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DRAFT TECHNICAL REPORT

To: Kenneth Schedig, AC Transit
Debra Jones, CHS Consulting

From: Darren Nielson, ATS Consulting

Date: December 1, 2005

Subject: Noise & Vibration Study, AC Transit SDP & WCSP

Introduction & Summary

This draft technical memorandum summarizes the results of the noise and vibration study for the proposed Service Deployment Plan (SDP) and West County Service Plan (WCSP) for AC Transit. The study included extensive noise and vibration measurements and an analysis of potential impacts resulting from the implementation of transit service. In addition, the study evaluated the relative differences in noise and vibration levels for three different vehicles: the gasoline vans that have already been phased out of service, a 30-foot bus (Gillig) that is currently in service on many routes, and a new 30-foot bus (Van Hool) that will be replacing all of the Gillig 30-foot buses.

The overall conclusions of this study are:

1. The implementation of modified or new transit service as part of the SDP and WCSP will not result in significant noise impacts. Increases in background noise levels would generally be less than 1 dB at noise-sensitive receptors throughout the project area.
2. At all measurement locations, the new Van Hool buses generate less noise than the existing Gillig buses. And, in most cases, the Van Hool buses are quieter than the gas vans.
3. Vibration levels from transit service, as measured inside adjacent sensitive receptors, will generally be below the threshold of perceptibility. Vibration from the buses may be perceptible inside some residences. However, in all cases, even with conservative assumptions, predicted vibration levels are below the impact threshold.
4. Ground-borne noise levels are predicted to be well below the impact threshold.
5. Mitigation is not recommended.

The remainder of this memo outlines acoustic concepts and terminology, describes the relevant noise and vibration impact criteria, details the results of the noise and vibration measurements, and identifies the predicted noise and vibration levels as a result of the proposed project.

Concepts and Terminology

Noise

Sound is mechanical energy transmitted by pressure waves in a compressible medium such as air. Noise is generally defined as unwanted or excessive sound. Sound can vary in intensity by over one million times within the range of human hearing. Therefore, a logarithmic scale, known as the decibel scale (dB), is used to quantify sound intensity and to compress the scale to a more manageable range.

Sound is characterized by both its amplitude and frequency (or pitch). The human ear does not hear all frequencies equally. In particular, the ear deemphasizes low and very high frequencies. To better approximate the sensitivity of human hearing, the A-weighted decibel scale (dBA) has been developed. On this scale, the human range of hearing extends from approximately 3 dBA to around 140 dBA. Figure 1 shows a range of typical noise levels from common indoor and outdoor activities.

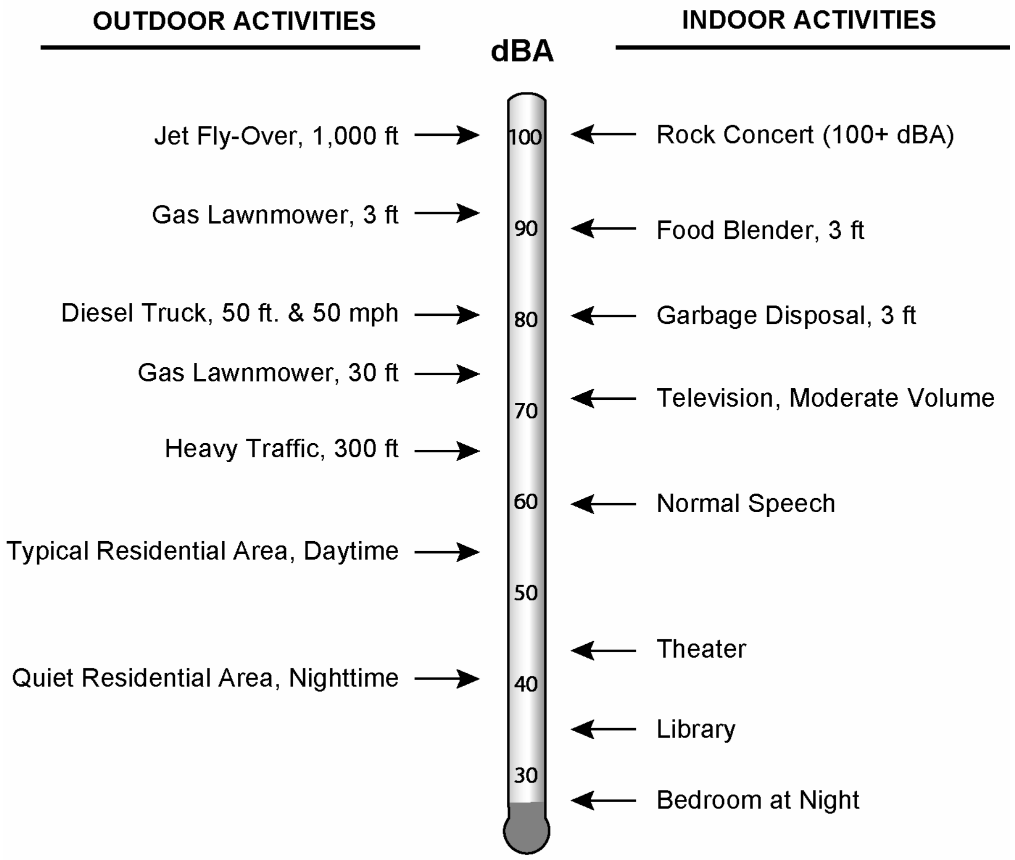
Using the decibel scale, sound levels from two or more sources cannot be directly added together to determine the overall sound level. Rather, the combination of two sounds at the same level yields an increase of 3 dB. The smallest recognizable change in sound level is approximately 1 dB. A 3-dB increase in the A-Weighted sound level is generally considered noticeable, whereas a 5-dB increase is readily noticeable. A 10-dB increase is judged by most people as an approximate doubling of the perceived loudness.

The two primary factors that reduce levels of environmental sounds are increasing the distance between the sound source and the receiver and having intervening obstacles such as walls, buildings, or terrain features that block the direct path between the sound source and the receiver. Factors that act to make environmental sounds louder include moving the sound source closer to the receiver, sound enhancements caused by reflections, and focusing caused by various meteorological conditions.

Below are brief definitions of the measurements and other terminology used in this chapter:

- Equivalent Sound Level (L_{eq}): Environmental sound fluctuates constantly. The equivalent sound level (L_{eq}), sometimes referred to as the energy average sound level, is the most common means of characterizing community noise. L_{eq} represents a constant sound that, over the specified period, has the same sound energy as the time-varying sound.
- Maximum Sound Level (L_{max}): The maximum sound level is the highest sound level measured during the measurement period on the FAST sound level meter setting.
- Minimum Sound Level (L_{min}): The minimum sound level is the lowest sound level measured during the measurement period on the FAST sound level meter setting.
- L_{xx}: This is the percent of time a sound level is exceeded during the measurement period. For example, the L_{90} is the sound level exceeded 90 percent of the measurement period.
- Sound Exposure Level (SEL): SEL is the cumulative noise exposure for a single event compressed into one second. As a result, SEL is influenced by both the sound level and the duration of the event. In other words, louder events have a higher SEL as do longer events. SEL can be used to calculate the 24-hour cumulative noise exposure (L_{dn}).
- Day-Night Sound Level (L_{dn}): L_{dn} is basically a 24-hour L_{eq} with an adjustment to reflect the greater sensitivity of most people to nighttime noise. The adjustment is a 10-dB penalty for all sound that occurs between the hours of 10 p.m. and 7 a.m. The effect of the penalty is that, when calculating L_{dn}, any event that occurs during the nighttime is equivalent to 10 of the same event during the daytime. L_{dn} is the most common measure of total community noise over a 24-hour period and is used by the Federal Transit Administration (FTA) to evaluate residential noise impacts from proposed transit projects.
- Community Noise Equivalent Level (CNEL): CNEL is effectively a 24-hour L_{eq} with adjustments to reflect the greater sensitivity of most people to evening and nighttime noise. The adjustments are a 5-dB penalty for all sounds that occur between 7 p.m. and 10 p.m. and a 10-dB penalty for all sounds

from 10 p.m. to 7 a.m. The effect of these penalties is that, in calculating the CNEL, any event that occurs during the evening hours is equivalent to 3 of the same event during the daytime hours and any event during the nighttime is equivalent to 10 daytime events. Ldn and CNEL values rarely differ by more than 1 dB.



Sources: FTA, 1995; ATS Consulting, 2005

Figure 1: Graph of Typical Indoor & Outdoor Noise Sources and Levels

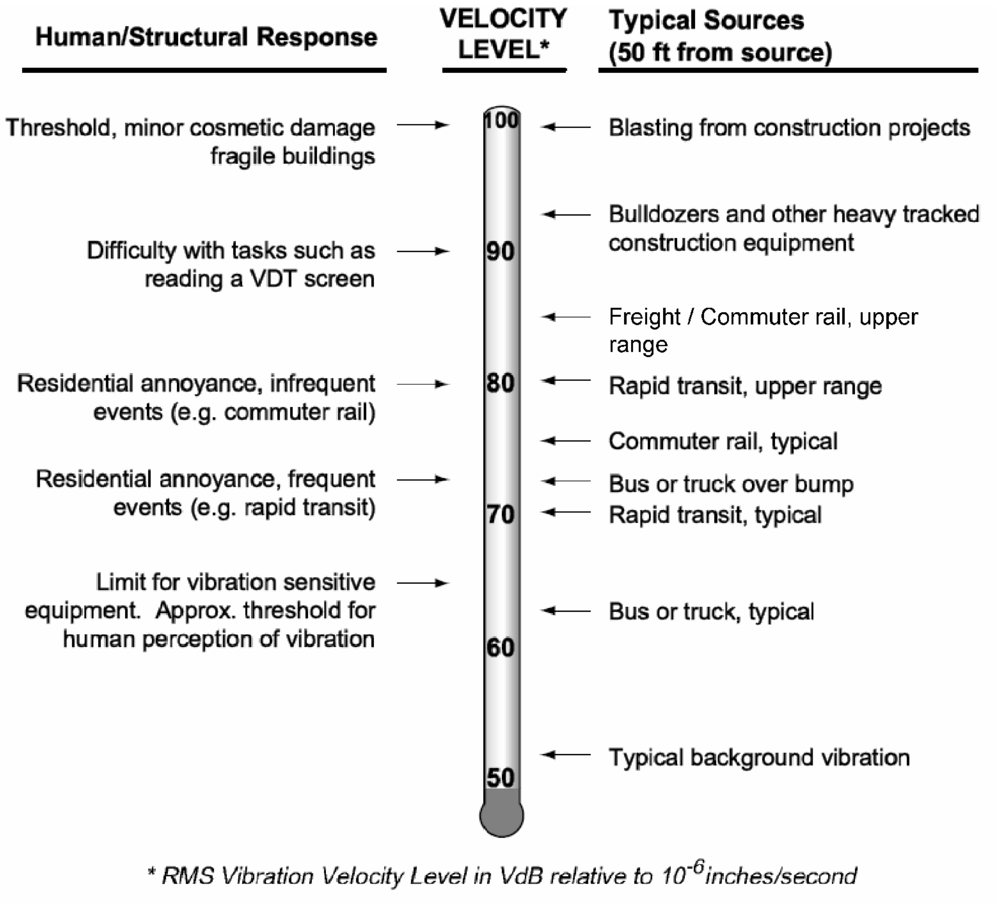
Vibration

One potential community impact from the project is vibration that is transmitted from the buses through the ground to adjacent houses. This is referred to as ground-borne vibration. Vibration from rubber-tire transit is rarely perceptible inside adjacent residences unless there are potholes or other irregularities in the road surface. In rare cases, it can cause windows, pictures on walls, or items on shelves to rattle.

Vibration is an oscillatory motion that can be described in terms of the displacement, velocity, or acceleration of the motion. The response of humans to vibration is very complex. However, the general consensus is that for the vibration frequencies generated by transit vehicles, human response is best approximated by the vibration velocity level. Therefore, vibration velocity has been used in this study to describe transit-generated vibration levels.

When evaluating human response, ground-borne vibration is usually expressed in terms of decibels using the root mean square (RMS) vibration velocity. RMS is defined as the average of the squared amplitude of the vibration signal. To avoid confusion with sound decibels, the abbreviation VdB is used for vibration decibels.

Figure 2 shows typical vibration levels from transportation and non-transportation related sources as well as the human and structure response to such levels.



Source: FTA, 1995; ATS Consulting, 2005

Figure 2: Typical Transit & Non-Transit Vibration Sources and Levels

Although there has been relatively little research into human and building response to ground-borne vibration, there is substantial experience with vibration from transit systems. In general, the collective experience indicates that:

- It is rare that ground-borne vibration from transit systems results in building damage, even minor cosmetic damage. The primary consideration therefore is whether vibration will be intrusive to building occupants or will interfere with interior activities or machinery.
- The threshold for human perception is approximately 65 VdB. Vibration levels in the range of 70 to 75 VdB are often noticeable but acceptable. Beyond 80 VdB, vibration levels are often considered unacceptable.
- For human annoyance, there is a relationship between the number of daily events and the degree of annoyance caused by ground-borne vibration. The FTA Guidance Manual includes an 8 VdB higher impact threshold if there are fewer than 70 events per day.

In addition, the vibration of walls, floors, and ceilings of rooms will radiate low-frequency noise that is sometimes perceived as a low-frequency rumble sound. This re-radiated low-frequency rumble is referred to as ground-borne noise. Because of the strong low-frequency character of most ground-borne noise, it can be more intrusive than might be expected from its sound level alone.

Impact Criteria

Noise and vibration impacts for federally-funded transit projects are based on the FTA impact criteria. These criteria are presented in the document, *Transit Noise and Vibration Impact Assessment* (FTA report DOT-T-95-16, April 1995), referred to as the FTA Guidance Manual. The FTA criteria are founded on well-documented research on community reaction to noise and vibration. Although this project is not federally funded, the FTA criteria are widely used in the industry and appropriate for analyzing the proposed service changes in the SDP and WCSP.

Noise

The FTA criteria account for the noise sensitivity of different land uses. Table 1 includes a description of the three categories for noise-sensitive land uses and the applicable noise metric for each land use category. The majority of noise-sensitive receptors in the project area are residential land uses, FTA Category 2. Outdoor L_{dn} is the noise metric used by the FTA criteria for Category 2 land uses. Category 3 (institutional) land uses are evaluated using outdoor L_{eq} during the peak noise period.

Table 1: FTA Land Use Categories and Noise Metrics

Land Use Category	Noise Metric (dBA)	Description of Land Use Category
1	Outdoor $L_{eq}(h)$[1]	Tracts of land where quiet is an essential element of their intended purpose. This includes lands set aside for serenity and quiet and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use.
2	Outdoor L_{dn}	Residences and buildings where people normally sleep. This includes homes, hospitals and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor $L_{eq}(h)$[1]	Institutional land uses with primarily daytime and evening uses. This includes schools, libraries, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material.

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

The FTA noise criteria are a sliding scale as shown in Figure 3. The existing noise is shown on the horizontal axis and the increase in the total noise exposure as a result of the project is on the vertical axis. The basic concept of the FTA noise impact criteria is that more project noise is allowed in areas where existing noise is higher, but that the decibel increase in total noise exposure (existing noise plus project noise) decreases. For example, if the existing noise exposure is 50 dBA L_{dn}, then an increase of more than 5 dB would result in an impact and an increase of more than 10 dB would result in a severe impact. Note that a "severe impact" is generally considered a significant impact under CEQA. In order to be conservative, the lower "impact" threshold is used in this analysis.

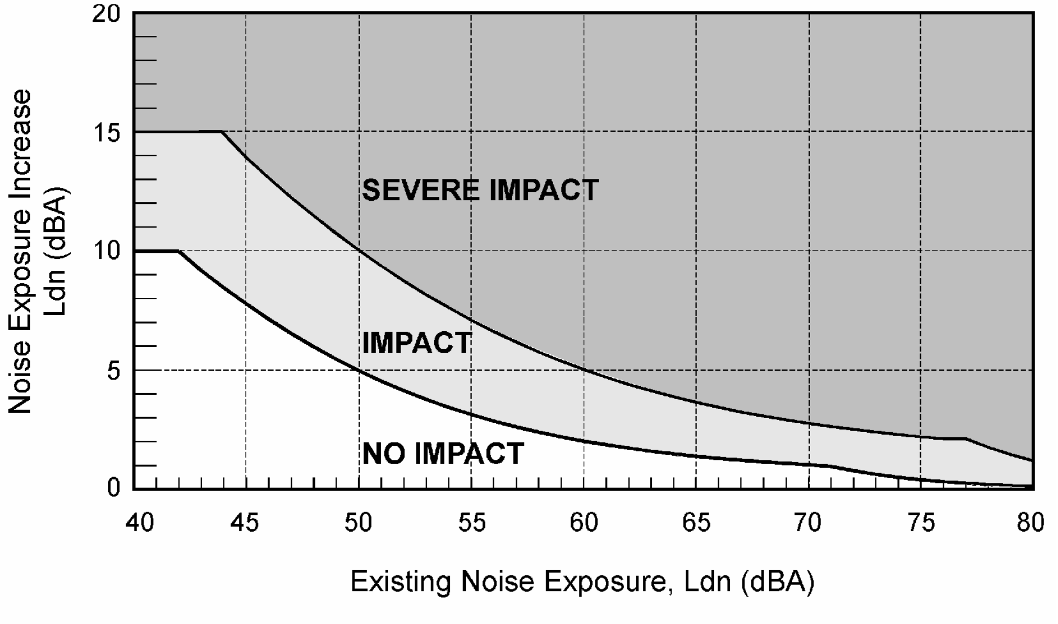


Figure 3: FTA Noise Impact Criteria for Category 1 and 2 Land Uses

Vibration

The FTA vibration criteria are based on the maximum ground vibration caused by a typical vehicle passby (e.g. an AC Transit bus or van). Unlike the FTA noise criteria, the vibration criteria are not based on a sliding scale. However, they do factor in the number of daily events. For relatively infrequent service, which is typical for commuter bus service, the FTA impact thresholds are 8 VdB higher than for frequent service. FTA defines "infrequent" service to be less than 70 events per day.

Table 2 shows FTA criteria for ground-borne vibration. Similar to the FTA noise criteria, the FTA vibration criteria are based on three land use categories. For residential buildings (Category 2), the threshold applicable to this project is 80 VdB.

Table 2: Ground-Borne Vibration and Noise Impact Criteria

Land Use Category	Ground-Borne Vibration (VdB re 1 micro inch/sec)		Ground-Borne Noise (dB re 20 micro Pa)	
	Frequent Events [1]	**Infrequent Events [2]**	**Frequent Events [1]**	**Infrequent Events [2]**
Category 1. Buildings where low ambient vibration is essential for interior operations.	65 VdB	65 VdB	--[3]	--[3]
Category 2. Residences and buildings where people normally sleep.	72 VdB	80 VdB	35 dBA	43 dBA
Category 3. Institutional land uses with primarily daytime use.	75 VdB	83 VdB	40 dBA	48 dBA

Notes:
[1] Frequent events are defined as more than 70 per day.
[2] Infrequent events are defined as less than 70 per day.
[3] Vibration sensitive equipment is not sensitive to ground-borne noise.

Table 2 also includes ground-borne noise thresholds, measured in terms of A-weighted decibels (dBA). Similar to ground-borne vibration, ground-borne noise thresholds are 8 dB higher for infrequent events compared to frequent events.

Measurements Locations & Procedures

Extensive noise and vibration measurements were taken in the project area. The purpose of these measurements was to identify the background noise levels and determine the amount of noise and vibration generated by three different vehicles. The measurements consisted of:

1. Long-Term Ambient Noise Measurements. Measurements of existing noise levels were taken over a 24-hour period at the following five residences:
    a. 1443 Hopkins: Near the northeast corner of the intersection of Hopkins Street and Gilman Street (AC Transit Line 9).
    b. 1440 Cedar: South side of Cedar Street, immediately west of Sacramento Street (AC Transit Line 52).

c. 487 Spruce: Uphill direction on Spruce Street between Michigan Avenue and Vassar Avenue (AC Transit Line 67).

d. 248 Trinity: Uphill direction on Trinity Avenue between Kenyon Avenue and Beloit Avenue (AC Transit Line 67).

e. 454 Beloit: Uphill direction on Beloit Avenue between Trinity Avenue and Colgate Avenue (AC Transit Line 67).

Figure 4 and Figure 5 are maps of the noise measurement sites. Long-term noise measurement data was used to determine the existing noise levels over the course of a day and the L_{dn} at representative locations throughout the project area. These five measurement locations are considered typical of the type and degree of noise exposure of sensitive receptors along existing and proposed AC Transit service routes potentially affected by the SDP and WCSP. Noise measurements were taken in the front yards of the residences at the approximate building setback distance from the roadway.

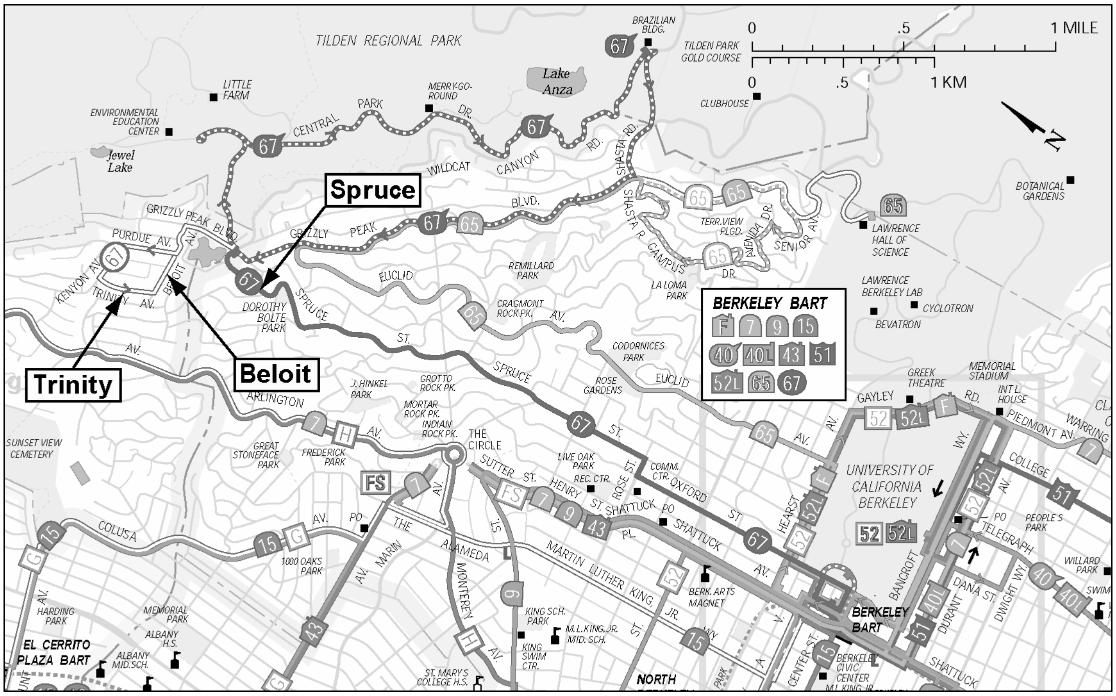


Figure 4: Map of Noise & Vibration Measurement Locations (1 of 2)

Figure 5: Map of Noise & Vibration Measurement Locations (2 of 2)

2. Short-Term Vehicle Noise Measurements. Multiple passbys of different vehicles were measured at each of the five sites listed above. The purpose of these tests was to measure vehicle noise levels at representative locations in the project area along existing and proposed routes and under normal operating conditions. The vehicles are:

   a. Van Hool: This new 30-foot bus will be replacing the Gillig bus.

   b. Gillig: This 30-foot diesel bus replaced gas vans on many AC Transit routes as part of the SDP.

   c. Gas Van: The last gasoline-powered van was phased out of service in late 2003.

   Figure 20 through Figure 22 in the Appendix are photographs of the different vehicles.

3. Controlled Vehicle Noise Measurements. Measurements of the three vehicles were performed at Golden Gate Fields following SAE International Standard J1470 (June 1998). The purpose of these tests was to measure noise levels under controlled conditions that are consistent with urban driving and that lead to reproducible noise emission results.
4. Vibration Measurements. Concurrent with the short-term vehicle noise measurements, vibration levels from all three vehicles were measured at each of the five sites.

Measurement Results

This section summarizes the results from the four sets of noise and vibration measurements.

Long-Term Noise Measurements

Existing noise levels are dominated by traffic on local roadways. Other noise sources include typical residential activities and limited overhead aircraft. Figure 6 is a graph of the hourly noise levels over the course of the measurement period. The graph extends from noon on day one to 3 p.m. (15:00) on day two.[1] As can be seen, noise levels are highest in areas with the most traffic (i.e., Hopkins and Cedar). Also, there is a substantial reduction (15 to 20 dB) in nighttime noise levels at all five sites.

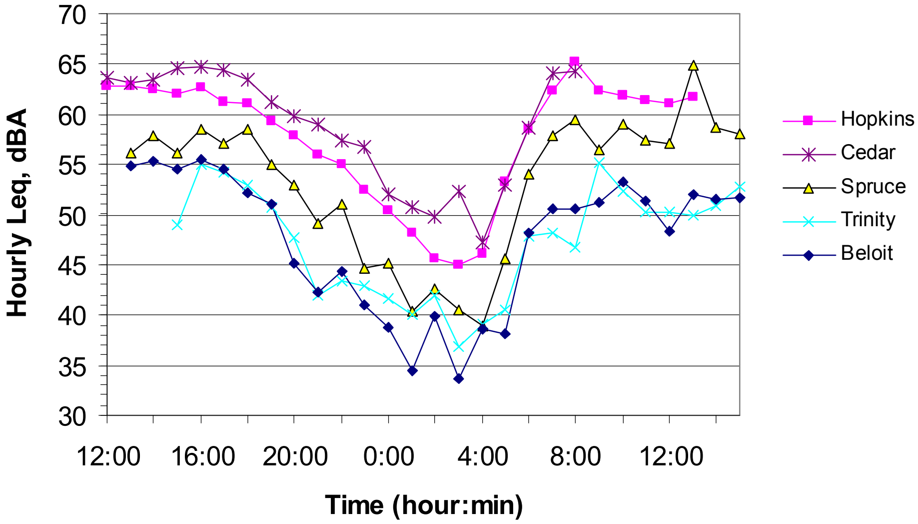


Figure 6: Hourly L_{eq} at Long-Term Noise Measurement Sites

Figure 7 shows the overall measurement results, including the L_{dn}, CNEL, and 24-hour L_{eq} over the measurement period. As expected, L_{dn} and CNEL values are within ± 1 dB at all sites. The 24-hour L_{eq} is lower than the L_{dn} and CNEL because it does not include any penalties for evening or nighttime noise.

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[1] Noise data for the Cedar site is a combination of data from two separate measurements.

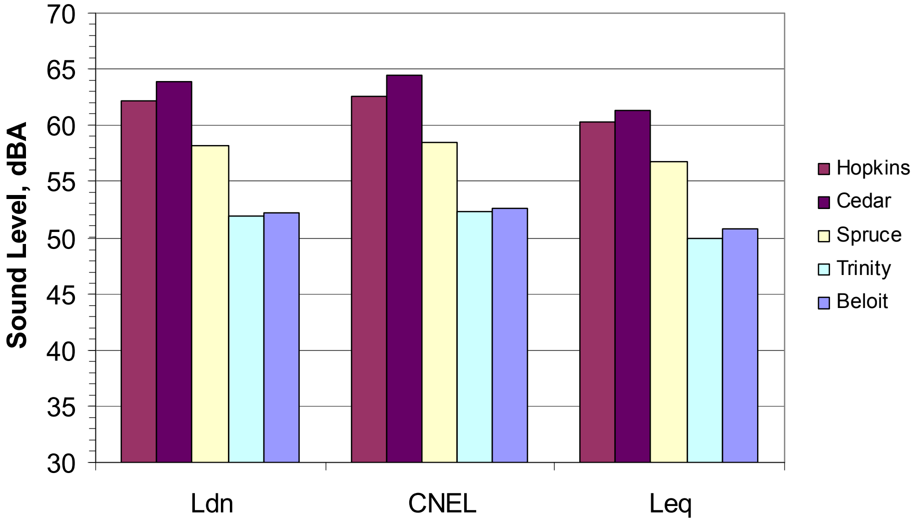

Figure 7: Overall Results for Long-Term Noise Measurement Sites

Short-Term Noise Measurements

Figure 8 shows the average SEL for each of the three vehicles at the five short-term noise measurement sites. Figure 9 is a similar graph showing the L_{max}. The Gillig was the loudest of the three vehicles in terms of both SEL and L_{max}. At most locations, noise levels from the Van Hool bus and gas van were very similar. Note that the term “near” or “far” refer to bus passbys on the near traffic lane and the far traffic lane, respectively. At the Beloit and Trinity sites, buses travel only in one direction. All three vehicles in the far lane at the Hopkins site generate higher sound levels than the vehicles in the near lane. This is because the far lane traffic is accelerating from the adjacent intersection and near lane traffic is slowing in advance of the intersection.

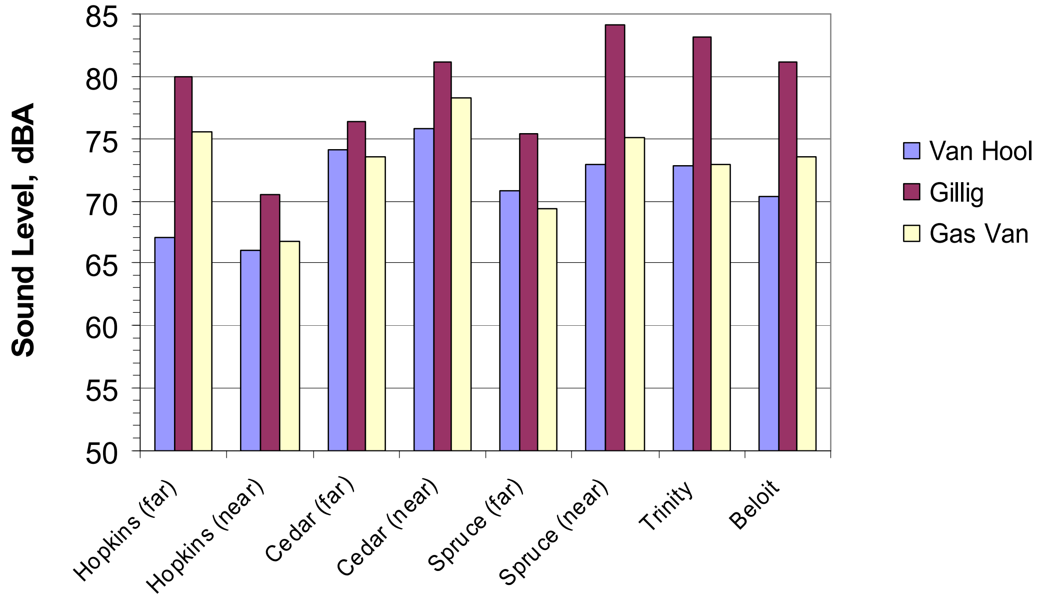

Figure 8: Average Vehicle SEL from Short-Term Measurement Sites

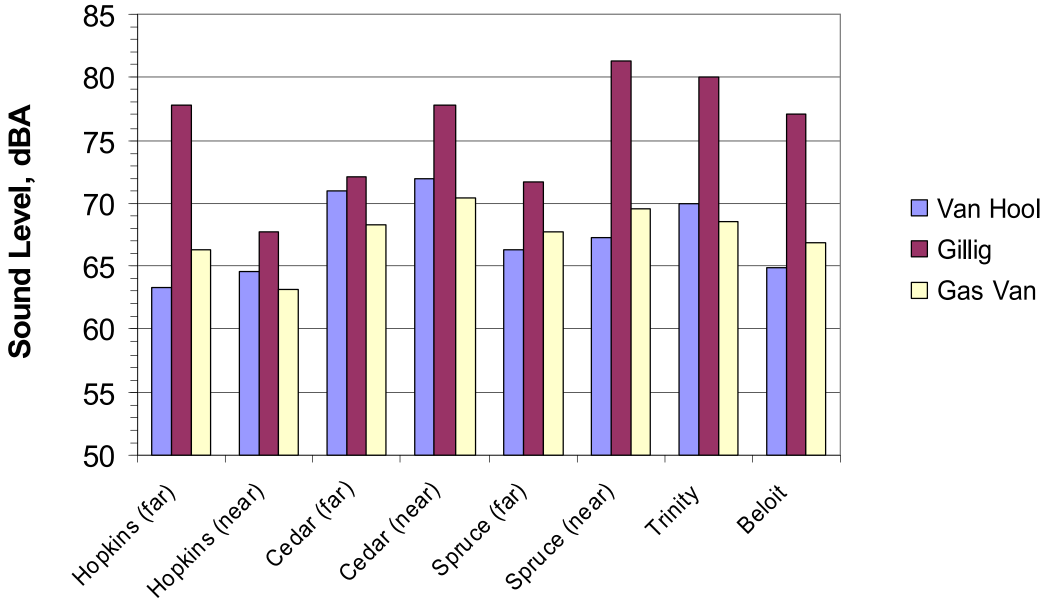

Figure 9: Average Vehicle Lmax from Short-Term Measurement Sites

Figure 10 shows the sound level versus time for a typical vehicle passbys. These data are from the Beloit measurement site. The graph shows that the Gillig bus is up to 15 dB louder than the Van Hool bus and that there is very little difference between the Van Hool bus and the gas van.

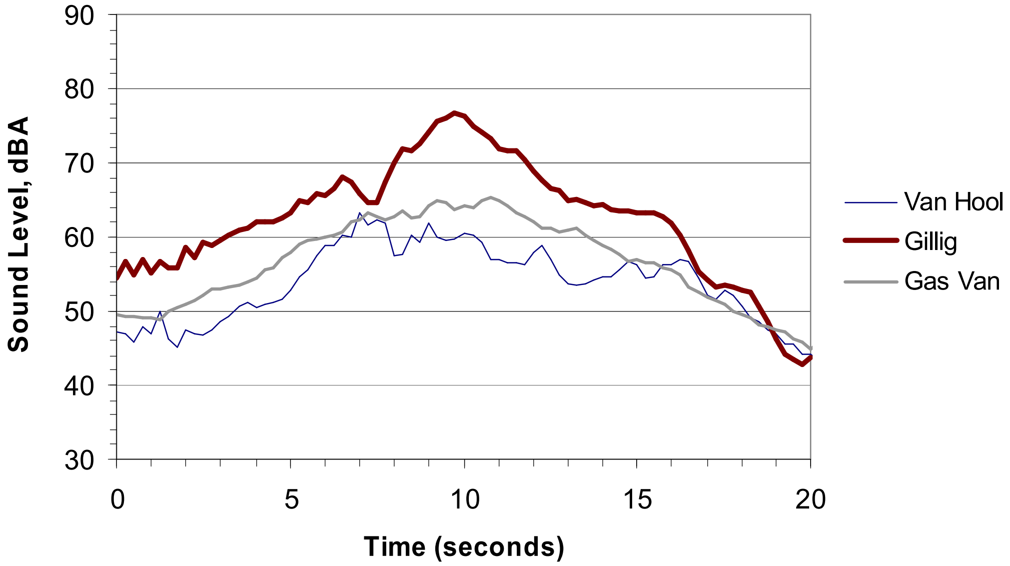

Figure 10: Typical Vehicle Passbys

Controlled Vehicle Noise Measurement Results

Measurements of each vehicle were taken in the parking lot at Golden Gates following SAE Standard J1470. Multiple measurements were taken at three different speeds: 19, 25, and 31 mph. For each measurement, noise levels were measured on both sides of the vehicles as they accelerated past the microphones. As can be seen in Figure 11, the gas van generates the highest noise levels at lower speeds whereas the Gillig bus was the loudest of the three vehicles operating at 31 mph. In all cases, the Van Hool bus generated the lowest noise levels.

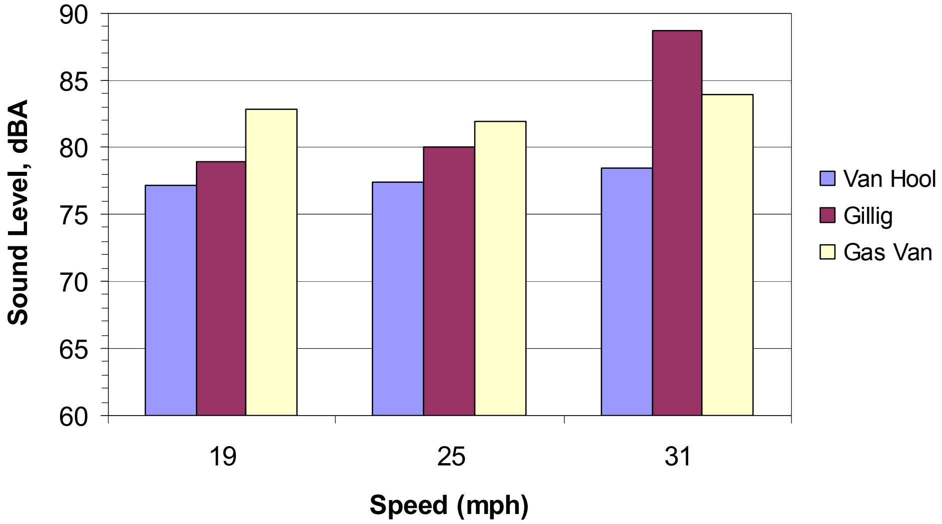

Figure 11: Average Maximum Sound Level (SPL) from Controlled Vehicle Noise Measurements

Vibration Measurements

Vibration measurements of the Van Hool, Gillig, and gas van were taken concurrent with the short-term noise measurements at each of the five sites. Vibration levels in the 6.3 to 16 Hz 1/3 octave bands are not available for the Spruce and Trinity sites because of an equipment problem. The vibration results at Cedar and Beloit were used to estimate the missing data as follows:

1. The average 1/3 octave band spectra at Beloit and Cedar were calculated.
2. The vibration levels in the 6.3 to 16 Hz 1/3 octave bands relative to the 20 Hz level were calculated (e.g., L_{REL} (6.3 Hz) = L_V (6.3 Hz) – L_V (20 Hz)).
3. The levels in the missing 1/3 octave bands were estimated using the relative levels from step 2 (e.g., $L_{EST-SRUCE}$ (6.3 HZ) = $_{LV-SPRUCE}$ (20 Hz) + L_{REL} (6.3 Hz)).

This process is illustrated in Table 3. Although this is an approximation that could introduce an error on the order of ± 2VdB in the overall levels at the Spruce and Trinity sites, the predicted levels are sufficiently below the impact threshold that any error introduced by this process will not affect the results of our impact assessment. The vibration levels below 20 Hz at the Spruce and Trinity sites should be sufficiently consistent with those at Beloit that additional measurements at these two sites are not necessary.

Figure 15 through Figure 14 are graphs of the 1/3 octave band frequency spectra for the three vehicles at Beloit, Cedar, Spruce, and Trinity sites. The graphs for Spruce and Trinity include the estimated levels in the 6.3 to 16 Hz 1/3 octave bands derived as discussed above.

Figure 16 is a graph of the quarter second vibration levels over a four minute period at the Hopkins site that included a Van Hool and Gillig passby. Vibration levels from both vehicles were below 50 VdB. The low vibration levels are a function of the relatively low speed of they approached the intersection of

Hopkins/Gilman. As can be seen in the graph, non-bus related traffic generated similar, and sometimes higher, vibration levels than the buses. Therefore, because of the low vibration levels of the vehicles and the high traffic volumes, a detailed analysis of vibration levels at the Hopkins site was not feasible.

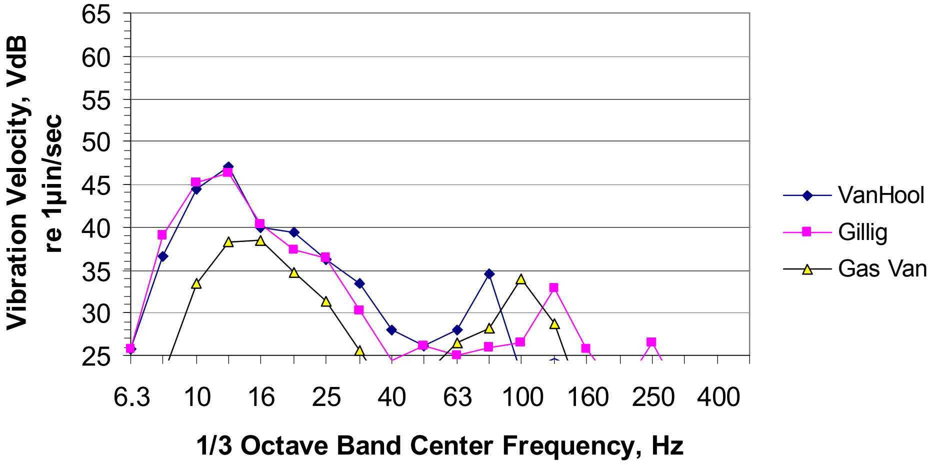

Figure 12: Frequency Spectra of Average Vehicle Passby at Cedar

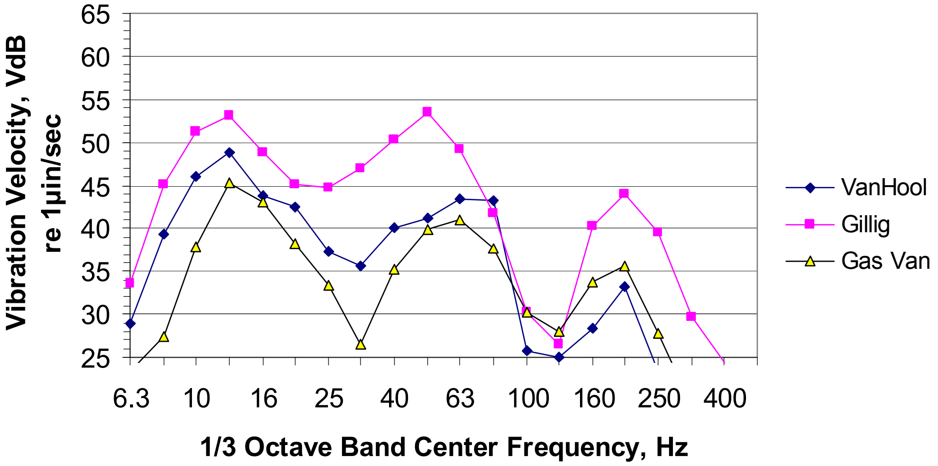

Figure 13: Frequency Spectra of Average Vehicle Passbys at Spruce

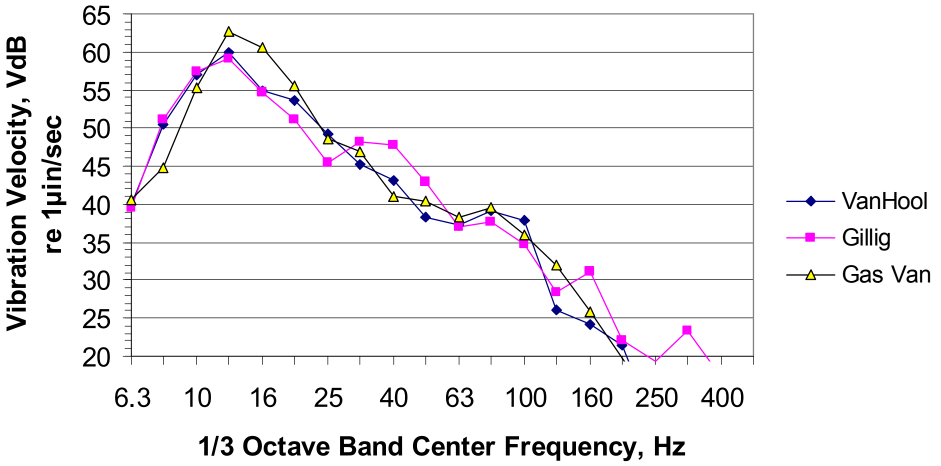

Figure 14: Frequency Spectra of Average Vehicle Passby at Trinity

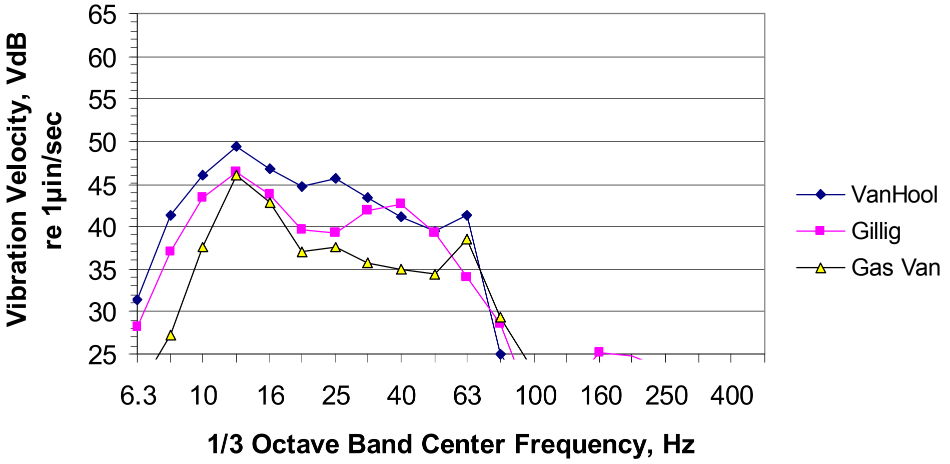

Figure 15: Frequency Spectra of Average Vehicle Passbys at Beloit

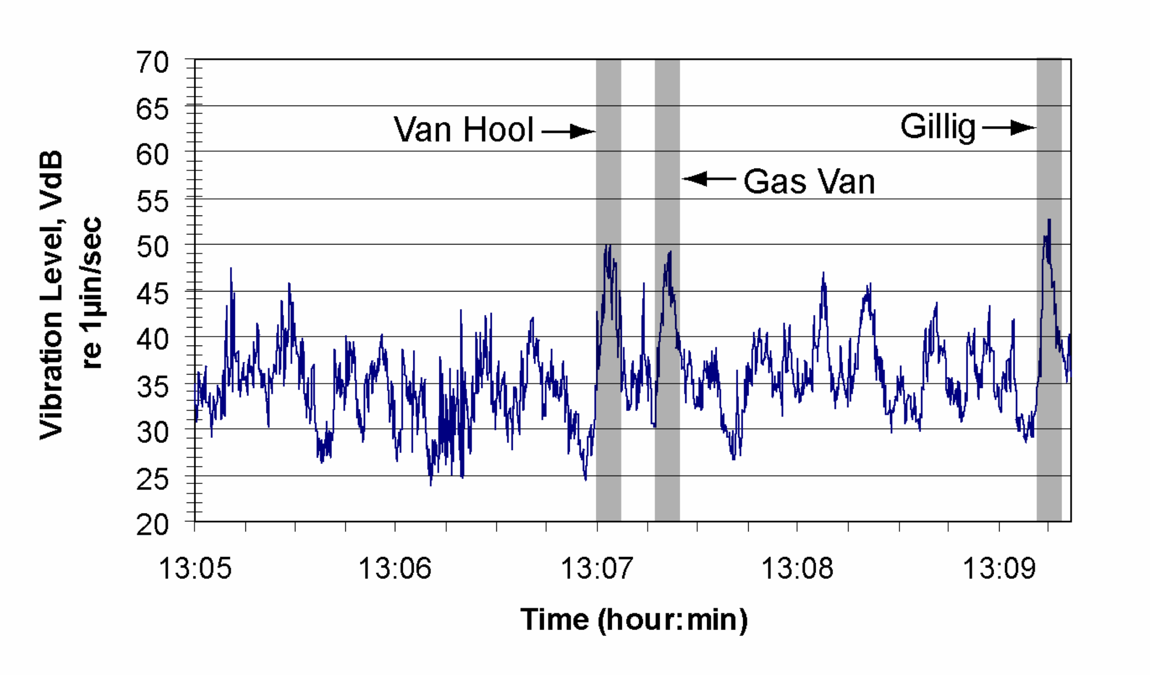

Figure 16: Vibration Time History - Hopkins

Table 3: Example Adjustments for 1/3 Octave Bands below 20 Hz at Spruce

	1/3 Octave Band, Center Frequency (Hz)					
	6.3	**8**	**10**	**12.5**	**16**	**20**
Average vibration levels at Cedar & Beloit for Van Hool bus	29	39	45	48	43	42
Level relative to 20 Hz	-13.5	-3.1	3.1	6.2	1.4	--
Measured vibration levels at Spruce for Van Hool bus	--	--	--	--	--	42
Estimated vibration levels at Spruce for Van Hool bus	29	40	46	49	44	42

Notes:
All vibration levels in terms of VdB, re 1µin/sec.

Figure 17 shows the overall vibration levels for each vehicle at the four measurement sites. As can be seen, vibration levels from the Van Hool bus were equal to or lower than the Gillig bus (which is currently in service) at two of the measurement sites and slightly higher (1 to 3 VdB) at the other two sites. The gas van generated the highest vibration levels at the Trinity site, which had the highest vibration levels for all three vehicles. We observed that:

- Vibration levels at Trinity were the highest of all five sites.
- Except at Spruce, the Gillig and Van Hool had similar vibration levels. This is due to vibration in the 25 to 60 Hz range.
- The Gas van tended to have lower vibration levels, except at Trinity.
- The vibration spectra vary substantially between sites, probably because of differences in soil properties.

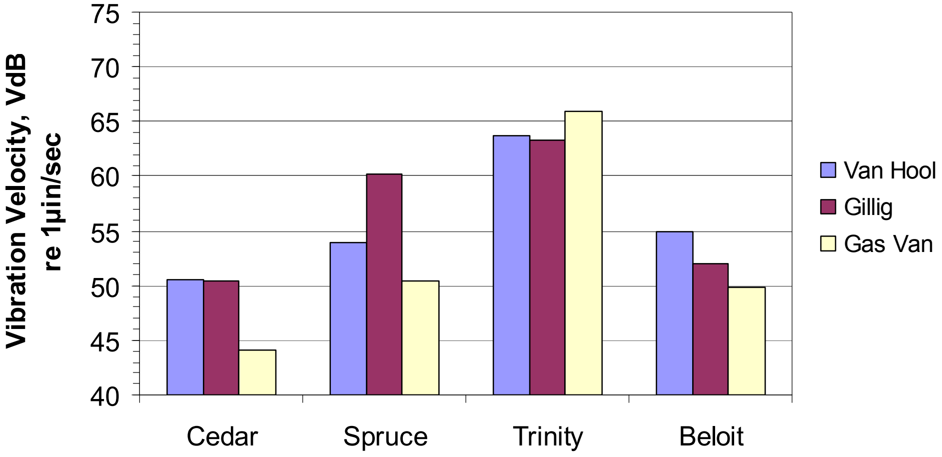

Figure 17: Overall Vibration Levels at Each Site

Predictions & Impacts

Noise

The following steps were taken to evaluate potential noise impacts resulting from the proposed project.

1. **Vehicle L_{dn}**: First, the L_{dn} from all three vehicles at each of the five measurement sites was calculated by:

$$Ldn = SEL + 10 \times log\left(N_{Day} + 10 \times N_{Night}\right) - 49.4$$

where SEL is the averaged measured SEL from the vehicle from the short-term noise measurements, N_{Day} is number of daytime (7 a.m. to 10 p.m.) bus passbys and N_{Night} is the number of nighttime (10 p.m. to 7 a.m.) bus passbys.

2. **Background L_{dn}**: Next, the background noise level (i.e., the noise levels without any vehicles) at each site was estimated by subtracting the Gillig L_{dn} from the measured L_{dn} as follows:[2]

$$Background\ Ldn = 10 \times \log\left(10^{\left(Measured\ Ldn/10\right)} - 10^{\left(Gillig\ Ldn/10\right)}\right)$$

   This provides a baseline to evaluate the noise impacts from adding bus service to a particular area.

3. **Predicted L_{dn}**: Lastly, the predicted L_{dn} (background plus vehicle) with the Van Hool bus and gas van was estimated as follows:

$$Predictd\ Ldn = 10 \times \log\left(10^{\left(Background\ Ldn/10\right)} + 10^{\left(Vehicle\ Ldn/10\right)}\right)$$

   Figure 18 shows the resulting predicted L_{dn} at all five measurement sites with each of the three vehicles. Also, the last column for each site shows the background L_{dn}.

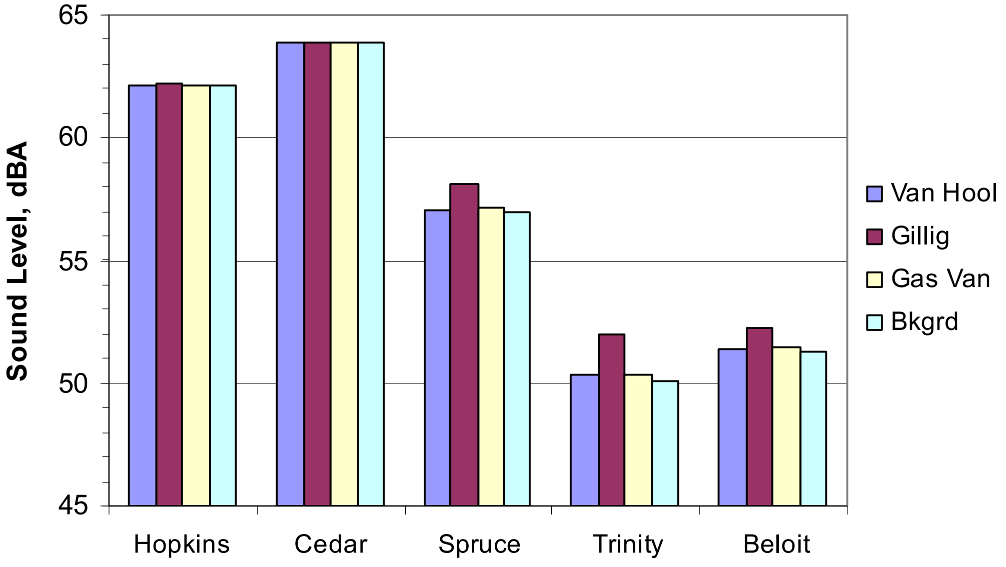

Figure 18: Predicted L_{dn} at Each Representative Receiver with Different Vehicles

4. **Impacts**: Potential noise impacts were predicted using the FTA noise impact criteria. Table 4 provides a summary of predicted noise levels and impacts for the five representative sites. The table lists the estimated background noise level, the vehicle L_{dn}, the predicted L_{dn}, the increase in noise levels caused by the introduction of service using each of the three vehicles, the FTA impact threshold for each site, and whether or not impacts are predicted.

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[2] Noise from the Gillig was removed because it currently operates on lines running in front of each of the measurement sites.

Due to the relatively low number of daily events, the contribution of each vehicle to the predicted L_{dn} is very small. At those locations with the highest background noise levels (Cedar and Hopkins), the addition of bus service has a negligible effect on the predicted noise levels, regardless of the vehicle. At the other three locations, the addition of transit service using the Van Hool or the gas van is predicted to increase the background L_{dn} by less than 0.5 dB. Predicted increases with the Gillig bus range from 1 to 2 dB. As can be seen in Table 4, impacts are not predicted at any of the representative receiver locations using any of the three vehicles. Predicted noise levels are highest with the Gillig bus and lowest with the Van Hool bus.

Table 4: Summary of Predicted Noise Levels (L_{dn}) and Impacts

Site	Vehicle	L_{dn}, dBA					
		Back-ground	Predicted, Bus/Van Only	Predicted [1]	Increase [2]	FTA Threshold [3]	Impact?
Hopkins	Van Hool	62	35	62	0.0	1.7	No
	Gillig	62	46	62	0.1		No
	Gas Van	62	42	62	0.0		No
Cedar	Van Hool	64	36	64	0.0	1.5	No
	Gillig	64	41	64	0.0		No
	Gas Van	64	38	64	0.0		No
Spruce	Van Hool	57	42	57	0.1	2.7	No
	Gillig	57	52	58	1.2		No
	Gas Van	57	43	57	0.2		No
Trinity	Van Hool	50	37	50	0.2	5.0	No
	Gillig	50	47	52	1.9		No
	Gas Van	50	37	50	0.2		No
Beloit	Van Hool	51	35	51	0.1	4.5	No
	Gillig	51	45	52	1.0		No
	Gas Van	51	38	51	0.2		No

Notes:
Background and predicted noise levels shown rounded to the nearest dB. Increases and FTA Thresholds shown to the nearest tenth of a dB.
[1] Predicted = Background L_{dn} + Bus/Van Only L_{dn}
[2] Increase = Predicted Ldn – Background L_{dn}
[3] FTA Threshold = maximum allowable increase in L_{dn} caused by project.

For Category 3 land uses (i.e., parks, schools, hospitals, etc.), the same process described above was followed to predict the peak hour L_{eq} at each of the measurement sites with and without AC Transit service. Figure 19 is a graph showing the peak hour L_{eq} with each vehicle. The final column for each site is the estimated existing background noise levels without any transit service. As can be seen, there is very little difference in the predicted noise levels with and without service. The largest increase is less than 2 dB at Trinity with the Gillig bus.

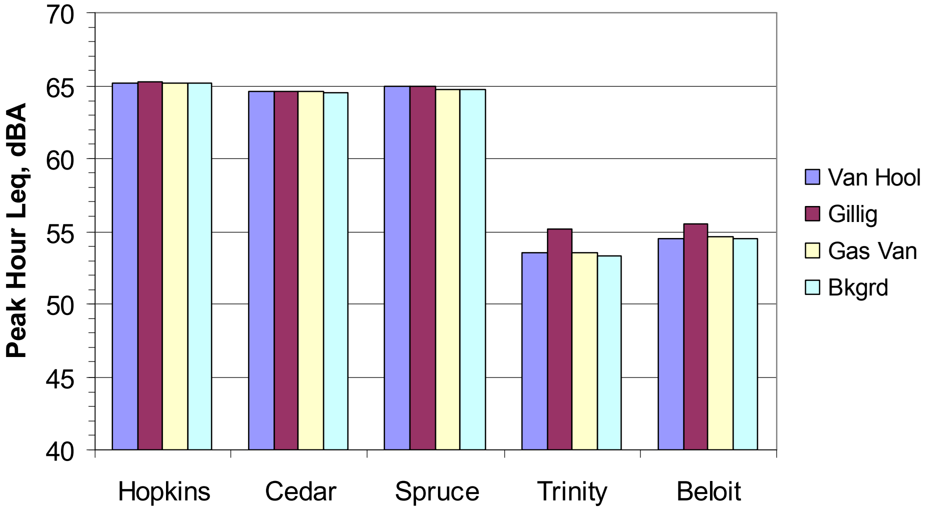

Figure 19: Predicted Peak Hour L_{eq} at Each Representative Receiver with Different Vehicles

Table 5 summarizes the results analysis and compares the predicted increases in the peak hour L_{eq} with the FTA impact criteria for Category 3 land uses. In summary, impacts are not predicted at any of the representative receiver locations using any of the three vehicles.

Table 5: Summary of Predicted Noise Levels (L_{eq}) and Impacts

Site	Vehicle	L_{eq}, dBA					
		Back-ground	Predicted, Bus/Van Only	Predicted [1]	Increase [2]	FTA Threshold [3]	Impact?
Hopkins	Van Hool	54	38	55	0.1	6.6	No
	Gillig	54	49	55	1.0		No
	Gas Van	54	41	55	0.2		No
Cedar	Van Hool	65	39	65	0.0	3.4	No
	Gillig	65	50	65	0.1		No
	Gas Van	65	45	65	0.0		No
Spruce	Van Hool	65	45	65	0.0	3.5	No
	Gillig	65	49	65	0.1		No
	Gas Van	65	46	65	0.1		No
Trinity	Van Hool	65	52	65	0.2	3.5	No
	Gillig	65	52	65	0.2		No
	Gas Van	65	44	65	0.0		No
Beloit	Van Hool	53	40	54	0.2	7.2	No
	Gillig	53	51	55	1.9		No
	Gas Van	53	40	54	0.2		No

Notes:
[2] Predicted = Background L_{eq} + Bus/Van Only L_{eq}
[2] Increase = Predicted L_{eq} – Background L_{eq}
[3] FTA Threshold = maximum allowable increase in L_{eq} caused by project.

Note: Predicted noise levels are shown rounded to the nearest dB, which is consistent with the accuracy of the measurements and predictions. The increases and FTA thresholds are shown to the nearest tenth of a dB, otherwise, the round-off value would often equal zero. The effects of round-off are why the noise levels with the gas van at the Hopkins site appear to increase by 1 dB (from a background of 54 dBA to a predicted of 55 dBA) when noise levels are only predicted to increase by 0.2 dB.

Vibration

Potential vibration impacts were analyzed by comparing the measured vibration levels relative to the appropriate FTA impact threshold. The vibration measurements were taken outside the residences; however, the criteria are based on interior vibration levels. Vibration levels will be changed when the ground vibration interacts with a building structure. Experience is that vibration levels on first floor spaces will typically be 0 to 3 VdB lower than outdoor vibration and that vibration in second floor spaces will sometimes be amplified by resonances in the building structure. A reasonable estimate is that second floor vibration will be 0 to 5 VdB greater than the outdoor vibration, although there are examples of second floor vibration being as much as 10 VdB great then the outdoor vibration.

For the purposes of this analysis, we have applied a conservative estimate that interior vibration is 5 VdB higher than the exterior vibration levels. Therefore, if the exterior vibration level was measured at 60 VdB, we estimate that the interior levels are likely to be 65 VdB or less.

There are currently less than 70 vehicle passbys at the vibration measurement locations. As a result, the "infrequent" vibration criterion of 80 VdB is applicable for the impact analysis. Table 6 is a summary of the predicted interior vibration levels based on the Van Hool bus. As can be seen, even with the conservative assumption regarding exterior-interior amplification, vibration levels are well below the impact threshold of 80 VdB. In fact, the predicted levels are below the "frequent" event criterion of 72 VdB. Although vibration levels may be perceptible inside some residences immediately adjacent to the bus service or when potholes form in the streets, impacts are not predicted as a result of the proposed project.

Table 6: Predicted Vibration Levels and Impacts – Van Hool

Location	Vibration Level, VdB re 1µin/sec				Impact? (Y/N)
	Exterior	Amplification	Interior	Threshold	
Hopkins [1]	--	+5	--	80	N
Cedar	51	+5	56	80	N
Spruce	54	+5	59	80	N
Trinity	64	+5	69	80	N
Beloit	55	+5	60	80	N

Note: Vibration levels from the Van Hool bus were not predicted for the Hopkins site because they were generally less than 50 VdB during the measurements and were difficult to separate from the background vibration.

Table 7 shows the predicted vibration levels with all three vehicles. The gas van has been replaced by the Gillig and is only shown for comparative purposes. In addition, the Van Hool bus will be replacing the Gillig buses. As can be seen, vibration levels are predicted to be the highest at Cedar, Trinity, and Beloit with the gas van and at Spruce with the Gillig. With all vehicles, predicted vibration levels are below the FTA impact threshold of 80 VdB.

Table 7: Predicted Vibration Levels – All Vehicles

	Vibration Velocity, VdB		
Location	**Van Hool**	**Gillig**	**Gas Van**
Hopkins [1]	--	--	--
Cedar	56	55	61
Spruce	59	65	64
Trinity	69	68	74
Beloit	60	57	65

Note: Vibration levels from the vehicles were not predicted for the Hopkins site because they were generally less than 50 VdB during the measurements and were difficult to separate from the background vibration.

Ground-Borne Noise

Table 8 lists the predicted ground-borne noise levels from AC Transit service using the Van Hool bus. These levels were estimated by applying the A-weighted scale to the average vibration frequency spectrum for the Van Hool bus at each of the representative receivers. Even with the +5 dB amplification of the vibration, the predicted ground-borne noise levels are well below the applicable FTA threshold of 43 dBA.

Table 8: Predicted Ground-Borne Noise Levels

Location	**Ground-Borne Noise Level, dBA**	**Threshold**	**Impact? (Y/N)**
Hopkins [1]	--	--	N
Cedar	23	43	N
Spruce	22	43	N
Trinity	32	43	N
Beloit	28	43	N

[1] Ground-borne noise levels from the Van Hool were not predicted for the Hopkins site because the measured vibration levels were generally less than 50 VdB and were difficult to separate from the background vibration.
Source: ATS Consulting, 2005

Table 9 compares the predicted ground-borne noise levels from the three vehicles. As can be seen, the Gillig buses generated the highest ground-borne noise levels while the gas van and the Van Hool bus are comparable.

Table 9: Predicted Ground-Borne Noise Levels – All Vehicles

Location	dBA		
	Van Hool	Gillig	Gas Van
Hopkins [1]			
Cedar	23	27	21
Spruce	22	28	23
Trinity	32	42	33
Beloit	28	30	28

[1] Ground-borne noise levels for the three vehicles were not predicted for the Hopkins site because the measure vibration levels were generally less than 50 VdB and were difficult to separate from the background vibration.

Source: ATS Consulting, 2005

APPENDIX

Figure 20: Photograph of Van Hool bus During Controlled Vehicle Noise Measurements

Figure 21: Photograph of Gillig Bus During Controlled Noise Measurements

Figure 22: Photograph of Gas Van During Controlled Noise Measurements