RSG INC.
ENVIRONMENT, ENERGY, & ACOUSTICS

Community Noise Assessment & Mitigation of the Kirtland Products Plant:

Boyne City, Michigan

July 2012

DATA ■ ANALYSIS ■ SOLUTIONS

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1.0 INTRODUCTION

The Kirtland Products plant was constructed at an existing facility in 2011 and commenced operation in in the fall. Since the start-up of the operation there have been numerous noise complaints in reference to the plant. The City of Boyne City with the cooperation of Kirtland Products retained RSG to assess the causes of the noise, provide mitigation recommendations and estimates of resulting sound levels in the community, and provide general cost estimates for equipment specific mitigation measures and for specialized mitigation measures such as noise barriers. This report includes:

1) A description of the area and plant operation
2) A noise primer
3) A discussion of the community design goal for mitigation
4) Sound level monitoring results
5) Sound propagation modeling results
6) Mitigation Recommendations
7) Summary and conclusions

2.0 PROJECT DESCRIPTION

2.1 Area Description

The Kirtland plant is located on the east side of Boyne City, Michigan at the end of Altair Drive in a zoned industrial area (Figure 1). It is bordered to the north by the Boyne City Municipal Airport, and to south, east, and west by other industrial and commercial uses. The nearest residence is the manse at the church on Beardsley Street which is approximately 440 feet southwest the site and 715 feet from the plant building. The closest zoned residential area is approximately 690 feet south of the site at the corner of M-75 and Boyne Summit Street. Other nearby residentially zoned areas include the:

- Nordic Drive area between 1,320 and 2,000 feet from the site
- Kunert Street-Boice Street-Harris Street area between 1,260 and 2,820 feet from the site
- State Street Area between 2,880 and 3,920 feet from the site

The primary roadway near the plant is M-75 (East Division Street) which is approximately 650 feet south of the site. This area of East Division Street is lined with commercial and industrial sites.

There is also a school between 1,280 and 2,540 feet west of the site and a cemetery between 2,090 and 3,470 feet west of the site.

Figure 1: Map of Kirtland Products Plant and Surrounding Area

2.2 Operation Description

Kirtland Products is a wood pellet manufacturer that, when production is underway, operates 24 hours per day. Their on-site process starts with wood chips were chipped in the field by their suppliers and brought in on trucks. The truck trailers are dumped via a hydraulic truck dumper on the south side of the site. After the chips are delivered, they go through several systems to eventually turn them into the end product, wood pellets. The process is generally described below with the material being moved around the site via conveyor belts, bucket elevators, screw conveyors, and air flows:

1. The wood chips are conveyed to and run through a disc scalping screen to remove large pieces of wood material that are mixed in with the wood chip delivery. (outside)
2. The chips are separated into hardwood and softwood storage piles via two screw conveyors. (outside)
3. A bucket loader moves the chips from the storage piles into the metering bins. (outside)
4. The chips are mixed from the metering bins onto a conveyor that feeds into the plant. (outside)
5. The chips are processed through the green[1] hammermill that further grinds them up. (inside)
6. The ground material is then blown through a cyclone that separates the material from air. (outside)
7. The air eventually goes to the main stack (outside) and the green material then goes to the rotary drum dryer via an enclosed screw conveyor. (inside)
8. The dry material leaves the dryer and blown through another cyclone that separates the material from air. (outside)
9. The air eventually goes to the main stack (outside) and the dry material then goes to the dry hammermill that further grinds the material. (inside)
10. The dry material from the dry hammermill is blown through a baghouse which collects the dry material and discharges the filtered air out of a stack located next to the baghouse. (outside)
11. The ground material from the baghouse is separated with some of it going through the fuel hammermill (inside) for the fuel system (inside) that operates the dryer and the other ground material is blown to to a cyclone.
12. The air from the cyclone goes into the primary baghouse (outside) that collects the particulate and discharges the filtered air out of an exhaust stack located next to the baghouse (outside), while the ground material is blown into a surge bin. (inside)
13. From the surge bin, the ground material is blown into pellet mills where the pellets are produced. (inside)
14. The hot pellets are then blown through cyclones (indoors) with the air being discharge through an outdoor stack and the hot pellets, then go into the pellet cooler (indoors).
15. Air is drawn off the pellet cooler through a cyclone and discharged through a stack located next to the cyclone. (outside)
16. The cooled pellets are then moved on to a shaker screen (inside) and eventually discharged through a pipe to a storage silo (outside) where they are stored until they are moved back indoors to go through the packaging process.

From a visual inspection of the site, photographs, and video, the plant appears to be well designed utilizing standard methodologies for this type of system and smooth transitions in the air piping and ductwork. The loudest pieces of equipment, the hammermills, are located indoors, but most of the centrifugal fans and air power units that create a notable amount of noise are located outdoors.

Pictures of the plant are provided in Appendix A.

[1] Chips have not been dried and still contain their natural amount of moisture.

3.0 A Noise Primer

3.1 What is Noise?

Noise is defined as “a sound of any kind, especially when loud, confused, indistinct, or disagreeable.”[1] Passing vehicles, a noisy refrigerator, or an air conditioning system are sources of noise which may be bothersome or cause annoyance. These sounds are a part of generally accepted everyday life, and can be measured, modeled, and, if necessary, controlled.

3.2 How is Sound Described?

Sound is caused by variations in air pressure at a range of frequencies. Sound levels that are detectable by human hearing are defined in the decibel (dB) scale, with 0 dB being the threshold of human hearing, and 135 dB causing pain and permanent damage to the ear. Figure 2 shows the sound levels of typical activities that generate noise.

The decibel scale can be weighted to mimic the human perception of certain frequencies. The most common of these weighting scales is the “A” weighting, and this scale is used most frequently in environmental noise analysis. Sound levels that are weighted by the “A” scale have units of dBA or dB(A).

To account for changes over time, a weighted average sound level called the “equivalent” sound level (L_{eq}) is often used. L_{eq} averages sound pressure rather than decibels, and results in weighting loud and infrequent noises more heavily than quieter and more frequent noises. For example, a train passing by for one minute out of an hour could produce sound levels around 90 dBA while passing by, but the equivalent sound level for the entire hour would be 72 dBA. L_{eq} is also often used in environmental noise analysis.

3.3 What is the Difference between Sound Pressure Levels and Sound Power Levels?

Both sound power and sound pressure levels are described in terms of decibels, but they are not the same thing. Sound power is a measure of the acoustic power emitted or radiated by a source. The sound power level of a source does not change with its surrounding conditions.

Sound pressure level is observed at a specific location and is related to the difference in air pressure above or below atmospheric pressure. This fluctuation in air pressure is a result of the sound power of a source, the distance at which the sound pressure level is being observed, and the characteristics of the path and environment around the source and receiver. When one refers to sound level, they are generally speaking of the sound pressure level.

For example, a coffee grinder will have the same sound power whether or not it is grinding indoors or outdoors. The amount of sound the coffee grinder generates is always the same. However, if you are standing six feet away from the coffee grinder indoors, you would experience a higher sound pressure level than you would if you were six feet away from the coffee grinder outdoors in an open field. The reason for this is that the sound being emitted from the coffee grinder would bounce off walls and other surfaces indoors which would cause sound to build up and raise the sound pressure level.

[1] “The American Heritage Dictionary of the English Language,” Houghton Mifflin Company, 1981.

Figure 2: Basic Theory: Common Sounds in Decibels

Sound power cannot be directly measured. However, since sound pressure and sound power are related, sound power can be calculated by measurements of sound pressure or sound intensity. It can be helpful to note that over soft ground outside, the sound pressure level of a small source observed 50 feet away is roughly 33 dB lower than its sound power level.

3.4 How is Sound Modeled?

The decibel sound level is on a logarithmic scale. One manifestation of this is that sound *power* increases by a factor of 10 for every 10 dB increase. However, for every 10 dB increase in sound pressure level, we *perceive* an approximate doubling of loudness. Small changes in sound pressure level, below 3 dB, are generally not perceptible.

For a point source, sound level diminishes or attenuates by 6 dB for every doubling of distance due to geometrical divergence. For example, if an idling truck is measured at 50 feet as 66 dBA, at 100 feet the level will decline to 60 dBA, and at 200 feet, 54 dBA, assuming no other influences. From a line source, like a gas pipeline or from closely spaced point sources, like a roadway or string of wind turbines, sound attenuates at approximately 3 dB per doubling distance. These "line sources" transition to an attenuation of 6 dB per doubling at a distance of roughly a third of the length of the line source.

Other factors, such as intervening vegetation, terrain, walls, berms, buildings, and atmospheric absorption will also further reduce the sound level reaching the listener. In each of these, higher frequencies will attenuate faster than lower frequencies. Finally, the ground can also have an impact on sound levels. Harder ground generally increases and softer ground generally decreases the sound level at a receiver. Reflections off of buildings and walls can increase broadband sound levels by as much as 3 dB.

If we add two equal sources together, the resulting sound level will be 3 dB higher. For example, if one machine registers 76 dBA at 50 feet, two co-located machines would register 3 dB more, or 79 dBA at that distance. In a similar manner, at a distance of 50 feet, four machines, all operating at the same place and time, would register 82 dBA and eight machines would register 85 dBA. If the two sources differ in sound level then 0 to 3 dB will be added to the higher level as shown in Table 1.

Table 1: Decibel Addition

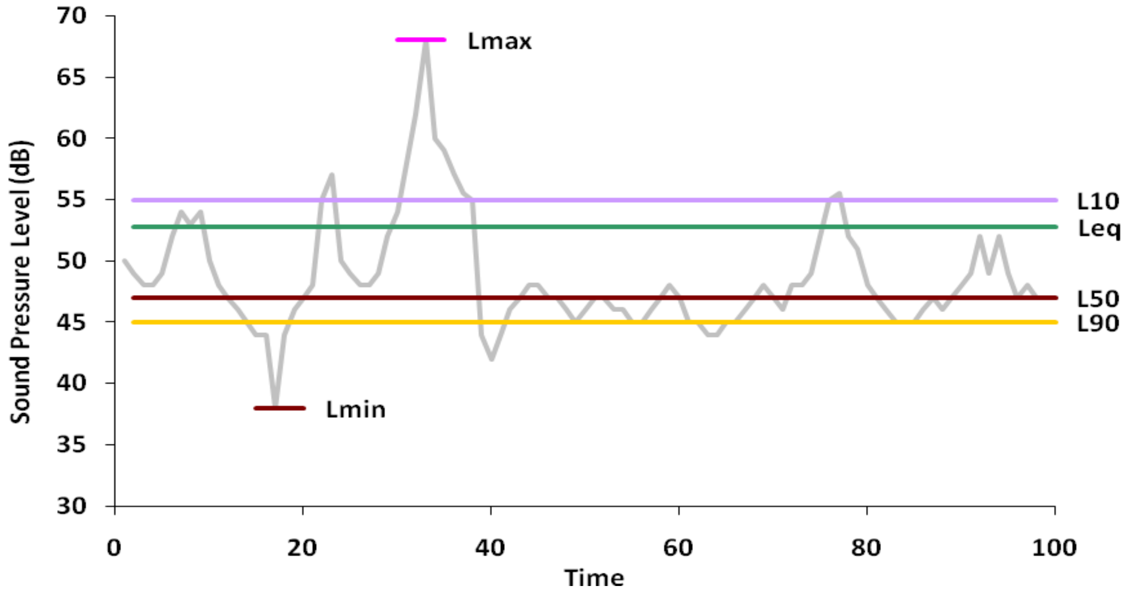
If Two Sources Differ By	Add
0-1 dB	3 dB
2-4 dB	2 dB
5-9 dB	1 dB
>9 dB	0 dB

3.5 Description of Terms

Sound can be measured in many different ways. Perhaps the simplest way is to take an instantaneous measurement, which gives the sound pressure level at an exact moment in time. The level reading could be 62 dB, but a second later it could 57 dB. Sound pressure levels are constantly changing. It is for this reason that it makes sense to describe noise and sound in terms of time.

The most common ways of describing noise over time is in terms of various statistics. Take, as an example, the sound levels measured over time shown in Figure 3. Instantaneous measurements are shown as a ragged grey line. The sound levels that occur over this time can be described verbally, but it is much easier to describe the recorded levels statistically. This is done using a variety of "levels" which are described below.

Figure 3: Example of Noise Measurement over Time and Descriptive Statistics



3.5.1 Equivalent Average Sound Level - Leq

One of the most common ways of describing noise levels is in terms of the continuous equivalent sound level (Leq). The Leq is the average of the sound pressure over an entire monitoring period and expressed as a decibel. The monitoring period could be for any amount of time. It could be one second ($Leq_{1\text{-sec}}$), one hour ($Leq_{(1)}$), or 24 hours ($Leq_{(24)}$). Because Leq describes the average pressure, loud and infrequent noises have a greater effect on the resulting level than quieter and more frequent noises. For example, in Figure 3, the median sound level is about 47 dBA, but the equivalent average sound level (Leq) is 53 dBA. Because it tends to weight the higher sound levels and is representative of sound that takes place over time, the Leq is the most commonly used descriptor in noise standards and regulations.

Other forms and averaging periods of the equivalent average sound level (Leq) are used in some federal and world guidelines. For example, a day-night equivalent level (Ldn) is the equivalent average sound level over a 24 hour period with a 10 dBA penalty applied to the nighttime levels (10 PM to 7 AM). An annual daytime average (Lday) is the equivalent average sound level during the day over the course of a year, and an annual nighttime average (Lnight) is the equivalent average sound level during the night over a course of a year.

3.5.2 Percentile Sound Level - Ln

Ln is the sound level exceeded *n* percent of the time. This type of statistical sound level, also shown in Figure 3, gives us information about the distribution of sound levels over time. For example, the L10 is the sound level that is exceeded 10 percent of the time, while the L90 is the sound level exceeded 90% of the time. The L50 is exceeded half the time. The L90 is a residual base level which most of the sound exceeds, while the L10 is representative of the peaks and higher, but less frequent levels. When one is trying to measure a continuous sound, like a wind turbine, the L90 is often used to filter out other short-term environmental sounds that increase the level, such as dogs barking, vehicle passbys, wind gusts, and talking. That residual sound, or L90, is then the sound that is occurring in the absence of these noises.

3.5.3 Lmin and Lmax

Lmin and Lmax are simply the minimum and maximum sound level, respectively, monitored over a period of time. These are shown in Figure 3.

4.0 NOISE STANDARDS, GUIDELINES, AND GOALS

4.1 Local Standards & State Standards

There are no local ordinances or state statutes or regulations that establish quantitative noise standards which are applicable to this project.

4.2 Federal Standards and Guidelines

There are no federal noise standards that apply to wood pellet plants on private land. Many federal agencies have adopted guidelines and standards that apply to other types of facilities. A summary of some of these standards is shown in Table 2. Note that these standards are in terms of Leq, Ldn, or L10. The Leq is the pressure weighted average sound level, over a specified period of time. The Ldn is the A-weighted day-night Leq, where a penalty of 10 dB is applied to nighttime sound. The L10 is the 10^{th} percentile sound level. It is the level that is exceeded 10% of the time, and thus represents the higher sound levels over a period of time.

4.3 World Health Organization

The United Nation's World Health Organization (WHO) has published "Guidelines for Community Noise" (1999) which uses the most current research on the health impacts of noise to develop guideline sound levels for communities. The forward of the report states, "The scope of WHO's effort to derive guidelines for community noise is to consolidate actual scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professionals trying to protect people from the harmful effects of noise in non-industrial environments."

The WHO guidelines suggest a daytime and nighttime protective noise level. During the day, the levels are 55 dBA $Leq_{(16)}$, that is, an average over a 16-hour day, to protect against serious annoyance and 50 dBA $Leq_{(16)}$ to protect against moderate annoyance.

During the night, the WHO recommends limits of 45 dBA $Leq_{(8)}$ and an instantaneous maximum of 60 dBA LAfmax (fast response maximum). These are to be measured outside the bedroom window. The guidelines are based on the assumption that indoor sound levels would be 15 dBA less than outdoor sound levels with windows open. That is, sound level inside the bedroom that is protective of sleep is 30 dBA $Leq_{(8)}$. Given the climate in this region, this is essentially a summertime standard, since residents are less likely to have their windows open during other times of the year. By closing windows, an additional ~15 dB of sound attenuation will result.

Table 4.1 of the WHO's "Guidelines for Community Noise" (1999) provides guideline values for community noise in specific environments. This table is provided in Appendix B.

In October, 2009, WHO Europe conducted an updated literature review and developed guidelines for nighttime noise in Europe. They expanded on the 1999 WHO guidelines by adding an *annual average* nighttime guideline level to protect against adverse effects on sleep disturbance. This guideline is 40 dBA Lnight, outside.

Table 2: Summary of Federal Guidelines and Standards for Exterior Noise

Agency	**Applies to**	**Standard (dBA)**
Environmental Protection Agency	Guideline to protect public health and welfare with an adequate margin of safety	55 dB Ldn
Federal Energy Regulatory Commission (FERC)	Compressor facilities under FERC jurisdiction	55 dB Ldn
Federal Highway Administration (FHWA)	Federally funded highway projects. For "Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose."	57 dBA Leq or 60 dBA L10 during the peak hour of traffic. Either standard can be used, but not both.
	For "residential" and "active sports areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings"	67 dBA Leq or 70 dBA L10
	For "Hotels, motels, offices, restaurants/bars"	72 dBA Leq or 75 dBA L10
Federal Interagency Task Force	This Taskforce is set up to develop consistency of noise standards among federal agencies	55 to 65 dB Ldn for impacts on residential areas

4.4 Noise Threshold Goals for Boyne City & Kirtland Products

It is the desire of the City of Boyne City, as expressed in the Request for Proposal for this study, to reduce the noise from the Kirtland Plant to "levels that can be reasonably expected as to not be disturbing to homes in surrounding residentially zoned areas which are approximately 1,000 to 2,000 feet away."

RSG's interpretation of this desire has been to utilize a noise threshold goal that is based on researched and documented knowledge on community annoyance due to noise. Noise annoyance is dependent on a number of factors some of which include:

- The level, spectral content, and other characteristics of the sound such as impulsivity and repetitiveness
- The frequency of the occurrences of intermittent sound events
- The time of day at which the sound events occur
- A communities tolerance towards noise in general
- The type of source producing the noise (road traffic, airplanes, construction equipment, etc.)

There are also a number of non-acoustical variables that contribute to noise annoyance. These variables are usually referred to as attitudinal variables[1] and include:

- Fear of the source
- Belief that the noise could be prevented
- Individual noise sensitivities
- Awareness of non-noise problems related to the source of the noise
- Perceived importance of the function of the noise source

One study has found that noise sensitivity is independent of noise level in terms of determining some people's annoyance to noise at least in reference to noise from airports[2]. This may imply that at all levels of noise, noise sensitive people are more likely to be annoyed than the general population and that even if noise is reduced to very low levels, there may still be highly sensitive people who are annoyed.

In establishing a noise threshold goal, RSG requested feedback from Boyne City to assess the community's tolerance towards noise in general. The results of this feedback were a request to utilize a noise threshold level that would be appropriate for a conservative tolerance towards noise. Based on this feedback, a noise threshold goal of 40 dBA Leq_{night} was chosen. This goal level is applied outside homes within zoned residential areas. This goal is based on research that indicates that a DENL[3] of 50 dBA will result in approximately 25% of the exposed population being lightly annoyed[4]. The noise threshold goal is also supported by 2009 WHO Europe nighttime guideline, and is more conservative than the 1999 World Health Organization guidelines.

In addition to the noise threshold goal of 40 dBA Leq_{night}, another acoustical factor should be accounted for which is the tonal pulsation or beat effect that is heard in neighboring areas around the plant. Pulsation is known to increase annoyance, so as is done in ANSI S12.9 Part 4 (2005), a 5 dB penalty should apply where and when the tonal pulsation is present. This would result in a penalized noise threshold goal of 35 dBA $Leq_{night,}$ if the pulsation or beat effect is present.

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[1] Fields, James M., "Effect of personal and situational variables on noise annoyance in residential areas", JASA 93:5 (1993)

[2] van Kamp, Irene, et al., "The role of noise sensitivity in the noise-response relation: A comparison of three international airport studies", JASA 116:6 (2004)

[3] DENL is an equivalent (Leq) day-evening-night level that applies a 5 dB penalty to a four hour evening and a 10 dB penalty to an eight hour night.

[4] Miedema, Henk M. E. & Vos, Henk, "Noise annoyance from stationary sources: Relationships with exposure metric day-evening-night level (DENL) and their confidence intervals", JASA 116:1 (2004)

5.0 SITE VISIT – SOUND LEVEL MONITORING

5.1 Site Visit Procedure & Equipment

RSG conducted a site visit to the Kirtland Plant and Boyne City communities from May 22 to May 25, 2012. The purpose of the site visit was to gather equipment-specific noise emission data from the plant for use in sound propagation modeling and to gather both operational and background sound levels throughout the community. During the site visit, the plant was in operation from May 22 to the morning of May 24 around 6 AM. Approximately 24 hours of background sound level data without the plant operating was gathered starting on the morning of May 24.

A total of four sound level monitors were used for the site visit. Three of them were installed as long-term monitors on May 22 and were picked up on May 25. The remaining monitor was utilized as a mobile monitor to gather noise emission data at the plant and to conduct short-term nighttime measurements throughout the community. Each monitor was an ANSI Type I Cesva SC310 integrating/logging sound level meter. The mobile monitor was field calibrated throughout the week, and the long-term monitors were field calibrated before and after the monitoring period. The long-term monitors also contained digital audio recorders to record audio for the entire monitoring period. All microphones were fitted with windscreens and were located approximately 4 to 5 feet above the ground. The ground in all three long-term monitoring locations was considered "soft", that is, it was suitable for the growth of vegetation.

5.2 Monitoring Areas

The location of the three long-term monitors and eight short-term community monitors were chosen in consultation with the City to account for the location of some of the complainants. The three long-term monitors were located:

- southwest of the plant at a tree line approximately 190 feet from the plant
- north of the plant on the north side of the airport property approximately 1,100 feet from the plant
- south of the plant outside a residence on the southwest corner of the Nordic Drive residential area approximately 2,075 feet from the plant

The eight short-term community monitors were located:

- in the Boice Street right-of-way at the west end of the airport runway approximately 2,030 feet west-northwest of the plant
- at the Kuhn Residence at the end of Kuhn Drive approximately 4,600 feet west-southwest of the plant
- in the church parking lot on Beardsley Street approximately 765 feet southwest of the plant
- next to the dance school at the north end of Beardsley Street approximately 695 feet west of the plant
- at the corner of Boyne Summit Street and East Division Street (M-75) approximately 910 feet south of the plant
- on the south side of the storage units on State Street (M-75) approximately 3,000 feet north of the plant

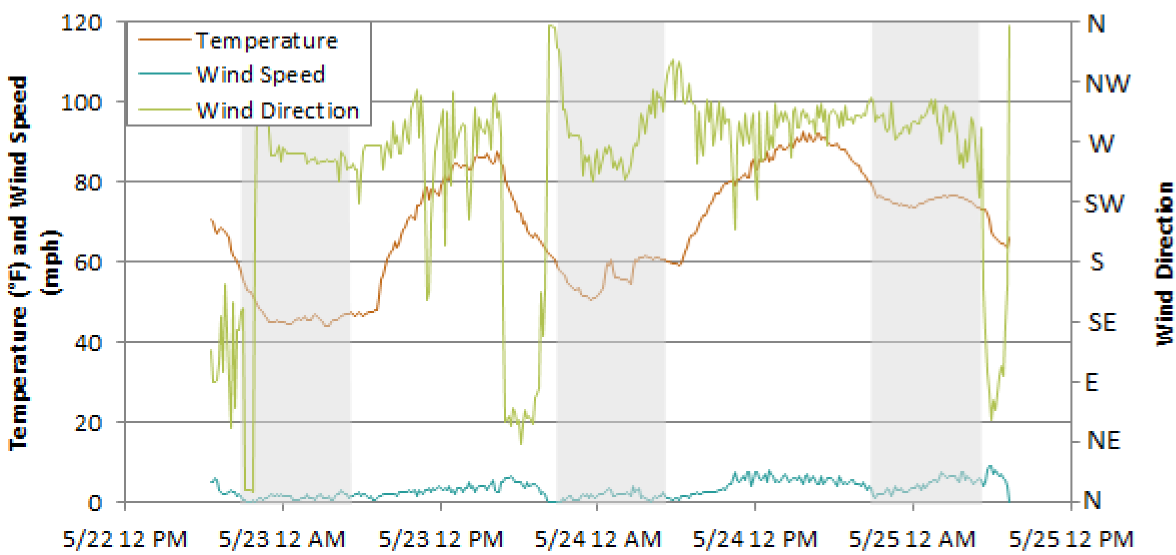
- at the corner of Call Street and Vogel Street approximately 4,620 feet north-northwest of the plant
- at the corner of Old M-75 Loop Road and M-75 approximately 5,760 feet northeast of the plant

Maps showing the locations of all the long-term and short-term monitoring locations are provided in the monitoring results to follow.

5.3 Weather

Weather data was collected by a 1.2 meter tall anemometer on the border between the plant and the airport. Weather for the monitoring period was clear to partly cloudy with temperatures ranging from 44 to 92 °F. Wind speeds ranged from calm to 9 mph. Wind direction was mostly southwest to northwest, with occasional periods out of the east to northeast. There was no precipitation during the monitoring period. A summary of the weather during the monitoring period is provided in Figure 4.

Figure 4: Monitoring Period Weather Summary



5.4 Long-term Monitoring Results

The long-term monitoring results have been summarized into equivalent (Leq) and 90th-percentile (L90) sound pressure levels utilizing the Ai-weighting scale. This scale[1] was designed to filter out high frequency insect noise that can produce higher sound levels primarily on spring and summer nights. Since the plant produces little sound at these frequencies, it is a more accurate representation of sound levels from the plant operation and background sound levels in the absence of insects which are not present year round.

[1] Schomer, Paul D., et al., "Proposed 'Ai'-weighting: A weighting to remove insect noise from A-weighted field measurements" InterNoise Proceedings, 221, pp. 3991-4000 (2010)

5.4.1 Kirtland Plant Monitor

A picture of the Kirtland Plant monitor is provided in Figure 5.

Figure 5: Photograph of the Long-term Monitor at the Kirtland Plant

Ai-weighted sound levels (L90) at the long-term monitor at the Kirtland Plant were typically between 72 and 74 dB while the plant was operation and ranged typically between 45 and 50 dB while the plant was shut down. The primary source of noise when the plant is in operation is the plant, and the primary source of background sound when the plant is not operating is traffic on local roads and weather related events (i.e. wind in the foliage). A summary of the data is provided in Figures 6 and 7. Figure 6 provides the overall results, while Figure 7 provides the sound level at the 125 Hz 1/3 octave band. The time of the plant shut down is clear in both of these figures with the 25 dB drop in sound level the morning of May 24.

Particularly noteworthy in these results are the levels shown in Figure 7. The 125 Hz sound levels are between 75 and 79 dB and drop to around 45 dB when the plant shuts down. This is just one indication of how much low frequency noise is produced by the operation. Review of the audio files at this site reveal strong tones at narrow bands centered at 138 Hz and 275 Hz which also pulsate with time. The tonality and pulsation are both known to cause increase annoyance with noise.

Figure 6: Long-term Overall Monitoring Results for the Kirtland Plant Monitor

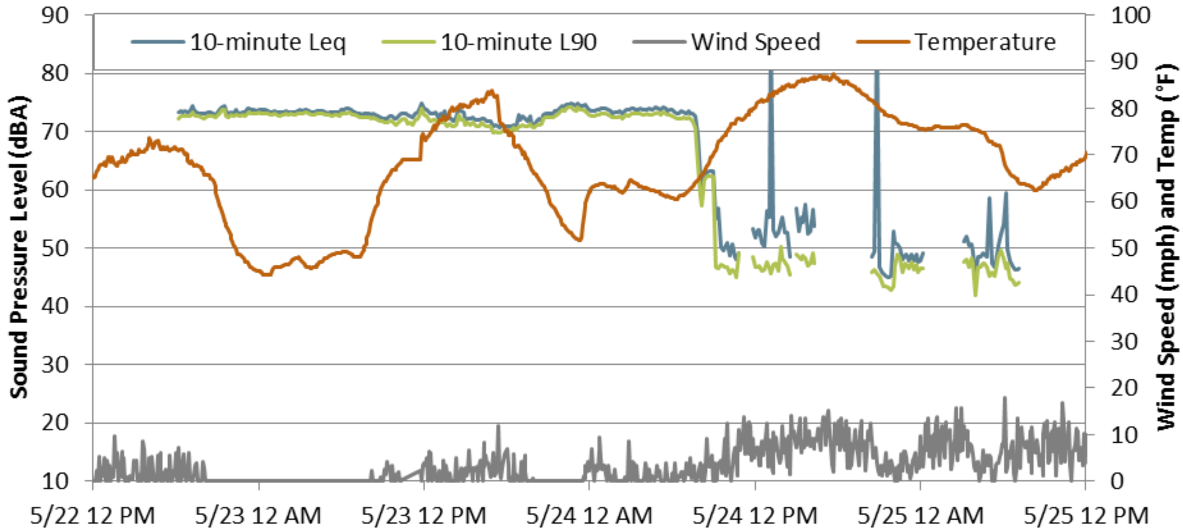
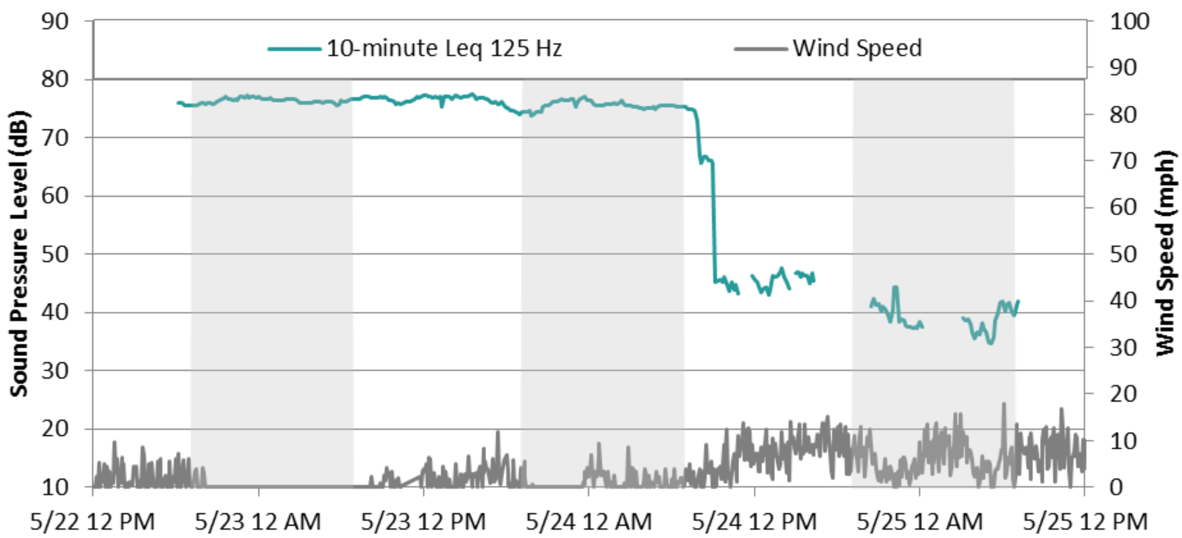


Figure 7: Long-term Monitoring Results for the 125 Hz 1/3 Octave Band for the Kirtland Plant Monitor



5.4.2 Airport Monitor

A picture of the airport monitor is provided in Figure 8.

Figure 8: Photograph of the Long-term Monitor at the Airport, with the Kirkland Plant in the Background

Ai weighted sound levels (L90) at the airport monitor were typically between 49 and 52 dB while the plant was operating and ranged typically between 40 and 48 dB while the plant was shut down. The primary source of noise when the plant is in operation is the plant, and the primary source of background sound when the plant is not operating is traffic on local roads and weather related events (i.e. wind in the foliage). A summary of the data is provided in Figures 9 and 10. Figure 9 provides the overall results, while Figure 10 provides the sound level at the 125 Hz 1/3 octave band. The time of the plant shut down, around 8:00 AM on May 24, is clear in both of these figures with the 4 dBA drop in the overall sound level and a 16 dB drop in the 125 Hz 1/3 octave band.

Review of the audio files at this site reveals the same tones and pulsation that were present at the plant monitor.

Figure 9: Long-term Overall Monitoring Results for the Airport Monitor

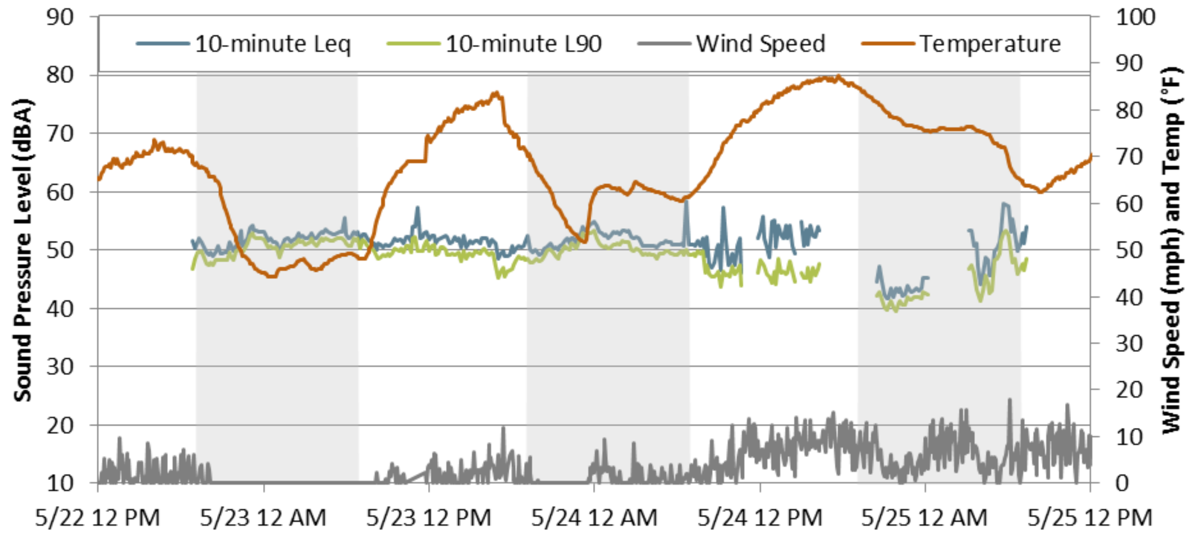
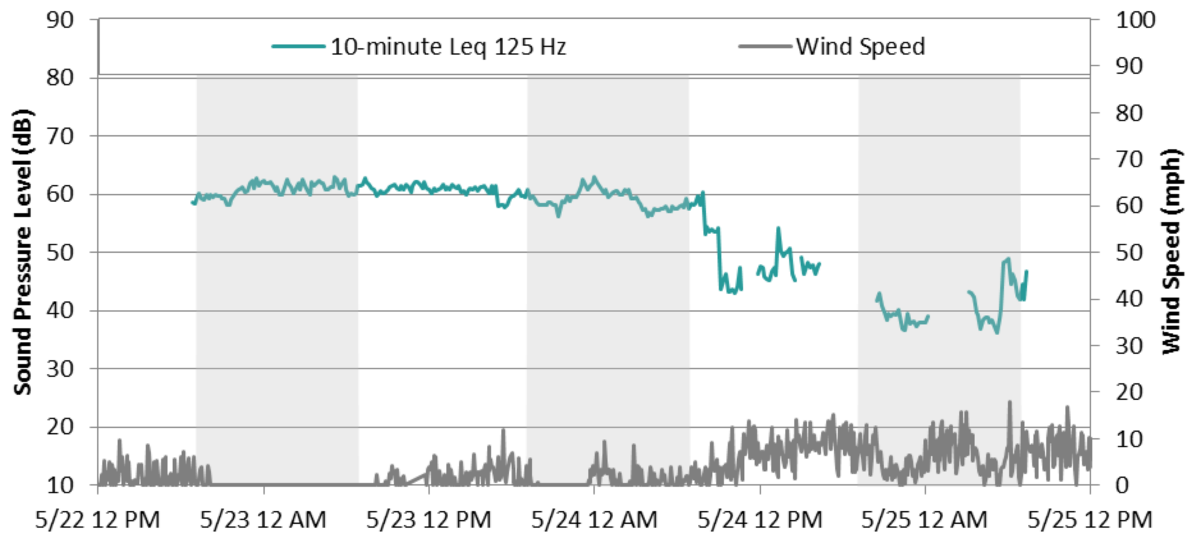


Figure 10: Long-term Monitoring Results for the 125 Hz 1/3 Octave Band for the Airport Monitor



5.4.1 Nordic Drive Residential Monitor

A picture of the Nordic Drive monitor is provided in Figure 11.

Figure 11: Photograph of the Long-term Monitor at the Nordic Drive Residential Monitor

Ai-weighted sound levels (L90) at the Nordic Drive monitor were typically between 39 and 50 dB while the plant was operating and ranged typically between 38 and 50 dB while the plant was shut down. The primary source of noise when the plant was in operation was traffic on local road, neighborhood related sounds such as lawn mowing, and weather related events. The plant was audible when it was operating, but was not the primary contributing factor to daytime levels. It was a larger contributor to the nighttime levels. The primary source of background sounds when the plant is not operating is traffic on local roads and weather related events (i.e. wind in the foliage). A summary of the data is provided in Figures 13 and 14. Figure 12 provides the overall results, while Figure 13 provides the sound level at the 125 Hz 1/3 octave band. The time of the plant shut down, around 8:00 AM on May 24, is clear in Figure 13 the 10 dB drop in the 125 Hz 1/3 octave band.

Review of the audio files at this site reveals the same tones and occasional pulsation that were present at the plant monitor.

Figure 12: Long-term Overall Monitoring Results for the Nordic Drive Monitor

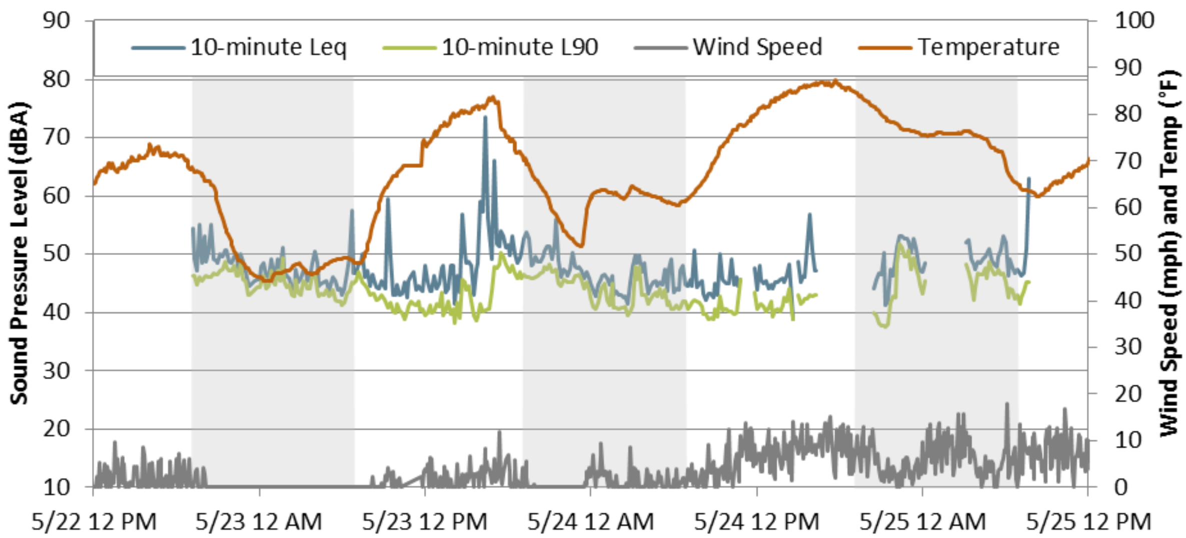
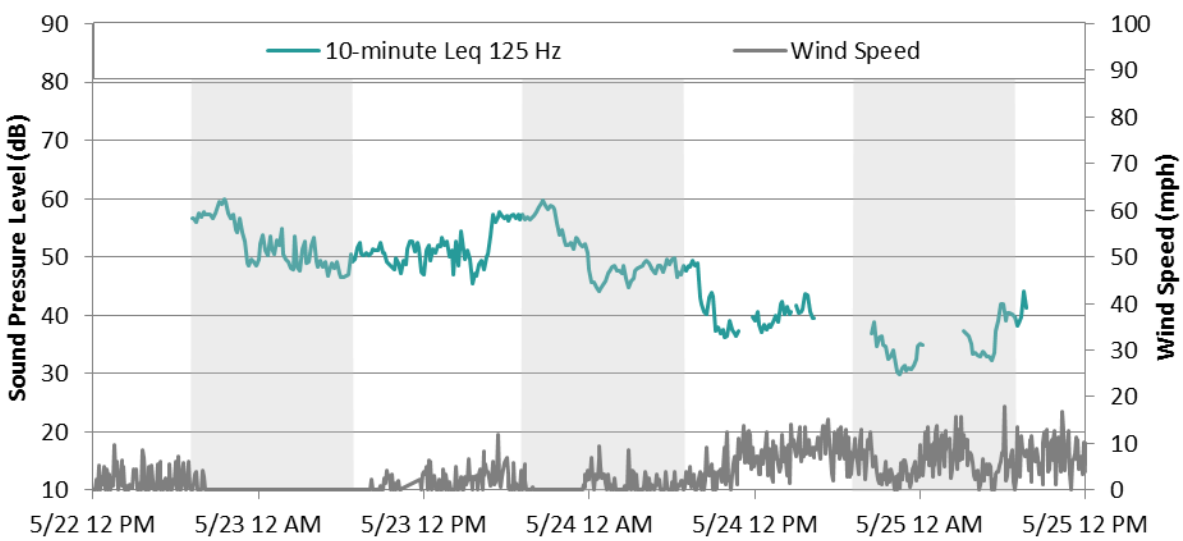


Figure 13: Long-term Monitoring Results for the 125 Hz 1/3 Octave Band for the Nordic Drive Monitor



5.4.2 Overall Long-term Monitoring Results

Figure 14 provides a map of the three long-term monitoring locations showing the L90 (Ai-weighted) sound level for the entire operational monitoring period and background monitoring period. As shown in the figure the overall sound levels increase by 3 dB at the airport, by 25 dB at the plant, and by 1 dB at the Nordic Drive Monitor when the plant is operating. It is important to note that this figure does not represent the greater differences in low frequency noise at each location between when the plant is and is not operating.

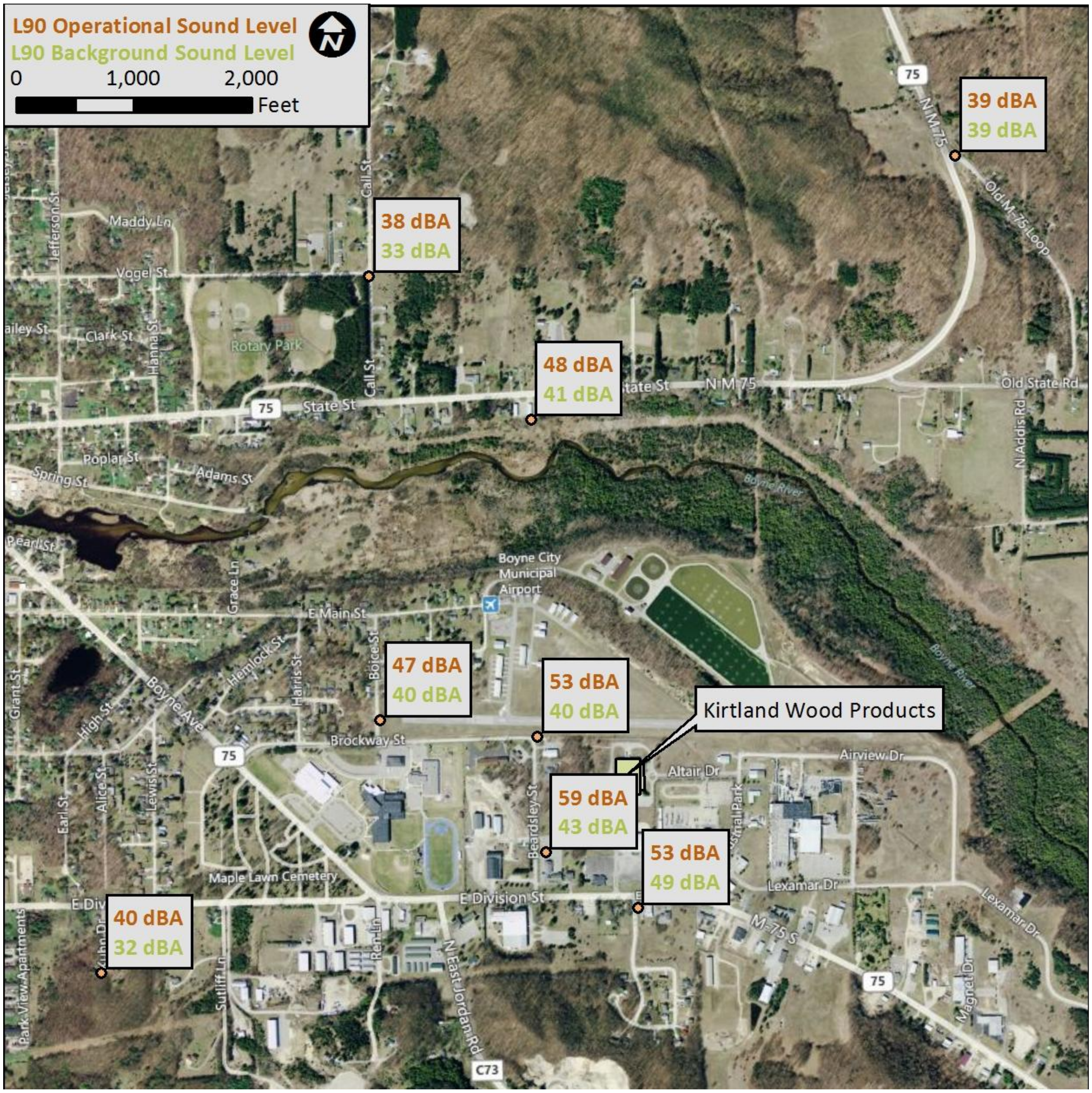
Figure 14: Summary Map of the Long-term Monitoring Results

5.5 Short-term Monitoring Results

Short-term monitoring was conducted for a period of five to fifteen minutes at each monitoring location at night between the hours of 10 PM and 12:30 PM on May 23 when the plant was operation and on May 24 when the plant was not operating.

An overall summary of the monitoring results is provided in the Figure 15 which shows the L90 (A-weighted) for each location with and without the plant operating. As seen in the figure, the sound levels monitored on May 23 are 5 to 13 dB higher than those monitored on May 24 except for the further monitoring location on Old M-75 Loop Road.

Figure 15: Summary Map of the Short-term Monitoring Results



To better understand the potential for the current noise annoyance within the community, the spectral content from each monitoring location is provided in Figures 16 through 24. As shown in these figures there is notably more low frequency sound present at most of the short-term monitoring locations when the plant is in operation versus when it is not operating. In addition, the tones at 138 Hz and 275 Hz present in the long-term audio files are represented in the 1/3 octave bands centered at 125 Hz and 250 Hz in the short-term monitoring results.

Figure 16: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at Boice Street

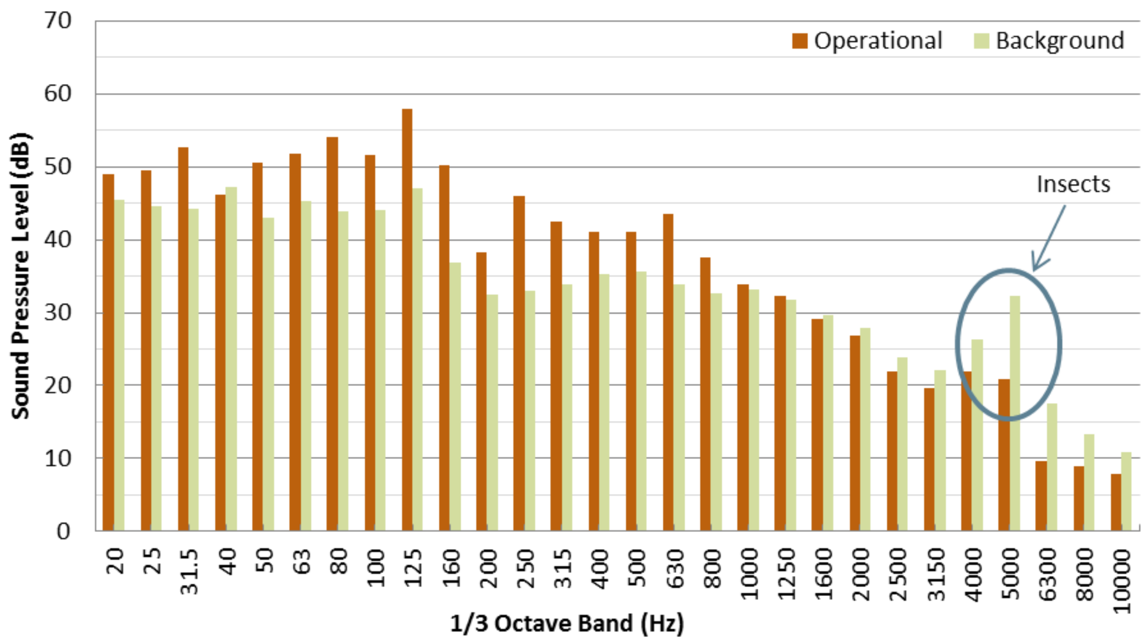


Figure 17: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at the Church on Beardsley Street

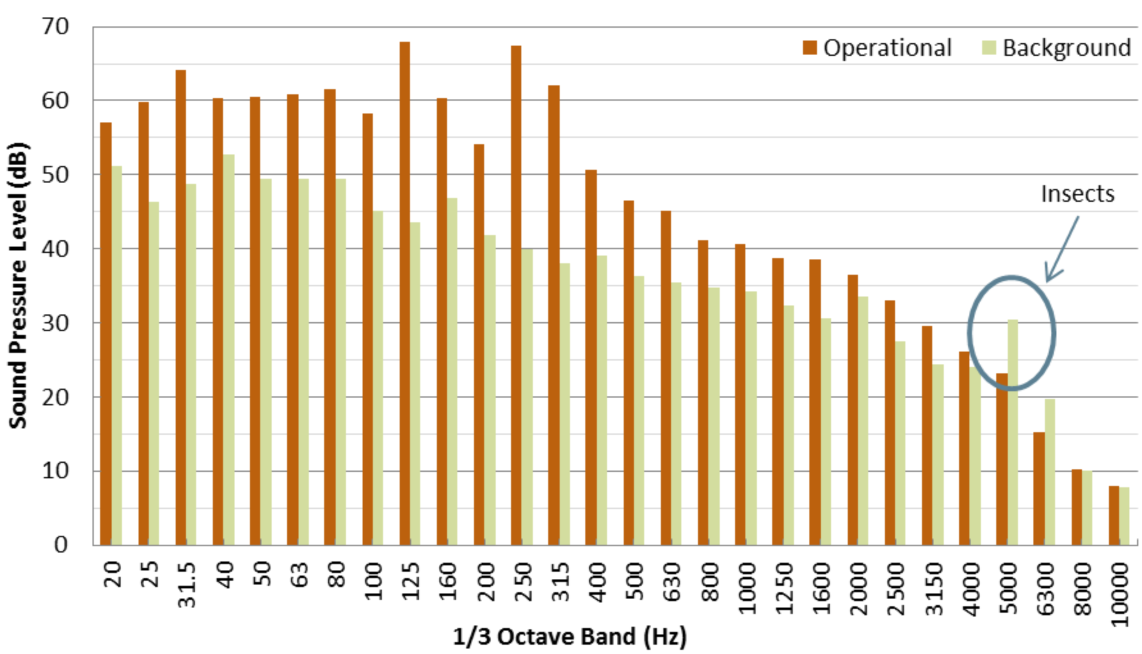


Figure 18: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at the North End of Beardsley Street

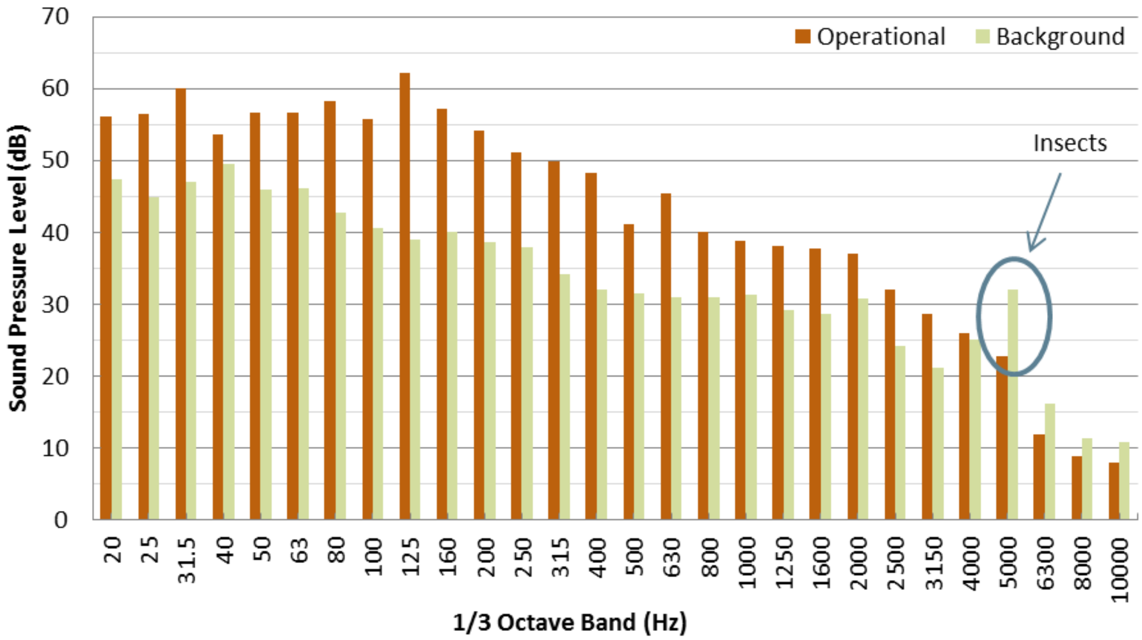


Figure 19: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at the Corner of Boyne Summit Road & East Division Street

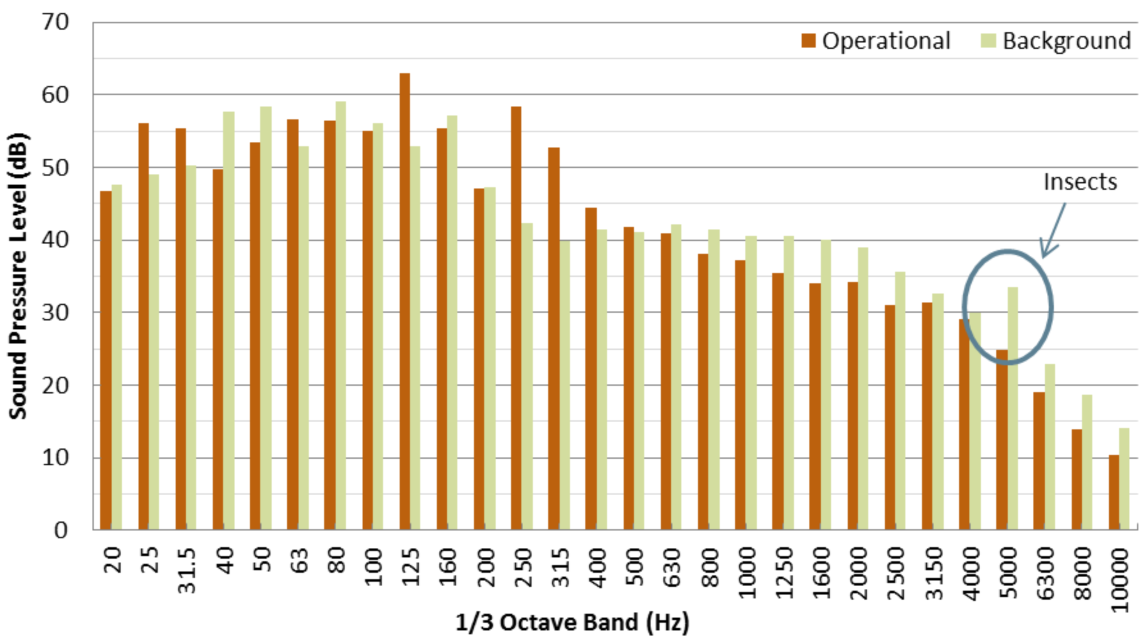


Figure 20: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at the Kuhn Residence at the Ene of Kuhn Drive

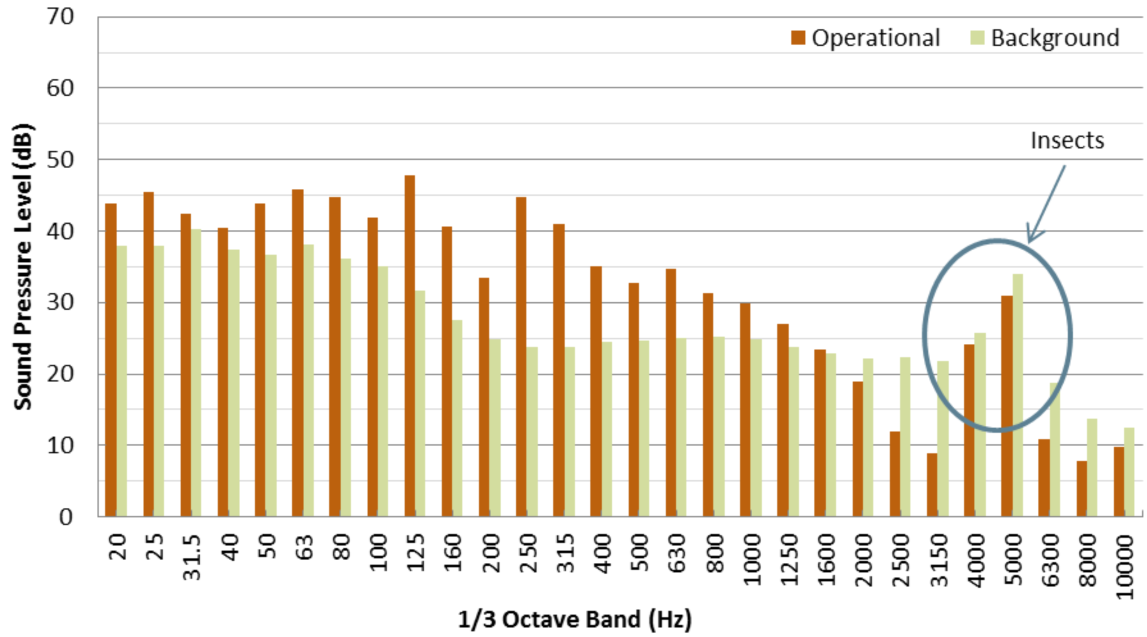


Figure 21: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at State Street Storage Units

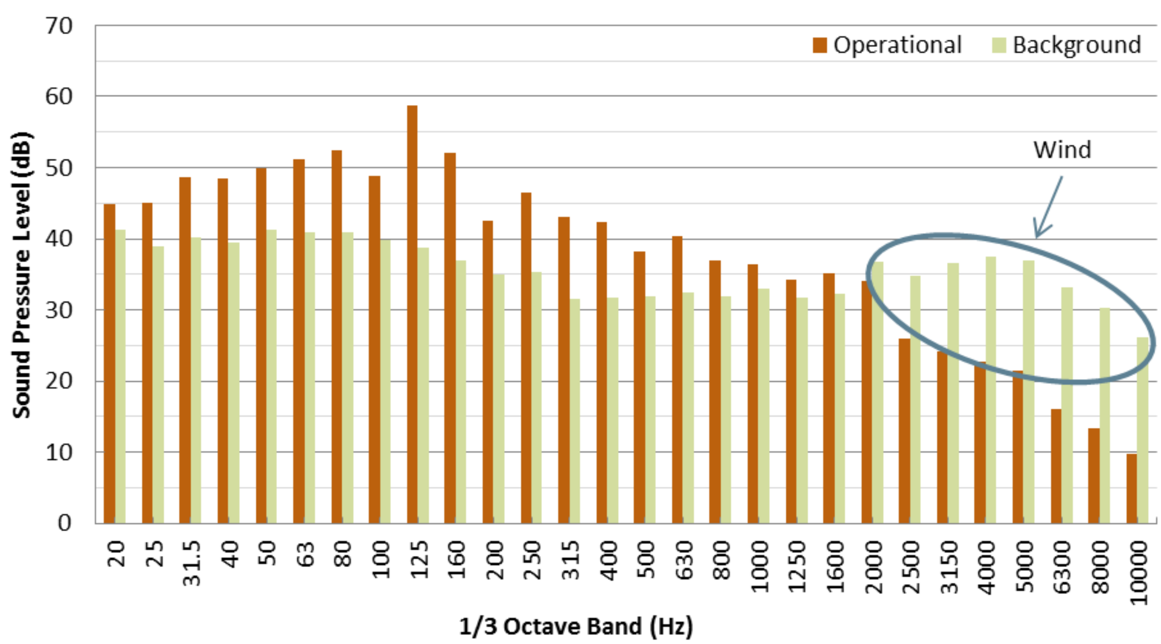


Figure 22: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at the Corner of Call Street & Vogel Street

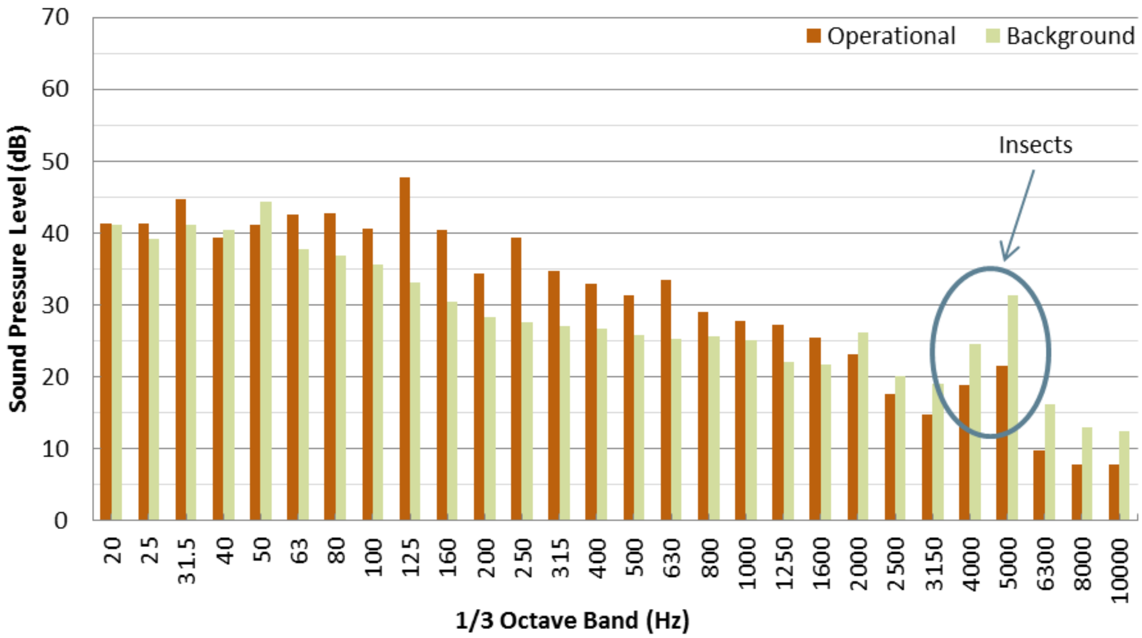
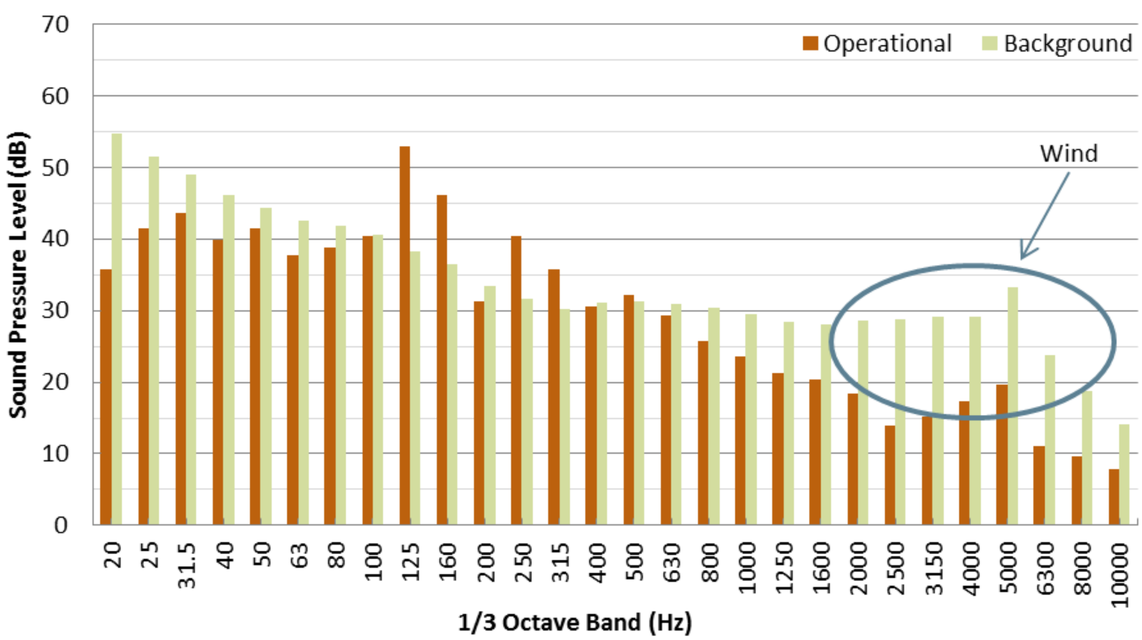
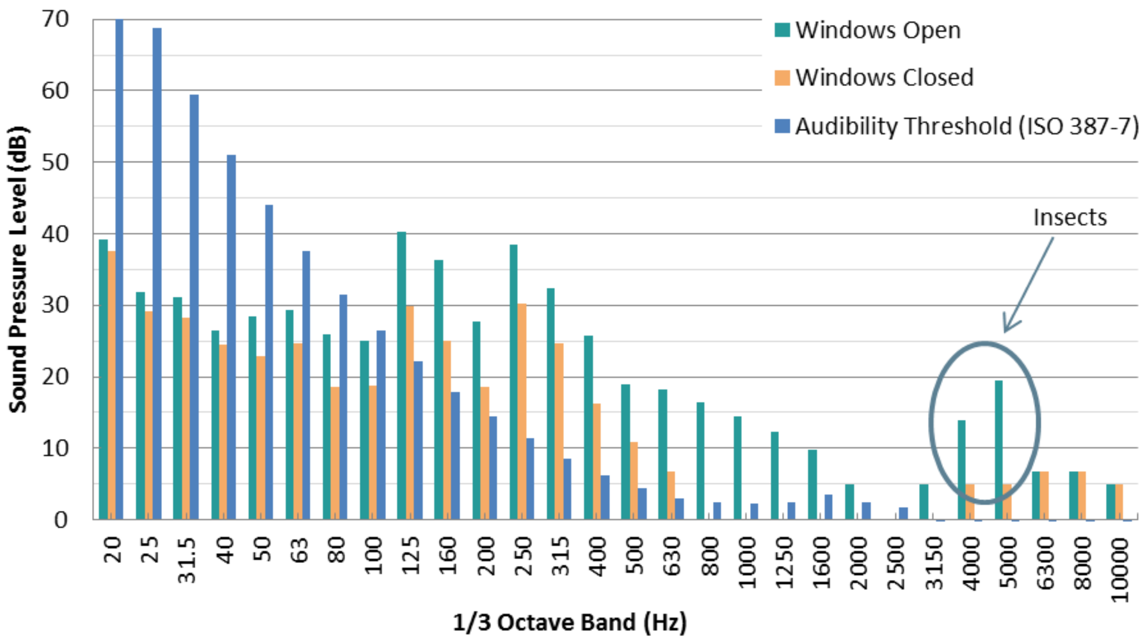


Figure 23: Operational & Background Sound Pressure Levels (L50, dB) for 1/3 Octave Bands at the Corner of Old M-75 Loop Road & M-75



We also had the opportunity to conduct sound level monitoring inside one house. At the Kuhn residence which, as previously mentioned, is located approximately 4,600 feet west-southwest of the Kirtland Plant at the end of Kuhn Drive, we conducted sound level monitoring in a second story bedroom while the plant was operating. Figure 24 provides the results of the bedroom monitoring with windows open and closed. The 138 Hz and 275 Hz tones while relatively quiet are clearly audible in the house even with the windows closed.

Figure 24: Operational Sound Pressure Levels (L50, dB) for 1/3 Octave Bands in a 2nd Story Bedroom with Windows Open & Closed



5.6 Noise Emissions of Equipment at the Kirtland Plant

As previously stated, the purpose of monitoring levels in and around the plant was to determine equipment specific noise emissions for use in sound propagation modeling. The sound propagation model, discussed in the next section, is used to determine the existing sound levels throughout the community, not just at the site visit monitoring locations. More importantly the model is used to determine which sources need to be mitigated to meet the noise threshold goal. The sound power levels by octave band of the primary exterior noise sources and the interior sound pressure levels are provided in Appendix C with the model input data. A ranking of exterior equipment from highest overall sound power levels to lowest is provided in Figure 25. A similar ranking for the 125 Hz octave band and 250 Hz octave band sound levels is provided in Figures 26 and 27 respectively. It is interesting to note the order of the sources in each graph is not the same. This shows that even though a piece of equipment is the loudest exterior source, it does not necessarily mean that it is the primary producer of the tonal sound of concern at the residences.

Figure 25: Overall Sound Power Levels (dBA) of Primary Exterior Sources

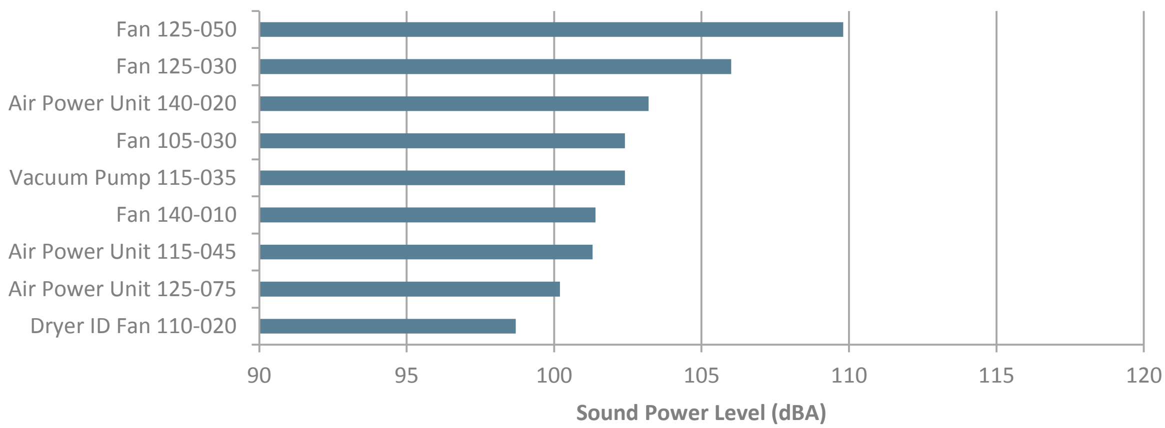


Figure 26: 125 Hz Sound Power Level (dB) of Primary Exterior Sources

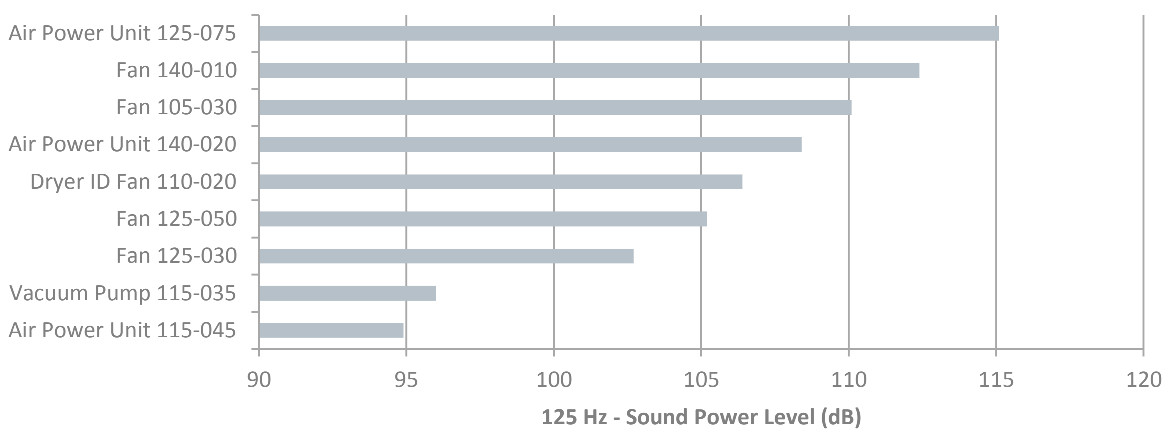
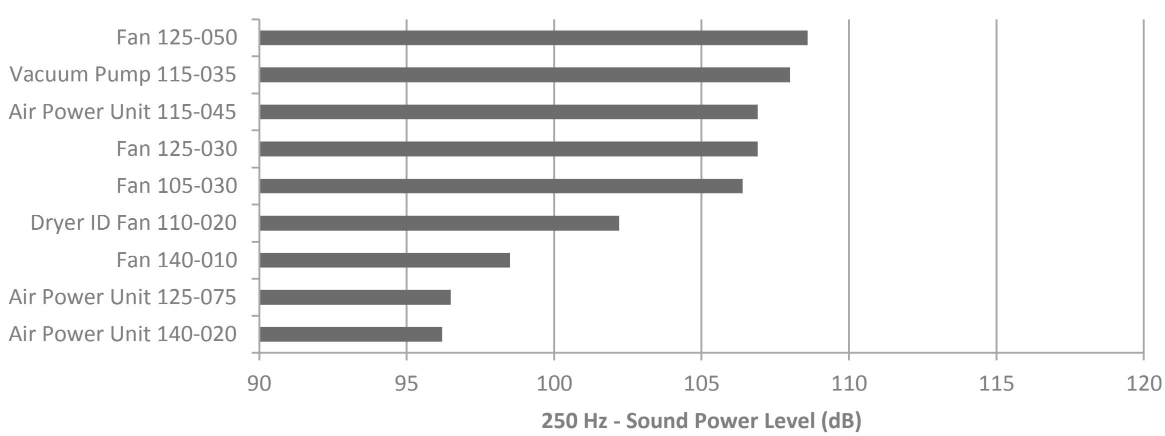


Figure 27: 250 Hz Sound Power Level (dB) of Primary Exterior Sources



Sound levels created within the plant have to potential to breakout of the building by propagating through the building envelope. This can happen particularly when there are openings in the envelope as is the case with the green hammermill conveyor opening, the dryer feed opening, and the pellet room louvers. Interior sound levels in the dryer room range typically between 87 and 97 dBA with the highest sound levels monitored near the green hammermill. Interior sound levels monitored directly next to the green hammermill conveyor opening were 103 dBA.

6.0 SOUND MODELING

6.1 Modeling Software, Setup, & Calibration

Modeling was completed for the project using Cadna A acoustical modeling software. Made by Datakustik GmbH, Cadna A is an internationally accepted acoustical model, used by many other noise control professionals in the United States and abroad. The software has a high level of reliability and follows methods specified by the International Standards Organization in their ISO 9613-2 standard, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." The ISO standard states,

> "This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level … under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation … or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night."

The model takes into account source sound power levels, surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain. Source emission data and modeling assumptions are provided in Appendix C. Additional model input data including elevation data and source and receiver coordinates can be provided upon request.

The model was calibrated utilizing data gathered at the short-term and long-term monitoring locations. Overall sound pressure levels from the model for the calibration points were found to be within 2 dB of the monitored results at most location and were within 3 dB for Boice Street and the Airport Monitor.

A 65 by 65 foot (20 meters) grid of receivers was set up covering approximately two square miles around the site.

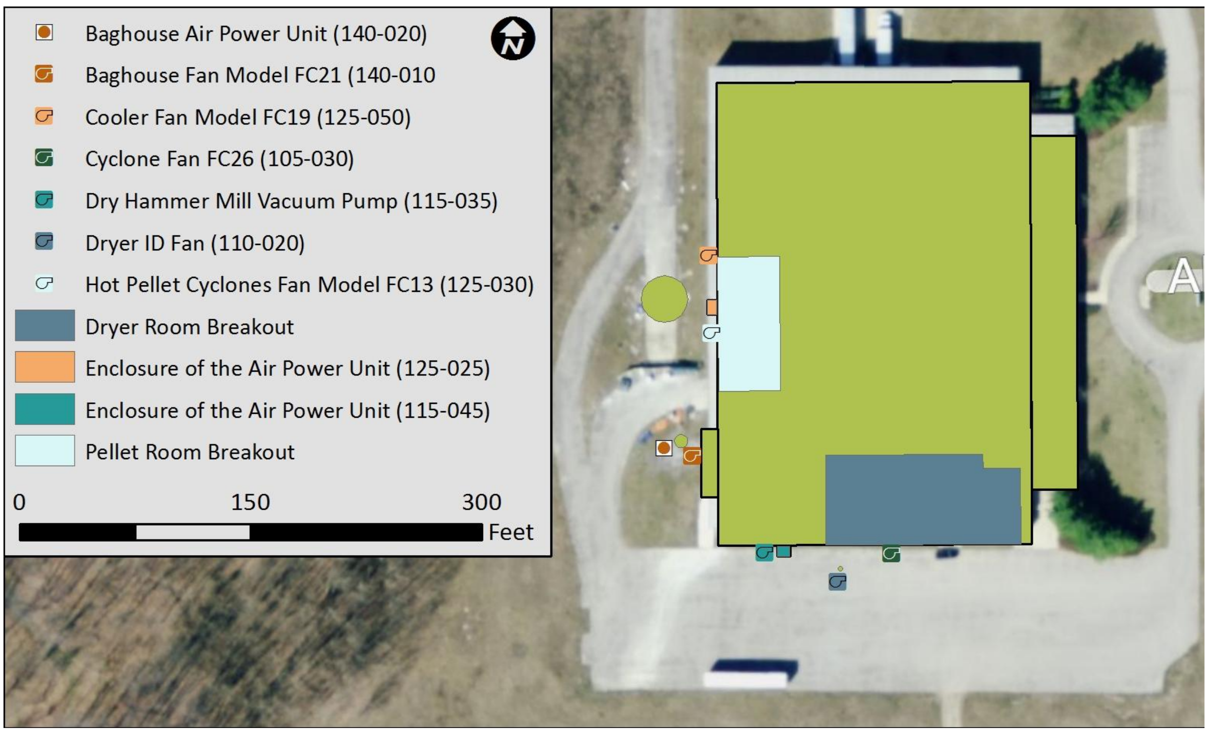
6.2 Modeled Sources

Figure 28 shows the location of all the sources (with Kirtland ID numbers) in the model which include:

- Cooler Fan Model FC19 (125-050)
- Breakout noise from the enclosed Air Power Unit on the west side of the building (125-025)
- Hot Pellet Cyclone Fan Model FC13 (125-030)
- Baghouse Fan Model FC21 (140-010)
- Baghouse Air Power Unit (140-020)

- Dry Hammer Mill Vacuum Pump (115-035)
- Breakout noise from the enclosed Air Power Unit on the south side of the building (115-045)
- Dryer I.D. Fan (110-020)
- Cyclone Fan Model FC26 (105-030)
- Breakout noise from the dryer room
- Breakout noise from the pellet room
- Breakout noise from the green hammermill conveyor opening
- Breakout noise from the dryer feed opening
- Breakout noise from the pellet room louver

Figure 28: Map of Noise Sources[1]



6.3 Model Results of Existing Sound Levels

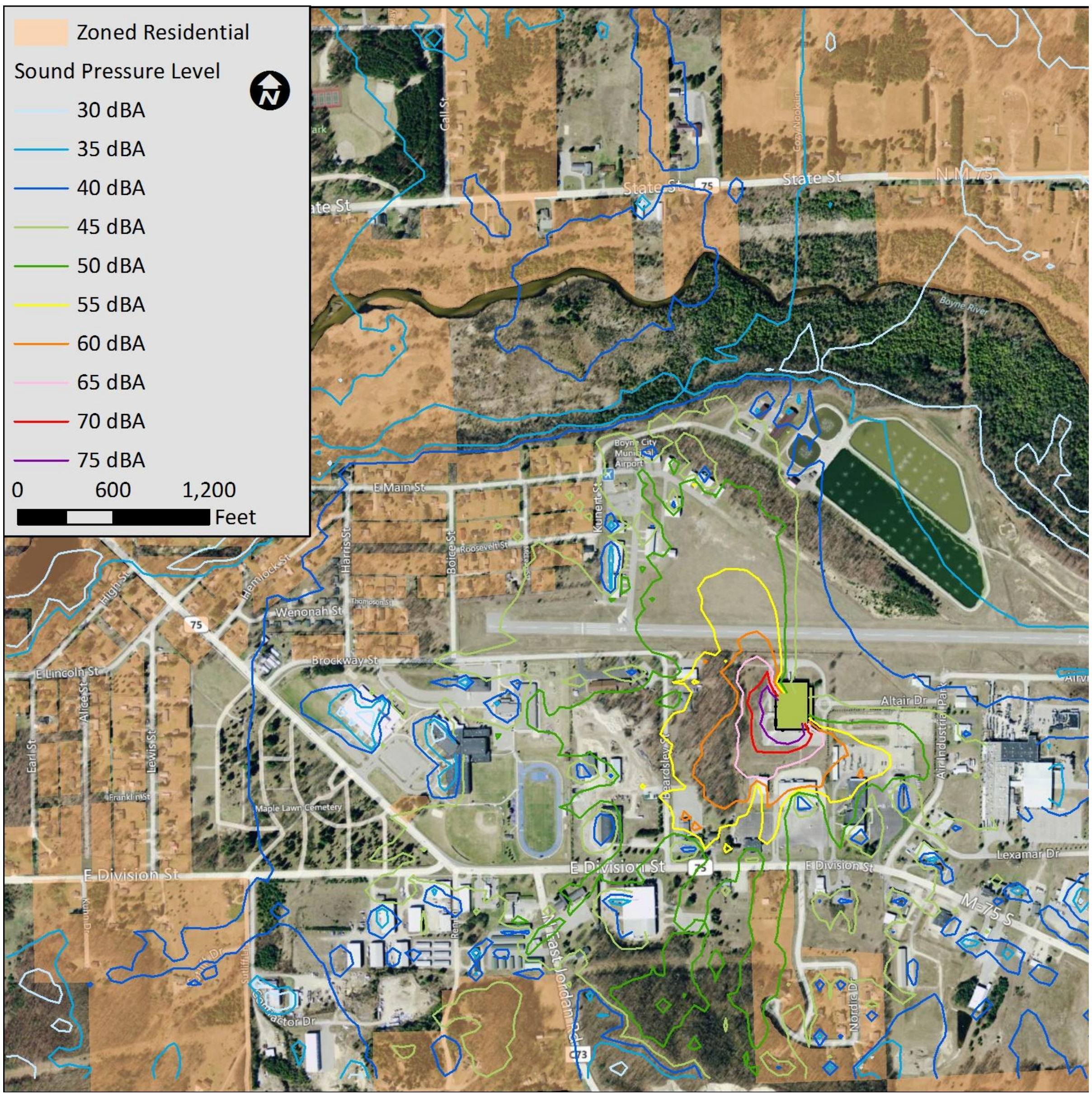
A map of the existing sound levels from the plant is provided in Figure 29. The highest sound level from the Kirtland Plant at a residence is at the manse for the church on Beardsley Street which is 62 dBA. The highest sound level at a zoned residential area is at the corner of Boyne Summit Road and East Division

[1] Breakout noise from conveyor openings and louvers is not shown in Figure 28 for the simplicity of graphical representation, but are included in the noise model.

Street which is 53 dBA. Sound levels in the Nordic Drive area at the façade of the residences range between 44 dBA and 51 dBA, and the highest sound level at a zoned residential property in the neighborhood around the airport is 46 dBA.

Sound levels that exceed the penalized noise threshold goal of 35 dBA extend up to approximately 1 mile west and 4,900 feet north northwest of the Kirtland site. If the tonal pulsation effect were to cease, sound levels that exceed the unpenalized noise threshold goal of 40 dBA extend approximately 3,920 feet west southwest and 4,140 feet north of the Kirtland site.

Figure 29: Model Results of the Existing Sound Pressure Levels from the Kirtland Plant



Mitigation is required to shift the noise threshold goal range to within 1,000 feet of the Kirtland site. Of particular interest are the partial levels at the nearest zoned residential areas which helps to determine the equipment that requires mitigation. The residence at the corner of Boyne Summit Road and East Division Street is the nearest zoned residential house within a range of approximately 1,000 feet. The partial levels of the Kirtland plant at this residence are shown in Table 3. Assuming the pulsation effect can be remedied the noise threshold goal at the nearest zoned residential house Upon quick inspection, we can see that the top six sources (shown in light blue) in Table 3 must be mitigated to meet the noise threshold goal of 40 dBA[1] since those sources exceed the goal individually. In addition the three sources shown in green will also require mitigation because their contribution to the sum of all the sources causes an exceedence of the 40 dBA noise threshold goal. Table 3 also shows that the primary contributors to the 125 Hz octave band (shown in orange) at this receiver is the baghouse fan (140-010) and the baghouse air power unit (140-020), but the primary contributors to the 250 Hz octave band (shown in grey) at this receiver is the dry mill vacuum pump (115-020) and the already enclosed air power unit on the south side of the plant (115-045).

The primary takeaway from the model results which is supported by the on-site monitoring is that all of the primary outdoor sources included in the model and the two already enclosed air power units require mitigation to achieve a noise threshold goal of 40 dBA at the nearest zoned residential area. The model also shows that breakout noise from the building does not currently appear to be a primary contributor to the sound level at neighboring residential areas.

Table 3: Partial Levels from the Kirtland Plant at the Nearest Zoned Residential House

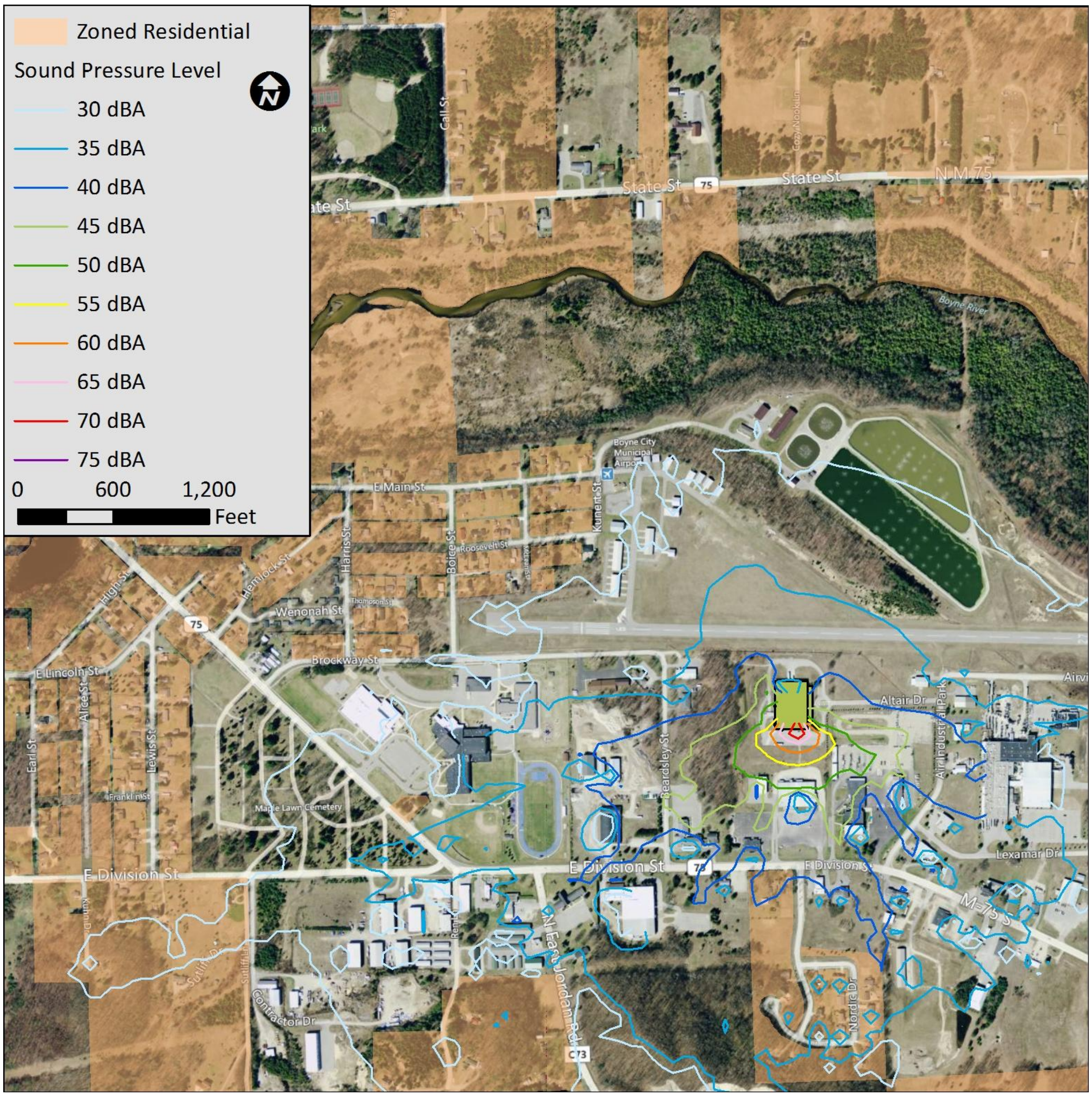
Noise Source	Sound Pressure Level		
	Overall (dBA)	125 Hz (dB)	250 Hz (dB)
Baghouse Air Power Unit (140-020)	49	36	33
Cooler Fan Model FC19 (125-050)	47	28	40
Baghouse Fan Model FC21 (140-010)	47	40	35
Dry Hammer Mill Vacuum Pump (115-035)	45	22	42
Hot Pellet Cyclones Fan Model FC13 (125-030)	44	26	38
Enclosure of the Air Power Unit M-D5009 (115-045)	44	22	42
Cyclone Fan FC26 (105-030)	41	33	38
Dryer ID Fan (110-020)	38	28	34
Enclosure of the Air Power Unit 6" (125-025)	37	15	35
Enclosure of the Air Power Unit M-D5009 (115-045)	37	14	34
Enclosure of the Air Power Unit 6" (125-025)	34	33	22
Dry Room Breakout Metal Siding Lower M	34	30	30
Green Mill Opening	33	26	25
Dryer Room Roof Breakout	33	32	27
Dry Room Breakout Upper M	26	25	20
Dry Mill Conveyor Opening	24	12	15
Dryer Room Breakout Upper W	23	21	16
Dry Room Breakout Upper East	19	18	10
Dry Room Breakout Metal Siding Upper M	14	13	7
Pellet Room Roof Breakout	11	7	7
Pellet Room Breakout Upper	9	6	5
Dry Room Breakout Lower M	3	-1	0
Pellet Room Louver	0	-4	-13
Dryer Room Breakout Lower W	-1	-5	-4
Dry Room Breakout Lower E	-7	-9	-10
Pellet Room Breakout Lower	-17	-23	-19

[1] This assumes that the pulsation effect is first remedied, otherwise the penalized noise threshold goal is 35 dBA.

6.4 Model Results with Proposed Mitigation Measures

We have developed mitigation recommendations which are described in Section 7 to meet the noise threshold goal. The model results with the mitigation recommendations implemented in the model are provided in Figure 30. As shown in Figure 30, the sound pressure level at the nearest zoned residential house is approximately 40 dBA which is a 13 dB reduction from the existing plant levels. In addition, the mitigated sound level at the church manse on Beardsley Street is approximately 44 dBA which is an 18 dB reduction from the existing plant levels. Lastly, the mitigated sound levels in most zoned residential areas are below 35 dBA.

Figure 30: Model Results of the Mitigated Sound Pressure Levels from the Kirtland Plant



7.0 MITIGATION RECOMMENDATIONS

Kirtland Products has already taken some steps to mitigate noise from the operation. Much of the equipment associated with the drying and grinding operations are located inside the plant. After the plant started up, they noticed that the dry hammermill blower was louder than expected so they replaced it. And in response to community complaints, they installed mufflers on the pellet mill and cooler stacks.

As mentioned in the previous section, to meet the noise threshold goal of 40 dBA, mitigation is necessary for all primary outdoor noise sources listed in Section 6.2. Since sound from the plant currently pulsates at a 138 and 275 Hz, a penalized noise threshold goal of 35 dBA would apply. As such we propose a three step approach to mitigation:

1. **Recommendation:** Address the pulsation sound through an air pressure and plant design review.

   Cause: The likely culprit of the pulsation noise is backpressure causing a stall condition on some of the centrifugal fans. This may cause decreased efficiency in Kirtland's operation which may be noticeable at the plant. This condition is typically caused by an issue in the design or installation of the fans and ductwork and is, in fact, one of the primary troubleshooting issues identified by the manufacturer of the fans (Figure 31).

   Figure 31: Troubleshooting Extract from Kice Industries Operator's Manual[1]

Excessive Noise	1. Fan operating near "stall" condition due to incorrect system design or installation 2. Vibration originating elsewhere in the system 3. System resonance or pulsation (type of cavitation) 4. Improper location or orientation of fan intake and discharge 5. Nearby sound reflecting off surfaces 6. Inadequate or faulty design of fan structural supports 7. Loose accessories or components 8. Loose V-belt drive or worn sheaves 9. Worn bearings

   Mitigation: We are unable to identify from our acoustical data exactly which fans may have the backpressure issue. Further investigation of the fans and pressure statuses within the ductwork/piping should be conducted by either the firm that designed the system or another design firm.

   General Cost Estimate: The cost associated with this mitigation is for the diagnostics services by the plant design firm and then the possibly the cost of replacing some of the fans. Kirtland can receive cost estimates from the design firm that they choose for the review.

2. **Recommendation:** Reduce sound levels from all primary outdoor noise sources identified in Section 6.2 via equipment enclosures.

   Cause: For the types of wood pellet systems that Kirtland has in place, the outdoor equipment is generally operating at expected sound emissions.

[1] Kice Industries, Centrifigual Fan Operator's Manual, *http://www.kice.com/pdfs/Fan%20Manual%20-%20CE.pdf*

Mitigation: Quieter equipment alternatives would likely require a redesign of the plant. We recommend enclosing the following sources in structures composed primarily of heavy concrete masonry units or similar:

- Cooler Fan Model FC19 (125-050)
- Hot Pellet Cyclone Fan Model FC13 (125-030)
- Baghouse Fan Model FC21 (140-010)
- Baghouse Air Power Unit (140-020)
- Dry Hammer Mill Vacuum Pump (115-035)
- Dryer I.D. Fan (110-020)
- Cyclone Fan Model FC26 (105-030)

In addition the enclosures for the two already enclosed air power units (125-025) and (115-045) should be rebuilt using a heavy concrete masonry unit construction or similar. The sound transmission loss of the structure used in our mitigation model is provided in Table 1. If the results presented in Section 6.4 are to be achieved, construction with similar transmission loss values will need to be used for the enclosures.

Table 4: Transmission Loss Values (dB) of Recommended Enclosures

Material	Octave Band Frequency (Hz)									Reference
	31.5	63	125	250	500	1000	2000	4000	8000	
Concrete Block 100lb/cu.ft.	39	38	37	37	44	52	60	65	70	INSUL

Some other design considerations include:

- For equipment requiring ventilation, acoustical louvers should be used with the size depending on the amount of air flow that is necessary. If possible, louvers should be directed away from residential areas. Examples of acoustical louvers can be found at: http://www.mfmca.com/acoustical_louvers.html. For the sources close to the façade of the plant, it may also be possible to attain ventilation from inside the building.
- To avoid low frequency resonance at 138 or 275 Hz, the dimensions of the length, width, or height should not be an even multiple of 2 feet.
- All penetrations in the enclosure for pipes, ducting, and stacks from the outside should be packed with insulation to the extent possible, and sealed with expandable foam, rubber, or a non-hardening calk.

General Cost Estimate: The primary cost of this mitigation will depend on local construction costs and as such is not estimated here. Acoustical louvers typically cost less than $1,000 each depending on the size.

3. **Recommendation:** Take additional readily available mitigation steps to further reduce noise impacts from the plant.

   Cause: Most of the intermittent sources at the plant such as truck traffic, the hydraulic truck dump, disc screener, loader, and backup alarm are generally quieter than the primary sources identified in Section 6.2. They were also not discussed as key sources of community annoyance.

There are however some basic noise mitigation measures that can be implemented to reduce the impact from some of these sources and indoor noise as well.

Mitigation:

To reduce the noise impact of the loader backup alarm, install a broadband, variable loudness, or radar type backup alarm. Broadband backup alarms are often found to be less annoying because they do not have the pure tonal qualities of regular backup alarms. They are also more directional and attenuate more over distances. Broadband backup alarms emit a sound that is often described as being similar to static. More information on these types of alarms can be found at http://www.brigade-electronics-inc.com/20.

To reduce breakout noise from the drying and pellet rooms, seal all unnecessary penetrations in the building envelop and repair areas where insulation has broken away from the metal siding (Figure 32). In addition, heavy vinyl stripping can be used on the interior as well as exterior for conveyor openings. This is already done on the outside façade where the conveyor feeding the green hammer mill (Figure 32).

Figure 32: Photographs from Inside the Dryer Room & of the Dry Hammermill Conveyor Opening

General Cost Estimate:

Alternative backup alarms are easy to install and typically cost between $200 and $400. Adding additional vinyl to the inside of the green hammermill conveyor opening and the dryer feed opening, would involve minimal costs of approximately $100 to $300.

It should be noted that these are mitigation recommendations that will help Kirtland Products meet the noise threshold design goal. Their purpose is to identify what can be done to meet the noise threshold design goals and provide general cost estimates when available. The recommendations presented here are not designs. If Kirtland decides to implement any of the mitigation recommendations, they may require further consultation with their noise control engineer to ensure that all necessary design details are planned and implemented.

8.0 SUMMARY AND CONCLUSIONS

Kirtland Products has been periodically operating their plant in Boyne City, Michigan since the fall of 2011 with noise complaints throughout the surrounding neighborhoods. RSG, at the request of Boyne City, has conducted a noise assessment to identify the causes of the noise and mitigation measures that can be taken to reduce the noise to "levels that can be reasonably expected as to not be disturbing to homes in surrounding residentially zoned areas which are approximately 1,000 to 2,000 feet away[1]." As part of the noise assessment and the goals of the town, RSG developed a noise threshold goal of 40 dBA Leq_{night}, with the caveat that a 5 dB penalty is applied if the plant continues to produce a tonal pulsation effect resulting in a penalized noise threshold goal of 35 dBA.

RSG conducted a site visit in May to gather noise emission data on sources at the plant and to measure community noise levels and background sound levels. During the site visit RSG noted some key contributors to noise annoyance in addition to the overall noise level, namely tonality and pulsation from the Kirtland Plant. The residences most impacted by noise from the plant is the manse to the church on Beardsley Street, the neighborhood around Nordic Drive, and the closest homes in the neighborhood around Kunert Street and Boice Street. Further residences which typically have lower background sound levels around a mile or more away from the plant are able to hear the low frequency noise from the plant as travels further due to less atmospheric absorption than what is achieved at higher frequencies. One example of this is at the Kuhn Residence located approximately 4,600 feet west-southwest of the Kirtland Plant where noise from the plant causes a 15 dB and 20 dB increase in the 125 Hz and 250 Hz one-third octave bands, respectively. While relatively quiet, the low frequency from the Kirtland Plant was clearly audible in Kuhn Residence during our site visit even with the windows closed.

Noise emissions from equipment at the plant were used to model sound levels throughout the surrounding the community. The model was used to identify what noise sources required mitigation to meet the noise threshold goal. It was found that all of the primary outdoor noise sources which run constantly require noise mitigation. Our recommended approach to mitigating noise from the plant and meeting the noise threshold goal is outlined in detail in Section 7, and includes:

1. Addressing the pulsation sound through an air pressure and plant design review as we think it may be due to excessive backpressure on some of the fans causing a stall condition. The findings of the recommended review may require replacing some of the fans in order to stop the tonal pulsation effect.
2. Reducing sound levels from all primary outdoor noise sources identified in Section 6.2 via equipment enclosures with transmission loss values specified in Section 7.
3. Take additional readily available mitigation steps to further reduce noise impacts from the plant such as replacing the backup alarm on the loader with an alternative backup alarm, and sealing penetrations in the building façade.

Noise modeling presented in Section 6.4 indicates if these recommendations are properly implemented the noise threshold goal can be achieved at the neighboring zoned residential areas and a significant reduction can be achieved at the church manse on Beardsley Street.

It should be noted that this noise assessment assumes that the plant must run 24 hours per day as indicated by Kirtland. If the plant were able to operate only during the daytime, the noise threshold goal would be increased to 45 or 50 dBA which would result in less necessary mitigation.

[1] Boyne City's goal as state in the RFP for this project.

Appendix A: Equipment Photographs

Figure A 1: Rotary Drum Dryer

Figure A 2: Dryer F.D. Fan

Figure A 3: Dryer Burner and Feed Conveyor

Figure A 4: Dryer Feed Conveyor Building Pentetration

Figure A 5: Green Hammermill

Figure A 6: Dry Hammermill

Figure A 7: Ground Material Surge Bin and Air Power Unit

Figure A 8: Fuel Hammermill

Figure A 9: Fuel Hammermill Cyclone

Figure A 10: Fuel Bin

Figure A 11: Pellet Mill

Figure A 12: Pellet Cyclones

Figure A 13: Pellet Cooler

Figure A 14: Pellet Packaging

Figure A 15: Cooler Fan Model FC19 (125-050)

Figure A 16: Hot Pellet Cyclone Fan Model FC13 (125-030), Note the Retrofitted Muffler on the Exhaust Stack

Figure A 17: Cooler Cyclone

Figure A 18: Pellet Storage Silo

Figure A 19: Pellet Discharge Conveyor and Elevator Leg

Figure A 20: Baghouse Model VR96-10 Venturi, Baghouse Fan Model FC21 (140-010), and Baghouse Air Power Unit (140-020)

Figure A 21: Dry Hammer Mill Vacuum Pump (115-035, on left), Air Power Unit in wood shed (115-045), Dry Hammer Mill Baghouse, and Dryer I.D. Fan (110-020)

Figure A 22: Wood Chip Storage Piles, Loader, and Screw Conveyors

Figure A 23: Green Hammermill Conveyor, Green Cyclone, and Dryer Feed Metering Bin

Figure A 24: Green Chip Metering Bins

Figure A 25: Hydraulic Truck Dump

Figure A 26: Precision Disc Screener

Figure A 27: Hydraulic Truck Dump

Appendix B: World Health Organization Guidelines for Community Noise Table 4.1

Table 4.1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30	16 8	 45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school Bedrooms, indoors	Sleep disturbance	30	sleeping -time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial, shopping and traffic areas, indoors and Outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music through headphones/ Earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3		

#1: as low as possible;
#2: peak sound pressure (not LAmax, fast), measured 100 mm from the ear;
#3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low;
#4: under headphones, adapted to free-field values

APPENDIX C: NOISE EMISSION DATA

Figure C 1: Noise Emission Data from Kirtland Plant

Emission Type	Source Description	Source ID	Octave Band Center Frequency (Hz)									Overall Levels	
			31.5	63	125	250	500	1000	2000	4000	8000	dBA	dB
Sound Power Levels (Lw)	Cooler Fan Model FC19	F125_050	102.2	99.5	105.2	108.6	108.2	101.0	102.9	99.7	94.3	109.8	113.8
	Hot Pellet Cyclones Fan Model FC13	F125_030	97.9	100.6	102.7	106.9	103.9	101.0	93.7	95.4	90.6	106.0	111.1
	Air Power Unit	A140_020	85.8	94.5	108.4	96.2	102.5	96.7	95.3	88.8	79.5	103.2	110.1
	Dry Hammer Mill Vacuum Pump	P115_035	92.8	92.7	96.0	108.0	100.1	93.2	88.0	86.2	81.7	102.4	109.3
	Cyclone Fan FC26	F105_030	102.5	103.2	110.1	106.4	100.6	91.0	89.0	87.9	80.6	102.4	113.0
	Baghouse Fan Model FC21	F140_010	91.2	100.1	112.4	98.5	98.4	94.1	91.3	87.4	82.2	101.4	113.1
	Air Power Unit M-D5009 - Enclosed in wood structure	A115_045Walls	91.7	91.6	94.9	106.9	99.1	92.1	86.9	85.2	80.6	101.3	108.2
	Air Power Unit 6" - Enclosed in wood structure	A125_075Walls	91.7	95.6	115.1	96.5	92.1	85.7	86.1	81.0	72.7	100.2	115.3
	Dryer ID Fan	F110_020	98.5	105.1	106.4	102.2	94.7	91.2	87.0	86.4	80.6	98.7	110.2
	Air Power Unit M-D5009 - Enclosed in wood structure	A115_045Roof	86.2	86.1	89.4	101.4	93.5	86.6	81.4	79.6	75.1	95.8	102.7
	Air Power Unit 6" - Enclosed in wood structure	A125_075Roof	86.5	90.3	109.9	91.3	86.9	80.5	80.9	75.8	67.5	95.0	110.1
Interior Sound Pressure Levels (Lp)	Interior Sound Level of Dryer Room West Side	DryerRoomWest	90.9	89.2	97.5	92.8	87.1	79.4	82.0	80.0	70.9	90.3	100.2
	Interior Sound Level of Dryer Room Middle	DryerRoomMiddle	93.0	92.3	105.0	100.6	94.3	83.1	84.7	81.8	77.0	96.5	107.0
	Interior Sound Level of Dryer Room East Side	DryerRoomEast	87.7	88.1	96.6	89.0	82.0	75.4	77.5	75.0	67.2	86.6	98.4
	Average Interior Sound Level of Dryer Room	DryerRoomRoof	91.1	90.2	101.4	96.8	90.5	80.4	82.3	79.7	73.5	93.0	103.5
	Interior Sound Level of Pellet Room	PelletRoom	79.6	74.0	78.7	77.8	71.6	78.6	77.0	80.0	75.1	84.9	87.2
	Green Mill Opening	GreenMillOpening	93.2	98.3	112.2	102.1	103.6	88.0	89.1	84.7	80.0	102.9	113.3
	Dryer Feed Opening	DryerFeedOpening	84.4	89.5	98.0	92.6	93.2	80.1	84.6	81.9	75.2	93.2	100.8
	Pellet Room Louver	LouverPelletRoom	80.4	78.2	92.7	75.6	73.0	76.6	77.2	79.7	75.7	85.1	93.7

Figure C 2: Model Parameter Settings

Parameter	Setting
Ground Absorption	ISO 9613-2 spectral, G=0 on paved areas, and G=0.5 elsewehere
Atmospheric Absorption	Based on 10 degree Celsius, 70% relative humidity, CONCAWE adjustments for stability class F
Foliage	No attenuation due to foliage accounted for
Search Radius	2000 meters from each source
Receiver Height	1.5 meters for sound contours & 4 meters for discrete receivers
Building Heights	5 to 6.1 meters for commercial and industrial buildings, 5 meters for residences