Chapter 8: Noise and Vibration

This chapter describes how noise and vibration were evaluated at the Cedar Hills Regional Landfill (CHRLF), and how changes associated with the alternatives could affect noise and vibration. Noise and vibration impacts were modeled and evaluated at landfill property lines and noise-sensitive residential locations within about 1,000 to 3,000 feet of the landfill.

This environmental review determined that there would be no significant unavoidable adverse impacts from noise and vibration as a result of implementing any of the action alternatives.

8.1 Affected Environment

Areas that may be potentially impacted by noise and vibration due to implementation of the alternatives include the surrounding residential community and CHRLF staff. The sources of potential noise and vibration would be construction and landfill operational equipment and vehicles, and the North Flare Station.

8.1.1 Characteristics of Noise

Sound travels through the air as waves of minute air pressure fluctuations caused by vibration, and travels away from the noise source as an expanding spherical surface. As a result, the energy contained in a sound wave is spread over an increasing area as it travels away from the source. This results in a decrease in loudness at greater distances from the noise source.

The decibel (dB) scale used to describe sound is a logarithmic scale that accounts for the large range of sound pressure levels in the environment. Most sounds consist of a broad range of sound frequencies. Among them, the A-weighted decibel (dBA) scale is most widely used for this purpose. Typical A-weighted noise levels for various types of sound sources are summarized in Table 8-1.

Varying noise levels are often described in terms of the equivalent sound level (L_{eq}). Equivalent sound levels are used to develop single-value descriptions of average noise exposure over stated periods of time. The L_{eq} data used for these average noise exposure descriptors are generally based on A-weighted sound level measurements.

The logarithmic nature of decibel scales is such that individual decibel ratings for different noise sources cannot be added directly to give the noise level for the combined noise source. For example, two noise sources that produce equal decibel ratings at a given location will produce a combined noise level that is approximately 3 dBA greater than either sound alone.

Table 8-1. Typical A-Weighted Noise Levels and Human Response

Sound Source (distance)	dBA[1]	Response Descriptor
Heavy truck (50 ft) Backhoe (50 ft) Excavator (50 ft) Grader (50 feet) Scrapers (50 ft)	80-92	Hearing damage (8-hour exposure)
Bulldozer (50 ft)	82-92	
Front-end loader (50 ft) Compactor (50 ft)	76-82	
Cranes (50 ft)	70-84	
Generators	70-80	
Freeway traffic (50 ft)	70	Intrusive
Light auto traffic (50 ft)	60	
Normal speech (15 ft)	50	Quiet
Living room, bedroom, library	40	
Soft whisper (15 ft)	30	Very quiet
Broadcasting studio	20	
	10	Just audible
	0	Threshold of hearing

[1] Typical A-weighted noise levels taken with a sound-level meter and expressed as decibels on the "A" scale. The "A" scale approximates the frequency response of the human ear.
Sources: U.S. CEQ 1970; U.S. DOT 1977; U.S. EPA 1971.

People generally perceive a 10 dBA increase as a doubling of loudness. For example, a 70 dBA sound will be perceived by an average person as twice as loud as a 60 dBA sound. People generally cannot detect differences of 1 dBA to 2 dBA between noise sources. Under ideal listening conditions, differences of 2 dBA or 3 dBA can be detected by some people. A 5 dBA change would probably be perceived by most people under normal listening conditions.

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

Noise levels at different distances can also be affected by factors other than the distance from the noise source, such as the following:

- Topographic features and structural barriers that absorb, reflect, or scatter sound waves can increase or decrease noise levels. Reflections off topographical features or buildings can sometimes result in higher noise levels (lower sound attenuation rates) than would normally be expected.

- Atmospheric conditions (wind speed and direction, humidity levels, and temperatures) can affect the degree to which sound is attenuated over distance. Temperature inversions and wind conditions can also diffract and focus a sound wave to a location at considerable distance from the noise source. Focusing effects are usually noticeable only for very intense noise sources, such as blasting operations.

The degree of impact also depends on the individual sensitivity of people listening and on ambient sound levels. For example, where background noise levels are high, introducing a new noise source tends to have less impact than in an environment where background noise levels are low. As a result of these factors, the existing noise environment can be highly variable depending on local conditions.

Noise Regulations and Criteria

The King County Code (KCC 12.88) establishes limits on the levels and durations of noise crossing property boundaries. Allowable maximum sound levels depend on the land use zoning designation of the noise source and the zoning designation of the receiving property. The King County noise limits are shown in Table 8-2.

This analysis evaluates noise according to the rural standards of the King County Code (KCC 12.88) because that is the most conservative standard. According to Chapter 12.88 of the King County Code, the allowable noise levels from the landfill at rural locations are 49 dBA during daytime hours (7 a.m. to 10 p.m. weekdays and 9 a.m. to 10 p.m. weekends) and 39 dBA during nighttime hours (10 p.m. to 7 a.m. weekdays and 10 p.m. to 9 a.m. weekends). Nighttime activity at the CHRLF is limited because disposal operations cease at 7:00 p.m. after daily cover is placed on the active face of the landfill. According to the King County Code, Chapter 12.88.040 (a)(1), construction noise may exceed maximum permissible sound levels (see Table 8-2) between 7 a.m. and 10 p.m. on weekdays and between 9 a.m. and 10 p.m. on weekends by no more than 25 dBA (King County 2009) at any time.

Table 8-2. King County Maximum Permissible Sound Levels (dBA)

District of Noise Source	District of Receiving Property			
	Rural Day/Night	Residential Day/Night	Commercial Day/Night	Industrial
Rural	49/39	52/42	55	57
Residential	52/42	55/45	57	60
Commercial	55/45	57/47	60	65
Industrial	57/47	60/50	65	70

King County Code, Chapter 12.88.020, Maximum Permissible Sound Levels (King County 2009)

8.1.2 Characteristics of Vibration

Ground-borne vibration may be induced by traffic and earthmoving machinery. The effects of ground-borne vibration may include perceptible movement of building floors, interference with vibration-sensitive instruments, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds.

Vibration consists of rapidly fluctuating motions. However, human response to vibration is a function of the average motion over a longer (but still short) time period, such as 1 second. The root mean square (RMS) amplitude of a motion over a 1-second period is commonly used to predict human response to vibration. For convenience, decibel notation is used to describe vibration velocities and acceleration relative to a reference level. For this analysis, vibration velocity is reported in decibels (VdB) relative to a reference of 10^{-6} inches per second (1 μ in/sec). Vibration acceleration is reported using a reference of 1 g_{rms} (9.807 m/s^2). In contrast to airborne noise, ground-borne vibration is not a phenomenon that most people experience every day. The background vibration level in residential areas is usually 50 VdB or lower – well below the threshold of perception for humans, which is around 65 VdB. Most perceptible indoor vibration is caused by sources within an individual building such as the operation of mechanical equipment, movement of people, or slamming of doors. Typical outdoor sources of perceptible ground-borne vibration include construction equipment, steel-wheeled trains, and traffic on rough roads.

Vibration Criteria

The vibration criteria used in the analysis of on-site landfill activities are consistent with Federal Transit Administration (FTA) guidelines published in the *Transit Noise and Vibration Impact Assessment*. Frequent events are defined as more than 70 events per day. Activities at CHRLF such as the use of earthmoving equipment and heavy truck movement fall under this category. Occasional events are defined as 30 to 70 events per day. Infrequent events are defined as fewer than 30 vibration events per day.

8.1.3 Methodology

Methodology for Evaluating Noise Impacts from Development of Alternatives

Noise impacts were evaluated at landfill property lines and noise-sensitive residential locations within about 1,000 to 3,000 feet of the landfill.

The Computer Aided Noise Abatement (Cadna-A 3.7.124) Model was used to predict the sound levels expected from the noise-producing equipment operating at the facility under several scenarios. A digital terrain map of the immediate area surrounding the landfill was used in the Cadna-A model. The digital terrain map assumed an elevation of 800 feet above sea level for the build-out elevation of the landfill, which would only occur near the end of the active life of the landfill cell. To be conservative, the model did not include the existing foliage and vegetation surrounding the landfill site. A propagation loss would be expected from the wooded areas between the site and the nearest residences. A standard value for attenuation due to this type of ground cover is 5 dBA for the first 100 feet, 5 additional dBA for the second 100 feet, to a 10 dBA maximum attenuation.

The following pieces of equipment were used in the model:

- Four scrapers (84 dBA at 50 feet from the source)
- Two trash compactors (78 dBA at 50 feet from the source)
- Two trash dozers (82 dBA at 50 feet from the source)
- One excavator (81 dBA at 50 feet from the source)

To develop a worst-case noise level scenario, it was assumed that all of the equipment would be operating simultaneously in one location at the working face of the landfill cell. Scenario 1 modeled all of the equipment operating in the southwest area of the landfill to represent noise associated with Alternative 1 – Southwest Corner Development, where the operations would be closest to the west property line and residences west of the landfill. Scenario 2 modeled all of the equipment operating in the southeast area of the landfill, representing Alternatives 4 (which was withdrawn from consideration) and 5, South Area Development, where landfill operations would be nearest the east property line and residences east of the landfill. In developing the worst-case scenario for the east side of the landfill, noise from operations on the ridgeline of the south main hill and excavation of the SE Pit Refuse Area, to the east of the ridge, were considered. It was concluded that noise levels from excavation on the ridge would be higher than those from the excavation of the SE Pit Refuse Area for two primary reasons. First is that the higher elevation of the ridgeline would allow noise to travel father and second is that fewer pieces of equipment would be needed to excavate in the SE Pit Refuse Area. Thus, excavation on the ridgeline was considered to represent the worst-case scenario.

Methodology for Evaluating Noise Impacts from the North Flare Station

Based on public comments received by KCSWD from nearby residents, a specific noise study (HDR 2009b) was conducted to evaluate noise impacts associated with the North Flare Station. Details of the study methodology are described in Appendix E2. The survey results show that the high-frequency noise emitted by the blowers at the North Flare Station radiates both upstream and downstream in the gas collection and distribution pipes. Additionally, using the dimensions of the flare towers, the resonance frequency was calculated and associated with the flares themselves. The calculated frequency matched the frequency measured during the site visit. This match provides confirmation that the blowers are the likely source of the high-frequency noise emissions.

Methodology for Evaluating Vibration Impacts from the Development of Alternatives

Vibration analysis was conducted (HDR 2009c) to assess the potential impact of ground-borne vibration associated with typical landfill activities. The analysis evaluated ground-borne vibration associated with transfer truck traffic off-site and landfill activities on-site to assess the potential impact to residences and structures in the vicinity. Potential ground-borne vibration associated with activities on-site were assessed using methods published by the Federal Transit Administration for construction-related vibration analyses (see Table 8-3). Ground-borne vibrations associated with transfer truck traffic were assessed using Federal Highway Administration (FHWA) methods published in the *Engineering Guidelines for the Analysis of Traffic-Induced Vibration* (FHWA 1978).

Table 8-3. Vibration Source Levels for Construction Equipment

Equipment	Peak Particle Velocity (PPV) at 25 feet (in/sec)	Approximate Velocity Level in decibels (Lv) at 25 feet
Large bulldozer	0.089	87
Loaded trucks	0.076	86
Small bulldozer	0.003	58

Source: FTA, *Transit Noise and Vibration Impact Assessment* (May 2006) (FTA-VA-90-1103-06), page 12-12

Landfill-induced vibration levels were evaluated at several distances including the property line, 500 feet beyond the property line, and at the nearest residence.

The detailed methodology and findings of the ground vibration analysis are described in Appendix E4.

8.1.4 Existing Noise Levels

The area around the landfill is hilly and heavily wooded in the west, north, south, and northeast boundaries of the site, and a 1,000-foot-wide forested buffer zone separates residences west of the landfill from landfill activity. To document existing noise levels, 15- to 20-minute noise measurements were taken at five locations on the property line of the landfill (see PL-1 through PL-5 in Figure 8-1). Other noise measurements were taken at residential locations on the east and west sides of the landfill (R-1 through R-9 in Figure 8-1). Noise measurements are shown in Table 8-4.

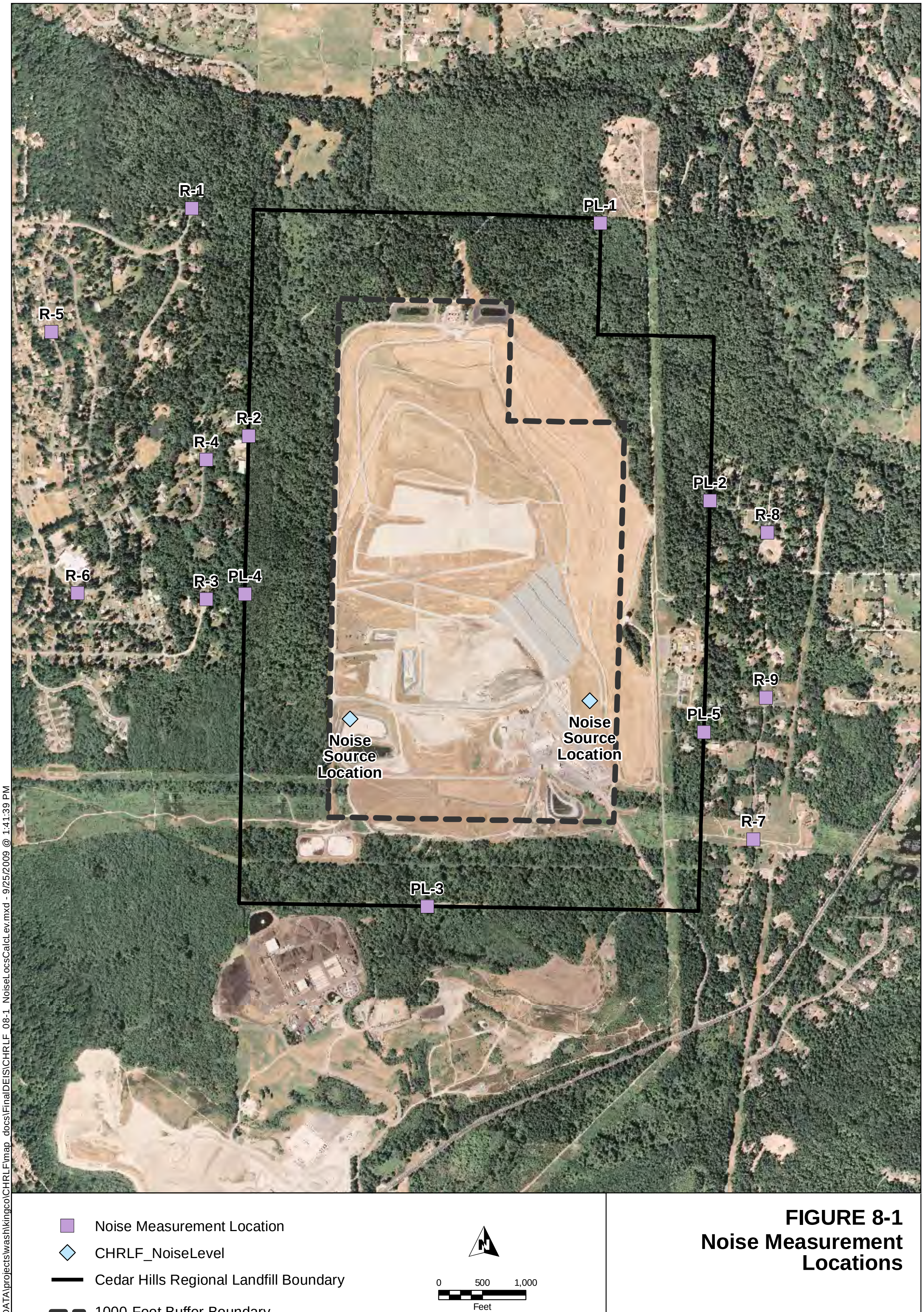


FIGURE 8-1
Noise Measurement Locations

Table 8-4. Measured Noise Levels

Monitoring Location	Land Use	Location	Distance (feet) to Active Landfill	Measured Noise Level (dBA)
PL-1	NA	Northeast Property Line	1,500	36
PL-2	NA	East Property Line	1,000	37
PL-3	NA	South Property Line	1,000	48
PL-4	NA	West Property Line	1,000	39
PL-5	NA	East Property Line	1,000	40
R-1	Residential	14424 209th PL SE	2,000	38
R-2	Residential	21117 SE 155th PL	1,000	47
R-3	Residential	21012 SE 159th ST	1,375	44
R-4	Residential	21105 SE 155th PL	1,500	38
R-5	Residential	1408 205th Ave SE	3,190	47
R-6	Residential	20429 SE 157th St.	2,875	54 (school with nearby residential construction)
R-7	Residential	16423 230th Ave. SE	1,500	49
R-8	Residential	22905 SE 154th St.	1,625	47
R-9	Residential	16020 230th Ave SE	1,625	45

PL- Property Line Location
R- Residential Receptor Location

Measured noise levels at the property line and at residential locations nearest to the facility were typical of suburban environments and ranged from about 36 dBA to 54 dBA. All measured noise levels at the property line locations were within the limits established in the King County Code for rural noise sources affecting rural land uses.

Residents in the project area commented on low-frequency and high-frequency noise emissions from the North Flare Station. Noise emissions levels from the existing blowers and flares at the station were observed during site visits on July 20 and 21, 2009. During the site visits, it was determined that the likely source of the low-frequency noise is the 40-foot-tall flare towers, each 12 feet in diameter. It was also determined that the likely source of the high-frequency noise is the blowers that move gas from the landfill to the flares (HDR 2009b).

8.2 Environmental Impacts

8.2.1 Direct Impacts

Action Alternatives – Noise and Vibration Impacts

Western Landfill

Under all action alternatives, landfilling activities would begin in the southwest corner of the facility, proceeding east as individual cells reach capacity. The closest residences west of the landfill are about 1,800 to 2,500 feet from the westernmost edge of the new disposal cell. As development of the cell moves to the east, operational noise levels would be lower due to the increased distance to the nearest residences (assuming the same equipment was being used).

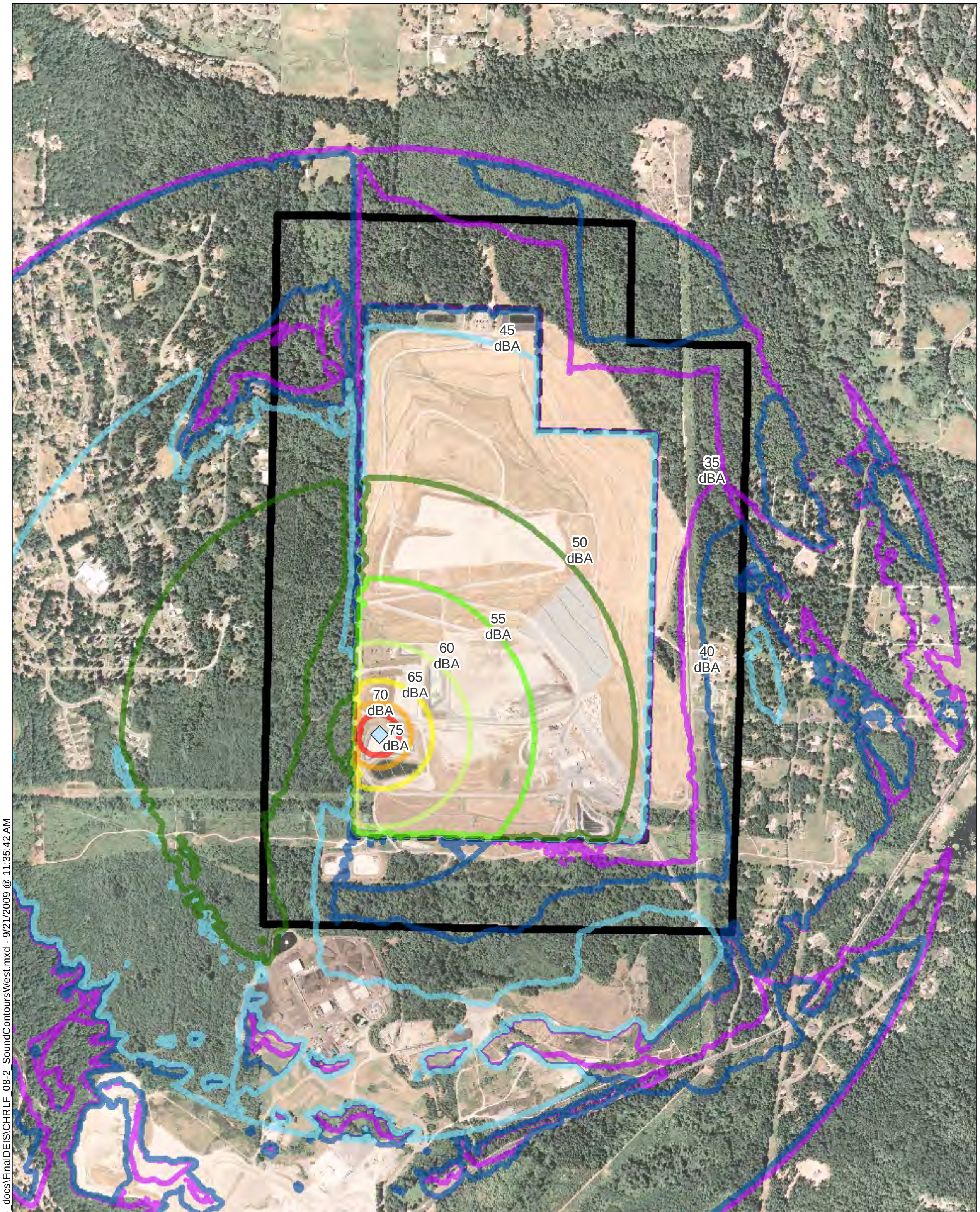
As described above, all of the landfill equipment operating simultaneously would produce an average noise level of 92 dBA at a distance of 50 feet from the source (U.S. EPA 1971; Toth 1979; Gharabegian et al. 1985). As shown in Figure 8-2, the Cadna noise model predicts that the resulting noise level at the west property line would be about 50 dBA without any attenuation due to the intervening vegetation. Therefore, the noise level at the west property line is predicted to be as low 40 dBA when attenuation due to the intervening vegetation is included. At the nearest residences west of the landfill, predicted noise levels are between 35 dBA and 45 dBA (including attenuation due to the dense intervening vegetation).

As shown in Figure 8-3, the results of the ground-borne vibration analysis demonstrate that vibration levels associated with on-site landfill activities and off-site hauling traffic associated with the CHRLF would not affect the nearest residences when compared with thresholds for human annoyance and structural damage. Calculated vibration levels associated with CHRLF work on-site are not predicted to exceed typical ambient vibration levels beyond the property line and would be imperceptible to the nearest residences. The 1,000-foot-wide buffer zone would provide sufficient distance to protect nearby residences from structural damage and annoyance.

Results from the ground-borne vibration analysis demonstrate that predictable vibration levels associated with heavy truck traffic activities near the landfill would not affect nearby residences when compared with thresholds for human annoyance. Project-related, traffic-induced, ground-borne vibration would not cause structural or cosmetic damage to residences.

Eastern Landfill

Figure 8-4 shows the noise levels in the eastern portion of the landfill predicted by the Cadna noise model. The worst-case noise scenario predicted by the model would occur during construction on the ridgeline formed by the Southwest Main Hill and East Main Hill refuse areas (proposed in Alternative 4, which was withdrawn, and Alternative 5). The model predicted that activity on the ridgeline would result in a noise level of about 50 dBA at the easternmost boundary in the absence of any on-site attenuation measures. The maximum permissible noise level for a rural noise source affecting a rural noise district is 49 dBA. Part of the reason for the increased noise level is the higher elevation of the activity, which would raise it above existing attenuation features such as forested land, berms, and other site elements. Noise levels for operations under all other alternatives, including excavation of the



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75 dBA
70 dBA
65 dBA
60 dBA
55 dBA
50 dBA
45 dBA
40 dBA
35 dBA

Noise Source Location
Cedar Hills Regional Landfill Boundary
1000-Foot Buffer Boundary

N

0 800 1,600
Feet

Note: Noise levels shown do not include up to 10 dBA of additonal attenuation due to intervening vegetation.

FIGURE 8-2
Estimated Sound Contours Western Worst-Case Scenario

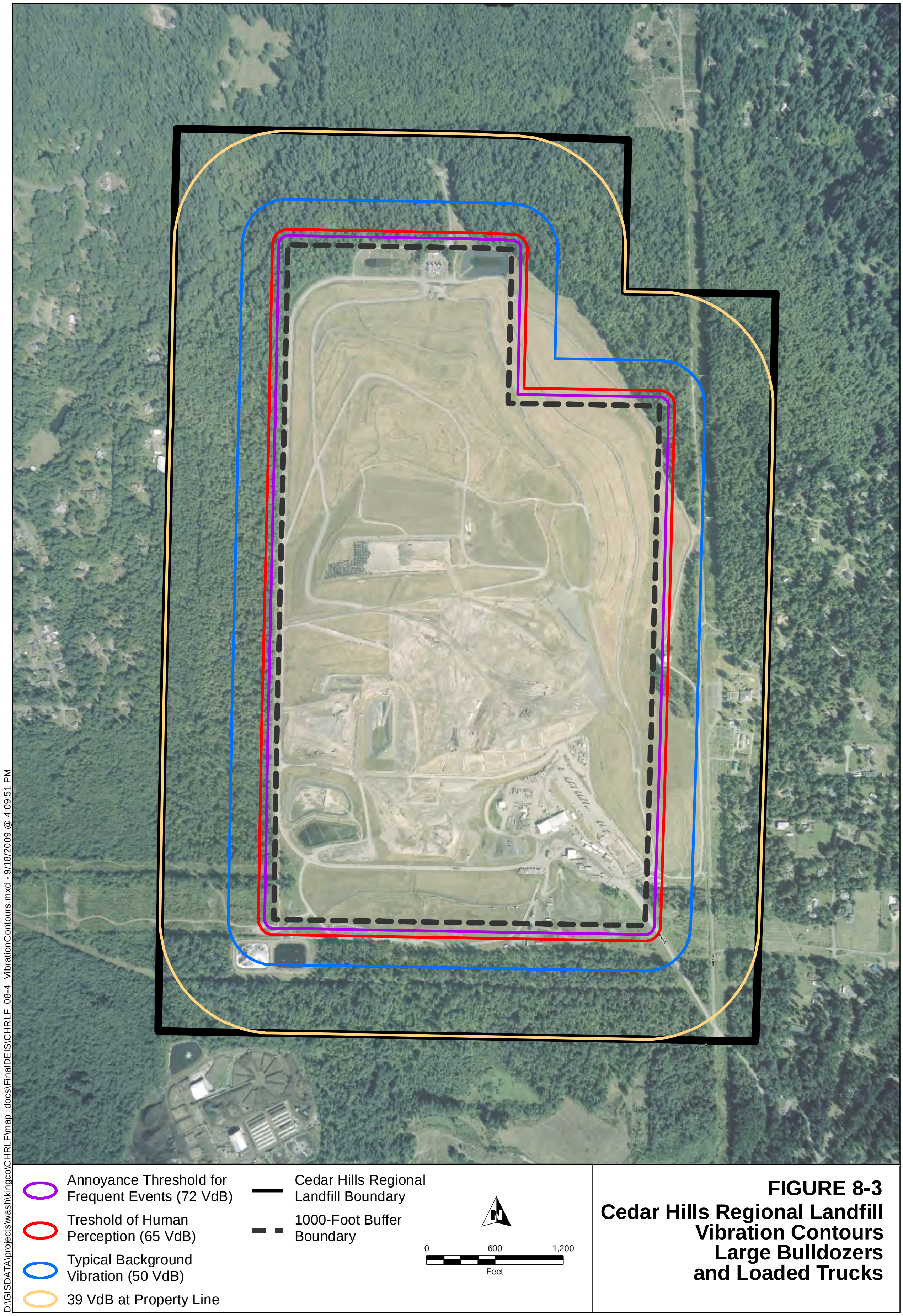

FIGURE 8-3
Cedar Hills Regional Landfill Vibration Contours Large Bulldozers and Loaded Trucks

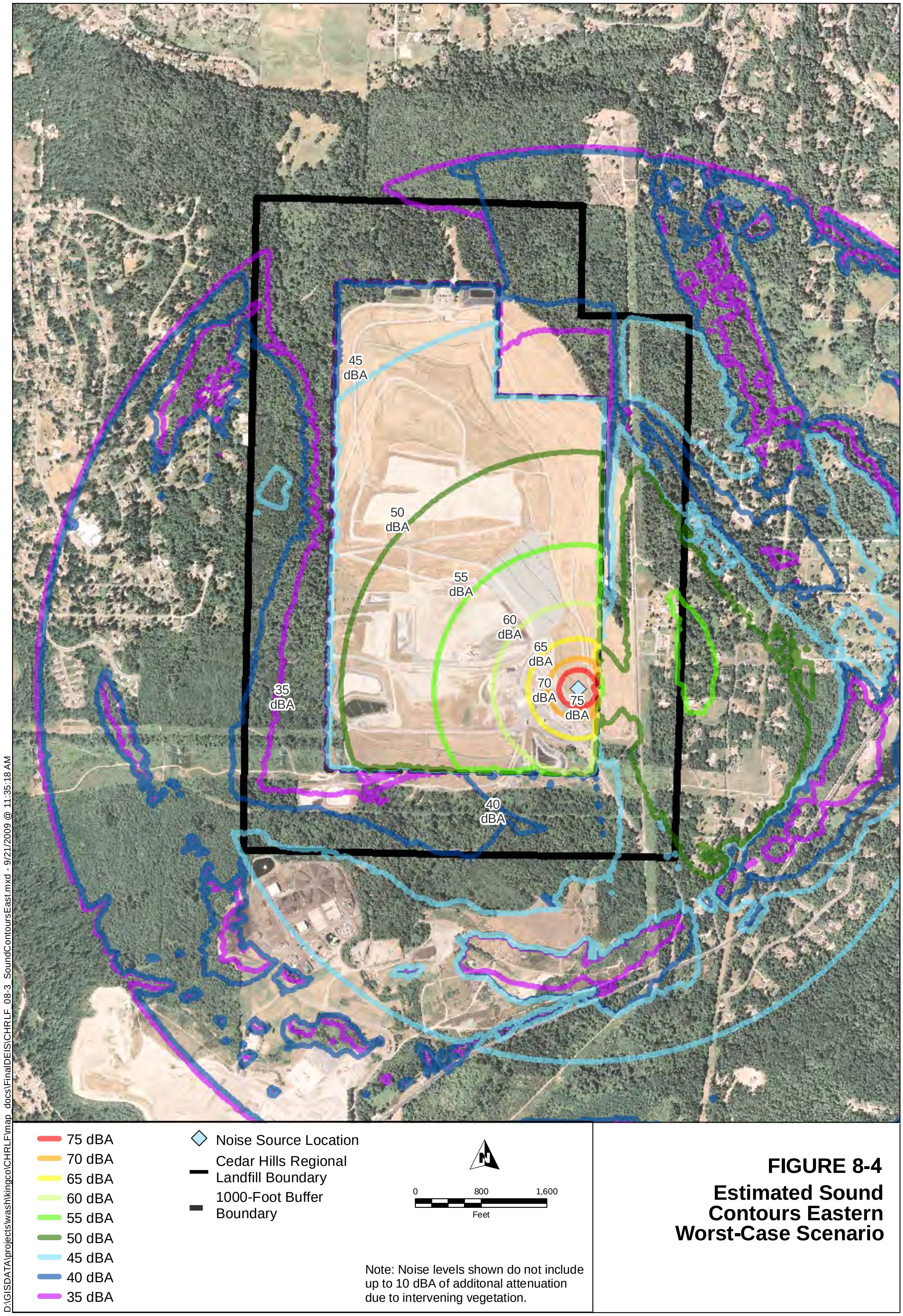

FIGURE 8-4
Estimated Sound Contours Eastern Worst-Case Scenario

SE Pit Refuse Area, fall within the permissible noise levels. For any alternative selected that involves activity on the ridgeline or excavation of the SE Pit Refuse Area, necessary noise attenuation measures would be planned and submitted for approval by Public Health before any construction activities occurred.

Under Alternatives 1 and 2, the newly developed disposal area extends progressively east to the maintenance and administration facilities. Under these alternatives, excavation and restoration of the SE Pit Refuse Area would be optional.

Under Alternative 3, the developed portion of the southwest main hill would not be excavated, but would be lined and overlain with solid waste. All activity would take place on the western side of the hill. Excavation and restoration of the SE Pit Refuse Area is optional.

Under Alternative 5, the new disposal area would extend to the border of the Southwest Main Hill Refuse Area and would involve construction activity on the ridgeline, as discussed. The developed portion of the southwest main hill would not be excavated, but would be lined and overlain with solid waste. Alternative 5 does not propose excavation in the SE Pit Refuse Area.

As with development in the eastern landfill area, the results of the ground-borne vibration analysis demonstrate that vibration levels associated with on-site landfill activities and off-site hauling traffic associated with the CHRLF would not affect the nearest residences when compared with thresholds for human annoyance and structural damage (Figure 8-3).

No Action Alternative – Noise and Vibration Impacts

Under the No Action Alternative, future development and landfilling operation at CHRLF would be limited to Area 7 and the filling of the top lifts of Areas 5 and 6 until 2018. Noise levels and vibration under the No Action Alternative would be similar to existing conditions. Based on KCSWD's noise monitoring results, noise levels would not exceed King County's maximum noise limit of 49 dBA (daytime) at the nearest western property line (not including any attenuation) as required for a rural noise source (landfill operations) affecting a rural noise district.

Operational Noise Impacts

From an operating perspective for noise impacts, the primary difference in the action alternatives is the duration and area of landfill operations that would take place under each alternative. Therefore, depending on which alternative was selected, the active life of the landfill would be extended from about 3 years under Alternative 1 to about 13 years under Alternative 5. This impact analysis assumes that the same amount of landfill construction and operational equipment would be used for each alternative and, therefore, noise levels at the landfill property line would remain within the King County noise limits.

North Flare Station

The noise emitted by flares at the North Flare Station is dominated by low-frequency energy. Through model analysis, it was determined that the low-frequency noise emitted by the flare stacks is created by the resonance of the flare stack. Resonance refers to the tendency of a system (in this situation a flare) to vibrate more at larger amplitudes at particular frequencies than at others when excited by an equal force. The low-frequency resonance created by the flares at the North Flare Station is difficult to attenuate because the resonance is a function of the physical dimensions of the 40-foot-tall, 12-foot-wide flares. There are no practical source or path mitigation options to abate the low-frequency noise from this station's flares. Typical path mitigation, such as sound barriers and partial enclosures, are ineffective at low frequencies due to diffraction and ground-borne propagation. However, use of the North Flare Station has diminished because the new landfill gas-to-energy system is operational. The North Flare Station is a back-up system and will only be used in emergency or maintenance conditions, effectively eliminating the low-frequency noise emissions.

The noise emitted by the gas collection and distribution system through blowers at the North Flare Station is dominated by mid-frequency energy, around the 1-kHz band. KCSWD regularly monitors along the property line for this noise, and the average noise level remains below 40 dBA.

Bio Energy (Washington), LLC Gas-to-Energy Facility

As discussed in Chapter 1, Bio Energy (Washington), LLC (BEW) operates an independent gas-to-energy facility on the CHRLF property and is responsible for compliance with all regulatory requirements, including the King County Noise Code (KCC12.88.020). BEW has gone through a separate environmental review process for the plant under the State Environmental Protection Act, which included noise impact evaluation and mitigation actions. For more information about the BEW facility, inquiries can be made directly to BEW at 425-392-3918, or at www.bioenergy-wa.com.

8.2.2 Indirect and Cumulative Impacts

Because there would be no direct impacts from noise and vibration as a result of implementing any of the alternatives, no indirect or cumulative impacts would be anticipated.

8.3 Mitigation Measures

Noise impacts from the action alternatives under Scenario 2 (east side of the landfill) may require noise attenuation measures. To minimize impacts, a noise attenuation plan would be prepared and approved by Public Health prior to beginning any construction activities in this area. KCSWD's construction contracts have provisions that limit hours of operation and permissible noise levels.

To further reduce noise associated with the gas collection system of the North Flare Station, KCSWD would install acoustical pipe cladding.

8.4 Significant Unavoidable Adverse Impacts

There would be no significant unavoidable adverse impacts from noise and vibration as a result of implementing any of the alternatives.