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Project 20058

Acoustical Analysis	**Requestor:**	**Client/Project Owner:**
Hydrogen Fueling Facility 4714 Artesia Blvd. Redondo Beach, CA 90278	Ben Steckler Fiedler Group ben.steckler@fiedlergroup.com 299 N. Euclid Ave. Ste 550 Pasadena, CA 91101	Iwatani Corporation of America

1 Executive Summary

45dB Acoustics ("**45dB**") has reviewed local regulatory requirements for the proposed Hydrogen Fueling Facility at the above address. The potential impact of noise from the nearby streets and proposed equipment for the fueling facility has been evaluated using SoundPLAN® modeled noise contours and published traffic counts. Analysis reveals existing hourly ambient sound levels at the nearest neighboring residential locations are 59-70 dBA during daytime hours and 51-62 dBA at nighttime.[1]

The proposed Hydrogen Fueling Facility includes two H2Station® units and a 12-foot surrounding wall with an angled awning at the southwest corner of the property with remote ventilation stacks at the northwest corner next to the new fueling pumps. With the new project in place, the daytime and nighttime hourly noise levels are anticipated to increase by less than 1 dB. Other than the planned 12-foot CMU wall and awning, no additional mitigation measures are required to comply with the City of Redondo Beach's Municipal Code.

for 45dB Acoustics, LLC:

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[1] As calculated by Federal Highway Administration's TNM calculation standard, see Section 4.1.

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2 Introduction

The proposed hydrogen fueling station is to be located at 2714 Artesia Boulevard in Redondo Beach, CA, at the intersection of Artesia Boulevard and Inglewood Avenue, as shown in Figure 1 and Figure 2. The existing site currently has a gas station, service station, and convenience store on premises.

The project property is within a Commercial (C-2) zone of Redondo Beach. Residential sites to the south of the Project are in a low-density multi-family Residential (R-3) zone.

The proposed project would add hydrogen fueling capabilities and canopy at the northwest corner of the site and two "H2Station®" hydrogen fuel units at the southwest corner of the site with a 12-foot wall surrounding the west, south, and east sides of the equipment yard along with a 23-foot by 9-foot awning, angled upward as shown in the site plan (Figure 3) and perspective view (Figure 4) provided by the client. Remote ventilation stacks will be 12-foot tall (minimum) and located at the northwest corner of the property near the customer fueling units. The gas station and convenience store operate 24-hours a day, and the service station operates between 8:00am and 6:00pm.

In this report we evaluate the proposed project against the City's Noise Element of the General Plan, the Municipal Code, and California Environmental Quality Act (CEQA) and compare existing and anticipated future noise levels at representative locations at the residential properties to the south of the project.

The following results are presented in this report:

- The topographical relationship of noise sources and applicable noise ordinances/laws
- Identification of noise sources and their characteristics, including predicted noise spectra at representative neighboring residential receiver locations, considering present and 20-year predicted average annual daily traffic counts
- Basis for the sound level prediction (i.e. engineering inputs and assumptions)
- Noise attenuation measures (mitigations) to be applied, if needed
- Information on fundamentals of noise and vibration to aid in interpreting the report (Section 0, Appendix)

CEQA assessments of impact are also included.

Figure 1: Vicinity Map

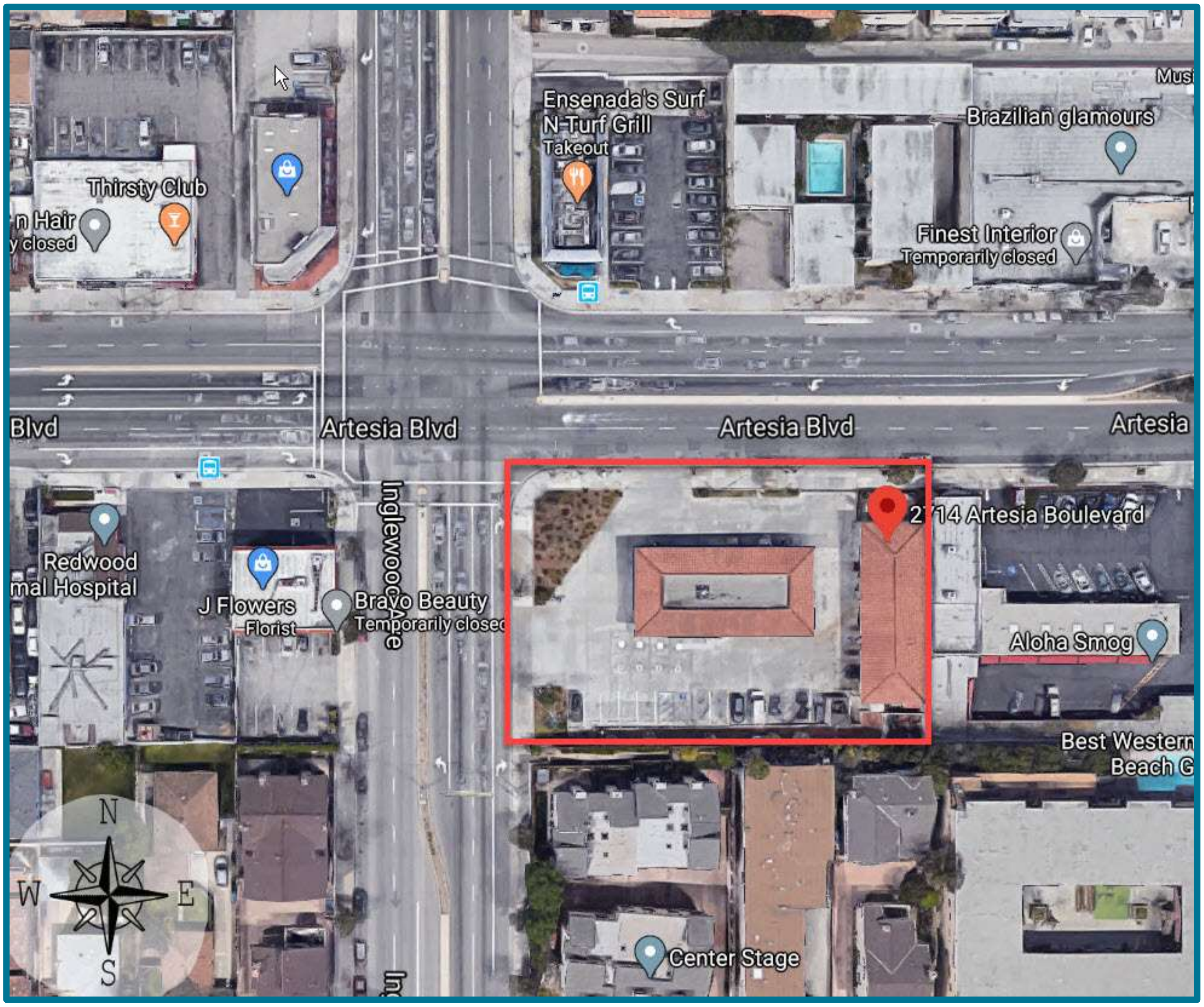


Figure 2: View of Site Vicinity

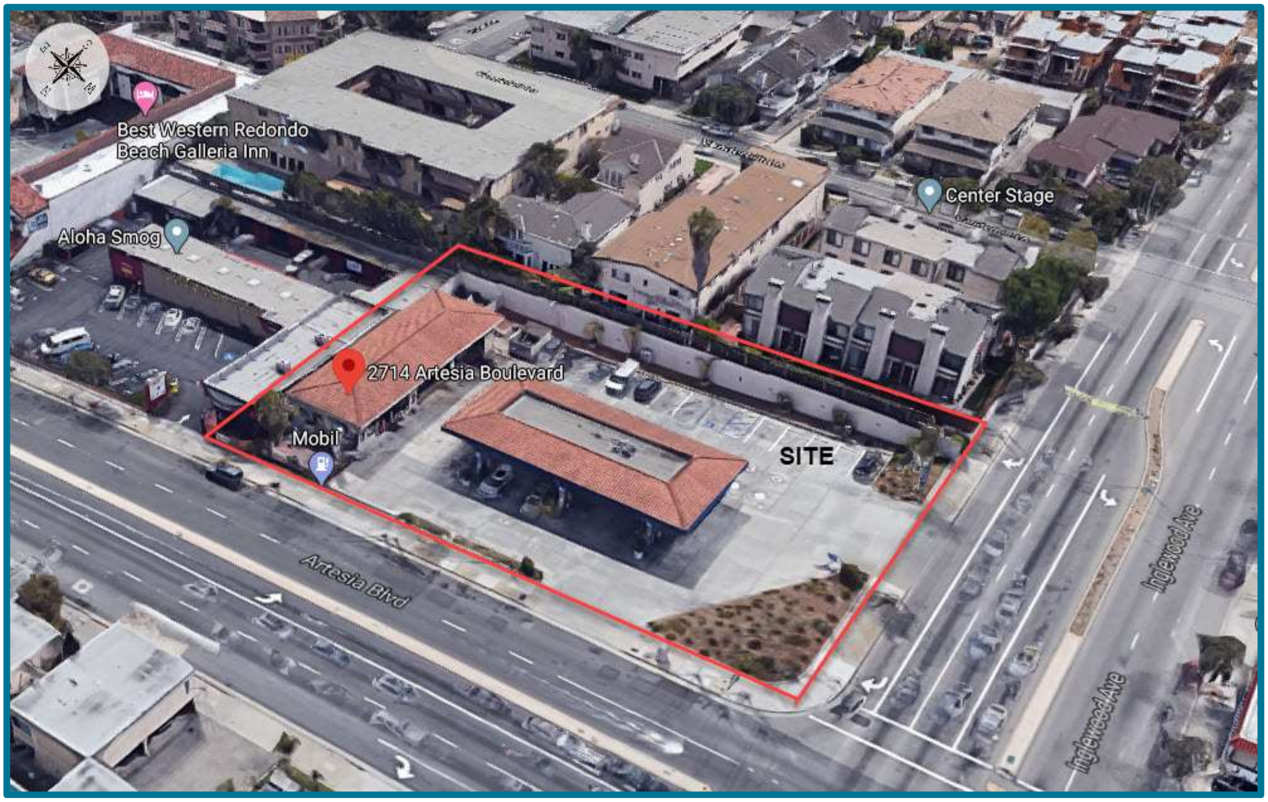


Figure 3: Project Site Plan

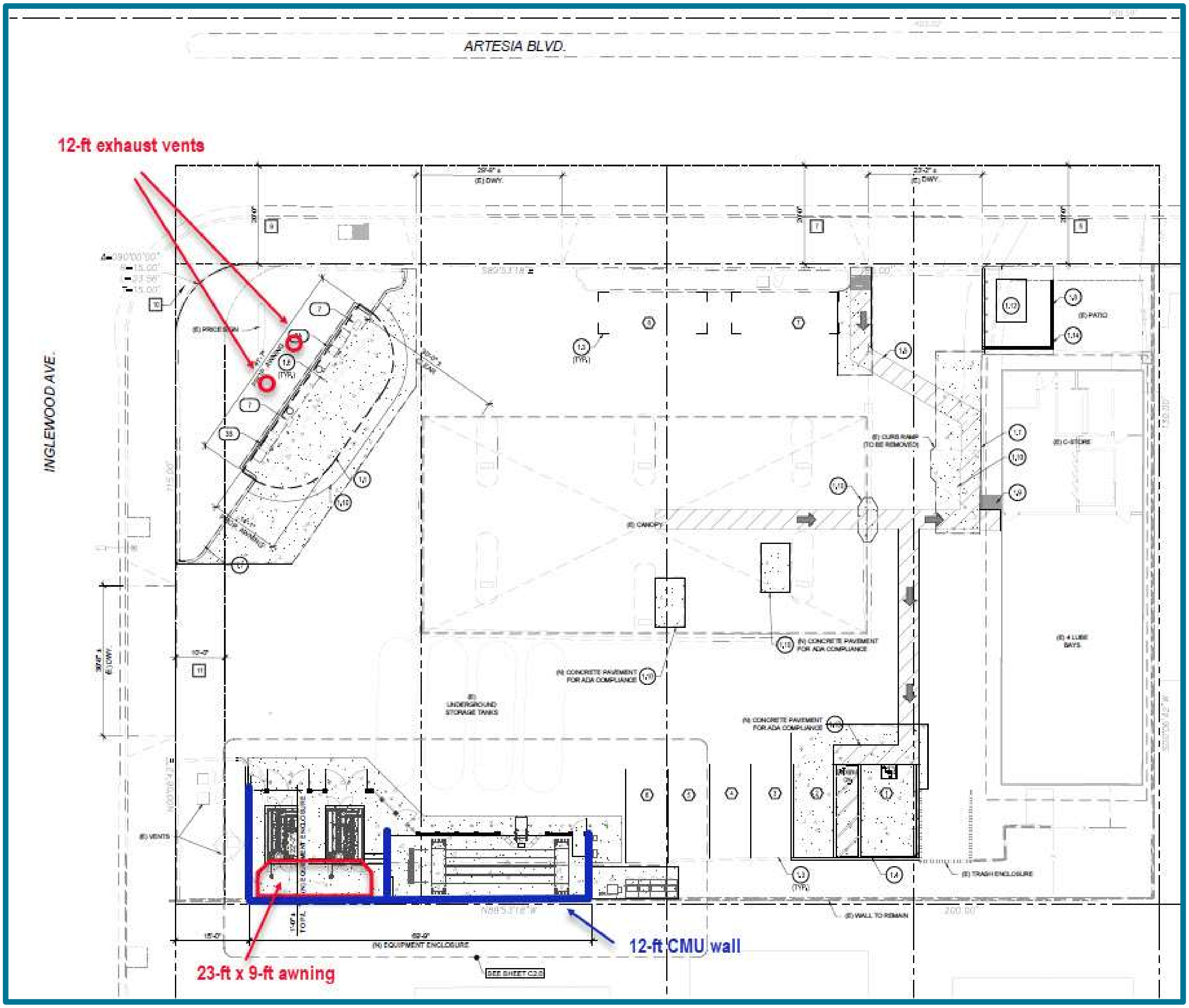
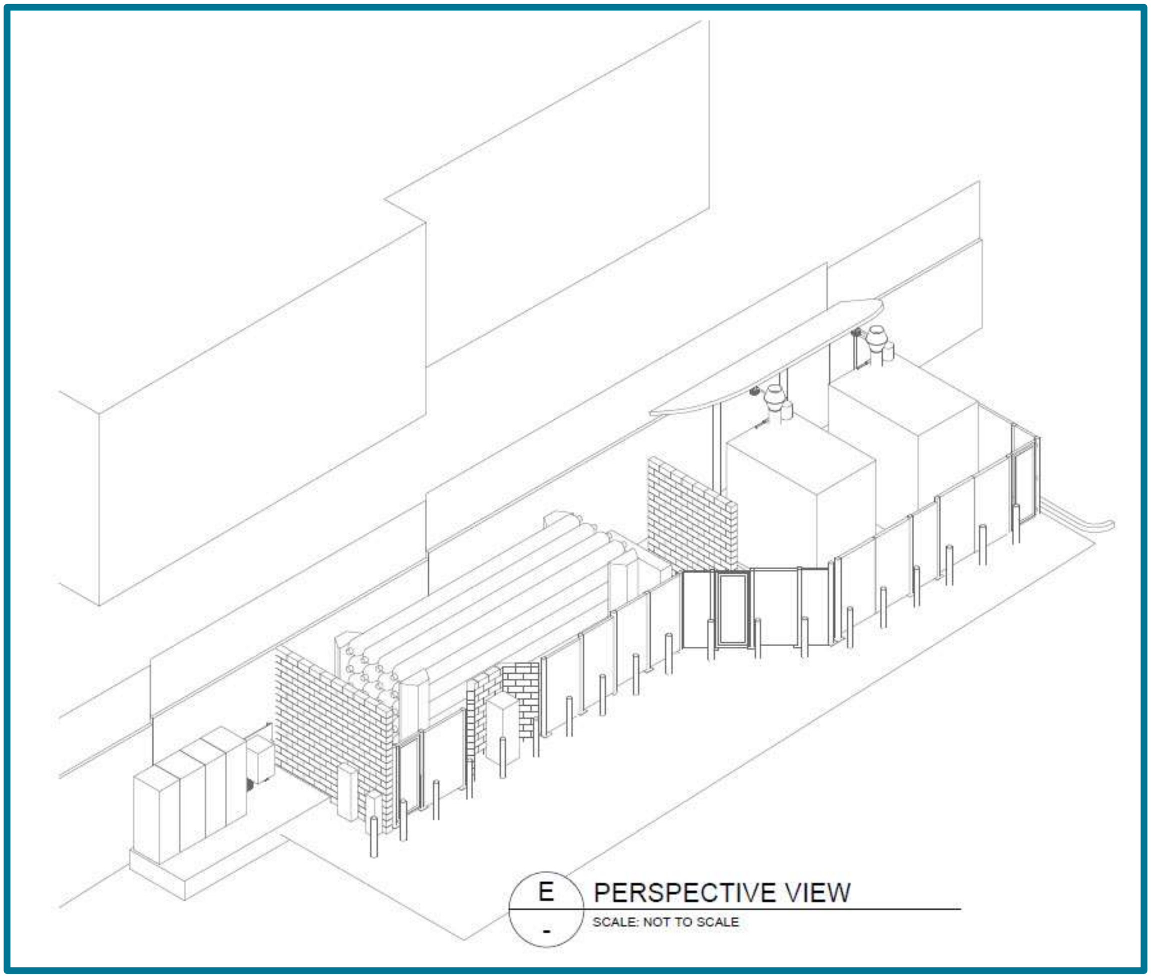


Figure 4: Perspective View of Hydrogen Fuel Units with Awning



3 Regulatory Setting

Noise regulations are addressed by federal, state, and local government agencies, discussed below. Local policies are generally adaptations of federal and state guidelines, adjusted to prevailing local condition.

3.1 Federal Regulation

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

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

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

For this project, the nearest airport (Los Angeles International Airport) is 5 miles north. The nearest railroad tracks are only 600 feet to the east of the Project. However, the road traffic noise is significant (and constant) enough that it is the only type of transportation noise that needs be modeled in this case in order to determine accurate background (i.e. non-Project related) noise levels.

3.2 State Regulation

3.2.1 State CEQA Guidelines

The significance of environmental noise impacts resulting from a proposed project are evaluated based on the California Environmental Quality Act (CEQA) guidelines. CEQA asks the following applicable questions. These will be answered in our Conclusion section.

Would the project result in:

> • *exposure of persons to or generation of noise levels in excess of standards established in the local General Plan or Noise Ordinance, or applicable standards of other agencies?*
>
> • *exposure of persons to or generation of excessive ground-borne vibration or ground-borne noise levels?*
>
> • *a substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?*
>
> • *a substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?*

3.3 Local Regulation

The Redondo Beach Municipal Code, Chapter 24 - Noise Regulation (Reference 2) provides regulation and guidelines regarding noise. Article 3 - Exterior Noise Limits, states that the maximum permissible sound levels for a land use district is the higher of either the presumed or actual measured ambient level. For an R-3 land use district, the presumed ambient level between 7:00am and 10:00pm is 55 dBA and between 10:00pm and 7:00am is 50 dBA.

The ambient levels may be corrected for time characteristics where the sound source operates for a cumulative of less than 30 minutes per hour. **For the proposed project, the H2Station units are not expected to operate for more than 50% of the time, or 15-30 minutes per hour, so the ambient levels may be increased by no more than 5 dB.** See excerpt below in Figure 5.

Figure 5: Excerpt from City of Redondo Beach Municipal Code, Chapter 24, Article 3

Article 3. Exterior Noise Limits

4-24.301 Maximum permissible sound levels by land use categories.

The noise standards for the various categories of land use districts identified shall be the higher of either the presumed or actual measured ambient and shall apply to all such property within a designated category as follows:

Receiving Land Use District Category	Time Period	Presumed Ambient Level (dBA)
Low Density	10:00 p.m. to 7:00 a.m.	45
Residential R-1-A, R-1, R-2, P-D-R, P-U-D Overlay	7:00 a.m. to 10:00 p.m.	50
Medium Density	10:00 p.m. to 7:00 a.m.	50
Residential R-3, R4, P-D-R, P-U-D Overlay	7:00 a.m. to 10:00 p.m.	55

...

As indicated above, the presumed ambient levels in the Planned Development Residential (P-D-R) and the Planned Unit Development (P-U-D) Overlay land use districts are categorized so as to be consistent with the actual density of the development. The presumed ambient levels for the Planned Development (P-D) and the Civic Center (C-C) land use districts shall be consistent with those established for the lowest adjacent land use district.

(a) Correction for time characteristics. No person shall operate, or cause to be operated, any source of sound at any location within the City or allow the creation of any noise on property owned, leased, occupied, or otherwise controlled by such person which causes the noise level when measured on any other property to exceed:

(1) The noise standard of the receiving land use district for a cumulative period of more than thirty (30) minutes in any hour; or

(2) The noise standard of the receiving land use district plus five (5) dB for a cumulative period of more than fifteen (15) minutes in any hour; or

(3) The noise standard of the receiving land use district plus ten (10) dB for a cumulative period of more than five (5) minutes in any hour; or

(4) The noise standard of the receiving land use district plus fifteen (15) dB for a cumulative period of more than one minute in any hour; or

(5) The noise standard of the receiving land use district plus twenty (20) dB for any period of time.

In order to evaluate these new noise sources, modern state-of-the-industry noise propagation modeling of sound level contours offers great precision and detail, provided the assumptions and inputs to the software model are well-founded and accurate.

45dB goes into great detail by accurately modeling and studying the ambient sound level contours for the existing traffic noise. Terrain, reflection and absorption from the built environment, and ground-cover attenuation factors are also included in these models. (See Sections 5.2 and 5.3 in the Appendix for more information.)

After adding in the contributing noise sources from the proposed hydrogen fueling station equipment, the predicted sound levels at the neighboring properties are evaluated to determine if a significant increase is predicted at any location along the property line and 10 feet from the nearest reflective surface. In this case, because a CMU wall exists at the property line, the levels are predicted for receiver locations at the apartment windows. It is also important to note that, provided accurate traffic counts are used, daytime traffic levels on an annualized basis are potentially more representative than field measurements taken during any single day or portion of one day, which may not accurately reflect typical daily traffic levels.

4 Noise Impact Assessment

All sound pressure levels in this report are in units of A-weighted decibels (dBA). Daytime hourly levels "$L_{eq,d}$" and nighttime hourly levels "$L_{eq,n}$" are evaluated for the fueling station operating hours, i.e., 7:00 am to 10:00pm during daytime hours and 10:00 pm to 7:00 am during nighttime hours. All noise level contour plots are at a typical receiver height of 1.5m (5 feet), unless otherwise specified.

Traffic counts in annual average daily traffic (AADT) are input directly into SoundPLAN®, which predicts exterior (outdoor) noise levels due to those noise sources. Traffic counts from 2007 have been provided for the Artesia Boulevard and Inglewood Avenue intersection contributing streets by the City of Redondo Beach (reproduced in Figure 6).

Traffic counts for the applicable roads were increased by 1% per year to 2020 for present-day noise contours.

Figure 6: City of Redondo Beach 2007 Traffic Counts

CITY OF REDONDO BEACH
TRAFFIC VOLUMES

Street	Boundary 1	Boundary 2	Average Daily Traffic Volume, Veh	Count Year
Artesia Blvd	Aviation Blvd	Rindge Ln	33,280	2007
	Rindge Ln	Inglewood Ave	35,540	2007
	Inglewood Ave	Hawthorne Blvd	36,850	2007
Inglewood Ave	190th St	Grant Ave	31,940	2007
	Grant Ave	Artesia Blvd	30,180	2007
	Artesia Blvd	Manhattan Beach Blvd	40,010	2007
	Manhattan Beach Blvd	Marine Ave	56,350	2007

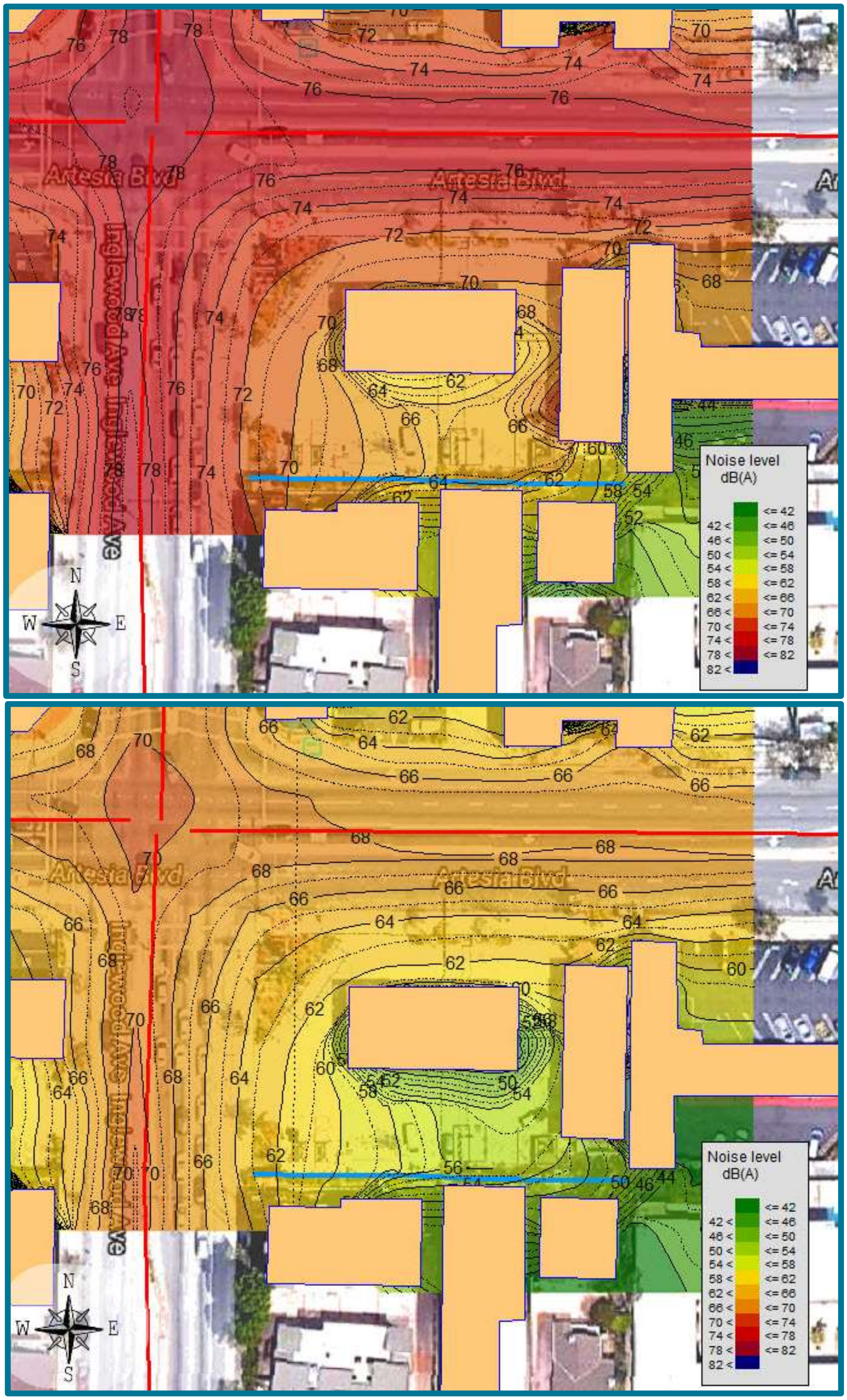
Traffic counts were input into SoundPLAN®, which by default apportions the count into vehicle types including automobiles and medium trucks. The count is distributed appropriately between daytime and nighttime hours and appropriate vehicle speeds are input in order to predict outdoor noise levels using the Traffic Noise Model.

4.1 Existing Noise Environment

Figure 7 shows the resulting daytime and evening noise contours from traffic around the property under existing conditions. The SoundPLAN noise model uses imported images from the Project plan as needed for the site layout. The blue horizontal line represents the existing CMU wall along the southern property line. Linear noise sources for roads and highways, modeled with Federal Highway Administration Transportation Noise Model, using the current and future traffic counts are added to the site plan.

The daytime noise levels are approximately 8-9 dB higher than the levels observed during the nighttime hours due to the differences in traffic volumes, the mix of cars versus trucks, and operating hours for the service center. Existing noise levels at the nearest residential properties to the south of the project site range between 59 – 70 dBA during the daytime and between 51 – 62 dBA during nighttime hours, which are higher than the presumed ambient levels from the municipal code.

Figure 7: Existing Site, Daytime (top) and Nighttime (bottom) Hourly Noise Contours From Traffic and Service Station



4.2 Future Noise Levels with Project

All sources that would potentially add significant increase in resulting noise levels for the area are included to the model to determine its unmitigated noise distribution pattern, interacting with existing noise levels in the area. Those are, namely:

- Two H2Station® units to be located at the southwest corner of the station parking area, which operate up to 30 minutes per hour throughout the day. Levels were provided by the client from the manufacturer, Nel Hydrogen.

- Two 12-foot high vents at the northwest corner of the property which operate momentarily after each customer fuels, which could occur approximately every 5-10 minutes at full capacity.

Additionally, the two H2Station® units are to be enclosed on the west, south, and east sides with a 12-foot CMU wall and a 23-foot long by 9-foot wide awning covering the south portion of the two units. A new canopy will be constructed at the northwest corner over the new fueling stations, as shown in the site plan provided by the client.

Noise emissions measured by the manufacturer were provided by the client, as shown in Table 1. Spectral data (i.e. frequency-dependent noise levels in octave or third-octave bands) is characteristic of mechanical pumps and other machinery and may have frequency-dependent tonal qualities to the sounds they emit. Highly pressurized fluids such as hydrogen can have high-frequency hisses emitting from valves required for their safe transfer between tanks. Rather than full spectral data for the hydrogen stations, overall decibel levels (in dBA) (centered at 500 Hz, without tones) were analyzed. As the ordinance is based on overall levels, this is sufficient and appropriate in determining compliance.

Table 1: NEL Hydrogen Station Noise Emissions

Noise emissions

Dimension	Day 12 hour average	Night 12 hour average
Total LW	90,4	74,7
Lmax	104,4	104,4
Lr, 5m*	69,9	54,2
Lr, 10m*	63,9	48,2
Lr, 20m*	57,9	42,2
Lr, 40m*	51,8	36,1

The provided sound power levels for day and night were applied to the two H2Station® units as planned. The awning and new CMU wall, which provides significant noise mitigation of the units, were also added to the acoustic model. The Lmax levels were applied to the two 12-foot vent pipes at the northwest corner of the property, which emit the loudest noise levels momentarily as each customer finishes fueling. For this model, we assumed full customer capacity and the fueling station during the daytime and 50% capacity at night. As such, we assumed the vents operated with a duty cycle of a total of 1 minute per hour during the day and 30 seconds per hour at night.

A parking area was also located along the southern property line and was reduced in size to provide space for the new H2Station® units. As the client has observed in prior Hydrogen fueling projects with similar scope, the overall traffic activity at the fueling station is not expected to increase. While the overall noise levels resulting from customer traffic should remain the same, fueling station traffic is not generally consistent throughout the day, and was not included in the model in order to provide a more conservative evaluation of the predicted levels for the proposed project.

A 3D visualization of the model is shown below in Figure 8, where the new H2Station® units are represented by the red boxes. The resulting daytime and nighttime noise contour plots, shown in Figure 9, illustrate the expected noise radiating from the H2Station® units at the southwest corner of the property and 12-foot vents at the northwest corner as well as the mitigation effects of the new awning and 12-foot CMU wall surrounding the equipment.

Figure 8: 3D View of Project

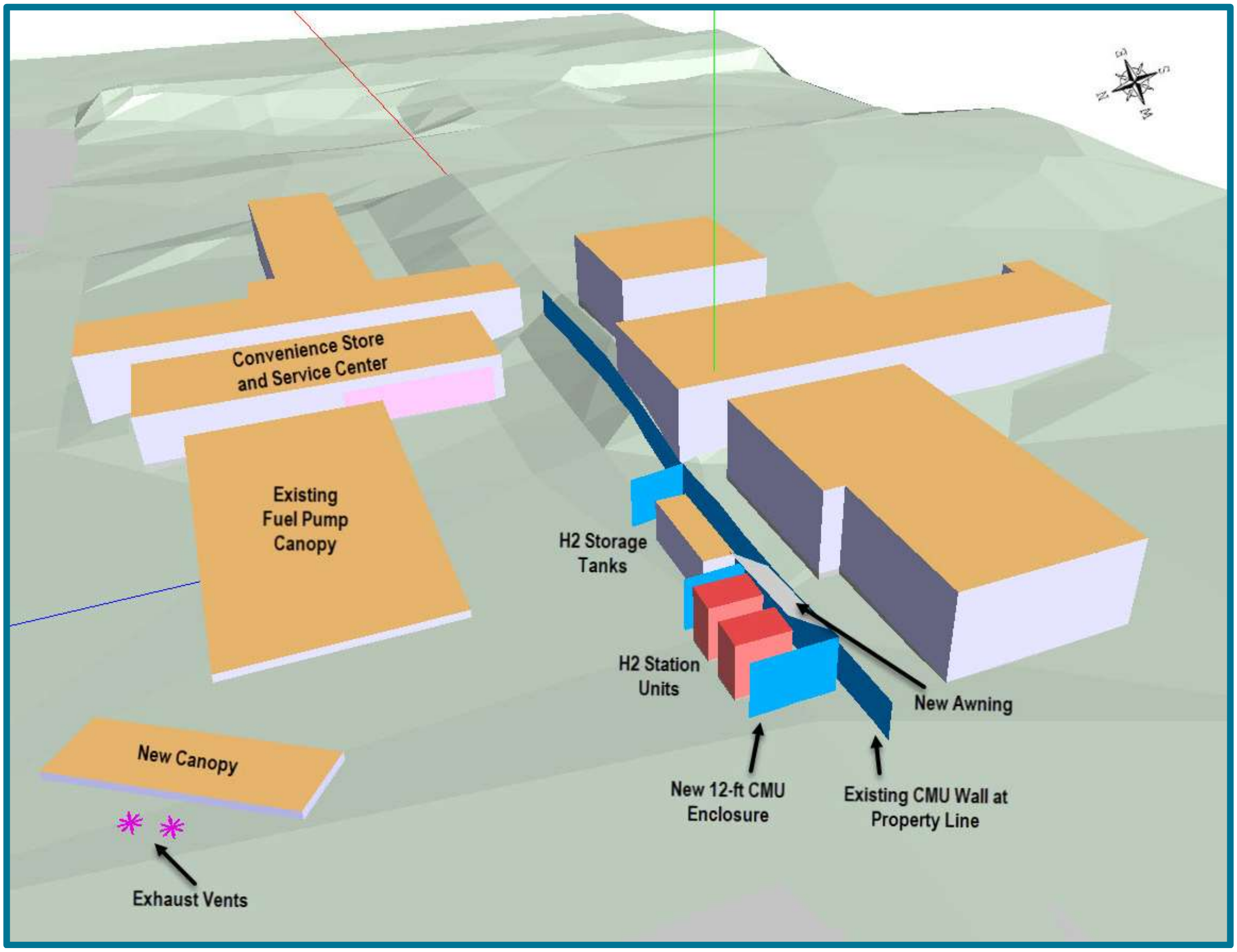


Figure 9: Daytime (top) and Nighttime (bottom) Noise Contours with Project

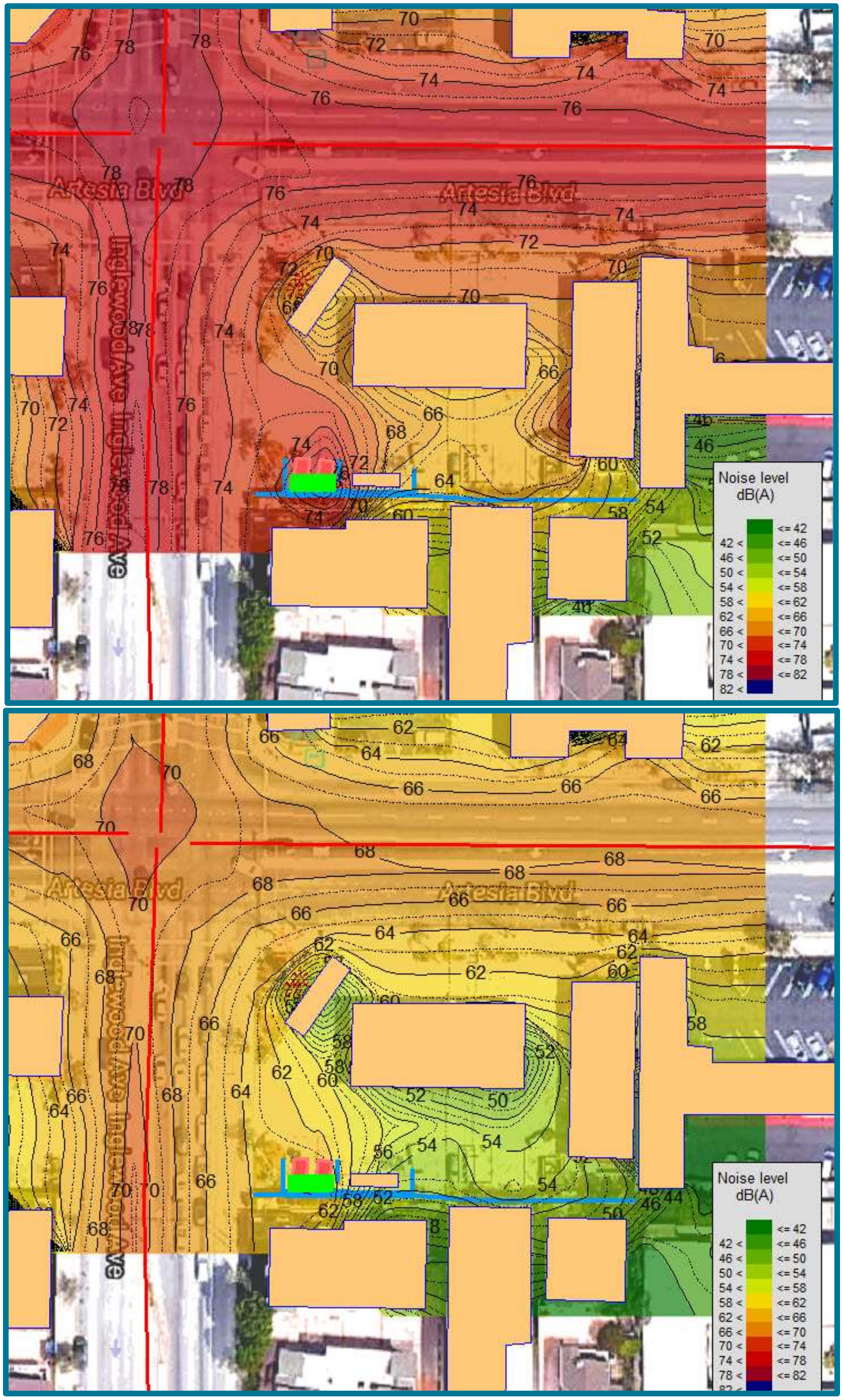
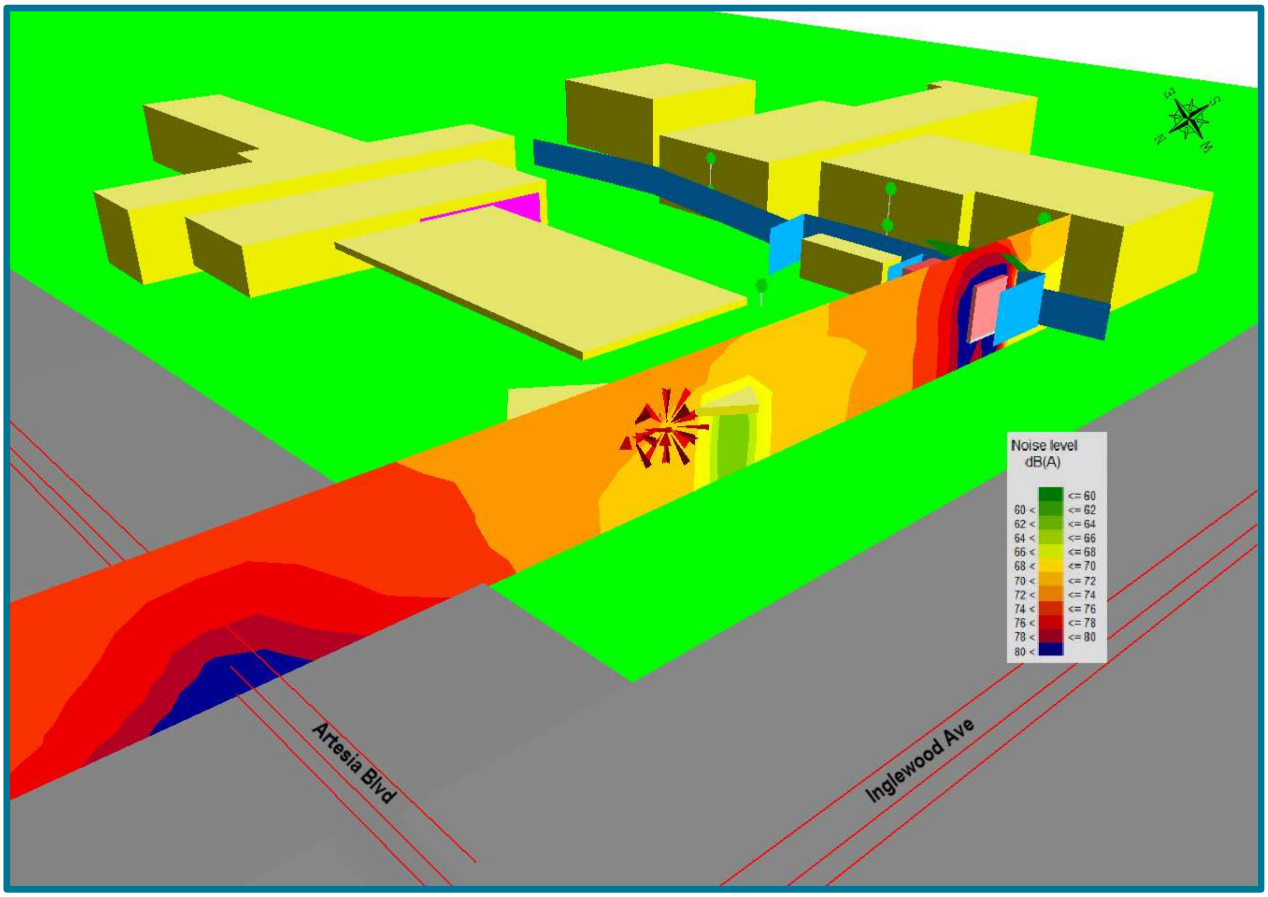


Figure 10, below, shows another perspective on the sound level contours for the vertical cross section through the Artesia Boulevard traffic, new H2 fueling canopy, H2Station® unit, awning, and CMU walls.

Figure 10: N-S Section Through Noise Contours Emitted By Two H2Station® Units



4.3 Future Noise Levels (2040)

With a population and traffic increase of 1% per year it is calculated that sound levels will increase no more than 1 dB in 20 years. It is also of note that, as electric and hydrogen vehicles become more and more prevalent, traffic noise levels are anticipated to be reduced.

4.4 Vibration

This project is expected to comply with the City's Municipal Code regulations for vibration, **Section 4-24.504 Vibration:**

The operation or permitting the operation of any device which creates vibration which is above the vibration perception threshold of an individual at or beyond the property boundary of the source if on private property, or at 150 feet (forty-six (46) meters) from the source if on a public space or public right-of-way, shall be prohibited. For the purposes of this section, "vibration perception threshold" shall mean the minimum ground or structure-borne vibrational motion necessary to cause a normal person to be aware of the vibration by such direct means as, but not limited to, sensation by touch or the visual observation of moving objects. The perception threshold shall be presumed to be .001 "g's" in the frequency range from zero to thirty (30) Hz and .003 "g's" in the frequency range between thirty (30) and 100 Hz. (§ 1, Ord. 2183 c.s., eff. August 11, 1976)

Vibration from the compressors of the two H2Station "cabinets" within the equipment yard may be perceptible by touch. However, as these units are contained within the equipment yard, this equipment is not accessible to unauthorized personnel. As such, this is not a significant impact.

4.5 Short Term Construction Noise and Vibration

The project construction should comply with the construction regulations of the Municipal Code, **Section 4-24.503 Construction Noise:**

(a) All construction activity shall be prohibited, except between hours of 7:00 a.m. and 6:00 p.m. on Monday, Tuesday, Wednesday, Thursday, and Friday and between the hours of 9:00 a.m. and 5:00 p.m. on Saturday. No construction activity shall be permitted on Sunday, or the days on which the holidays designated as Memorial Day, the Fourth of July, Labor Day, Thanksgiving Day, Christmas Day, and New Year's Day are observed.

(b) In the case of an emergency, the Building Officer may issue a permit for construction activity for periods during which construction activity is prohibited by subsection (a) of this section. Such permit shall be issued for only the period of the emergency. Where feasible, the Building Officer shall notify the residential occupants within 300 feet of any emergency construction activity of the issuance of any permit authorized by this subsection.

(c) If the Building Officer should determine that the peace, comfort, and tranquility of the occupants of residential property will not be impaired because of the location or nature of the construction activity, the Building Officer may issue a permit for construction activity for periods during which construction activity is prohibited by subsection (a) of this section.

(d) For purposes of this section, "construction activity" shall mean the erection, excavation, demolition, alteration, or repair of any building.

(e) Exemption. This section shall not be applicable to minor repairs or routine maintenance of residential dwelling units. (§ 1, Ord. 2183 c.s., eff. August 11,

1976, as amended by § 2, Ord. 2535 c.s., eff. April 13, 1989, and § 1, Ord. 2608 c.s., eff. January 3, 1991)

Construction of the project would generate noise that may temporarily increase noise levels at nearby residential receivers. Noise impacts resulting from construction depend on the noise generated by various pieces of construction equipment operating on site, the timing and duration of noise generating activities, and the distance between construction noise sources and sensitive receptors. Construction of the project would involve site improvements, excavation, construction of foundations, building framing, paving, and landscaping. The hauling of excavated material and construction materials would generate truck trips on local roadways. Construction activities for individual projects are typically carried out in stages. During each stage of construction, there would be a different mix of operating equipment. Construction noise levels would vary by stage and vary within stages based on the amount of equipment in operation and location where the equipment is operating. The phases of construction and associated larger equipment are shown in Table 2 below.

Table 2: Large equipment used for construction

Scope of Work	Anticipated Large Equipment
Grading	Dump Truck, Dozer, Backhoe
Utilities	Backhoe, Mini Excavator
Foundations and Pads	Concrete Mixer Truck, Concrete Pump
Framing	Forklift, Compressor
Driveways	Concrete Mixer Truck, Concrete Pump

Short-term construction activities for a project of this scope can generate moderate noise levels, especially during the construction of project infrastructure when limited heavy equipment is used. Noise impacts resulting from construction depend on the noise generated by various pieces of construction equipment, the timing and duration of noise generating activities, and the distance between construction noise sources and noise sensitive receptors. Specific sound levels from construction equipment are shown in Table 3. Since the nearest homes are approximately 80 feet away from the nearest project buildings, noise levels are expected to be in the 71-78dBA range at those receptors for the type of equipment expected here (in Table 2).

Table 3: Typical Construction Equipment Noise Levels (dBA)

Equipment Onsite	Typical Noise Level 50ft from Source	Typical Noise Level 400ft from Source	Typical Noise Level 800ft from Source	Typical Noise Level 1,000ft from Source	Typical Noise Level 1,600ft from Source
Air Compressor	78	60	54	52	48
Backhoe	78	60	54	52	48
Bobcat Tractor	78	60	54	52	48
Concrete Mixer	79	61	55	53	49
Bulldozer	82	64	58	56	52

Jack Hammer	89	71	65	63	59
Pavement Roller	80	62	56	54	50
Street Sweeper	82	64	58	56	52
Man Lift	75	57	51	49	45
Dump Truck	76	58	52	50	46

Notes:
1) The distances shown in this table represent minimum distances at which sources can be located from construction activity before a potentially significant impact would occur.
2) Noise levels based on actual maximum measured noise levels at 50 feet (Lmax).
3) Noise levels assume a noise attenuation rate of 6 dBA per doubling of distance. Source: FHWA Roadway Construction Noise Model (2006) Users Guide Table 1.

The project developer/applicant is expected to adhere to San Diego's requirements for construction activities with respect to hours of operation, muffling of internal combustion engines, and other factors which affect construction noise generation and its effects on noise sensitive land uses. Therefore, the following controls should be adhered to during Project construction:

- Limit noise-generating construction operations to between the least noise-sensitive periods of the daytime hours Monday through Saturday; no construction operations on Sundays or holidays
- Ensure that construction equipment is properly maintained and equip all internal combustion engine-driven equipment with intake and exhaust mufflers that are in good condition and appropriate for the equipment.
- Locate stationary noise generating equipment (e.g., compressors) and equipment staging areas as far as possible from adjacent residential receivers.

It is recommended, but not required, that the project developer/applicant designate a "disturbance coordinator" responsible for responding to any complaints about construction noise. The disturbance coordinator will determine the cause of the noise complaint (e.g., bad muffler, etc.) and will require that reasonable measures be implemented to correct the problem. Implementation of the controls outlined by the above measures would reduce construction noise levels emanating from the site, limit construction hours, and minimize disruption and annoyance.

With the implementation of these controls, and the limited duration of the noise generating construction period, the substantial temporary increase in ambient noise levels associated with construction activities would be less-than-significant.

5 Project Compliance Evaluation and Conclusion

Three receiver locations at the residential properties nearest to the new H2Station® units were identified and evaluated for potential impact. As discussed in Section 3.3, an increase of 5 dB or more is not allowable per the Redondo Beach Municipal Code. Based on this evaluation, the daytime and nighttime noise levels at these locations are not anticipated to increase by more than

1 dB with the Project, including the planned awning and CMU wall surrounding three sides of the new H2Station® units. As such, the project as designed meets all applicable acoustic regulations and requirements with no additional noise mitigation required above or beyond typical best architectural design practices.

Additionally, CEQA requirements are answered below.

Would the project result in:

a) generation of noise levels in excess of standards established in the local General Plan or Noise Ordinance, or applicable standards of other agencies? **The project has incorporated mitigation measures into the design which reduce the anticipated increase in noise due to operational equipment of the project down to 1dB above existing road traffic noise levels. Mitigation measures—namely the relocation of vent stacks to NW corner of site, a 12-foot-high solid 3-sided CMU wall around the equipment yard, and awning above equipment—are determined to be sufficient and reasonable measures to bring the levels down to less than significant.**

b) generation of excessive ground-borne vibration or ground-borne noise levels? **Less than significant. Vibration of the H2Station cabinets are contained within the equipment yard.**

c) For a project located within the vicinity of a private airstrip or an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels? **Not applicable**

Appendix

5.1 Terminology/Glossary

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

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

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

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

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

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

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

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

Energy Equivalent Level (L_{eq})
Because sound levels can vary markedly in intensity over a short period of time, some method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, one describes ambient sounds in terms of an

average level that has the same acoustical energy as the summation of all the time-varying events. This energy-equivalent sound/noise descriptor is called L_{eq}. In this report, an hourly period is used.

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

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

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

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

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

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

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

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

5.2 FHWA Traffic Noise Model

The Federal Highway Administration Traffic Noise Model (TNM) used for the sound level analysis in this study, contains the following components:

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

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

5.3 SoundPLAN Acoustics Software

SoundPLAN, the software used for this acoustic analysis, is an acoustic ray-tracing program dedicated to the prediction of noise in the environment. Noise emitted by various sources propagates and disperses over a given terrain in accordance with the laws of physics. Worldwide, governments and engineering associations have created algorithms to calculate acoustical phenomena to standardize the assessment of physical scenarios. Accuracy has been validated in published studies to be + / - 2.7 dBA with an 85% confidence level.

The software calculates sound attenuation of environmental noise, even over complex terrain, uneven ground conditions, and with complex obstacles. The modeling software calculates the sound field in accordance with ISO 9613-2 "Acoustics - Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." This standard states that "this part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors, in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night."

5.4 Characteristics of Sound

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

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

0 dBA	Reference 0%
-3 dBA	Barely Perceptible Change 50%
-5 dBA	Readily Perceptible Change 67%
-10 dBA	Half as Loud 90%
-20 dBA	1/4 as Loud 99%
-30 dBA	1/8 as Loud 99.9%

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

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

When sound is measured for distinct time intervals, the statistical distribution of the overall sound level during that period can be obtained. The L_{eq} is the most common parameter associated with such measurements. The L_{eq} metric is a single-number noise descriptor that represents the average sound level over a given period of time. For example, the L50 noise level is the level that is exceeded 50 percent of the time. This level is also the level that is exceeded 30 minutes in an hour. Similarly, the L02, L08 and L25 values are the noise levels that are exceeded 2, 8, and 25 percent of the time or 1, 5, and 15 minutes per hour. Other values typically noted during a noise survey are the L_{min} and L_{max}. These values represent the minimum and maximum root-mean-square noise levels obtained over the measurement period.

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

6 References

1. American National Standards Institute, Inc. 2004. *ANSI 1994 American National Standard Acoustical Terminology*. ANSI S.1.-1994, (R2004), New York, NY.
2. City of Redondo Beach Municipal Code, Chapter 24, Noise Regulation.
3. Federal Highway Administration. 2006. *FHWA Roadway Construction Noise Model User's Guide Final Report.* FHWA-HEP-05-054 DOT-VNTSC-FHWA-05-01