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# Final Analysis of Lightweight Transparent Noise Barriers on I-30 Elevated Structures in Dallas, Texas

Dr. Manuel Trevino

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16. Abstract

The Texas Department of Transportation commissioned a study to analyze the feasibility and effectiveness of lightweight noise barriers on Interstate Highway 30, near downtown Dallas. The highway segment in question, an elevated structure next to a creek, had presented noise problems for the adjacent neighborhood ever since its expansion in the early 2000s. The highway carries substantial commuter traffic as well as heavy trucks. The neighborhood is hilly and sits at a higher elevation relative to the highway, except for a few residences on the street adjacent to the creek. The material for the noise barriers needed to be lightweight in order to be supported by the existing bridge structures without having to retrofit them. The project consisted of two phases: the first one, the westernmost segment, installed in 2013, consists of 10-ft tall transparent acrylic noise panels mounted on top of the existing 8-ft concrete wall. The success of the first phase led TxDOT to proceed with the extension of the wall towards the east for the second phase in 2018; it consists of three segments of noise wall of the same material, also mounted on the existing concrete walls, with 13-ft tall panels for one segment and 10-ft tall panels for the other two segments. Residential sound pressure level tests were performed at various locations before and after the transparent wall installations and continued for several years. A portable weather station was used to monitor the conditions at the time of the tests. Measurements were conducted at various times of the day. A statistical analysis of the various weather variables and their influence on the noise levels was performed. The results indicate that the walls are effective, although the acoustic benefits appear to be small; this is due to the fact that the high levels of tire-pavement noise generated by aging pavements on the roadway likely diminished the apparent effectiveness of the walls. The neighbors are satisfied with the walls' performance and their aesthetic appearance.

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Dr. Manuel Trevino


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Research Supervisor: Manuel Trevino

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The cooperation of the Kessler Park neighbors is acknowledged, especially those who kindly allowed and continue to allow the researcher to perform the measurements at their property at all times of the day.

# Table of Contents

## List of Figures

# List of Tables

# Chapter 1. Introduction

This is one of the two final reports developed under Research Project 0-6804, Life *Cycle Cost and Performance of Lightweight Noise Barrier Materials along Bridge Structures*, a study funded by the Texas Department of Transportation (TxDOT). This final report (0-6804-4) documents all findings about the lightweight noise barriers installed on Interstate Highway (IH) 30, including field data as well as analyses and conclusions derived from the data. The first report in this series, 0-6804-1, contained information and analysis up to nine months after the installation of the Phase 1 wall. The second report, 0-6804-2, presented the results up to August 2018, including the complete analysis for the Phase 1 wall, and a preliminary analysis for the Phase 2 wall. The third report, 0-6804-3, submitted to TxDOT in August 2019, included the preliminary noise analysis and recommendations for the State Highway (SH) 190 and President George Bush Turnpike project site, which was added to this research project in June 2017. Report 0-6804-5 will be the final report for the SH 190 study, including analysis, conclusions, and recommendations.

## 1.1. Background

Noise associated with transportation has progressively become a nuisance to communities along roads, especially in densely populated areas. As traffic volumes of people and freight continue to grow, roads expand and noise levels rise. Nowadays, transportation agencies have become more environmentally sensitive and make efforts to address pollution problems, including those related to noise. Multiple factors affect the level of traffic noise, such as vehicle speed, terrain, grade, surface absorption, and shielding provided by walls, fences, buildings, or even dense vegetation. The most frequently used noise abatement measure has been the construction of noise barriers on the side of the road. Such barriers are normally built along highways that carry heavy traffic in urban areas, where noise pollution is likely to be greater and affect more people.

Noise barriers are normally solid wall structures built between the highway and the impacted activity area to reduce noise levels. Barriers do not eliminate the noise; they only reduce the noise levels perceived by certain benefitted receivers, normally those in proximity to the road. Barriers are especially effective for those receivers situated directly behind it; they can experience a decrease in noise level of typically 5 to 10 dBA. Noise barriers are not effective for homes on a hillside overlooking a road, or for buildings that rise above the barrier; the barrier must be high enough and long enough to block the view of the road. Common materials for barrier construction are concrete and masonry; other materials are metal and acrylic.

The height, length, and material are key components to the effectiveness of the barrier. Openings in the barriers, such as those designed to allow access to side roads or driveways, decrease their effectiveness.

Noise barriers can reduce visibility and lighting for both the receivers behind the barrier and the drivers using the facility. Barriers can also present a problem for businesses along the road by restricting views and access by customers. Barriers constructed with transparent materials can address these problems by reducing the visual impact of opaque barriers and thus preserving scenic vistas.

## 1.2. Project Description

The TxDOT Dallas District asked researchers at The University of Texas at Austin's Center for Transportation Research (CTR) to develop a pilot project to investigate the feasibility of two lightweight noise barriers on I-30, just west of downtown Dallas. The highway segment in question, an elevated structure next to a creek, has presented noise problems for the adjacent neighborhood ever since its expansion in the early 2000s. The highway carries substantial commuter traffic as well as heavy trucks. The material for the noise barriers needed to be lightweight in order to be supported by the existing bridge structures without having to retrofit them. The two adjacent highway sections are the subject of this investigation. The westernmost barrier was installed in 2013 at what has been labeled as Site 1, and the easternmost wall was completed in August 2018, at Site 2. The time gap between Site 1 and Site 2 occurred because of the "Horseshoe Project" adjacent to Site 2, a 5-year project that replaced the bridges of I-30 and I-35E that cross the Trinity River. TxDOT wanted to wait for the finalization of this project before the design of the Site 2 barrier began.

An existing 8-ft tall concrete wall at Site 1 already provided some noise mitigation to the residences. The highway segment at Site 2 also has an existing 4.5-ft tall concrete barrier. However, the neighborhood is hilly and sits at a higher elevation relative to the highway, except for a few residences on the street adjacent to the creek, therefore, TxDOT wanted to provide a taller barrier to increase the noise abatement, without entirely blocking the views of the residences towards downtown. Therefore, an aesthetic solution was also sought. Noise barriers are normally not effective for receivers on a hillside overlooking the highway or for receivers at heights above the top of a noise barrier; thus, it was not expected that the residences at the higher elevations would be substantially benefited.

A 10-ft tall transparent acrylic noise barrier was designed and installed on top of the existing 8-ft concrete wall at Site 1.

At Site 2, the second noise barrier had to be split into three separate segments, given the geometry of the highway. The panels for the first segment are 13.2-ft tall and those for the second and third segments are 10-ft tall.

The transparent noise barrier that was recommended, designed, and installed as the outcome of the first part of this project was the first one of its kind in Texas. TxDOT's intent for this project, besides the benefit to Kessler Park (the adjacent neighborhood on the south side of I-30), is to provide cost and performance information for future project comparisons and, based upon this experience, to develop this type of project on other highways facing similar problems. An example of this application is the aforementioned SH 190 project, which was subsequently developed as part of this 0-6804 research project.

### 1.1.1 Objective and Tasks

The main objective of this study is to assess the feasibility and effectiveness of lightweight noise barriers on I-30 in Dallas, and to serve as a pilot project for TxDOT for future similar projects. The tasks are as follows:

- Conduct a feasibility study for lightweight traffic noise walls.
- Select barrier material types and vendors.
- Perform the acoustical design of the barriers.
- Conduct periodic inspections of the barriers condition.
- Perform sound measurements before and after the barriers' installation.
- Analyze measurements and evaluate performance.

## 1.3. Report Organization

This report is organized as follows:

- Chapter 1 presents the background and the objectives of the study.
- Chapter 2 reviews vendors' and various state DOTs' experiences with and materials used for lightweight and transparent noise barriers.
- Chapter 3 provides a description of the highway, the pavements, and the neighborhood that are the subject of the investigation.
- Chapter 4 discusses the Site 1 barrier design and recommendation presented to TxDOT's Dallas District.
- Chapter 5 presents the Site 2 barrier design and recommendation presented to TxDOT's Dallas District.
- Chapter 6 describes the noise testing program.
- Chapter 7 presents the noise test results and analysis for both sites.
- Chapter 8 explains the Site 1 barrier construction inspection and monitoring, as well as the findings from these activities.
- Chapter 9 describes the construction inspection and monitoring of the Site 2 barrier, and the findings from these tasks.
- Chapter 10 discusses the conclusions of the study and the recommendations to TxDOT.

# Chapter 2. Review of Experiences and Literature

## 2.1. Introduction

This chapter presents a review of various lightweight noise barrier materials that were considered as candidates for the noise wall installation planned for the south side of the elevated structures on I-30 in Dallas. Specifically, the project contained the segments between Edgefield Avenue and Sylvan Avenue (Site 1), as well as from Sylvan Avenue towards Beckley Avenue (Site 2), in the vicinity of the Kessler Park neighborhood.

The need to investigate lightweight materials for the Dallas District in this project was driven by the characteristics of study area on I-30. Both segments in the study are elevated highway structures above a creek, and both have existing concrete walls.

The District's plan was to install noise barriers on top of the existing concrete walls, which are approximately 8-ft tall for the segment between Edgefield Avenue and Sylvan Avenue, and 4.5-ft tall for the section between Sylvan Avenue and Beckley Avenue. Both segments are long, elevated structures above Coombs Creek, so the materials needed to be lightweight and possibly transparent. The lightweight requirement was needed to allow the existing structure to withstand the additional loading from the noise wall without having to structurally reinforce the bridges. Concrete walls of comparable heights as the lightweight barriers placed on these bridges would have undoubtedly required retrofitting the structures.

Additionally, the lightweight material would enable the installation of a taller wall that can cover the line of sight to the highway for as many of the residences in the adjacent hilly neighborhood as possible.

From the aesthetics standpoint, transparent walls were desired. Transparent materials have the advantage over opaque materials in that they block sound without obstructing views, allowing sunlight to penetrate. A tall transparent barrier on top of the existing concrete wall would have less visual impact on the surrounding area than would a tall opaque barrier. At meetings with the District personnel, it was mentioned that this was an important characteristic contemplated for the walls in this project; however, this idea did not preclude the review of non-transparent options. On the other hand, concerns associated with transparent materials (as compared with other more common noise barrier materials, such as concrete) are their higher cost, possible deterioration with time, and maintenance requirements.

The review was not limited to documents available in the literature. Also included were interviews, meetings, and email and telephone conversations with material vendors and suppliers, as well as with representatives from state DOTs and other entities that have used such materials. Other states' experiences were a valuable source of information that cannot necessarily be found in publications.

Some of the organizations consulted included the following:

- The Federal Highway Administration (FHWA)
- Various DOTs (Kentucky, Washington, Ohio, and California)
- Three noise barrier lightweight material manufacturers in the U.S. (Acrylite, Plaskolite, and AIL Soundwalls, the first two of which manufacture transparent barriers)
- The following sections in this chapter present findings from the literature and from the interviews of the contacted organizations.

## 2.2. Noise Barriers and Material Selection

Barriers do not eliminate the noise; they only reduce the noise levels perceived for certain benefitted receivers, normally those in proximity to the road. Barriers are especially effective for those receivers situated directly behind it; these receivers can experience a decrease in noise level of typically 5 to 10 dBA. Noise barriers are not effective for homes on a hillside overlooking a road, or for buildings that rise above the barrier; the barrier must be high enough and long enough to block the view of the road. Common materials for barrier construction are concrete and masonry; other materials are metal and acrylic. Such barriers are mostly reflective (*Trevino 2013*).

The FHWA, in its noise barriers guidelines (*FHWA-HEP-10-025*), recommends that, to effectively reduce sound transmission through the barrier, the material chosen must be rigid and sufficiently dense (at least 20 kg/m$^2$, or about 4 lb/sq ft, with density here expressed as a function of the surface area of wall considered). All noise barrier material types are equally effective, acoustically, if they have this density. Noise barriers reduce the sound that enters a community from a busy highway by absorbing the sound, transmitting it, reflecting it back across the highway, or forcing it to take a longer path over and around the barrier (*FHWA Noise Barrier Design*). Therefore, noise barriers work by reflecting some of the acoustic energy, while part of the energy is transmitted through the barrier, part of it is diffracted, and some of it reaches the receiver directly, for those receivers with a line of sight of the source (Figure 2.1). Therefore, the density of the barrier material is of foremost importance.

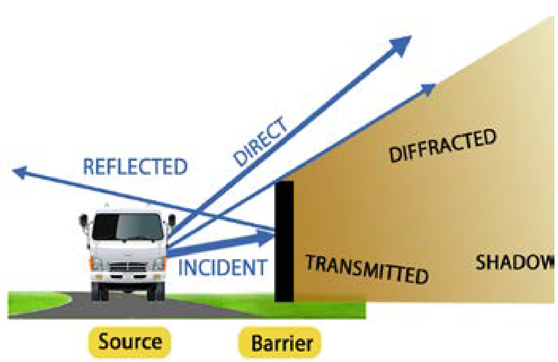



*Figure 2.1 Acoustic energy and noise barrier (Bowlby 2012)*

There are no federal requirements specifying the materials to be used in the construction of highway traffic noise barriers. Individual state DOTs can select the materials when building these barriers (*FHWA-HEP-10-025*). The selection is based upon structural considerations, safety, aesthetics, durability, materials availability, maintenance, cost, and the desires of the public.

A single-number rating used to compare the sound insulation properties of barriers is the sound transmission class (STC). The STC rating is the transmission loss value for the reference contour at 500 Hz. Thus, the STC rating is not designed for lower frequencies of traffic noise, so it is typically 5 to 10 dB greater than the transmission loss provided (*FHWA-EP-00-005*). Approximate transmission loss values for common noise barrier materials are as follows: concrete barriers provide 34 to 40 dB; metal barriers, 18 to 27 dB; and transparent barriers, 22 dB (*FHWA-EP-00-005*).

Lightweight noise barrier projects are not the most common among the existing noise walls installed throughout the country. Ohio has the greatest number of transparent barriers, followed by California, and then by other states such as New Jersey, Tennessee, Florida, Minnesota, Wisconsin, and Virginia.

The FHWA keeps an inventory of noise barriers throughout the country (*FHWA-HEP-12-044*), which, in its most recent issue, contains information on barriers constructed from 1963, when the FHWA noise program started, up to 2016. According to this inventory, Texas had 86.7 linear miles of noise barriers of any materials in 2016. Caltrans (California's DOT) has the most linear miles of barriers, with 610.1. Ohio, a state that is prominent for its use of transparent barriers, has 231.9 miles of noise barriers of all materials, second in the nation only to California.

Of a total of 247,567,044 sq ft of barriers constructed in that period nationwide, representing 3,263 total linear miles of noise walls, concrete is by far the most common material, accounting for 55% of these barriers. Other common materials are block (18%) and wood (5%). Metal, berm, and brick together account for another 5% of single material barriers. A broad category named 'Other' comprise the final 1% of these barrier materials. This category includes acrylic, composite, undefined concrete, fiberglass, glass, other, plastic opaque, plastic other, or plastic transparent. Figure 2.2 shows the various materials within this category and their respective contribution to the 1%.

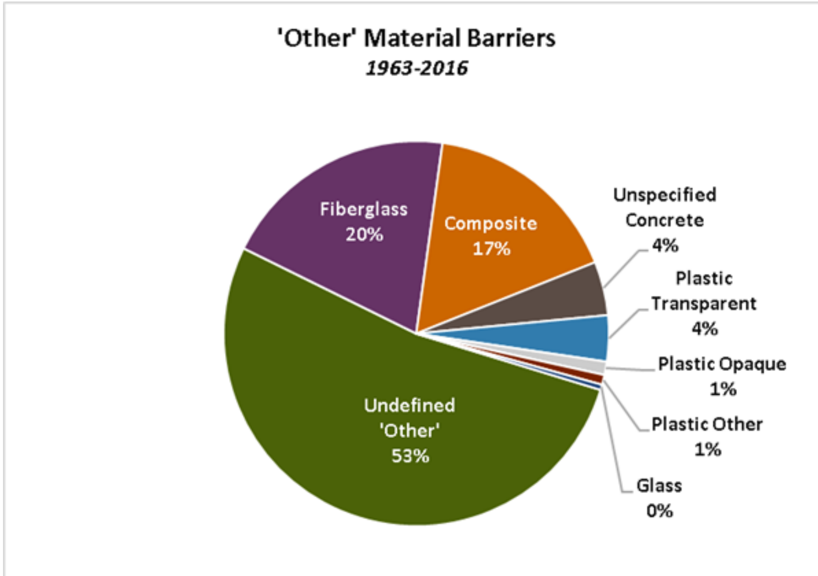



*Figure 2.2 Transparent noise barriers (source: FHWA Inventory of Noise Barriers)*

### 2.2.1. Aesthetics and Transparent Barriers

The main advantage of transparent materials over traditional materials in noise barriers is aesthetics (*Rocchi 1990*). Several communities have objected the installation of acoustic barriers because of fears over loss of views or other perceived visual impacts. Some objections concern specific designs, heights, or materials (*FHWA-HI-88-054*; *Austin Chronicle 2014*).

Some of the most outstanding benefits of transparent noise barriers are that they:

- Are aesthetically pleasing
- Preserve views and sunlight for both residents and driving public
- Could relieve the feeling of enclosure
- Could attract graffiti, but the graffiti is easier to clean than on other surfaces
- Are acoustically as effective as concrete walls
- Are lightweight

Disadvantages include cost (they are generally more expensive) and a shorter service life than concrete barriers. The service life of a noise barrier can be defined as the period of trouble-free performance with no discernible change in barrier insertion loss or appearance (*Morgan and Kay 2001*). The normal estimated service life for transparent barriers is 25 years (*McAvoy 2014*; *Morgan, Kay and Bodapati 2001*), whereas concrete's, for instance, is 50 years (*McAvoy 2014*; *Morgan Kay and Bodapati 2001*; *NCRHP 1992*).

Relative to barriers made with other materials, transparent barrier cost more, which is one major reason for the low number of installations (*McAvoy 2014*).

Despite their estimated higher cost relative to other materials, the research team determined that transparent barriers, given the properties listed above, provided a feasible alternative for this project.

## 2.3. The Experiences of Various Organizations

### 2.3.1. Ohio DOT

Among the various organizations and DOTs contacted by CTR, one of the most informative conversations was held with the Ohio DOT (ODOT). Ohio is the state with the most transparent noise barriers. At the time of this conversations, they had 11 transparent noise barrier installations, and they were very satisfied with their performance, both from the structural and acoustical standpoints. The selection of transparent barriers is attributed mainly to the lighter weight and aesthetics. In many instances, it has been the public that has requested that ODOT use this type of barrier. The first transparent barriers in Ohio were constructed as pilot projects. The first one was installed in 2005. No major maintenance problems have arisen.

ODOT's tallest barrier has a clear area 10 ft high, not including the concrete barrier below it. The fact that the barriers let the sunlight penetrate is an attractive feature for both the public and the DOT.

The drawback of these barriers is their cost, which is approximately twice that of an equivalent (opaque) concrete wall.

Most of the ODOT barriers are within the cities of Columbus, Cincinnati, and Cleveland-Akron. The transparent walls are, for the most part, self-cleaning.

ODOT has about 180 miles of noise barriers, of which only 4,000 ft correspond to transparent barriers (*Mr. Noel Alcala, ODOT, unpublished data*).

### 2.3.2. The FHWA

Only a handful of states have clear barriers: Alaska, Virginia, Ohio, New Jersey, New York, and California. Acrylic barriers are the most common because some other plastics tend to turn yellow over time. Acrylite and Plaskolite are the only manufacturers whose products have been approved for use in the U.S., with Acrylite's product being the most commonly used. The FHWA does not know of any reports of maintenance issues post-installation.

The oldest barrier of this kind is in New Jersey, and it is about 20 years old. The material was made by Cyro, which is now Acrylite (*Mr. Adam Alexander, FHWA, unpublished data*).

## 2.3.3. Acrylite

This noise barrier material manufacturer has many installations throughout the U.S.; the first was built in 1995 in East Brunswick, New Jersey. This project was a predecessor for several other New Jersey projects, including a rather large one in New Brunswick in 2008. They have many installations in Ohio, but also in California, and some smaller but multiple barriers in states such as Tennessee, Florida, Minnesota, Wisconsin, and Virginia (the Woodrow Wilson Bridge), plus Ontario, and British Columbia, in Canada (*Mr. Nathan Binnette, Acrylite, unpublished data*).

The Acrylite material has an STC rating, when tested in accordance with ASTM E-90, of 32 dB for a 15-mm thick panel, 34 dB for the 20-mm thick panel, and 36 dB for the 25-mm thick panel (*Acrylite 2013*). Figure 2.3 displays Acrylite barrier samples.


*Figure 2.3 Acrylite Soundstop product samples*

## 2.3.4. Plaskolite

The transparent noise barrier product manufactured by this company is called OPTIX NB (noise barrier acrylic sheet). This material is lightweight, ranging from under 3 lbs per sq ft at 0.5-in. thick, up to about 6 lbs per sq ft at 1.0-in. thick. It is UV stable, meaning it will not degrade with exposure to outdoor elements. The first noise barrier project using this material was installed in Columbus, Ohio in 2009 (*Mr. Justin Bradford, Plaskolite, unpublished data*).

Optix NB has an STC rating of 32 for the 0.5-in.-thick sheet and 34 for the 0.75-in.-thick sheet (*Plaskolite 2011*).

## 2.3.5. AIL Sound Walls

AIL has two products of interest for the Dallas project: one absorptive and one reflective. The applicability of such products to this project is due to the products' lightweight characteristics. Neither of them is transparent.

The absorbent product is called Silent Protector, while the reflective product is called Tuf-Barrier. Both are labeled as lightweight and easy-to-install by the manufacturer.

The absorbent product consists of panels made of recycled PVC with acoustical mineral wool inside. Its noise reduction coefficient (NRC) rating is 1.0, the highest achievable rating.

The reflective product panels are similar to the absorbent product, as they are also PVC, but have no openings and do not have anything inside them (*Mr. Craig Cook, AIL Sound Walls, unpublished data*). Photographs of samples of both products delivered to CTR are presented in Figures 2.4–2.6.

*Figure 2.4 AIL Sound Walls product sample delivered to CTR showing the absorptive material (acoustical mineral wool) encased in the PVC stackable panel*

*Figure 2.5 AIL Sound Walls product sample delivered to CTR: Silent Protector product*


*Figure 2.6 AIL Sound Walls product samples delivered to CTR: Tuf-Barrier product (reflective) made of PVC*

## 2.4. Summary

Various materials and manufacturers were reviewed for the possible installation of the noise barriers on I-30. The knowledge conveyed by the state DOTs and other entities experienced with the use of lightweight and transparent materials was very valuable. Despite its higher cost, the use of transparent material was considered a viable option, as it is lightweight and offers important acoustic and aesthetic benefits.

# Chapter 3. Project Site Description

This chapter describes the highway segment of I-30 subject of the noise barrier installations, as well as the neighborhood that is affected by the highway noise.

## 3.1. Location

The scope of the project encompasses two noise walls on I-30 in Dallas, in the vicinity of the Kessler Park Neighborhood, to be installed at two different stages. Figure 3.1 shows a map of Dallas with the location of the project.

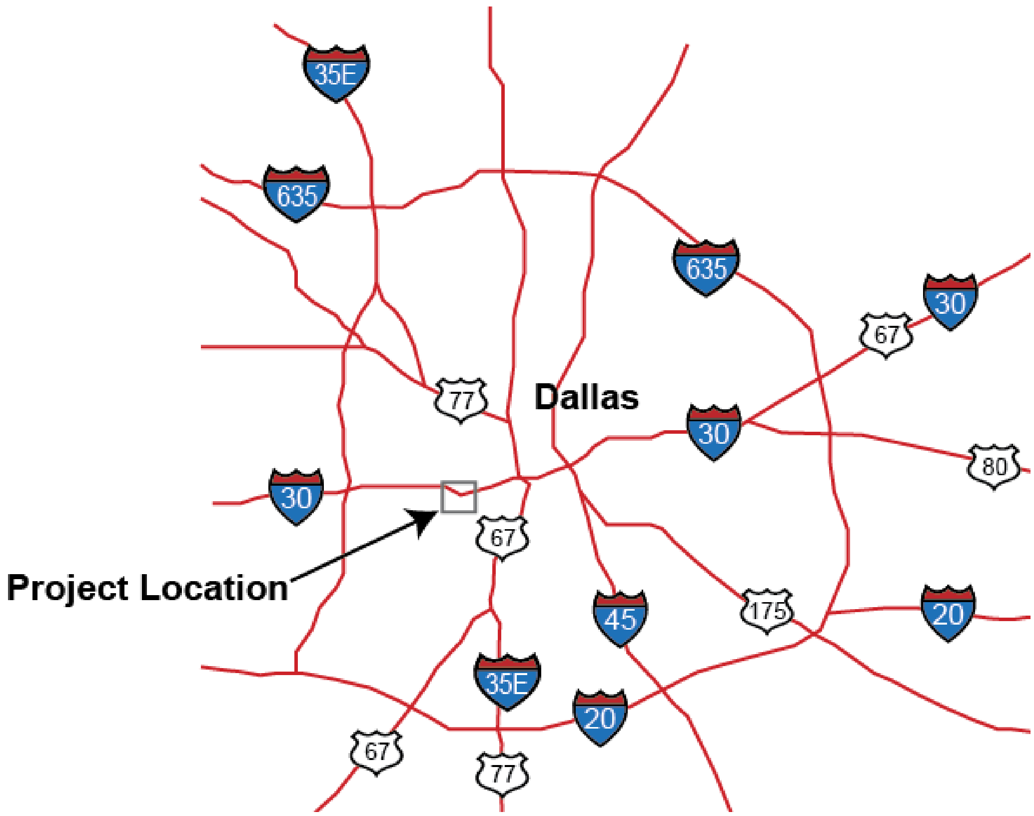



*Figure 3.1 Project location on I-30*

Each of the two sites feature elevated sections of I-30, west of downtown Dallas. They are located north of the Kessler Park neighborhood. The sound barriers studied in this project were installed on the south side of the highway, i.e., adjacent to the eastbound shoulder.

The first site location (Site 1) corresponds to the segment between Edgefield Avenue and Sylvan Avenue, with an approximate length of 2,500 ft and an existing concrete sound wall approximately 8 ft in height on the south side. The second site location (Site 2) extends from Sylvan Avenue towards Beckley Avenue; the highway segment at Site 2 has a traditional safety barrier rather than a dedicated concrete reflective sound wall and is approximately 2,270-ft long. The research team evaluated the performance of the lightweight reflective traffic noise wall for both sections, which have extended the height of the existing wall and safety barrier with the purpose of attenuating sound propagation and blocking the line of sight from parts of the adjacent neighborhood to the highway. Figure 3.2 shows a map with the proposed location of the barriers.

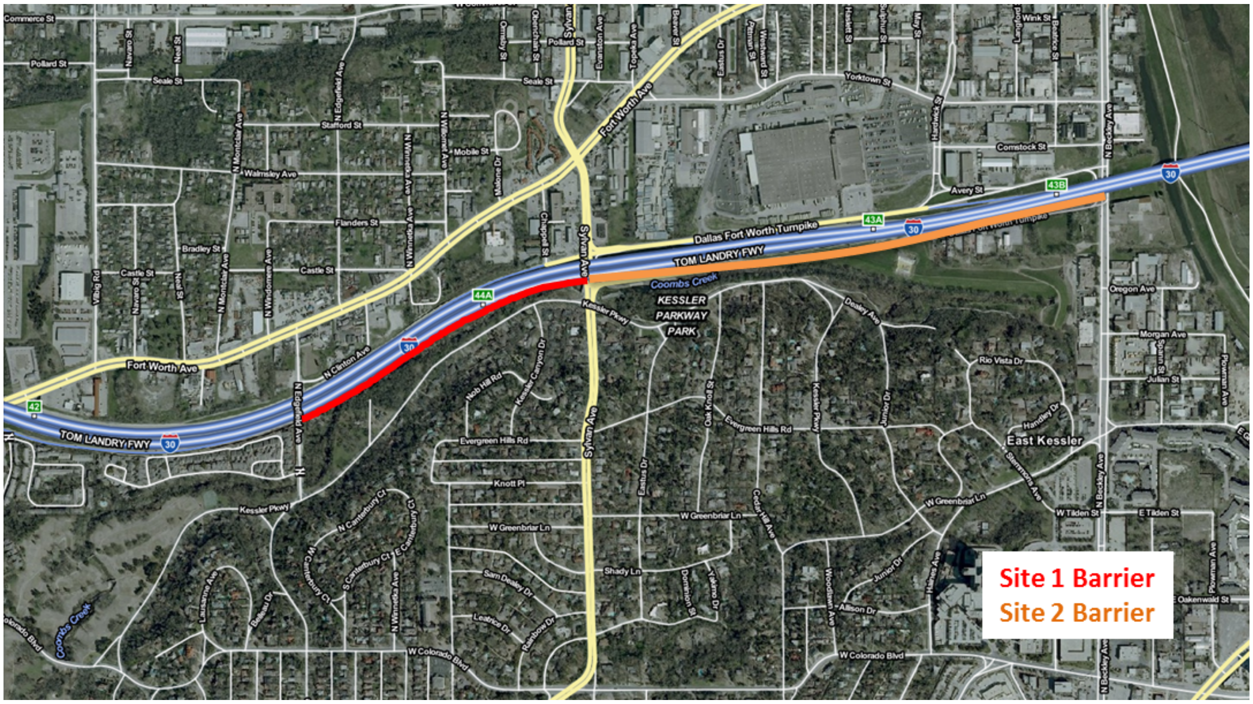



*Figure 3.2 Proposed noise barriers for Site 1 and Site 2, on I-30*

## 3.2. I-30

The highway carries substantial commuter traffic as well as heavy trucks (Figure 3.3). The facility has an average daily traffic of 167,500 vehicles, of which 7.7% are trucks. The highway segment for Site 1 studied in this project is illustrated in Figure 3.4, and the Site 2 segment is shown in Figure 3.5.

*Figure 3.3 I-30 Truck traffic*

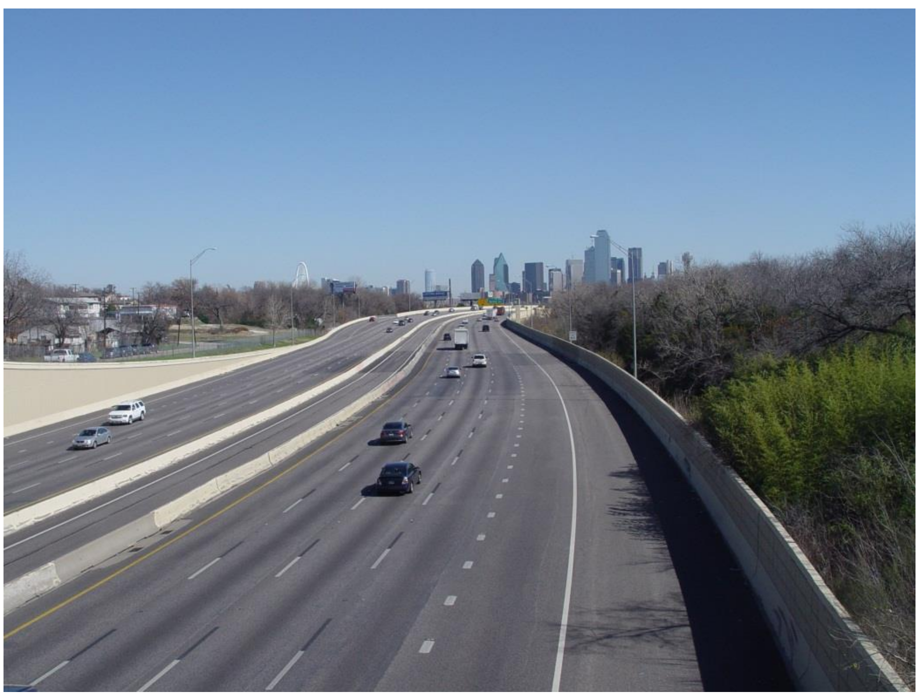


*Figure 3.4 View of I-30 towards the east from Edgefield Avenue Bridge, showing the south-side concrete wall on the right (Site 1)*

*Figure 3.5 View of I-30 towards the west approaching Sylvan Avenue (Site 2)*

The highway segment comprises elevated sections (bridges) above a creek (Coombs Creek), and it is next to a residential neighborhood. Figures 3.6 to 3.9 show views of the elevated structure of I-30 and the creek.

*Figure 3.6 I-30 elevated highway structure and concrete wall*

*Figure 3.7 I-30 underside of elevated highway structure, seen from below Sylvan Avenue*

*Figure 3.8 Coombs Creek, seen from the Sylvan Avenue underpass (Site 1)*

*Figure 3.9 Coombs Creek, east of Sylvan Ave (Site 2); elevated highway structure in the background*

A lightweight noise barrier was considered a viable solution to avoid having to retrofit the bridges to accommodate a heavier structure.

Concrete walls were already in place on the south side of the highway, both at Site 1 and Site 2; therefore, the new noise walls would be placed on top of the existing barriers to provide additional benefit to the residences. Images of the existing south side walls are presented in Figures 3.10 and 3.11 (Site 1), and 3.12 to 3.14 (Site 2).


*Figure 3.10 South side wall on I-30 at Site 1 seen from Edgefield Avenue*

*Figure 3.11 South side wall on I-30 at Site 1 seen from the creek side*

*Figure 3.12 South side wall on I-30 at Site 2 seen from Sylvan Avenue*


*Figure 3.13 South side wall on I-30 at Site 2 seen from Beckley Avenue highway exit ramp*

*Figure 3.14 South side wall on I-30 at Site 2 seen from eastbound shoulder*

East of the Site 2 barrier is the location of the TxDOT's $798 million Dallas Horseshoe Project, which upgraded the bridges over the Trinity River, and the connection between I-30 and I-35E (Figures 3.15 and 3.16). This major construction project took about 5 years to complete, and it is the reason for 5-year gap between the Site 1 and Site 2 wall installations.

*Figure 3.15 Dallas Horseshoe Project: I-30 McDermott Bridge over the Trinity River*

*Figure 3.16 Dallas Horseshoe Project: I-30 McDermott Bridge over the Trinity River*

### 3.2.1. Pavements

The pavements in this section of I-30 consist of two permeable friction course (PFC) overlays that were placed for the purpose of mitigating the noise. These two pavements were in place for almost the entire duration of this research project, except for the last three months of it, when a new overlay was placed. The original pavement was transversely tined continuously reinforced concrete pavement (CRCP). A photograph from May 2006 shows the original pavement (Figure 3.17).

*Figure 3.17 Original transversely-tined CRCP on I-30 (May 2006)*

A similar photograph from 2010 shows the PFC overlay, shortly after its placement (Figure 3.18).

*Figure 3.18 2010 PFC on I-30*

The first of such porous overlays was placed in the summer of 2006. This 1.5-in. thick PFC layer covered the easternmost segment of interest, extending from just east of Sylvan Avenue for about half a mile to the west. Figure 3.19 shows four aspects of the 2006 PFC, shortly after its placement.


*Figure 3.19 2006 PFC overlay on I-30 (September 2006)*

In the summer of 2010, a second PFC overlay was constructed (Figures 3.20 and 3.21). This 1-in.-thick PFC is adjacent to the 2006 PFC, and extends to the west of it, for about three-fourths of a mile to the Fort Worth Avenue Bridge. Figure 3.22 shows the location of both overlays.

*Figure 3.20 2010 PFC overlay on I-30 (2010)*

*Figure 3.21 1-in.-thick 2010 PFC overlay on I-30 on top of CRCP (2010)*

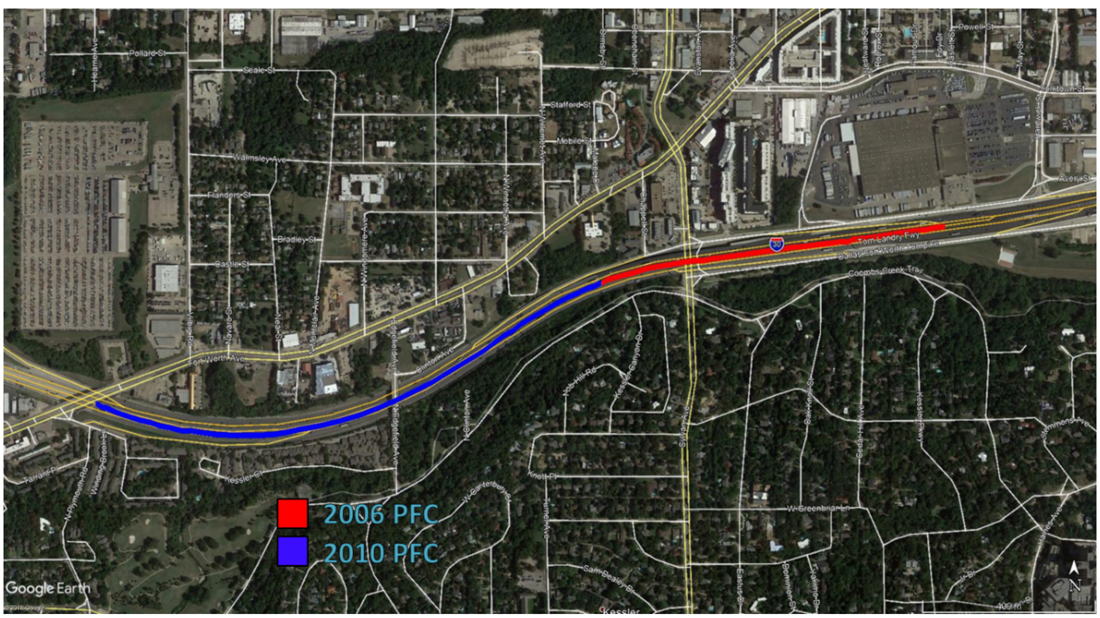



*Figure 3.22 PFC overlays on I-30*

As shown in Figure 3.22, the residential locations at Site 1 are affected by the tire-pavement noise generated by both the 2006 and 2010 overlay, but it is mostly the 2010 overlay that sits next to Site 1; for Site 2, it is mostly the noise generated by the 2006 overlay that affects those locations.

### 3.2.1.1. 2019 PFC Overlay

When this research project was almost finished, a new PFC overlay was constructed to replace the 2006 and 2010 overlays. The old overlays had deteriorated to the stage in which the surfaces looked so worn out, compacted, and lacking their void content characteristic of a PFC, that they resembled a dense-graded asphalt pavement. For more on the degradation of the surfaces, please see the next section on tire-pavement testing.

This PFC overlay project included milling and replacing the old overlays with a new 1.5-in.-thick PFC. The project limits are Fort Worth Avenue on the west, and east of Sylvan Avenue on the east. However, the westbound and eastbound overlays are of different lengths: the easternmost limit is slightly different for the westbound and eastbound lanes. The westbound overlay and HOV lane easternmost limit is about 0.75 mi from the Fort Worth Avenue, and the eastbound overlay easternmost limit is about 1.3 mi east of the Fort Worth Avenue bridge. Figure 3.23 shows the project limits, using a screenshot of the project page on the TxDOT website.

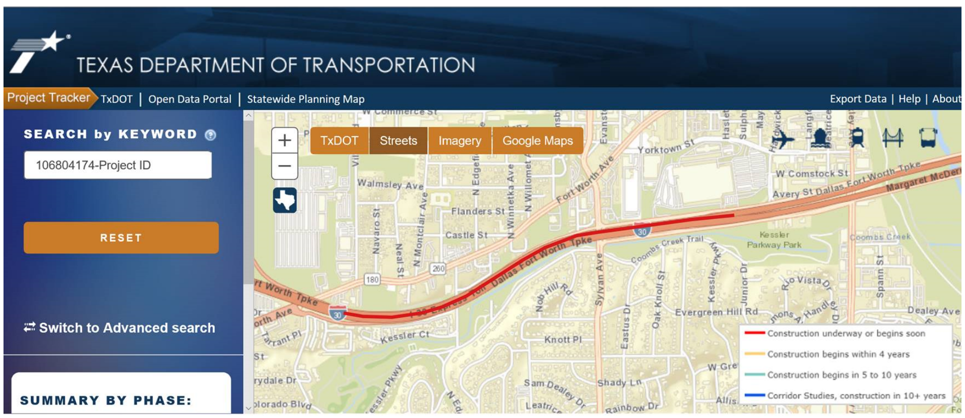



*Figure 3.23 Approximate limits for 2019 PFC project*

This $1.9 million project was let in June 2018, started in September 2018, was interrupted during the winter months, and resumed in the spring of 2019; the finished new overlay was first seen completed by the CTR researcher in June 2019. Therefore, the finished overlay was just completed for the June, July, and August 2019 measurements at Site 2, the last three months of testing for this research project. Figures 3.24 to 3.26 show images of the new PFC overlay.

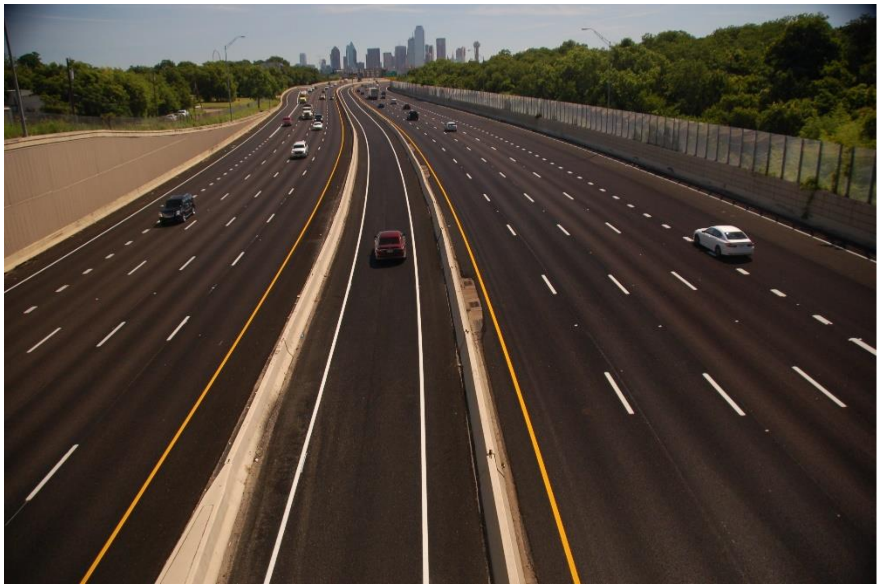


*Figure 3.24 2019 PFC (June 2019)*

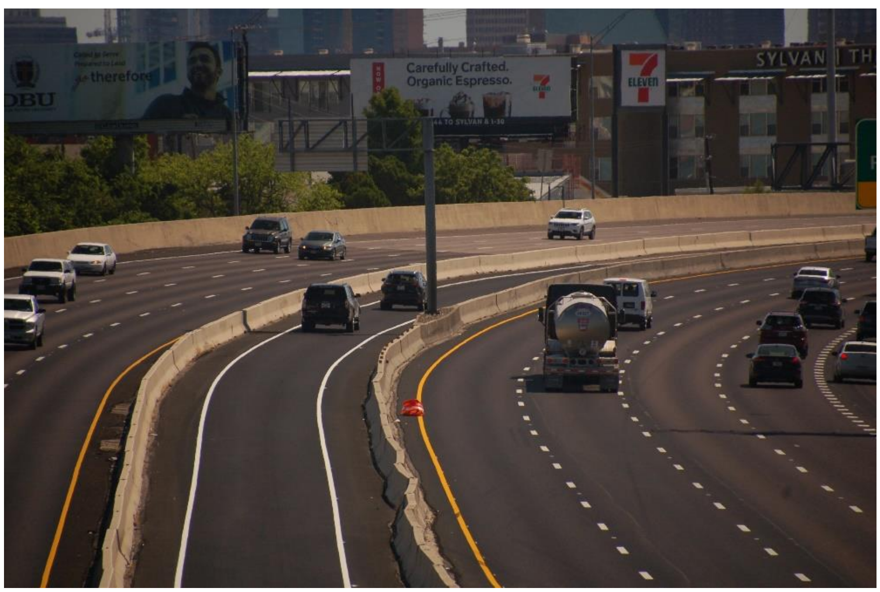



*Figure 3.25 2019 PFC WB easternmost limit is visible in the background (L) (June 2019)*

*Figure 3.26 2019 PFC on top of existing CRCP (June 2019)*

### 3.2.1.2. Tire-Pavement Noise Testing

Even though tire-pavement noise testing was not a part of this research project, CTR had studied these pavements for a long period of time as part of other projects in the past *(Trevino 2009)*. The knowledge of this information and the interest in investigating the overlay performance prompted CTR to continue with the pavement tests every time there was an opportunity to conduct the tests. The field evaluations were done by means of the on-board sound intensity (OBSI) *(AASHTO, n.d.)* test procedure. Initially, these pavement overlays provided some important noise reductions when they were newer, as shown by the earlier results. CTR began testing this site prior to the placement of these overlays in May 2006 (Figure 3.27) and performed various rounds of tests throughout their service lives. An example of those initial benefits is illustrated in the chart of Figure 3.28, displaying OBSI test results conducted before and after the 2006 overlay construction.


*Figure 3.27 Preparing to conduct OBSI tests on I-30 CRCP (May 2006)*

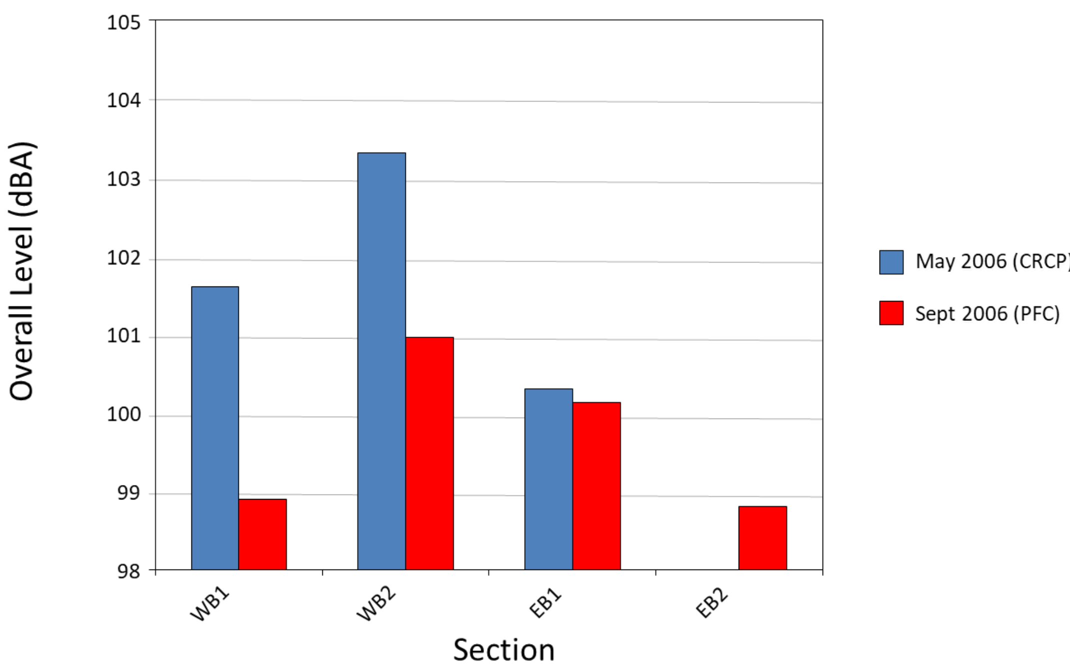



*Figure 3.28 Initial noise reduction provided by 2006 PFC from OBSI tests*

Unfortunately, this type of pavement tends to lose its acoustic benefits over time, as its void content diminishes due to clogging and compaction. Clogging occurs when debris from the road fills the original pores that make these pavements quieter, while compaction under heavy traffic loading has a similar effect of reducing the voids over time. The degradation of the acoustical properties of PFC pavement surfaces over time is documented in the literature *(Arambula 2013, Smit 2016)*. Figures 3.29 to 3.31 illustrate this degradation of the PFCs, showing how the pavements resembled dense-graded asphalt surfaces after clogging and compaction had decreased their void content.

*Figure 3.29 2006 PFC in April 2011*

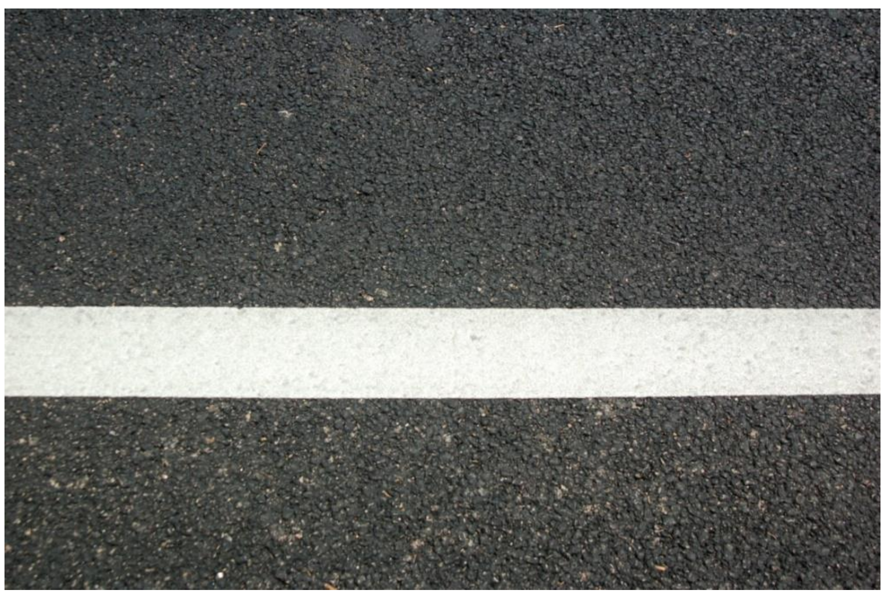


*Figure 3.30 2010 PFC shortly after it was placed*

*Figure 3.31 2010 PFC in May 2016*

More recent OBSI results, from 2016 (Figure 3.32), confirmed that these overlays had gotten much louder, indicating that their acoustic benefits had substantially diminished over time; the 2006 PFC (PFC1 in the chart) was about 107 dBA, on average, while 2010 PFC (PFC2 in the chart) was almost 106 dBA, on average. Figure 3.33 compares two series of recent OBSI tests (the data from 2014 and 2016) indicating the trend that both PFCs were producing higher levels of noise.

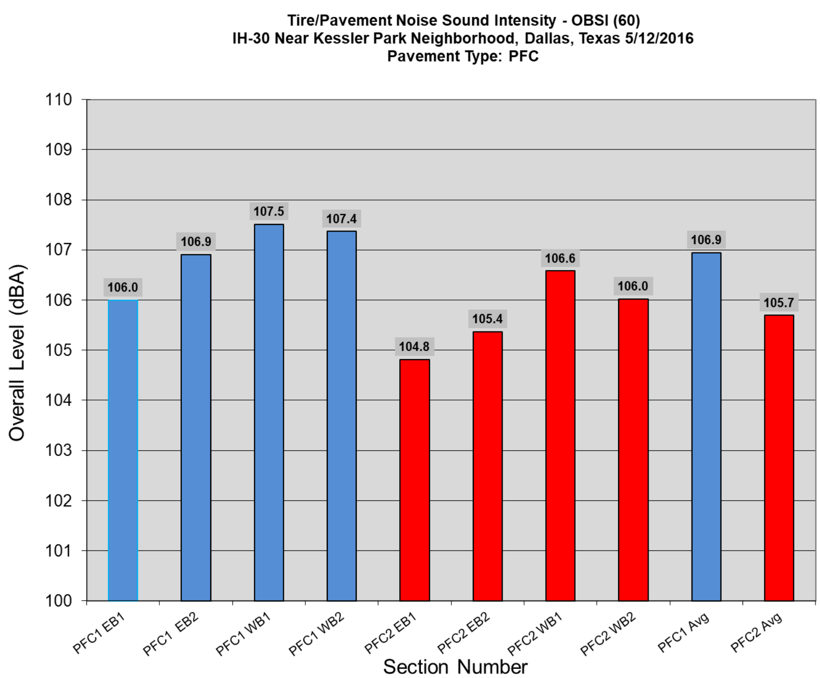



*Figure 3.32 Recent OBSI results confirming degradation of acoustic benefits of both PFCs*

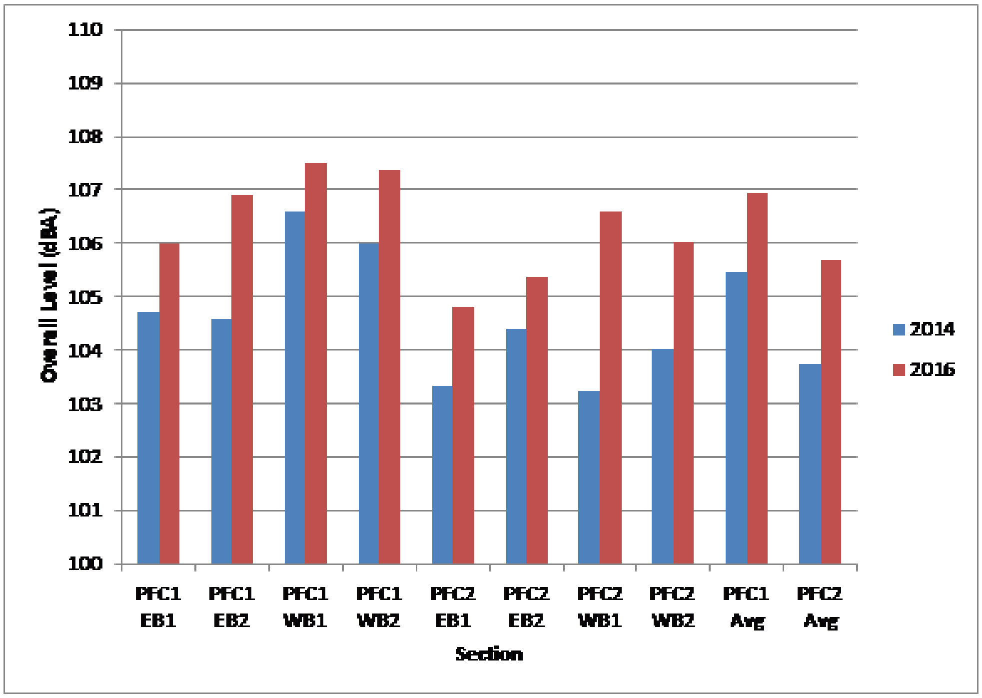



*Figure 3.33 Comparison of two recent series of OBSI tests on PFCs on I-30*

## 3.3. Kessler Park Neighborhood

The neighborhood is located just south of the highway, separated by a linear park surrounding the creek, the Coombs Creek Trail Park (Figures 3.34 and 3.35).

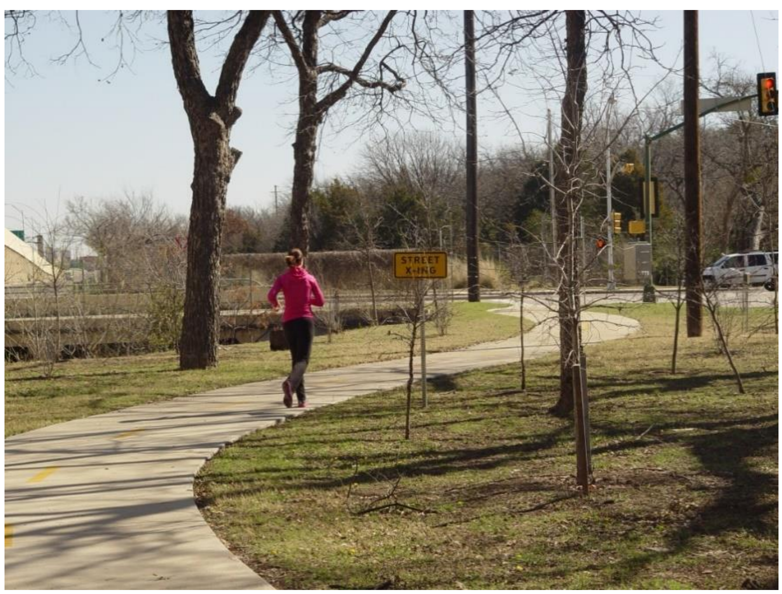



*Figure 3.34 Coombs Creek Trail Park, at Site 1*

*Figure 3.35 Coombs Creek Trail Park, at Site 2*

Kessler Parkway, a busy street that carries local traffic, runs along the park approximately parallel to I-30; on the south side of this street are the first-row residences that are affected by the highway noise because of their proximity to it. Figure 3.36 shows an example of a first-row residence on Kessler Parkway, across the street from the park.

*Figure 3.36 First-row residence on Kessler Parkway, at Site 1*

These residences are below or slightly above the highway level, but further south, the topography of the Kessler Park area is hilly, with many homes sitting at a higher elevation relative to I-30. Figure 3.37 presents a photograph taken from a residence at much higher elevation relative to I-30, and with clear line of sight to the highway. This photograph illustrates the steepness of the terrain just south of the highway and the elevation that some of these hills reach above the highway.

The benefits of a noise wall of any reasonable height are minimal for any residence with a similar situation relative to the highway.

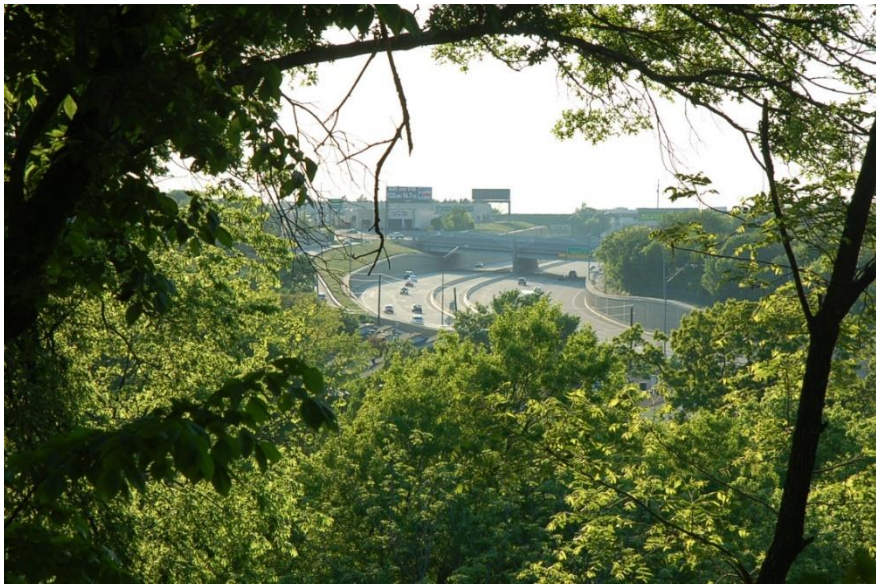


*Figure 3.37 View from a residence at higher elevation and clear line of sight to I-30*

A foremost concern of the residents, as well as of TxDOT, was to preserve the views from some of the homes towards the city (Figure 3.38), and to minimize the visual impact of the highway; since the barrier added height to the existing wall, in all likelihood, this was not going to be possible with an opaque barrier.

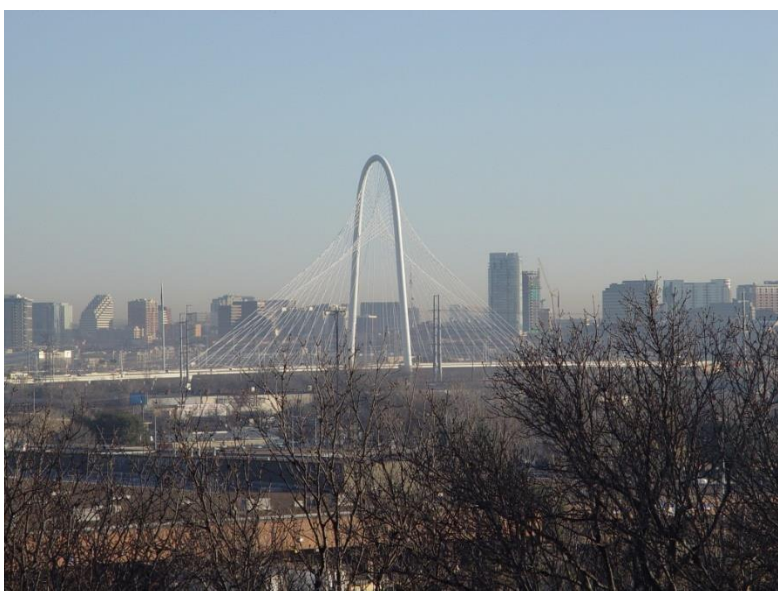


*Figure 3.38 Example of a scenic view from a residence at Site 2*

## 3.4. Summary

This chapter presents the description of the locations for the noise barriers proposed for I-30 near the Kessler Park neighborhood, for both Site 1 and Site 2, including the highway, the pavements and their acoustical properties, the neighborhood, and its topography.

# Chapter 4. Site 1 Barrier Design

This chapter discusses the design of the barrier corresponding to Site 1, the first stage of this project, for the elevated highway section of I-30 between Edgefield Avenue on the west side, and Sylvan Avenue on the east side.

## 4.1. Introduction

The design of the noise wall was performed by means of the FHWA Traffic Noise Model (TNM) program, Version 2.5 (Figure 4.1).

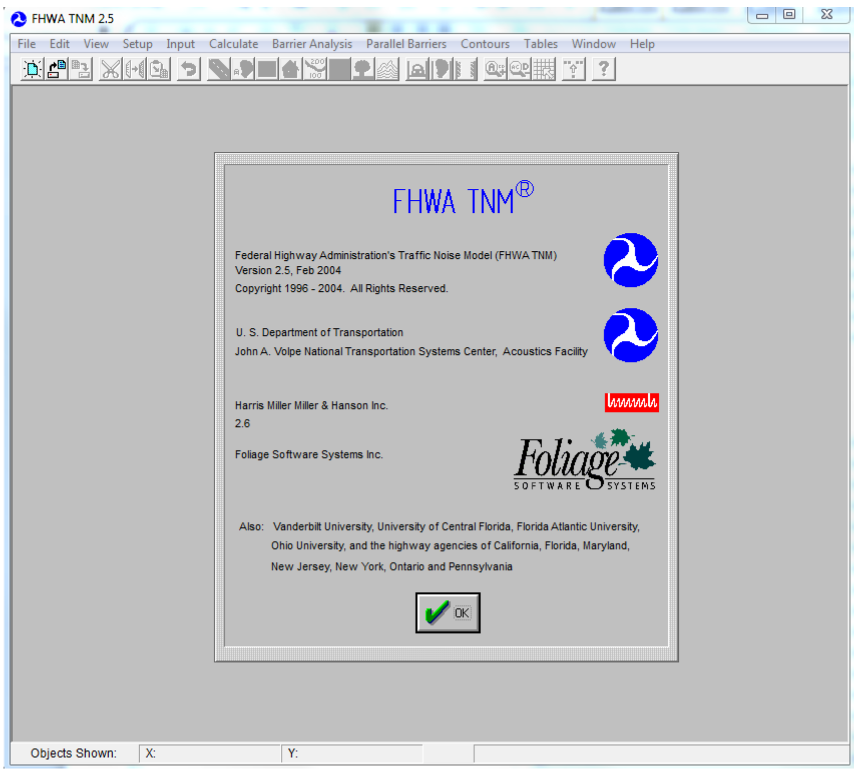



*Figure 4.1 FHWA Traffic Noise Model (TNM) program, version 2.5*

This program makes use of the geometry and topography of the highway and adjacent terrain, including number of lanes in each direction; presence of barriers or walls (e.g., concrete traffic barrier [CTB] or jersey barriers); curves, elevations, etc.; the location of the receivers, terrain lines, and the traffic; its composition (i.e., passenger cars, trucks, etc.); and its forecast. Figure 4.2 presents a representation of a plan view of the model, as seen on the computer screen, showing the highway lanes, walls, receivers, and terrain lines.

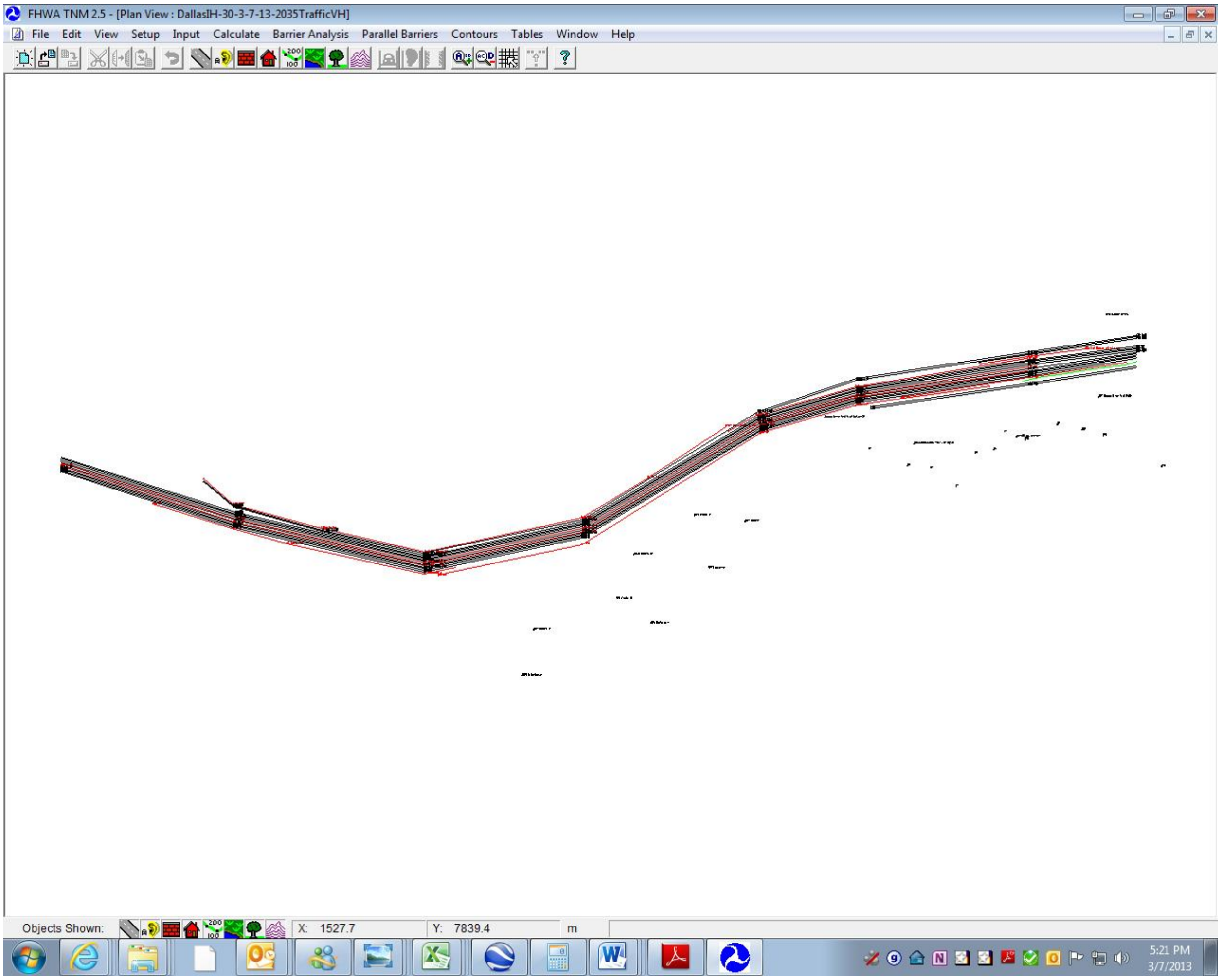



*Figure 4.2 Plan view of the Site 1 I-30 TNM model*

The noise impacts were evaluated for existing and future traffic conditions. Various wall heights were analyzed to supplement the attenuation provided by the existing 8-ft wall situated on the south side of I-30, between Edgefield Avenue and Sylvan Avenue. The analysis indicates the benefits, quantified as noise level reductions, that the various wall heights proposed are able to provide at several locations.

## 4.2. Receivers

Twenty-six receivers were included in the model. All of them are located between Fort Worth Avenue and Beckley Avenue. Eighteen of them correspond to receivers identified in the Dallas Horseshoe Project Environmental Assessment. Also modeled were the original seven receivers identified during the 2010 and 2011 study conducted by CTR for the Dallas District (all located between Fort Worth Avenue and Sylvan Avenue), and one additional receiver on Coombs Creek Trail west of Sylvan Avenue. The Horseshoe Project receivers included the first 15 residential sites (R1 through R15), two receivers along the Coombs Creek Trail (R27 and R28), and the U.S. Post Office on the north side of I-30 (R29).

The locations of the receivers included in the TNM analysis are shown on the map in Figure 4.3. The plan view extends from Hampton Road on the west to close to Beckley Avenue on the east.


*Figure 4.3 Receivers for TNM analysis*

## 4.3. Traffic

Traffic values were obtained from the Dallas Horseshoe Project Environmental Assessment provided by the District for the I-30 segment, which provided values for the existing traffic and the future projected traffic for the year 2035.

## 4.4. Noise Impacts

According to FHWA policies (*FHWA-HEP-10-025*), a traffic noise impact occurs when the existing or future noise levels approach or exceed the noise abatement criteria (NAC); TxDOT defines the level of approach as 1 dBA. The NAC are presented in Table 4.1 (*TxDOT 2011*). An impact can also occur when predicted future traffic noise levels substantially exceed the existing noise level, even though the predicted levels may not exceed the NAC.

**Table 4.1 Noise abatement criteria**

| Activity Category | FHWA (dB(A) Leq) | **TxDOT (dB(A) Leq)** | Description of Land Use Activity Areas |
|---|---|---|---|
| A | 57 (exterior) | **56 (exterior)** | Lands on which serenity and quiet are of extra-ordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. |
| B | 67 (exterior) | **66 (exterior)** | Residential |
| C | 67 (exterior) | **66 (exterior)** | Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools , television studios, trails, and trail crossings |
| D | 52 (interior) | **51 (interior)** | Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios |
| E | 72 (exterior) | **71 (exterior)** | Hotels, motels, offices, restaurants/bars, and other developed lands, properties, or activities not included in A-D or F. |
| F | -- | **--** | Agricultural, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing. |
| G | -- | **--** | Undeveloped lands that are not permitted. |

Thus, TxDOT policy indicates that an outdoor residential area, such as the subject of these analyses (Type B Land Use Category in Table 4.1) is considered to have an impact if the noise level is 66 dBA or above (*TxDOT 2011*).

TNM analyses were performed for both existing traffic and projected traffic. For both types of runs, an impact was identified for four receivers without additional height added to the barrier (existing wall: 8 ft). Table 4.2 shows the calculated noise levels for the future traffic for the four impacted receivers, considering only the existing 8-ft wall.

**Table 4.2 Impacted receivers—existing wall (2035 traffic)**

| Receiver | Level (dBA) |
|---|---|
| 1820 Kessler Parkway (Receiver C) | 68.2 |
| R8-1650 Oak Knoll (A) | 69.2 |
| Coombs Creek Trail W of Sylvan (B) | 80.9 |
| U.S. Post Office (R29) | 68.3 |

According to TNM, the existing concrete wall provided a maximum of 1.4 dBA reduction for Receiver D (not impacted), and an average reduction for all receivers of 0.3 dBA. The maximum reduction provided by the existing wall for an impacted receiver occurs for Receiver C, located along Kessler Parkway, and it is 1.1 dBA. Therefore, there are some small benefits provided by the concrete wall, but these are below a perceptible level.

## 4.5. Barrier Analysis

The barrier analysis was conducted for the existing 8-ft high wall, on the south side of I-30, between Edgefield Avenue and Sylvan Avenue. Additional barrier increments of 2 ft each on top of the existing wall were calculated, up to 20 ft total, i.e., new barrier heights of 2, 4, 6, 8, 10, and 12 ft on top of the existing wall.

The analyses results for impacted receivers are provided in Tables 4.3 through 4.8.

**Table 4.3 Impacted receivers—existing wall + 2-ft (10-ft total) (2035 traffic)**

| Receiver | Original Level (dBA) | With 2-ft addition (dBA) | Noise Reduction (dBA) |
|---|---|---|---|
| 1820 Kessler Parkway (Receiver C) | 68.2 | 65.8 | 2.4 |
| R8-1650 Oak Knoll (A) | 69.2 | 69.2 | 0 |
| Coombs Creek Trail W of Sylvan (B) | 80.9 | 80.5 | 0.4 |
| U.S. Post Office (R29) | 68.3 | 68.3 | 0 |

**Table 4.4 Impacted receivers—existing wall + 4-ft (12-ft total) (2035 traffic)**

| Receiver | Original Level (dBA) | With 4-ft addition (dBA) | Noise Reduction (dBA) |
|---|---|---|---|
| 1820 Kessler Parkway (Receiver C) | 68.2 | 64.7 | 3.5 |
| R8-1650 Oak Knoll (A) | 69.2 | 69.2 | 0 |
| Coombs Creek Trail W of Sylvan (B) | 80.9 | 80 | 0.9 |
| U.S. Post Office (R29) | 68.3 | 68.3 | 0 |

**Table 4.5 Impacted receivers—existing wall + 6-ft (14-ft total) (2035 traffic)**

| Receiver | Original Level (dBA) | With 6-ft addition (dBA) | Noise Reduction (dBA) |
|---|---|---|---|
| 1820 Kessler Parkway (Receiver C) | 68.2 | 63.7 | 4.5 |
| R8-1650 Oak Knoll (A) | 69.2 | 69.2 | 0 |
| Coombs Creek Trail W of Sylvan (B) | 80.9 | 78.5 | 2.4 |
| U.S. Post Office (R29) | 68.3 | 68.3 | 0 |

**Table 4.6 Impacted receivers—existing wall + 8-ft (16-ft total) (2035 traffic)**

| Receiver | Original Level (dBA) | With 8-ft addition (dBA) | Noise Reduction (dBA) |
|---|---|---|---|
| 1820 Kessler Parkway (Receiver C) | 68.2 | 62.3 | 5.9 |
| R8-1650 Oak Knoll (A) | 69.2 | 69.2 | 0 |
| Coombs Creek Trail W of Sylvan (B) | 80.9 | 77 | 3.9 |
| U.S. Post Office (R29) | 68.3 | 68.3 | 0 |

**Table 4.7 Impacted receivers—existing wall + 10-ft (18-ft total) (2035 traffic)**

| Receiver | Original Level (dBA) | With 10-ft addition (dBA) | Noise Reduction (dBA) |
|---|---|---|---|
| 1820 Kessler Parkway (Receiver C) | 68.2 | 61.2 | 7 |
| R8-1650 Oak Knoll (A) | 69.2 | 69.2 | 0 |
| Coombs Creek Trail W of Sylvan (B) | 80.9 | 73.3 | 7.6 |
| U.S. Post Office (R29) | 68.3 | 68.3 | 0 |

**Table 4.8 Impacted receivers—existing wall + 12-ft (20-ft total) (2035 traffic)**

| Receiver | Original Level (dBA) | With 12-ft addition (dBA) | Noise Reduction (dBA) |
|---|---|---|---|
| 1820 Kessler Parkway (Receiver C) | 68.2 | 60.3 | 7.9 |
| R8-1650 Oak Knoll (A) | 69.2 | 69.2 | 0 |
| Coombs Creek Trail W of Sylvan (B) | 80.9 | 70 | 10.9 |
| U.S. Post Office (R29) | 68.3 | 68.3 | 0 |

The analyses show that Receiver 29, the U.S. Post Office, on the north side of the highway, as expected, does not get any benefit for any height of wall. The other receiver that is impacted that does not benefit from the wall heights analyzed in this report is Receiver 8 (also labeled as Receiver A when the initial residential measurements were performed). This residence is located at 1650 Oak Knoll, east of Sylvan Avenue. The reason this receiver does not benefit from the addition of any height to the wall is because of the site's high elevation relative to the highway. Figure 4.4 shows a photograph taken from the residence at the time the residential measurements were performed, showing clear line of sight to I-30, which will be difficult to block with any noise wall.

*Figure 4.4 View of I-30 from Receiver 8*

Receiver C is one of the closest residential locations relative to the highway—about 250 ft from the wall in question. Figure 4.5 shows the location on 1820 Kessler Parkway. Its proximity to the highway places this receiver in the acoustical shadow of the barrier, making it the residential receiver that benefits the most from the barrier.

*Figure 4.5 Measurements taken at Site C, on Kessler Parkway*

Finally, the other impacted location is the site in the Coombs Creek Trail Park identified when the residential measurements were conducted. This site is just west of Sylvan Avenue, near the highway as well, as shown in Figure 4.6. In the acoustical shadow of the wall, this location also benefits from any height added to the wall. This location could be representative of other sites along the park. Therefore, the park would significantly benefit from the wall's additional height.

*Figure 4.6 Measurement taken at Site B, the Coombs Creek Trail Park*

## 4.6. Conclusion

The noise produced by the current and future traffic conditions creates impacts for only a limited number of receivers. Only two residences are impacted, one of which cannot receive benefit from any realistic height of wall in addition to the existing one, given its elevation relative to the highway.

The feasibility criterion indicates that the noise barrier should provide a substantial reduction, defined as a reduction of at least 5 dBA at impacted receivers. In this case, an 8-ft additional height (i.e., on top of the existing 8-ft wall for a total height of 16 ft) or higher is feasible for Receiver C, and only a 10-ft additional height or higher is feasible for Receiver B (the park). A 16-ft wall (in total height) would provide a 3.9-dBA noise reduction for locations along the park, which is a perceptible benefit, and an 18-ft wall (in total height) would provide a 7.6 dBA noise reduction.

The recommendation to the Dallas District was to install a barrier of at least 8 ft on top of the existing concrete wall, and a barrier of 10 ft if acoustic benefits were desired for the park locations. TxDOT decided to install a barrier consisting of 10-ft-tall panels on top of the existing concrete at Site 1, for a total of 18 ft.

# Chapter 5. Site 2 Barrier Design

This chapter presents the design of the barrier corresponding to Site 2, the second stage of this project, for the elevated highway section of I-30 adjacent to Site 1, between Sylvan Avenue on the west side and Beckley Avenue on the east. This design was performed after the adjacent Horseshoe Project on I-30 was finalized.

## 5.1. Introduction

A Traffic Noise Model (TNM) analysis was also conducted for Site 2. This program makes use of the geometry and topography of the highway and adjacent terrain, including number of lanes in each direction, presence of barriers or walls (e.g., CTB or jersey barriers); curves, elevations, etc.; the location of the receivers, terrain lines, and the traffic; and the traffic composition (i.e., passenger cars, trucks, etc.) and forecast. Figure 5.1 presents a representation of a plan view of the model, as seen on the computer screen, showing the highway lanes, walls, receivers, and terrain lines. This model considers the upgraded geometry of the highway after the conclusion of the Horseshoe Project.

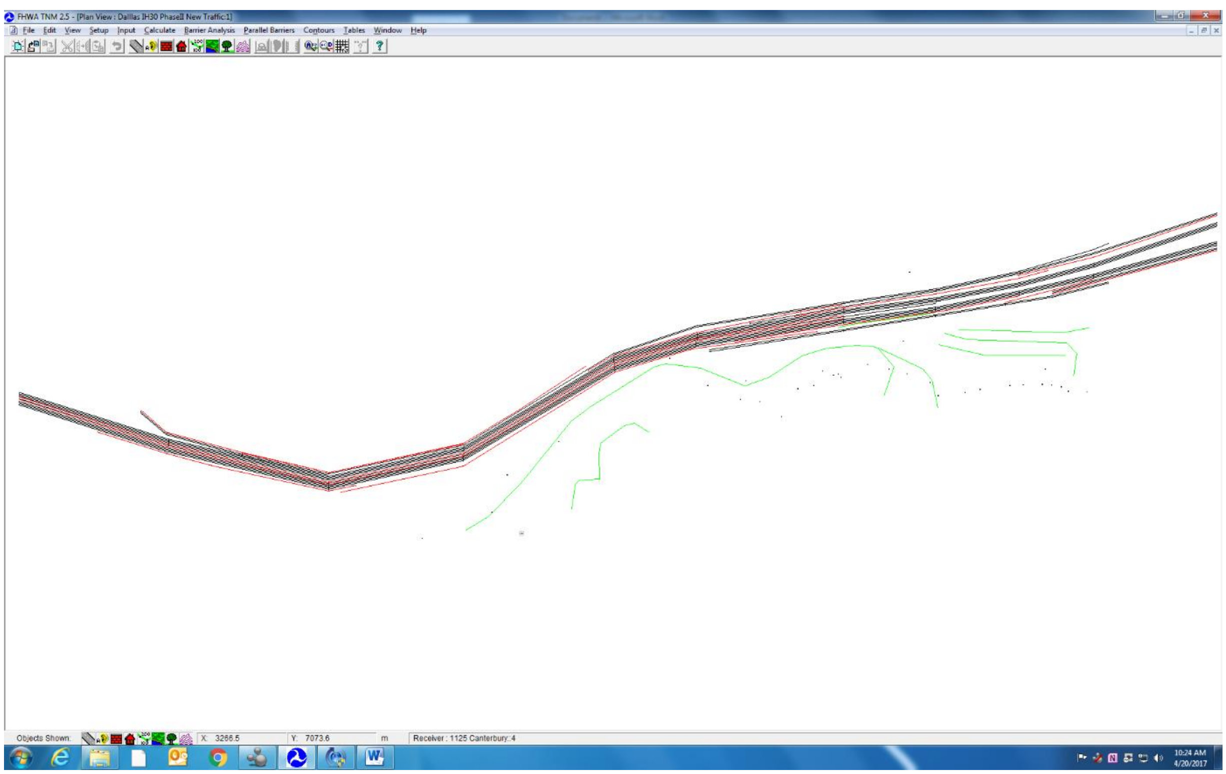


*Figure 5.1 Plan view of the Site 2 I-30 model in TNM*

## 5.2. Traffic

The traffic figures included in the model correspond to future traffic projections. The predicted values for traffic volumes correspond to the year 2035. Traffic values were obtained from the

Dallas Horseshoe Project Environmental Assessment, provided by the District, for the I-30 segment, for the "Existing" traffic condition and for the future projection for 2035.

## 5.3. Receivers

Thirty-nine receivers were included in the model, all of them located between Fort Worth Avenue and Beckley Avenue. Twenty-nine of them correspond to receivers identified in the Dallas Horseshoe Project Environmental Assessment, plus ten receivers identified during for the Phase 1 part of the study, which are all located between Fort Worth Avenue and Sylvan Avenue. The Horseshoe project receivers included the first 25 residential sites (R1 through R25), three receivers along the Coombs Creek Trail (R26, R27, and R28), and the U.S. Post Office on the north side of I-30 (R29).

The location of the receivers included in the TNM analysis is shown in Figure 5.2. The list of receivers is shown in Table 5.1, from a TNM screen.

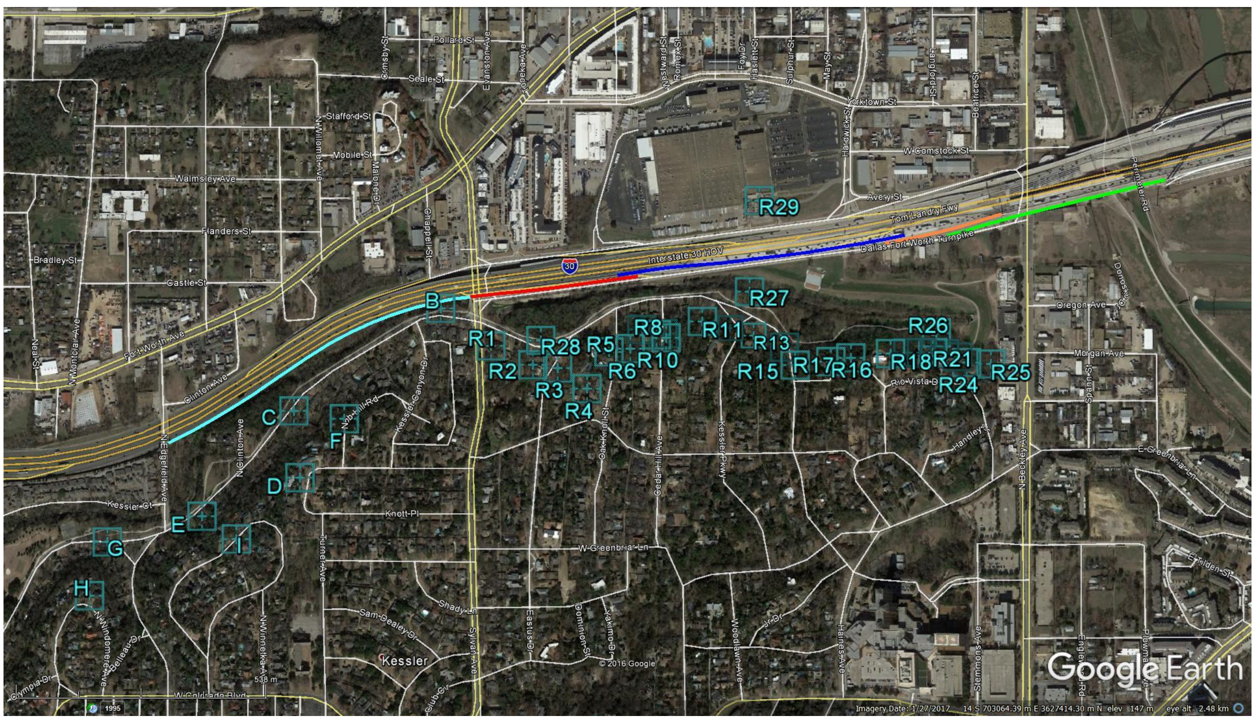



*Figure 5.2 Site 2 receivers' locations*

**Table 5.1 List of receivers in TNM**

FHWA TNM 2.5 - [Receiver Input Table : Dalllas IH30 PhaseII New Traffic:5]

File Edit View Setup Input Calculate Barrier Analysis Parallel Barriers Contours Tables Window Help

CTR 21 April 2017
Manuel Trevino TNM 2.5

INPUT: RECEIVERS
PROJECT/CONTRACT: Dallas District IH-30 Noise Project
RUN: IH-30 Dallas K. April 2017 Future Traffic

| Receiver Name | No. | #DUs | Coordinates (ground) X | Y | Z | Height above Ground | Input Sound Levels and Criteria: Existing LAeq1h | Impact Criteria LAeq1h | Sub'l | NR Goal | Active in Calc. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | m | m | m | m | dBA | dBA | dB | dB | |
| 2114 Kessler P. | 1 | 1 | 1,945.1 | 7,002.9 | 145.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| 1340 N. Windomere | 2 | 1 | 1,917.1 | 6,889.7 | 159.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| 2010 Kessler P. (E) | 3 | 1 | 2,145.6 | 7,077.8 | 132.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| 1125 Canterbury | 4 | 1 | 2,231.3 | 7,017.3 | 155.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| 1027 Evergreen (D) | 5 | 1 | 2,370.7 | 7,152.0 | 153.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| 1627 Nob Hill (F) | 6 | 1 | 2,462.0 | 7,267.0 | 159.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| 1820 Kessler P. (C) | 7 | 1 | 2,337.5 | 7,281.4 | 148.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| WB CRCP2 | 8 | 1 | 1,215.0 | 7,296.5 | 150.00 | 1.20 | 0.00 | 66 | 11.0 | 5.0 | Y |
| David Nelson's Mic | 9 | 1 | 2,189.8 | 7,185.9 | 135.00 | 1.20 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R8-1650 Oak Knoll (A) | 10 | 1 | 3,126.1 | 7,473.4 | 160.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| Coombs Creek Trail W of Sylvan (B) | 11 | 1 | 2,656.5 | 7,521.1 | 139.60 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R1 | 12 | 1 | 2,765.1 | 7,442.6 | 130.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R2 | 13 | 1 | 2,859.4 | 7,403.2 | 131.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R3 | 14 | 1 | 2,915.6 | 7,396.4 | 131.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R4 | 15 | 1 | 2,978.2 | 7,353.2 | 140.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R5 | 16 | 1 | 3,024.3 | 7,434.2 | 141.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R6 | 17 | 1 | 3,070.2 | 7,442.6 | 129.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R7 | 18 | 1 | 3,094.8 | 7,484.6 | 129.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R9 | 19 | 1 | 3,140.4 | 7,476.1 | 129.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R10 | 20 | 1 | 3,147.6 | 7,467.1 | 129.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R11 | 21 | 1 | 3,225.5 | 7,504.4 | 128.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R12 | 22 | 1 | 3,286.0 | 7,491.0 | 127.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R13 | 23 | 1 | 3,337.9 | 7,476.5 | 127.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R18 | 24 | 1 | 3,634.0 | 7,443.0 | 140.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R27-Coombs Creek Trail Middle | 25 | 1 | 3,327.1 | 7,571.6 | 127.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R28-Coombs Creek Trail E of Sylvan | 26 | 1 | 2,875.2 | 7,456.5 | 130.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R29-US Post Office | 27 | 1 | 3,344.9 | 7,769.8 | 127.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R14 | 28 | 1 | 3,405.0 | 7,452.0 | 135.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R15 | 29 | 1 | 3,428.0 | 7,414.0 | 138.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R16 | 30 | 1 | 3,505.0 | 7,423.0 | 140.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R17 | 31 | 1 | 3,548.0 | 7,432.0 | 141.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R19 | 32 | 1 | 3,672.0 | 7,446.0 | 138.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R20 | 33 | 1 | 3,702.0 | 7,446.0 | 137.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R21 | 34 | 1 | 3,727.0 | 7,447.0 | 135.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R22 | 35 | 1 | 3,753.0 | 7,445.0 | 134.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R23 | 36 | 1 | 3,781.0 | 7,439.0 | 134.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R24 | 37 | 1 | 3,801.0 | 7,427.0 | 135.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R25 | 38 | 1 | 3,855.0 | 7,425.0 | 131.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |
| R26-Coombs Creek Trail East End | 39 | 1 | 3,736.0 | 7,490.0 | 127.00 | 1.50 | 0.00 | 66 | 11.0 | 5.0 | Y |

## 5.4. Noise Impacts

Refer to Section 4.4 in the previous chapter for the definition of noise impact according to FHWA and TxDOT policies. As indicated in that section, TxDOT policy for noise impact specifies that an outdoor residential area, such as the subject of these analyses (Type B Land Use Category in Table 4.1), is considered to have an impact if the level is 66 dBA or above (*TxDOT 2011*).

The TNM analysis was performed to determine impacts for the no-wall condition, i.e., the model analyzes noise levels only using the existing CTBs, with no noise wall. An impact was identified for the following five receivers without any additional height for the barrier (existing CTB: 4.5-ft). Table 5.2 shows the calculated noise levels for the future traffic for the five impacted receivers, considering only the existing CTBs. Figure 5.3 shows the impacted receiver locations.

**Table 5.2 Impacted receivers—existing conditions: no-wall (2035 traffic)**

| Receiver | Level (dBA) |
|---|---|
| Coombs Creek Trail W of Sylvan (B) | 70.4 |
| R5 | 67.3 |
| R8 | 70.3 |
| R27 | 66.3 |
| US Post Office (R29) | 68.5 |

The blue line along the highway, west of Sylvan Avenue, is the Site 1 transparent lightweight wall already in place at the time of this analysis.

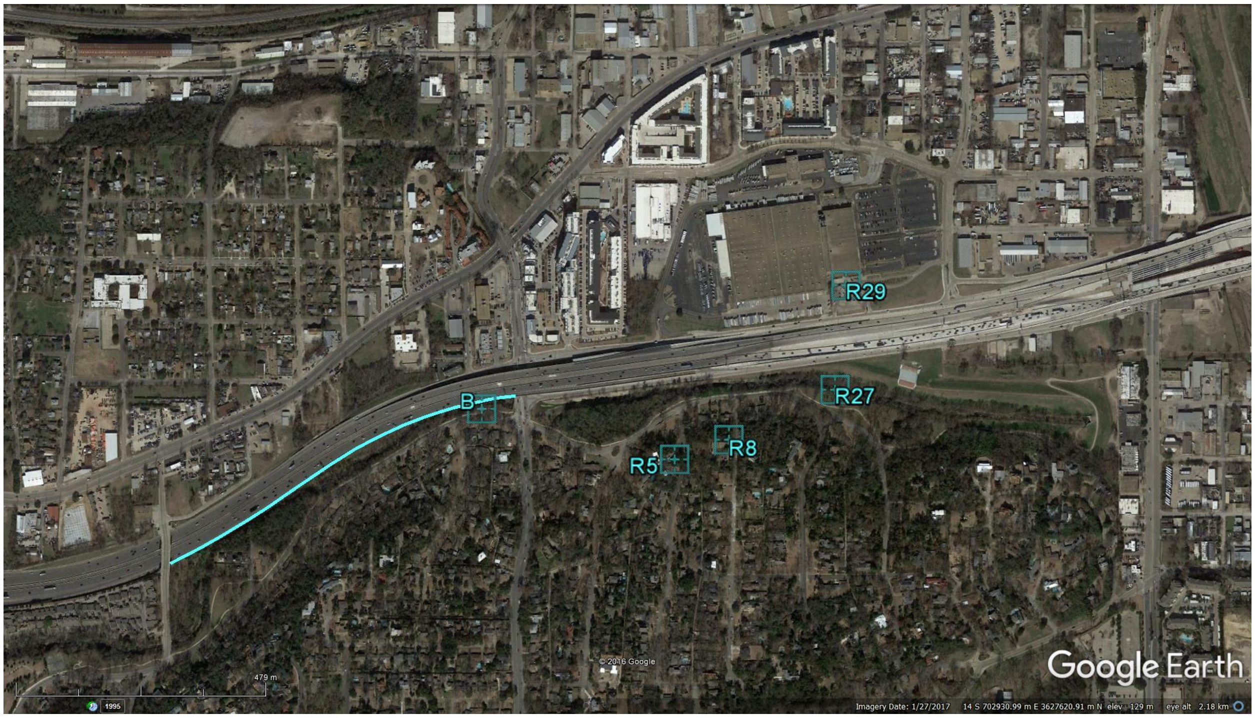



*Figure 5.3 Impacted receivers' locations (no-wall, Site 2)*

As Figure 5.3 shows, R29, the U.S. Post Office, is on the north side of the highway. This receiver was kept on the analysis as a way to check consistency in the model, as it was known that, regardless of the heights and lengths of noise wall segments applied by the model on the south side, those will have no effect on the noise levels at that particular location because it is on the opposite side of I-30.

## 5.5. Traffic Noise Barrier Analysis

The TNM analysis was conducted for eight height increments for four proposed wall segments, with their corresponding starting height being the existing height of the CTBs, which is 4.5 ft. Each height increment was set to 2.25 ft. Table 5.3 lists the trials for the various heights for the program runs.

**Table 5.3 Noise wall heights for TNM runs**

| Height Increment | CTB height + increment (ft) | Height (ft) |
|---|---|---|
| 1 | 4.5 + 2.25 | 6.75 |
| 2 | 4.5 + 2(2.25) | 9 |
| 3 | 4.5 + 3(2.25) | 11.25 |
| 4 | 4.5 + 4(2.25) | 13.5 |
| 5 | 4.5 + 5(2.25) | 15.75 |
| 6 | 4.5 + 6(2.25) | 18 |
| 7 | 4.5 + 7(2.25) | 20.25 |
| 8 | 4.5 + 8(2.25) | 22.5 |

These height increments were used for the four segments proposed, which cover the section between Sylvan Avenue and Beckley Avenue. The stretch was divided into four segments because of the geometry of the highway: the entrance and exit ramps, as well as the configuration of the existing CTBs, considering the fact that the new noise wall will utilize the existing CTBs as its base for installation and structural support. The four segments were designated as A, B, C, and D, respectively, proceeding from west to east. These are illustrated in Figure 5.4.

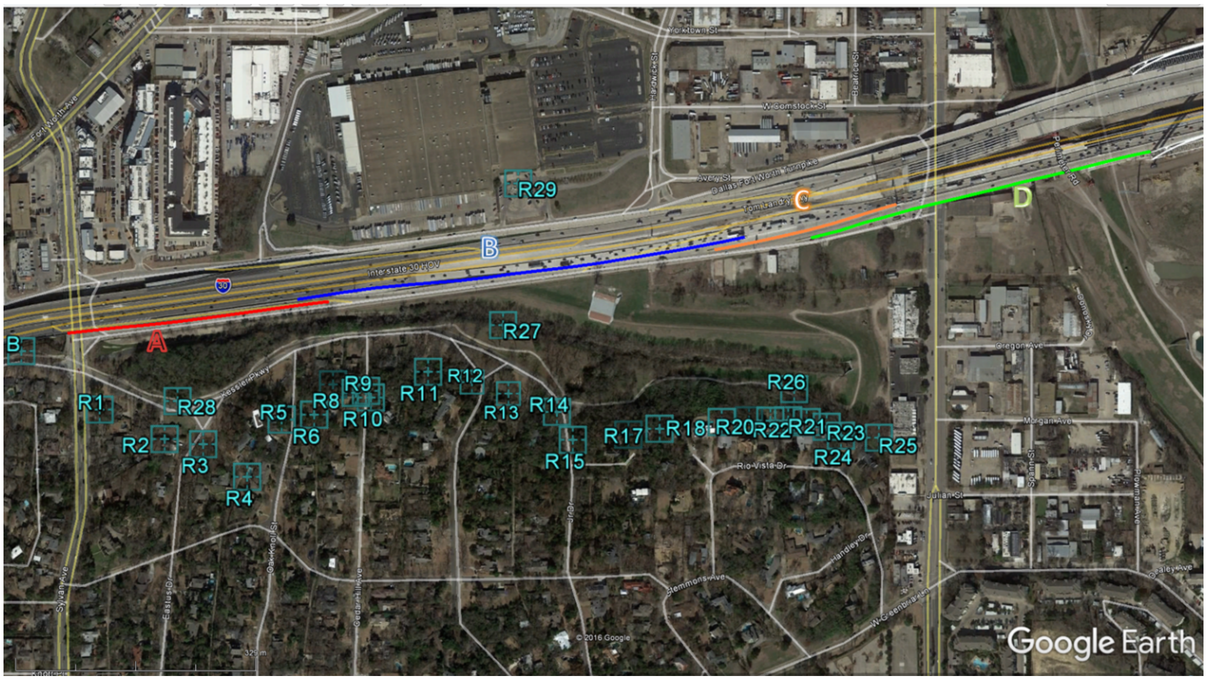



*Figure 5.4 Proposed wall segments*

An illustration of how TNM performs the various height trials is shown in Figure 5.5. It shows a perspective view of part of the model, displaying the road lanes as black lines and the walls as red lines; the receivers are in the foreground, on the bottom left part of the screen. The analyst selects the barriers and increases the height with each iteration, and the results for each trial are calculated.

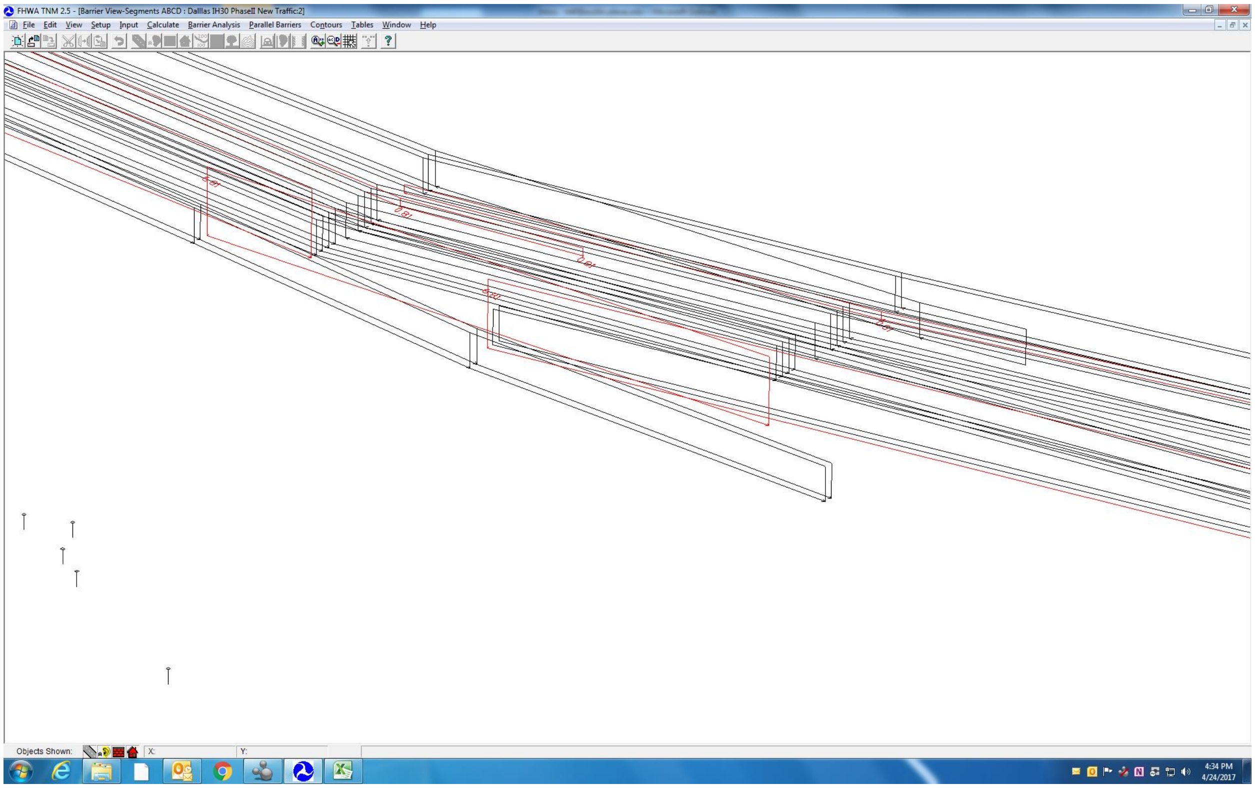



*Figure 5.5 Perspective view of a TNM run showing wall heights*

The barriers were analyzed from west to east; it was known with certainty that the westernmost end of the proposed barrier would be adjacent to the Site 1 barrier easternmost end, at Sylvan Avenue. This location is illustrated in Figures 5.6 and 5.7.

*Figure 5.6 Easternmost end of Site 1 noise barrier at Sylvan Avenue, seen from the highway eastbound shoulder*

*Figure 5.7 Easternmost end of Site 1 noise barrier at Sylvan Avenue, seen from street level*

From this end, the barrier will extend east on top of the CTB shown in Figures 5.8 and 5.9. This is segment A on the map in Figure 5.4.

*Figure 5.8 Existing concrete wall (Segment A)*

*Figure 5.9 Existing concrete wall (Segment A)*

The analysis results for the noise wall corresponding to Segment A are shown for total heights of 11.25 ft and 18 ft in Figures 5.10 and 5.11, respectively, for the impacted receivers. Total heights include the CTB. A height of 18 ft would match the height of the Site 1 barrier.

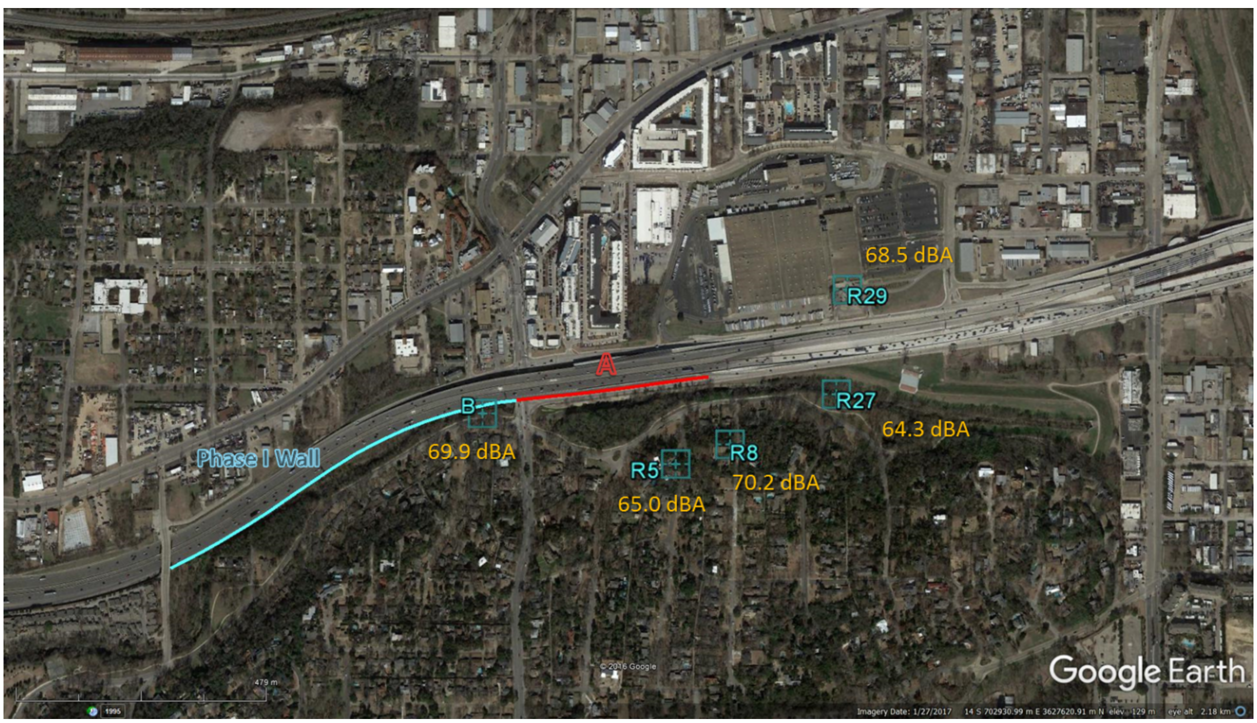



*Figure 5.10 Noise level results for impacted receivers, for Segment A total height of 11.25 ft*

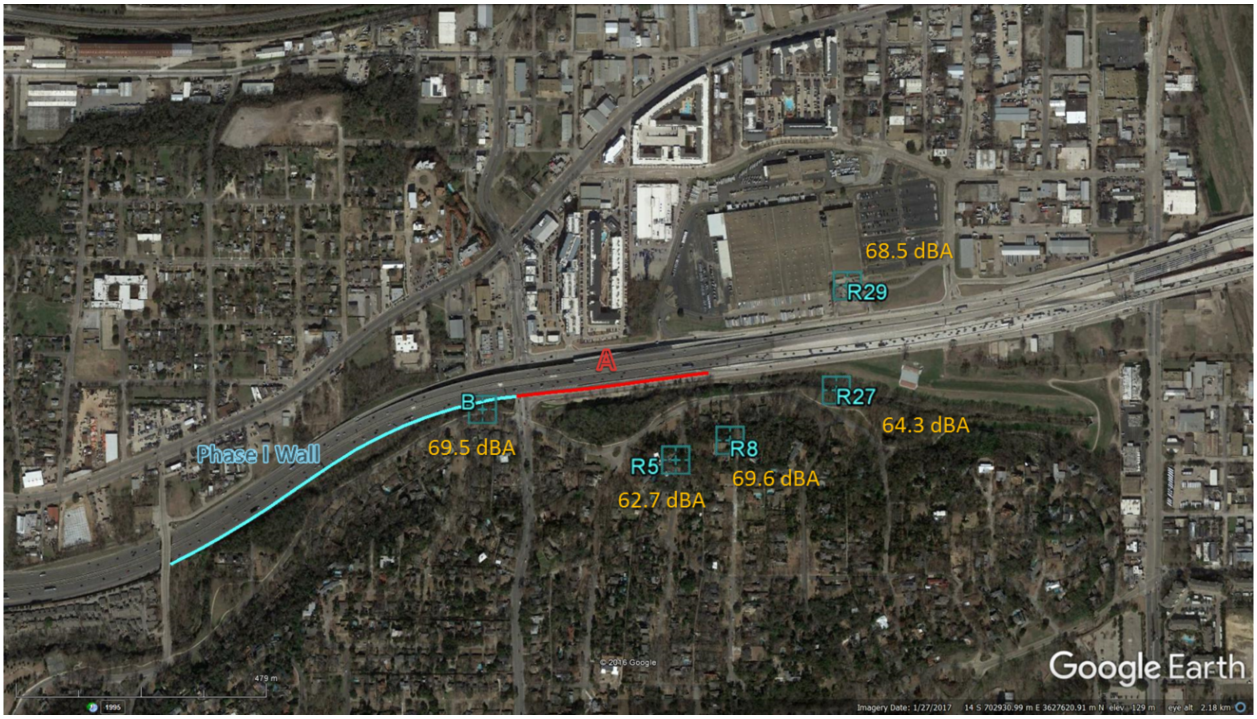



*Figure 5.11 Noise level results for impacted receivers, for Segment A total height of 18 ft*

As expected, receivers R27 and R29 do not receive a benefit from this wall, as both are located beyond the limits of the wall and R29 is on the north side of the highway.

The receivers that, regardless of the impact, would get the highest benefits in terms of noise reductions are illustrated in Figure 5.12, where the reductions in dBA are presented, comparing the no-wall condition to the Segment A wall with a total height of 18 ft.


*Figure 5.12 Highest noise level results for Segment A wall with total height of 18 ft*

Although no barrier higher than 18-ft would be installed, the results for a total height of 22.5 ft are shown in Figure 5.13, just to illustrate the potential reductions, according to the model.

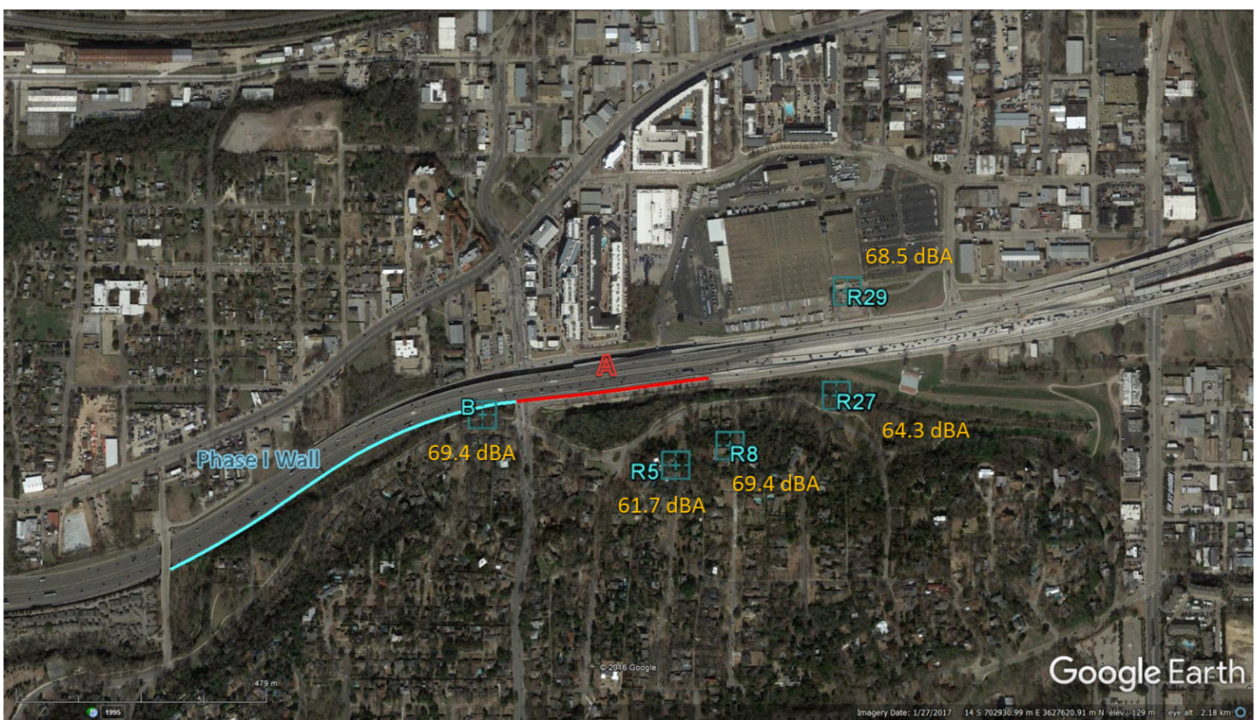



*Figure 5.13 Noise level results for impacted receivers, for Segment A total height of 22.5 ft*

In this case, receiver R5 would certainly benefit from the additional height, but most of the remaining receivers would get a minimal additional benefit.

The next part of the analysis includes the next segment to the east, designated as Segment B, to be placed on top of the main lanes CTB, as shown in Figure 5.14.


*Figure 5.14 Jersey barriers for proposed Segment A and Segment B of the Site 2 noise barrier*

The results of the analysis of Segments A and B together for the total heights of 11.25 and 18 ft are presented in Figures 5.15 and 5.16, respectively.

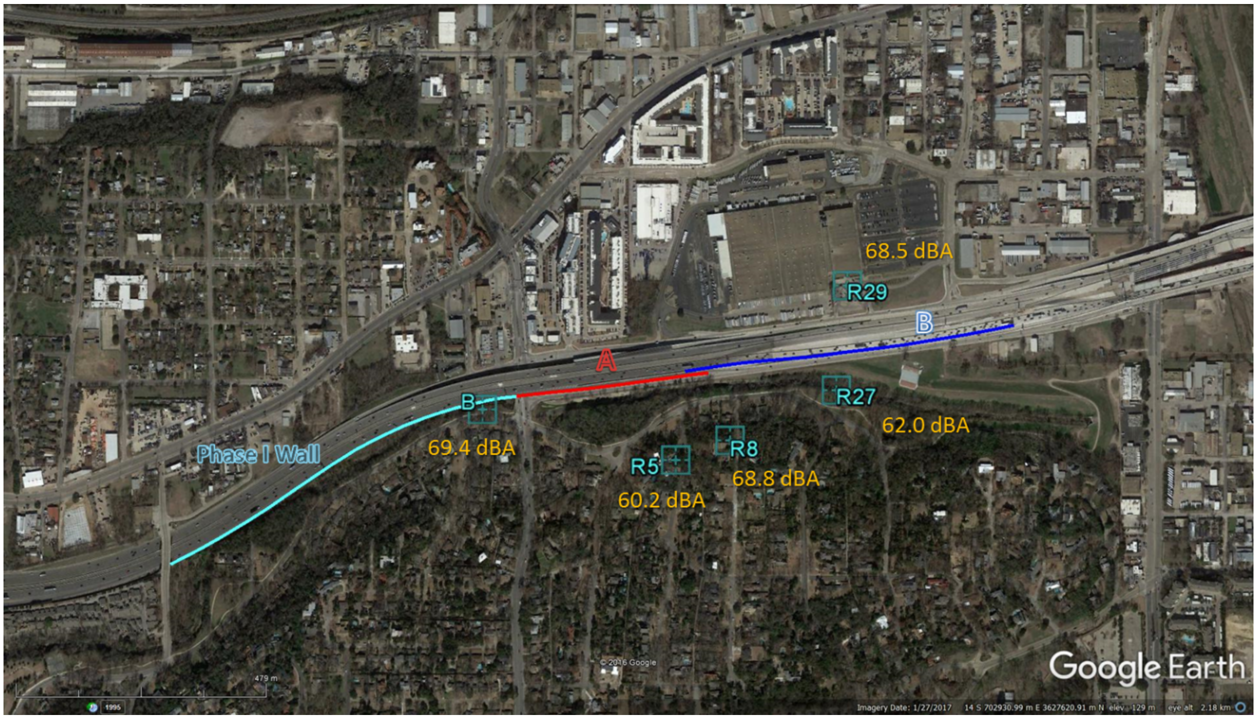


*Figure 5.15 Noise level results for impacted receivers, for Segments A and B (total height: 11.25 ft)*

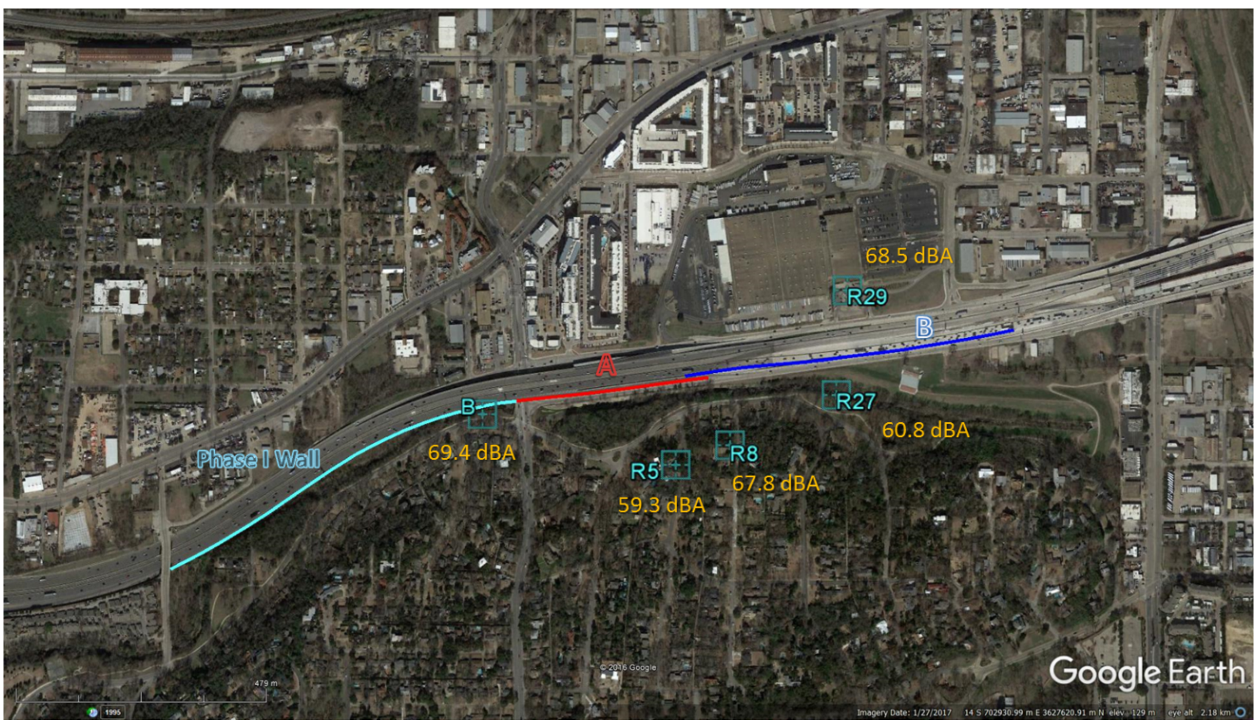


*Figure 5.16 Noise level results for impacted receivers, for Segments A and B (total height: 18 ft)*

The receivers with the highest benefits from Segments A and B, with a total height of 18 ft are shown in Figure 5.17, where the noise level reductions compared to the no-wall condition are presented.


*Figure 5.17 Highest noise level results for Segments A and B walls (total height:18 ft)*

Even though the model performed calculations for the remaining wall segments to the east (C and D), the results are not presented in this document, as TxDOT indicated that extending the wall towards the McDermott Bridge approach (Figure 5.18) was not feasible. Figures 5.19 and 5.20 show the easternmost limit of where the new wall was placed; it was not possible to install panels further east, due to the reduced height of the supporting concrete wall, which impacts the anchoring distance of the vertical posts to the concrete (Figure 5.20).

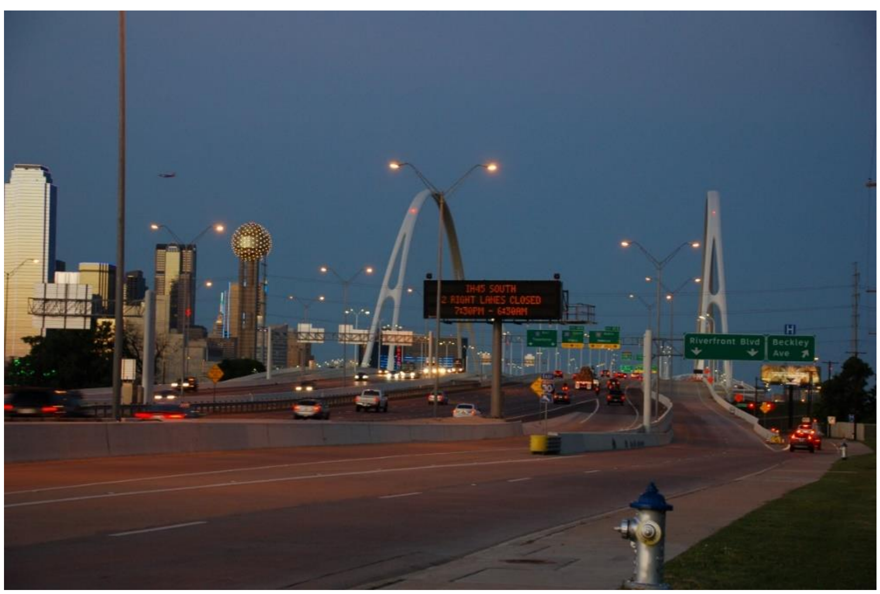



*Figure 5.18 McDermott Bridge approach looking east*

*Figure 5.19 Proposed easternmost limit of the Site 2 wall from the CTB (McDermott Bridge approach in the background)*

*Figure 5.20 Proposed easternmost limit of the Site 2 wall, seen from the main lanes*

## 5.6. Recommendations

From the TNM analysis it was recommended to place Segments A and B, and extend Segment B to about 1000 ft to the east to protect as many receivers as possible, and to reach at least the location of R27 (i.e., the park).

The proposed height for Segment A was 13.2 ft; this matched the height of the Site 1 wall, thus making a seamless transition from Site 1 and Site 2 at Sylvan Avenue. The proposed height for Segment B was 10 ft.

TxDOT conducted a visit to the site and performed measurements of the sections to determine feasible limits for the wall segments, based upon the configuration of the existing CTBs. Also, a general rule-of-thumb is that the ratio between overlap distance and gap width should be at least 4:1 to ensure negligible degradation of barrier performance (*FHWA-EP-00-005*), as illustrated in Figure 5.21. Therefore, it was recommended to add overlaps accordingly to the end of each segment. As a result of such measurements and the overlap consideration, Segment A was shortened as the profile of the road makes the additional length beyond the beginning of Segment B unnecessary; Segment B was also split into two sections due to the geometry of the road and the existing concrete traffic barriers.

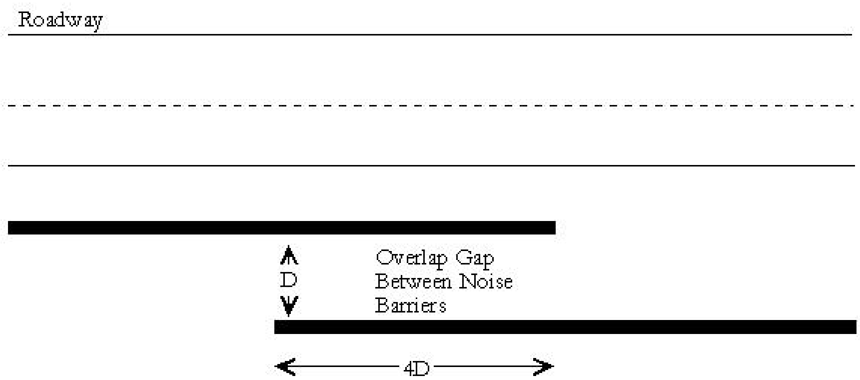



*Figure 5.21 Plan view representation of overlapping barriers (FHWA-EP-00-005)*

From those measurements conducted during the visit, taking into account that overlap, and the fact that the panels sections are commonly 7-ft wide, the following estimates were obtained (Table 5.4):

**Table 5.4 Phase 2 noise wall quantities estimate**

| Segment | Proposed length based on 7-ft width panels (ft) | Height (ft) | Quantity (sq ft) |
|---|---|---|---|
| A (Beckley Ramp) | 490 | 13.167 | 6,452 |
| B (Main lane) | 1,099 | 10 | 10,990 |
| B (Frontage Road) | 847 | 10 | 8,470 |
| **Total** | 2,436 | | 25,912 |

These segments covered the maximum number of receivers given the existing configuration of the CTBs.

# Chapter 6. Noise Testing Program

This chapter presents the field-testing procedure conducted as part of the research work on the noise wall installation on the south side of the elevated structures on I-30 in Dallas. The field test program consisted of noise measurements at Site 1, which is the segment between Edgefield Avenue and Sylvan Avenue, and at Site 2, which comprises the adjacent segment from Sylvan Avenue to Beckley Avenue in the vicinity of the Kessler Park neighborhood, an area which is affected by the highway noise from I-30.

## 6.1. Introduction

The noise data collection took place at both Site 1 and Site 2 in the Kessler Park neighborhood before the noise wall installation at Site 1, and continued after the completion of the wall for the locations on Site 1, and also continued after the completion of the Site 2 wall. Five locations were selected at each site. Measurements were performed at these locations approximately once or twice per month. During each test day, tests were conducted at all locations on three different occasions: once in the morning, once in the early afternoon, and once in the evening, to cover a wide range of traffic conditions. The purpose of the task was to gather noise data before and after the new sound wall were installed, to assess the noise levels prevailing at the various locations. With the "before" measurements and subsequent measurements after the wall installation, the effectiveness of the walls can be determined. For Site 1, the pre-barrier condition covered a 5-month period, from the end of May to the end of October 2013, when the barrier was completed. The post-barrier testing period started when the wall was finished and continued through August 2017. For Site 2, the pre-barrier condition occurred from the end of May to the end of October 2013; it resumed in June 2017 and ended in July 2018. The post-barrier testing period started with the August 2018 measurements and finished in August 2019.

## 6.2. Test Equipment and Procedure

The noise measurements performed consisted of sound pressure level (SPL) tests. For these, a sound pressure meter measures the noise level over a specified period, and the average noise level over that time period is the result of the test. The sound pressure level meter is illustrated in Figure 6.1. The time-averaged value of the sound pressure level during the test interval, i.e., the "equivalent continuous sound level" [Leq(A)] is used. Leq(A) is defined as the equivalent steady-state sound level that, in a given time period, contains the same acoustic energy as a time-varying sound level during the same period (Figure 6.2). Leq(A) is used for all traffic noise analyses for TxDOT highway projects. The meter is placed on a tripod standing 1.50 meters above the ground. Initially, the test interval was set for 15-minute periods. Because of the number of locations that needed to be tested, which included five locations at Site 1 and five locations at Site 2, and the need to gather data over the three specified times of the day (morning, early afternoon, and evening) at each one of the 10 test locations, it was impossible to measure Leq(A) for 15-minute intervals and complete all the tests necessary throughout the day, so it was decided to shorten the test intervals to 10-minute periods. Shortening the time intervals did not have any adverse effects on the test results, as the noise levels normally tend to stabilize within just a few minutes (much less than 10 minutes).


*Figure 6.1 Sound pressure level meter*

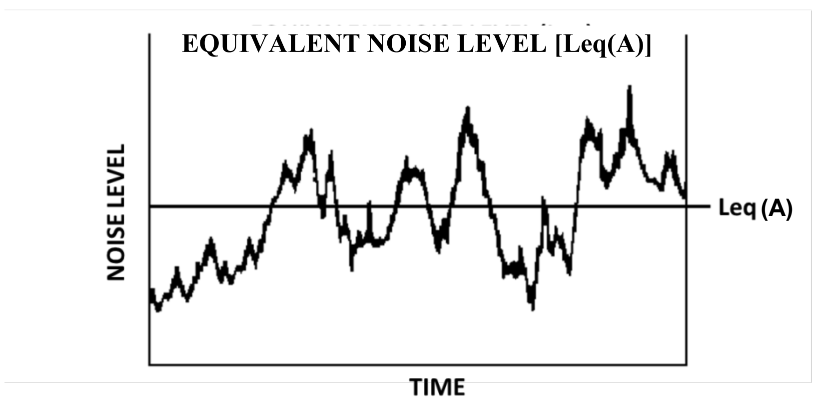



*Figure 6.2 Leq(A): average noise level over a period of time*

Weather conditions at the time of each test were monitored by means of a portable weather station equipped with a data logger and software. The weather station purchased for this project is manufactured by Davis Instruments and the model is called Vantage Vue (shown in Figure 6.3). It consists of an Integrated Sensor Suite (ISS) and a wireless console. The ISS contains all the sensors and devices to measure weather variables—a rain collector, temperature and humidity sensors, an anemometer, and a wind vane. It is solar-powered, and a lithium battery provides backup. It communicates wirelessly to the console by means of low-power radio transmission. The console is battery-operated and has an LCD display (Figure 6.4). The ISS measures temperature, relative humidity, dew point, wind speed, wind direction, highest wind speed (gust), gust direction, wind chill, heat index, barometric pressure, total rain, and rain rate; and records the values for each of these variables at 1-minute intervals. Figure 6.5 shows the weather station mounted in the back of the research vehicle. The software, also created by Davis Instruments, is called WeatherLink, version 6.0.0.


*Figure 6.3 Davis Instruments portable weather station, showing the ISS*


*Figure 6.4 Vantage Vue wireless console*


*Figure 6.5 Weather station mounted in the back of research vehicle*

The sequence of operations for noise measurements is as follows:

- Mount weather station on its base.
- Verify communication between ISS and console.
- Calibrate the SPL meter.
- Mount the SPL meter on tripod approximately 1.5 m above the ground.
- Level the weather station.
- Position the weather station in such way that the solar panel faces south.
- Start recording period.

The process of leveling and finding the correct orientation of the weather station must be done at each location to obtain accurate wind speed and wind direction readings. Leveling is done with the aid of a bubble level on top of the ISS. A mirror compass, shown in Figure 6.6, was used to confirm the orientation of the weather station. The sighting mirror in the compass allows for higher precision; its use with the weather station is shown in Figure 6.7.


*Figure 6.6 Mirror compass used for orientation of the weather station*

*Figure 6.7 Use of the mirror compass for orientation of the weather station: the solar panel of the weather station, in the background, is positioned so that it faces south*

Steps 1 through 3 are necessary only at the beginning of a series of measurements, i.e., the beginning of each of the three recording periods (morning, afternoon, and evening).

At the end of the day, the weather station data is downloaded from the console to the computer by means of a USB connection. The WeatherLink software facilitates analyses and graphic interpretation of weather data. Some images from the screens generated by the software are presented in Figures 6.8 and 6.9.

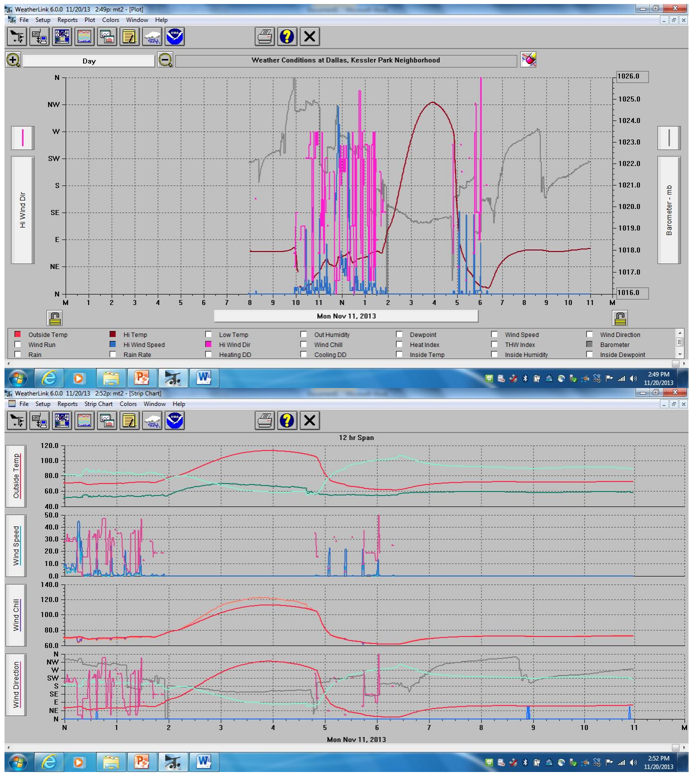
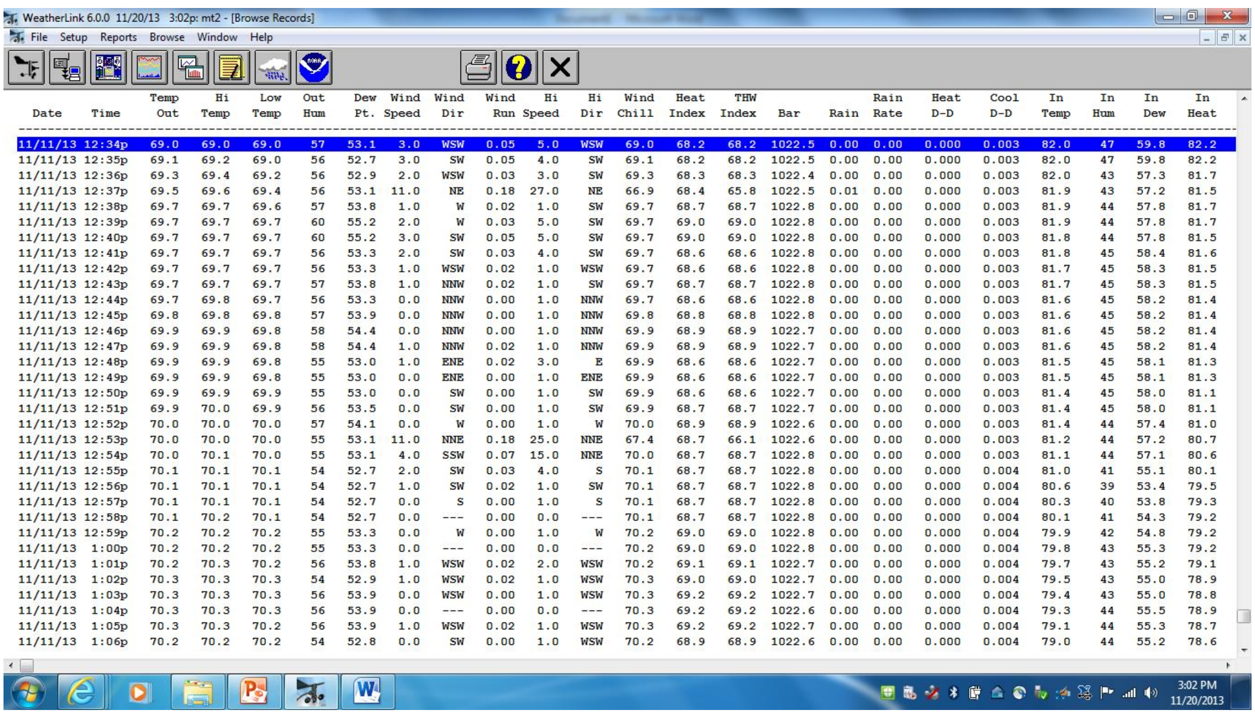



*Figure 6.8 Weather plots of daily records generated by WeatherLink*



WeatherLink 6.0.0 11/20/13 3:02p: mt2 - [Browse Records]

| Date | Time | Temp Out | Hi Temp | Low Temp | Out Hum | Dew Pt. | Wind Speed | Wind Dir | Wind Run | Hi Speed | Hi Dir | Wind Chill | Heat Index | THW Index | Bar | Rain | Rain Rate | Heat D-D | Cool D-D | In Temp | In Hum | In Dew | In Heat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/11/13 | 12:34p | 69.0 | 69.0 | 69.0 | 57 | 53.1 | 3.0 | WSW | 0.05 | 5.0 | WSW | 69.0 | 68.2 | 68.2 | 1022.5 | 0.00 | 0.00 | 0.000 | 0.003 | 82.0 | 47 | 59.8 | 82.2 |
| 11/11/13 | 12:35p | 69.1 | 69.2 | 69.0 | 56 | 52.7 | 3.0 | SW | 0.05 | 4.0 | SW | 69.1 | 68.2 | 68.2 | 1022.5 | 0.00 | 0.00 | 0.000 | 0.003 | 82.0 | 47 | 59.8 | 82.2 |
| 11/11/13 | 12:36p | 69.3 | 69.4 | 69.2 | 56 | 52.9 | 2.0 | WSW | 0.03 | 3.0 | SW | 69.3 | 68.3 | 68.3 | 1022.4 | 0.00 | 0.00 | 0.000 | 0.003 | 82.0 | 43 | 57.3 | 81.7 |
| 11/11/13 | 12:37p | 69.5 | 69.6 | 69.4 | 56 | 53.1 | 11.0 | NE | 0.18 | 27.0 | NE | 66.9 | 68.4 | 65.8 | 1022.5 | 0.01 | 0.00 | 0.000 | 0.003 | 81.9 | 43 | 57.2 | 81.5 |
| 11/11/13 | 12:38p | 69.7 | 69.7 | 69.6 | 57 | 53.8 | 1.0 | W | 0.02 | 1.0 | SW | 69.7 | 68.7 | 68.7 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.9 | 44 | 57.8 | 81.7 |
| 11/11/13 | 12:39p | 69.7 | 69.7 | 69.7 | 60 | 55.2 | 2.0 | W | 0.03 | 5.0 | SW | 69.7 | 69.0 | 69.0 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.9 | 44 | 57.8 | 81.7 |
| 11/11/13 | 12:40p | 69.7 | 69.7 | 69.7 | 60 | 55.2 | 3.0 | SW | 0.05 | 5.0 | SW | 69.7 | 69.0 | 69.0 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.8 | 44 | 57.8 | 81.5 |
| 11/11/13 | 12:41p | 69.7 | 69.7 | 69.7 | 56 | 53.3 | 2.0 | SW | 0.03 | 4.0 | SW | 69.7 | 68.6 | 68.6 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.8 | 45 | 58.4 | 81.6 |
| 11/11/13 | 12:42p | 69.7 | 69.7 | 69.7 | 56 | 53.3 | 1.0 | WSW | 0.02 | 1.0 | WSW | 69.7 | 68.6 | 68.6 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.7 | 45 | 58.3 | 81.5 |
| 11/11/13 | 12:43p | 69.7 | 69.7 | 69.7 | 57 | 53.8 | 1.0 | NNW | 0.02 | 1.0 | SW | 69.7 | 68.7 | 68.7 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.7 | 45 | 58.3 | 81.5 |
| 11/11/13 | 12:44p | 69.7 | 69.8 | 69.7 | 56 | 53.3 | 0.0 | NNW | 0.00 | 1.0 | NNW | 69.7 | 68.6 | 68.6 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.6 | 45 | 58.2 | 81.4 |
| 11/11/13 | 12:45p | 69.8 | 69.8 | 69.8 | 57 | 53.9 | 0.0 | NNW | 0.00 | 1.0 | NNW | 69.8 | 68.8 | 68.8 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.6 | 45 | 58.2 | 81.4 |
| 11/11/13 | 12:46p | 69.9 | 69.9 | 69.8 | 58 | 54.4 | 0.0 | NNW | 0.00 | 1.0 | NNW | 69.9 | 68.9 | 68.9 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.003 | 81.6 | 45 | 58.2 | 81.4 |
| 11/11/13 | 12:47p | 69.9 | 69.9 | 69.8 | 58 | 54.4 | 1.0 | NNW | 0.02 | 1.0 | NNW | 69.9 | 68.9 | 68.9 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.003 | 81.6 | 45 | 58.2 | 81.4 |
| 11/11/13 | 12:48p | 69.9 | 69.9 | 69.8 | 55 | 53.0 | 1.0 | ENE | 0.02 | 3.0 | E | 69.9 | 68.6 | 68.6 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.003 | 81.5 | 45 | 58.1 | 81.3 |
| 11/11/13 | 12:49p | 69.9 | 69.9 | 69.8 | 55 | 53.0 | 0.0 | ENE | 0.00 | 1.0 | ENE | 69.9 | 68.6 | 68.6 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.003 | 81.5 | 45 | 58.1 | 81.3 |
| 11/11/13 | 12:50p | 69.9 | 69.9 | 69.9 | 55 | 53.0 | 0.0 | SW | 0.00 | 1.0 | SW | 69.9 | 68.6 | 68.6 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.003 | 81.4 | 45 | 58.0 | 81.1 |
| 11/11/13 | 12:51p | 69.9 | 70.0 | 69.9 | 56 | 53.5 | 0.0 | SW | 0.00 | 1.0 | SW | 69.9 | 68.7 | 68.7 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.003 | 81.4 | 45 | 58.0 | 81.1 |
| 11/11/13 | 12:52p | 70.0 | 70.0 | 70.0 | 57 | 54.1 | 0.0 | W | 0.00 | 1.0 | W | 70.0 | 68.9 | 68.9 | 1022.6 | 0.00 | 0.00 | 0.000 | 0.003 | 81.4 | 44 | 57.4 | 81.0 |
| 11/11/13 | 12:53p | 70.0 | 70.0 | 70.0 | 55 | 53.1 | 11.0 | NNE | 0.18 | 25.0 | NNE | 67.4 | 68.7 | 66.1 | 1022.6 | 0.00 | 0.00 | 0.000 | 0.003 | 81.2 | 44 | 57.2 | 80.7 |
| 11/11/13 | 12:54p | 70.0 | 70.1 | 70.0 | 55 | 53.1 | 4.0 | SSW | 0.07 | 15.0 | NNE | 70.0 | 68.7 | 68.7 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.003 | 81.1 | 44 | 57.1 | 80.6 |
| 11/11/13 | 12:55p | 70.1 | 70.1 | 70.1 | 54 | 52.7 | 2.0 | SW | 0.03 | 4.0 | S | 70.1 | 68.7 | 68.7 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.004 | 81.0 | 41 | 55.1 | 80.1 |
| 11/11/13 | 12:56p | 70.1 | 70.1 | 70.1 | 54 | 52.7 | 1.0 | SW | 0.02 | 1.0 | SW | 70.1 | 68.7 | 68.7 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.004 | 80.6 | 39 | 53.4 | 79.5 |
| 11/11/13 | 12:57p | 70.1 | 70.1 | 70.1 | 54 | 52.7 | 0.0 | S | 0.00 | 1.0 | S | 70.1 | 68.7 | 68.7 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.004 | 80.3 | 40 | 53.8 | 79.3 |
| 11/11/13 | 12:58p | 70.1 | 70.2 | 70.1 | 54 | 52.7 | 0.0 | --- | 0.00 | 0.0 | --- | 70.1 | 68.7 | 68.7 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.004 | 80.1 | 41 | 54.3 | 79.2 |
| 11/11/13 | 12:59p | 70.2 | 70.2 | 70.2 | 55 | 53.3 | 0.0 | W | 0.00 | 1.0 | W | 70.2 | 69.0 | 69.0 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.004 | 79.9 | 42 | 54.8 | 79.2 |
| 11/11/13 | 1:00p | 70.2 | 70.2 | 70.2 | 55 | 53.3 | 0.0 | --- | 0.00 | 0.0 | --- | 70.2 | 69.0 | 69.0 | 1022.8 | 0.00 | 0.00 | 0.000 | 0.004 | 79.8 | 43 | 55.3 | 79.2 |
| 11/11/13 | 1:01p | 70.2 | 70.3 | 70.2 | 56 | 53.8 | 1.0 | WSW | 0.02 | 2.0 | WSW | 70.2 | 69.1 | 69.1 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.004 | 79.7 | 43 | 55.2 | 79.1 |
| 11/11/13 | 1:02p | 70.3 | 70.3 | 70.3 | 54 | 52.9 | 1.0 | WSW | 0.02 | 1.0 | WSW | 70.3 | 69.0 | 69.0 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.004 | 79.5 | 43 | 55.0 | 78.9 |
| 11/11/13 | 1:03p | 70.3 | 70.3 | 70.3 | 56 | 53.9 | 0.0 | WSW | 0.00 | 1.0 | WSW | 70.3 | 69.2 | 69.2 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.004 | 79.4 | 43 | 55.0 | 78.8 |
| 11/11/13 | 1:04p | 70.3 | 70.3 | 70.3 | 56 | 53.9 | 0.0 | --- | 0.00 | 0.0 | --- | 70.3 | 69.2 | 69.2 | 1022.6 | 0.00 | 0.00 | 0.000 | 0.004 | 79.3 | 44 | 55.5 | 78.9 |
| 11/11/13 | 1:05p | 70.3 | 70.3 | 70.2 | 56 | 53.9 | 1.0 | WSW | 0.02 | 1.0 | WSW | 70.3 | 69.2 | 69.2 | 1022.7 | 0.00 | 0.00 | 0.000 | 0.004 | 79.1 | 44 | 55.3 | 78.7 |
| 11/11/13 | 1:06p | 70.2 | 70.2 | 70.2 | 54 | 52.8 | 0.0 | SW | 0.00 | 1.0 | WSW | 70.2 | 68.9 | 68.9 | 1022.6 | 0.00 | 0.00 | 0.000 | 0.004 | 79.0 | 44 | 55.2 | 78.6 |

*Figure 6.9 WeatherLink screen showing weather records for every minute*

## 6.3. Test Locations

Noise tests were conducted at ten different locations close to I-30, five corresponding to Site 1 and five to Site 2. At each site, four locations were at residences and the fifth was in the Coombs Creek Trail Park adjacent to the highway, an area of frequent human activity. This park lies between the highway and the residences. The measurements at the homes were taken at either front patios or backyards, all outdoor places where residents would be affected by noise.

### 6.3.1. Site 1 Locations

Figure 6.10 maps the five Site 1 locations and the location of the noise barrier.

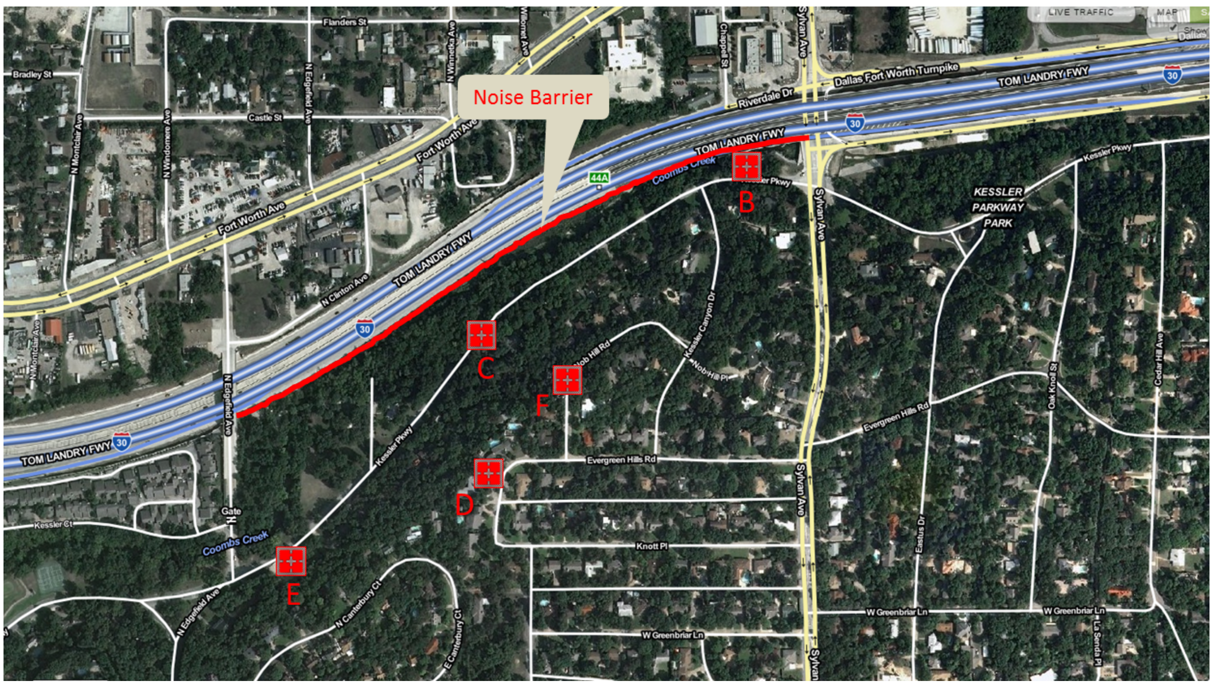



*Figure 6.10 Site 1 noise measurement locations*

Table 6.1 presents the addresses and coordinates for the Site 1 locations.

**Table 6.1 Site 1 locations' information**

| Location | Address | Latitude | Longitude | Elev. (ft) |
|---|---|---|---|---|
| E | 2010 Kessler Parkway | N 32° 45.773' | W 96° 50.519' | 434 |
| D | 1027 Evergreen | N 32° 45.819' | W 96° 50.381' | 505 |
| F | 1627 Nob Hill | N 32° 45.887' | W 96° 50.322' | 521 |
| C | 1820 Kessler Parkway | N 32° 45.896' | W 96° 50.393' | 486 |
| B | Coombs Creek Trail Park, on Kessler Parkway, west of Sylvan Avenue | N 32° 46.016' | W 96° 50.189' | 458 |

The following paragraphs briefly describe the five Site 1 locations.

### 6.3.1.1. Location E

This is the residence of Ms. Sara Reidy, one of the most active neighbors from the Kessler Park Neighborhood Association in terms of her involvement with this project. The distance to the highway from this residence is 630 ft. This location is close to the highway and at a low elevation, but there is no clear line of sight to I-30. The sound meter position at this location is in the front porch, just outside the front door, facing I-30. Figures 6.11 and 6.12 illustrate this location.

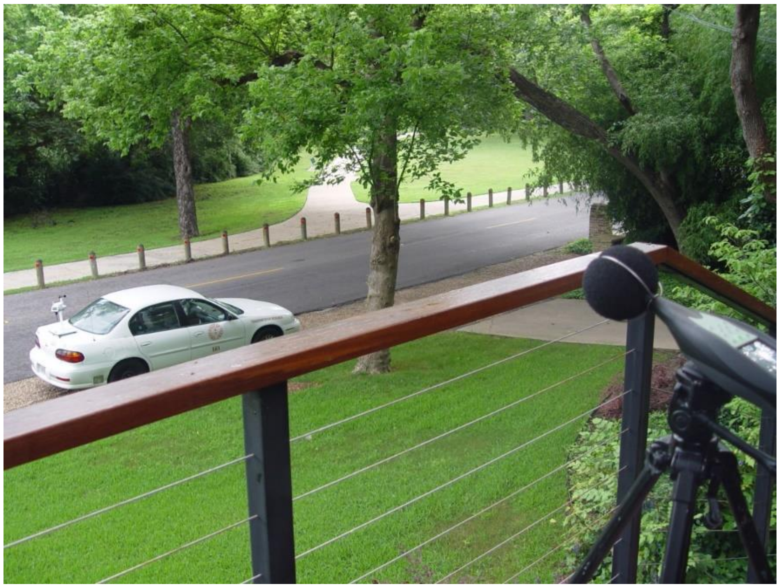


*Figure 6.11 Residential measurement at Location E*

*Figure 6.12 Residential measurement at Location E*

### 6.3.1.2. Location D

This residence is at a higher elevation and is slightly farther from I-30. The distance to the highway is 670 ft. The measuring position at this location is in the front yard. Figures 6.13 and 6.14 show some aspects of this location.

*Figure 6.13 Residential measurement at Location D*


*Figure 6.14 Residential measurement at Location D*

### 6.3.1.3. Location F

This residence is at the highest elevation relative to the highway among the locations measured at Site 1. The distance to the highway is 500 ft. Figures 6.15 and 6.16 demonstrate that the street, Nob Hill, is on a steep grade, indicative of the hilly terrain just south of Kessler Parkway; the residence is to the right of the sound meter, but cannot be seen from the curb because of the dense vegetation and the steepness of the grade. The measurement position is by the curb, facing the highway.

*Figure 6.15 Residential measurement at Location F*

*Figure 6.16 Residential measurement at Location F*

### 6.3.1.4. Location C

The distance of this location to the highway is 300 ft. This residence is the closest to I-30 among those measured. It is also slightly below the level of the highway; the only visual obstructions are vegetation and the existing concrete wall. The measurement location is at the entrance of the driveway, in front of the house (Figures 6.17 and 6.18).

*Figure 6.17 Residential measurement at Location C*

*Figure 6.18 Residential measurement at Location C*

### 6.3.1.5. Location B

This is the Site 1 location along the Coombs Trail chosen for noise measurements. It was chosen for its proximity to I-30. The distance to the highway is 32 ft and, as Figure 6.19 shows, it is at a lower elevation relative to the highway. Coombs Creek separates this location from the highway. This location is close to Sylvan Avenue, the easternmost end of the first phase of the project. The existing concrete wall blocks the view to the highway, but the top of taller vehicles, such as trucks circulating on I-30, can be seen from this location. This is the only location at Site 1 that offers a clear view of the wall regardless of the lushness of the vegetation. Figures 6.19 and 6.20 show measurements performed at this location before and after the barrier installation, respectively.

*Figure 6.19 Noise measurement at Coombs Creek Trail Park (Location B) prior to noise barrier installation*

*Figure 6.20 Noise measurement at Coombs Creek Trail Park (Location B) after noise barrier installation*

### 6.3.2. Site 2 Locations

Figure 6.21 maps the five Site 2 locations and the location of the noise barrier.

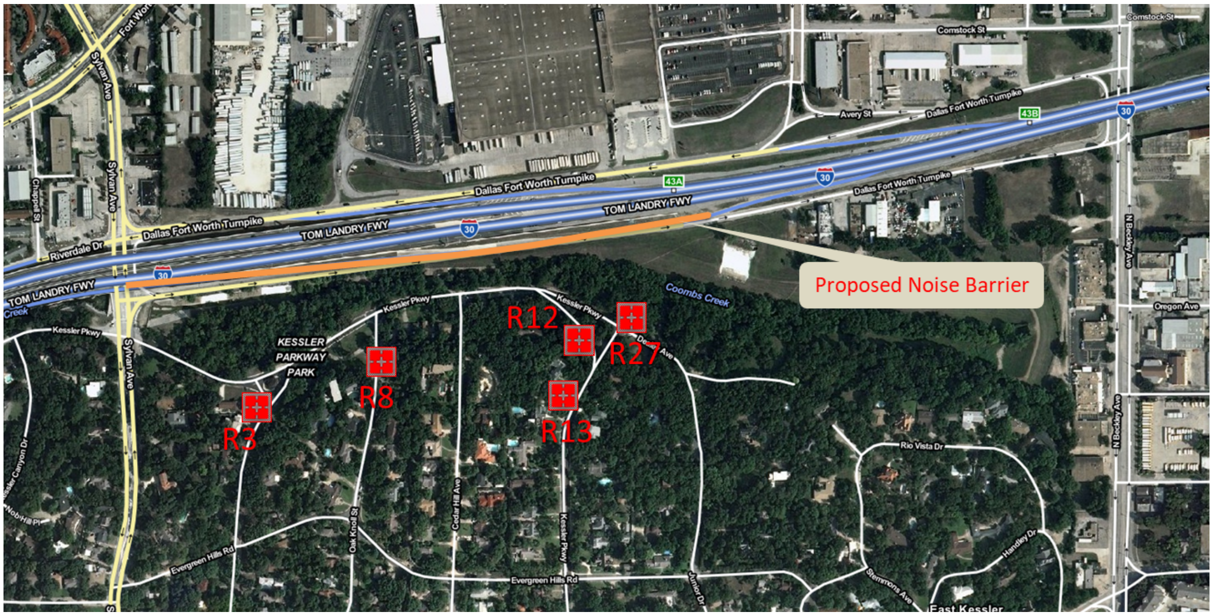



*Figure 6.21 Site 2 noise measurement locations*

Table 6.2 presents the addresses and coordinates for the Site 2 locations.

**Table 6.2 Site 2 locations' information**

| Location | Address | Latitude | Longitude | Elev. (ft) |
|---|---|---|---|---|
| R3 | 1645 Eastus Road | N 32° 45.954' | W 96° 50.042' | 428 |
| R8 | 1650 Oak Knoll | N 32° 45.972' | W 96° 49.940' | 449 |
| R12 | 1126 Kessler Parkway | N 32° 46.023' | W 96° 49.827' | 418 |
| R13 | 1060 Kessler Parkway | N 32° 45.961' | W 96° 49.797' | 465 |
| R27 | Coombs Creek Trail Park, on Kessler Parkway, east of Sylvan Avenue | N 32° 46.020' | W 96° 49.756' | 418 |

The following paragraphs present brief descriptions of the five Site 2 locations.

### 6.3.2.1. Location R3

The distance to the highway from this residence is 490 ft. This location is close to the highway and at a low elevation, but there is no clear line of sight to I-30 because of the park vegetation. The sound meter position at this location is in the front yard, facing I-30. Figures 6.22 and 6.23 illustrate this location.

*Figure 6.22 Residential measurement at Location R3*


*Figure 6.23 Residential measurement at Location R3, with TxDOT's George Reeves*

### 6.3.2.2. Location R8

This residence is at a higher elevation and is slightly farther from I-30. The distance to the highway is 500 ft. This residence has a clear line of sight to the highway, only partially and seasonally obstructed by vegetation (Figures 6.24 and 6.25).

*Figure 6.24 Residential measurement at Location R8*

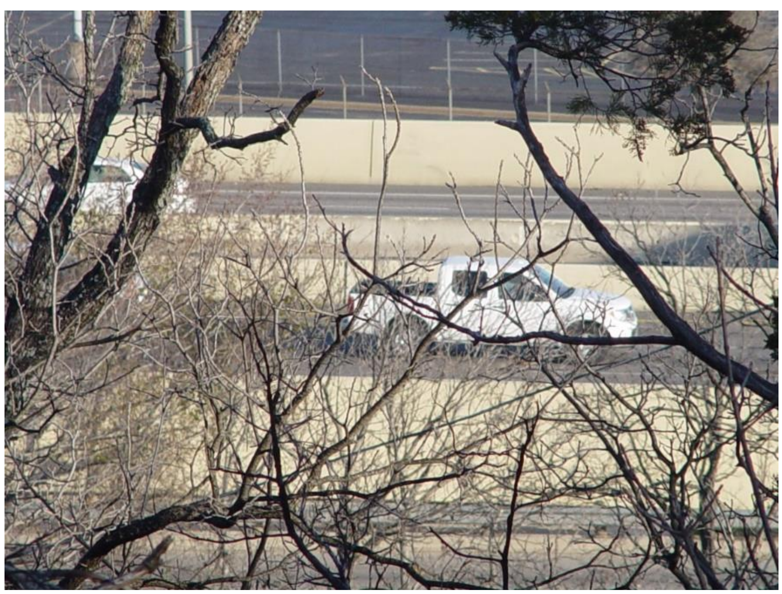


*Figure 6.25 I-30 view from residence at Location R8*

### 6.3.2.3. Location R12

This residence is at the lowest elevation relative to the highway among the locations measured at Site 2. It is also the closest to I-30. The distance to the highway is 280 ft. It is just across the street from the Coombs Creek Trail Park. The measurement position is in the front yard, close to the curb, facing the highway (Figures 6.26 and 6.27).

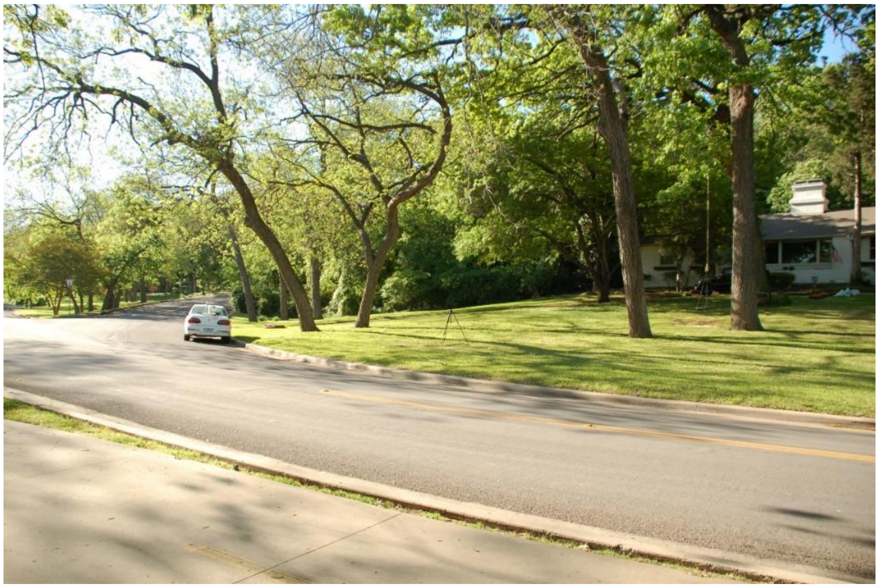


*Figure 6.26 Residential measurement at Location R12*

*Figure 6.27 Residential measurement at Location R12*

### 6.3.2.4. Location R13

This is the furthest location from the highway, among the Site 2 locations. The distance of this location to the highway is 675 ft. It is also at the highest elevation from the highway, as Kessler Parkway climbs steeply as it turns south, away from I-30, quickly gaining considerable elevation above the highway level. The measurement location is in the front yard, on the steps leading to the entrance of the house (Figures 6.28 and 6.29).


*Figure 6.28 Residential measurement at Location R13*


*Figure 6.29 Residential measurement at Location R13*

### 6.3.2.5. Location R27

This is the Site 2 location along the Coombs Trail Park chosen for noise measurements. The distance to the highway is 335 ft. Coombs Creek separates this location from the highway. This location is the easternmost testing spot for Site 2, the closest to Beckley Avenue. The test site is on the paved trail, next to a park bench, slightly below the highway level (Figures 6.30 and 6.31).

*Figure 6.30 Noise measurement at Coombs Creek Trail Park (Location R27)*

*Figure 6.31 Noise measurement at Coombs Trail Park (Location R27)*

## 6.4. Test Dates

Noise tests for this project were performed approximately once or twice per month, starting at the end of May 2013 and continuing until August 2019.

The installation of the wall at Site 1 started on September 9, 2013, at night, with the placement of the metal structure that supports the wall panels. During this time, as only the support structure was being placed, and throughout the trips in the month of September, the measurements were considered to have been taken under the "before wall installation" conditions. The support structure without the panels did not have any effect on the noise measured at receivers' locations.

By the mid-October measurements, a substantial number of panels were already in place; about 95% of the structure was finished. At this time, the measurements were categorized as having been taken under the "post-barrier condition." At this time, the measurements at Site 2, which were also started in May 2013, concluded. Site 1 tests continued until August 2017, when the Site 1 wall study finished. In June 2017, the tests at Site 2 resumed. The Site 2 installation started on January 24, 2018. The installation was interrupted in March, due to problems with the design of the supporting posts; it resumed in July and concluded in August 2018. The post-barrier measurements for Site 2 started in August 2018 and continued until August 2019.

## 6.5. Summary

This chapter presents the noise testing program for the residential locations in the Kessler Park neighborhood, just south of I-30, before and after the lightweight transparent noise barriers were installed. Five locations at Site 1 and five locations at Site 2 were monitored. The noise measurements, performed with sound pressure level meters, were collected for the purpose of evaluating the effectiveness of this type of noise barrier. The tests were conducted at different times of the day to account for the variability in traffic and climatic conditions. At the same time the noise tests were performed, a weather station was used to monitor climatic variables. A detailed description of the equipment employed for the measurements was presented, as well as the methodology for the field work.

# Chapter 7. Test Results and Analysis

This chapter presents the data processing, results, and analysis of the noise data collected as part of the research work conducted before and after the noise wall installations on the south side of the elevated structures on I-30 in Dallas.

The work consisted of organizing and analyzing the noise and weather data collected for about a year in the vicinity of the Kessler Park neighborhood, an area affected by the highway noise from I-30. The noise and weather data corresponds to both Site 1 and Site 2. Site 1 is the segment between Edgefield Avenue and Sylvan Avenue, south of the highway, and Site 2 corresponds to the area between Sylvan Avenue and Beckley Avenue, also south of I-30, just west of downtown Dallas. The data analyzed was gathered at both sites for the pre- and the post-barrier conditions. The test procedures, methodology and equipment were described in the previous chapter.

## 7.1. Analysis of Overall Results and TNM Predictions

A total of 1,228 noise tests were conducted in the Kessler Park neighborhood, from May 2013 until August 2019, accounting for about 205 hours of noise monitoring throughout the project. At Site 1, there were 130 noise measurements taken before the wall was installed, and 646 measurements after the wall was installed. For Site 2, there were 289 noise measurements for the pre-barrier condition. Some of these occurred with a partial installation of the Site 2 wall, but since the wall was not completed until August 2018, these are considered for the pre-barrier condition. After the entirety of the Site 2 was in place, there were 163 noise measurements. About 12,280 weather records (one for every minute) were collected while the noise tests were taking place.

Following are the average noise measurements for both sites, before and after the wall was installed:

- Average level before wall, Site 1: 58.2 dBA
- Average level after wall, Site 1: 55.8 dBA
- Average level before wall, Site 2: 58.6 dBA
- Average level after wall, Site 2: 58.4 dBA

Therefore, before the noise walls were installed, the noise measurements were similar at both Site 1 and Site 2; after the Site 1 wall was installed, there was a 2.4 dBA reduction, on average. For Site 2, the reduction was only 0.2 dBA, on average. The following section presents the analysis of the measurements, including comparisons with the design program's predictions.

An important aspect of the noise level data is that the measurements, despite the widespread perception by residents, are generally low, for both the pre-barrier and post-barrier conditions at both sites. Using the "Impact" from the Noise Abatement Criteria (Table 4.1) value of 66 dBA as a threshold, and analyzing the data, it can be observed that at Site 1, for the pre-barrier condition there were no measurements that corresponded to impact, while for the post-barrier condition only one test resulted in impact. For Site 2, there were seven occasions in which the test outcome was an impact, and all of these correspond to the pre-barrier period. For the high amount of data collected, the number tests that resulted in impact (66 dBA or above) is negligible: 8 out of 1,228 tests (0.65%).

### 7.1.1. Site 1

This analysis corresponds to the pre- and post-barrier conditions for Site 1. Figure 7.1 shows average before and after noise wall average measurements by location for Site 1.


*Figure 7.1 Site 1 average noise measurements, before and after noise wall installation*

All the locations at Site 1 show some small benefit, on average, from the noise wall. The location with the smallest average benefit is location E (1.3 dBA), the westernmost residential location, which is very close to the west end of the noise wall, at Edgefield Avenue. In all likelihood, highway noise coming from west of Edgefield Avenue still reaches this residence and this is the reason for the marginal noise reduction after the wall was installed. The location with the highest average noise reduction after the wall was in place is residence C, the closest residence to the highway. This location shows a 3.6 dBA average noise reduction with the Site 1 noise wall, which is a significant, noticeable benefit. Besides its proximity to the highway, this location is at a lower elevation relative to the highway, which results in higher benefit from the wall. Another location that is very close to the highway, and at a lower elevation, is the park location, identified as B; its benefit, on average, is 1.9 dBA. It would be expected that this location would obtain a greater noise reduction from the wall, but some of that benefit was negated by its proximity to the easternmost end of the wall (that is, until the placement of the Site 2 barrier), at Sylvan Avenue—noise from the highway segment not protected by the wall still reached this park location, as is the case with location E, at the other end of the project. However, with the subsequent installation of the adjacent Site 2 wall, part of this problem was greatly diminished. All of the post-barrier condition measurements for Site 1 were taken when the Site 2 was not in place; therefore, the noise coming from above Sylvan Avenue and beyond to the east traveled unblocked towards the easternmost end of Site 1, which is represented by location B. It should be noted that, independently from the highway traffic noise, the street intersection of Sylvan Avenue and the I-30 frontage roads under the highway is a very loud location: besides being a busy interchange, the noise is magnified by the underside of the I-30 bridge; once the Sylvan Avenue southbound traffic passes that bridge, the vehicles have to accelerate to overcome the steep grade ahead on Sylvan Avenue and this street noise reaches those residences located near Sylvan and Kessler Parkway, as well as location B.

For the design of the noise wall, the TNM program was utilized, as described in Chapter 4. Besides enabling the wall design, the program provides the predicted traffic noise, with and without walls. The comparison of actual measurements, before and after the Site 1 wall, as well as with the TNM predictions is shown in Figure 7.2. The TNM predictions correspond to two levels of traffic, the current and the future (year 2035) traffic, which was used as an input for the wall's design.


*Figure 7.2 Site 1 average noise measurements, before and after noise wall installation, compared with TNM predictions*

The TNM predicts substantial reductions for the 2035 traffic at all locations shown in Figure 6.2 when comparing the no-wall condition to the wall condition, except for location E, where the benefit is only 0.5 dBA, according to the prediction. This confirms why this location was the test site with the smallest actual benefit as indicated in the previous paragraphs. According to the program's predictions, comparing 2035 traffic no-wall versus wall conditions, the highest benefit for these traffic levels would be achieved at location B (7.6 dBA), with location C following closely (7.0 dBA). In regard to the comparisons between actual measurements and TNM current traffic, no wall predictions, the program over-predicts in four of the locations—in three of them by a wide margin—and it under-predicts for location E. The largest over-prediction is for location B, about 17 dBA.

### 7.1.2. Site 2

Pre-barrier noise measurements at Site 2 started in May 2013, stopped at the time the Site 1 noise wall installation was completed (mid-October 2013); tests resumed when the Horseshoe Project was mostly finished, and when it was considered that the construction noise from that project was not going to disturb noise tests at Site 2 anymore (June 2017), and continued until July 2018. The new barrier at Site 2 was completed in August 2018. Therefore, the post-barrier noise tests at Site 2 started in August 2018 and concluded in August 2019.

Figure 7.3 shows the average measurements by location at Site 2, for both the pre-barrier and the post-barrier condition.


*Figure 7.3 Site 2 average noise measurements, before and after noise wall installation*

The comparisons between the TNM program's predictions and actual results are shown in Figure 7.4. This figure presents a comparison of the actual measurements and the TNM predictions for the current traffic and the future (year 2035) traffic.


*Figure 7.4 Site 2 average noise measurements, before noise wall installation, compared with TNM predictions*

TNM over-predicted noise levels for four of the five locations corresponding to Site 2. The average over-prediction is 4.85 dBA. However, this number is inflated by the result at one location, R8, where the program's over-prediction is 10.5 dBA. For receiver R12, the only one for which TNM under-predicted the noise level, the under-prediction is 3.3 dBA. Also, the TNM-predicted noise levels at the current level of traffic are very similar to those predicted for the future traffic.

## 7.2. Analysis of Measurements

In this section, the noise results are analyzed by date, and in relationship to the weather variables.

### 7.2.1. By Test Date

Noise levels are analyzed by measurement date throughout the several years of testing in this project. A chart showing total averages for measurements by date, for both Site 1 and Site 2, is shown in Figure 7.5. There is a certain cyclical trend with the seasons, where noise levels drop during the warmer months and increase during the colder season. For Site 1, before October 2013, the measurements correspond to the pre-barrier condition, and after that date, they correspond to the post-barrier condition. In general, the levels dropped after the barrier was placed, with the exception of a few outliers (e.g., March 2016, February 2017). For Site 2, as it has been mentioned before in this chapter and as it is apparent in the graph, the data collection occurred in two separate periods: the first one in 2013, and the second one after the completion of the adjacent Dallas Horseshoe Project, from June 2017 to August 2019; it is interesting to note that the measurements were higher when the data collection at this site resumed (that is, during the second period), as compared to the levels recorded in 2013. This finding seems correlated with the small benefit that apparently is provided by the barrier at this site. However, the second data collection period at this site includes data corresponding to both the pre-barrier condition and the post-barrier condition, so perhaps the increase is due to an increase in traffic from 2013 to 2017. Another hypothesis is that the high noise levels correspond to the degradation of the pavements in this section, which are two adjacent permeable friction courses (PFCs) placed in 2006 and 2010, respectively (the older overlay is the one closer to Site 2). This has been observed when the pavements were subjected to tire-pavement noise tests performed by means of the on-board sound intensity method (OBSI). Refer to Section 3.2.2 in this report for OBSI results. It was not until June 2019 that the old pavement overlays were fully replaced by a new PFC surface.

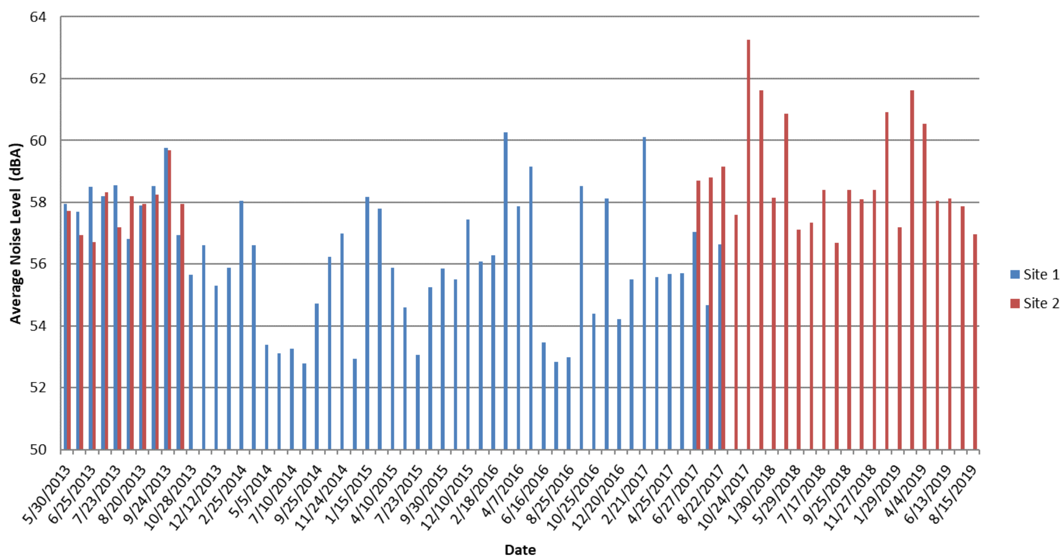



*Figure 7.5 Average noise levels by date*

The seasonal variation of noise measured throughout years of this research was analyzed, for both Site1 and Site 2. The plots shown in Figure 7.6 and 7.7 attempt to summarize the temperature effect on noise measured at the various residential locations for Site 1 and Site 2, respectively. The trends are not very well defined, as noise levels go up and down, but do not necessarily match the expected weather patterns.

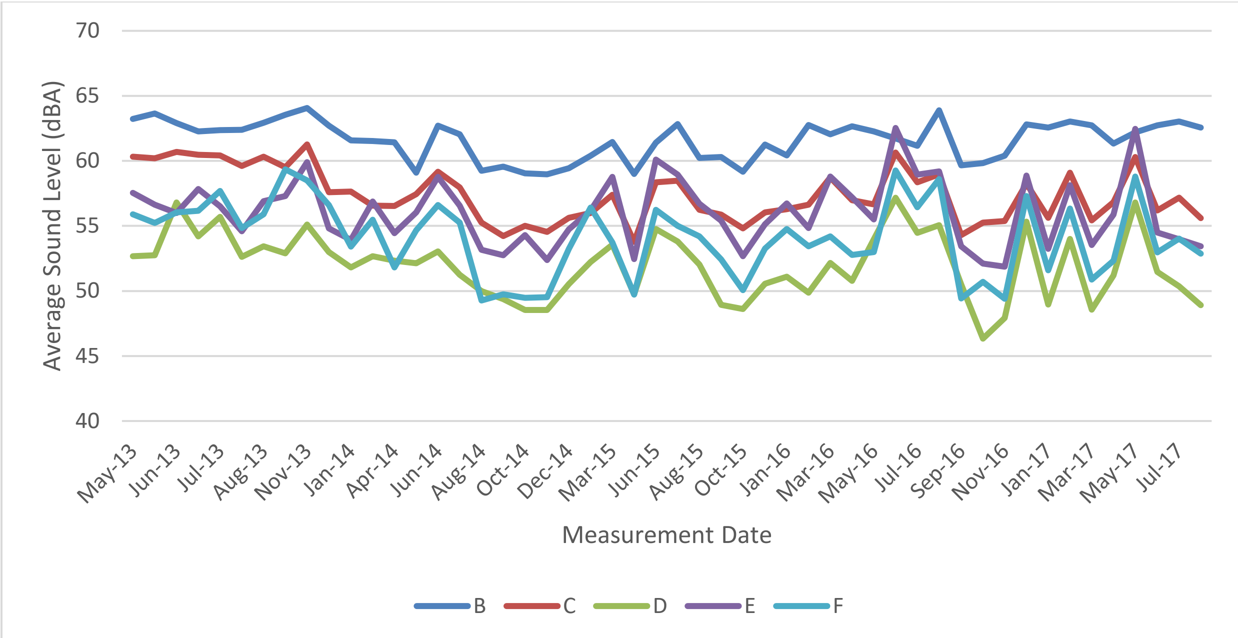



*Figure 7.6 Average noise levels for Site 1 locations by measurement date*

Figure 7.6 also shows that location B, the Coombs park measuring spot, as well as location C, are consistently the loudest locations due to their proximity to the highway, followed by location E. Similarly, location D is consistently the quietest as it is farther away from the highway.

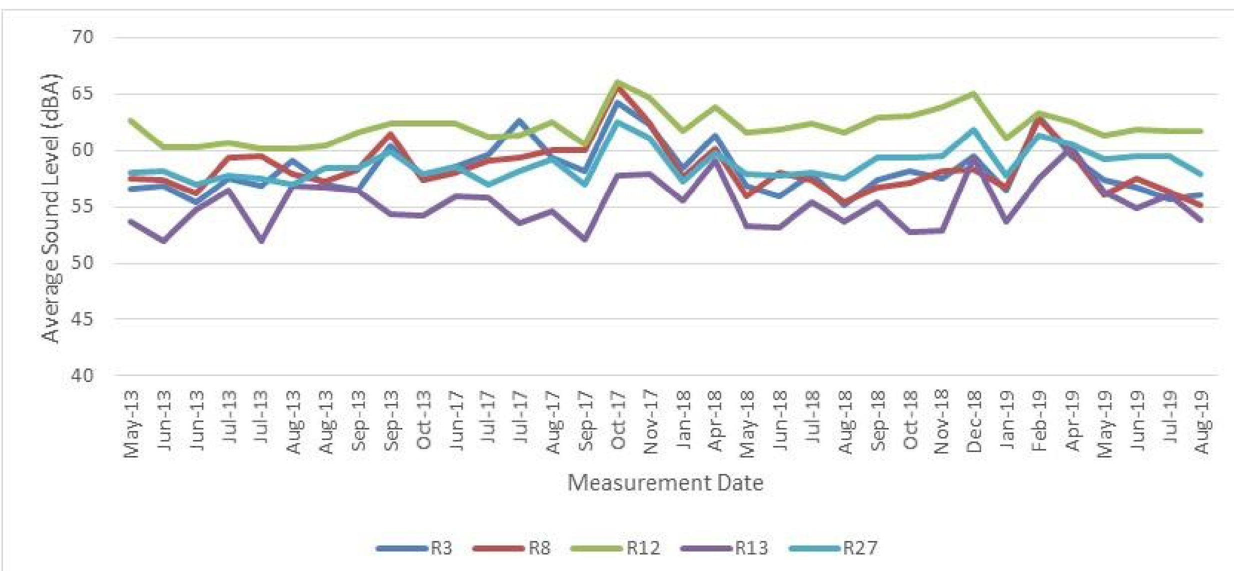



*Figure 7.7 Average noise levels for Site 2 locations by measurement date*

Similarly, for Site 2, Figure 7.7 shows that location R12 is consistently the loudest, and it also happens to be the closest location to the highway, among the Site 2 locations, as R13 is the quietest and also the location that is farther away from I-30.

### 7.2.2. By Time of the Day

Noise measurements were taken at different times of the day and night, to account for different atmospheric conditions as well as variations in traffic patterns according to the time of the day. The measurements were grouped into three categories: morning, afternoon, and evening. For most test days, three sets of measurements were performed, each set corresponding to one of these blocks of time. The influence of the time of the day on the noise results is shown in Figure 7.8, for Site 1, and in Figure 7.9, for Site2.

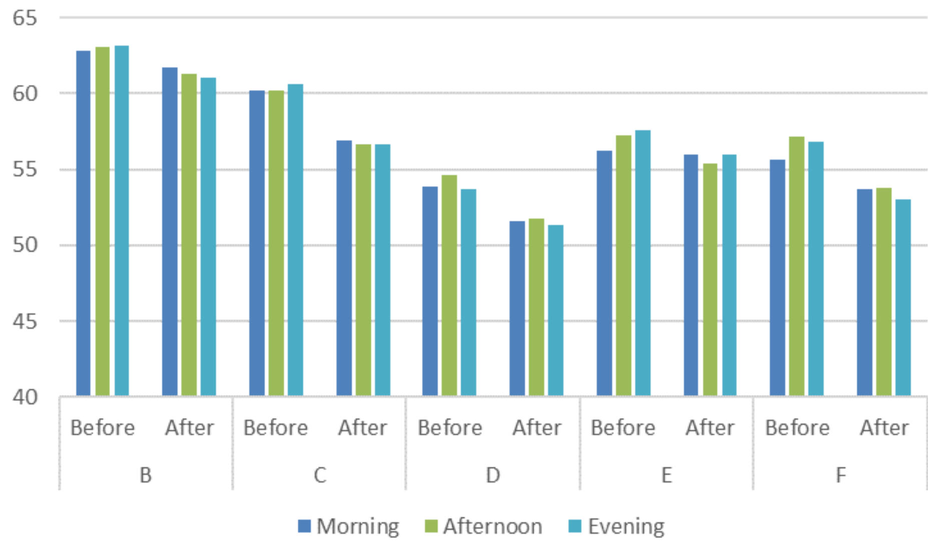



*Figure 7.8 Site 1 measurements by time of the day (before and after sound wall)*


*Figure 7.9 Site 2 measurements by time of the day (before and after sound wall)*

Both charts show minimal variation among morning, afternoon, and evening measurements within each particular test location, indicating that there is not a consistent pattern of noise levels in relation to the time of the day in which the tests are performed. For Site 1, Figure 7.8 shows that the post-barrier measurements were consistently lower than those before the barrier for each testing location, confirming that the wall has provided a reduction in noise levels. However, that is not the case for Site 2. For some of the Site 2 receivers, there is a slight reduction after the barrier was in place (R3, R8), but for others the levels stayed similar (R12, R13) or even increased (R27). Both charts also confirm that the higher levels were recorded at locations B and R12, for Site 1 and Site 2, respectively, and the lower levels correspond to locations D and R13, for Site 1 and Site 2, respectively, regardless of the time of the day.

## 7.2.3. Weather Variables

### 7.2.3.1. Temperature

The weather variable that is known to have a greater influence on tire-pavement noise generation is temperature. In general, under colder conditions, the pavement materials as well as the rubber in the tires are stiffer and produce higher noise levels than during warmer conditions. Thus, cold temperatures are correlated to higher tire-pavement noise generation (1 dBA per 10°C) *(Sandberg 2002)*. Therefore, for instance, a change from a temperature of 95°F, typical for the summer in Dallas, to a temperature of 40°F, which is very common in the winter, represents an increase of 3 dBA in tire-pavement noise generation alone, with all the other conditions staying constant. Such a difference in noise levels, attributable to temperature change only, represents a significant increase.

The relationship between noise measurements and air temperature was investigated in Figure 7.10, which includes only Site 1, before and after the noise wall was installed. As expected, the measurements were more consistent and less scattered before the wall was in place (due to the much shorter monitoring period for the pre-barrier condition: May through October 2013), whereas the variability increased in the measurements after the wall was installed. It is very noticeable that all of the measurements before the wall installation were taken in warm temperatures, between 70 and 110 °F, while the measurements after the installation correspond to a wide range of temperatures between 25 and 100 °F.

The average temperature for the tests before the barrier was 90.1 °F, with an average noise level of 58.2 dBA, whereas for the post-barrier tests, the average temperature was 75.0 °F, with an average noise level of 55.8 dBA. This indicates that, despite the high temperature differential, the barrier has provided important benefits. A flaw of this data set, due to the time in which the project started, is that there were no tests conducted in cold weather for the pre-barrier condition. The assumption is that the noise levels for cold-weather conditions before the barrier would have been much higher than 58.2 dBA, and this would have made the barrier's benefit more obvious.

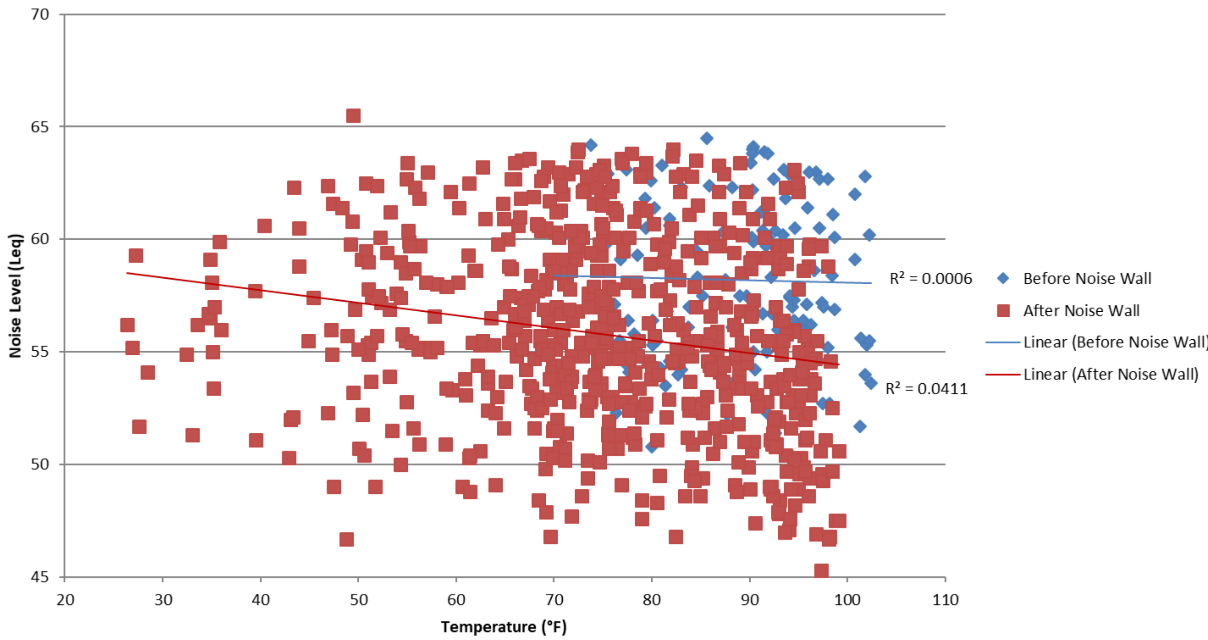



*Figure 7.10 Noise level and temperature for Site 1*

The plot in Figure 7.10 indicates that temperature and noise levels are correlated (higher temperatures corresponding to low noise, and vice versa) but the correlations are weak, especially for the data collected before the wall was in place (probably due to the limited size of the data set).

The statistics for temperature and noise levels for Site 1 are shown comparatively in Table 7.1, for measurements before and after the wall installation. It is interesting to note the variability of the temperature and noise levels, especially after the wall was installed.

**Table 7.1 Statistics for temperature and noise level for Site 1**

| | Before Wall | | After Wall | |
|---|---|---|---|---|
| | Temperature (°F) | $L_{eq}$ (dBA) | Temperature (°F) | $L_{eq}$ (dBA) |
| Mean | 89.0 | 58.2 | 75.0 | 55.8 |
| Standard Deviation | 8.1 | 3.5 | 15.2 | 4.2 |
| Median | 90.5 | 57.8 | 72.4 | 55.5 |
| Mode | 81.8 | 55.5 | 74.8 | 52.8 |
| C.V. (%) | 9.1 | 6.1 | 20.3 | 7.5 |
| Minimum | 70.0 | 50.4 | 26.4 | 45.3 |
| Maximum | 102.4 | 64.5 | 99.1 | 65.5 |
| Range | 32.4 | 14.1 | 72.7 | 20.2 |
| Count | 130 | 130 | 646 | 646 |

An analogous plot for Site 2 is presented in Figure 7.11. This plot shows a better correlation between noise and temperature.

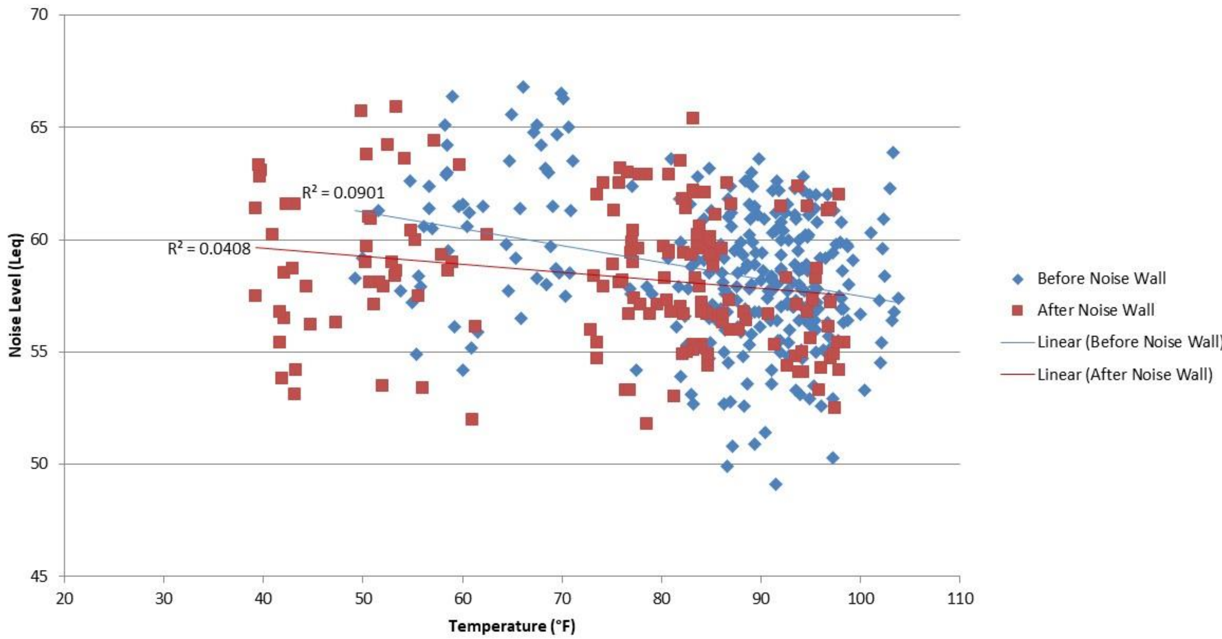



*Figure 7.11 Noise level and temperature for Site 2*

The statistics for temperature and noise levels for Site 2 are shown comparatively in Table 7.2, for measurements before and after the wall installation.

**Table 7.2 Statistics for temperature and noise level for Site 2**

| | Before Wall | | After Wall | |
|---|---|---|---|---|
| | Temperature (°F) | $L_{eq}$ (dBA) | Temperature (°F) | $L_{eq}$ (dBA) |
| Mean | 85.8 | 58.6 | 74.5 | 58.4 |
| Standard Deviation | 12.6 | 3.1 | 17.7 | 3.1 |
| Median | 89.4 | 58.4 | 80.8 | 58.3 |
| Mode | 91.1 | 56.4 | 83.2 | 56.7 |
| C.V. (%) | 14.7 | 5.3 | 23.8 | 5.3 |
| Minimum | 49.2 | 49.1 | 39.2 | 51.8 |
| Maximum | 103.9 | 66.8 | 98.4 | 65.9 |
| Range | 54.7 | 17.7 | 59.2 | 14.1 |
| Count | 289 | 289 | 163 | 163 |

Figure 7.12 presents a plot of the same variables, but for both Site 1 and Site 2 together. With a larger data set the correlations between noise levels and temperature are higher.

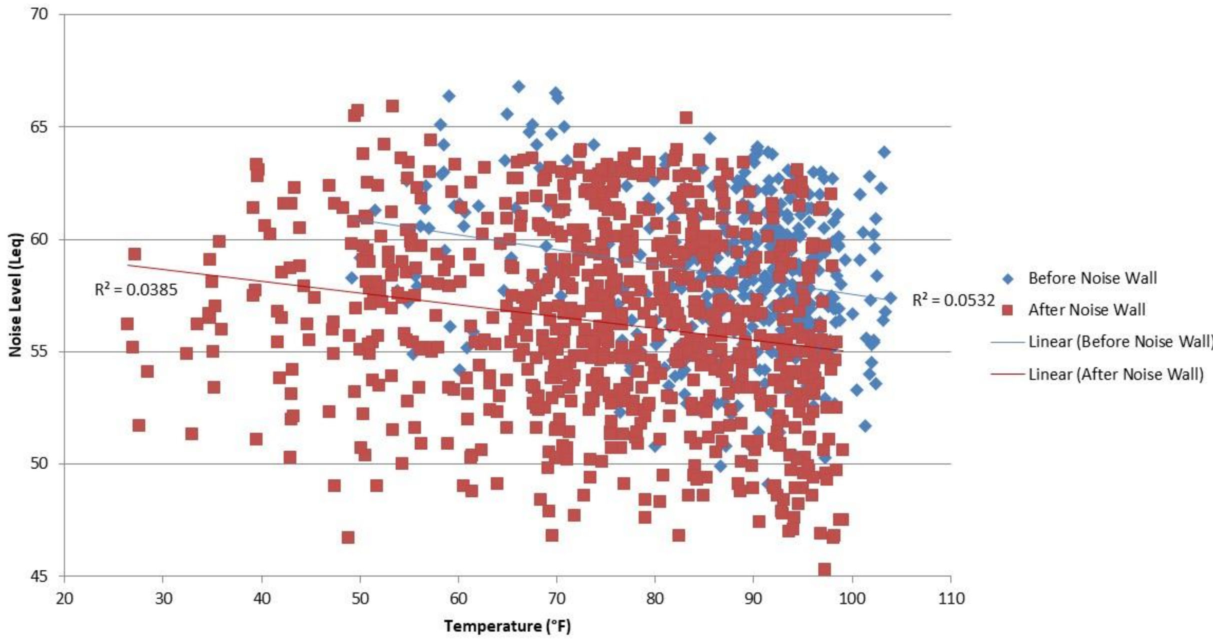



*Figure 7.12 Noise level and temperature for Site 1 and Site 2 together*

### 7.2.3.2. Wind

The wind and its direction were expected to be important factors influencing the noise levels reached at the neighborhood residential locations. According to residents' accounts, the noise problem was exacerbated by strong winds blowing from the north and carrying the noise from the highway towards the residential area.

#### *7.2.3.2.1. Wind Speed*

Considering only the magnitude of the wind speed, the large amount of data collected at the various locations does not confirm the hypothesis of the wind influencing the noise. Neither the average wind speed nor the higher wind speeds (gusts) provide a strong correlation with noise levels. Figure 7.13 shows a plot of noise levels and wind speed (Site 1 and Site 2 together), in which each data point corresponds to a noise measurement and the average wind speed that was obtained by the weather station during the noise measurement. It shows both before and after noise wall measurements for both sites and the two weak correlations are not consistent in indicating whether higher noise levels occurred with higher winds. In fact, for the post-barrier condition, the correlation indicates that higher winds are associated with lower noise levels. Similarly, Figure 7.14 presents the relationship between noise levels and high wind speeds (gusts), showing poor correlations as well, indicating no influence of the gusts on noise levels measured at the neighborhood, without considering the wind direction yet.

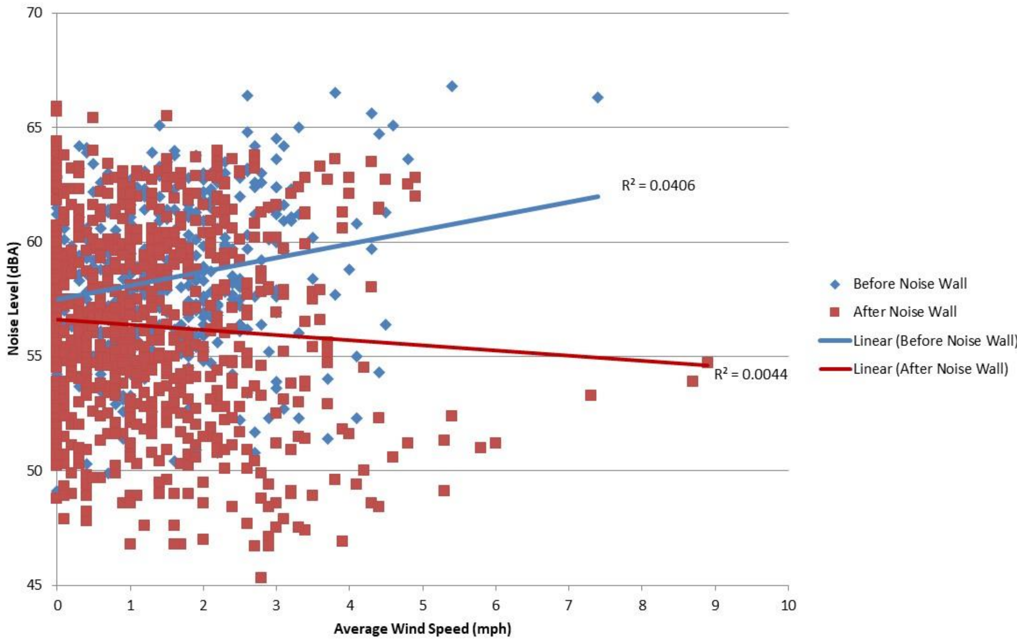



*Figure 7.13 Noise level and average wind speed*

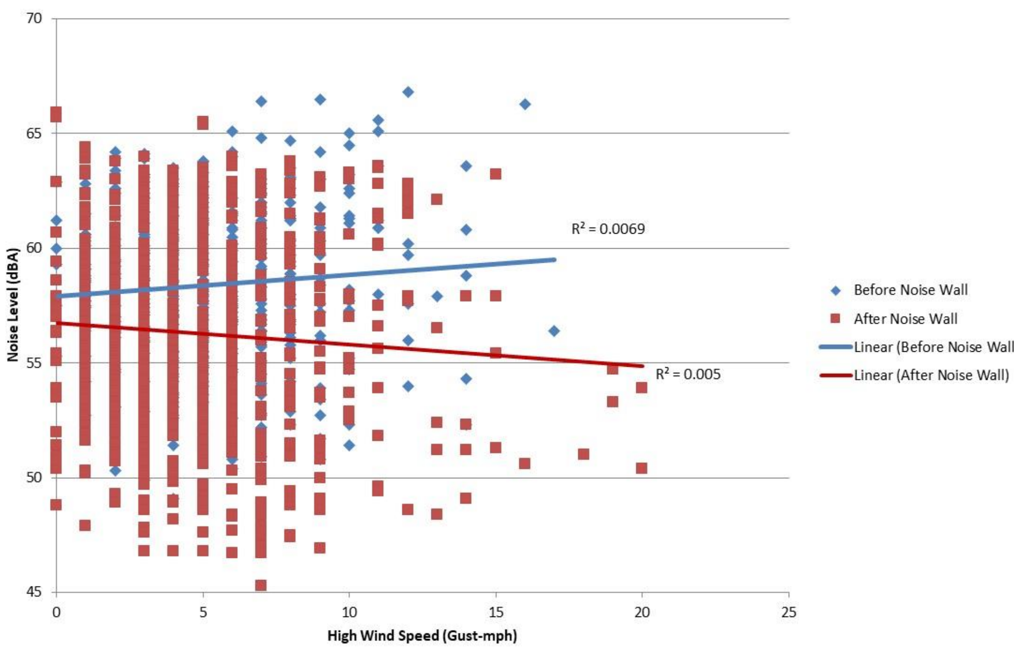



*Figure 7.14 Noise level and high wind speed*

### *7.2.3.2.2. Wind Direction*

For the wind direction analysis, given that throughout each test period for an individual test the wind direction commonly fluctuates, the dominant wind direction for each test is considered to be that of the highest gust within that period. Therefore, for each test there is an average noise level, an average wind speed, a high wind speed (gust), and a high wind direction. The average wind speed is a scalar, whereas the gust is a vector. For this analysis, a 16-point compass rose is utilized. This means that there are 16 wind directions considered: the four cardinal directions north (N), east (E), west (W), and south (S); the four intercardinal directions, formed by bisecting the angle of the cardinal directions—northeast (NE), southeast (SE), southwest (SW), and northwest (NW); and the eight half-winds, i.e., the direction points obtained by bisecting the angles between the previous directions: north-northeast (NNE), east-northeast (ENE), east-southeast (ESE), south-southeast (SSE), south-southwest (SSW), west-southwest (WSW), west-northwest (WNW), and north-northwest (NNW). Each of these 16 directions forms a 22 ½° angle with the adjacent direction in the wind rose (Figure 7.15). Therefore, all the data for this wind direction analysis are grouped and averaged for each of those 16 directions.

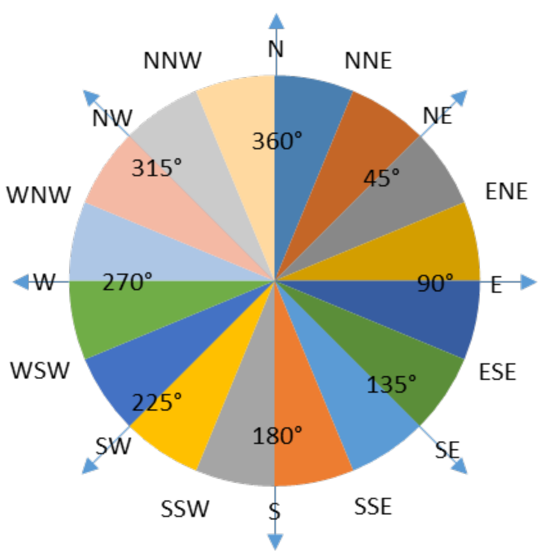



*Figure 7.15 16-point compass rose*

Due to the large amount of data collected, in order to facilitate the analysis, the results are grouped in four categories:

- Site 1-before the barrier
- Site 1-after the barrier
- Site 2-before the barrier
- Site 2-after the barrier

The results of the wind direction analysis are shown in a group of four charts. The first chart (labeled as "a") shows the percentage of the tests associated with each wind direction. In the second chart (b), the average noise levels were plotted with the wind direction of the gust as well as the gust speed. Finally, in the third (c) and fourth (d), the gust levels were plotted against the average noise levels, with (c) showing the values for each wind direction, and (d) showing the correlation. Therefore, the data points for (c) and (d) are identical.

The charts are shown in Figures 7.16, 7.17, 7.18, and 7.19, for Site 1-before the barrier, Site 1-after the barrier, Site 2-before the barrier, and Site 2-after the barrier, respectively.

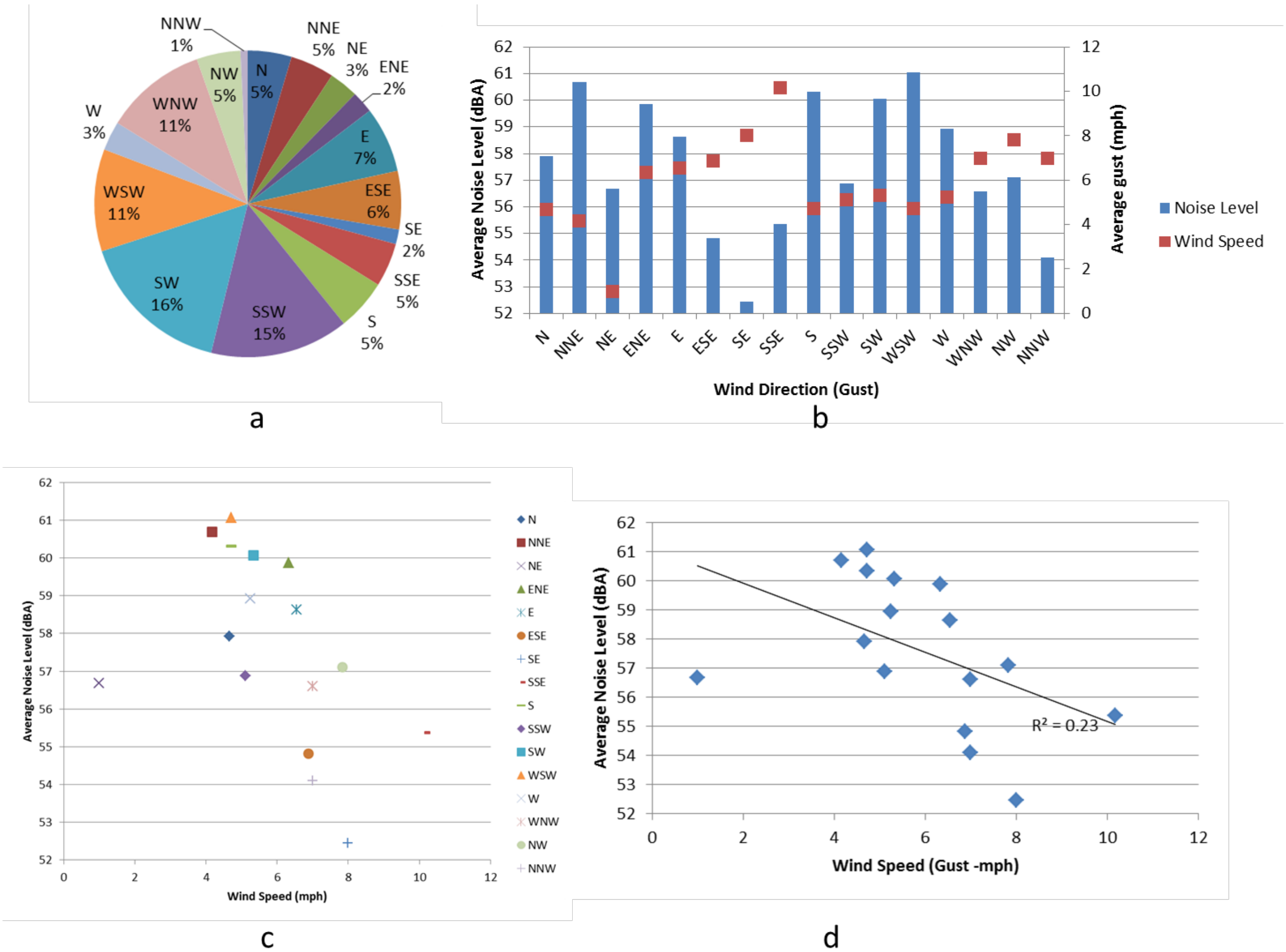
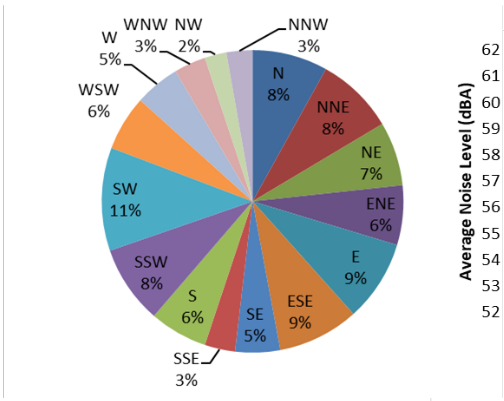
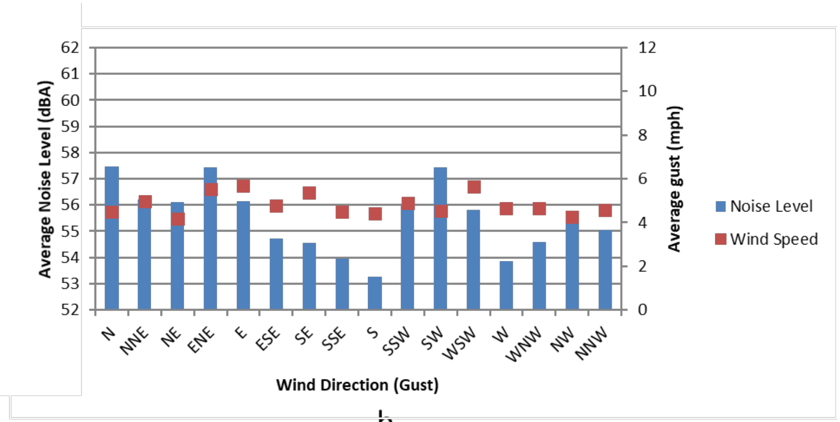



*Figure 7.16 Site 1 before barrier: a) Dominant wind direction by percentage of time; b) Average noise levels and average gusts by direction; c) Average noise level vs. average gust by direction; and d) Average noise level and average gust correlation*

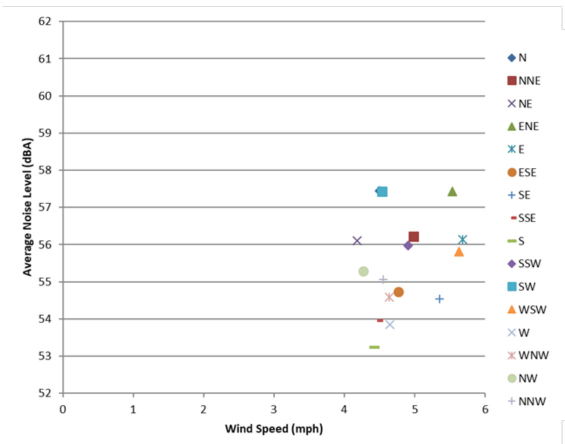
For Site 1 in the pre-barrier condition, the majority of the time (16%) the gusts blew from the SW direction, with the SSW being the second most dominant gust direction (15%) (Figure 7.16 a). However, the highest average noise level (61.1 dBA) occurred when the gusts blew from the WSW direction (Figure 7.16 b and c). The lowest average noise level (52.5 dBA) occurred when the dominant wind came from the SE, which is reasonable, considering that the wind coming from that direction will carry the noise away from the neighborhood, and the average wind speed for the gusts was 8 mph, which is relatively high, and this is also reasonable (Figure 7.16 b and c). The correlation between gust speeds and average noise levels is poor and shows that louder noise levels happened with lower gusts, and vice versa (Figure 7.16 d).



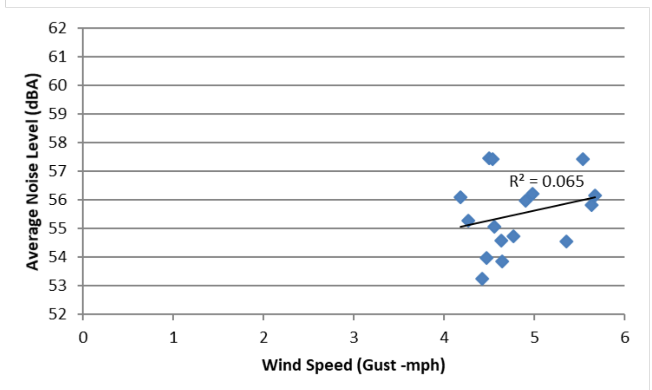

a




b




c




d

*Figure 7.17 Site 1 after barrier: a) Dominant wind direction by percentage of time; b) Average noise levels and average gusts by direction; c) Average noise level vs. average gust by direction; and d) Average noise level and average gust correlation*

For Site 1 in the post-barrier condition, the most dominant gust direction was SW (11%) (Figure 7.17 a). However, the highest average noise level (57.5 dBA) occurred when the gusts blew from the north (Figure 7.17 b and c), which is reasonable and in agreement with residents' experiences about high noise levels with winds coming from the north. The correlation between gust speeds and average noise levels is positive and shows that louder noise levels happened with higher gusts (Figure 7.17 d), which is also reasonable.

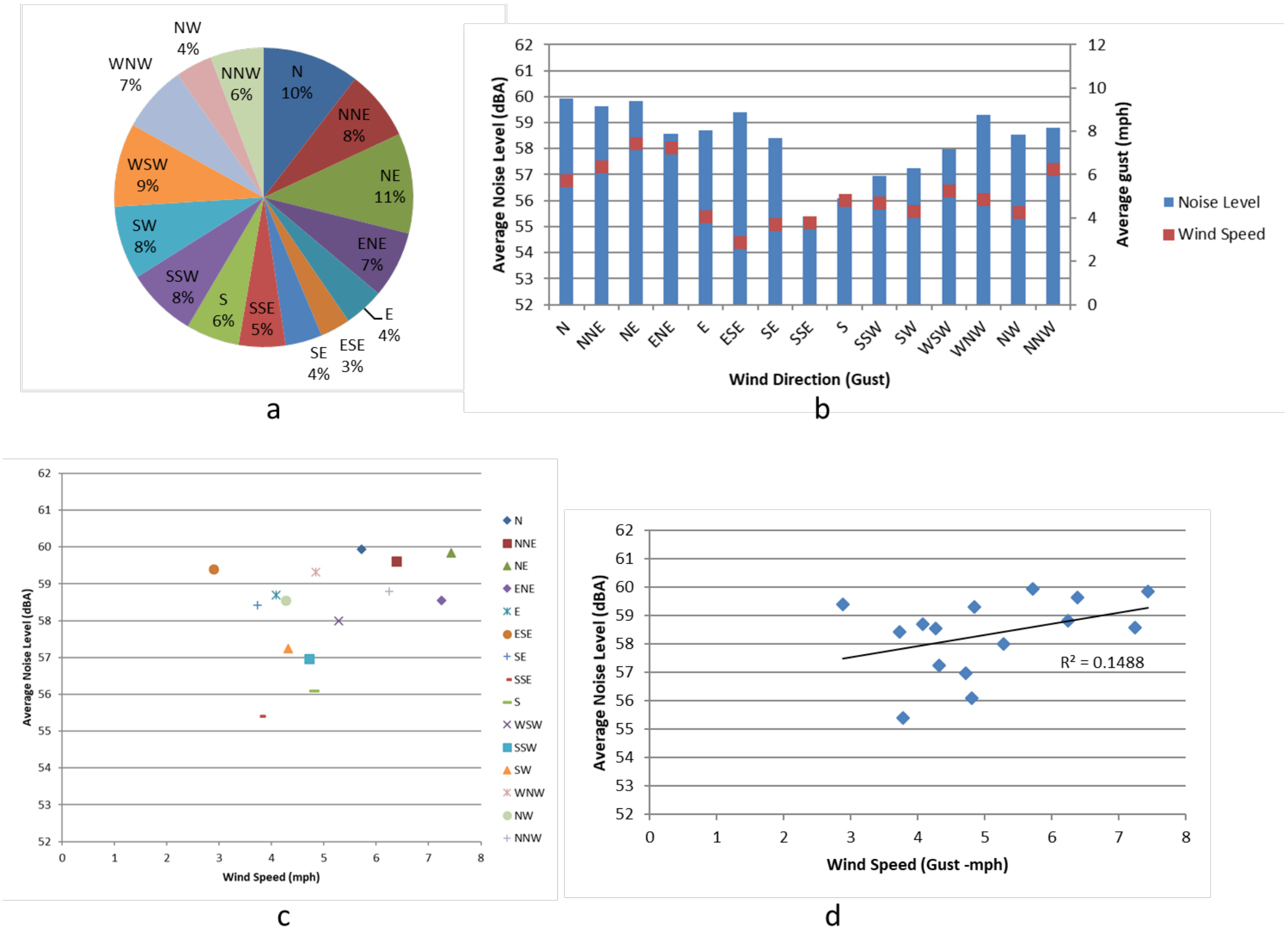



*Figure 7.18 Site 2 before barrier: a) Dominant wind direction by percentage of time; b) Average noise levels and average gusts by direction; c) Average noise level vs. average gust by direction; and d) Average noise level and average gust correlation*

For Site 2, for the pre-barrier condition (Figure 7.18), there is some positive correlation between gusts and noise levels, indicating that for the higher gust speeds corresponded higher noise levels (Figure 7.18 d). The dominant wind direction was NE (11%), followed closely by the N (10%) (Figure 7.18 a). The higher average noise levels (59.9 dBA) occurred when the gusts blew from the N (Figure 7.18 b and c), which also agrees with the aforementioned residents' experiences.

Finally, for Site 2 after the barrier was in place, the results are presented in Figure 7.19. The dominant wind direction was NE (11%) (Figure 7.19 a); the higher average noise levels (60.1 dBA) occurred in conjunction of winds from the north (Figures 7.19 b and c), and there is no correlation between gust speeds and noise levels in this case (Figure 7.19 d).

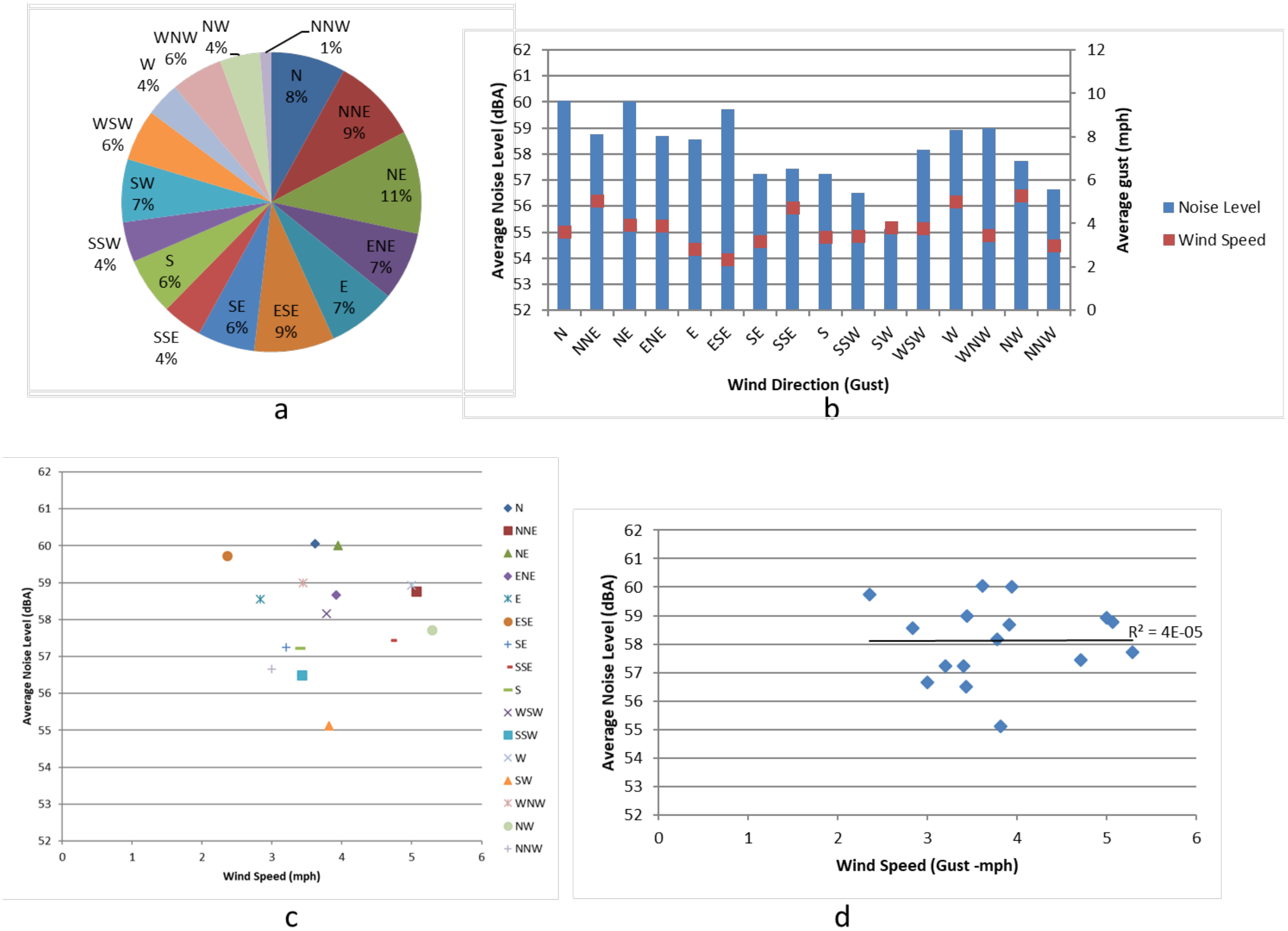



*Figure 7.19 Site 2 after Barrier: a) Dominant wind direction by percentage of time; b) Average noise levels and average gusts by direction; c) Average noise level vs. average gust by direction; and d) Average noise level and average gust correlation*

In summary, the wind direction has a positive correlation with the noise at the neighborhood locations for the Site 1 post-barrier condition and for the Site 2 measurements for the pre-barrier condition only.

### 7.2.3.3. Relative Humidity

The measurements for relative humidity were fairly uniform for the pre- and post-barrier conditions. The mean value was 52%. The correlation with noise levels in both cases is negligible (Figure 7.20) and very similar, showing that this weather variable had no influence on the noise measurements.

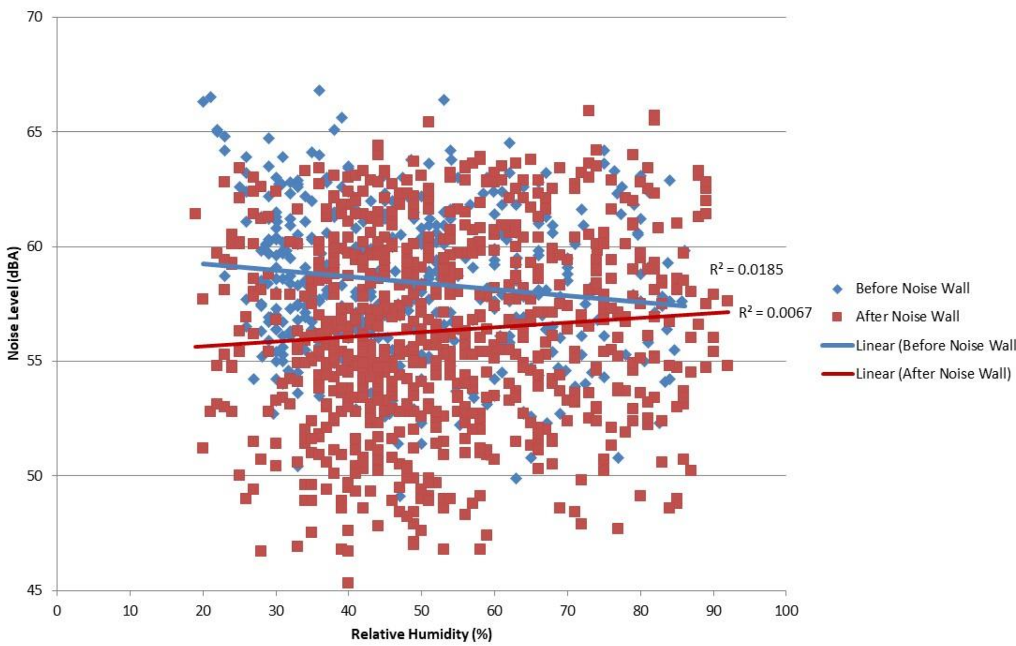



*Figure 7.20 Noise level and relative humidity*

Table 7.3 summarizes the analysis of weather variables, presenting the descriptive statistics for Site 1, showing data separately for pre- and post-barrier conditions.

**Table 7.3 Statistics for weather variables and noise level for Site 1**

| | Before Wall | | | | | After Wall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature (°F) | Relative Humidity | Avg. Wind Speed | Max. Wind Speed | $L_{eq}$ (dBA) | Temperature (°F) | Relative Humidity | Avg. Wind Speed | Max. Wind Speed | $L_{eq}$ (dBA) |
| Mean | 89.0 | 52.8 | 1.6 | 5.8 | 58.2 | 75.0 | 52.0 | 1.4 | 4.9 | 55.8 |
| Standard Deviation | 8.1 | 19.1 | 1.1 | 3.1 | 3.5 | 15.2 | 16.3 | 1.2 | 3.2 | 4.2 |
| Median | 90.5 | 50.2 | 1.4 | 5 | 57.8 | 75.2 | 49.0 | 1.2 | 4.0 | 55.5 |
| Mode | 81.8 | 33.0 | 0.4 | 7 | 55.5 | 74.8 | 42.0 | 0.0 | 4.0 | 52.8 |
| C.V. (%) | 9.1 | 36.2 | 68.2 | 52.8 | 6.0 | 20.3 | 31.3 | 88.6 | 65.8 | 7.5 |
| Minimum | 70.0 | 26.0 | 0.0 | 0 | 50.4 | 26.4 | 19.0 | 0.0 | 0.0 | 45.3 |
| Maximum | 102.4 | 86.1 | 4.5 | 17 | 64.5 | 99.1 | 92.0 | 8.9 | 20.0 | 65.5 |
| Range | 32.4 | 60.1 | 4.5 | 17 | 14.1 | 72.7 | 73.0 | 8.9 | 20.0 | 20.2 |
| Count | 130 | 130 | 130 | 130 | 130 | 646 | 646 | 646 | 646 | 646 |

Table 7.4 summarizes the analysis of weather variables, presenting the descriptive statistics for Site 2, for pre- and post-barrier conditions.

**Table 7.4 Statistics for weather variables and noise level for Site 2**

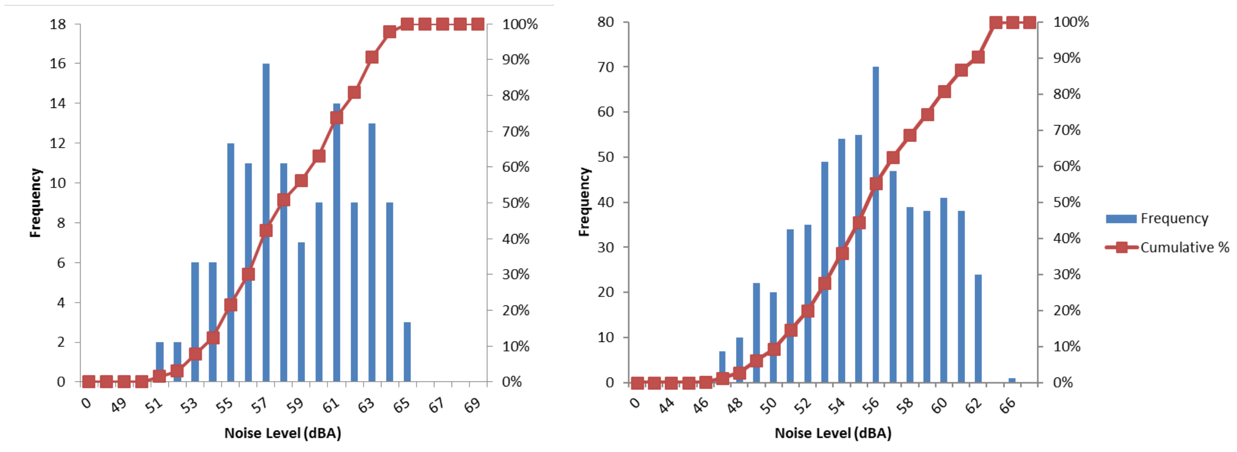
| | Before Wall | | | | | After Wall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature (°F) | Relative Humidity | Avg. Wind Speed | Max. Wind Speed | $L_{eq}$ (dBA) | Temperature (°F) | Relative Humidity | Avg. Wind Speed | Max. Wind Speed | $L_{eq}$ (dBA) |
| Mean | 85.8 | 46.8 | 1.5 | 5.4 | 58.6 | 74.5 | 55.3 | 0.9 | 3.8 | 58.4 |
| Standard Deviation | 12.6 | 14.2 | 1.1 | 2.8 | 3.2 | 17.7 | 16.5 | 1.0 | 2.7 | 3.1 |
| Median | 89.4 | 45.0 | 1.4 | 5 | 58.4 | 80.8 | 51 | 0.7 | 3 | 58.3 |
| Mode | 91.1 | 30.0 | 2.0 | 4 | 56.4 | 83.2 | 42 | 0 | 1 | 56.8 |
| C.V. (%) | 14.7 | 30.3 | 71.2 | 51.9 | 5.4 | 23.7 | 29.9 | 107.2 | 71.4 | 5.3 |
| Minimum | 49.2 | 20.0 | 0.0 | 0 | 49.1 | 39.2 | 30 | 0 | 0 | 51.8 |
| Maximum | 103.9 | 84.0 | 7.4 | 16 | 66.8 | 98.4 | 90 | 4.9 | 15 | 65.9 |
| Range | 54.7 | 64.0 | 7.4 | 16 | 17.7 | 59.2 | 60 | 4.9 | 15 | 14.1 |
| Count | 289 | 289 | 289 | 289 | 289 | 163 | 163 | 162 | 162 | 163 |

## 7.2.4. Pre- and Post-Barrier Analysis

In this section, the effectiveness of the barriers is analyzed using the before and after noise level residential measurements and applying a t-test.

### 7.2.4.1. t-test

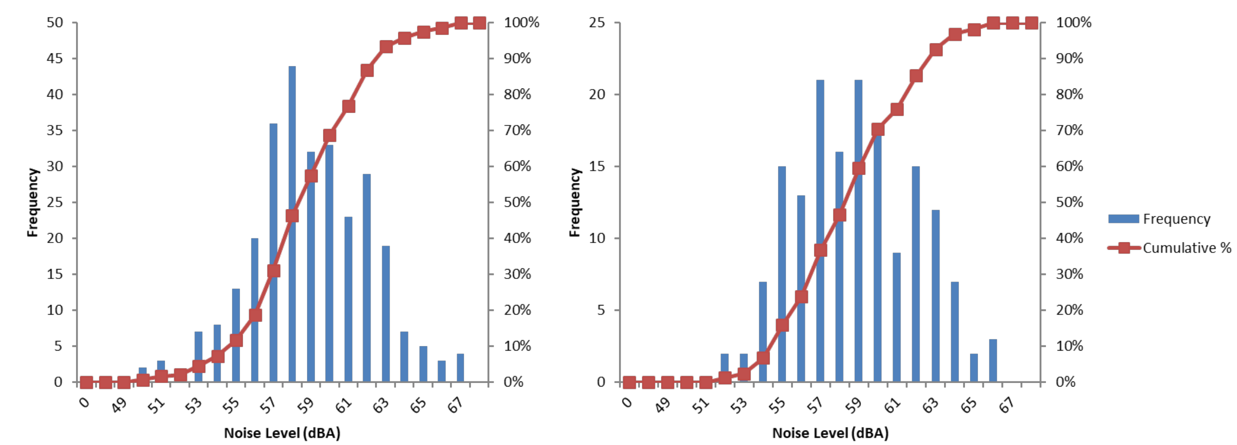
The first part of this analysis of the barrier's effectiveness involves a comparison of the noise levels before and after the barriers were in place and determining whether the differences between the pre- and post-barrier conditions are significant. Therefore, separate analyses are conducted for Site 1 and Site 2. A t-test is used to determine if two sets of data are significantly different from each other. The test assumes that the variables being studied—in this case, measured noise levels—follow a normal distribution. The distribution of measured noise levels for both the pre- and post-barrier for Site 1 tests are shown in Figure 7.21, along with their histograms.




a b

*Figure 7.21 Site 1 frequency distribution for pre-barrier (a) and post-barrier (b) tests*

Similarly, the distribution of measured noise levels for both the pre- and post-barrier for Site 2 tests are shown in Figure 7.22, as well as their histograms.




a b

*Figure 7.22 Site 2 frequency distribution for pre-barrier (a) and post-barrier (b) tests*

The frequency distributions for both Site 1 and Site 2, before and after the barriers, look to follow a normal distribution. Even though the shapes in all four plots for frequency and cumulative frequency look similar, it should be noted that an obvious difference is the sizes of the datasets:

the Site 1 pre-barrier condition and the Site 2 post-barrier condition have small sample sizes than the other two datasets, especially when compared with the Site 1 post-barrier condition, for which much more time was available for the data collection.

For each of the sites data, a two-sample t-test was performed, with independent (unpaired) samples; the assumptions were equal variances, α=0.05, and a two-tailed distribution. The null hypothesis in this case is that the barrier had no effect on the measured noise levels, and the alternative hypothesis is that the barrier had an effect. If the difference between these distributions is large enough, the null hypothesis would be rejected.

Table 7.5 shows the results for the Site 1 and Site 2 data. The row containing the probability for the t-tests (p-value) is the second to last, and it has been highlighted. If the p-value is less than the significance level α, the difference in noise levels between the groups being compared is considered statistically significant; this was the case for the pre- and post-barrier noise tests for Site 1. Therefore, the null hypothesis is rejected, indicating that there is a statistically significant difference between the groups of tests; hence, the t-test supports the measurements indicating that the barrier has had indeed an effect on noise levels. However, for Site 2, the p-value is greater than the significance level α, (0.6 > 0.05); therefore, the null hypothesis is accepted, and the difference in noise levels between the groups being compared is not considered statistically significant. This means that the t-test indicates that the barrier at Site 2 did not have an effect on noise levels.

**Table 7.5 t-test for pre- and post-barrier noise levels for Site 1 and Site 2**

| | Site 1 | | Site 2 | |
|---|---|---|---|---|
| | *Before* | *After* | *Before* | *After* |
| Mean (dBA) | 58.2 | 55.8 | 58.6 | 58.4 |
| Variance | 12.588 | 15.484 | 9.896 | 9.712 |
| Observations | 130 | 646 | 289 | 163 |
| Pooled Variance | 16.919 | | 9.830 | |
| t Stat | 6.074 | | 0.505 | |
| P(T<=t) | 1.96E-09 | | 6.14E-01 | |
| t Critical | 1.963 | | 1.965 | |

### 7.2.4.2. Spectral Differences

The noise data was analyzed in one-third octave band spectra averaged throughout the pre- and post-barrier testing periods for each location. This analysis illustrates the distribution of noise levels before and after the barrier, among the different frequencies. The graphs for Site 1 are shown in Figure 7.23. Locations C and D show the higher difference between pre- and post-barrier spectra, showing the benefits of the barrier. Location C—the site with the greatest acoustic benefit from the barrier, but also the loudest one with and without barrier—has higher noise levels at the lower frequencies. This is due perhaps to the location's proximity to the highway; with the barrier, this location gets important reduction in the frequencies between 500 and 1250 Hz. Location D gets higher benefits from the wall in the middle and higher frequencies. Location E is the one that shows more similarity between the pre- and post-barrier spectra. Locations D and F, the more distant sites from the highway, have lower levels, and a peak at 3150 Hz, which is more prominent for Location F.

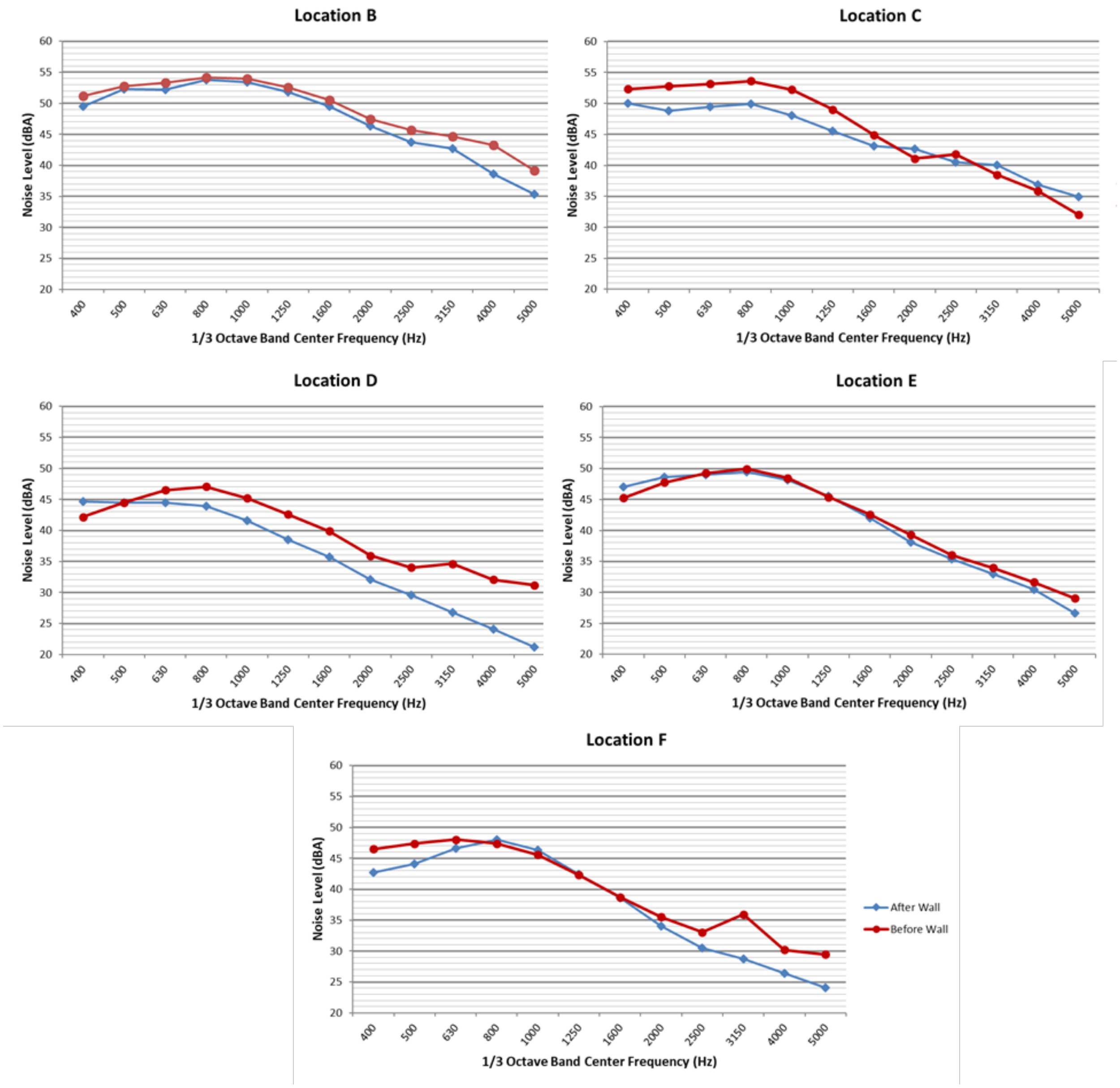



*Figure 7.23 Average frequency spectra for Site 1 locations for pre-barrier and post-barrier tests*

The graphs for Site 2 are shown in Figure 7.24. Unlike the charts for Site 1, these graphs show that for all locations, the after-barrier spectra have higher levels for the low and mid-frequencies than the pre-barrier spectra, and this is more pronounced for Location R3, R8, and R27. On the other hand, the barrier reduced the noise more in the higher frequencies at all locations.

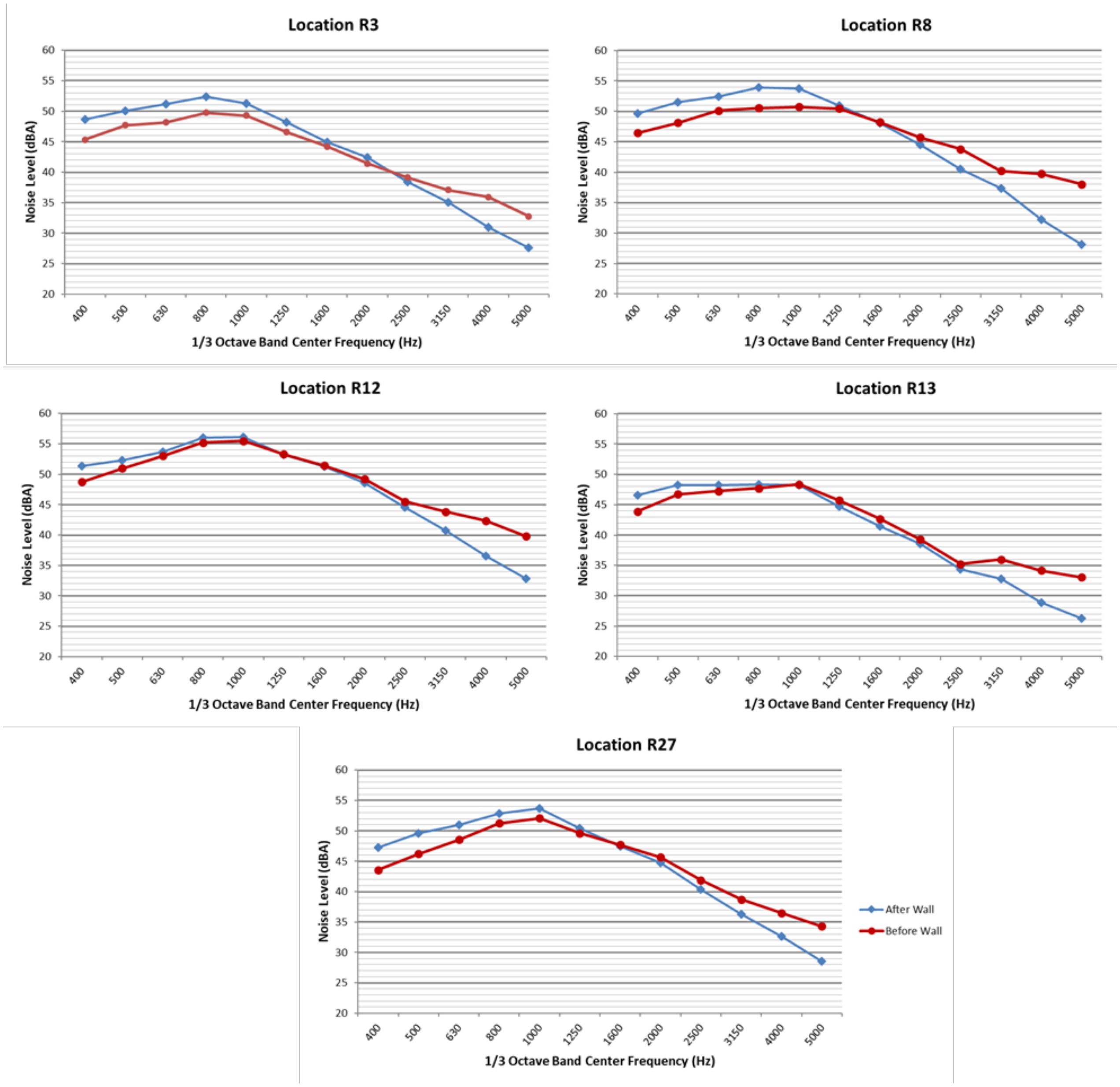



*Figure 7.24 Average frequency spectra for Site 2 locations for pre-barrier and post-barrier tests*

## 7.3. Summary and Discussion of Results

This chapter presents the data analysis for before and after the barrier conditions for both sites of the I-30 sound walls. The measurements analyzed comprise tests conducted from May 2013 until August 2019. The tests show that all locations on Site 1 have received some benefit from the noise wall. Although the average benefits may seem acoustically small for most locations, the t-test showed that they are statistically significant, confirming that the barrier has had an effect on noise levels. For Site 2, some of the locations received some benefits, but in others the noise levels increased after the wall was in place, which indicates that the noise generation actually increased, possibly due to an increase in traffic, and also because of the degradation of the pavement, which was evident in the last years of the project and was confirmed by on-board sound intensity tests.

Weather variables—primarily temperature and wind direction—appeared to have influenced the noise levels. The various times of the day during which the tests are performed—morning, afternoon, and evening—seemed to have no impact on noise levels. It would have been desirable to have a longer data collection period for the pre-barrier condition at Site 1, to include the colder part of the year, as all the tests for this condition were conducted during the warmer months of the year (May through October); similarly, a longer data collection period for the post-barrier phase for Site 2 would have been ideal.

# Chapter 8. Site 1 Monitoring

This chapter presents the results of field inspections performed at Site 1's transparent sound wall, as part of the research work conducted on the elevated highway structure on I-30 in Dallas. The work consisted of periodic monitoring of the wall, which extends from Edgefield Avenue to Sylvan Avenue, in the vicinity of the Kessler Park neighborhood, an area affected by the highway noise from I-30. The monitoring started when the Site 1 noise barrier installation began, and continued after the wall's completion until August 2017; this chapter covers all the monitoring activities, which consisted of visual inspecting the wall, documenting its status, and photographing visible defects. The research team documented any special measures needed following physical damage to the lightweight barriers after the noise wall installation and reported any damages or defects to the District personnel.

## 8.1. Sound Wall Installation

The noise barrier installation on I-30 in Dallas for the segment between Edgefield Avenue and Sylvan Avenue began in September 2013 and concluded by mid-October 2013. The wall consists of transparent acrylic panels, made of a material called Acrylite, manufactured by Evonic, which are 15-mm thick, 7-ft wide, and 10-ft tall, placed on top of the existing 8-ft tall concrete barrier on the south side of I-30. Some panels are narrower to allow for the expansion joints of the elevated structure; those are 4-ft wide instead of 7-ft wide. Also, at the easternmost end of the barrier, over Sylvan Avenue, the last few panels are 13-ft tall, as the existing concrete barrier is shorter. The total length of the wall is 2,395 ft.

The project was bid at $885,000. With a surface area of 23,950 sq ft, the cost per unit area is approximately $37/sq ft. The bid tabulations for the job show the cost per unit area for the winning bidder to be $35.89/sq ft because the bid did not account for traffic control, barricades, etc.

The installation took place at night (Figures 8.1 and 8.2). Work required one-lane closures between 10:00 p.m. and 6:00 a.m. only. The contractor performing the installation was Highway Intelligent Traffic Solutions, Inc., and the transparent material and structural design for the wall were provided by Armtec.

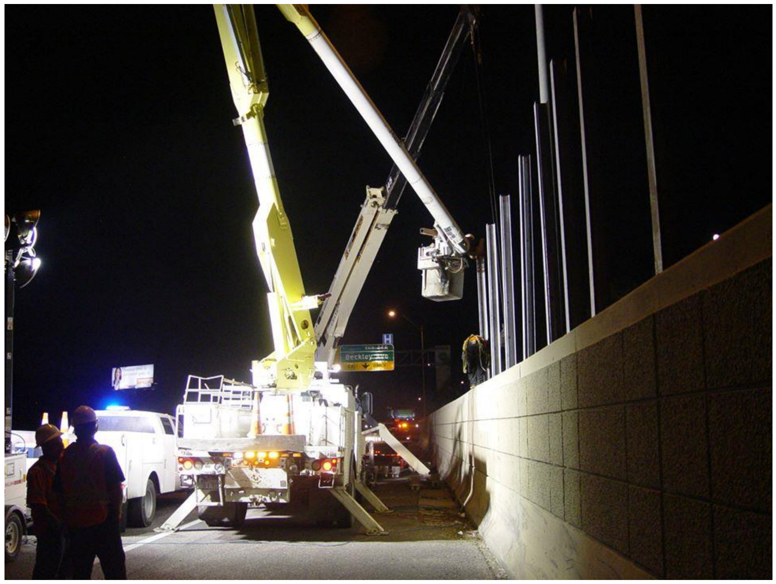


*Figure 8.1 Nighttime installation*

*Figure 8.2 Vertical support placement*

Some images of the completed wall are shown in Figures 8.3 to 8.8.


*Figure 8.3 Sound wall as seen from Edgefield Avenue Bridge*

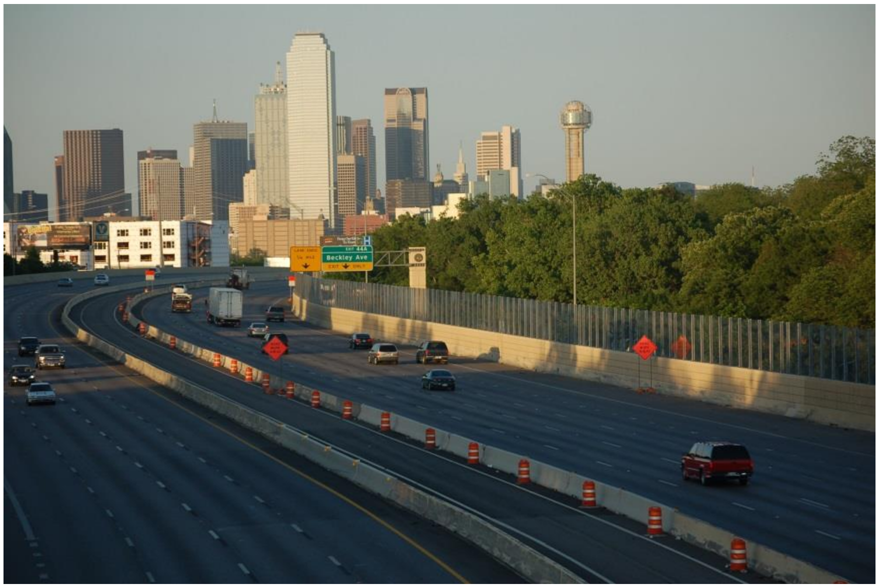



*Figure 8.4 Sound wall as seen from Edgefield Avenue Bridge*

*Figure 8.5 Sound wall as seen from Edgefield Avenue Bridge*

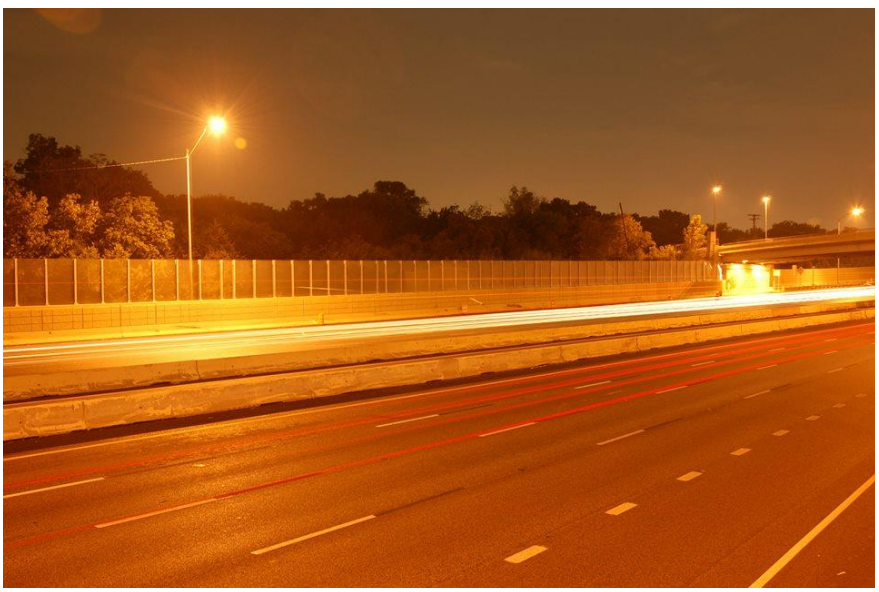


*Figure 8.6 Sound wall as seen from westbound I-30*

*Figure 8.7 Sound wall as seen from westbound I-30 looking towards Edgefield Avenue Bridge*

*Figure 8.8 Sound wall as seen from westbound lanes looking towards downtown*

A few problems were noticed before the completion of the installation, such as some supports not being completely vertical (Figures 8.9 and 8.10), some apparently missing rubber gaskets between panels and the metal supports, some gaskets slightly out of place (Figure 8.11), as well as some gaps between gaskets and metal supports, both for vertical and horizontal gaskets (Figures 8.12 and 8.13).

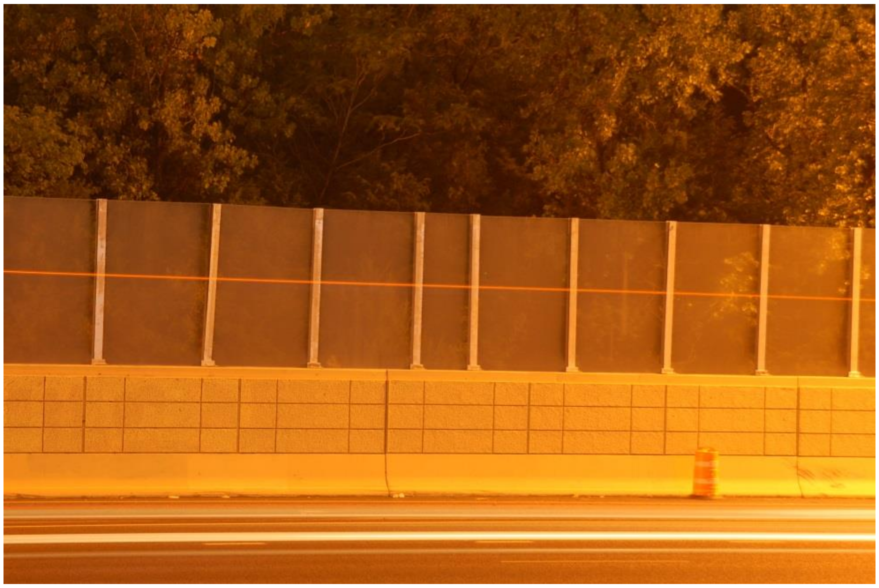


*Figure 8.9 Some vertical supports off-plumb*

*Figure 8.10 Vertical support off-plumb*

*Figure 8.11 Gasket protruding from metal support*


*Figure 8.12 Gap between vertical gasket and metal support*


*Figure 8.13 Gap between horizontal gasket and metal support*

CTR spoke with Mr. Mark McIlheran, P.E., structural engineer from Armtec, about some of these defects. He suggested CTR meet with him and Mr. George Reeves, from TxDOT, to inspect the wall so that CTR could show the location of some of these issues. On October 28, 2013, CTR's

Manuel Trevino met with Mr. McIlheran and Mr. Reeves at the site (Figure 8.14) and inspected the wall, both from the Edgefield Avenue Bridge and walking along the wall from the eastbound-side shoulder of I-30. Mr. McIlheran said he would contact the contractor, Highway Intelligent Traffic Solutions, to fix the off-plumb posts, the gaskets apparently missing or out of place, and a panel that is warping because the vertical supports are too tight and off-plumb for one of the spans of the wall.

*Figure 8.14 Armtec's Mark McIlheran inspecting the wall, showing the gap size between a panel and the gasket*

Attending this request, the contractor fixed some of the problems at no cost to TxDOT, such as the off-plumb posts and the missing gaskets.

Additionally, some gaps were observed in the existing concrete wall at the expansion joints of the bridge (Figures 8.15 and 8.16), gaps that should be filled with some elastic joint sealing material allowing for the bridge's thermal expansion and contraction. Such material should prevent the sound from traveling from the highway to the neighborhood to further attenuate the noise at the receivers' locations and contribute to the wall's effectiveness. This would be TxDOT's responsibility, as it is not an issue of the transparent noise wall, but rather of the existing structure.

The gaps between gaskets and frames and the gaps in the concrete wall are important elements of concern in regard to the acoustical performance of the wall, as any opening will hinder the wall's effectiveness.

*Figure 8.15 Gap in existing concrete wall at bridge expansion joint as seen from Coombs Creek*

*Figure 8.16 Gap in existing concrete wall at bridge expansion joint as seen from the highway side*

## 8.2. Graffiti

On November 11, 2013, while performing the wall inspection, it was noticed that some of the panels had been damaged by graffiti. Ten transparent panels, from spans # 135 to 144 (as marked by the contractor on the concrete wall during installation) were sprayed with paint. The concrete wall under span # 144 was also painted. From the distance, the damage was barely noticeable, and from some angles, it was not visible at all. However, when seen from the proximity of the eastbound shoulder and at walking speed the paint was very noticeable. The appearance of the sprayed material was that of some type of drywall mud or acoustic texture that is used in ceilings.

Pictures of the graffiti are shown in Figures 8.17 to 8.23. The damage was reported immediately to TxDOT.


*Figure 8.17 Graffiti as seen from the highway shoulder on November 11, 2013*

*Figure 8.18 Graffiti as seen from the highway shoulder on November 11, 2013*

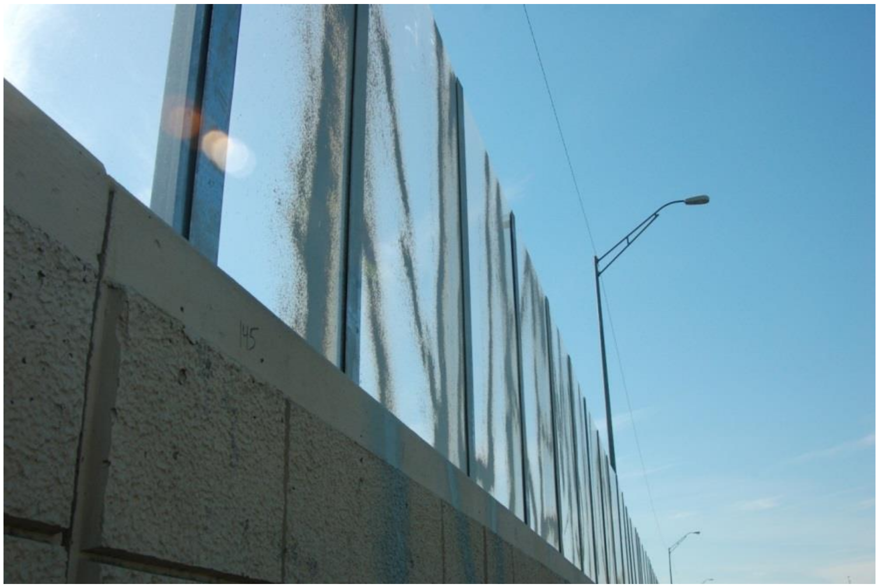


*Figure 8.19 Graffiti as seen from the highway shoulder on November 11, 2013. The damage extends to the concrete wall under span #144.*

*Figure 8.20 Graffiti as seen from the highway shoulder on November 11, 2013*

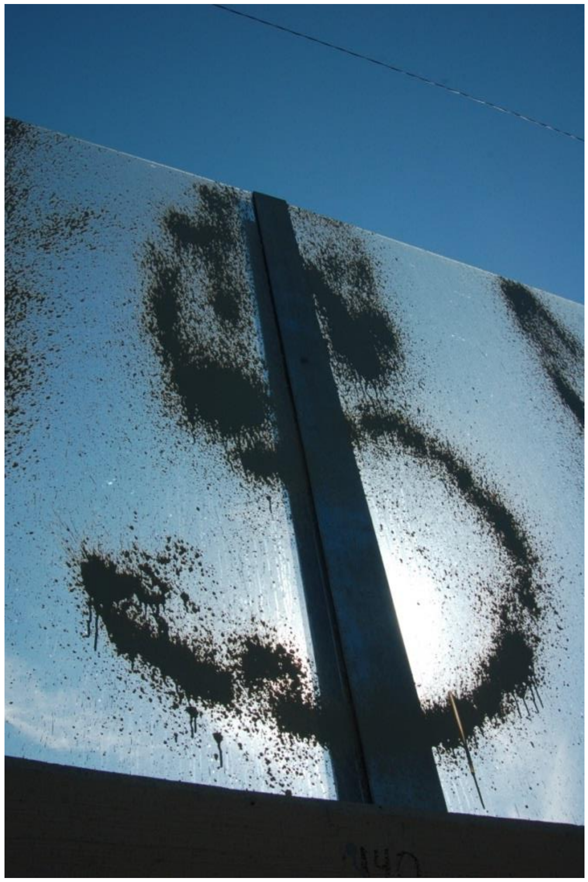


*Figure 8.21 Graffiti as seen from the highway shoulder on November 11, 2013*

*Figure 8.22 Graffiti seen from the north side of I-30*

*Figure 8.23 Graffiti seen from the north side of I-30*

During the remaining part of November and December 2013, no work was performed to clean the sound wall. By January 28, 2014, the panels had been cleaned. The following cost information for the cleaning operations was kindly provided by Mr. Frank Jett, with the Dallas District, Heavy Equipment Maintenance:

Traffic Control: $3,893.27

Steam Cleaner: $200.00

Graffiti Removal: $73.50

Total: $4,166.77

The following photographs illustrate the appearance of the cleaned acrylic panels during the January 28, 2014 site visit (Figures 8.24 and 8.25).

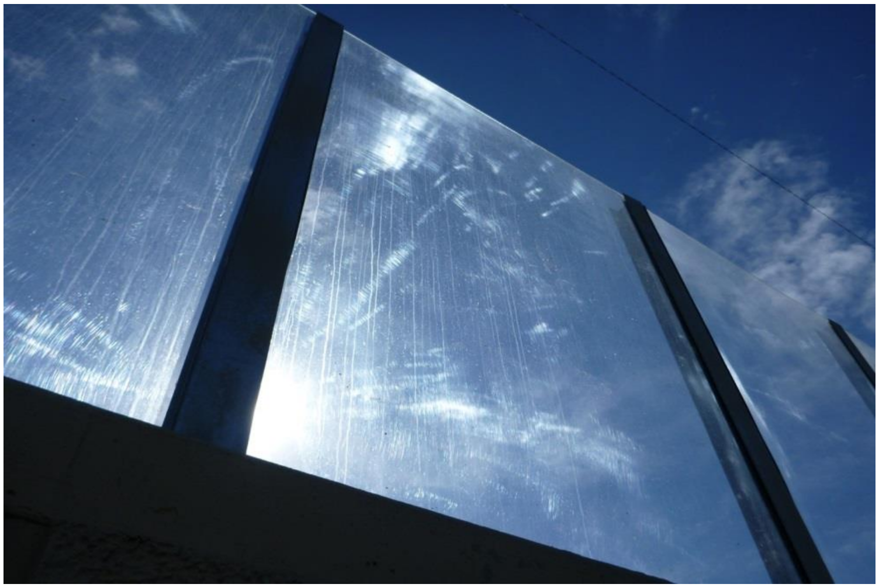


*Figure 8.24 Cleaned panel showing traces of the cleaning operation*

*Figure 8.25 Cleaned panel showing traces of the cleaning operation*

Figure 8.26 shows that the graffiti that extended to the concrete wall could not be entirely removed, and Figure 8.27 shows a photograph taken from afar after the panels had been cleaned.

*Figure 8.26 Remnants of the graffiti on the concrete wall below the panels*


*Figure 8.27 Graffiti removed from acrylic panels*

## 8.3. Gasket Deterioration and Openings

Besides the graffiti, which was successfully removed, the main problem with the wall was the deteriorating condition of the rubber gaskets that are supposed to seal the spaces between panels and the metal supports and the existing concrete walls. This problem was reported shortly after the wall was installed, as it was detected in the inspections during the installation, as mentioned before in this chapter. In the subsequent months, the condition of such gaskets appeared to worsen. Many of the gaskets were not properly placed from the time the wall was installed, and then, perhaps due to the weather, some of them fell out of place, sagging and even breaking, leaving open gaps through which the noise travels from the highway to the neighborhood. Making an analogy with architectural acoustics, this is similar to leaving an opening (e.g., an open window or a gap under a door) in a room, in which case, the acoustic energy goes through the opening, and the transmission loss of the walls is undermined by the area of the opening, significantly reducing the wall's effectiveness. The problem with the gaskets occurred in both the vertical and horizontal gaskets, but the worst cases correspond to the horizontal gaskets that seal the bottom of the acrylic panels with the concrete wall. The sagging of the horizontal gaskets can be seen in Figures 8.28 through 8.31.

*Figure 8.28 Sagging of horizontal rubber gaskets*

*Figure 8.29 Sagging of horizontal rubber gaskets*

*Figure 8.30 Sagging of horizontal rubber gaskets*

*Figure 8.31 Sagging of horizontal rubber gaskets*

Some of the gaskets have broken, as shown in Figures 8.32, 8.33, and 8.34.

*Figure 8.32 Broken horizontal rubber gasket*

*Figure 8.33 Broken horizontal rubber gasket*

*Figure 8.34 Broken horizontal rubber gasket*

In some cases, the vegetation from the creek side grows through the openings in the gaskets and gets in front of the panels on the highway side, illustrating how widespread the problem has become (Figures 8.35 and 8.36). This occurs especially during the summer months, when the vegetation is more abundant.

*Figure 8.35 Vegetation from the creek side growing through the openings in the gaskets under noise barrier*

*Figure 8.36 Vegetation from the creek side growing through the openings in the gaskets under noise barrier*

It was estimated that about 80% of the horizontal gaskets were in poor condition (broken, sagging, or out of place), which significantly hinders the acoustic performance of the barrier. In May 2014, CTR learned that the contractor had offered to fix the problems with the gaskets at no cost to TxDOT. In the following months, it was noticed that the sagging and broken gaskets had been removed, eliminating the negative visual impression of disrepair; however, those gaskets were not replaced with new ones, leaving the openings intact. At this stage, after a few years have passed, it is very unlikely that the contractor will still replace those gaskets.

Another problem not directly related to the acrylic wall, but one that minimizes its effectiveness, is the high number of open joints in the existing concrete wall. This was mentioned before in this chapter, as it was noticed shortly after installation of the wall had been completed. These gaps are as wide as 3 or 4 in. (Figure 8.37); the joint sealants are old and have disintegrated with time and weather (Figure 8.38), and in some cases cannot be seen at all (Figure 8.39), allowing the acoustic energy to travel to the neighborhood. The vegetation is also growing through these gaps, as can be seen Figure 8.40. If these can be sealed and the gaskets can be repaired, the wall could be much more effective in mitigating the noise.


*Figure 8.37 Expansion joint opening due to lack of sealant*

*Figure 8.38 Damaged, old sealant material in the expansion joints of bridge structure*

*Figure 8.39 Open joint seen from the eastbound main lanes*

*Figure 8.40 Vegetation from the creek side growing through the openings in the concrete structure*

## 8.4. Summary

This chapter presents the results of the monitoring activities of the Site 1 lightweight transparent noise barrier on the south side of I-30, in the area delimited by Edgefield Avenue in the west, and Sylvan Avenue in the east, starting with its installation and continuing through its subsequent service life, including periodic inspections and documentation of its condition. The main issues identified were the following:

- Some of the vertical metal posts of the support structure off-plumb
- Gaskets sealing the joints between posts and panels not properly installed
- Gaskets sagging and even breaking as a result of faulty initial placement and weather
- An occurrence of vandalism: graffiti temporarily damaged 10 panels; the damage was removed by maintenance crews without further consequences
- Openings in concrete bridge structure expansion joints without sealant or gaskets that allow sound to travel from highway to receivers and reduce the wall's effectiveness

# Chapter 9. Site 2 Monitoring

This chapter presents the results of field inspections performed at Site 2's new transparent sound wall, as part of the research work conducted on the elevated highway structure on I-30 in Dallas, west of downtown, which extends from Sylvan Avenue in the west towards Beckley Avenue in the east, in the vicinity of the Kessler Park neighborhood, an area affected by the highway noise.

The monitoring work consisted in inspection of the site, prior to the design to determine the sound wall limits, and inspection of the installation, as well as periodic inspections of the conditions of the wall after the installation was completed.

## 9.1. Initial Site Inspection

The first visit took place on Tuesday, March 28, 2017, prior to the design of the wall; CTR met with Mr. George Reeves, from TxDOT, at Site 2 to take noise readings at various locations and to inspect the location to come up with a recommendation regarding the easternmost limit for the barrier. With this visit, it was intended to assess a feasible limit for the wall, considering the noise sources locations, the geometry of the roadway, as well as the extent of the existing concrete jersey barriers, given that the new sound barrier panels needed to be placed on top of existing structures, i.e., the concrete traffic barriers.

As part of the brief visit, sound pressure level (SPL) tests were conducted at four different locations close to I-30 and Beckley Avenue, near the easternmost end of the segment considered for the projected noise barrier. This area does not have many residences nearby; there is a large grass berm as well as other drainage structures designed for flood control. Noise tests were conducted at two locations on top of such berm (designated as Berm 1 and Berm 3, respectively) with direct line of sight to the highway, and at two other locations (designated as Berm 2 and Berm 4, respectively), which are directly below the berm. These tests, besides evaluating noise levels in the proximity of the highway, also intended to show how much noise is blocked by the berm. The Kessler Park residences are south of the berm. The berm offers significant protection from the noise, but unfortunately, most of the residential area sits at a higher elevation relative to the berm, so in fact, the residences receive little to no benefit from the berm. Also, next to the berm is the current end of the Coombs Trail, which is part of the linear park that exists along Coombs Creek, just north of the residences, and next to Coombs Creek. A map showing the first four measurement locations is shown in Figure 9.1. This map also shows the trail, Beckley Avenue, and on the right side of it, part of the Trinity River, and the new Margaret McDermott Bridge, a steel suspended arch bridge, part of the Dallas Horseshoe Project. It was noticed that the noise from the traffic on the bridge and its ramp approach reaches the test locations; the new pavement on this section is transversely tined continuously reinforced concrete pavement (CRCP) (Figure 9.2); thus, the characteristic "whining" noise of traffic traveling on this type of pavement could be perceived from the Berm 1 and Berm 3 locations. This is accentuated by the fact that the bridge approach is higher than the highway segment west to it (see Figure 9.3). Therefore, the noise from the approach travels unobstructed and reaches some residential locations. These were all important considerations to evaluate the height of the future noise barrier, as well as its easternmost limit.


*Figure 9.1 Site 2 noise measurement locations close to Beckley Avenue*

*Figure 9.2 CRCP on the deck of the new McDermott Bridge*

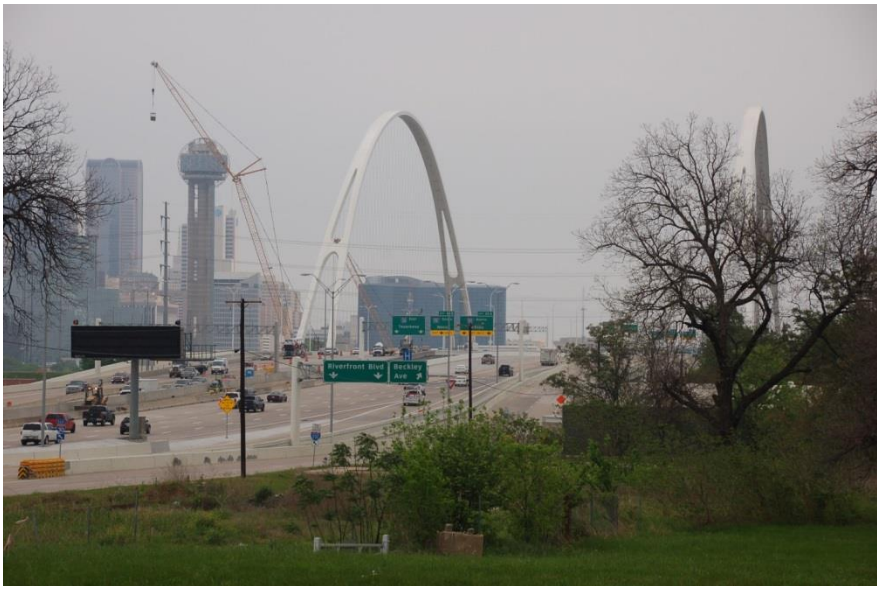



*Figure 9.3 Photograph of the bridge approach from the Berm 3 location looking east towards the Trinity River*

The description and location information for the berm tests are presented in Table 9.1. The elevation information, although approximate, due to GPS accuracy, indicates that the top of the berm is approximately 21 feet above the bottom.

**Table 9.1 Site 2 berm noise test locations' information**

| Location | Description | Latitude | Longitude | Elev. (ft) |
|---|---|---|---|---|
| Berm 1 | On top of the berm, east side | N 32° 46.029' | W 96° 49.482' | 429 |
| Berm 2 | Behind the berm, east side | N 32° 46.013' | W 96° 49.497' | 408 |
| Berm 3 | On top of the concrete depression on the berm, west side | N 32° 46.041' | W 96° 49.671' | 426 |
| Berm 4 | Behind the berm, west side | N 32° 46.031' | W 96° 49.675' | 419 |

Additionally, on the next day, CTR conducted SPL tests at the five locations that were initially selected for testing for Site 2.

Figures 9.4 to 9.7 show some of the tests being conducted at the berm locations.

*Figure 9.4 Berm 1 noise measurement location*

*Figure 9.5 Berm 2 noise measurement location*

*Figure 9.6 Berm 3 noise measurement location*

*Figure 9.7 Berm 3 noise measurement location*

## 9.1.1. SPL Test Results

The results of the noise tests in Leq(A) are presented in Table 9.2.

**Table 9.2 Site 2 berm noise test results**

| Location | Noise Level-Leq (A) |
|---|---|
| Berm 1 | 66.6 |
| Berm 2 | 54.5 |
| Berm 3 | 71.6 |
| Berm 4 | 59.9 |

Note that the noise levels drop significantly behind the berm. The test results of the residential locations, performed the following day, are shown in Table 9.3.

**Table 9.3 Site 2 residential noise test results**

| Location | Noise Level-Leq (A) |
|---|---|
| R3 | 57.4 |
| R8 | 58.5 |
| R12 | 62.7 |
| R13 | 55.3 |
| R27 | 59.6 |

For analysis purposes, these results were compared to the results obtained at Site 2 when this project started in 2013, prior to the installation of the Site 1 wall. Before the installation of the noise wall on Site 1, there were 260 noise measurements taken before the wall was installed (130 at Site 1, 130 at Site 2). Those were taken in 2013 between the months of May and September. The average results from those tests are as follows:

- Average level before wall, Site 1: 58.2 dBA
- Average level before wall, Site 2: 58.2 dBA

Therefore, before the noise wall was installed, the noise measurements were similar at both Site 1 and Site 2.

At that stage of the project, measurements at Site 2 concluded at the time the Site 1 noise wall installation was completed. Figure 9.8 shows the average measurements by location at Site 2 compared to the results obtained during the March 2017 visit:


*Figure 9.8 Site 2 noise measurements prior to Site 1 wall installation compared to March 2017 tests*

In general, the results of the March 2017 tests were very similar to the average levels recorded in 2013, but higher. This suggests that due to the geometry of the road and its elevation, the noise barrier at Site 1 provided only limited protection from the noise to the residential locations on Site 2, as expected. Because of the elevation—the highway on the east side of this segment (close to Beckley Avenue) sitting at a higher elevation than the west side, close to Sylvan Avenue (see Figure 9.3)—it seems that a higher proportion of the acoustic energy from the traffic comes from that side of the highway. The fact that the pavement on the east side (the bridge approach and the bridge itself) consists of transversely tined CRCP and it is at a higher elevation also supports that statement. The perception of the noise while conducting the tests on the berm confirms that idea as well.

### 9.1.2. Recommendations

The purpose of this visit and the tests was to come up with a recommendation about the limits for the prospective noise barrier. There was no doubt that the limit on the westernmost end of the project needed to be at Sylvan Avenue, just where the transparent barrier for Site 1 ends, so that there would be no gaps between the Site 1 barrier and the new Site 2 barrier. Any opening would let the noise reach the neighborhood. In fact, the regular tests for the Site 1 locations indicated that the noise recorded at the easternmost edge of Site 1 comes from the end of the existing transparent barrier, above Sylvan Avenue, i.e., the Sylvan Avenue overpass and further east. Therefore, the new barrier segment would also benefit the Site 1 residences, west of Sylvan. The end of the Site 1 barrier at Sylvan Avenue is shown in Figure 9.9.

*Figure 9.9 Easternmost end of Site 1 noise barrier at Sylvan Avenue*

As for the easternmost end of the new barrier, it was recommended that it extended as far as possible to the new McDermott Bridge to prevent the highway noise coming from the approach and from the bridge itself from reaching the neighborhood. However, even though this would have been the ideal situation acoustically, to offer the best possible shielding from the noise, it was not feasible. TxDOT indicated that extending the wall towards the bridge approach was not going to be possible; the wall would have to end before that bridge approach. Also, before that approach, the existing concrete wall ends in a wedge-like shape, preventing installation of any more vertical supports for the noise wall (Figure 9.10). See Chapter 5, Section 5.6 for more information on the determination of the easternmost limit of the barrier, as dictated by the geometric configuration of the highway and existing CTBs.

*Figure 9.10 Frontage road and main lanes CTBs converge in a wedge-like shape (May 2018)*

## 9.2. Noise Wall Installation

The Site 2 noise wall installation started on January 24, 2018. The work was scheduled to take place at night, from 9:00 p.m. until 5:00 a.m., to minimize the construction impact, and was initially supposed to last about 34 days. However, due to a design problem with the vertical metallic posts that support the acrylic panels and the way they are anchored in the existing CTBs, the construction had to be temporarily stopped to address the problem. It resumed in July 2018, finishing in early August 2018.

The panels are made of a material called Acrylite, manufactured by Evonic, which are 15-mm thick; this is the same product that was installed at the Site 1 barrier; therefore, the appearance of the Site 2 wall matches the Site 1 wall (Figure 9.11). The panels at Site 2 vary in their dimensions; in terms of height, they vary according to the segment—those in Segment 1 are 13.2-ft tall and match the height of the panels at the eastern end of Site 1 wall. The panels of Segments 2 and 3 are 10-ft tall. Some panels are narrower than others to allow the structure to adjust to the dimensions of the existing CTBs; the majority of the panels are 7-ft-wide, but there are some that are 6, 8, and 9-ft-wide.

The project was bid at $813,925.20, for a surface area of 26,004 sq ft, and the cost per unit area is $31.30/sq ft.

The contractor in charge of the installation job was Gibson & Associates, Inc.; the transparent material and structural design for the wall were provided by Armtec, as was the case for the Site 1 wall (this company is the distributor of the Evonik products for North America).

*Figure 9.11 Seamless transition between Site 1 wall and Site 2 wall at Sylvan Avenue*

### 9.2.1. Segments and Limits

The wall consists of three separate segments of transparent acrylic panels, mounted on top of the existing concrete barriers on the south side of I-30. Those three segments are separated because they are placed on different concrete barriers of the highway, due to the presence of an exit ramp (exit 44A). The three are designated as Segment 1, Segment 2, and Segment 3, with Segment 1 being the westernmost segments, adjacent to the end of the Site 1 wall at Sylvan Avenue, extending for 503 ft. Segment 2 starts at the CTB at exit 44A and continues for 1,155 ft. Segment 3 is the easternmost stretch, which starts where Segment 2 ends, just transferring the panels on to an adjacent CTB, and ends where it becomes impossible to affix any more vertical posts to that CTB, just before the approach of the McDermott Bridge starts, extending for 634 ft. The total length of the wall is 2,692 ft, including overlaps at the wall gaps. A map with the actual segments' limits is shown in Figure 9.12. The maps and approximate limits were obtained from GPS coordinates taken in the field from the actual wall limits.

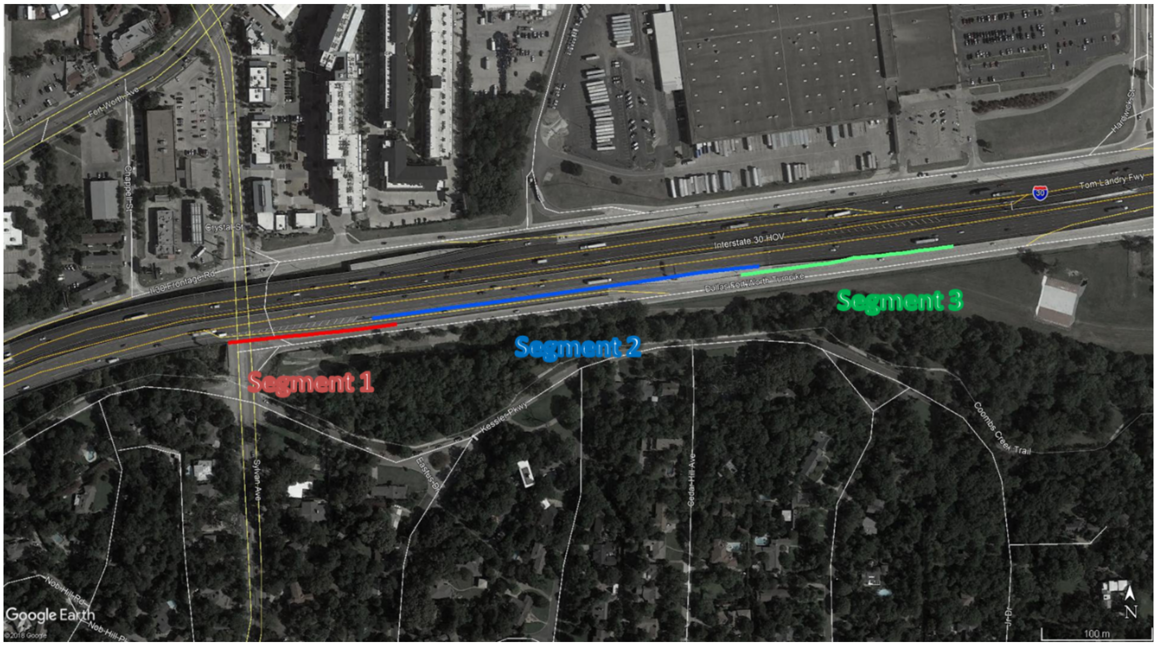



*Figure 9.12 Site 2 Wall segments*

Some photographs illustrating the segments' limits are shown in Figures 9.13 to 9.18.

*Figure 9.13 Segment 1, still under construction, seen from the eastbound frontage road (March 2018)*

*Figure 9.14 Segment 1 still under construction, seen from the eastbound main lanes above Sylvan Avenue (March 2018)*


*Figure 9.15 Easternmost end of Segment 1, still under construction, and westernmost end of Segment 2 at exit 44A ramp, seen from the eastbound main lanes (March 2018)*

The easternmost end of the wall (Segment 3) was initially supposed to be at station 1040+93 (Figure 9.16), about 200 ft to the east of where it actually ends, close to station 1039 (Figure 9.17). The stations are painted on the outside of the CTB, for Segment 3. There is also a paint mark at the spot where the wall is supposed to end, at station 1040 + 93. The reason for shortening the wall length was due to the difficulty of installing vertical posts beyond the actual end, as there is no more room to anchor the posts where the concrete wall's height decreases. This can be seen in Figure 9.18, which shows the actual end of the wall as seen from the main lanes' side.

*Figure 9.16 Supposed easternmost end of the wall at Station 1040+93 (March 2018)*


*Figure 9.17 Actual easternmost end of the wall a few feet before Station 1039 (August 2018)*

*Figure 9.18 Actual easternmost end of the wall as seen from the main lanes (August 2018)*

### 9.2.2. Installation Field Observations

The following are some observations on the wall installation:

- The rubber gaskets that seal the panels and the metal frames were properly installed by the contractor. There were a few defective installations of these gaskets at the Site 1 noise wall back in 2013, but none were seen at Site 2.

- In March, there were 85 vertical posts already installed for Segment 3, almost all the way to the end of the segment. There were panels already in place up to the twenty-sixth post. Some of the posts and panels had to be removed, as there was a design problem with the mounting of the posts to the existing concrete wall, as explained before in this chapter (Figures 9.19 and 9.20). Then the construction had to be interrupted to fix the problem. By the April 19th visit, the segment only had 15 posts and only 14 panels and reached approximately halfway between station 1033 and 1034. Once the design problem was resolved, construction resumed and the posts and panels were put back in place all the way to the end in August 2018.

*Figure 9.19 Vertical posts were removed in April to fix design problem (April 2018)*

*Figure 9.20 Only plates and bolts remained after some posts were removed in April to fix design problem (May 2018)*

- Initially, only one of the two overlaps designed to reduce the noise traveling through the gaps between segments was installed; this was the overlap between the Segment 1 easternmost end and the Segment 2 westernmost end (Figure 9.21). Before August, there was no overlap between Segment 2 and Segment 3 (Figure 9.22). In fact, there was a small gap of about 5 ft between segments (Figure 9.23). Once the installation work resumed in July 2018, the segment was extended to the east to include the overlap at the request of TxDOT (Figures 9.24 and 9.25). Notice the green paint marks on the CTB in Figures 9.23 (before) and 9.25 (after) that indicate the initial contractor's end of Segment 2, and the length of the overlap extended to the east in Figure 9.25 beyond the paint mark (11 panels added beyond the paint).

*Figure 9.21 Segment 1 and Segment 2 overlap, seen from the eastbound main lanes (April 2018)*


*Figure 9.22 No overlap between Segment 2 and Segment 3 (April 2018)*


*Figure 9.23 No overlap between Segment 2 and Segment 3, seen from the main lanes (April 2018)*

*Figure 9.24 Segment 2 extended to the east to include overlap (August 2018)*


*Figure 9.25 Segment 2 extended to the east to include overlap (August 2018)*

- There were some difficulties installing the acrylic panel under a cantilever highway sign. This panel was missing for several months (Figure 9.26 and 9.27) until it was finally successfully installed in August 2018. This was accomplished by removing the adjacent panel, sliding the panel under the truss, and replacing the adjacent panel.

*Figure 9.26 Missing panel under cantilever highway sign seen from behind the wall*

*Figure 9.27 Missing panel under cantilever highway sign seen from the main lanes*

- The system that attaches the vertical supports to the concrete walls seems more robust than the one used for the Site 1 wall. There is also more length of the posts bolted to the concrete

(Figure 9.28). In this photograph, a red clamp is attached to the last post from the Site 1 wall.

*Figure 9.28 Different anchoring for vertical posts at Site 1 wall (L) and Site 2 wall (R)*

- Some of the vertical posts for Segments 2 and 3 required the construction of small foundations: due to height of the existing walls, they needed to be embedded into the existing concrete, requiring sawing of the slabs to make room for anchoring the posts. The excavations were filled with concrete once the anchoring of the posts was secured. Some of the small foundations for the posts at end of Segment 2, and some of those for Segment 3, can be seen in Figures 9.29 to 9.31.

*Figure 9.29 Small foundations to anchor vertical posts in Segment 2 (April 2018)*

*Figure 9.30 Small foundations to anchor vertical posts sawing existing concrete for Segment 3 (May 2018)*

*Figure 9.31 Small foundation under construction for Segment 2, sawing existing slab (July 2018)*

Additional aspects of the construction are shown in Figures 9.32 to 9.40.

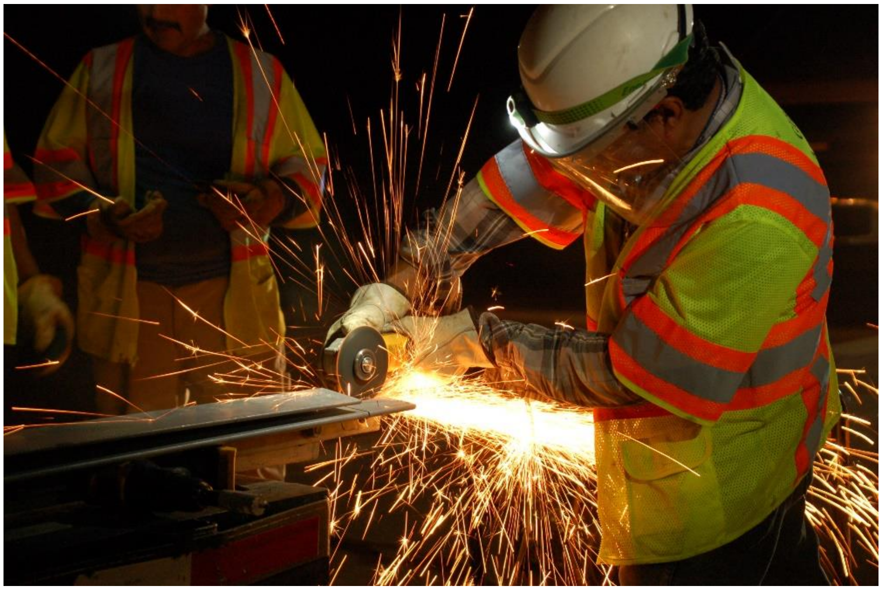


*Figure 9.32 On-site cutting of metal post*

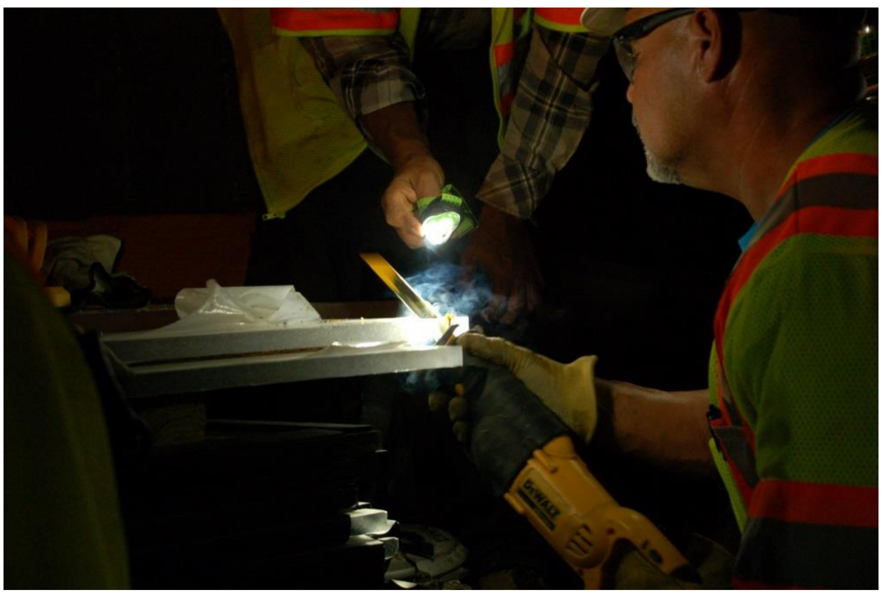


*Figure 9.33 On-site cutting of acrylic panel*

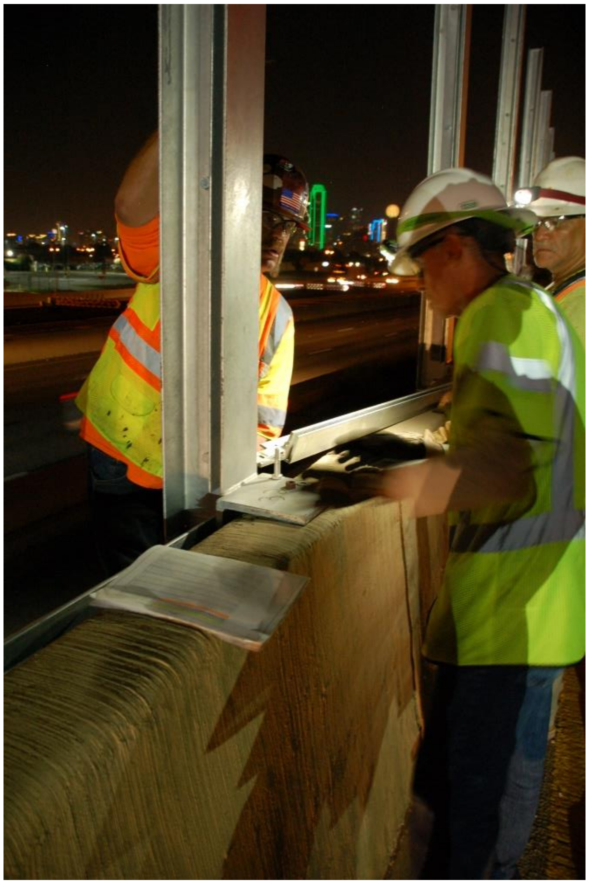


*Figure 9.34 Installation of horizontal metal support*

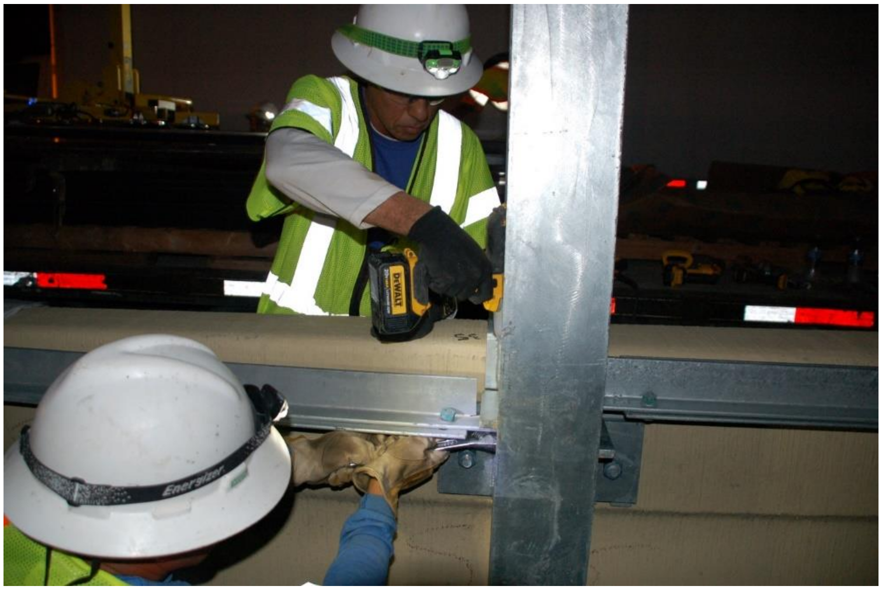


*Figure 9.35 Bolting the metal supports to the concrete wall*

*Figure 9.36 Mr. Mark McIlheran, from Armtec, inspecting the installation*

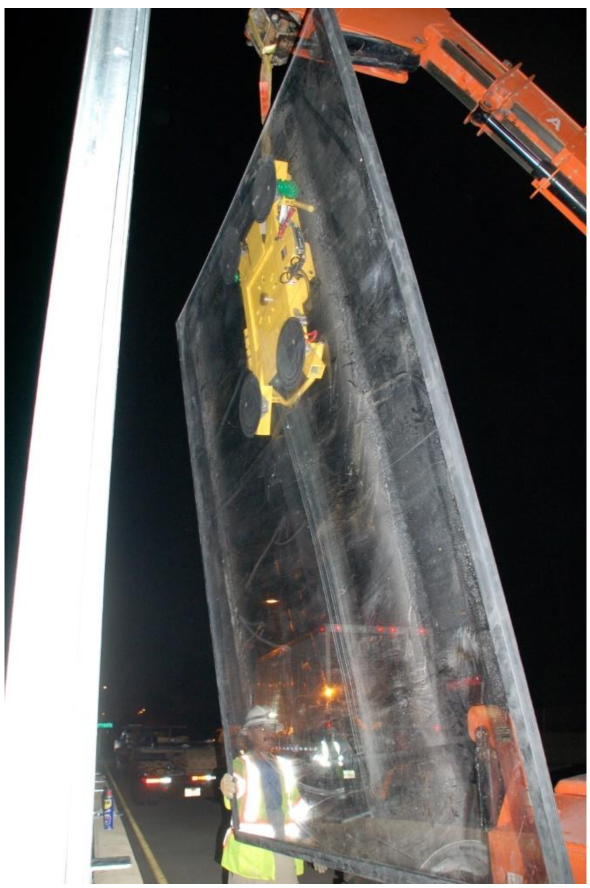


*Figure 9.37 Hoisting acrylic panel*

*Figure 9.38 Hoisting acrylic panel*


*Figure 9.39 Acrylic panel installation*

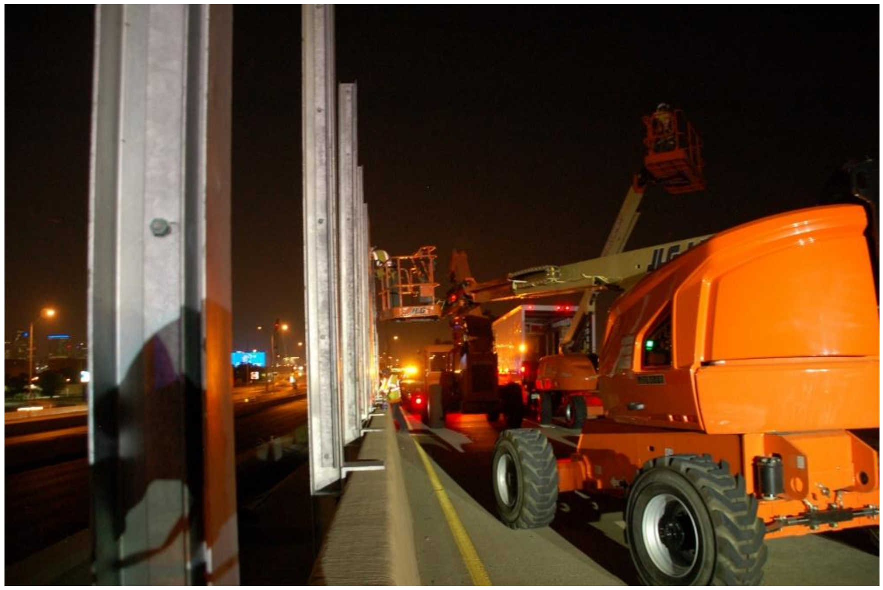


*Figure 9.40 Finalizing panel installation from the bucket truck*

### 9.2.3. Additional Observations

The following are some observations aside from the construction of the wall itself:

- There is a badly damaged, open expansion joint in the pavement that extends across the right four eastbound main lanes and the shoulder. It causes a loud thumping noise every time a vehicle goes over it, which is very frequently. It is located just to the east of where Segment 2 ends, so there is no noise barrier shielding from that loud and frequent noise. Hopefully, this joint can be fixed when the road is repaved (Figures 9.41 to 9.43).

*Figure 9.41 Open, damaged expansion joint in the pavement, eastbound outside lane (April 2018)*

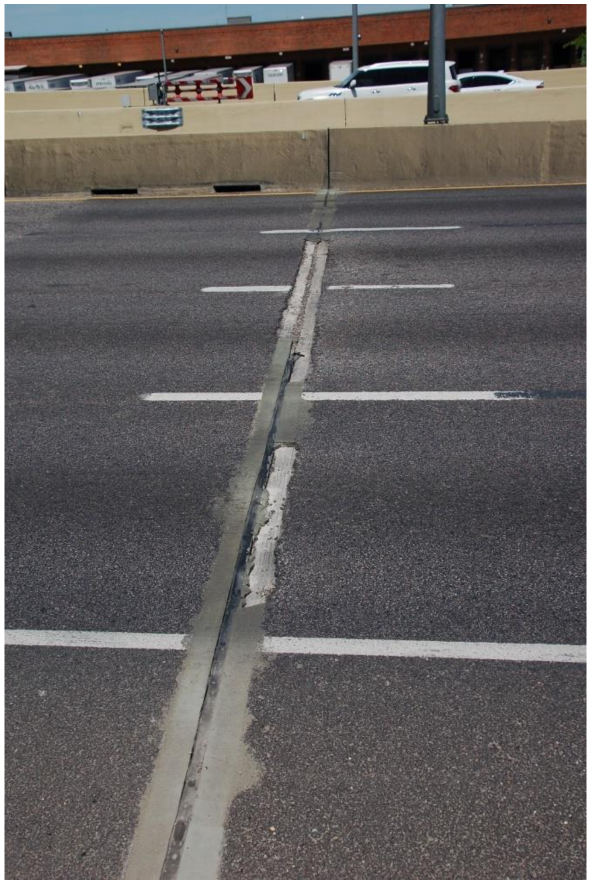


*Figure 9.42 Open, damaged expansion joint in the pavement, main lanes (April 2018)*

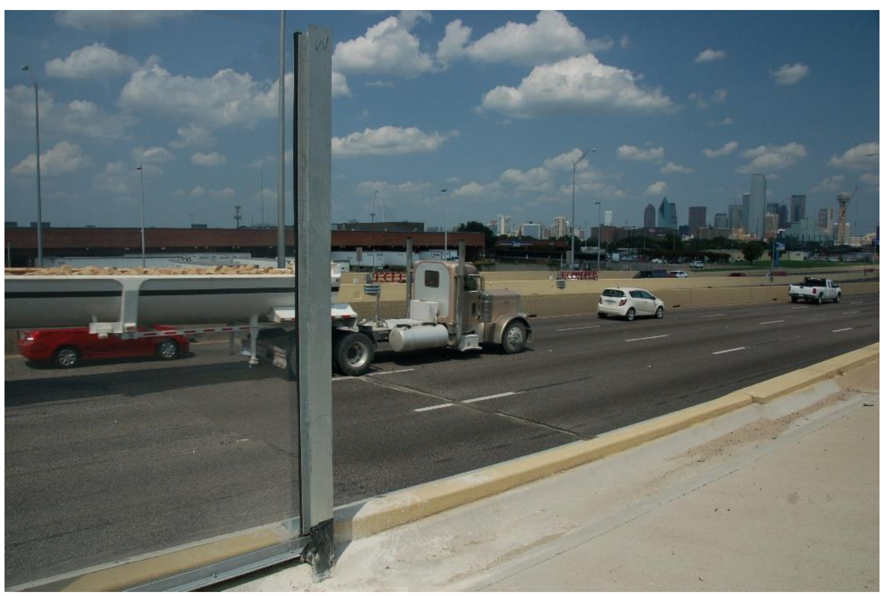


*Figure 9.43 Location of the open joint in relation to the end of Segment 2*

- An asphalt overlay was placed on the main-lanes CRCP approaching the McDermott Bridge, east of the Site 2 barrier, as can be seen in Figures 9.44 to 9.46, showing comparisons of photographs from March 2017 and April 2018.


*Figure 9.44 CRCP on both the main lanes and frontage road (March 2017)*


*Figure 9.45 Asphalt overlay on main lanes (L), CRCP on frontage road (R) (April 2018)*

*Figure 9.46 Asphalt overlay on main lanes (L), CRCP on frontage road (R) (April 2018)*

- Shortly after being finalized, there was already a bird-crash on one of the panels of Segment 1, east of Sylvan Avenue, close to the easternmost end of the segment (Figure 9.47).

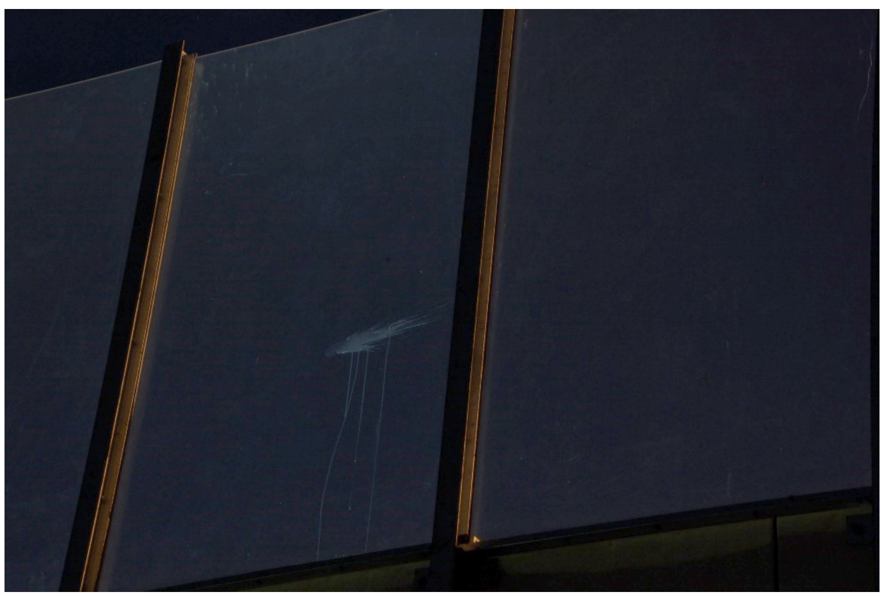


*Figure 9.47 Bird-crash in one of the panels of Segment 1 (April 2018)*

## 9.3. Graffiti

On January 30, 2019, the occurrence of vandalism in the form of graffiti was observed on the noise wall. Three panels corresponding to Segment 3 (the easternmost segment) were sprayed with green and black paint. The graffiti also included the concrete under the panels as well as the metal supports. The twelfth, thirteenth, and fourteenth panels of Segment 3, counting from the west, were the ones involved. The damage was done from the highway side. This section is easy to access as there is an area between the main lanes and the frontage road where anyone can walk and stand next to the panels, away from the traffic; this is also the area where the wall Segments 2 and 3 overlap. The graffiti was probably done the night before. The researcher had seen the wall during the day, on January 29, while doing the inspection and did not see any damage. The next morning the graffiti was noticed on the panels, and the Dallas District was immediately notified.

*Figure 9.48 Graffiti on Segment 3 of the Site 2 barrier, seen from the frontage road (January 30, 2019)*

*Figure 9.49 Graffiti on Segment 3 of the Site 2 barrier, seen from the roadway side (January 30, 2019)*

*Figure 9.50 Graffiti on Segment 3 of the Site 2 barrier, seen from the roadway side (January 30, 2019)*

By mid-February 2019, the graffiti had been cleaned from the Site 2 I-30 noise wall. Figures 9.51 to 9.58 show the cleaned wall. The paint was removed from the panels and, because it could not be removed from the concrete of the CTB, the CTB had to be painted over with a similar color as shown in some of the photographs (Figures 9.51 to 9.53). Some of the photos show remnants of the green graffiti on the ground, as well as on some of the steel supports (Figures 9.53 and 9.54).

The cleaning process for the graffiti resulted in some damage to the two panels in question: on a rainy day, such as February 19, 2019, it seemed that the cleaned panels were wet with soap, as can be seen in the pictures from that day (Figures 9.51, 9.52 and 9.55). When they were touched on dry days (June 13 and August 15, 2019), they appeared wet but were in fact dry; they had been actually textured by the cleaning product (Figures 9.56 to 9.58).

*Figure 9.51 Graffiti cleaned from acrylic panels and CTB painted to cover graffiti (February 19, 2019)*

*Figure 9.52 Cleaned panels after graffiti removal (February 19, 2019)*

*Figure 9.53 Painted CTB to cover graffiti and remnants of graffiti on the ground (February 19, 2019)*

*Figure 9.54 Paint remaining on metal support after graffiti removal (February 19, 2019)*

*Figure 9.55 Panel damage after cleaning (February 19, 2019)*

*Figure 9.56 Panel showing permanent damage after cleaning (June 13, 2019)*

*Figure 9.57 Panel showing permanent damage after cleaning (August 15, 2019)*

*Figure 9.58 Three panels showing permanent damage after cleaning (August 15, 2019)*

CTR contacted the Dallas District asking for the cost of the graffiti removal, so that it could be stated in this report and quantified along with the other expenditures related to the noise walls, but no response was obtained.

## 9.4. Insertion Loss Tests

Insertion loss (IL) is defined as the reduction of noise level at a given location due to the placement of a noise control device in the sound path between the sound source and that location. In this case, such noise control device is the transparent wall. IL tests indicate the benefit that the sound wall provides in the form of a noise level reduction.

During the April 2018 site visit, it was noticed, while walking the area for inspection of the wall installation, that there was a significant noise difference between the noise perceived directly next to the highway and just behind the panels of the wall still under construction. During the May 2018 monitoring trip, taking advantage of the availability of space to walk in between Segment 2 and Segment 3, and the ease of setting up a noise meter in this area, CTR measured the noise level differences directly in front of the traffic and behind the noise wall. These readings would give a clear indication of the IL due to the presence of the transparent wall, and therefore of its effectiveness. In the early afternoon of May 29, 2018, two 15-minute tests were conducted: the first test was done next to the highway (Figures 9.59 to 9.61) and the second test was behind the panels of Segment 2 (Figures 9.62 to 9.64). The first test result was 85.9 dBA, and the second test was 77.2 dBA (Table 9.4).

**Table 9.4 May 29, 2018 IL test**

| Start | End | SPL Meter Placement | $L_{eq}$ (dBA) | IL (dBA) |
|---|---|---|---|---|
| 13:53 | 14:08 | Next to traffic | 85.9 | 8.7 |
| 14:09 | 14:24 | Behind noise wall | 77.2 | |

For both tests, the meter was set as close as possible to the noise source. Therefore, by standing behind the panels, the highway noise is reduced by almost 9 dBA. This is indeed a very significant difference, considering that the decibel scale is logarithmic. Ideally, these tests should have been conducted simultaneously with two noise meters, so that both would have the exact same traffic, but unfortunately, there was only one working sound pressure level meter at the time. Also, the almost 9-dBA difference should have been greater. For the second test, there is no shielding from the noise coming from the frontage road behind the meter (Figure 9.63), whereas for the first test, the short wall of Segment 3 was placed at the time, thus shielding the meter from the frontage road noise (Figure 9.60).

*Figure 9.59 Test conducted next to the I-30 main lanes traffic (May 29, 2018)*

*Figure 9.60 Test conducted next to the I-30 main lanes traffic; Segment 2 on the left, Segment 3 on the right (May 29, 2018)*


*Figure 9.61 Test conducted next to the I-30 main lanes traffic: 85.9 dBA next to main-lane traffic (May 29, 2018)*


*Figure 9.62 Test conducted behind noise wall panels of Segment 2 (May 29, 2018)*

*Figure 9.63 Test conducted behind noise wall panels of Segment 2 (May 29, 2018)*


*Figure 9.64 Test conducted behind noise wall panels of Segment 2: 77.2 dBA (May 29, 2018)*

The frequency spectra for these tests are presented in Figure 9.65. This chart indicates that the main benefits from the wall occur from 400 to 1000 Hz, and for the higher frequencies there is still a benefit, but it is smaller.

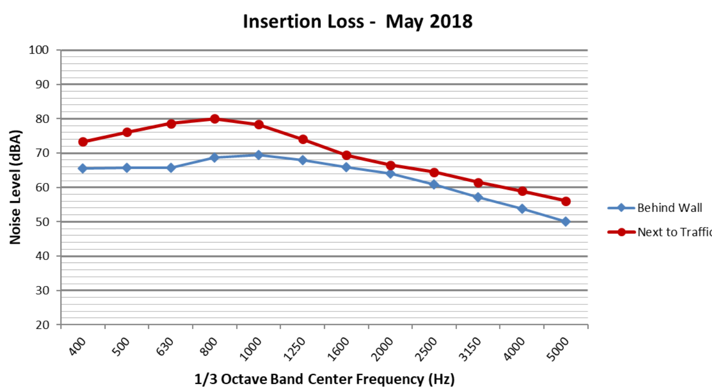



*Figure 9.65 Frequency spectra for May 2018 IL tests*

In June 2019, CTR finally was able to get a replacement for one of the sound pressure level meters that had stopped working in January of 2018. With two sound meters, it was possible to conduct simultaneous tests. On June 13, 2019, in the evening, a new round of IL tests was conducted, but this time with simultaneous measurements. Two sets of tests were conducted; the results are summarized in Table 9.5.

**Table 9.5 June 13, 2019 IL test**

| Test | Start | End | Next to traffic $L_{eq}$ (dBA) | Behind Noise Wall $L_{eq}$ (dBA) | IL (dBA) |
|---|---|---|---|---|---|
| 1 | 20:39 | 20:49 | 84.7 | 76.5 | 8.2 |
| 2 | 20:51 | 21:01 | 83.7 | 75.7 | 8.0 |

Figures 9.66 to 9.68 show photographs of the IL test with simultaneous noise meters.

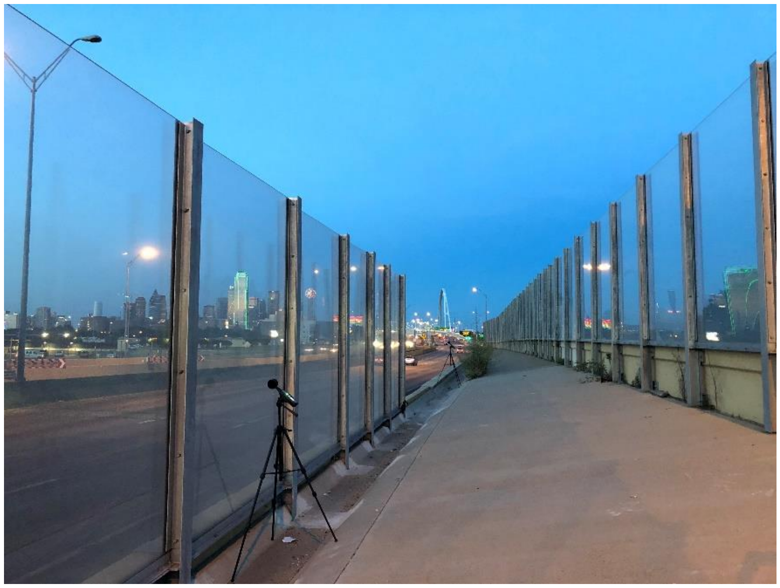


*Figure 9.66 IL test with simultaneous meters (June 13, 2019)*

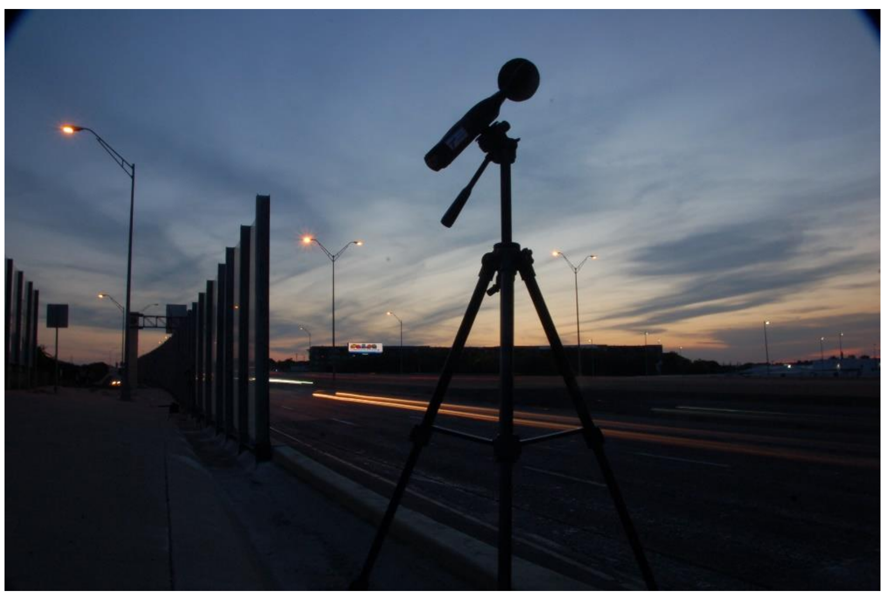


*Figure 9.67 IL test with simultaneous meters; meter next to traffic (June 13, 2019)*

*Figure 9.68 IL test with simultaneous meters; meter behind noise wall (June 13, 2019)*

Unfortunately, the spectral comparison of these IL tests cannot be presented, as the new SPL meter is not capable of performing the frequency analysis.

## 9.5. New PFC

As mentioned in Chapter 3, in the Pavements section, towards the end of the research project, a new pavement replaced the 2006 and 2010 PFCs. This new 1.5-in.-thick PFC overlay was completed in time for the June 2019 tests, and therefore, it was only in place for the last three months of testing for this project. The old overlays were badly deteriorated, which, in turn, increased noise levels as indicated by OBSI tests (see Chapter 3). The new overlay limits are similar to those old overlays; the westernmost limit for both directions is the Fort Worth Avenue Bridge. Figures 9.69 to 9.71 show some pictures of the new pavement surface, shortly after its placement.

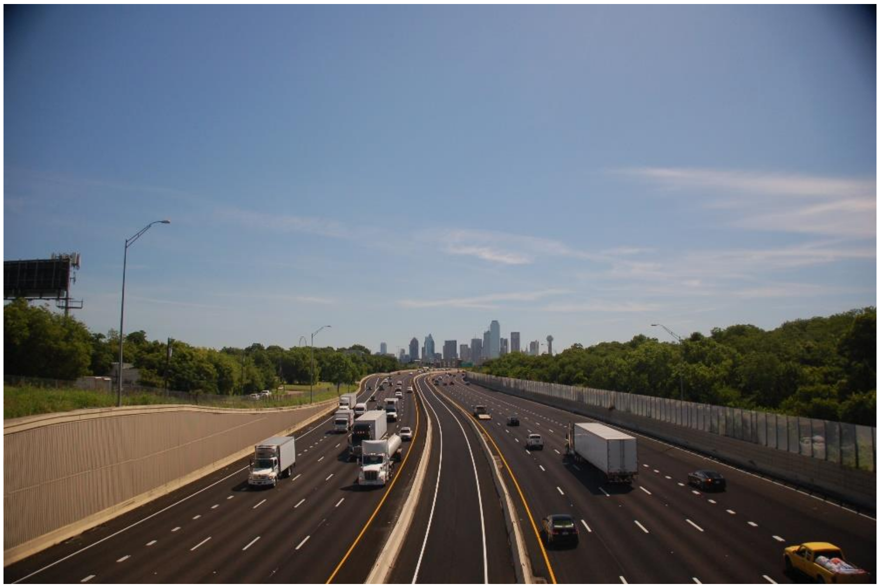


*Figure 9.69 2019 PFC overlay (June 13, 2019)*

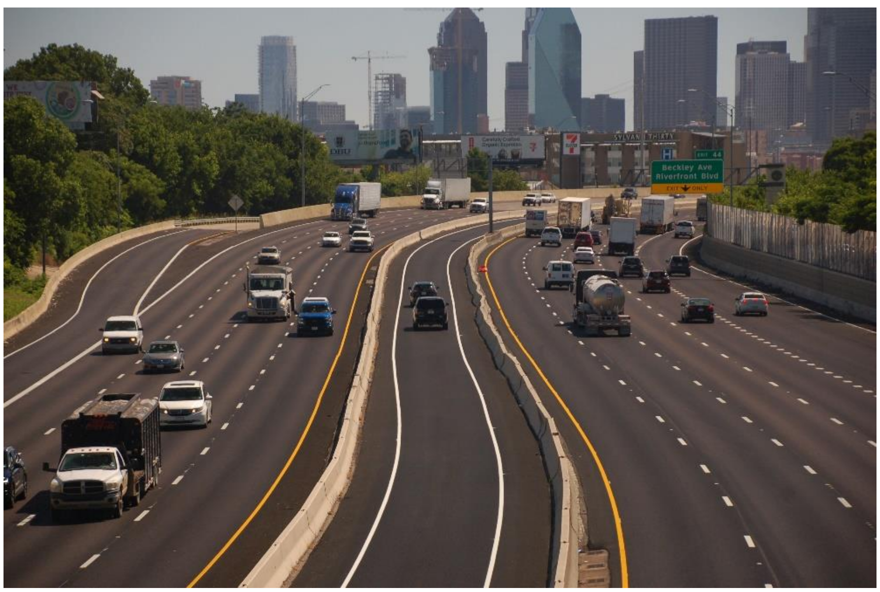



*Figure 9.70 2019 PFC overlay (June 13, 2019)*

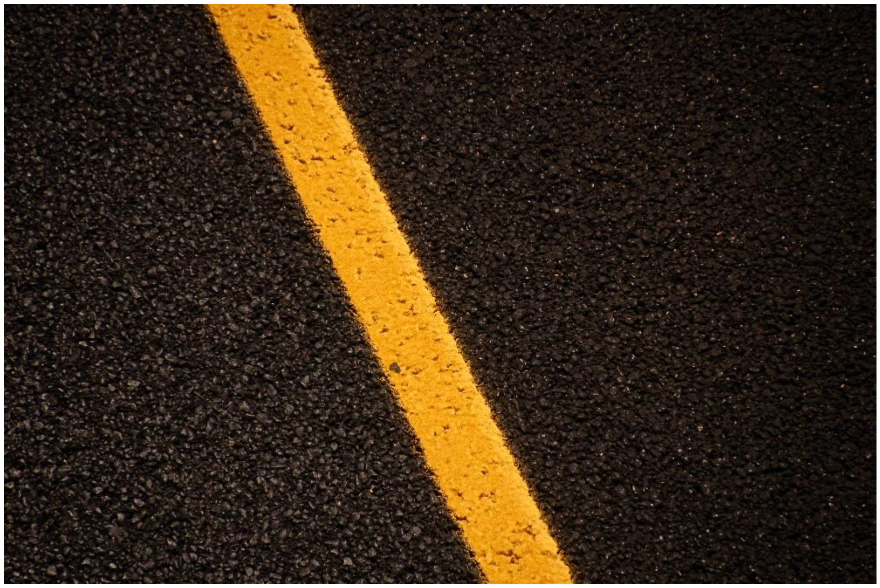


*Figure 9.71 2019 PFC overlay (June 13, 2019)*

The westbound overlay ends west of Sylvan Avenue. The eastbound overlay ends close to the easternmost end of the Segment 2 of Site 2 barrier. The easternmost limit of the eastbound overlay can be seen in Figure 9.72. Also, the very loud, damaged open expansion joint that had been identified as a major noise source (see Section 9.2.4 earlier in this chapter), next to the end of Segment 2, is just beyond the limits of the new overlay, and it was not repaired (Figures 9.73 and 9.74). Therefore, it remained in poor condition, still producing loud noise as vehicles go by.

*Figure 9.72 Easternmost limit of the new eastbound overlay*

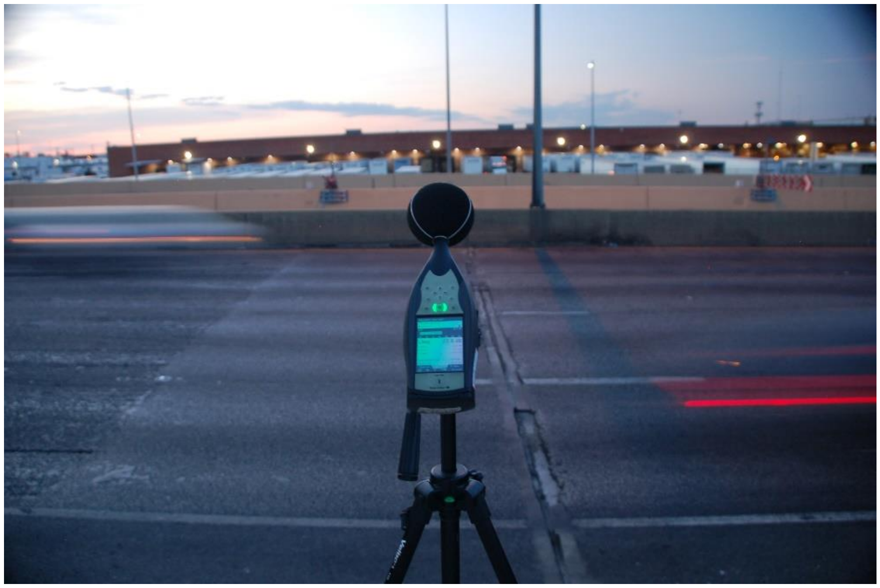


*Figure 9.73 Pavement transition and unrepaired damaged joint*

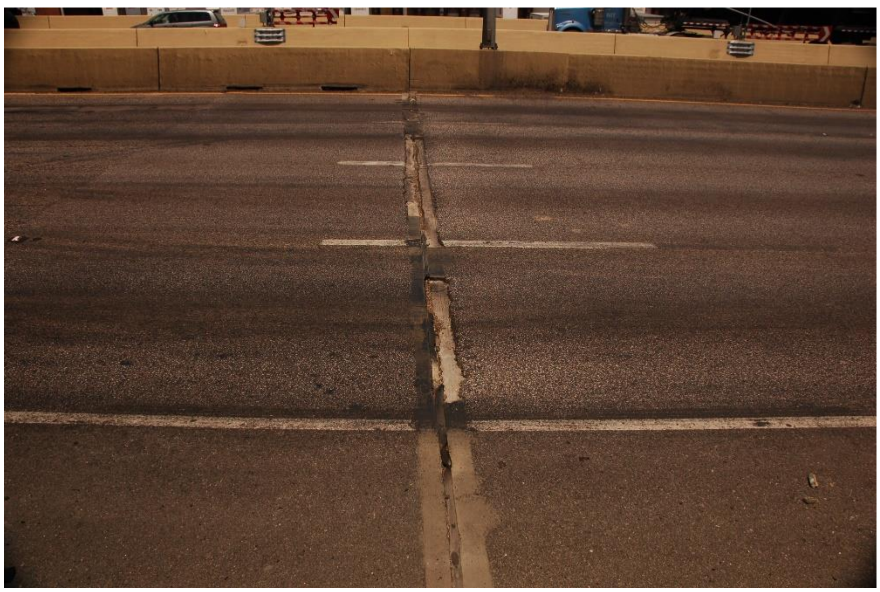


*Figure 9.74 Unrepaired damaged joint*

The old PFC surfaces, corresponding to 2006 and 2010, were identified as major reasons for the loud measurements at the various residential locations pertaining to Site 2, especially, reducing the potential benefits of the noise barrier. Site 1 measurements concluded in August 2017, so the latter deterioration of these pavements had a more adverse effect on the Site 2 measurements. The new overlay was only in place for the last three measurement dates for this project at Site 2 (June, July, and August 2019). It is expected that the new overlay will enhance the future perceived effectiveness of the Site 2 wall. For now, it can be said that the comparatively small benefits of the Site 2 wall can be explained by the loudness of the old overlays.

To study the importance of the pavement in the noise levels perceived in the neighborhood, the following analysis was performed, separating the post-barrier condition data for the old overlays and for the new overlay. Unfortunately, the data for the new overlay represents a very small sample size compared to the data collected with the old overlays. Table 9.6 shows the sample sizes in regard to the pavement in service at the time of the noise tests.

**Table 9.6 Sample size (number of tests)**

| | Site 1 | | Site 2 | |
|---|---|---|---|---|
| | Pre-Barrier | Post-Barrier | Pre-Barrier | Post-Barrier |
| 2006 and 2010 PFC | 130 | 646 | 289 | 118 |
| 2019 PFC | 0 | 0 | 0 | 45 |

The average sound pressure levels by pavement overlay is shown in Table 9.7 for both Site 1 and Site 2. This table shows that the 2019 PFC was beneficial for Site 2.

**Table 9.7 Average sound pressure level (dBA) by pavement overlay**

| | Site 1 | | Site 2 | |
|---|---|---|---|---|
| | Pre-Barrier | Post-Barrier | Pre-Barrier | Post-Barrier |
| 2006 and 2010 PFC | 58.2 | 55.8 | 58.6 | 58.7 |
| 2019 PFC | - | - | - | 57.6 |

Knowing the completion date of the three PFC overlays that are part of this stretch of highway (2006, 2010, and 2019 overlays) that contribute to the tire-pavement noise subject of this study, an approximate pavement age was associated with each of the noise measurements of this project based upon the overlay date and the test date, by subtracting the overlay date from the test date in days. The plot in Figure 9.75 shows the data, for both Site 1 and Site 2 and for both the pre-barrier and post-barrier conditions, relating each noise level measurement with its corresponding pavement age at the time of the measurement. Site 1 tests are assumed to be influenced mostly by the 2010 PFC, while Site 2 tests are assumed to be related mostly to the 2006 PFC for the majority of the study, and to the 2019 PFC from June 2019 until the end.

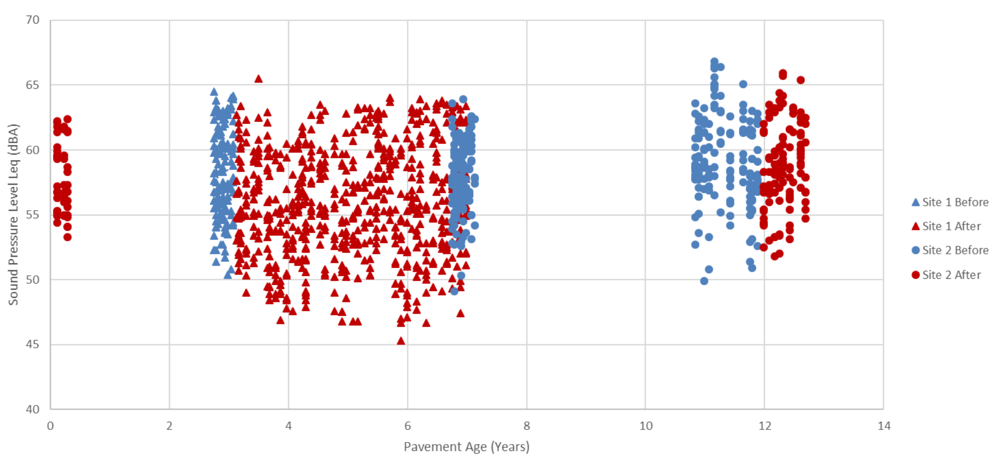



*Figure 9.75 Noise level and pavement age*

This graph shows the Site 1 pre-barrier data to be grouped close to a pavement that is about 3 years old, and those are the 2013 tests that are mostly related to the 2010 PFC. The Site 1 post-barrier data correspond to a pavement that is between 3 and 7 years old, and those are the tests conducted from 2013 to 2017. The Site 2 pre-barrier data are grouped in two clusters: one that corresponds to a pavement that is approximately 7 years old, which is the 2006 PFC tested in 2013, and the other one that corresponds to a pavement that is between 11 and 12 years old, which are the tests conducted for the 2006 PFC in 2017 and 2018. For the post-barrier condition at Site 2, the data is grouped in two clusters, the first one corresponding to a pavement that is about 12 to 13 years old (tests conducted in 2018–2019, related to the 2006 PFC), and the second one corresponding to the new 2019 PFC, for which the pavement was less than a year old. The purpose of the graph is to observe whether there is a relationship between pavement age and measured noise levels in the neighborhood. In general, higher noise levels occurred with older pavements, and this is an important conclusion. This could be interpreted also as the influence of traffic volume, assuming that there was an increase in traffic volume with time, as the overlays got older.

Another way to analyze whether the 2019 PFC had an influence on noise levels measured at the neighborhood is presented in Figure 9.76, which shows noise levels for Site 2 for the post-barrier condition only, for the tests with the older PFCs and with the new 2019 PFC, for each of the neighborhood locations. This graph shows that the noise levels were lower for the 2019 PFC.

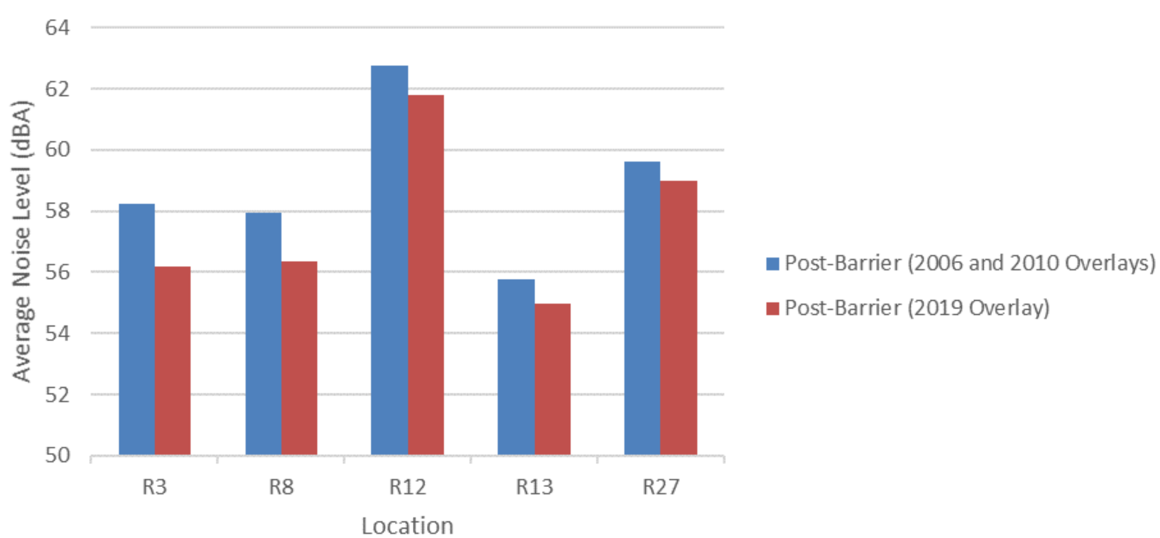



*Figure 9.76 Site 2 post-barrier average noise level comparison of pavement surface by residential location*

## 9.5.1. Finished Wall

The installation of the wall was finalized in early August 2018. Some images of the finished wall from various angles and locations, at several times of the day and night, are shown in Figures 9.77 to 9.84.

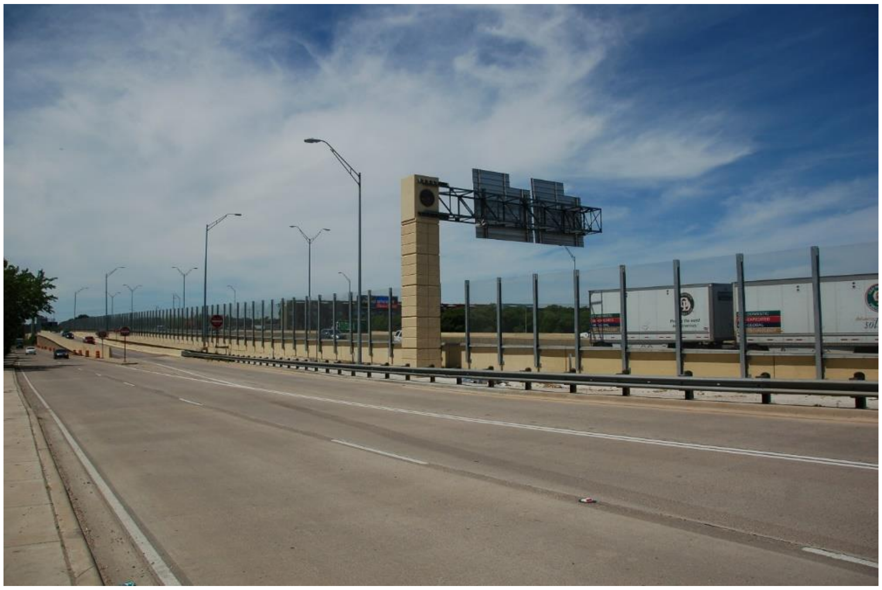


*Figure 9.77 View of Segment 2 from the eastbound frontage road*

*Figure 9.78 Driver's perspective at exit 44A ramp between Segment 2 (L) and Segment 1(R)*

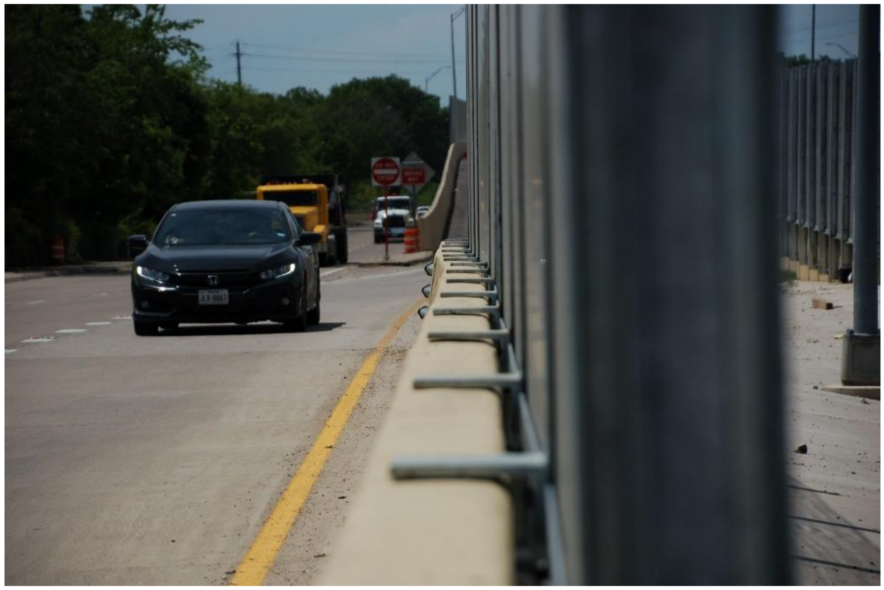


*Figure 9.79 From L to R:Segment 1 in the background, Segment 3 in the foreground, Segment 2 in the background*


*Figure 9.80 View of Segment 3 from berm south of I-30*

*Figure 9.81 Segment 1 from eastbound frontage road*

*Figure 9.82 Segment 1 and Segment 2 at exit ramp from eastbound frontage road*

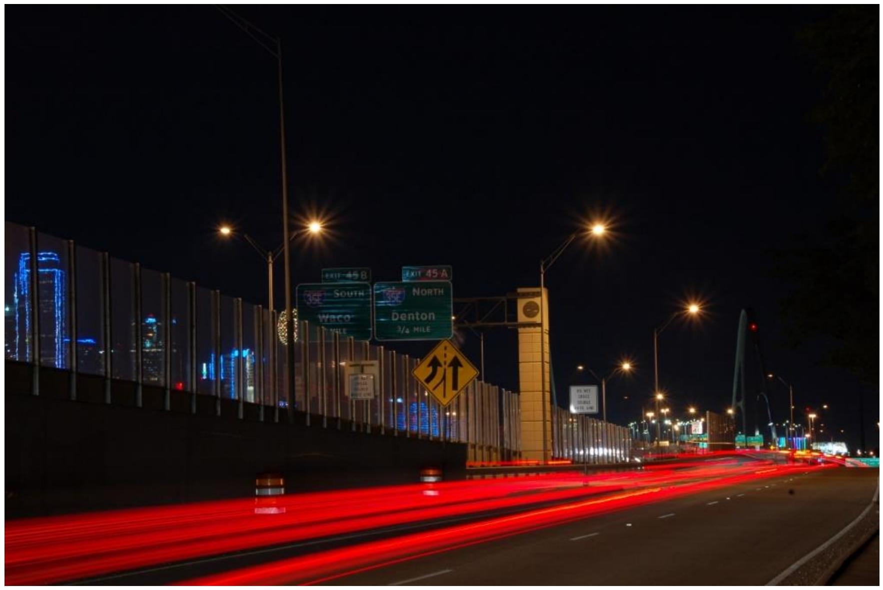



*Figure 9.83 Segment 2 from eastbound frontage road*

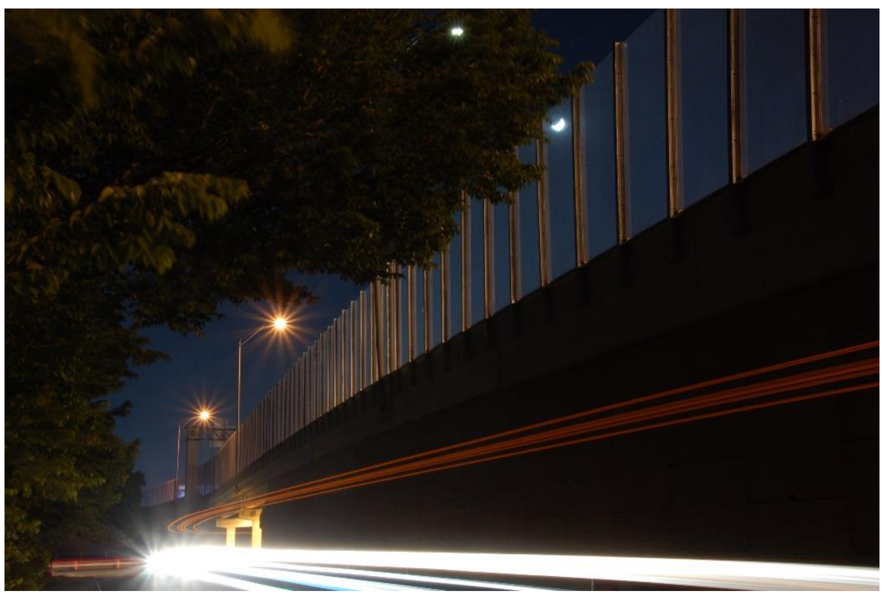


*Figure 9.84 Segment 1 from eastbound frontage road*

## 9.6. Summary

This chapter presents the monitoring activities of the Site 2 wall, from the visits that took place before the design through the completion of the wall and beyond, including the establishment of feasible limits, the construction, and some of the setbacks that occurred, and how these difficulties were resolved. The monitoring of the wall continued to assess its condition until August 2019, when this task ended. The monitoring involved documenting the installation, construction, and condition with photographs, videos, and GPS.

# Chapter 10. Conclusions and Recommendations

This chapter presents the final conclusions of the study. This research project studied the feasibility of lightweight noise barriers for a section of I-30 in Dallas. An investigation of lightweight and transparent materials for noise barriers was conducted, gathering information from the literature and the experiences of other DOTs and organizations, including vendors and material manufacturers.

Two transparent lightweight noise walls were planned and designed for both Site 1 and Site 2, corresponding to adjacent segments of the highway, each developed during separate stages of the project.

For the first phase, corresponding to Site 1, after the TNM noise barrier design was performed for various heights, a minimum height of 8 ft was recommended (on top of the existing wall) to provide benefits to some residential receivers, and a 10-ft wall was recommended to provide benefits for locations along the park. TxDOT agreed to install a 10-ft barrier of transparent acrylic material. The Acrylite product was selected, with 15-mm thick panels. The installation of the barrier was completed in mid-October 2013.

A comprehensive noise testing program was initiated prior to the noise wall installation, and measurements continued for almost four years after the barrier's completion. Monitoring and inspection of the wall's condition occurred ever since the start of its installation and concluded in August 2017.

For Site 2, the design included three separate wall segments. For Segment 1, a 13.2-ft tall wall was designed to be installed next to the Site 1 wall; for Segment 2 and 3, 10-ft panels were recommended. All segments were placed on top of the existing concrete walls. The installation started in late January 2018 and concluded in early August 2018. The same Acrylite product was selected for the noise wall material, providing a uniform appearance between the Site 1 and Site 2 barriers. A similar noise testing program took place for Site 2 as well.

The noise testing program showed that all locations on Site 1 received acoustic benefits from the noise wall in the form of noise level reductions. As expected, the benefits vary by location, with the residences that are closer to the wall and at lower elevation receiving the most benefit. The average noise level reduction for all the Site 1 locations is 2.4 dBA. Although the average reductions may seem acoustically small for some locations, they are statistically significant, confirming that the barrier has had a positive effect on noise levels. For Site 2, the overall average benefit was 0.2 dBA, which is negligible. And not all the residential locations received a benefit: the two westernmost locations (R3 and R8) had some small benefit from the wall; however, the three easternmost locations present an increase in average noise levels after the noise wall installation. As the noise barrier could not be the reason for an increase in noise, CTR investigated this increase in noise generation and attributed it to the following factors:

- **Increase in traffic.** The initial pre-barrier tests for Site 2 started in 2013 and the final post-barrier tests were finished in August 2019; therefore, an increase in traffic on the facility is very likely given the 6-year span.

- **Increase in tire-pavement noise generation from the old overlays.** The 2006 and 2010 PFC overlays experienced considerable deterioration throughout the duration of this project, as documented in Chapter 3. Tire-pavement noise tests, also presented in Chapter 3, support these observations, and show that the pavements got louder. A new overlay was constructed in 2019 (finished in June), but it was too late in the testing period to make a significant difference in the average noise levels.

- **Tire-pavement noise generated on the CRCP approach and CRCP deck of the McDermott Bridge.** Noise coming from the easternmost end of the Site 2 barrier travels unobstructed to the residential locations even after the completion of the barrier. The bridge and approach are elevated and the surfaces are transversely tined CRCP, generating the loud and whiny noise characteristic of CRCP. Part of the approach was overlaid with asphalt in April 2018.

With these considerations, even though the overall noise at the neighborhood sites is higher after the barrier, it could only be reasonably assumed that without the barrier, the noise perceived at the Kessler Park residences would be even higher than the measurements.

Other conclusions include the following:

- This project comprises a large data collection effort over the course of several years, which has resulted in a sizeable data base of noise and weather records. The large amount of data increases the reliability and confidence in the information obtained. This is confirmed by the normal distributions of the noise level data.

- Notwithstanding the amount of data, the data collection had a couple of important flaws, dictated by the timing of the project: for Site 1, the pre-barrier data collection period was significantly shorter than the post-barrier period collection time, and includes only warm-weather information as the pre-barrier collection time only included from May 2013 to October 2013, whereas the post-barrier data collection period comprised almost four years —October 2013 to August 2017—and corresponded to all the seasons and weather conditions. At Site 1, 130 noise measurements were taken before the wall was installed, and 646 measurements for the post-barrier condition. Therefore, the reliability of the post-barrier data is much higher than the pre-barrier data for Site 1. For Site 2, the drawback is that a significant period passed between the first group of data collected for the pre-barrier condition (2013) and the resumption of the project after the completion of the Horseshoe Project (2017), which makes for a larger variability in the traffic and pavement conditions. On the other hand, this could be seen as a positive aspect of the research project, as it captured a longer span of conditions. Also, the Site 2 post-barrier condition measurements were conducted at the latter stage of the life of the old PFC overlays, when they were most worn-out and at their worst condition (meaning when the PFC sections were generating more tire-pavement noise), and these results were compared to the pre-barrier condition, which started four years before, making the time span more significant in the results.

- The data consistently showed that the Site 1 barrier resulted in lower noise levels, indicating that the wall works in reducing the noise at the neighborhood.

- Noise levels are generally higher in the colder months and lower in the warmer months.

- Cold temperatures are correlated to higher tire-pavement noise generation.

- Some weather variables such as wind speed and relative humidity appear to have no significant influence on noise levels overall.

- However, wind direction is correlated with noise levels in the neighborhood locations: higher noise levels occur when the winds blow from the north, which corresponds to some residents' empirical observations.

- The time of the day when the tests were conducted appears to have had no influence on the noise levels.

- The pre-barrier condition and post-barrier condition data analysis for Site 1 (t-test) indicates that the two data sets are statistically significantly different, which means that the noise levels are significantly lower after the wall has been in place. For Site 2, the t-test indicates that difference in noise levels between the two data sets is not considered statistically significant, and therefore, the barrier did not have an effect on noise levels.

- Despite the widespread perception by residents, measured noise levels are generally low, for both the pre-barrier and post-barrier conditions at both sites. Using the "Impact" from the Noise Abatement Criteria value of 66 dBA as a threshold, and analyzing the data, it was observed that at Site 1, for the pre-barrier condition there were no measurements that corresponded to impact, while for the post-barrier condition only one test resulted in impact. For Site 2, there were seven occasions in which the test outcome was an impact. For the high amount of data collected, the number tests that resulted in impact (66 dBA or above) is negligible (0.65%).

- Even though OBSI tire-pavement tests were not strictly part of the testing program in this research project, their usefulness and the valuable information they provide about the pavement performance are essential in explaining noise levels and why apparently the walls may not be producing optimum results. The highest contribution to traffic noise at highway speeds comes from the noise generated at the tire-pavement interface *(Sandberg 2002)*. The PFC overlays next to the sound walls did not perform as "quieter" pavements due to the normal degradation of their acoustic properties over time that occurs when the void content is diminished by compaction from traffic loads and clogging with debris. This resulted in higher tire-pavement noise and higher noise levels measured at the neighborhood.

- For Site 2, the pre-barrier condition data was collected in two stages: from May through October 2013, and from June 2017 through July 2018. Noise levels were higher in the second collection period due to the increasing loudness of the pavements, as demonstrated by OBSI, and also very likely due to an increase in traffic on I-30.

- The following are important considerations that can affect how the acoustic benefits of the walls are perceived and evaluated:

    - As mentioned before, there were no tests conducted in cold weather for the pre-barrier condition at Site 1. It could be assumed that the noise levels for cold weather conditions before the barrier would have been much higher, and this would have made the barrier's benefit more obvious. This was confirmed at Site 2, where the pre-barrier condition was tested over a longer period including a variety of seasons.

    - The presence of an existing 8-ft concrete barrier at Site 1 provided some noise mitigation to the neighborhood, as mentioned in Chapter 4.

    - Many other sources of noise are present (besides the I-30 traffic noise) for which the noise barriers cannot provide any shielding: airplane noise; traffic noise from Kessler Parkway, the residential street between I-30 and the neighborhood; traffic noise from Sylvan Avenue, and especially from the underside of the I-30 overpass above Sylvan Avenue; loud noises from birds and insects, especially in the warm months at dusk; and noise from air blowers and lawnmowers used by residents. Every effort was made to eliminate such noises from the measurement recordings by using the "pause and delete the previous 5 s" feature provided by the SPL meters (back-erase). Frequently, however, these additional noises were prevalent in the background while the tests were being performed, and on many occasions surpassed the highway noise levels.

    - Locations E and B are close to the westernmost end and the easternmost end, respectively, of the Site 1 noise barrier. The highway noise coming from the sides of the barrier at either end reached these locations without any protection from the barrier, as the Site 2 wall was not in place throughout the first phase of this project when the Site 1 post-barrier condition was evaluated. Location E is approximately 570 ft from the west end of the barrier, while Location B is approximately 280 ft away from the east end of the barrier.

    - For Locations D and F, also at Site 1, their distance to the highway and their higher elevation limit the effectiveness of the barrier.

    - For Site 2, there is no shielding protecting the neighborhood from the highway noise coming from the McDermott Bridge and its approach, which are transversely tined CRCP. At a latter stage of the testing program, part of the approach was overlaid with asphalt, but the bridge deck and part of the approach remained as CRCP, which generates higher noise levels. The noise barrier does not help with this, as the noise comes from further east from the easternmost limit of the wall, and from higher elevation.

## 10.1. Additional Discussion of Results and Comments

Understanding how noise from traffic traveling on the highway is propagated to the nearby residential areas is a challenging task, as noise is affected by a variety of factors, including meteorological phenomena. One aspect that could not be analyzed in this project is the influence of vertical gradients of wind speed and temperature. This aspect could affect how the sound waves are refracted and change their trajectories and the distances that the noise can reach.

Among the atmospheric factors, temperature is the most significant in regard to noise generation and propagation, while wind speed and relative humidity also show influence on noise levels. It was expected that wind speed would have some measurable effect, but it was not the case. However, wind direction produced the expected result.

An aspect that has not been discussed in this report, but that was observed throughout the measurement periods over the seasons, is the effect of the foliage on the way noise propagates at this location; the absence of foliage appears to result in higher noise propagation; therefore, foliage might have some influence on the noise levels. It diffracts and absorbs sound. There is a considerable difference in the aspect of the foliage between the hot and cold seasons in this area, as illustrated in Figure 10.1. Therefore, the hypothesis is that when the vegetation looks as barren as the pictures on the right side of Figure 10.1 show (late fall, winter, and early spring), the noise from the highway propagates without obstruction towards the receivers, whereas when the foliage obstructs the view of the highway from the receivers locations, it contributes to lowering the noise levels.

*Figure 10.1 Foliage differences between warm (left) and cold (right) seasons in the proximity of the barrier*

The neighbors are very satisfied with both walls, as revealed by numerous informal conversations between the residents and the researcher over the years. The public perception is very positive in regard to both acoustic benefits and aesthetics. The psychoacoustical effect of being able to see the traffic flow behind the transparent barrier while not perceiving the same level of noise as before might be an important factor.

This project has been an overall success as a pilot project: the accomplishment of the Site 1 noise barrier—the first of its kind in Texas—resulted in the continuation of the project to the east, with the Site 2 barrier, and in some other new transparent barriers at other highway locations where the lightweight transparent option is a viable solution, such as the SH 190 new noise walls, east of Dallas, project which was part of this research. This success made this project the recipient of the TxDOT Environmental Achievement Award for 2014.

## 10.2. Recommendations

During the project, it was recommended that TxDOT replace the noise wall rubber gaskets that were broken or out of place and seal any openings in the wall, as well as between the wall and the concrete, to keep the noise from reaching the neighborhood at Site 1. Many of the gaskets were broken, sagging, or not in an adequate position to fulfill their purpose. Some of those gaskets were completely removed, but not replaced with new ones. Therefore, the recommendation still stands, as the openings are still there. Also, it is recommended to work on the concrete expansion joints on the concrete wall that are wide open without any sealant, and to replace the old sealant that is in bad condition in some other joints. Closing these openings will improve the apparent barrier's performance.

Throughout the duration of this research, it was recommended to replace the old PFC overlays, which were constructed in 2006 and 2010, respectively, and this finally occurred in June 2019, towards the very end of the project testing period. These older pavements were very loud, and performed like dense-graded asphalt surfaces, as they had lost their acoustic benefits by losing their void content due to compaction and clogging. After so many years in service, this is a normal occurrence due to the heavy loads that the pavements are subjected to, the high traffic volume that the facility carries, as well as the debris from the highway, resulting in higher tire-pavement noise generation, as shown by the OBSI results over time. The new quieter surfaces will result in apparent improved performance of both walls by reducing the noise perceived at the residential locations. Therefore, as the new pavements age, it is recommended to continue monitoring their tire-pavement generation and their acoustic performance, and to replace them before they begin generating considerable noise.

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