Environmental Noise and Vibration Assessment

Lincoln Meadows Residential Development

Lincoln, California

BAC Job # 2015-291

Prepared For:

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Introduction

The proposed Lincoln Meadows Residential Development (project) is located on Virginiatown Road, West of Hungry Hollow Road, in the City of Lincoln, California. The project consists of 144 single-family residential units. The project vicinity and site plan are illustrated in Figures 1 and 2, respectively.

Traffic on Virginiatown Road is considered to be a significant noise source which may affect the design of the project. As a result, Bollard Acoustical Consultants, Inc. (BAC) was retained by Raney Planning & Management, Inc. to prepare this acoustical analysis. Specifically, this analysis was prepared to determine whether traffic noise from this roadway would cause exterior and interior noise levels in the proposed residences at the project site to exceed acceptable limits as described in the Noise Element of the City of Lincoln General Plan. In addition, this analysis evaluates potential impacts associated with off-site increases in traffic noise resulting from the proposed project.

Environmental Setting

Noise Fundamentals and Terminology

Noise is often described as unwanted sound. Sound is defined as any pressure variation in air that the human ear can detect. If the pressure variations occur frequently enough (at least 20 times per second), they can be heard, and thus are called sound. Measuring sound directly in terms of pressure would require a very large and awkward range of numbers. To avoid this, the decibel scale was devised. The decibel scale allows a million-fold increase in pressure to be expressed as 120 dB. Another useful aspect of the decibel scale is that changes in levels (dB) correspond closely to human perception of relative loudness. Appendix A contains definitions of Acoustical Terminology. Figure 3 shows common noise levels associated with various sources.

The perceived loudness of sounds is dependent upon many factors, including sound pressure level and frequency content. However, within the usual range of environmental noise levels, perception of loudness is relatively predictable, and can be approximated by weighing the frequency response of a sound level meter by means of the standardized A-weighing network. There is a strong correlation between A-weighted sound levels (expressed as dBA) and community response to noise. For this reason, the A-weighted sound level has become the standard tool of environmental noise assessment. All noise levels reported in this section are in terms of A-weighted levels in decibels.

Community noise is commonly described in terms of the “ambient” noise level, which is defined as the all-encompassing noise level associated with a given noise environment. A common statistical tool to measure the ambient noise level is the average, or equivalent, sound level (L_{eq}) over a given time period (usually one hour). The L_{eq} is the foundation of the Day-Night Average Level noise descriptor, L_{dn}, and shows very good correlation with community response to noise.

Figure 1
Project Area and Noise Measurement Location
Lincoln Meadows Residential Development - City of Lincoln, California

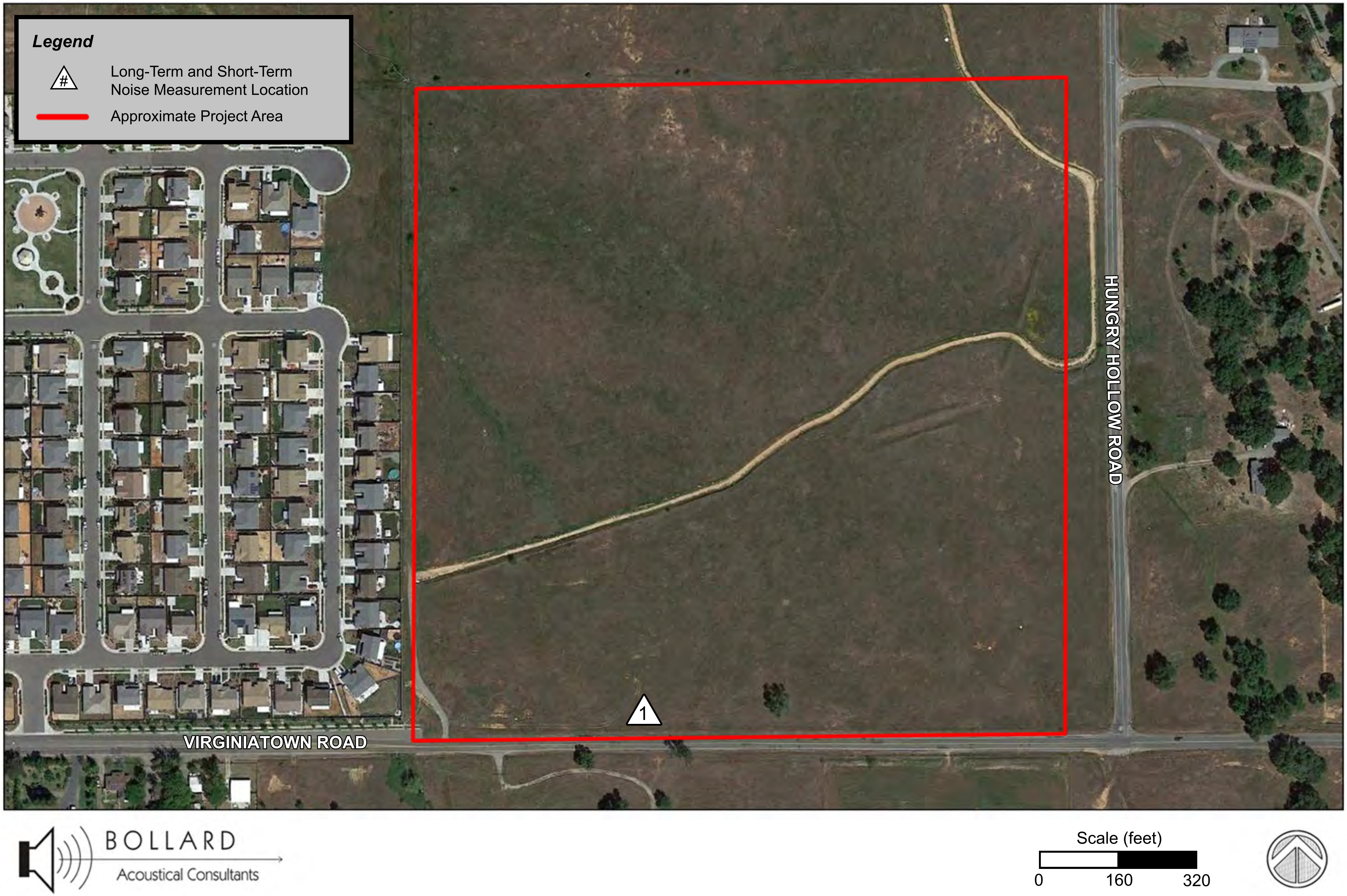
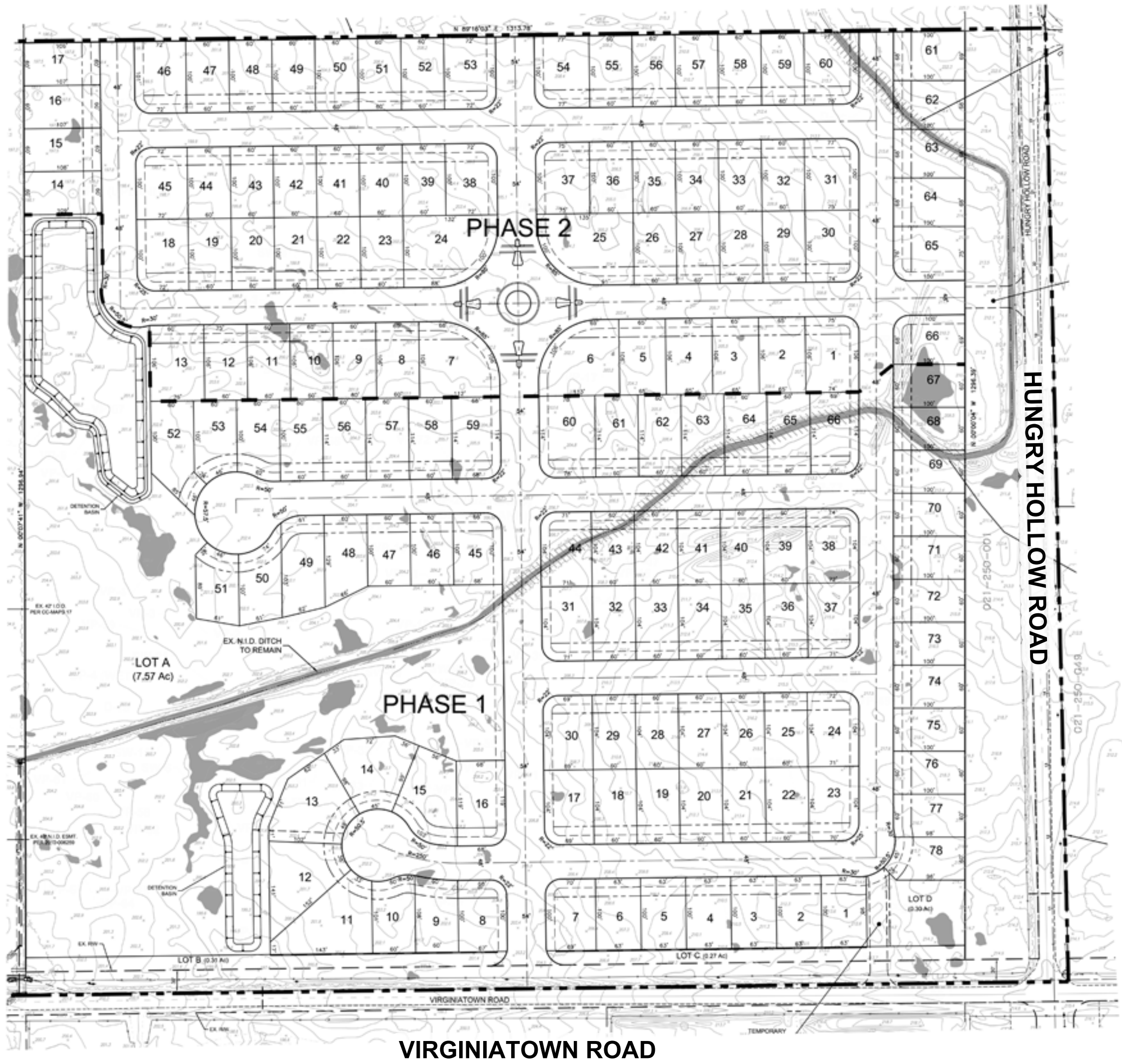


Figure 2

Proposed Site Plan

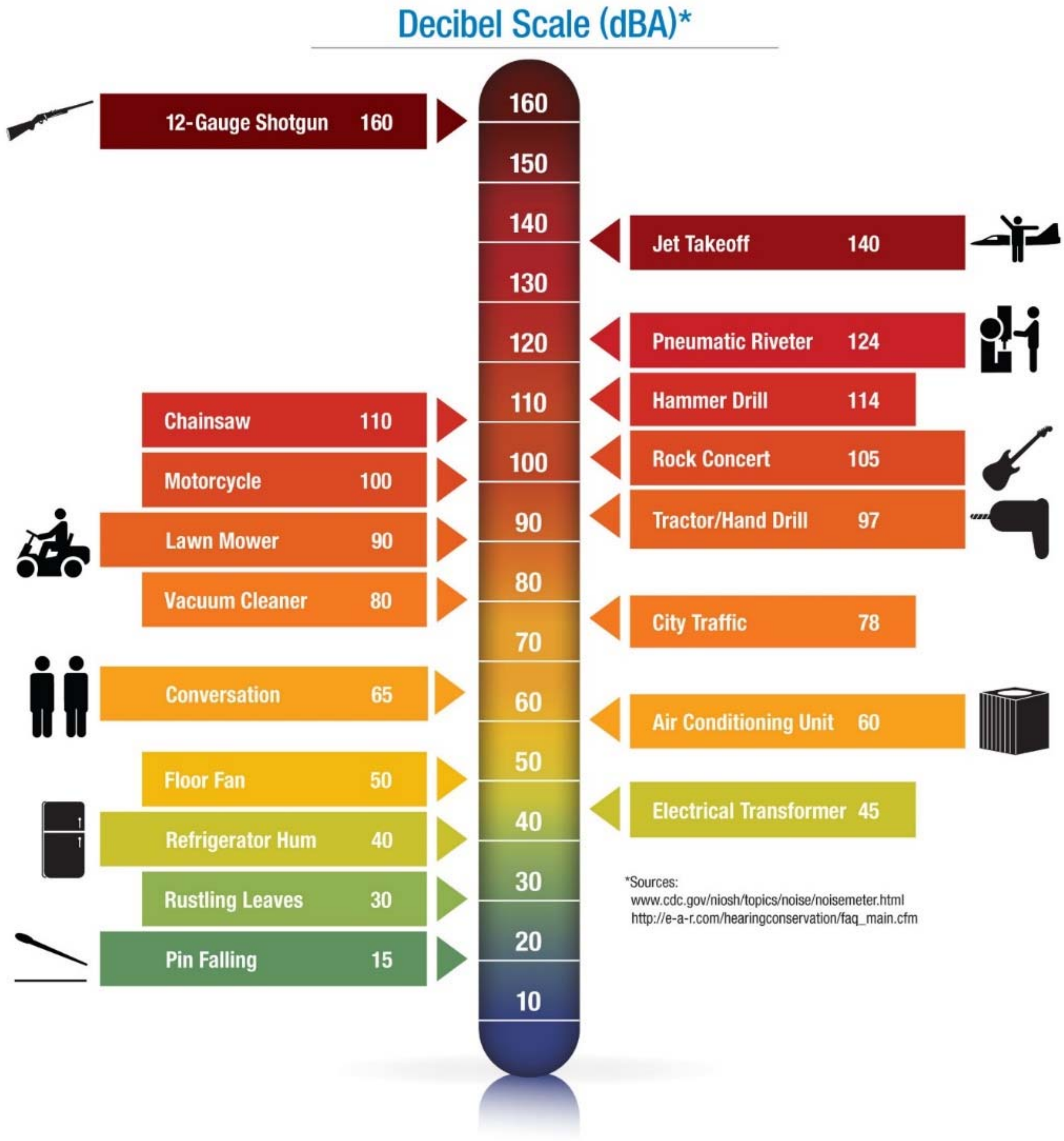
Lincoln Meadows Residential Development - City of Lincoln, California



Scale (feet)

0 200 400

Figure 3
Typical A-Weighted Sound Levels of Common Noise Sources



Vibration Fundamentals

Vibration is like noise in that it involves a source, a transmission path, and a receiver. While vibration is related to noise, it differs in that noise is generally considered to be pressure waves transmitted through air, while vibration is usually associated with transmission through the ground or structures. As with noise, vibration consists of an amplitude and frequency. A person's response to vibration will depend on their individual sensitivity as well as the amplitude and frequency of the source.

Vibration can be described in terms of acceleration, velocity, or displacement. A common practice is to monitor vibration measures in terms of peak particle velocities (inches/second). Standards pertaining to perception as well as damage to structures have been developed for vibration in terms of peak particle velocity.

As vibrations travel outward from the source, they excite the particles of rock and soil through which they pass and cause them to oscillate. Differences in subsurface geologic conditions and distance from the source of vibration will result in different vibration levels characterized by different frequencies and intensities. In all cases, vibration amplitudes will decrease with increasing distance. The maximum rate, or velocity of particle movement, is the commonly accepted descriptor of the vibration "strength".

Human response to vibration is difficult to quantify. Vibration can be felt or heard well below the levels that produce any damage to structures. The duration of the event has an effect on human response, as does the frequency of the event. Generally, as the duration and vibration frequency increase, the potential for adverse human response increases.

According to the Transportation and Construction-Induced Vibration Guidance Manual (Caltrans, June 2004), operation of construction equipment and construction techniques generate ground vibration. Traffic traveling on roadways can also be a source of such vibration. At high enough amplitudes, ground vibration has the potential to damage structures and/or cause cosmetic damage (e.g., crack plaster). Ground vibration can also be a source of annoyance to individuals who live or work close to vibration-generating activities. However, traffic, including heavy trucks traveling on a highway, rarely generates vibration amplitudes high enough to cause structural or cosmetic damage.

Existing and Future Noise and Vibration Environments

The existing ambient noise environment in the immediate project vicinity is defined primarily by noise from traffic on Virginia Town Road and to a lesser extent by natural sounds and noise from traffic on Hungry Hollow Road, which is lightly travelled. As no other substantive sources of ambient noise were identified in the immediate project vicinity, this analysis focuses on existing and future traffic noise environments.

To quantify existing traffic noise levels in the project vicinity, noise surveys were conducted on the project site. Those data were supplemented with noise modeling data where appropriate. Because no discernible sources of vibration were identified through project area inspections, ambient vibration monitoring was not conducted for this project. The following sections describe the existing and projected future traffic noise environment in the immediate project vicinity, both with and without the proposed project.

General Ambient Noise Environment

To generally quantify existing background noise levels in the project area, continuous (24-hour) ambient noise monitoring was conducted at the project site on September 20, 2016 at the location shown on Figure 1.

A Larson Davis Laboratories (LDL) Model 820 precision integrating sound level meter was used for the ambient noise level measurement survey. The meter was calibrated before use with an LDL Model CA200 acoustical calibrator to ensure the accuracy of the measurements. The equipment used meets all pertinent specifications of the American National Standards Institute for Type 1 sound level meters (ANSI S1.4).

The noise level meter was programmed to record the maximum and average noise level during each hour of the noise survey, in addition to other statistical descriptors. The ambient noise monitoring results indicate that daytime and nighttime average noise levels were 60 and 54 dB Leq, respectively, with a computed day/night average level of 62 dB L_{dn}. The complete continuous noise measurement results and graphical depictions of the results are shown in Appendices B and C, respectively.

The noise level data shown in Appendices B & C spans the complete 24-hour period of September 20, 2016. As a result, it includes all sources of noise present during that 24-hour period, including nighttime automobile and heavy truck traffic on the local roadways, primarily Virginiatown Road.

Regulatory Setting

Criteria for Acceptable Noise and Vibration Exposure

City of Lincoln General Plan Noise Standards

The City of Lincoln General Plan Noise Element establishes standards for acceptable noise exposure levels at noise-sensitive land uses, presented below in Table 1.

Table 1
Land Use Compatibility Guidelines for Development (CNEL)
City of Lincoln General Plan Noise Element

Locations	Normally Acceptable	Conditionally Acceptable	Normally Unacceptable	Unacceptable
Residential - Low Density Single Family, Duplex, Mobile Homes	< 60	61 - 70	71 – 75	>75
Residential – Multiple Family, Group Homes	<60	61 – 70	71 – 75	>75
Motels / Hotels	< 60	61 - 70	71 – 80	>80
Schools, Libraries, Churches, Hospitals, Extended Care Facilities	< 60	61 – 70	71 - 80	> 80
Auditoriums, Concert Halls, Amphitheaters	< 65	N/A	66 – 70	> 70
Sports Arenas, Outdoor Spectator Sports	<70	N/A	71 – 75	>75
Playgrounds, Neighborhood Parks	<70	N/A	N/A	>70
Golf Courses, Riding Stables, Water Recreation, Cemeteries	<70	N/A	71-80	>80
Office Buildings, Business Commercial and Professional	< 65	66 - 75	75 - 81	N/A
Industrial, Manufacturing, Utilities, Agriculture	<70	71 - 80	>81	N/A

Notes:
Normally Acceptable: Specified land use is satisfactory, based on the assumption that any buildings involved are of normal conventional construction, without any special noise insulation requirements.
Conditionally Acceptable: New construction or development should be undertaken only after a detailed analysis of the noise reduction requirements is made and needed insulation features have been included in the design.
Normally Unacceptable: New construction or development should generally be discouraged. If new construction or development does proceed, a detailed analysis of the noise reduction requirements must be made and needed noise insulation features included in the design. Outdoor areas must be shielded.
Unacceptable: New construction or development should not be undertaken.
Source: Page 8-10 of City of Lincoln General Plan, Noise Element.

In addition to the exterior noise standards shown above, the City of Lincoln applies a 45 dB L_{dn} interior noise standard to new residential uses.

Significance of Project-Related Noise Level Increases

Table 2 is based upon recommendations made in August 1992 by Federal Interagency Committee on Noise (FICON) to provide guidance in the assessment of changes in ambient noise levels resulting from aircraft operations. The recommendations are based upon studies that relate aircraft noise levels to the percentage of persons highly annoyed by noise. Although the FICON recommendations were specifically developed to assess aircraft noise impacts, these criteria have been applied to other sources of noise similarly described in terms of cumulative noise exposure metrics such as the L_{dn}.

Table 2
Significance of Changes in Cumulative Noise Exposure

Ambient Noise Level Without Project, L_{dn}	Increase Required for Significant Impact
<60 dB	+5.0 dB or more
60-65 dB	+3.0 dB or more
>65 dB	+1.5 dB or more

Source: Federal Interagency Committee on Noise (FICON)

According to Table 2, an increase in noise from similar sources of 5 dB or more would be noticeable where the ambient level is less than 60 dB. Where the ambient level is between 60 and 65 dB, an increase in noise of 3 dB or more would be noticeable, and an increase of 1.5 dB or more would be noticeable where the ambient noise level exceeds 65 dB L_{dn}. The rationale for the Table 2 criteria is that, as ambient noise levels increase, a smaller increase in noise resulting from a project is sufficient to cause annoyance.

Vibration Criteria

Although the City of Lincoln does not have specific vibration standards, CEQA requires an evaluation of potential vibration-related impacts of a project. Lacking local vibration standards, criteria developed for Caltrans are utilized in this assessment for the evaluation of vibration impacts for the project. Table 3 indicates that the threshold for damage to structures ranges from 2 to 6 in/sec. One-half this minimum threshold, or 1 in/sec ppv is considered a safe criterion by Caltrans that would protect against architectural or structural damage. The general threshold at which human annoyance could occur is notes as 0.1 in/sec ppv.

Table 3
General Human and Structural Responses to Vibration Levels

Effects on Structures & People	Peak Vibration Threshold (in/sec PPV)
Structural damage to commercial structures	6
Structural damage to residential buildings	2
Architectural damage	1.0
General threshold of human annoyance	0.1
General threshold of human perception	0.01

Sources: Survey of Earth-borne Vibrations due to Highway Construction and Highway Traffic, Caltrans 1976. Final Environmental Impact Report: Richmond Transport Project, Orion Environmental Associates, 1990. Weekly Progress Report for Vibration Monitoring for Richmond Transport, Wilson, Ihrigg & Associates, 1994.

Impacts and Mitigation Measures

Traffic Noise Impact Evaluation

Traffic Noise Prediction Methodology

The Federal Highway Administration Highway Traffic Noise Prediction Model (FHWA-RD-77-108) with the Calveno vehicle noise emission curves was used to predict traffic noise levels at the project site. The FHWA Model is the traffic noise prediction model preferred by the Federal Highway Administration and the State of California Department of Transportation (Caltrans) for use in traffic noise assessment.

Traffic Noise Prediction Model Calibration

The FHWA Model provides reasonably accurate traffic noise predictions under “ideal” roadway conditions. Ideal conditions are generally considered to be long straight roadway segments with uniform vehicle speeds, a flat roadway surface, good pavement conditions, a statistically large volume of traffic, and an unimpeded view of the roadway from the receiver location. Such conditions did not appear to be in effect at this project site due to varied traffic speed and frequency of vehicle passbys. As a result, Bollard Acoustical Consultants, Inc. conducted a calibration of the FHWA Model through site-specific traffic noise level measurements and concurrent traffic counts.

The calibration process was performed for Virginiatown Road on the project site for 15 minutes at 12:58 PM on December 4, 2015. The traffic noise measurement location is shown in Figure 1. The detailed results of this procedure are provided in Appendix D. The FHWA Model was found to reasonably predict traffic noise levels at the measurement site. As a result, no calibration adjustment to the FHWA Model applied for the prediction of future traffic noise levels at the project site. Due to the low traffic volume on Hungry Hollow Road, a traffic calibration could not be performed for this roadway.

Predicted Existing Exterior Traffic Noise Levels at the Proposed Lincoln Meadows Residences

The FHWA Model was used with existing traffic data to predict existing plus project Virginiatown Road and Hungry Hollow Road traffic noise levels at the nearest noise-sensitive interior and exterior areas which are located adjacent to these roadways. The future Average Daily Traffic (ADT) volumes were obtained from the traffic study prepared for the Lincoln Meadows project by Fehr & Peers Transportation Engineers. The FHWA Model inputs are shown in Appendix E. The predicted future traffic noise levels are summarized below in Table 4.

Table 4
Predicted Existing + Project Traffic Noise Levels at the Nearest Lots[1]
Lincoln Meadows Residential Development – Lincoln, California

Roadway	Description	Distance From Centerline (feet)	Predicted Noise Level (L_{dn}, dB)
Virginiatown Road	Nearest Backyards	65	63
	Nearest Facades	80	61
	Nearest Upper-Floor Facades	80	64
Hungry Hollow Road	Nearest Backyards	90	55
	Nearest Facades	115	54
	Nearest Upper-Floor Facades	115	57

Notes:
[1] A complete listing of FHWA Model inputs and results are provided in Appendix E.
Source: Bollard Acoustical Consultants, Inc. (2016); Fehr & Peers (2016).

As shown in Table 4, existing plus project Virginiatown Road traffic noise levels at the nearest proposed outdoor activity areas are predicted to comply with the City of Lincoln exterior standard along Hungry Hollow Road but not along Virginiatown Road.

Predicted Future Exterior Traffic Noise Levels at the Proposed Lincoln Meadows Residences

The FHWA Model was used with future traffic data to predict future Virginiatown Road and Hungry Hollow Road traffic noise levels at the nearest noise-sensitive interior and exterior areas which are located adjacent to these roadways. The future Average Daily Traffic (ADT) volumes were obtained from the traffic study prepared for the Lincoln Meadows project by Fehr & Peers Transportation Engineers. The FHWA Model inputs are shown in Appendix E. The predicted future traffic noise levels are summarized below in Table 5.

Table 5
Predicted Future (Cumulative + Project) Traffic Noise Levels at the Nearest Lots[1]
Lincoln Meadows Residential Development – Lincoln, California

Roadway	Description	Distance From Centerline (feet)	Predicted Noise Level (L_{dn}, dB)
Virginiatown Road	Nearest Backyards	65	68
	Nearest Facades	80	67
	Nearest Upper-Floor Facades	80	70
Hungry Hollow Road	Nearest Backyards	90	58
	Nearest Facades	115	57
	Nearest Upper-Floor Facades	115	60

Notes:
[1] A complete listing of FHWA Model inputs and results are provided in Appendix E.
Source: Bollard Acoustical Consultants, Inc. (2016); Fehr & Peers (2016).

As shown in Table 5, future Virginiatown Road traffic noise levels at the nearest proposed outdoor activity areas are predicted to exceed the City of Lincoln exterior standard by approximately 8 dB. As a result, noise mitigation is required. No traffic noise impacts are predicted for residences along Hungry Hollow Road.

BAC evaluated the effectiveness of solid noise barriers in reducing traffic noise levels to compliance with the City of Lincoln 60 dB L_{dn} exterior standard at outdoor activity areas adjacent to Virginiatown Road. Detailed noise barrier inputs and results are shown in Appendix F, and the results are summarized below in Table 6.

Table 6
Noise Barrier Effectiveness[1]
Lincoln Meadows Residential Development – Lincoln, California

		Resulting Noise Level (dB L_{dn})	
Roadway	**Barrier Height (feet)**	**Existing + Project**	**Cumulative + Project**
Virginiatown Road	0	62	68
	6	56	61
	7	54	60
	8	53	59

Notes:
[1] A complete listing of inputs and results is provided in Appendix F.
Source: Bollard Acoustical Consultants, Inc. (2016)

The Table 6 data indicate that a solid noise barrier of 7 feet in height relative to the residential pad elevation would be required to satisfy the City's 60 dB L_{dn} exterior noise standard at nearest residences adjacent to Virginiatown Road for cumulative plus project conditions. Recommended noise barrier locations are shown in Figure 4.

Predicted Future Interior Traffic Noise Levels within the Proposed Lincoln Meadows Residences

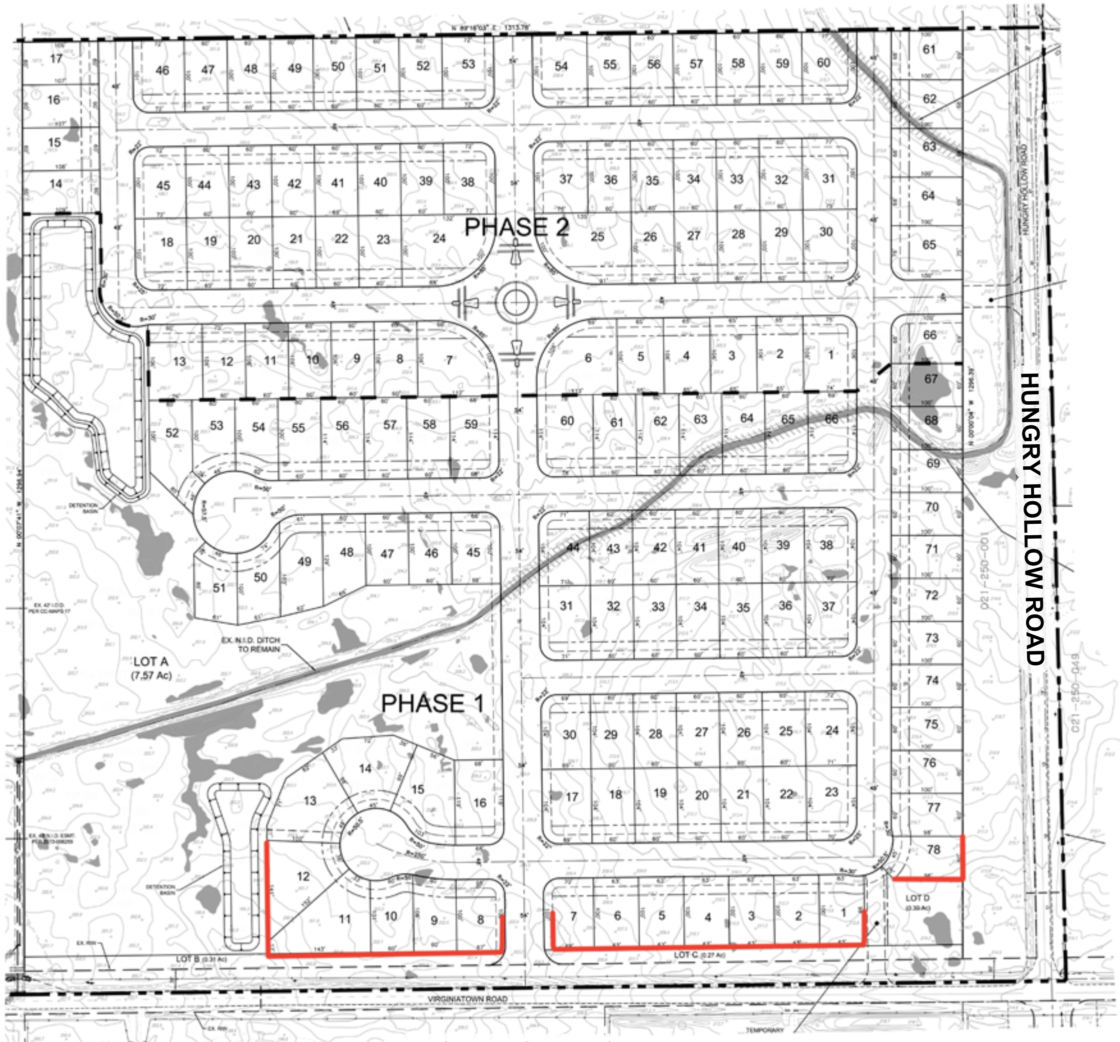
After construction of the required noise barrier, future traffic noise levels at the project site are predicted to be less than 60 dB L_{dn}. At upper-floor locations, reduced ground absorption and lack of shielding by the required barrier would result in noise levels of up to 70 dB L_{dn} at upper-floor facades located along Virginiatown Road and 60 dB L_{dn} along Hungry Hollow Road. As a result, building facade noise reductions of up to 25 dB would be required of proposed residences to achieve compliance with the City of Lincoln 45 dB L_{dn} interior noise standard.

Standard residential construction (wood siding, STC-27 windows, door weather-stripping, exterior wall insulation, composition plywood roof), results in an exterior to interior noise reduction of at least 25 dB with windows closed and approximately 15 dB with windows open. Therefore, standard construction would be acceptable for all residences in this development. However, to provide an additional measure of safety, BAC recommends that all upper-floor windows of residences located along Virginiatown Road with a view of the roadway be upgraded to a Sound Transmission Class (STC) rating of 32.

Figure 4

Recommended Sound Wall

Lincoln Meadows Residential Development - City of Lincoln, California



VIRGINIATOWN ROAD

Legend

Recommended 7-foot Sound Wall

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Scale (feet)

0 200 400

Existing Vs. Existing Plus Project Off-Site Traffic Noise Levels

With development within the project area as a whole, traffic volumes on the local roadway network will increase. Those increases in daily traffic volumes will result in a corresponding increase in traffic noise levels. The FHWA Model was used with traffic data provided by the client to predict existing and existing plus project traffic noise levels, and the project-related noise level increases. The FHWA Model input data is contained in Appendix G. Table 7 shows existing versus existing-plus-project traffic noise levels on the regional roadway network.

Table 7
Existing Vs. Existing Plus Project Traffic Noise Levels
Lincoln Meadows Residential Development

Roadway	Segment Description	Existing	Existing + Project	Change	Substantial Increase?
East Avenue	North of 7th Street	63.3	63.8	0.5	No
East Avenue	South of 7th Street	63.6	63.9	0.3	No
7th Street	East of East Avenue	49.4	49.4	0.0	No
7th Street	West of East Avenue	60.3	60.6	0.3	No
East Avenue	South of 12th Street	62.5	63.1	0.6	No
12th Street	East of East Avenue	60.4	61.1	0.7	No
12th Street	West of East Avenue	55.9	56.1	0.2	No
McCourtney Road	North of Virginiatown Road	59.5	59.7	0.1	No
Harrison Avenue	South of Virginiatown Road	46.9	46.9	0.0	No
12th Street	West of McCourtney Road	59.7	60.6	0.8	No
Hungry Hollow Road	North of Virginiatown Road	56.0	58.0	1.9	No
Oak Tree Lane	South of Virginiatown Road	Roadway Does Not Exist			
Virginiatown Road	East of Hungry Hollow Road	57.9	58.2	0.3	No
Virginiatown Road	McCourtney Rd to Virginiatown Rd	62.7	64.3	1.6	No

Source: FHWA-RD-77-108 with inputs prepared by Fehr & Peers

Table 7 data indicates that the proposed project would not result in any significant off-site traffic noise impacts relative to existing baseline conditions.

Cumulative Vs. Cumulative Plus Project Off-Site Traffic Noise Levels

Using the same methodology described above, traffic noise levels were predicted for cumulative (future) and cumulative-plus-project conditions. Table 8 shows the results of the cumulative traffic analysis.

Table 8
Cumulative Vs. Cumulative Plus Project Traffic Noise Levels
Lincoln Meadows Residential Development

Roadway	Segment Description	Cumulative	Cumulative + Project	Change	Substantial Increase?
East Avenue	North of 7th Street	64.0	64.2	0.1	No
East Avenue	South of 7th Street	64.9	65.0	0.1	No
7th Street	East of East Avenue	51.1	51.1	0.0	No
7th Street	West of East Avenue	63.6	63.7	0.1	No
East Avenue	South of 12th Street	63.8	63.9	0.0	No
12th Street	East of East Avenue	64.8	64.9	0.1	No
12th Street	West of East Avenue	63.7	63.8	0.1	No
McCourtney Road	North of Virginiatown Road	63.2	63.2	0.0	No
Harrison Avenue	South of Virginiatown Road	54.1	54.1	0.0	No
12th Street	West of McCourtney Road	64.7	64.8	0.1	No
Hungry Hollow Road	North of Virginiatown Road	59.9	60.8	0.9	No
Oak Tree Lane	South of Virginiatown Road	67.6	68.0	0.3	No
Virginiatown Road	East of Hungry Hollow Road	65.2	65.2	0.1	No
Virginiatown Road	McCourtney Rd to Virginiatown Rd	70.0	70.2	0.2	No

Source: FHWA-RD-77-108 with inputs prepared by Fehr & Peers

Table 8 data indicates that the proposed project would not result in any significant off-site traffic noise impacts relative to cumulative baseline conditions.

Construction Noise Impact Evaluation

Policy HS-8.8 of the City of Lincoln General Plan Noise Element addresses construction noise:

> Policy HS-8.8: Construction Noise
>
> The City will provide guidelines to developers for reducing potential construction noise impacts on surrounding land uses.

During project construction, heavy equipment would be used for grading excavation, paving, and building construction, which would increase ambient noise levels when in use. Noise levels would vary depending on the type of equipment used, how it is operated, and how well it is maintained. Noise exposure at any single point outside the project site would also vary depending on the proximity of construction activities to that point. Standard construction equipment, such as graders, backhoes, loaders, and trucks, would be used for this work.

The range of maximum noise levels for various types of construction equipment at a distance of 50 feet is provided in Table 9. The noise values represent maximum noise generation, or full-power operation of the equipment. As one increases the distance between equipment, or increased separation of areas with simultaneous construction activity, dispersion and distance attenuation reduce the effects of combining separate noise sources.

Table 9
Construction Equipment Noise Emission Levels

Equipment	Typical Sound Level (dBA) 50 Feet from Source
Air compressor	81
Backhoe	80
Compactor	82
Concrete mixer	85
Concrete pump	82
Concrete vibrator	76
Crane, mobile	83
Dozer	85
Generator	81
Grader	85
Impact wrench	85
Jackhammer	88
Loader	85
Paver	89
Pneumatic tool	85
Pump	76
Roller	74
Saw	76
Truck	88

Source: Federal Transit Administration, 2006.

Noise would also be generated during the construction phase by increased truck traffic on area roadways. A significant project-generated noise source would be truck traffic associated with transport of heavy materials and equipment to and from the construction site. Given the relatively low ambient noise environment in the project vicinity and the proximity of the nearest existing residences to the west, short-term increases in construction noise could result in significant noise impacts. As a result, the following construction noise mitigation measures are recommended.

Construction Noise Mitigation Measures

There is typically an increase in ambient noise between the hours of 7a.m. and 7p.m. in any area with traffic and development. By limiting the hours of construction to these hours, the potential for nuisance noise is reduced because project construction-related noise would be less noticeable. The use of mufflers on construction equipment would decrease the overall noise generated by construction equipment. Because sound diminishes with distance, locating noise-generating equipment away from noise sensitive uses would protect nearby residences from excessive noise levels. Notifying residents within 300 feet of construction areas would enable residents who are particularly sensitive to noise to take precautions, such as keeping windows closed.

Implementation of the following noise mitigation measures would reduce the potential for adverse noise impacts on nearby residences during construction to a *less-than-significant level*.

a) *Construction hours shall be limited to 7am to 7pm, Monday through Friday (unless extended by special permit).*

b) All internal combustion engines associated with stationary and mobile construction equipment shall have adequate mufflers equal to or better than those supplied with the equipment by the manufacturer.

c) Onsite construction staging areas shall be located as far as practical from existing residential areas.

Vibration Impact Evaluation

During field visits to the site, BAC staff subjectively evaluated vibration levels as being below the threshold of perception. In addition, the project would not introduce any significant sources of vibration. As a result, no long-term vibration impacts are identified due to or upon this project. However, short-term increases in vibration during construction activities would result in the immediate vicinity of heavy earthmoving equipment operations.

To quantify reference vibration levels commonly generated by construction equipment, the publication, *Transportation and Construction Vibration Guidance Manual* (Caltrans, September 2013), was utilized. Table 18 of that publication, which is reproduced below as Table 10, contains reference peak particle velocity data for such equipment.

Table 10
Vibration Amplitudes for Construction Equipment

Vibration Source	Measurement Distance, ft.	Peak Particle Velocity (in/sec)
Vibratory Roller	25	0.210
Large Bulldozers	25	0.089
Loaded Trucks	25	0.076
Jackhammer	25	0.035

Source: Bollard Acoustical Consultants, Inc. (BAC)

The vibration data shown in Table 10 indicate that, with the exception of the vibratory roller, heavy equipment-generated vibration levels are below the thresholds for annoyance and damage to structures even at the very close measurement locations of 25 feet from the operating equipment.

The existing residences nearest to the project site are separated from proposed residences by distances of 200 feet or more. Falloff due to spherical spreading would result in a peak particle velocity of approximately 0.021 inches per second or less at this distance, which is well below the thresholds of damage to structures and human perception. As a result, no off-site construction vibration impacts are identified for this project.

Conclusions

A portion of the Lincoln Meadows Residential Development project site will be exposed to future traffic noise levels in excess of Lincoln's noise standards. As a result, the following noise mitigation measures are recommended:

- A solid noise barrier with a height of 7 feet relative to building pad elevation should be constructed along Virginiatown Road as shown in Figure 4.

- Upper-floor windows of residences located adjacent to Virginiatown Road with views of the roadway should be upgraded to STC 32.

These conclusions are based on the traffic assumptions cited in Appendix E, and on noise reduction data for standard residential dwellings. Deviations from the Appendix E data, or the project site plan shown in Figure 2, could cause future traffic noise levels to differ from those predicted in this analysis. In addition, Bollard Acoustical Consultants, Inc. is not responsible for degradation in acoustic performance of the residential construction due to poor construction practices, failure to comply with applicable building code requirements, or for failure to adhere to the minimum building practices cited in this report.

This concludes BAC's noise and vibration impact assessment for the proposed Lincoln Meadows Residential Development. Please contact BAC at (916) 663-0500 or paulb@bacnoise.com with any questions regarding this assessment.

Appendix A

Acoustical Terminology

Acoustics The science of sound.

Ambient Noise The distinctive acoustical characteristics of a given space consisting of all noise sources audible at that location. In many cases, the term ambient is used to describe an existing or pre-project condition such as the setting in an environmental noise study.

Attenuation The reduction of an acoustic signal.

A-Weighting A frequency-response adjustment of a sound level meter that conditions the output signal to approximate human response.

Decibel or dB Fundamental unit of sound, A Bell is defined as the logarithm of the ratio of the sound pressure squared over the reference pressure squared. A Decibel is one-tenth of a Bell.

CNEL Community Noise Equivalent Level. Defined as the 24-hour average noise level with noise occurring during evening hours (7 - 10 p.m.) weighted by a factor of three and nighttime hours weighted by a factor of 10 prior to averaging.

Frequency The measure of the rapidity of alterations of a periodic signal, expressed in cycles per second or hertz.

Ldn Day/Night Average Sound Level. Similar to CNEL but with no evening weighting.

Leq Equivalent or energy-averaged sound level.

Lmax The highest root-mean-square (RMS) sound level measured over a given period of time.

Loudness A subjective term for the sensation of the magnitude of sound.

Masking The amount (or the process) by which the threshold of audibility is for one sound is raised by the presence of another (masking) sound.

Noise Unwanted sound.

Peak Noise The level corresponding to the highest (not RMS) sound pressure measured over a given period of time. This term is often confused with the Maximum level, which is the highest RMS level.

RT_{60} The time it takes reverberant sound to decay by 60 dB once the source has been removed.

Sabin The unit of sound absorption. One square foot of material absorbing 100% of incident sound has an absorption of 1 sabin.

SEL A rating, in decibels, of a discrete event, such as an aircraft flyover or train passby, that compresses the total sound energy of the event into a 1-s time period.

Threshold of Hearing The lowest sound that can be perceived by the human auditory system, generally considered to be 0 dB for persons with perfect hearing.

Threshold of Pain Approximately 120 dB above the threshold of hearing.

Appendix B
Lincoln Meadows Residential Development
Ambient Noise Monitoring Results - Site 1
Tuesday, September 20, 2016

Hour	Leq	Lmax	L50	L90
0:00	46	71	43	42
1:00	44	71	42	40
2:00	46	70	41	39
3:00	49	72	40	32
4:00	52	74	39	32
5:00	57	77	42	39
6:00	61	81	46	40
7:00	62	79	50	42
8:00	61	83	43	38
9:00	59	78	41	36
10:00	58	75	40	35
11:00	60	79	43	38
12:00	59	83	41	37
13:00	59	80	40	35
14:00	60	78	41	34
15:00	61	77	45	35
16:00	61	77	45	34
17:00	62	78	48	35
18:00	61	82	48	35
19:00	59	75	46	38
20:00	58	75	45	43
21:00	56	74	44	42
22:00	52	73	42	41
23:00	50	71	40	37

	Statistical Summary					
	Daytime (7 a.m. - 10 p.m.)			Nighttime (10 p.m. - 7 a.m.)		
	High	Low	Average	High	Low	Average
Leq (Average)	62	56	60	61	44	54
Lmax (Maximum)	83	74	78	81	70	73
L50 (Median)	50	40	44	46	39	42
L90 (Background)	43	34	37	42	32	38

Computed Ldn, dB	62
% Daytime Energy	87%
% Nighttime Energy	13%

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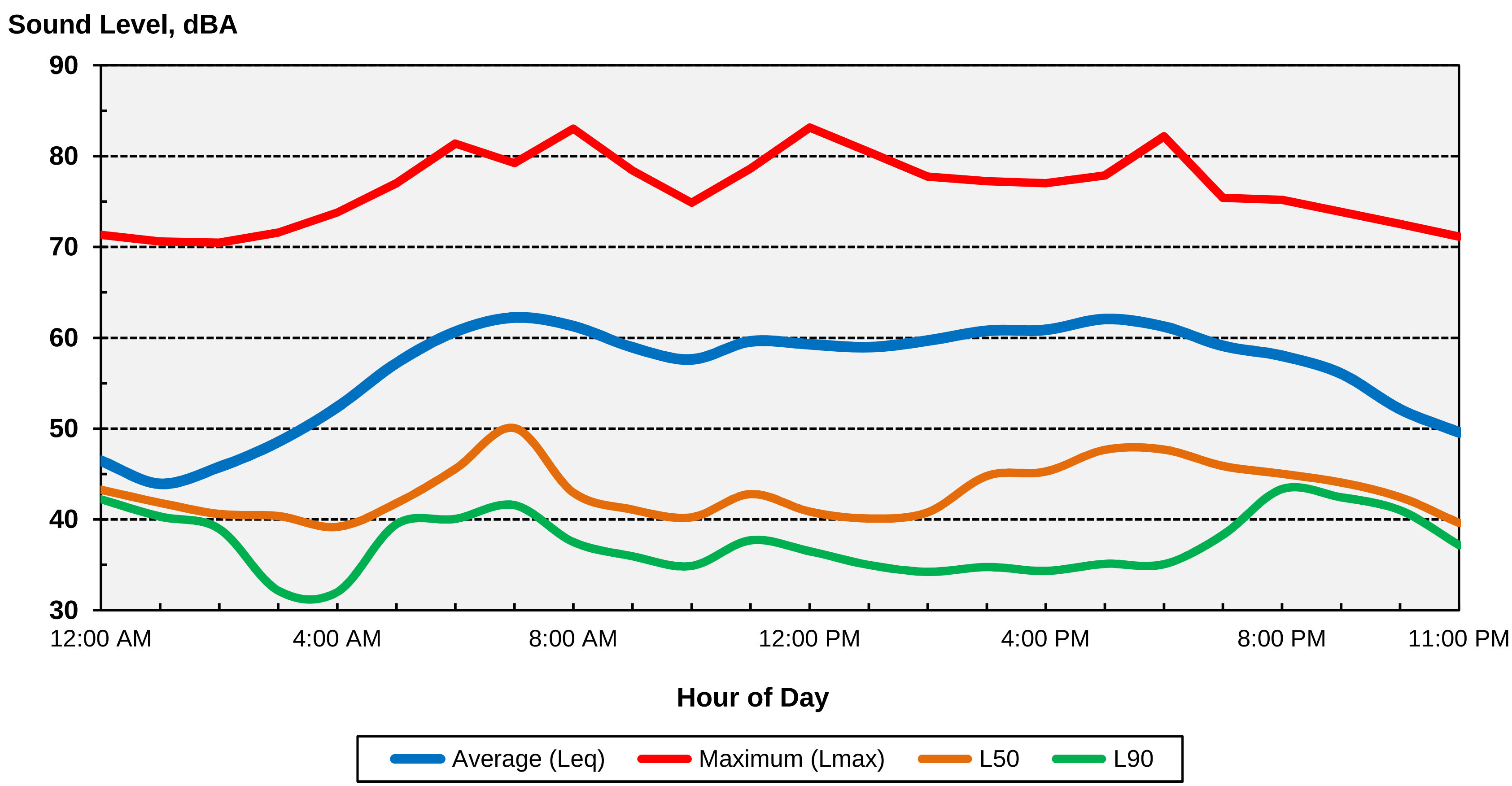
Appendix C
Lincoln Meadows Residential Development
Ambient Noise Monitoring Results - Site 1
Tuesday, September 20, 2016



Ldn: 62 dB

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Appendix D

FHWA Traffic Noise Prediction Model (FHWA-RD-77-108)
Calibration Worksheet

Project Information:	Job Number:	2015-291
	Project Name:	Lincoln Meadows Residential Development
	Roadway Tested:	Virginiatown Road
	Test Location:	Site 1
	Test Date:	December 4, 2015
Weather Conditions:	Temperature (Fahrenheit):	63
	Relative Humidity:	49%
	Wind Speed and Direction:	SW 6mph
	Cloud Cover:	Partly Cloudy
Sound Level Meter:	Sound Level Meter:	LDL Model 820 (BAC #8)
	Calibrator:	LDL Model CAL200
	Meter Calibrated:	Immediately before
	Meter Settings:	A-weighted, slow response
Microphone:	Microphone Location:	On project site
	Distance to Centerline (feet):	60
	Microphone Height:	5 feet above ground
	Intervening Ground (Hard or Soft):	**Soft**
	Elevation Relative to Road (feet):	5
Roadway Condition:	Pavement Type	Asphalt
	Pavement Condition:	Good
	Number of Lanes:	2
	Posted Maximum Speed (mph):	45
Test Parameters:	Test Time:	12:58 PM
	Test Duration (minutes):	15
	Observed Number Automobiles:	35
	Observed Number Medium Trucks:	4
	Observed Number Heavy Trucks:	1
	Observed Average Speed (mph):	43
Model Calibration:	Measured Average Level (L_{eq}):	59.4
	Level Predicted by FHWA Model:	59.7
	Difference:	***0.3 dB***

Conclusions: No calibration adjustment required.

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Appendix E-1

FHWA Traffic Noise Prediction Model (FHWA-RD-77-108)
Noise Prediction Worksheet

Project Information:

Job Number:	2015-291
Project Name:	Lincoln Meadows Residential Development
Roadway Name:	Virginiatown Road

Traffic Data:

Year:	Existing plus Project
Average Daily Traffic Volume:	4,700
Percent Daytime Traffic:	83
Percent Nighttime Traffic:	17
Percent Medium Trucks (2 axle):	2
Percent Heavy Trucks (3+ axle):	1
Assumed Vehicle Speed (mph):	45
Intervening Ground Type (hard/soft):	**Soft**

Traffic Noise Levels:

				----------------L_{dn}, dB-----------------			
Lots	**Description**	**Distance**	**Offset (dB)**	**Autos**	**Medium Trucks**	**Heavy Trucks**	**Total**
1 - 11	Nearest Backyards	65	0	61	53	54	63
1 - 11	Nearest Facades	80	0	60	51	53	61
1 - 11	Nearest Upper-Floor Facades	80	3	63	54	56	64

Traffic Noise Contours (No Calibration Offset):

L_{dn} Contour, dB	Distance from Centerline, (ft)
75	10
70	21
65	45
60	96

Notes: Future ADT obtained from the Lincoln Meadows traffic study by Fehr & Peers.

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Appendix E-2

FHWA Traffic Noise Prediction Model (FHWA-RD-77-108)

Noise Prediction Worksheet

Project Information:

Job Number: 2015-291
Project Name: Lincoln Meadows Residential Development
Roadway Name: Hungry Hollow Road

Traffic Data:

Year: Existing plus Project
Average Daily Traffic Volume: 1,460
Percent Daytime Traffic: 83
Percent Nighttime Traffic: 17
Percent Medium Trucks (2 axle): 2
Percent Heavy Trucks (3+ axle): 1
Assumed Vehicle Speed (mph): 45
Intervening Ground Type (hard/soft): **Soft**

Traffic Noise Levels:

				-----------------L_{dn}, dB------------------			
Lots	**Description**	**Distance**	**Offset (dB)**	**Autos**	**Medium Trucks**	**Heavy Trucks**	**Total**
61-78	Nearest Backyards	90	0	54	46	47	55
61-78	Nearest Facades	105	0	53	45	46	54
61-78	Nearest Upper-Floor Facades	105	3	56	48	49	57

Traffic Noise Contours (No Calibration Offset):

L_{dn} Contour, dB	Distance from Centerline, (ft)
75	4
70	10
65	21
60	44

Notes: Future ADT obtained from the Lincoln Meadows traffic study by Fehr & Peers.

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Appendix E-3

FHWA Traffic Noise Prediction Model (FHWA-RD-77-108)
Noise Prediction Worksheet

Project Information:

Job Number:	2015-291
Project Name:	Lincoln Meadows Residential Development
Roadway Name:	Virginiatown Road

Traffic Data:

Year:	Cumulative plus Project
Average Daily Traffic Volume:	18,200
Percent Daytime Traffic:	83
Percent Nighttime Traffic:	17
Percent Medium Trucks (2 axle):	2
Percent Heavy Trucks (3+ axle):	1
Assumed Vehicle Speed (mph):	45
Intervening Ground Type (hard/soft):	**Soft**

Traffic Noise Levels:

				-----------------L_{dn}, dB------------------			
Lots	**Description**	**Distance**	**Offset (dB)**	**Autos**	**Medium Trucks**	**Heavy Trucks**	**Total**
1 - 11	Nearest Backyards	65	0	67	59	60	68
1 - 11	Nearest Facades	80	0	66	57	59	67
1 - 11	Nearest Upper-Floor Facades	80	3	69	60	62	70

Traffic Noise Contours (No Calibration Offset):

L_{dn} Contour, dB	**Distance from Centerline, (ft)**
75	24
70	51
65	110
60	238

Notes: Future ADT obtained from the Lincoln Meadows traffic study by Fehr & Peers.

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Appendix E-4

FHWA Traffic Noise Prediction Model (FHWA-RD-77-108)
Noise Prediction Worksheet

Project Information:

Job Number:	2015-291
Project Name:	Lincoln Meadows Residential Development
Roadway Name:	Hungry Hollow Road

Traffic Data:

Year:	Cumulative plus Project
Average Daily Traffic Volume:	2,800
Percent Daytime Traffic:	83
Percent Nighttime Traffic:	17
Percent Medium Trucks (2 axle):	2
Percent Heavy Trucks (3+ axle):	1
Assumed Vehicle Speed (mph):	45
Intervening Ground Type (hard/soft):	**Soft**

Traffic Noise Levels:

				L_{dn}, dB			
Lots	**Description**	**Distance**	**Offset (dB)**	**Autos**	**Medium Trucks**	**Heavy Trucks**	**Total**
61-78	Nearest Backyards	90	0	57	48	50	58
61-78	Nearest Facades	105	0	56	47	49	57
61-78	Nearest Upper-Floor Facades	105	3	59	50	52	60

Traffic Noise Contours (No Calibration Offset):

L_{dn} Contour, dB	Distance from Centerline, (ft)
75	7
70	15
65	32
60	68

Notes: Future ADT obtained from the Lincoln Meadows traffic study by Fehr & Peers.

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Appendix F-1

FHWA Traffic Noise Prediction Model (FHWA-RD-77-108)
Noise Barrier Effectiveness Prediction Worksheet

Project Information:

Job Number: 2015-291
Project Name: Lincoln Meadows Residential Development
Roadway Name: Virginiatown Road
Location(s): Nearest Backyards

Noise Level Data:

Year: Existing Plus Project
Auto L_{dn}, dB: 61
Medium Truck L_{dn}, dB: 53
Heavy Truck L_{dn}, dB: 54

Site Geometry:

Receiver Description: Nearest Backyards
Centerline to Barrier Distance (C_1): 65
Barrier to Receiver Distance (C_2): 15
Automobile Elevation: 202
Medium Truck Elevation: 204
Heavy Truck Elevation: 210
Pad/Ground Elevation at Receiver: 206
Receiver Elevation[1]: 211
Base of Barrier Elevation: 206
Starting Barrier Height: 0

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height[2] (ft)	L_{dn}, dB				Barrier Breaks Line of Sight to…		
		Autos	Medium Trucks	Heavy Trucks	Total	Autos?	Medium Trucks?	Heavy Trucks?
206	0	61	52	54	**62**	No	No	No
207	1	60	52	54	**62**	No	No	No
208	2	57	49	54	**59**	No	No	No
209	3	56	48	51	**58**	No	No	No
210	4	56	48	50	**58**	Yes	Yes	No
211	5	55	47	49	**57**	Yes	Yes	Yes
212	6	54	46	49	**56**	Yes	Yes	Yes
213	7	53	45	48	**54**	Yes	Yes	Yes
214	8	51	43	46	**53**	Yes	Yes	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix F-2

FHWA Traffic Noise Prediction Model (FHWA-RD-77-108)
Noise Barrier Effectiveness Prediction Worksheet

Project Information:

Job Number: 2015-291
Project Name: Lincoln Meadows Residential Development
Roadway Name: Virginiatown Road
Location(s): Nearest Backyards

Noise Level Data:

Year: Cumulative plus Project
Auto L_{dn}, dB: 67
Medium Truck L_{dn}, dB: 59
Heavy Truck L_{dn}, dB: 60

Site Geometry:

Receiver Description: Nearest Backyards
Centerline to Barrier Distance (C_1): 65
Barrier to Receiver Distance (C_2): 15
Automobile Elevation: 202
Medium Truck Elevation: 204
Heavy Truck Elevation: 210
Pad/Ground Elevation at Receiver: 206
Receiver Elevation[1]: 211
Base of Barrier Elevation: 206
Starting Barrier Height: 0

Barrier Effectiveness:

Top of Barrier Elevation (ft)	Barrier Height[2] (ft)	L_{dn}, dB				Barrier Breaks Line of Sight to…		
		Autos	Medium Trucks	Heavy Trucks	Total	Autos?	Medium Trucks?	Heavy Trucks?
206	0	67	58	60	**68**	No	No	No
207	1	66	58	60	**68**	No	No	No
208	2	63	55	59	**65**	No	No	No
209	3	62	54	57	**64**	No	No	No
210	4	62	54	55	**63**	Yes	Yes	No
211	5	61	53	55	**63**	Yes	Yes	Yes
212	6	60	52	55	**61**	Yes	Yes	Yes
213	7	59	51	53	**60**	Yes	Yes	Yes
214	8	57	49	52	**59**	Yes	Yes	Yes

Notes: 1.Standard receiver elevation is five feet above grade/pad elevations at the receiver location(s)

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Appendix G-1

FHWA-RD-77-108 Highway Traffic Noise Prediction Model
Data Input Sheet

Project #: 2015-291 Lincoln Meadows Residential Development
Description: Existing
Ldn/CNEL: Ldn
Hard/Soft: Soft

Segment	Roadway Name	Segment Description	ADT	Day %	Eve %	Night %	% Med. Trucks	% Hvy. Trucks	Speed	Distance	Offset (dB)
1	East Avenue	North of 7th Street	8,690	83		17	2	1	30	50	
2	East Avenue	South of 7th Street	9,275	83		17	2	1	30	50	
3	7th Street	East of East Avenue	510	83		17	2	1	25	50	
4	7th Street	West of East Avenue	4,375	83		17	2	1	30	50	
5	East Avenue	South of 12th Street	7,235	83		17	2	1	30	50	
6	12th Street	East of East Avenue	6,390	83		17	2	1	25	50	
7	12th Street	West of East Avenue	2,275	83		17	2	1	25	50	
8	McCourtney Road	North of Virginiatown Road	2,865	83		17	2	1	35	50	
9	Harrison Avenue	South of Virginiatown Road	285	83		17	2	1	25	50	
10	12th Street	West of McCourtney Road	5,505	83		17	2	1	25	50	
11	Hungry Hollow Road	North of Virginiatown Road	935	83		17	2	1	40	50	
12	Oak Tree Lane	South of Virginiatown Road	--	83		17	2	1	45	50	
13	Virginiatown Road	McCourtney Rd to Hungry Hollow Rd	3,300	83		17	2	1	45	50	
14	Virginiatown Road	East of Hungry Hollow Road	1,080	83		17	2	1	45	50	

Appendix G-2

FHWA-RD-77-108 Highway Traffic Noise Prediction Model

Data Input Sheet

Project #: 2015-291 Lincoln Meadows Residential Development
Description: Existing + Project
Ldn/CNEL: Ldn
Hard/Soft: Soft

Segment	Roadway Name	Segment Description	ADT	Day %	Eve %	Night %	% Med. Trucks	% Hvy. Trucks	Speed	Distance	Offset (dB)
1	East Avenue	North of 7th Street	9,735	83		17	2	1	30	50	
2	East Avenue	South of 7th Street	10,005	83		17	2	1	30	50	
3	7th Street	East of East Avenue	510	83		17	2	1	25	50	
4	7th Street	West of East Avenue	4,690	83		17	2	1	30	50	
5	East Avenue	South of 12th Street	8,280	83		17	2	1	30	50	
6	12th Street	East of East Avenue	7,540	83		17	2	1	25	50	
7	12th Street	West of East Avenue	2,380	83		17	2	1	25	50	
8	McCourtney Road	North of Virginiatown Road	2,955	83		17	2	1	35	50	
9	Harrison Avenue	South of Virginiatown Road	285	83		17	2	1	25	50	
10	12th Street	West of McCourtney Road	6,655	83		17	2	1	40	50	
11	Hungry Hollow Road	North of Virginiatown Road	1,460	83		17	2	1	45	50	
12	Oak Tree Lane	South of Virginiatown Road	--	83		17	2	1	45	50	
13	Virginiatown Road	McCourtney Rd to Hungry Hollow Rd	4,700	83		17	2	1	45	50	
14	Virginiatown Road	East of Hungry Hollow Road	1,165	83		17	2	1	45	50	

Appendix G-3

FHWA-RD-77-108 Highway Traffic Noise Prediction Model
Data Input Sheet

Project #: 2015-291 Lincoln Meadows Residential Development
Description: Cumulative
Ldn/CNEL: Ldn
Hard/Soft: Soft

Segment	Roadway Name	Segment Description	ADT	Day %	Eve %	Night %	% Med. Trucks	% Hvy. Trucks	Speed	Distance	Offset (dB)
1	East Avenue	North of 7th Street	10,270	83		17	2	1	30	50	
2	East Avenue	South of 7th Street	12,740	83		17	2	1	30	50	
3	7th Street	East of East Avenue	750	83		17	2	1	25	50	
4	7th Street	West of East Avenue	9,430	83		17	2	1	30	50	
5	East Avenue	South of 12th Street	9,825	83		17	2	1	30	50	
6	12th Street	East of East Avenue	17,815	83		17	2	1	25	50	
7	12th Street	West of East Avenue	13,590	83		17	2	1	25	50	
8	McCourtney Road	North of Virginiatown Road	6,690	83		17	2	1	35	50	
9	Harrison Avenue	South of Virginiatown Road	1,500	83		17	2	1	25	50	
10	12th Street	West of McCourtney Road	17,160	83		17	2	1	25	50	
11	Hungry Hollow Road	North of Virginiatown Road	2,275	83		17	2	1	40	50	
12	Oak Tree Lane	South of Virginiatown Road	10,185	83		17	2	1	45	50	
13	Virginiatown Road	McCourtney Rd to Hungry Hollow Rd	17,600	83		17	2	1	45	50	
14	Virginiatown Road	East of Hungry Hollow Road	5,780	83		17	2	1	45	50	

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Appendix G-4

FHWA-RD-77-108 Highway Traffic Noise Prediction Model
Data Input Sheet

Project #: 2015-291 Lincoln Meadows Residential Development
Description: Cumulative+Project
Ldn/CNEL: Ldn
Hard/Soft: Soft

Segment	Roadway Name	Segment Description	ADT	Day %	Eve %	Night %	% Med. Trucks	% Hvy. Trucks	Speed	Distance	Offset (dB)
1	East Avenue	North of 7th Street	10,625	83		17	2	1	30	50	
2	East Avenue	South of 7th Street	12,975	83		17	2	1	30	50	
3	7th Street	East of East Avenue	750	83		17	2	1	25	50	
4	7th Street	West of East Avenue	9,550	83		17	2	1	30	50	
5	East Avenue	South of 12th Street	9,900	83		17	2	1	30	50	
6	12th Street	East of East Avenue	18,300	83		17	2	1	25	50	
7	12th Street	West of East Avenue	14,000	83		17	2	1	25	50	
8	McCourtney Road	North of Virginiatown Road	6,700	83		17	2	1	35	50	
9	Harrison Avenue	South of Virginiatown Road	1,500	83		17	2	1	25	50	
10	12th Street	West of McCourtney Road	17,650	83		17	2	1	40	50	
11	Hungry Hollow Road	North of Virginiatown Road	2,800	83		17	2	1	45	50	
12	Oak Tree Lane	South of Virginiatown Road	10,950	83		17	2	1	45	50	
13	Virginiatown Road	McCourtney Rd to Hungry Hollow Rd	18,200	83		17	2	1	45	50	
14	Virginiatown Road	East of Hungry Hollow Road	5,850	83		17	2	1	45	50	

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