Northern Rail Extension Phase 1

Memo

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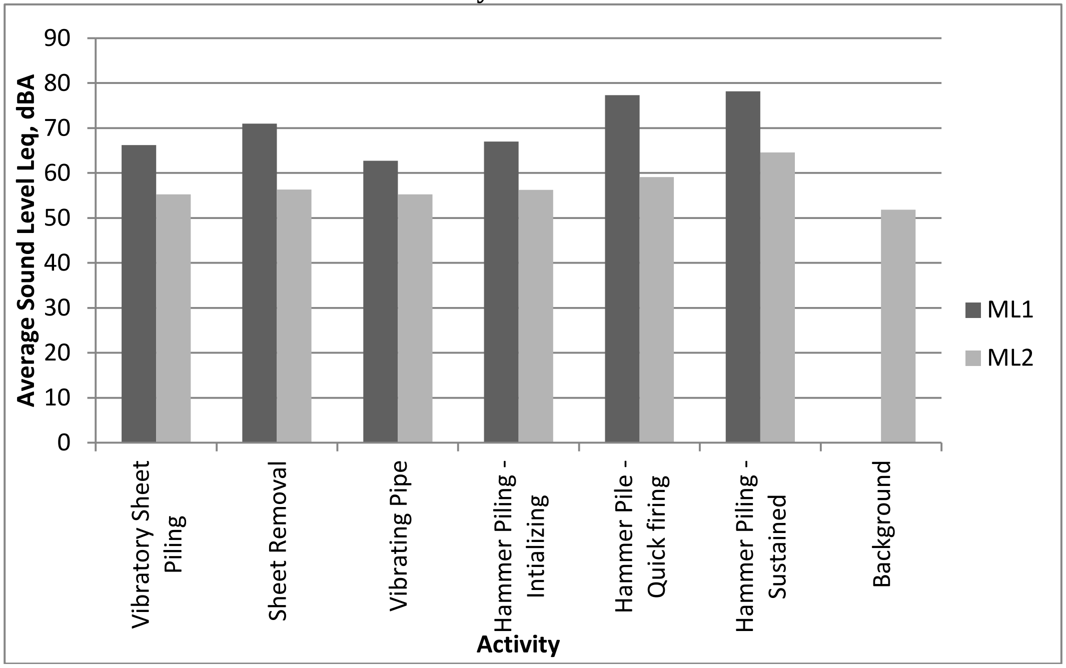
From:	Tim Casey and Gina Ramirez	**Project:**	NRE1
CC:	Sim Brubaker		
Date:	November 18, 2011		

RE: DRAFT Noise & Vibration Measurements During Test Pile Driving

Summary

Figure 1 summarizes noise levels measured at Monitoring Locations 1 and 2 (ML1, ML2) during vibratory and impact pile driving. The figure shows average noise levels, expressed as the equivalent sound level (L_{eq}) in A-weighted decibels (dBA). The L_{eq} is an energy-based average noise level: it's also a mean noise level.

Figure 1
Summary of Noise Measurements

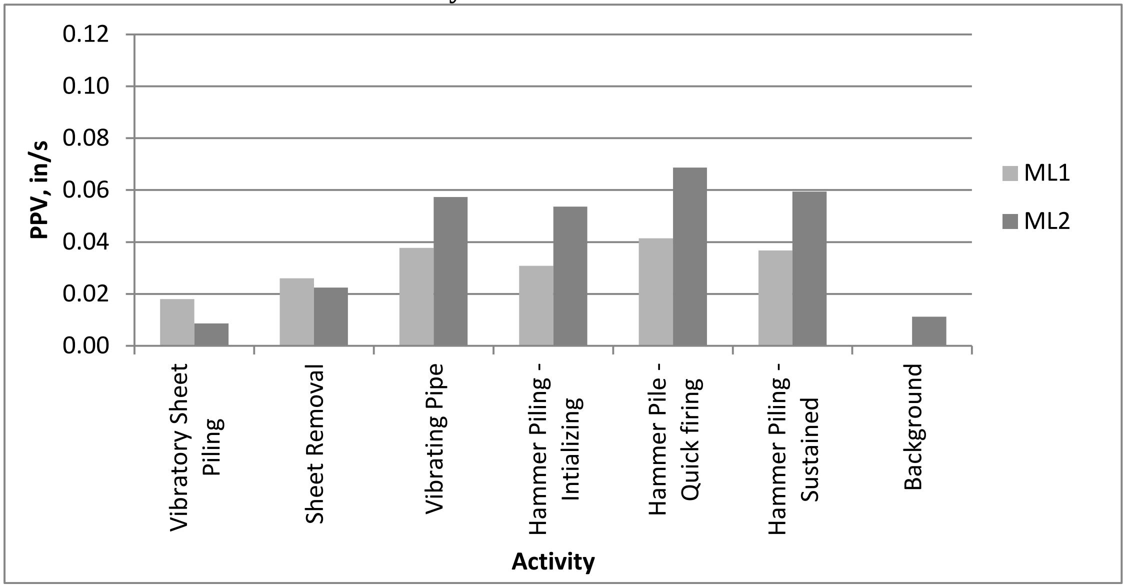


Data in the figure show that noise levels measured at both locations during both vibratory and impact pile driving were higher than background levels measured at the nearest residence when no pile driving occurred. Figure 1 also shows that impact pile driving (hammer piling) is approximately 10 dBA louder than vibratory pile driving when measured at the nearest home.

The primary concern with construction noise is annoyance and sleep disturbance at night. Average outdoor noise levels between 50-60 dBA are generally considered acceptable (in municipal noise limits) for nighttime, in areas where overnight sleep occurs. Nighttime noise levels in excess of 65 dBA are generally considered unacceptable for areas where overnight sleep occurs. Also, by virtue of their nature impulsive noise events are more audible than noise events that blend into the background soundscape. Impact pile driving is one example of impulsive noise. So while pile-driving noise levels reached the 60-65 dBA range, because of the impulsive nature of the pile-driving these noise levels may have greater potential to annoy residents.

Figure 2 summarizes ground-borne vibration levels measured at ML1 and ML2. Figure 2 expresses ground-borne vibration in peak particle velocity (PPV) units of inches/second. Immediately before impact pile driving began, the vibration monitor was moved from the nearest residence (ML2) to a point approximately 237 feet from the pile driving site. So the vibratory pile driving results below represent the clear-cut zone (ML1) where pile driving occurred and the nearest residence (ML2), and the impact pile driving results represent two locations in the clear-cut zone where pile driving occurred. The vibration monitor was relocated from the nearest home to the clear-cut zone because it was highly unlikely that ground-borne vibration levels measured 1500 feet from the source would reach perception or damage thresholds.

Figure 2
Summary of Vibration Measurements



Data in the figure show that ground-borne vibration levels measured at the nearest residence during vibratory sheet pile driving is comparable to background levels measured at that location in the absence of pile driving. Figure 2 also shows that peak ground-borne vibration levels were higher during start-up phase of impact pile driving than during periods of sustained impact pile driving. The highest measured ground-borne vibration level occurred at approximately 237 feet from the pile driving site: approximately 0.07 in/sec PPV.

The threshold of human perception for ground-borne vibration is approximately 0.01 in/sec PPV, so this was likely perceivable. Note how dramatically the PPV attenuates between 237 feet and 392 feet (from approximately 0.07 to 0.04 in/sec). The relevant thresholds for damage to buildings include the following.

- - damage to extremely fragile (or historic) buildings 0.12 in/sec
- - damage to fragile buildings, 0.2 in/sec
- - damage to normal buildings 0.5 in/sec

This comparison suggests that at distances beyond 237 feet from the pile driving site, vibration levels are not anticipated to reach levels recognized as having potential to damage fragile or normal buildings.

Introduction

On behalf of the Alaska Railroad's Northern Extension project, HDR measured air-borne noise and ground-borne vibration on Tuesday, October 20, 2011. HDR performed these measurements at the Tanana River Crossing site near Salcha, Alaska. The purpose of the measurements was to evaluate noise and vibration associated with vibratory and hammer pile driving. HDR used a pair of Larson Davis model 824 real-time analyzers to measure air-borne sound. HDR also used a pair of Instantel Mini-mate monitors to measure ground-borne vibration.

Monitoring location 1 (ML1) represents a spot approximately 392 feet directly in front of where pile driving occurred. There were no obstructions between ML1 and the pile driving activities. The ground was covered with gravel fill; it was relatively flat. HDR installed a sound level meter (SLM1) and vibration monitor (VM1) at this location.

Monitoring location 2 (ML2) represents a residence approximately 1500 feet away from where pile driving occurred. A large portion of the propagation path between the pile driving site and ML2 was clear-cut, leveled, and paved with gravel fill. Thick forested areas exist outside the clear-cut zone, between ML2 and the clear-cut area. Trees were the primary obstructions between ML2 and the pile driving activities; some project-related trailers also may be in the propagation path. However the pile driving noise exists at the ground level (the power pack) and also at the point of impact. Throughout much of the range of displacement during pile driving, the point of impact occurs at an elevation that is taller than project-related trailers. So the trailers have limited potential to provide acoustical shielding. The ground at ML2 was covered with vegetation; it was relatively flat. HDR installed a sound level meter (SLM2) and vibration monitor (VM2) at this location.

The noise and vibration monitors collected data at the locations described above throughout all of the vibratory pile driving activities. Immediately prior to the impact pile driving, HDR relocated VM2 to a point located approximately 237 feet directly in front of where impact pile driving occurred. Therefore, during impact pile driving: sound levels meters were installed at their original locations, but the vibration monitors were now both directly in front of the pile driving site at distances of 237 and 392 feet, respectively.

Discussion

Results of this study show that, at the nearest residence, noise from impact pile driving reaches levels that are generally considered unacceptable for residential areas where overnight sleep occurs. The impulsive nature of the pile driving noise makes it inherently more annoying than a steady-state noise source. As the footprint of the pile driving activities move farther away from the residences, project-related noise levels at the residences will decrease. The height of the impact is so far above the ground, that objects on the ground in the propagation path, will provide very little acoustical shielding. There is merit in investigating the potential to install a non-rigid curtain-like barrier surrounding the point of impact to act as a noise barrier. HDR can help with this design.

Results of this study also show that ground-borne vibration levels measured during the test piling do not reach human perception levels or building damage levels at the nearest residence included in this study.

Background

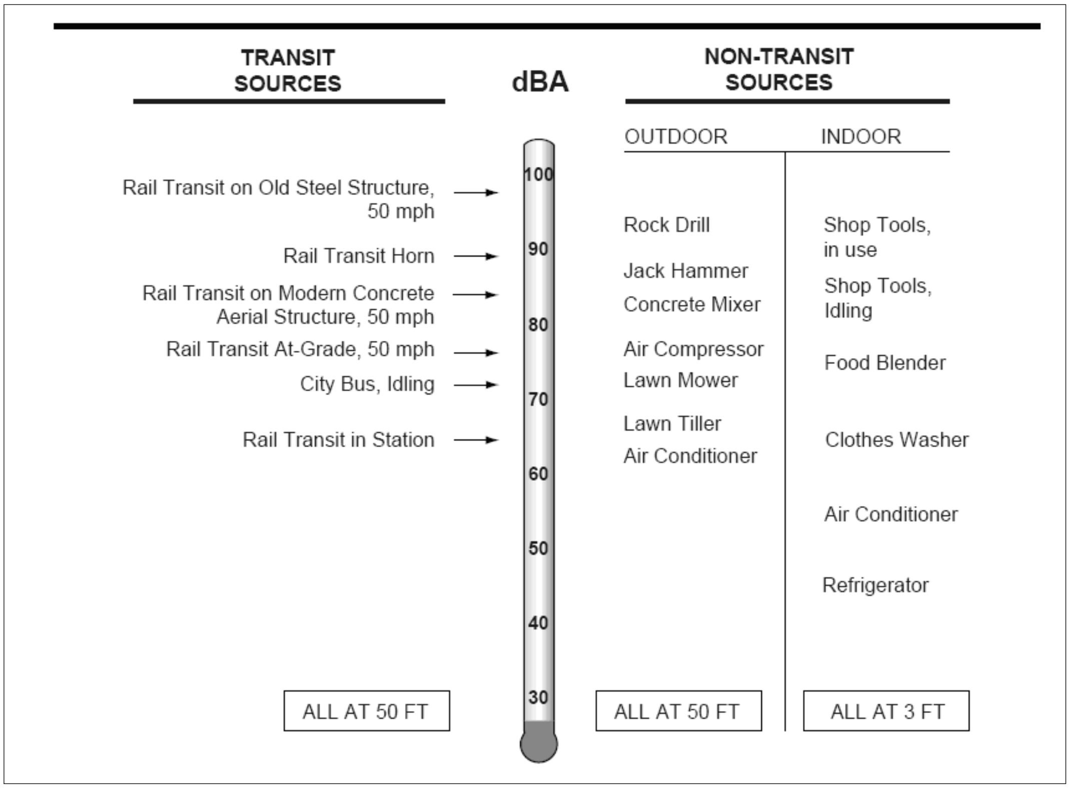
Human Perception Levels

Sound travels through the air as waves of tiny air pressure fluctuations. In general, sound waves travel away from the noise source as an expanding spherical surface. As a result, the energy contained in a sound wave is spread over an increasing area as it travels away from the source, resulting in a decrease in loudness at greater distances from the noise source. Noise is typically defined as unwanted or undesirable sound.

The intensity or loudness of a sound is determined by how much the sound pressure fluctuates above and below the atmospheric pressure and is expressed in units of decibels. The decibel (dB) scale used to describe sound is a logarithmic scale that accounts for the large range of sound pressure levels in the environment. By using this scale, the range of normally encountered sound can be expressed by values between 0 and about 140 dB. Sound-level meters measure the actual pressure fluctuations caused by sound waves and record separate measurements for different frequency ranges. Most sounds consist of a broad range of sound frequencies, from low frequencies to high frequencies. The average human ear does not perceive all frequencies equally. Therefore, the A-weighting scale was developed to approximate the way the human ear responds to sound levels; it mathematically applies less “weight” to frequencies we don’t hear well, and applies more “weight” to frequencies we do hear well. Typical A-weighted noise levels for various types of sound sources are summarized in Figure 3 (Typical A-Weighted Sound Levels).

Figure 3 Typical A-Weighted Sound Levels

Source: FTA, “Transit Noise and Vibration Impact Assessment” (May 2006)



The equivalent sound level (Leq) is often used to describe sound levels that vary over time, usually a one-hour period. The Leq is considered an energy-based average noise level, and it is often used to express average noise outdoor noise levels.

The logarithmic nature of dB scales is such that individual dB levels for different noise sources cannot be added directly to give the noise level for the combined noise source. For example, two noise sources that produce equal dB levels at a given location will produce a combined noise level that is 3 dBA greater than either sound alone. When two noise sources differ by 10 dBA, the combined noise level will be 0.4 dBA greater than the louder source alone.

People generally perceive a 10-dBA increase in a noise level as a doubling of loudness. For example, a 70-dBA sound will be perceived by an average person as twice as loud as a 60-dBA sound. People generally cannot detect differences of 1 dBA to 2 dBA. Differences of 3 dBA can be detected by most people with average hearing abilities. A 5-dBA change would likely be perceived by most people under normal listening conditions.

When distance is the only factor considered, sound levels from isolated point sources of noise typically decrease by about 6 dBA for every doubling of distance from the noise source. When the noise source is a continuous line (for example, vehicle traffic on a highway), noise levels decrease by about 3 dBA for every doubling of distance away from the source.

Noise levels at different distances can also be affected by factors other than the distance from the noise source. Topographic features and structural barriers that absorb, reflect, or scatter sound waves can increase or decrease noise levels. Atmospheric conditions (wind speed and direction, humidity levels, and temperatures) can also affect the degree to which sound is attenuated over distance.

Reflections off topographical features or buildings can sometimes result in higher noise levels (lower sound attenuation rates) than would normally be expected. Temperature inversions and wind conditions can also diffract and focus a sound wave to a location at considerable distance from the noise source. As a result of these factors, the existing noise environment can be highly variable depending on local conditions.

Human Response and Perception of Vibration Levels

Ground-borne vibration can be a concern for residents or at facilities that are vibration-sensitive, such as laboratories or recording studios. The effects of ground-borne vibration include perceptible movement of building floors, interference with vibration sensitive instruments, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds.

Vibration consists of rapidly fluctuating motions. However, human response to vibration is a function of the average motion over a longer (but still short) time period, such as one second. The root mean square (RMS) amplitude of a motion over a one second period is commonly used to predict human response to vibration. Building response is usually assessed in units of Peak Particle Velocity (PPV).

In contrast to airborne noise, ground-borne vibration is not a phenomenon that most people experience every day. The background vibration level in residential areas is usually well below the threshold of perception for humans, which is around 0.01 in/sec PPV. Levels at which vibration interferes with sensitive instrumentation such as nuclear magnetic resonance (NMR) equipment and other optical instrumentation can be much lower than the threshold of human perception.

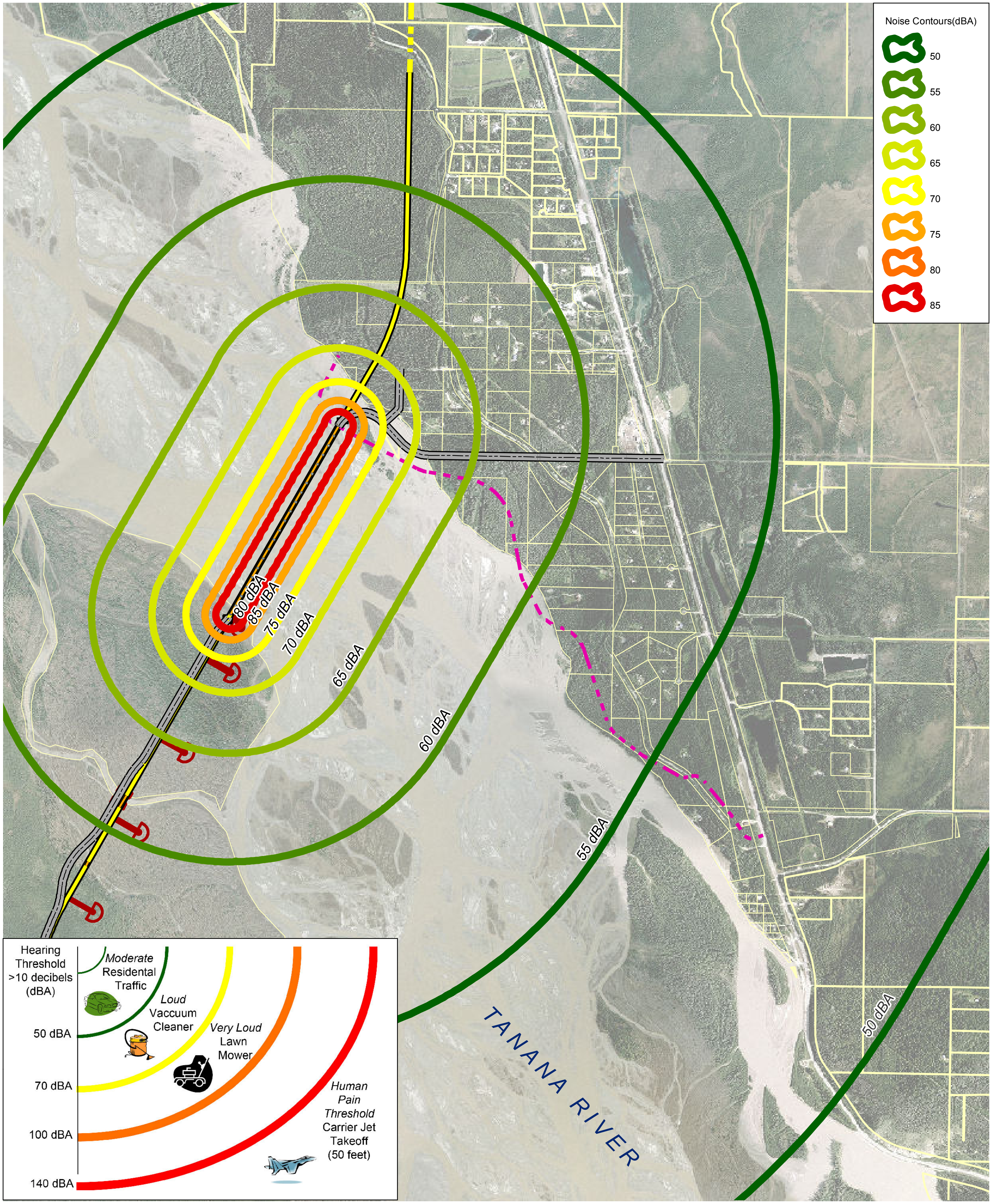
Most perceptible indoor vibration is caused by sources within a building such as the operation of mechanical equipment, movement of people, or slamming of doors. Typical outdoor sources of perceptible ground-borne vibration are construction equipment, steel-wheeled trains, and traffic on rough roads.

IMPACT HAMMER PILE DRIVING – NOISE PREDICTION

Onsite measurement performed on October 18th 2011 are representative of noise and vibration levels due to impact pile driving using a 24 inch pipe. Future construction activity onsite may include impact hammer pile-driving utilizing pipes of up to 72 inches in diameter. The difference in airborne sound level from impact pile driving using various diameter pipes is not well documented. Currently available references and noise prediction methods commonly use a singular reference noise for impact pile driving activities and do not account for variations in pipe size.

Using noise measurements of the 24 inch diameter pipe HDR predicted noise levels of impact pile driving using a 72 inch pipe. An adjustment factor of approximately 5 dB was applied to account for the increase in diameter. The diameter adjustment was calculated using the following equation: $10 * LOG10(\frac{diameter_{new}}{diameter_{reference}})$ where the reference diameter is 24 inches.

The figure below depicts noise contours of impact pile driving with a 72” pipe. The figure shows noise levels from pile driving activities in increments of 5 decibels moving away from the work area.



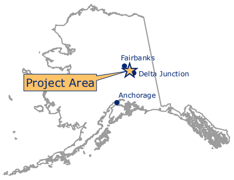
Legend

- Bridge
- Spur Dikes
- Access Road
- Levee
- Rail
- Future Rail
- Parcels

*Parcel boundaries shown are graphic representations only, not legal surveyed boundaries. The information displayed here is for planning and review purposes only.

0 500 1,000
Feet

N



Noise Contours

Map Projection: NAD 83 ASP 3 Feet
Data Sources: HDR, PDC Inc. FNSB
Author: HDR Alaska, Inc.
Date: 14 November 2011

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PHASE I