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MEMORANDUM

To:	Darlene Walter (Seaworld San Diego)
From:	Mark Storm, INCE Bd. Cert. (Dudek)
Subject:	Outdoor Noise Propagation Prediction for Proposed Nighttime "Drone" Display
Date:	April 1, 2019
cc:	Asha Bleier (Dudek)
Attachment(s):	A – Glossary of Acoustical Terms

At the request of Ms. Darlene Walter, this technical memorandum details the results of four studied scenarios for the predictive modeling of outdoor noise propagation of a planned aerial display of unmanned aerial systems (UAS, or "drones") proximate to the SeaWorld site in San Diego, CA.

In summary, predicted aggregate noise level from anticipated flight of the drones would, depending on the studied operation scenario, range from 31 to 38 decibels A-weighted (dBA) equivalent sound level (L_{eq}) at the southeastern edge of the Stony Point least tern nesting area in Mission Bay just north of the SeaWorld San Diego attractions.

1 Background

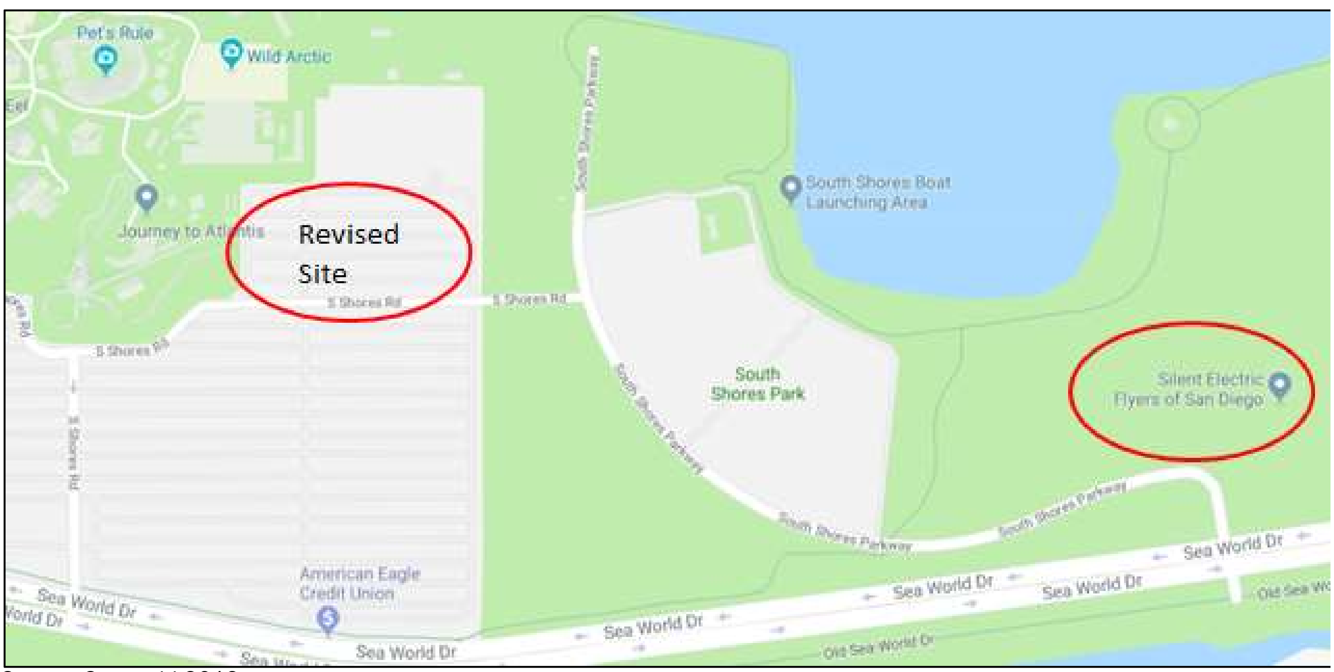
1.1 Project Description

As summarized in an email from Ms. Walter to Alexander Llerandi of the California Coastal Commission on March 4, 2019, Dudek understands that SeaWorld San Diego is proposing to commence a new 5-minute duration summer night show that utilizes approximately five hundred (500) drones. Figure 1 depicts the first of two locations considered for the proposed drone activity, shown by the blue trapezoidal-shaped area just north of the SeaWorld attractions on the shore of Mission Bay and located approximately 1,500 feet from the Stony Point least tern nesting area. Additional information in Ms. Walter's email regarding the planned aerial drone display included the following: drones would be flying 400 feet above grade, and "anticipated dB level at the source will be approximately 60-65dB."

Subsequent email correspondence informed Dudek of an alternate drone display location, shown in Figure 2. Additionally, Ms. Walter requested that Dudek consider two operation scenarios for each proposed location: one involving the original proposed quantity of 500 drones, and an alternate featuring only 300 drones.

Source: Seaworld 2019

Figure 1. Stony Point location (circled in yellow dashes) in proximity to SeaWorld park area and proposed drone activity location (blue trapezoid) in Mission Bay



Source: Seaworld 2019

Figure 2. Alternate proposed location (red-encircled "Revised Site") of planned drone aerial display

1.2 Acoustical Fundamentals

Sound is a process that consists of three components: the sound source, sound path, and sound receiver. All three components must be present for sound to exist. Without a source to produce sound, there is no sound. Similarly, without a medium to transmit sound pressure waves, there is no sound. Finally, sound must be received; a hearing organ, sensor, or object must be present to perceive, register, or be affected by sound or noise. Noise is defined as sound that is loud, unpleasant, unexpected, or undesired.

Attachment A contains a glossary of common acoustical terms, metrics, and descriptors, among which several are used in this memorandum to frame the presentation and discussion of noise propagation prediction for the proposed drone display.

Sound propagation (i.e., the passage of sound from a noise source to a receiver) is influenced by geometric divergence, acoustical ground absorption, atmospheric effects, and shielding by natural and/or man-made features. Sound levels attenuate (or diminish) at a rate of approximately 6 dB per doubling of travel distance from an outdoor point source due to spherical spreading of the sound wave energy. Atmospheric conditions such as humidity, temperature, and wind gradients can also affect sound levels; and in general, the greater the distance the receiver is from the source, the greater the potential for variation in sound levels due to atmospheric effects. Porous ground surfaces, such as loose soils or dense vegetative cover (grasses) absorb a portion of the propagating sound energy as it travels in proximity to grade, while smooth or hard ground surfaces (e.g., pavement, bodies of water) offer little or no acoustical absorption and instead provide a means of acoustical reflection. Additional sound attenuation can result due to linear occlusion of the direct source-to-receptor sound path, made possible by geographically intervening man-made structures or natural topography such as hills or ridgelines.

2 Methodology

A Microsoft Excel 2016 workbook was used to predictively model noise propagation from the proposed drone display for each of four studied scenarios as follows:

A. 500 drones in an area over the Mission Bay water just north of SeaWorld;

B. 300 drones at this same location as scenario A;

C. 500 drones in an alternate location, hovering over the eastern SeaWorld parking area; and

D. 300 drones at the alternate location of scenario C.

The Excel-based noise prediction model includes sound propagation algorithms consistent with relevant portions of International Organization of Standardization (ISO) 9613-2[1] that consider geometric divergence, atmospheric acoustical absorption at 1 kilohertz (kHz) to approximate A-weighted influence on overall sound pressure level

[1] ISO. 1996. Standard 9613-2: Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation. Available at https://www.iso.org/standard/20649.html

[SPL]), and ground effects. In summary, the predictive noise model was setup and "run" with input parameters that included the following:

- The quantity of drones are modeled as a collective point source 400 feet in the air above grade, at the geographic center of the proposed bounded flight area. This means that 65 dBA (assumed per-source SPL at a distance of one meter) for each drone is logarithmically combined into a total per the following expression:

  $SPL_{total} = SPL_{single} + 10*LOG(\text{quantity of drones})$

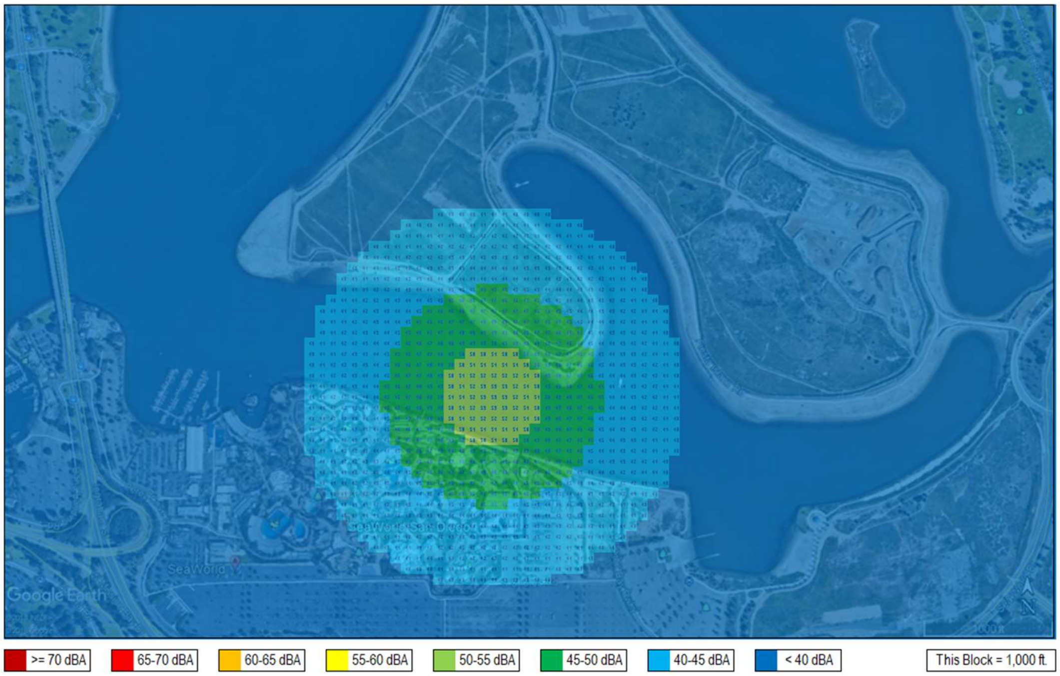
  For example, 500 drones yields a source SPL of 65+10*LOG(500) = 65 + 27 = 92 dBA at one meter.

- The Mission Bay water surface or the SeaWorld San Diego parking lot is acoustically reflective, adding 3 dB to the point-source sound power level.
- Noise levels are predicted over a horizontal plane 5' above grade (akin to a standing listener).
- Meteorological conditions presume an air temperature of 10 degrees Celsius and seventy percent (70%) relative humidity.
- Consistent with ISO 9613-2, the sound propagation algorithm conservatively presumes a "downwind" condition regardless of actual wind direction.
- Structures and terrain are conservatively ignored (i.e., the model space is flat and featureless).

3 Predicted Results

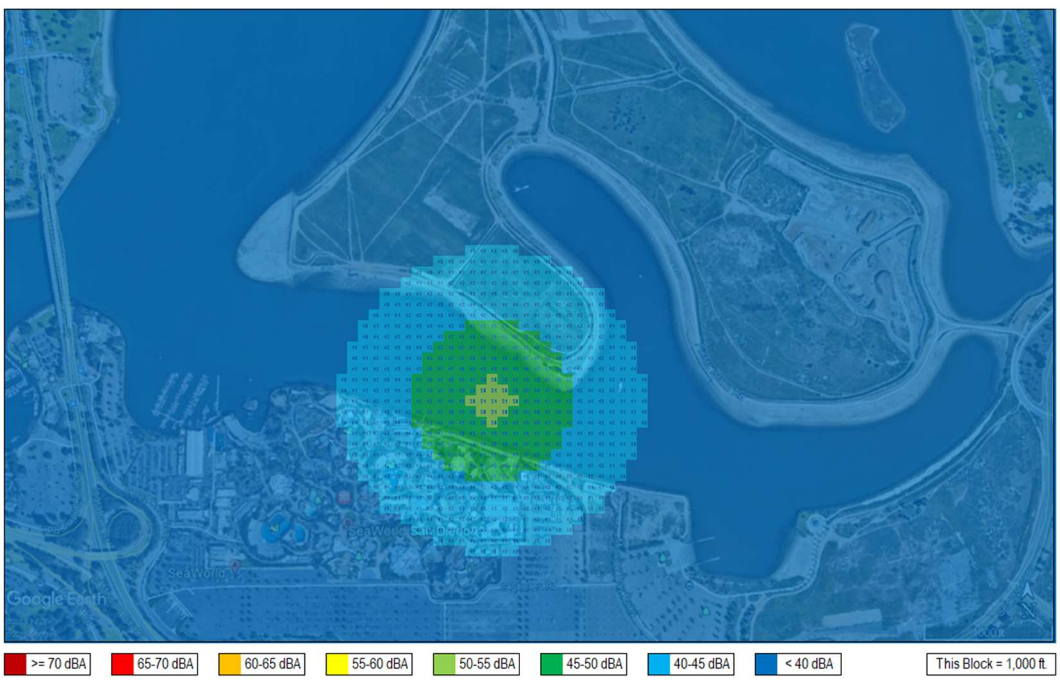
Figures 3, 4, 5, and 6 display the predicted results for each of the afore-listed scenarios A, B, C, and D, respectively. As shown, expected noise levels during the drone show are not expected to exceed 40 dBA L_{eq} in the vicinity of Stony Point. At a distance of approximately 1,400 feet from roadway traffic on Ingraham Street, Stony Point is already exposed to existing outdoor ambient noise levels that are likely to be at least 40 dBA L_{eq} based on guidance from the Federal Transit Administration (FTA).[2]

[2] FTA. 2006. Transit Noise and Vibration Impact Assessment. Available at: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Noise_and_Vibration_Manual.pdf



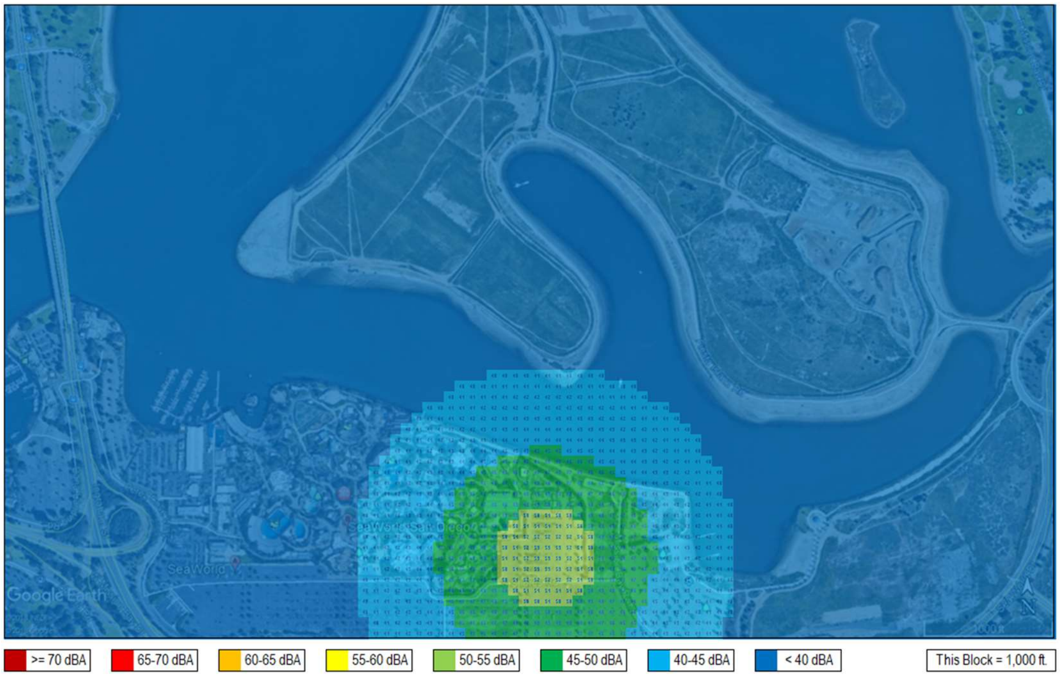
Sources: Dudek 2019, Google Earth 2019

Figure 3. Predicted noise propagation of proposed drone aerial display (Scenario A – 500 drones) across Mission Bay in vicinity of Stony Point and SeaWorld San Diego



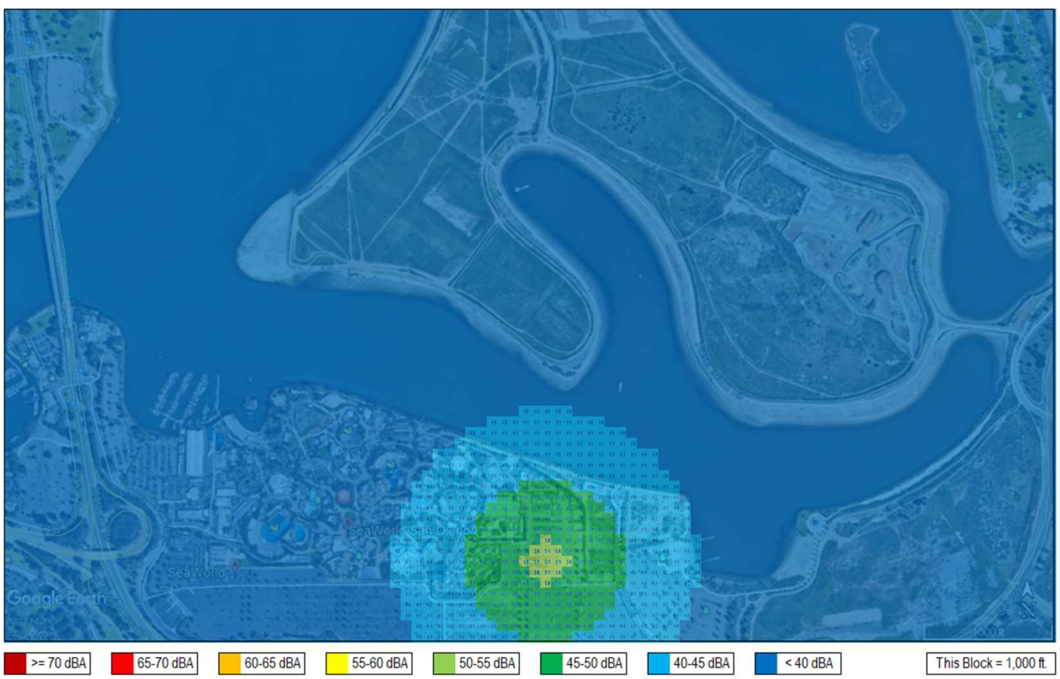
Sources: Dudek 2019, Google Earth 2019

Figure 4. Predicted noise propagation of proposed drone aerial display (Scenario B – 300 drones) across Mission Bay in vicinity of Stony Point and SeaWorld San Diego



Sources: Dudek 2019, Google Earth 2019

Figure 5. Predicted noise propagation of proposed drone aerial display (Scenario C – 500 drones) across Mission Bay in vicinity of Stony Point and SeaWorld San Diego



Sources: Dudek 2019, Google Earth 2019

Figure 6. Predicted noise propagation of proposed drone aerial display (Scenario D – 300 drones) across Mission Bay in vicinity of Stony Point and SeaWorld San Diego

Attachment A

Glossary of Acoustical Terms

Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
A-Weighted Sound Level (dBA)	The sound pressure level (SPL) in decibels as measured on a sound level meter (SLM) using the A-weighted filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the measured sound in a manner similar to the frequency response of the average healthy human ear, and thus correlates well with assessment of environmental noise in a community setting where noise-sensitive receptors may be present.
Community Equivalent Noise Level (CNEL)	The A-weighted equivalent continuous sound level over a 24-hour period with a 10 dB adjustment added to sound levels occurring during the nighttime hours (10 p.m. to 7 a.m.), and 5 dB added to the sound during the evening hours (7 p.m. to 10 p.m.).
Decibel (dB)	The unit for expressing SPL and is equal to 10 times the logarithm (to the base 10) of the ratio of the measured sound pressure squared to a reference pressure, which is 20 micropascals.
Equivalent Sound Level (L_{eq})	The value corresponding to a steady-state sound level containing the same total energy as a time-varying signal over a given sample period.
Maximum Sound Level (L_{max})	The highest value measured by an SLM over a given sample period, based on a time-weighted sound level in dB using a “fast” or “slow” time constant.
Minimum Sound Level (L_{min})	The lowest value measured by an SLM over a given sample period, based on a time-weighted sound level in dB using a “fast” or “slow” time constant.
Statistical Sound Level (L_{xx})	The sound level, in dB, that is exceeded “xx” percent of the time during a given measurement period. For instance, L_{50} is often called the “median” value as it is not the average or mean sound level. The L_{90} is often referred to as a “background” sound level, as it is exceeded 90% of the time and would therefore characterize the acoustical contribution of continuous or steady-state sources from a measurement period. The L_{10} level, in contrast, indicates infrequent high levels.