearing Protector Tested as a Control

9.3 Earbud Testing Results

The test system had a dynamic range in excess of 100 decibels and was acoustically calibrated at a nominal sound level of 124 dB. An EAR® personal protective earplug was used as a control and its IL may be seen in Figure 9-1. The calibration point, excitation level and noise floor of the testing system are provided in figures in Appendix 21.8.

A total of 22 pairs, thus 44 individual earbuds were tested for attenuation. Based on the results of the testing, it was observed that the tested samples fell into four acoustic attenuation classes, categorized as A (most attenuation) through D (least attenuation). All the class D earbuds are the most common *concha*-type, flat-face devices that (to the study team's knowledge) are originally supplied with all MP3 players and Apple™ I-Pods.

Table 9—1. Earbud Attenuation Classification Table

Class A		**Class B**		**Class C**		**Class D (Concha)**	
Brand	*Price*	*Brand*	*Price*	*Brand*	*Price*	*Brand*	*Price*
Skullcandy	$21.99	Sony	$29.99	IMIXID	$14.99	Apple	$29.00
Sennheiser	$99.95	IMIXID	$14.99	iFrogs	$10.00	JVC	$10.99
Ultimate Ears	$49.99	2XL	$6.00	Memorex	$8.00	Panasonic	$6.00
Auvio	$19.19	Sony	$89.99	Vibe	$4.99	Maxell	$2.47
Sony*	$89.99	Auvio	$19.19				

*Sony headset with the ANC turned on (normally Class B with ANC off)

A review of the attenuation performance of the earbuds in Figure 9-1, below, clearly indicates that the most common class D, concha-style earbuds have virtually no effect on the audibility of train horns or a WH or AWS type substitute device because they measure at or near the zero line over the entire frequency range of interest (250 Hz to slightly approximately 2000 Hz) that is produced by the typical WH and train horn (Thunder 2003). The class C insert-style earbuds test the same in the lower frequencies, with increased attenuation in the higher frequencies. The typically more expensive headphones in class B and the very few models in class A do exhibit a better ability to reduce exterior noise. However, the attenuation from earbuds affects both audible warnings

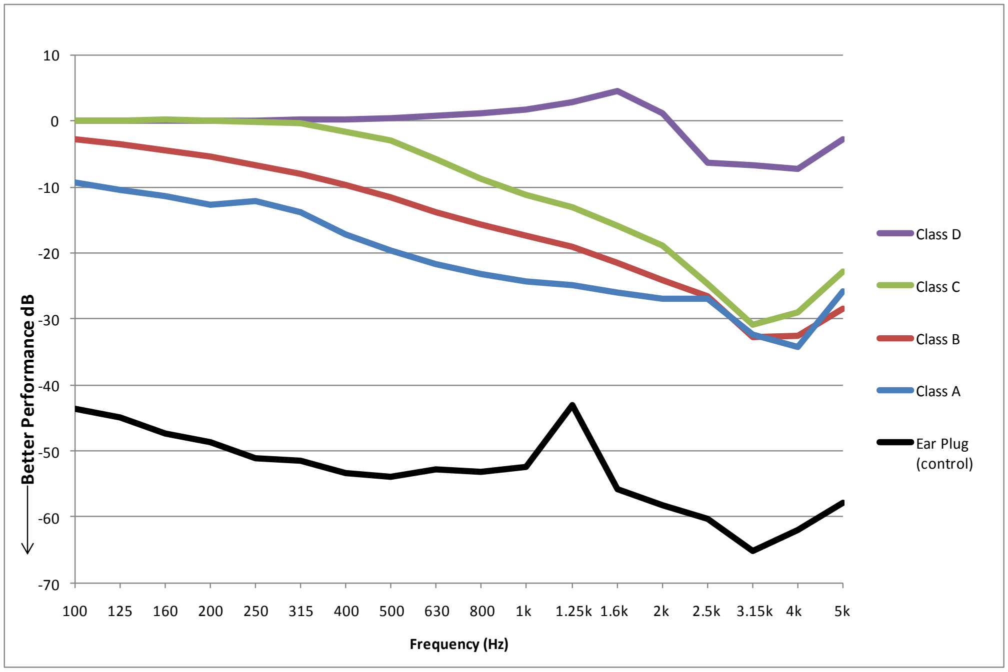

Figure 9—1. Attenuation (IL) of All 4 Classes Plus Control Ear*plug*

and ambient/background noise equally, thus the signal-to-noise ratio of these two factors is maintained. More significant, however, is that none of the earbuds provide attenuation equal to that provided by a car "shell" when compared to data from Rapoza (Rapoza 2002), from Fidell (Fidell 2007), or Brach (Brach 2009) (also see Figure 12-2 for comparison, but note difference in data presentation and bandwidth). Finally, no earbud comes anywhere close to providing the attenuation obtained from a true ear *plug*, shown as "control" in Figure 9-1.

To provide a conservative analysis, the wearing of earbuds alone is assigned a 5 decibel value. The additional distraction from engaging in conversation or listening to music or talk radio is addressed in the next section.

10.0 SCBT User Distractions

"Distractions" may include an audible component such as listening to talk radio or music or having a conversation, but are generally considered secondary cognitive activities whether audible or not that require, absorb, or monopolize a person's attention which might otherwise be applied to a different primary task such as detecting and responding to a warning signal (Consiglio 2003).

10.1 Walking, Jogging, Bicycle Riding

The authors believe that riding a bicycle and especially walking and jogging do not require a high degree of cognitive "attentiveness" and agree with current researchers that "Control of the human walking pattern requires little thought, with conscious control used only in the face of a challenging environment or a perturbation." (Malone and Bastian 2010). The authors also believe that operating a motor-vehicle does require and utilize more cognitive capacity than walking, jogging, or riding a bicycle on the SCBT. Thus, an audible warning from an AWS presented to a SCBT User should be more easily and quickly recognized and acted upon (i.e., shorter reaction time) than a WH warning presented to a motor vehicle driver. Also, the decision faced by the SCBT Users of “Stop” or “Don’t Stop” is not as complex (and may be more quickly made) as is the likely decision matrix facing the vehicle driver. Thus, the AWS study approach is consistent with the review comment provided by the Volpe Center: “Although an activity such as walking may be a simpler task than driving, other distractions contribute to the overall level of attentiveness, where it is unknown if pedestrians and bicyclists would be more or less distracted than their driving counterparts. It is the expert opinion of Volpe Center Human Factors staff that it should not be assumed that non-motorists are more attentive/less distracted than motorists, and that when calculating or applying reaction times, non-motorists and motorists should be treated equally, assuming no further information or research is available stating otherwise.”

Notwithstanding the “further information” cited above, the authors used a conservative reaction time of 500 milliseconds (Consiglio 2003) compared to the expected typical, non-distracted reaction time to audible stimuli of 160 milliseconds (Kosinski 2010) in calculations of required warning time for the AWS and, as discussed below, the AWS signal level was also increased to 80 dBA (i.e., twice as loud) to accommodate “other distractions”.

10.2 Conversation

Most SCBT Users are individuals and this distraction does not apply to this subgroup. Some Users are in pairs, with very few in larger groups as discussed elsewhere in this report. Infrequent conversations were observed between and among the SCBT Users. The sound levels of conversations between SCBT Users were noted by acoustically trained observers to be in the normal range for speech (approximately 60 dBA at 3 feet). No excessive vocal effort was noted. These observations included periods of high surf activity. Conversation sound would not interfere with the audibility of an AWS signal but could contribute to distraction of the SCBT users engaged in conversation. This is consistent with the findings of Consiglio *et al* regarding conversation and reaction time (Consiglio 2003).

10.3 Surf Noise

Surf noise was incorporated into the analysis and calculation of required sound level of an effective AWS. Surf noise does not present a significant distraction or potential “masking” of an AWS warning signal.

10.4 Speech/Music

This distraction would apply only to those SCBT Users wearing earbuds *and* listening to talk or music. It is assumed that a “normal” listening level above ambient would be used. Note that ambient sound level along the SCBT is lower than in a moving vehicle, thus the listening level could also be lower. Although other studies (Consiglio 2003) have found that music listening appears to have a minimal effect on reaction time (4%) compared to control subjects; the effect of “talk” radio listening is more ambiguous. Thus, this general distraction is assigned a 5 decibel value.

11.0 Audible Warning System Signal

Many attributes contribute to the overall characteristics of an audible warning signal and its effectiveness. These include the tonality or frequency components of the signal (e.g., discrete pure tone(s), even or oddly related harmonics of a fundamental or predominate tone, contiguous or separate noise bands); temporal factors such as overall duration, duration of parts of the signal, continuous or regularly or irregularly or randomly intermittent signals; time variability of the signal's overall duration; frequency content and manipulation (e.g., pseudo-Doppler, perceived continuously rising pitch); the absolute or relative value of the sound pressure level (SPL), (e.g., constant SPL or time varying SPL with very short-term (e.g., warble), short-term, or longer term variability), to mention a few of the highly variable characteristics of potential audible warning signals.

Acoustic warning signals have been developed by humans, in many cases mimicking nature, over hundreds and perhaps thousands of years. Of more interest to this study are audible warning signals developed since the Industrial Age, that would include various gongs, bells, whistles, horns, tones, and more complicated electronically synthesized sounds, some found in nature, some not. A portion of these warning sounds have become strongly associated (iconic) with a particular action or hazard. This association of an audible sound with a particular event, or a warning sound with a particular hazard, may endure for generations if it is continually repeated, or the sound may lose its meaning due to disuse.

For example, on nearly all continents, a train whistle or horn and the crossing bells heard at many highway/railroad at-grade crossings still signify the hazard of an approaching railroad train. One iconic sound that younger residents of many areas of North America may have never experienced is the traditional "air raid siren", although in some parts of the country that type of sound is currently used to signal an impending hazardous event such as a tornado or hurricane, or a potentially disastrous event at a nuclear power station. It is noteworthy that through movies, television, and radio, many persons will recognize and associate historic audible warnings with specific events even though they may not have personally experienced the "real" sound and event. Such sounds include the Dive! Dive! warning using a "klaxon" horn on a submarine that may be heard at http://www.defenselink.mil/multimedia/audio/index.html and another warning sound associated with a physical hazard, the foghorn. A sample of this classic sound from the Portland Lighthouse may be heard at http://www.youtube.com/watch?v=bdi7t475F0s&feature=related

11.1 Train Horn Sound

The determination of whether a specific sound is iconic is subjective and anecdotal unless a statistically significant survey of the general population has been obtained. The authors are not aware of such an objective study being done for a train horn sound, but anecdotally, it is assumed that the traditional sound of a "modern" locomotive air horn is strongly associated with a railroad train. Curiously, this phenomenon appears to be the case when train horns (and WH) are generally similar and do not sound exactly alike. Train horn recordings of ten different locomotive-mounted train horns, most similar and a couple of dissimilar horns, may be heard at http://en.wikipedia.org/wiki/Train_horn#Audio_samples

11.2 Traditional versus Novel Sound

Two important considerations when evaluating the required characteristics of an audible warning signal are:

1. Whether there exists a traditional or iconic warning signal associated with the hazard that will reliably provide an adequate audible warning with the necessary degree of safety; or,
2. Whether the ambient acoustic environment is adverse to such a degree that a novel, specially designed acoustic signal will be required to provide the necessary degree of safety.

Evaluating the above two considerations is not trivial; it requires specific knowledge of the existing and typically expected acoustic environment, including variability and incorporation of non-acoustic factors such as the feasibility of educating SCBT Users who would be considered "naive" listeners with respect to the introduction of a "novel" audible warning signal. It would obviously be unproductive and in fact dangerous to develop and use a 100 percent audible sound that had no inherent meaning as a warning of an impending hazard. Thus, consideration number one above to use a traditional signal would be the preferable choice, perhaps with enhancements promoting additional safety, if it can be shown to maintain the required safety aspects under the expected conditions.

11.3 Warning Signal Enhancements

An enhancement of the potential AWS signal, considered by this study's authors prior to review of the Mundelein Study (Thunder 2003) and receipt of the Volpe review recommendations (Volpe 2011), was to dynamically modify the sound level of the standard "long-long-short-long" warning signal to mimic the increasing sound level provided by an approaching train horn. In the Volpe review it was observed "Of particular interest to this [AWS] project, the authors of the Mundelein study also provide several recommendations to improve the design of the wayside horn. They state that "it is insufficient to simply reproduce the static amplitude, frequency, and duration of a train horn blast. We believe it is also important to mimic the dynamic features of a train horn, which would be to include only one sequence, adjusting the onset of the sequence, and providing an amplitude ramp to avoid startling pedestrians." The authors of this AWS study agree and recommend that these warning signal enhancements be considered during the design phase.

11.4 Warning Signal Effectiveness Evaluation

Scientifically-based methods for assisting in this evaluation of warning effectiveness are available. They include measuring or calculating the simple relationship (overall, or within the frequency bands of interest) between the average SPL of ambient sound in the existing environment ("noise") compared to the SPL of the audible warning ("signal"). This is called the "signal to noise ratio", defined in units of decibels. Another method is to evaluate the frequency content and its relative SPL in the ambient acoustic environment that might "mask" the important frequency or frequencies in the warning signal, indicating that the warning signal SPL should be increased or it should contain different frequencies to avoid the masking effect. An effective method for evaluating the degree to which a warning signal will be (clearly) audible in the midst of the ambient acoustic environment is the theory and metric of *Detectability*, and related measures of noticeability, signal-to-noise-ratio, and effectiveness. Additional methods were noted in the Volpe review (Volpe 2011).

The following section is likely the most important in this report and assesses whether an Audible Warning System signal similar to a traditional train horn or WH type sound is the most suitable for the specific acoustic and User characteristics of the SCBT.

12.0 Audibility Calculations for an Audible Warning Signal in the Presence of Surf Noise

12.1 Analysis

A sample of a WH warning signal (a digital capture of a train horn) and samples of surf noise recorded by Parsons Brinckerhoff during the ambient sound measurements along the SCBT, were prepared as .wav files. These files were provided to and analyzed by Fidell Associates to yield a series of slow time constant, one half second, linear, one-third octave band spectra. One-third octave band levels of the surf noise were compared to the one-third octave band levels of the WH warning signal. The goal of this comparative analysis was to determine the appropriate level required of an audible warning signal, such as from an AWS along the SCBT, with the acoustical effectiveness provided by the WH for motorists. Figure 12-1 comparatively displays the resulting spectra. The WH warning signal is plotted at a 92 dB (A-weighted)[4] reproduction level, along with the surf noise L_{eq}. Because even relatively consistent “heavy surf” produces some variability in sound pressure levels, the variability of this “masking noise” is indicated by the bars depicting the L_{10} and L_{90} surf noise levels in each one-third octave band.

[4] This is the sound level specified for WH warning signals intended to provide adequate notification to vehicular traffic approaching a grade level crossing, at a distance of 100 feet from the tracks.

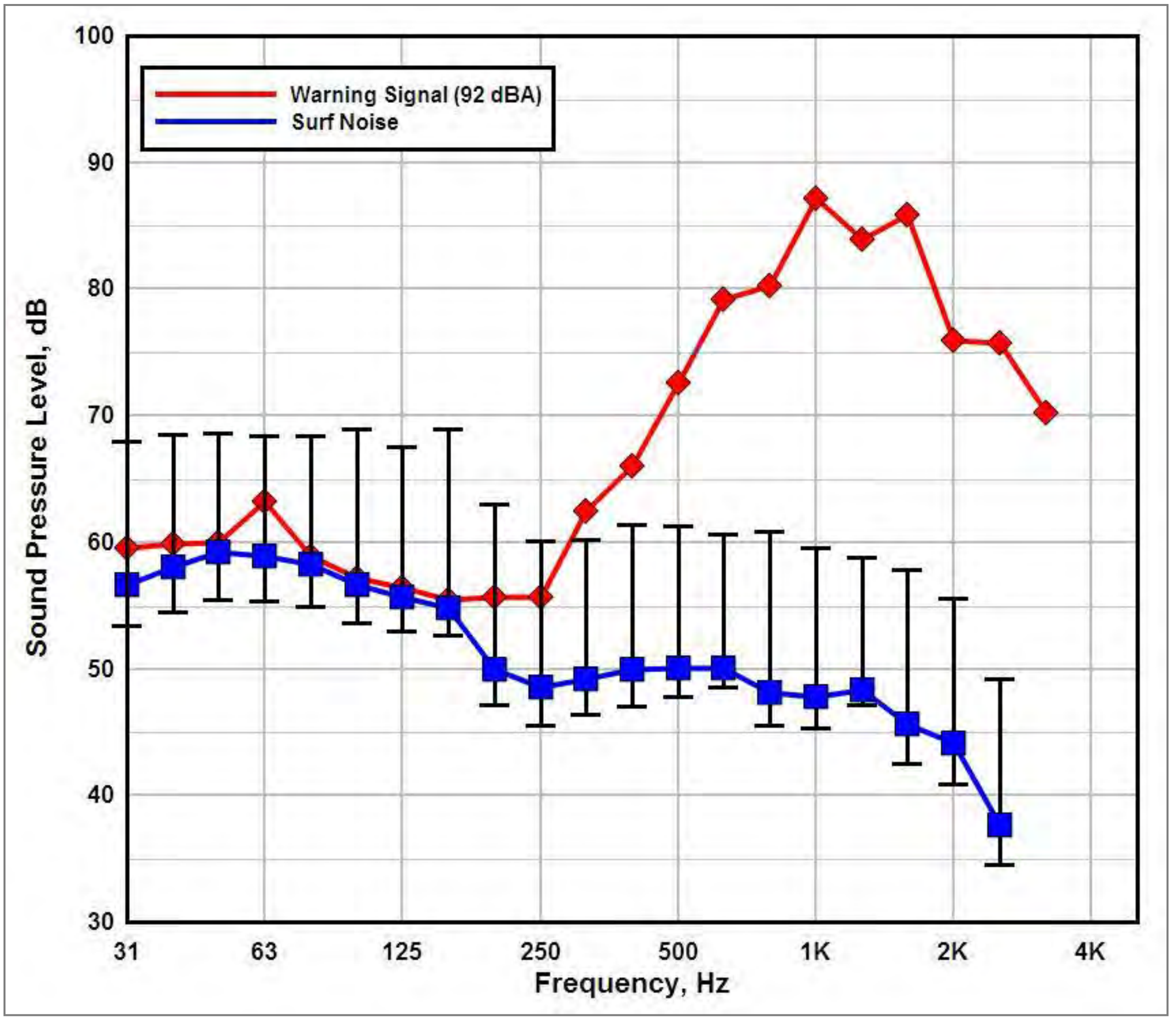

Figure 12—1. One-third octave spectra of masking noise and warning signal.

The next step was to select an audibility level goal by calculating the d'*L* (defined as 10 log d') corresponding to that associated with a WH warning signal at a reference level of 92 dB(A), for an observer inside a closed passenger vehicle traveling at 35 mph. An insertion loss spectrum and background noise levels for the vehicle were estimated from the information shown in Figures 12-2 and 12-3.[5] The warning signal levels were first reduced by an average value taken from Figure 12-2, after which d'*L* was calculated using the 35 mph background levels from Figure 12-3.

[5] The information in these figures was adapted from empirical measurements made by Fidell Associates.

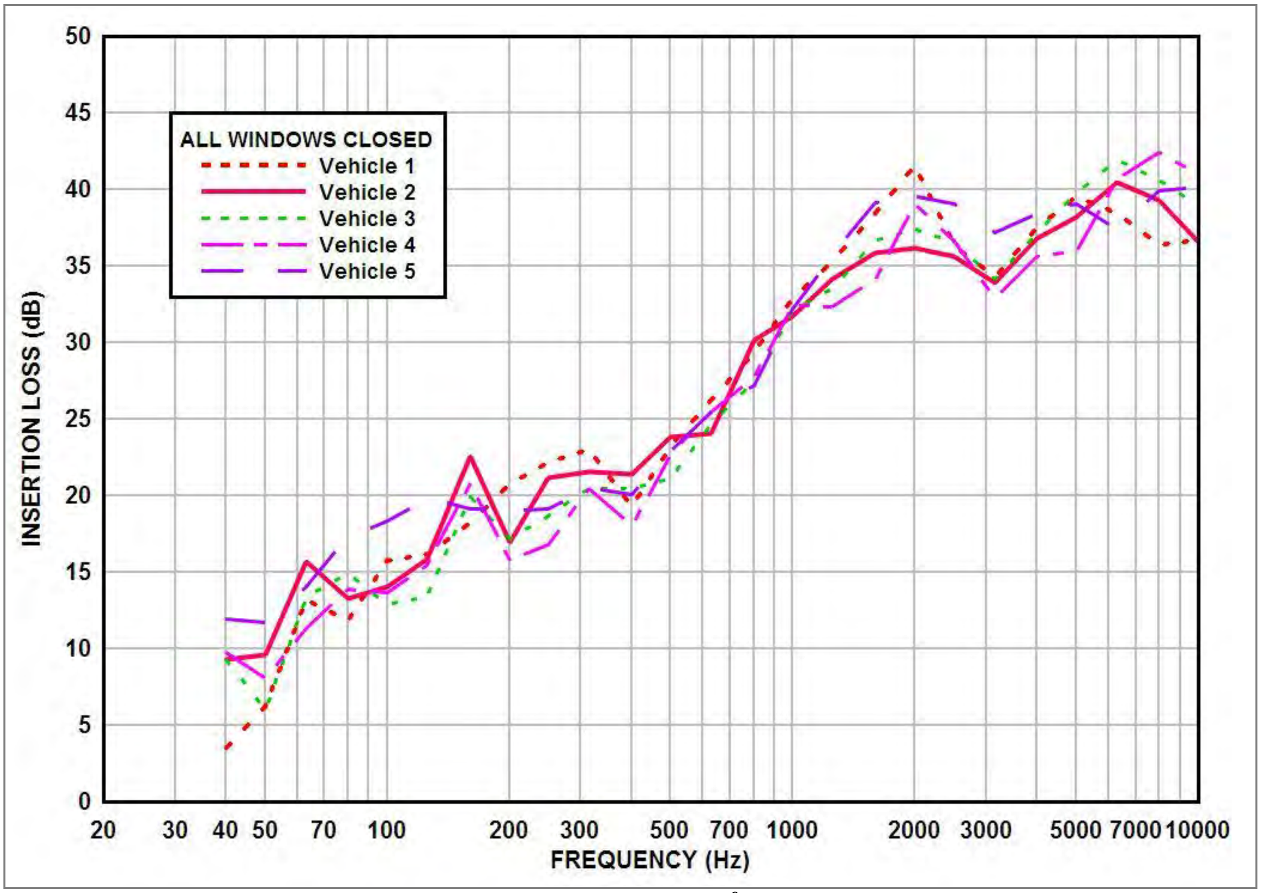

Figure 12—2. **Measured Insertion Loss Spectra for five 2005 Test Vehicles**[6].

Under these assumptions, the calculated d'*L* of an audible train horn warning at the driver's ear is 18.9 dB for the radio-off case, that corresponds to the radio condition assumed for the WH sound level requirement. This level is more than 10 dB greater than those generally observed in a typical field (uncontrolled, non-laboratory) measurement where the typical detection threshold of d'*L* = 7 dB.

The 18.9 dB d´*L* value corresponds more closely to the noticeability level of the signal, defined as the point at which a listener engaged in a foreground task other than listening for the signal becomes aware of the signal (*cf.* Sneddon *et al*., 2004). During the Rule development, the audibility calculations were based on an adjusted noticeability level of 23.3 dB assuming "passive" highway-railroad at-grade crossings with no lights, bells, or gates with the motorists having less expectation of a train. For an "active" crossing with active safety features the adjusted noticeability level is about 22 dB per Volpe (Volpe 2011) The Noticeability level noted by Fidell in this AWS study is slightly lower than that used earlier by Volpe to evaluate WH because the more recent Sneddon data was not available to Volpe researchers during the Rule development and the Rule developers incorporated very conservative assumptions. Thus, we now believe that any warning signal which

[6] The 2005 model vehicles were: Pontiac Grand Am (4 door compact); Ford Taurus (4 door, mid-size sedan); Ford Focus (4 door, compact); Lincoln Town car (Full size sedan); and Honda Odyssey (Hatchback minivan)

produces a d'*L* of 19 dB at the "target" receptors (i.e., walkers, joggers, and bicyclists) approaching the SCBT's "active" crossings (all equipped with active warning devices) will be as effective as current WH horns are for motorists approaching highway-railroad crossings, as discussed below.

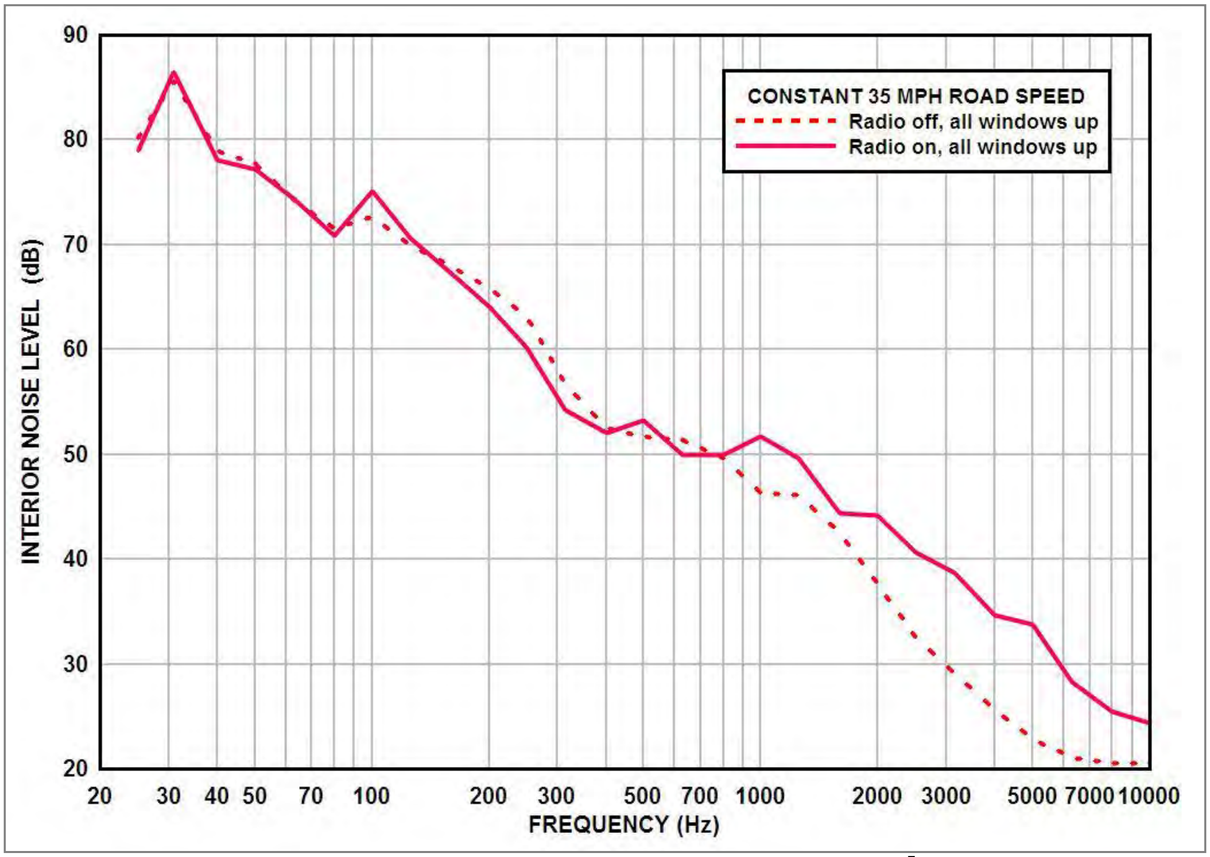

Figure 12—3. Vehicle Interior Background Noise Levels, 35 mph for five 2005 test vehicles[7].

The final step was to use the resulting one-third octave spectrum of the warning signal to calculate its audibility (d') at various absolute levels in the presence of the surf noise. Values of d'*L* were calculated for each half-second interval of a 30-second duration wayside warning signal and a 30-second sample of the surf noise background. The minimum, maximum, and average d'*L* values were extracted. To ensure that the (rather variable) character of the surf noise was adequately represented in this analysis, the process was repeated ten times with different instantiations of the surf background noise. The absolute level of the warning signal was adjusted until the desired d'*L* values were observed.

12.2 Results

The result of this process is shown in Figure12-4 for the case of a 70 dB A-weighted reproduction level for the warning signal expected at the SCBT User's ear. Considerable range in d'*L* values is evident: d'L reaches a minimum when the surf noise is at its highest, or the wayside signal is at a minimum, or both. The range of d'L values is seen to be about 10 to 20 dB from trial to trial,

[7] Ibid.

depending on variation in surf and warning signal levels, but d'L nearly always remains greater than about 20 dB.

The lowest observed d'*L* was from Trial 3, with a $d'L_{min}$ of 19.0 dB. This case represents a reasonable worst-case detection level in a surf noise background, for an Audible Warning Signal level of 70 dBA. Also note that this worst-case noticeability level is above the d´*L* = 17 dB shown by Sneddon *et al* (Sneddon 2004) to be effective, and that the noticeability level of all the other trials are near or above the d´*L* = 22.3 dB very conservatively presumed by the Rule developers to be effective for motorists at passive crossings.

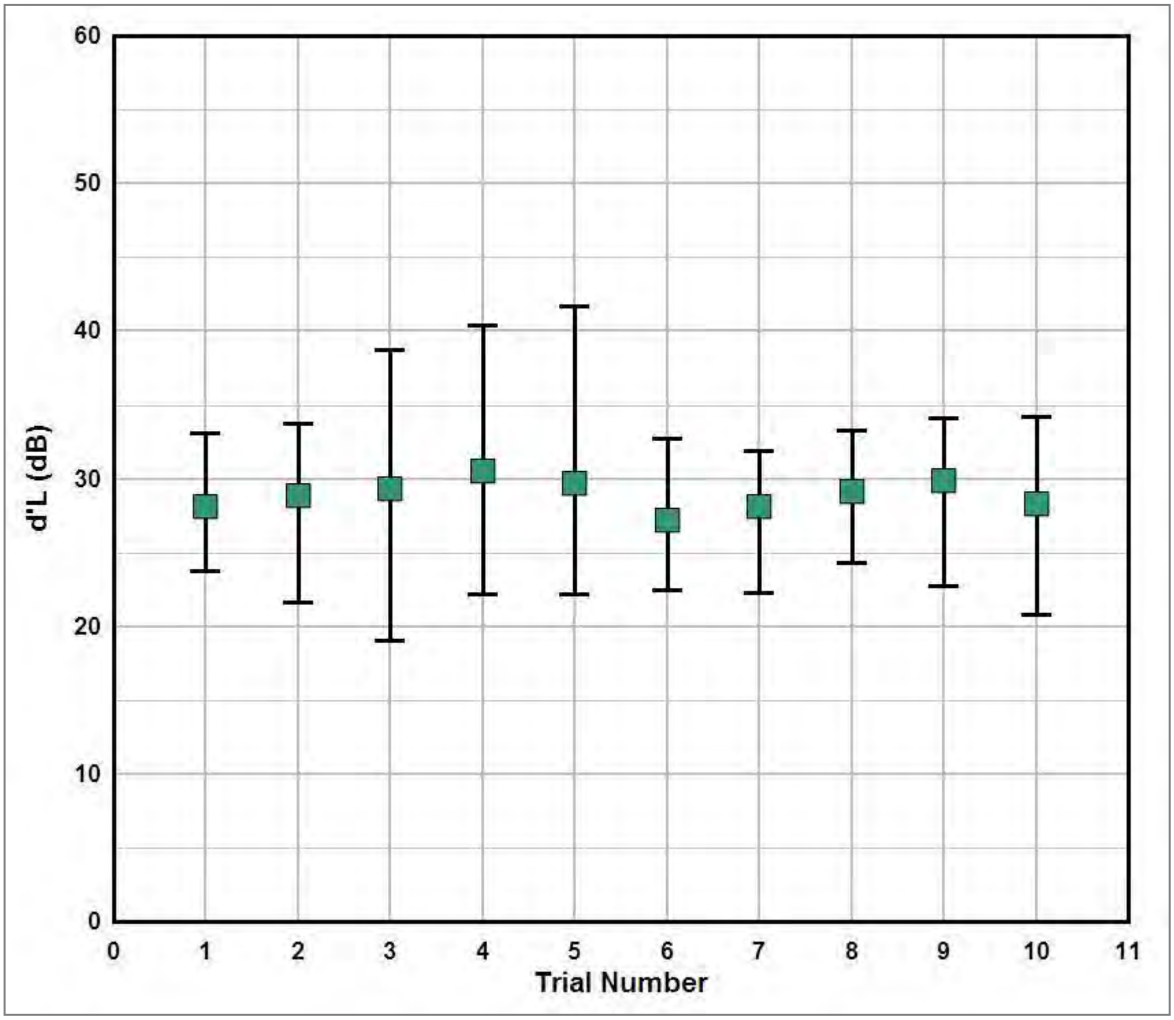

Figure 12—4. Calculated d'L values for a 70 dB (A-weighted, at User's ear) warning signal

12.3 Conclusion

The above analytic assumptions and calculations lead to a preliminary conclusion that producing an Audible Warning Signal (similar to a traditional train horn or WH type sound) that delivers a sound pressure level of 70 dBA at the uncovered ear of a SCBT User provides the acoustic equivalent of a 92 dB at 100 feet WH warning signal (or a 110 dBA at 100 feet locomotive horn warning signal) sent toward the driver of a motor vehicle approaching an at-grade highway/railroad crossing.

12.4 Recommendation

In determining the required sound level of an AWS for SCBT Users, this study has considered the absence of motor-vehicle body attenuation, the absence of masking noise from engine, road, and wind noise; and that interference with an AWS signal by other "distractions" if they occur at all, would be at lower sound levels than similar factors affecting motor vehicle drivers. If this were all the considerations, a sound pressure level of 70 dBA at the uncovered ear of a SCBT User would be the recommendation. However, this study acknowledges that some SCBT Users wear earbuds.

Thus, the next step in recommending an absolute sound level for the AWS at a reference distance is to calculate the minimum critical warning distance and sound level appropriate for all SCBT Users, including a margin of safety to deal with those wearing earbuds.

12.5 Adjustment and Recommendation of AWS level with Ear Bud Use

Based on observations and counts, twenty-two percent of SCBT Users wear earbuds. Thus, an extensive acoustical evaluation of earbuds was conducted as part of this study and was presented previously in Section 9.0. Additional discussion about the evaluation process, the measurement methodology, etc. plus the detailed results are presented in Appendix 21.7. The testing found, most importantly, that all earbuds are distinctly *not* earplugs (personal hearing protective devices). Earbuds do not reduce exterior sound by anywhere near the degree of attenuation provided by a standard earplug. In fact, the testing found that the most commonly used earbuds (flat-faced, concha style) as provided with nearly all MP3 players, including the expensive Apple™ products, provided very little attenuation of sound over the audible range of interest in this study. The less commonly used "insert" style earbuds did provide more attenuation of exterior sound, but even the most expensive ones tested did not approach the attenuation supplied by the least effective car body. To be conservative, a total decibel adjustment of 10 dB was assigned for wearing earbuds along with the possible distraction of listening to "talk" or music. Thus, an AWS sound pressure level of 80 dB at the ear of *any* SCBT User (wearing or not wearing earbuds) is recommended, which will provide the acoustic effectiveness of a 92 dBA at 100 feet WH warning signal sent toward the driver inside a motor vehicle approaching an at-grade highway/railroad crossing.

12.6 Determination of Warning Time/Distance for SCBT Users

Conservatively using the 85th percentile of the highest measured velocities (just under 10 miles per hour or 14.7 feet per second) of SCBT Users approaching the crossings, reaction time, and a comfortable deceleration rate, all Users would be able to notice the AWS and come to a controlled, safe, stop within 20 feet. Converted to a time-based measure, this requires the AWS to be activated approximately six seconds before the SCBT User arrives at the arm of the crossing's gate in the horizontal position. Thus, the absolute sound level requirements of an AWS will consider this warning time/distance, the previously calculated and adjusted AWS sound level required at the User's ear, and the method and physical configuration of the system that will deliver the audible warning to the Users.

12.7 Reaction Times and Stopping Distances for the Wayside Warning Signal

The warning time (or calculated distance) needed for a SCBT User to come to a stop after hearing the AWS signal depends on two principal factors: 1) the user's *reaction time*, and 2) the *velocity* at which the User is travelling when the warning signal occurs. The following calculations estimate the distance needed for various Users to comfortably come to a safe stop.

12.7.1 Reaction Times and Stopping Distances

It is assumed that most walkers can come to a complete stop in one or two paces, and that joggers need perhaps twice as many paces. For a 30-inch stride, this implies a stopping distance of 2 times 30-inches, which equals 5 feet for walkers and 10 feet for joggers. It is further assumed that cyclists will decelerate at a constant rate from their initial velocity. Under ideal conditions, bicycles can decelerate at a rate as great as 0.6 gravity (*g*), where 1*g* equals a rate of 32 feet per second^2. A more conservative (and comfortable) estimate appropriate for current purposes is 0.25 *g*. Thus, a cyclist traveling at 14 feet per second (about 10mph) can comfortably come to a stop within 12 feet.

Personal reaction times must be added to stopping times. A typical reaction time for auditory signals is on the order of 160 milliseconds (i.e., less than 2 tenths of a second) (Kosinski 2010), although this time can vary considerably due to lapses in attention from distractions. Reaction times also increase if complex choices are required, which the authors do not believe to be the case for SCBT Users who only have to decide to "stop". The authors used a conservative reaction time of 500 milliseconds for this study.

The total stopping distance, for a given initial speed, reaction time, and deceleration rate is thus:

$$d_{total} = v_0 \; t_r + \frac{v_0^2}{2a}$$

Where *d* is distance, v_0 is initial velocity, t_r is reaction time, and *a* is acceleration.

Table 12—1. Stopping distances required for different SCBT Users.

User	Initial Speed (fps)	Deceleration Rate (g)	Reaction Time(s)	Reaction Distance (ft)	Stopping Distance (ft)	Total Distance (ft)
Walker	6	(n/a)	0.5	3.0	5	8.0
Jogger	7	(n/a)	0.5	3.5	10	13.5
Bicycle	14	0.25	0.5	7.0	12	19

12.7.2 Required Signal Levels

The audibility analysis presented above had determined a desired warning signal level (at the User's ear) of 70 dBA. This baseline level was adjusted upward to 80 dBA external to the User's uncovered or covered ear to include all Users. This criterion sound level and the time of delivery of the warning signal before a train arrives at the crossing are the most important characteristics of the AWS. To accommodate the stopping distance of 19 feet required by a bicyclist traveling at 14 fps, including 500 ms reaction time, the AWS shall produce a warning signal level of 80 dB at a slightly more conservative distance of 20 feet before the crossing gate arm that the User is approaching.

For a sound level value to be meaningful in most instances, a location for the sound level must be specified (or inferred by convention). In this study the critical location is *at the User's ear* when the User is 20 feet before the gate arm. However, in order to compare this AWS level to other sound levels such as from a WH, a simple reference distance may be assumed and resultant sound levels at various other distances may be calculated.

Acoustically, the audible warning signal acts as a point source and exhibits a 6 dB reduction in level for each doubling of distance away from the warning signal source (loudspeaker). Thus, the requisite source sound level at a specified reference distance is dependent on the distance between the source of the audible warning (the AWS loudspeaker) and the User's ear. If the SCBT User were to be 10 feet from the AWS loudspeaker (when 20 feet from the gate arm), then the source sound level for the AWS loudspeaker could be specified as "80 dBA at 10 feet". The sound level of the AWS at 100 feet (the distance specified for WH) would be 60 dBA. A WH sound level of "92 dBA at 100 feet" would be 112 dBA at a distance of 10 feet from its loudspeaker. Importantly, in a direct comparison of sound levels, the AWS is 32 dBA lower than a WH when compared at the same distance. Using the following Table 12-2, the WH warning would be perceived as approximately eight times louder than the AWS warning (conversely, the AWS is about 1/8 as loud as a WH).

Table 12—2. Sound Levels of Typical Noise Sources and Noise Environments.

SOUND LEVELS OF TYPICAL NOISE SOURCES AND NOISE ENVIRONMENTS			
Noise Source (at a Given Distance)	**Scale of A-Weighted Sound Level in Decibels**	**Noise Environment**	**Human Judgment of Noise Loudness (Relative to a Reference Loudness of 70 Decibels*)**
Military Jet Take-off with After-burner (50 ft)	140		
Civil Defense Siren (100 ft)	130	Aircraft Carrier Flight Deck	
Commercial Jet Take-off (200 ft)	120		**Threshold of Pain** *32 times as loud
Locomotive Horn (100 ft) Pile Driver (50 ft)	110	Rock Music Concert (typical maximum levels)	*16 times as loud
Ambulance Siren (100 ft) Newspaper Press (5 ft) Power Lawn Mower (3 ft)	100	Action Movie Theater Sound	*8 times as loud
Motorcycle (25 ft) Propeller Plane Flyover (1,000 ft) Diesel Truck, 40 mph (50 ft)	90	Boiler Room Printing Press Plant.	**Very Loud** *4 times as loud
Garbage Disposal (3 ft)	80	High Urban Ambient Sound	*2 times as loud
Passenger Car, 65 mph (25 ft) Vacuum Cleaner (10 ft)	70		**Loud** *70 decibels (Reference Loudness)
Normal Conversation (3 ft) Air Conditioning Unit (100 ft)	60	Data Processing Center Department Store	**Moderately Loud** *1/2 as loud
Light Traffic (100 ft)	50	Business Office	*1/4 as loud
	45	Private Business Office	**Quiet**
Bird Calls (distant)	40	Lower Limit of Urban Ambient Sound	*1/8 as loud
Soft Whisper (5 ft)	30	Bedroom at night	**Very Quiet**
	15	Recording Studio Very remote outdoor location	**Extremely Quiet**
	10		
	0		Threshold of Hearing

Source: PB compiled 2008

13.0 Railroad Track Users and Existing Safety Systems

13.1 Existing Railroad Track Users

The current users of the railroad track include freight rail (e.g., BNSF), commuter rail (e.g., Metro Link) and passenger rail (e.g., Amtrak). The latter user is shown in Photo 13-1, below taken on July 5, 2010 during a preliminary high-surf noise measurement.

Photo 13—1. Southbound Passenger Rail Train in the Calafia Beach Area.

13.1.1 Fencing, signs, grade-crossing bells, physical gates, and flashing lights

In addition to sounding of train horns, existing safety features include fencing to direct pedestrians-bicycles to legal crossings, informational and warning signs of various sorts, and two each of the standard pole-mounted cross-buck, automated gate arm with flashing gate arm lights, two alternating flashing lights, and electronic crossing bells. Photo triplet 13-2, below shows some of these features.

Photo Triplet 13—2. Safety Features of Typical SCBT/Railroad Crossing Locations.

13.2 Safety deficiencies

Mr. Greene, and Dr. Fidell, and Dr. Rochat visited the SCBT and noted some safety issues that could be improved. These included locations where the gate arm in its down position was easily bypassed by pedestrians-bicycles (this behavior was observed), locations where signs were located such that they were blocked from view by other signs (such as “No Smoking”) or enclosures (such as the pay parking vending machine) or were not immediately obvious to SCBT Users. Evidence of “sign overload” may be clearly seen in Photo 13-3, below. A quick glance reveals that one should really pay for parking, there is no lifeguard, be aware of earthquakes and tsunami’s, and, by the way, this is a pedestrian-bicycle/railroad crossing. The report by Richard Clark (2008) contains very useful information regarding sign pollution. The City is aware of and addressing these concerns.

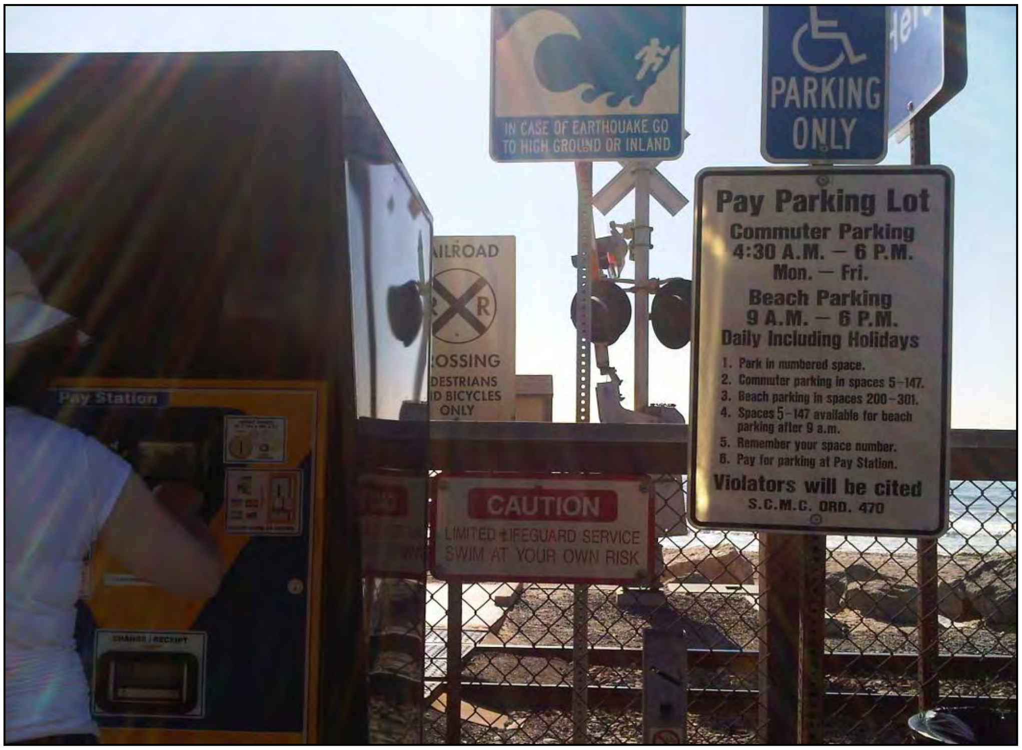

Photo 13—3. Sign Overload at the Threshold of a Crossing.

Also noted was the lack of obvious "awareness of rail safety" posters or other educational aids at the entrances to the SCBT, for adults and especially for children. Although assuredly satisfying standards for railroad signage, many of the safety-oriented signs along the SCBT do not appear to be at an appropriate height for a pedestrian-bicycle-focused facility as may be seen in Photo 13-4, below. The recommended height for pedestrian-oriented signage is 1.2 m (4 feet) according to Joaquin Siques, where the sign would be "…in the cone of vision where pedestrians tend to look while they are walking," (Siques 2001).

Photo 13—4. Pedestrians and Bicycles Crossing Sign Way Up the Pole.

As shown in Photo 13-5, below, one often needs to actively look for a warning sign that is not necessarily in the line-of-sight of the User's physical orientation, and then decipher its meaning.

Photo 13—5. Small and Somewhat Cryptic Warning Sign

The investigators also note that while a warning requires a sufficient interval before the train arrives at a crossing and sufficient duration to be effective, there can be excessive pre-train warning time and warning signal duration that serves to *reduce* the efficacy of the warning system. To be effective, any warning must be heeded. If the recipient of the warning does not believe that the warning is serious or the danger is not imminent, the recipient may tend to discount or ignore the warning. In the case of the SCBT/Railroad crossings, this can result in Users trying to "beat the gate" or more likely just walk around the lowered gate, notwithstanding the barrier itself or the flashing lights and ringing bells. This behavior was observed during field visits. The study authors note that this issue was discussed among the study team and was raised in the Volpe review (Volpe 2011) as an excerpt attributed to the Mundelein Study (Thunder 2003). This issue should be addressed in the AWS design phase.

Highly important pedestrian-bicycle and railroad track safety signs should be more plentiful and prominent. The signs should be placed at the pedestrian-bicycle eye level (including children). The sign content needs to be evaluated by a safety communications specialist. This is especially true of the graphics only "international" signs; one question posed by an investigator regarding the "Don't" sign Photo 13-5 was "What is someone not supposed to do with that ladder?"

13.3 Planned Additional Safety Improvements

The potential implementation of an AWS is only one part of an extensive program of safety enhancements that will include additional fencing, signage, etc. More comprehensive information is provided in the meeting minutes of the "Trail and beach crossings field diagnostic review meeting" conducted by the State of California's Consumer Protection and Safety Division Rail Crossings Engineering Section. A copy of the minutes is included in Appendix 21.10. A standard Rail Crossing Hazards Analysis is discussed in Section 15.0.

14.0 Delivery of a Warning Signal

14.1 Systems Considered

While the previous discussion focused on a traditional WH or AWS, the investigators conceptualized, considered, and dismissed alternative types of warning systems as not practicable, unreliable, having a poor cost/benefit ratio or some combination of these factors. These other systems included high intensity strobe lights, radio frequency activated disc vibrators (as used by some restaurants to signal table availability), loaned and then collected personal speaker-phone/radios for each User while on the SCBT that would deliver a train horn sound to each User, etc. It was concluded that personal warning systems or non-audible, non-traditional warning systems were not appropriate, and not really necessary to warn SCBT Users of an approaching train. It is believed that an AWS delivering a traditional train horn sound is the best approach. However, other audible warning signal content could be considered such as "Train Approaching, Look Both Ways" (in one or two languages) as is provided by some transit systems as a pedestrian warning (Siques, 2001).

14.2 Airborne AWS

Mechanical and Electro-mechanical systems include bells and gongs that are too limited in signal characteristics and are limited in the ability to control sound level and the pattern of sound propagation. Thus, these are not considered suitable for an AWS.

Electro-acoustic methods offer a broad range of devices, can offer synthesized or stored actual warning sounds, may be easily adjusted for sound level, and may be designed or modified to control the dispersion of sound. Additional options or features include:

- single point-of-origin at the crossing proper, farther from Users with higher relative sound level reaching adjacent residences
- multiple points-of-origin (distributed) or a single point-of-origin, but closer to the SCBT Users with lower relative sound level reaching residences
- adjustability for optimum coverage and minimum annoyance through design and orientation

14.3 Signal Delivery

A detailed system design is beyond the scope of this report and would be accomplished in final design if the AWS is authorized. Individualized design solutions should be developed for each of the seven unique crossings. However, the following conceptual discussion is provided to show that implementing an AWS is practicable.

Preliminary calculations indicate that typically two loudspeaker locations per crossing, each approximately 20 feet walking distance before the crossing gate in the horizontal position will be suitable to deliver an effective audible warning signal to SCBT Users. This conceptual configuration is based on the loudspeaker(s) being located just outside the trail's edge, close to the Users. A maximum trail width of ten feet is assumed at the loudspeaker location, and a typical ear height of five feet above ground is assumed which is the prescribed receptor height in nearly all noise assessment and measurement regulations and standards. It is further assumed that the electronic portion of the AWS may be located within the existing signal control boxes with the signal cable placed in buried conduit connecting to the AWS loudspeaker(s).

As mentioned above, the exact location for the AWS loudspeaker(s) will be determined during the design and engineering phase of the project. The AWS loudspeaker(s) could be located near ground level (for example under the seat of a trailside bench or within a concrete or metal bollard) or on an approximately 12-feet-high pole. The audible warning zones for an AWS loudspeaker and the gate bell loudspeaker are shown schematically in Figure 14-1 that presents the approach from one direction on the SCBT to a typical crossing gate. The approach from the other direction may be on the same side or the other side of the tracks, thus there would be two loudspeaker-equipped benches or bollards or poles (or some combination) at each pedestrian-bicycle crossing. Note that the actual crossing of the railroad tracks by the short branch trails are oriented at 90° to the main SCBT directions of travel. Importantly, the size and shape of the audible warning zone from the AWS loudspeaker(s) may be modified by design and readily adjusted during installation as field conditions warrant. The conceptual location of the AWS loudspeaker shown in the figure would provide the required 80 dBA audible warning at a distance of 20 feet before the automatic gate arm. Depending on type and orientation of the loudspeaker, this location could additionally provide the required warning level approximately 30 feet before the gate, a 50 percent greater distance than the required 20 feet, without materially increasing the sound projected toward the community. With the AWS loudspeaker located at 20 feet from the gate, the sound level from either AWS loudspeaker within ten feet of the gate would be augmented by the warning sound from the other AWS loudspeaker; however, the overall AWS level within 10 feet of the gate could be slightly less than 80 dBA and might be interfered with by the sound of the crossing bells that generate their own distinct warning signal at 80 dBA approximately 12 feet from the electronic bell. This potential for interference may be reduced by locating the AWS loudspeakers 10 feet from the gate, where they can still provide the necessary warning and sound level to SCBT Users, or by reorienting and adjusting the sound level of the AWS directional loudspeakers located 20 feet from the gate. Again, the AWS is envisioned to be highly flexible in this regard.

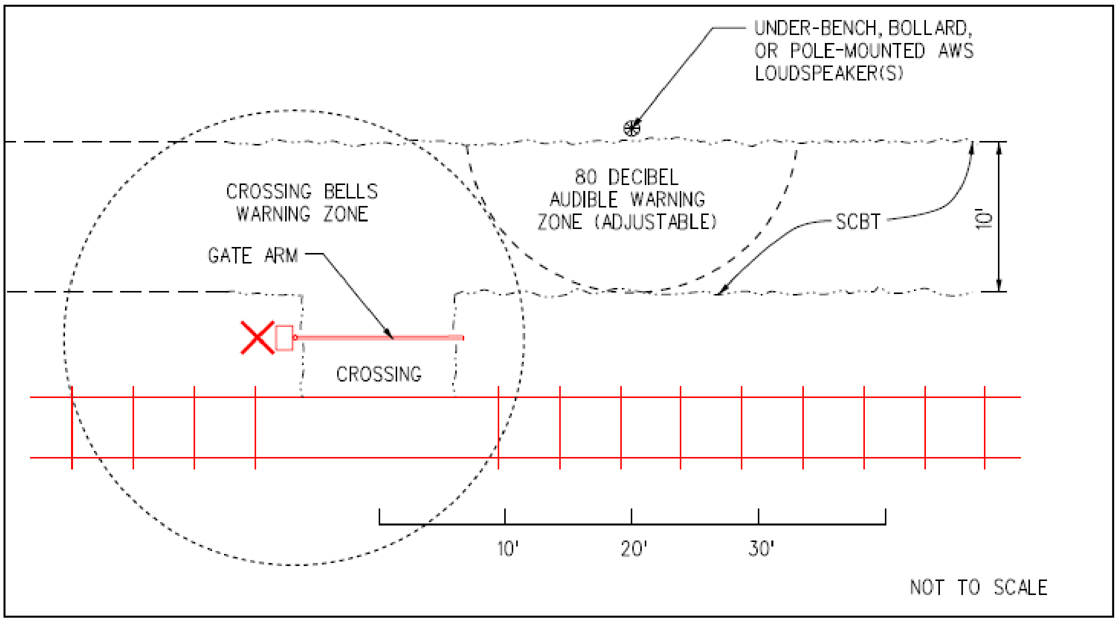

Figure 14—1. Schematic Representation of a Typical AWS Loudspeaker Location Approaching a Gate.

A reasonable range of truly weather resistant (including marine applications) loudspeakers are readily available for this application. These include commercial/industrial grade units with integral transformers for 70 volt line operation that can provide the frequency response, sensitivity, power handling and directionality to reliably generate the SPL required for the SCBT AWS. Typical loudspeakers suitable for delivering the necessary SPL and withstanding the physical environment include, but are not limited to, the Electro Voice® EV 850T, the Cobreflex III horn plus 1829BT driver, and the Technomad® Vernal 15. These devices may be seen in Photographs 14-1 through 14-4, below. Technical specifications for these representative devices are in Appendix 21.9. Typical loudspeaker-equipped bollards are shown in Photograph set 14-5.

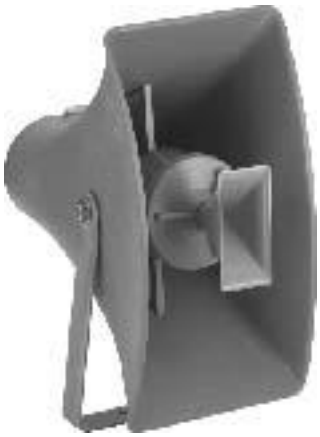

Photo 14—1. EV® 950T

Photo 14—2. EV® Cobreflex III

Photo 14—3. EV® 1829BT driver

Photo 14—4. Pole-mounted Vernal 15s adjacent to Hong Kong Harbor

Photo 14—5. Loudspeaker-equipped bollards of various styles in natural stone, cast concrete, and aluminum

14.4 Modeling of AWS Sound Level

The audible warning from the proposed AWS was modeled using a three dimensional acoustic software program (SoundPLAN® Ver. 7) in order to evaluate the reduced noise compared to a train horn, a WH, and to allow comparison to earlier studies (Greene 2010). The graphic output from the modeling program showing the expected maximum sound levels near the typical pedestrian-bicycle/railroad crossings, including those where residential use is very close to the crossing, is presented in Figure 14-2.

Figure 14—2. Typical Sound Distribution from AWS at a Crossing. Shown is the Corto Lane Crossing.

Inspection of this figure (and a comparison with train and wayside horns) shows a much reduced and minimal noise "footprint" in the adjacent residential areas from the AWS. This would result in a much improved community noise environment compared to the current practice of sounding the train horn warning signal.

15.0 Rail Crossing Hazard Analysis

15.1 Purpose

A Rail Crossing Hazard Analysis (RCHA) is performed to identify potential hazards and systematically assess conditions which could potentially affect the safety of pedestrians and bicyclists at the railroad crossings. Identifying potential hazards will enable their elimination or control, together with their associated causes and effects. There are seven pedestrian-bicycle/railroad at-grade crossings. Because the hazards associated with these crossings are the same, a single hazard analysis was performed for all seven at-grade crossings. The identified resolutions are also applicable to all seven crossings. The Rail Crossing Hazard Analysis methodology, definitions of specialized terminology, and more detailed information are provided in Appendix 21.11.

15.2 Findings

The RCHA conducted for the seven pedestrian-bicycle/railroad at-grade crossings along the SCBT considered the following safety improvements, some of which are currently implemented and some that represent future conditions:

1. fencing to promote channelization of Users and beach goers to designated crossings;
2. automatic gates to interdict pedestrian passage across the tracks in both directions before and during a railroad train event;
3. crossing bells, flashing lights, and an AWS to provide visual and audible warning of an approaching train; and,
4. a neighborhood education program on railroad safety.

The RCHA found that with implementation of the various safety improvements listed above, the risks associated with pedestrian-bicycle/railroad at-grade crossings are substantially reduced.

15.3 Safety Risk Conclusions and Recommendations

Based on evaluation of risks and safety improvement actions already in place and improvements such as AWS to be implemented, safety would be improved and the risks that affect all seven pedestrian-bicycle/railroad at-grade crossings along the SCBT would be in the acceptable range. Thus, with all safety features implemented as identified in the Hazard Risk Index, the risks associated with the SCBT pedestrian-bicycle crossings would be lower than or equal to the risks for a highway/railroad at-grade crossing equipped with Supplemental Safety Measures. The recommended AWS nominal signal level of 80 dBA delivered to ear height at a point 20 feet walking distance before the automatic gates (horizontal position) is conservative and provides equivalent or better safety as the measures approved for federal Quiet Zones that include public highway/railroad grade crossings with no horn sounding requirements. While not required, efforts in addition to those enumerated above that would further improve safety are always encouraged.

16.0 Overall AWS Report Summary

16.1 Findings

The findings of the study team are summarized in the following list.

1. The acoustic environment along the SCBT is mild and benign, thus development and use of a special, non-traditional warning signal is not warranted.
2. The relatively quiet background sound levels along the SCBT are lower than the sound levels experienced inside a moving vehicle, thus the AWS warning signal levels may also be lower.
3. The maximum speed of SCBT pedestrians and bicyclists is substantially less than that accommodated by a WH warning for motorists. The SCBT Users can come to a safe stop in less time and within a shorter distance. Thus, the sound level and duration of an AWS warning may be lower and shorter than a WH warning.
4. The "shell" of a vehicle provides substantial attenuation of exterior sounds, including audible warning signals such as from a WH system. There is no "vehicle shell" attenuation around most of the SCBT Users, although some Users wear earbuds.
5. The required attentiveness, complexity of decisions, and competing distractions for SCBT Users are believed by the authors to be less than for motor vehicle operators. Thus, the sound level and duration of an AWS warning signal may be reduced compared to a WH without compromising safety.
6. The recommended AWS nominal sound level of 80 dBA delivered to ear height at a point 20 feet walking distance before the horizontal automatic gate(s) provides an effective warning to all persons on the SCBT, including walkers, joggers, bicyclists, beach goers, earbud wearers and persons engaged in conversation, etc.
7. Modification of the warning signal with respect to timing and progressive increases of the warning sound level to emulate a train horn may improve the effectiveness of the warning signal.
8. Several configurations of electronic and electro-acoustic components exist that may be optimized for use at SCBT/Railroad crossing locations to provide a focused audible warning from a loudspeaker located close to Users at the necessary sound pressure level, while reducing warning noise spillover into the adjacent noise-sensitive community.
9. By using the AWS instead of sounding of the train horn warning signal, in conjunction with the other installed safety features of the SCBT, all potential hazards can be considered to be at an acceptable risk level.

16.2 Conclusions

1. A reproduction of a standard 5-chime train horn sound in the FRA-prescribed sequence is an appropriate content of an AWS. Dynamically increasing the level of the AWS signal to mimic the change in sound level of a train horn on an approaching train and optimizing the warning signal timing should be addressed during the AWS design phase.
2. Because the ambient sound levels on the SCBT are lower than in a car interior, the sound level of an effective (safety-equivalent) AWS can also be lower than a WH.

3. Because the SCBT AWS does not have to penetrate and overcome "vehicle shell" attenuation as a WH system must accomplish, lower AWS sound levels will achieve the same degree of safety warning for SCBT Users, including those who wear earbuds.
4. A conservative approach was chosen when evaluating each variable in the study, thus the study results and conclusions are also conservative. Analysis bias, if any, is toward safety.
5. The acoustically preferred configuration of an AWS would use the "local, nearby" loudspeaker concept to deliver the required 80 dBA warning sound level to SCBT Users ears at a point at least 20 feet before the horizontal crossing gate arm(s). Because of the conservative recommendation, a field verification measurement indicating an AWS sound pressure level tolerance within two decibels of the nominal criterion warning sound pressure level is satisfactory (i.e., 80±2 dBA).
6. Using an AWS instead of train horns greatly minimizes the sound from train horns projecting into nearby residential areas, thus substantially improving the community noise environment for coastal San Clemente.
7. The process for discontinuing the routine sounding of train horns should be started to allow for the regular use of the AWS when the AWS is operational.

The overall study conclusion is that a properly designed AWS can deliver an audible warning signal at a nominal sound level of 80 dBA, Lmax (slow), to SCBT Users' ears at least 20 feet before a crossing gate and thereby provide a safe and effective audible warning of an approaching railroad train to all persons on the SCBT, *at a lower sound level*, than is necessarily provided to motor-vehicle operators by a louder WH system.

This conclusion was reached within the study's "Guiding Principles" which were to:

1. Maintain or improve safety at SCBT crossings of rail road tracks.

2. Improve the existing community noise environment regarding the sounding of train horns.

According to the review of this AWS study provided by Volpe staff (Volpe 2011), the warning effectiveness of the proposed AWS to be used at SCBT crossings is at least equal to the warning effectiveness provided by WH located at highway-railroad grade crossings.

16.3 Recommendations

Based on the study conclusions, it is recommended to:

- Move forward with the design, engineering, and installation of an Audible Warning System at the seven pedestrian-bicycle crossings of the SCBT and railroad tracks.
- Maintain/improve safety, by requiring the AWS to deliver an audible warning of an approaching railroad train at a nominal 80 dBA $Lmax_{(F)}$ sound level to SCBT Users at least 20 feet walking distance before the horizontal automatic gate arm(s) at the pedestrian-bicycle/railroad crossings. The AWS would be triggered by activation of the automatic gate; the potential dynamic level modifications to the warning signal and the timing parameters

of signal onset delay, duration, number of warning sequences provided, etc. should be determined during the system design phase.

- Implement the other planned safety features of the SCBT.
- Review existing safety deficiencies and correct as necessary.
- Discontinue the routine use of train horns and use the AWS at the seven identified SCBT-railroad crossings to provide an audible warning of an approaching railroad train.

Although not required to maintain acceptable risk levels, consider development of additional safety efforts such as placing educational kiosks with interactive (audible and visual) features at strategic locations along the SCBT, providing revised and additional warning and directional signage that include strong discouragement of a failure to heed the warnings of an oncoming train.

The Audible Warning System, AWS, as developed in this investigation and described in this Technical Memorandum will provide a safe and effective audible warning of an approaching train at the seven identified pedestrian-bicycle/railroad crossings along the San Clemente Beach Trail. This will allow the routine sounding of train horns to be discontinued at these crossings, resulting in an improvement in the quality of life for San Clemente's coastal residents and visitors with no compromise of safety.

17.0 Glossary of Terms

A

A-weighted, A-weighting filter - Refers to application of the internationally standardized A-weighing filter or as computed from sound spectral data to which adjustments have been made. A-weighting de-emphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

Acceleration – The rate of change of velocity (technically includes deceleration also).

Acoustic near field – An area in close proximity to a noise source where appreciable variations in sound pressure may exist along a given radius or annulus to the noise source.

Ambient Noise Level The prevailing or energy-average noise level in an area comprised of all sounds from near and far. Usually described by the Leq or an Hourly Leq-based sound descriptor such as Ldn. May be described by the Statistical sound descriptors.

ANC – Active noise control

Area of Potential Effect (APE) – This is the geographic area or areas within which an undertaking may cause changes in the character or use of an environmental resource. In the context of this study an APE would be the area(s) where project activities may adversely increase or beneficially decrease existing levels of ambient noise.

Attenuation – A decrease in sound pressure at a receiver caused by a physical or mechanical difference in system. A physical barrier will often cause attenuation in sound pressures when place in between a noise source and a noise receiver.

Audible Frequency Range – The range of sound frequencies normally heard by the human ear. The audible range spans from 20 Hz to 20 kHz, but for most engineering investigations only frequencies between 63 Hz to 8 kHz octave bands are considered unless more or fewer “frequencies of interest” are of concern.

B

Background Noise, Noise Level - The general composite of non-recognizable noise from all distant sources, not including nearby sources or the source of interest. Generally, background noise consists of a large number of distant noise sources and can be characterized by L90. (Also see Existing noise level).

C

Community Noise Equivalent Level (CNEL) - A legacy metric, still used to some degree in California only. The Leq of the A-weighted noise level over a 24-hour period with a 5 dB penalty applied to noise levels between 7 p.m. and 10 p.m. and a 10 dB penalty applied to noise levels between 10 p.m. and 7 a.m.

Community noise – Sound of a type and character typically perceived in an urbanized area. Includes natural sound but is focused on sound associated with human activity. Also called environmental noise.

D

D’, d’ – (See Detectability)

Day – The period from 7:00 AM to 10:00 PM.

Day-Night Sound Level (Ldn) – The predominate environmental noise metric used in the United States. The Leq of the A-weighted noise over a 24-hour period with a 10 dB penalty applied to noise levels between 10 PM and 7 AM

Decibel (dB) – A unit describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for sound in air is 20 micro Pascals (the threshold of audibility for young, hearing-healthy humans).

Decibel, A-weighted, dBA, dB(A) – A unit of A-weighted sound pressure level. See A-weighted.

DNL See Ldn.

Detectability – The bandwidth-adjusted signal to noise ratio that yields a value for “D-prime”, abbreviated D’ or d’.

E

Energy-averaged – (See Energy Equivalent Level, Leq)

Energy Equivalent Level (Leq) - The level of a steady noise which has the same energy as the fluctuating noise level integrated over the time period of interest. Leq is widely used as a single-number descriptor of environmental noise. Leq is based on the logarithmic or energy summation, and it places more emphasis on high noise level periods than does L50 or a straight arithmetic average of noise level over time. This energy average is not the same as the arithmetic average of sound pressure levels over the period of interest, but must be computed by a procedure involving summation or mathematical integration.

Environmental noise – (See Community noise) Sound occurring in all areas, including suburban and rural areas, natural parks and reserves, open spaces and other places where unwanted sound may produce an adverse effect; generally outdoor noise that affects outdoor and indoor activities.

Event – A discrete noise-producing activity.

Existing noise level(s) – The noise, resulting from natural and mechanical sources and human activity, considered normally present in a particular area. Generally consisting of noise from all sources both near and far. Also described as ambient sound level(s). Background noise level generally describes the mixture of indistinguishable sounds from many sources, without any one dominating sound.

F

Frequency The number of times per second that the sine wave of sound repeats itself, or that the sine wave of a vibrating object repeats itself. Frequency is expressed in cycles per second and is abbreviated as Hertz (Hz). The frequency corresponds to the perceived pitch of a sound (e.g., high or low).

Frequency Spectrum – Distribution of sound pressure vs. frequency for a waveform, dimension in RMS pressure and defined frequency bandwidth.

G

g – Acceleration due to one gravity force. 32 feet per second^2

H

Hertz (Hz) – A unit of frequency. Defined as the number of complete oscillations of a quantity during a period of time. Hertz is equivalent to cycles per second. Normal human hearing range is between 20 Hz and 20,000 Hz.

I

Impacted (Affected) receivers – Receivers that will receive a noise impact/effect.

Insertion Loss (IL) – The actual noise level reduction at a specific receiver or point due to placing (inserting) a noise barrier between the noise source and the receiver. IL may describe the reduction in sound level resulting from use of a barrier such as a headphone. IL is frequency dependent.

L

L1, L10, L50, L90, and L99 – See Statistical Sound levels.

Ldn - Day-Night Average Sound Level (also DNL). An annual measure of cumulative noise exposure in a community that applies a penalty during nighttime hours (10:00 PM to 7:00 AM) to account for increased sensitivity to noise at night. The time weighting is applied by adding 10 dBA to the measured level of all sound that occurs during the nighttime period.

Leq(t) – The equivalent steady-state sound level that, during a specific period, contains the same sound energy as a time-varying sound occurring during the same period. The Leq is the energy summation and average of sound energy during quiet and noisy portions of a measurement period (t) in seconds, minutes or hours. Because the Leq represents an energy quantity in decibels, the numerical values of Leq are added, subtracted, averaged, etc. in the mathematical energy domain using logarithms.

Leq - Energy-equivalent sound level - The equivalent continuous constant amplitude sound level calculated to occur during a stated period, that contains the same acoustical energy as a time-varying sound occurring (or predicted to occur) during the same period. The Leq is computed by summing the noise energy during the stated period using mathematical integration.

Leq(h) - Energy-equivalent noise level for a one-hour period. Sometimes referred to as Hourly Noise Level.

Lmaximum, Fast - A-weighted sound pressure level. Greatest Fast (125-milli-second) A-weighted sound pressure level, within a stated time interval or during a measurement period. Unit, decibel (dBA); symbol, L{sub AFmax}. Used for description and measurement of impulsive sound (> 1 maxima/impulse per second)

Lmaximum, Slow - A-weighted sound pressure level. Greatest Slow (one second) A-weighted sound pressure level, within a stated time interval or during a measurement period. Unit, decibel (dBA); symbol, L{sub ASmax}. Used for description and measurement of non-impulsive sound. (<1 maxima per second)

Ln - The “statistical” sound level equaled or exceeded "n" percent of the time during a measurement. (See Statistical Sound Level)

M

Masking – When one sound prevents another sound from being audible or substantially interferes with the signal of the sound being masked.

Maximum noise level – Abbreviated Lmax, denotes the highest amplitude root-mean-square (rms) sound level occurring during a measurement period.

Maximum peak noise level – Abbreviated Lmax-pk, denotes the highest amplitude instantaneous sound level occurring during a measurement period. Potential exposure to very high levels of over 140 dB (un-weighted) Lmax-pk require the wearing of personal hearing protection such as ear plugs or muffs or both. Typically associated with occupational noise exposure.

Measurement location – A specific place on a property or within a site where a noise measurement was or would be conducted.

Minimum noise level – Abbreviated Lmin, denotes the lowest amplitude sound level occurring during a measurement period.

N

Night – The period from 10:00 PM to 7:00 AM.

Noise – Subjectively defined as “unwanted sound”. Occurrence at low sound pressure levels or at loud levels for brief isolated periods does not generally result in adverse effects or complaints. Sustained and/or repeatedly elevated levels are typically associated with nuisance and annoyance “to a reasonable person of normal sensibilities” and may result in adverse effects.

Noise abatement – Noise attenuation provided to reduce non-significant levels of increased environmental noise.

Noise effect or impact – Impact that occurs at a receiver when a discretionary action results in a change of noise level affecting noise-sensitive receivers. Generally, increased noise results in adverse impacts/effects and reduction in noise results in beneficial effects.

Noise mitigation – Noise attenuation provided to reduce significant adverse environmental effects due to noise increases.

Noticeability – the point at which a listener engaged in a foreground task other than listening for the signal becomes aware of the signal.

O

Octave Band, full, 1/1 – Frequency ranges in which the upper limit of each band is twice the lower limit. Octave bands are identified by their geometric mean frequency (center frequency). One octave is an interval between two sound frequencies that have a ratio of two. For example, the frequency range of 200 Hz to 400 Hz is one octave, as is the frequency range of 2000 Hz to 4000 Hz.

Octave Band, 1/3 – Frequency ranges where each octave is divided into one-third octaves with the upper frequency limit 1.26 times the lower frequency. Each band is identified by its center frequency. In acoustics, to increase resolution, the frequency content of a sound or vibration is often analyzed in terms of 1 /3 octave bands, where each octave is divided into three 1 /3 octave bands.

P

Pedestrian-bicycle/Rail At-Grade Crossing - The general area where a pathway and a railroad cross at the same level, within which are included the railroad tracks, pathway, design features, and traffic and/or pedestrian control devices for pathway traffic traversing that area. Motor vehicles are not generally expected or permitted at these crossings.

Potential effect – Adverse environmental consequences that could result from project activities.

Predicted noise level(s) – Future noise levels, resulting from the natural and mechanical sources and human activity considered being usually present in a particular area (i.e., ambient noise) plus the estimated future project-related noise increase or decrease.

R

Receiver, Receptor – A designated location (potentially) affected by noise. Receivers refer to both modeling locations and monitoring locations that are selected because of their sensitivity to noise and/or because they are representative of other sensitive uses. Also denotes a person who may be mobile or stationary.

Reverberant Field - The region in a room where the reflected sound dominates, as opposed to the region close to the noise source, where the direct sound dominates.

Reverberation - The continuation of sound reflections within an enclosed space after the sound source has stopped.

RMS, rms – The square root of the arithmetic average of a set of squared instantaneous values such as sound pressures. The quantity described represents the energy contained in the time-averaged signal.

S

Sound – Physically, very small rapid perturbations in ambient atmospheric pressure containing sufficient energy to displace the eardrum. Perceptually, the acoustic sensation resulting from collection, detection, transmission, analysis, and interpretation of the small pressure changes by the ear-brain system. (Also see noise).

Sound Pressure Level (SPL), Sound level – The amplitude of a sound presented as a ratio of the sound's pressure squared to a reference pressure squared. The numerical value of the ratio is given in units of decibels. The numeric value of the reference pressure is 20 µPa (twenty micro Pascals) that corresponds to 0 decibels, representing the approximate threshold of hearing for young, hearing-healthy humans.

Source, Sound source, Noise source. – Typically a vehicle, machinery, or other device that generates sound, or loud sound that is considered noise by Receivers.

Statistical Sound levels. – The most common are L1, L10, L50, and L90, used to define noise levels that are exceeded for 1 percent, 10 percent, 50 percent, 90 percent of a specified time period, respectively. Environmental noise and vibration data are often described in these terms.

SSM, Supplemental Safety Measures – Specific devices identified in the federal Train Horn Rule that serve to improve safety compared to a highway/railroad grade crossing with no safety features. SSM's include flashing lights, signage, automatic gates, warning bells, Wayside Horns, channelizing medians/curbs, full road closure gates ("quad-gates", or equivalent).

Additional sound descriptors and terms may be found in publications of the American National Standards Institute (e.g., ANSI S1.1-1994 and ANSI S12.9-1988, Reaffirmed September 1998). An extensive Glossary of Acoustic terms prepared by the Institute of Noise Control Engineering of the United States may be found at http://inceusa.org/old_site/pubs_papers/nni_glossary.asp

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19.0 Disclaimer

This Technical Memorandum is provided for informational purposes only. It does not necessarily represent the official views of the United States of America or agencies or departments thereof, or of the State of California or political subdivisions thereof. The information contained in this document reflects the professional work product of scientists, planners, and engineers who have followed the standard of care as is practiced in their respective fields of expertise. This document does not constitute a standard, specification, or regulation unless adopted by an entity of competent jurisdiction. The authors alone are responsible for the accuracy of the data and findings contained herein.

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21.0 Appendices

21.1 Study Team

Rob Greene, INCE, is PB's Technical Manager and principal investigator for this special study. He is board certified by the Institute of Noise Control Engineering of the United States as a noise and vibration engineer (84004, exp.2012). Mr. Greene has over 40 years experience in several of the specific disciplines used in this study, including environmental acoustics and community reaction to environmental noise; Wayside Horn projects (LA Metro Blue Line and Alaska Railroad Eielson Branch); appearance at trial as an expert witness before the California Public Utilities Commission Administrative Law Judge pertaining to at-grade railroad crossing warning device sound levels; design, implementation, and test of electro-acoustic generation and propagation of high level acoustic warning signals in outdoor environments; hundreds of in-vehicle acoustic measurements; and expert testimony regarding the testing and efficacy of hearing protectors.

Sanford Fidell, Ph.D., is the team's specialist in bio-acoustics and human behavior with four decades of experience and a voluminous list of projects and publications. Dr. Fidell's clients include federal and local agencies and large corporations. His published work includes several reports and technical papers focused on the audibility and effectiveness of audible warning signals. Dr. Fidell has led numerous studies of the human perception of sound and community response to environmental noise.

Gulzar Ahmed, P.E., the team's safety specialist, also with 40+ years of experience, is an ASQ Certified Reliability Engineer (CRE) and Registered Professional Engineer in California, 1985 (M25193) and Florida, 1984 (PE0034775). Mr. Ahmed is experienced in the design, installation, testing, and safety certification of transit engineering projects. He has been responsible for numerous safety compliance issues for transit projects, including safety codes and standards enforcement. He has performed Rail Crossing Hazard Analysis (RCHA) to identify potential hazards which may be present at grade crossing and the associated alignments for several commuter rail and heavy rail transit systems in the western United States including CA, WA, HI, UT and AZ.

W. Gary Sokolich, Ph.D., assisted the team with independent acoustic testing of the earbuds. Dr. Sokolich's doctoral work in Sensory Auditory Research and post-doctoral work on Auditory Physiology developed into nearly four decades of scientific investigations with numerous awarded patents and a recent focus on inter-aural measurements and development and test of insert hearing protectors and similar devices.

Additional specialists assisting on the project were **Amy Volz**, who was the lead for the radar speed measurements and earbud survey; **Scott Noel, AICP** and **Mike Lieu**, who were responsible for ambient noise measurements and secondary earbud survey; **Kevin Keller, AICP** who assisted with digital data processing and impact modeling; **Edward Tadross** who assisted with technical review; and **Teresea Colomac** and **Lauren Loetterle** who provided administrative support.

21.2 Federal Train Horn Rule and Wayside Horn Technical Basis

The following section is summarized from the updated April 20, 2007 CRS Report for Congress regarding the Federal Railroad Administration's Train Horn Rule (Rule). This is an excellent summary of the entire development of the Rule. [8] The entire Rule may be found at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title49/49cfr222_main_02.tpl

In the late 1970s many communities had placed a ban on the sounding of train whistles at highway-rail grade crossings in response to complaints from nearby residents regarding train whistle noise. As a result, the number of accidents and injuries increased at rail grade-crossings with whistle bans. In an effort to reduce the number of accidents and injuries at rail grade-crossings, Congress enacted the Swift Rail Development Act in 1994 which directed the FRA to issue a regulation on the sounding of train horns at grade-crossings. On June 24, 2005 the FRA Rule on the Use of Locomotive Horns and Highway-Rail Grade Crossings was established (49 CFR 222. The rule also amends 49 CFR 229). It took eleven years for FRA to publish a final rule due in part to the contentious nature of the regulation. The Rule took precedence over approximately 2,000 existing state and local bans on the sounding of locomotive horns at public highway-rail grade crossings. In some instances it required communities to spend substantial funds on safety measures in order to maintain their whistle bans or to fall under one of the Rule's exemptions. In writing the Rule, FRA attempted to balance safety (the reduction in risk of accidents and injuries from having trains sound horns at each grade crossing) with the quality of life of the millions of citizens living near train tracks who are disturbed by train horns.

This Rule requires that locomotive horns be sounded at all public highway-rail crossing, with the following exemptions: if there is no significant risk to persons (the risk must be below specified thresholds), if supplementary safety measures fully compensate for the absence of the warning provided by the horn, or if sounding the horn as a warning is not practical. This is intended to encourage public safety at the grade crossing locations, while giving communities an option to protect individuals and businesses located near grade crossings from the sound of train horns. Provided certain safety measures and requirements are satisfied, a community may qualify one or more sequential crossings as exempt and may create a "quiet zone" in which the sounding of locomotive horns is not permitted (except in an emergency).

Prior to the Rule, locomotive horns did not have a maximum noise level and many operated at 111 dBA [or higher, at 100 feet in front of the horn]. Also, prior to the Rule, the standard industry practice was for locomotive engineers to begin sounding the train horn one-quarter mile from the intersection. If a train were going less than 45 miles per hour, as trains often do in heavily-populated areas with numerous grade crossings, the train horn would have been sounded for longer than 20 seconds.

The National Transportation Safety Board (NTSB) tested the sound level inside 13 passenger and emergency vehicles of various types located 100 feet from the locomotive horn. The sound level of

[8] http://ncseonline.org/NLE/CRSreports/07May/RL33286.pdf

the horn outside the vehicles was 96 dBA. Inside the vehicles, with windows closed and engines idling, the NTSB found that the sound level of the train horn was less than 10 dBA above the ambient sound level, and not loud enough to alert the drivers to the presence of the horn. When the fans in the vehicles were turned on, the horn was not audible at all in seven of the vehicles, and the sound of the horn was less than 10 dBA above the ambient sound level in all the remaining vehicles.

In the Rule, FRA set the permissible sound level of train horns, at a distance 100 feet ahead of the horn, at a range of 96 to 110 dBA. FRA claimed that an analysis indicated a 95% likelihood that a train horn adjusted to emit 108 dBA at a distance of 100 feet would be heard by motorists approaching a grade crossing (70 F.R. 21880). The Rule will reduce existing train horn noise levels over time by limiting the maximum sound level for train horns to 110 dBA and limiting the duration of sounding horns at the grade crossings to no more than typically 15-20 seconds.

U.S. Department
Of Transportation
Federal Railroad
Administration

Research Results

RR07-06
February 2007

Railroad Horn Systems

SUMMARY

From 1992 to 2002, the Federal Railroad Administration (FRA) Office of Research and Development (ORD) sponsored a multi-dimensional study of horns as warning devices, conducted by the Volpe Center. The purpose of the study was to assess ways to provide adequate warning. The results were used as the basis for a final rule, established in June of 2005, for sounding audible warnings before a train arrives at a grade crossing.

The study consisted of two components: (1) technology assessment and (2) human perception and recognition. The technology assessment addressed physical characteristics. It consisted of (1) measurement of the acoustic properties of three typical railroad horns and prototype automated horn systems (AHS), (2) measurement of the insertion loss and interior noise levels of several 1990 and 1991 motor vehicles, (3) laboratory studies to assess the effectiveness and detectability of horn signals, and (4) measurement of horn sound levels at multiple measurement locations. The human perception and recognition research addressed the effectiveness of those systems as warning devices and their impact on the daily activities of residents. It consisted of (1) use of video cameras at selected grade crossings to observe driver behavior after sounding of three-chime train horns and AHS mounted on the wayside and (2) surveys of residents along railroad corridors about the effects of those two horn systems on their daily activities.

The wayside AHS was shown as a potential solution for providing an effective, detectable warning to motorists with acceptable community noise levels. AHS installed on the wayside can be directed down the roadway toward oncoming traffic to greatly reduce the amount of community exposure.

The technology assessment showed the sound level of a wayside AHS that used a digital recording of a five-chime train horn was equal to or exceeded that of a train-mounted three-chime horn for drivers approaching a crossing. The laboratory studies showed a five-chime train horn to be far more effective in warning motorists than a three-chime train horn or a single-tone AHS. The technology assessment also showed that wayside AHS lowered community noise levels. The human perception and recognition tests showed that wayside AHS significantly reduced violations at grade crossings and reduced the disruption of daily activities experienced by nearby residents. The digital five-chime AHS was developed as a result of the tests performed.

Figure 1. Five-Chime Train Horn

Figure 2. Three-Chime Train

Figure 3. Automated Wayside Horn

BACKGROUND

In 1980, the FRA regulation requiring that all trains have a horn mounted on the lead vehicle was expanded to require that the horn must produce a signal with a minimum sound level of 96 dB at 100 feet forward of the train in its direction of travel.

In 1991, the FRA Office of Safety requested FRA ORD to study the ability of train-mounted horn signals to penetrate motor vehicle interiors and other background noise and the impact of the signals on motorist behavior and community noise levels. At that time, the Union Pacific (UP) Railroad was evaluating a prototype single-tone AHS as an alternative or supplement to train horns and offered it for testing.

Results of tests of the prototype AHS showed that it was not a viable alternative to train-mounted horns. Efforts were then initiated to develop a more effective, potentially viable AHS. Several years later, a prototype AHS was developed that used a digital recording of a five-chime train horn. The new prototype was offered to FRA for testing in Illinois.

RESEARCH OBJECTIVES

Technology Assessment:

- Characterize the acoustic properties of traditional locomotive horns and potentially viable alternative systems, and create a database of the acoustic information.
- Determine the insertion loss characteristics of late-model motor vehicles.
- Determine the probability of detection of railroad horn systems by motorists as a danger warning.
- Calculate the effectiveness of railroad horn systems in reducing accidents at grade crossings.

Human Perception and Recognition:

- Compare the effect of a train horn and a wayside AHS on driver behavior at grade crossings.
- Determine the impact of a train horn and wayside AHS on the activities of residents near grade crossings.

RESEARCH METHODS

Technology Assessment:

Field Measurements of Acoustic Characteristics:

In 1992, sound level and frequency spectrum measurements were recorded for a five-chime train horn, a radio frequency (RF) three-chime train horn, a conventional three-chime train horn, and a prototype single-tone AHS. The test sites were all isolated from competing sound sources. Data were collected within a 30.5-meter radius circle around each horn system to provide information on its spectral output, the directivity of the source, the drop-off rate, the maximum sound pressure level produced, and the sound exposure level.

In 1992, baseline interior noise levels and sound insulation (insertion loss) characteristics were also established for several model year 1990 and 1991 motor vehicles. The interior noise levels were measured while the motor vehicles traveled at a constant speed of 30 mph with windows closed, ventilation systems off, and radios off. The sound levels were measured at a reference position inside the vehicle and at the same position with the vehicle removed. The recorded levels were used to populate an insertion loss model.

Laboratory Tests:

The horn acoustic measurements and the vehicle insertion loss calculations were used to predict the probability of a motorist detecting the signals of the three train horns and the prototype AHS. The information was also used to predict the effectiveness of the horn systems in reducing grade crossing accidents. Detectability and effectiveness were predicted for the three traditional horns mounted on the top at the front of in-service locomotives approaching both passive and active crossings at speeds from 20 to 110 mph (in 10-mph increments). The predictions were also performed for motorists approaching active crossings with an AHS mounted on a wayside utility pole at speeds from 20 to 110 mph (in 10-mph increments). The horn acoustics data were also used to predict the noise impact of the four horns on the community.

Data Collection in Gering, NE

In 1995, the single-tone AHS was mounted on wayside utility poles at three crossings in Gering, NE. Sound levels were measured from the AHS and from traditional three-chime horns mounted on UP revenue-service locomotives. Two sets of measurements were taken for both horn systems perpendicular to the track at 14 wayside locations surrounding the three crossings—one set in November 1995 and the other in February 1996. This information was coupled with the number of trains traversing the crossing to compute the community noise exposure, in terms of an average day-night sound level, in the vicinity of the crossings.

Data Collection in Mundelein, IL:

In 2001, an enhanced wayside AHS using a digital recording of a five-chime train horn was installed at three crossings in Mundelein, IL. Sound level and frequency spectrum measurements were taken to characterize the acoustics of the AHS.

Sound levels were then measured on the roadway approaches to the three crossings for both the AHS and a conventional three-chime horn mounted on UP revenue-service locomotives. Sound levels were also measured at residences in Mundelein for both horn systems over a 2-week period, in the fall of 2001 and again in the spring of 2002. Readings were taken in 1-second intervals for 24 hours at nine locations. The residences were located between 500 and 1,500 feet from the track where use of a train horn was expected.

Human Perception and Recognition:

Data Collection in Gering, NE

Video cameras were installed at two of the UP crossings in Gering where the single-tone AHS was installed. Motorist behavior was recorded following activation of the three-chime train horn for 12 weeks from November 1994 through January 1995. Motorist behavior was also recorded following activation of the single-tone wayside AHS for a total of 12 weeks between May and October 1995.

In July 1994, a telephone survey was conducted of residents in the vicinity of the crossings concerning the impact of the UP train horns on their lives for the entire time they had lived at that location. During the following summer, another telephone survey was conducted of the same residents about the sound from the AHS.

Data Collection in Mundelein, IL

Video cameras were installed at the three UP crossings in Mundelein where the digital five-chime AHS was installed. Motorist behavior was recorded following activation of both the enhanced wayside AHS and the three-chime in-service train horns—between September and December 2001 and again between April and July 2002.

Figure 4. Three-Chime Train Horn Tested in Mundelein

Figure 5. AHS Installation in Mundelein

Surveys were distributed to examine opinions of both the wayside AHS and its perceived safety effectiveness to more than 1,250 Mundelein residents.

The results of these studies were used by the FRA Office of Safety in its rulemaking activities resulting in 49 CFR Parts 222 and 229, *Use of Locomotive Horns at Highway-Rail Grade Crossings*.

Technology Assessment:

The acoustic properties were characterized for three typical railroad horn systems and two prototype AHS. Notable findings included the following:

- The five-chime train horn had a broader-band spectral output that was more likely than that of the three-chime train horn to penetrate background noise.
- The single-tone AHS had a bandwidth that made penetration of background noise difficult. That AHS also produced a signal that was quite different from that of train horns and is possibly not recognizable as a train horn.
- The wayside digital five-chime AHS had a sound level that was equal to or exceeded that of the three-chime train horn for a driver approaching a crossing. It also had a broader-band spectral output that was more likely than that of the three-chime train horn to penetrate the background noise.
- Detectability and effectiveness probabilities for the five-chime train horn were 99 and 80 percent, respectively; the three-chime train horns were 96 and 75 percent, respectively.
- The single-tone AHS was predicted to be undetectable by a motorist at motor vehicle speeds of 30 mph and over.
- The area near the tracks affected by noise decreased by up to 85 percent in Mundelein when the digital five-chime AHS was sounded instead of the train horn.
- Mounting the train horn as far front and as high as possible on the locomotive produced the most sound output forward of the locomotive.

FINDINGS AND CONCLUSIONS

- Motor vehicle insertion loss ranged from 25 to 35 decibels.

Human Perception and Recognition:

Notable findings included the following:

- The video data from the evaluation of the digital five-chime AHS showed a 70 percent decrease in violations of grade crossing laws.
- A substantial majority of the Mundelein residents who responded to the survey found the wayside horn much less annoying than the train horns.
- Motorist behavior in Gering in response to the single-tone AHS was slightly better than the behavior response to the train horn.

REFERENCES

[1] *Study of the Acoustic Characteristics of Railroad Horn Systems*. Keller, A.; Rickley, E. Final Report. July 1993. DOT/FRA/ ORD-93/25, DOT-VNTSC-FRA-93-1.

[2] *Field Evaluation of a Wayside Horn at a Highway-Railroad Grade Crossing*. Multer, J., Rapoza, A. Final Report. June 1998. DOT/ FRA/ORD-98/04, DOT-VNTSC-FRA-97-1.

[3] *Railroad Horn Systems Research*. Raposa, A.; Raslear, T.; Rickley, E. Final Report. January 1999. DOT/FRA/ORD-99/10, DOT-VNTSC-FRA-98-2

[4] *Evaluation of the Automated Wayside Horn System in Mundelein, Illinois*. Raub, R.A.; Lucke, R.; Thunder, T. Final Report.

CONTACT

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21.3 Ambient Acoustics Survey

The PB field team conducted sound level and spectrum measurements and observations on Saturday, October 2, 2010. The weather was warm; little to no cloud cover with sunny skies and negligible wind (calm to slight breeze), plus high surf throughout the day. The high for the day was 81° F. Thus, the conditions were good for beach activity, SCBT activity, and for acoustic measurements. A summary of the measured sound level data is presented in Table 20-1 below. Sound levels were measured simultaneously on both sides (within approximately 100 feet) of each SCBT/railroad crossing, with sound spectra also measured at one side of each crossing. Except for the sound level during the immediate railroad train pass-by, the ambient sound levels, including the high surf were mostly in the low to mid 50's, with two locations up to mid 60's dBA Leq. Note that the measured ambient sound levels along the SCBT are generally lower than the in-car noise levels from road noise, air conditioning and radio reported by Rapoza[9] and by Fidell[10].

The observers also noted that the sandy beach areas adjacent to the SCBT were being used by a variety of people involved in various activities, including children playing and beach volleyball games, however, the sound of these activities were barely audible along the SCBT and at the crossing locations. The dominant ambient sound was from the surf along the shoreline. Also noteworthy is that surf noise is very cyclical with maximum levels of one to three seconds duration connected by periods of relative quiet (40's and 50's dBA L_{90}), compared to the mostly continuous interior noise in moving vehicles. The actual time duration of potential interference or acoustic masking by surf noise of a longer duration AWS is minimal. The collected ambient environmental noise data well describes a representative sample of the SCBT acoustic environment during active surf conditions. The area would be quieter during calm surf conditions. Samples of the collected surf noise spectral data were used during the detectability/audibility analyses discussed in Section 12.0.

[9] Rapoza, A. and Raslear, T. 2001. Analysis of Railroad Horn Detectability.
[10] Fidell, S. 2007. Acoustic Insertion Loss Measurements of Current Production Passenger Cars.

Table 21—1. Short-Term Ambient Noise Measurement Data, Saturday, October 2, 2010

Measurement ID	Measurement Location	Measurement Period		Noise Sources	Measurement Results, dBA					
		Start Time (hh:mm)	Duration (mm:ss)		L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}
Corto Lane North (1)	Approximately 100 feet north of the trail crossing on the Beach Trail	8:40AM	10:27	Train (train came through ten minutes into the ambient measurement. Train data saved; ambient measurement aborted and restarted)	80.0	103.8	51.3	56.5	59.1	66.0
Corto Lane South (1)	Approximately 75 feet south of the trail crossing on the Beach Trail	8:40AM	10:27		72.9	97.6	54.0	59.9	62.2	65.9
Corto Lane North (2)	Approximately 100 feet north of the crossing on the Beach Trail	8:54AM	15:00	Distant aircraft, surf	59.1	70.5	57.8	56.3	58.3	61.1
Corta Lane South (2)	Approximately 75 feet south of the trail crossing on the Beach Trail	8:55AM	15:00	Ocean waves (measurement approximately 50-75 feet from shoreline)	64.1	83.3	53.4	60.3	61.9	64.8
Califia North	Approximately 75 feet north of the crossing on the Beach Trail	10:08AM	15:00	Heavy surf, car alarm	57.0	67.2	45.7	50.6	55.4	59.9
Califia South	Approximately 150 feet south of the crossing on the Beach Trail	10:09AM	15:00	Some parking lot traffic, 3 automobiles, people talking approximately 50 feet from meter Note: position was below grade of railroad tracks and shielded some surf noise	52.1	62.2	43.8	47.9	51.4	54.6
Lost Winds North	Approximately 100 feet north of the crossing on the Beach Trail	10:39AM	15:00	Aircraft (helicopter), distant people playing vollyball	54.1	70.4	46.1	48.5	51.8	55.9
Lost Winds South	Approximately 100 feet south of the crossing on the Beach Trail	10:39AM	15:00	Dominant surf	57.5	74.5	47.1	50.1	51.8	60.2
T-Street North	Approximately 150 feet north of the crossing on the Beach Trail	11:09AM	15:00	Ocean waves (measurement approximately 100-150 feet from shoreline)	64.8	74.6	60.9	62.7	64.2	66.3
T-Street South	Approximately 50 feet south of the crossing on the Beach Trail	11:09AM	15:00	Surf noise (this location farther from waves and some obstruction by terrain and tracks on slight berm)	58.5	64.6	54.2	56.2	57.9	60.4
El Portal North	Near entrance to El Portal/204's beach, approximately 200 feet north of the crossing on the Beach Trail	11:53AM	15:00	Ocean waves	55.9	71.5	45.5	50.8	54.6	58.1
El Portal South	Near entrance to El Portal/204's beach, approximately 20 feet south of the crossing on the Beach Trail	11:52AM	15:00		53.6	64.5	43.8	49.4	52.4	55.8
Dije Court North	Approximately 75 feet north of the crossing on the Beach Trail	12:14PM	15:00	People talking; surf; distant aircraft, boats, jet ski's	57.1	79.5	46.3	51.0	54.5	58.5
Dije Court South	Approximately 100 feet south of the crossing on the Beach Trail	12:15PM	15:00	Dominant surf	55.5	65.8	47.4	51.9	54.9	57.8

FIELD NOTES

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Field Study Job # 11977 5.7.9.1

SITE IDENTIFICATION: ~~[illegible]~~ 4A Corto Ln
OBSERVER(s): Scott Noel
START DATE & TIME: 10/2/10 8:42
END DATE & TIME: 10/2/10 9:10
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

ID

TEMP: ° F HUMIDITY: % R.H. WIND: CALM LIGHT MODERATE VARIABLE
WINDSPEED: MPH DIR: N NE E SE S SW W NW STEADY GUSTY MPH$_{max}$
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other:

Weather

INSTRUMENT: LD 820 TYPE: 1 (2) SERIAL #: 1232
CALIBRATOR: LD CAL 200 SERIAL #: 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST dBA SPL WINDSCREEN X
SETTINGS: (A-WEIGHTED) (SLOW) FAST FRONTAL (RANDOM) ANSI OTHER:

Rec #	Start Time / End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1 (Train)	8:42 / 8:53	72.9	97.6	54.0	59.9	62.2	65.9	Ls 67.9
2	8:55 / 9:10	64.1	83.3	53.4	60.3	61.9	64.8	Ls 66.1
/	/							
/	/							

COMMENTS: Measurement 1 went for 10 min 27 sec.
MEASUREMENT #2 15-min, NO TRAINS
Traffic Count 1 for measurement #1. Traffic Count #2 for measurement #2

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT (RAIL) INDUSTRIAL AMBIENT (OTHER) SURF
ROADWAY TYPE:

COUNT DURATION: ~~15~~ 10-MINUTE SPEED (mph) #2 COUNT: 15-min - NO TRAINS SPEED (mph)

	(NB) / EB / (SB) / WB	NB EB / SB WB	(NB) / EB / (SB) / WB	NB EB / SB WB
PEDS (Total):	72 /	/	Total 103 /	/
BICYCLE:	3 /	/	/	/
OTHER (Dogs):	6 /	/	9 /	/
EAR BUDS:	7 /	/	16 /	/
~~OTHER~~ (Train / Stroller):	/ 1 (Train) ; 1 (Stroller)	/	Stroller 2 /	/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant AIRCRAFT overhead / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER: SURF 50'-75' away. Dominated by Surf

Source Info and Traffic Counts

TERRAIN: HARD SOFT (MIXED) FLAT OTHER:
PHOTOS: 2
OTHER COMMENTS / SKETCH: (See attached)

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

PB

Project Name: OCTA AWS Field Study Job # 11977 5.7.9.1

SITE IDENTIFICATION: 7A Lost Winds OBSERVER(s): Scott Noel
START DATE & TIME: 10/2/10 10:37 END DATE & TIME: 10/2/10 10:52
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

ID

TEMP: ____ °F HUMIDITY: ____ % R.H. WIND: CALM LIGHT MODERATE VARIABLE
WINDSPEED: ____ MPH DIR: N NE E SE S SW W NW STEADY GUSTY ____ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: ____

Weather

INSTRUMENT: LD 820 TYPE: (1) 2 SERIAL #: 1232
CALIBRATOR: LD CAL 200 SERIAL #: 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST ____ dBA SPL WINDSCREEN X
SETTINGS: A-WEIGHTED (SLOW) FAST FRONTAL (RANDOM) ANSI OTHER: ____

Rec # / Start Time / End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1 / 10:37 / 10:52	57.5	74.5	47.1	50.1	51.8	60.2	62.6
/ /							
/ /							
/ /							

COMMENTS: Two pedestrians ~~stop~~ stopped to ask about measurement. We spoke for approx. 1 min @ 10' from mic. 2 other people stopped to talk for approx 30 sec @ 6'-10'

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT OTHER Surf
ROADWAY TYPE:
COUNT DURATION: 15 -MINUTE

	(NB) / EB / (SB) / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB / SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	Total 46 /	/	/	/
BICYCLE:	1 /	/	/	/
~~OTHER~~: Dog	4 /	/	/	/
EAR BUDS:	9 /	/	/	/
OTHER:	/	/	/	/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant AIRCRAFT overhead / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER: Surf dominant. ~~Ske~~ [illegible]

Source Info and Traffic Counts

TERRAIN: HARD (SOFT) (MIXED) FLAT OTHER:
PHOTOS: 1 photo
OTHER COMMENTS / SKETCH: See attached

Description / Sketch

measform.xls

FIELD MEASUREMENT DATA SHEET

PB 100 YEARS

Project Name: OCTA AWS Field Study **Job #** 11977 5.7.9.1

SITE IDENTIFICATION: 8A Calafia **OBSERVER(s):** Scott Noel
START DATE & TIME: 10/2/10 10:09 **END DATE & TIME:** 10/2/10 10:27
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

ID

TEMP: ____ °F **HUMIDITY:** ____ % R.H. **WIND:** CALM LIGHT MODERATE VARIABLE
WINDSPEED: ____ MPH **DIR:** N NE E SE S SW W NW STEADY GUSTY ____ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: ____

Weather

INSTRUMENT: LD 820 **TYPE:** (1) 2 **SERIAL #:** 1232
CALIBRATOR: LD CAL 200 **SERIAL #:** 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST ____ dBA SPL **WINDSCREEN** X
SETTINGS: (A-WEIGHTED) (SLOW) FAST FRONTAL (RANDOM) ANSI OTHER: ____

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	10:09	10:27	52.1	62.7	43.8	47.9	51.4	54.6	L5 55.6

COMMENTS: Surf dominant. Pedestrians mostly crossing to beach and not following trail further South of crossing. Some access from parking lot further south of measurement site. Approx 30-50'.

Acoustic Measurements

PRIMARY NOISE(S): (TRAFFIC) AIRCRAFT RAIL INDUSTRIAL (AMBIENT) (OTHER) SURF
ROADWAY TYPE: Trail (SAND)
COUNT DURATION: 15 **-MINUTE** **SPEED (mph)** **#2 COUNT:** **SPEED (mph)**

	Total NB / EB	SB / WB	NB EB / SB WB	#2 NB / EB	SB / WB	NB EB / SB WB
PEDS:	16					
BICYCLE:	—					
OTHER: Dogs	1					
EAR BUDS:	3					
OTHER: 3 (Autos Parking Lot)						

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant **AIRCRAFT** overhead / **RUSTLING LEAVES** / distant **BARKING DOGS** / (**BIRDS**)
distant **CHILDREN PLAYING** / distant **TRAFFIC** / distant **LANDSCAPING** / distant **TRAINS**
OTHER: Some Parking lot traffic, 3 autos, People talking @ 50'

Source Info and Traffic Counts

TERRAIN: HARD (SOFT) (MIXED) FLAT OTHER: ____
PHOTOS: 3 pics
OTHER COMMENTS / SKETCH: (See attached)

Note: Below grade of Rail Road tracks. Surf noise shielded

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Field Study **Job #** 11977 5.7.9.1

SITE IDENTIFICATION: 6A T-St **OBSERVER(s):** Scott Noel
START DATE & TIME: 10/2/10 11:05 **END DATE & TIME:** 10/2/10 11:20
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

TEMP: ___ °F **HUMIDITY:** ___ % R.H. **WIND:** CALM LIGHT MODERATE VARIABLE
WINDSPEED: ___ MPH **DIR:** N NE E SE S SW W NW STEADY GUSTY ___ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: ___

INSTRUMENT: LD 820 **TYPE:** (1) 2 **SERIAL #:** 1232
CALIBRATOR: LD CAL 200 **SERIAL #:** 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST ___ dBA SPL **WINDSCREEN** X
SETTINGS: A-(WEIGHTED) (SLOW) FAST FRONTAL (RANDOM) ANSI OTHER: ___

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	11:05	11:20	58.5	64.6	54.2	56.2	57.9	60.4	L5 61.2

COMMENTS:

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT (OTHER) Surf
ROADWAY TYPE:

COUNT DURATION: 15 -MINUTE

	NB / EB	SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB	SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	55		/			/
BICYCLE:	4		/			/
~~OTHER~~ Dogs:	5		/			/
EAR BUDS:	10		/			/
~~OTHER~~ Stroller:	1		/			/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant **AIRCRAFT** overhead / **RUSTLING LEAVES** / distant **BARKING DOGS** / **BIRDS** distant **CHILDREN PLAYING** / distant **TRAFFIC** / distant **LANDSCAPING** / distant **TRAINS**
OTHER: Surf Dominant

TERRAIN: (HARD) (SOFT) (MIXED) FLAT OTHER:
PHOTOS: 1
OTHER COMMENTS / SKETCH: See attached

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

PB

Project Name: OCTA AWS Field Study Job # 11977 5.7.9.1

SITE IDENTIFICATION: 3A El Portal/204
OBSERVER(s): Scott Noel
START DATE & TIME: 10/2/10 11:52
END DATE & TIME: 10/2/10 12:07
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

ID

TEMP: ____ °F HUMIDITY: ____ % R.H. WIND: CALM LIGHT MODERATE VARIABLE
WINDSPEED: ______ MPH DIR: N NE E SE S SW W NW STEADY GUSTY ____ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: ______

Weather

INSTRUMENT: LD 820 TYPE: (1) 2 SERIAL #: 1232
CALIBRATOR: LD CAL 200 SERIAL #: 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST ____ dBA SPL WINDSCREEN ✓
SETTINGS: A-WEIGHTED (SLOW) FAST FRONTAL (RANDOM) ANSI OTHER: ______

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	11:52	12:07	53.6	64.5	43.8	49.4	52.4	55.8	L_5 57.1

COMMENTS:

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT (OTHER) Surf
ROADWAY TYPE:
COUNT DURATION: 15 -MINUTE

	NB / EB	SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB	SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	46		/			/
BICYCLE:	3		/			/
~~OTHER~~ Dogs:	6		/			/
EAR BUDS:	7		/			/
OTHER:	–		/			/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant AIRCRAFT overhead / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER: Surf Dominant

Source Info and Traffic Counts

TERRAIN: HARD SOFT MIXED FLAT OTHER:
PHOTOS: 2 pics
OTHER COMMENTS / SKETCH: See attached

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Field Study **Job #** 11977 5.7.9.1

SITE IDENTIFICATION: 2A Dije Ct **OBSERVER(s):** Scott Noel
START DATE & TIME: 10/2/10 12:14 **END DATE & TIME:** 10/2/10 12:29
ADDRESS: Along San Clemente Beach Trail

GPS coordinates:

ID

TEMP: ______ °F **HUMIDITY:** ______ % R.H. **WIND:** CALM LIGHT MODERATE VARIABLE
WINDSPEED: __________ MPH **DIR:** N NE E SE S SW W NW STEADY GUSTY ____ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: __________

Weather

INSTRUMENT: LD 820 **TYPE:** (1) 2 **SERIAL #:** 1232
CALIBRATOR: LD CAL 200 **SERIAL #:** 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST ______ dBA SPL **WINDSCREEN** X
SETTINGS: A-(WEIGHTED) (SLOW) FAST FRONTAL (RANDOM) ANSI OTHER: __________

Rec #	Start Time / End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	12:14 / 12:29	55.5	65.8	47.4	51.9	54.9	57.8	L_5 58
	/							
	/							
	/							

COMMENTS:

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT (OTHER) Surf
ROADWAY TYPE:

COUNT DURATION: 15 **-MINUTE**

	NB / EB	SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB	SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	23		/			/
BICYCLE:	6		/			/
Dog OTHER:	3		/			/
EAR BUDS:	10		/			/
Strollers OTHER:	1		/			/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant **AIRCRAFT** overhead / **RUSTLING LEAVES** / distant **BARKING DOGS** / **BIRDS**
distant **CHILDREN PLAYING** / distant **TRAFFIC** / distant **LANDSCAPING** / distant **TRAINS**
OTHER: Surf Dominant

Source Info and Traffic Counts

TERRAIN: HARD SOFT (MIXED) FLAT OTHER:
PHOTOS: 1 pic
OTHER COMMENTS / SKETCH: See attached

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Field Study Job # 11977 5.7.9.1

ID

SITE IDENTIFICATION: 4B Corto Lane OBSERVER(s): Mike Lieu
START DATE & TIME: 10/2/10 8:40 END DATE & TIME: 10/2/10
ADDRESS: Along San Clemente Beach Trail

GPS coordinates:

Weather

TEMP: 70 °F HUMIDITY: 50 % R.H. WIND: (CALM) LIGHT MODERATE VARIABLE
WINDSPEED: 0-5 MPH DIR: N NE E SE S SW W NW STEADY GUSTY ____ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY (OVRCST) FOG DRIZZLE RAIN Other:

Acoustic Measurements

INSTRUMENT: Soundbook™ w/LD 377B02 mic TYPE: 1 2 SERIAL #: 06451 & 116608
CALIBRATOR: LD CAL 200 SERIAL #: 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST 94.0 dBA SPL WINDSCREEN 3
SETTINGS: A-WEIGHTED (SLOW) FAST FRONTAL RANDOM ANSI OTHER:

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	8:49	8:51	80.0	103.8	51.3	56.5	59.1	66.0	— Train passby
2	8:54	9:10	59.1	70.5	52.8	56.3	58.2	61.1	

COMMENTS:

Source Info and Traffic Counts

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL (AMBIENT) OTHER Waves
ROADWAY TYPE: Dirt Trail

COUNT DURATION: 15 -MINUTE

	#1 NB / EB	SB / WB	SPEED (mph) NB EB	SB WB	#2 COUNT: NB / EB	SB / WB	SPEED (mph) NB EB	SB WB
PEDS:	66							
BICYCLE:	3							
OTHER:								
EAR BUDS:	12							
OTHER:								

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: (distant AIRCRAFT overhead) / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER:

Description / Sketch

TERRAIN: HARD SOFT (MIXED) FLAT OTHER: Dirt Trail
PHOTOS:
OTHER COMMENTS / SKETCH: See attached

measform.xls

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Field Study Job # 11977 5.7.9.1

SITE IDENTIFICATION: 8B - Califia
OBSERVER(s): Mike Lieu
START DATE & TIME: 10/2/10
END DATE & TIME: 10/2/10
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

TEMP: 70 °F HUMIDITY: 50 % R.H. WIND: (CALM) LIGHT MODERATE VARIABLE
WINDSPEED: 0-5 MPH DIR: N NE E SE S SW W (NW) (STEADY) GUSTY ____ MPH_{max}
SKY: (CLEAR SUNNY) DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other:

INSTRUMENT: Soundbook™ w/LD 377B02 mic TYPE: 1 2 SERIAL #: 06451 & 116608
CALIBRATOR: LD CAL 200 SERIAL #: 3415
CALIBRATION CHECK: PRE-TEST 94 dBA SPL POST-TEST 94 dBA SPL WINDSCREEN ____
SETTINGS: A-WEIGHTED (SLOW) FAST FRONTAL RANDOM ANSI OTHER:

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	10:08	10:24	57.0	67.2	45.7	50.6	55.4	59.9	

COMMENTS:

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL (AMBIENT) OTHER – Ocean Waves
ROADWAY TYPE: Dirt Trail

COUNT DURATION: 15-MINUTE	NB / EB / SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB / SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	30 /	/	/	/
BICYCLE:	2 /	/	/	/
OTHER:	/	/	/	/
EAR BUDS:	11 /	/	/	/
OTHER:	/	/	/	/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant AIRCRAFT overhead / RUSTLING LEAVES / distant BARKING DOGS / BIRDS distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER: - Heavy Surf / Car Alarm

TERRAIN: (HARD SOFT) MIXED FLAT OTHER:
PHOTOS:
OTHER COMMENTS / SKETCH: See attached

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

PB

Project Name: OCTA AWS Field Study   Job # 11977 5.7.9.1

SITE IDENTIFICATION: Site 7B Lost minds   **OBSERVER(s):** Mike Lieu
START DATE & TIME: 10/2/10   **END DATE & TIME:** 10/2/10
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

ID

TEMP: 75 °F **HUMIDITY:** 35 % R.H. **WIND:** (CALM) LIGHT MODERATE VARIABLE
WINDSPEED: 6.5 MPH **DIR:** N NE E SE S SW W (NW) STEADY GUSTY ____ MPH_{max}
SKY: (CLEAR) SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other:

Weather

INSTRUMENT: Soundbook™ w/LD 377B02 mic **TYPE:** 1 2 **SERIAL #:** 06451 & 116608
CALIBRATOR: LD CAL 200 **SERIAL #:** 3415
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST 94.0 dBA SPL **WINDSCREEN** Y
SETTINGS: (A-WEIGHTED SLOW) FAST FRONTAL RANDOM ANSI OTHER:

Rec #	Start Time / ~~End Time~~	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
70	10:39 / 10:54	54.1	70.4	46.1	48.5	51.8	55.9	
	/							
	/							
	/							

COMMENTS:

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL (AMBIENT) OTHER ~~voices~~ Ocean Waves
ROADWAY TYPE:
COUNT DURATION: 15 -MINUTE

	NB / EB	SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB	SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	53		/			/
BICYCLE:	3		/			/
OTHER:			/			/
EAR BUDS:	10		/			/
OTHER:			/			/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant (AIRCRAFT) overhead (Helicopter) / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
(distant CHILDREN PLAYING) / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER: → Distant People playing Volleyball

Source Info and Traffic Counts

TERRAIN: HARD SOFT MIXED FLAT OTHER:
PHOTOS:
OTHER COMMENTS / SKETCH: See attached

Description / Sketch

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Field Study Job # 11977 5.7.9.1

SITE IDENTIFICATION: Site 6B T-Street **OBSERVER(s):** Mike Lieu
START DATE & TIME: 10/2/10 **END DATE & TIME:** 10/2/10
ADDRESS: Along San Clemente Beach Trail

GPS coordinates:

ID

TEMP: 75 °F **HUMIDITY:** 25 % R.H. **WIND:** (CALM) LIGHT MODERATE VARIABLE
WINDSPEED: 0-5 MPH **DIR:** N NE E SE S SW W NW **STEADY GUSTY** ____ MPH_{max}
SKY: (CLEAR SUNNY) DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: ____

Weather

INSTRUMENT: Soundbook™ w/LD 377B02 mic TYPE: 1 2 SERIAL #: 06451 & 116608
CALIBRATOR: LD CAL 200 SERIAL #: 3415
CALIBRATION CHECK: PRE-TEST 94 dBA SPL POST-TEST 94 dBA SPL **WINDSCREEN** 9
SETTINGS: A-WEIGHTED (SLOW) FAST FRONTAL RANDOM ANSI OTHER: ____

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	11:09	11:24	64.8	74.6	60.9	62.7	64.2	66.3	

COMMENTS:

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT OTHER Ocean
ROADWAY TYPE: Trail
COUNT DURATION: 15 **-MINUTE**

	NB / EB	SB / WB	SPEED (mph) NB EB	SPEED (mph) SB WB	#2 COUNT: NB / EB	#2 COUNT: SB / WB	SPEED (mph) NB EB	SPEED (mph) SB WB
PEDS:								
BICYCLE:								
OTHER:								
EAR BUDS:								
OTHER:								

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant **AIRCRAFT** overhead / **RUSTLING LEAVES** / distant **BARKING DOGS** / **BIRDS**
distant **CHILDREN PLAYING** / distant **TRAFFIC** / distant **LANDSCAPING** / distant **TRAINS**
OTHER: ≈ 100-150 from shore

Source Info and Traffic Counts

TERRAIN: HARD SOFT MIXED FLAT OTHER:
PHOTOS:
OTHER COMMENTS / SKETCH: See attached

measform.xls

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Field Study **Job # 11977 5.7.9.1**

SITE IDENTIFICATION: Site 3B El Portal **OBSERVER(s):** Mike Lieu
START DATE & TIME: 10/2/10 **END DATE & TIME:** 10/2/10
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

ID

TEMP: 78 °F **HUMIDITY:** 20 % R.H. **WIND:** CALM LIGHT MODERATE VARIABLE
WINDSPEED: 0-5 MPH **DIR:** N NE E SE S SW W NW **STEADY GUSTY** ____ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other:

Weather

INSTRUMENT: Soundbook™ w/LD 377B02 mic **TYPE: 1 2** **SERIAL #: 06451 & 116608**
CALIBRATOR: LD CAL 200 **SERIAL #: 3415**
CALIBRATION CHECK: PRE-TEST 94 dBA SPL POST-TEST 94 dBA SPL **WINDSCREEN** Y
SETTINGS: A-WEIGHTED SLOW FAST FRONTAL RANDOM ANSI OTHER:

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	11:53	12:09	55.9	76.5	45.5	50.8	54.6	58.1	

COMMENTS:

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT OTHER Ocean Waves
ROADWAY TYPE:

COUNT DURATION: 15 -MINUTE	NB / EB	SB / WB	**SPEED (mph)** NB EB / SB WB	**#2 COUNT:** NB / EB	SB / WB	**SPEED (mph)** NB EB / SB WB
PEDS:	52		/			/
BICYCLE:	3		/			/
OTHER:			/			/
EAR BUDS:	10		/			/
OTHER:			/			/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant **AIRCRAFT** overhead / **RUSTLING LEAVES** / distant **BARKING DOGS** / **BIRDS**
distant **CHILDREN PLAYING** / distant **TRAFFIC** / distant **LANDSCAPING** / distant **TRAINS**
OTHER:

Source Info and Traffic Counts

TERRAIN: HARD SOFT MIXED FLAT OTHER:
PHOTOS:
OTHER COMMENTS / SKETCH: **See attached**

Description / Sketch

measform.xls

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

PB

Project Name: OCTA AWS Field Study Job # 11977 5.7.9.1

SITE IDENTIFICATION: Site 2B (Dije) OBSERVER(s): Mike Lieu
START DATE & TIME: 10/2/10 END DATE & TIME: 10/2/10
ADDRESS: Along San Clemente Beach Trail
GPS coordinates:

ID

TEMP: 80 °F HUMIDITY: 70 % R.H. WIND: (CALM) LIGHT MODERATE VARIABLE
WINDSPEED: 0-5 MPH DIR: N NE E SE S (SW) W NW STEADY GUSTY ____ MPH$_{max}$
SKY: (CLEAR SUNNY) DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: ____

Weather

INSTRUMENT: Soundbook™ w/LD 377B02 mic TYPE: 1 2 SERIAL #: 06451 & 116608
CALIBRATOR: LD CAL 200 SERIAL #: 3415
CALIBRATION CHECK: PRE-TEST 94 dBA SPL POST-TEST 94 dBA SPL WINDSCREEN Y
SETTINGS: A-WEIGHTED SLOW FAST FRONTAL RANDOM ANSI OTHER: ____

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
1	12:15	12:30	57.1	78.5	46.3	51.0	54.5	58.5	

COMMENTS:

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL (AMBIENT) (OTHER) Ocean Waves
ROADWAY TYPE:
COUNT DURATION: 15 -MINUTE

	NB / EB	SB / WB	SPEED (mph) NB EB	SB WB	#2 COUNT: NB / EB	SB / WB	SPEED (mph) NB EB	SB WB
PEDS:	32							
BICYCLE:	1							
OTHER:								
EAR BUDS:	2							
OTHER:								

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: (distant AIRCRAFT) overhead / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER: Boats / Jet Ski's / People Talking

Source Info and Traffic Counts

TERRAIN: HARD SOFT MIXED FLAT OTHER:
PHOTOS:
OTHER COMMENTS / SKETCH: See attached

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

PB

Project Name: Audible Warning Signals Job #

SITE IDENTIFICATION: OBSERVER(s): R. Greene
START DATE & TIME: 7-5-10 1245 END DATE & TIME: 7-5-10 1415
ADDRESS: Beach Trail @ Calafia Trail Head
GPS coordinates:

ID

TEMP: 65 °F HUMIDITY: % R.H. WIND: CALM **[LIGHT]** MODERATE VARIABLE
WINDSPEED: MPH DIR: N NE E SE S SW W NW STEADY GUSTY MPH
SKY: CLEAR SUNNY DARK PARTLY CLOUDY **[OVRCST]** FOG DRIZZLE RAIN Other:

Weather

INSTRUMENT: BK 2231 TYPE: (1) 2 SERIAL #: 1506448
CALIBRATOR: BK 4230 SERIAL #: 1351753
CALIBRATION CHECK: PRE-TEST 94.0 dBA SPL POST-TEST 94.0 dBA SPL WINDSCREEN Z
SETTINGS **[A-WEIGHTED]** **[SLOW]** FAST FRONTAL **[RANDOM]** **[ANSI]** OTHER:

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}
1	1305	1307	68.5	85.0	56.7	58.0	61.0	73.0
2	1308	1318	62.0	70.0	51.6	57.0	61.5	64.5
4	1324	1334	62.5	69.8	52.9	58.5	62.0	65.0
5	1334	1344	62.1	70.6	50.2	57.0	61.5	64.5

Acoustic Measurements

COMMENTS: #1 Surf noise + train horn + bells - Amtrak Surfliner N/B
#2 a few trail users - peds and cyclists + 5'-8' surf
#3 same as #2 but cyclist asked loud question Restart #4 = Same as #2
#6 1354 1355 Same as #1 except S/B 62.0 90.0 91.6 105.5 58.8 59.9

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL **[AMBIENT]** **[OTHER]** SURF
ROADWAY TYPE: walking trail

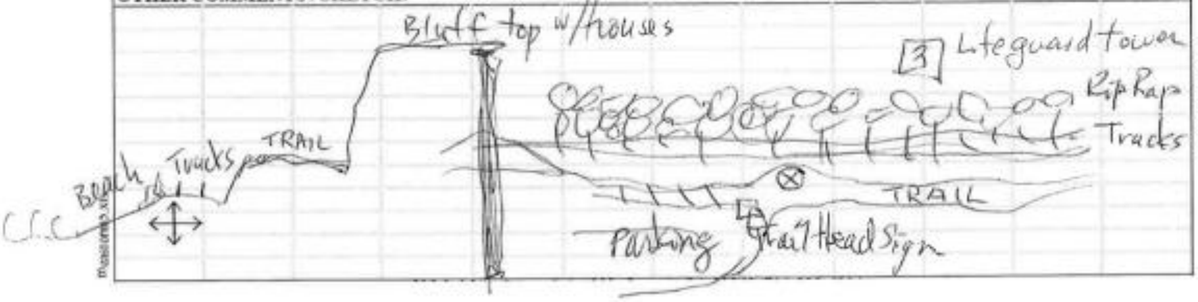
COUNT DURATION: ____ -MINUTE	NB / EB / SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB / SB / WB	SPEED (mph) NB EB / SB WB
AUTOS:	/	/	/	/
MED. TRUCKS:	/	/	/	/
HVY TRUCKS:	/	/	/	/
BUSES:	/	/	/	/
MOTORCYCLES:	/	/	/	/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant AIRCRAFT overhead / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER: Surf dominant except during train pass-by

Source Info and Traffic Counts

TERRAIN: **[HARD]** SOFT MIXED FLAT OTHER:
PHOTOS: yes
OTHER COMMENTS / SKETCH:



Description / Sketch

FIELD MEASUREMENT DATA SHEET

Project Name: OCTA AWS Study **Job #** 11977 5.7.9.1

SITE IDENTIFICATION: #4 **OBSERVER(s):** Rob Greene
START DATE & TIME: 10/2/10 0800 **END DATE & TIME:** 10/2/10 0915
ADDRESS: Along San Clemente Beach Trail
North of Pier - Corto Lane
GPS coordinates:

ID

TEMP: ____ °F **HUMIDITY:** ____ % R.H. **WIND:** CALM LIGHT MODERATE VARIABLE
WINDSPEED: 0 MPH **DIR:** N NE E SE S SW W NW **STEADY GUSTY** ____ MPH_{max}
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other:

Weather

INSTRUMENT: Stalker Sport **TYPE:** ~~1 2~~ KA **SERIAL #:** SS 79355
CALIBRATOR: tuning fork 65.3 mph, 24.15 GHz **SERIAL #:** FH 00 3859
CALIBRATION CHECK: PRE-TEST 65 Mph ~~dBA SPL~~ POST-TEST 65 mph ~~dBA SPL~~ **WINDSCREEN** N/A

SETTINGS: A-WEIGHTED SLOW FAST FRONTAL RANDOM ANSI OTHER:

Rec #	Start Time / End Time							
#1	0850 /	TRAIN	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
#2	0921 /	TRAIN	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
	/ /	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
	/ /	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	

COMMENTS:

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT OTHER
ROADWAY TYPE:

COUNT DURATION: ____ -MINUTE	NB / EB / SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB / SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	/	/	/	/
BICYCLE:	/	/	/	/
OTHER:	/	/	/	/
EAR BUDS:	/	/	/	/
OTHER:	TRAIN S/B #1 /	40 mph	/	/
	TRAIN N/B #2	41 mph		

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant **AIRCRAFT** overhead / **RUSTLING LEAVES** / distant **BARKING DOGS** / **BIRDS**
distant **CHILDREN PLAYING** / distant **TRAFFIC** / distant **LANDSCAPING** / distant **TRAINS**
OTHER:

Source Info and Traffic Counts

TERRAIN: HARD SOFT MIXED FLAT OTHER:
PHOTOS:
OTHER COMMENTS / SKETCH: See attached

Ped	5 seconds	50'	jogger	5 sec	jogger
Ped	9.8 s	50'	~~Ped~~ walker	11 sec	walker
Ped	4 s	50'	jogger	14 sec	walker
ped	11 s	50'	walker	9.5 sec	walker
ped	10 sec	50'	walker w/dog	6 sec	jogger
	8 sec	walker		4 sec	jogger
	7.5 sec	jogger		11.5 sec	walker
				8 sec	jogger

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

PB

Project Name: OCTA AWS Study   Job # 11977 5.7.9.1

ID

SITE IDENTIFICATION: Dije Court   OBSERVER(s): Rob Greene
START DATE & TIME: 10/2/10 0930   END DATE & TIME: 10/2/10 1110
ADDRESS: Along San Clemente Beach Trail

GPS coordinates:

Weather

TEMP:____ °F HUMIDITY:____% R.H. WIND: CALM LIGHT MODERATE VARIABLE
WINDSPEED:____MPH DIR: N NE E SE S SW W NW STEADY GUSTY____MPH$_{max}$
SKY: CLEAR SUNNY DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other:

Acoustic Measurements

INSTRUMENT: Stalker Sport   TYPE: Ka   SERIAL #: SS 79355
CALIBRATOR: 65.3 mph tuning fork 24.15 GHz   SERIAL #: FH 003859
CALIBRATION CHECK: PRE-TEST 65 mph   POST-TEST 65 mph   WINDSCREEN N/A

SETTINGS: A-WEIGHTED SLOW FAST FRONTAL RANDOM ANSI OTHER:

Rec #	Start Time	End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
#1	1005	TRAIN							
#2	1040	Train							
#3	1112	Train							

COMMENTS: #1 S/B Train 37 mph
#2 N/B Train 39 mph
#3 S/B Train 25-27 mph starting

Source Info and Traffic Counts

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT OTHER
ROADWAY TYPE:

COUNT DURATION: ____-MINUTE	NB / EB / SB / WB	SPEED (mph) NB EB / SB WB	#2 COUNT: NB / EB / SB / WB	SPEED (mph) NB EB / SB WB
PEDS:	/	/	/	/
BICYCLE:	/	/	/	/
OTHER:	/	/	/	/
EAR BUDS:	/	/	/	/
OTHER:	/	/	/	/

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant AIRCRAFT overhead / RUSTLING LEAVES / distant BARKING DOGS / BIRDS
distant CHILDREN PLAYING / distant TRAFFIC / distant LANDSCAPING / distant TRAINS
OTHER:

Description / Sketch

TERRAIN: HARD SOFT MIXED FLAT OTHER:
PHOTOS:
OTHER COMMENTS / SKETCH: See attached

9.5 sec	walker	4.5 sec	life guard quad	9	jogger
11 sec	walkers	8.5	elderly jogger	11	dog walkers
6 sec	joggers	4	jogger	7.5	walker
9.5	walker	7	double stroller	6	joggers
6.2	jogger	17	walking dog	5.5	jogger
10.3	walkers	5.3	bicycle	7.8	jogger
		10	dog walker	4.5	jogger
		8	jogger	4.7	jogger

S
E ↔ W
N

16 peds 1 bicycle

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

FIELD MEASUREMENT DATA SHEET

PB 100 YEARS

Project Name: OCTA AWS Study **Job #** 11977 5.7.9.1

SITE IDENTIFICATION: Calafia
START DATE & TIME: 10/2/10 1215
ADDRESS: Along San Clemente Beach Trail
OBSERVER(s): Rob Greene
END DATE & TIME: 10/2/10 1400

GPS coordinates:

ID

TEMP: ____ °F **HUMIDITY:** ____ % R.H. **WIND:** CALM LIGHT MODERATE VARIABLE
WINDSPEED: ____ MPH **DIR:** N NE E SE S SW W NW **STEADY GUSTY** ____ MPH$_{max}$
SKY: [CLEAR] [SUNNY] DARK PARTLY CLOUDY OVRCST FOG DRIZZLE RAIN Other: ____

Weather

INSTRUMENT: Stalker Sport **TYPE:** ~~1 2~~ KA **SERIAL #:** SS 79355
CALIBRATOR: Tuning fork 65.3 mph 24.15 GHz **SERIAL #:** FH 003859
CALIBRATION CHECK: PRE-TEST 65 mph ~~dBA SPL~~ POST-TEST 65 mph ~~dBA SPL~~ **WINDSCREEN** N/A

SETTINGS: A-WEIGHTED SLOW FAST FRONTAL RANDOM ANSI OTHER:

Rec #	Start Time / End Time	L_{eq}	L_{max}	L_{min}	L_{90}	L_{50}	L_{10}	
#1	1236 /	Train						
#2	1313 /	Train						
	/							
	/							

COMMENTS:
#1 S/B Train 40 mph
#2 N/B Train 37 mph

Acoustic Measurements

PRIMARY NOISE(S): TRAFFIC AIRCRAFT RAIL INDUSTRIAL AMBIENT [OTHER] SURF
ROADWAY TYPE: dirt trail

COUNT DURATION: ____ **-MINUTE**

	NB / EB	SB / WB	SPEED (mph) NB EB	SB WB	#2 COUNT: NB / EB	SB / WB	SPEED (mph) NB EB	SB WB
PEDS:	94							
BICYCLE:	6							
OTHER:								
EAR BUDS:	3							
OTHER:								

SPEED ESTIMATED BY: RADAR / DRIVING / OBSERVER

OTHER NOISE SOURCES: distant **AIRCRAFT** overhead / **RUSTLING LEAVES** / distant **BARKING DOGS** / **BIRDS**
distant **CHILDREN PLAYING** / distant **TRAFFIC** / distant **LANDSCAPING** / distant **TRAINS**

OTHER:

Source Info and Traffic Counts

TERRAIN: HARD SOFT [MIXED] / FLAT **OTHER:**
PHOTOS: ✓
OTHER COMMENTS / SKETCH: See attached

1236
2 bicycles slow
1 Jogger w/ earbuds
1 Walker
7 walkers
1 walker w/ earbuds
1 walker w/ dog Trail
1 walker w/ ear buds
2 walkers
1 walker
↕↔

4 walkers
9 walkers
2 walkers
2 walkers for photo
2 walkers
4 walker
1 walker
2 child joggers
4 walkers
3 walkers
1 bicycle

6 kids
1 walker
1 bicycle slow
5 walkers
1 child
3 walkers
2 bicycle slow
2 walkers
4 walkers
1 walker
2 walkers

1 walker
2 kids
5 walkers
5 walkers
1 walker
1 walker
3 trail walker
2 walkers
1 walker
1 walker 1300

Description / Sketch

505 S. Main Street, Suite 900, Orange, CA 92868, 714-835-6886

PCB PIEZOTRONICS
A PCB GROUP COMPANY

Certificate of Calibration and Conformance

Certificate Number 2010-125466

Instrument Model 828, Serial Number 1967, was calibrated on 06JAN2010. The instrument meets factory specifications per Procedure D0001.8135.

Instrument found to be in calibration as received: YES
Date Calibrated: 06JAN2010
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL. DUE	TRACEABILITY NO.
Hewlett Packard	34401A	MY41044529	12 Months	15JAN2010	4204375
Larson Davis	LDSigGn/2209	0277 / 0109	12 Months	25MAR2010	2009-118756

Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Temperature: 22 ° Centigrade

Relative Humidity: 34 %

Affirmations

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the U.S. National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at Provo Engineering & Manufacturing Center. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with the requirements of ISO 17025 and ANSI Z540. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. A one year calibration is recommended, however calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of the issuer.

"AS RECEIVED" data same as shipped data.

Signed: Ron Harris
Technician: Ron Harris

Provo Engineering and Manufacturing Center, 1681 West 820 North, Provo, Utah 84601
Toll Free: 888.258.3222 Telephone: 716.926.8243 Fax: 716.926.8215
ISO 9001-2000 Certified

PCB PIEZOTRONICS
A PCB GROUP COMPANY

Certificate of Calibration and Conformance

Certificate Number 2010-125528

Microphone Model 2560, Serial Number 2979, was calibrated on 07JAN2010. The microphone meets factory specifications per Test Procedure D0001.8167.

Instrument found to be in calibration as received: YES
Date Calibrated: 07JAN2010
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL DUE	TRACEABILITY NO
Larson Davis	2900	0575	12 Months	24JUN2010	2009-119575
Larson Davis	CAL250	4963	12 Months	21JUL2010	2009-120504
Larson Davis	PRM915	0102	12 Months	25AUG2010	2009-121224
Larson Davis	PRM902	0206	12 Months	25AUG2010	2009-121219
Larson Davis	2559	3003427	12 Months	21AUG2010	2009-121293
Larson Davis	2559	2586	12 Months	03SEP2010	98666-1
Larson Davis	PRM900	0424	12 Months	08SEP2010	2009-121767
Larson Davis	PRM902	0528	12 Months	08SEP2010	2009-121766
Larson Davis	MTS1000 / 2201	0100 / 0102	12 Months	08SEP2010	[illegible]
Hewlett Packard	34401A	3146A12099	12 Months	03NOV2010	4546881
Larson Davis	PRM916	0102	12 Months	17DEC2010	2009-125069

Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Affirmations

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the U.S. National Institute of Standards and Technology (NIST). [illegible] Evidence of traceability and accuracy is on file at Provo Engineering & Manufacturing Center. [illegible]

This calibration complies with the requirements of ISO 17025 and ANSI Z540. [illegible]

The results documented in this certificate relate only to the item(s) calibrated or tested. [illegible]

"AS RECEIVED" data is the same as shipped data.

Signed: Abraham Ortega
Technician: Abraham Ortega

Provo Engineering and Manufacturing Center, 1681 West 820 North, Provo, Utah 84601
Toll Free: 888.258.3222 Telephone: 716.926.8243 Fax: 716.926.8215
ISO 9001-2000 Certified

PCB PIEZOTRONICS
A PCB GROUP COMPANY

Certificate of Calibration and Conformance

Certificate Number 2010-125498

Instrument Model CAL150B, Serial Number 2399, was calibrated on 06JAN2010. The instrument meets factory specifications per Procedure D0001.8190.

Instrument found to be in calibration as received: YES
Date Calibrated: 06JAN2010
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL. DUE	TRACEABILITY NO
Larson Davis	2001	0881	12 Months	07APR2010	2009-117163
Hewlett Packard	34401A	US36033450	12 Months	15JUN2010	4382218
Hewlett Packard	34401A	3146A10352	12 Months	13JUL2010	4413817
Larson Davis	2559	2506	12 Months	03SEP2010	16868-1
Larson Davis	PRM915	0112	12 Months	08SEP2010	2009-121808
Larson Davis	PRM902	0480	12 Months	08SEP2010	2009-121820
Larson Davis	MTS1000/2201	0111	12 Months	08SEP2010	SM090909-1
PCB	1502B02FJ15PSIA	1342	12 Months	27NOV2010	3341845067

Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Environmental test conditions as shown on calibration report.

Affirmations

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the U.S. National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at Provo Engineering & Manufacturing Center. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with the requirements of ISO 17025 and ANSI Z540. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. A one year calibration is recommended, however calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of the issuer.

Before: 113.93 dB, 93.93 dB, 1000.2 Hz @ sea level
After: Refer to Certificate of Measured Output

Signed: [signature]
Technician: Scott Montgomery

Provo Engineering and Manufacturing Center 1681 West 820 North Provo, Utah 84601
Toll Free: 888.258.3222 Telephone: 716.926.8243 Fax: 716.926.8215
ISO 9001-2000 Certified

CERTIFICATE OF CALIBRATION
17588-10A
FOR BRÜEL & KJAER INTEGRATING SOUND LEVEL METER

Model **2231** — Serial No. **1506448**
ID No. **N/A**

With Microphone Model **4176** — Serial No. **1523674**
P.O.# **Letter**

Customer: **Parsons Brinckerhoff**
Orange, CA 92868

was tested and met factory specifications at the points tested according to the Referenced Test Procedure

on **21 JUL 2010** **BY** **HAROLD LYNCH**
Service Manager

As received condition: Inoperative
Returned: Within Specification.
Re-calibration due: **21 JUL 2011**

Certified References*

Mfg.	Type	Serial No.	Date Due
B&K	2636	1614877	25 MAY 2011
HP	34401A	3146A48348	01 JUL 2011
HP	3458A	2823A17713	09 JUL 2011
B&K	4226	1774068	16 MAR 2011
B&K	4231	1770857	13 AUG 2010

Performed in Compliance with ANSI, NCSL Z-540-1, 1994 and ISO 17025, ISO 9001:2008 Certification NQA No. 11252
*References are traceable to NIST (National Institute of Standards and Technology).

Note: For calibration data see enclosed pages.
The data represents both the "as left" condition.

Reference Test Procedure: **ACCT Procedure 2231 Ver. 1.1**

Brüel & Kjær Factory Service Instructions: **2231** Rev. Apr. 1985

Temperature	Relative Humidity	Barometric Pressure
23°C	**40** %	**985.89** hPa

Note: This calibration report shall not be reproduced, except in full, without written consent by Odin Metrology, Inc.

Signed: Harold Lynch

ODIN METROLOGY, INC.

CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 OLD CONEJO ROAD; SUITE 125 THOUSAND OAKS CA 91320
PHONE: (805) 375-0830 FAX: (805) 375-0405

21.4 SCBT User Velocity Survey Methodology

21.4.1 Primary Methodology for Speed Survey

The surveys to determine User velocities by group are divided into two categories: extended and limited surveys. Extended surveys were conducted for three locations along the trail and the limited surveys were performed by different staff and at different times at pedestrian beach trail/railroad crossings. For each survey, the observer was stationed on the SCBT near the railroad crossing. Speed (velocity) information was measured and noted, and is summarized in the Data Tables. SCBT Users were divided into two primary user groups, "pedestrian" and "bicyclist". The pedestrian group can further be divided into "walker" and "jogger", though it is important to note that at any point a walker can become a jogger and vice versa. Each User that entered the survey area was counted, which includes individuals that went through the survey area, turned around, and came back. The observer did not differentiate between new and repeat Users.

21.4.2 Extended Surveys

Northern, central and southern locations were chosen for the extended surveys. The locations are approximately 0.60 mile apart (3168 feet) along the SCBT and the entire SCBT is approximately 2.3 miles long (12,144 feet). Dije Court is the northern survey location and is located approximately 0.23 mile (1215 feet) south of the North Beach Metrolink Station parking lot and the entrance to the SCBT. There is a public pedestrian staircase near the intersection of Buena Vista and Dije Court that allows access from the residential neighborhood to the beach. Users at this location are not required to cross the train tracks in order to stay on the main SCBT, and crossing the railroad tracks is only required if trying to access the beach using what this study refers to as a branch trail. The survey time for Dije Court was from 10:05am to 11:07am, the second site surveyed on Saturday, October 2, 2010.

Corto Lane is the central survey location and is found approximately 0.19 mile (1003 feet) north of the San Clemente Pier. Users are required to cross the tracks in order to remain on the trail at this location. There is both public and private access from the residential neighborhoods to the beach trail via two staircases. The survey time for Corto Lane was from 8:30am to 9:15am, the first site surveyed on Saturday, October 2, 2010.

T-Street is the southern survey location and is found approximately 0.41 mile (2165 feet) south of the San Clemente Pier. The closest pedestrian staircase is located approximately 0.12 mile (634 feet) northerly, near the intersection of Esplande and West Paseo De Cristobal. Users must cross the train tracks in order to remain on the main SCBT at this location. The survey time for T-Street was from 11:45a-12:45p, the last site surveyed on Saturday, October 2, 2010.

The extended surveys lasted approximately 45 minutes to one hour and the observer recorded speed information, denoted what user entered the survey area, and noted if the User was wearing earbuds. Therefore, the extended survey has data for all three user groups (walker, jogger, and bicyclist), plus speed measurements and earbud information.

In order to obtain accurate speed measurements, a low-speed, high-resolution Stalker Pro radar gun was positioned approximately 5 feet, 5 inches above the ground and displayed speed information in miles per hour (mph) with one-tenth mph resolution. The radar gun sensitivity was adjusted to ensure the speed measurements displayed were for the Users within close proximity to the equipment. For the Dije Court and Corto Lane locations, the radar gun was facing north along the trail and positioned on a diagonal (approximately northwest). For T-Street, the radar gun was facing south along the trail and positioned on a diagonal (approximately southwest).

21.4.3 Limited Observations

Limited observations were conducted by different staff observers and at different times at the pedestrian crossings along the SCBT and the observations lasted for approximately 15 minutes at each location. The two observers collecting acoustic data did not collect speed data at the limited observation locations. However, these observers did note if the Users were wearing headphones (earbuds) and User counts were obtained. The counts were divided into two categories: total pedestrian, which included walker and jogger, plus bicyclist.

21.4.4 Cross Reference and Quality Assurance

Additionally, for Quality Assurance purposes, independent real-time and post-survey video-derived SCBT User speed measurements were obtained at Corto Lane and Dije Court (south leg) crossings by the project's Technical Manager using two variations of a different methodology. The independent method used measured transit time per measured distance to determine SCBT User velocities in feet per second. The SCBT was marked with two stripes of orange surveyor's paint delineating a measured 50 feet interval on the trail at the two identified locations. A tripod-mounted Hi-Definition video camcorder was set up and oriented to view both stripes plus SCBT Users in its field of view. In real time during the field survey, the Technical Manager used a stopwatch to measure, and then note the time (in seconds) it took for random SCBT Users in each category to travel the 50 feet distance between the markers. This method was also used as a post-process while observing playback of the video recording and timing the SCBT Users transition between the visible paint stripes. Analyses of this data yielded very good agreement with the primary observer measurements using the radar gun method. The measured speeds of SCBT Users were also found to be consistent with a third source of typical pedestrian velocities (Nichols and Walker 2010).

An additional observation was also conducted at the Calafia crossing to obtain pedestrian counts, and general observations of the User categories for this location, that is located at the southerly terminus of the SCBT. Observation was conducted between 12:36pm and 1:06pm (30 minute duration) on Saturday, October 2, 2010. The information obtained at this crossing was not incorporated into the overall counts for the extended surveys in part due to the shorter duration of the observation period. The results obtained are consistent with the findings of the extended surveys, and were used as a cross reference only. The data from the secondary observations conducted at Calafia, Corto Lane and Dije Court crossings was used for quality assurance of the primary observation data only and, thus is not included in the data analyses summary provided below.

21.5 SCBT User Survey Results

21.5.1 Results for Velocity Surveys

For the extended surveys, a total of 731 people were counted, which includes all three extended locations. Dije Court represents 40% of the total sample, Corto Lane represents 43% and T-Street represents 16%, respectively (total at each location/total sample size). The percentages for each user group are found in the following table.

Table 21—2. Combined Data for All Three Extended Survey Locations

User Group	*Count*	*Percentage*	*Average Speed (mph)*
Walker	490	67	3.3
Jogger	215	29	6.2
Bicyclist	26	4	7.6
Total	731	100	

The majority of Users are in the walker user group with 67 percent of the total sample size. In addition to the average speed for the user groups, the 85th percentile speeds were also calculated as well as the velocity in feet per second (fps) and miles per hour (mph). The 85th percentile results, calculated for all locations, are as follows: walkers, 4 mph (5.9 fps); joggers, 7.2 mph (10.6 fps); bicyclists, 9.63 mph (14.1 fps). It should be noted the posted speed limit on the SCBT is 10 mph (14.67 fps).

The results of the headphone wearers' surveys are presented in Table 21-3, below.

Table 21—3. Data from All Three Extended Surveys

	Count with Earbuds	*Percentage*
Walker	59	12
Jogger	102	47
Bicyclist	3	12

The general Users group data was also analyzed for each location. The following table shows the percentages for Users by category at each location. For example, this table shows that 69% of the Users at Dije Court were walkers.

Table 21—4. User Groups

	Dije Court		*Corto Lane*		*T-Street*	
	Count	Percentage	Count	Percentage	Count	Percentage
Walker	203	69%	214	68%	73	62%
Jogger	86	29%	99	31%	30	25%
Bicyclist	7	2%	4	1%	15	13%
Total	296	100%	317	100%	118	100%

The largest variation across locations is found in the bicyclist user group. The largest percentage of bicyclists compared to the overall sample size was found at T-Street, which was 11 to 12 percentage points higher than the other two sites. Based on the overall sample counts, T-Street is considered the least crowded SCBT/RR crossing with only 118 Users, compared to 296 for Dije Court and 317 for Corto Lane respectively. Because it is less crowded at the T-Street location, the bicyclists may have an easier time maneuvering around people and therefore may be more likely to stay in this area of the SCBT. The walker and jogger user groups are fairly consistent at all locations, within five percentages points of one another. The lower counts found at T-Street could be in part due to the time of survey at that location. Most fitness oriented Users appear to be on the SCBT earlier and their numbers dwindled with primarily beach going Users increasing as the afternoon progressed. T-Street was the very last survey conducted by the primary User observer, and started at 11:45am and ended at 12:45pm Saturday, October 2, 2010.

Speed data statistical analysis by User group is presented below.

San Clemente Pedestrian Survey Speed Distribution

Table 21—5. Statistics Table: Walkers

Statistics	*All 3 Crossings*	*T-Street*	*Corto Lane*	*Dije Court*
Mean	3.3	3.0	3.3	3.4
Standard Error	0.0321	0.1007	0.0428	0.0430
Median	3.3	2.7	3.3	3.4
Mode	3.4	2.7	3.4	3.2
Standard Deviation	0.6056	0.8118	0.5157	0.5216
Sample Variance	0.3668	0.6590	0.2659	0.2720
Range	4.8	4.8	2.4	3.9
Minimum	1.8	1.8	2.1	1.9
Maximum	6.6	6.6	4.5	5.8
Sum	1178.1	192.5	479.7	505.9
Count	357	65	145	147
Confidence Level (95.0%)	0.0630	0.2011	0.0846	0.0850

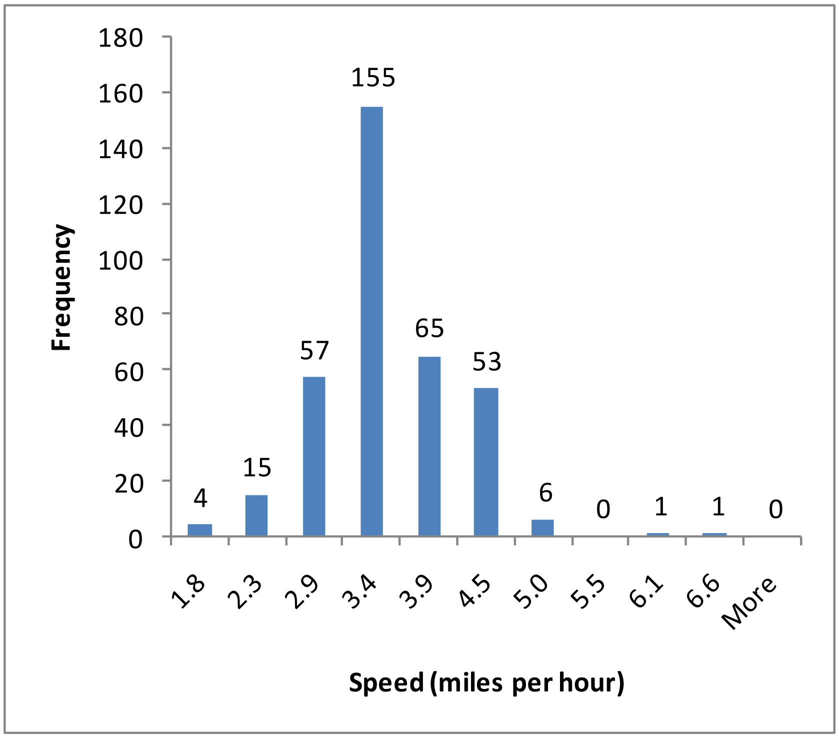


Figure 21—1. Sample Speed Distribution for Walkers at All Three Extended Locations (Corto Lane, Dije Court, and T-Street Crossings)

Table 21—6. Statistics Table: Joggers

Statistics	*All 3 Crossings*	*T-Street*	*Corto Lane*	*Dije Court*
Mean	6.2	6.4	6.4	5.9
Standard Error	0.0727	0.1763	0.09740	0.1193
Median	6.3	6.3	6.4	6.0
Mode	6.4	6.3	6.4	6.0
Standard Deviation	0.9675	0.9327	0.8265	1.0470
Sample Variance	0.9360	0.8699	0.6830	1.0963
Range	5.2	3.8	4.4	4.4
Minimum	3.6	4.7	4.4	3.6
Maximum	8.8	8.5	8.8	8.0
Sum	1094.9	179.8	459	456.1
Count	177	28	72	77
Confidence Level (95.0%)	0.1435	0.36166	0.1942	0.2376

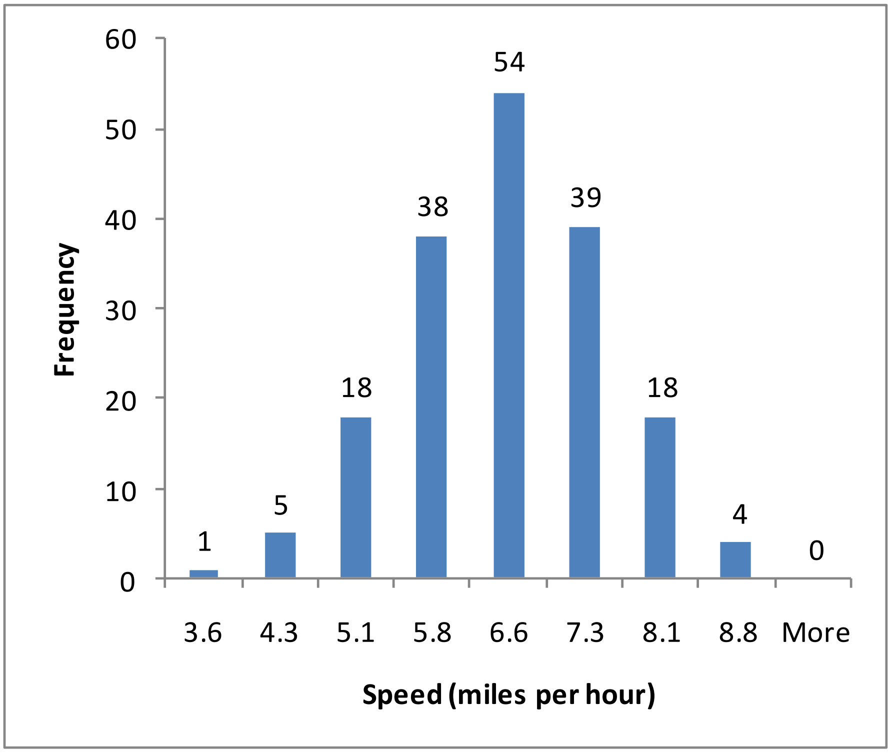


Figure 21—2. Sample Speed Distribution for Joggers at All Three Extended Locations (Corto Lane, Dije Court, and T-Street Crossings)

Table 21—7. Statistics Table: Bicyclists

Statistics	*All 3 Crossings*	*T-Street**	*Corto Lane**	*Dije Court**
Mean	7.6	7.9	7.0	7.4
Standard Error	0.370	0.5785	0.5282	0.5431
Median	7.7	8.4	6.8	7.6
Mode	5.0	5	#N/A	#N/A
Standard Deviation	1.889	2.2406	1.0563	1.4369
Sample Variance	3.566	5.0203	1.1158	2.0648
Range	6.6	6.6	2.5	4.2
Minimum	5.0	5	6	5
Maximum	11.6	11.6	8.5	9.2
Sum	198.6	118.8	28.1	51.7
Count	26	15	4	7
Confidence Level (95.0%)	0.7628	1.2408	1.6809	1.3289

*Sample size for location was under 30 subjects

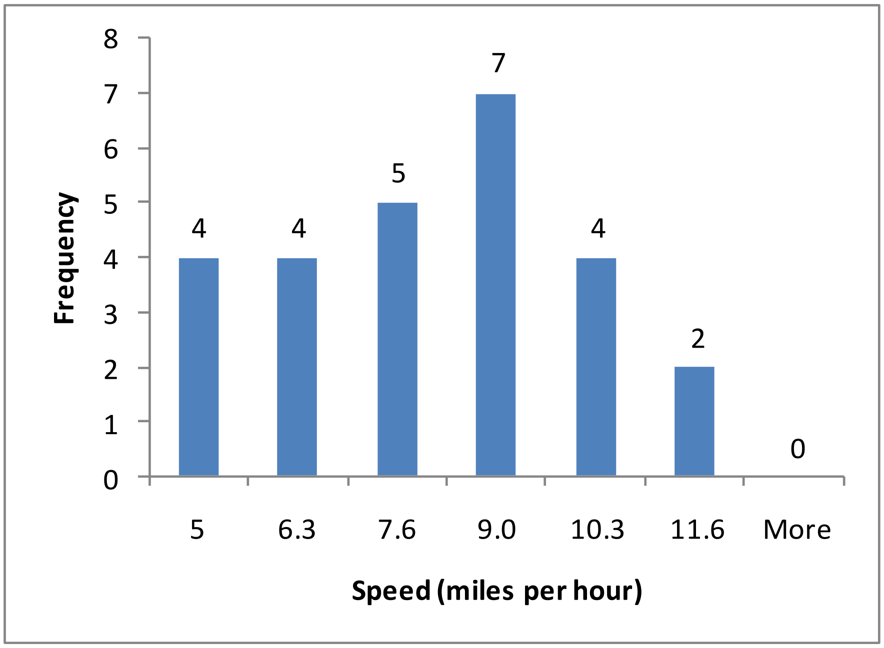


Figure 21—3. Sample Speed Distribution for Bicyclists at All Three Extended Locations (Corto Lane, Dije Court, and T-Street Crossings)

21.5.2 Earbud Use

Another purpose of the survey was to determine the percentage of Users wearing earbuds while on the SCBT. Of the total noted population, 22 percent (164 Users) were wearing earbuds, which does not differentiate among the user groups. Almost half (47 percent) of the joggers using the trail were wearing earbuds. The percentage of earbud-wearing Users is appreciable and was the rationale for conducting the acoustic testing of typical earbuds believed likely to be worn by Users of the SCBT.

The individual location results for earbud use are as follows:

Table 21—8. Earbud Use

	Dije Court		*Corto Lane*		*T-Street*	
	Count	Percentage	Count	Percentage	Count	Percentage
Walker	20	10%	26	12%	13	18%
Jogger	44	51%	44	44%	14	47%
Bicyclist	3	43%	0	0%	0	0%
Total	67	23%	70	22%	27	23%

T-Street has the highest percentage of walkers wearing earbuds with 18 percent. Dije Court was the only location with bicyclists wearing earbuds with a total of three; however, the observer noted that it was actually only two bicyclists, with one passing the counting point twice.

21.6 Audible Warning Signal Delivery Method

Technical discussions within the team regarding a range of delivery methods indicate that mechanical and electro-mechanical systems including bells and gongs are too limited in signal characteristics, and limit the ability to control sound level and the pattern of sound propagation. Thus, these methods are not considered suitable for an AWS. Electro-acoustical methods offer a broad range of devices, can offer synthesized or stored actual warning sounds, may be easily adjusted for sound level, and may be designed or modified to control the dispersion of sound. Additional flexibility options include:

- single point-of-origin with higher relative sound level potentially reaching adjacent residences
- multiple points-of-origin (distributed) with lower relative sound level reaching nearby residences
- adjustable for optimum coverage through design, placement, directivity and orientation

A Wayside Horn (WH) warning signal and any alternative audible warning signal would likely be “delivered” to the ear of a SCBT User as an airborne acoustic signal generated electro-acoustically by a loudspeaker (in essence, the same way the sound from a television set is sent to those watching TV). While this method is a traditional, robust approach to delivering an audible warning signal to a specified group, there are several considerations that make the details more complex. For example, the frequency range and sound level required to be generated by the loudspeaker dictate the physical dimensions and power handling capacity, thus the dimensions of the loudspeaker. The loudspeaker size and type determine to a great extent how it is to be mounted and oriented. Other considerations include environmental factors such as sun, wind, and salt-air; plus vandalism, reliability, longevity, and low maintenance. The typical type (single-point horn) and substantial sound level/power requirements of a WH result in its typically large, horn shape appearance and strong mounting arrangements. A technique to reduce the loudspeaker size requirement that is not practical in most high-sound-level audible warning systems but may be very suitable to the proposed Audible Warning System (AWS) is called a "multi-point/distributed" system that uses multiple lower-sound-level loudspeakers located closer to the warning's recipients instead of a single point, high-sound-level loudspeaker located at a greater distance from the warning's recipients. Although a detailed system design is beyond the scope of this report, preliminary calculations indicate that two loudspeakers, each located approximately 10 to 20 feet before the crossing gates (horizontal position) at each crossing will be suitable to deliver an effective audible warning signal to SCBT Users.

21.7 Attenuation from Wearing Ear Buds

21.7.1 Background

An important component of the Audible Warning System (AWS) study is an evaluation of the typical noise reduction (attenuation) provided by *concha* located, flat-faced micro-speakers that occlude the opening to the ear canal, and by inter-aural (inserted into the ear canal) type of audio headphones, both commonly called *ear buds or earbuds*. The reason for this interest is that an appreciable percentage of SCBT Users, especially in the "jogger" classification wear earbuds while using the SCBT.[11]

Based on formal observations by PB investigators of more than 1200 SCBT Users conducted on Saturday, October 2, 2010, plus informal observations of and anecdotal conversations with earbud wearers during three other visits to various portions of the Beach Trail, the earbuds most often seen are the ubiquitous white original equipment devices (concha, flat-front style) and, in multiple colors, various brands of aftermarket replacement devices (concha and insert styles). The investigators did not observe over or behind the head or pendant, or other styles. Subsequent physical inspection of various earbuds indicate that the acoustical reduction of external sound would not be materially affected by the hook-over-the –ear (so called *sport* earbuds) or other headband style options because the actual element of the earbud that rests in the concha or is inserted into the ear canal is the same size and shape as that of the simple style earbud without a sport hook or band.

[11] SCBT Users are generally classified in this study as *walker*, *jogger*, or *bicyclist*. See Section 21.5.2 for the earbud use statistics by category.

In determining the appropriate sound level for WH one factor considered by Volpe researchers and the FRA was the acoustical attenuation provided by the body (or “shell”) of the typical motor-vehicle that reduces the sound level of the warning signal as experienced by the driver. For most SCBT Users this attenuation element does not exist, thus an AWS signal is not typically subject to this extra (“excess”) attenuation. However, because they wear earbud style headphones, a small but appreciable percentage of the SCBT User population has an acoustical attenuating element corresponding to the car body for motorists. Thus, it was considered important to quantify the attenuation provided by the typical earbuds observed in use on the SCBT to enable a comparison to the typical attenuation reported for an automobile body or “shell”.

A characteristic of any material or device that is placed in front of the opening of or into the ear canal is the attenuation of the level (or intensity) of sound that would otherwise enter the ear unabated. Of concern to this study is the degree to which the perception of a potential audible warning sound might be reduced for persons wearing earbud style headphones. This characteristic is referred to as the *attenuation* of “exterior” sounds, whether desired or not, that occur in the environment.

Several questions were considered: Do all earbuds exhibit a “typical” attenuation of external sound? Is there such a device as a “typical” earbud? Is there any readily available acoustic test data for earbuds in general, or for specific models? Based on some team members’ experience with earbuds, and the paucity of published studies of earbud acoustics, an earbud test component was developed to provide quantitative data about germane acoustical characteristics of earbuds likely to be worn by SCBT Users. The general protocol, and a summary of the results, and findings of the testing are presented below.

The effects on design characteristics of an AWS due to attenuation of exterior sound and the “distraction” or masking effect of music and speech played through the earbuds, which is analogous to the “car stereo” sound in a motor vehicle, will be addressed in another section of this report.

21.7.2 Approach to Earbud Evaluation

A methodology was developed to objectively quantify the earbud’s acoustic property of attenuating external sound by measuring the *Insertion Loss* of a diverse sample of earbuds.

21.7.2.1. Defining and Obtaining the Test Population of Earbuds

Based on previous experience testing and reviewing the test results of insert hearing protectors, and consultation with the independent testing facility’s owner[12], it was decided to purchase, primarily from available off-the-shelf stock of national retailers, an assortment of earbuds that would be representative of the range of earbuds likely to be worn by those Users of the SCBT who chose to wear earbuds. The three factors considered significant in selecting the earbuds to be tested were availability, range of cost, and diversity of

[12] W. Gary Sokolich, Ph. D., Custom Sound Systems, Newport Beach, CA.

manufacturers. The range of color of the test earbuds was not a significant acoustic factor but was useful in keeping track of the samples tested. It was determined to initially purchase two of each sample earbud headphones to provide confidence in the statistical result of the test measurement. If one unit (two independent buds) of the same earbud device yielded acoustical results in close agreement then the sample point could be deemed representative. If the two buds did not yield comparable results a second sample (two additional buds) of the same brand/model device would be tested to see if insertion loss performance could be matched to either of the first two sample buds or if a conclusion of high product variability could be made. If poor agreement between or among each sample pair or pairs of buds but a fairly well defined range of insertion loss values were obtained among all of the samples, a conclusion might be reached that each sample was an independent data point and the variability of the entire earbud sample population should be considered by the AWS study team in its evaluation. In some cases the second sample set was tested only to increase the sample size for a particular type of earbud.

21.7.2.2. Range of Cost

The retail price of a pair earbuds ranges from about $1.99 to over $450.00. The earbuds that cost $75 to $100.00 a pair are approaching “audiophile” or high quality and are only occasionally considered for recreational use. Earbuds that cost over $100.00 are generally considered “audiophile” or very- high-end quality and would rarely, if at all, be considered for recreational use such as jogging. This is because typical casual/recreational use earbuds are subject to damage in transit, excessive perspiration, catching on obstructions, dropping resulting in contamination by dirt or water, etc. Thus, a range of earbuds was selected for testing that cost between $2.50 and $100.00, with a rough cost progression of $2.50, $5.00, $10.00, $15-20, $30-40, $50-60, and $80-100.

Several of the devices tested are described by their manufacturers’ as “noise isolating”. With one exception, all devices were passive (i.e., not active noise cancelling). No active noise cancelling type earbuds were identified by the investigators during the observation of SCBT Users and none of the Users who were asked about their earbuds (not during the observation period so as to not interfere with other data being collected) indicated that they were using noise cancelling types. Notwithstanding this anecdotal finding, two samples of one model active noise-cancelling earbuds were obtained for testing to satisfy any concerns about the typical insertion loss of noise-cancelling earbuds. Priced at approximately $90 a pair, they are in the most expensive category of the earbud test population.

21.7.2.3. Diversity of Manufacturers and Retailers

The manufacturers of the sample earbuds include Apple™, Vibe Sound™/DGL Group, 2XL™, Gummy/JVC®, Sony®, Ink’d/Skullcandy™, Memorex™, PLUGZ Ear Pollution/ifrogz™, Maxell Corporation of America®, Auvio™, IMIXID™, Panasonic®, Ultimate Ears™, and Sennheiser™ electronic GmbH.

The sample earbuds were purchased by the principal investigator at local facilities of national retailers Best Buy, Fry's Electronics, Radio Shack, Micro Center, the Apple Store, Borders, Big Lots, and Walmart. Similar products were found at Target, Sears, Sav-on/Osco, and Walgreens stores. One brand was purchased at a local hi-end specialty store. The list of models tested, source, price, and type is provided below on following page.

Table 21—9. EARBUD TESTING LIST OF PRODUCTS

Pair Designator	Retail Price, $	Brand	Model	Color/ID	Source	Type: **I**nsert/**C**oncha
A-1	29.00	Apple	MB770G/B	White	Apple Store	C
A-2		Apple	MB770G/B	White	Apple Store	C
B-1	29.99	Sony	MDR-EX36V	Black	Best Buy	I
B-2		Sony	MDR-EX36V	Red	Best Buy	I
C-1	10.99	JVC	Gummy HA-F140	White	Best Buy	C
C-2		JVC	Gummy HA-F140	Black	Best Buy	C
D-1	21.99	Skullcandy	Ink'd S2INCB	Silver/Black	Best Buy	I
D-2		Skullcandy	Ink'd S2INCB	Blue/Black	Best Buy	I
E-1	6.00	Panasonic	RP-HV 152	Black	Micro Center	C
E-2		Panasonic	RP-HV 152	Black	Micro Center	C
F-1	4.99	Vibe/DGL	VS-505	Purple	Fry's Electronics	I
F-2		Vibe/DGL	VS-505	Black	Fry's Electronics	I
G-1	14.99	IMIXID	Earbuttons	Pink	Borders	I
G-2		IMIXID	Earbuttons	White	Borders	
H-1	2.47	Maxell	PL1	Black	Walmart	C
H-2		Maxell	PL1	Black	Walmart	C
I-1	10.00	Ifrogs Earpollution	PLUGZ	Pink	Walmart	I
I-2		Ifrogs Earpollution	PLUGZ	Green	Walmart	I
J-1	99.95	Sennheiser	CX-400-II Precision	Gray	Audio Video Today	I
J-2		Sennheiser	CX-400-II Precision	Gray	Audio Video Today	I
K-1	8.00	Memorex	CB-25	White	Big Lots	I
K-2		Memorex	CB-25	White	Big Lots	I
L-1	6.00	2XL	Rasta	Red-Yellow	Big Lots	I
L-2		2XL	Rasta	White-Green	Big Lots	I
M-1	89.99	Sony	MDR-NC33	Black	Best Buy	I ANC*
M-2		Sony	MDR-NC33	Black	Best Buy	I ANC*
N-1	49.99	Ultimate Ears	Metro Fi 170	Purplish Black	Micro Center	I
N-2		Ultimate Ears	Metro Fi 170	Purplish Black	Micro Center	I
O-1	19.19	Auvio	33-266	Black w/silver band	Radio Shack	I
O-2		Auvio	33-266	Black w/silver band	Radio Shack	I

*Active Noise Cancelling

21.7.3 Test Methodology

The prescribed methodology is essentially a step-by-step process for ensuring valid, repeatable measurement results with a satisfactory degree of statistical significance.

21.7.4 Test Procedure and Report of Test of Earbud Samples

The sample pairs of earbuds were marked as A-1, A-2; B-1, B-2; C-1, C-2 and so on. These identification designators, the manufacturer and model number, the retail source, and the cost were recorded by the study team. The designator-identified earbud samples in their original packaging were provided to the testing service.

21.7.4.1. Recommended Earbud Testing Protocol

Testing to be performed monophonically using an ear simulator or artificial pinna. A mannequin with artificial ear should be used for selected earbuds to confirm the hearing simulator tests.

Quasi Free field or a reverberant acoustic testing environment was discussed, with quasi free field being the most representative of the actual conditions of earbuds use along the SCBT (hemi-anechoic over a reflecting plane).

Test Sound level should be approximately 70 to 80 dB—The typical ambient sound level in the test area was <50 dB and most narrow bands of frequencies were<40 dB.

As an additional test, the frequency response of selected samples should be measured over the bandwidth of interest to see if frequency response anomalies would unduly interfere with a warning signal.

21.7.4.2. Insertion Loss (IL) protocol:

Determine if the frequency spectrum of airborne excitation source is adequate over the bandwidth of interest.

Measure test system total noise floor (acoustical and electrical) with no excitation and no earbud, note result.

Acoustically check system dynamic range and accuracy with nominal 124 dB at 250 Hz from Pistonphone calibrator source.

Measure frequency response of system with acoustical excitation and no earbud, note result.

Measure with earbud L(eft) of pair (e.g., A-1/L) and note IL

Measure with acoustical excitation and earbud R(ight) of pair (e.g., A-1/R) and compare to results for L of pair

Note difference between no earbud and with earbud 1 of pair, (i.e., difference in IL between each bud of pair)

Repeat, with matching earbud sample (e.g., A-2/L and A-2/R as practicable to increase sample size and note all data

Repeat test procedure with next sample (e.g., B-1/L, B-1/R; *if necessary*, B-2/L, B-2/R)…

Evaluate insertion loss agreement between L and R of each sample pair (and if necessary to obtain more consistency, between A and B samples of each Brand/model), and among all samples tested

Determine if an additional sample of a particular earbud needs to be obtained and tested or if the Brand/model's performance is an outlier to be reported but not used in calculation of the aggregated data.

21.7.5 Testing Process

Most of the factory packaged, pre-marked earbud sets are shown in Photo 24-1, below before delivery to testing service.

Photo 21—1. Identical Pairs of Earbud Samples Marked and Ready for Delivery

Thirty unopened packages of earbuds were delivered by Parsons Brinckerhoff (PB) for testing. Fifteen of the thirty packages were labeled A1, B1, etc, through N1 and O1, and fifteen were labeled A2, B2, through N2 and O2. The pairs of earbuds in packages A1 and A2 were identical in terms of manufacturer and model number, as were those in packages B1 and B2, etc. through O1 and O2. Packages labeled A1, B1, through N1, O1 were cut open with a razor blade, carefully opened and the pair of earbuds and, if provided, its associated alternative size silicone rubber tips were placed into labeled zip-lock plastic sandwich bags for easier access and logistics. Eleven of the fifteen different models of earbuds were of the type that are designed to be inserted into the entrance to the ear canal (insert type) with soft silicone rubber tips. Four of the fifteen pairs were of the “original equipment” flat-face type that come with most MP-3 players and fit up against the opening to the ear canal by fitting loosely into the concha of the ear (concha type).

21.7.6 Earbud Frequency Response Measurements

The frequency responses of all of the “-1” pairs’ Left and Right earbuds were measured on a calibrated Brüel & Kjær 4175 ear simulator with a an associated DB 2012 ear canal extension and DP 0286 retaining collar. The microphone at the eardrum location in the ear simulator was affixed to a Brüel & Kjær 2639 microphone preamplifier which was powered by a Brüel & Kjær 2805 microphone power supply. A Brüel & Kjær 4220 Pistonphone, producing 123.3dB sound pressure level (SPL) at 250Hz in the ear simulator, was used to confirm the 12.1 mV/Pa sensitivity that was specified on the calibration certificate for the ear simulator. The signal from the microphone preamplifier was applied to Channel B of a Brüel & Kjær 2035 dual-channel FFT signal analyzer. Electrical “pink” (equal energy per octave) noise was applied simultaneously to the earbud under test and to Channel A of the signal analyzer. The correct functionality of the analyzer was verified by its ability to pass all the manufacturer's internal digital and analog self tests. The analyzer was set up to measure frequency response over the frequency range from 3Hz to 6.4kHz using dual-channel 2048-line FFT analysis, Hanning weighting, and 256 linear averages. The narrow-band measurement results were converted by the analyzer to a 1/6th octave constant percentage bandwidth display extending over the frequency range between 92Hz and 5kHz; the 1/6th octave band values were stored by the analyzer in ASCII text format on an internal disc drive. Hard copy plots were made, as necessary for quick views during testing, using a Hewlett Packard plotter that was directly connected to the analyzer via the HPIB bus.

The frequency responses of the insert type of earbuds were measured using the bare Brüel & Kjær 4175 ear simulator with an associated DB 2012 ear canal extension in a stand-alone configuration. The insert earbuds were pushed into the open end of the ear canal simulator extension using light finger pressure sufficient to obtain an acoustic seal at the interface between the rubber tip of the earbud under test and the entrance of the simulated ear canal as shown in Photo 21-2, below. The adequacy of the seal was confirmed by the absence of any gross droop of the response below 500Hz in the frequency response measurement. When necessary, light finger pressure was used to prevent the earbud under test from either sliding or creeping out of the entrance of the ear simulator.

Photo 21—2. Earbud Inserted into Ear Simulator In Front of Excitation Source

The frequency responses of the flat-front, loose-fit concha earbuds were measured using a silicone rubber KEMAR right-ear pinna that was installed on the Brüel & Kjær ear simulator. The concha loose-fit earbud under test was fitted into the concha of the KEMAR rubber pinna and was held in place by the elasticity of the pinna in a manner that is virtually identical to the way it would be held in place in the concha of a human ear.

21.7.7 Earbud Attenuation Measurements

Measurements of earbud attenuation were made using a calibrated Brüel & Kjær 4175 ear simulator with a an associated DB 2012 ear canal extension and DP 0286 retaining collar. The microphone at the eardrum location in the ear simulator was screwed onto Brüel & Kjær 2639 microphone preamplifier which was powered by a Brüel & Kjær 2805 microphone power supply. A Pistonphone producing 123.3dB SPL at 250Hz in the ear simulator was used to confirm the 12.1 mV/Pa sensitivity that was specified on the calibration certificate for the ear simulator. The signal from the microphone preamplifier was applied to Channel A of a Brüel & Kjær 2133 real-time digital signal analyzer. The correct functionality of the analyzer was verified by its ability to pass both digital and analog internal self tests. The analyzer was set up to perform 1/3rd octave band analysis over the frequency range from 100Hz to 5KHz, using linear averaging for thirty seconds. The excitation signal for all measurements of earbud attenuation was broadband pink noise containing equal energy per octave. The electrical pink noise signal was generated by the analyzer and input applied to a to Brüel & Kjær 2706 power amplifier which was used to driving a Fulton Musical Industries FMI 60 loudspeaker to produce an acoustical output. The FMI loudspeaker has a flat frequency response (+/-3dB) over the frequency range from 100Hz to 8kHz. The un-weighted sound pressure level (SPL) as measured by the microphone in the ear simulator without an earbud present was approximately 100dB. The measurement results displayed consisted of 1/3third-octave band spectral levels over the frequency range from 100Hz to 5000Hz. The attenuation of each earbud was determined by making two measurements: one with the earbud under test in place, and another with the earbud under test removed. The 1/3rd octave band spectral levels of ambient room noise, in the absence of the loudspeaker pink noise excitation, was also measured as a check for a sufficiently low acoustical and electrical residual noise level or “noise floor”. Measurement results were stored by the analyzer in ASCII text format on an internal disc drive. Hard copy plots were made, as necessary for quick views during testing, using a plotter directly connected to the analyzer.

Measurements of the attenuation of the *insert* type earbuds were made using the Brüel & Kjær 4175 ear simulator with an associated DB 2012 ear canal extension. The ear simulator was located approximately 39 inches above a carpeted floor at the end of a flexible gooseneck that was attached to a microphone floor stand as shown in Photo 21-2. The orientation of the ear simulator was such that the longitudinal axis of the ear canal simulator was vertical. The insert earbud under test was pushed into the open end of the ear canal simulator using light finger pressure. When necessary, a thin, high-compliance rubber band (that was cut in half and taped to opposite sides the body of the ear simulator) was used to prevent the earbud under test from creeping out of the entrance of the ear simulator with a consequent loss of the acoustic seal. The FMI loudspeaker that provided the acoustic pink-noise excitation was placed on a high chair, elevated such that the center of the 8-inch-diamenter cone of the loudspeaker was located approximately 39 inches above the floor at the same height as the ear bud under test. The distance between the loudspeaker and the ear simulator was measured and set to approximately 36± inches, thus the test ear bud was in the direct field of the acoustic excitation. The distance between the ear simulator and the nearest reflecting surface of interest (closest wall) was approximately seven feet, and the distance between the ear simulator and the high vaulted ceiling was in excess of ten feet.

Measurements of the attenuation of *concha* type loose-fit earbuds were made in a manner that was identical to the measurements of the attenuation of insert earbuds, but with the silicone rubber KEMAR right-ear pinna installed on the ear simulator. The orientation of the pinna was such that the wavefront of sound produced by the loudspeaker passed over the pinna as it would if a human subject were looking directly at the loudspeaker. The flat-front loose-fit earbud under test was placed into the concha of the rubber pinna and was held in place by the elasticity of the pinna in a manner that is virtually identical to the way it would be held in place in the concha of a human ear. Photo 21-3shows the test fixture with a control earplug inserted.

Photo 21—3. Close up of KEMAR Rubber Pinna Used for Testing the Loose Fit, Flat-faced Concha Type Earbuds. Shown with EAR© Insert Hearing Protector (earplug) Tested as a Control

In order to evidence the similarity between stand-alone test fixture measurements and earbuds worn by a human, measurements of the attenuation of several insert type earbuds were also made with the ear simulator installed in the right ear of a clothing store mannequin. The mannequin was positioned such that it faced the loudspeaker with the entrance of the ear simulator being approximately 39 inches above the carpeted floor, and the distance between the ear canal and the center of the loudspeaker being again set at approximately 36± inches. The insert earbud under test was pushed into the mannequin-mounted ear simulator using light finger pressure, and was held in place with a small, ¼ inch-diameter wad of sticky, viscous modeling clay that was placed between the plastic housing of the earbud and a nearby ridge on the mannequin's pinna. This test set up is shown in Photo 21-4.

Photo 21—4. Mannequin Facing Excitation Source

Based on the above described orientation of the acoustic test fixtures, the excitation source, and the dimensions from the test fixture to the nearest surfaces of interest, the overall acoustic test condition specified by Parsons Brinckerhoff of essentially free-field hemi-anechoic (over a reflecting plane), with a frontal source orientation (± 20°) (i.e., provides approximately grazing incidence of the ear bud with a potential audible warning signal source) was fulfilled.

21.8 Earbud Testing Results

The results of the earbud testing are summarized in the following figures. They show the calibration point (upper tested limit of the system); the ambient or noise floor (the lower limit of the test system); the condition of excitation signal active but with no earbud present; and the resultant difference in sound level created by the attenuation of the earbud (Insertion Loss) for a mannequin, KEMAR ear, or an ear simulator test as appropriate for the earbud under test. Also shown is the attenuation provided by an EAR© insert hearing protector used as a "control" to illustrate substantial attenuation.

A total of 22 headphone sets, thus 44 individual earbuds were tested. Based on the results of the testing, it was observed that the tested samples fell into four acoustic attenuation classes, categorized as A (best performance) through D (poorest performance). All the class D earbuds are the most common *concha*-type, flat-face devices that (to the study team's knowledge) are originally supplied with all MP3 players and Apple™ I-Pods.

A review of the attenuation performance of the earbuds (Figure 12-2) clearly indicates that the most common concha-style earbuds have virtually no effect on the audibility of the existing train horns or a WH or AWS type substitute system. The class C insert-style earbuds perform the same in the lower frequencies, with a slight attenuation improvement in the higher frequencies. The typically more expensive headphones in class B and the very few models in class A do exhibit a better ability to reduce exterior noise. However, the attenuation is applied equally to both audible warnings and ambient/background noise, thus the signal-to-noise ratio is maintained. More significant however, is that none of the earbuds provide attenuation close to that provided by a car "shell" when compared to data from Rapoza and from Fidell.

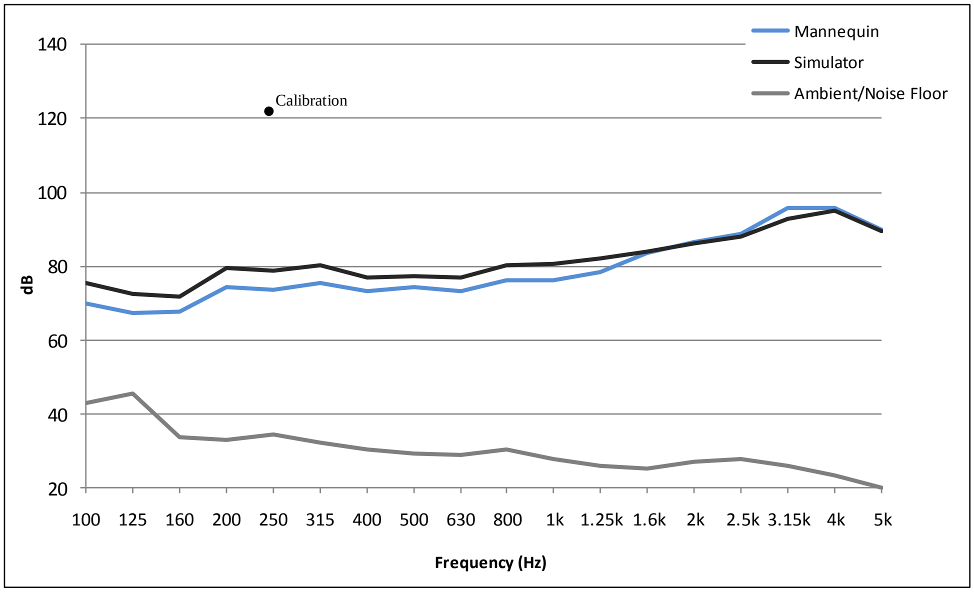


Figure 21—4. Test System Showing Calibration Level, Excitation Level for Mannequin and Simulator with Earbuds Not Inserted, and Noise Floor Level, All with Respect to Frequency

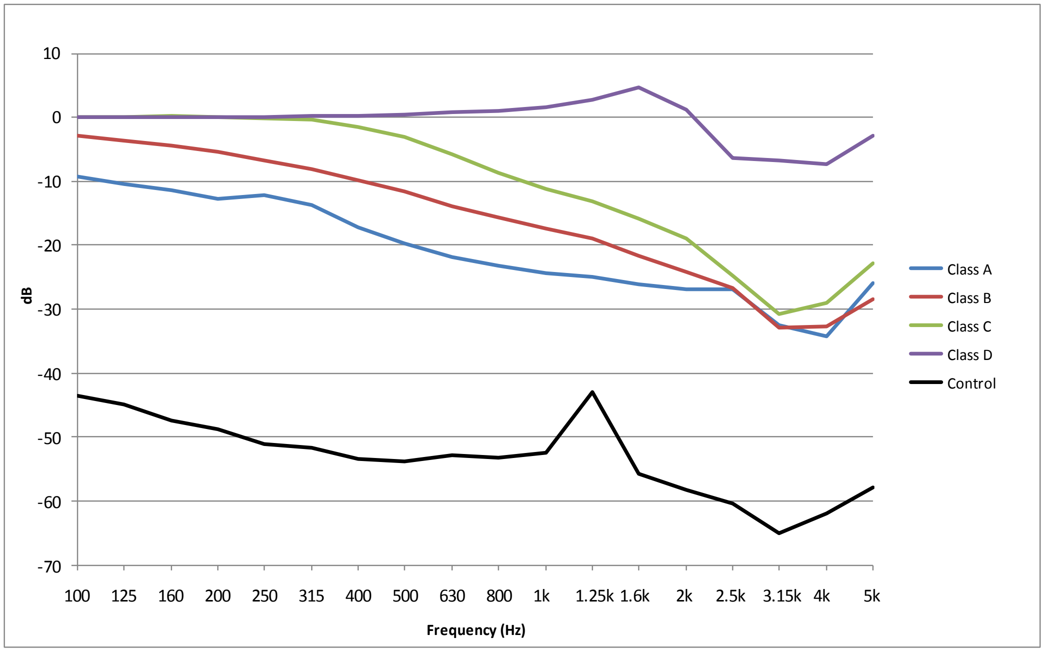


Figure 21—5. Attenuation (IL) of All 4 Classes, Plus Control Earplug

Table 21—10. Classification Table

Class A		**Class B**		**Class C**		**Class D (Concha)**	
Brand	*Price*	*Brand*	*Price*	*Brand*	*Price*	*Brand*	*Price*
Skullcandy	$21.99	Sony	$29.99	IMIXID	$14.99	Apple	$29.00
Sennheiser	$99.95	IMIXID	$14.99	iFrogs	$10.00	JVC	$10.99
Ultimate Ears	$49.99	2XL	$6.00	Memorex	$8.00	Panasonic	$6.00
Auvio	$19.19	Sony	$89.99	Vibe	$4.99	Maxell	$2.47
Sony*	$89.99	Auvio	$19.19				

*Sony headset with the ANC turned on

Individual Graphs for each class of earbud based on IL performance are presented on the following pages.

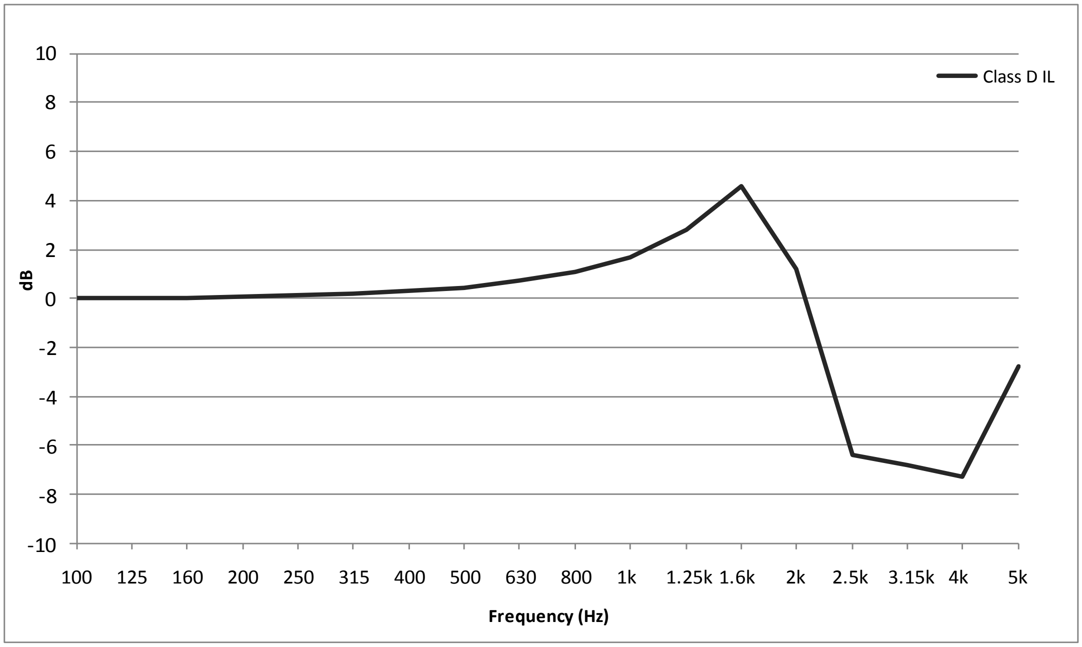


Figure 21—6. Class D, Concha

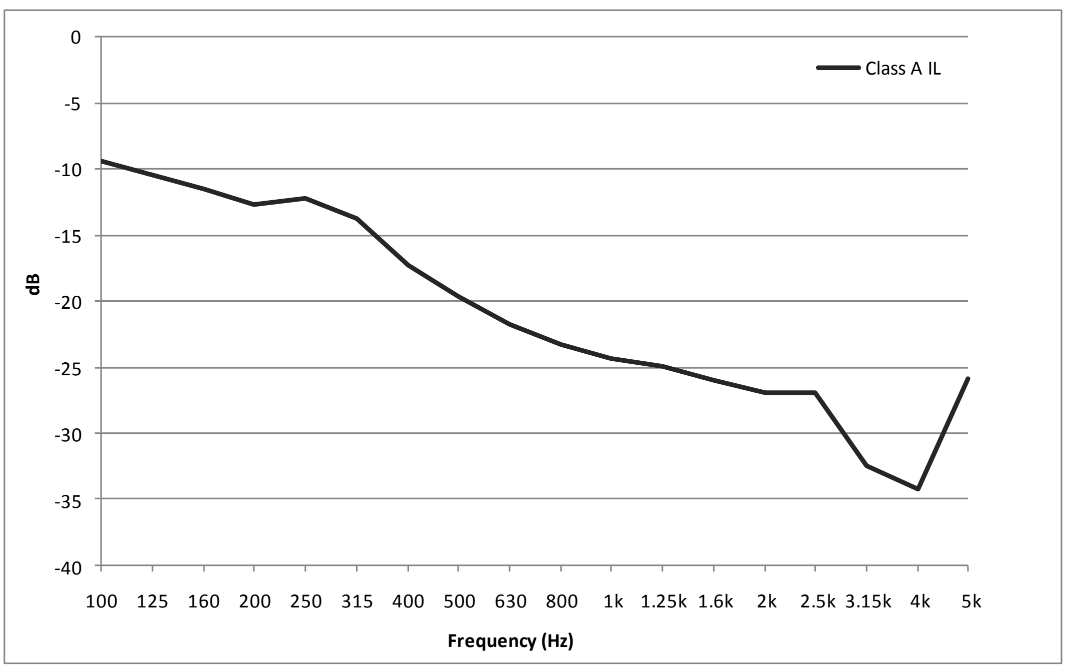


Figure 21—7. Class A

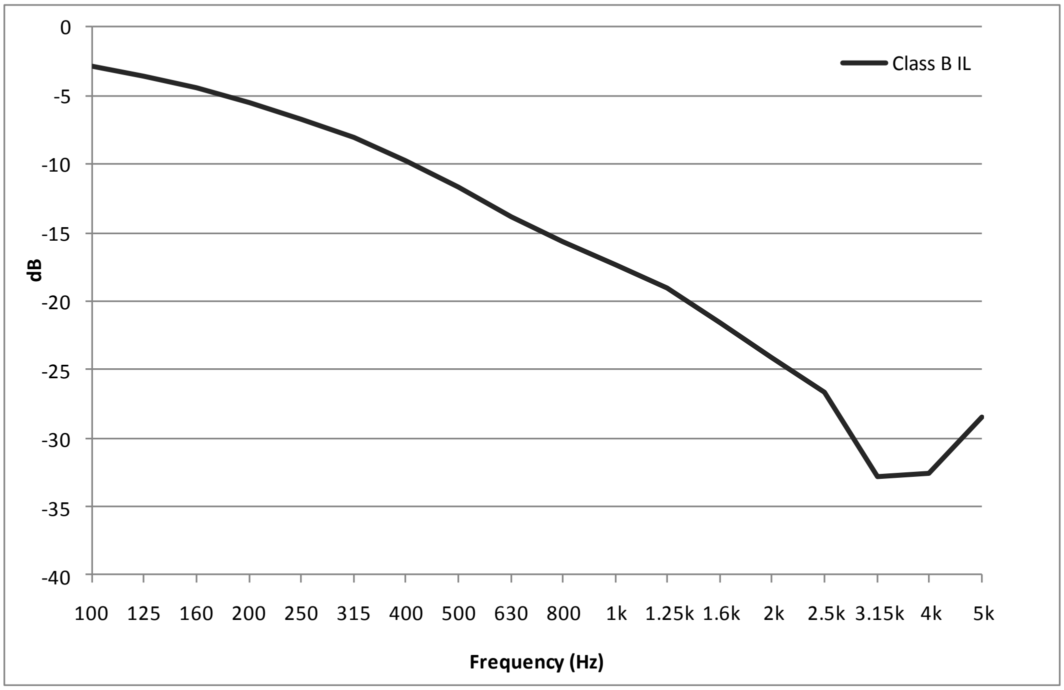


Figure 21—8. Class B

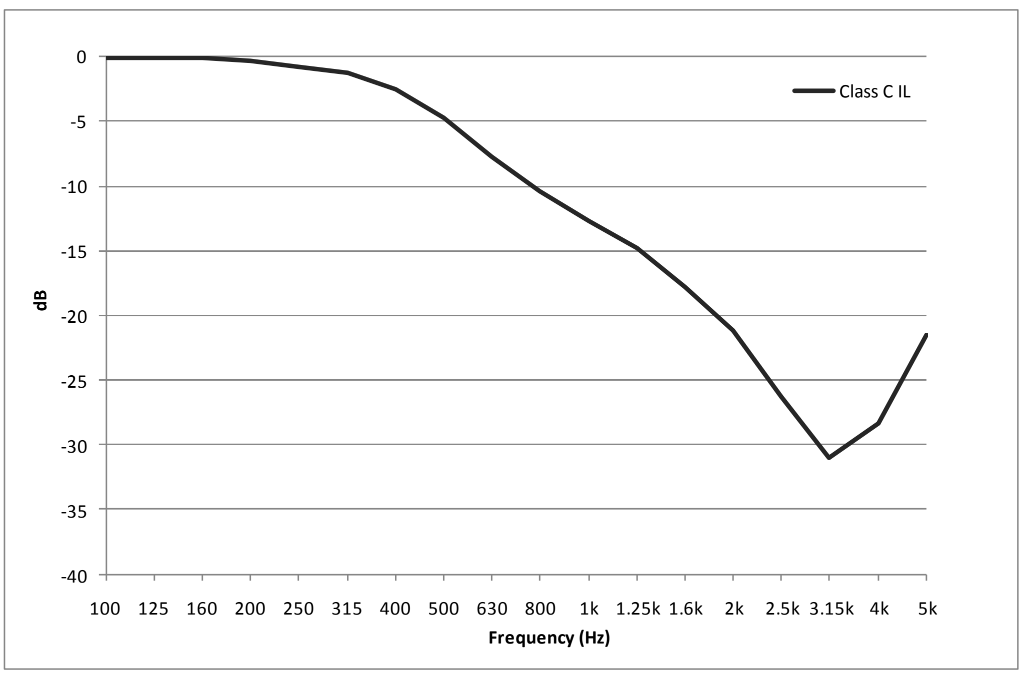


Figure 21—9. Class C

Table 21—11. Earbud Testing Equipment List

Manufacturer	Model	Serial No.	Description
Brüel & Kjær	4257	none	IEC-711 ear simulator
Brüel & Kjær	DB 2012	none	Ear Canal Extension
Brüel & Kjær	DP 0286	none	Retaining Collar
Brüel & Kjær	2639	1373843	Microphone Preamplifier
Brüel & Kjær	2807	866579	Microphone Power Supply
Brüel & Kjær	4220	221367	Pistonphone
Brüel & Kjær	2706	2175408	Power Amplifier
Brüel & Kjær	2133	1755266	Signal Analyzer
Knowles	DB 065	none	KEMAR Right Pinna
Fulton	FMI-60	none	Loudspeaker
Tektronix	475	B185689	Oscilloscope
Custom	none	none	Store Mannequin

CERTIFICATE OF CALIBRATION
FOR BRÜEL & KJÆR EAR SIMULATOR Type 4157

The Sensitivity is measured in a Special "T" Coupler Pistonphone with the 4157 being compared to a **Brüel & Kjær 9545** referenced by **4231 # 1839105**
Calibrated on Date: **29 APR 2010**
Due: **29 APR 2011**

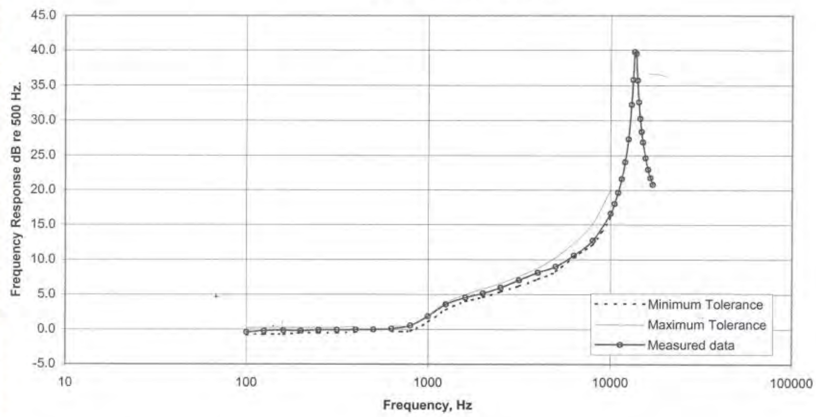
a) Estimated uncertainty of comparison:
± ***0. 13*** dB at 95% confidence level.

b) Estimated uncertainty of 4231
± ***0. 13*** dB at 95% confidence level.

c) Absolute uncertainty:
Sq. Root (a^2+b^2) = ***0.18*** dB at 95% confidence level.

Ear Simulator Type: **4157**
Serial No. **N/A**
ID # **N/A**
With built in Microphone **4134# N/A**
and Preamplifier **2639 # 1373843, ID# N/A**
This calibration is traceable to:
NIST Test # **822/277993-09, D1280**
System Sensitivity (4157 with 4134 and Preamplifier at 250 Hz)
S : **-38.32** dB re 1 Volt/Pa or **12.13** mV/Pa
Open Circuit Sensitivity at 250 Hz
S_o : **N/A** dB re 1 Volt/Pa or **N/A** mV/ Pa

Artificial Ear Frequency Response: Type 4157
S/N NA : Measured 1 Dec 2010



The curve is the Ear Simulator frequency response recorded with a sender microphone 4136 as specified in the B & K instruction manual Type 4157
The curve was obtained as a system curve including the built in condenser Microphone Type 4134, and preamplifier

For further details regarding compliance To IEC 711, see Page 2

Condition of Test:

Ambient Pressure:	**994.14**	hPa
Temperature:	**23**	°C
Relative Humidity:	**28**	%
Polarization voltage:	**200**	V
Frequency:	**250**	Hz
Date of calibration:	**01 DEC 2010**	
Due for calibration	**01 DEC 2011**	

Calibration performed by

Torben Ehlert, Quality Assurance Manager
Certificate # **17895-1** **PO # Verbal**
For :**Custom Sound Systems/ Dr. Gary Sokolich**
Newport Beach, CA 92663

ODIN METROLOGY, INC.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS.
3533 OLD CONEJO ROAD, SUITE 125
THOUSAND OAKS, CA 91320
TEL. (805) 375-0830 FAX : (805) 375-0405

Note: At the time of calibration this Ear Simulator was performing within Mfg. specifications. Data is both "As Received" and "As Final"

Page 1 of 2

21.9 Typical Technical Specifications for AWS Loudspeakers

The loudspeakers presented below were selected for illustrative purposes only because they possess design and environmental considerations that are important for use in an AWS that is located outdoors next to the ocean. Similar devices may be more or less suitable for incorporation into the SCBT AWS.

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850T

Compound Diffraction Horn

COMMERCIAL

General Product Description

Model 850T is a wide-range, integrated horn and driver system with a single driver unit having two coaxial horns coupled to opposite sides of the driver diaphragm.

The folded construction of the rear horn coupled with the smaller dimensions of the front horn, present a 1,000 Hz acoustic crossover. This separation of frequencies provides a more extended high-frequency response and cleaner sound.

The 150° horizontal by 110° vertical dispersion pattern is beneficial in many applications requiring a wide coverage pattern. Furthermore, excellent loading is maintained to a low-frequency cutoff of 180 Hz.

Architects' and Engineers' Specifications

The loudspeaker shall be of the integrated driver and horn style, utilizing two coaxial horns coupled to opposite sides of the driver diaphragm and a larger horn compression molded from fiberglass, a zinc die-cast front horn and phenolic-constructed inner horns. The driver uses a high-temperature rated 5.2 cm (2.0-inch) diameter voice coil.

The axial frequency response will extend from 280 to 8,000 Hz and the horn shall exhibit a low frequency cutoff of 180 Hz. Sound pressure level will be 105 dB (1 W/1 M) with a 500 to 5,000 Hz pink noise signal applied, and the horn will produce a horizontal beamwidth of 150° and a vertical beamwidth of 110° at 2 kHz. The horizontal coverage shall be constant over the frequency range of 3 kHz to 10 kHz.

The loudspeaker shall be compression molded fiberglass capable of satisfactory mechanical performance in the temperature range from - 40°C to +40°C and not subject to sunlight embrittlement.

Other major external speaker parts shall be diecast zinc finished in gray polyester paint to match the molded horn parts. All components shall be resistant to damage from weather, moisture and fungus.

A swivel bracket capable of providing either vertical or horizontal installation and a variety of adjustments, is provided.

The loudspeaker shall be 52.0 cm (20.5 in.) high, 26.5 cm (10.5 in.) wide and 51.0 cm (20.0 in.) long. The loudspeaker shall be the 850T, which includes a 70-V transformer and weighs no more than 8.4 kg (19.0 lb).

Specifications:

Frequency Response:
280-8,000 Hz ±5 dB (see Figure 3)

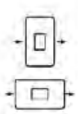
Power Handling, 8 Hours, 6 dB Crest Factor:
60 watts (500-5,000 Hz pink noise)

Transformer Taps and Impedances:
See Table 1

Sound Pressure Level at 1 Meter, 1 Watt Input Averaged, Pink Noise Band-Limited from 500 to 5,000 Hz:
105 dB

Horizontal Beamwidth:
150° @ 2 kHz (see Figure 2)

Vertical Beamwidth:
110° @ 2 kHz (see Figure 2)



Directivity Factor R_θ (Q):
5.2 @ 2 kHz

Usable Low-Frequency Limit:
180 Hz

Construction:
Large fiberglass compression molding with gray finish, front horn of gray die-cast zinc and phenolic compression-molded inner horns with steel "U" bracket

Voice-Coil Diameter:
5.08 cm (2.0 in.)

Magnet Weight:
0.45 kg (1.00 lb)

Magnet Material:
Strontium ferrite

Flux Density:
1.35 Tesla

Dimensions,
Height: 52.0 cm (20.5 in.)
Width: 26.5 cm (10.5 in.)
Length: 51.0 cm (20.0 in.)

Net Weight: 8.4 kg (19 lb)

Shipping Weight: 9.5 kg (21.0 lb)

Electro-Voice®

Installation

As shipped, the "U" bracket is in position for vertical mounting. For horizontal dispersion, (or for mounts where the bracket mounting holes must be vertical), move bracket to the rear mounting position. The horn can be mounted in a variety of horizontal and vertical configurations by using adjustments of the swivel connections (bracket to horn).

Polar Response

The directional characteristics of the 850T, with driver attached, were measured by running a set of horizontal/vertical polar responses, in a large anechoic chamber, at each one-third-octave center frequency. The test signal was one-third-octave pseudo-random pink noise centered at the indicated frequencies. The measurement microphone was placed 6.1 m (20 ft.) from the horn mouth, while rotation was about the wave guide geometric apexes. These axes of rotation are quite close to the apparent (acoustic) apexes across the frequency range of measurement. Errors attributable to the slight differences between the geometric and acoustic apexes are reduced to an inconsequential level by the relatively long, 20-foot measuring distance. The horn was suspended freely with no baffle. The polar plots shown in Figure 1 display the results of these tests. The center frequency is noted on each plot. The wider plot on each chart is the horizontal polar (-) and the narrower plot is the vertical polar (- - -).

Beamwidth

A plot of the 850T's 6 dB-down total included beamwidth angle is shown in Figure 2 for each one-third-octave center frequency.

Frequency Response

Figure 3 shows the axial frequency response of the 850T. It was measured at a distance of 1 meter, using a swept sine wave.

Transformer

A transformer and power selector switch are installed in the rear housing. Power taps for the transformer are listed in Table 1.

Low-Frequency Driver Protection

When frequencies below the low-frequency cutoff for the horn assembly are fed to the driver, excessive current may be drawn by the driver. For protection of driver, amplifier, and transformer, capacitor(s) in series with driver, or transformer primary are recommended. Table 1 (below) indicates recommended values. The values shown are for 200 Hz. Values for other frequencies can be determined by using the formula:

$$C = \left[C_{200} \times \frac{200}{f} \right]$$

C_{200} = Values shown in the following table
f = New Frequency

	70-Volt Lines	
Power	Impedance	Capacitance
60W	83	10
30W	166	5
15W	333	2
8W	625	1

TABLE 1 - Series Protection Capacitors for 200 Hz and Below

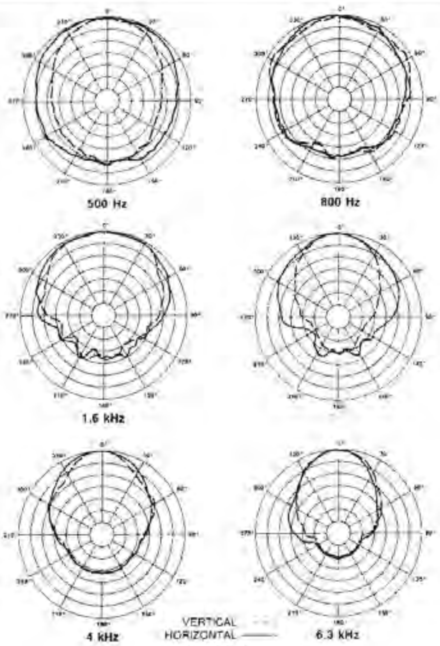


Figure 1
850T Polar Response

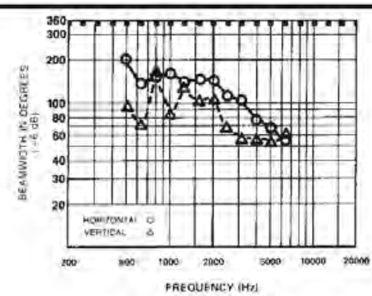


Figure 2
850T Beamwidth vs. Frequency

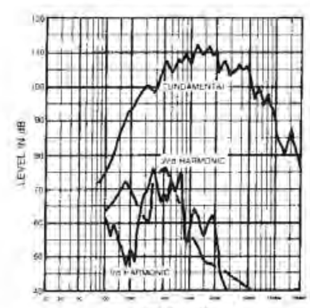


Figure 3
850T Frequency Response (1 watt at 1 meter)

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Canada 705 Progress Avenue, Unit 46, Scarborough, Ontario, Canada, M1H2X1, Phone: 416-431-4975, 800/881-1685, FAX: 416-431-4588
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Germany Hirschberger Ring 45, D94315 Straubing, Germany, Phone: 49 9421-706 392, FAX: 49 9421-706 267
France Parc de Courcerin, Allée Lech Walesa, Lognes, 77185 Marne La Vallée, France, Phone: 33/1-6480-0090, FAX: 33/1-6480-4538
Australia Unit 28, Block C, Slough Business Park, Slough Avenue, Silverwater, N.S.W. 2128, Australia, Phone: 61/2-9648-3455, FAX: 61/2-9648-5585
Hong Kong Unit E & F, 21/F, Luk Hop Industrial Bldg., 8 Luk Hop St., San Po Kong, Kowloon, Hong Kong, Phone: 852-2351-3628, FAX: 852-2351-3329
Japan 2-5-60 Izumi, Suginami-ku Tokyo, Japan 168, Phone: 81-3-3325-7900, FAX: 81-3-3325-7789
Singapore 3015A Ubi Rd 1, 05-10, Kampong Ubi Industrial Estate, Singapore 408705, Phone: 65-746-8760, FAX: 65-746-1206
Mexico Av Parque Chapultepec #66-201, Col. El Parque Edo. Mex. 53390, Phone: (52) 5358-5434, FAX: (52) 5358-5588
UK 4 The Willows Centre, Willow Lane, Mitcham, Surrey CR4 4NX, UK, Phone: 44 181 640 9600, FAX: 44 181 646 7084
Africa, Mid-East 12000 Portland Ave South, Burnsville, MN 55337, Phone: 952/887-7424, FAX: 952/887-9212
Latin America 12000 Portland Ave South, Burnsville, MN 55337, Phone: 952/887-7451, FAX: 952/887-9019

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Specifications subject to change without notice.

Cobreflex III

Folded Sectoral Horm

COMMERICAL

General Product Description

The Cobreflex III is a folded sectoral, wide-angle horn for use in public address, paging, and voice warning systems.

This folded sectoral construction results in both compactness and high efficiency when combined with appropriate compression drivers.

The patented (patent #4.176.731) folded design features two separate air columns in a single assembly that virtually eliminates high-frequency phase cancellation present in reentrant designs.

The 100-degree horizontal by 60-degree vertical dispersion pattern is beneficial in many applications requiring a wide coverage pattern. Furthermore, excellent loading is maintained to a low-frequency cutoff of 250 Hz.

The Cobreflex III is constructed from a non-resonant glass fibre reinforced polyester with a self-colored gray finish. A serrated positive-lock "U" mounting bracket is provided for maximum mounting flexibility and ease of installation.

University Sound® Series

Architects' and Engineers' Specifications

The horn shall be of the folded sectoral type featuring two separate air columns within the single assembly. It shall produce a horizontal beamwidth of 100 degrees and a vertical beamwidth of 60 degrees at 2.0 kHz. In addition, it shall provide useful acoustic loading at all frequencies above 250 Hz.

The horn shall be constructed from a non-resonant glass fibre reinforced polyester and self-finished in an ultraviolet-inhibiting gray.

A serrated, positive-lock "U" mounting bracket shall be affixed to the bell by self-locking nuts and shall provide orientation adjustment in all three planes.

The horn shall possess a throat of 2.54-cm (1.00 in.) diameter and shall be provided with a 1 3/8"-18 thread for the mounting of a compression driver. The horn shall be 36.8 cm (14.5 in.) high, 69.9 cm (27.5 in.) wide and 38.1 cm (15.0 in.) deep. It shall weight no more than 3.2 kg (7.0 lb).

The horn shall be the Cobreflex III folded sectoral horn.

Specifications:

Horizontal Beamwidth:
100° @ 2 kHz (see Figure 2)

Vertical Beamwidth:
60° @ 2 kHz (see Figure 2)

Directivity Factor R_θ (Q):
15.9 @ 2 kHz (see Figure 3)

Usable Low-Frequency Limit:
250 Hz

Construction:
Non-resonant glass-fibre reinforced polyester compression molding with self-colored gray finish. Positive-lock painted steel U-bracket.

Mechanical Construction of Driver:
Threaded metal throat insert to accommodate a screw-in driver with a throat opening of 0.7-inch to 1.0-inch diameter and a standard 1 3/8-inch thread.

Dimensions:
Height: .... 36.8 cm (14.5 in.)
Width: .... 69.2 cm (27.5 in.)
Depth: .... 38.1.0 cm (15.0 in.)

Net Weight: .... 3.2 kg (7.0 lb)

Shipping Weight: .... 4.5 kg (10.0 lb)

Recommended Horns:

ID30C-8	7110XC	ID30C-16	1824S
ID30CT	1828C	ID60C-8	1828T
ID60C-16	1829	ID60CT	1829T
ID75			

Electro-Voice®

Polar Response

The directional characteristics of the Cobreflex III, with driver attached, were measured by running a set of polar responses, in a large anechoic chamber, at each one-third-octave center frequency. The test signal was one-third-octave pseudorandom pink noise centered at the indicated frequencies. The measurement microphone was placed 6.1 m (20 ft.) from the horn mouth, while rotation was about the waveguide geometric apexes. These apexes of rotation are quite close to the apparent (acoustic) apexes across the frequency range of measurement. Errors attributable to the slight differences between the geometric and acoustic apexes are reduced to an inconsequential level by the relatively long, 20-foot measuring distance. The horn was suspended freely with no baffle. The polar plots shown in Figure 2 display the results of these tests. The center frequency is noted on each plot. The wider plot on each chart is the horizontal polar (–) and the narrower plot is the vertical polar (– – –).

Beamwidth

A plot of the Cobreflex III's 6-dB-down total included beamwidth angle is shown in Figure 1 for each one-third-octave center frequency.

Directivity

The axial directivity factor R_θ (formerly Q) of the Cobreflex III horn was computed at each one-third-octave center frequency from the horizontal/vertical polars and is displayed in Figure 3.

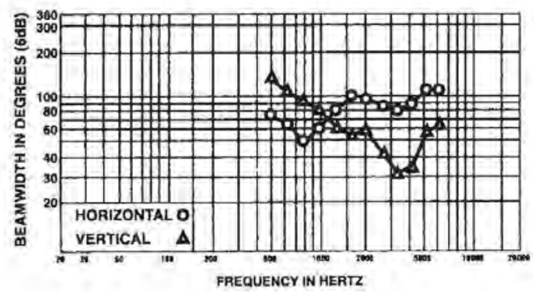

Figure 1.
Cobreflex III Beamwidth vs. Frequency

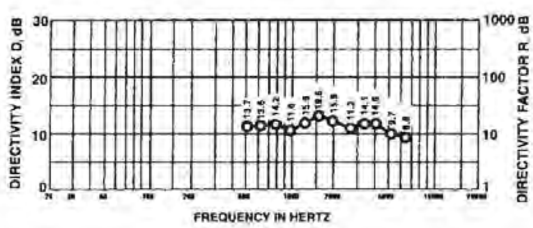

Figure 3.
Cobreflex III Directivity Factor and Directivity Index vs. Frequency

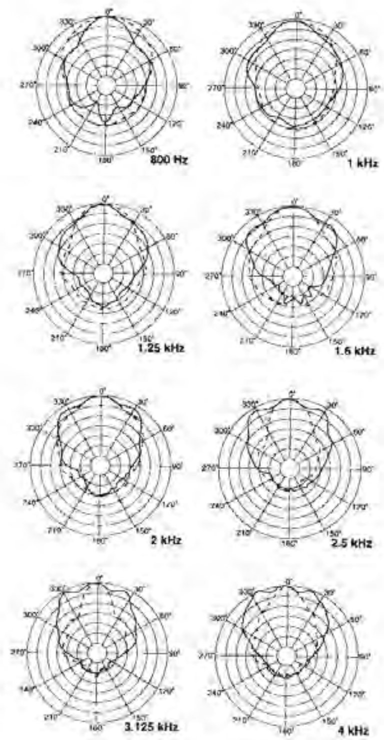

Figure 2.
Cobreflex IIB Polar Response

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Canada [illegible]
Switzerland [illegible]
Germany [illegible]
France [illegible]
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Specifications subject to change without notice

1829B
1829BT
Convertible Drivers

COMMERICAL

General Product Description

The ElectroVoice 1829B and 1829BT are heavy-duty convertible drivers for use in high-power public address installations.

The drivers have rugged phenolic diaphragms, two-inch diameter voice coils, and "rim centered" ferrite magnet structures for long life and reliability under extreme operating conditions.

The transformer model (1829BT) includes connections for 25V/70 V distributed systems and a power tap select switch.

The exterior is finished in durable waterproof paint, and all metal parts have been treated for resistance to high humidity and fungus.

Ideal for both indoor and outdoor applications, these drivers are well suited for any installation requiring rugged high-power performance.

University Sound® Series

Architects' and Engineers' Specifications

The loudspeakers shall be of the compression-driver type having a rugged phenolic diaphragm and a high-temperature rated 5.08-cm (2.0-in.) voice coil.

The loudspeakers) shall exhibit essentially flat power response from 280 to 8,000 Hz with a smoothly rolled-off response beyond. Their sensitivity, when mounted on a ElectroVoice FC100 horn, will be 105 dB (1 W/1 m) with a 500-to-5,000-Hz pink noise signal applied.

The loudspeakers) will be capable of handling a 60-watt, 500-to-5,000-Hz pink noise signal with a 6-dB crest factor for a period of eight hours.

The loudspeakers shall have a diameter of 13.5 cm (5.3 in.), the 1829, a length of 10.3 cm (4.1 in.) and the 1829BT, a length of 16.2 cm (6.4 in.). Both shall have a throat opening of 3.0 cm (1.2 in.) with a 1 3/8"-18 thread for mounting.

The loudspeakers are the ElectroVoice 1829BT which includes a 70V line-matching transformer (see Table III) and weighs no more than 3.2 kg (9.8 lb), and the ElectroVoice 1829B which has a nominal impedance of 16 ohms and weighs no more than 4.5 kg (7.0 lb).

Specifications:

Frequency Response:
...... 280 - 8,000 Hz (see Figure 2)

Power Handling, 8 Hours, 6-dB Crest Factor:
...... 60 watts (500-5,000 Hz pink noise)

Impedance, Nominal: ...... 16 ohms
Minimum: ...... 11 ohms (FC100 horn)

Sound Pressure Level at 1 Meter, 1 Watt Input Averaged, Pink Noise Band-Limited from 300-3,000 Hz:
...... 105 dB on FC100 horn

Voice Coil Diameter: ...... 5.08 cm (2.0 in.)

Magnet Weight: ...... 0.45 kg (1.0 lb)

Magnet Material: ...... Strontium ferrite

Flux Density: ...... 1.38 Tesla

Construction:
Rugged weatherproof finish for outdoor use

Mechanical Construction of Driver:
1 3/8"-18 thread allows the 1829B to be mounted on most University Sound horns

Dimensions:
Diameter: ...... 13.5 cm (5.3 in.)
Length:
1829B: ...... 10.3 cm (4.1 in.)
1829BT: ...... 16.2 cm (6.4 in.)

Net Weight:
1829B: ...... 3.2 kg (7.0 lb)
1829BT: ...... 4.5 kg (9.8 lb)

Shipping Weight:
1829B: ...... 3.5 kg (7.8 lb)
1829BT ...... 4.8 kg (10.6 lb)

Recommended Horns:
FC100 SMH Cobraflex III
Cobraflex IIB

Electro-Voice®

Installation

For use with compound horns, remove both protective plastic caps and the plastic foam loading plug from the rear. Note: front end is the one with wiring terminals.

Next, screw the large horn section onto the rear of the driver and the small section onto the front. Hand tighten to slightly compress rubber gaskets.

For use with all other horn types, rear cap and foam plug are left in place and firmly handtightened with horn attached to the front directly to the driver terminals.

Transformer Model (1829BT)

The input terminal and power selection switch is installed in the base of the housing. See Figure 5 below.

Low-Frequency Driver Protection

When frequencies below the low-frequency cutoff for the horn assembly are fed to the driver, excessive current may be drawn by the driver. For protection of driver, amplifier, and transformer (if driver with built-in transformer is used), capacitor(s) in series with driver, or transformer primary are recommended. Table I indicates recommended values. The values shown are for 200 Hz. Values for other frequencies can be determined by using the formula:

$$C = \left[C_{200} \times \frac{200}{f} \right]$$

C_{200} Values shown in the following table
f = New Frequency

For drivers without transformers: 8-ohm driver, 25 V - 100 *mf* 150 Vdc or 150 V non-polarized electrolytic, or two 150 Vdc electrolytics of two times required value in series, back to back, for 70 volt lines.

Horn	SPL for 1 W @ 1 M
HC400	106 dB
SMH	109 dB
PH	108 dB
FC100	105 dB

Table I.
Sound Pressure Level for 1829 with Various Horns

	70-Volt Lines	
Power	**Impedance**	**Capacitance**
60 W	83	10
30 W	166	5
15 W	333	2
8 W	625	1

Table III. Series Protection Capacitors for 200 Hz and Below

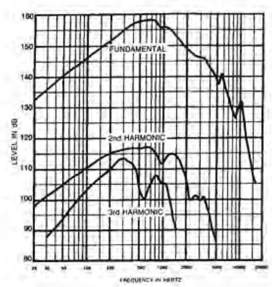

Figure 1.
Disortion Response - Plane Wave Tube (1 inch) (6 watt input)

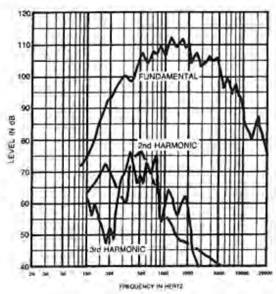

Figure 2.
Disortion Response - FC100 Horn

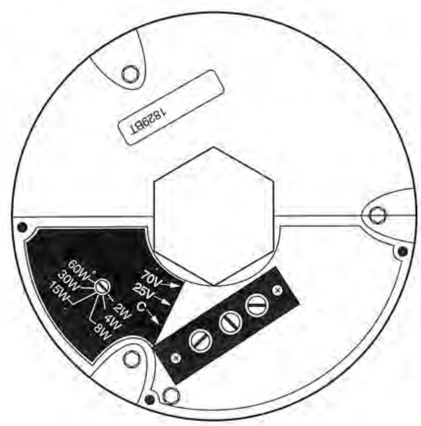

Figure 5

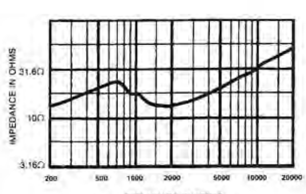

Figure 3.
Impedance Response - Plane Wave Tube (1 inch)

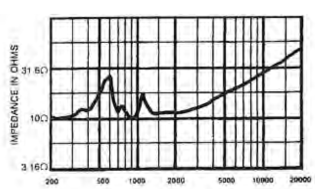

Figure 4.
Impedance Response - FC100 Horn

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Canada	705 Progress Avenue, Unit 46,Scarborough, Ontario, Canada, M1H2X1,Phone: 416-431-4975, 800-881-1685, FAX: 416-431-4588
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France	Parc de Courcerin, Alle Lech Walesa, Lognes, 77185 Marne La Vallee, France, Phone: 33/1-6480-0090, FAX: 33/1-6480-4538
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Singapore	3015A Ubi Rd 1, 05-10, Kampong Ubi Industrial Estate, Singapore 408705, Phone: 65-746-8760, FAX: 65-746-1206
Mexico	Av. Parque Chapultepec #66-201, Col. El. Parque Edo. Mex. 53390, Phone: (52) 5358-5434, FAX: (52) 5358-5588
UK	4, The Willows Centre, Willow Lane, Mitcham, Surrey CR4 4NX, UK, Phone: 44 181 640 9600, FAX: 44 181 646 7084
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The Vernal 15

Ultra-compact, IP56 Weatherproof, 2-Way Full-range Loudspeaker.

The smallest of the MP Series of loudspeakers, the Vernal 15 is the perfect loudspeaker for any application where ultra-compact size and powerful full-spectrum sound are required. No other ultra-compact loudspeaker can rival the sensitivity and power-handling of the Vernal 15.

The Vernal features a true horn-loaded high frequency driver, resulting in much better throw and vocal intelligibility in high ambient noise environments than any dome-tweeter loaded loudspeaker. Only the highest quality metalized polypropylene capacitors and heavy gauge inductors are used in Technomad networks, minimizing insertion loss and producing smooth response throughout the operating bandwidth.

The Vernal is extremely weather resistant. Both the rubber-surround polypropylene mid/bass driver and the high-frequency compression driver offer excellent performance in even the most severe weather conditions. The three layer WeatherTech™ grill system sheds water off of the loudspeaker before it can penetrate to the components and all internal assemblies are treated to prevent damage by any moisture which gets past the grill. Rust is never a problem as all external hardware, including the grill, is black stainless steel. Technomad cabinets are cast from Mil-Spec polyethylene, carry a 10-year warranty and are self-draining. From the inside out, every part of every Technomad loudspeaker is designed to provide optimum performance in even the worst conditions.

The Vernal is designed for maximum flexibility and ease of use. Developed with the needs of contractors in mind, it incorporates a wide range of mounting options: For easy suspension – threaded 1/4-20 inserts on each side. Compatible with a wide range of wall-mounting brackets including models from Omnimount™, APC™, and Quik-Lok™ – two 1/4-20 inserts on the back. The Vernal is also compatible with Bose™ mounting hardware.

Combining excellent sound reproduction with high power-handling in an architecturally neutral cabinet, the Vernal 15 is used worldwide in applications such as resorts, theme parks, restaurants, residences, and cruise ships.

Specifications

Size	9.1" high x 6.1" wide x 6.1" deep
Weight	8.5 lbs
Cabinet	One-piece 3/8" Thick Molded
Freq Response	100 Hz - 18 KHz (+/- 2 dB)
Sensitivity	91 dB SPL (1W/1M, swept sine)
Continuous Power	60 Watts (based on EIA test 426B)
Max Peak Power	120 Watts (based on EIA test 426B)
Dispersion/Range*	120° V x 120° H / 20 yds
Impedance	8 ohms (nominal)
Connector	1 X Screw Terminal
HF Driver	High-SPL, 1" Horn-loaded Compression Driver
LF Driver	5.25" Custom Polypropylene Driver
Crossover	Passive Internal

*Suggested effective operating distance, 85 dBa

Features:

- Superb Audio Quality
- Unrivaled Projection in the Ultra Compact Loudspeaker Class
- Three Layer, Chemically Treated, WeatherTech™ Grill
- Mil-Spec 810F Compliant
- Warranty – 10 Year Cabinet / 5 Year Hardware / 2 Year Electronics

Options:

- 14 Available Colors – black or white is Standard
- Dual Mode Operation – Multi-tap (10, 20, 40, 60 Watt) Internal 70 Volt Transformer, 8 Ohm
- Wallmount / Pole Mount Bracket / Yoke Mount
- PowerChiton Weatherproof Amplifier

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21.10 Consumer Protection and Safety Division Rail Crossings Engineering Section Meeting

Date: September 24, 2009

Location: San Clemente Trail

Subject: Trail and beach crossings field diagnostic review meeting

Attendees:

NAME	TITLE	REPRESENTING	CONTACT INFO.
Daren Gilbert	Supervisor, RCES	CPUC	Phone: (916) 324-8325 Fax: (916) 322-3041 Email: dar@cpuc.ca.gov
Dain Pankratz	Senior Engineer Supervisor	CPUC	Phone: (213) 576-7097 Fax: Email: dam@cpuc.ca.gov
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Charlie Hagood	Manager, Grade Crossing Safety	FRA	Phone: (559) 641-7649 Fax: Email: charles.hagood@dot.gov
John Shurson	Assistant Director Public Projects	BNSF Railway	Phone: (909) 386-4470 Fax: Email: John.Shurson@bnsf.com
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Justin Fornelli	Project Manager	PB (OCTA rep)	Phone: (714) 326-5474 Fax: Email: jfornelli@octa.net
Jim Holloway	Community Development Director	City of San Clemente	Phone: (949) 361-6106 Fax: Email: HollowayJ@san-clemente.org
Tom Bonigut	Acting Public Works Director	City of San Clemente	Phone: (949) 361-6187 Fax: Email: BonigutT@san-clemente.org
John Dorey	Citizen	San Clemente QZ Task Force	Phone: (949) 412-9413 Fax: Email: ajohndorey@gmail.com

PURPOSE:

The purpose of this meeting was to perform a field diagnostic of the crossings and the adjacent San Clemente Beach Trail, in their current configuration, to determine whether any further improvements are necessary and appropriate for overall safety and for the purposes of the City ultimately pursuing silencing the train horn at these crossings. Participating individuals represented the City, CPUC, FRA, Metrolink, BNSF Railway, and the Orange County Transportation Authority (OCTA).

BACKGROUND:

With the addition of the pedestrian crossings along the San Clemente Trail, designed to provide an improved trail experience as well as provide legitimate crossing locations for the 2.5 + million visitors to the San Clemente beaches each year, significant train horn noise resulted and appreciable trespassing across the tracks persists. Although the pathway for creation of a quiet zone on these pedestrian-only crossings remains muddled, the parties agreed to meet to consider what improvements, if any, might be necessary to account for the absence of the train horn, when a pathway forward is determined.

Because they are pedestrian-only crossings that are not within the confines of an FRA quiet zone, nor are they within ¼ mile of the end of a lawfully created FRA quiet zone, FRA indicates the crossings do not qualify for FRA quiet zone inclusion and the sounding of the horn is a State matter. State law in Public Utilities Code Section 7604 requires the sounding of the horn at these mainline crossings.

The City is exploring a number of options in seeking relief from the train horn noise, including crossing consolidation/closure, additional grade separations to replace current at-grade crossings, wayside horns, and other potential options.

A FRA Quiet Zone will be pursued for the City's northern-most crossing and the single pedestrian crossing within ¼ mile of it: Senda de la Playa highway-rail crossing and the North Beach Ped crossing. This diagnostic review looks at the remainder of the crossings and the separation between the trail and tracks for potential improvements.

NOTE: Recommended modifications are underlined in the meeting notes text.

San Clemente Trail – Northern segment

San Clemente Trail – Southern segment

See Quiet Zone Diagnostic Meeting notes dated 8/3/09 for specific notes on these locations:

<u>Senda de la Playa Highway-Rail Crossing</u> –

<u>San Clemente Metrolink Station</u> –

<u>North Beach At-Grade Pedestrian Crossing (MP 203.75)</u> –

<u>Trail along ROW (MP203.75-204.00) -</u> The trail between the North Beach crossing and the Dije Court crossing appears to be adequately fenced along its entire length. <u>Additional signage warning of possible fines for crossing the ROW at unauthorized locations is recommended.</u>

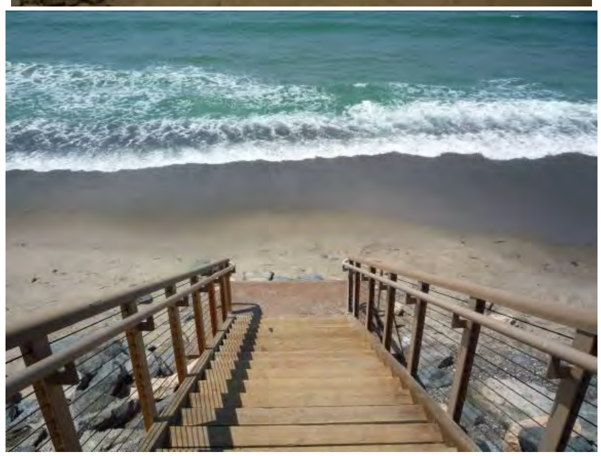
Fencing between North Beach and Dije Court crossings

Dije Court At-Grade Pedestrian Crossing (MP 204) - The crossing is pedestrian only, and is equipped with Commission standard 9 warning devices, with an extra set of backlights on each device. The crossing leads pedestrians directly to a stairway to a narrow stretch of beach in this area. Because of the narrow beach, pedestrians are prone to sitting on the boulder rip-rap in the area and occasionally violating the west side of the RR ROW. Warning signage of possible fines for violating the ROW is recommended. The parties discussed proposed improvements including; Swing Gates on east side of track only, due to space considerations on the west side.

Djie Court ped crossing
Pedestrians congregating on the rip-rap south of the Dije Court crossing

Trail along ROW (MP204.00-204.10) - The trail between the Dije Court crossing and the El Portal crossing appears to be adequately fenced along its entire length. No recommendations for this segment.

El Portal At-Grade Pedestrian Crossing (MP 204.10) - The crossing is pedestrian only, and is equipped with Commission standard 9 warning devices, with an extra set of backlights on each device. The El Portal crossing is located about 400 feet south of the Dije Court crossing. This crossing also leads pedestrians directly to a stairway down to the narrow portion of beach.



El Portal crossing Beach stairway at El Portal crossing

Parties were in general agreement that the crossing is redundant. Due to concerns such as, poor line-of-sight, proximity to nearby crossings (including the El Portal grade separated underpass) and train horn noise, crossing closure is recommended. At a recent San Clemente community meeting, citizens discussed the closure of the El Portal crossing. Given their responses, the City is considering closure of this crossing. If the crossing is not closed, it should have swing gates installed on the east side, similar to Djie Court crossing.

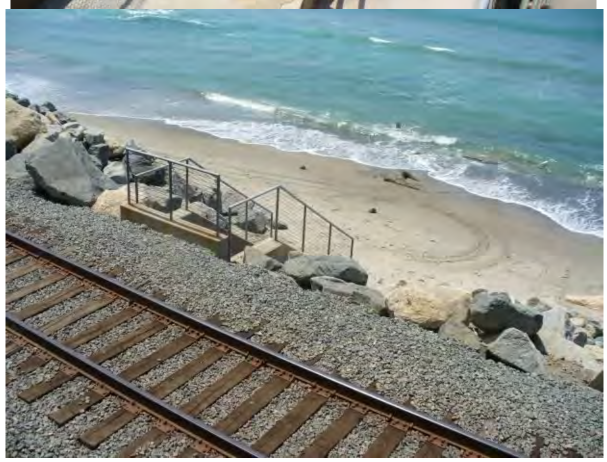
> NOTE*UPDATE: 10-20-2009 - The City reports that citizen opposition to closure at the City Council meeting, as well as concerns regarding Coastal Commission reaction to closure resulted in the Council voting to postpone indefinitely the issue of closing the El Portal at-grade crossing.

El Portal Grade-Separated Pedestrian Crossing (MP 204.11) Immediately south (approximately 50 feet) of the El Portal at-grade crossing is the El Portal grade-separated pedestrian crossing with a stairway off the trail leading to it. No Recommendations.

El Portal Grade-Separated crossing

Trail along ROW (MP204.10- Trail Boardwalk) - The trail between the El Portal at-grade crossing and the beginning of the trail boardwalk appears to be adequately fenced along its entire length. Warning signage of possible fines for violating the ROW is recommended at certain locations, such as the start of the boardwalk, where the boardwalk railing and adjacent fence may invite climbing.

Mariposa Grade-Separated Pedestrian Crossing - At the south end of the trail boardwalk there is the Mariposa grade separated crossing. No recommendations.



Mariposa grade separation

Trail along ROW (Trail Boardwalk to MP 204.54) - The trail between the south end of the boardwalk and the Linda Lane grade-separated crossing appears to be adequately fenced along its entire length. Warning signage of possible fines for violating the ROW is recommended at certain locations, such as the start of the boardwalk.

Linda Lane Grade-Separated Pedestrian Crossing (MP 204.54) – The Linda Lane grade-separated crossing is accessible from a nearby parking lot and has smoothly sloping ramps from both the parking lot/Linda Lane from the south, and from the trail on the north. No Recommendations.

<u>Trail along ROW (MP 204.54 – MP 204.60) -</u> The trail between the Linda Lane grade-separated crossing and Corto Lane at-grade pedestrian crossing appears to be adequately fenced along its entire length. <u>Warning signage of possible fines for violating the ROW is recommended at certain locations.</u>

<u>Corto Lane At-Grade Pedestrian Crossing (MP 204.60)</u> - The crossing is pedestrian only, and is equipped with Commission standard 9 warning devices, with an extra set of backlights on each. The trail crosses from the land side of the tracks north of the crossing to the beach side of the tracks south of the crossing, so all trail users must cross at this point. Southbound peds on the trail would benefit from <u>trimming several of the trees in the southeast quadrant of the crossing to improve sightlines looking south down the track</u>. <u>Swing gates on both approaches are recommended.</u> At the crossing a public restroom is on the beach side of the tracks. There is fencing on the beach side of the crossing going north approximately 30 feet, however, it is not having the intended affect, and well worn trails from the beach side leading to the end of the fence, where pedestrians cut to the track side of the fence and walk the 30 feet along the ROW to access the crossing. Additionally, there is a gap between the end of the fence nearest the crossing and the channelization along the beach side of the trail, allowing pedestrians to shortcut behind the restroom building to get to the crossing along a well worn but unimproved pathway. Parties recommended that the fencing on the beach side north of the crossing be extended further north to the rip-rap, with a sign placed on the beach side at the end of the fence warning of the prohibition and fines for violating the ROW. Additionally, parties recommend that the unimproved pedestrian pathway either be blocked/fenced, or preferably improved to provide a legitimate pathway north from the crossing on the beach side. Simply closing that route may promote further trespassing from areas north of the crossing to the ROW.

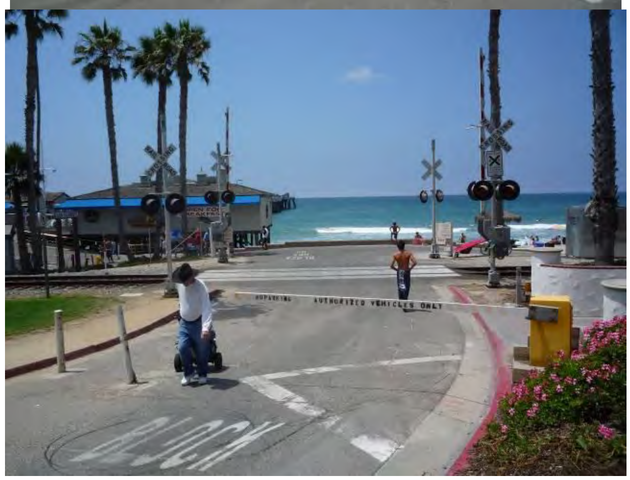
Corto Lane crossing - Well worn path going north on beach side

End of fence north of crossing on beach side

Trail along ROW (MP204.60-204.70) - The trail between the Corto Lane crossing and the Pier Access Road crossing, located on the beach side of the tracks, appears to be adequately fenced along its entire length. Fencing along this segment is the taller, 6 foot vandal resistant type. No recommendations along this segment.

Pier Access Road At-Grade Private Crossing (MP 204.70) – This crossing is a private at-grade highway rail crossing used by local businesses at the pier for deliveries and by employees and beach patrol/lifeguards. It is equipped with Commission standard 9 warning devices, with an extra set of backlights on each device, as well as an off-quadrant Commission standard 8 warning device on both approaches. The OCTA/Metrolink Pedestrian Improvement Project will add exit gate warning devices on both approaches, pedestrian improvements to the sidewalk, fencing, and channelization in all quadrants, as well as improved signage to this crossing. A GO88 request was approved for those enhancements on July 23, 2009.

There is no parking on the beach side of the tracks at the pier, however there is an employee parking area and small building housing the beach patrol/lifeguard offices north of the crossing. There is a non-railroad parking lot gate arm preventing public access in advance of the crossing on the westbound approach. Although some steps have been taken to limit pedestrians over this at-grade crossing, anecdotal evidence suggests well over 75% of pedestrians crossing the tracks to access the pier and beach in the vicinity use it rather than the pedestrian tunnel about 80 feet further south. OCTA funded improvements here will likely shift more ped traffic to the tunnel, but the parties acknowledge that any shift is likely to be modest, and most pedestrians will continue to use the at-grade crossing, as it is more of a direct route from parking areas east of the tracks. The City also noted the lack of ADA compliant pathways at the nearby tunnel.



CPUC has verified that the approved GO88 authority to improve the crossing under the OCTA/Metrolink Pedestrian Improvement Project includes additional fencing along the open grassy area east of the tracks (SE quadrant), between the Amtrak platform and the crossing.

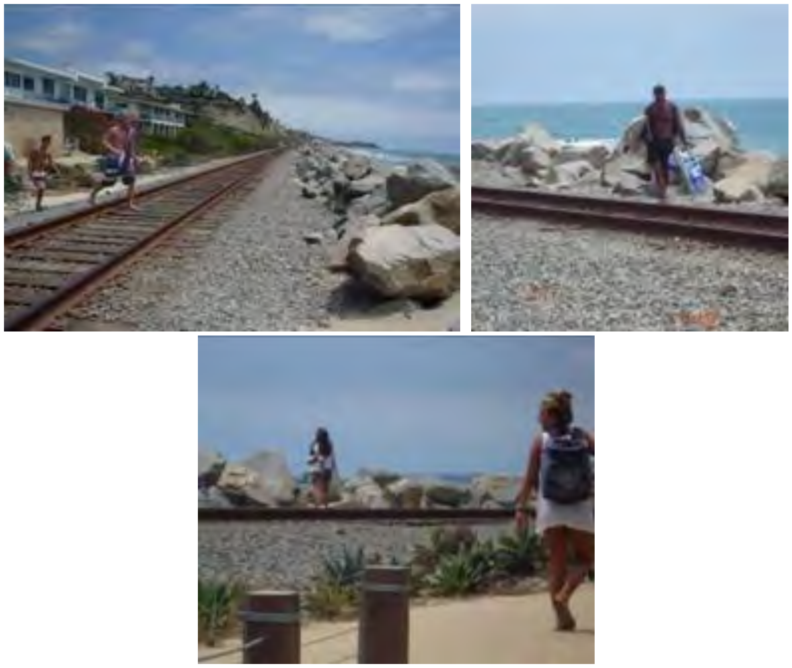
Pier/Amtrak Station Pedestrian Tunnel (MP 204.71) – This crossing is a public pedestrian grade-separated crossing located at the San Clemente Pier, about 100 feet south of the at-grade Pier Access Road private crossing. It is underutilized and more efforts should be made to encourage its use. The City noted that the pedestrian tunnel requires that steps be negotiated upon both entering and exiting the tunnel, and that it is not ADA compliant. Increased use may be further promoted by making the tunnel ADA compliant.

Esplanade Overhead Grade-Separated Pedestrian Crossing (MP 205.10) - The crossing is a pedestrian-only grade-separation connecting the trail and beach west of the tracks with San Clemente city streets east of the tracks. No recommendations.

Trail along ROW (MP204.71-205.20) - The trail between the Pier/Amtrak grade separated tunnel crossing and the T Street at-grade crossing, located on the beach side of the tracks, is adequately fenced along its entire length. Fencing along this segment is the taller, 6 foot vandal resistant type. No recommendations along this segment.

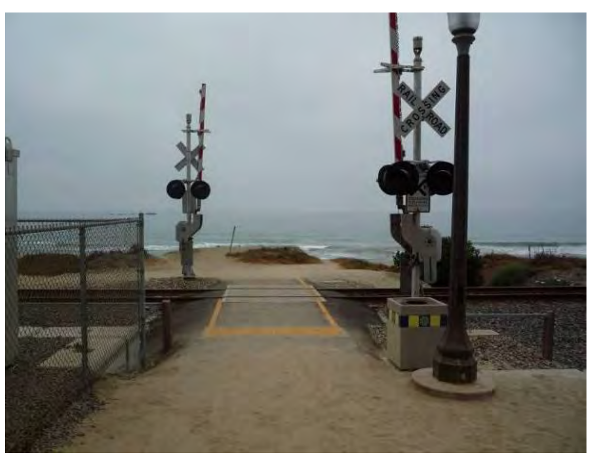
T-Street At-Grade Pedestrian Crossing (MP 205.20) - The crossing is pedestrian only, and is equipped with Commission standard 9 warning devices, with an extra set of backlights. The T-Street crossing is where the San Clemente trail crosses over the tracks, with the trail north of the crossing on the beach side and the trail south of the crossing on the land (east) side. Some additional channelization or fencing is appropriate on the east side of the crossing where the trail turns to cross the tracks. There is evidence of unauthorized paths from around and behind the warning device bungalow in the NE quadrant, leading north where there is no trail. Missing retaining wall section may invite pedestrians down to the RR ROW from the unauthorized trail on that side and should be added; also, missing boards further north should be replaced. South of the crossing, fencing on the east side extends approximately 250 feet. Recommended improvements are addition of swing gates, which may require the crossing be widened.

Trail along ROW (MP205.20 -205.60) - The trail between the T Street at-grade crossing and the Lost Wind at-grade crossing, located on the land (east) side of the tracks, requires additional fencing to complete the fencing along its entire length. Clear evidence of goat trails and unauthorized pathways, as well as witnessing trespassing during our review are justification. Fencing is recommended to fence the gaps between the existing fencing. Fencing extends south from T Street, has a large gap of approximately 350 feet, then begins again behind the homes on Boca del Cannon, adjacent to the trail; has another large gap of approximately 750 feet; then is fenced for the last 300 feet before Lost Winds.



Pedestrians were observed trespassing where the fence is absent between T Street and Lost Winds

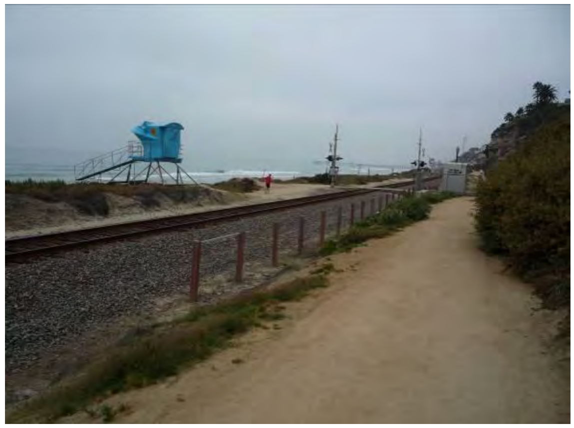
<u>Lost Wind Pedestrian Crossing (MP 205.60)</u> - The crossing is pedestrian only, and is equipped with Commission standard 9 warning devices, with an extra set of backlights. This crossing provides beach access, with the main trail remaining on the east side of the tracks. Because the beach-side terrain is not so imposing, peds are prone to cutting off the crossing to walk along the west side of the RR ROW, cutting down to the beach at various more convenient locations. <u>Recommendations are to extend fencing on the west side of the tracks approximately 350 feet north and 60 feet south from the crossing to prevent such trespassing to the ROW. Additionally, swing gates, which may necessitate widening the crossing are recommended.</u>



Lost Winds crossing

Pedestrians observed walking along the railroad Right-Of-Way near the Lost Winds Pedestrian Crossing.

Trail along ROW (MP205.60 -205.80) - The trail between the Lost Winds at-grade crossing and the Riviera grade separated (storm drain) crossing, located on the land (east) side of the tracks, requires additional fencing to complete the fencing along its entire length. Clear evidence of goat trails and unauthorized pathways, as well as witnessing trespassing during our review offer evidence of need. Fencing extends south from the Lost Winds crossing, has a large gap, then begins again for the last 200 feet before the Riviera crossing. Additional fencing is recommended to close the approximate 650 feet gap between the existing fencing



Fencing ends south of Lost Winds   Fencing ends north of Riviera crossing

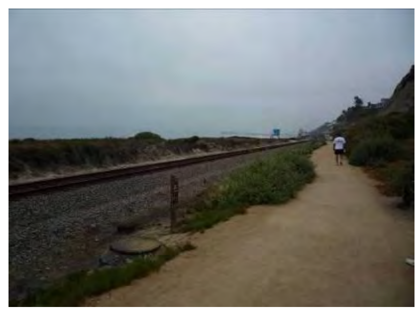
Riviera Grade-Separated Pedestrian Crossing (MP 205.80) - This grade-separated crossing is an improved storm drain converted to a pedestrian crossing, with an improved pathway off the main trail leading to it. Fencing exists north of the crossing and south of the crossing between the trail and tracks. No recommendations.

Trail along ROW (MP205.80 -205.90) - The trail between the Riviera grade separated crossing and the Montalvo grade separated crossing, located on the land (east) side of the tracks, appears to be adequately fenced along its entire length. Additional signage warning of possible fines for crossing the ROW at unauthorized locations is recommended.

Motalvo Pedestrian Crossing (MP 205.90) – This crossing is a grade-separated crossing with a trail leading to the grade separation under the tracks from the main trail. No recommendations.

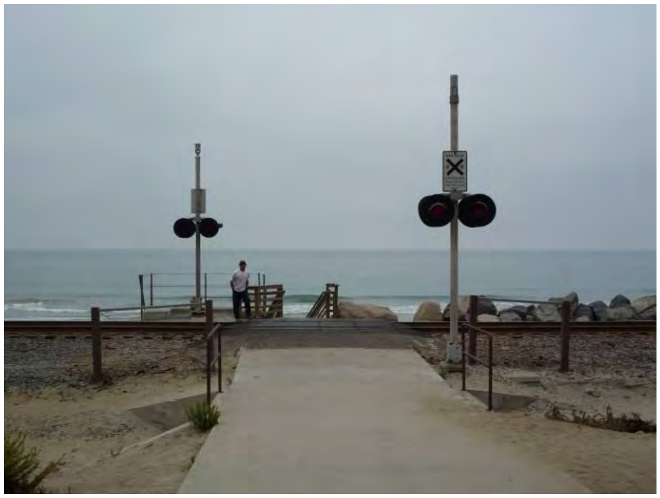
Trail along ROW (MP205.90 -206.00) - The trail between the Montalvo grade separated crossing and the Calafia Beach State Park crossing, located on the land (east) side of the tracks, requires additional fencing to complete the fencing along its entire length. Fencing ends approximately 150 feet south of the Montalvo grade separation and starts again about 500 feet north of the Calafia Beach crossing. Where the fencing meets the approach channelization for trail overcrossing on the south side of the Montalvo crossing, a relatively narrow 1 – 1.5 foot gap shows evidence of significant pedestrian trespass. It should be closed off or otherwise blocked, which the City of San Clemente stated they would be completing. Further south, the break in fencing of approximately 180 feet offers pedestrians clear access to the RR ROW and significantly promotes trespassing, and should be fenced. Clear evidence of goat trails and unauthorized pathways were evident, and CPUC Staff has witnessed trespassing at this fencing gap. The Calafia Beach parking lot is adjacent to the east side of the trail, and fencing gap offers a more direct route to beach areas north of the fencing.

> ***Action item** – City of San Clemente to block the gap between the ROW fencing and the south side trail channelization approaching the trail overcrossing of the Montalvo grade separation..



Gap at trail railing and ROW fence

Calafia Pedestrian Crossing (MP 206.00) - The crossing is pedestrian only, and is equipped with Commission standard 8 warning devices (i.e. No Gates)



CPUC representatives believe that as part of a settlement agreement stated in Decision D.04-05-053, all of the at-grade pedestrian crossings must be gated. Railroad and CPUC representatives believe that at a minimum the crossing must be gated to consider any horn silencing. The City does not agree and feels that a grade separation underpass of the tracks is the preferred solution here, but has not been able to acquire funding for such a project. City indicates it has studied adding gates here and that the ocean side landing and stairway presents design issues they cannot resolve. The City recommends interim measures consisting of wayside horns rather than gates. This issue must be resolved in order to move forward.

The parties discussed relocating gates from another Metrolink crossing to significantly reduce cost, if available. The crossing leads to a stairway down to the beach, and the landing/stairway will need to be modified to accommodate gates. The City should consider upgrading the rubber surface to concrete panels. Swing gates are recommended with the ped gates.

The city indicates that this crossing may be recommended for grade separation as a result of their grade-separation study, and if a funding source can be identified.

THE CITY INDICATES THAT THE FOLLOWING ITEM IS BEYOND THE SCOPE OF THE CITY'S BEACH TRAIL AND THAT THE RESPONSIBILITY WOULD FALL TO CALIFORNIA STATE PARKS, WHO IS RESPONSIBLE FOR THE PARKING LOT AND OTHER FACILITIES AT THIS LOCATION. BECAUSE THE IDENTIFIED CONCERNS AND PROPOSED SOLUTIONS URGE CHANGES THAT WILL ENCOURAGE BEACHGOERS TO UTILIZE THE CALAFIA CROSSING TO ACCESS THE BEACH, WE INCLUDE THE FOLLOWING COMMENTS BUT ACKNOWLEDGE THEY ARE NOT CITY RESPONSIBILITY.

Trail along ROW (MP206.00 - South) - Approximately 150 feet south of the Calafia crossing, fencing terminates. Pathways off the State Parks parking lot encourages beachgoers to head south from the parking lot, which results in significant trespassing across the RR ROW on State Parks property. There is a grade separated crossing under the tracks (State Parks Ped Underpass) approximately 0.3/mile south, but without fencing, peds often cut across the RR ROW at various locations. Steps should be taken to encourage such beachgoers to cross to the beach at the Calafia crossing, then walk south, perhaps with <u>signage at the southwest corner of the parking lot or possibly increased enforcement at that location</u>.

Pedestrians observed not using the trespassing along the RR ROW and crossing the railroad tracks just south of the Calafia pedestrian crossing.

<u>GENERAL ITEMS:</u>

Signage – Additional signage should be placed at regular intervals along the trail where they are currently absent or sparsely placed. They should also be placed at each crossing location, placed so as to be conspicuous where pedestrians might decide to step off the crossing onto the ROW as a shortcut north or south along the beach. Finally, at certain locations along the beach side, as indicated by goat trails or other visual evidence, signs should be placed directing pedestrians to legitimate crossings. This will help to prevent pedestrians from walking up onto the ROW to travel to nearby crossings.

Tactile Strips – ADA compliant tactile strips should be placed on all crossing approaches where they are not currently present.

Fence location – Metrolink expressed concern that fencing locations could hamper maintenance activities along the track bed and recommends that the fencing installations proposed avoid the drainage swale bottoms and be placed slightly (1-2 Feet) on the land-side, away from the ditch bottoms.

Wayside Horns – City of San Clemente has recently performed testing with directional wayside horns. The city tested the horns at 92, 85, 80 and 70-dBA. During the testing, the city surveyed the sound level at various locations including homes along the bluffs, at the crossings and along the beach. The city is preliminary recommending a level of 70-dBA and will provide test data. The City is exploring wayside horns at some or all of its at-grade pedestrian crossings to assist with quiet zone implementation.

> ***Action item*** – City of San Clemente to provide wayside horn test results to CPUC Staff.

Crossing Designation – Metrolink and CPUC staff to review current CPUC number designation of the Pedestrian crossings along the San Clemente alignment. Pedestrian crossings should be designated with "D" (not "DX") and the San Clemente crossing is an automotive crossing (should not be "D"). Some input from the city may be necessary to determine whether all crossings are properly designated as public or private. Given the public use, from CPUC perspective all crossings should be designated as public, except perhaps the San Clemente Pier private access road, but even that crossing is used by the public as a pedestrian crossing.

> ***Action item*** – CPUC Staff and Metrolink to evaluate / correct Pedestrian CPUC Number designation with advice from the City.

End

21.11 Hazard Analysis

21.11.1 Purpose

The purpose of this Rail Crossing Hazard Analysis (RCHA) is to identify potential hazards and systematically assess conditions which could potentially affect the safety of pedestrians and bicyclists at the railroad crossings. Identifying potential hazards will enable their elimination or control, together with their associated causes and effects. There are seven non-motorized-vehicle (i.e., pedestrian-bicycle only) at-grade crossings. Because the hazards associated with these crossings are the same, a single hazard analysis was performed for all seven at-grade crossings. The identified resolutions are applicable to all seven crossings.

21.11.2 Objectives

The objectives of this Rail Crossing Hazard Analysis are to identify hazardous conditions, which could exist; evaluate the effects of the hazards to pedestrians and bicyclists using the crossings; and define measures to eliminate or mitigate the identified hazards.

21.11.3 Definitions

The following are definitions of key terms used in the RCHA.

<u>Accident</u> – An unplanned event or series of events resulting in fatality, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment.

<u>Hazard</u> – Any real or potential condition that can cause injury, death, or damage to or loss of equipment or property; a prerequisite to an accident; the potential to do harm.

<u>Hazard Description</u> – A description of the specific hazardous condition.

<u>Hazard Effects</u> – The anticipated "worst case" results that are expected to occur if the hazard causes are left uncorrected and an accident occurs.

<u>Hazard Risk</u> – An expression of the impact and/or possibility of an accident in terms of hazard severity and hazard probability.

<u>Possible Controlling Measures</u> – Actions that can be taken to prevent the potential accident from occurring.

<u>Resolution</u> – Changes that have been or could be made relative to system design or operation to eliminate or control the hazard.

21.12 Methodology

The RCHA provides an initial assessment of hazards associated with at-grade crossings, and identifies possible controls and follow-on actions to eliminate or mitigate the hazards. An inductive, or top-down, approach is used to develop the RCHA. Significant or top-level events (i.e. hazards) are initially identified, followed by what might have caused them, and then by a determination of their potential effect on the total system. This methodology is shown in Table 1 and is discussed below.

21.12.1 Hazard Identification

The methods used for identifying hazards contained in this RCHA included review of the crossings design and operational concepts. Only hazards likely to result in an accident involving personal injury, fatality, or property damage are identified.

Table 21—12. Hazard Identification and Resolution Process

1. DEFINE THE SYSTEM
Define the physical and functional characteristics and understand and evaluate the people, procedures, facilities, equipment, and environment.
2. IDENTIFY HAZARDS
Identify hazards and undesired events. Determine the causes of hazards.
3. ASSESS HAZARDS
Determine severity. Determine probability. Decide to accept risk or eliminate/control risk.
4. RESOLVE HAZARDS
Assume risk, or Implement corrective action. - Eliminate - Control
5. FOLLOW-UP
Monitor for effectiveness. Monitor for unexpected hazards.

21.12.2 Hazard Analysis

Hazards are identified and classified in terms of the severity or consequence of the hazard and the probability of occurrence. The analysis is performed in conformity to Federal Transit Administration (FTA) Hazard Analysis Guidelines for Transit Projects and MIL-STD-882E. The following definitions are used to develop the hazard analysis.

21.12.2.1. Hazard Severity

Hazard severity categories are defined to provide a qualitative measure of the worst credible mishap resulting from personnel error, environmental conditions, design inadequacies, procedural deficiencies, system, subsystem or component failure, or malfunction, as follows:

- Category I: Catastrophic: Death, system loss or severe environmental damage.
- Category II: Critical: Severe injury, severe occupational illness, major system damage, or environmental damage.
- Category III: Marginal: Minor injury, minor occupational illness, minor system damage, or environmental damage.
- Category IV: Negligible: Less than minor injury, occupational illness, or less than system damage or environmental damage.

21.12.2.2. Frequency of Occurrence

The assessment of the hazard should also include a probability of occurrence analysis. Assigning a quantitative probability to a hazard is generally not possible early in the design or planning process. A qualitative hazard probability can be derived from research, analysis, and evaluation of historical safety data from similar systems. The frequency of occurrence levels for hazards is defined in Table 21-9.

Table 21—13. Frequency of Occurrence

Descriptive Word	Level	Specific Individual Item	Fleet or Inventory
Frequent	A	Likely to occur frequently	Continuously experienced
Reasonably Probable	B	Will occur several times in life of an item	Will occur frequently
Occasional	C	Likely to occur sometime in life of an item	Will occur several times
Remote	D	Unlikely, but possible to occur in life of an item	Unlikely, but can reasonably be expected to occur
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced	Unlikely to occur, but possible

21.12.2.3. Risk Assessment

Hazard analysis establishes hazard severity category (I through IV) and hazard probability ranking (A through E) which are combined into a Hazard Risk Index, reflecting the combined severity and probability ranking for each identified hazard. Risk assessment criteria are applied to the identified hazards based on their severity and probability of occurrence, to determine acceptance of the risk or the need for corrective action to further reduce the risk. The hazard risk index and risk assessment and acceptance criteria are defined in Tables 21-10 and 21-11.

Table 21—14. Risk Assessment Matrix

Event Frequency of Occurrence	Event Severity			
	I (Catastrophic)	II (Critical)	III (Marginal)	IV (Negligible)
(A) Frequent	IA	IIA	IIIA	IVA
(B) Probable	IB	IIB	IIIB	IVB
(C) Occasional	IC	IIC	IIIC	IVC
(D) Remote	ID	IID	IIID	IVD
(E) Improbable	IE	IIE	IIIE	IVE

Table 21—15. Risk Acceptance Criteria

Hazard Risk Index	Acceptance Criteria
IA, IB, IC, IIA, IIB, IIIA	Unacceptable
ID, IIC, IID, IIIB, IIIC	Undesirable (decision required)
IE, IIE, IIID, IIIE, IVA, IVB	Acceptable with review by OCTA management
IVC, IVD, IVE	Acceptable without review

21.12.3 Hazard Resolution

After the hazard assessment is completed, hazards can be resolved by deciding to either assume the risk associated with the hazard or to eliminate or control the hazard. Mitigation of the risk associated with each hazard to an acceptable level can be accomplished in a variety of ways.

21.12.3.1. Unacceptable and Undesirable Hazards

Corrective action for the elimination or control of unacceptable and undesirable hazards includes the following order of precedence:

- Design to Eliminate Hazards. Design, redesign or retrofit to eliminate (i.e., design out) the hazards through design selection. This strategy generally applies to acquisition of new equipment or expansion of existing systems; however, it can also be applied to any change in equipment or individual subsystems. In some cases, hazards are inherent and cannot be eliminated completely through design.
- Design for Minimum Risk. If an identified hazard cannot be eliminated, reduce the associated risk to an acceptable level. This may be accomplished, for example, through the use of fail-safe devices and principles in design, the incorporation of high-reliability systems and components and use of redundancy in hardware and software design.

- Incorporate Safety Devices. Hazards that cannot be eliminated or controlled through design selection will be controlled to an acceptable level through the use of fixed, automatic or other protective safety design features or devices. This could result in the hazards being reduced to an acceptable risk level. Safety devices may be part of the system, subsystem or equipment. Examples of safety devices include interlock switches, protective enclosures and safety pins. Care must be taken to ascertain that the operation of the safety device reduces the loss or risk and does not introduce an additional hazard. Safety devices will also permit the system to continue to operate in a limited manner. Provisions will be made for periodic functional checks of safety devices.
- Provide Warning Devices. When neither design nor safety devices can effectively eliminate or control an identified hazard, devices will be used to detect the condition and to generate an adequate warning signal to correct the hazard or provide for personnel or individual remedial action. Warning signals and their application will be designed to minimize the probability of incorrect personnel individual reaction to the signals and will be standardized within like types of systems. Warning signals and their application should also be designed to minimize the likelihood of false alarms that could lead to creation of secondary hazardous conditions.
- Implement Procedures and Training. Where it is not possible to eliminate or adequately control a hazard through design selection or use of safety and warning devices, procedures and training will be used to control the hazard. Special equipment operating procedures can be implemented to reduce the probability of a hazardous event and a training program can be conducted. The level of training, required will be based on the complexity of the task and minimum trainee qualifications contained in training requirements specified for the subject system element and element subsystem. Procedures may include the use of personal protective equipment. Precautionary notations in manuals will be standardized. Safety critical tasks, duties and activities related to the system element/subsystem will require certification of personnel proficiency. However, without specific written approval, no warning, caution or other form of written advisory will be used as the only risk reduction method for Category I and II hazards.
- Hazard Acceptance or System Disposal. Hazards identified as having an unacceptable and undesirable risk will be reduced to an acceptable level before design acceptance.

21.12.3.2. Acceptable with Review Hazards

Hazards identified as “acceptable with review” may be accepted in an “as-is” condition with no further corrective action. Alternatively, operating and maintenance procedures must be developed for periodic tests and inspections of the subject item to ensure an acceptable level of safety is maintained throughout the life of the system.

21.12.3.3. Acceptable without Review Hazards

Hazards with combination of severity and probability IVC, IVD, and IVE are acceptable.

21.12.4 Documentation of Findings

The format of the RCHA worksheets is as follows:

- Column 1, Item Number: A unique number that identifies the hazard.
- Column 2, Hazard Description: Describe each hazard postulated for the at-grade crossing, considering the following categories of hazards:
  - Function Loss/ Malfunction
  - Human Error / Misuse
  - External Circumstances
- Column 3, Potential Cause: Describe the cause of the identified hazard such as design deficiency, component malfunction, human error, or environment that can propagate a hazard into an accident if adequate controls are not provided.
- Column 4, Effect on Subsystem/System: Describe the probable effect and consequence of the hazard. This is a failure condition. Its severity is what determines the minimum safety level requirements for the design. The description should assess the impact on and the state of the system.
- Column 5, Hazard Risk Index: This assigned classification is an estimate of event severity and probability of an accident from the hazard before any safeguard or safety mitigation is provided.
- Column 6, Possible Controlling Measures and Remarks: Possible controls used to mitigate hazards include: design to eliminate hazards, “fail-safe” design, safety devices, warning devices, use of special procedures, training, safety verification and testing.
- Column 7, Final Risk Index and Resolution: This assigned classification is an estimate of the hazard severity and frequency of occurrence after the mitigation measures are accepted for implementation. Resolution describes changes made or steps taken relative to design and/or procedures, training, etc. to eliminate or control the hazard.

21.12.5 Documentation of Hazard Resolutions

All undesirable and unacceptable Hazards (safety critical) should be tracked for resolution. The identified items may require additional analysis to be performed in the detail design/ construction stage. Action taken to resolve each hazard identified in the RCHA should be recorded in the Resolution section of the appropriate hazard assessment form. All open unresolved hazards should be tracked until the mitigation measures are identified and accepted. Implementation of all accepted mitigation measures in the PHA should be verified and tracked until closure.

21.12.6 Hazard Risk Index

The Hazard Risk Index for the SCBT with AWS (GX-1 through GX-4) follows.

Table 21—16. Hazard Risk Index

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		HAZARD RISK INDEX	CORRECTIVE ACTION	
Item No.	**Hazard Description**	**Potential Cause**	**Effect on System /Subsystem**		**Possible Controlling Measures and Remarks**	**Resolution & Final Risk Index**
GX-1	Collision between train and bicyclist at the crossing	• Insufficient warning of approaching train to the bicyclist, bicyclist enters the crossing in front of approaching train • Bicycle speed too high • Bicyclist using earbuds, unable to hear approaching train • Distraction • Audible masking by surf noise, wind noise, music • Not clear line of sight, bicyclist unable to see the crossing from a safe distance. • Bicyclist enters the crossing not realizing that there is not enough time to cross.	• Fatality, • Facilities damage, • Major disruption to revenue operation.	**I C**	a) Install audible warning devices at sufficient distance from the crossing and provide audible warning for a duration that gives sufficient time to the bicyclist to slow down and stop at the crossing b) Review sight line for bicyclist c) Provide automatic mechanical gates at the crossing d) Provide electronic bells at the crossing e) Provide flashing lights f) Provide warning signs g) Post speed limit signs	a) Place Audible Warning System (AWS) loudspeaker at 20 feet from crossing gate b) Provide AWS signal for six seconds at 80 dBA c) Maintain area around crossings to keep clear line of sight. d) Crossings are already equipped with warning signs, automated mechanical gate arms, electronic bells (ding, ding, ..) and flashing lights e) Standard pole mounted crossbucks are already installed to identify the crossing. f) Speed limit is posted **Final Risk Index: I E**

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		HAZARD RISK INDEX	CORRECTIVE ACTION	
Item No.	**Hazard Description**	**Potential Cause**	**Effect on System /Subsystem**		**Possible Controlling Measures and Remarks**	**Resolution & Final Risk Index**
GX-2	Collision between train and pedestrian at the crossing	• Pedestrian enters the crossing not realizing that there is not enough time to cross • Not clear line of sight, pedestrian unable to see the crossing from a safe distance. • Pedestrian using earbuds, unable to hear approaching train • Distraction • Audible masking by surf noise, wind noise, music	• Fatality, • Facilities damage, • Major disruption to revenue operation.	I C	a) Install audible warning devices at sufficient distance from the crossing providing audible warning at a sound pressure level that the pedestrian using earbuds and/or with ambient noise can hear the train approach audible warning b) Provide clear line of sight of the crossing c) Provide automatic mechanical gates at the crossing d) Provide electronic bells at the crossing e) Provide flashing lights f) Provide warning signs	a) Place Audible Warning system loudspeaker at 20 feet from crossing gate b) Provide AWS signal for six seconds at 80dBA c) Maintain area around crossings to keep clear line of sight. d) Crossings are already equipped with warning signs, automated mechanical gate arms, electronic bells (ding, ding, ..) and flashing lights e) Standard pole mounted crossbucks are already installed to identify the crossing. Final Risk Index: I E

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		HAZARD RISK INDEX	CORRECTIVE ACTION	
Item No.	**Hazard Description**	**Potential Cause**	**Effect on System /Subsystem**		**Possible Controlling Measures and Remarks**	**Resolution & Final Risk Index**
GX-3	Collision between train and jogger at the crossing	• Jogger enters the crossing not realizing that there is not enough time to cross • Not clear line of sight, jogger unable to see the crossing from a safe distance. • Jogger using earbuds, unable to hear approaching train • Distraction • Audible masking by surf noise, wind noise, music, etc.	• Fatality, • Facilities damage, • Major disruption to revenue operation.	I C	a) Install audible warning devices at sufficient distance from the crossing providing audible warning at a sound pressure level that the jogger using earbuds and/or with high ambient noise can hear the train approach audible warning b) Provide clear line of sight of the crossing c) Provide automatic mechanical gates at the crossing d) Provide electronic bells at the crossing e) Provide flashing lights f) Provide warning signs g) Post biker speed limit signs	a) Place Audible Warning System (AWS) loudspeaker at 20 feet from crossing gate b) Provide AWS signal for six seconds at 80dbA c) Maintain area around crossings to keep clear line of sight. d) Crossings are already equipped with warning signs, automated mechanical gate arms, electronic bells (ding, ding, ..) and flashing lights e) Standard pole mounted crossbucks are already installed to identify the crossing. Final Risk Index: I E

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		HAZARD RISK INDEX	CORRECTIVE ACTION	
Item No.	**Hazard Description**	**Potential Cause**	**Effect on System /Subsystem**		**Possible Controlling Measures and Remarks**	**Resolution & Final Risk Index**
GX-4	Collision between train and trespasser	• Trespasser crosses the tracks not realizing that there is not enough time to cross • Not clear line of sight, trespasser unable to see the nearby crossing and instead decides to trespass. • Trespasser using earbuds, unable to hear approaching train • Distraction • Audible masking by surf noise, wind noise, music	• Fatality, • Facilities damage, • Major disruption to revenue operation.	I C	a) Provide fencing to direct pedestrians to legal crossing b) Install information and warning signs c) Install warning signs of possible fines for crossing the right-of-way (ROW) at unauthorized locations d) Provide Audible Warning System with devices at sufficient distance from the crossing providing audible warning at a sound pressure level such that a pedestrian using earbuds and/or with high ambient noise can hear the audible warning of an approaching train e) Provide clear line of sight of the crossing f) Introduce neighborhood education program on the hazard of trespassing	a) Review of ROW and installation of additional fencing to discourage trespassing b) Install warning signs of possible fines for crossing the right-of-way (ROW) at unauthorized locations c) Place Audible Warning system loudspeaker at 20 feet from crossing gate or provide audible warning from AWS at this point. d) Provide AWS signal for six seconds at 80dbA. e) Maintain area around crossings to keep clear line of sight. f) Introduce neighborhood education program on the hazard of trespassing. g) Standard pole mounted crossbucks are already installed to identify the crossing. Final Risk Index: I E