Cotton Belt Corridor Regional Rail
Noise and Vibration Existing Conditions
Technical Memorandum

December 2013

Prepared by URS Corporation
## Document Revision Record

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1.0 INTRODUCTION

This technical memorandum presents the noise and vibration existing conditions for the Cotton Belt Corridor Regional Rail Project (Cotton Belt Project). This report was carried out for Dallas Area Rapid Transit (DART) by Harris Miller Miller & Hanson Inc. (HMMH) under subcontract to URS Corporation. The objective of this report is to document the existing noise and vibration conditions along the Cotton Belt Corridor. The noise and vibration information contained in this report is in conformance with the procedures and criteria established in the Federal Transit Administration (FTA) guidance manual “Transit Noise and Vibration Impact Assessment” (Final Report No. FTA-VA-90-1003-06, May 2006).

Section 2 provides a discussion of environmental noise and vibration basics, Section 3 describes the criteria used to assess noise and vibration impacts, and the existing noise and vibration conditions and measurement results are contained in Section 4. Appendix A includes measurement site photographs, and detailed noise and vibration measurement data are provided in Appendix B and Appendix C, respectively.
2.0 NOISE AND VIBRATION BASICS

2.1 Noise Fundamentals and Descriptors

Noise is typically defined as unwanted or undesirable sound, where sound is characterized by small air pressure fluctuations above and below the atmospheric pressure. The basic parameters of environmental noise that affect human subjective response are (1) intensity or level, (2) frequency content and (3) variation with time. The first parameter is determined by how greatly the sound pressure fluctuates above and below the atmospheric pressure and is expressed on a compressed scale in units of decibels. By using this scale, the range of normally encountered sound can be expressed by values between 0 and 120 decibels. On a relative basis, a 3-decibel change in sound level generally represents a barely noticeable change outside the laboratory, whereas a 10-decibel change in sound level would typically be perceived as a doubling (or halving) in the loudness of a sound.

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

Because environmental noise fluctuates from moment to moment, it is common practice to condense all of this information into a single number called the “equivalent” sound level (Leq). Leq can be thought of as the steady sound level that represents the same sound energy as the varying sound levels over a specified time period (typically 1 hour or 24 hours). Often the Leq values over a 24-hour period are used to calculate cumulative noise exposure in terms of the Day-Night Sound Level (Ldn). Ldn is the A-weighted Leq for a 24-hour period with an added 10-decibel penalty imposed on noise that occurs during the nighttime hours (between 10:00 PM and 7:00 AM). Many surveys have shown that Ldn is well correlated with human annoyance, and therefore, this descriptor is widely used for environmental noise impact assessment. Figure 2-1 provides examples of typical noise environments and criteria in terms of Ldn. While the extremes of Ldn are shown to range from 35 dBA in a wilderness environment to 85 dBA in noisy urban environments, Ldn is generally found to range between 55 dBA and 75 dBA in most communities. As shown in Figure 2-1, this spans the range between an “ideal” residential environment and the threshold for an unacceptable residential environment according to U.S. Federal agency criteria.
2.2 Ground-Borne Vibration Fundamentals and Descriptors

Ground-borne vibration is the oscillatory motion of the ground about some equilibrium position that can be described in terms of displacement, velocity or acceleration. Because sensitivity to vibration typically corresponds to the amplitude of vibration velocity within the low-frequency range of most concern for environmental vibration (roughly 5 Hz to 100 Hz), velocity is the preferred measure for evaluating ground-borne vibration from transit projects.

The most common measure used to quantify vibration amplitude is the peak particle velocity (PPV), defined as the maximum instantaneous peak of the vibratory motion. PPV is typically used in monitoring blasting and other types of construction-generated vibration, since it is related to the stresses experienced by building components. Although PPV is appropriate for evaluating building damage, it is less suitable for evaluating human response, which is better related to the average vibration amplitude. Thus, ground-borne vibration from transit systems is usually characterized in terms of the "smoothed" root mean square (RMS) vibration velocity level, in decibels (VdB), with a reference quantity of one micro-inch per second. VdB is used in place of dB to avoid confusing vibration decibels with sound decibels.
Figure 2-2 illustrates typical ground-borne vibration levels for common sources as well as criteria for human and structural responses to ground-borne vibration. As shown, the range of interest is approximately 50 to 100 VdB, from imperceptible background vibration to the threshold of damage. Although the approximate threshold of human perception to vibration is 65 VdB, annoyance is usually not significant unless the vibration exceeds 70 VdB.

### Figure 2-2

**Typical Ground-Borne Vibration Levels and Criteria**

<table>
<thead>
<tr>
<th>Human/Structural Response</th>
<th>Velocity Level*</th>
<th>Typical Sources (50 ft from source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold, minor cosmetic damage to fragile buildings</td>
<td>100</td>
<td>Blasting from construction projects</td>
</tr>
<tr>
<td>Difficulty with tasks such as reading a VDT screen</td>
<td>90</td>
<td>Bulldozers and other heavy tracked construction equipment</td>
</tr>
<tr>
<td>Residential annoyance, infrequent events (e.g. commuter rail)</td>
<td>80</td>
<td>Commuter rail, upper range</td>
</tr>
<tr>
<td>Residential annoyance, frequent events (e.g. rapid transit)</td>
<td>70</td>
<td>Rapid transit, upper range</td>
</tr>
<tr>
<td>Limit for vibration sensitive equipment. Approx. threshold for human perception of vibration</td>
<td>60</td>
<td>Commuter rail, typical</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>Bus or truck over bump</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapid transit, typical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus or truck, typical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Typical background vibration</td>
</tr>
</tbody>
</table>

* RMS Vibration Velocity Level in VdB relative to $10^{-8}$ inches/second
3.0 NOISE AND VIBRATION IMPACT CRITERIA

Noise and vibration impact for this project is based on the criteria as defined in the U.S. FTA guidance manual “Transit Noise and Vibration Impact Assessment” (FTA-VA-90-1003-06, May 2006). These criteria are consistent with DART policy as described in “Environmental Impact Assessment and Mitigation Guidelines for Transit Projects” (DART, May 2012.)

3.1 Transit Noise Criteria

FTA noise impact criteria are founded on well-documented research on community reaction to noise and are based on change in noise exposure using a sliding scale. Although higher rail noise levels are allowed in neighborhoods with high levels of existing noise, smaller increases in total noise exposure are allowed with increasing levels of existing noise. The FTA noise impact criteria place noise sensitive land uses into three categories as indicated in Table 3-1.

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Noise Metric (dBA)</th>
<th>Description of Land Use Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outdoor $L_{eq}(h)^1$</td>
<td>Tracts of land where quiet is an essential element in their intended purpose. This category includes land set aside for serenity and quiet, and such land use as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use. Also included are recording studios and concert halls.</td>
</tr>
<tr>
<td>2</td>
<td>Outdoor $L_{dn}$</td>
<td>Residences and buildings where people normally sleep. This category includes homes, hospitals and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.</td>
</tr>
<tr>
<td>3</td>
<td>Outdoor $L_{eq}(h)^1$</td>
<td>Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, theaters, and churches where it is important to avoid interference with such activities as speech, meditation and concentration on reading material. Places for meditation or study associated with cemeteries, monuments, museums, campgrounds and recreational facilities can also be considered to be in this category. Certain historical sites and parks are also included.</td>
</tr>
</tbody>
</table>

$^1$ $L_{eq}$ for the noisiest hour of transit-related activity during hours of noise sensitivity.

Source: FTA, May 2006

$L_{dn}$ is used to characterize noise exposure for residential areas (Category 2). For other noise sensitive land uses, such as outdoor amphitheaters and school buildings (Categories 1 and 3), the maximum 1-hour $L_{eq}$ during the facility’s operating period is used.

There are two levels of impact included in the FTA criteria. The interpretation of these two levels of impact is summarized below:

- **Severe Impact**: Project-generated noise in the severe impact range can be expected to cause a significant percentage of people to be highly annoyed by the new noise and...
represents the most compelling need for mitigation. Noise mitigation will normally be specified for severe impact areas unless there are truly extenuating circumstances which prevent it.

- **Moderate Impact:** In this range of noise impact, the change in the cumulative noise level is noticeable to most people but may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These factors include the existing level, the predicted level of increase over existing noise levels, the types and numbers of noise-sensitive land uses affected, the noise sensitivity of the properties, the effectiveness of the mitigation measures, community views, and the cost of mitigating noise to more acceptable levels.

According to FTA guidance, historically significant sites fall into noise-sensitive categories according to their land use activities. Sites where outdoor interpretation is important fall into Category 1. Buildings in commercial or industrial areas that are significant because they represent a particular style of architecture or are prime examples of work of an historically significant designer are not intrinsically noise-sensitive. They may be protected under other legislation (Section 4(f) of the DOT Act and Section 106 of the National Historic Preservation Act), but do not fall into any of the land use categories associated with noise-sensitivity.

The noise impact criteria are summarized in graphical form in **Figure 3-1**. This figure shows the existing noise exposure and the additional noise exposure from the rail project that would cause either “moderate” or “severe” impact. The future noise exposure would be the combination of the existing noise exposure and the additional noise exposure caused by the proposed rail project. **Figure 3-2** expresses the same criteria in terms of the increase in total or cumulative noise that can occur in the overall noise environment before impact occurs.
Figure 3-1
FTA Project Noise Impact Criteria

Figure 3-2
Increase in Cumulative Noise Exposure Allowed by FTA Criteria

Note:
Noise exposure is in terms of \( L_{eq} (h) \) for Category 1 and 3 land uses, \( L_{dn} \) for Category 2 land uses.
3.2 Transit Ground-Borne Vibration Criteria

The FTA groups vibration-sensitive land uses into three categories. Since ground-borne vibration does not typically annoy people who are outdoors, vibration impact is only assessed inside buildings. In addition to the potential for human annoyance, vibration impact is also assessed for certain equipment that is sensitive to vibration.

- **Vibration Category 1 – High Sensitivity**: Included in this category are buildings where vibration would interfere with operations. Vibration levels may be well below those associated with human annoyance. These buildings include vibration-sensitive research and manufacturing facilities, hospitals with sensitive equipment and university research operations. The sensitivity to vibration is dependent on the specific equipment present. Some examples of sensitive equipment include electron-scanning microscopes, magnetic resonance imaging scanners and lithographic equipment.

- **Vibration Category 2 – Residential**: Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels.

- **Vibration Category 3 – Institutional**: This category includes buildings with primarily daytime and/or evening use. This category includes schools, libraries and churches.

The FTA vibration impact criteria are based on land use and operational frequency, as shown in Table 3-2 and are given in terms of the maximum RMS vibration level for an event. There are some buildings, such as concert halls, recording studios and theaters that can be very sensitive to vibration, but do not fit into any of the three categories listed in Table 3-2. Due to the sensitivity of these buildings, they usually warrant special attention during the environmental assessment of a transit project. Table 3-3 gives criteria for acceptable levels of ground-borne vibration for various types of special buildings.

It should be noted that Table 3-2 and Table 3-3 include separate FTA criteria for ground-borne noise; the "rumble" that can be radiated from the motion of room surfaces in buildings due to ground-borne vibration. Although expressed in dBA, which emphasizes the more audible middle and high frequencies, the criteria are set significantly lower than for airborne noise to account for the annoying low-frequency character of ground-borne noise.

In addition to the criteria provided in Table 3-2 and Table 3-3 for general assessment purposes, FTA has established criteria in terms of one-third octave band frequency spectra for use in detailed analyses. Table 3-4 and Figure 3-3 present these more detailed vibration criteria (VC) and describe their application. For residential buildings with night-time occupancy, the applicable criterion for a detailed analysis is a maximum vibration velocity level of 72 VdB, measured in one-third octave bands.
Table 3-2
FTA Ground-Borne Vibration and Ground-Borne Noise Impact Criteria

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch /sec)</th>
<th>Ground-Borne Noise Impact Levels (dB re 20 micro-Pascals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequent Events¹</td>
<td>Occasional Events²</td>
</tr>
<tr>
<td>Category 1: Buildings where vibrations would interfere with interior operations.</td>
<td>65 VdB⁴</td>
<td>65 VdB⁴</td>
</tr>
<tr>
<td>Category 2: Residences and buildings where people normally sleep.</td>
<td>72 VdB</td>
<td>75 VdB</td>
</tr>
<tr>
<td>Category 3: Institutional land uses with primarily daytime use.</td>
<td>75 VdB</td>
<td>78 VdB</td>
</tr>
</tbody>
</table>

¹ "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
² "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
³ "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.
⁴ This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
⁵ Vibration-sensitive equipment is generally not sensitive to ground-borne noise.
Source: FTA, May 2006

Table 3-3
Ground-Borne Vibration and Noise Impact Criteria for Special Buildings

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch /sec)</th>
<th>Ground-Borne Noise Impact Levels (dB re 20 micro Pascals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequent Events¹</td>
<td>Occasional or Infrequent Events²</td>
</tr>
<tr>
<td>Concert Halls</td>
<td>65 VdB</td>
<td>65 VdB</td>
</tr>
<tr>
<td>TV Studios</td>
<td>65 VdB</td>
<td>65 VdB</td>
</tr>
<tr>
<td>Recording Studios</td>
<td>65 VdB</td>
<td>65 VdB</td>
</tr>
<tr>
<td>Auditoriums</td>
<td>72 VdB</td>
<td>80 VdB</td>
</tr>
<tr>
<td>Theaters</td>
<td>72 VdB</td>
<td>80 VdB</td>
</tr>
</tbody>
</table>

¹ "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
² "Occasional or Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
³ If the building will rarely be occupied when the trains are operating, there is no need to consider impact. As an example, consider locating a commuter rail line next to a concert hall. If no commuter trains will operate after 7 pm, it should be rare that the trains interfere with the use of the hall.
Source: FTA, May 2006
<table>
<thead>
<tr>
<th>Criterion Curve</th>
<th>Maximum Vibration Level (VdB re: 1 micro-inch/sec)(^1)</th>
<th>Description of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop</td>
<td>90</td>
<td>Distinctly feelable vibration. Appropriate to workshops and non-sensitive areas</td>
</tr>
<tr>
<td>Office</td>
<td>84</td>
<td>Feelable vibration. Appropriate to offices and non-sensitive areas</td>
</tr>
<tr>
<td>Residential Day</td>
<td>78</td>
<td>Barely feelable vibration. Adequate for computer equipment and low-power optical microscopes (up to 20X)</td>
</tr>
<tr>
<td>Residential Night, Operating Rooms</td>
<td>72</td>
<td>Vibration not feelable, but ground-borne noise may be audible inside quiet rooms. Suitable for medium-power optical microscopes (100X) and other equipment of low sensitivity</td>
</tr>
<tr>
<td>VC-A</td>
<td>66</td>
<td>Adequate for medium- to high-power optical microscopes (400X), microbalances, optical balances, and similar specialized equipment</td>
</tr>
<tr>
<td>VC-B</td>
<td>60</td>
<td>Adequate for high-power optical microscopes (1000X), inspection and lithography equipment to 3 micron line widths</td>
</tr>
<tr>
<td>VC-C</td>
<td>54</td>
<td>Appropriate for most lithography and inspection equipment to 1 micron detail size</td>
</tr>
<tr>
<td>VC-D</td>
<td>48</td>
<td>Suitable in most instances for the most demanding equipment, including electron microscopes operating to the limits of their capability</td>
</tr>
<tr>
<td>VC-E</td>
<td>42</td>
<td>The most demanding criterion for extremely vibration-sensitive equipment</td>
</tr>
</tbody>
</table>

\(^1\) As measured in one-third octave bands of frequency.

Source: FTA, May 2006
3.3 Construction Noise Criteria

Construction noise criteria are based on the guidelines provided in the FTA guidance manual. These criteria, summarized in Table 3-5 below, are based on land use and time of day and are given in terms of Leq for an 8-hour work shift.

![Figure 3-3: Criteria for Detailed Vibration Analysis](image)

<table>
<thead>
<tr>
<th>Table 3-5: FTA Construction Noise Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land Use</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Residential</td>
</tr>
<tr>
<td>Commercial</td>
</tr>
<tr>
<td>Industrial</td>
</tr>
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</table>

Source: FTA, May 2006
3.4 Construction Vibration Criteria

In addition to ground-borne vibration criteria for humans in residential, institutional and special buildings and vibration-sensitive equipment, there are ground-borne vibration criteria for potential damage to structures. The limits of vibration that structures can withstand are substantially higher than those for humans and for sensitive equipment. Table 3-6 presents criteria from the FTA guidance manual for assessing the potential for vibration damage to structures based on the type of building construction. As shown in the table, these criteria are given in terms of RMS vibration levels in VdB referenced to 1 micro-inch per second as well as in terms of peak-particle velocity in inches per second. A crest factor of four, representing a difference of 12 decibels between peak and RMS, is assumed in this table. It should be noted that these criteria are more conservative than other standards such as the U.S. Bureau of Mines frequency-dependent vibration criterion which is equivalent to approximately 114 VdB at 40 Hz and above.

<table>
<thead>
<tr>
<th>Building Category</th>
<th>PPV (in/sec)</th>
<th>Approximate Lv ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Reinforced-concrete, steel or timber (no plaster)</td>
<td>0.5</td>
<td>102</td>
</tr>
<tr>
<td>II. Engineered concrete and masonry (no plaster)</td>
<td>0.3</td>
<td>98</td>
</tr>
<tr>
<td>III. Non-engineered timber and masonry buildings</td>
<td>0.2</td>
<td>94</td>
</tr>
<tr>
<td>IV. Buildings extremely susceptible to vibration damage</td>
<td>0.12</td>
<td>90</td>
</tr>
</tbody>
</table>

¹ RMS velocity in VdB re: 1 micro-inch/second.

Source: FTA, May 2006
4.0 EXISTING NOISE AND VIBRATION CONDITIONS

4.1 Noise and Vibration Sensitive Land Use

The noise and vibration sensitive land uses along the Cotton Belt Corridor were identified based on project aerial photography and mapping, as well as a field survey of the Cotton Belt Corridor conducted by HMMH staff on December 6-10, 2010.

The existing land uses along the Cotton Belt Corridor include many industrial and commercial buildings, along with apartment complexes and other multi-family buildings, such as Highland Springs Retirement Community in Dallas. Several schools are located along the Cotton Belt Corridor, including daycare facilities and the University of Texas at Dallas (UTD) buildings. Other sensitive land uses include parks, cemeteries, medical facilities and hotels. There are also stretches of adjacent single-family homes in Coppell, Carrollton and Dallas.

Starting from the western end of the Cotton Belt Corridor, there is no noise and vibration sensitive land use until Freeport Parkway in Coppell. After Freeport Parkway, the corridor parallels Belt Line Road until the Dallas, Garland and Northeastern Railroad (DGNO) rail yard near the Carrollton Heights neighborhood. Sensitive land uses in this area are mainly single-family residences to South MacArthur Boulevard, with the exception of W.W. Pinkerton Elementary School on Southwestern Boulevard. Sensitive land uses near the rail yard include schools, churches, single-family residences and several multi-family buildings, such as St. Marin apartments on Belt Line Road.

The Cypress Waters Alternatives deviate from the existing Cotton Belt Corridor right-of-way in the vicinity of North Lake. The sensitive land uses include single-family residences and W. W. Pinkerton Elementary School on Southwestern Boulevard and a church on East Belt Line Road.

The Cotton Belt Corridor follows the existing rail alignment through Carrollton where sensitive land uses include residences, schools and churches, as well as Perry Cemetery on Perry Road. Ted Polk Middle School is adjacent to the Cotton Belt Corridor in Carrollton on Kelly Boulevard.

The corridor continues along the existing rail alignment into Addison where the sensitive land use includes several hotels near Addison Airport. The corridor continues through Dallas, where there is a high concentration of residential neighborhoods adjacent to Cotton Belt Corridor. Other sensitive land uses include several schools, parks, and churches. Both the Fairhill School on Preston Road and Frankford Middle School on Osage Plaza Parkway are adjacent to the Cotton Belt Corridor. At Waterview Parkway, the corridor passes near the UTD campus. The closest school building, the Waterview Science and Technology Center, is located approximately 900 feet from the existing rail alignment. The future site of the Dallas International School is located between the Cotton Belt Corridor and the Waterview Science and Technology Center.

The Cotton Belt Project terminates in Plano, still following the existing rail alignment. The sensitive land uses along this section of the Cotton Belt Corridor includes residences, schools and churches. The Collinwood Nursing Home is adjacent to the corridor on South Rigsbee Drive.
4.2 Existing Noise Conditions

Representative sites were chosen in accordance with FTA guidelines to characterize the existing baseline noise conditions at sensitive receptors along the corridor. Noise measurements were conducted at these representative sites during the period from December 6 through December 10, 2010. The measurement program included both long-term (LT) (24-hour) and short-term (ST) (1-hour) monitoring of the A-weighted sound level. Nineteen sites, designated as LT-1 through LT-19, were selected throughout the Cotton Belt Corridor for long-term monitoring. Five sites, designated as ST-1 through ST-5, were selected for short-term monitoring in a few areas where needed to supplement the long-term measurements. The locations of the measurement sites are shown in Figure 4-1 and site photographs are included in Appendix A.

At the LT measurement sites, unattended portable, automatic noise monitors were used to continuously sample the A-weighted sound level (with slow response), over one 24-hour period. The noise measurement equipment included Bruel & Kjaer model 2250 and Larson Davis models 870 and 820 noise monitors. The noise monitors gathered hourly results, including the maximum sound level (Lmax), Leq, and the statistical percentile sound levels (Ln, denoting the sound level exceeded n-percent of the time). Ldn was subsequently computed from the hourly Leq data. At the ST sites, an attended noise monitor was used to obtain the equivalent, A-weighted sound level for 1-minute intervals over the 1-hour measurement period. The 1-minute Leq data were then combined to obtain the hourly Leq for the period.

All the noise measurement equipment described above conforms to American National Standards Institute (ANSI) Standard S1.4 for Type 1 (Precision) sound level meters. Calibrations, traceable to the U.S. National Institute of Standards and Technology (NIST) were carried out in the field before and after each set of measurements using acoustical calibrators. In all cases, the measurement microphone was protected by a windscreen and supported on a tripod at a height of four to six feet above the ground. Furthermore, the microphone was positioned to characterize the exposure of the site to the dominant noise sources in the area. For example, microphones were located at the approximate setback lines of the receptors from adjacent roads or rail lines, and were positioned to avoid acoustic shielding by landscaping, fences or other obstructions.

The results of the existing ambient noise measurements are summarized in Table 4-1 and detailed noise data are included in Appendix B. These measurement results serve as the basis for determining the existing noise conditions at all noise-sensitive receptors along the proposed Cotton Belt Corridor. The results at each LT and ST monitoring site are described below.

Existing noise conditions at sensitive receptors other than measurement sites were determined by adjusting the measurement results relative to the distance to the dominant noise source (if applicable).
Figure 4-1
Noise and Vibration Measurement Site Locations
<table>
<thead>
<tr>
<th>Site No.</th>
<th>Measurement Location Description</th>
<th>Start of Measurement</th>
<th>Meas. Duration (hrs)</th>
<th>Noise Exposure (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT-1</td>
<td>803 Bullock Street – Coppell</td>
<td>12-9-10 9:00</td>
<td>24</td>
<td>60 56</td>
</tr>
<tr>
<td>LT-2</td>
<td>177 Glendale Drive – Coppell</td>
<td>12-9-10 10:00</td>
<td>24</td>
<td>56 50</td>
</tr>
<tr>
<td>LT-3</td>
<td>609 Swan Drive – Coppell</td>
<td>12-9-10 16:00</td>
<td>24</td>
<td>61 55</td>
</tr>
<tr>
<td>LT-4</td>
<td>857 Crestview Drive – Coppell</td>
<td>12-8-10 13:00</td>
<td>24</td>
<td>65 61</td>
</tr>
<tr>
<td>LT-5</td>
<td>1717 E Belt Line Road – Coppell</td>
<td>12-8-10 17:00</td>
<td>24</td>
<td>66 62</td>
</tr>
<tr>
<td>LT-6</td>
<td>1506 Cecil Drive – Carrollton</td>
<td>12-8-10 11:00</td>
<td>24</td>
<td>62 51</td>
</tr>
<tr>
<td>LT-7</td>
<td>1845 North Josey Lane – Carrollton</td>
<td>12-9-10 16:00</td>
<td>24</td>
<td>59 52</td>
</tr>
<tr>
<td>LT-8</td>
<td>2610 Lakehill Lane – Carrollton</td>
<td>12-8-10 11:00</td>
<td>24</td>
<td>57 45</td>
</tr>
<tr>
<td>LT-9</td>
<td>3232 San Sebastian Drive – Carrollton</td>
<td>12-9-10 12:00</td>
<td>24</td>
<td>55 49</td>
</tr>
<tr>
<td>LT-10</td>
<td>5665 Arapaho Road – Addison</td>
<td>12-7-10 18:00</td>
<td>24</td>
<td>54 50</td>
</tr>
<tr>
<td>LT-11</td>
<td>16144 Chalfont Circle – Dallas</td>
<td>12-7-10 17:00</td>
<td>24</td>
<td>57 51</td>
</tr>
<tr>
<td>LT-12</td>
<td>16907 Davenport Court – Dallas</td>
<td>12-7-10 16:00</td>
<td>24</td>
<td>52 47</td>
</tr>
<tr>
<td>LT-13</td>
<td>6802 Duffield Drive – Dallas</td>
<td>12-6-10 15:00</td>
<td>24</td>
<td>57 52</td>
</tr>
<tr>
<td>LT-14</td>
<td>17490 Meandering Way – Dallas</td>
<td>12-9-10 12:00</td>
<td>24</td>
<td>55 48</td>
</tr>
<tr>
<td>LT-15</td>
<td>8000 Frankford Road – Dallas</td>
<td>12-6-10 13:00</td>
<td>24</td>
<td>54 51</td>
</tr>
<tr>
<td>LT-16</td>
<td>800 W Renner Road – Richardson</td>
<td>12-6-10 12:00</td>
<td>24</td>
<td>55 51</td>
</tr>
<tr>
<td>LT-17</td>
<td>3560 Alma Road – Richardson</td>
<td>12-7-10 17:00</td>
<td>24</td>
<td>68 62</td>
</tr>
<tr>
<td>LT-18</td>
<td>908 Avenue F – Plano</td>
<td>12-6-10 11:00</td>
<td>24</td>
<td>65 56</td>
</tr>
<tr>
<td>LT-19</td>
<td>2628 Ezekial Way – Plano</td>
<td>12-6-10 10:00</td>
<td>24</td>
<td>63 46</td>
</tr>
<tr>
<td>ST-1</td>
<td>1615 West Belt Line Road – Carrollton</td>
<td>12-10-10 10:50</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>ST-2</td>
<td>1107 Jackson Street – Carrollton</td>
<td>12-10-10 13:26</td>
<td>1</td>
<td>–</td>
</tr>
</tbody>
</table>
Table 4-1  
Summary of Existing Ambient Noise Measurement Results

<table>
<thead>
<tr>
<th></th>
<th>Location</th>
<th>Date</th>
<th>Time</th>
<th>Average</th>
<th>Type</th>
<th></th>
<th>Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-3</td>
<td>1901 Kelly Boulevard – Carrollton</td>
<td>12-10-10</td>
<td>14:52</td>
<td>1</td>
<td>–</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>ST-4</td>
<td>3100 South Rigsbee Drive – Plano</td>
<td>12-6-10</td>
<td>17:20</td>
<td>1</td>
<td>–</td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>ST-5</td>
<td>3760 14th Street – Plano</td>
<td>12-6-10</td>
<td>15:50</td>
<td>1</td>
<td>–</td>
<td></td>
<td>53</td>
</tr>
</tbody>
</table>

\(^1\) The reported Leq value at the long-term measurement site locations is the lowest hourly Leq value during the periods from 6:00 AM to 9:00 AM and 3:00 PM to 6:00 PM.  
Source: Harris Miller Miller & Hanson Inc., 2013

Site LT-1: 803 Bullock Street – Coppell. This site was located in the backyard of a single-family residence. The Ldn measured over a 24-hour period was 60 dBA. The existing noise environment was dominated by freight traffic, as well as noise from overflights, community activities and traffic.

Site LT-2: 177 Glendale Drive – Coppell. This site was located in the backyard of a single-family residence. The Ldn measured over a 24-hour period was 56 dBA. The existing noise environment was dominated by freight traffic, as well as traffic in the alley behind the backyard. Noise from community activities and overflights also contributed to the existing environment.

Site LT-3: 609 Swan Drive – Coppell. This site was located in the backyard of a single-family residence. The Ldn measured over a 24-hour period was 61 dBA. The existing noise environment was dominated by freight traffic, as well as noise from community activities and overflights.

Site LT-4: 857 Crestview Drive – Coppell. This site was located in the backyard of a single-family residence. The Ldn measured over a 24-hour period was 65 dBA. The existing noise environment was dominated by traffic on Crestview Drive, as well as noise from community activity, freight traffic and overflights.

Site LT-5: 1717 East Belt Line Road – Coppell. This site was located in the front yard of the St. Marin apartment complex. The Ldn measured over a 24-hour period at this multi-family building was 66 dBA. The existing noise environment was dominated by traffic on Belt Line Road, as well as noise from community activities and traffic, overflights and freight traffic.

Site LT-6: 1506 Cecil Drive – Carrollton. This site was located in the backyard of a single-family residence. The Ldn measured over a 24-hour period was 62 dBA. The existing noise environment was dominated by traffic on Cecil Drive, as well as noise from community activity, freight traffic and overflights.

Site LT-7: 1845 North Josey Lane – Carrollton. This site was located in the yard near building 1829 in the Josey Place apartment complex. The Ldn measured over a 24-hour period at this multi-family building was 59 dBA. The existing noise environment was dominated by traffic on the freight tracks and Josey Lane, as well as noise from community activities, overflights and other local roads.
Site LT-8: 2610 Lakehill Lane – Carrollton. This site was located in the yard near the pool in the Lakehill Townhomes apartment complex. The Ldn measured over a 24-hour period at this multi-family building was 57 dBA. The existing noise environment was dominated by community activities and traffic, as well as noise from overflights and freight traffic.

Site LT-9: 3232 San Sebastian Drive – Carrollton. This site was located in the backyard of a residence in the Trafalgar Square condominiums complex. The Ldn measured over a 24-hour period at this multi-family building was 55 dBA. The existing noise environment was dominated by freight traffic, as well as traffic in the alley behind the backyard. Noise from community activities and overflights also contributed to the existing environment.

Site LT-10: 5665 Arapaho Road – Addison. This site was located in the yard near building 13 in the St. Moritz apartment complex. The Ldn measured over a 24-hour period at this multi-family building was 54 dBA. The existing noise environment was dominated by community activities and traffic, as well as noise from overflights and a nearby golf course.

Site LT-11: 16144 Chalfont Circle – Dallas. This site was located in the yard of a single-family residence. The Ldn measured over a 24-hour period was 57 dBA. The existing noise environment was dominated by traffic on Chalfont Circle, as well as noise from community activities, other local roads and overflights.

Site LT-12: 16907 Davenport Court – Dallas. This site was located in the yard of a single-family residence. The Ldn measured over a 24-hour period was 52 dBA. The existing noise environment was dominated by traffic on Davenport Court, as well as noise from community activities, other local roads and overflights.

Site LT-13: 6802 Duffield Drive – Dallas. This site was located in the yard of a single-family residence. The Ldn measured over a 24-hour period was 57 dBA. The existing noise environment was dominated by traffic on Duffield Drive, as well as noise from community activities, other local roads and overflights.

Site LT-14: 17490 Meandering Way – Dallas. This site was located next to the pool at the Willow Greene condominiums complex. The Ldn measured over a 24-hour period at this multi-family building was 55 dBA. The existing noise environment was dominated by traffic on Meandering Way, as well as noise from community activities, other local roads and overflights.

Site LT-15: 8000 Frankford Road – Dallas. This site was located in the back parking lot of the Highland Springs Retirement Community. The Ldn measured over a 24-hour period at this multi-family building was 54 dBA. The existing noise environment was dominated by community traffic and activities, as well as noise from overflights and local roads.

Site LT-16: 800 West Renner Road – Richardson. This site was located in the yard near a playground in the Marquis at Waterview apartment complex. The Ldn measured over a 24-hour period at this multi-family building was 55 dBA. The existing noise environment was dominated by community activities, as well as noise from freight traffic, local roads and overflights.
Site LT-17: 3560 Alma Road – Richardson. This site was located in the yard near building 33 in the Prairie Creek Villas apartment complex. The Ldn measured over a 24-hour period at this multi-family building was 68 dBA. The existing noise environment was dominated by traffic on President George Bush Turnpike, as well as noise from freight traffic, overflights and other community roads and activities.

Site LT-18: 908 Avenue F – Plano. This site was located in the yard of a single-family residence. The Ldn measured over a 24-hour period was 65 dBA. The existing noise environment was dominated by traffic on Avenue F, as well as noise from freight traffic, overflights and other community roads and activities.

Site LT-19: 2628 Ezekiel Way – Plano. This site was located in the yard of a single-family residence. The Ldn measured over a 24-hour period was 63 dBA. The existing noise environment was dominated by traffic on Ezekiel Way, as well as noise from freight traffic, overflights and other community roads and activities.

Site ST-1: 1615 West Belt Line Road – Carrollton. This site was located in the front parking lot of the North Church and Vista Academy. The Leq measured over a 1-hour period was 64 dBA. The existing noise environment was dominated by traffic on Belt Line Road, as well as noise from freight traffic, community activities and overflights.

Site ST-2: 1107 Jackson Street – Carrollton. This site was located in the parking lot of the Miracle Tabernacle Pentecostal Church. The Leq measured over a 1-hour period was 61 dBA. The existing noise environment was dominated by traffic on Interstate Highway 35E and Belt Line Road, as well as noise from other local roads, overflights and community activities.

Site ST-3: 1901 Kelly Boulevard – Carrollton. This site was located in the parking lot of the Islamic Association of Carrollton. The Leq measured over a 1-hour period was 55 dBA. The existing noise environment was dominated by traffic on Kelly Boulevard, as well as noise from freight traffic, overflights, and other community roads and activities.

Site ST-4: 3100 South Rigsbee Drive – Plano. This site was located in the backyard of The Collinwood nursing home. The Leq measured over a 1-hour period was 52 dBA. The existing noise environment was dominated by traffic on 14th Street and Rigsbee Drive, as well as noise from freight traffic, overflights, and other community roads and activities.

Site ST-5: 3760 14th Street – Plano. This site was located in the back parking lot of the Sehion Mar Thoma Church. The Leq measured over a 1-hour period was 53 dBA. The existing noise environment was dominated by traffic on 14th Street, as well as freight traffic, overflights and other community roads and activities.

4.3 Existing Vibration Conditions

The operation of freight trains in the project corridor occurs infrequently. Other than these infrequent freight trains operating in some segments of the corridor there are no other significant sources of existing vibration. Vibration measurements for this project therefore focused on characterizing the ground-borne vibration propagation properties of the soil at representative locations along the corridor.
Field measurements were conducted during the period from December 6 through December 10, 2010. Ground-borne vibration propagation measurements were conducted at ten sites, numbered V-1 through V-10, along the project corridor. The vibration testing sites were selected to represent the existing vibration propagation characteristics along the alignment. At each of the sites the ground-borne vibration propagations tests were conducted by impacting the ground and measuring the input force and corresponding ground vibration response at various distances. The resulting force-response transfer function can be combined with the known input force characteristics of the vehicle to predict future vibration levels at locations along the alignment. The locations of these vibration measurement sites are shown in Figure 4-1 above. Detailed descriptions of the vibration measurement sites are provided below and site photographs are included in Appendix A.

**Site V-1**: This site was located to the south of the existing tracks at the intersection of Dawn Lane and Easy Street in Grapevine. This site was adjacent to Grapevine Park.

**Site V-2**: This site was located at W. W. Pinkerton Elementary School, at 260 Southwestern Boulevard in Coppell. This test was conducted in the parking lot and athletic field of the school which was located south of the existing tracks.

**Site V-3**: This site was located in a parking lot of athletic fields on Elm Fork Drive in Carrollton. This site was located to the north of the existing tracks and Belt Line Road.

**Site V-4**: This site was located in the parking lot of a multi-family residential development at 1455 North Perry Road in Carrollton. This site was located to the south of the existing tracks just west of the at-grade crossing of Perry Road.

**Site V-5**: This site was located in an open field south of the existing tracks, adjacent to a commercial property, at 3799 Arapaho Road in Addison.

**Site V-6**: This site was located at Fairhill School, at 16150 Preston Road in Dallas. This test was conducted in the athletic field adjacent to the school, which was located south of the existing tracks.

**Site V-7**: This site was located at Preston Green Park, at 6964 Duffield Drive in Dallas. This test site was located to the north of the existing tracks.

**Site V-8**: This site was located in the back parking lot of the Highland Springs Retirement Community, at 8000 Frankford Road in Dallas. This site was located to the north of the existing tracks.

**Site V-9**: The site was located to the south of the existing tracks near the intersection of Plano Parkway and Taylor Drive in Plano. This test was conducted in a parking lot adjacent to the Love & War in Texas restaurant and Sports Authority.

**Site V-10**: This site was located in the back parking lot of the Sehion Mar Thoma Church, at 3760 14th Street in Plano. This site was located to the north of the existing tracks.
The vibration propagation testing method is shown schematically in Figure 4-2. As shown in the cross-section view at the top, the test consists of dropping a 60-pound weight from a height of about three feet onto the ground. A Sensotec load cell was used to measure the force of the impact, and PCB 393 A/C accelerometers, mounted in a vertical orientation on either paved surfaces or metal stakes driven into the soil, were used to measure the resulting vibration pulses on the ground at various distances (25 to 150 feet). The impact force and acceleration signals were recorded using a multi-channel TEAC LX-110 digital recorder and subsequently analyzed using digital signal processing software. The relationship between the input force and the ground surface vibration, called the transfer mobility, characterizes vibration propagation at each location. It is then possible to estimate the ground vibration that would be caused by another source, such as a train, by substituting the train force for the impact force.

**Figure 4-2**

Vibration Propagation Test Procedure
The bottom sketch in Figure 4-2 shows how impact tests are made at regularly spaced locations along a proposed rail alignment to simulate the vibration generated by a line source such as a train. For these tests, impacts were made at 11 points, spaced 15 feet apart. Accelerometers are positioned perpendicular to the proposed rail alignment at various distances. The measurement sites were selected to be open and free of buildings so as not to affect the vibration propagation conditions. The integration of the point source transfer mobility ($T_{M_{\text{point}}}$) measured at each position along the entire train length is termed the line source transfer mobility ($T_{M_{\text{line}}}$). More details on the propagation test and analysis procedures are given in the FTA guidance manual.

To summarize the results of the vibration propagation tests, line source transfer mobilities at a distance of 50 feet are shown for all measurement sites in Figure 4-3. This figure illustrates the variability in vibration propagation efficiency at all measurement sites. Depending on the site location, vibrations from the proposed operations may vary over a range 20 to 35 VdB. Detailed vibration propagation test data are included in Appendix C.
5.0 LITERATURE/SOURCES CITED


APPENDIX A: MEASUREMENT SITE PHOTOS
Figure A-1
Noise Measurement Site LT-1

Figure A-2
Noise Measurement Site LT-2
Figure A-3
Noise Measurement Site LT-3

Figure A-4
Noise Measurement Site LT-4
Figure A-5
Noise Measurement Site LT-5

Figure A-6
Noise Measurement Site LT-6
Figure A-7
Noise Measurement Site LT-7

Figure A-8
Noise Measurement Site LT-8
Figure A-9
Noise Measurement Site LT-9

Figure A-10
Noise Measurement Site LT-10
Figure A-13
Noise Measurement Site LT-13

Figure A-14
Noise Measurement Site LT-14
Figure A-15
Noise Measurement Site LT-15

Figure A-16
Noise Measurement Site LT-16
Figure A-19
Noise Measurement Site LT-19

Figure A-20
Noise Measurement Site ST-1
Figure A-21
Noise Measurement Site ST-2

Figure A-22
Noise Measurement Site ST-3
Figure A-23
Noise Measurement Site ST-4

Figure A-24
Noise Measurement Site ST-5
Figure A-25
Vibration Measurement Site V-1

Figure A-26
Vibration Measurement Site V-2
Figure A-27
Vibration Measurement Site V-3

Figure A-28
Vibration Measurement Site V-4
Figure A-29
Vibration Measurement Site V-5

Figure A-30
Vibration Measurement Site V-6
Figure A-31
Vibration Measurement Site V-7

Figure A-32
Vibration Measurement Site V-8
Figure A-33
Vibration Measurement Site V-9

Figure A-34
Vibration Measurement Site V-10
Figure B-1
Site LT-1 Noise Measurement Results

Site LT1: 803 Bullock Street - Coppell, TX
Ldn = 60 dBA (12/09/09 to 12/10/09)

Figure B-2
Site LT-2 Noise Measurement Results

Site LT2: 177 Glendale Drive - Coppell, TX
Ldn = 56 dBA (12/09/09 to 12/10/09)
Site LT-3 Noise Measurement Results

Site LT3: 609 Swan Drive - Coppell, TX
Ldn = 61 dBA (12/09/09 to 12/10/09)

Site LT4: 857 Crestview Drive - Coppell, TX
Ldn = 65 dBA (12/08/09 to 12/09/09)
Figure B-5
Site LT-5 Noise Measurement Results

Site LT5: St. Marin Apartments 1717 East Belt Line Road - Coppell, TX
Ldn = 66 dBA (12/08/09 to 12/09/09)

Figure B-6
Site LT-6 Noise Measurement Results

Site LT6: 1506 Cecil Drive - Carrollton, TX
Ldn = 62 dBA (12/08/09 to 12/09/09)
Figure B-7
Site LT-7 Noise Measurement Results

Site LT7: Josey Place Apartments 1845 North Josey Lane - Carrollton, TX
Ldn = 59 dBA (12/09/09 to 12/10/09)

Figure B-8
Site LT-8 Noise Measurement Results

Site LT8: Lakehill Townhomes 2610 Lakehill Lane - Carrollton, TX
Ldn = 57 dBA (12/08/09 to 12/09/09)
Figure B-9
Site LT-9 Noise Measurement Results

Site LT9: 3232 San Sebastian Drive - Carrollton, TX
Ldn = 55 dBA (12/09/09 to 12/10/09)

Figure B-10
Site LT-10 Noise Measurement Results

Site LT10: St. Moritz Apartments 5665 Arapaho Road - Addison, TX
Ldn = 54 dBA (12/07/09 to 12/08/09)
Figure B-11
Site LT-11 Noise Measurement Results

Site LT11: 16144 Chalfont Circle - Dallas, TX
Ldn = 57 dBA (12/07/09 to 12/08/09)

Figure B-12
Site LT-12 Noise Measurement Results

Site LT12: 16907 Davenport Court - Dallas, TX
Ldn = 52 dBA (12/07/10 to 12/08/10)
Figure B-13
Site LT-13 Noise Measurement Results

Site LT13: 6802 Duffield Drive - Dallas, TX
Ldn = 57 dBA (12/06/10 to 12/07/10)

Figure B-14
Site LT-14 Noise Measurement Results

Site LT14: 17490 Meandering Way - Dallas, TX
Ldn = 55 dBA (12/09/10 to 12/10/10)
Figure B-15
Site LT-15 Noise Measurement Results

Site LT15: Highland Springs 8000 Frankford Road - Dallas, TX
Ldn = 54 dBA (12/06/10 to 12/07/10)

Figure B-16
Site LT-16 Noise Measurement Results

Site LT16: The Marquis at Waterview 800 W Renner Road - Richardson, TX
Ldn = 55 dBA (12/06/10 to 12/07/10)
Figure B-17
Site LT-17 Noise Measurement Results
Site LT17: Prairie Creek Villas 3560 Alma Road - Richardson, TX
Ldn = 68 dBA (12/07/10 to 12/08/10)

Figure B-18
Site LT-18 Noise Measurement Results
Site LT18: 908 Avenue F - Plano, TX
Ldn = 65 dBA (12/06/10 to 12/07/10)
Figure B-19
Site LT-19 Noise Measurement Results

Site LT19: 2628 Ezekial Way - Plano, TX
Ldn = 63 dBA (12/06/10 to 12/07/10)
APPENDIX C: VIBRATION MEASUREMENT DATA
Figure C-1
Site V-1 Line Source Transfer Mobility Results

Site V-1

Line Source Transfer Mobility (dB re 1 μin/sec/lb)

1/3 Octave Band Center Frequency (Hz)

-50 -40 -30 -20 -10 0 10 20 30 40 50 60

6.3 8 10 12.5 16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400

- 25 ft ▲- 50 ft ▲- 75 ft ▲- 100 ft ▲- 125 ft ▲- 150 ft

Figure C-2
Site V-2 Line Source Transfer Mobility Results

Site V-2

Line Source Transfer Mobility (dB re 1 μin/sec/lb)

1/3 Octave Band Center Frequency (Hz)

-50 -40 -30 -20 -10 0 10 20 30 40 50 60

6.3 8 10 12.5 16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400

- 25 ft ▲- 50 ft ▲- 75 ft ▲- 100 ft ▲- 125 ft ▲- 150 ft

Figure C-3
Site V-3 Line Source Transfer Mobility Results

Site V-3

Figure C-4

Site V-4 Line Source Transfer Mobility Results

Site V-4

Figure C-5
Site V-5 Line Source Transfer Mobility Results

Figure C-6

Site V-6 Line Source Transfer Mobility Results

Figure C-7
Site V-7 Line Source Transfer Mobility Results

![Graph of Site V-7 Line Source Transfer Mobility Results]

Site V-8 Line Source Transfer Mobility Results

![Graph of Site V-8 Line Source Transfer Mobility Results]

Figure C-8

Figure C-9
Site V-9 Line Source Transfer Mobility Results

Figure C-10
Site V-10 Line Source Transfer Mobility Results
Alliance Transportation Group
Arredondo, Zepeda & Brunz
Bowman Engineering
Connetics Transportation Group
Cox|McLain Environmental Consulting
CP&Y
Criado & Associates
Dunbar Transportation Consulting
HMMH
KAI Texas
K Strategies Group
Legacy Resource Group
Mas-Tek Engineering & Associates
Nathan D. Maier Consulting Engineers
Pacheco Koch Consulting Engineers
Parsons
Schrader & Cline
Spartan Solutions
Stantec Consulting Services Inc.