Expressway Corridor Environmental Health Study

Study Report

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Introduction

The city of Plano has grown significantly over the past 50 years, and during that time the city's long range planning policies have focused on limiting residential development in expressway corridors for the dual purposes of preserving land for economic development and maintaining quality of life. Previously residential development within 1,200 feet of expressway centerlines was restricted in order to buffer the negative quality of life impacts of expressways on residents. As a continuation of the prior comprehensive plan philosophy related to expressway corridor setbacks, the following action statement was adopted within the Comprehensive Plan:

Redevelopment of Regional Transportation Corridors Action Statement RTC4 - Develop design guidelines for residential development adjacent to expressways that reduce noise and provide for proper filtering, ventilation, and exhaust of vehicle air emissions.

This study was proposed to examine the science and best practices of the quality of life issues; the results will provide the City Council and Planning & Zoning Commission more solid, defensible data for making decisions on where and how to be accommodating regarding residential setback goals. The goal of this study is to provide more precise, accurate, and flexible tools to aid in determining reasonable development outcomes while preserving quality of life goals.

Health Impacts

Since passage of the Clean Air Act in 1963 and the Noise Control Act of 1972 research has been undertaken to understand the impact of automobile exhaust and noise on people's health. Based on studies in the U.S. and Europe, a body of evidence has been established that identifies several adverse health effects related to proximity to high volume and high speed roadways. Higher levels of air pollution often related to living in close proximity to highways have been demonstrated to result in increased rates of asthma, heart and circulatory diseases, and poor health conditions in newborns and children. In addition, high levels of highway noise have been found to increase sleep disturbance and the associated adverse health impacts such as increased rates of heart disease, hypertension, and diabetes.

Noise Exposure

Noise is most commonly measured using the logarithmic decibel (dB) scale and corrected using an "A" weighting that correlates best to human noise perception. Since noise exposure changes over time, there are many ways to measure noise, ranging from measuring the loudest noise, background noise, ambient noise, and total noise exposure. Most studies evaluating the health impacts of noise consider the 24 hour average noise level; these studies include an adjustment for nighttime noise to account for the significant impact of sleep disturbance. This measure, called the Day Night Average Sound Level (or L_{dn}), has been used throughout the country by both state and federal agencies to determine acceptable noise levels.

As it relates to acceptable levels of noise in a residential environment, the United States Department of Housing and Urban Development (HUD) has identified standards for acceptable noise levels. They have identified that locations with 75 dBA L_{dn} are typically unacceptable for residential development. Locations that are between 65 and 75 dBA L_{dn} are considered normally unacceptable but can be permissible with certain levels of mitigation. Locations that are 65 dBA L_{dn} and below are considered acceptable for residential development. In addition, HUD identified a goal for interior noise levels from outside noise sources be no greater than 45 dBA L_{dn}. Since the HUD standards are most appropriate for residential development and are consistent with acceptable levels identified in health research it is recommended that the City of Plano utilize these same standards in development of residential development guidelines.

To determine existing and future noise levels in the city, a noise model was developed for the areas surrounding Plano's expressways. The model takes into account the effects of terrain features including elevations of noise sources, receivers, and intervening objects (buildings, hills, and trees), and ground effects due to areas of hard ground (pavement and water) and soft ground (grass, field, and forest). The model was developed with data from the Plano GIS system, DART train schedules, and traffic data from the Texas Department of Transportation and the North Texas Tollway Authority. The model was calibrated with noise data collected at 19 locations across Plano (both short- and long-term monitors).

Environmental Health Maps were created based on the model data which identify noise levels in the areas adjacent to the expressways (See Appendix D). The maps include two noise contours which identify the areas with noise levels:

- Between 65 dBA Ldn and 75 dBA Ldn.
- Above 75 dBA Ldn.

Air Pollution Exposure

Air pollution is generally a regional issue because air pollutants can travel far distances before dispersion. Concentrations of air pollutants are highly variable and can change dramatically due to weather, wind, time of day, topography, and micro-climates, and therefore cannot be reliably modeled and mapped at the local or parcel level. However, increased levels of some pollutants are found in close proximity to expressways and are a cause for concern. Studies have shown that concentrations of some air pollutants are generally higher within 300 to 500 feet of the edge of the roadway and although highly variable, represent a condition that may be effectively mitigated.

Recommendations for Land Use

After review of approaches that other communities used to control or guide residential and other sensitive land uses adjacent to expressways, the recommended approach to account for the potential impacts of noise and air quality adjacent to expressways in Plano include the following:

- Integrate into the site design process the review of noise and air quality conditions for Planning & Zoning Commission consideration in the overall evaluation of the development.
- Each new residential and other sensitive land use constructed or expanded in the city should be reviewed for compliance with the noise exposure standards established by the Department of Housing and Urban Development as they relate to residential development.
- Mitigation for noise and air quality impacts should be considered for each applicable land use located in an area where mitigation may be appropriate.

Mitigation options to minimize the effects of noise and air pollution should include:

- Increased distance between the expressway and the building;

- Installation of sound barriers, which could include noise walls, earthen berms, or other buildings;
- Develop the site design to locate bedrooms, balconies, and open spaces away from the expressways;
- Enhanced building design using improved window, door, and wall materials and/or designs to achieve interior noise level goals (noise mitigation only);
- Locating air intake vents on buildings to face away from expressways and as far away from the expressway as practical (air pollution mitigation only); and
- Providing indoor air quality filtration system that reduces at least 90% of particulate matter emissions (air pollution only).

1 Introduction

The city of Plano has grown significantly over the past 50 years. Many large corporations moved to the city in the 1980's, which led to high levels of growth, so that by 2016, the population totaled over 275,000, making it one of the largest suburbs of Dallas. This growth is anticipated to continue with a projected population of 300,000 residents by 2040. This growth results in more demand for residential housing, with an estimated demand of 15,000 additional housing units in the next 20 to 30 years.

With all of the anticipated growth, the pressure on identifying locations to construct new housing units is increasing. Plano has an exceptional variety of neighborhood choices and plans on maintaining that variety to ensure a high quality of life. However, with only 0.8% of Plano's total land area currently undeveloped and planned for future residential development, additional strategies need to be considered on how to accommodate the growth while conserving established residential neighborhoods.

One identified strategy is to reconsider standards and guidelines for development in the city's expressway corridors. In 1999, the City established a policy that promoted commercial development in areas located within 1,200 feet of the centerline of Sam Rayburn Tollway, and in 2012 this policy was applied to each of the other three expressways in Plano. This policy was focused on buffering the negative quality of life impacts of expressways on residents. Upon adoption of the 2015 Comprehensive Plan, the expressway buffer was not continued as policy, but instead the plan recommended an action to:

> *"Develop design guidelines for residential development adjacent to expressways that reduce noise and provide for proper filtering, ventilation, and exhaust of vehicle air emissions."*

The goal of this study is to support the creation of appropriate guidelines for sensitive land uses that are proposed to be developed near expressways in the city of Plano to better evaluate these development requests. The study will undertake to:

- Research existing policies that address human health impacts related to proximity to high volume highways in conditions similar to those in Plano, and
- Conduct an analysis of existing and projected future noise conditions for locations adjacent to expressways within the city of Plano.

The report documents the review of literature and research focused on health impacts related to proximity to highways, metrics commonly used in measuring and categorizing noise, measurements of noise conditions adjacent to Plano expressways, the development of a noise model, examples of noise and air quality control in other communities, and recommendations for minimizing the impacts of expressway proximity on human health in Plano.

2 Literature Review

Air and noise pollution and their impact on communities are long-standing concerns. In 1963, the United States federal government took a major step in the control of air pollution with the passage of the Clean Air Act. The act included steps to control common pollutants and required the Environmental Protection Agency (EPA) to establish national ambient air quality standards based on the latest science. With a federal requirement to base national standards on science, research on the impacts of air pollution has continued over the years.

Federal actions to control noise pollution began in the early 1970s with passage of the Noise Pollution and Abatement Act of 1970 and the Noise Control Act of 1972. The Noise Control Act gave the EPA the authority to develop noise control methods, set standards, and coordinate noise control programs. Research was quickly advanced to assist the EPA in the establishment of standards and noise control methods. Although much of the research done at that time regarding standards still forms the backbone of noise control, research regarding the health impacts of noise has continued to advance.

The following literature review is provided to document the latest scientific research on the health impacts of air and noise pollution, as they relate to land uses and their proximity to highways. The literature review provides summaries of relevant research and examples of policies that have been established related to the placement of sensitive land uses adjacent to highways.

2.1 Air Pollution – Health Impacts

Air Pollution from motor vehicles is a significant source of urban air pollution and is an increasingly important contributor of carbon dioxide and other greenhouse gases. Motor vehicles emit large quantities of pollutants into the atmosphere. The primary pollutants of concern to health from highway traffic emissions are:

- nitrogen dioxide,
- carbon monoxide,
- PM10 (Particulate Matter with a diameter of less than 10 µm), PM2.5 and Ultrafine Particles,
- black smoke,
- benzene,
- polycyclic aromatic hydrocarbons (PAHs), and
- metals, including lead.

Each of these can cause adverse effects on health and the environment. Pollutants from vehicle emissions are related to vehicle type, fuel type, age and condition of the vehicle, and exhaust treatments used. Although regulations and other pollution-control approaches have led to a reduction of exhaust emissions for each individual vehicle, with the overall increase in vehicle usage, air pollution remains a major health concern. Continued research regarding transportation related air pollution continues to advance our understanding of health impacts and potential ways to minimize these impacts. Some of the findings of studies related to the health impacts of air pollution are below:

Children's Health

- Reduced lung function in children was associated with traffic density, especially truck density, within 1,000 feet and the association was strongest within 300 feet (Brunekreef et al., 1997).
- A San Diego study found increased medical visits in children living within 550 feet of heavy traffic (English et al., 1999).

Asthma

- Increased child asthma hospitalizations were associated with living within 650 feet of heavy traffic and truck volume (Lin et al., 2002).
- Asthma symptoms increased with proximity to roadways and the risk was greatest within 300 feet (Venn et al., 2001).
- Asthma and bronchitis symptoms in children were associated with proximity to high traffic in a San Francisco Bay Area community that otherwise had good overall regional air quality (Kim et al., 2004).

Heart / Circulatory Disease

- Increased incidence of new heart disease (Kan et al., 2008).
- Increased risk of premature death from circulatory disease (Jerrett et al., 2009).
- Increased risk of new-onset chronic obstructive pulmonary disease (Andersen et al., 2011).
- A faster progression of atherosclerosis in those living within 100 meters of highways in Los Angeles (Künzli et al., 2010).

Pregnancy

- Increased risk of pre-term delivery (Wilhelm & Ritz, 2003; Laurent et al., 2016) for mothers living very near heavy traffic.
- Increased risk of low birth weight (Ferrero et al., 2017).

In reviewing any individual health impact study, it is often not appropriate to translate the results into generalizations for all people at all locations. Differences in emission patterns, exposure, populations, and urban structure often lead to differences that cannot, or will not, be repeated. That said, there is a growing field of evidence under numerous conditions that lead to the understanding that pollutants from highway traffic affect human health.

In 2008, a panel of experts critically reviewed the latest relevant studies that addressed traffic-based air pollution and concluded that, based on the compilation of all the studies conducted to date, there is evidence to relate traffic-based air pollution and the aggravation of asthma. The panel also concluded that links exist between exposure to traffic-based air pollution and the onset of childhood asthma, non-asthma respiratory symptoms, impaired lung function, cardiovascular disease, and related fatalities. Due to the limitations of the studies and the difficulties with studying long-term air pollution exposure, they could not fully conclude that traffic-based air pollution causes any of the aforementioned health outcomes (Health Effects Institute, 2010).

In summary, on-going studies show that people continuously exposed to traffic-based air pollution can experience serious health impacts, including worsening of asthma, cardiovascular disease, and adverse birth outcomes.

2.2 Noise – Health Impacts

Long-term exposure to traffic noise has been found to result in a wide variety of adverse health effects including sleep disturbance, cardiovascular disease, increased incidence of diabetes, stress, and annoyance. Studies with definitive conclusions related to adverse health outcomes have focused on heart disease related to sleep disturbance, increased hypertension and diabetes, and increased levels of stress. The primary cause for these negative health effects are related to sleep disturbance and physiological stress responses. The following summarizes key points of relevant studies:

Sleep Disturbance

Exposure to noise disturbs sleep through altering the duration of each sleep stage and increasing the number of awakenings experienced each night. It has been found that both of these sleep impacts are proportional to the level of noise (Gitanjali & Ananth, 2003). Nighttime road traffic noise causes awakenings and arousals without awakenings, both of which lead to sleep fragmentation. An evaluation of increased heart rates resulting from noise-based sleep disturbances found that the heart rate response did not decrease over time, and therefore may play a key role in promoting traffic noise induced cardiovascular disease (Griefahn et al., 2008).

Furthermore, during the day following a disturbed sleep there may be after-effects which influence mood and reaction time performance. Studies show that, if indoor noise level can be reduced, the amount of rapid eye movement (REM) sleep and slow wave sleep can be increased, which lead to sleep patterns that are more restful (Stansfeld & Matheson, 2003).

Heart Disease

Studies have concluded that noise-based sleep disturbances in turn lead to cardiovascular morbidity and mortality. A number of studies conducted during the past twenty years suggest that transportation noise is associated with negative cardiovascular effects (Babisch, 2002).

One study examined incidents of heart attacks in Berlin between 1998 and 2001 and found a correlation between roadway noise annoyance and heart attack rates in males (Babisch et al., 2005). Follow-up studies conducted to identify the association between road-traffic noise levels and the risk of heart attacks found an increase in risk with increasing noise levels above 60 dBA (Babisch, 2008). A long-term study conducted in Vancouver, BC, found that a 10 dBA increase in residential noise levels was associated with a 9% increase in the risk of death from coronary heart disease (Gan, 2012). The evidence demonstrating a link between transportation noise and coronary heart disease has increased considerably over the past two decades (Babisch, 2011) leading to little question about the linkage.

Hypertension/Diabetes

Studies evaluating health and peoples' living environments have demonstrated a relationship between ambient noise levels and increased blood pressure (Babisch & Kamp, 2009 and van Kempen & Babisch, 2012). Studies have identified the same correlation between noise and an increased incidence of diabetes (Sørensen M et al., 2013).

Recent studies suggest that noise exposure increases the risk of hypertension. One study examined adults with diagnosed hypertension and found an association between residential traffic noise and hypertension, with those exposed to high levels of environmental noise being almost two times more likely to suffer from hypertension (Barregard et al., 2009). A separate study found similar results regarding increased incidence of hypertension with a 38% increase in hypertension for each 5 dBA increase in highway noise levels (Bluhm et al., 2007). A 2006 study of eight European cities found a statistically significant relationship between road traffic noise and hypertension (Niemann et al., 2006). This study found the effect of severe noise exposure in both the cardiovascular system and the respiratory system.

In addition to sleep and cardiovascular impacts, road traffic noise may have other impacts, such as stress, annoyance, hearing loss, and learning difficulties. Numerous other studies have examined potential impacts of road traffic noise for certain conditions or situations. For example, one study found that road traffic noise exposure at home may be related to increased hyperactivity and more emotional symptoms in children (Tiesler & Birk, 2013).

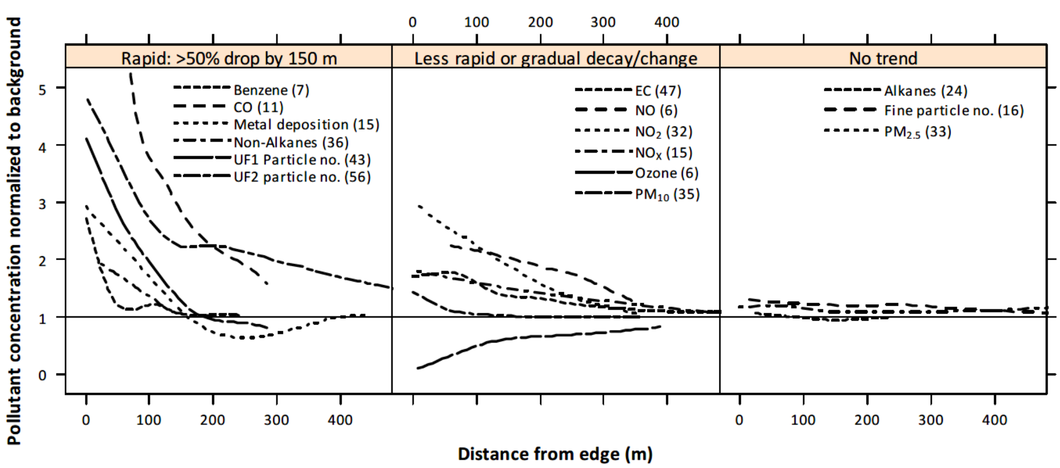
3 Air Pollution and Noise Pollution Basics

3.1 Air Pollution Basics

Air pollution is a regional issue which occurs via a variety of pollutants and pollutant sources. These pollutants can spread away from the direct source, through the region and across city and county lines. However, proximity to expressways does increase exposure to some pollutants. The spread of pollutants is affected by a number of variables including wind direction and speed as well as time of day and year. Additionally, each pollutant disperses at different rates.

It is generally understood that adverse health impacts increase with increased exposure to air pollution. The duration of contact to, and the concentration of, the pollutant where contact occurs determines the magnitude of the exposure and the extent of potential for health effects. While the amount of exposure that is acceptable to minimize or eliminate risk is not known at this time, the following section will review dispersion estimates and analysis that is generally thought to minimize exposure:

- Concentrations of some air pollutants, notably ultrafine particles (UFP) and nitrogen oxides (e.g., NO, NO_2), are highest closer to major roads and highways (Health Effects Institute, 2010).
- On average, particulate matter concentration is significantly higher within 330 feet (100 meters) of major highways than it is further away (Zhu et al., 2002).
- Different traffic-related air pollutants disperse at different rates (Karner et al., 2010).
- Concentrations of primary pollutants such as NO and UFP, which are emitted directly into the air from vehicles, decrease rapidly with increasing distance from roads (Karner et al., 2010).
- In comparison, the concentrations of secondary pollutants such as NO_2 and particulate matter (PM2.5), which form in the atmosphere when primary pollutants react, decrease more gradually with increasing distance from major roadways (Karner et al., 2010).
- The concentrations of some traffic-related air pollutants decrease by over 50% within the first 100-150 meters from the roadway and are generally at background levels by 500 meters from the roadway (See Figure 1 below, Karner et al., 2010).



Source: Karner A.A., D.S. Eisinger, and D.A. Niemeier, 2010

Figure 1 Pollutant Concentrations Compared to Distance from Edge of Highway

Distance from the road is not the only factor affecting traffic related air pollutant concentrations. Other variables include:

- Traffic speed, traffic volume and the proportion of older vehicles and heavy-duty vehicles (e.g. fleet mix), such as trucks and buses on the roadway.
- Meteorological factors including wind direction, wind speed, precipitation, and solar radiation. For example, air pollution levels upwind of roads decrease much faster compared to levels downwind.
- Built environment factors such as tall buildings in continuous rows alongside roads.
- Topographical factors including land surface characteristics, such as whether roads are surrounded by open land or ridges.

3.2 Noise Basics

3.2.1 Noise Fundamentals and Descriptors

Noise is typically defined as unwanted or undesirable sound, whereas sound is characterized by small air pressure fluctuations above and below the atmospheric pressure. The basic parameters of environmental noise that affect human subjective response are (1) intensity or level, (2) frequency content, and (3) variation with time.

The first parameter – intensity or level – is determined by how greatly the sound pressure fluctuates above and below the atmospheric pressure, and is expressed on a compressed scale in units of decibels (dB). By using this scale, the range of normally encountered sound can be expressed by values between 0 and 120 decibels. On a relative basis, a 3-decibel change in sound level generally represents a barely noticeable change outside the laboratory, whereas a 10-decibel change in sound level would typically be perceived as a doubling (or halving) in the loudness of a sound. A 5-decibel change is readily noticeable by people with average hearing.

The frequency content of noise is related to the tone or pitch of the sound, and is expressed based on the rate of the air pressure fluctuation in terms of cycles per second (called Hertz and abbreviated as Hz). The human ear can detect a wide range of frequencies from about 20 Hz to 17,000 Hz. However, because the sensitivity of human hearing varies with frequency, the A-weighting system is commonly used when measuring environmental noise to provide a single number descriptor that correlates with human subjective response. Sound levels measured using this weighting system are called "A-weighted" sound levels, and are expressed in decibel notation as "dBA." The A-weighted sound level is widely accepted by acousticians as a proper unit for describing environmental noise. Most commonly encountered outdoor noise sources generate sound levels within the range of 60 dBA to 90 dBA at a distance of 50 feet.

Because environmental noise fluctuates from moment to moment, it is common practice to condense all of this information into a single number, called the “equivalent” sound level (L_{eq}). L_{eq} can be thought of as the steady sound level that represents the same sound energy as the varying sound levels over a specified time period (typically 1 hour or 24 hours). Often, the L_{eq} values over a 24-hour period are used to calculate cumulative noise exposure in terms of the Day-Night Sound Level (L_{dn}). L_{dn} is the A-weighed L_{eq} for a 24-hour period with an added 10-decibel penalty imposed on noise that occurs during the nighttime hours (between 10:00 p.m. and 7:00 a.m.). Many surveys have shown that L_{dn} is well correlated with human annoyance, and therefore this descriptor is widely used for environmental noise impact assessment. L_{dn} is generally found to range between 55 dBA and 75 dBA in most communities.

3.2.1.1 Measurement Metrics

To assist reviewers in interpreting the complex noise metrics used in evaluating roadway traffic noise, we present below an introduction to relevant fundamentals of acoustics and noise terminology. Five acoustical descriptors of noise are introduced here in increasing degree of complexity:

- Decibel, dB;
- A-weighted decibel, dBA;
- Sound Exposure Level, SEL;
- Equivalent Sound Level, L_{eq}; and
- Day-Night Average Sound Level, L_{dn} or DNL.

These noise metrics form the basis for the majority of environmental noise analysis conducted for most transportation projects throughout the U.S.

Decibel, dB

All sounds come from a sound source – a musical instrument, a voice speaking, an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source is transmitted through the air in sound waves – tiny, quick oscillations of pressure just above and just below atmospheric pressure. These oscillations, or sound pressures, impinge on the ear, creating the sound we hear.

Our ears are sensitive to a wide range of sound pressures. Although the loudest sounds that we hear without pain have about one million times more energy than the quietest sounds we hear, our ears are incapable of detecting small differences in these pressures. Thus, to better match how we hear this sound energy, we compress the total range of sound pressures to a more meaningful range by introducing the concept of sound pressure level.

Sound pressure levels are measured in decibels (or "dB"). Decibels are logarithmic quantities reflecting the ratio of the two pressures, the numerator being the pressure of the sound source of interest, and the denominator being a reference pressure (the quietest sound we can hear).

The logarithmic conversion of sound pressure to sound pressure level (SPL) means that the quietest sound that we can hear (the reference pressure) has a sound pressure level of about 0 dB, while the loudest sounds that we hear without pain have sound pressure levels of about 120 dB. Most sounds in our day-to-day environment have sound pressure levels on the order of 30 to 100 dB.

Because decibels are logarithmic quantities, combining decibels is unlike common arithmetic. For example, if two sound sources each produce 100 dB operating individually and they are then operated together, they produce 103 dB – not the 200 decibels we might expect. Four equal sources operating simultaneously produce another three decibels of noise, resulting in a total sound pressure level of 106 dB. For every doubling of the number of equal sources, the sound pressure level goes up another three decibels. A tenfold increase in the number of sources makes the sound pressure level go up 10 dB. A hundredfold increase makes the level go up 20 dB, and it takes a thousand equal sources to increase the level 30 dB.

If one noise source is much louder than another, the two sources operating together will produce virtually the same sound pressure level (and sound to our ears) that the louder source would produce alone. For example, a 100 dB source plus an 80 dB source produce approximately 100 dB of noise when operating together (actually, 100.04 dB). The louder source "masks" the quieter one. But if the quieter source gets louder, it will have an increasing effect on the total sound pressure level such that, when the two sources are equal, as described above, they produce a level three decibels above the sound of either one by itself.

Conveniently, people also hear in a logarithmic fashion. Two useful rules of thumb to remember when comparing sound levels are:

1. a 6 to 10 dB increase in the sound pressure level is perceived by individuals as being a doubling of loudness, and
2. changes in sound pressure level of less than about three decibels are not readily detectable outside of a laboratory environment.

A-Weighted Decibel, dBA

Another important characteristic of sound is its frequency, or "pitch." This is the rate of repetition of the sound pressure oscillations as they reach our ear. When analyzing the total noise of any source, acousticians often break the noise into frequency components (or bands) to determine how much is low-frequency noise, how much is middle-frequency noise, and how much is high-frequency noise. This breakdown is important for three reasons:

1. People react differently to low-, mid-, and high-frequency noise levels. This is because our ear is better equipped to hear mid- and high-frequencies but is quite insensitive to lower frequencies. Thus, we find mid- and high-frequency noise to be more annoying.
2. Mid- and high-frequency sound is in the same range as and therefore interferes with our speech communication.
3. Engineering solutions to a noise problem are different for different frequency ranges. Low-frequency noise is generally harder to control.

The normal frequency range of hearing for most people extends from a low frequency of about 20 Hz to a high frequency of about 10,000 to 15,000 Hz. People respond to sound most readily when the predominant frequency is in the range of normal conversation, typically around 1,000 to 2,000 Hz. Acousticians have developed several filters which roughly match this sensitivity of our ear and thus help us to judge the relative loudness of various sounds made up of many different frequencies. The so-called A-weighting network, does this best for most environmental noise sources. Sound pressure levels measured through this filter are referred to as A-weighted sound levels (measured in A-weighted decibels, or dBA).

The A-weighting network significantly discounts those parts of the total noise that occur at lower frequencies (those below about 500 Hz) and also at very high frequencies (above 10,000 Hz) where people do not hear as well. The network has very little effect, or is nearly "flat," in the middle range of frequencies between 500 and 10,000 Hz where our hearing is most sensitive. Because this network generally matches our ears' sensitivity, sounds having higher A-weighted sound levels are judged to be louder than those with lower A-weighted sound levels, a relationship which otherwise might not be true. A-weighted sound levels correlate better with human response to noisiness than other metrics do, most likely due to the emphasis the network has on the mid- and high-frequencies and the interference with speech such noise causes. It is for these reasons that A-weighted sound levels are normally used to evaluate environmental noise sources. Figure 2 presents typical A-weighted sound levels of several common environmental sources.

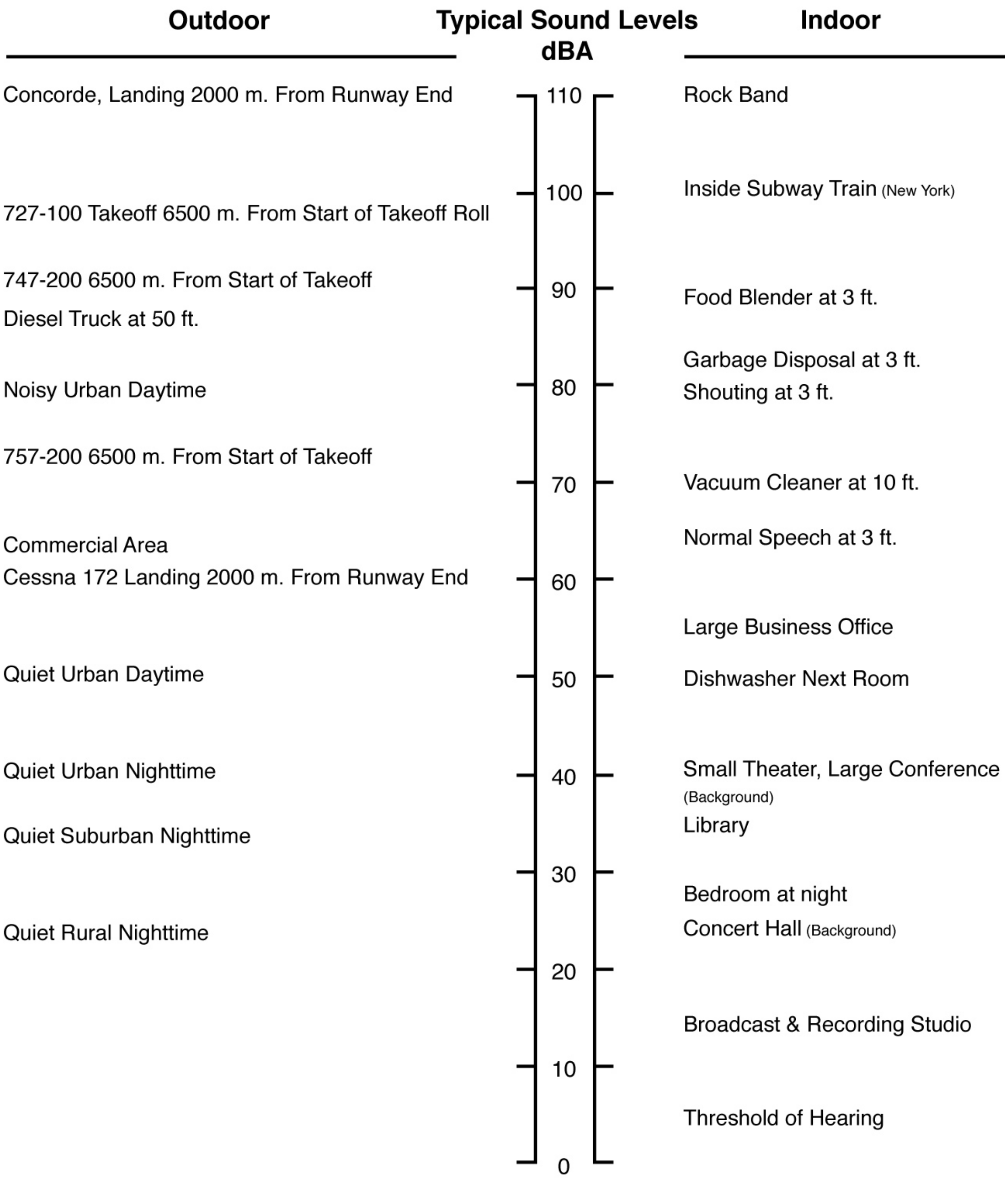


Figure 2 Common Environmental Sound Levels, in dBA

An additional dimension to environmental noise is that A-weighted levels vary with time. For example, the sound level increases as a truck approaches, then falls and blends into the background as the truck recedes into the distance (though even the background varies as birds chirp, the wind blows, or a vehicle passes by). This is illustrated in Figure 3.

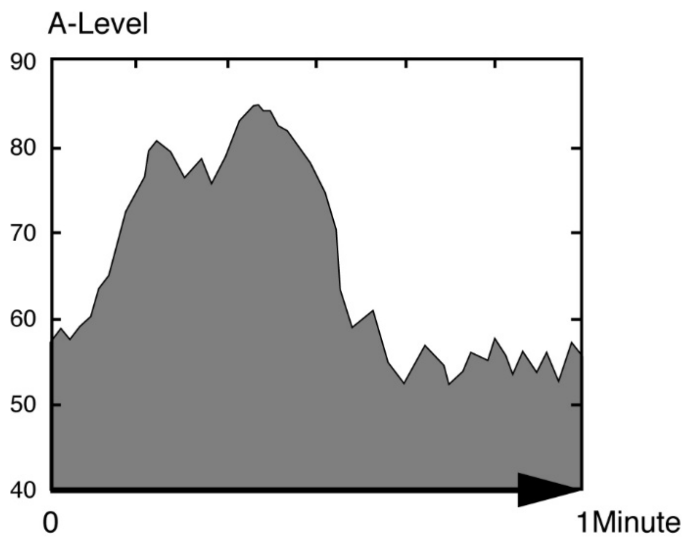


Figure 3 Variation in the A-Weighted Sound Level over Time

Because of this variation, it is often convenient to describe a particular noise "event" by its maximum sound level, abbreviated as L_{max}. In Figure 3, the L_{max} is approximately 85 dBA. However, the maximum level describes only one dimension of an event; it provides no information on the cumulative noise exposure generated by a sound source. In fact, two events with identical maximum levels may produce very different total exposures. One may be of very short duration, while the other may continue for an extended period and be judged much more annoying. The next section introduces a measure that accounts for this concept of a noise "dose."

Sound Exposure Level, SEL

The most common measure of cumulative noise exposure for a single event, such as a truck pass-by or aircraft overflight, is the Sound Exposure Level, or SEL. SEL is an accumulation of the sound energy over the duration of a noise event. The shaded area under the red curve in Figure 4 illustrates the portion of the sound energy included in this dose for a given duration. To account for the variety of durations that occur among different noise events, the noise dose is normalized (standardized) to a one-second duration. This normalized dose is the SEL; it is shown as the shaded "bar" between the vertical black lines in Figure 4. Mathematically, the SEL is the summation of all the noise energy compressed into one second.

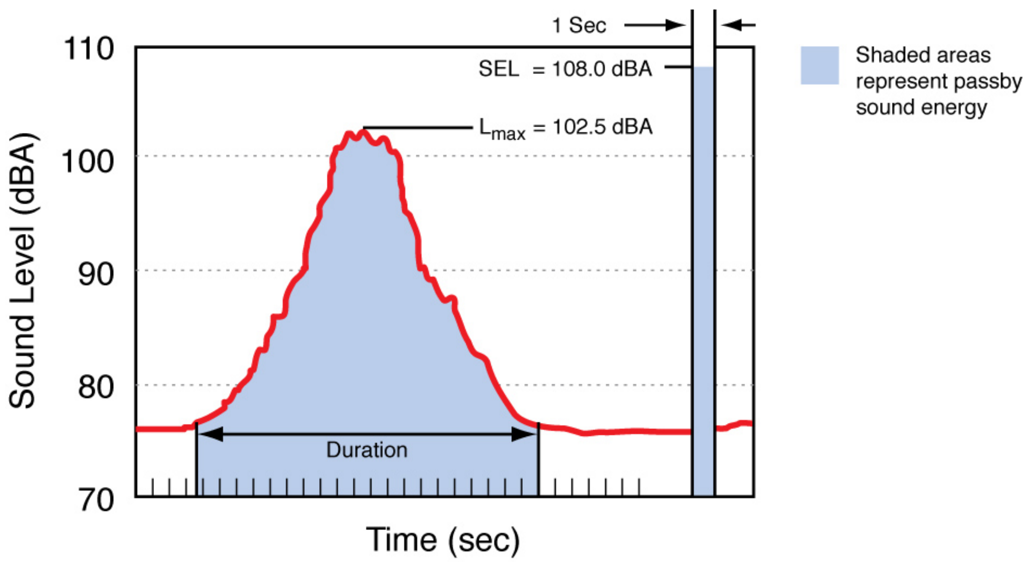


Figure 4 Sound Exposure Level

Note that because the SEL is normalized to one second, it will almost always be larger in magnitude than the maximum A-weighted level for the event. In fact, for many transportation sources such as truck pass-bys and aircraft overflights, the SEL is on the order of 5 to 12 dBA higher than the L_{max}. Also, the fact that it is a cumulative measure means that not only do louder events have higher SEL values than do quieter ones, but also events with longer durations have greater SEL than do shorter ones.

With this metric, we now have a basis for comparing noise events that generally matches our impression of the sound -- the higher the SEL, the more annoying it is likely to be. In addition, SEL provides a comprehensive way to describe a noise event for use in modeling noise exposure. Computer noise models base their computations on these SELs.

Equivalent Sound Level, L_{eq}

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest -- for example, an hour, an eight-hour school day, nighttime, or a full 24-hour day. However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric.

L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as the actual time-varying sound level. This is illustrated in Figure 5. The equivalent level is, in a sense, the total sound energy that occurred during the time in question, but spread evenly over the time period. It is a way of assigning a single number to a time-varying sound level. Since L_{eq} includes all sound energy, it is strongly influenced by the louder events that occurred during the period.

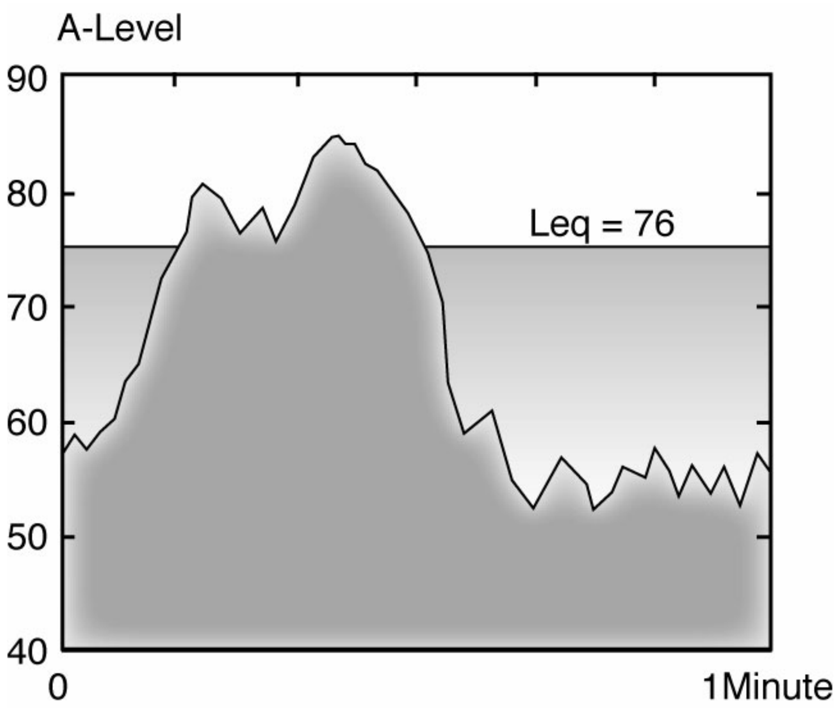


Figure 5 Example of a 1-Minute Equivalent Sound Level

For the assessment of highway noise, L_{eq} is evaluated over a period of one hour.

Day-Night Average Sound Level, L_{dn} or DNL

In the previous sections, we have been addressing noise measures that account for the moment-to-moment or short-term fluctuations in A-weighted levels as sound sources come and go affecting our overall noise environment. The Day-Night Average Sound Level (L_{dn} or DNL) represents a concept of noise dose as it occurs over a 24-hour period. It is the same as a 24-hour L_{eq}, with one important exception; L_{dn} treats nighttime noise differently from daytime noise. In determining L_{dn}, it is assumed that the A-weighted levels occurring at night (10 p.m. to 7 a.m.) are 10 dB louder than they really are. This 10 dB penalty is applied to account for greater sensitivity to nighttime noise, and the fact that events at night are often perceived to be more intrusive because nighttime ambient noise is less than daytime ambient noise.

Earlier, we illustrated the A-weighted level due to a noise event, such as a truck pass-by. The example is repeated in the top frame of Figure 6. The level increases as the truck approaches, reaching a maximum of 85 dBA, and then decreases as the truck passes. The ambient A-weighted level around 55 dBA is due to the background sounds that dominate after the truck passes. The shaded area reflects the noise dose that a listener receives during the one-minute period of the sample.

The center frame of Figure 6 includes this one-minute interval within a full hour. Now the shaded area represents the noise dose during that hour with sixteen noise events (e.g. truck pass-by or aircraft overflight), each producing a single event dose represented by an SEL. Similarly, the bottom frame includes the one-hour interval within a full 24 hours. Here the shaded area represents the noise dose over a complete day. Note that several noise events occur at night, when the background noise drops some 10 decibels, to approximately 45 dBA.

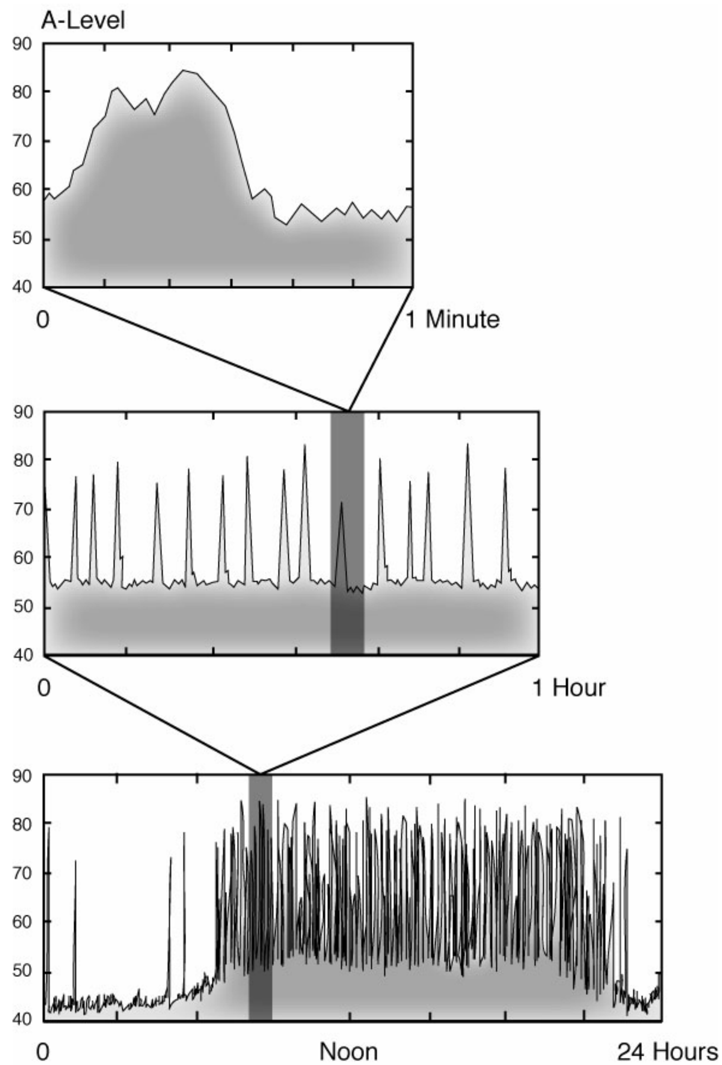


Figure 6 A-Weighted Level Fluctuations and Noise Dose

Values of L_{dn} are normally measured with standard monitoring equipment or are predicted with computer models. Measurements are practical for obtaining L_{dn} values for only relatively limited numbers of locations, and, in the absence of a permanently installed monitoring system, only for relatively short time periods. Thus, most noise studies utilize computer-generated estimates of L_{dn}, determined by accounting for all of the SEL from individual noise events (e.g. aircraft operations or train pass-bys) that comprise the total noise dose at a given location on the ground. This principle is used in the computer modeling of airport noise and railroad noise.

Computed values of L_{dn} may be depicted as noise contours, which are lines of equal exposure around a noise source, such as an airport. Noise contours are analogous to topographic maps, which have contour lines of equal ground elevation. When displayed in this manner for an airport, the noise contours usually reflect long-term (annual average) operating conditions, taking into account the average flights per day, how often each runway is used throughout the year, and where over the surrounding communities the aircraft normally fly.

Figure 7 presents a representative sample of L_{dn} values measured at various locations across the United States.

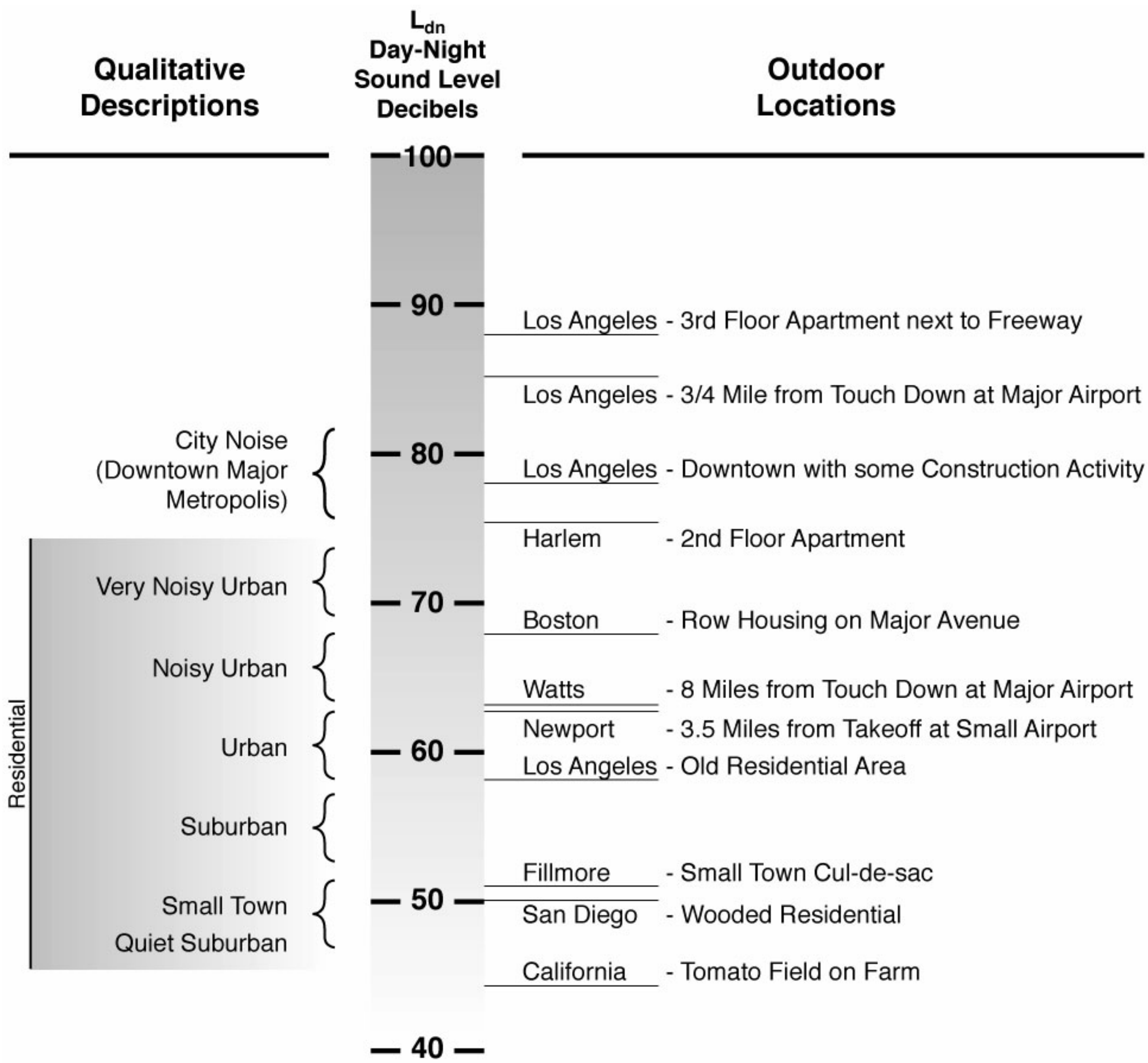


Figure 7 Representative Examples of Day-Night Average Sound Levels

Source: United States Environmental Protection Agency, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, March 1974, p.14.

Statistical Sound Level Descriptors

Statistical descriptors of the time-varying sound level are often used instead of, or in addition to, L_{eq} to provide more information about how the sound level varied during the time period of interest. The descriptor includes a subscript that indicates the percentage of time the sound level is exceeded during the period. The L_{50} is an example, which represents the sound level exceeded 50 percent of the time, and equals the median sound level. Another commonly used descriptor is the L_{10}, which represents the sound level exceeded 10 percent of the measurement period and describes the sound level during the louder portions of the period. The L_{90} is often used to describe the quieter background sound levels that occurred, since it represents the level exceeded 90 percent of the period.

Expressway Noise

Noise pollution from expressways is primarily generated from the friction of vehicle tires on pavement. The noise will vary based upon vehicle speeds, the volume of trucks and larger vehicles, and the overall volume of traffic.

4 Highway Noise and Air Pollution Exposure Criteria

4.1 Air Pollution – Highway Setback Examples

At this time no federal standard has been established specific to the siting of residential uses and other sensitive land uses, such as parks and retirement housing, near expressways. Some agencies in California, however, have established setback requirements to reduce the impact of air pollution from highways.

4.1.1 California Air Resource Board (CARB)

The recommendation from the California Air Resource Board (CARB) guidance with regard to freeways/roadways is to, "avoid siting new sensitive land uses within 500 feet [150 meters] of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day." The rationale provided for the setback distances included the data indicating exposure is "greatly reduced at approximately 300 feet [90 meters]" and that "health risk attributable to the proximity effect was strongest within 1,000 feet [300 meters]" (CARB, 2005).

4.1.2 Sacramento Metropolitan Air Quality Management District (SMAQD)

SMAQMD recognized that strict adherence to CARB's Land Use Handbook recommendations would effectively prohibit development patterns that were desired in Sacramento, which included high-density, mixed-use, and urban infill projects in close proximity to job centers. SMAQMD enacted a *Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways* in 2011. The protocol uses a process that evaluates health risks at the site from vehicle exhaust within 500 feet of freeways and major roadways. If an acceptable level of risk can be demonstrated within 500 feet after evaluation of site area traffic, air quality, and provided mitigation, then the sensitive land use is approvable. In some cases, residential developments have been approved as close as 200 feet to major freeways. Several California air quality resource boards have adopted the same protocol process. Although the 2011 protocol was replaced in 2018 with an on-line tool for evaluation, the new process is similar to the previous one, but with more up-to-date information.

4.2 Noise – Highway Setback Examples

A variety of exposure metrics are used to identify appropriate limits to environmental noise related to residential land uses.

4.2.1 U.S. Environmental Protection Agency (EPA)

The EPA was originally tasked under the Noise Control Act of 1972 with developing noise level criteria for the protection of public health and welfare. These general noise standards were published in what is referred to as the EPA "levels" document (EPA, 1974). As later identified by the Federal Interagency Committee on Urban Noise, the EPA levels document identifies in scientific terms the threshold of effect. Furthermore, while the levels have relevance for planning, they do not in themselves form the sole basis for appropriate land use action because they do not consider cost, feasibility, or the development needs of the community.

The EPA recommends an outdoor level not exceeding 55 A-weighted decibels (dBA), utilizing a day-night average metric (L_{dn}) to protect the public from the adverse effects of noise on health and welfare with an adequate margin of safety. The recommended indoor residential level limit is 45 dBA L_{dn}. The levels are identified to prevent activity interference and annoyance. These noise levels are considered those that will not interfere with daily activities and will permit spoken conversation and other activities such as sleeping, working, and recreation.

4.2.2 U.S. Federal Highway Administration (FHWA)

FHWA generally assesses and evaluates impacts from highway improvement projects or will provide assistance to abate noise impacts from existing highways. FHWA has established Noise Abatement Criteria based upon noise levels associated with the interference of speech which differ according to land use. The criteria for residential land uses does not consider abatement unless the traffic noise levels are greater than 66 dBA during the worst noise hour, expressed in terms of the equivalent sound pressure level (L_{eq}). FHWA noise regulations are included in 23 CFR 772, Procedures for Abatement of Highway Traffic Noise and Construction Noise.

FHWA does not have any recommended setbacks or specific noise exposure metrics, aside from the abatement criteria listed above, but advocates that local governments use their regulatory authority to prohibit incompatible development adjacent to highways or require planning, design, and construction of developments that minimize highway traffic noise impacts.

4.2.3 U.S. Department of Housing and Urban Development (HUD)

The goal of the HUD noise program is to support the agency mission to achieve a "decent home and suitable living environment of every American family" (as established in the Housing Act of 1949) and to support the noise control efforts of other federal agencies. The HUD noise program is primarily concerned with transportation noise and its effect on HUD-assisted dwelling units. The program is based on federal regulation, 24 CFR 51B.

Generally, new construction projects, which are exposed to a noise level of 75 L_{dn} or greater is considered unacceptable and cannot be assisted with HUD funds. If the noise level is between 65 and 75 dBA L_{dn} then the project can only be constructed if the interior noise levels are reduced to 65 dBA L_{dn} or lower, and any outdoor spaces connected to the project are mitigated. Residential sites with noise levels between 65 and 75 dB are considered normally unacceptable. Projects in areas where the outdoor noise level is below 65 dB L_{dn} are considered acceptable. Figure 8 presents comparison of HUD thresholds and noise levels in typical environments.

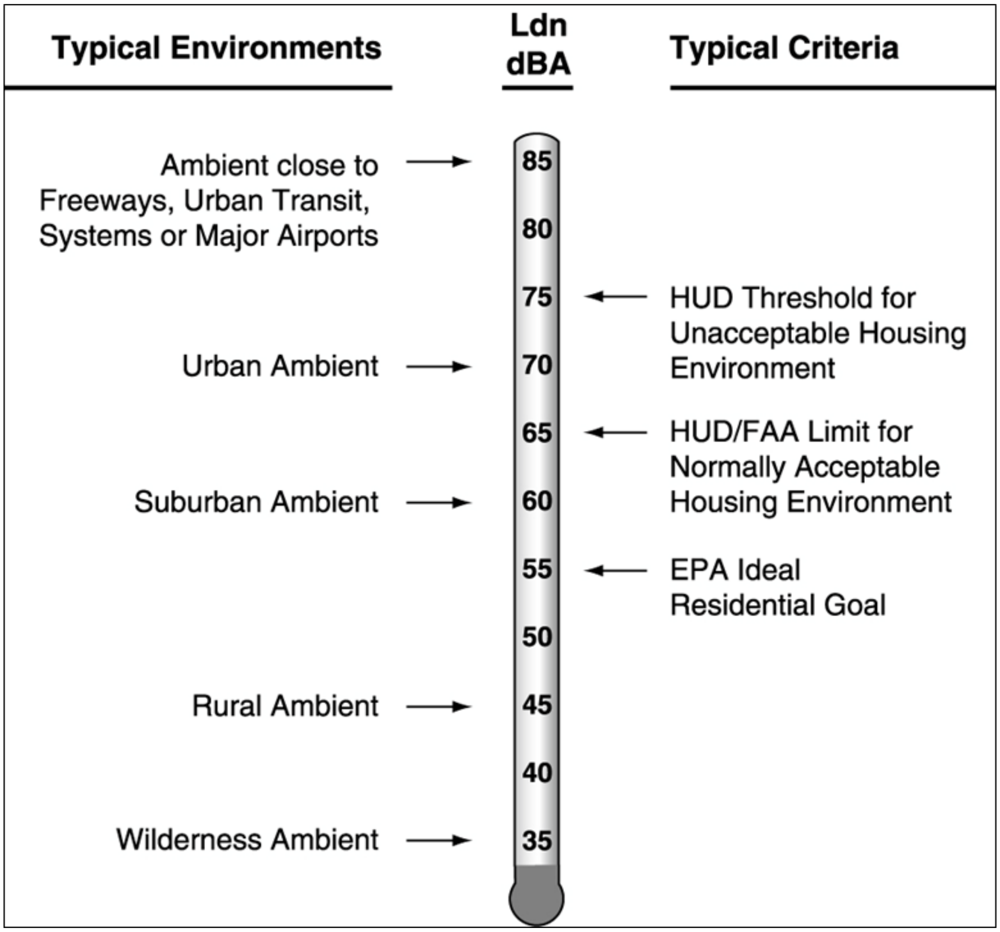


Figure 8 Comparison of HUD/EPA Criteria with Typical Environments

4.2.4 World Health Organization (WHO)

The World Health Organization established health-protective guidelines of 55 dBA outdoors (L_{eq} 16 hours) for daytime and evening exposures and night-noise exposure guidelines of 40 dBA (outdoors L_{eq} night 8 hours). WHO acknowledged that 40 dBA L_{eq} is difficult to achieve in urban environments and established an interim nighttime guidance of 55 dBA L_{eq}.

In 2018, the WHO Regional Office for Europe developed environmental noise guidelines for the purpose of providing recommendations for protecting human health from exposure to environmental noise originating from various sources (WHO, 2018). The guidelines include recommendations for noise exposure levels related to road traffic noise. The recommendation is to reduce noise levels produced by road traffic below 53 decibels (dB) day-evening-night level (L_{den}). For night noise exposure, the recommendation is to reduce noise levels produced by road traffic during nighttime below 45 dB (L_{night}).

4.2.5 California Building Code

The California Building Code establishes that interior noise levels attributable to exterior sources must not exceed 45 dB in any habitable room. Additionally, the code specifies that multi-family residential buildings or structures that will be located within exterior L_{dn} contours of 60 dB or greater from most transportation sources shall require an acoustical analysis showing that the building has been designed to limit intruding noise to an interior L_{dn} of 45 dB.

4.2.6 City of Plano

The City of Plano regulates noise via the Municipal Code, Chapter 14, Article V: Noise. This regulation provides noise level limits, which are referred to as "maximum specific noise levels," for daytime (7:00 a.m. to 10:00 p.m.) and nighttime (10:01 p.m. to 6:59 a.m.) exposure – see Table 1. These standards are focused on regulating specific noise generators and not establishing an appropriate background noise level. Although these limits are not specifically applicable to new developments nor to the operation of motor vehicles, they provide a basis for demonstrating acceptable noise exposure in the Plano.

Table 1 City of Plano Maximum Specific Noise Levels

Land Use	Timeframe	
	Day	Evening/Night
Residential	65 dB or 10 dB above the background noise level, whichever is lower	55 dB or 5 dB above the background noise level, whichever is lower
Commercial/ Mixed-Use	70 dB or 10 dB above the background noise level, whichever is lower	60 dB or 5 dB above the background noise level, whichever is lower
Industrial	75 dB or 10 dB above the background noise level, whichever is lower	65 dB or 5 dB above the background noise level, whichever is lower

Source: Plano Municipal Code, 2017

Therefore, the City does not currently have a policy or standard in place to consider the impacts of noise pollution created by vehicles on expressways.

4.3 Residential Development Setbacks for the City of Plano

4.3.1 Air Pollution Setbacks/Criteria

As noted above, no federal standard has been established regarding the siting of sensitive land uses near expressways in regards to air pollution. Due to the site-specific nature of air pollutant dispersion, a standard setback is not considered the most efficient method for minimizing adverse effects.

4.3.2 Noise Setbacks/Criteria

As noted above, many national agencies have adopted noise goals and standards, including the Environmental Protection Agency (EPA), the Federal Highway Administration (FHWA), and the Department of Housing and Urban Development (HUD). The standard established by HUD most directly considers the environment at residential units and therefore is the most appropriate reference when considering the effects of noise pollution on residential development in Plano.

Furthermore, unlike the goals established by the World Health Organization and the Environmental Protection Agency, the HUD standard specifically incorporates cost and feasibility considerations into the standard. The federal regulation states:

> *"It is a HUD goal that exterior noise levels do not exceed a day-night average sound level of 55 decibels. This level is recommended by the Environmental Protection Agency as a goal for outdoors in residential areas. The levels recommended by EPA are not standards and do not take into account cost or feasibility. For the purposes of this regulation and to meet other program objectives, sites with a day-night average sound level of 65 and below are acceptable and are allowable." (Section 24 CFR § 51.101)*

Therefore, existing noise conditions and the noise model described in the following chapters, focus on identifying locations with:

- L_{dn} lower than 65 dBA and considered acceptable for residential development
- L_{dn} between 65 dBA and 75 dBA and could be considered acceptable with appropriate mitigation
- L_{dn} greater than 75 dBA and considered unacceptable for residential development

It is also noteworthy that HUD has a goal (not a standard) that the interior spaces should not exceed an L_{dn} of 45 decibels, with an emphasis given to noise sensitive spaces, such as bedrooms. However, standard construction is assumed to provide approximately 20 L_{dn} of sound attenuation; therefore a residential unit meeting the 65 L_{dn} exterior noise level would also meet the 45 L_{dn} interior noise goal. In locations between 65 L_{dn} and 75 L_{dn} it may be advisable to evaluate the noise reduction levels of the proposed construction materials.

4.3.3 Noise and Air Pollution Mitigation Options

A variety of methods may be used to mitigate the effects of noise pollution, including:

- Increased distance between the expressway and the residential building;
- Installation of sound barriers, which could include noise walls, earthen berms, or other buildings;
- Develop the site design to locate bedrooms, balconies, and open spaces away from the expressways; and
- Enhanced building design using improved window, door, and wall materials and/or designs to achieve interior noise level goals.

The methods for mitigating for traffic-related air pollution are similar to mitigating for traffic-related noise pollution. These include:

- Increased distance between the expressway and the residential building;
- Installation of barriers to minimize the direct flow of pollutants to residential buildings. These may include noise walls, earthen berms, or other buildings; and
- Develop the site design to locate bedrooms, balconies, and open spaces away on the far side of the building from the expressways.

Other mitigation measures that can be considered include:

- Locating air intake vents on buildings to face away from expressways and as far away from the expressway as practical; and
- Providing indoor air quality filtration systems that reduces at least 90% of particulate matter emissions.

5 Existing Noise Conditions

The existing noise environment along expressways in Plano varies depending on proximity to, and occurrence of, sound sources. The dominant sound sources are roadway traffic, and rail traffic in some segments, with local community noise and air traffic as secondary sources.

A baseline sound level survey was conducted throughout the city's expressway corridors to establish the existing sound levels. The sound measurement locations were selected to be representative of the sound environment at clusters of land uses.

5.1 Noise Measurement Program

A noise measurement program was conducted consistent with FHWA recommended procedures to document existing ambient noise levels in noise-sensitive residential locations throughout the study area. The long-term noise measurement locations are shown in Figure 9 on page 30. Noise monitoring was conducted at 12 long-term (at least 24 hours in duration) sites and six short-term (30 minutes in duration) sites between September 25 and September 27, 2018. Measurement sites were identified to provide representative locations through the city that are directly impacted by highway noise without the likelihood of noise impacts from other sources.

At each site, the measurement microphone was positioned to characterize the exposure of the site to the dominant noise sources in the area. Brüel & Kjær noise monitors (models 2250 and 2270) were used for gathering noise data. These are ANSI Type I integrating sound level meters, and are calibrated annually at a certification laboratory, with calibrations traceable to the National Institute of Standards and Technology. During the monitoring program, the meters were calibrated in the field using a handheld acoustic calibrator at the beginning and end of each measurement period.

The long-term data collection procedure involved measurement of broadband one-second equivalent sound levels (L_{eq}s) over the full duration of the measurement. In addition, one-second L_{eq}s were also taken for individual 1/3 octave frequency bands from 12.5 Hz to 20 kHz, as well as .wav file recordings for the entire measurement duration. For all of the long-term monitoring sites, hourly L_{eq}s were reported as well as the Day-Night Average Sound Level (abbreviated "DNL" or "L_{dn}"). Table 2 presents the site location, measurement time, and L_{dn} for each long-term monitoring site. Appendix C provides graphs of the hourly sound level metrics at the long-term sites.

At one long-term site (PGB Tollway Site 3A) a diesel generator was periodically active and determined to be sufficiently loud and prevalent as to prevent the direct determination of hourly L_{eq}s and L_{dn} that could be considered representative of road traffic noise levels. For this site, HMMH staff listened to the .wav recordings of every noise event determined to be sufficiently disruptive, and then excluded (or "filtered") such non-traffic noise events from the calculation of L_{dn} and L_{eq} presented in Table 2 below. The filtered measurement data are considered to be representative of traffic noise levels for the monitoring period. Graphs of both the hourly "Raw" and Filtered L_{eq}s measured at these sites are provided in Appendix C.

During some of the measurements the roadways were wet due to precipitation that passed through the Plano area. Wet roads are generally louder than dry roads; however, these conditions are also present during various time periods throughout the year in the Plano area. Comparisons of monitoring periods with and without wet roadways indicate that traffic noise levels were not greatly influenced by the periodic wet roadway conditions that were present during the measurements. For this reason, no adjustments were made to account for wet roadway conditions. Additionally, somewhat high wind speeds also occurred during the measurement effort; however, these wind speeds were not high enough to greatly influence sound levels. What was observed is that roadway traffic noise in the vicinity of the expressways in Plano is the dominant sound source regardless of these weather conditions.

The short-term data collection procedure involved attended measurement of broadband one-second L_{eq}s over a period of 30 minutes. Continuous logging of events was conducted during the monitoring, so that intervals that included events that were not traffic-related could be excluded later on a minute by minute basis. For each 30-minute period, an L_{eq} was determined. Table 3 presents the site location, measurement time, Total L_{eq}, and L_{dn} for each short-term measurement site.

Narrative descriptions of the location and a summary of the measurement results at each long-term site are provided in the paragraphs that follow. Appendices A and B provide additional detail on the monitoring locations and results.

5.2 Measurement Location Summaries

- DNT-1: Northwest Plano Park and Ride. The L_{dn} measured over a 24-hour period in the open area near the Dallas North Tollway was 65.4 dBA.
- PGBT-1: Vista Court Drive and North President George Bush Turnpike. The L_{dn} measured over a 26-hour period in the open area near the highway was 70.0 dBA. Local roadway traffic on Vistacourt Drive also contributed to the noise level. The peak hour L_{eq} sound level at this location was 69.91 dBA.
- PGBT-3a: Generator near Mapleshade Lane. The L_{dn} estimated for a period of 24 hours, using 1-hour samples in the open area near the generator, was 70.0 dBA. The peak hour L_{eq} at this location was 68.11 dBA.
- PGBT-3A (adjusted): Generator near Mapleshade Lane. The L_{dn} estimated for a period of 24 hours, using 1-hour samples in the open area near the generator, was 68.0 dBA. The peak hour L_{eq} at this location was 69.99 dBA.
- PGBT-3: Baylor Scott & White Medical Center. The L_{dn} measured over a 24-hour period from an open area near the Baylor Scott & White Medical Center, was 74.3 dBA. The peak hour L_{eq} at this location was 74.21 dBA.
- SRT-1: Rowlett Creek. The L_{dn} measured over a 24-hour period in open area near Rowlett Creek was 64.9 dBA. The peak hour L_{eq} sound level was at this location was 64.86 dBA.
- SRT-2: Gillespie Drive and TX-121. The L_{dn} measured over a 24-hour period in open area adjacent to Gillespie Drive was 75.5 dBA. The peak hour L_{eq} sound level was at this location was 75.01 dBA.
- SRT-3A: Leadership Drive and TX-121. The L_{dn} measured over a 24-hour period on the sidewalk adjacent to Leadership Drive was 66.9 dBA. The peak hour L_{eq} sound level at this location was 69.48 dBA.
- SRT-3B: Pump station on Dallas Parkway. The L_{dn} measured over a 24-hour period in open area adjacent to the pump station was 72.5 dBA. The peak hour L_{eq} sound level at this location was 71.77 dBA.
- US75-1: Central Expressway and Chase Oaks Boulevard. The L_{dn} measured over a 24-hour period in the open area adjacent to Chase Oaks Boulevard near Central Expressway was 79.0 dBA. The peak hour L_{eq} sound level at this location was 78.66 dBA.

- US75-2: Central Expressway and Maroon Lane. The L_{dn} measured over a 24-hour period in the open parking lot near Maroon Lane and Central Expressway was 74.3 dBA. The peak hour L_{eq} sound level at this location was 73.72 dBA.
- US75-3: 3501 Premier Drive. The L_{dn} measured over a 24-hour period in open area behind 3501 Premier Drive was 70.5 dBA. The peak hour L_{eq} sound level at this location was 69.48 dBA.
- US75-4: Harrington Park. The L_{dn} measured over a 24-hour period in the open field in Harrington Park was 67.8 dBA. The peak hour L_{eq} sound level at this location was 65.47 dBA.

Table 2 Summary of Existing Ambient Noise Long-term Measurement Results

Site No.	Measurement Location	Start of Measurement		Meas. Duration (hrs)	Existing Sound Exposure (dBA)						
		Date	Time		L_{dn}	Peak Hour L_{eq} (time)	L_{eq} (day)	L_{eq} (evening)	L_{eq} (night)	L_{eq} (24-hour)	CNEL
DNT-1	Northwest Plano Park and Ride	9/26/2018 10:00		24	65.4	65.68 (15:00)	63.2	60.2	57.6	61.9	65.7
PGBT-1	Vista Court Drive & N. President George Bush Turnpike	9/26/2018 11:00		26	70.0	68.91 (6:00)	67.0	66.0	62.9	66.0	70.4
PGBT-3a	Generator near Mapleshade Lane	9/25/2018 10:00		24	70.0	68.11 (16:00)	66.2	64.3	63.2	65.4	70.3
PGBT-3A (adjusted)	Generator near Mapleshade Lane	9/25/2018 10:00		24	68.0	69.99 (9:00)	63.7	62.2	66.8	64.7	68.5
PGBT-3	Baylor Scott & White Medical Center	9/25/2018 10:24		24	74.3	74.21 (7:00)	72.0	70.0	66.7	70.7	74.7
SRT-1	Rowlett Creek	9/25/2018 8:05		24	64.9	64.86 (7:00)	60.4	59.9	58.2	59.8	65.3
SRT-2	Gillespie Drive and TX-121	9/25/2018 8:00		24	75.5	75.01 (7:00)	73.1	73.3	68.0	71.9	76.2
SRT-3A	Leadership Drive and TX-121	9/25/2018 7:14		24	66.9	69.48 (8:00)	62.8	60.5	59.9	62.0	67.1
SRT-3B	Pump Station on Dallas Parkway	9/26/2018 9:29		24	72.5	71.77 (15:00)	70.6	68.5	64.7	69.3	72.9
US75-1	Central Expressway and Chase Oaks Boulevard	9/27/2018 11:15		26	79.0	78.66 (7:00)	76.0	74.8	71.9	74.9	79.4
US75-2	Central Expressway and Maroon Lane	9/27/2018 11:28		25	74.3	73.72 (11:00)	71.1	70.5	67.3	70.1	74.7
US75-3	3501 Premier Drive	9/27/2018 11:39		25	70.5	69.48 (11:00)	66.2	66.6	64.1	65.6	70.9
US75-4	Harrington Park	9/27/2018 13:27		25	67.8	65.47 (11:00)	61.5	63.7	61.5	61.5	68.2

Source: Harris Miller Miller & Hanson Inc., 2018

Short-term measurements were completed at the locations provided in Table 3 to provide additional information.

Table 3 Summary of Existing Ambient Noise Short-term Measurement Results

Site No.	Measurement Location	Start of Measurement Date/Time	Measurement. Duration (hrs)	Measured L_{eq}
ST-M1	Bishop Road near Dallas North Tollway	9/26/2019 15:58	0.25	67.5
ST-M2	1640 Dallas Parkway	9/26/2018 15:08	0.5	68.0
ST-M3	6635 Villa Road	9/27/2018 9:02	0.5	72.0
ST-M4	Residence Inn Plano	9/26/2018 13:25	0.33	72.3
ST-M5	Parking Lot near Exchange Drive	9/27/2018 14:19	0.33	72.1
ST-M6	National Tire and Battery near SRT	9/27/2018 9:48	0.33	72.2

Source: Harris Miller Miller & Hanson Inc., 2018

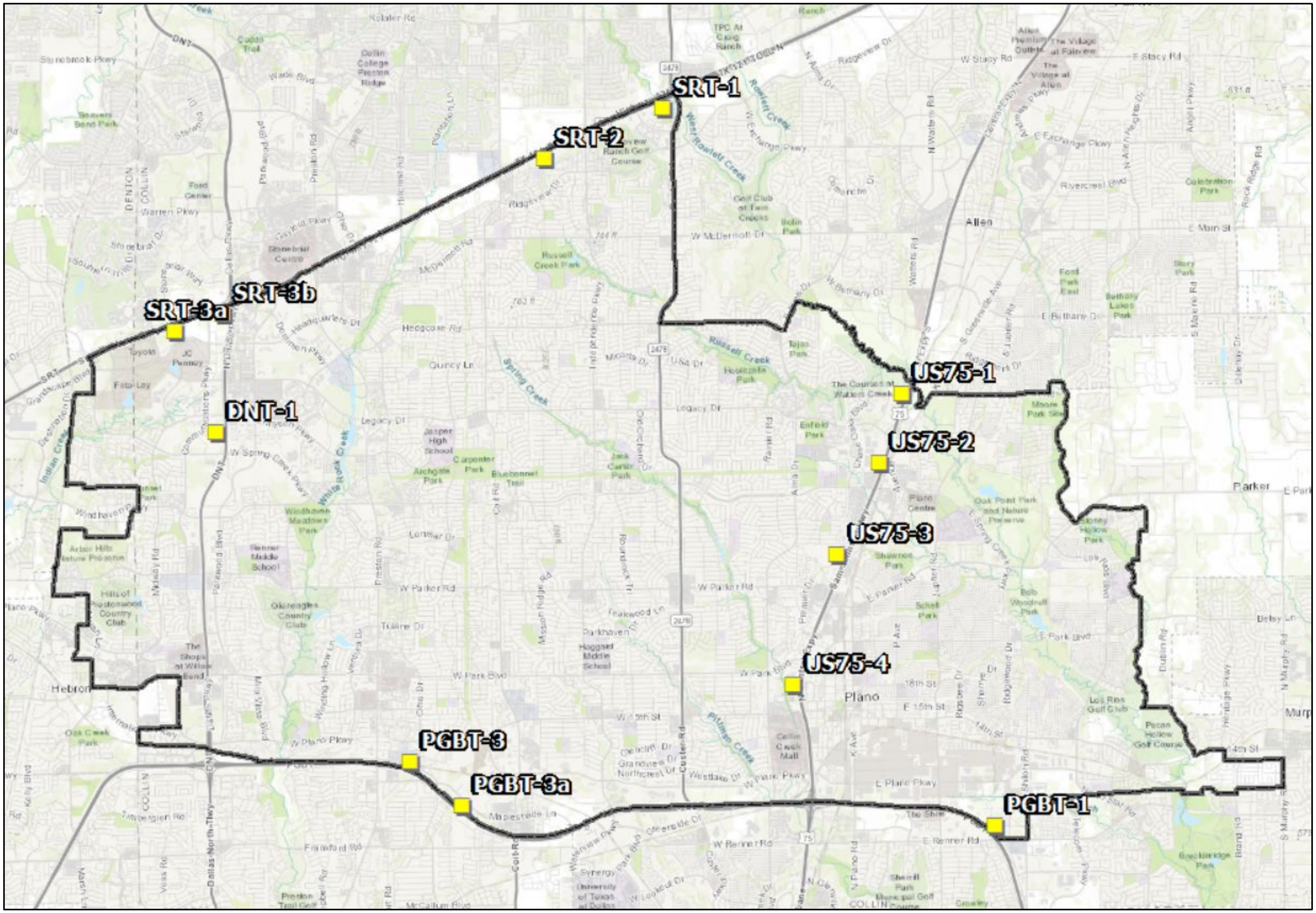


Figure 9 Overview of 24 Hour Measurement Locations

6 Methodology for Assessment of Noise

This section describes the noise prediction model and summarizes the input to the model.

6.1 Noise Prediction Model

The SoundPLAN® computer noise model was used for computing noise levels in the area surrounding Plano's expressway corridors. An industry standard, SoundPLAN® was developed by Braunstein + Berndt GmbH to provide estimates of sound levels at distances from specific noise sources taking into account the effects of terrain features including relative elevations of noise sources, receivers, and intervening objects (buildings, hills, trees), and ground effects due to areas of hard ground (pavement, water) and soft ground (grass, field, forest). In addition to computing sound levels at specific receiver positions, SoundPLAN® can produce noise contour graphics that show areas of equal and similar sound level.

The sound propagation model within SoundPLAN that was used for this study were a combination of ISO 9613-2 standard, the FHWA TNM 2.5 standard, and the FTA/FRA 2018 standard.[1] These standards are frequently used in the United States for environmental noise studies, due to their conservative propagation equations.

6.2 Noise Model Input

As input, SoundPLAN incorporated a geometric model of the corridor areas and the measured noise levels at the 13 locations described above. HMMH developed a three-dimensional geometric model of the study area from geographic data from the city's GIS system. All buildings were modeled as objects that both obstruct (attenuate) and reflect the sound emitted from a source.

6.2.1 Geographic Data

The following is the geographic data incorporated into the model:

- Imagery: Aerial photographs provided by the City of Plano (dated 2018)
- Geometric Data: Within city of Plano - Elevation contours derived from 2017 Lidar provided by the City of Plano; Outside the city of Plano - Texas Natural Resources Information System (dated 2009) and United States Geological Survey 10 meter Digital Elevation Model (dated 4/20/2018)

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[1] International Organization for Standardization (ISO), International Standard ISO 9613-2, "Acoustics – Attenuation of Sound during Propagation Outdoors", Part 2: General Method of Calculation, 1996-12-15.

- Buildings Data: Information: City of Plano 3D Buildings GIS layer (2015 and 2016). Additional data incorporated into model for new developments approved 12/3/2018, as provided by City of Plano Planning Department.
- Parcel Data: City of Plano GIS parcel layer (dated 2/3/2018)

6.2.2 Train Data

- DART Existing Train Schedule Data: Dallas Area Rapid Transit Schedules available at www.dart.org (accessed on 1/23/19)
- DART Future Train Schedule Data: DART Cotton Belt DEIS, dated April 2018
- DART Vehicle Noise Data: Communication from DART staff, and the Cotton Belt Corridor Regional Rail Noise and Vibration Test Program for the DCTA Stadler DMU, dated April 2014
- Freight Train Operations Data: Federal Railroad Administration grade crossing inventory database, available at safetydata.fra.dot.gov (accessed on 1/23/19)

6.2.3 Traffic Data

2017 Volumes on North Texas Tollway Authority Expressways

The North Texas Tollway Authority (NTTA) Comprehensive Traffic & Toll Revenue Study[2] includes 2018 traffic volumes for the Dallas North Tollway (DNT), President George Bush Turnpike (PGBT), and the Sam Rayburn Tollway (SRT). These data focus on Average Weekday Daily Traffic (AWDT) volumes, which were taken from Figures 6-20, 6-21, and 6-22 in the report for sections of the mainlines on the Expressways in Plano. Since the noise analysis utilizes AADT, the AWDT in the report was adjusted based on a comparison of 2017 AADT from TxDOT sources and the AWDT included in the report. The AWDT volumes are about 10 to 15 percent higher than the Annual Average Daily Traffic (AADT) volumes needed for the noise analysis. NTTA volumes are reported and forecast for gantries above the mainline roadways only in a few locations. For the DNT, the only gantry in Plano is called MLGP#3, and for the PGBT, the gantry is MLP#7. There are no mainline gantries on the SRT in Plano, however there are gantries east and west of the city (MLG#3 and MLG#2, respectively), so the AWDT values for those two gantries were averaged to estimate values for Plano.

2017 US 75 / Sam Rayburn Tollway Volumes

The Statewide Traffic Analysis and Reporting System (STARS) maintained by TxDOT, includes recent AADT data on the expressways in the Plano study. Several count locations along the SRT and U.S. 75 mainlines in Plano are included in this data set, as well as most of the frontage roads along the expressways. The STARS data was used to establish the 2017 AADTs for U.S. 75 and for most sections of the SRT. The AADT

[2] "Comprehensive Traffic & Toll Revenue Study, North Texas Tollway Authority System," CDM Smith, September 2017.

values from STARS and the NTTA along the SRT in Plano were averaged to a single value used for the noise modeling.

2040 Expressway Volumes

The North Texas Tollway Authority (NTTA) Comprehensive Traffic & Toll Revenue Study includes both 2017 and 2040 AWDT data. To determine future AADT volumes, the 2017-2040 forecast growth percentages were taken from the AWDT values. These growth percentages are 25% for the DNT, 27% for the PGBT, and 51% as an average for the two SRT locations included in the report on either side of Plano. Forecast traffic volume growth for U.S. 75 was taken from AADT traffic data provided via TxDOT in a GIS layer for state highways (TxDOT, 2018), and was 35% for 2040.

Hourly Traffic Distributions

Hourly expressway volume data for 2017 and January to June 2018 was received from NTTA at all of the toll gantry locations included in the previously cited report. The data included vehicle type classification by number of axles for each tollway as a whole. The 2017 AADT data and percentages of heavy vehicles was used for the DNT, PGBT and SRT mainline roadways The hourly distribution of traffic needed for the calculation of L_{dn} was developed from the hourly data provided from the gantries for each of the expressways provided by NTTA.

Truck Volumes

Truck percentages for all roadways were developed from NTTA and TxDOT classification data. The NTTA classification separated vehicles only by number of axles, so all medium trucks (MT) with 2 axles and 6 tires were included with the automobiles, and heavy trucks (HT) were the sum of all vehicles with 3 axles or more. The TxDOT STARS data separates vehicles by FHWA classification, and included two classifications: automobiles and trucks (all trucks and buses). To derive appropriate volumes for medium and heavy trucks needed for noise modeling on all roadways, HMMH used a combination of the NTTA data, STARS data and HMMH's traffic classification counts conducted during the field noise measurement program.

Total truck percentages were available for all mainline and frontage roads from STARS. For the mainline tollways, the NTTA heavy truck percentages were used with the STARS data to develop the medium/heavy truck splits. For U.S. 75 and all frontage roads, HMMH used field-counted ratios for the medium/heavy truck split applied to the total truck percentages from STARS. Average total truck percentages on the mainlines of the expressways were 4% on DNT and PGBT, 5% for SRT, and 8% for U.S. 75.

Traffic Speeds

Posted speeds on the various roadways were used for the noise modeling. The posted speed on all of the expressway mainlines is 70 mph, and on the frontage roads speeds vary from 45 to 55 mph. Details are shown in Table 4.

Table 4 Traffic Data Used in Noise Modeling

DNT	2017 AADT	MT + HT	% Trucks	Posted Speed	2040 AADT
Mainline	141,109	5,482	3.9%	70	177,039
NB Frontage	16,632	725	4.4%	45	20,867
SB Frontage	17,642	775	4.4%	45	22,133
PGBT	**2017 AADT**	**MT + HT**	**% Trucks**	**Posted Speed**	**2040 AADT**
Mainline	131,856	5,356	4.1%	70	167,978
EB Frontage	12,608	600	4.8%	55	16,062
WB Frontage	12,758	700	5.5%	55	16,253
SRT Averages	**2017 AADT**	**MT + HT**	**% Trucks**	**Posted Speed**	**2040 AADT**
Mainline	93,380	4,762	5.1%	70	141,311
EB Frontage	29,410	900	3.1%	55	44,506
WB Frontage	33,200	1,100	3.3%	55	50,241
U.S. 75	**2017 AADT**	**MT + HT**	**% Trucks**	**Posted Speed**	**2040 AADT**
Mainline	183,577	14,229	7.8%	70	248,563
NB Frontage	29,447	900	3.1%	50	39,871
SB Frontage	24,819	900	3.6%	50	33,605

6.3 Noise Prediction Model Output – Environmental Health Map

The noise model developed for the city of Plano was used to identify locations where highway or rail noise is projected to exceed 65 dBA L_{dn} in 2040. The future year (2040) was used to incorporate planned changes in traffic volume levels over time and account for the long term nature of investment in residential developments. Contours were developed for the 65 dBA L_{dn}, 70 dBA L_{dn}, and 75 dBA L_{dn} levels and reflect the existing geographic and transportation data previously identified. These contours are displayed in the Expressway Corridor Environmental Health Map, available in Appendix D.

Since the contours are based on topography, structure locations, and traffic volumes, the distances between the roadway, identified as the edge of the pavement, and the contours are highly variable. Table 5 identifies the average, minimum, and typical and absolute maximum distances for both existing conditions and 2040 conditions. The average distance between the road and the 65 dBA L_{dn} contour is 875 feet. In some locations this distance is as short as 130 feet. This is typically where buildings, retaining walls, a roadway bridge, or other structure is shielding the noise from propagating further into the community. The typical maximum distance between the roadway and the 65 dBA L_{dn} is 1,350 feet, however there are a few locations and roadway segments, primarily near interchanges, where the noise levels are a further distance from the roadways. As can be seen from the information in Table 5, the noise contours do not change dramatically between 2017 and 2040, with an increased average distance of only 17% even though the traffic is projected to increase by 50 percent on some expressways.

Table 5 Distances of Noise Contours from Expressways

	Contours			
	75 dBA L_{dn} (2040)	65 dBA L_{dn} (2040)	75 dBA L_{dn} (2017)	65 dBA L_{dn} (2017)
Minimum Distance	21 feet	130 feet	17 feet	120 feet
Average Distance	240 feet	875 feet	200 feet	745 feet
Typical Maximum Distance (90 percentile)	350 feet	1,350 feet	280 feet	1,100 feet
Absolute Maximum Distance	1,100 feet	4,000 feet	1,000 feet	4,000 feet

7 Noise and Air Pollution and Land Use Control

For many decades, regulation of land uses adjacent to high volume roadways or other transportation facilities was expected to minimize the adverse effects of those facilities. However, since land use decisions are made locally and often transportation infrastructure is made at the regional, state, or national level, consistent planning and management of development has not occurred.

In fact, forty years ago, in 1979, an Urban Noise Initiative was established by the federal government to reduce urban noise, which included the establishment of The Federal Interagency Committee on Urban Noise. The purpose of the committee was to coordinate federal programs and "to encourage noise sensitive development, such as housing, to be located away from major noise sources." The committee created a document that consolidated all federal guidance related to noise with the goal of making it easy to understand and integrate into locally controlled land use planning efforts. The introduction of the report states:

> *"The purpose of considering noise in the land use planning process is not to prevent development but rather to encourage development that is compatible with various noise levels. The objective is to guide noise sensitive land uses away from the noise and encourage non-sensitive land uses where there is noise. Where this is not possible, measures should be included in development projects to reduce the effects of the noise."*[3]

Although the federal government has recognized for four decades the importance of noise in land use planning there has been only limited action at the local level to integrate noise into the planning and land use control process.

The following examples demonstrate how communities have integrated noise into land use decisions.

7.1 Example Land Use Control – Air Pollution

There are no municipalities that are known to have enacted land use controls specifically with the purpose of minimizing the impact of transportation related air pollution. As previously noted, air pollution is not as location-specific of an issue as noise, or other nuisances addressed through zoning, and is typically addressed across an entire metropolitan area or state.

However, some guidance has been developed related to air pollution and proximity to expressways. As noted in Section 4.2 of this report, the California Air Resources Board has recommended that sensitive uses not be developed within 500 feet of a major expressway. This recommendation is taken into account by air quality management districts throughout California as they review developments in their regions as part of the state California Environmental Quality Act (CEQA) process.

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[3] United States. Federal Interagency Committee on Urban Noise. (1981). Guidelines for considering noise in land use planning and control. [Washington, D.C.]: Federal Interagency Committee on Urban Noise.

7.2 Example Land Use Control – Noise

7.2.1 Setback and Buffer Standard

The County of Chesterfield, Virginia established a standard setback requirement for residential development adjacent to a limited access highway as part of their development standards. The 200 foot setback is required to be maintained as a natural vegetative buffer, which based on the characteristics of natural vegetation in Chesterfield, could provide a 10 dBA reduction in highway noise. The county development standards only permit removal of the natural vegetation in order to provide noise attenuation.

7.2.2 Highway Noise Overlay Districts

Several communities have enacted zoning overlay districts that establish requirements as part of their zoning ordinance for developments to comply with that are otherwise allowed by-right. Approaches to this include restricting development, with provisions allowing development when it can be demonstrated that exterior noise levels can be mitigated, restricting development unless interior noise levels can be met, and including the requirement for mitigation directly in the zoning requirements for development.

Restricted Development

The cities of Portsmouth, New Hampshire, and Frederick, Maryland, have established zoning overlay districts that are based on a certain distance from the highway edge, which restrict by-right development within the zone. In the case of Frederick, the width of the zone varies between 325 feet and 675 feet from the edge of pavement and was based on the loudest traffic hour 66 L_{eq} contour for each roadway. In the case of Portsmouth, the zone is 500 feet from the nearest highway centerline, including ramps. In each case there are allowances for development of sensitive uses in the zone, either through a conditional use permit, subdivision approval, or site plan review, if it can be determined through a noise study that the resulting noise levels would be at the allowed loudest traffic hour, which is 65 dBA for Portsmouth and 66 dBA for Frederick. Both of these cases were established in developed communities, in response to state programs, called a Type II Noise abatement program, where the state department of transportation may pay for highway noise barriers to address noise impacts that are occurring at existing adjacent development.

Interior Noise Standard

The City of Vancouver, Washington, established a zoning overlay district based on the 65 dBA L_{dn} contour that incorporated noise from area expressways, railroads, and the Portland International Airport. Development or substantial expansion of residential structures is restricted within the zone unless sufficient insulation or materials are included in the structure to ensure that the interior noise levels are below 45 dBA L_{dn}. When new or expanded residential structures are built within the overlay zone, a disclosure statement must be recorded that the premises may be adversely affected by noise.

Noise Barrier Mitigation

The Town of Gilbert, Arizona, enacted a noise-based zoning overlay district that includes all land within 300 feet of the right of way of a new highway. Development of all noise-sensitive uses within the overlay district must include construction of an eight foot high noise barrier between the development and the highway right of way and must be designed to achieve a maximum interior L_{dn} of 43 dBA. Noise-sensitive uses include residential uses, hospitals, nursing homes, places of worship, libraries, schools, and day care centers. In addition, any structures built on lots within 150 feet of the right of way are limited to a single story unless it can be demonstrated that the noise levels on the upper floors achieve the same interior noise levels as the height restriction.

7.2.3 Development Policy / Site Plan Review

Many communities have taken an approach that includes integrating review of noise as part of overall development planning, or through community policy, integrating noise conditions as part of a site plan review when balancing many development related issues.

Long-term Planning

The City of Woodside, California, includes a Noise Element as part of the community General Plan. This is similar to all communities in California as the state planning regulations require that a community's General Plan include a noise element. The Noise Element provides an overview of existing noise conditions in the community, standards for maximum noise levels throughout the community, and identifies strategies and approaches to incorporate noise issues into both short and long range planning. The plan establishes the justification for incorporating noise into the site plan review process and for incorporating noise rated windows or other sound insulation into building specifications.

Environmental Review

Most cities in California, such as San Diego, have specific guidance on how each development should be reviewed in relation to meeting noise standards that are identified in the city's Noise Element. Municipal review typically includes both a development's impact on the existing environment and the noise conditions in which the development may be constructed. In California, evaluation of noise conditions is integrated into each stage of development review, including the building permit process, and therefore any development constructed has been fully vetted and has either incorporated the noise mitigation necessary to meet the city interior or exterior noise standard, or has been required to go through the state environmental review process, the California Environmental Quality Act, that includes a full review of noise conditions and requirements.

Development Review

In Montgomery County, Maryland, guidelines have been established to guide staff review of new developments to identify conditions when development restriction or noise mitigation would be an appropriate recommendation to the County Planning Board. The County identified preferred maximum noise levels for different parts of the County. The guidelines provide a way for staff to evaluate noise conditions and work with developers to achieve the preferred noise conditions. The County established 65 dBA L_{dn} as the preferred maximum noise levels for the region of the County near expressways. The guidelines are used during the site plan review process to understand the anticipated conditions and any noise abatement measures that may be appropriate for the site. Staff can then provide recommendations to the Planning Board as it relates to the existing or future noise condition as they weigh all the various issues related to approval of the development.

7.3 Sensitive Land Uses in Plano

This study has been focused on evaluating the impact of noise and air pollution on residential development. Based on the research included in the literature review, long-term exposure to elevated noise levels associated with expressways has the most negative health consequences when it impacts sleep. For this reason it is reasonable to focus noise-based land use control on residential development. Health impacts from air quality are estimated based on overall exposure, which also coincides with residential land uses, due to the extended times people are typically located at their residence.

The City of Plano Zoning Ordinance includes the following list of land uses which could be considered potential sensitive land uses in the context of noise and air pollution when adjacent to expressways.

Single-Family and Small Institutional Dwellings:

- Boarding/Rooming House
- Day Care (In-home)
- Household Care Facility
- Mobile Home/Trailer Park
- Rehabilitation Care Facility
- Rooming/Boarding House
- Single-Family Residence (Attached)
- Single-Family Residence (Detached)
- Studio Residence
- Trailer/Mobile Home Park
- Two-Family Residence

Institutional Dwellings:

- Assisted Living Facility
- Continuing Care Facility
- Household Care Institution
- Independent Living Facility
- Long-term Care Facility
- Mid-Rise Residential
- Multifamily Residence
- Rehabilitation Care Institution

Others:

- Day Care Center
- Day Care Center (Accessory)
- Day Care Center (Adult)
- School (Private)
- Park/Playground
- Playground/Park

7.4 Recommended Control and Mitigation

Based on the information developed as part of this study, the recommended approach to establish guidelines for sensitive land uses adjacent to expressways to account for the potential impacts of noise and air quality are identified in the following sections. These recommended approaches incorporate the information compiled through the literature review on health impacts, measurement of existing noise conditions, modeling of future noise conditions, and a review of previously enacted land use controls employed across the country.

7.4.1 Noise

Review each new development constructed or expanded in the city for compliance with the noise exposure standards established by the Department of Housing and Urban Development as they relate to residential development. The HUD standards are specifically tailored to address issues related to residential development but are still in general conformance with standards developed by other federal agencies and are based on well researched health impacts. This includes a standard of acceptable conditions for residential development when noise exposure levels are below 65 dBA L_{dn}. Any development that includes a residential or sensitive land use when noise exposure levels are at or between 65 dBA Ldn and 75 dBA L_{dn} should be reviewed and mitigation incorporated so that the noise levels are below 65 dBA. Areas where noise levels are projected to be greater than 75 dBA are not acceptable for residential development.

Review of the development should be conducted in association with the recently developed City of Plano Expressway Corridor Environmental Health Map so that assumptions related to traffic volumes and rail services, the largest noise generators in the city, can be consistent across all development review and updated with new information as it is made available.

Understanding that development types and conditions across the city of Plano are diverse and that in any development there are many issues, both positive and negative, that need to be addressed and incorporated into the plans, conformance to the noise standard is strongly recommended, for the health of existing and future residents of Plano, but should not be an absolute requirement. For this reason it is recommended that review of noise conditions be conducted similarly to the approach undertaken by Montgomery County, Maryland, where review of noise conditions is integrated into the site design process as part of the recommendations for the Planning Board to consider in evaluation of the development.

7.4.2 Air Pollution

Significant research has been conducted that clearly relates air pollution to negative health outcomes. However, it is not as clear that residential proximity to an expressway results in higher exposure over prolonged times that will definitively result in higher risks. Secondary influences, such as wind direction and strength, season, air flow, air pollutant dispersion, and indoor filtration effectiveness all contribute to varying levels of exposure at similar distances.

However, it is clear based on recent research that the zone located within 300 feet of the edge or the roadway has the potential to have higher levels of some pollutants, specifically ultrafine particulates. In Plano the 75 dBA L_{dn} contour is on average 240 feet from the highway edge of pavement and therefore, the recommendations regarding restriction of residential development due to noise conditions will typically also address air quality concerns.

Furthermore, most of the mitigation actions for air quality impacts that are feasible for an individual development are the same as those for noise, with two exceptions (high efficiency air filtration systems and location of air intake vents). Therefore it is recommended that in the review of developments where elevated noise levels are a concern (those above 65 dBA L_{dn}), that air quality mitigation also be incorporated into the review process.

8 Recommended Development Evaluation Guidelines

The recommended process to be employed by the City of Plano Planning Department to evaluate transportation noise and air quality impacts may be summarized in four steps:

1. A screening procedure identifies planning or site areas with potential noise impacts.
2. If the area is shown to be potentially impacted by high noise levels, a detailed analysis of the existing and/or future noise levels is conducted by a recognized expert experienced in the fields of environmental noise and air pollution assessment and architectural acoustics. This includes incorporating the planned development's site plan into the existing City of Plano Expressway Corridor Environmental Health Map to compute existing and future noise levels on the development site.
3. The noise levels projected for the area are evaluated against the noise level guidelines.
4. If the noise levels projected for the area exceed the appropriate guideline values, the expert will recommend the use of noise abatement/mitigation techniques for the impacted area.

Screening

The City of Plano Planning Department will conduct an initial screening of all zoning change requests or site plan reviews that are located with a portion of the property within the zone encompassed by the 65 dBA Ldn contour. The screening would entail a review of the uses planned within the high noise zone. Review would entail assessment of the planned locations of noise sensitive areas including interior habitable rooms, outdoor living spaces, and useable open space. In cases where all noise sensitive areas are located outside of the 65 dBA Ldn contour, no further noise assessment is necessary.

Outdoor spaces would include outdoor living spaces (i.e. patios and decks) or usable open space primarily intended for use by occupants of a development, either privately or communally, normally including swimming pools, recreation courts, patios, open landscaped passive or active recreation areas, but not including greenbelts, walkways, off-street parking, and loading areas or driveways.

Noise Analysis

An analysis of existing and future noise conditions would be conducted of the proposed development.

Required information from the project would include:

- Project site plan that includes changes to topography and identifies the location of outdoor living spaces and useable open spaces.
- Location and layout of buildings containing sensitive land uses.
- Location and massing of other planned buildings or structures on site, particularly ones which might serve to shield sensitive buildings or areas from the noise source.
- Design and construction features of buildings, particularly features such as use of central air conditioning which could provide noise reduction benefits by permitting windows to be kept closed.

A long-term (24-hour) noise measurement program would be undertaken on the proposed site in order to document the existing noise conditions at the site and make any calibration necessary to the city noise model.

The project information along with auto volumes on local area roadways would be incorporated into the city noise model to project future noise conditions on the site with the project built. Contours of future noise levels would be created for the site and noise levels would be modelled for each floor of the project's buildings that include sensitive land uses.

Noise Level Evaluation

The projected future noise levels would be compared to the standards identified by HUD to determine the appropriateness of the site and/or site plan for sensitive land uses. The evaluation will identify if the following areas are planned to be under 65 dBA L_{dn}:

- Planned outdoor living spaces
- Planned useable open space
- Exterior walls of residential units

In cases where exterior walls of residential units are projected to be at noise levels over 65 dBA L_{dn}, outside to inside noise loss would be calculated, based on planned building construction type and window conditions to determine if the inside of the sensitive uses would be exposed to noise above 45 dBA L_{dn}. The analysis would utilize the HUD Noise Guidebook to determine the Sound Transmission Cost of the products and configurations being considered.

The FHWA provides general rules of thumb for noise levels transitioning from the exterior of a building to the interior, assuming various building types and window conditions consistent with levels identified by other sources. Table 6 provides the assumed attenuation (i.e., noise reduction) for some relevant building and window scenarios.

Table 6 Exterior to Interior Building Noise Reduction Factors

Building Type	Window Condition	Structure
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
Light Frame	Storm Window s	25 dB
Masonry	Single Glazed	25 dB
Masonry	Double Glazed	35 dB

Source: FHWA 2011

Noise Abatement/Mitigation

In cases where the proposed development is located within the area where interior or exterior projected noise levels are in excess of the recommended levels, mitigation options will need to be explored and identified.

Many different methods can mitigate excess noise. The effectiveness of the mitigation depends on the configuration of the site, area traffic volumes, and construction and layout of the building. Typical mitigation options include:

- Noise barriers/berms
- Building orientation and/or massing modifications
- Interior layout modifications
- Changes to building materials or construction methodology

In addition to mitigation actions for noise, the plan would be reviewed with regard to exposure to air pollutants. Particular attention would be paid to site design issues that would shield users of outdoor spaces from direct and nearby exposure to the potentially higher concentrations of air pollutants. In addition to noise mitigation, the review would include an analysis of the proposed air filtration system and air intake vent locations.

The evaluation would include identification of possible mitigation options and preliminary feasibility for the developers to provide the appropriate mitigation. The mitigation options would be made available to the project owners for their consideration and integration into the development plans.

After review of the plans and proposed mitigation, identification of whether the development meets the noise standards with the inclusion of the mitigation would be reported and provided to the Planning and Zoning Commission for their consideration in the evaluation of the development.

Appendix A Measurement Site Photographs

A.1 Long and Short Term Noise Measurement Locations

Figure A-1A. Site DNT-1: Northwest Plano Park and Ride

Figure A-1B. Site DNT-1: Northwest Plano Park and Ride

Figure A-2. Site PGBT-1: Vista Court Drive and N. President George Bush Highway

Figure A-3. Site PGBT-3a: Generator near Mapleshade Lane

Figure A-3A. Site PGBT-3a: Generator near Mapleshade Lane

Figure A-4. Site PGBT-3: Baylor Scott & White Medical Center

Figure A-4A. Site PGBT-3: Baylor Scott & White Medical Center

Figure A-5. Site SRT-1: Rowlett Creek Church

Figure A-6. Site SRT-2: Gillespie Drive and TX-121

Figure A-7. Site SRT-3A: Leadership Drive and TX-121

Figure A-8. Site SRT-3B: Pump Station on Dallas Parkway

Figure A-9. Site US75-1: Central Expressway and Chase Oaks Boulevard

Figure A-10. Site US75-2: Central Expressway and Maroon Lane

Figure A-11. Site US75-3: 3501 Premier Drive

Figure A-12. Site US75-4: Near Mt Olivet Baptist Church

Figure A-13. Site ST-M1: Bishop Road near Dallas North Tollway

Figure A-14. Site ST-M2: 1640 Dallas Parkway

Figure A-15. Site ST-M3: 6635 Villa Road

Figure A-16. Site ST-M4: Residence Inn Plano

Figure A-17. Site ST-M5: Parking Lot near Exchange Drive

Figure A-18. Site ST-M6: National Tire and Battery near SRT

Appendix B Long Term Noise Measurement Data

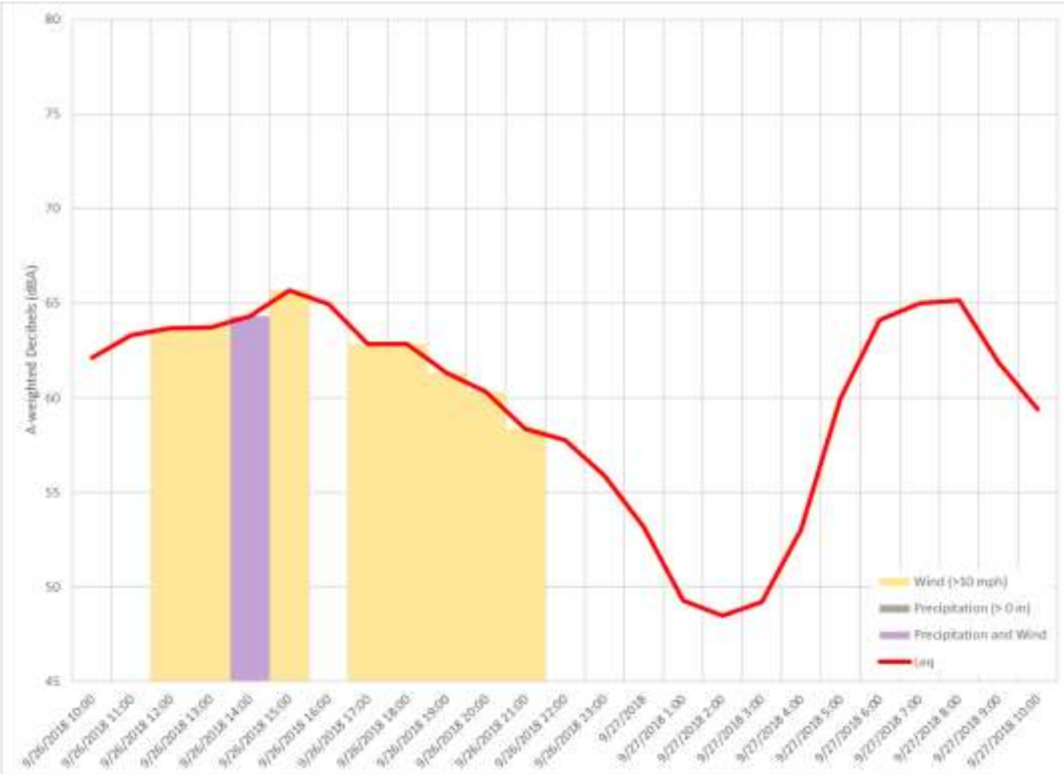

Figure B-1. Site LT-DNT-1 Time History Chart

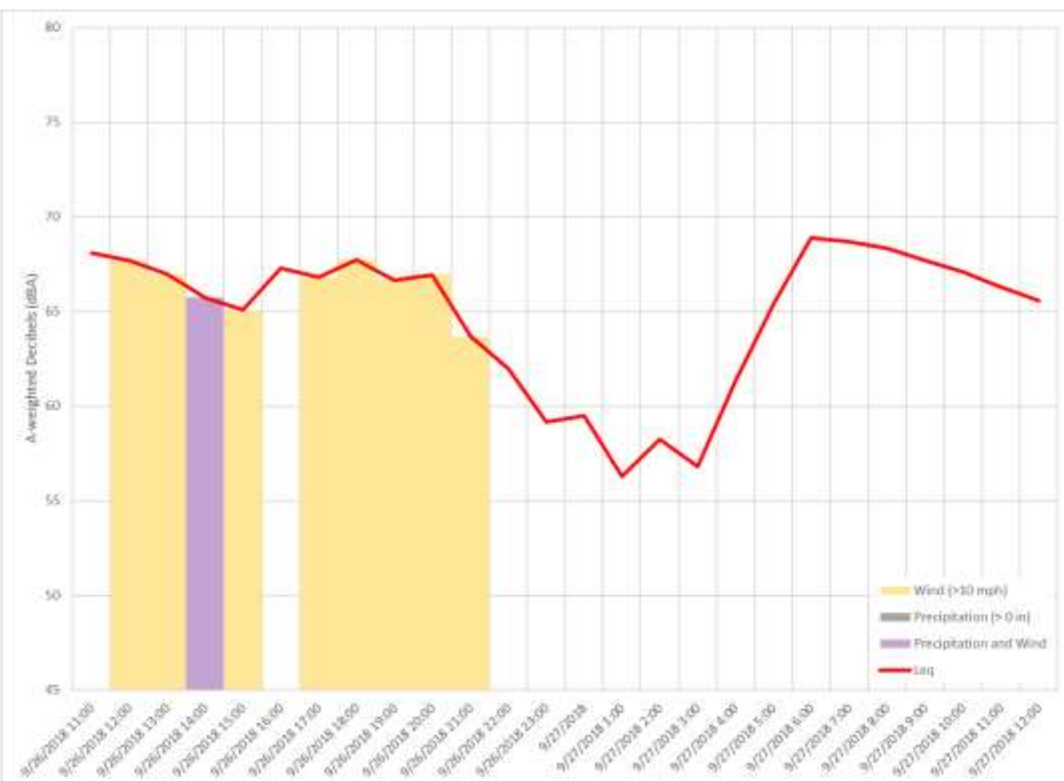

Figure B-2. Site LT-PGBT-1 Time History Chart

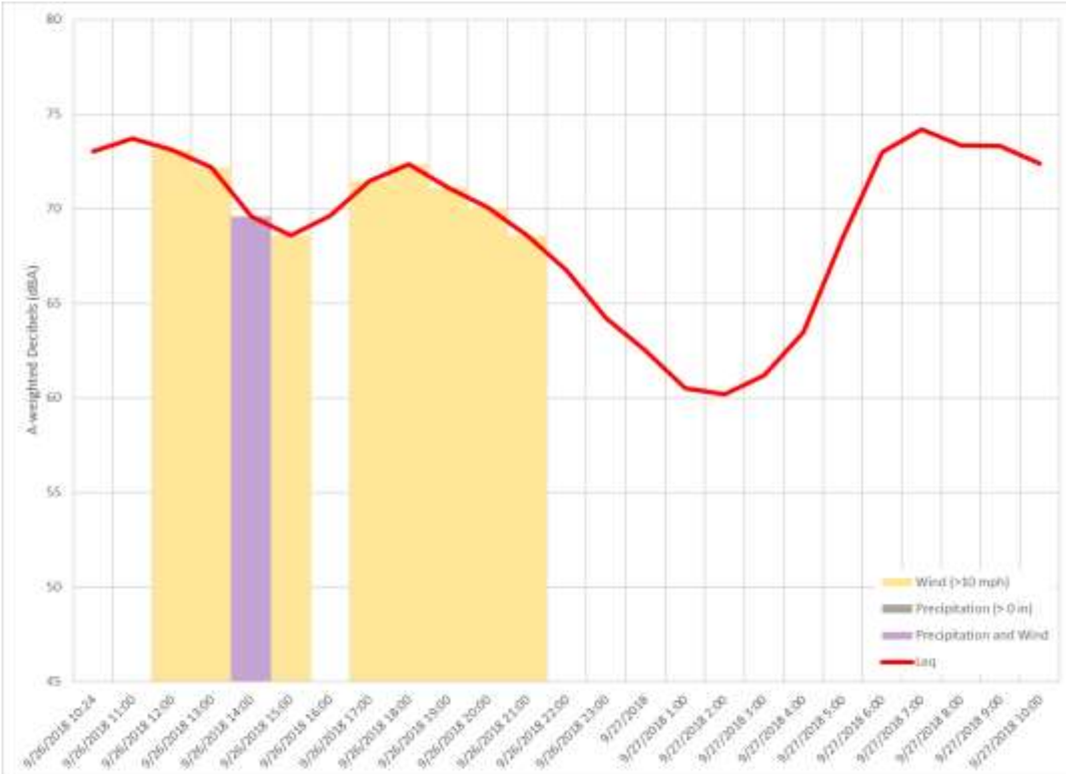

Figure B-3. Site PGBT-3 Time History Chart

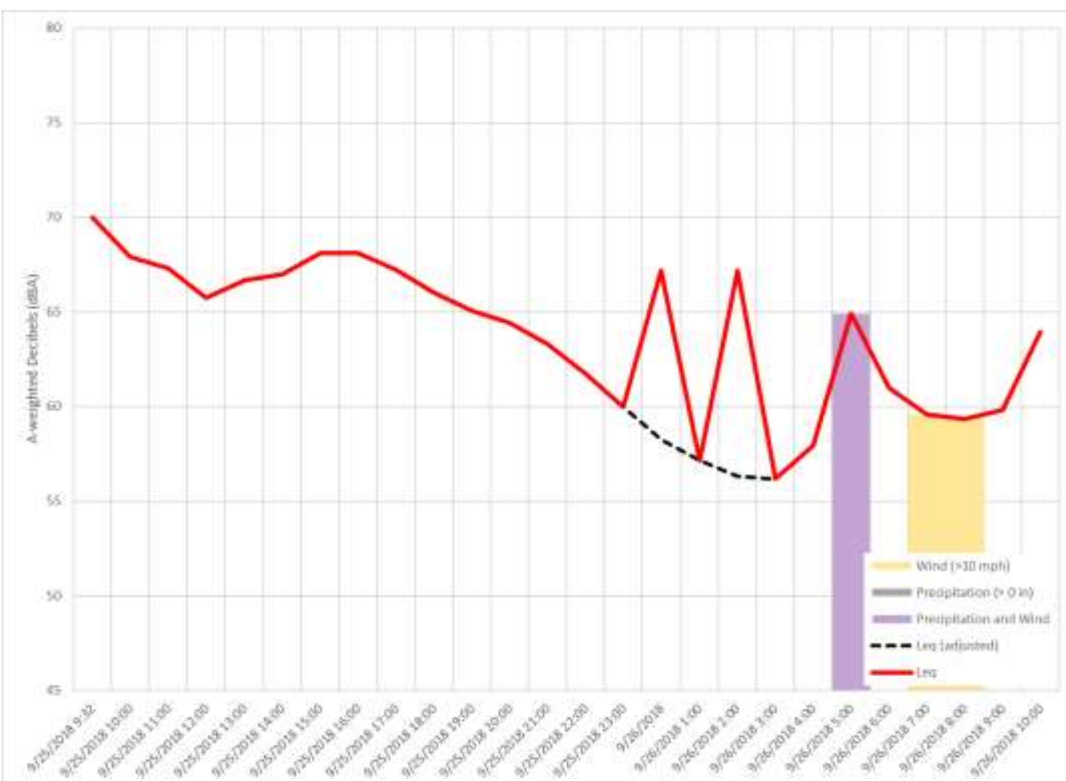

Figure B-4. Site PGBT-3A Time History Chart

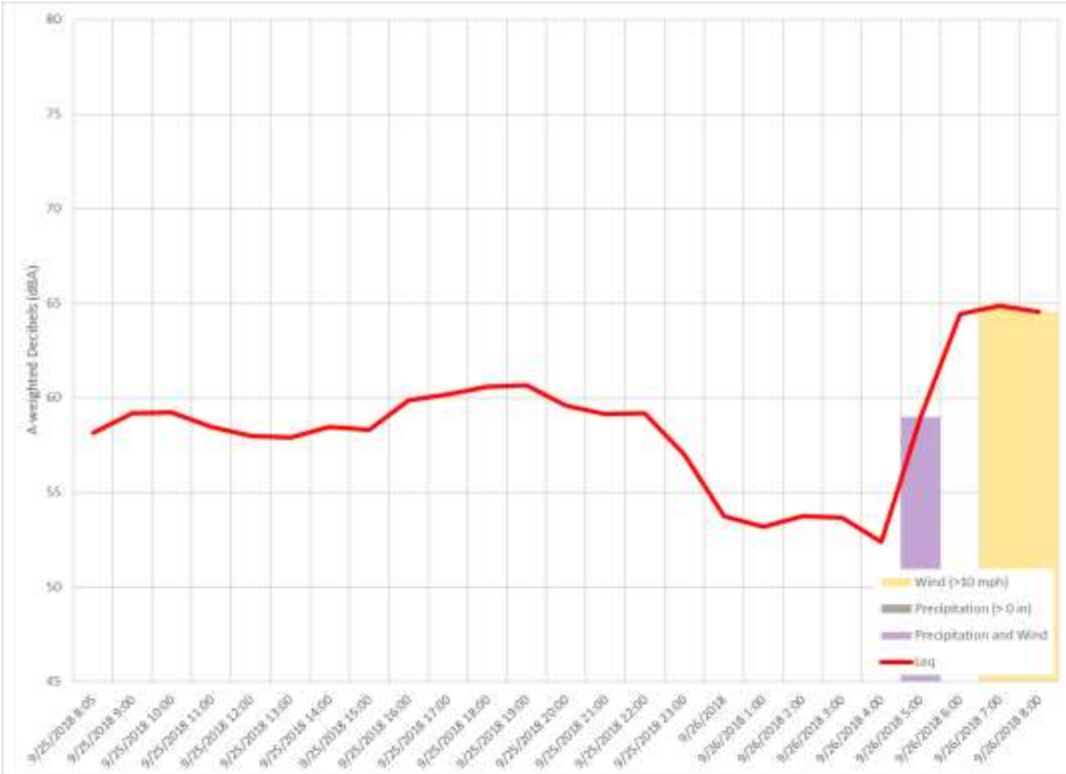

Figure B-5. Site SRT-1 Time History Chart

Figure B-6. Site SRT-2 Time History Chart

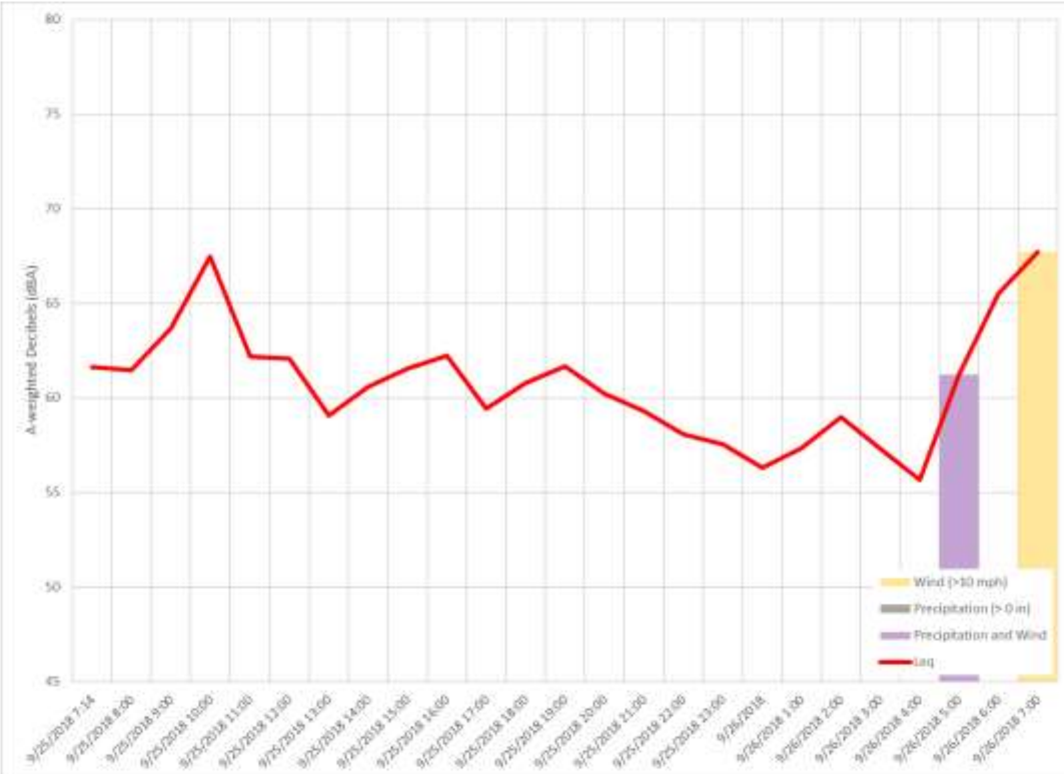

Figure B-7. Site SRT-3A Time History Chart

Figure B-8. Site SRT-3B Time History Chart

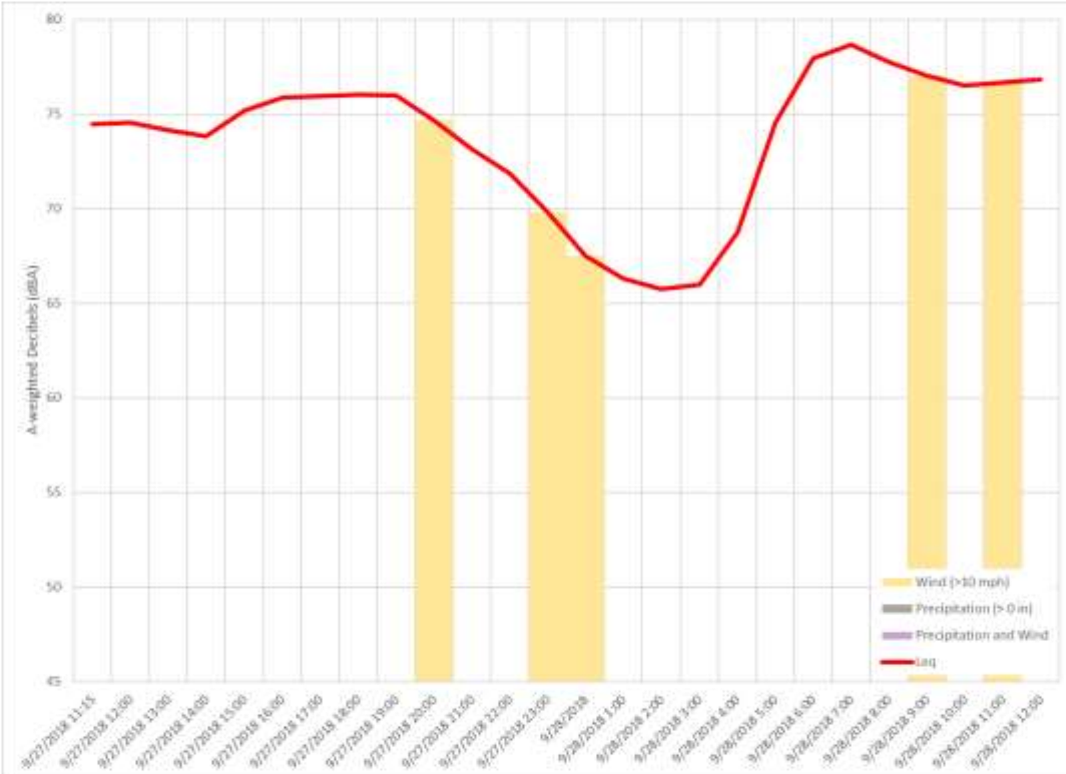

Figure B-9. Site US75-1 Time History Chart

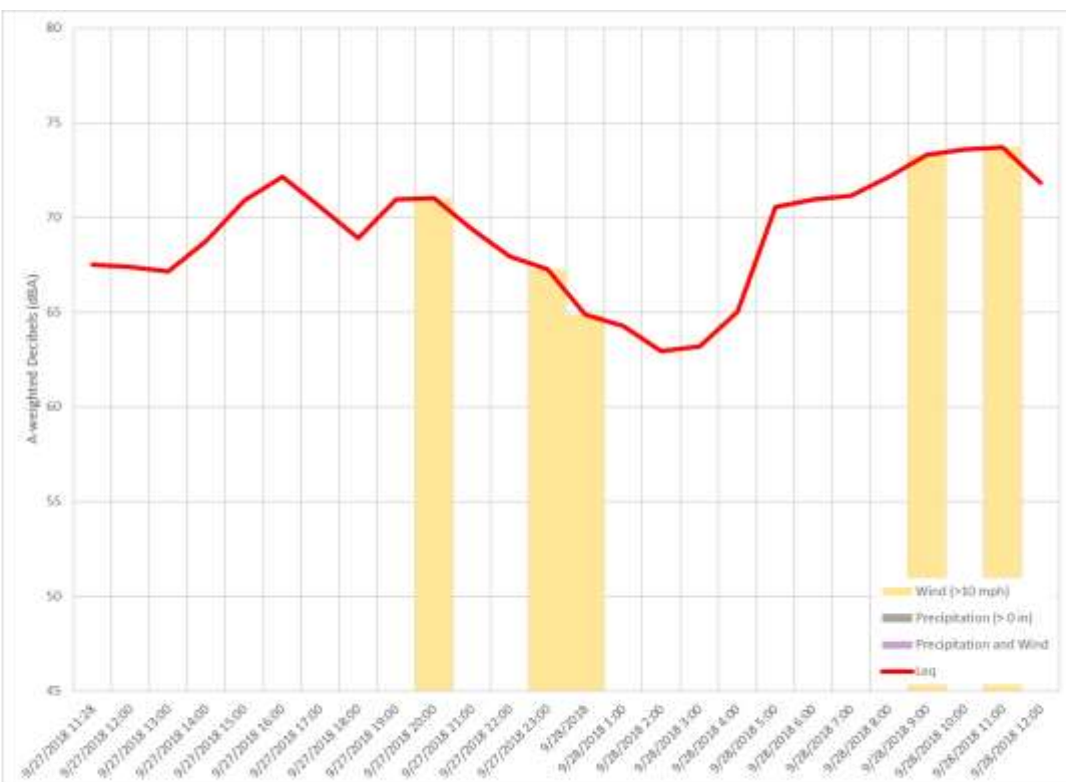

Figure B-10. Site US75-2 Time History Chart

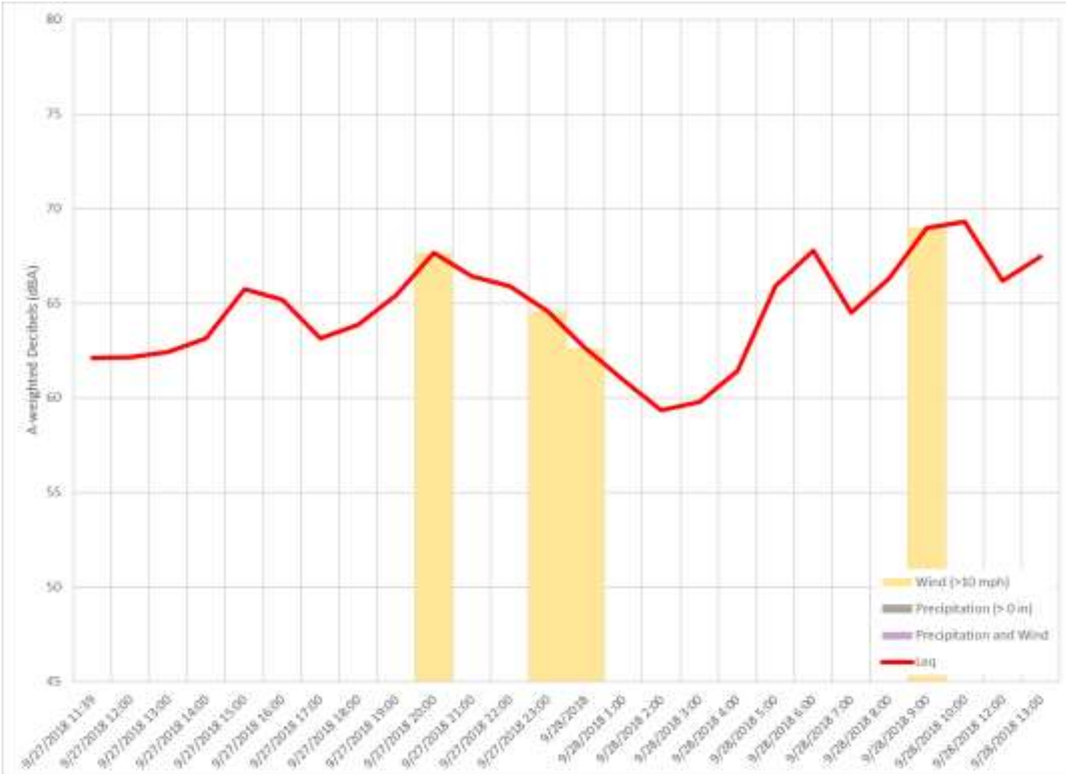

Figure B-11. Site US75-3 Time History Chart

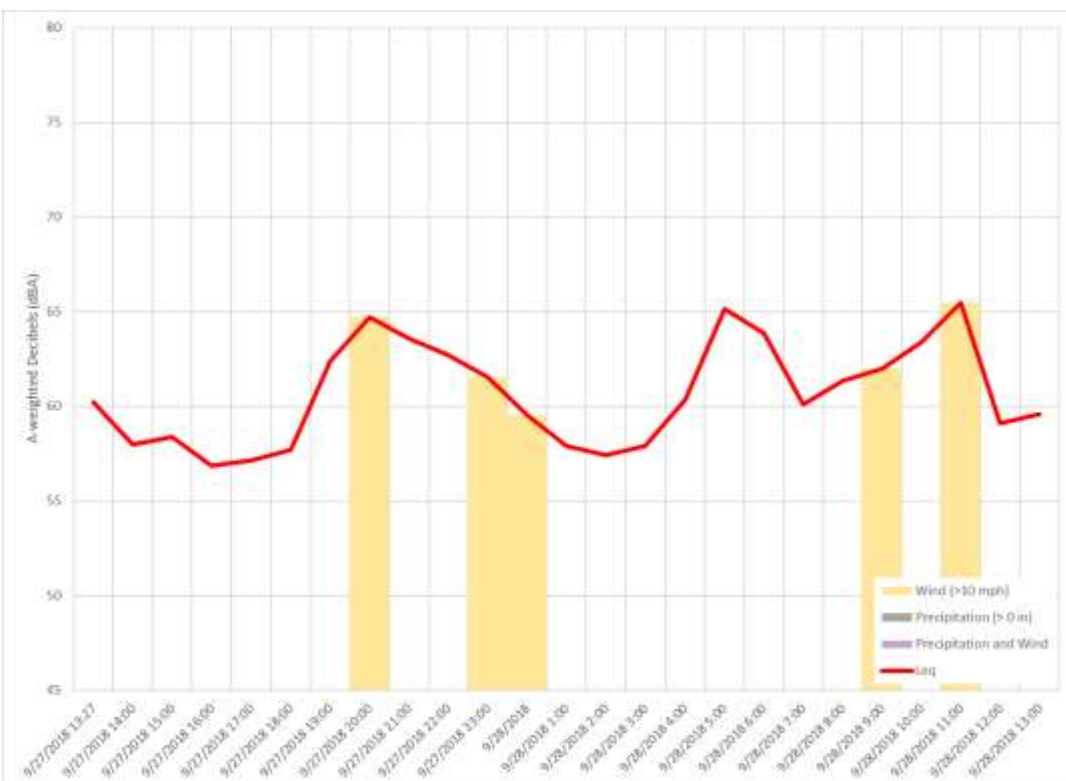

Figure B-12. Site US75-4 Time History Chart

Appendix C References

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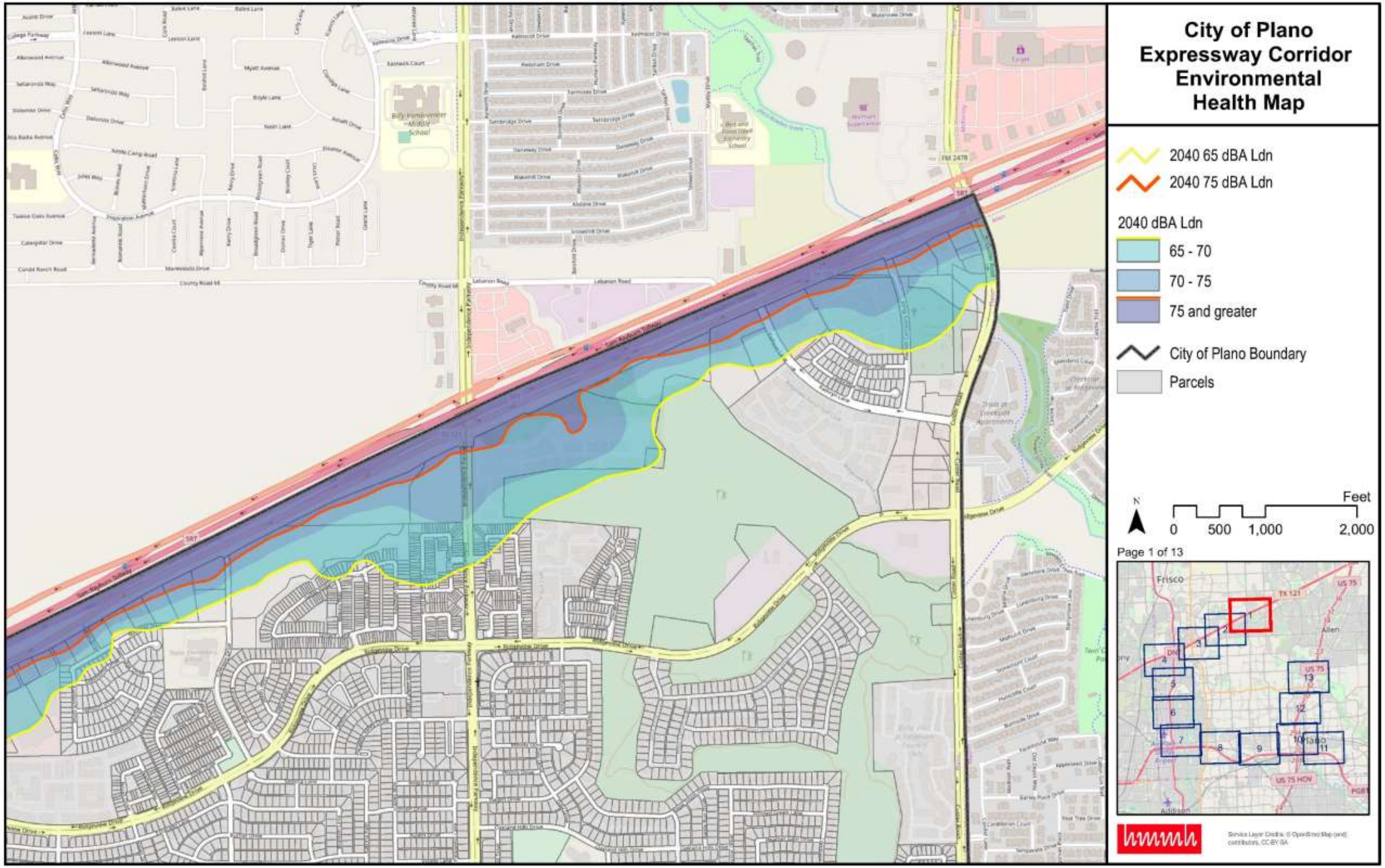
Appendix D Expressway Corridor Environmental Health Map

Figure D-1. Noise Impact Map 1



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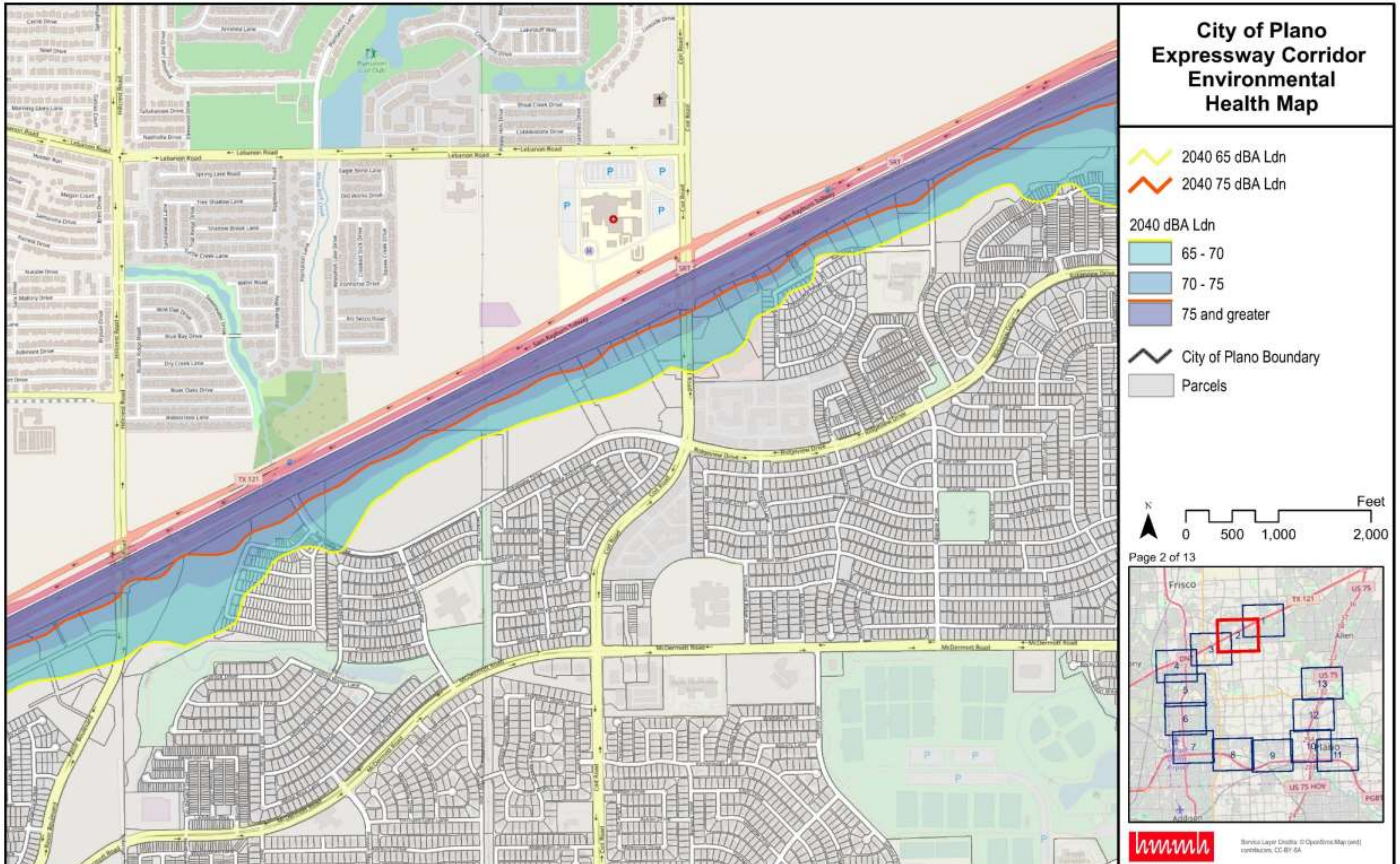

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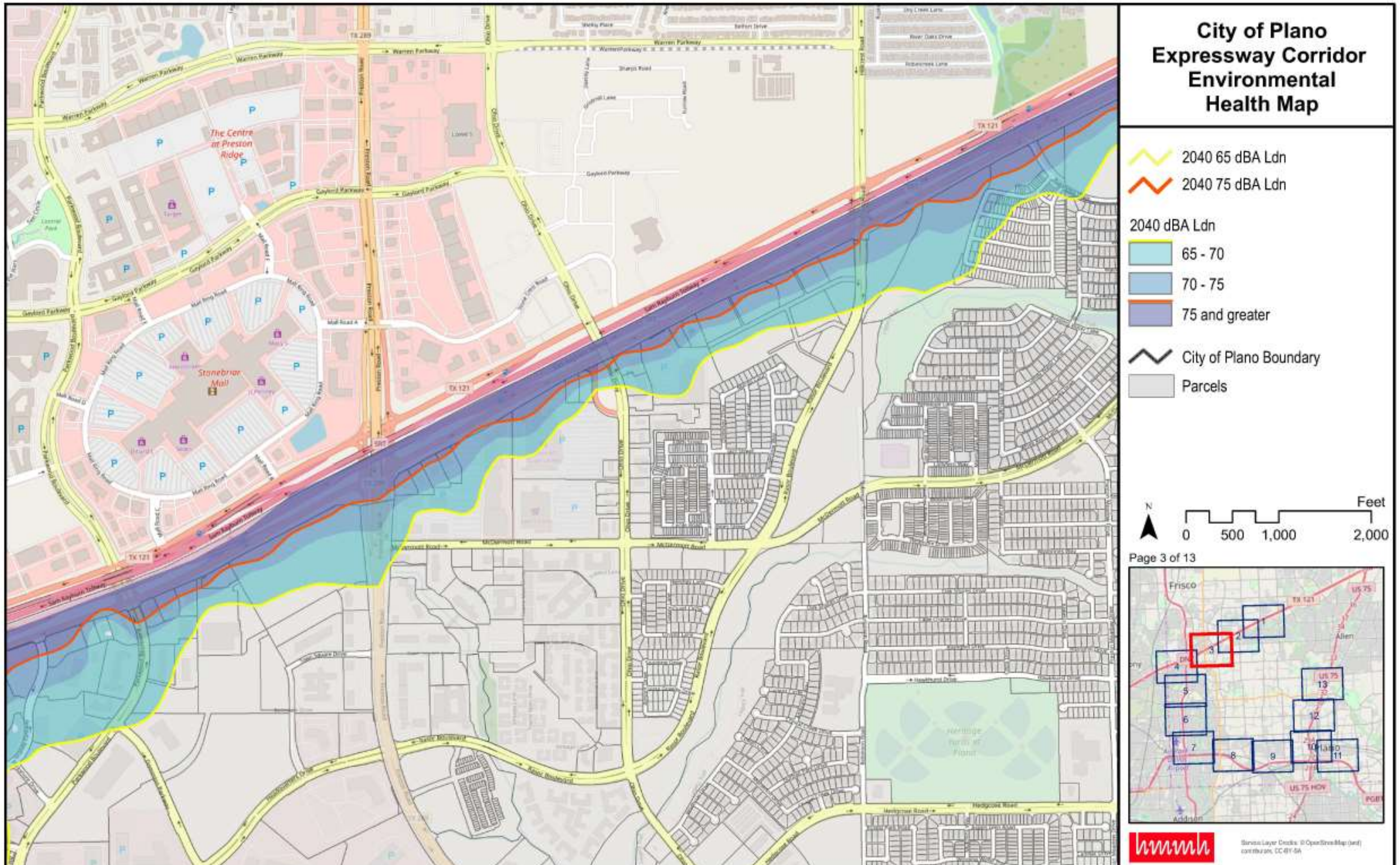

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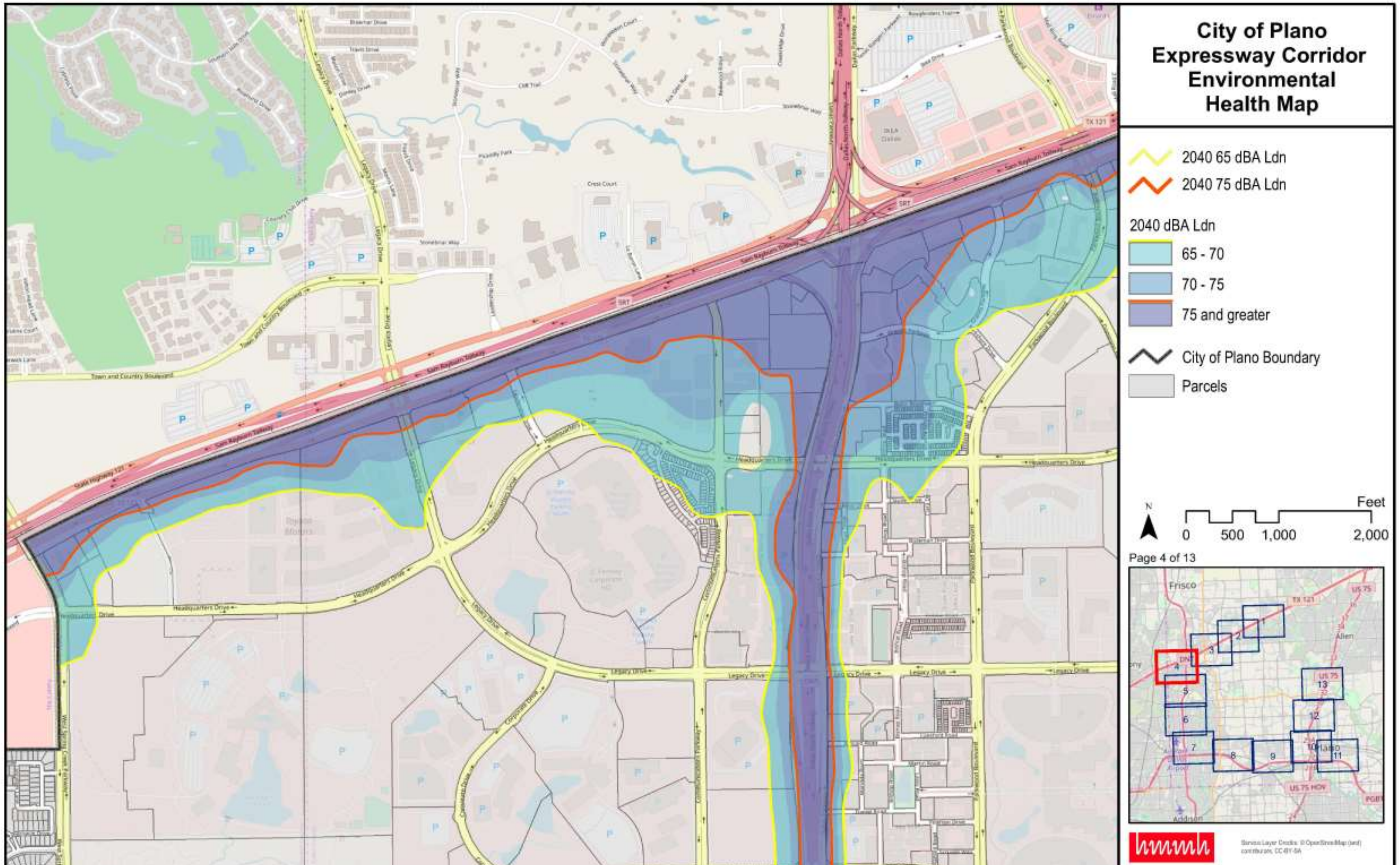

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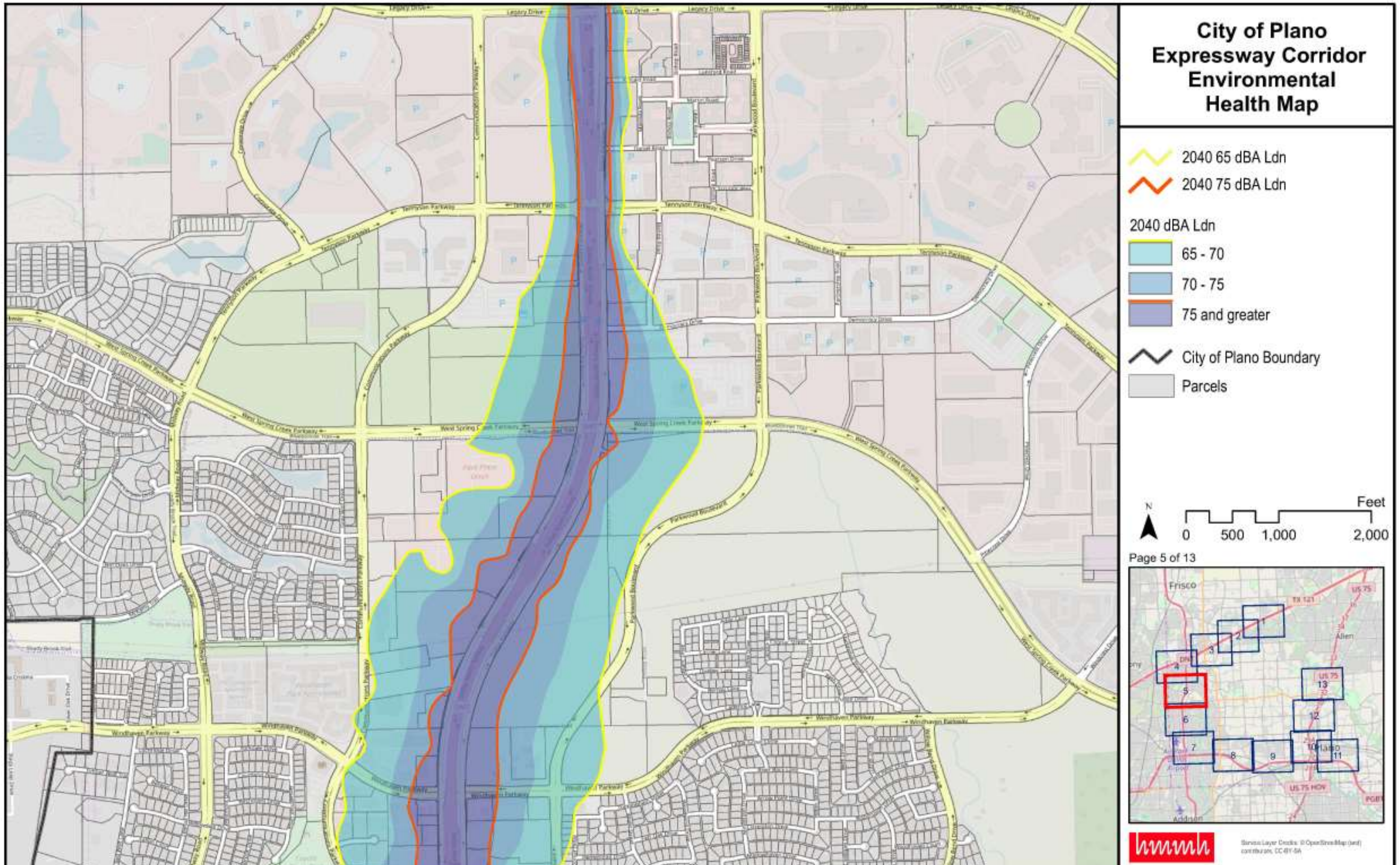

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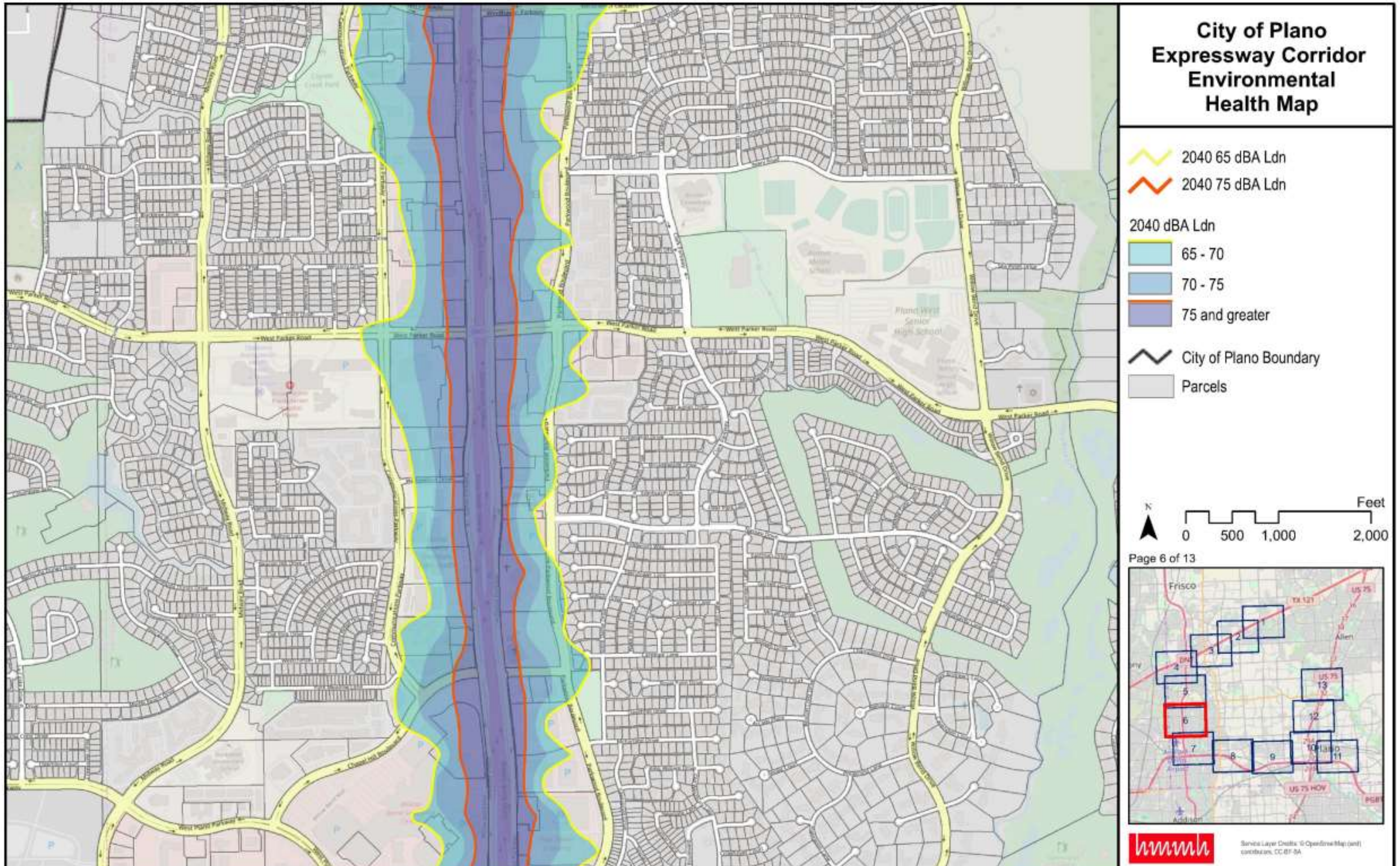

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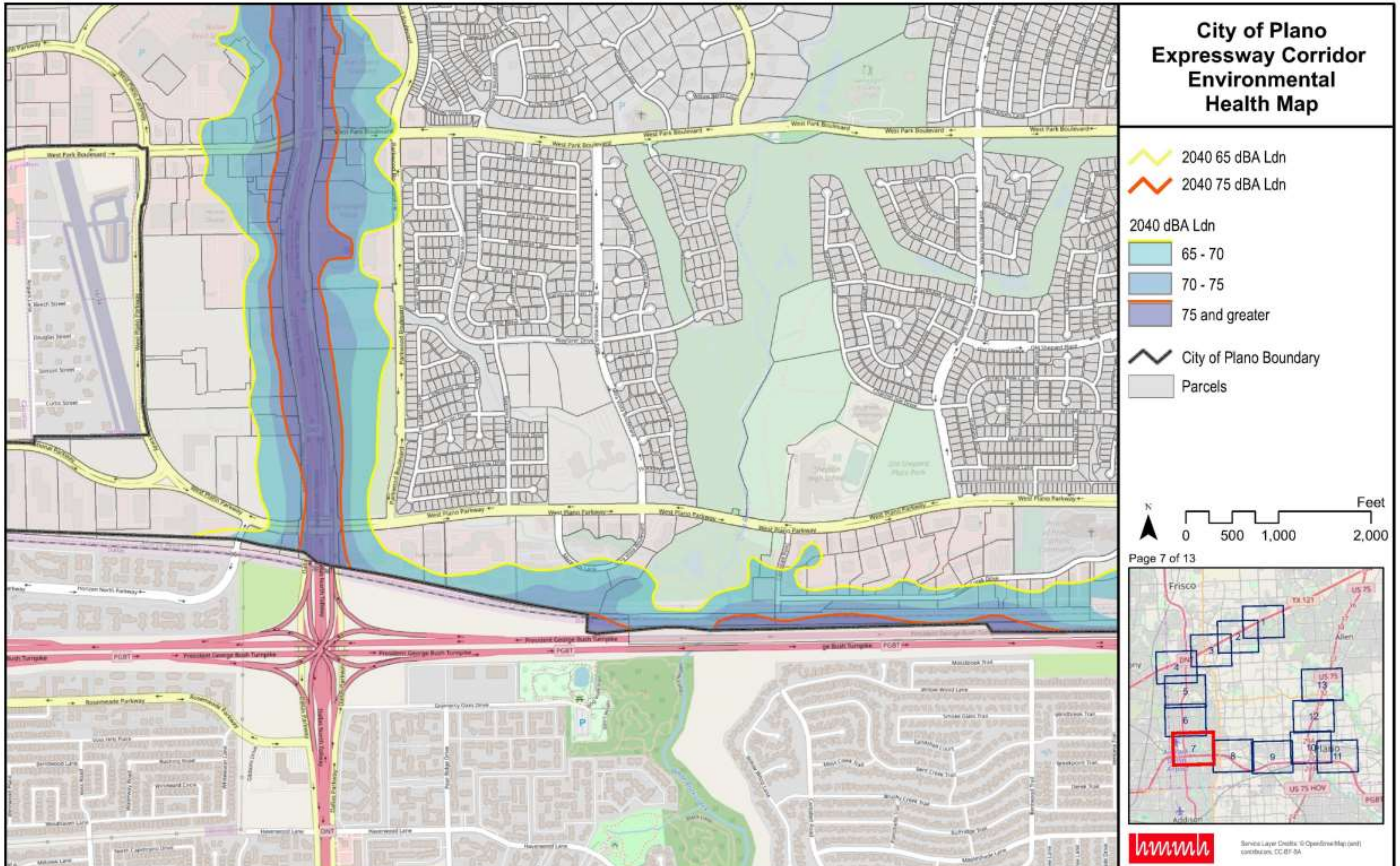

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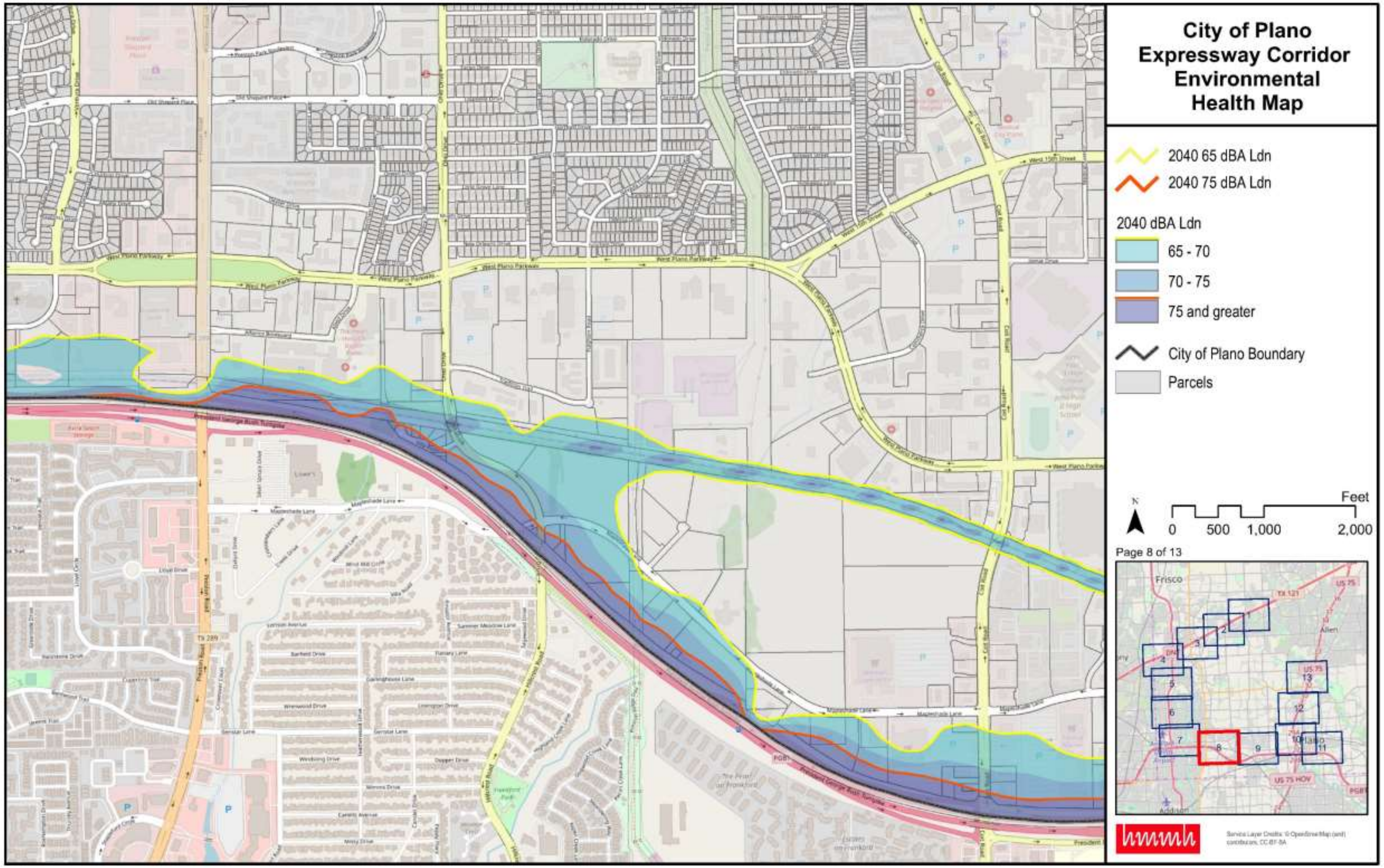

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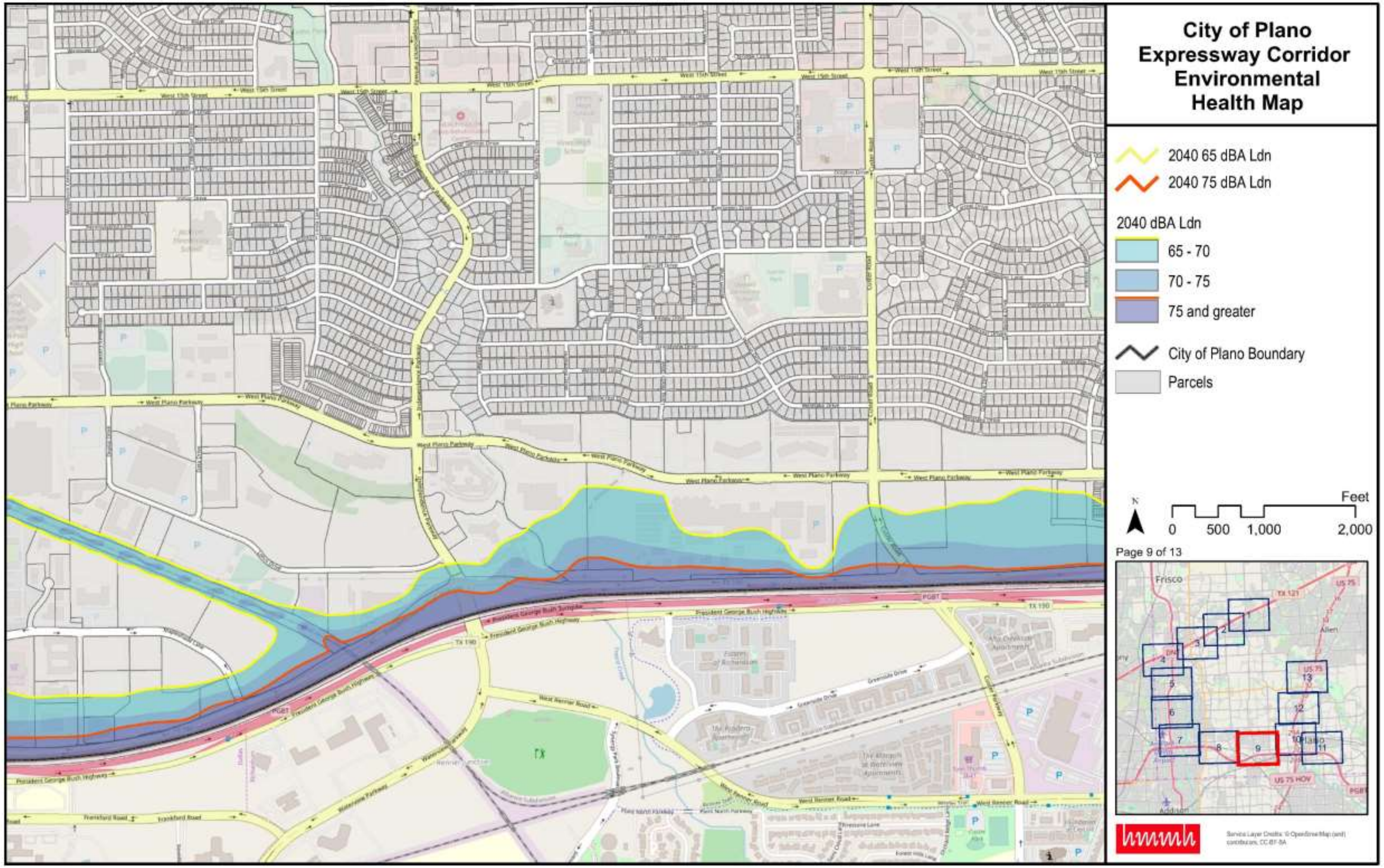

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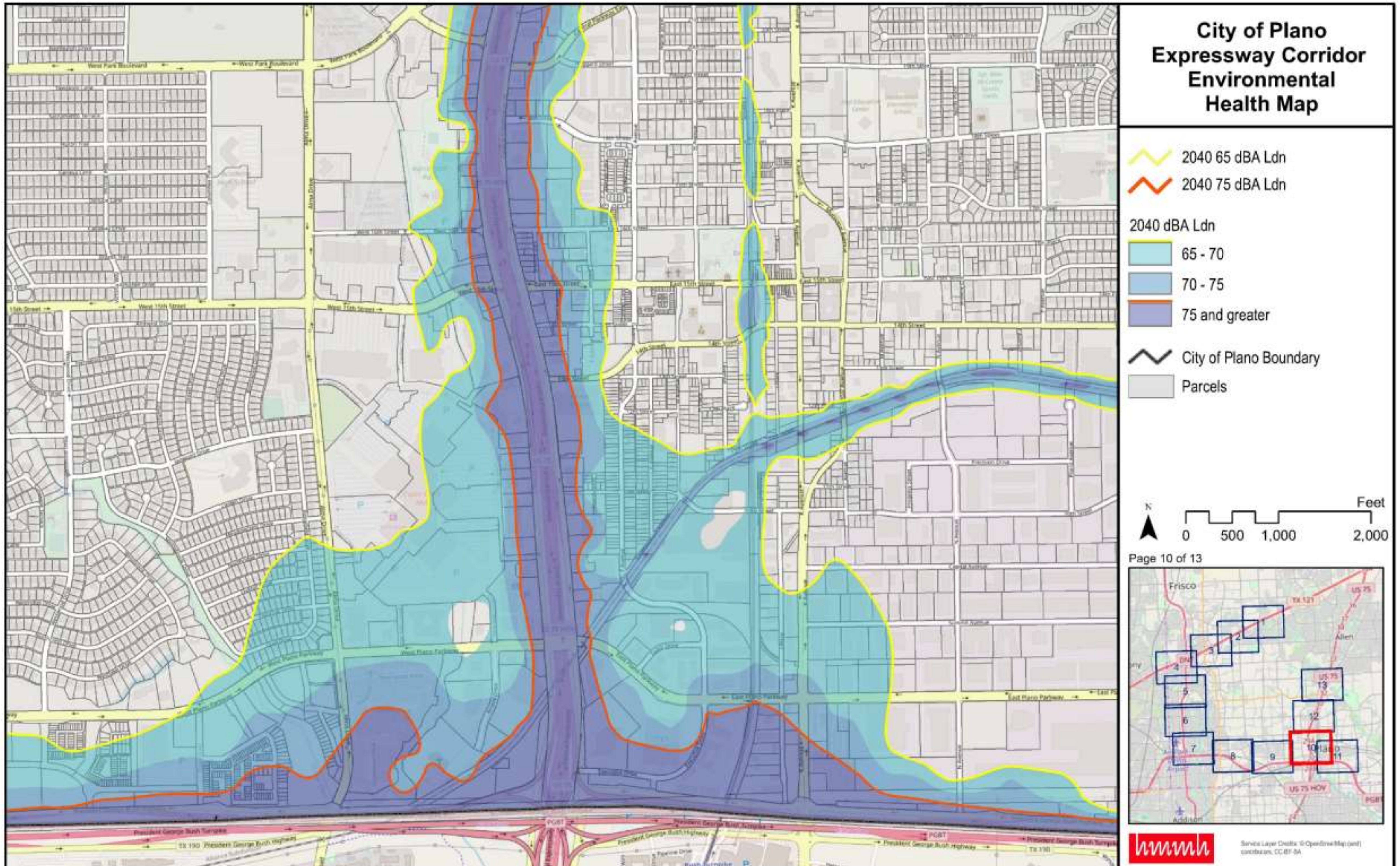

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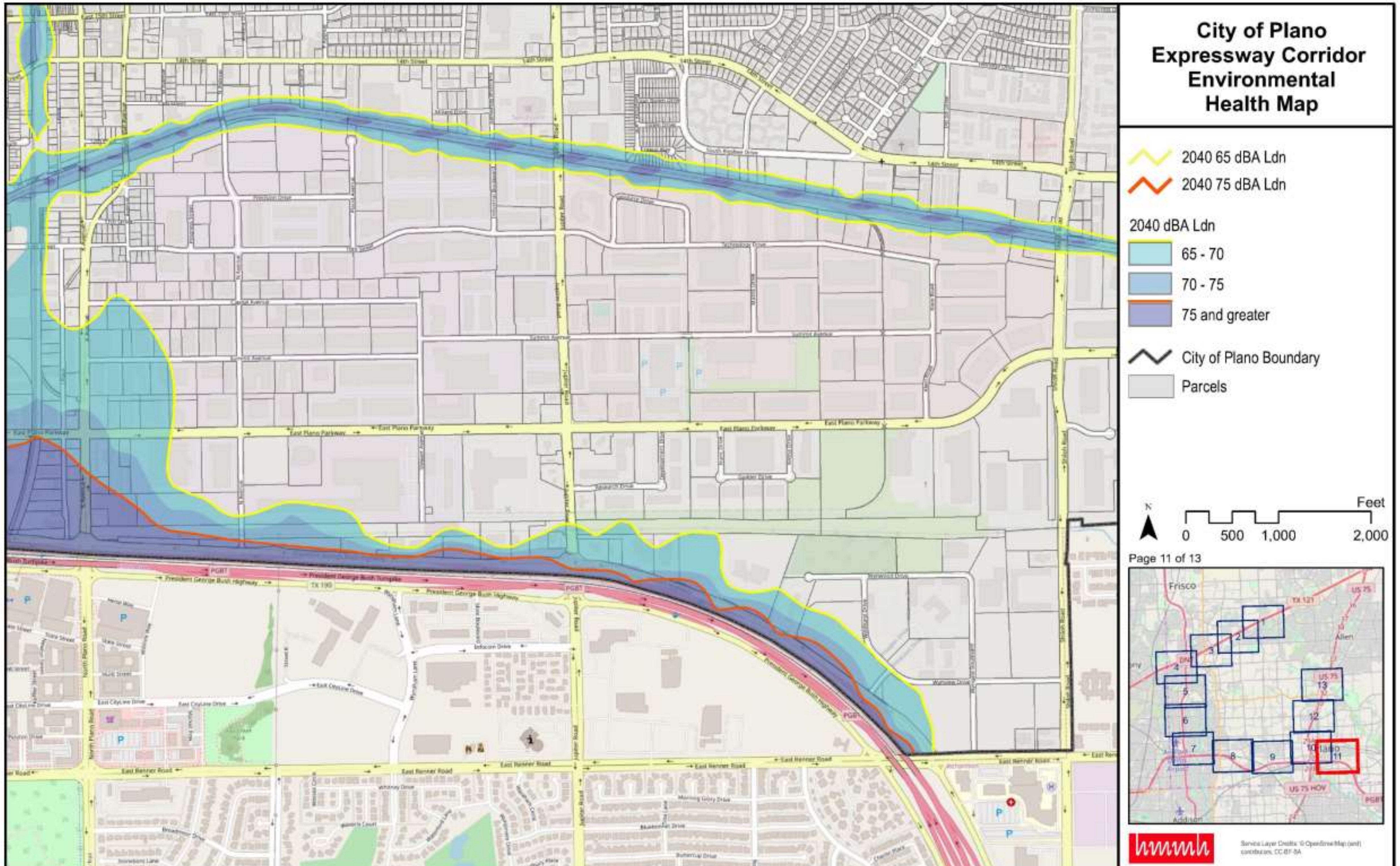

Figure D-12. Noise Impact Map 12

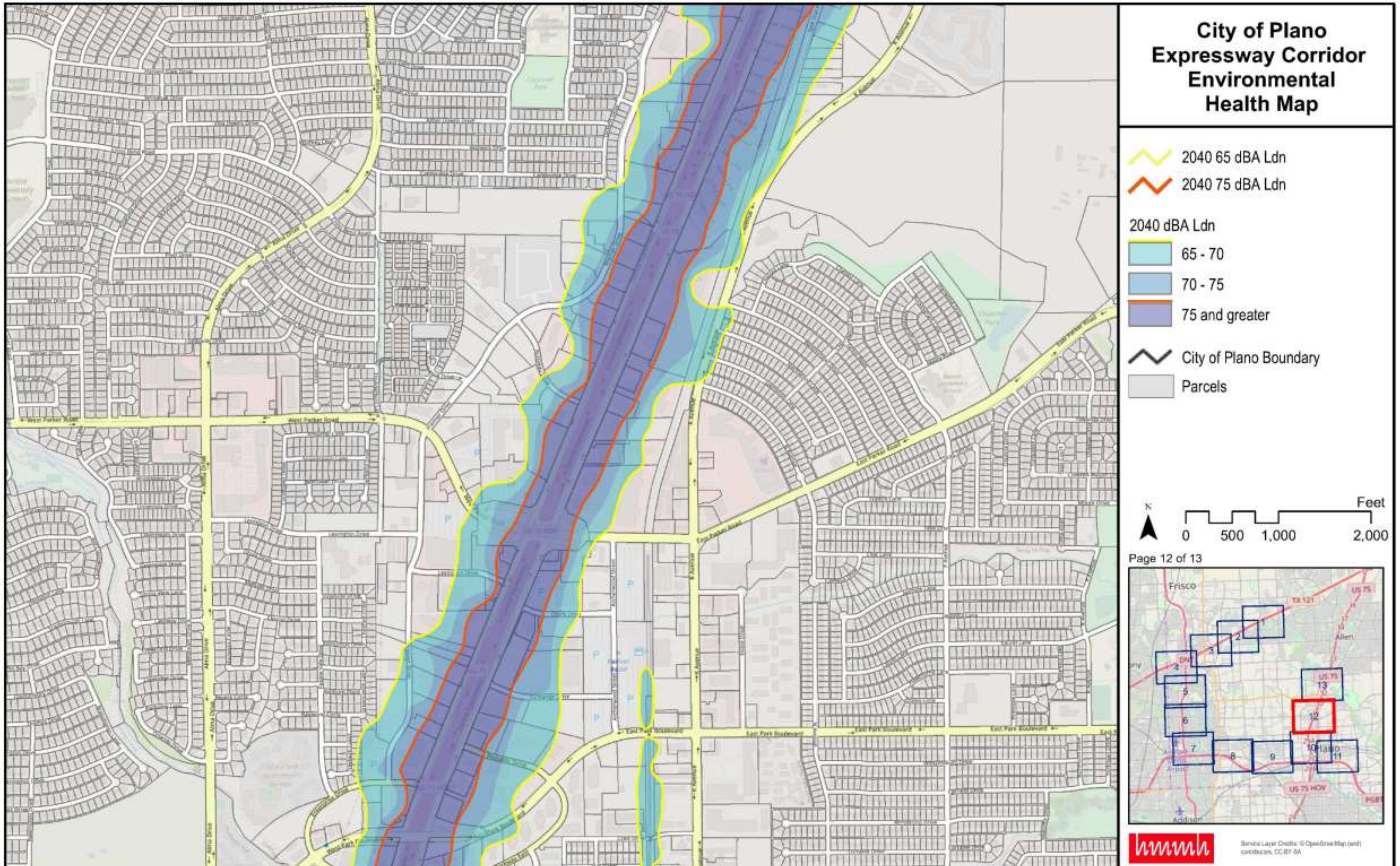

Figure D-13. Noise Impact Map 13