

## Sound levels of fire equipment used at Grand Canyon National Park



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## **INTRODUCTION**

Fire management activities use power tools and vehicles which can create significant noise. Prescribed fire preparation includes the use of chainsaws to thin trees. Chainsaws are also used post-fire and at other times to clear roads of fallen trees. Water pumps are used in fire suppression. Diesel and gasoline trucks and ATVs are used to access fire activity areas. These activities often occur in the backcountry where natural ambient levels (no human-caused noise) in forested areas can average as low as 23 dBA (Levy and Falzarano 2007). In an effort to quantify the noise from equipment used in fire management for the Fire Management Plan, acoustic measurements were taken.

## **METHODS**

### **Location**

On 12 March 2007, the Fire and Aviation Program operated equipment as it would typically be used in fire preparation and suppression settings and sound data were collected. Sound levels were measured from several distances to determine how the sounds attenuate with distance in an open forest environment.

Sound systems were set up 50 ft (Site A), 100 ft (Site B), and 400 ft (Site C) from the sound source (Figure 1) off of Rowe Well Road at a location approximately 2 miles southwest of Grand Canyon Village. Sound data were collected from stationary equipment for at least one minute at idle, and at least one minute at full throttle. Chainsaws were also measured while cutting through wood. For the sound measurements of vehicles, the systems were relocated to an area nearer to Rowe Well Road (Figure 1) where data could be collected at idle and while moving. Vehicles drove past the systems twice, maintaining a constant speed.

### **Sound Measurement Equipment**

The sound systems consisted of an ANSI Type 1 Larson-Davis sound level meter (model 824, powered by three AA batteries), a microphone (GRAS 40AE; protected by a Larson-Davis foam windscreen) and a preamplifier (Larson-Davis 902; Figure 2). The sound level meter and microphone were mounted on a tripod at a height of ~1.5 m, to mimic the average ear height of a person. The sound level meters collect sound pressure level data every second and are known to be accurate within 1 dBA. While measuring vehicles, a Panasonic CF-18 Toughbook laptop (powered by a 12-volt battery) was added to the system to collect sample digital recordings. Recordings were collected for 60 seconds with 10-20 second intervals between recordings for the system to save the data to hard disk.

### **Acoustic Terms**

*Sound pressure level (L)* – the logarithmic expression of sound pressure, or loudness; often reported in decibels (dB).

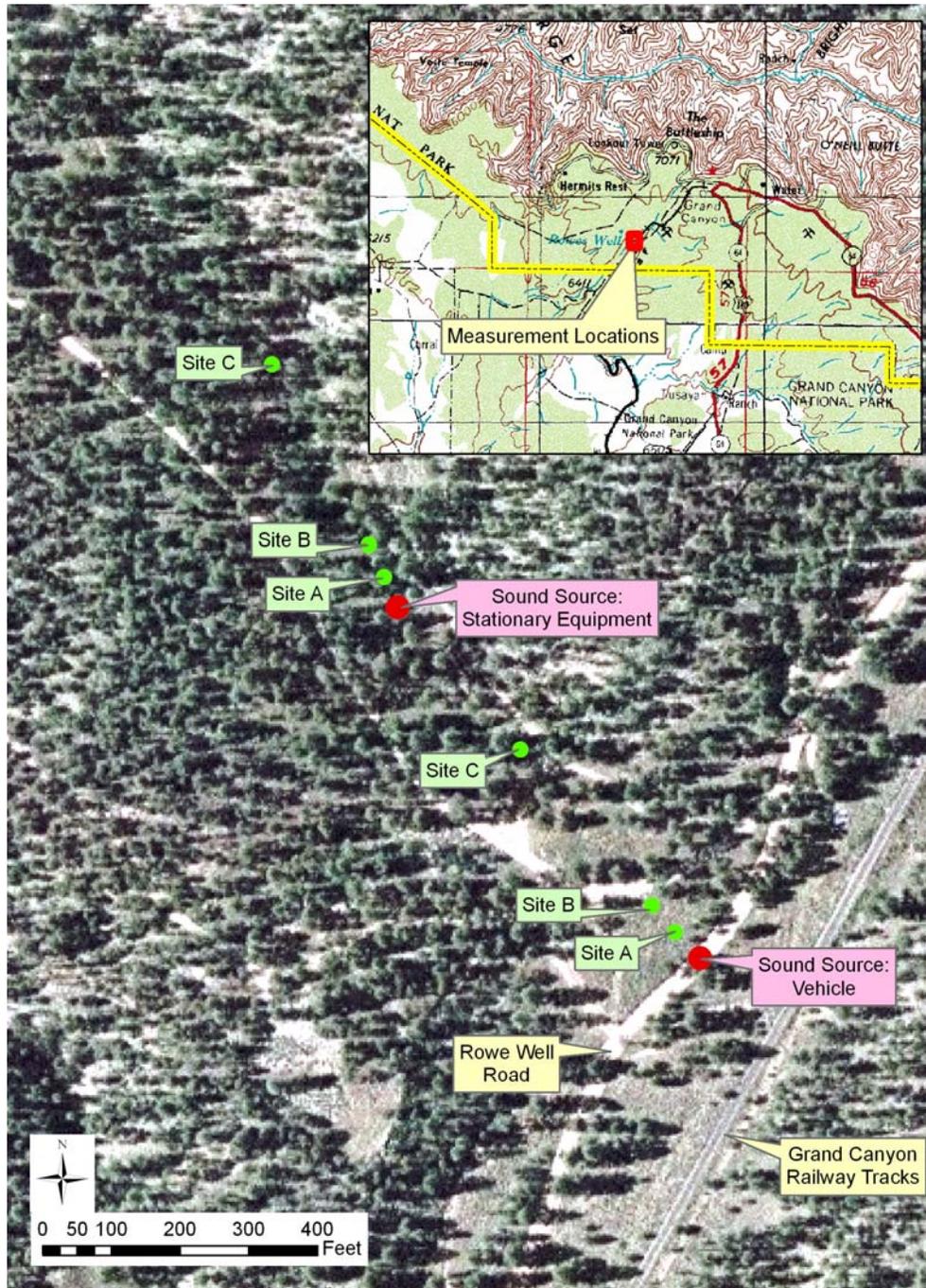
*Frequency* – the number of times per second that the wave of sound repeats itself; responsible for the pitch or tone of the sound; often expressed in cycles per second, or Hertz (Hz).

*dBA* – A-weighting de-emphasizes the high (6300 Hz and above) and low (below 1000 Hz) frequencies in an effort to simulate the relative response of human hearing.

*L<sub>max</sub>* – maximum sound pressure level reported in decibels adjusted for human hearing, or dBA.

*L<sub>eq</sub>* – energy equivalent sound pressure level; the level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period reported in dBA.

*One-third octave band* – a frequency band whose cut-off frequencies have a ratio of 2 to one-third (approximately 1.26); humans have the ability to differentiate one-third octaves.



**Figure 1. Locations of sound source and measurement equipment of stationary fire equipment and vehicles.**



**Figure 2. Sound level meter with microphone on tripod, 50 ft (Site A) from sound source.**

## Data Analysis

During data collection, extraneous sounds (passing aircraft, trucks, gusts of wind) were identified and the time and duration were noted. Data was not included in analysis when extraneous sounds may have affected the sound measurement of the fire equipment. The same time intervals were analyzed for sites A, B, and C. An attempt was made to analyze at least one minute of data for each of the sound sources, although there were instances when less than a minute of data was analyzed because of interfering sounds.

For each of the sound sources the  $L_{max}$  was determined. Because of micro-habitat environmental factors (e.g., wind in trees, insect buzzing near microphone) the  $L_{max}$  at further sites may have occurred at a different time and been *higher* than at the closest site, contradicting theory and common sense that sound levels decrease with increasing distance from the sound source. Therefore, the  $L_{max}$  at the closest site was determined and the same time was used to determine the  $L_{max}$  at the further sites. The  $L_{eq}$  for the data analysis period was calculated, and in some cases may be *higher* than the  $L_{max}$  because of the micro-habitat environmental factors mentioned above. The higher  $L_{max}$  of the two vehicle drive-bys was used.  $L_{eq}$  was not calculated for the vehicle drive-bys because of the variability in sound pressure levels with passing the measurement equipment. The accompanying  $L_{max}$  for each one-third octave frequency band are listed in the Appendix.

## RESULTS

The minimum sound pressure level measured (without equipment operating) was 25.5 dBA. This gives an indication of the lowest possible background, or natural ambient, sound pressure levels at the site during data collection. Louder natural ambient sounds were also present in the form of wind rustling leaves and needles of trees. Human-caused sound sources such as aircraft, trains, and vehicles passing by were excluded from analysis.

The Stihl 440 and 044 chainsaws at full throttle have the loudest  $L_{max}$  at 50 ft of almost 83 dBA (Table). In fact, the chainsaws are among the loudest equipment measured, even at idle. Fortunately, none of the equipment measured exceeds 85 dBA at 50 ft, eliminating the need for hearing protection at that distance.

For the louder equipment, sound pressure levels quickly drop off with distance, greater than the 6 dBA with doubling of distance estimated by the inverse distance formula for point sound sources in a free field environment (Everest 2001). However, other equipment such as the Honda water pump at idle had lower or no drop-off rates with increasing distance from the sound source which could have been due to approaching the average natural ambient sound pressure level.

The leaf blower have a maximum sound pressure level of almost 54 dBA at idle at 50 ft, but that increases to 75 dBA at full throttle. The maximum sound pressure levels of the water pumps are around 65 dBA at 50 ft.

Of the vehicles, the ATV has the loudest idle at 50 ft of almost 55 dBA, although the safety beep for the F450 surpassed that sound pressure level with 64.3 dBA. By far, the ATV has the loudest drive-by sound pressure level of 62 dBA at 50 ft.

### Micro-Habitat Influence

In some cases, the further sites had  $L_{max}$  or  $L_{eq}$  values *larger* than a closer site, likely due to the microphone measuring a micro-habitat, or localized, natural sound such as a nearby bird singing, wind rustling the trees, or insects rather than the fire equipment source.

In general, the stationary equipment operating at a continuous power level (such as idling chainsaw) have  $L_{max}$  and  $L_{eq}$  within 3 dBA of each other at 50 and 100 ft, as expected. Variability between  $L_{max}$  and  $L_{eq}$  are introduced at 400 ft, likely due to the fact that the sound source is not as loud at the furthest measurement site, and the site is influenced more by micro-habitat sounds. In fact, in several instances, most notably for the Ford F450 at idle measured at 400 ft, the  $L_{eq}$  is *higher* than the  $L_{max}$ . This is due to micro-habitat environmental factors causing the maximum sound pressure level to occur at a different time at the 400 ft site than it did at the 50 ft measurement site. Therefore, since the  $L_{max}$  reported at the 400 ft site was determined by the time of  $L_{max}$  at the 50 ft site, it may not represent the true  $L_{max}$  at that site, but the  $L_{eq}$  includes that true  $L_{max}$  measurement, and is therefore higher.

The  $L_{max}$  at 100 ft for the Ford F450 drive-by is louder than the drive-by at 50 ft. Similarly, the  $L_{max}$  at 400 ft for the Ford F250 at idle is louder than the idle at 100 ft. It is likely that the microphones recorded noise from a nearby source rather than the trucks, indicating the  $L_{max}$  levels at these two sites are not representative of the fire equipment.

**Table. L<sub>max</sub> and L<sub>eq</sub> of fire equipment (in dBA).**

Equipment	Power Level	Amount of data collected (m:ss)	Amount of data analyzed (m:ss)	L <sub>max</sub> @ 50 ft	L <sub>eq</sub> @ 50 ft	L <sub>max</sub> @ 100 ft	L <sub>eq</sub> @ 100 ft	L <sub>max</sub> @ 400 ft	L <sub>eq</sub> @ 400 ft
Chainsaw - Stihl 044 28" bar	idle	2:00	1:00	63.7	62.8	55.3	55.0	37.4	37.7
	full throttle	4:00	1:00	82.6	80.2	73.4	72.8	49.6	49.2
	cutting through wood	1:24	1:00	77.3	71.3	69.3	64.3	47.0	41.0
Chainsaw - Stihl 036 24" bar	idle	2:00	1:00	60.0	58.2	55.1	54.6	38.8	41.3
	full throttle	2:00	1:00	81.0	78.9	76.1	73.5	52.0	48.9
	cutting through wood	1:00	1:00	73.2	70.0	63.3	63.3	43.4	43.8
Chainsaw - Stihl 440 28" bar	idle	2:00	2:00	59.2	57.1	55.8	53.2	40.2	39.6
	full throttle	2:00	0:56	82.9	81.2	74.5	75.5	51.4	50.5
	cutting through wood	2:00	0:41	76.8	75.0	71.1	69.5	46.7	46.1
Leafblower - Stihl BR550	idle	2:00	1:00	53.8	52.3	49.6	47.7	36.0	35.6
	full throttle	2:00	1:00	75.0	73.2	65.2	65.9	45.4	45.0
Water pump - Waterous E-50 1-A onboard a 2001 Ford F450 turbodiesel 7.3L (truck is idling)	idle @ 1000 rpm	2:00	0:51	59.9	59.2	54.4	53.7	35.6	35.2
	100psi 1900 rpm	2:00	1:00	62.1	61.4	56.9	56.0	35.9	38.2
	150 psi 2400 rpm	2:00	1:00	64.8	64.2	59.3	58.3	41.5	39.8
Water pump - Honda GXH50 4-stroke	idle	1:00	0:41	43.7	43.0	36.9	36.2	35.6	35.1
	full throttle	2:00	1:00	65.5	59.8	56.9	51.0	36.6	37.7
Vehicle - Honda Foreman ES 2004 ATV 450cc	idle	2:00	1:00	54.8	49.4	45.1	46.2	43.3	43.5
	drive-by (~20 mph)	*	0:21	62.0		49.6		44.9	
Vehicle - 2002 Ford F450 7.3L Powerstroke turbodiesel	idle	2:00	1:00	52.2	50.9	45.7	46.4	39.2	44.1
	idle with safety beep	1:00	1:00	64.3	54.6	44.9	44.6	38.0	39.6
	drive-by (~15 mph)	*	0:21	42.7		44.2**		39.9	
Vehicle - 2001 Ford F250 XL SuperDuty	idle	2:00	0:31	49.1	46.3	42.2	42.6	44.4**	45.8
	drive-by (~15 mph)	*	0:21	50.0		44.4		40.6	

\* For vehicle drive-bys, 10 second pre and post drive-by were analyzed and the louder of the two drive-bys is reported.

\*\* This L<sub>max</sub> value may reflect a sound close to the microphone rather than from the truck.

## ***ACKNOWLEDGEMENTS***

Thanks to Dave Robinson and Chris Marks for operating the fire equipment in a safe manner. Rick Ernenwein helped with coordination and field data collection.

## ***LITERATURE CITED***

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Levy, Laura, and Sarah Falzarano. 2007. Summer Replicate Ambient Sound Levels in Grand Canyon National Park. NPS Report No. GRCA-07-06.

**APPENDIX: L<sub>max</sub> one-third octave band frequency sound pressure levels in dBA**

Equipment		Chainsaw- Stihl 044 28" bar								
Power Level	idle	full throttle	cutting through wood	idle	full throttle	cutting through wood	idle	full throttle	cutting through wood	
	50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft	
Distance to Source	50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft	
dBA	63.7	82.6	77.3	55.3	73.4	69.3	37.4	49.2	41.0	
Frequency (Hz)	12.5	39.5	39.9	33.5	41.4	43.4	36.1	34.2	41.4	33.9
	16	49.7	40.9	42.9	50.3	44.8	42.9	43.3	40.2	41.4
	20	38.6	42.2	43.9	37.7	43.2	41.8	36.1	43.8	42.4
	25	42.3	41.0	38.1	38.1	42.6	43.5	37.0	36.9	47.8
	31.5	50.3	37.7	39.4	50.9	34.5	38.1	35.5	34.0	36.5
	40	43.6	38.0	37.1	40.7	39.4	35.8	39.4	39.1	32.8
	50	56.5	40.5	39.1	49.1	37.3	36.3	44.2	34.9	35.9
	63	42.6	47.3	40.6	38.5	42.1	38.8	45.3	36.1	35.1
	80	43.7	53.1	46.8	41.4	48.3	41.7	43.7	38.1	34.0
	100	46.1	54.5	51.4	44.6	49.0	45.6	43.6	38.3	36.3
	125	47.3	53.8	44.1	40.3	47.0	37.6	33.7	34.3	27.4
	160	45.7	45.2	44.5	41.0	39.2	35.8	30.6	32.1	33.0
	200	47.5	74.6	70.0	41.7	68.5	61.4	27.1	29.5	28.1
	250	46.1	53.7	43.7	38.3	47.4	36.5	25.9	26.3	22.2
	315	48.5	51.8	46.1	38.3	43.7	37.0	27.8	28.0	24.9
	400	43.2	69.9	60.2	32.1	57.1	49.9	28.4	40.5	27.2
	500	38.8	53.2	56.2	32.7	45.3	47.9	29.4	31.0	25.8
	630	37.7	61.5	62.4	32.0	57.5	54.1	29.2	37.3	31.6
	800	42.2	74.4	64.8	35.4	62.6	56.7	27.8	45.5	36.7
	1000	43.9	65.0	67.0	35.0	57.1	59.2	25.5	33.6	32.7
1250	58.2	74.9	70.7	46.4	63.0	60.1	25.1	40.2	36.7	
1600	54.6	70.5	66.8	44.4	63.5	58.1	22.7	37.8	35.4	
2000	47.8	64.9	63.1	40.3	61.8	56.2	19.3	34.6	32.9	
2500	51.8	71.2	63.7	46.9	64.3	58.5	23.6	37.7	36.6	
3150	54.9	74.9	67.0	49.0	65.2	61.3	26.4	39.4	40.7	
4000	52.6	71.4	65.9	41.9	60.4	57.5	28.4	37.0	36.5	
5000	50.3	69.4	65.2	39.7	57.7	57.8	19.8	31.9	33.3	
6300	46.7	67.4	62.8	40.8	60.4	54.0	12.7	26.9	24.8	
8000	44.0	63.4	60.7	40.7	56.1	50.2	10.2	19.4	17.1	
10000	41.8	59.9	56.3	32.8	51.0	47.1	7.4	12.7	11.7	
12500	38.3	55.9	53.1	27.6	46.7	41.8	7.5	8.3	8.3	
16000	35.9	52.6	49.8	21.5	39.2	34.9	6.4	6.7	6.6	
20000	30.9	48.2	44.1	16.7	32.6	28.0	5.4	5.6	5.5	

Equipment		Chainsaw- Stihl 036 24" bar								
Power Level	idle	full throttle	cutting through wood	idle	full throttle	cutting through wood	idle	full throttle	cutting through wood	
Distance to Source	50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft	
dBA	60.0	81.0	73.2	55.1	76.1	63.3	38.8	52.0	43.4	
Frequency (Hz)	12.5	49.9	44.2	40.4	61.3	46.7	37.2	40.9	45.2	37.1
	16	47.2	48.7	44.0	55.4	51.6	40.0	48.7	47.8	39.9
	20	42.5	63.0	41.4	53.0	63.0	40.3	37.3	59.8	39.2
	25	45.4	43.3	43.3	50.7	42.8	41.7	46.3	41.9	42.5
	31.5	45.4	45.2	40.1	44.7	44.7	39.2	44.8	44.6	37.0
	40	43.4	54.7	39.1	43.0	54.0	40.2	40.1	51.8	37.8
	50	46.5	44.7	37.3	45.7	38.1	34.9	40.3	37.9	38.7
	63	44.4	47.3	41.2	41.9	40.9	40.1	37.8	38.8	41.2
	80	44.4	53.4	46.2	41.7	47.7	48.1	33.4	39.7	45.3
	100	45.5	59.5	53.1	42.1	52.6	48.2	34.2	42.0	39.7
	125	46.9	56.9	45.6	40.0	49.4	40.0	31.0	36.8	36.8
	160	48.1	45.6	75.0	41.7	39.6	68.2	28.1	26.7	49.1
	200	53.5	73.8	67.5	45.2	59.0	58.3	27.8	33.2	31.5
	250	51.5	59.5	52.6	41.7	45.2	45.9	28.3	28.7	36.1
	315	52.3	59.2	64.7	41.8	48.6	51.1	30.1	30.7	33.0
	400	45.7	69.9	64.6	36.8	63.4	50.5	32.8	39.5	32.8
	500	45.3	58.0	64.0	38.1	50.9	54.3	34.1	34.9	34.8
	630	45.6	68.4	60.0	38.1	55.8	50.0	33.6	38.1	35.3
	800	44.2	67.5	61.9	37.5	55.8	51.5	32.3	35.8	35.8
	1000	45.9	67.6	57.4	38.0	57.2	49.1	30.4	35.5	35.3
1250	47.7	73.0	60.5	38.4	64.4	49.2	26.7	39.9	32.6	
1600	48.6	74.9	58.3	39.7	67.3	47.5	22.2	42.0	29.6	
2000	51.6	68.3	60.9	44.0	64.4	50.5	20.4	40.7	28.6	
2500	51.2	67.7	61.6	46.1	66.3	52.2	19.5	44.1	27.5	
3150	50.5	69.5	62.8	49.1	68.7	52.5	18.0	44.2	25.7	
4000	46.6	67.8	63.1	44.0	65.7	52.7	12.7	41.8	23.0	
5000	45.4	64.5	61.4	43.0	64.3	52.3	9.7	37.2	17.5	
6300	44.0	64.1	58.9	41.7	61.6	49.5	8.6	28.8	11.7	
8000	41.2	61.1	57.5	39.5	58.3	47.3	7.5	20.7	8.3	
10000	34.6	57.8	52.9	32.7	53.5	41.8	7.6	14.6	7.4	
12500	31.5	52.9	48.0	26.8	46.9	34.5	7.6	10.6	7.3	
16000	29.9	48.6	44.9	21.4	39.2	27.3	6.6	8.3	6.6	
20000	23.1	45.3	37.4	14.2	32.7	20.1	5.5	6.3	5.5	

Equipment		Chainsaw- Stihl 440 28" bar									Leafblower- Stihl BR550					
Power Level	idle	full throttle	cutting through wood	idle	full throttle	Cutting through wood	idle	full throttle	cutting through wood	idle	full throttle	idle	full throttle	idle	full throttle	
	50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft	50 ft	50 ft	100 ft	100 ft	400 ft	400 ft	
Distance to Source	50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft	50 ft	50 ft	100 ft	100 ft	400 ft	400 ft	
dBA		59.2	82.9	76.8	55.8	74.5	71.1	40.2	51.4	46.7	53.8	75.0	49.6	65.2	36.0	45.4
Frequency (Hz)	12.5	50.0	36.2	49.9	46.6	60.5	48.8	47.7	42.5	46.9	35.4	34.2	32.8	32.5	35.7	39.3
	16	51.2	43.3	44.2	49.2	61.0	40.9	53.4	42.6	39.9	42.5	38.4	38.9	29.5	35.2	33.6
	20	45.4	44.0	39.4	46.0	53.3	40.2	46.2	42.8	37.8	42.7	37.3	40.2	33.5	35.5	34.0
	25	44.7	47.6	42.4	45.1	57.9	43.3	45.4	45.3	44.7	42.9	38.4	34.4	33.7	36.5	34.3
	31.5	42.4	37.4	44.3	44.1	53.3	45.2	44.0	35.6	47.0	43.5	40.1	40.6	35.4	31.7	32.2
	40	46.5	37.0	38.0	45.0	49.2	37.3	41.2	37.9	38.4	40.5	37.9	38.0	31.5	30.8	27.6
	50	44.6	38.1	40.7	45.4	48.3	38.2	37.2	37.7	39.1	42.5	58.9	35.8	52.3	32.1	42.1
	63	39.8	36.4	36.6	39.7	43.7	33.4	33.7	39.5	37.4	40.5	39.0	34.8	32.4	32.1	29.2
	80	40.9	35.2	38.7	37.6	40.9	35.5	36.0	33.4	30.8	43.2	42.5	38.3	36.4	37.2	35.5
	100	40.9	39.2	42.8	37.2	37.6	36.7	30.7	30.8	32.3	44.1	58.0	39.2	56.7	32.6	46.0
	125	39.9	40.1	37.6	36.5	37.8	32.3	28.9	26.7	27.4	43.6	46.1	38.2	38.7	35.0	25.6
	160	45.5	38.5	64.5	36.9	33.2	48.8	25.0	24.7	33.3	42.5	60.1	36.4	52.3	34.1	37.4
	200	47.1	38.7	69.7	38.0	31.9	59.8	26.4	25.1	34.1	46.5	60.7	39.6	52.4	27.2	25.1
	250	42.6	75.2	38.7	35.7	68.1	32.0	28.9	33.9	24.3	40.2	45.7	33.4	41.1	27.7	26.0
	315	44.1	44.0	50.1	36.4	35.3	39.1	31.1	29.6	29.3	38.3	54.0	30.8	39.5	28.9	28.4
	400	38.3	49.9	63.2	35.7	39.0	55.1	34.5	32.0	35.6	40.4	56.1	33.4	43.7	30.8	31.5
	500	39.3	63.6	52.6	36.4	65.3	42.5	35.0	40.2	32.5	36.3	65.1	33.2	56.8	31.7	35.8
	630	42.7	70.2	63.9	38.0	61.5	51.4	34.3	39.7	33.7	42.6	65.7	36.4	57.9	30.6	36.0
	800	44.1	78.9	71.5	37.3	70.1	62.6	33.6	47.9	40.9	39.8	65.1	33.0	56.7	28.9	35.1
	1000	42.9	75.4	65.5	36.5	60.2	55.5	31.8	41.7	35.4	37.8	72.7	32.0	58.8	25.6	42.1
1250	46.8	71.0	66.3	39.5	59.2	58.0	28.0	39.6	33.3	45.7	62.8	38.0	56.6	22.2	33.3	
1600	53.0	70.5	64.1	46.0	57.8	55.8	26.5	37.4	34.3	46.0	53.9	40.2	53.0	20.5	28.9	
2000	50.1	72.5	64.6	46.5	61.6	59.6	23.3	42.8	34.7	45.5	61.4	40.2	55.5	18.7	34.3	
2500	49.0	69.4	67.6	46.6	59.0	63.5	23.0	38.5	38.8	43.9	57.0	40.4	48.3	14.2	30.0	
3150	48.1	65.1	63.9	47.0	63.6	60.7	22.3	36.1	35.8	40.5	55.3	40.8	49.2	12.4	29.7	
4000	46.5	63.2	61.8	46.0	63.0	61.3	21.4	31.3	33.4	35.4	51.3	40.3	45.7	11.7	24.5	
5000	46.7	67.8	64.6	46.5	64.3	61.7	19.7	30.6	27.3	34.9	47.3	33.0	41.4	8.5	14.1	
6300	42.2	66.0	61.1	41.0	62.5	56.2	10.6	23.4	22.1	34.8	46.0	29.0	39.2	6.8	9.0	
8000	37.3	58.3	56.0	35.7	56.8	50.8	7.5	13.8	16.6	30.8	42.2	25.3	35.9	14.0	7.4	
10000	33.5	55.9	51.7	32.1	50.2	47.7	7.5	9.9	9.6	27.1	39.2	23.7	33.2	7.1	7.3	
12500	31.7	52.2	47.7	27.8	43.8	41.4	7.6	8.6	7.5	22.8	34.8	18.1	27.6	7.1	7.5	
16000	27.0	48.7	42.5	18.6	37.2	33.0	6.5	7.6	6.2	18.4	29.7	12.0	19.6	6.2	6.6	
20000	19.1	43.1	36.4	12.9	27.0	25.9	5.3	6.3	5.4	14.7	23.5	9.6	12.8	5.4	5.6	

Equipment		Water pump- Waterous E-50 1-A onboard a 2001 Ford F450 turbodiesel 7.3L (truck is idling)								
Power Level		idle @ 1000 rpm	100psi 1900 rpm	150 psi 2400 rpm	idle @ 1000 rpm	100psi 1900 rpm	150 psi 2400 rpm	Idle @ 1000 rpm	100psi 1900 rpm	150 psi 2400 rpm
Distance to Source		50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft
	dBa	59.9	62.1	64.8	54.4	56.9	59.3	35.6	35.9	41.5
Frequency (Hz)	12.5	50.1	52.9	51.6	47.6	45.1	41.6	36.6	38.4	33.8
	16	39.3	45.5	44.3	46.9	42.0	42.1	45.7	34.9	33.1
	20	44.3	43.0	42.6	45.4	42.6	38.2	36.2	33.9	37.0
	25	53.9	47.8	48.9	49.2	43.9	42.1	38.9	30.8	35.4
	31.5	62.5	49.0	44.3	57.1	43.2	39.0	47.6	35.3	34.0
	40	58.5	57.4	60.4	52.7	50.7	54.8	41.3	38.1	43.7
	50	60.9	62.2	66.1	55.3	55.9	60.5	44.9	44.9	49.8
	63	60.4	52.4	68.3	55.5	49.3	62.4	47.9	40.3	52.1
	80	61.2	56.6	55.2	53.9	50.5	48.1	42.4	41.8	41.4
	100	57.2	65.7	59.5	49.3	60.2	53.3	41.3	49.6	43.9
	125	59.7	61.6	59.4	47.8	52.1	50.3	38.6	33.7	38.1
	160	61.6	57.7	66.7	50.3	47.9	57.8	34.3	30.3	31.6
	200	52.3	52.2	55.5	40.4	41.9	46.6	24.7	28.4	24.3
	250	46.0	48.7	51.9	37.5	39.3	43.6	23.4	25.9	26.3
	315	46.2	43.8	47.1	39.8	38.7	40.6	26.0	25.6	28.3
	400	45.3	48.3	50.3	38.4	39.9	42.8	28.1	26.2	29.8
	500	46.6	50.8	52.7	39.6	42.8	44.3	27.7	26.9	31.9
	630	50.7	53.2	57.0	43.7	45.9	48.9	26.8	25.1	32.5
	800	51.2	53.5	56.1	46.1	46.7	50.4	27.2	24.9	32.3
	1000	51.1	51.1	54.4	46.4	45.6	48.7	25.1	22.9	30.6
1250	48.5	50.3	53.1	43.0	43.9	47.9	23.6	22.2	29.5	
1600	48.0	54.6	51.6	44.8	50.0	48.3	25.1	27.4	30.5	
2000	51.1	51.0	57.4	44.9	47.4	51.3	23.6	22.3	33.6	
2500	47.7	49.9	52.9	43.4	46.2	48.3	18.9	18.9	26.8	
3150	45.1	49.7	50.2	41.1	46.0	47.8	14.5	16.2	31.0	
4000	42.4	42.4	46.1	38.3	39.4	45.3	10.0	8.8	22.6	
5000	37.5	38.9	42.8	33.6	36.5	41.1	6.6	6.7	14.9	
6300	34.1	37.1	40.4	28.9	35.7	39.2	6.5	6.4	14.1	
8000	31.1	33.3	37.5	25.0	31.2	36.0	6.5	6.8	7.7	
10000	26.7	30.2	34.1	20.5	27.0	31.1	7.0	7.0	7.2	
12500	21.6	26.7	31.2	15.0	21.6	26.7	7.2	7.2	7.2	
16000	17.9	23.1	27.9	9.7	14.5	19.2	6.4	6.4	6.4	
20000	13.4	19.3	23.0	9.3	11.0	13.0	5.5	5.5	5.5	

Equipment		Water pump - Honda GXH50 4-stroke					
Power Level	idle	full throttle	idle	full throttle	idle	full throttle	
	50 ft	50 ft	100 ft	100 ft	400 ft	400 ft	
Distance to Source	50 ft	50 ft	100 ft	100 ft	400 ft	400 ft	
dBA	43.7	65.5	36.9	56.9	35.6	36.6	
Frequency (Hz)	12.5	47.5	36.7	50.9	32.9	34.1	38.5
	16	41.5	35.2	44.2	34.4	36.5	33.8
	20	44.6	36.4	42.5	36.5	42.4	34.6
	25	38.6	35.7	44.4	36.2	36.9	32.3
	31.5	39.6	28.9	38.0	30.4	35.2	26.9
	40	39.5	38.2	38.9	31.5	33.8	29.6
	50	39.9	55.3	37.5	39.2	36.9	46.7
	63	33.3	64.8	31.8	59.7	36.8	46.8
	80	44.8	56.5	36.9	52.5	32.7	33.9
	100	44.0	43.8	38.3	37.1	31.7	47.4
	125	47.7	71.5	36.1	60.6	37.2	44.2
	160	48.6	64.8	41.3	56.7	35.6	29.8
	200	46.3	53.8	38.3	41.4	33.6	22.6
	250	45.2	60.1	37.9	51.4	28.8	25.0
	315	34.3	62.1	27.4	53.0	31.0	26.9
	400	31.4	60.4	25.4	50.5	30.3	27.6
	500	31.7	54.3	25.5	43.4	28.9	29.3
	630	33.5	56.5	25.2	45.1	28.0	29.8
	800	30.5	53.2	23.7	47.0	25.0	27.5
	1000	25.6	53.5	22.1	44.0	23.3	26.0
1250	24.0	50.0	21.6	42.0	21.8	22.4	
1600	30.7	48.7	25.2	41.7	24.4	22.2	
2000	26.7	52.3	25.7	44.6	25.4	21.4	
2500	26.5	53.6	18.5	45.3	11.9	19.3	
3150	29.2	52.3	20.5	44.6	8.5	15.2	
4000	26.6	50.9	18.0	42.8	14.7	13.5	
5000	27.9	50.0	21.6	43.5	11.2	12.0	
6300	24.7	48.7	19.7	43.9	6.9	7.3	
8000	22.7	44.1	18.4	39.0	7.0	6.9	
10000	17.6	40.6	15.1	37.0	7.2	7.2	
12500	17.6	37.9	13.1	35.1	7.5	7.2	
16000	15.3	34.8	9.7	26.5	6.8	6.5	
20000	11.6	30.1	9.6	18.7	5.6	5.6	

Equipment		Vehicle - Honda Foreman ES 2004 ATV 450cc						Vehicle - 2002 Ford F450 7.3L Powerstroke turbodiesel								
Power Level	idle	drive-by	idle	drive-by	idle	drive-by	idle	idle with safety beep	drive-by	idle	idle with safety beep	drive-by*	idle	idle with safety beep	drive-by	
	50 ft	50 ft	100 ft	100 ft	400 ft	400 ft	50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft	
Distance to Source	50 ft	50 ft	100 ft	100 ft	400 ft	400 ft	50 ft	50 ft	50 ft	100 ft	100 ft	100 ft	400 ft	400 ft	400 ft	
dBA	54.8	62.0	45.1	49.6	43.3	44.9	52.2	64.3	42.7	45.7	44.9	44.2	39.2	38.0	39.9	
Frequency (Hz)	12.5	63.3	35.8	58.1	52.8	46.6	36.3	52.4	49.5	41.4	48.2	48.1	49.5	41.9	39.9	44.2
	16	44.4	38.8	54.3	52.4	43.8	33.6	44.6	45.0	31.5	46.1	39.2	48.1	37.0	40.6	42.8
	20	50.5	34.4	55.0	45.6	46.1	35.5	44.8	53.4	30.4	45.7	39.3	50.9	34.1	36.6	45.8
	25	61.2	41.2	47.2	46.8	39.4	37.7	48.4	60.7	34.5	45.1	43.1	49.9	41.4	35.4	42.6
	31.5	46.6	48.0	48.4	40.8	45.6	34.7	47.4	46.4	38.6	43.4	41.3	49.3	34.8	34.0	42.3
	40	59.8	45.9	52.6	58.7	41.9	55.1	56.2	52.5	34.8	46.8	54.6	52.5	32.5	36.5	45.8
	50	59.7	46.4	51.4	43.7	40.5	37.1	63.9	64.5	39.6	55.2	58.0	54.6	35.7	40.1	47.9
	63	57.8	50.0	52.6	37.5	40.2	33.9	48.5	52.2	33.6	42.2	42.2	50.1	34.4	30.6	44.3
	80	61.6	50.8	53.7	55.6	40.8	48.4	49.7	63.3	32.7	43.7	43.7	52.6	35.4	33.8	48.9
	100	60.5	58.3	54.0	45.4	43.0	37.2	49.1	64.6	33.1	41.9	42.5	49.5	36.8	38.6	44.9
	125	53.2	53.9	46.1	55.0	35.4	46.6	48.7	57.0	27.8	40.7	42.5	50.2	29.0	31.1	38.3
	160	49.5	45.4	35.7	57.7	30.2	45.9	45.0	58.7	28.8	39.4	38.0	47.0	25.5	27.1	39.5
	200	44.0	42.9	34.8	48.2	32.0	34.7	42.0	54.7	30.4	34.8	33.0	43.7	23.4	25.2	36.2
	250	43.7	38.4	32.9	38.1	31.5	33.5	42.1	57.7	30.2	34.3	32.5	40.3	25.1	28.4	30.7
	315	41.8	37.7	34.2	39.6	34.3	35.5	39.8	51.6	30.7	34.1	32.1	36.3	28.5	29.9	30.6
	400	49.1	37.9	35.1	36.9	36.3	35.7	40.8	51.3	31.9	35.2	35.1	33.7	31.2	32.3	31.8
	500	52.5	38.1	37.8	38.8	37.6	37.9	42.8	51.2	33.9	37.5	35.7	32.9	33.3	34.2	32.4
	630	50.0	40.1	39.7	40.3	38.5	39.3	42.0	52.3	40.6	38.3	34.6	34.0	33.9	33.9	32.9
	800	47.1	40.4	38.6	40.6	37.5	38.7	42.8	50.9	33.9	37.9	33.5	33.4	33.2	32.1	32.2
	1000	44.9	38.7	36.3	39.6	35.3	36.8	43.9	53.0	32.3	37.9	35.3	34.0	31.7	29.5	31.8
1250	38.1	35.4	33.5	37.0	32.2	34.1	44.3	56.8	29.9	36.7	37.8	34.7	29.0	25.3	30.3	
1600	33.7	32.9	29.2	35.6	28.1	30.8	40.1	55.4	28.6	33.5	30.9	30.5	25.6	20.3	24.7	
2000	28.1	28.9	25.3	32.0	23.8	26.5	38.9	53.2	27.1	30.7	29.9	28.2	21.3	17.2	22.1	
2500	24.5	26.2	22.0	29.8	18.9	22.8	40.1	56.0	25.8	31.4	33.2	26.9	20.0	19.3	18.5	
3150	24.8	23.2	18.8	27.3	16.1	18.8	38.7	48.6	26.4	31.4	34.6	22.4	12.1	11.2	14.2	
4000	21.4	19.6	16.4	23.5	18.3	14.4	37.7	42.9	26.7	29.3	30.8	20.0	11.5	12.5	14.5	
5000	19.7	16.7	14.0	19.4	15.9	10.4	31.5	45.4	24.0	24.7	27.1	18.1	9.6	9.5	9.2	
6300	15.4	14.8	13.7	17.9	8.9	9.1	28.9	41.8	23.2	20.3	21.6	12.9	6.5	7.3	7.2	
8000	13.2	12.3	12.8	15.4	8.0	7.7	27.2	39.8	21.3	17.8	17.1	10.4	6.2	6.9	6.7	
10000	13.8	12.4	12.2	13.1	7.2	7.0	28.6	34.1	21.6	16.7	16.5	10.2	6.2	6.7	6.3	
12500	11.6	12.5	10.8	11.3	7.3	6.7	28.3	31.5	21.5	14.3	15.0	9.4	6.3	6.6	6.2	
16000	9.4	12.3	9.4	9.6	9.5	8.1	21.9	24.5	19.0	10.0	10.0	8.7	8.4	8.1	7.6	
20000	6.7	8.8	10.0	10.1	7.1	7.2	10.7	16.5	13.9	9.5	9.4	9.5	9.1	8.1	7.4	

\* This L<sub>max</sub> value may reflect a sound close to the microphone rather than from the truck.

Equipment		Vehicle - 2001 Ford F250 XL SuperDuty					
Power Level	idle	drive-by	idle	drive-by	Idle*	drive-by	
Distance to Source	50 ft	50 ft	100 ft	100 ft	400 ft	400 ft	
dBA	49.1	50.0	42.2	44.4	44.4	40.6	
Frequency (Hz)	12.5	45.2	53.5	43.5	48.3	44.9	40.6
	16	47.7	44.1	40.6	44.1	45.1	38.5
	20	46.0	40.7	38.2	48.4	39.6	44.0
	25	43.8	39.8	37.2	47.7	39.4	41.1
	31.5	40.6	34.4	43.4	39.0	42.1	34.3
	40	45.4	34.8	36.5	40.7	35.1	37.9
	50	52.2	51.5	45.9	43.6	33.5	36.7
	63	40.6	40.2	40.0	42.8	36.1	42.4
	80	49.2	33.9	34.3	40.9	32.5	34.7
	100	48.3	36.6	34.7	48.7	30.1	40.7
	125	51.7	38.3	45.7	45.2	33.3	35.4
	160	45.6	36.7	41.3	45.3	29.5	35.0
	200	37.7	33.9	29.0	48.6	28.9	32.2
	250	35.3	34.2	27.7	35.8	31.6	29.1
	315	34.3	34.6	29.9	32.8	33.4	31.2
	400	37.4	37.0	33.4	34.7	36.1	32.4
	500	38.9	39.2	35.4	36.1	37.9	34.7
	630	40.4	41.3	37.0	36.7	39.4	35.2
	800	41.4	42.9	36.4	36.8	38.8	35.3
	1000	42.1	43.1	34.2	35.1	37.3	32.9
1250	41.1	43.3	31.2	32.2	34.5	28.9	
1600	39.2	40.6	27.0	29.0	30.3	25.0	
2000	35.3	36.3	22.8	26.2	25.5	20.0	
2500	30.5	31.6	19.9	24.7	21.2	15.8	
3150	27.2	27.8	20.1	22.3	17.5	12.3	
4000	23.9	24.7	14.1	20.8	14.6	18.3	
5000	20.9	22.1	12.5	18.0	12.1	15.6	
6300	18.9	19.6	12.9	16.5	10.9	7.1	
8000	16.4	17.2	10.0	14.3	9.3	6.5	
10000	14.6	16.6	9.9	12.2	7.6	6.3	
12500	13.5	15.5	9.1	9.8	7.1	6.4	
16000	10.1	12.3	9.8	12.1	7.9	9.4	
20000	7.1	8.7	11.2	16.0	7.6	8.2	

\* This L<sub>max</sub> value may reflect a sound close to the microphone rather than from the truck.