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13. ABSTRACT (Maximum 200 words)
The Volpe Center Acoustics Facility, in support of the California Department of Transportation, participated in a long-term study to assess several types of pavement for the purpose of noise abatement. On a 6.4-km (4-mi) stretch of a 2-lane highway in Southern California, several asphalt pavement overlays were examined. Acoustical, meteorological, and traffic data were collected in each pavement overlay section, where microphones were deployed at multiple distances and heights. Single vehicle pass-by events were recorded primarily for 3 vehicle types: automobiles, medium trucks, and heavy trucks. Data were analyzed to determine the noise benefit of each pavement as compared to the reference dense-graded asphalt pavement; this includes a modified Statistical Pass-By Index as well as average L_{AFmx} values for each vehicle type. In addition, 1/3-octave band data were examined. Results from the study indicate that applying a quieter pavement overlay can reduce wayside-measured sound levels.

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Highway traffic noise, tire/pavement interaction noise, asphalt pavements

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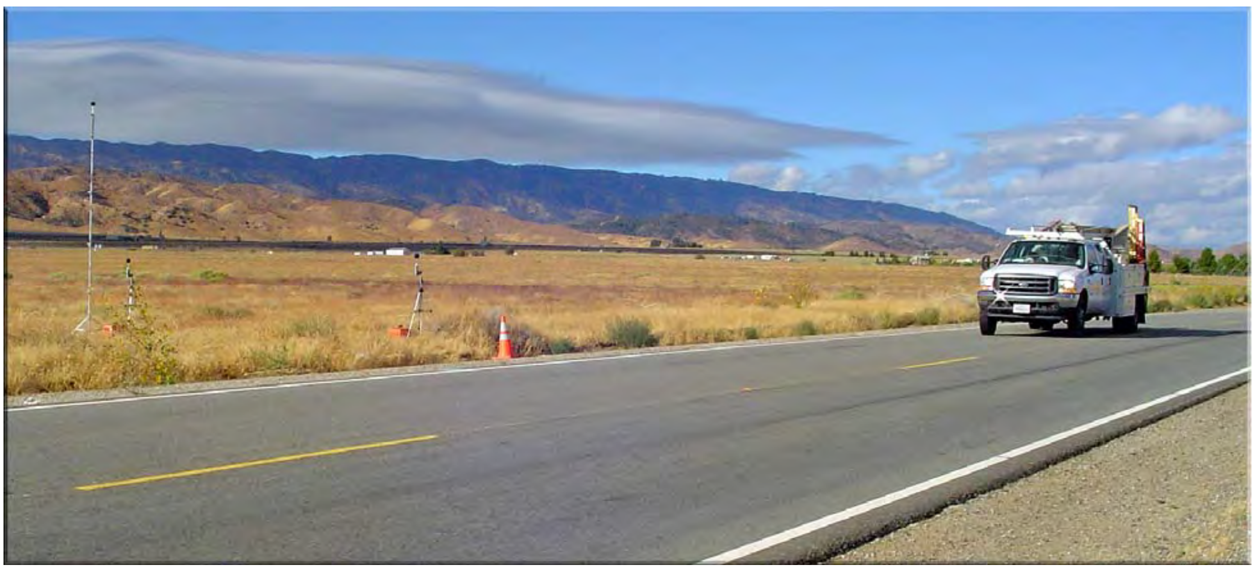
Effects of Asphalt Pavements on Wayside Noise



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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	= 2.5 centimeters (cm)
1 foot (ft)	= 30 centimeters (cm)
1 yard (yd)	= 0.9 meter (m)
1 mile (mi)	= 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	= 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	= 0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	= 0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	= 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	= 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	= 28 grams (gm)
1 pound (lb)	= 0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	= 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	= 5 milliliters (ml)
1 tablespoon (tbsp)	= 15 milliliters (ml)
1 fluid ounce (fl oz)	= 30 milliliters (ml)
1 cup (c)	= 0.24 liter (l)
1 pint (pt)	= 0.47 liter (l)
1 quart (qt)	= 0.96 liter (l)
1 gallon (gal)	= 3.8 liters (l)
1 cubic foot (cu ft, ft^3)	= 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	= 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F	= y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	= 0.04 inch (in)
1 centimeter (cm)	= 0.4 inch (in)
1 meter (m)	= 3.3 feet (ft)
1 meter (m)	= 1.1 yards (yd)
1 kilometer (km)	= 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	= 0.16 square inch (sq in, in^2)
1 square meter (m^2)	= 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	= 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	= 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	= 0.036 ounce (oz)
1 kilogram (kg)	= 2.2 pounds (lb)
1 tonne (t)	= 1,000 kilograms (kg)
	= 1.1 short tons

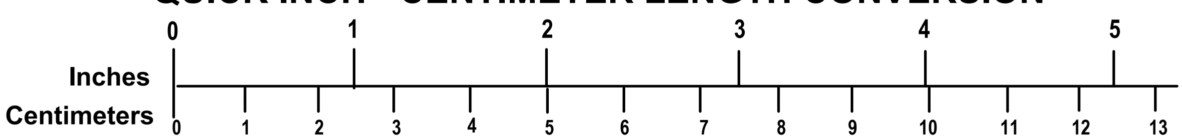
VOLUME (APPROXIMATE)

1 milliliter (ml)	= 0.03 fluid ounce (fl oz)
1 liter (l)	= 2.1 pints (pt)
1 liter (l)	= 1.06 quarts (qt)
1 liter (l)	= 0.26 gallon (gal)
1 cubic meter (m^3)	= 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	= 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C	= x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

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1. INTRODUCTION

1.1 Background

Quieter pavements have the potential to help reduce highway traffic noise, both at the tire/pavement interface and through absorption of propagating sound. Several aspects of this non-traditional method of noise abatement are currently being investigated in many parts of the world;[1] included are investigations of noise measurement methodologies, pavement design parameters, quantification of noise reduction and its longevity, and introduction of pavement influence into traffic noise prediction models. In California, the Department of Transportation (Caltrans) would like to add quieter pavements to their noise abatement repertoire. Caltrans is conducting several studies, using various measurement methodologies, to help determine the amount and longevity of noise reduction for various types of quieter pavements and surface treatments.

1.2 Study Overview

On a 6.4-km (4-mi) stretch of a two-lane highway in Southern California (on LA138, northwest of Lancaster, 130 km or 80 mi north of Los Angeles), several asphalt pavement overlays are being examined over time to evaluate degradation of noise performance due to pavement deterioration (referred to as Thin Lift Study). The pavements are being assessed for potential use as noise abatement and to provide valuable information for the development of the Federal Highway Administration's Traffic Noise Model® (FHWA TNM),[2,3,4,5] currently being evaluated for the inclusion of pavement noise effects for a large range of pavement types. This model is mandatory for use in determining noise impacts in the vicinity of highways and designing noise abatement features, for projects receiving U.S. Federal aid.

For the Thin Lift Study, a total of five pavement sections are being evaluated, each having been paved for the study (more details are provided in Section 2):

1. dense-graded asphaltic concrete (DGAC) of 30 mm (1 in) thickness;
2. open-graded asphaltic concrete (OGAC) of 75 mm (3 in) thickness;
3. OGAC of 30 mm (1 in) thickness;
4. rubberized asphaltic concrete, Type O (open) (RAC) of 30 mm (1 in) thickness; and

5. bonded wearing course (BWC) of 30 mm (1 in) thickness.

The DGAC serves as the reference pavement (typical of standard asphalt), to which all others are compared.

The primary noise measurement methodology being applied to the work reported here was a modified Statistical Pass-By Method (SPB);[6] this method is used to determine the pavement effects on wayside noise (noise adjacent to a highway). The SPB application was supplemented with measurements of pavement sound absorption, applying a methodology that utilizes effective flow resistivity.[7] (Other methodologies, including On-Board Sound Intensity, are being applied to the study, where results are also being reported.[8]) Wayside data were collected in all pavement test sections simultaneously, allowing for direct comparisons of the reference section to the other test sections. Measurements have been completed for the pavement aged up to 52 months.

Data were analyzed and are reported in terms of individual vehicle types (both broadband and spectrally) and the SPB index, examining differences among the aging pavements.

1.3 Report Organization

Following this introduction, Section 2 describes the measurement sites, including the pavement types; Section 3 reviews the dates of data collection as well as procedures and methodologies; Section 4 reviews the data analysis procedures; Section 5 provides study results and discussion for the performance of the pavements, both overall, and for individual vehicle types; and Section 6 provides conclusions. Also included in this report are several appendices, to supplement the related sections: Appendix A shows the measurement sites, Appendix B shows instrumentation used in the study, Appendix C shows tables and plots for the vehicle pass-by data, Appendix D shows tables and plots for the overall pavement performance, Appendix E shows tables and plots for the pavement performance by vehicle type, and Appendix F shows results for the test vehicle. References are listed at the end.

2. MEASUREMENT SITES

2.1 Site Locations

The location for the asphalt overlays and noise testing is on LA138 in Southern California (a desert area about 32 km or 20 miles northwest of Lancaster and 130 km or 80 mi north of Los Angeles) on a 6.4-kilometer (4-mi) stretch of roadway. (Please refer to Figure 1 and Figure 2.) LA138 is a two-lane highway (one lane each direction), with a speed limit posted as 55 mph, with relatively sparse traffic and a substantial percentage of heavy trucks (ADT 4000-5000). The testing area of LA138 extends from station 101.16+00 to 180.00+00, from 230th St West to 0.2 km (0.12 mi) west of 180th St West (the eastern most part of the test area was not used for the wayside noise testing).

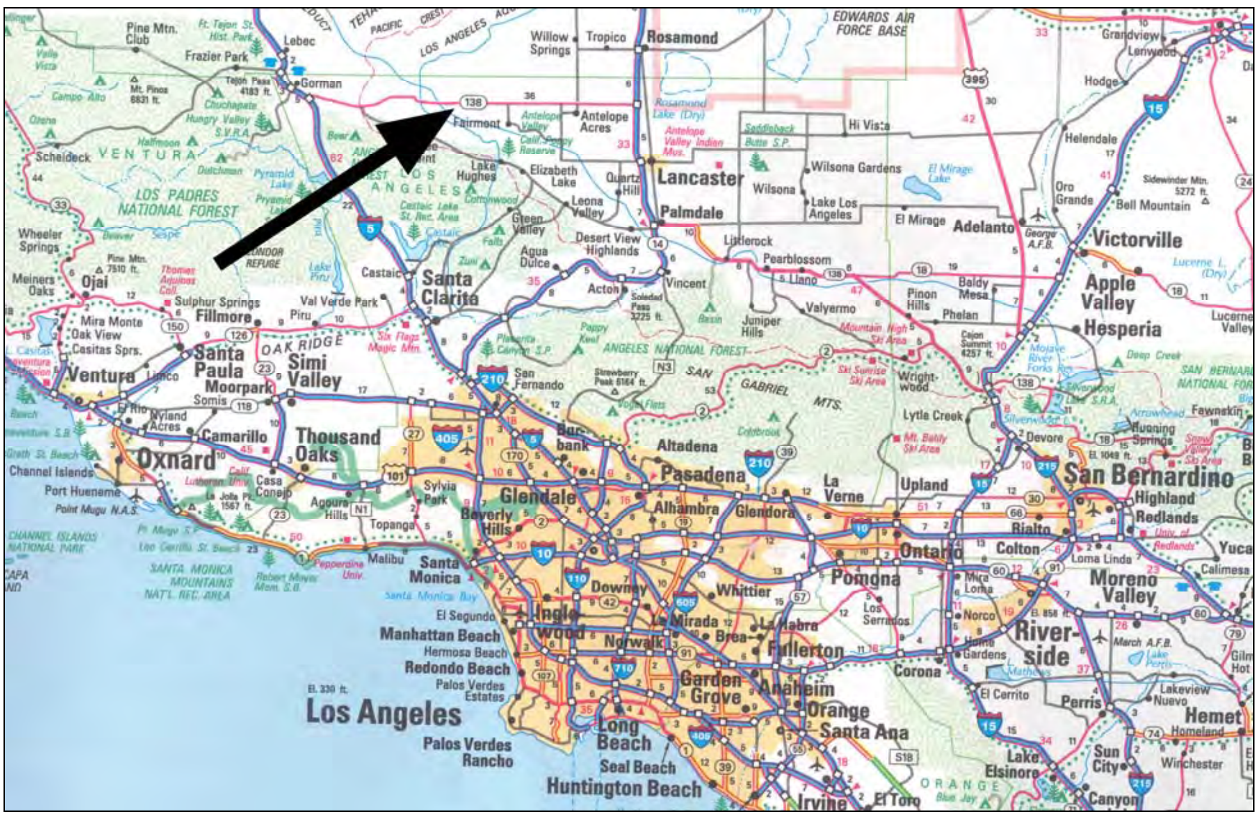

Figure 1. LA138 pavement testing area map.

Figure 2. LA138 pavement testing area photograph.

2.2 Five Test Sections

In the LA138 test area, there are five main test sections. Each site (1-5) can be seen in Appendix A. The sites and associated pavement types are listed in Table 1. Figure A-1 in Appendix A shows the five pavements.

Table 1. Five test sections.

	Pavement type	Specified thickness	Specified maximum aggregate size*	Measured % air void content**
Site 1 (S1) (reference section)	Dense-graded asphalt concrete (DGAC) (STA 101+16.60 to 108+00.00)	30 mm	12.5 mm (1/2 in)	9% center
Site 2 (S2)	Open-graded asphalt concrete (OGAC, 75 mm) (STA 108+00.00 to 120+00.00)	75 mm	12.5 mm (1/2 in)	12% center
Site 3 (S3)	Open-graded asphalt concrete (OGAC, 30 mm) (STA 120+00.00 to 148+00.00)	30 mm	12.5 mm (1/2 in)	15% center
Site 4 (S4)	Rubberized asphalt concrete type O (RAC Type O) (STA 148+00.00 to 168+00.00)	30 mm	12.5 mm (1/2 in)	12% center
Site 5 (S5)	Bonded wearing course (BWC) (STA 168+00.00 to 174+00.00)	30 mm	12.5 mm (1/2 in)	7 % center

Note: The shortest overlay covers a distance of 0.4 km (0.25 mi), where the total of all five sections span the 6.4-kilometer (4-mi) piece of LA138.

* Pavement analyses show finer gradations than the standard specifications; actual gradations are similar and not listed here.[9]

** Measured air void content in the center of the lane shows percentages lower than specified.[9]

Prior to the May/June 2002 construction of the pavement overlays seen in Table 1 and Figure A-1 in Appendix A, LA138 was treated with a leveling course of new DGAC (completed December 2001). The DGAC leveling course is associated with the baseline set of measurements described later in this report (noise measurements taken at each of the sites with the same type of pavement, before the different overlays were constructed). The December 2001-constructed leveling course was determined to be necessary due to the poor pavement condition;[10] prior to the leveling course, the pavement type was DGAC estimated to be aged at least 20 years. Although baseline wayside noise measurements were performed with the old DGAC (referred to as preliminary measurements later in this report), analysis and results are not reported here since baseline data were re-collected with the December 2001-constructed DGAC leveling course.

3. DATA COLLECTION

Wayside noise measurements were performed with existing traffic to help determine the noise reduction over time for the four pavements as compared to DGAC. The methodologies applied to this study are described first, followed by the specifications for the data collected and instrumentation used, and lastly, the data collection sessions performed are listed by date and pavement age.

3.1 Methodologies

3.1.1 Wayside vehicle pass-by noise

For the wayside vehicle pass-by noise, data are collected in general conformance with the Statistical Pass-By Method (SPB) standard, ISO 11819-1,[6] where the number of measurement locations is augmented and the data analysis is modified to meet the requirements of this study (described in Section 4). Acoustical, meteorological, and traffic speed and identification data are collected for each pavement overlay section simultaneously, where microphones are deployed at multiple distances (from the center of the near travel lane) and heights:

1. distance: 7.5 m (25 ft), height: 1.5 m (5 ft) above the ground (low), which ranged from ~1.2-1.5 m (~4-5 ft) above the roadway surface, depending on the site;
2. distance: 15 m (50 ft), height: 1.5 m (5 ft) above the ground (low, FHWA-recommended distance[11]);
3. distance: 15 m (50 ft), height: 4.5 m (15 ft) above the ground (high); and
4. at Sites 1 and 2, distance: 60 m (200 ft), height: 1.5 m (5 ft) above the ground (low).

Figure 3 shows an illustration of the instrumentation set-up, and Figure 4 shows the instrumentation deployed on one of the LA138 sites. Each of the sites was relatively flat with mostly medium- to hard-packed dirt; there were occasional grasses and shrubs (depending on the measurement session, some sites, usually Sites 3 and 4, had more shrubs than the others). Other key factors of applying the SPB methodology to this study are listed below the figures.

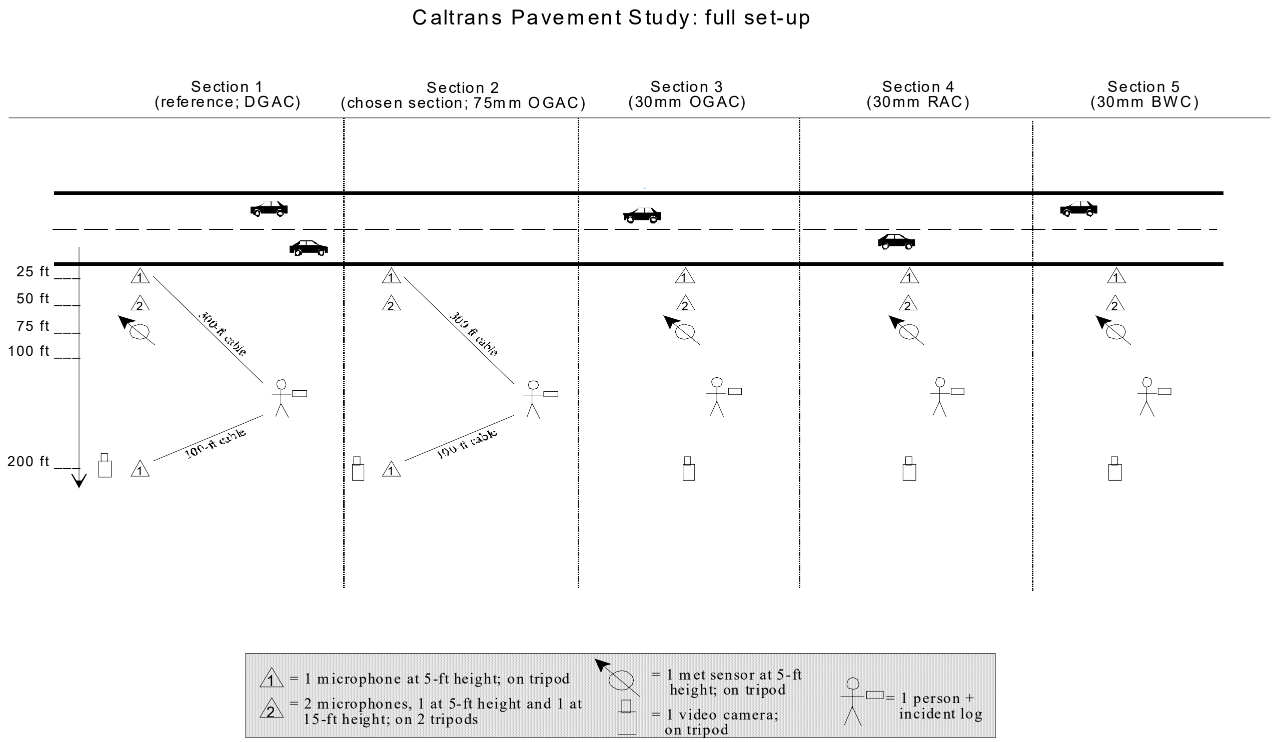

Figure 3. Illustration of basic instrumentation set-up. (Not proportional or to scale)

Figure 4. Example of the deployed instrumentation.

Originally, it was thought that traffic flow could be recorded continuously, where the average 5- to 15-minute sound level for each site could be determined. After the first set of measurements at the sites (preliminary measurements), it was determined that the traffic on LA138 was too sparse to apply the continuous flow / sound level averaging methodology. At that time, it was determined that the SPB methodology would be more appropriate to measuring at the LA138 sites.

In addition to the SPB methodology, controlled pass-bys with a single vehicle (the "test vehicle") are measured at four different speeds at each of the 5 pavement sites. The test vehicle is a Subaru Outback with Goodyear Aquatred 3 tires, provided and operated by Illingworth and Rodkin, Inc. (the vehicle was on site for the primary purpose of conducting On-Board Sound Intensity Measurements, and its secondary purpose was to serve as a test vehicle for the pass-by measurements). Maximum sound levels (average L_{AFmx}) are extracted for these events and compared among the 5 pavement sites.

3.1.2 Sound absorption of pavement

For measurements of the sound absorption of the pavement, data are collected in general conformance with the Template Method for Ground Impedance standard, ANSI S1.18-1999, one-parameter model, geometry A (uses a specified geometry for a source and two microphones),[7] where the effective flow resistivity (EFR, a measure of sound absorption and a preliminary metric before obtaining acoustical ground impedance) table is augmented to include a broader and finer range of values, and the data analysis is modified to meet the requirements of this study. This methodology is still experimental for the purposes of distinguishing types of pavements.

3.2 Data and Instrumentation

Data were collected in all pavement test sections simultaneously, allowing for direct comparisons of the reference section to the other test sections and also to observe the degradation of noise benefits of individual sections over time (exception: measurements at Site 5 were stopped after the pavement was aged 16 months; see section "Data Collection Sessions" for an explanation). Microphones were deployed in multiple configurations, the set-up dependent on the test section and the date of data collection. In addition to acoustical data collection, meteorological data, traffic composition and speed data, ground impedance (sound absorption), event descriptions log, and extraneous noise log data were also acquired. After each set of measurements, all data were analyzed.

Following is a list of each type of data that is collected, the procedure of collecting the data, the primary instrumentation used, and the parameters of the data collected.

3.2.1 Acoustical data

Acoustical data are collected at a distance of 7.5 m (25 ft) from the center of the highway travel lane. Additional microphones (described later) are deployed to provide data at FHWA-recommended positions[11] and also to obtain a better understanding of the tire/pavement noise farther from the vehicles. Data are recorded continuously with a sound level meter or spectrum analyzer (and also captured with a DAT recorder) where vehicle pass-by events are later extracted.

The acoustical data consists of continuous, 1-second time histories, along with the A-weighted fast response maximum sound levels (L_{AFmx}), using Type 1 sound level meters and spectrum analyzers; data are also recorded to Digital Audio Tape (DAT).

Key factors of acoustical data:

- At each measurement site, three microphones are deployed (distance=25 ft, height=5 ft; distance=50 ft, heights=5 and 15 ft), with an additional two microphones (distance=200 ft, height = 5 ft) at Sites 1 and 2. The heights are measured above the ground; there is some variation in the ground elevation compared to the roadway elevations, so the actual heights above roadway vary by about 1 ft.
- The primary acoustical instrumentation includes
  - LDL Model 820 Sound Level Meters (some with frequency-weighting circuits appropriate for use with B&K Model 4155 and 4189 microphones for grazing incidence)
  - LDL Model 2900 2-Channel Spectrum Analyzers

  - B&K Model 4155 and 4189 or GRAS Model 40AE ½-in Microphones (make/model matched to the appropriate sound level meter)
  - B&K Model 2671 Preamplifiers
  - B&K Model WB 1372 Power Supplies
  - B&K Model 0237 Foam Windscreens
  - Sony Model TCD-D100 Digital Audio Tape (DAT) Recorders
- The sound level meters and spectrum analyzers are set up to continuously measure A-weighted equivalent sound levels (Leq) in 1-second intervals. For the sound level meters, the L_{AFmx} values for each second of data are also available. For the spectrum analyzers, one-third octave band data are stored. DAT recordings allow for sound level meter or spectrum analyzer processing at a later time.
- The acoustical data are recorded continuously for up to 6 hours per day, weather permitting, with the exception of saving files in the spectrum analyzers every 2 hours and changing the DAT tapes after 4 hours. Occasionally, 7 hours of data will be recorded. Three full days of data collection typically allow for the adequate number of pass-by events for the SPB, paired measurement methodology (described in Section 4.1).
- Prior to measurements, all microphone/sound level meter and spectrum analyzer systems are time synchronized; then each is calibrated, and the electronic noise floor is established. Each system is also calibrated at the end of each measurement day to document sensitivity drift, if any.

3.2.2 Meteorological data

Meteorological data are collected during all acoustical data collection. This includes wind speed, wind direction, air temperature, and relative humidity. Data are recorded in 1-second intervals. (Acoustical data collected during wind speeds exceeding 5 m/s or 11 mph are eliminated during data processing.)

Key factors of meteorological data:

- At each measurement site, with the exception of Site 2 (which is close to Site 1 and is equipped with a hand held wind anemometer), meteorological sensors are deployed (distance=75 ft, height=5 ft).
- The primary meteorological instrumentation includes
  - Qualimetrics Transportable Automated Meteorological Stations (TAMS)
  - HP 200 LX Palmtop Computer
- The meteorological sensors are set up to continuously measure wind speed, wind direction, air temperature, and relative humidity (among other parameters) in 1-second intervals.
- The meteorological data are recorded during all acoustical data collection.
- Prior to measurements, all meteorological systems are time-synchronized with the acoustical instrumentation.

3.2.3 Traffic data

Highway traffic is recorded using a video camera (to minimize influence on drivers, such as might be caused by the presence of a radar gun) at each site. The camera is close enough to the roadway to allow identification of vehicles while viewing the videotape, and far enough away to allow speed calculations; distinctive landmarks and the associated separation distance are documented for speed calculation purposes. For the October 2006 measurements, in addition to the video, a radar gun facing downstream was used to obtain speeds at Site 4 (site farthest east in 2006 – traffic traveling from west to east), so as not to influence driver behavior at any of the sites, while still allowing for the validation of video-based speed measurements.

Key factors of traffic data:

- At each measurement site, video cameras are deployed (distances vary from about 200-300 ft, height=5 ft). The variation in distance from the roadway is due to the visibility of distinctive landmarks in the camera's view.
- The primary traffic data instrumentation includes
  - Sony 8-mm or Hi-8 Video Cameras

  - Television with VCR (for post-measurement processing)
- The video cameras are set up to continuously record all traffic that passes the measurement sites.
- The traffic data are recorded during all acoustical data collection.
- Prior to measurements, all video cameras are time-synchronized with the acoustical instrumentation.

3.2.4 Pavement data

Pavement data are collected, including pavement temperature [which can possibly influence tire/road noise by about -1 dB per 10° C (50° F), hotter being quieter[1]] and core samples (to allow for later evaluation of the pavement – macro texture, porosity, etc.). In addition, ground impedance measurements are performed in accordance with ANSI S1.18[7] (data were collected only in 2001 and 2002). Pavement temperatures are collected hourly.

Key factors of pavement data:

- At each measurement site, temperature guns (Extech Model 42520 IR Thermometer) are used at least once an hour to determine and log the pavement temperature.
- At least once a year, two core samples are extracted from each pavement section to allow for post-measurement analysis of the pavement, including determining the macro texture and the porosity. Note: These are the core samples that Volpe participated in through 2003; other organizations gathered samples later, dates unknown.
- When appropriate, acoustical impedance measurements are performed in accordance with ANSI S1.18 to determine the effective flow resistivity (EFR) of each pavement. The primary instrumentation used are two of the ½-in microphones and a spectrum analyzer (as listed under Acoustical Data), a Larson Davis SRC20 tone generator, and a driver feeding a long narrow tube to simulate a point source.

3.2.5 Pass-by event log and extraneous noise log data

Individual vehicle pass-by events are evaluated in real time for acceptability using observer logs at each site (additional acceptability tests conducted during post-analysis). With computerized data logs the observer notes the description of each acceptable vehicle pass-by event at each site; the observer listens for acoustical contamination from nearby vehicles or other sources and follows general guidelines of identifying a clean event, typically by allowing for 300 feet or 5 seconds of vehicle separation distance (more for heavy trucks). (Note: Identification of clean pass-by events was in conformance with ISO 11819-1, which includes the elimination of vehicles with atypical sounds.)

In the logs the vehicles are identified by type, where automobiles are vehicles with 2 axles, 4 tires, and generally < 4,500 kg or 9,900 lb (cars, pick-up trucks, and sports utility vehicles); medium trucks are vehicles with 2 axles, more than four tires, and generally > 4,500 kg or 9,900 lb and < 12,000 kg or 26,400 lb; and heavy trucks are vehicles with 3 or more axles and generally > 12,000 kg or 26,400 lb. Buses and motorcycles are identified but not included in this analysis due to low populations. The logs are also used to identify extraneous noise events that may have contaminated the vehicle pass-by noise measurements.

Key factors for pass-by event log and extraneous noise log data:

- At each measurement site, personnel operate an HP 200 LX palmtop computer electronic log to identify all acceptable vehicle pass-by events (including the type of vehicle, a brief description, and the time of the event) and to note the description and time of any noise event that may have possibly contaminated the acoustical data.
- Prior to measurements, all electronic logs are time-synchronized with the acoustical instrumentation.

3.3 Data Collection Sessions

There have been several wayside data measurement sessions: baseline measurements (both preliminary and repeated) prior to the overlays being paved (to help determine potential site bias, i.e., differences among the sites due to parameters other than pavement, e.g., slight differences in ground elevations) and four post-overlay measurements, with the pavement overlays aged 4, 10, 16, and 52 months. Each measurement session occurred over a period of several days and included four to seven hours of continuous attended noise measurements simultaneously at each site each day.

In collecting data at the LA138 sites, wind played a major role in determining the time of year and number of days that would be required to collect useful data. Even with careful consideration, the wind limited the amount of data collected (see Section 3.2.2 for wind speed restrictions). For each measurement session, however, a minimum number of 300 pass-by events per site was achieved. Following is a list of the completed measurement sessions:

Preliminary Measurements:
May 2001 – This set of measurements was performed with the existing old DGAC. It was originally going to be used as the baseline set of measurements until it was determined by Caltrans and University of California Pavement Research Center that the pavement was structurally failing and would not support pavement overlays. [10] Also, at some of the sites, cracks in the pavement acoustically contaminated the collected data.

For the May 2001 set of measurements, a continuous flow/sound level averaging methodology was applied, and data were collected on both sides of the highway at 16 different sites, not all simultaneously (study was going to include more than 5 pavement types). The data were collected for 7 days. Pass-by events were not logged since that type of methodology was not being used. However, all other data were collected in a manner similar to that for all subsequent measurements, and the 16 sites include the 5 sites measured in subsequent measurements. Some of the May 2001 data could be used to extract vehicle pass-by events if it is ever of interest to compare the very old DGAC to the newer overlays.

Baseline Measurements:
March 2002 – This set of measurements was performed with a new DGAC leveling course,

aged approximately 3 months. The leveling course covered all pavement test sections, where the original 16 sections were reduced to 5. For these measurements, the SPB methodology was applied. The data were collected for 5 days. Over 600 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events are eliminated as described in that section). For this measurement trip, EFR data were also collected. The March 2002 data allow for a direct comparison between sites, with the variability of pavement removed.

Post-Overlay Measurements (4 sets as of April 2007):

October 2002 (beginning of October) – **Aged ~4 Months** – This set of measurements was performed with 5 overlays covering the DGAC leveling course. The overlays were aged approximately 4 months. Again, the SPB methodology was applied. The data were collected for 4 days. Over 500 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events are eliminated as described in that section). For this measurement trip, EFR data were also collected.

March 2003 (end of March) – **Aged ~10 Months** – This set of measurements was performed with the same 5 overlays. The overlays were aged approximately 10 months. Again, the SPB methodology was applied. The data were collected for 2 days. Over 300 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events are eliminated as described in that section).

October 2003 (beginning of October) – **Aged ~16 Months** – This set of measurements was performed with the same 5 overlays. The overlays were aged approximately 16 months. Again, the SPB methodology was applied. The data were collected for 3 days. Over 500 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events are eliminated as described in that section).

October 2006 (beginning of October) – **Aged ~52 Months** – This set of measurements was performed for 4 of the 5 overlays (excluded Site 5, BWC[a]). The overlays were aged approximately 52 months. Again the SPB methodology was applied. The data were collected for 3 days. Over 700 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events are eliminated as described in that section).

[a] Results out to the pavement age of 16 months indicated that BWC is not considered a quieter pavement as compared to DGAC. Due to this fact and to save on funds, Caltrans and the Volpe Center agreed to discontinue wayside measurements for Site 5, BWC.

4. DATA PROCESSING AND ANALYSIS

Upon capturing all of the data, processing and analysis for the acoustical, meteorological, traffic, pavement temperature and EFR, pass-by event log, and extraneous noise log data are performed. Thorough pavement analyses were performed by the University of California Pavement Research Center; more information about the LA138 pavements can be found in the UCPRC 2006 reference.[9] Applying the SPB methodology to the current study is first described followed by a section describing the data processing and analysis procedure.

4.1 SPB Methodology Applied to Thin Lift Study

A modified SPB analysis is performed for each of the data sets. The result of applying the SPB methodology is a single number called the Statistical Pass-By Index (SPBI), accounting for noise from automobiles, medium trucks, and heavy trucks. Intermediate results for each vehicle type (part of SPBI calculations) are also extracted. For the processing and analysis *the following key factors apply*:

- The SPB "paired measurements" technique is applied: this technique employs the selection of the same vehicles from the traffic stream as they pass each measurement site, improving accuracy due to the elimination of differences in traffic composition. For determination of the overall performance of the pavements, four pairs of sites are examined: Site 1 and Site 2, Site 1 and Site 3, Site 1 and Site 4, and Site 1 and Site 5.
- The baseline set of data (March 2002) is used to determine site biases, without the influence of pavement type. Differences in average baseline sound levels for each site pair are calculated, determining each site bias, which is applied to the average post-overlay sound levels.
- For the spectral sound level processing and analysis, the "paired measurement" technique is extended to include all sites: analysis includes the exact same vehicle set for each site being examined. Using identical vehicle sets reduces the number of pass-by events included in the averages for the spectral levels. With this reduction in number of pass-by events and due to the collection of fast response values (L_{AFmx}), it was determined that site bias values could not be considered in the spectral comparison. Therefore, spectral data are presented as measured. (For the spectral results, sound levels for several pass-by events of the same vehicle type are arithmetically averaged for each 1/3-octave band.)

- The speed category of interest for this study is "highway speeds". The ISO 11819-1 standard sets the minimum highway speed to be 100 km/h (~60 mph) for automobiles. For medium and heavy trucks, the standard allows for unspecified lower speeds. Reviewing all of the recorded traffic on LA138, it is clear that lower minimum speeds apply to the LA138 site, and that many pass-by events (~15 %) would be forfeited if applying the ISO restriction. To better capture the traffic on LA138 and use highway speeds that are more appropriate for the U.S., the minimum automobile highway speed is dropped to ~90 km/h (55 mph); the minimum medium and heavy truck speed is set at ~80 km/h (50 mph).
- In order to calculate the SPBI, the standard requires a minimum number of clean pass-by events for each vehicle category: 100 for automobiles and 80 for combined medium and heavy trucks, with a minimum of 30 medium trucks and a minimum of 30 heavy trucks. These requirements are based on single measurements (as opposed to paired measurements, which should allow the requirements to be relaxed). For the current study, minimum requirements for the medium and heavy trucks were not always met, however, totals appear to be adequate for a paired measurement analysis with the modified SPBI calculations. Typically, 100 or more automobiles are included in each of the averages and 30 or more heavy trucks (combined medium and heavy trucks numbers not always reaching the minimum of 80); the baseline measurements yielded fewer pass-by events, although enough to determine site biases.
- Calculating the SPBI first requires calculating the vehicle sound level (Lveh), which is calculated for each vehicle type (automobiles, medium trucks, and heavy trucks). Lveh is a representative (an "average") sound level for a specific vehicle type for the highway speed category. In the ISO 11819-1 standard, Lveh uses a regression through the accumulated maximum sound level (L_{AFmx}) data points for each vehicle type; a single number, Lveh, is extracted from the regression line at a specified reference speed. It was determined that the regression methodology breaks down when the minimum number of vehicle pass-bys is not obtained or when speeds are off even by small amounts (there is error associated with obtaining vehicle speeds, whatever the methodology/instrumentation). After a brief investigation with LA138 data, it was determined that the linear arithmetic average of the L_{AFmx} data for all the events equaled the single value extracted from the regression line at the reference speed (for data sets with the minimum number of events achieved). Thus, for the

current study, Lveh is obtained by taking the linear arithmetic average L_{AFmx} of all events for each vehicle category. A side benefit to obtaining Lveh in this manner is that it relaxes the need for precise vehicle speeds. So, for the current study, where there are limitations to obtaining precise speed data and where the SPB minimum numbers for events were occasionally not met, the L_{AFmx} averages were calculated for all events for highway speeds greater than 90 km/h (55 mph) for automobiles and 80 km/h (50 mph) for medium and heavy trucks (any pass-bys greater than 145 km/h or 90 mph were eliminated).

- The equation below is applied to calculate the SPBI.[6] A modified SPBI is calculated using the L_{AFmx} averages as the Lveh variables in the equation. The vehicle mix ratios in the equation are maintained as in the standard, and the speeds are updated to better represent LA138 (approximate average speeds at the sites): 100 km/h (60 mph) for autos and 90 km/h (55 mph) for medium and heavy trucks.
- ISO 11819-1[6] provides discussion of expected errors and uncertainty for the SPB method.
- The parameters calculated and presented for this study include the modified Lveh for each of the three vehicle types and also the modified SPBI for highway speeds.

$$SPBI = 10*\log[W_1*10^\wedge(L_1/10) + W_{2a}*(v_1/v_{2a})*10^\wedge(L_{2a}/10) + W_{2b}*(v_1/v_{2b})*10^\wedge(L_{2b}/10)],$$

where SPBI = Statistical Pass-By Index, for a standard mix of light and heavy vehicles

L_x = vehicle sound level for vehicle category x – refer to Section 3.2.5 for vehicle categories
(average L_{AFmx} for each vehicle type is applied; this differs from Lveh calculations in ISO 11819-1)

W_x = weighting factor, which is the proportion of vehicle category x in the traffic (taken from Table 1 in ISO 11819-1)

v_x = reference speed of vehicle category x
[60 mph (~100 km/h) for autos, 55 mph (~90 km/h) for medium and heavy trucks; reference speeds differ from those in Table 1 in ISO 11819-1].

4.2 Processing Procedure

4.2.1 Modified SPBI and average vehicle sound level

First, pass-by events are extracted from the vehicle pass-by event log for each site; the vehicle type, description, and time are entered into a spreadsheet. Events are eliminated where comments indicate that the event may not have been acceptable.

Events are also eliminated where sound levels 10 decibels down from the event maximum sound level both before and after an event were not achieved (i.e., events were eliminated when the vehicle pass-by event was acoustically influenced by another sound source). Next, pass-by events are paired for each of the four site pairs; only pass-by events that are described to be acoustically clean at both sites are retained. Meteorological data are then extracted for each event for each site; the average wind speed around each pass-by event (10 seconds before and after the event) is calculated, and the maximum wind speed is extracted. Events with maximum wind speeds exceeding 5 m/s (11.24 mph) are eliminated. Using the remaining list of pass-by events, vehicle speeds are extracted from the videotapes and entered into the spreadsheets with the corresponding pass-by events. If the speeds are not in the same speed category for both sites for a site pair, the vehicle pass-by event is eliminated. Finally L_{AFmx} is determined for each remaining vehicle pass-by event for each site. (Pavement temperatures are also entered for each event.) The pass-by data can be seen in Appendix C. For each site pair, vehicle type, microphone location, and pavement age, tables show the average pass-by L_{AFmx} (also shown graphically in Appendix E, Section 1) and standard deviation; the average vehicle speed and standard deviation; and the average, maximum, and minimum pavement and air temperatures. Plots show all the L_{AFmx} data points with regression lines and equations.

Calculations are then performed to obtain the modified SPBI. First, the data are sorted into three vehicle categories: automobiles, medium trucks, and heavy trucks; then the data are sorted into vehicle speed categories. Most of the events fall within the highway speed category, and all remaining analysis is performed just for that category. The average L_{AFmx} is calculated for each vehicle category for each pavement site; these averages are determined to be the modified vehicle sound levels (modified Lveh). Then the ISO 11819-1 equation is used to calculate the SPBI.

The results that are reported are the average L_{AFmx} (modified Lveh) for each of the three vehicle types for each of the pavement sites (Appendix C and Appendix F, Section 1). Also reported is the modified SPBI for each of the pavement sites (Appendix E). Each of these parameters is calculated for each of the microphone locations (except the 200-ft microphones).

4.2.2 Test vehicle

The test vehicle data are included in the SPBI calculations if the event meets all the criteria described above. In addition, the test vehicle data are separated from the other data. The average L_{AFmx} is calculated for each speed (40, 50, 60, and 70 mph; ~65, 80, 100, and 112 km/h) for each pavement site. These averages are plotted across speed for comparison.

4.2.3 Existing traffic spectral data

Spectral sound level data are also analyzed, including identical vehicle sets for each site being examined. For this small set of vehicles, the L_{AFmx} values and the spectral data are examined for all microphones, including the microphones located at 200 ft (60 m) at Sites 1 and 2.

4.2.4 Sound absorption of pavement

For the pavement sound absorption data (effective flow resistivity, EFR), an average sound level delta is determined for the two microphone positions in the instrumentation set-up; this is determined for each of thirteen frequencies. Using a table that matches deltas and frequencies to theoretically calculated ground absorption curves (based on the ANSI S1.18-specified geometry), the EFR values are extracted for each type of pavement. The table provided in the ANSI standard has little resolution and excludes higher impedance surfaces. As such, a new table with greater resolution was generated, and the effectiveness of this type of methodology for determining differences in pavement surfaces is being evaluated. During this evaluation process, it was determined that further analysis techniques (beyond those in ANSI S1.18) are necessary to allow for extraction of EFR values related to various pavement types. A "curve selecting" methodology was developed[a]; this method first

[a] Due to funding constraints, it was agreed between Caltrans and the Volpe Center that the EFR data captured for the LA138 study could be used in the FHWA TNM Pavement Effects Implementation Study. Starting in 2006,

examines peaks and dips in the absorption curves (and based on that, limits the possible range of EFR values), then the method normalizes the data to better match amplitudes (assuming cement concrete is 20,000 cgs rayls and old dense-graded asphalt is 30,000 cgs rayls – these are acoustically hard, reflective ground surfaces), and then matches amplitudes at specific frequencies. Preliminary results related to this analysis technique are presented in the Results and Discussion section.

development of the EFR data analysis technique and assessment was funded by FHWA, and information to date from the FHWA study is included in this report.

5. RESULTS AND DISCUSSION

The Thin Lift (LA138) Study generates an extensive data set. The following results are included in this section and corresponding appendices: 1) overall performance of the pavements over time, compared to DGAC; 2) pavement performance by vehicle type, both broadband and spectral examinations; 3) pavement performance for the test vehicle (broadband only); and 4) pavement performance related to sound absorption of the pavement. There are some limitations to the results presented, related to microphone positions and pavement age; each subsection will note which results are being presented.

5.1 Overall Performance of Pavements

The performance over time of each of the pavements tested compared to the DGAC of the same age can be seen in Table 2 and Table 3. Table 2 shows the SPBI *values* and Table 3 shows the differences or *deltas* between the SPBI values. An attempt was made to remove any site bias by applying corrections determined with the baseline measurements – refer to Appendix D, Section D.3 for more information on site bias corrections. In addition to the tables, Figure 5 shows the SPBI *deltas* over time for just the 7.5 m (25 ft) microphone position (as an example); plots for other microphone positions can be found in Appendix D, Section D.2. Plots of the SPBI *values* over time can be found in Appendix D, Section D.1.

Table 2. Post-overlay measurements: sound levels for each pavement type (SPBI*) by site pairs with identical vehicle sets.**

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* (dBA)							
		Site 1 (DGAC, 30 mm)	Site 2 (OGAC, 75 mm)	Site 1 (DGAC, 30 mm)	Site 3 (OGAC, 30 mm)	Site 1 (DGAC, 30 mm)	Site 4 (RAC Type O, 30 mm)	Site 1 (DGAC, 30 mm)	Site 5 (BWC, 30 mm)
4 months	7.5 m (25 ft) low	82.1	78.9	82.0	80.6	82.1	79.7	na	na
	15m (50 ft) low	75.3	72.7	75.3	73.6	75.3	72.7	75.3	75.5
	15m (50 ft) high	77.1	73.8	77.1	75.4	77.2	75.1	76.9	76.2
10 months	7.5 m (25 ft) low	82.3	78.7	82.6	80.6	82.7	80.0	82.7	80.6
	15m (50 ft) low	75.2	72.4	75.5	73.8	75.7	72.9	75.6	76.0
	15m (50 ft) high	77.4	73.7	77.7	75.8	77.8	75.4	77.9	75.9
16 months	7.5 m (25 ft) low	82.5	79.0	82.4	80.7	82.4	80.2	82.5	80.7
	15m (50 ft) low	75.6	72.6	75.5	73.9	75.5	73.3	75.4	75.9
	15m (50 ft) high	77.5	74.4	77.3	76.2	77.3	75.9	77.4	75.9
52 months	7.5 m (25 ft) low	83.2	79.4	83.5	81.2	83.6	81.3	na	na
	15m (50 ft) low	75.5	72.5	75.9	74.1	75.9	73.6	na	na
	15m (50 ft) high	78.0	74.2	78.4	76.7	78.5	76.5	na	na

Note: This table is also seen in Appendix D (Table D-1), with baseline values included. SPBI values with site bias not removed can be seen in Appendix D, Table D-2.

Table 3. Post-overlay measurements: site differences due to type of pavement (SPBI* deltas) by site pairs with identical vehicle sets.**

*modified SPB methodology
** other sites **calibrated to Site 1 to remove site bias** unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* delta (dBA)			
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)	Site 3 – Site 1 (OGAC, 30 mm – DGAC)	Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)	Site 5 – Site 1 (BWC, 30 mm – DGAC)
4 months	7.5 m (25 ft) low	-3.1	-1.5	-2.5	na
	15m (50 ft) low	-2.6	-1.7	-2.6	0.2
	15m (50 ft) high	-3.2	-1.7	-2.1	-0.7
10 months	7.5 m (25 ft) low	-3.6	-2.0	-2.6	-2.1
	15m (50 ft) low	-2.8	-1.8	-2.7	0.4
	15m (50 ft) high	-3.6	-1.9	-2.4	-2.0
16 months	7.5 m (25 ft) low	-3.5	-1.7	-2.3	-1.8
	15m (50 ft) low	-2.9	-1.5	-2.2	0.5
	15m (50 ft) high	-3.1	-1.1	-1.4	-1.5
52 months	7.5 m (25 ft) low	-3.8	-2.4	-2.3	na
	15m (50 ft) low	-3.0	-1.7	-2.3	na
	15m (50 ft) high	-3.8	-1.7	-2.0	na
Average (all locations, all time)		-3.3	-1.7	-2.3	-0.9

Note: Decibel values show in Table 3 may not agree with the source data in Table 2 due to rounding. A slightly modified version of this table is seen in Appendix D (Table D-3), with baseline values included. SPBI deltas with site bias not removed can be seen in Appendix D, Table D-4.

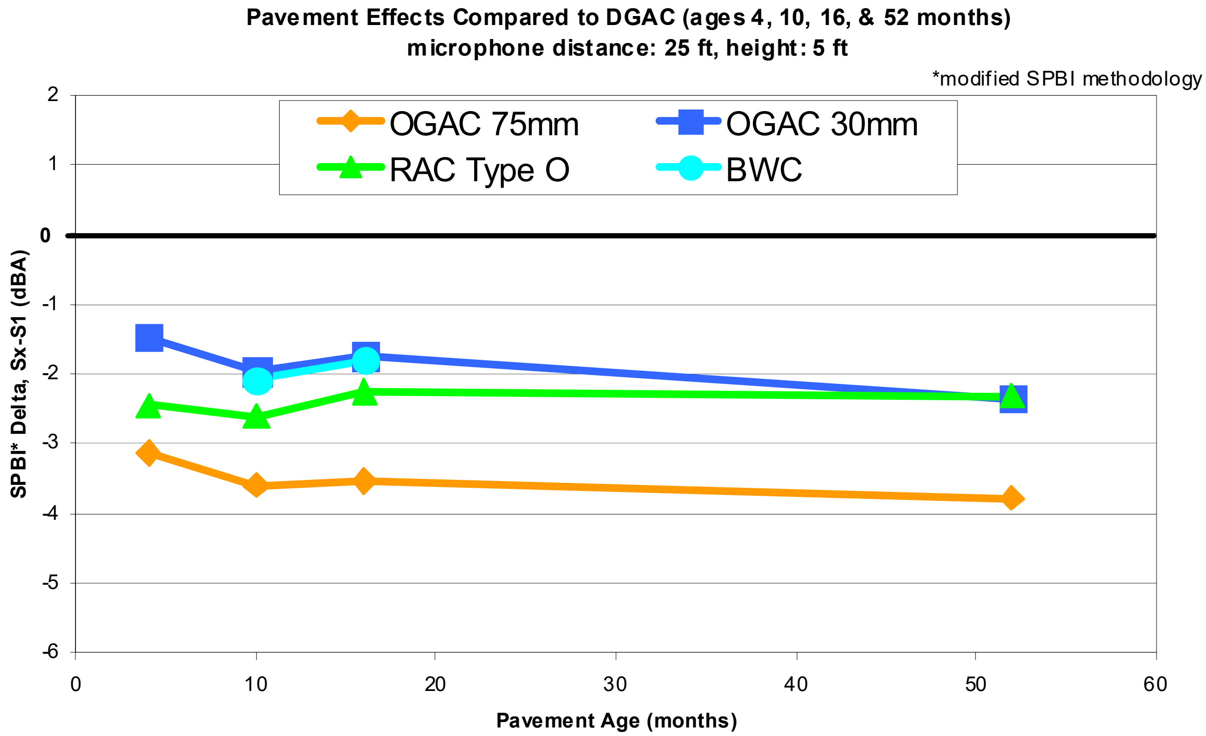

Figure 5. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI (limited data for BWC). Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

Note: This plot can also be seen in Appendix D, Figure D-12. Refer to Figures D-13 and D-14 for the other two microphone positions.

As can be seen in Table 3 and Figure 5, the SPB results (with the modified SPB methodology) indicate that, over a 52-month period, OGAC 75 mm is the quietest pavement, with the average benefit over DGAC being 3.3 dBA, benefit ranging from 2.6-3.8 dBA, variation depending on microphone position and pavement age. Observation on microphone position variation: the low microphone at the 15-m (50-ft) position shows the least benefit. For each microphone position, the benefit varies only slightly over time (< 1 dBA).

The second quietest pavement is RAC Type O 30 mm, where the average benefit over DGAC is 2.3 dBA, benefit ranging from 1.4-2.7 dBA, variation depending on microphone position and pavement age. Observation on microphone position variation: all microphone positions show approximately the same benefit, with the exception of the 15-m (50-ft) high microphone with the pavement aged 16 months. For each microphone position, the benefit varies only slightly over time (≤ 1 dBA).

The third quietest pavement is OGAC 30 mm, where the average benefit over DGAC is 1.7 dBA, benefit ranging from 1.1-2.4 dBA, variation depending on microphone position and pavement age. Observation on microphone position variation: the two 15-m (50-ft) microphone positions often show almost the exact same benefit (except for the pavement aged 16 months). For each microphone position, the benefit varies only slightly over time (< 1 dBA).

The final pavement, BWC 30 mm, is actually louder than DGAC for one of the microphone positions, where the average benefit over DGAC is 0.9 dBA, "benefit" ranging from -0.5 (no benefit) to 2.1 dBA, variation depending on microphone position and pavement age. Observation on microphone position variation: although the BWC sometimes shows about a 2-dBA benefit at the 7.5-m (25-ft) and high 15-m (50-ft) positions, there is no indication of a benefit at the low 15-m (50-ft) position. For each microphone position, the benefit varies some over time (< 2 dBA). The BWC 30 mm at Site 5 should not be considered a quieter pavement.

As mentioned, the pavement benefits do vary somewhat by microphone position (although general trends are the same), and different observations were made for each pavement type. Possible contributions to the variation include: differences in angle of reflection off pavement, differences in the ground effect during propagation, and possible differences in meteorological effects during propagation, although care was take to minimize the meteorological effects. This aspect of the study should be further investigated; results could affect future guidance on microphone placement for wayside tire/pavement noise measurements.

It should be noted that the modified SPBI values (not the deltas) show a general trend of slightly increasing over time for all pavements types except BWC (data not available to identify trends for this pavement type). Please refer to Figure 6 as an example (also found in Appendix D, Figure D-5), which shows the increase in SPBI values over time, as compared to values at four months, for the 7.5-m (25-ft) position (plots for the other microphone positions are found in Appendix D, Figures D-6 and D-7). Although there is variation by microphone position, DGAC increases approximately 1.5 dBA over 52 months. OGAC 75 mm increases approximately 0.5 dBA. OGAC 30 mm increases approximately 1.5 dBA. RAC Type O increases approximately 1.5 dBA. Because there are only slight sound level increases for test and reference pavements, the SPBI deltas are fairly consistent over time. However, because the increase in SPBI values for each of the test pavements can vary from DGAC, the SPBI deltas can be slightly affected. As an example, for the 7.5-m (25-ft) position, Figure 6 shows that DGAC increases over time more than both the OGAC pavements. This is reflected in the Figure 5 SPBI delta plot, where it is seen that the deltas (the benefits) for the OGAC pavements increase slightly at 52 months. Measurements taken beyond the age of 52 months would help to further determine trends related to age, both for the SPBI values and the deltas (benefit over DGAC).

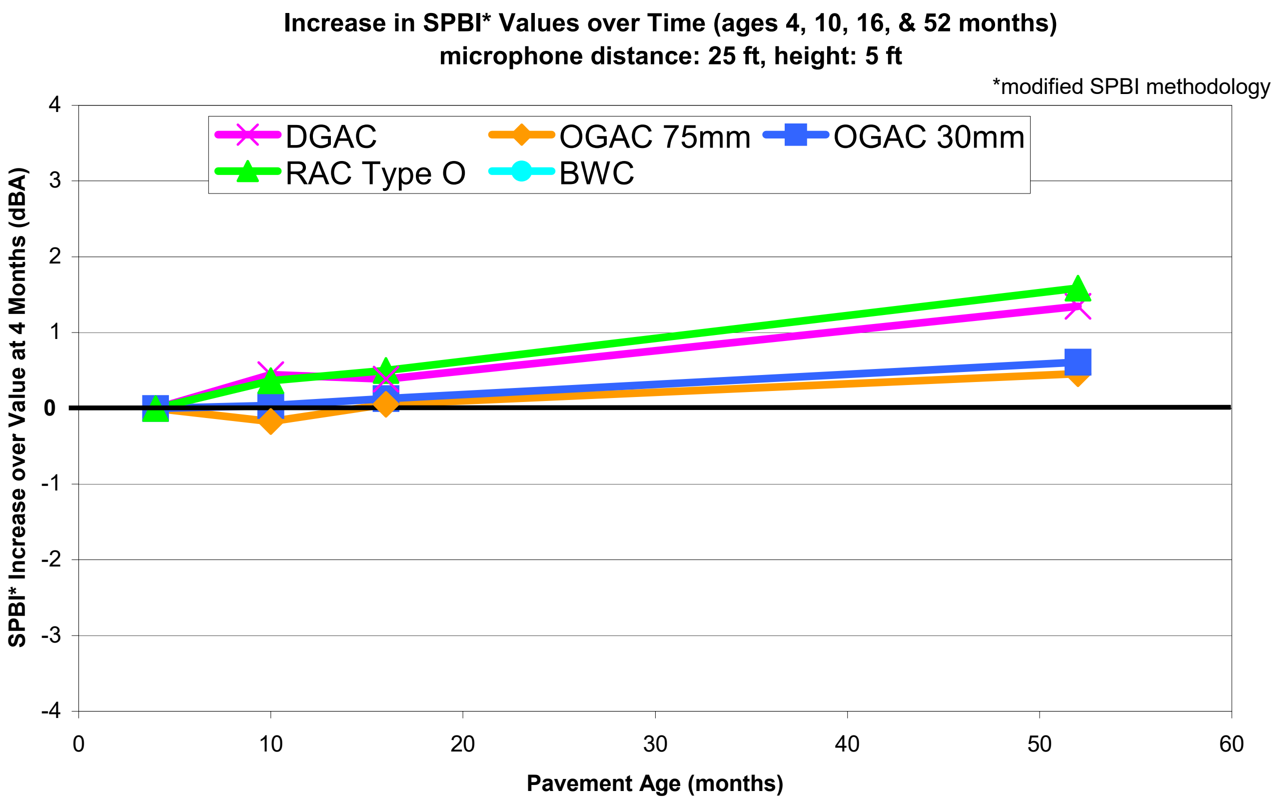

Figure 6. Increase in SPBI* values over time, as compared to values at 4 months. Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

Note: This plot can also be seen in Appendix D, Figure D-5. Refer to Figures D-6 and D-7 for the other two microphone positions.

5.2 Pavement Performance by Vehicle Type

The pavement performance by vehicle type is presented in terms of both broadband and spectral sound levels.

5.2.1 Broadband examination

For this examination, the average L_{AFmx} values for automobiles (autos), medium trucks (med trucks), and heavy trucks (hvy trucks) are considered. Table E-1 in Appendix E shows the average L_{AFmx} values. The baseline values are used to remove site bias, then each of the test pavements is compared to the DGAC (Site 1); the average differences or deltas between the test pavements and DGAC can be seen in Table 4.

As shown in Table 4, the noise benefit relative to the reference DGAC of the same age, listed in order of the best performance (considering pavement benefits as average over all microphone locations and time), is as follows:

1. OGAC 75 mm: 3.7 dBA for autos, 3.1 dBA for med trucks, and 3.0 dBA for hvy trucks;
2. RAC 30 mm: 3.5 dBA for autos, 2.0 dBA for med trucks, and 1.3 dBA for hvy trucks;
3. OGAC 30 mm: 2.6 dBA for autos, 1.2 dBA for med trucks, and 1.2 dBA for hvy trucks; and
4. BWC 30 mm: 0.4 dBA for autos, 0.4 dBA for med trucks, and 1.1 dBA for hvy trucks.

It should be noted that the order of performance is the same for all vehicle types. It should also be noted that there is a greater benefit for automobiles than for medium or heavy trucks, except in the case of the BWC (Site 5). Lastly, it should be noted that the difference in benefit comparing automobiles to either medium or heavy trucks is not consistent among pavement types; for example, the difference in average benefit between automobiles and heavy trucks for OGAC 75 mm is 0.7 dBA, and the difference for RAC 30 mm is 1.4 dBA. This indicates that some pavements can reduce noise about the same amount for both automobiles and heavy trucks, where as other pavements see more of a disparity in reduction between vehicle types.

Figure 7 shows the average difference between the four test pavements and the reference DGAC (of the same age) at the 7.5 m (25 ft) position for automobiles and heavy trucks (results for the other microphone positions can be seen in Appendix E, Figures E-2 and E-3). As with Table 4, Figure 7 also indicates that the noise benefit provided by each of the test pavements is greater for automobiles than for heavy trucks (exception being BWC). This is also indicated for each of the other microphone positions and also when site bias is not considered. Table 4 and Figure 7 also indicate that increasing the thickness of the OGAC layer provides additional benefit for both automobiles and heavy trucks. In addition, rubberized asphalt seems to provide additional benefit for automobiles, when comparing the OGAC and RAC of the same thickness.

Such results can be considered when choosing or designing a pavement for highways. When targeting a highway with a low percentage of heavy truck traffic, 30 mm of RAC Type O may be almost as effective as 75 mm of OGAC; however, when heavy trucks are dominant, 75 mm of OGAC should reduce the traffic noise more than 30 mm of RAC Type O.

Table 4. Post-overlay measurements: for each vehicle type, site differences due to type of pavement (Lveh* deltas) by site pairs with identical vehicle sets. **

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	Modified Lveh* (or average L_{AFmx}) delta (dBA)											
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)			Site 3 – Site 1 (OGAC, 30 mm – DGAC)			Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)			Site 5 – Site 1 (BWC, 30 mm – DGAC)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
4 months	25 ft (7.5 m) low	-3.7	-2.9	-3.0	-2.2	-0.6	-1.2	-3.5	-2.0	-1.7	na	na	na
	50 ft (15 m) low	-3.1	-2.4	-2.4	-2.3	-0.5	-1.6	-4.0	-2.3	-1.3	0.5	1.0	0.0
	50 ft (15 m) high	-4.0	-3.4	-2.5	-2.7	-0.6	-0.9	-3.3	-1.7	-1.1	0.0	0.4	-1.0
10 months	25 ft (7.5 m) low	-3.9	-3.3	-3.6	-2.8	-2.4	-1.5	-3.6	-2.6	-1.8	-1.7	-1.6	-2.3
	50 ft (15 m) low	-3.0	-2.6	-2.7	-2.4	-1.6	-1.5	-3.6	-3.2	-1.6	0.7	-0.3	0.4
	50 ft (15 m) high	-4.2	-3.9	-3.0	-2.6	-2.0	-0.9	-3.4	-1.8	-1.6	-0.9	-1.3	-2.3
16 months	25 ft (7.5 m) low	-4.1	-3.0	-3.4	-2.7	-1.0	-1.4	-3.6	-2.2	-1.4	-1.8	-1.1	-1.9
	50 ft (15 m) low	-3.6	-2.7	-2.7	-2.1	-0.4	-1.4	-3.7	-2.6	-0.8	0.7	0.3	0.4
	50 ft (15 m) high	-3.7	-2.9	-2.5	-2.4	-0.2	0.0	-2.8	-1.0	-0.4	-0.8	-0.8	-1.6
52 months	25 ft (7.5 m) low	-3.6	-3.3	-4.0	-2.9	-2.1	-2.1	-3.0	-1.6	-1.8	na	na	na
	50 ft (15 m) low	-3.1	-2.6	-2.9	-2.7	-1.3	-1.4	-3.9	-2.2	-1.0	na	na	na
	50 ft (15 m) high	-4.0	-4.4	-3.4	-2.8	-2.0	-0.6	-3.1	-1.2	-1.1	na	na	na
Average (all locations, all time)		-3.7	-3.1	-3.0	-2.6	-1.2	-1.2	-3.5	-2.0	-1.3	-0.4	-0.4	-1.1

Note: A slightly modified version of this table is seen in Appendix E (Table E-2), with baseline values included. Lveh deltas with site bias not removed can be seen in Appendix E, Table E-3.

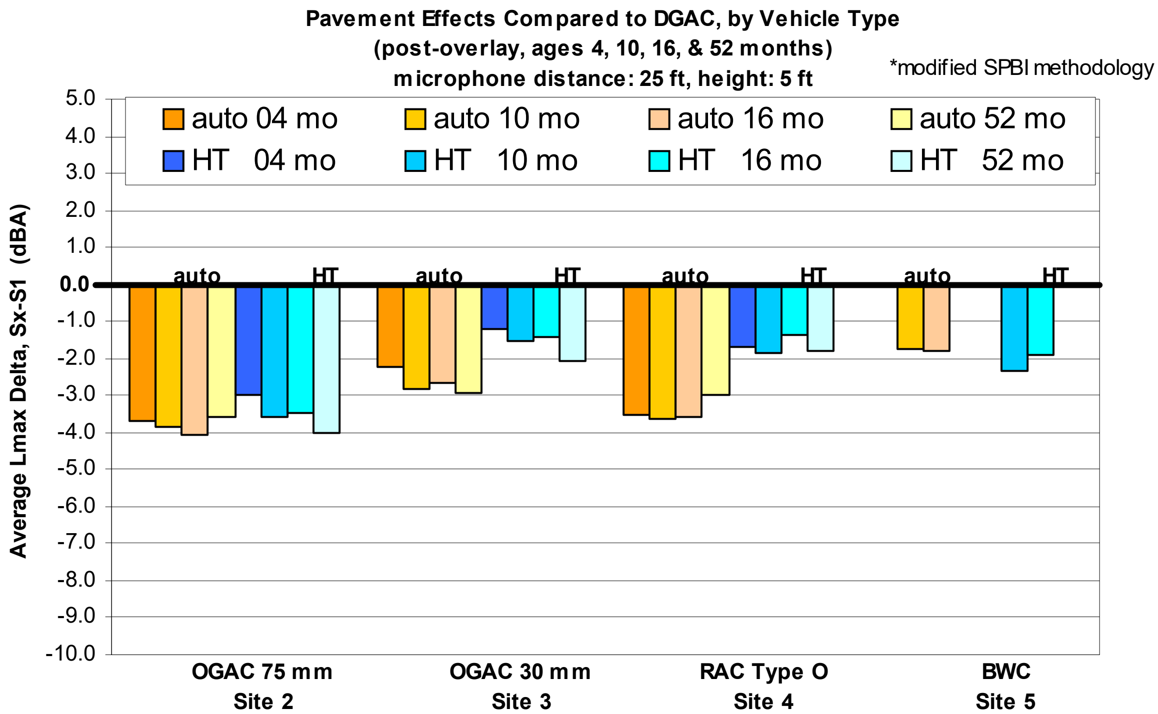

Figure 7. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

Note: This plot can also be seen in Appendix E, Figure E-1.

5.2.2 Spectral examination

For this examination, averages of L_{AFmx} spectral data by vehicle type are considered; the vehicle types examined here are automobiles and heavy trucks. The spectral data can be examined in several different ways, each providing a useful perspective, including: 1) comparing different pavements for a single pavement age and single microphone location; 2) comparing different pavement ages for a single pavement and single microphone location; and 3) comparing different microphone locations for a single pavement and pavement age. Data for all these scenarios are presented as plots in Appendix E. This data set has *not* been adjusted for site bias and includes far fewer data points than the average L_{AFmx} data (broadband) discussed in the previous sub-section.

Presented first is an example of the first scenario: comparing different pavements for a single pavement age and single microphone location. Figure 8 shows the A-weighted measured 1/3-octave band levels for the reference DGAC pavement and the four test pavements at the 7.5-m (25-ft) position for the pavement aged 16 months, for automobiles and heavy trucks. Please refer to Appendix E, Figures E-4 through E-18 for all microphone positions and pavement ages.

The top plot in Figure 8 shows the spectral levels for **automobiles**. It indicates that the quieter pavements provide noise benefits in a critical range around 1000 Hz; for the DGAC (Site 1), ~70% of the energy is in the 800-1600 Hz range, where the quieter pavements are showing a noticeable reduction (except BWC). The additional thickness for the OGAC (Site 2) provides additional benefit (over Site 3) for frequencies greater than or equal to 1000 Hz. Also the rubberized pavement (Site 4) seems to provide additional benefit over the open-graded of equal thickness (Site 3) at the most dominant frequency, 1000 Hz. The BWC (Site 5) provides no noticeable benefit.

The bottom plot in Figure 8 shows the spectral levels for **heavy trucks**. It indicates that the quieter pavements provide noise benefits in a critical range around 1000 Hz; for the DGAC, ~60% of the energy is in the 630-1600 Hz range, where the quieter pavements are showing a noticeable reduction. The frequency of 500 Hz is also a critical frequency for heavy trucks (~17% of the total energy for DGAC), where very little reduction is seen due to the quieter pavement types. As with the automobiles, the additional thickness for the OGAC provides additional benefit for frequencies greater than or equal to 1000 Hz. Again the rubberized pavement is providing additional benefit over the open-graded of equal thickness at 1000 Hz, but this is not the most dominant frequency for heavy trucks (there is some benefit with rubberized at 500 Hz). The BWC provides a small benefit at frequencies 630 Hz and up.

Results for other microphone positions and pavement ages are similar. Some variation occurs with the range of 1/3-octave bands affected. For example, the lower 1/3-octave band for the range of benefit of the thicker OGAC over the thinner one can range from 800 Hz to 1250 Hz. Also, the benefit of RAC over OGAC of the same thickness can show an effect above 1000 Hz.

It should also be noted that a trend is seen when considering the **benefits of pavement as a function of distance**. In Appendix E, Figures E-7, E-11, and E-15 show the results for DGAC and the thick OGAC at the 60-m (200-ft) distance, each figure representing a different pavement age. In the plots for both automobiles and heavy trucks, it can be seen that some lower frequencies that were contributing little, if any, to the overall sound level closer to the road, are now within 10 dBA of the dominant frequency, and are contributing to the overall sound level. These lower frequencies see little, if any, benefit due to the quieter pavement. To demonstrate the distance effect and lower frequency contributions, an example is described here: for the pavement aged 4 months, the benefit of OGAC over DGAC at a distance of 7.5 m (25 ft) is 3.3 dBA for automobiles and 2.3 dBA for heavy trucks (broadband). At a distance of 60 m (200 ft), the benefit is 2.5 dBA for automobiles and 1.1 dBA for heavy trucks. So the benefit for automobiles has reduced 1.0 dBA over 52.5 m (175 ft), and the benefit for heavy trucks has reduced 1.4 dBA over 52.5 m (175 ft).

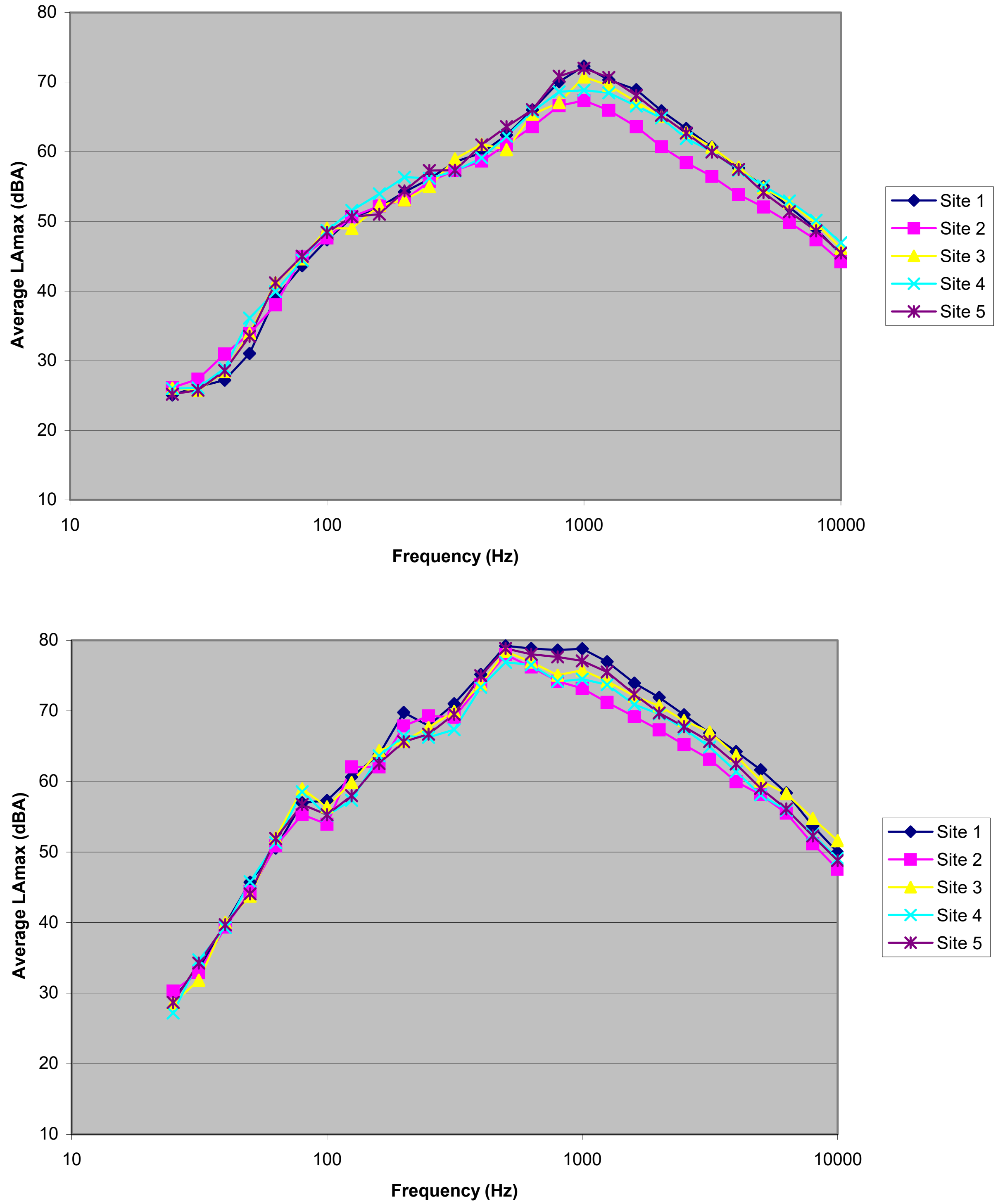

Figure 8. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 25 ft, height 5 ft.

The second scenario, comparing different pavement ages for a single pavement and single microphone location, is presented in Appendix E, Figures E-19 through E-23. For automobiles, trends based on pavement age appear to be microphone location dependent (for all but the DGAC, which does not show clear trends). For the 7.5-m (25-ft) location, frequencies from about 400 to 1000 Hz get louder with age. For the 15-m (50-ft) locations, there is some increase in sound level below 1000 Hz, but frequencies above 1000 Hz also get louder with age. For heavy trucks, no aging trends can be identified. Further investigations are necessary to extract meaning from these trends or lack of trends.

The third scenario, comparing different microphone locations for a single pavement and pavement age, is presented in Appendix E, Figures E-24 through E-28. These plots show how the spectral shape evolves through propagation. The lower frequencies (below 1000 Hz) become more important to the overall sound level, as discussed in the first scenario.

The **spectral content should be considered when choosing or designing a pavement for highways**. In this study, critical differences among the quieter pavements start around 1000 Hz, although benefits for all pavements affect lower frequencies, in many cases, down to about 630 Hz. Thicker layers of both OGAC and RAC should be investigated to determine if the benefit due to thickness can expand down to 500 Hz, which would help reduce heavy truck noise.

5.3 Pavement Performance for Test Vehicle

The test vehicle data are included in the SPBI calculations if the event meets all the criteria previously described. In addition, the test vehicle data are separated from the other data. The average L_{AFmx} is calculated for each speed (~65, 80, 100, and 112 km/h; 40, 50, 60, and 70 mph) for each pavement site. The microphone positions analyzed are the low and high microphones at 15 m (50 ft). The data sets analyzed are for the pavements aged 4 months, 10 months, and 16 months (52 months excluded).

Test vehicle L_{AFmx} values can be found in Appendix F, Tables F-1 and F-2, F-1 showing the site-bias-removed data and F-2 showing the average measured data. Figure 9 shows an example of the test vehicle results for the four different speeds [pavement aged 16 months, 15-m (50-ft) low microphone position]; similar plots for the other pavement ages and the higher 15-m (50-ft) microphone position are found in Appendix A, Section F.1. The general trend is that OGAC 75 mm is the quietest pavement, followed by RAC Type O 30 mm, OGAC 30 mm, BWC 30 mm, and then DGAC, considering both microphone positions and the other data sets (other pavement ages).

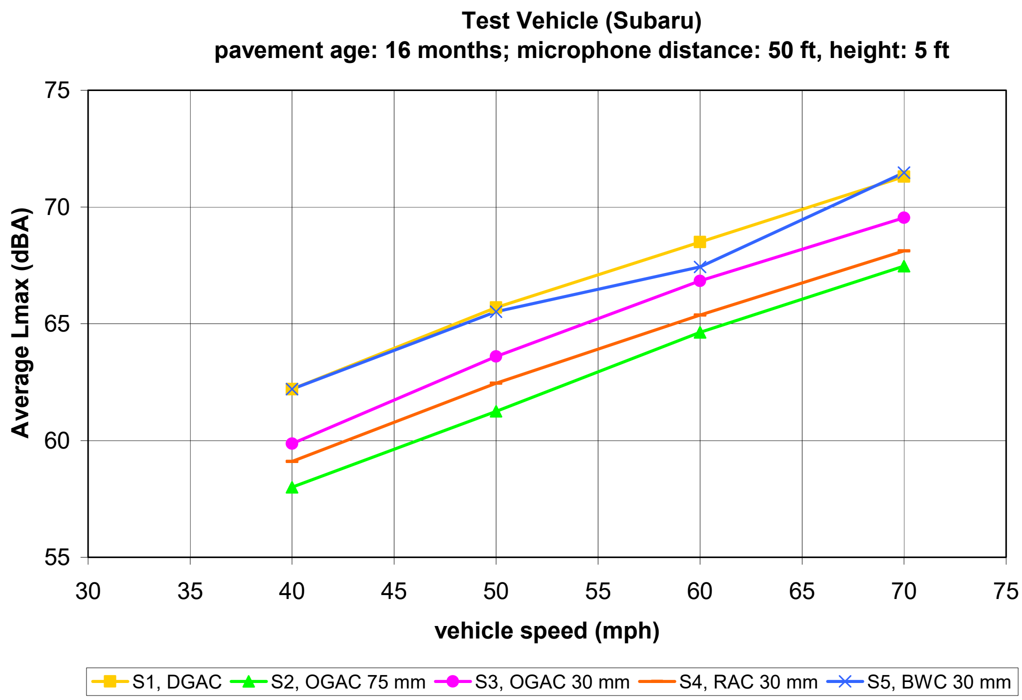

Figure 9. Test vehicle average L_{AFmx} values for pavement aged 16 months, multiple speeds. Microphone position: distance 15 m (50 ft), height 1.5 m (5 ft). Site bias removed.

Data are presented in Table 5 as average L_{AFmx} differences (Site x minus Site 1) over time (both measured and site-bias-removed L_{AFmx} values can be found in Appendix F, Tables F-2 and F-1, respectively). The figures that follow present samples of the data. Figure 10 shows the average L_{AFmx} differences (deltas) (Site x minus Site 1) for only the 16-month old pavements, for the low 15-m (50-ft) position, for 60 mph (plot for high position can be seen in Appendix F, Figure F-4). For all results, site bias has been removed by applying the differences found with the baseline measurements.

Table 5 and Figure 10 again show the general trend that OGAC 75 mm is the quietest pavement, followed by RAC Type O 30mm, OGAC 30 mm, BWC 30 mm, and then DGAC. Table 5 shows that the benefit of OGAC 75 mm over the DGAC ranges from 2.7-4.9 dB(A), OGAC 30 mm over the DGAC ranges from 1.1-3.5 dB(A), RAC over the DGAC ranges from 2.5-5.0 dB(A), BWC over the DGAC ranges from -0.2 (no benefit) to 1.5 dB(A), where the benefits vary over microphone position, speed, and time.

Table 5. Post-overlay measurements: for the test vehicle, site differences due to type of pavement (average L_{AFmx} deltas). Site bias removed.*

other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements of test vehicle)

Pavement age	Microphone location	Average L_{AFmx} delta (dBA)															
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)				Site 3 – Site 1 (OGAC, 30 mm – DGAC)				Site 4 – Site 1 (RAC type O, 30 mm – DGAC)				Site 5 – Site 1 (BWC, 30 mm – DGAC)			
		Speed (mph)															
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
4 months	50 ft (15 m) low	-3.4	-3.1	-3.3	-2.7	-3.5	-3.1	-2.4	-1.8	-3.9	-4.4	-3.2	-3.1	-1.3	-1.0	-0.8	-0.3
	50 ft (15 m) high	-3.6	-3.9	-4.8	-4.2	-2.5	-2.2	-2.9	-1.8	-4.0	-3.4	-4.0	-4.0	-0.9	-0.6	-0.8	-0.2
10 months	50 ft (15 m) low	-3.4	-3.6	-3.6	-3.6	-2.4	-2.9	-1.1	-1.8	-2.8	-4.3	-2.5	-3.3	-1.3	-1.4	-0.3	-0.1
	50 ft (15 m) high	-3.7	-4.5	-4.7	-4.9	-2.0	-2.4	-1.8	-2.8	-4.0	-3.5	-3.5	-5	-1.4	-0.8	-0.7	-0.8
16 months	50 ft (15 m) low	-4.2	-4.5	-3.9	-3.8	-2.3	-2.1	-1.7	-1.8	-3.1	-3.3	-3.1	-3.2	0.0	-0.2	-1.1	0.2
	50 ft (15 m) high	-3.7	-4.5	-4.5	-4.3	-1.8	-2.0	-2.2	-2.0	-3.8	-2.7	-3.8	-4.4	-0.6	0.1	-1.5	-0.5
Average (both locations, all time)		-3.7	-4.0	-4.1	-3.9	-2.4	-2.5	-2.0	-2.0	-3.6	-3.6	-3.4	-3.8	-0.9	-0.7	-0.9	-0.3
Average (both locations, all time, all speeds)		-3.9				-2.2				-3.6				-0.7			

Note: A slightly modified version of this table is seen in Appendix F (Table F-3), with baseline values included.

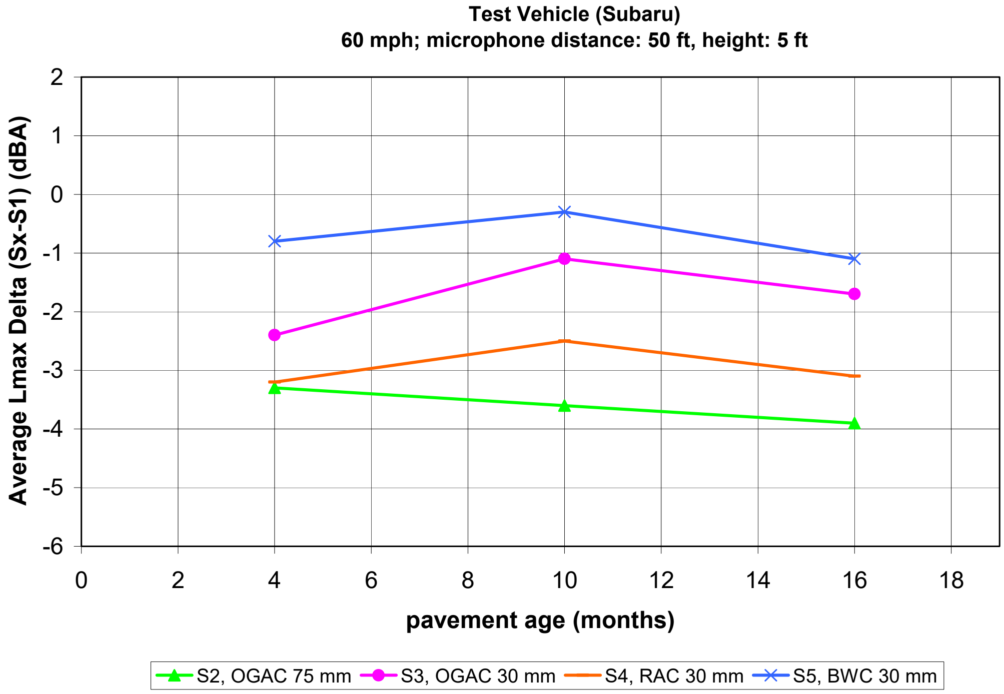

Figure 10. Test vehicle average L_{AFmx} deltas (Site x minus Site 1) for pavement ages 4 months, 10 months, and 16 months, 100 km/h (60 mph). Microphone position: distance 15 m (50 ft), height 1.5 m (5 ft). Site bias removed.

5.4 Pavement Performance Related to Sound Absorption

The sound absorption of the pavements tested on LA138 is being examined in terms of the effective flow resistivity (EFR), data collection and analysis briefly described in previous sections. This section expands more on the data analysis process in addition to the results, since the process evolved as results were obtained.

Initial investigations using data from LA138 and other locations determined that the original ANSI S1.18 methodology provided reasonable values for extreme ground surfaces. For example, the differences between lawn and cement concrete were readily apparent: lawn is associated with an EFR value of 300 cgs rayls, and cement concrete is associated with an EFR value of 20,000 cgs rayls. Based on the success with extreme ground types, the standard was expanded upon to include finer resolution and greater range in the potential EFR values (ANSI S1.18 is very limited in this aspect because it was likely not intended to be sensitive to similar ground types). New EFR deltas/curves were calculated for EFR values of 100 to 20,000 cgs rayls in steps of 100 and 20,000 to 30,000 cgs rayls in steps of 2000.

The Volpe data (that from LA138 and other data Volpe has collected) were then analyzed again using the new EFR curves. Although it was possible to extract EFR values for extreme ground types, sensitivity in the pavement range was still not possible. Upon further investigation of the theoretical and measured curves, it was seen that the measured amplitudes do not match the theoretical amplitudes, so reasonable curve matching was not possible. Based on this information, it was determined that the analysis methodology needed to be adapted to allow for the extraction of EFR values related to various pavement types. (The new "curve selecting" analysis methodology is described in the Data Analysis section.)

Applying the curve selecting methodology to the measured data, reasonable EFR values for various pavement types were extracted:

Pavement type	Sidewalk (cement concrete)	Old DGAC	New DGAC (30mm thick)	New OGAC (30mm thick)	New RAC (30mm thick)	New OGAC (75mm thick)
EFR value [cgs rayls, g/(s·cm^3) or (kPa·s)/m^2]	20000	30000	12200	9800	7400	7200

These values are characterized as reasonable because: 1) absorptive pavement can very likely be just as absorptive as hard packed soil (or a dirt road), which has a published EFR value of 5,000 cgs rayls; and 2) the order of EFR values from highest to lowest corresponds with the order of modified SPBI levels (loudest to quietest) for the new LA138 pavements.

In order to fully assess the accuracy of the EFR method and results, the measured and calculated values need to be validated. The validation is being done as part of the FHWA TNM Pavement Effect Implementation Study; information from the FHWA study will be made available as it progresses.

6. CONCLUSIONS

The research conducted in Caltrans Thin Lift (LA138) Study provides: 1) information for ranking the tested asphalt pavements according to noise reduction capabilities; 2) sound level information on a broadband and spectral basis, by vehicle type, to help determine appropriate applications for the pavements tested and to help design quieter pavements; and 3) data that may be used to include or help validate pavement effects in traffic noise predictions.

Results from the study indicate that applying a quieter pavement overlay can reduce wayside-measured sound levels.[a] The amount of reduction is vehicle-type dependent, and the relative noise reduction is maintained over 52 months when comparing test pavements and the reference pavement of the same age; although the noise reduction is maintained when comparing pavements of the same age, each of the pavements tested shows some deterioration in noise benefit as it ages (up to 1.5 dBA, depending on pavement type, over 52 months).

Of the pavements examined, the OGAC 75 mm thickness provides the greatest noise benefit, as compared to the reference DGAC 30 mm, with noticeably more benefit than the thinner overlays at frequencies greater than or equal to 1000 Hz. Considering all data sets (includes ages 4-52 months and multiple microphone positions) the average OGAC 75 mm benefit over DGAC is 3.3 dBA. The RAC Type O 30 mm and OGAC 30 mm also provide noise benefits. The average RAC Type O 30 mm benefit is 2.3 dBA, and the average OGAC 30 mm benefit is 1.7 dBA. The rubberized asphalt (RAC) provides extra benefit at some critical frequencies (frequencies with substantial contribution to the broadband noise level), which affects the overall sound level for automobiles more than for heavy trucks. The overlay of BWC 30 mm is actually louder than DGAC for one of the microphone positions, where the average benefit over DGAC for all microphone positions is 0.9 dBA. The BWC 30 mm should not be considered a quieter pavement.

[a] The amount of reduction reported in literature is highly dependent on the reference pavement used for comparison. The Caltrans Thin Lift Study uses a reference asphalt pavement with the same nominal aggregate size and same age as the other test pavements, resulting in relatively small reductions: on average, about 3 dBA or less. It should be noted that decreases in overall sound level of less than 3 dBA are not typically considered to be perceptible,[12] although changes in spectral content may be perceived.

When examining the results by vehicle type, the following is observed: 1) the *order* of the performance (most noise reduction to least noise reduction) is the same as indicated in the overall results; 2) the *order* of the performance is the same for automobiles, medium trucks, and heavy trucks; 3) for the quieter pavements, each of the pavements provides greater reductions for automobile noise than for medium or heavy truck noise; and 4) some pavements can reduce noise about the same amount for both automobiles and heavy trucks, where as other pavements see more of a disparity in reduction between vehicle types. The disparity between vehicle types indicates the importance of accounting for light and heavy vehicles when assessing the noise reduction benefits of pavements.

Spectral results indicate that quieter pavements do provide noise reduction in a critical range around 1000 Hz, although little to no benefit is seen around 500 Hz, a frequency band with substantial energy for heavy trucks. Spectral results also indicate that some lower frequencies that were contributing little, if any, to the overall sound level closer to the road, are within 10 dBA of the dominant frequency farther from the road, and are contributing to the overall sound level (as is expected due to propagation effects). These lower frequencies see little, if any, benefit due to the quieter pavement. One example shows the benefit for automobiles decreasing 1.0 dBA, and for heavy trucks decreasing 1.4 dBA, over a distance of 52.5 m (175 ft).

Results from the test vehicle data are similar to those for autos in the existing traffic, identifying this vehicle as being a good representative of the auto category. Test vehicle data show that noise reduction due to pavement is fairly consistent over speeds ranging from 40 mph to 70 mph (~65 to 112 km/h). This is encouraging when considering the use of pavement for noise abatement on roadways with medium- or high-speed traffic.

Concerning pavement sound absorption, applying an adapted ANSI S1.18 methodology to measure effective flow resistivity (EFR) is showing reasonable results. For the test pavements, EFR values from highest to lowest corresponds with the order of modified SPBI levels (loudest to quietest). The method and results still need to be validated before conclusions can be reached regarding the relationship between wayside noise levels and pavement absorption and before specific pavement EFR values can be used as part of noise prediction.

In order to further understand noise benefits related to quieter pavements, the following research should be conducted:

- Measurements and analysis for the pavements on LA 138 aged beyond 52 months – This will help determine the longevity of noise reduction benefits, a necessary component before using quieter pavements for noise abatement.
- Investigate thicker layers of both OGAC and RAC – This would help to determine if the benefit due to thickness can expand down to 500 Hz, which would help reduce heavy truck noise.
- Further investigate the variation of measured pavement benefits by microphone position. Results of such an investigation could affect future guidance on microphone placement for wayside tire/pavement noise measurements. It is clear when examining the SPB results that different values for benefit can be obtained for the three different microphone positions (25 ft low, 50 ft low, and 50 ft high), but which one is best characterizing the pavement benefit? That is difficult to determine. The low 50-ft position better captures the angle for sound propagating toward communities adjacent to highways, although it is more influenced by the ground than the other positions. The 25-ft and high 50-ft positions minimize ground effects, but capture angles for sound propagation that may not be representative of what the communities are receiving. The low and high 50-ft positions are more influenced by meteorological effects than the 25-ft position, although care can be taken to minimize these effects. The 25-ft position is more likely to be influenced by near-field effects, and there is the possibility that distinct individual sound sources on a vehicle, particularly for heavy trucks, may be influencing what is captured as the maximum sound level when the vehicle drives by.
- Further examine pavement sound absorption – Validate the modified ANSI S1.18 EFR measurement and analysis method and continue measurements over time; this may provide EFR data for input into traffic noise models for more accurate noise predictions. Also, examine relationships between EFR and wayside sound levels; this may help to determine the potential noise benefit of a pavement while minimizing wayside measurements.

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APPENDIX A. MEASUREMENT SITE PHOTOS

This appendix shows photos and descriptions of each pavement type and photos of each measurement site.

A.1 Pavement Types

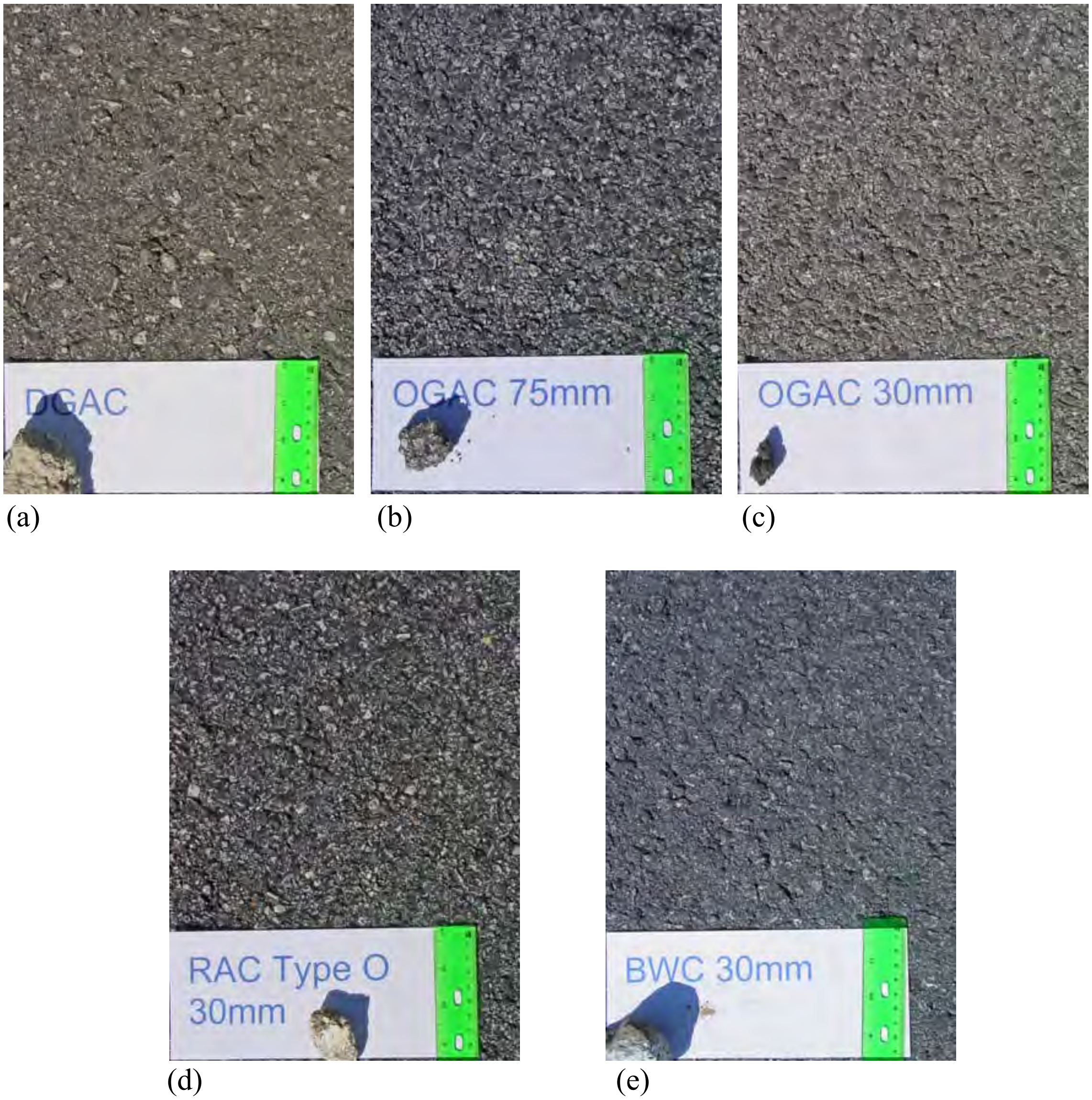


Figure A-1. Pavement types for asphalt overlays on LA138.

(a) Pavement section 1 (Site 1): dense-graded asphaltic concrete (DGAC) of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 9%.

(b) Pavement section 2 (Site 2): open-graded asphaltic concrete (OGAC) of 75 mm (3 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 12%.

(c) Pavement section 3 (Site 3): OGAC of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 15%.

(d) Pavement section 4 (Site 4): rubberized asphaltic concrete, Type O (open) (RAC) of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 12%.

(e) Pavement section 5 (Site 5): bonded wearing course (BWC) of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 7%.

A.2 Site 1 (S1): DGAC 30mm

Figure A-2. LA138 Site 1 (S1), DGAC 30 mm.

A.3 Site 2 (S2): OGAC 75mm

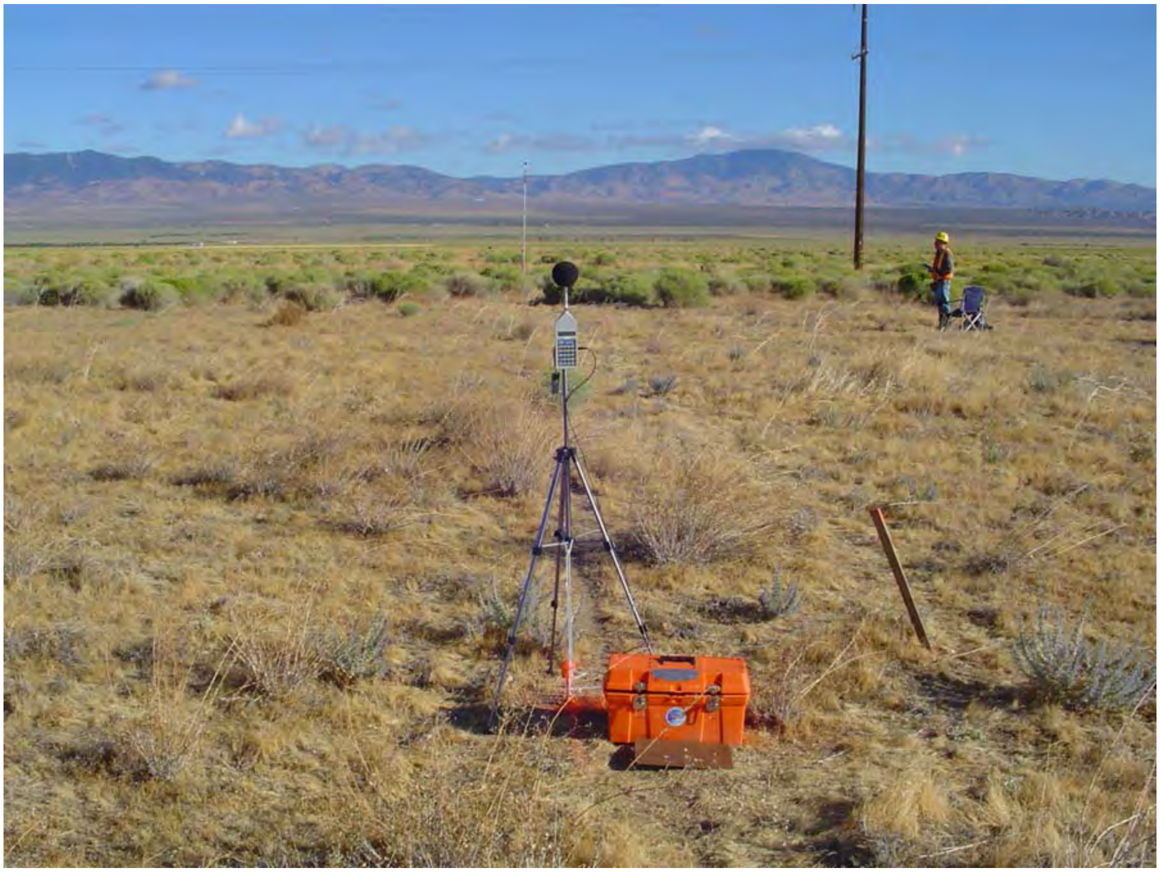


Figure A-3. LA138 Site 2 (S2), OGAC 75 mm.

A.4 Site 3 (S3): OGAC 30mm

Figure A-4. LA138 Site 3 (S3), OGAC 30 mm.

A.5 Site 4 (S4): RAC Type O 30mm

Figure A-5. LA138 Site 4 (S4), RAC Type O 30 mm.

A.6 Site 5 (S5): BWC 30mm

Figure A-6. LA138 Site 5 (S5), BWC 30 mm.

APPENDIX B. INSTRUMENTATION PHOTOS

This appendix shows the instrumentation utilized for data collection, including instrumentation for collection of acoustical data, meteorological data, traffic data, pavement data, vehicle pass-by event identification, and extraneous noise event identification.

B.1 Acoustical Data Collection Instrumentation

Figure B-1. Deployed sound level meters (LDL Model 820 Sound Level Meters) and DAT recorder (Sony Model TCD-D100 Digital Audio Tape (DAT) Recorder).

Figure B-2. Deployed spectrum analyzers (LDL Model 2900 2-Channel Spectrum Analyzers).

B.2 Meteorological Data Collection Instrumentation

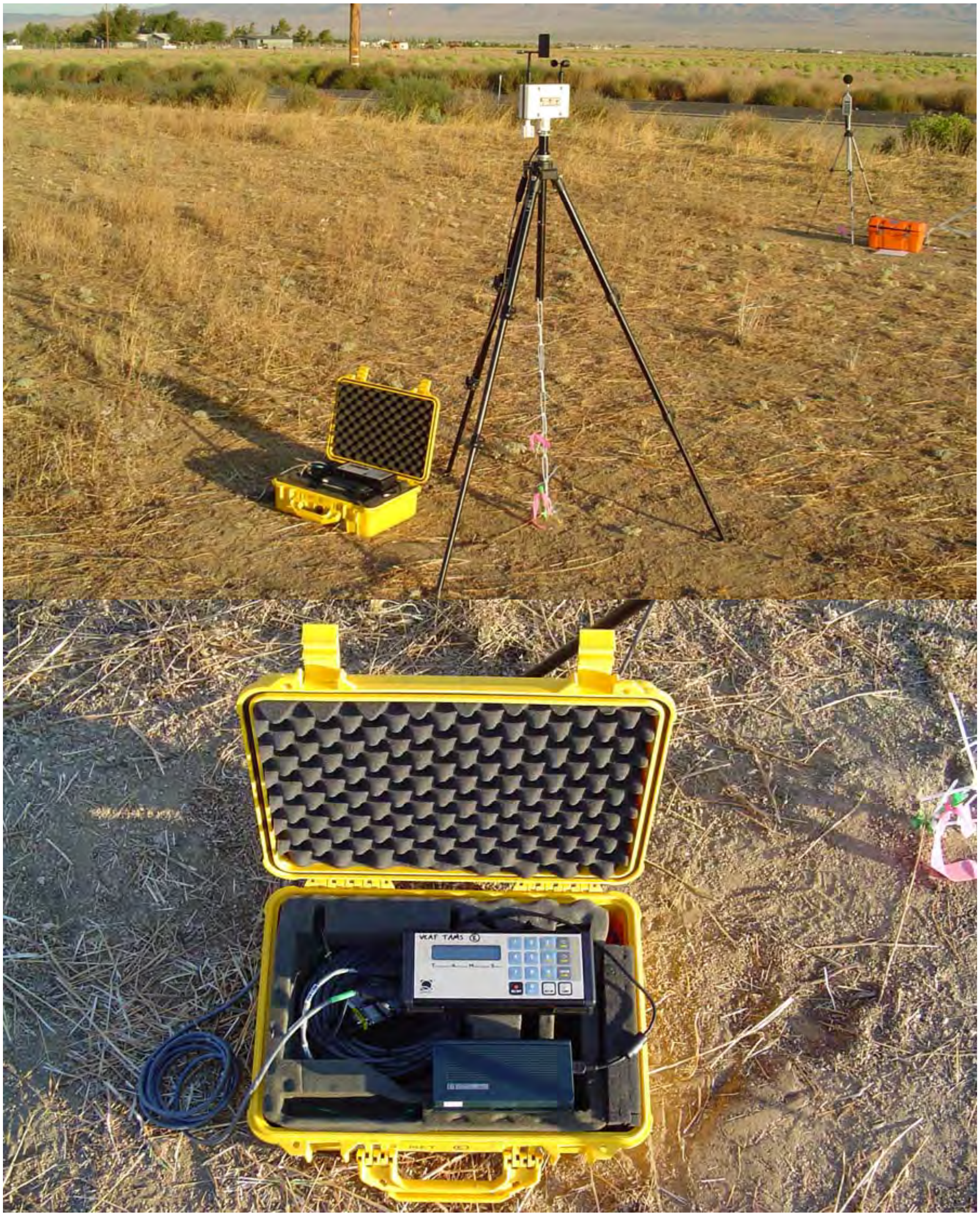


Figure B-3. Deployed meteorological data collection system (Qualimetrics Transportable Automated Meteorological Stations (TAMS)).

B.3 Traffic Data Collection Instrumentation

Figure B-4. Video cameras and radar gun.

B.4 Pavement Data Collection Instrumentation

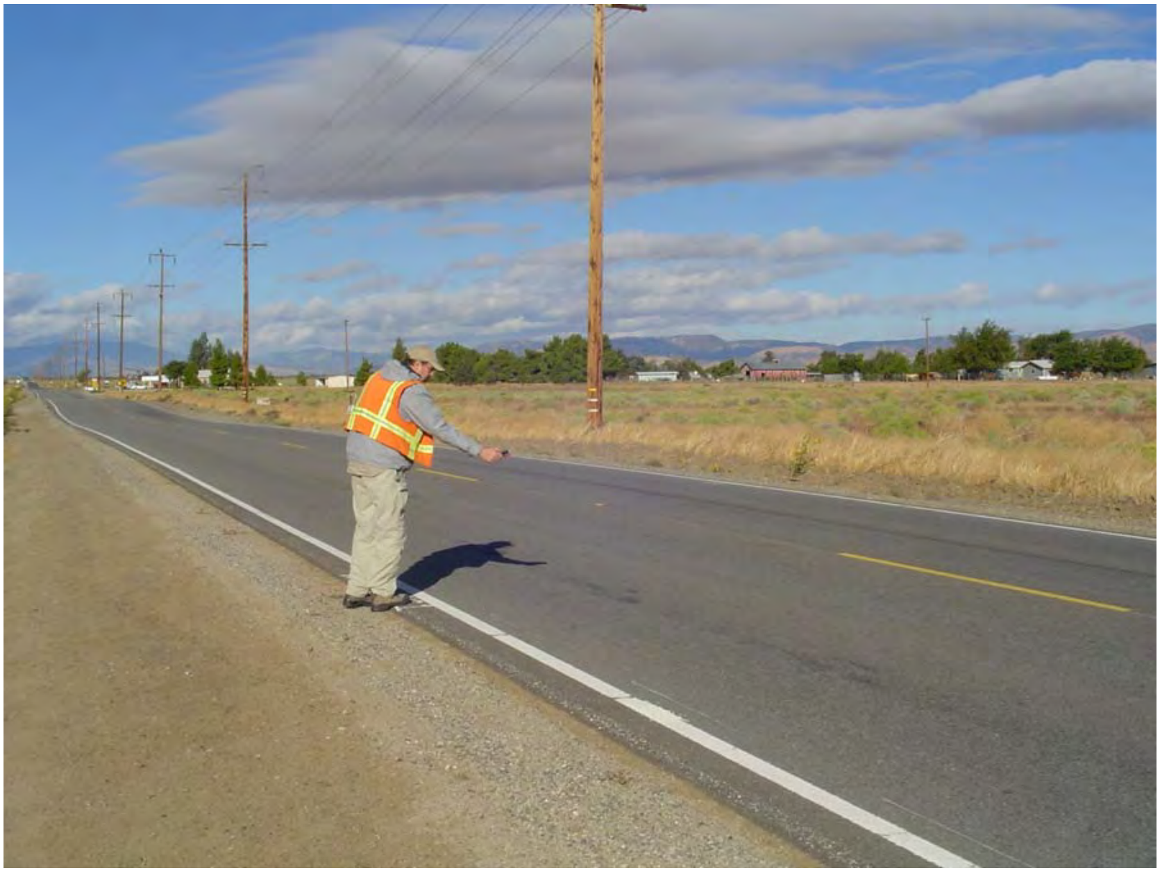


Figure B-5. Infrared temperature gun (also seen in Figure B-2).

B.5 Pass-By Event Identification and Extraneous Noise Event Identification Data Collection Instrumentation

Figure B-6. Palmtop computer for logging (HP 200 LX palmtop computer) (also seen in Figure B-2).

APPENDIX C. VEHICLE PASS-BY DATA

The first section in this appendix shows summary tables of vehicle pass-by data, including the average pass-by sound level, vehicle speed data, and air and pavement temperature data. The remaining sections (listed by age, starting with the pre-overlay baseline measurements, then post-overlay 4 months, 10 months, 16 months, and 52 months) show plots of the pass-by events (sound level as a function of speed) with corresponding regression lines and equations. Data shown in this appendix are by site pairs and by vehicle type for each age and each microphone location.

C.1 Vehicle Pass-By Summary

This section summarizes the vehicle pass-by data, providing values for each site pair, each vehicle type, each microphone location, and each pavement age. Each of the tables show: 1) number of pass-by events; 2) average pass-by sound level (A-weighted maximum sound level, L_{AFmx} – listed as Lmax) and standard deviation; 3) average vehicle speed and standard deviation; 4) average, maximum, and minimum air temperature; and 5) average, maximum, and minimum pavement temperature.

Table C-1. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 25 ft, height 5 ft. Vehicle type: automobile.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		104	104	141	141	99	99	74	74
	Lmax (dBA)	average	76.5	76.5	76.4	77.5	76.6	77.8	76.4	77.5
		standard deviation	2.5	2.6	2.9	2.9	2.8	2.6	2.7	2.6
	vehicle speed (mph)	average	63.3	67.3	64.8	73.6	64.4	75.7	64.2	69.4
		standard deviation	6.1	7.0	6.3	5.8	5.8	6.2	6.1	6.6
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		150	150	104	104	105	105	na	na
	Lmax (dBA)	average	78.6	74.8	78.4	77.3	78.6	76.3	na	na
		standard deviation	2.4	2.6	2.4	2.4	2.5	2.4	na	na
	vehicle speed (mph)	average	66.7	68.9	65.7	74.3	65.1	73.3	na	na
		standard deviation	6.6	6.7	5.6	6.9	5.7	7.0	na	na
	air temperature (deg F)	average	64	64	63	63	63	61	na	na
		maximum	74	73	74	75	73	74	na	na
		minimum	47	47	40	39	41	40	na	na
	pavement temperature (deg F)	average	83	81	82	75	81	78	na	na
		maximum	109	120	109	111	109	103	na	na
		minimum	47	47	46	42	46	46	na	na
10 months	number of data points		113	113	89	89	82	82	79	79
	Lmax (dBA)	average	78.9	75.0	78.8	77.1	78.9	76.5	79.0	78.4
		standard deviation	2.2	2.4	1.8	2.1	2.3	2.6	1.9	2.0
	vehicle speed (mph)	average	66.3	66.4	66.5	70.0	66.1	68.4	66.4	67.9
		standard deviation	6.4	6.6	5.7	7.0	6.0	7.0	6.4	6.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		136	136	107	107	97	97	107	107
	Lmax (dBA)	average	78.8	74.7	78.9	77.3	78.6	76.2	78.7	78.1
		standard deviation	2.3	2.7	2.3	2.4	2.3	2.5	2.3	2.2
	vehicle speed (mph)	average	64.7	65.6	64.3	67.5	64.4	69.0	63.6	67.7
		standard deviation	5.6	5.4	5.7	7.3	5.9	6.6	5.3	5.8
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		166	166	108	108	74	74	na	na
	Lmax (dBA)	average	79.6	76.0	79.7	78.0	79.6	77.8	na	na
		standard deviation	2.1	2.4	2.3	2.6	2.1	2.3	na	na
	vehicle speed (mph)	average	70.7	71.1	70.4	68.8	69.1	66.5	na	na
		standard deviation	7.1	7.2	6.1	6.4	7.0	6.8	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-2. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 25 ft, height 5 ft. Vehicle type: medium truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		5	5	10	10	3	3	5	5
	Lmax (dBA)	average	83.6	83.9	81.0	81.6	81.9	82.3	81.3	81.9
		standard deviation	1.9	1.7	3.7	4.1	3.3	2.3	3.2	3.4
	vehicle speed (mph)	average	61.6	66.5	61.1	73.0	71.1	77.7	65.0	59.7
		standard deviation	7.6	5.4	6.2	5.8	10.5	6.6	10.6	4.3
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		13	13	8	8	9	9	na	na
	Lmax (dBA)	average	82.8	80.2	82.4	82.3	82.0	80.5	na	na
		standard deviation	1.7	2.0	1.9	2.2	1.6	1.5	na	na
	vehicle speed (mph)	average	61.2	62.2	62.7	69.7	62.0	66.8	na	na
		standard deviation	3.4	3.8	4.6	7.2	3.0	4.4	na	na
	air temperature (deg F)	average	64	64	63	63	63	61	na	na
		maximum	74	73	74	75	73	74	na	na
		minimum	47	47	40	39	41	40	na	na
	pavement temperature (deg F)	average	83	81	82	75	81	78	na	na
		maximum	109	120	109	111	109	103	na	na
		minimum	47	47	46	42	46	46	na	na
10 months	number of data points		10	10	7	7	3	3	5	5
	Lmax (dBA)	average	82.5	79.4	86.7	85.7	82.8	80.6	82.5	81.5
		standard deviation	2.2	2.7	1.4	1.8	2.3	2.3	1.8	1.6
	vehicle speed (mph)	average	62.0	59.6	60.1	59.7	63.1	60.4	63.9	66.0
		standard deviation	5.7	6.1	6.4	5.8	6.1	4.6	5.6	6.7
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75
		minimum	58	58	59	61	57	60	57	60

	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		19	19	14	14	11	11	15	15
	Lmax (dBA)	average	82.7	79.9	83.1	82.7	83.6	81.8	83.4	83.0
		standard deviation	2.3	2.8	2.3	2.5	2.5	2.3	2.9	3.1
	vehicle speed (mph)	average	60.2	61.4	60.2	64.9	62.1	68.4	61.3	65.4
		standard deviation	4.6	4.8	4.6	4.4	4.9	4.7	5.2	5.3
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		19	19	17	17	13	13	na	na
	Lmax (dBA)	average	82.8	79.7	84.4	82.8	83.1	81.9	na	na
		standard deviation	3.5	3.3	3.2	3.0	4.1	4.5	na	na
	vehicle speed (mph)	average	64.6	65.8	67.7	67.0	65.5	63.4	na	na
		standard deviation	8.2	7.4	8.3	7.8	6.9	5.0	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-3. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 25 ft, height 5 ft. Vehicle type: heavy truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		8	8	5	5	3	3	10	10
	Lmax (dBA)	average	83.4	84.0	83.6	84.1	82.2	82.1	84.0	85.7
		standard deviation	2.3	2.9	2.1	2.3	2.4	1.0	2.9	3.1
	vehicle speed (mph)	average	59.8	61.4	62.2	70.1	58.9	71.4	76.4	48.7
		standard deviation	4.1	5.8	7.6	8.1	3.0	7.7	8.3	5.5
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		50	50	40	40	46	46	na	na
	Lmax (dBA)	average	85.9	83.5	86.0	85.3	86.1	84.3	na	na
		standard deviation	2.1	2.1	2.1	2.1	2.0	2.2	na	na
	vehicle speed (mph)	average	59.6	61.0	59.5	64.5	59.2	63.8	na	na
		standard deviation	3.6	3.5	3.7	4.7	3.0	4.0	na	na
	air temperature (deg F)	average	64	64	63	63	63	61	na	na
		maximum	74	73	74	75	73	74	na	na
		minimum	47	47	40	39	41	40	na	na
	pavement temperature (deg F)	average	83	81	82	75	81	78	na	na
		maximum	109	120	109	111	109	103	na	na
		minimum	47	47	46	42	46	46	na	na
10 months	number of data points		25	25	20	20	12	12	14	14
	Lmax (dBA)	average	86.3	83.3	86.7	85.7	86.7	84.8	86.8	86.2
		standard deviation	1.9	2.1	1.4	1.8	2.3	2.6	1.5	1.9
	vehicle speed (mph)	average	59.6	59.7	60.1	59.7	60.6	60.7	60.8	58.3
		standard deviation	5.8	5.5	6.4	5.8	5.2	3.8	5.1	2.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		53	53	44	44	44	44	37	37
	Lmax (dBA)	average	86.6	83.7	86.3	85.4	86.4	84.9	86.5	86.2
		standard deviation	1.5	1.8	1.5	1.9	1.6	2.0	1.6	1.1
	vehicle speed (mph)	average	58.9	60.6	58.5	61.0	58.6	62.3	59.1	62.3
		standard deviation	3.3	3.5	2.8	3.8	3.4	4.2	3.2	3.0
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		54	54	43	43	35	35	na	na
	Lmax (dBA)	average	87.2	83.8	87.5	85.9	87.8	85.9	na	na
		standard deviation	2.3	2.2	2.0	2.4	1.6	2.1	na	na
	vehicle speed (mph)	average	64.2	65.1	63.6	61.8	63.8	61.1	na	na
		standard deviation	5.4	5.0	5.3	5.5	3.4	3.9	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-4. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 5 ft. Vehicle type: automobile.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		104	104	141	141	99	99	74	74
	Lmax (dBA)	average	69.3	70.0	69.1	70.1	69.4	71.2	69.2	68.5
		standard deviation	2.5	2.6	2.9	3.0	2.9	3.2	2.8	2.4
	vehicle speed (mph)	average	63.3	67.3	64.8	73.6	64.4	75.7	64.2	69.4
		standard deviation	6.1	7.0	6.3	5.8	5.8	6.2	6.1	6.6
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		150	150	104	104	105	105	86	86
	Lmax (dBA)	average	71.2	68.9	71.3	69.9	71.5	69.3	71.4	71.1
		standard deviation	2.6	2.8	2.5	2.5	2.6	2.6	2.3	2.1
	vehicle speed (mph)	average	66.7	68.9	65.7	74.3	65.1	73.3	65.4	72.4
		standard deviation	6.6	6.7	5.6	6.9	5.7	7.0	6.2	7.2
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		113	113	89	89	82	82	79	79
	Lmax (dBA)	average	71.2	68.9	71.2	69.7	71.2	69.4	71.3	71.2
		standard deviation	2.2	2.5	2.0	2.3	2.4	2.7	2.1	2.0
	vehicle speed (mph)	average	66.3	66.4	66.5	70.0	66.1	68.4	66.4	67.9
		standard deviation	6.4	6.6	5.7	7.0	6.0	7.0	6.4	6.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		136	136	107	107	97	97	107	107
	Lmax (dBA)	average	71.3	68.4	71.4	70.2	71.2	69.3	71.2	71.2
		standard deviation	2.4	2.9	2.4	2.4	2.4	2.6	2.4	2.3
	vehicle speed (mph)	average	64.7	65.6	64.3	67.5	64.4	69.0	63.6	67.7
		standard deviation	5.6	5.4	5.7	7.3	5.9	6.6	5.3	5.8
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		166	166	108	108	74	74	na	na
	Lmax (dBA)	average	71.7	69.3	71.9	70.2	71.8	69.7	na	na
		standard deviation	2.3	2.5	2.4	2.9	2.1	2.2	na	na
	vehicle speed (mph)	average	70.7	71.1	70.4	68.8	69.1	66.5	na	na
		standard deviation	7.1	7.2	6.1	6.4	7.0	6.8	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-5. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 5 ft. Vehicle type: medium truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		5	5	10	10	3	3	2	2
	Lmax (dBA)	average	76.4	77.3	74.4	74.3	75.0	76.2	74.9	74.5
		standard deviation	1.8	1.8	3.7	4.0	1.9	2.4	3.3	2.5
	vehicle speed (mph)	average	61.6	66.5	61.1	73.0	71.1	77.7	65.0	59.7
		standard deviation	7.6	5.4	6.2	5.8	10.5	6.6	10.6	4.3
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		13	13	8	8	9	9	9	9
	Lmax (dBA)	average	75.9	74.5	75.5	74.9	75.0	73.8	74.6	75.2
		standard deviation	1.9	2.3	2.1	2.5	1.7	1.7	1.3	2.9
	vehicle speed (mph)	average	61.2	62.2	62.7	69.7	62.0	66.8	61.9	64.4
		standard deviation	3.4	3.8	4.6	7.2	3.0	4.4	4.8	2.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		10	10	7	7	3	3	5	5
	Lmax (dBA)	average	75.0	73.4	80.0	78.9	76.1	74.0	75.0	74.3
		standard deviation	2.2	2.5	1.6	2.0	2.4	2.1	2.3	2.0
	vehicle speed (mph)	average	62.0	59.6	60.1	59.7	63.1	60.4	63.9	66.0
		standard deviation	5.7	6.1	6.4	5.8	6.1	4.6	5.6	6.7
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		19	19	14	14	11	11	15	15
	Lmax (dBA)	average	75.6	73.9	76.1	75.5	76.6	75.1	76.3	76.2
		standard deviation	2.6	2.9	2.6	2.5	2.8	1.9	3.2	3.0
	vehicle speed (mph)	average	60.2	61.4	60.2	64.9	62.1	68.4	61.3	65.4
		standard deviation	4.6	4.8	4.6	4.4	4.9	4.7	5.2	5.3
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		19	19	17	17	13	13	na	na
	Lmax (dBA)	average	74.8	73.2	76.5	75.1	75.2	74.1	na	na
		standard deviation	3.5	3.2	3.4	3.2	4.0	4.6	na	na
	vehicle speed (mph)	average	64.6	65.8	67.7	67.0	65.5	63.4	na	na
		standard deviation	8.2	7.4	8.3	7.8	6.9	5.0	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-6. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 5 ft. Vehicle type: heavy truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		8	8	5	5	3	3	9	9
	Lmax (dBA)	average	76.9	77.7	76.8	77.2	75.5	74.9	77.2	76.5
		standard deviation	2.5	2.7	2.6	2.0	2.1	1.5	3.4	2.7
	vehicle speed (mph)	average	59.8	61.4	62.2	70.1	58.9	71.4	76.4	48.7
		standard deviation	4.1	5.8	7.6	8.1	3.0	7.7	8.3	5.5
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		50	50	40	40	46	46	45	45
	Lmax (dBA)	average	79.5	77.9	79.5	78.3	79.5	77.6	79.5	78.9
		standard deviation	2.3	2.2	2.3	2.2	2.1	2.0	1.9	1.5
	vehicle speed (mph)	average	59.6	61.0	59.5	64.5	59.2	63.8	59.2	64.3
		standard deviation	3.6	3.5	3.7	4.7	3.0	4.0	3.3	4.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		25	25	20	20	12	12	14	14
	Lmax (dBA)	average	79.5	77.6	80.0	78.9	80.0	77.8	80.0	79.7
		standard deviation	2.2	2.5	1.6	2.0	2.6	2.8	1.7	2.3
	vehicle speed (mph)	average	59.6	59.7	60.1	59.7	60.6	60.7	60.8	58.3
		standard deviation	5.8	5.5	6.4	5.8	5.2	3.8	5.1	2.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		53	53	44	44	44	44	37	37
	Lmax (dBA)	average	79.9	78.0	79.6	78.6	79.6	78.3	79.6	79.4
		standard deviation	1.7	1.9	1.8	1.7	1.8	1.9	1.8	1.2
	vehicle speed (mph)	average	58.9	60.6	58.5	61.0	58.6	62.3	59.1	62.3
		standard deviation	3.3	3.5	2.8	3.8	3.4	4.2	3.2	3.0
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		54	54	43	43	35	35	na	na
	Lmax (dBA)	average	79.6	77.6	79.9	78.9	80.2	78.7	na	na
		standard deviation	2.3	2.3	1.9	2.6	1.7	2.1	na	na
	vehicle speed (mph)	average	64.2	65.1	63.6	61.8	63.8	61.1	na	na
		standard deviation	5.4	5.0	5.3	5.5	3.4	3.9	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-7. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 15 ft. Vehicle type: automobile.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		104	54	114	114	84	84	58	58
	Lmax (dBA)	average	71.1	71.6	71.0	72.1	71.3	72.4	71.3	71.5
		standard deviation	2.4	2.2	2.5	3.0	2.7	2.3	2.6	3.3
	vehicle speed (mph)	average	63.3	67.3	64.8	73.6	64.4	75.7	64.2	69.4
		standard deviation	6.1	7.0	6.3	5.8	5.8	6.2	6.1	6.6
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		150	150	104	104	105	105	86	86
	Lmax (dBA)	average	73.3	69.8	73.3	71.8	73.4	71.2	73.4	73.7
		standard deviation	2.3	2.5	2.3	2.3	2.4	2.4	2.1	2.4
	vehicle speed (mph)	average	66.7	68.9	65.7	74.3	65.1	73.3	65.4	72.4
		standard deviation	6.6	6.7	5.6	6.9	5.7	7.0	6.2	7.2
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		113	113	89	89	82	82	79	79
	Lmax (dBA)	average	73.5	69.9	73.5	72.0	73.6	71.3	73.7	73.0
		standard deviation	2.1	2.2	1.7	2.5	2.2	2.5	1.9	1.9
	vehicle speed (mph)	average	66.3	66.4	66.5	70.0	66.1	68.4	66.4	67.9
		standard deviation	6.4	6.6	5.7	7.0	6.0	7.0	6.4	6.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		136	136	107	107	97	97	107	107
	Lmax (dBA)	average	73.3	70.1	73.5	72.2	73.2	71.4	73.2	72.7
		standard deviation	2.2	2.5	2.3	2.3	2.2	2.4	2.2	2.2
	vehicle speed (mph)	average	64.7	65.6	64.3	67.5	64.4	69.0	63.6	67.7
		standard deviation	5.6	5.4	5.7	7.3	5.9	6.6	5.3	5.8
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		166	166	108	108	74	74	na	na
	Lmax (dBA)	average	74.3	70.7	74.5	72.9	74.3	72.2	na	na
		standard deviation	2.0	2.3	2.2	2.3	2.0	2.2	na	na
	vehicle speed (mph)	average	70.7	71.1	70.4	68.8	69.1	66.5	na	na
		standard deviation	7.1	7.2	6.1	6.4	7.0	6.8	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-8. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 15 ft. Vehicle type: medium truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		4	4	7	7	2	2	3	3
	Lmax (dBA)	average	78.0	78.9	75.7	75.9	77.1	77.0	74.8	75.4
		standard deviation	2.1	1.9	2.8	3.1	2.5	2.2	2.8	3.8
	vehicle speed (mph)	average	61.6	66.5	61.1	73.0	71.1	77.7	65.0	59.7
		standard deviation	7.6	5.4	6.2	5.8	10.5	6.6	10.6	4.3
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		13	13	8	8	9	9	9	9
	Lmax (dBA)	average	77.3	74.8	77.1	76.8	76.8	75.0	76.2	77.1
		standard deviation	2.0	2.4	2.0	2.3	1.7	1.9	1.2	2.8
	vehicle speed (mph)	average	61.2	62.2	62.7	69.7	62.0	66.8	61.9	64.4
		standard deviation	3.4	3.8	4.6	7.2	3.0	4.4	4.8	2.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		10	10	7	7	3	3	5	5
	Lmax (dBA)	average	76.8	73.8	82.1	80.7	77.1	75.2	76.6	75.8
		standard deviation	2.1	2.5	1.8	1.9	2.4	2.0	2.0	2.0
	vehicle speed (mph)	average	62.0	59.6	60.1	59.7	63.1	60.4	63.9	66.0
		standard deviation	5.7	6.1	6.4	5.8	6.1	4.6	5.6	6.7
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

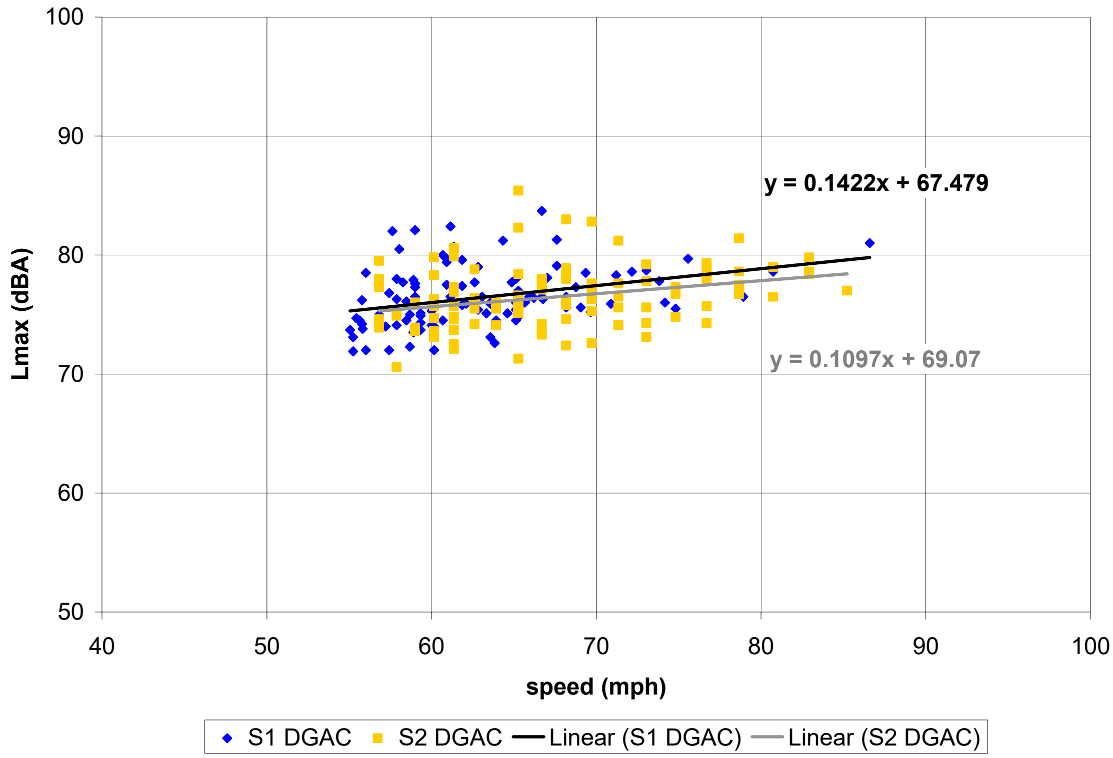
		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		19	19	14	14	11	11	15	15
	Lmax (dBA)	average	76.9	74.9	77.4	77.4	77.9	76.7	77.6	77.4
		standard deviation	2.5	2.8	2.4	2.6	2.7	2.4	3.2	3.3
	vehicle speed (mph)	average	60.2	61.4	60.2	64.9	62.1	68.4	61.3	65.4
		standard deviation	4.6	4.8	4.6	4.4	4.9	4.7	5.2	5.3
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		19	19	17	17	13	13	na	na
	Lmax (dBA)	average	77.7	74.2	79.3	77.5	77.7	76.4	na	na
		standard deviation	3.7	3.4	3.2	3.1	4.1	4.5	na	na
	vehicle speed (mph)	average	64.6	65.8	67.7	67.0	65.5	63.4	na	na
		standard deviation	8.2	7.4	8.3	7.8	6.9	5.0	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

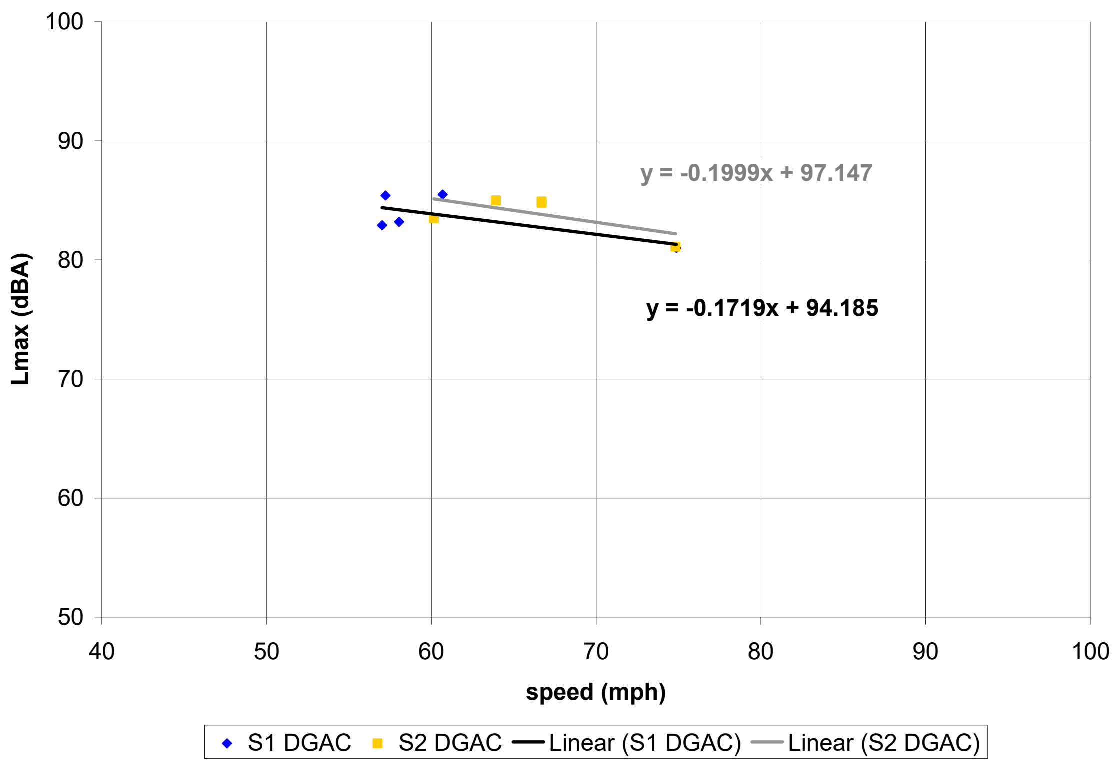
Table C-9. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 15 ft. Vehicle type: heavy truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		1	1	1	1	3	3	1	1
	Lmax (dBA)	average	75.1	75.1	75.1	74.7	77.4	76.3	82.8	83.9
		standard deviation	na	na	na	na	2.9	2.0	na	na
	vehicle speed (mph)	average	59.8	61.4	62.2	70.1	58.9	71.4	76.4	48.7
		standard deviation	4.1	5.8	7.6	8.1	3.0	7.7	8.3	5.5
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		50	50	40	40	46	46	45	45
	Lmax (dBA)	average	81.1	78.6	81.2	79.9	81.3	79.1	81.0	81.1
		standard deviation	2.4	2.4	2.3	2.4	2.2	2.2	1.8	2.0
	vehicle speed (mph)	average	59.6	61.0	59.5	64.5	59.2	63.8	59.2	64.3
		standard deviation	3.6	3.5	3.7	4.7	3.0	4.0	3.3	4.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		25	25	20	20	12	12	14	14
	Lmax (dBA)	average	81.5	78.5	82.1	80.7	82.2	79.5	82.4	81.1
		standard deviation	2.3	2.3	1.8	1.9	2.7	2.9	1.9	2.0
	vehicle speed (mph)	average	59.6	59.7	60.1	59.7	60.6	60.7	60.8	58.3
		standard deviation	5.8	5.5	6.4	5.8	5.2	3.8	5.1	2.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		53	53	44	44	44	44	37	37
	Lmax (dBA)	average	81.8	79.3	81.4	81.0	81.6	80.1	81.6	81.1
		standard deviation	1.6	2.1	1.7	2.0	1.8	2.0	1.8	1.2
	vehicle speed (mph)	average	58.9	60.6	58.5	61.0	58.6	62.3	59.1	62.3
		standard deviation	3.3	3.5	2.8	3.8	3.4	4.2	3.2	3.0
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		54	54	43	43	35	35	na	na
	Lmax (dBA)	average	82.1	78.8	82.4	81.4	82.8	80.6	na	na
		standard deviation	2.5	2.4	2.1	2.6	1.8	2.1	na	na
	vehicle speed (mph)	average	64.2	65.1	63.6	61.8	63.8	61.1	na	na
		standard deviation	5.4	5.0	5.3	5.5	3.4	3.9	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

C.2 Pre-Overlay Baseline





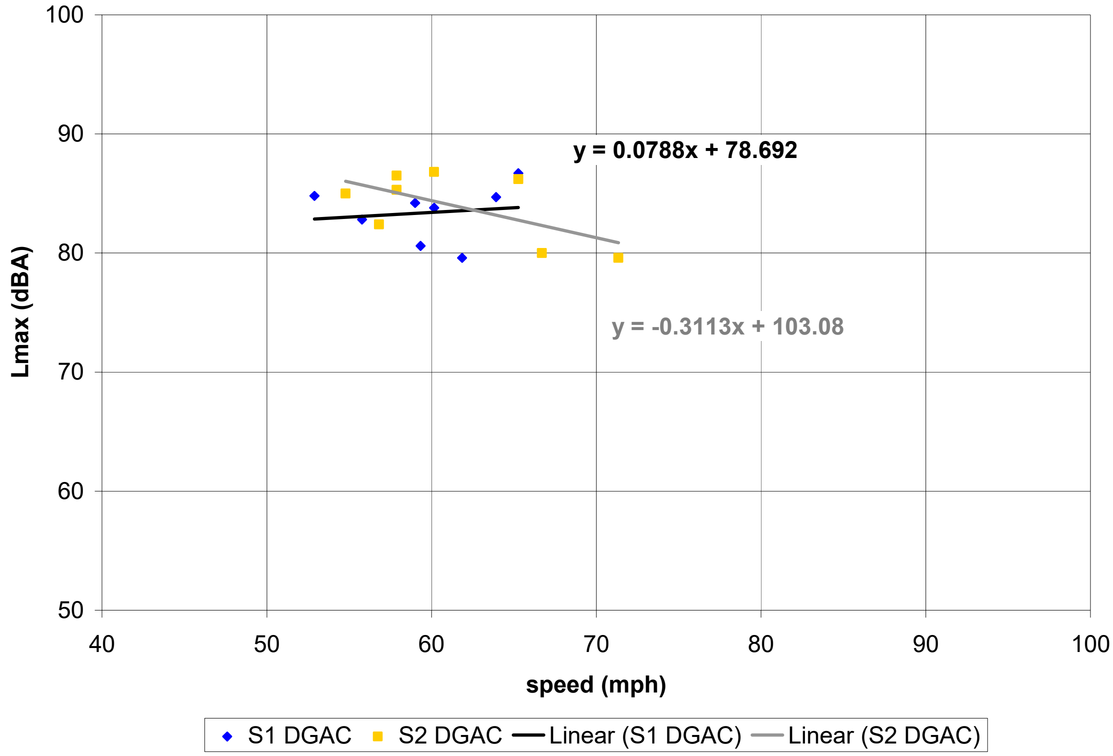
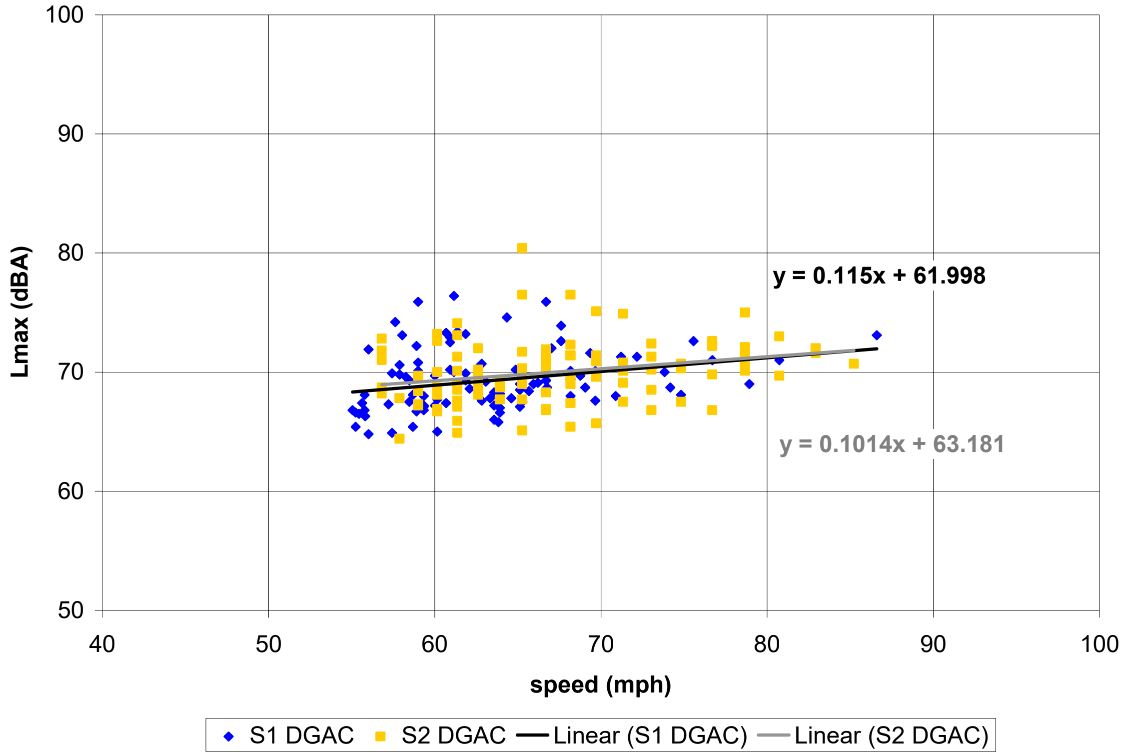
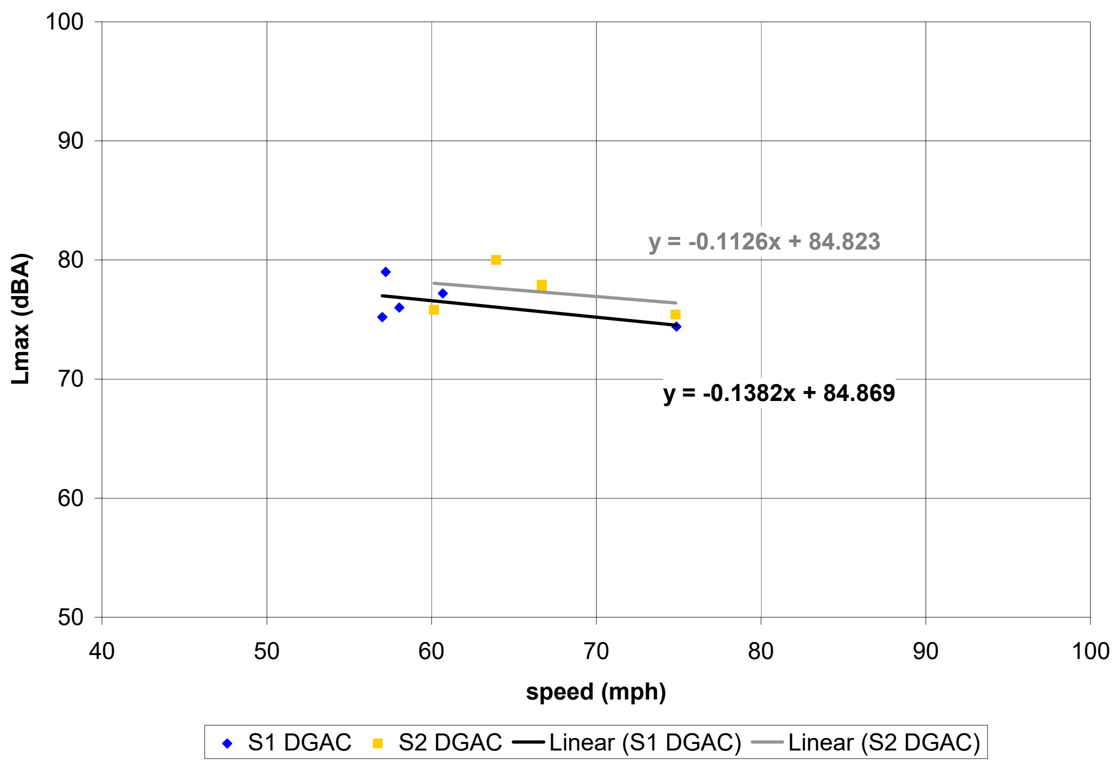


Figure C-1. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 2 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.115x + 61.998
y = 0.1014x + 63.181
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = -0.1126x + 84.823
y = -0.1382x + 84.869
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)

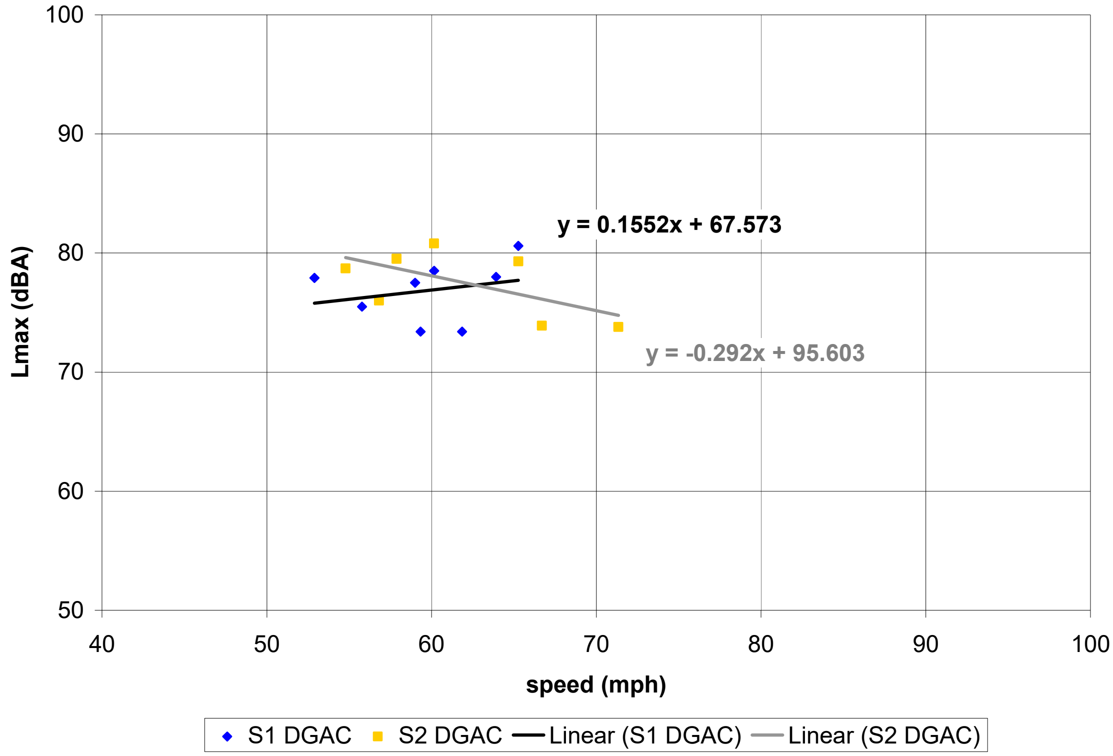
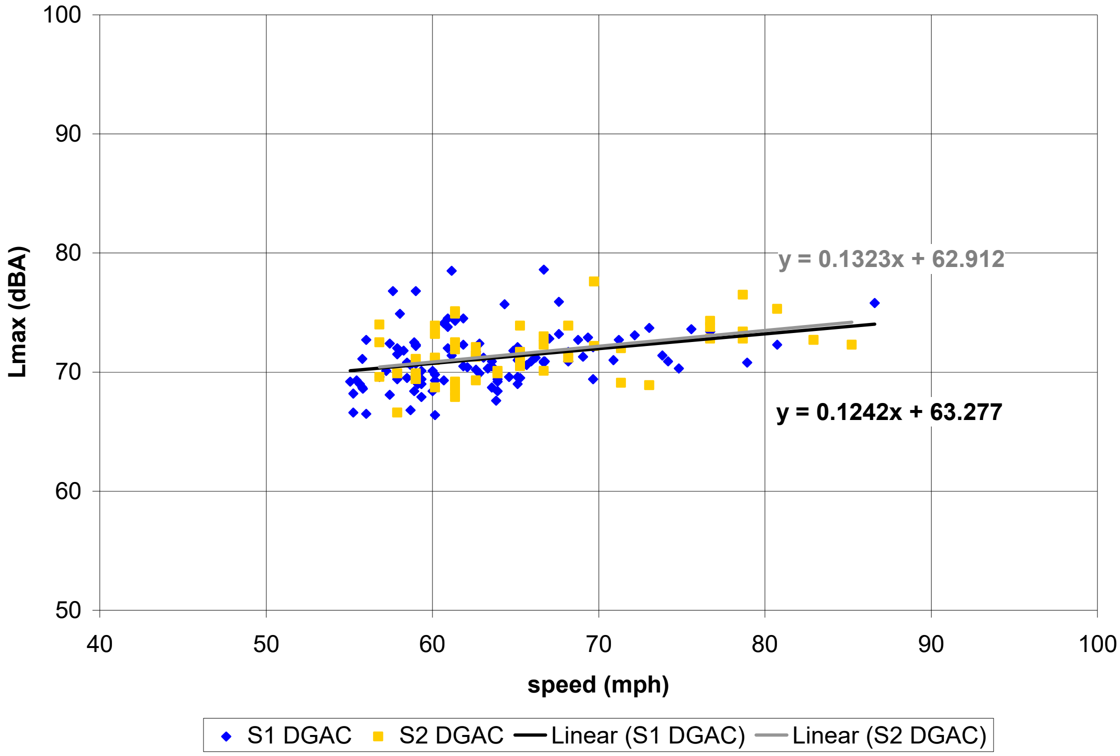
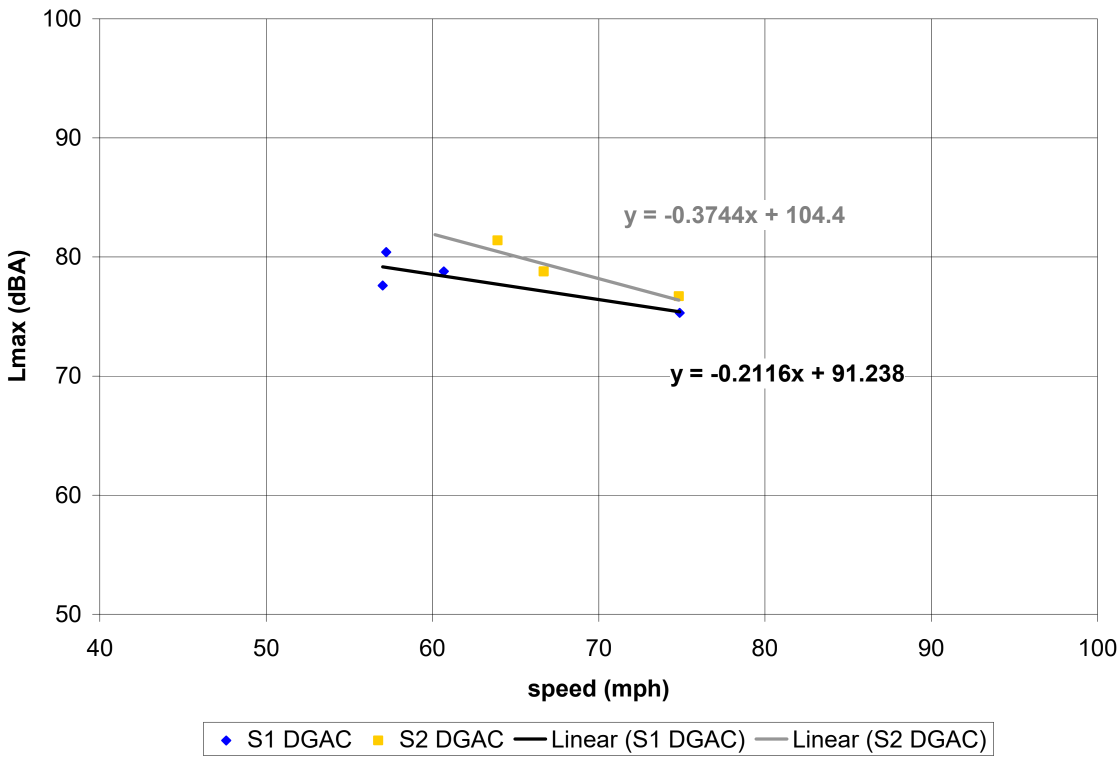


Figure C-2. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 2 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1323x + 62.912
y = 0.1242x + 63.277
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = -0.3744x + 104.4
y = -0.2116x + 91.238
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)

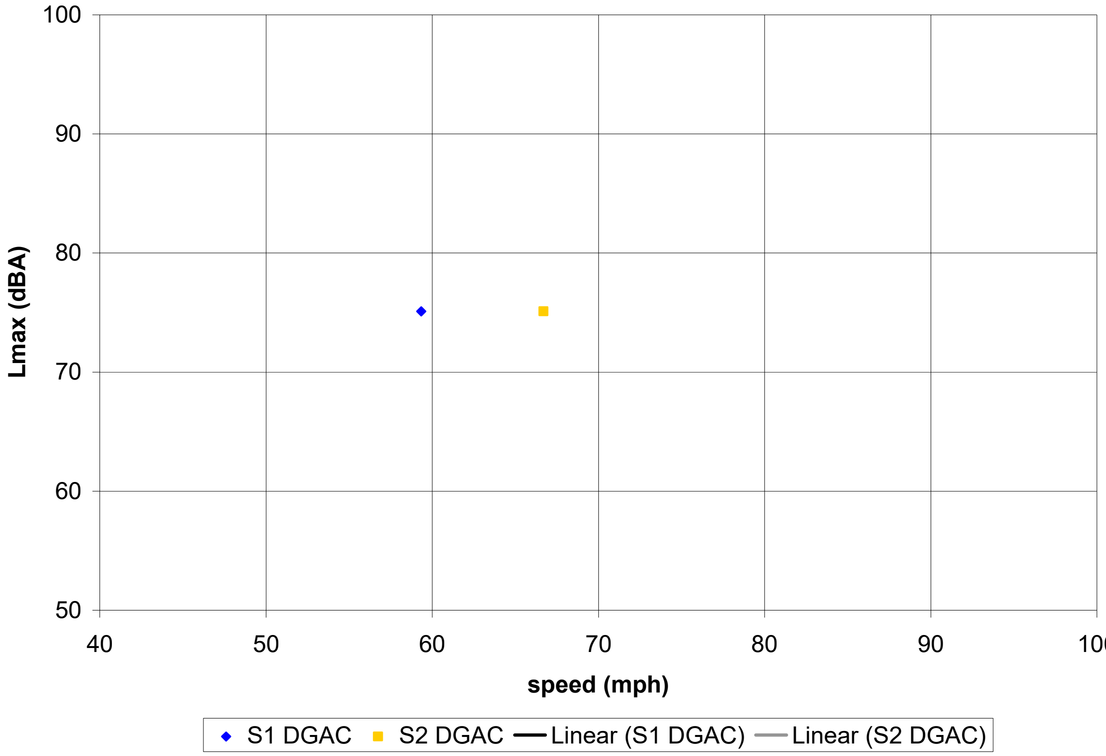
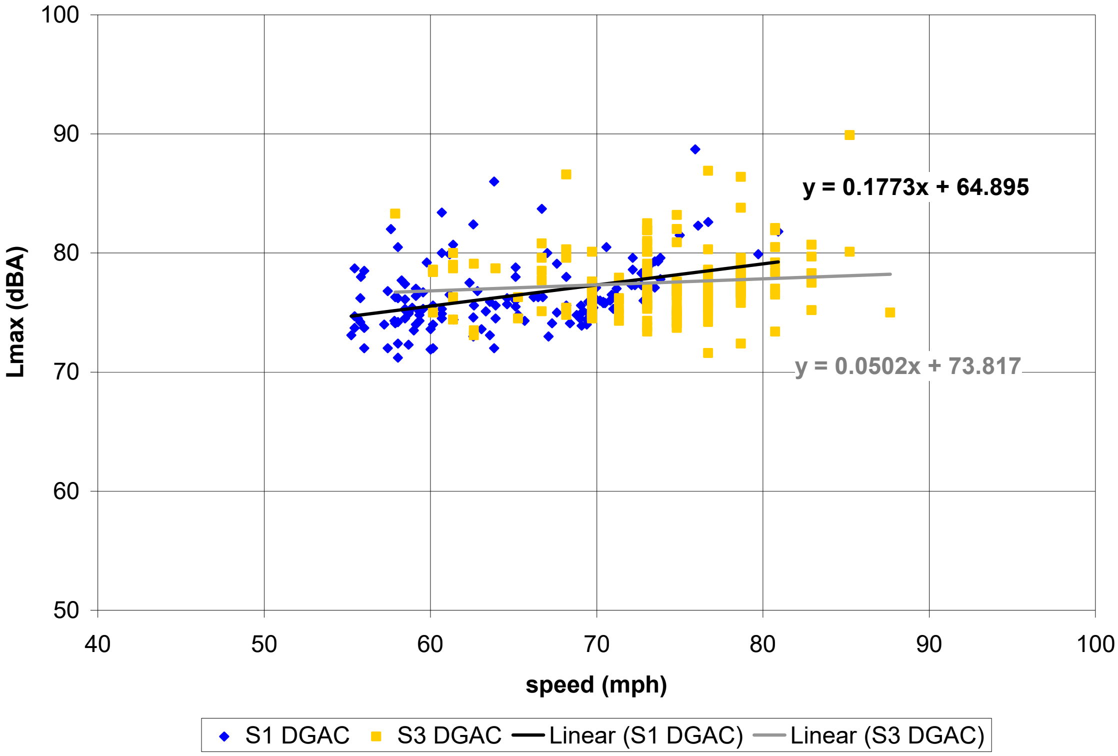
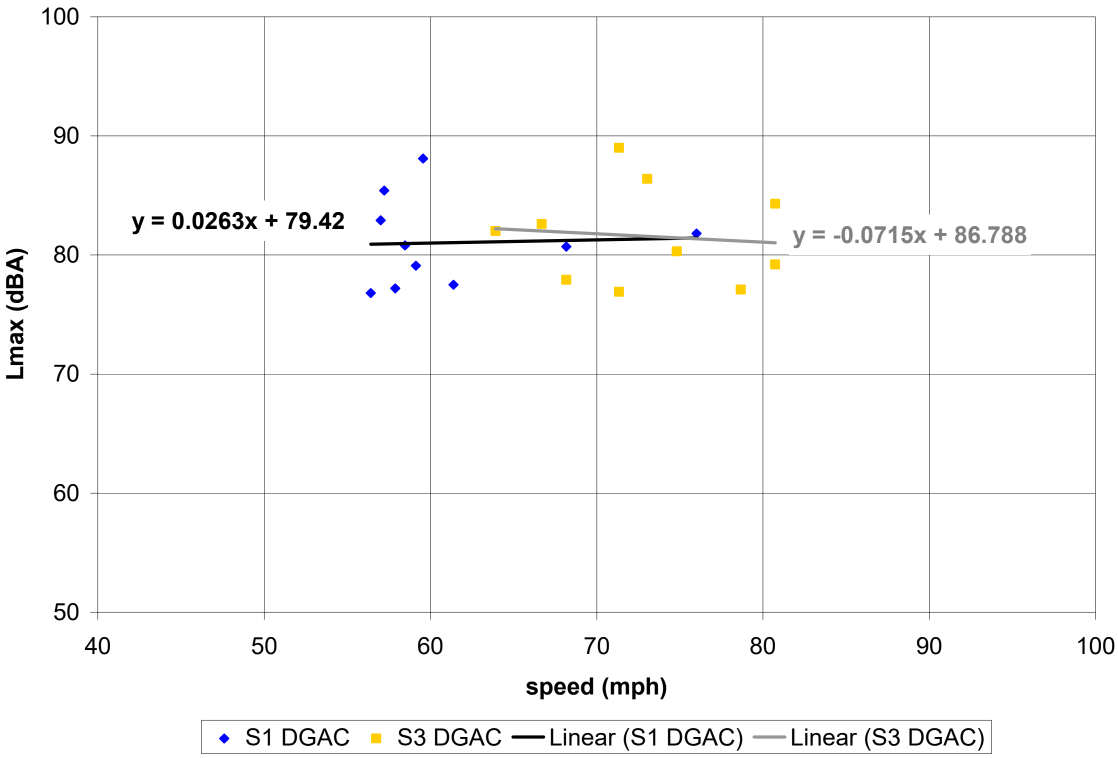


Figure C-3. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 2 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1773x + 64.895
y = 0.0502x + 73.817
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0263x + 79.42
y = -0.0715x + 86.788
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)

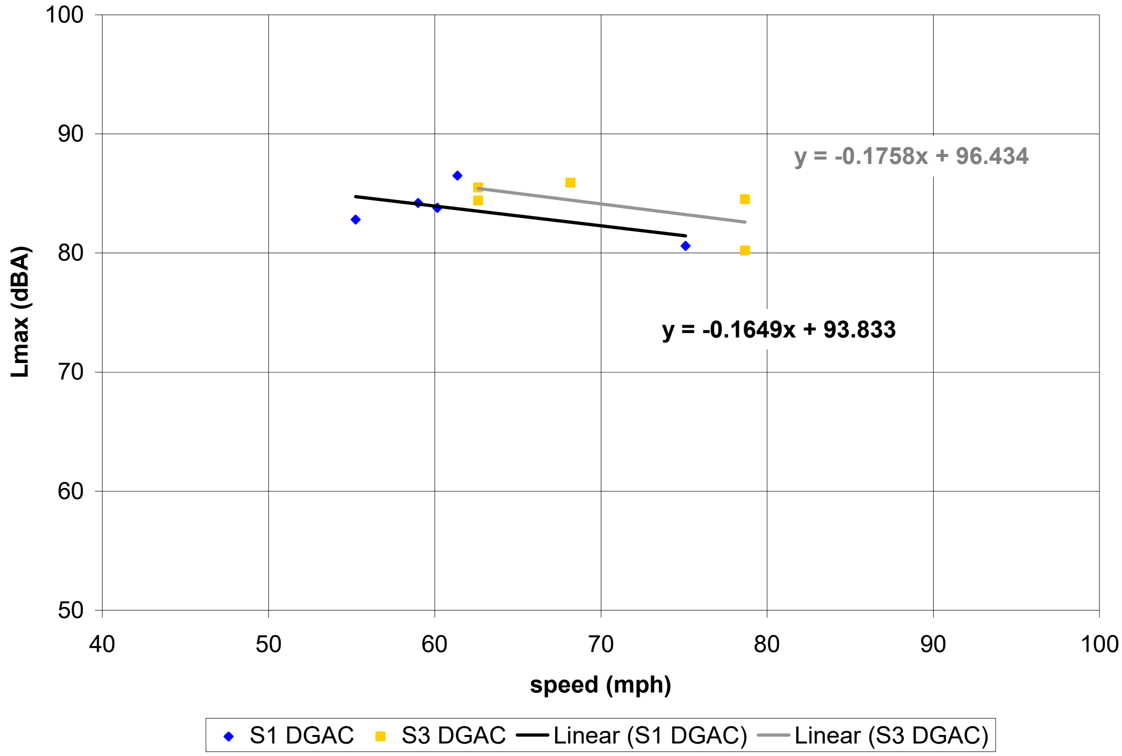
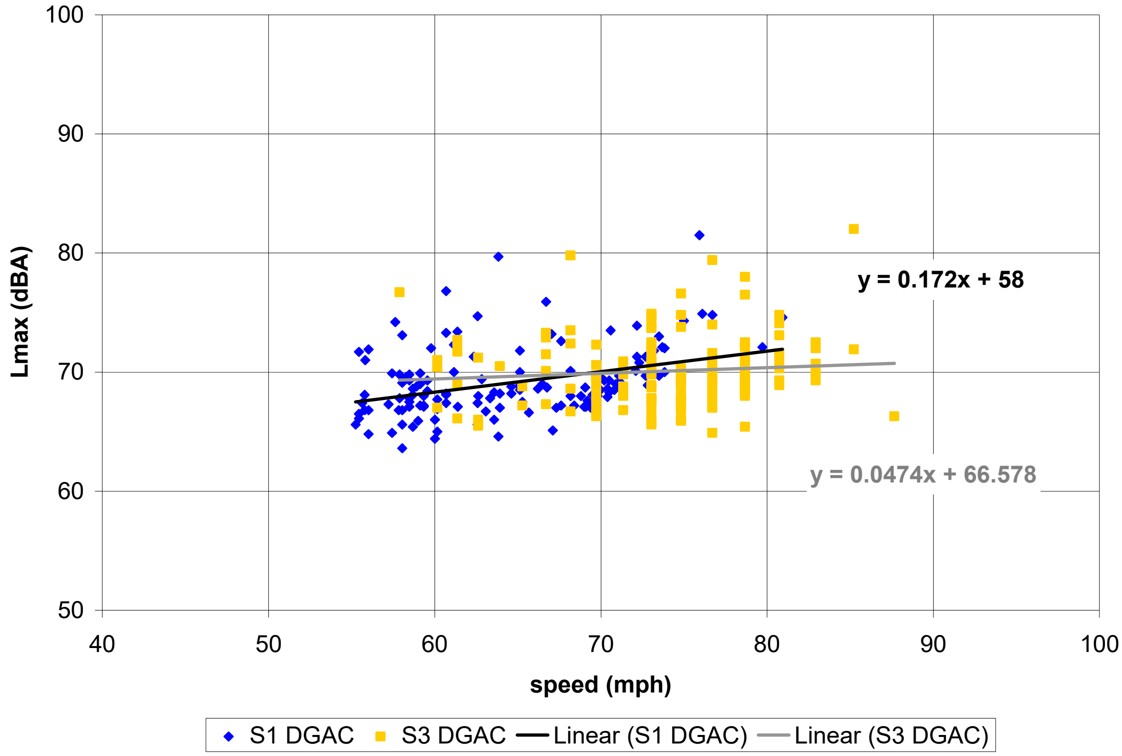
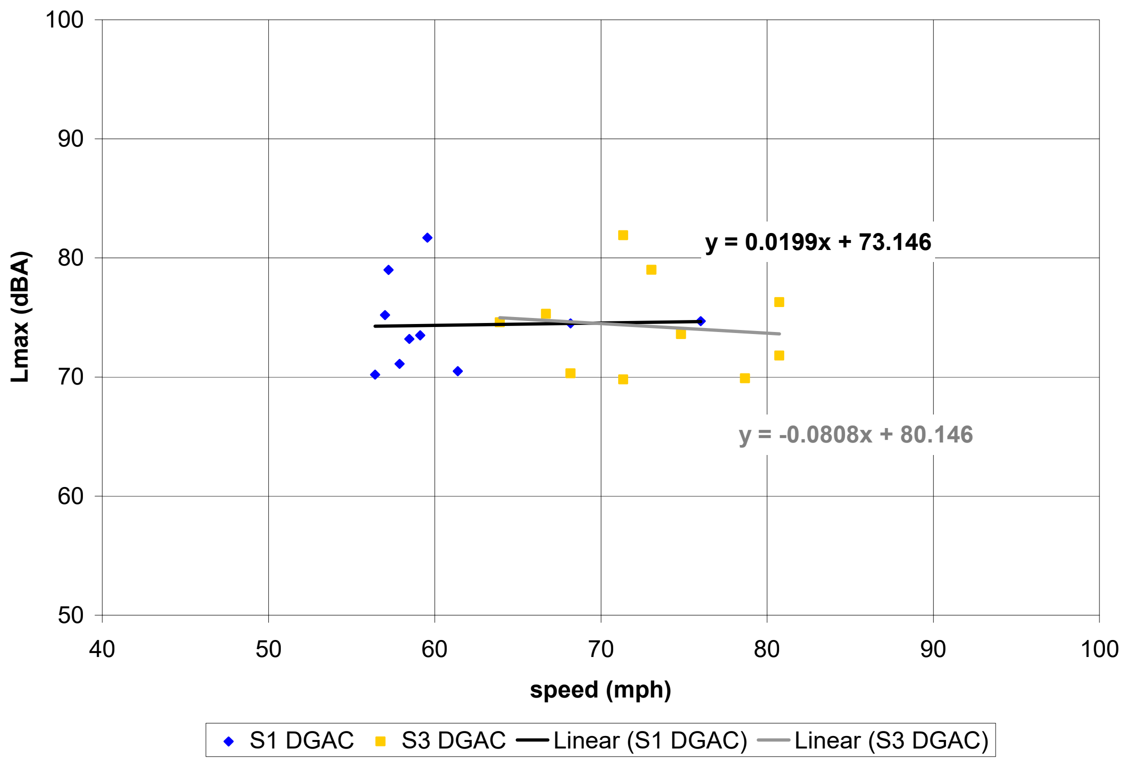


Figure C-4. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 3 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.172x + 58
y = 0.0474x + 66.578
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0199x + 73.146
y = -0.0808x + 80.146
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)

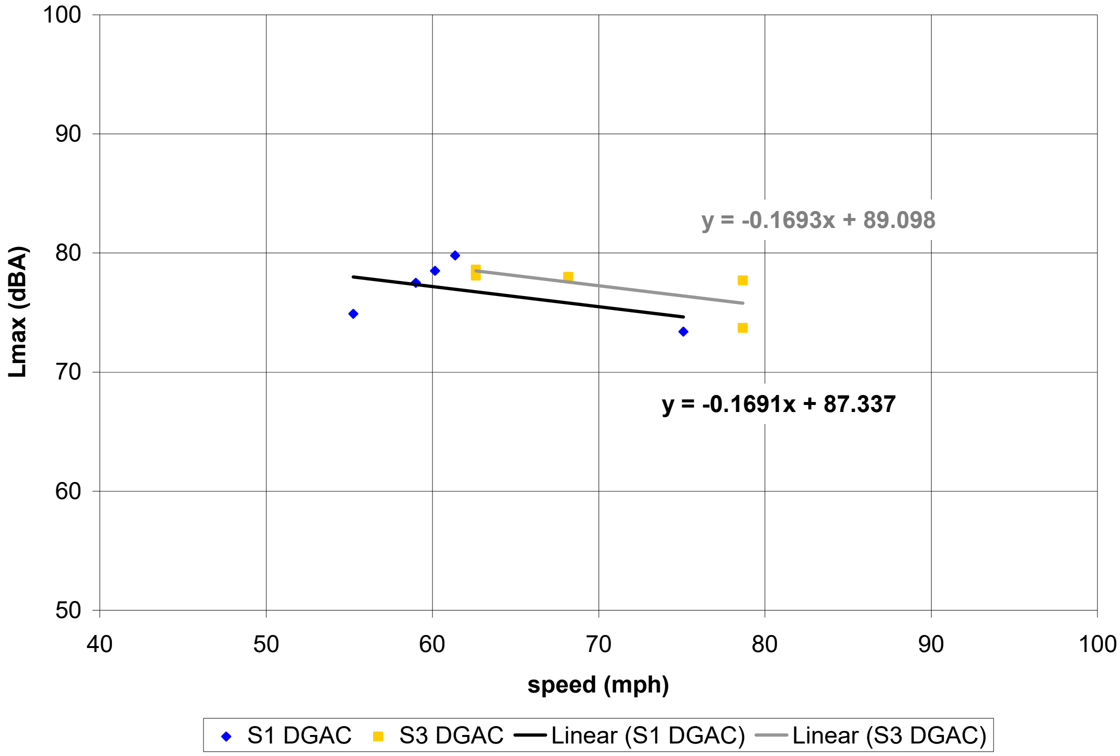
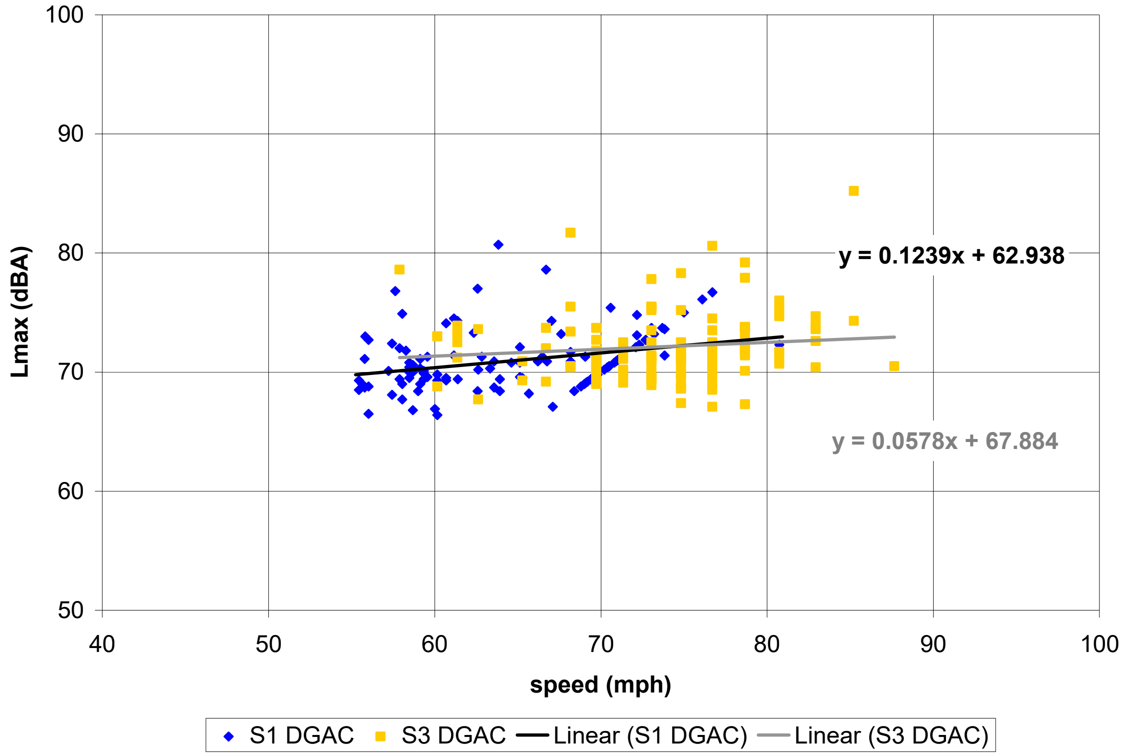
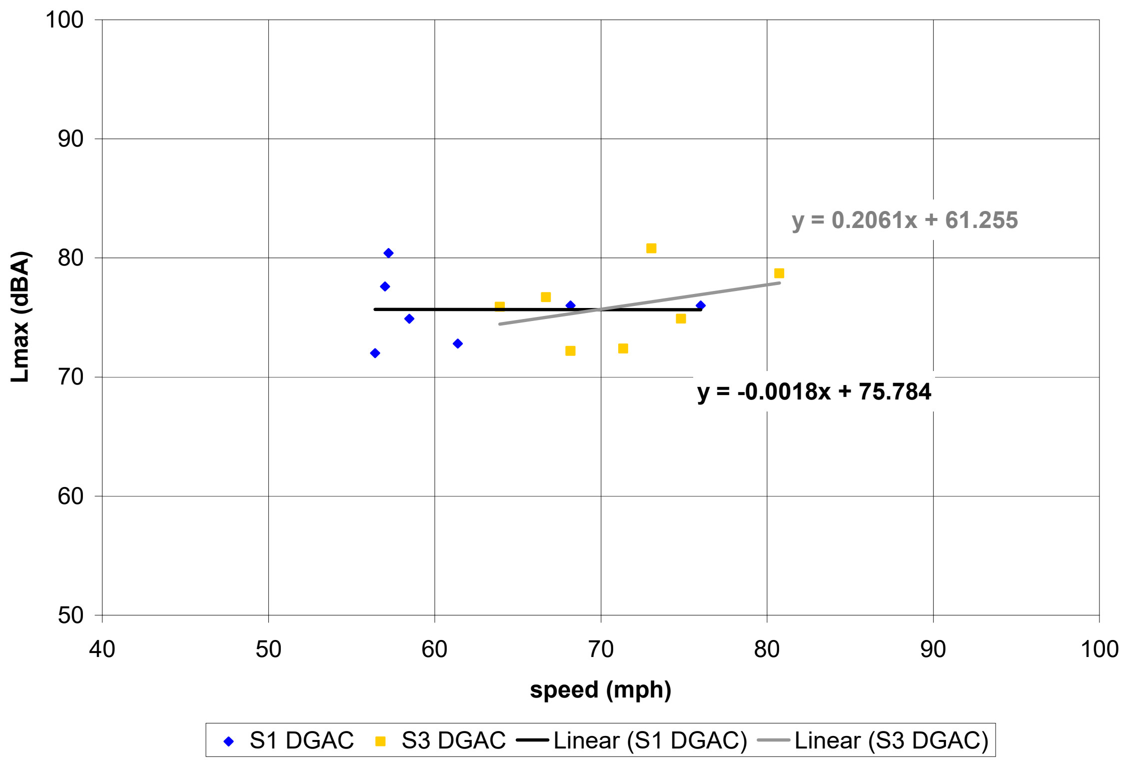


Figure C-5. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 3 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1239x + 62.938
y = 0.0578x + 67.884
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2061x + 61.255
y = -0.0018x + 75.784
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)

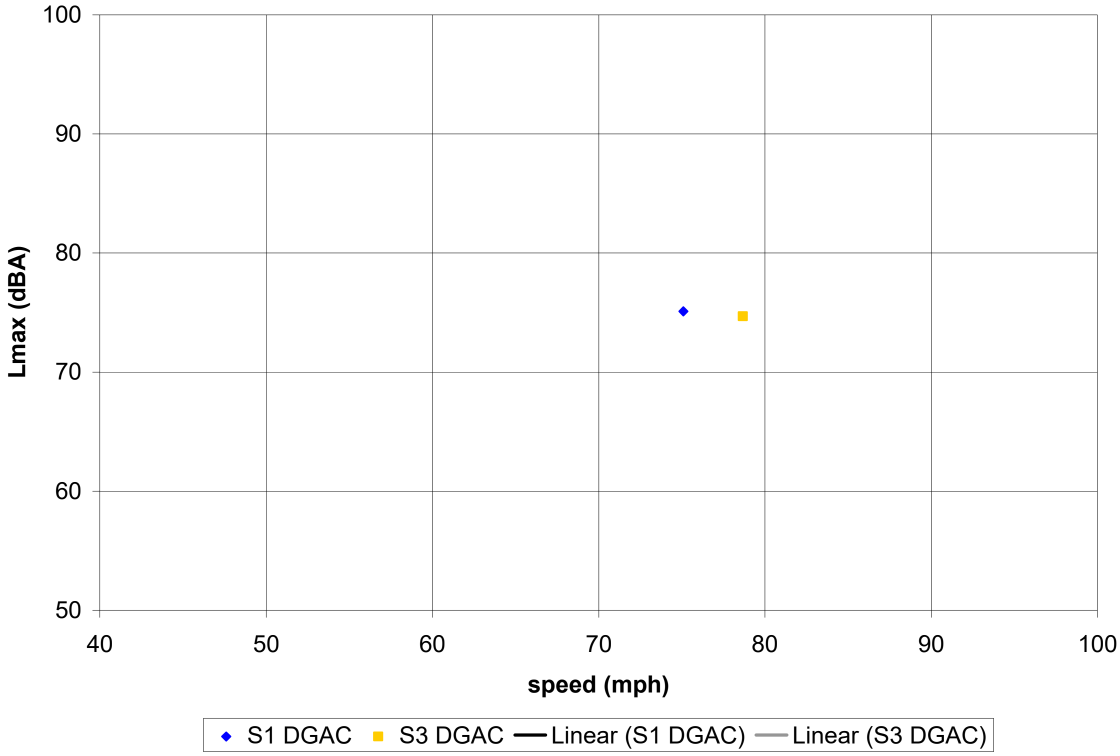
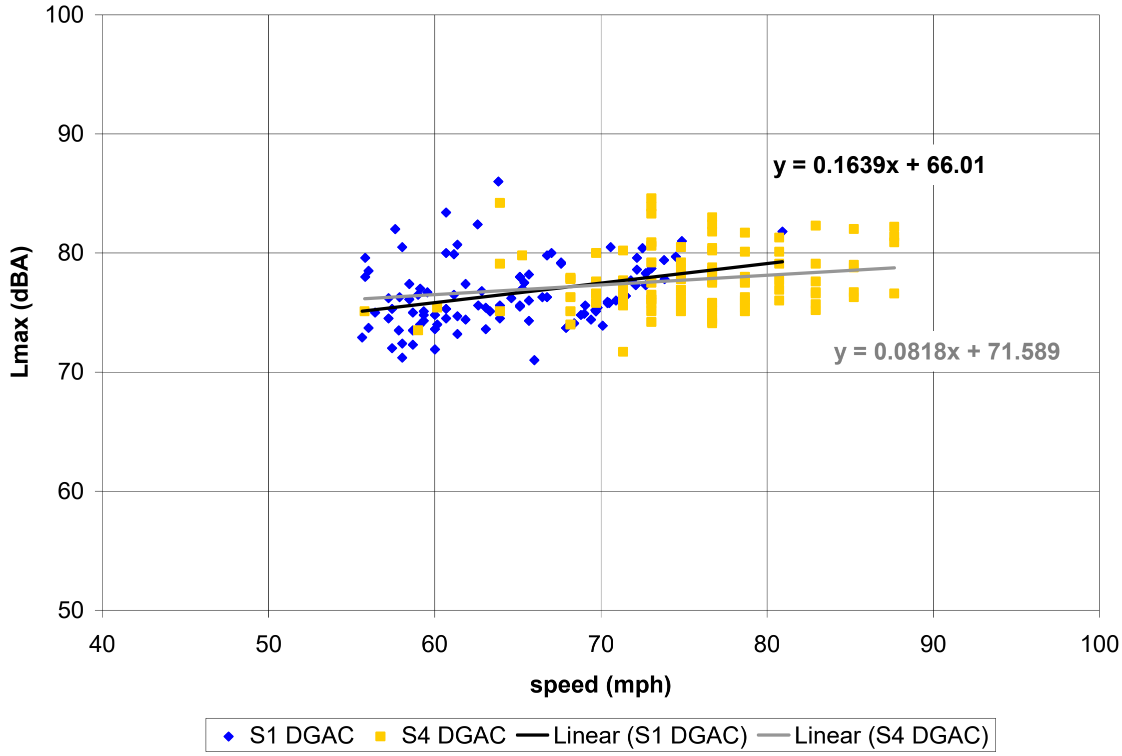
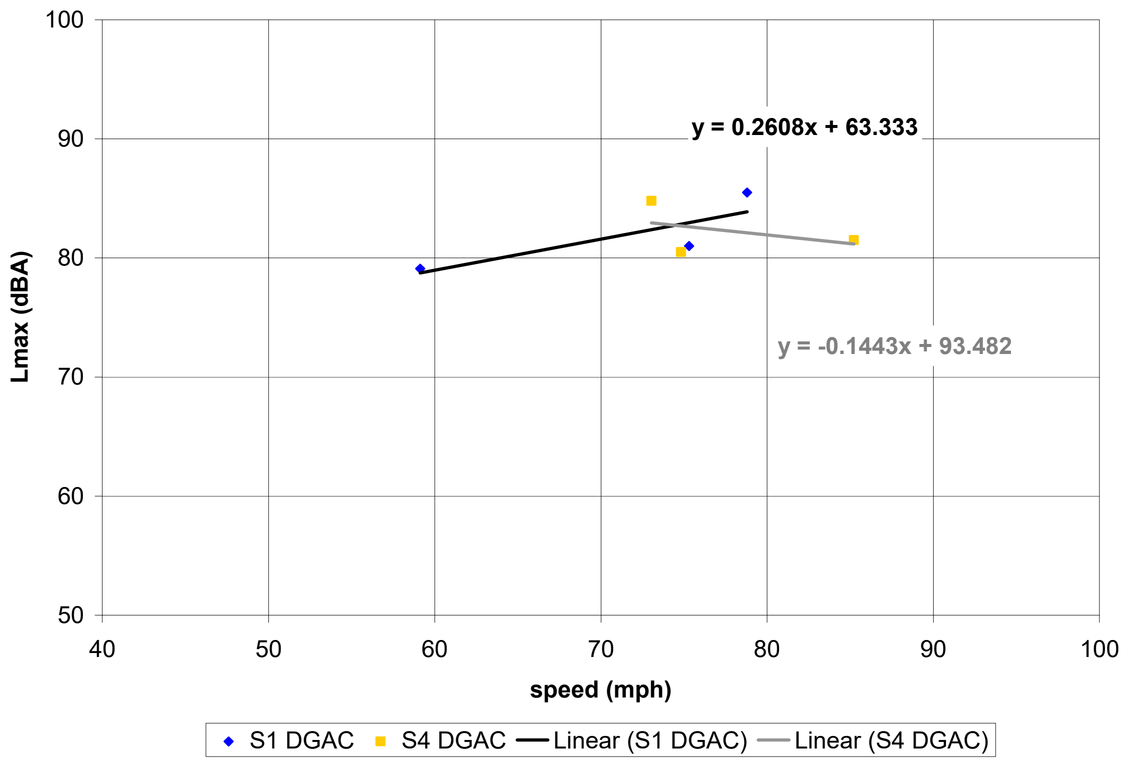


Figure C-6. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 3 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



y = 0.1639x + 66.01
y = 0.0818x + 71.589
Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)



y = 0.2608x + 63.333
y = -0.1443x + 93.482
Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)

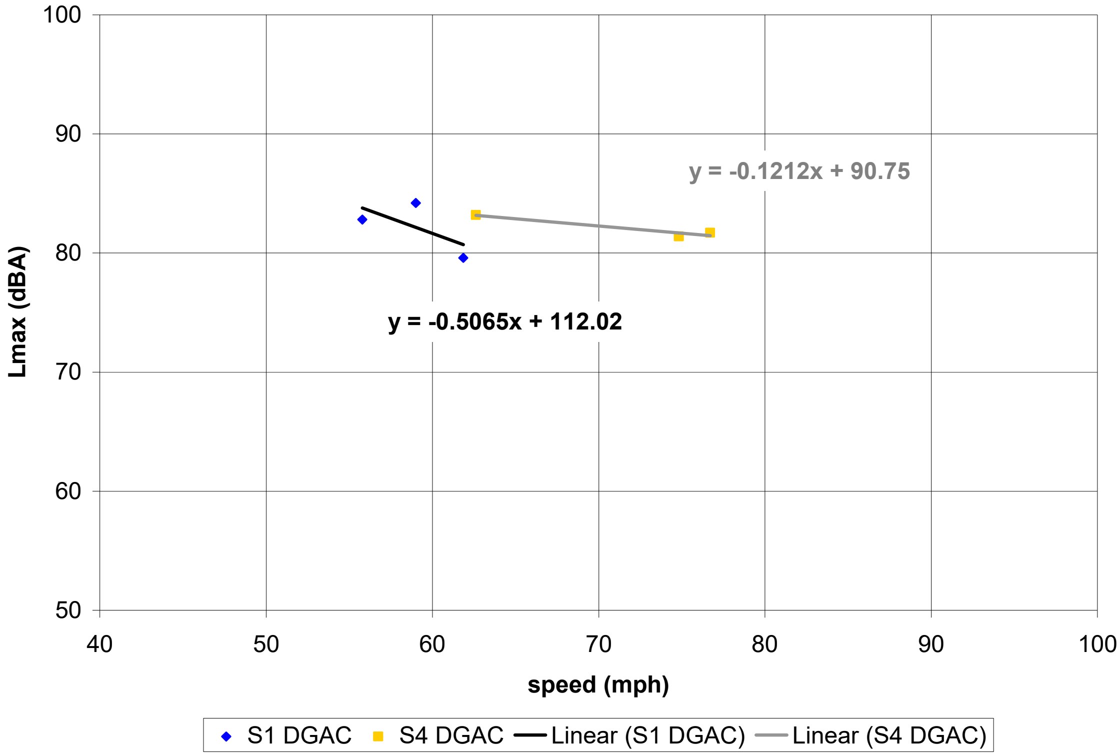
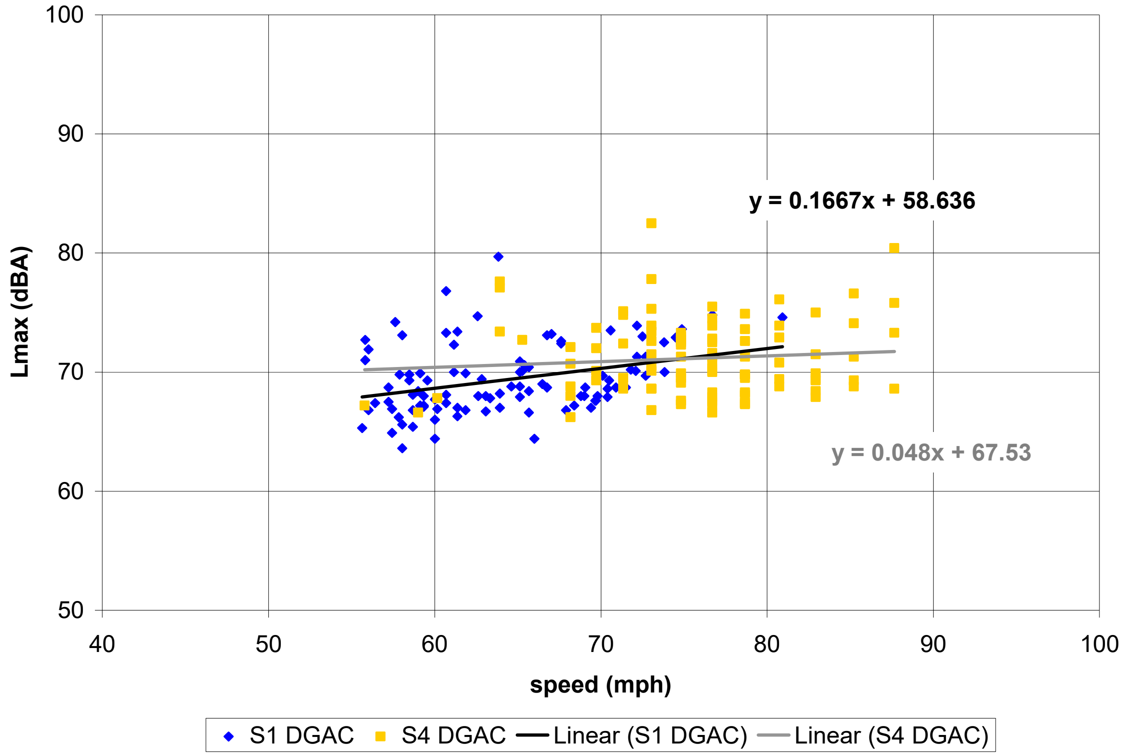
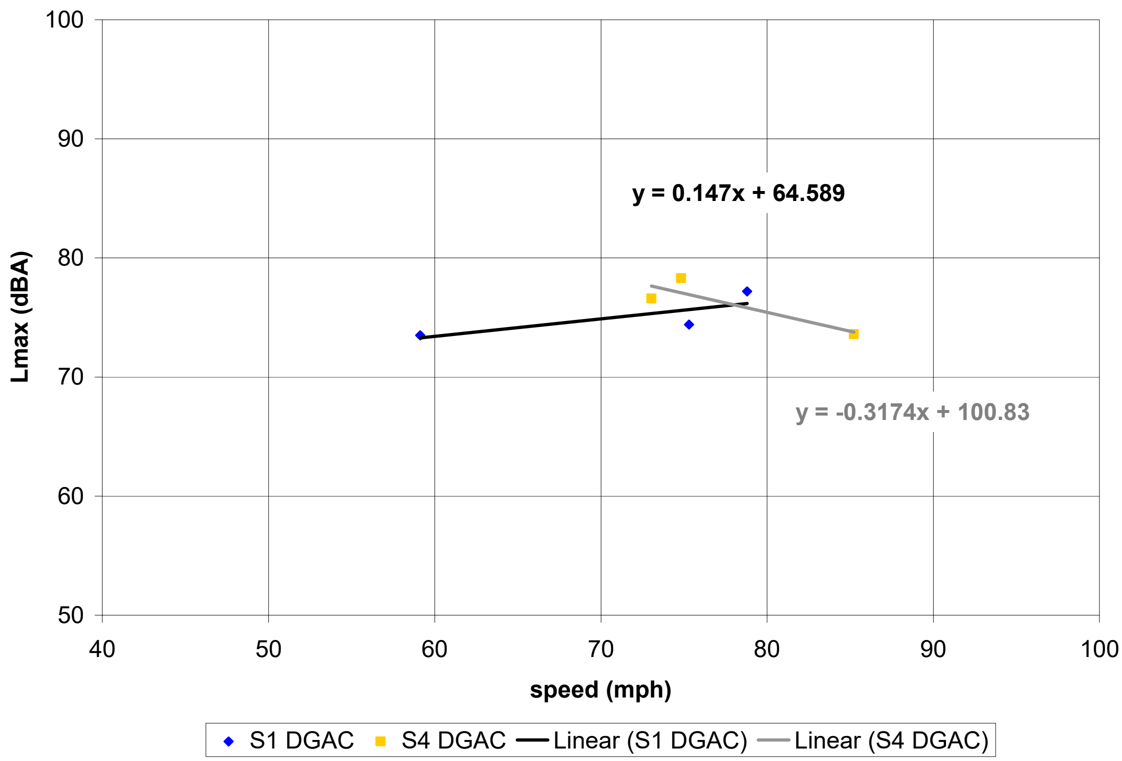


Figure C-7. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 4 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
y = 0.1667x + 58.636
y = 0.048x + 67.53
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)



Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
y = 0.147x + 64.589
y = -0.3174x + 100.83
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)

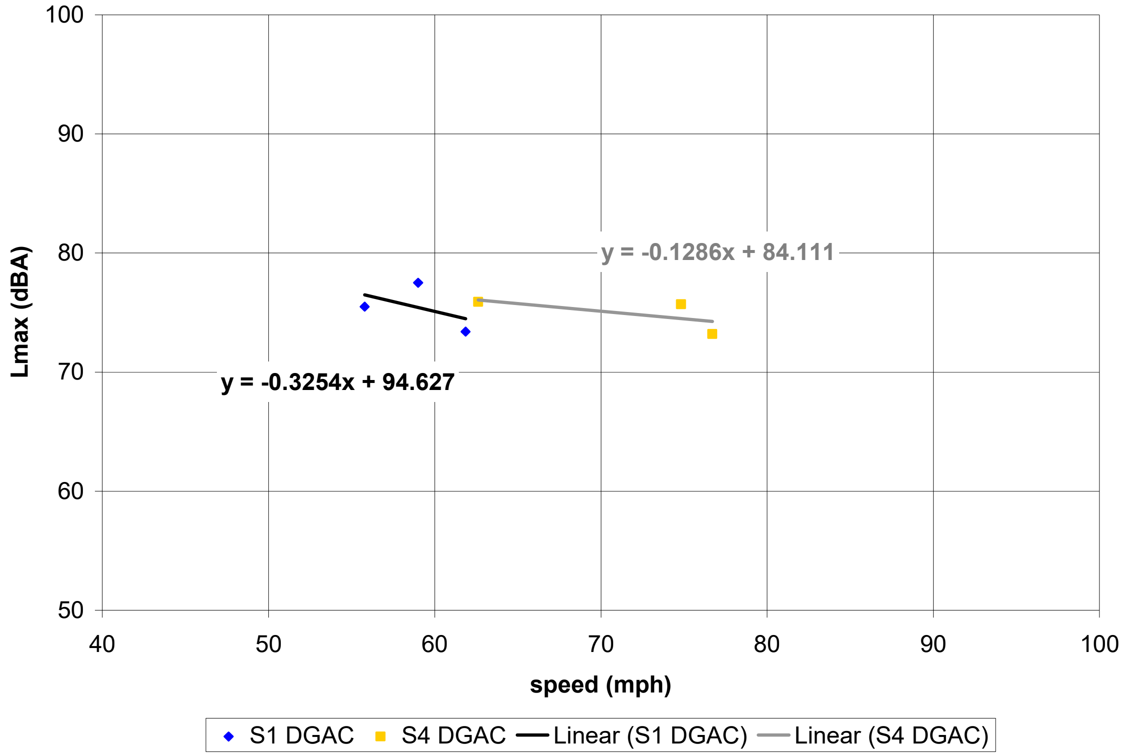
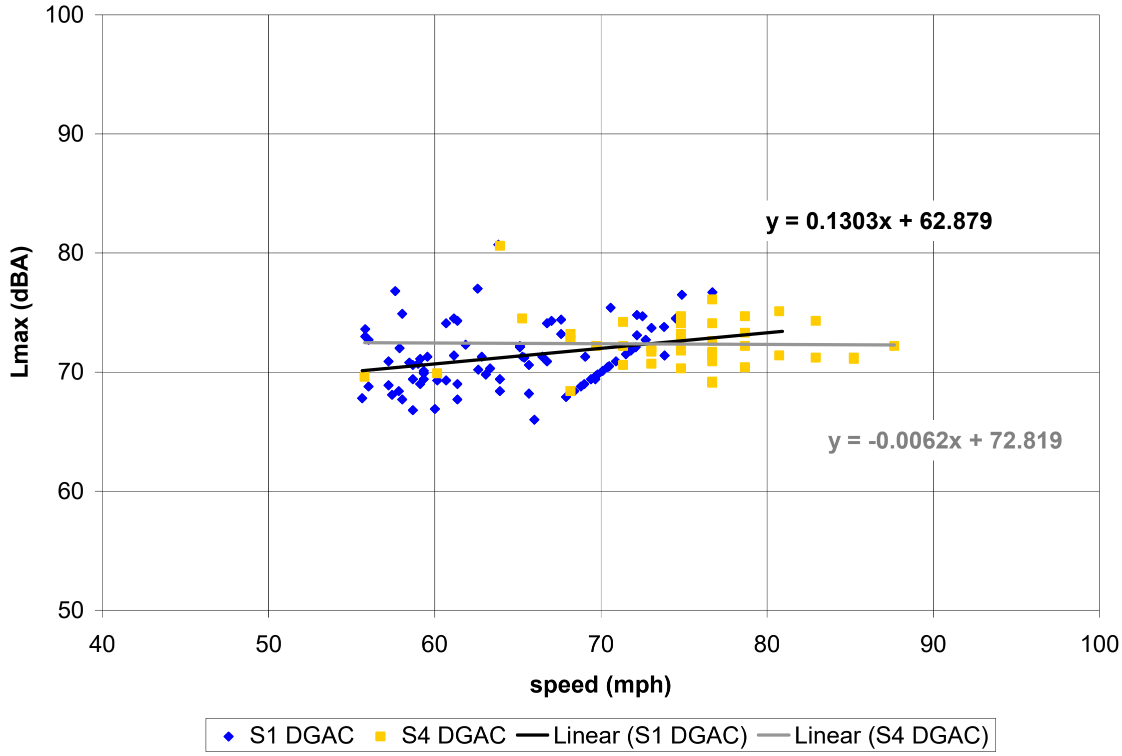
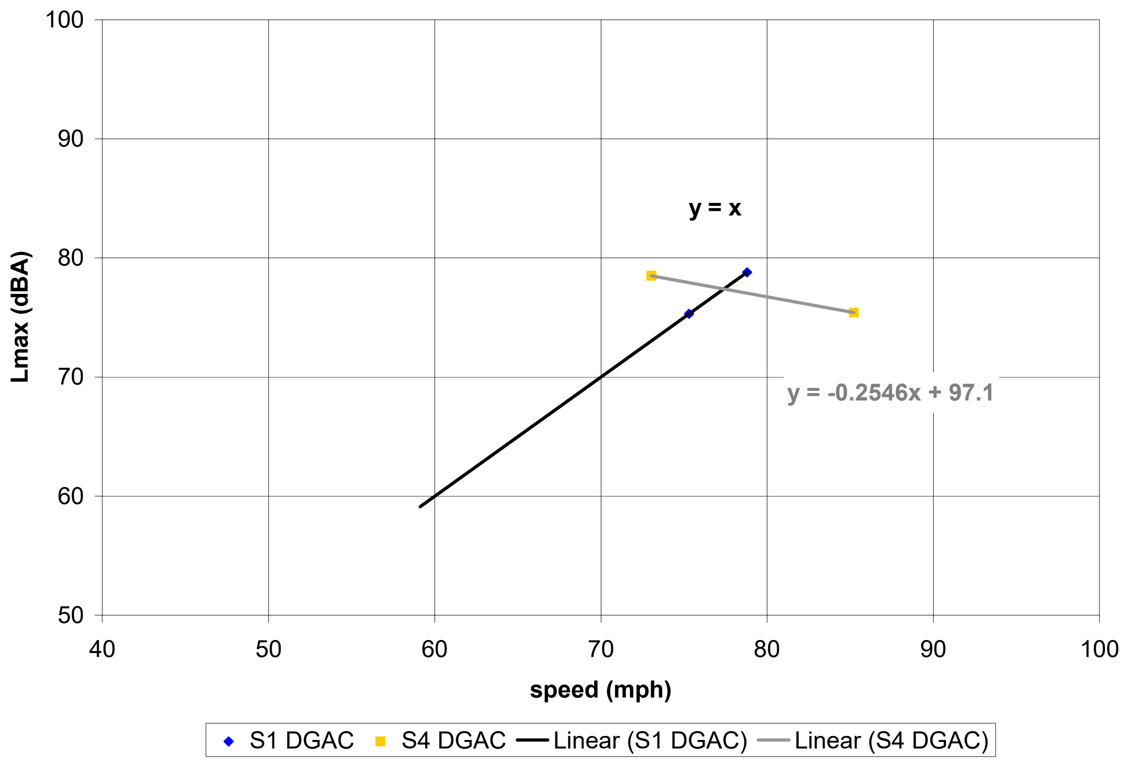


Figure C-8. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 4 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1303x + 62.879
y = -0.0062x + 72.819
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = x
y = -0.2546x + 97.1
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)

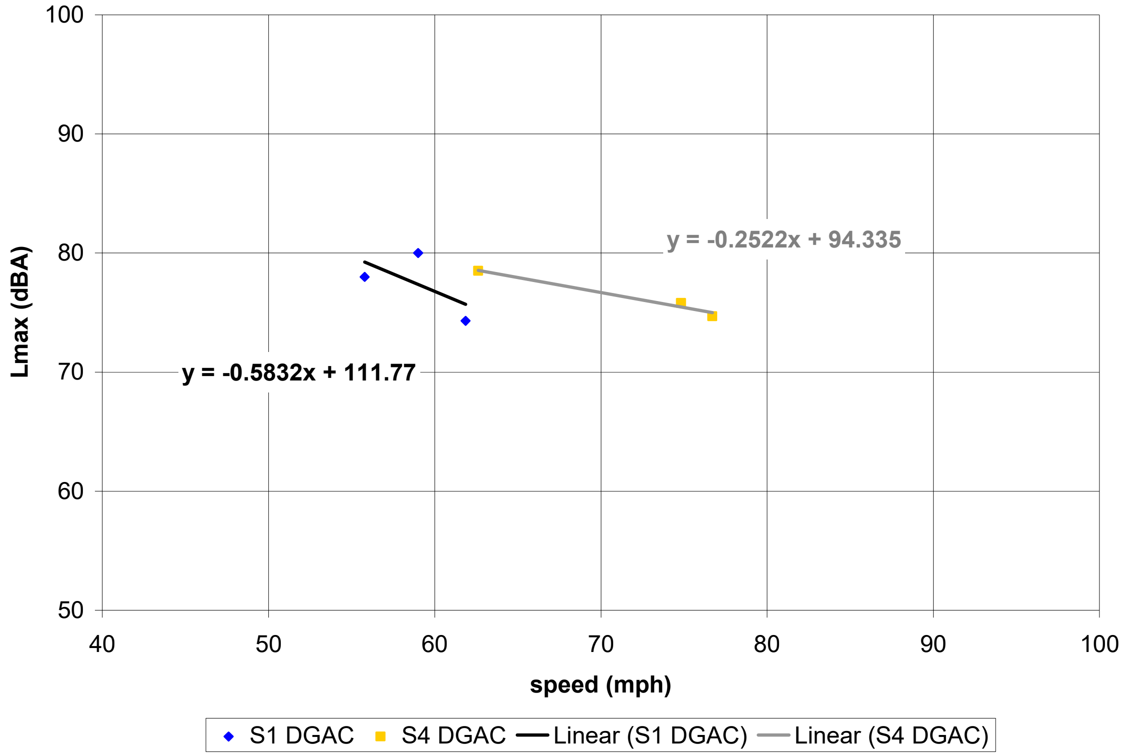
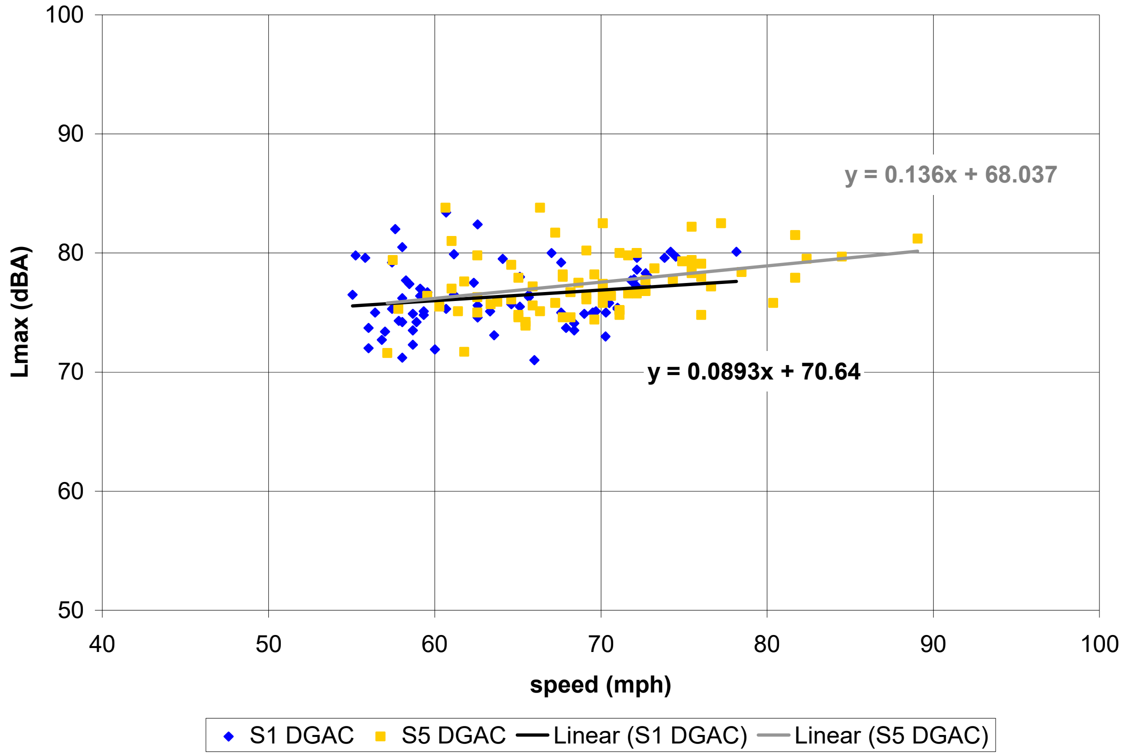
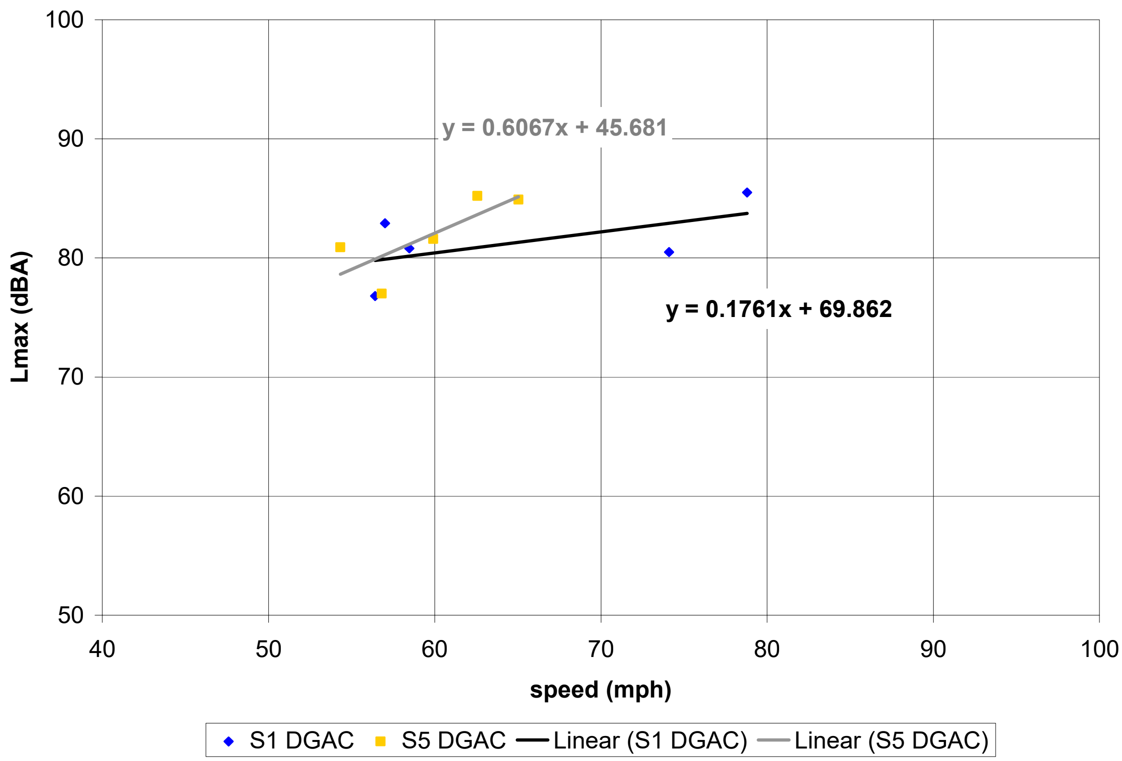


Figure C-9. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 4 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


y = 0.136x + 68.037
y = 0.0893x + 70.64
Lmax (dBA)
speed (mph)
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)


y = 0.6067x + 45.681
y = 0.1761x + 69.862
Lmax (dBA)
speed (mph)
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)

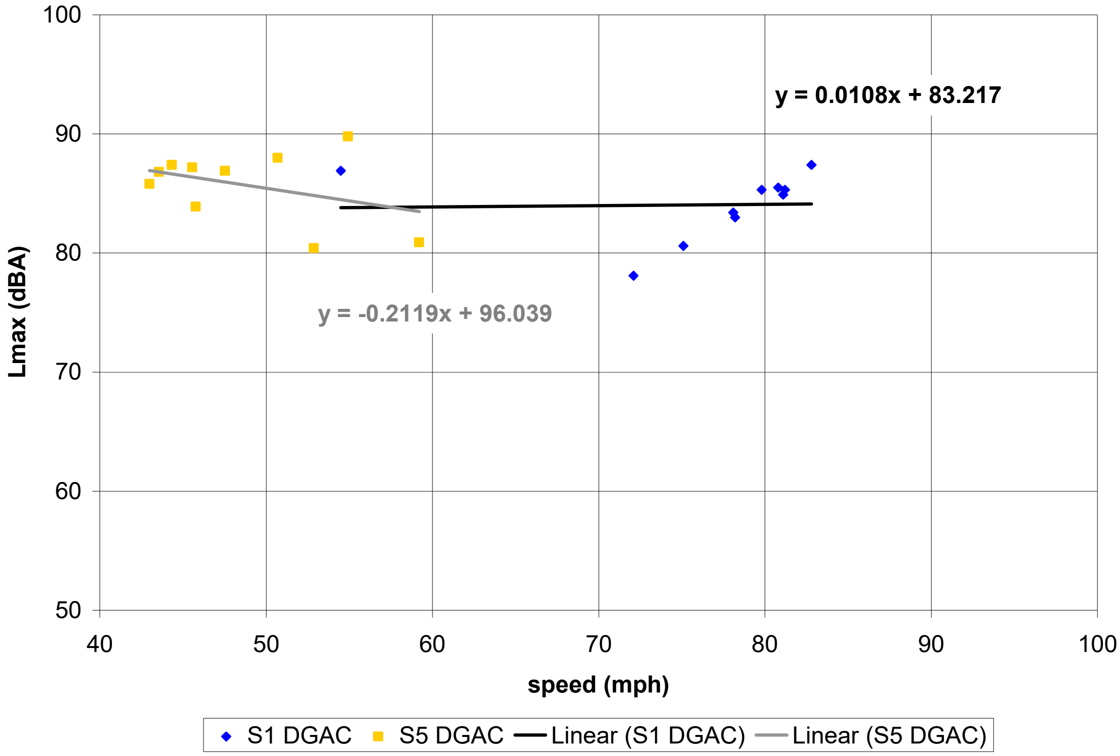
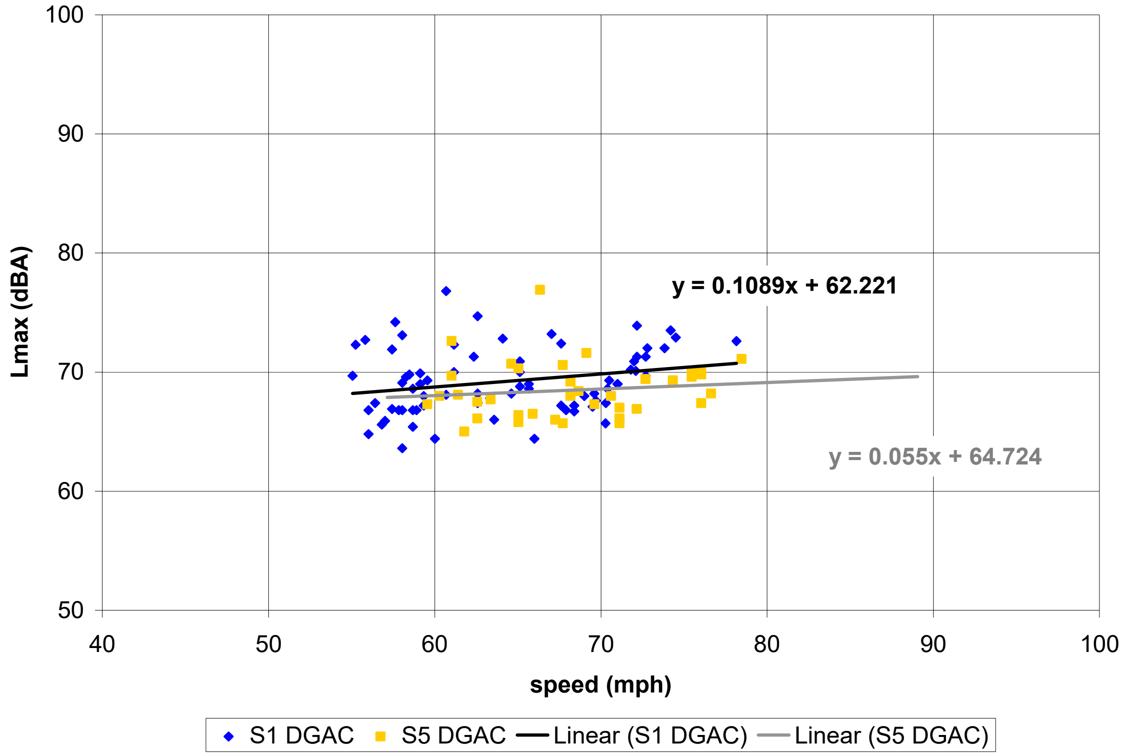
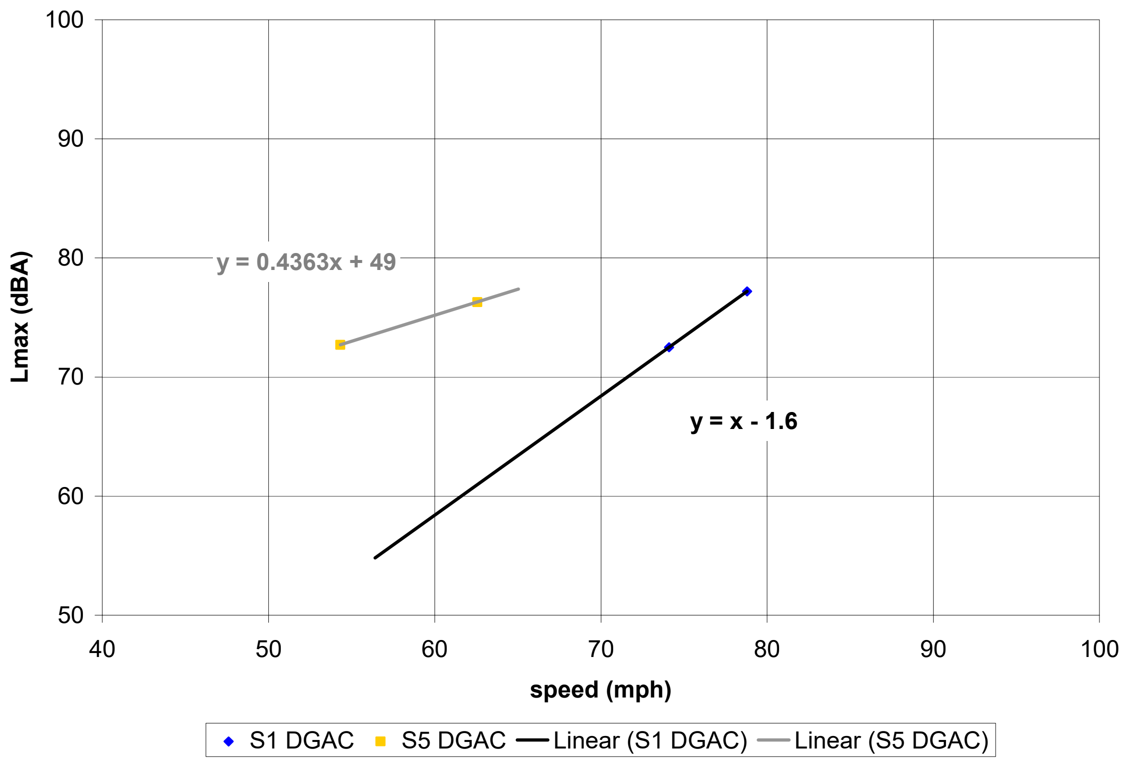


Figure C-10. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 5 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1089x + 62.221
y = 0.055x + 64.724
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.4363x + 49
y = x - 1.6
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)

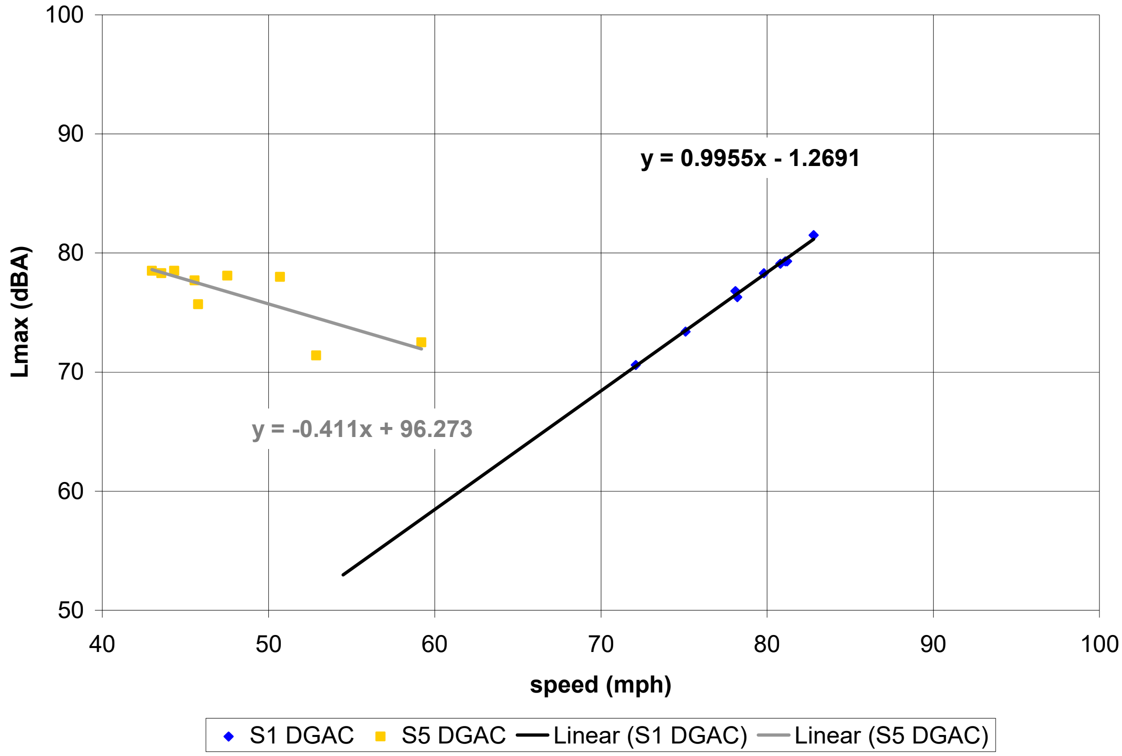
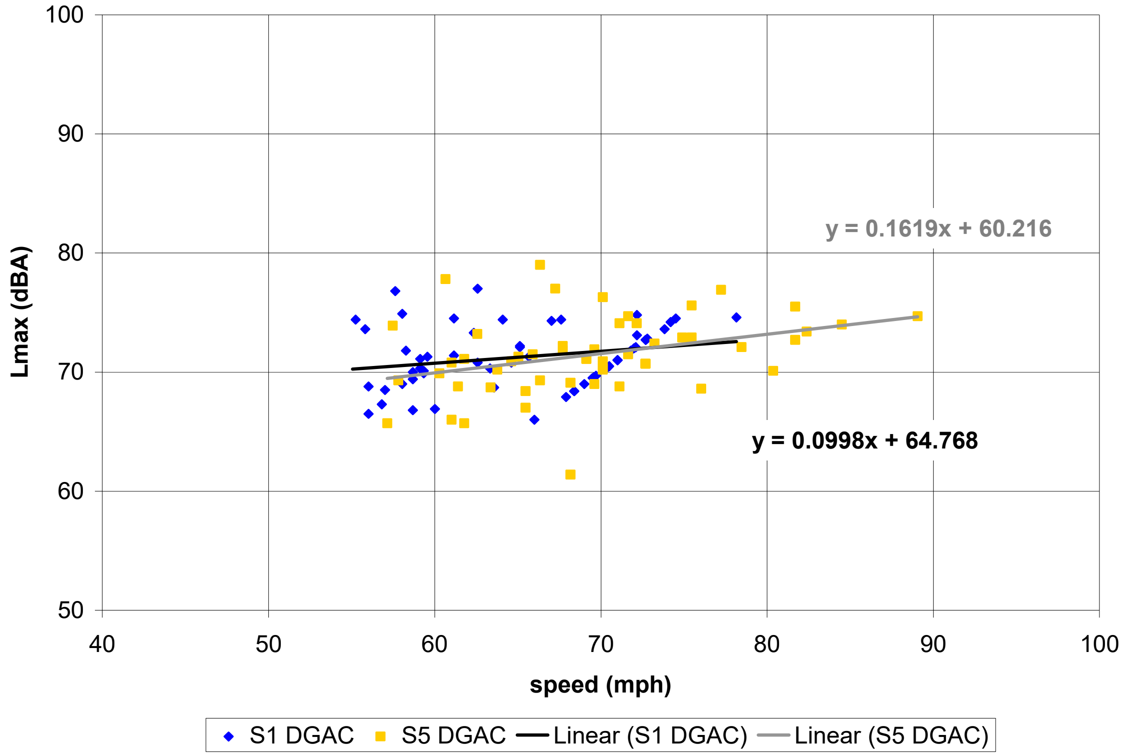
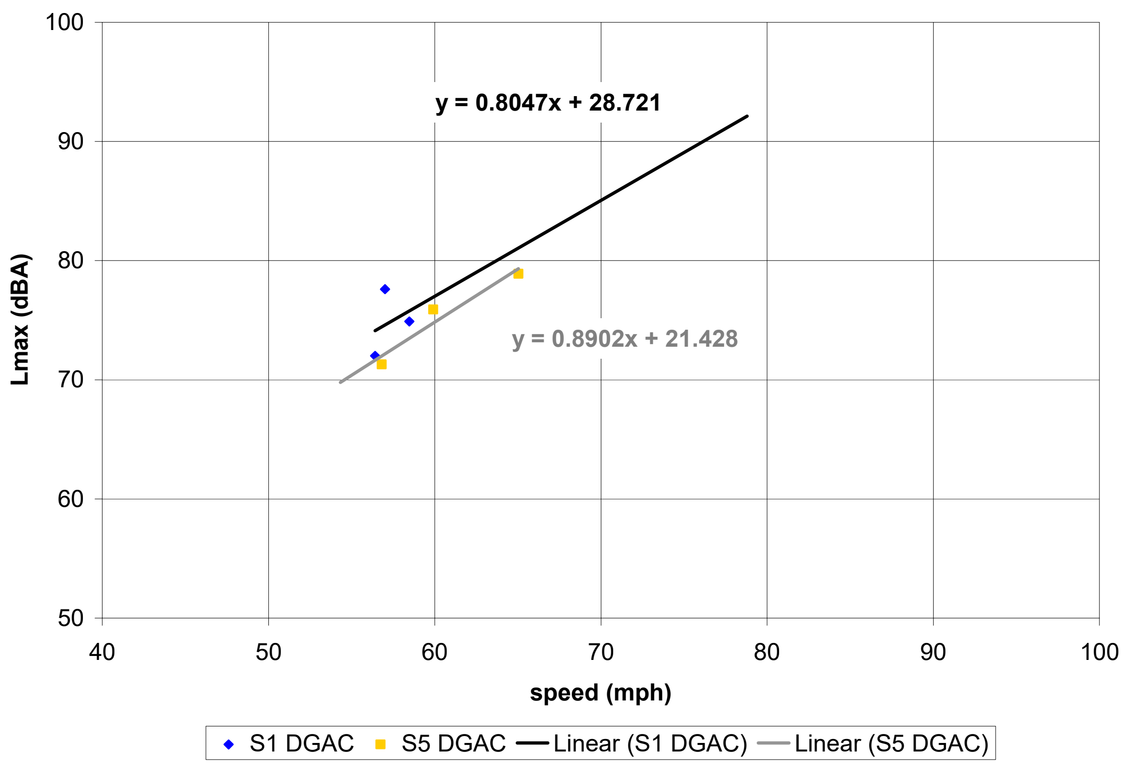


Figure C-11. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 5 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1619x + 60.216
y = 0.0998x + 64.768
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.8047x + 28.721
y = 0.8902x + 21.428
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)

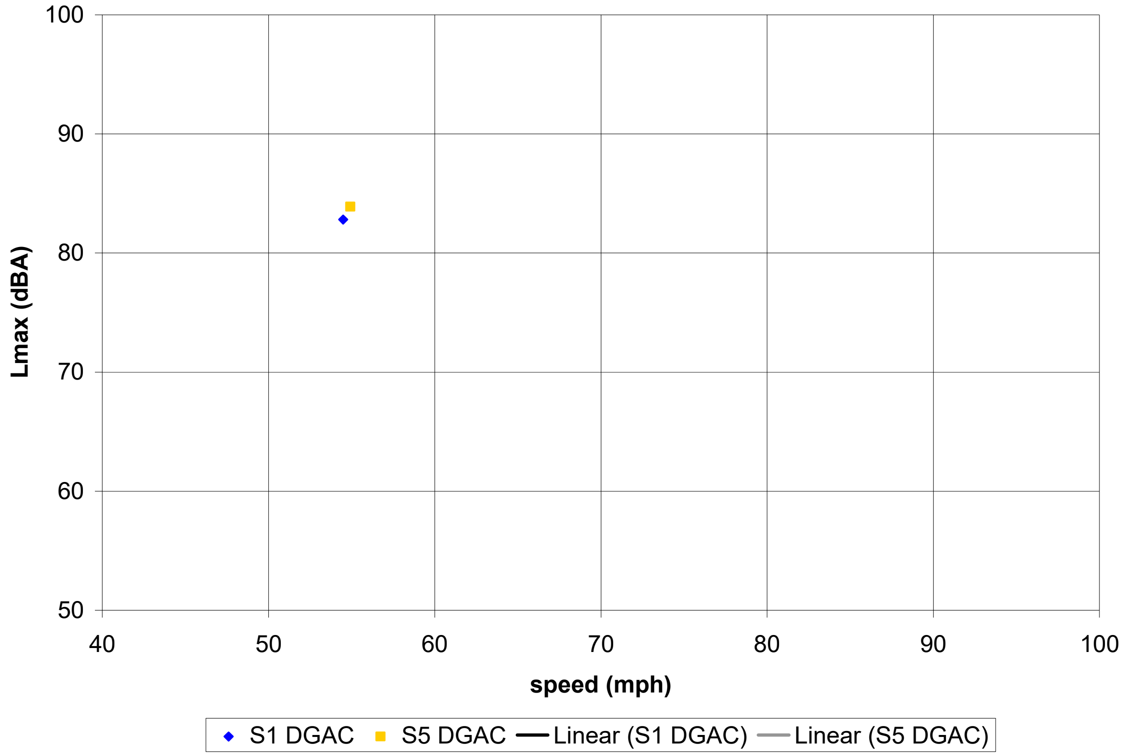
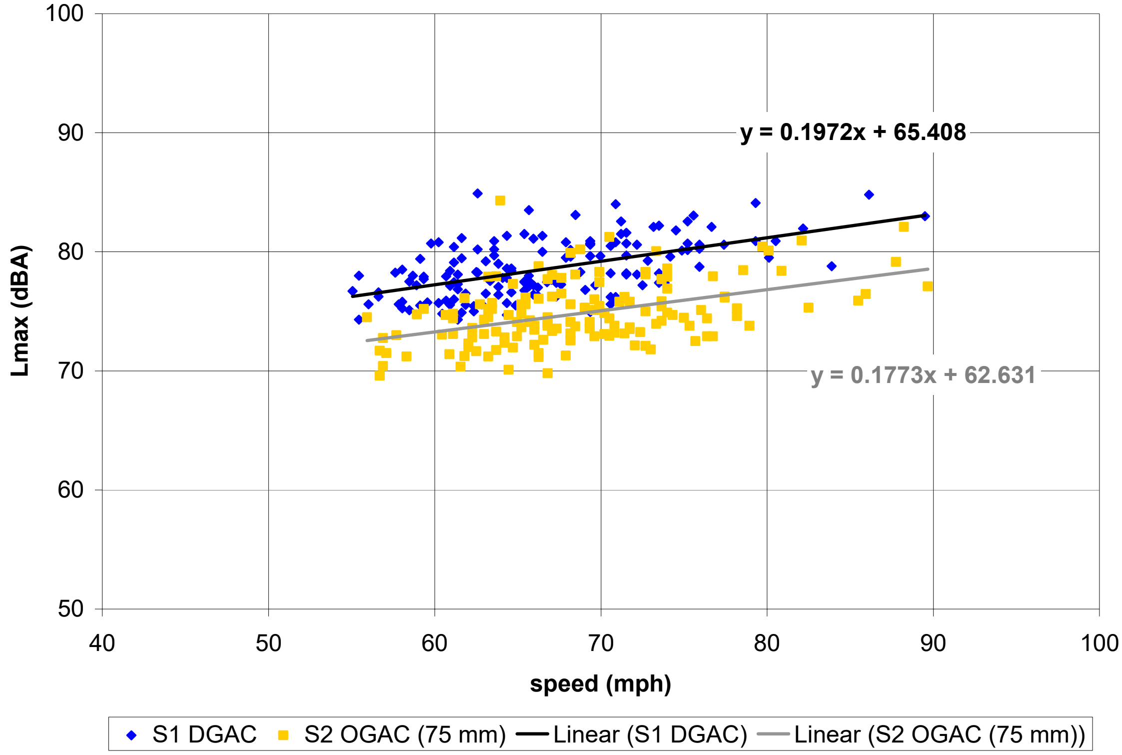
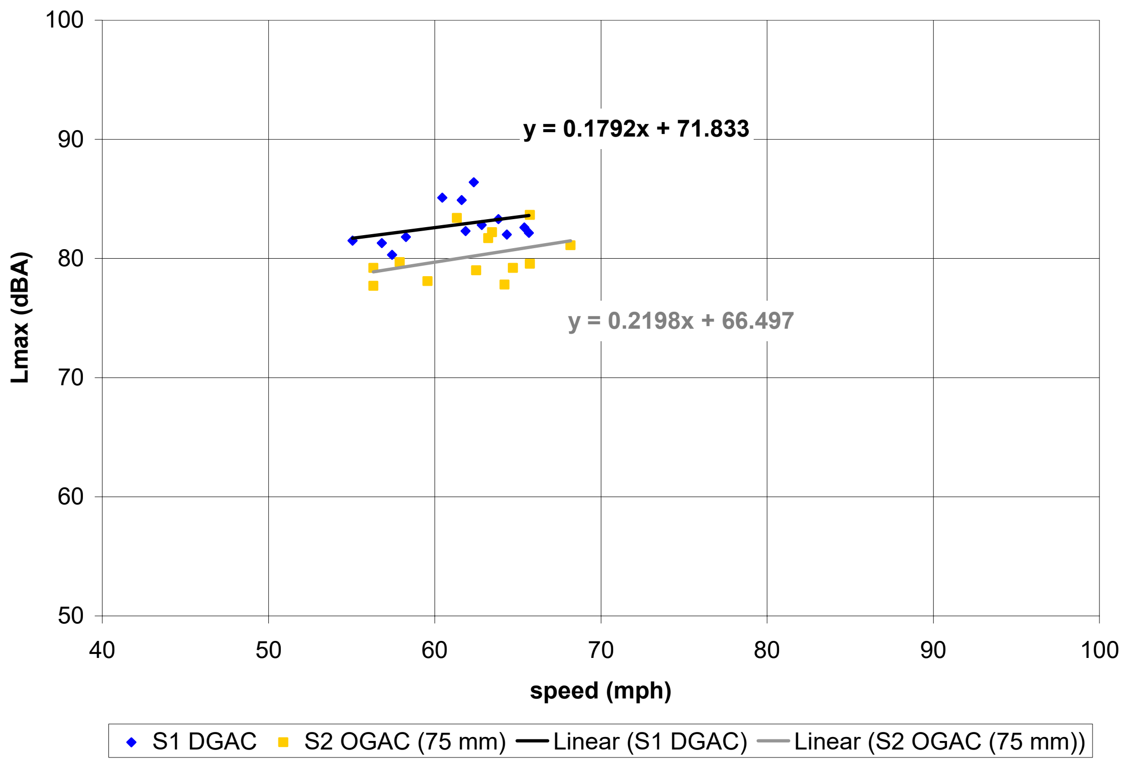


Figure C-12. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 5 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.3 Post-Overlay – Pavement Age: 4 months





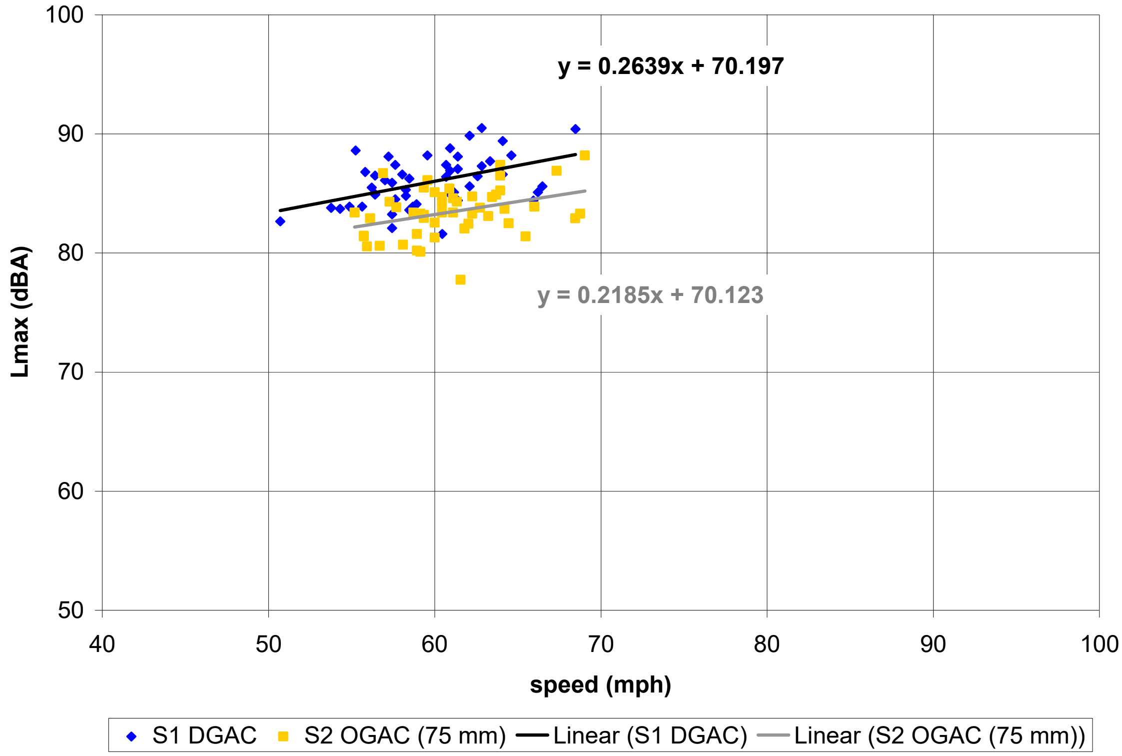
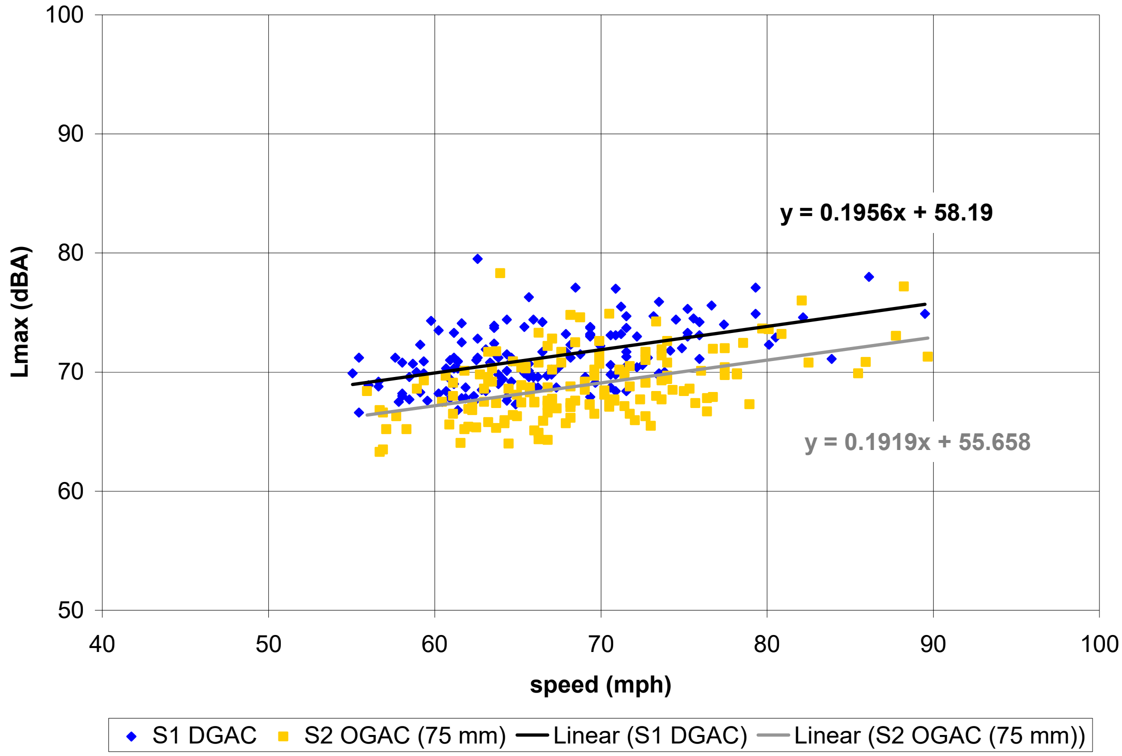
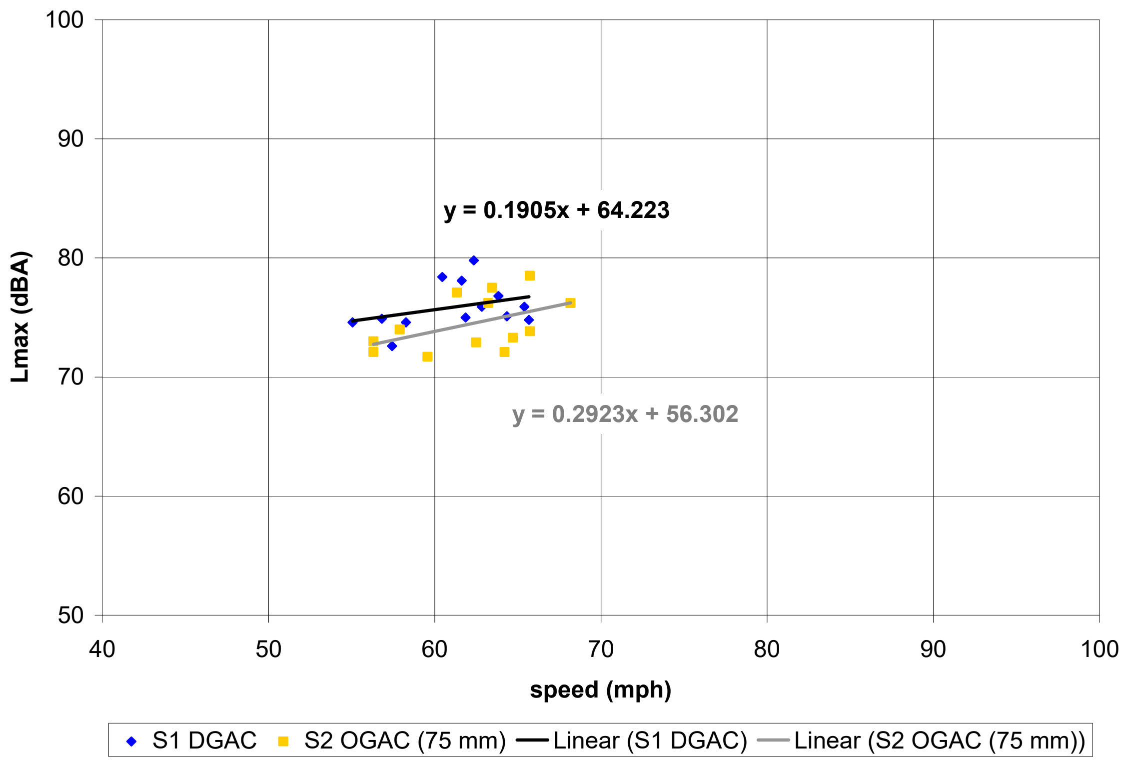


Figure C-13. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1956x + 58.19
y = 0.1919x + 55.658
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1905x + 64.223
y = 0.2923x + 56.302
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

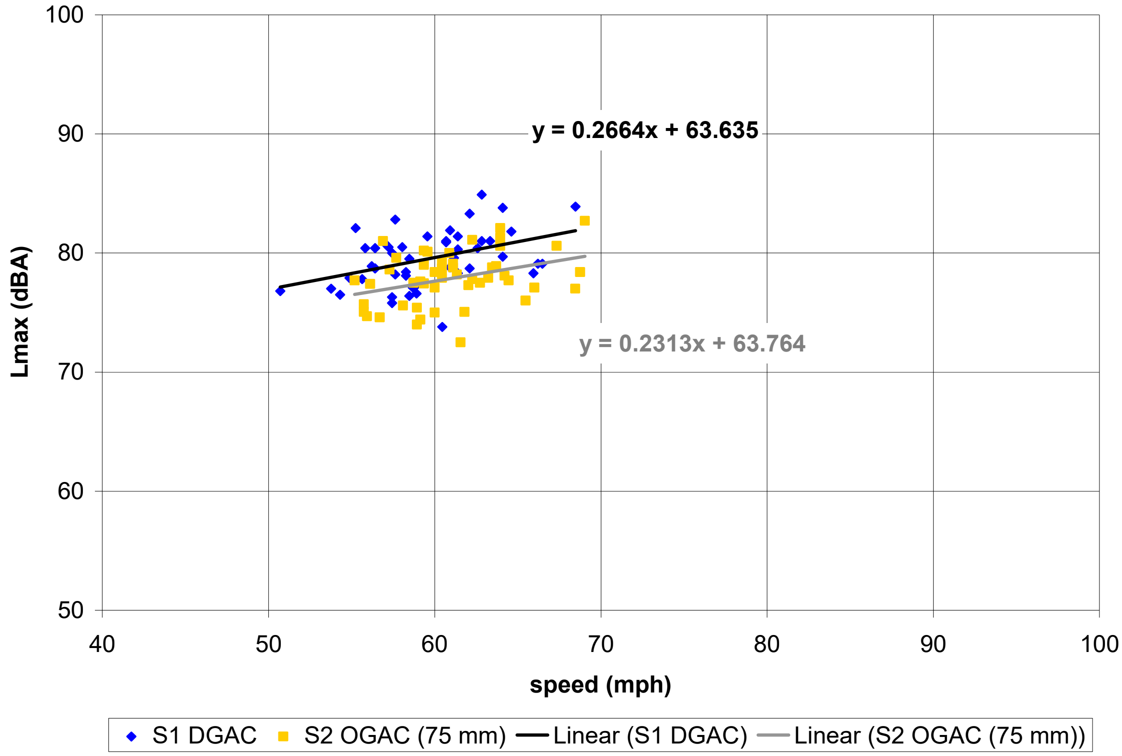
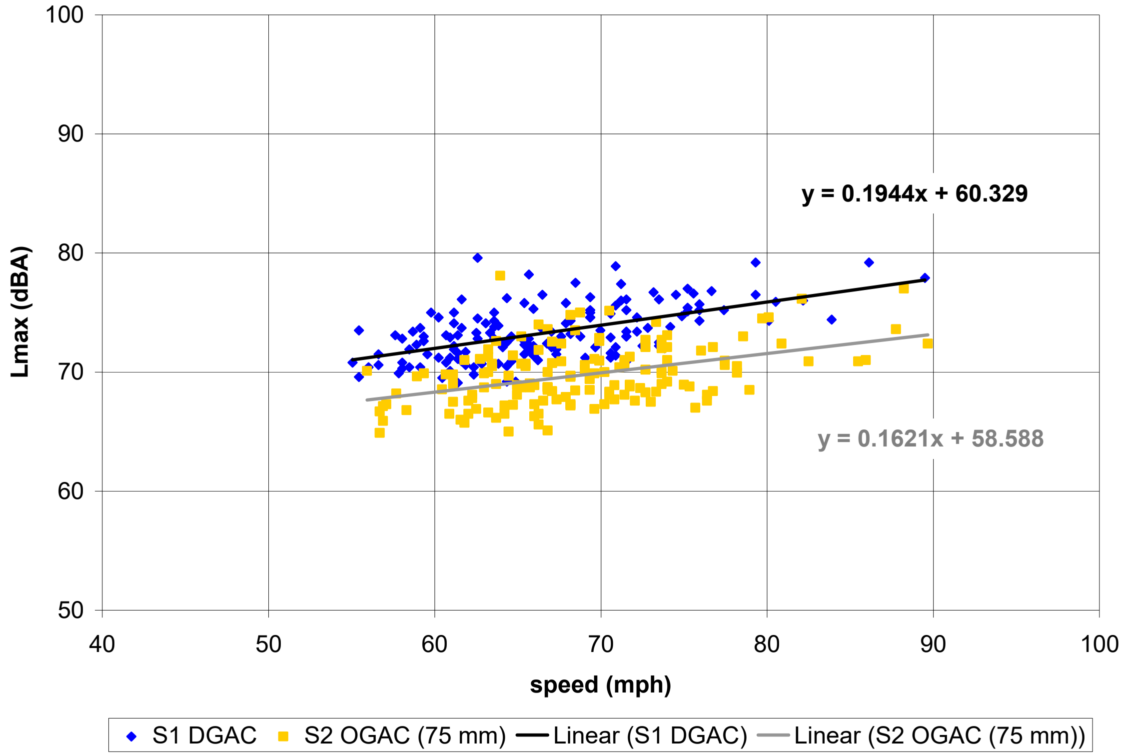
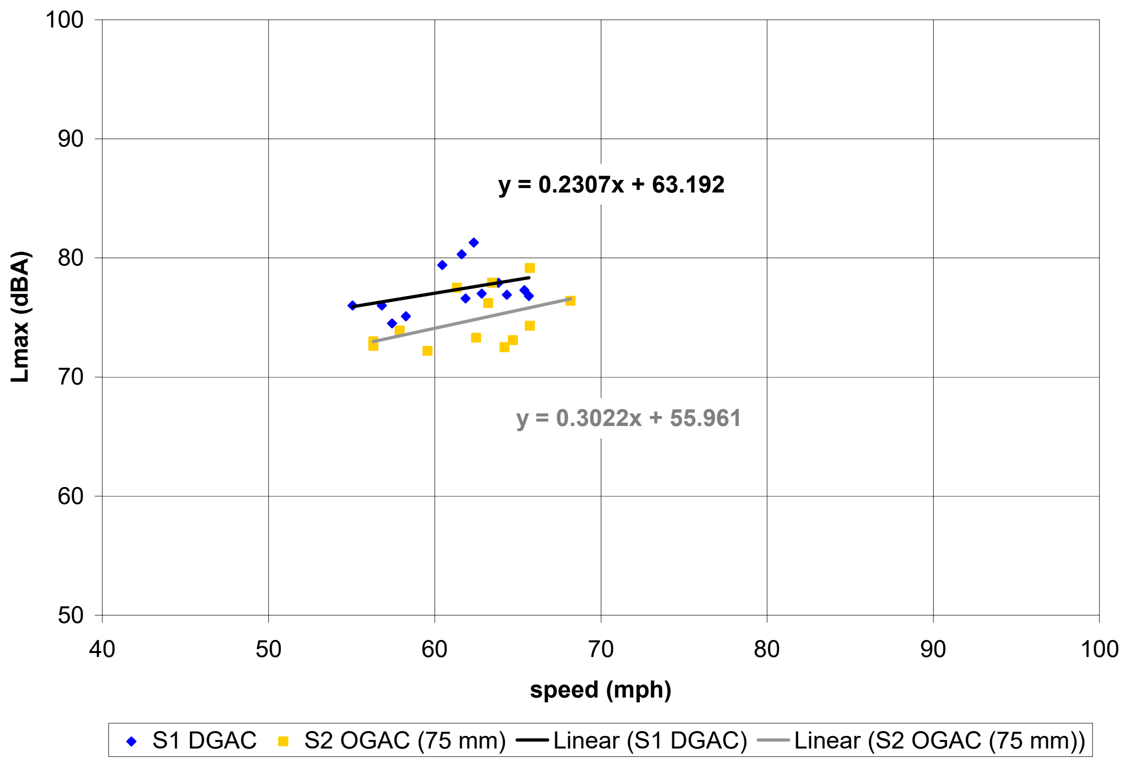


Figure C-14. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



y = 0.1944x + 60.329
y = 0.1621x + 58.588
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



y = 0.2307x + 63.192
y = 0.3022x + 55.961
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

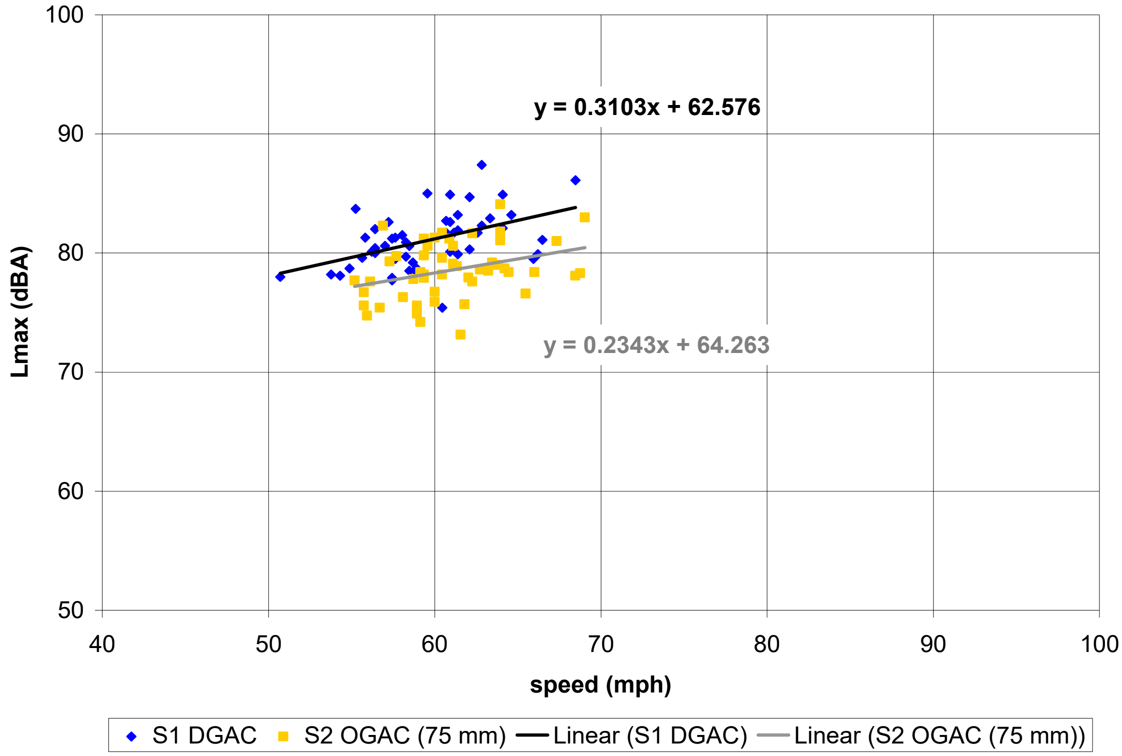
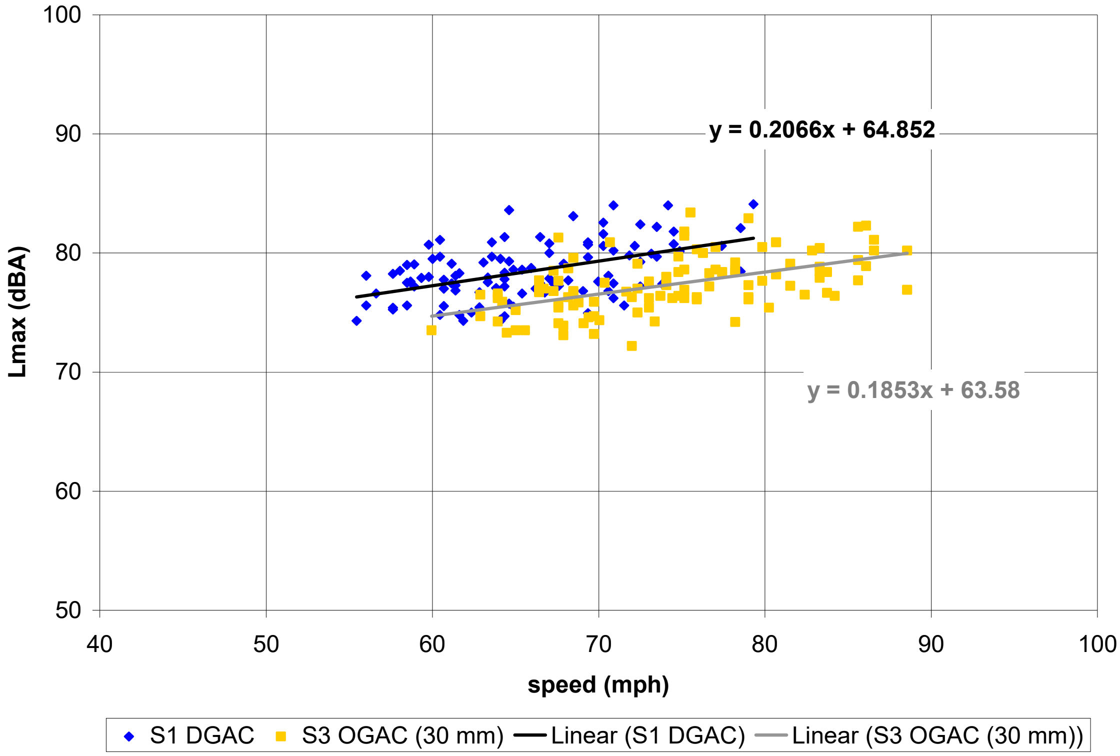
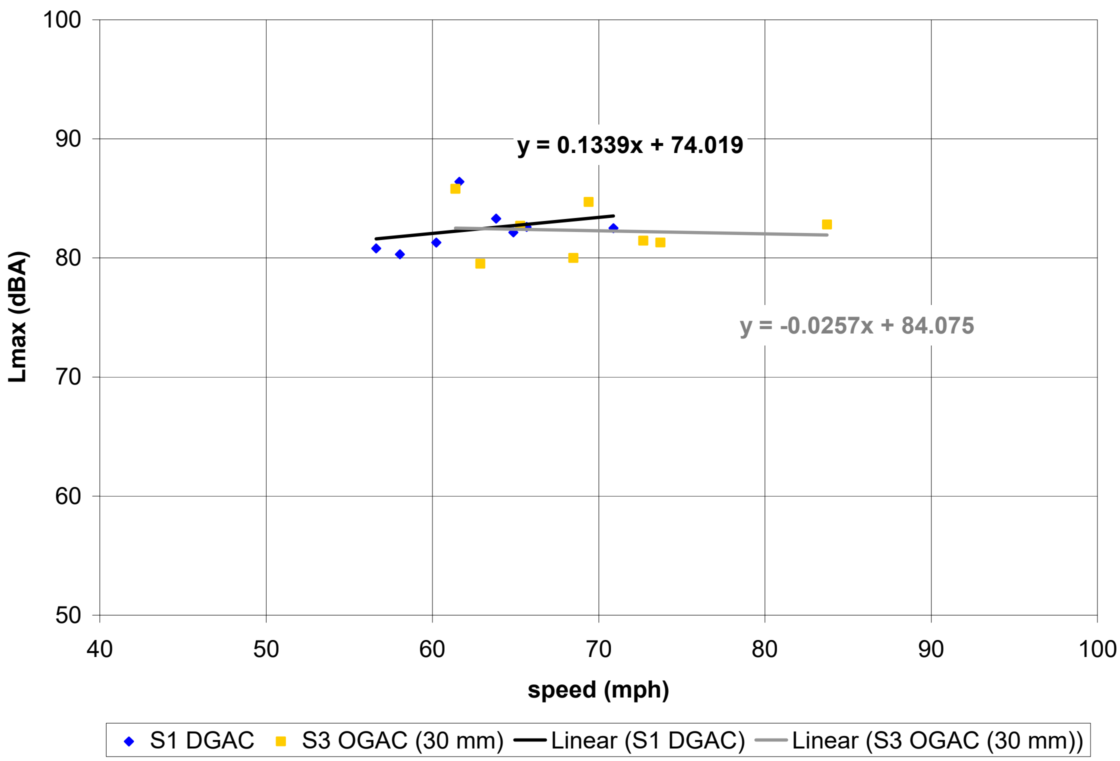


Figure C-15. Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



y = 0.2066x + 64.852
y = 0.1853x + 63.58
Lmax (dBA)
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



y = 0.1339x + 74.019
y = -0.0257x + 84.075
Lmax (dBA)
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

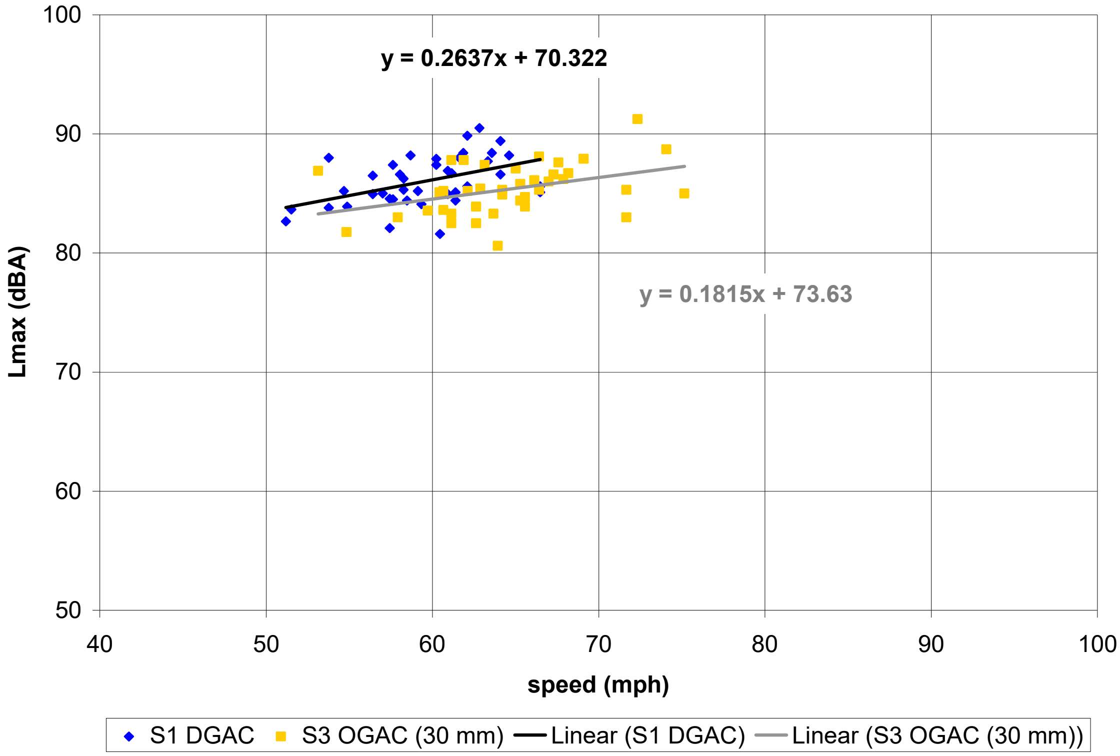
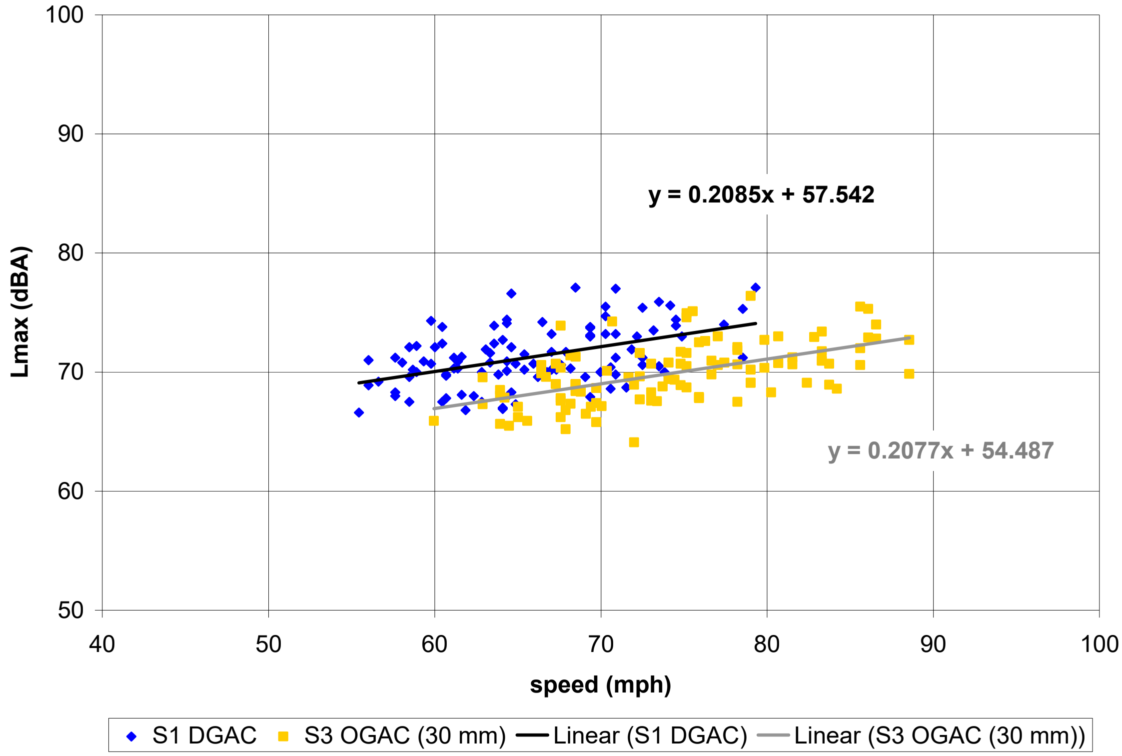
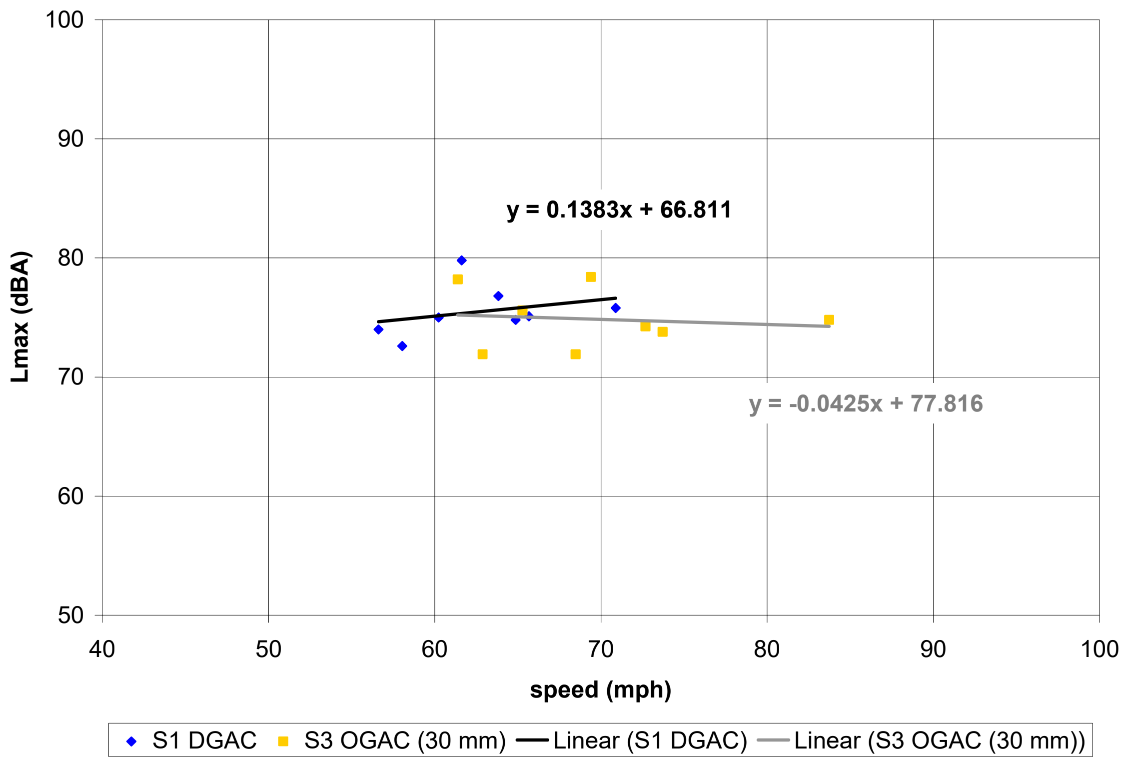


Figure C-16. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2085x + 57.542
y = 0.2077x + 54.487
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1383x + 66.811
y = -0.0425x + 77.816
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

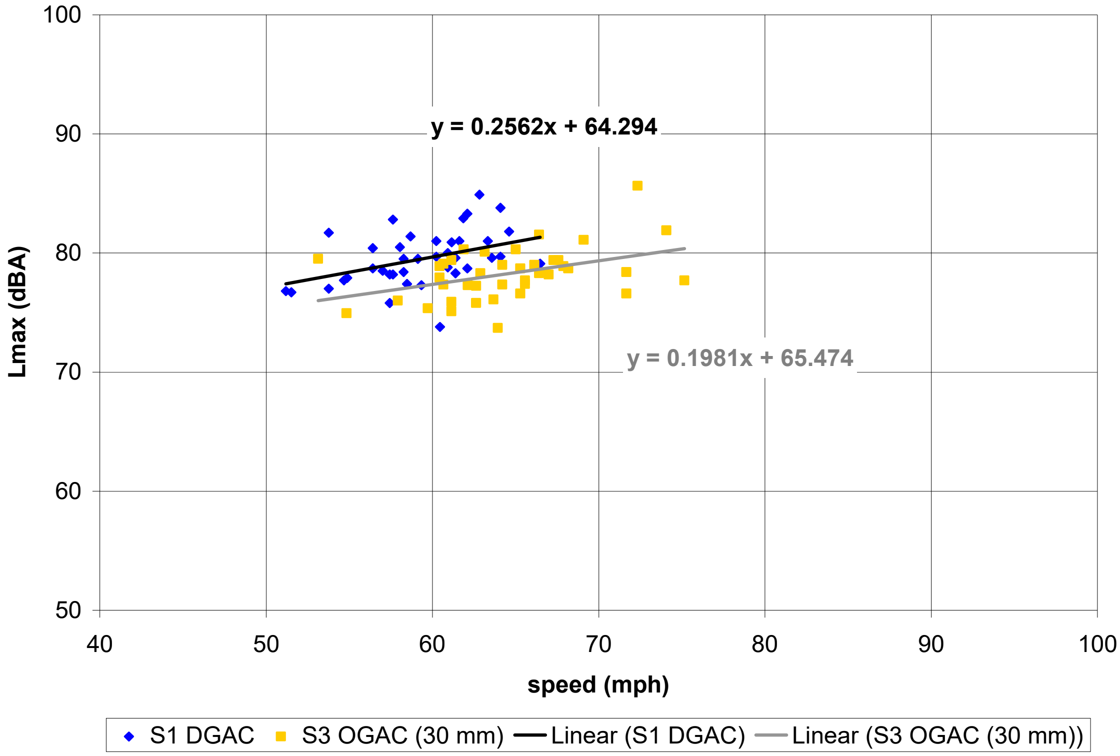
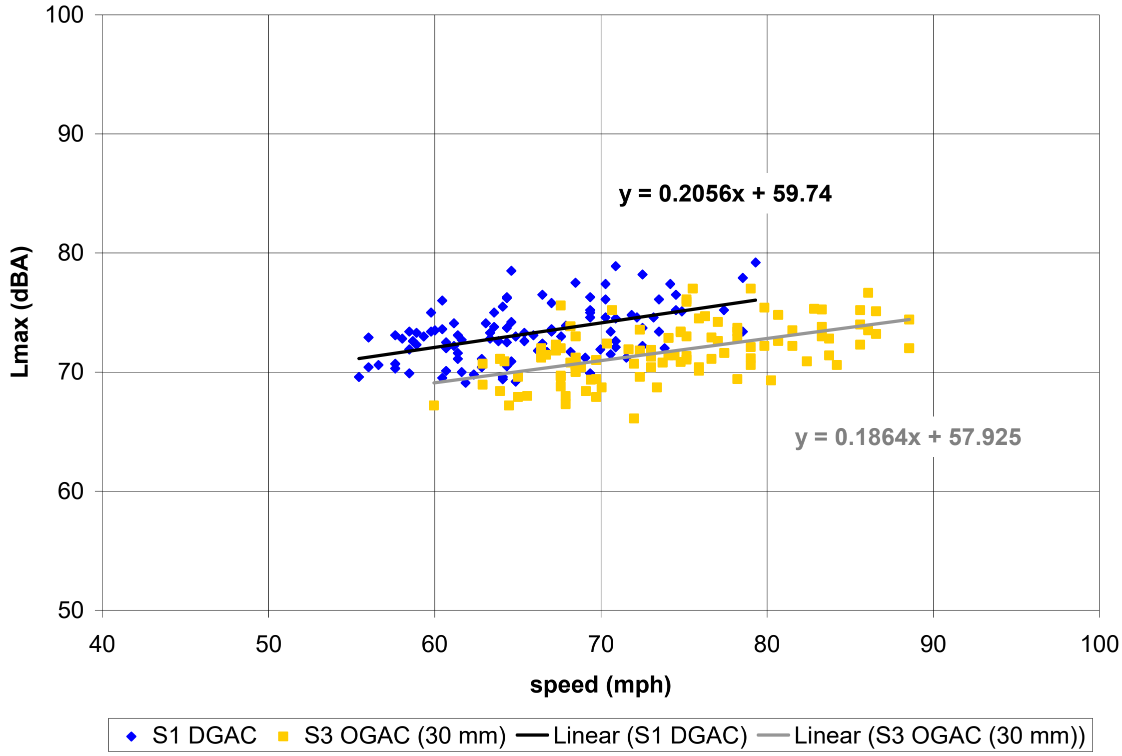
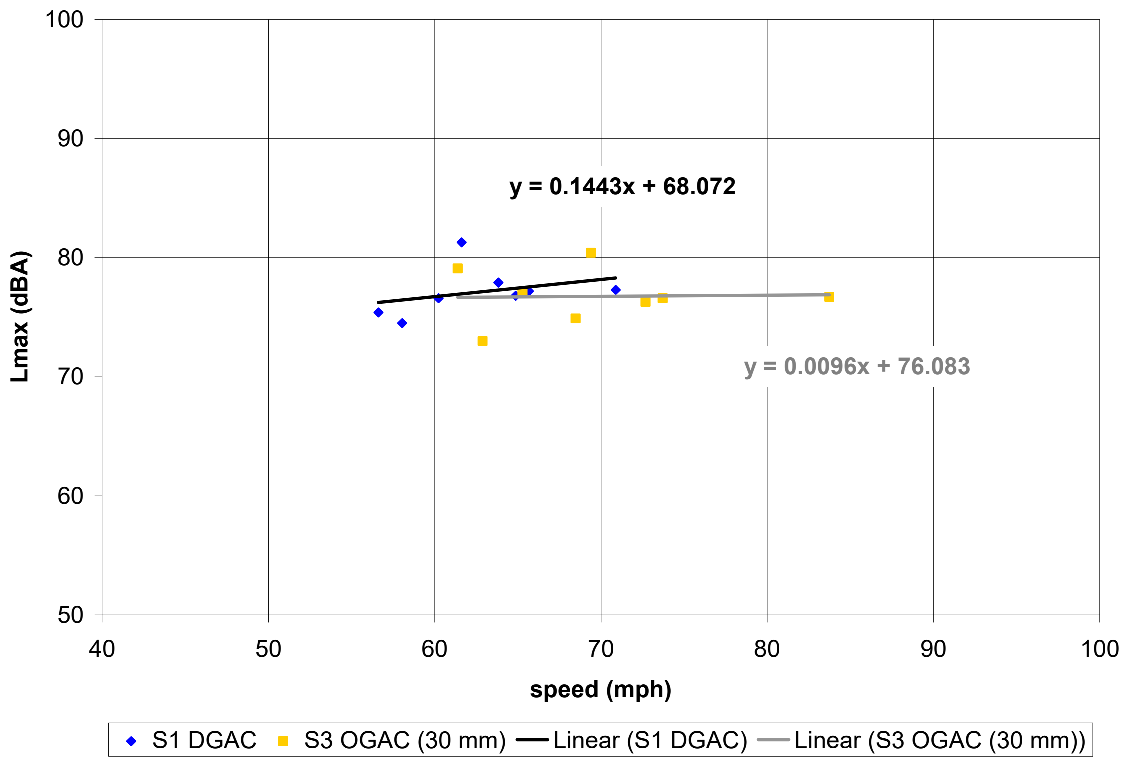


Figure C-17. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2056x + 59.74
y = 0.1864x + 57.925
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1443x + 68.072
y = 0.0096x + 76.083
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

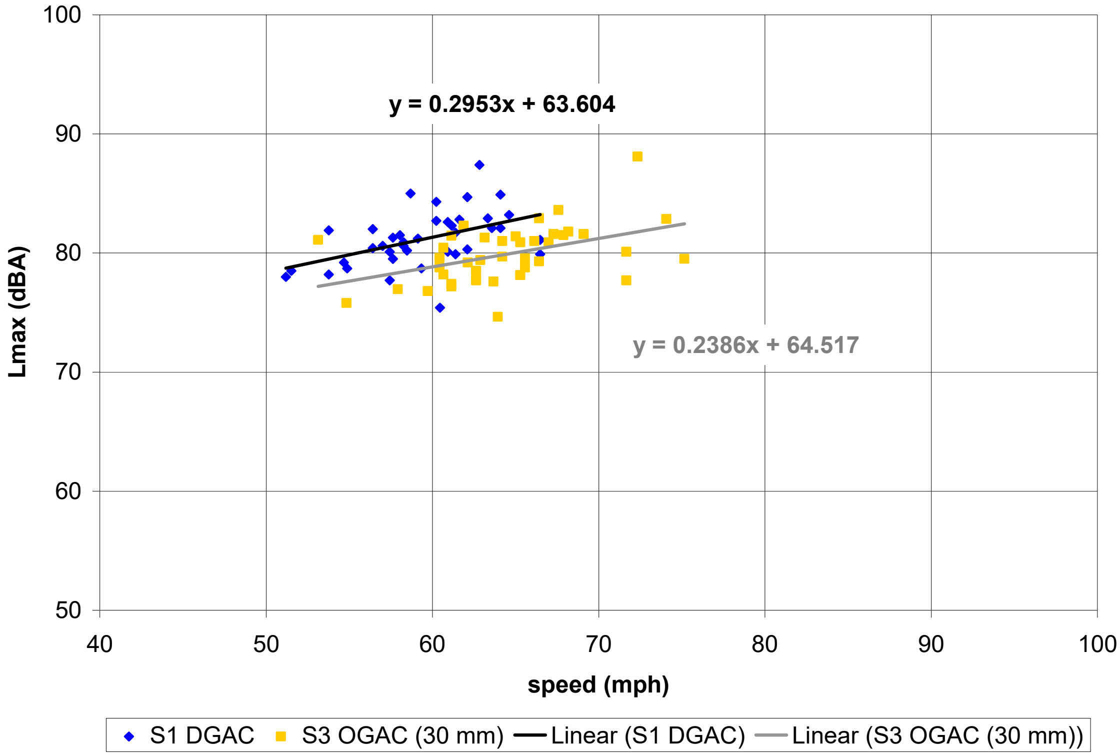
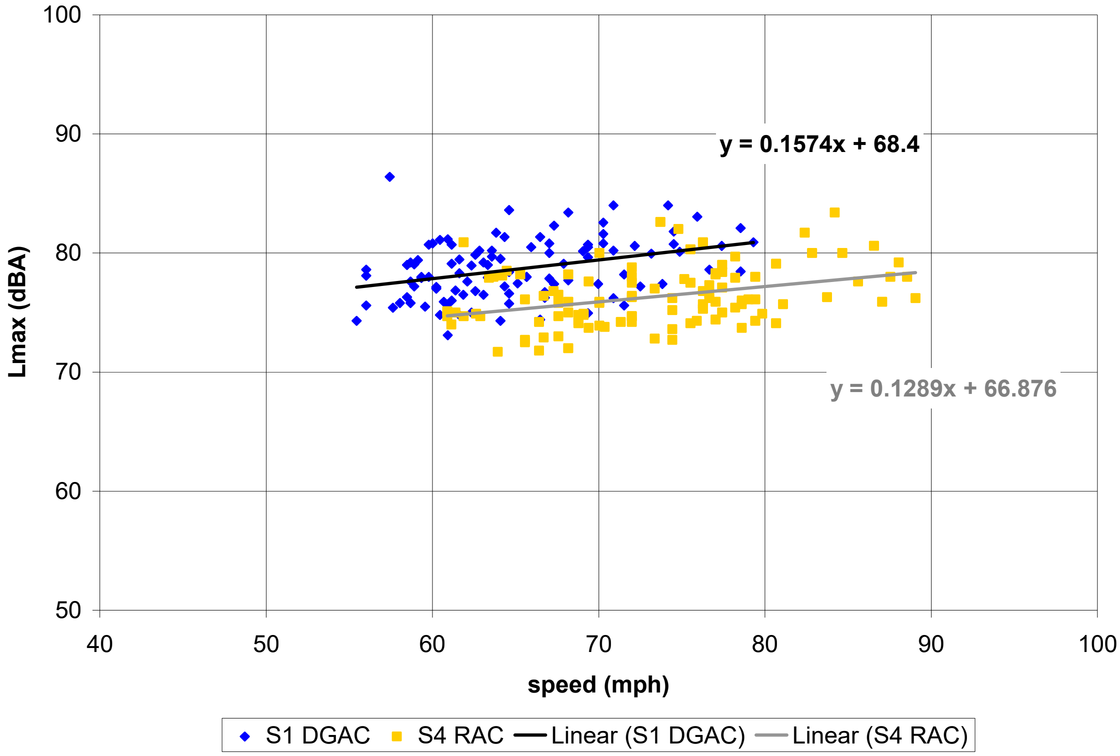
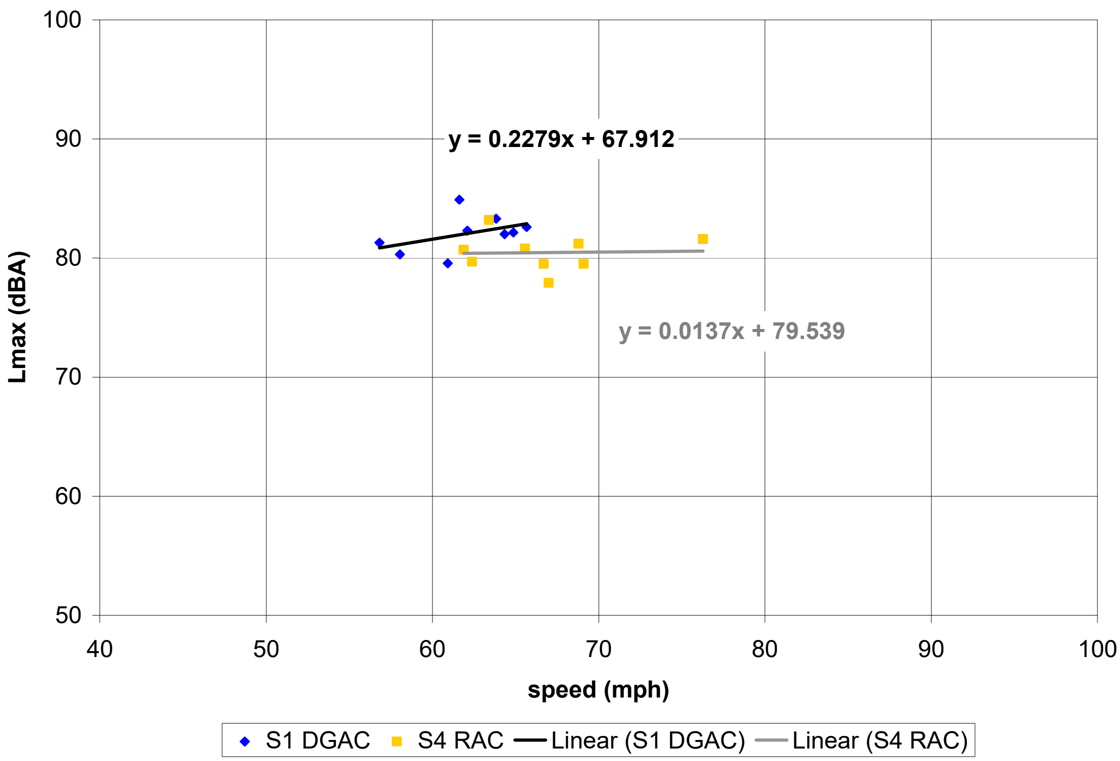


Figure C-18. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1574x + 68.4
y = 0.1289x + 66.876
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2279x + 67.912
y = 0.0137x + 79.539
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

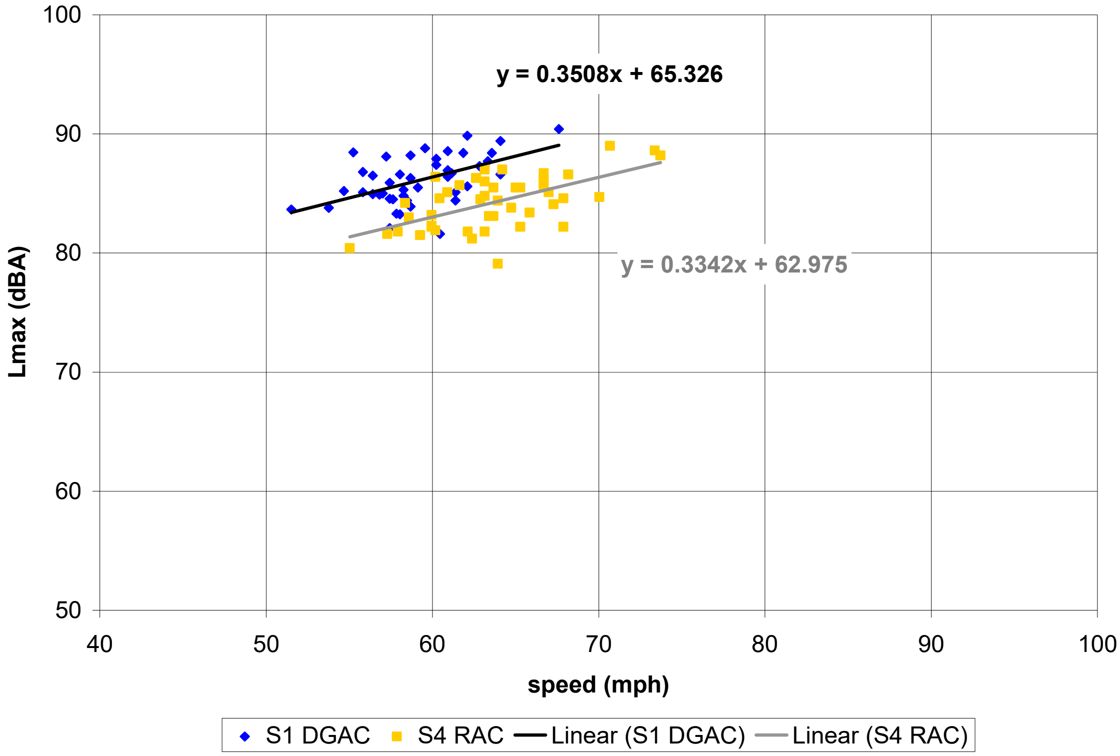
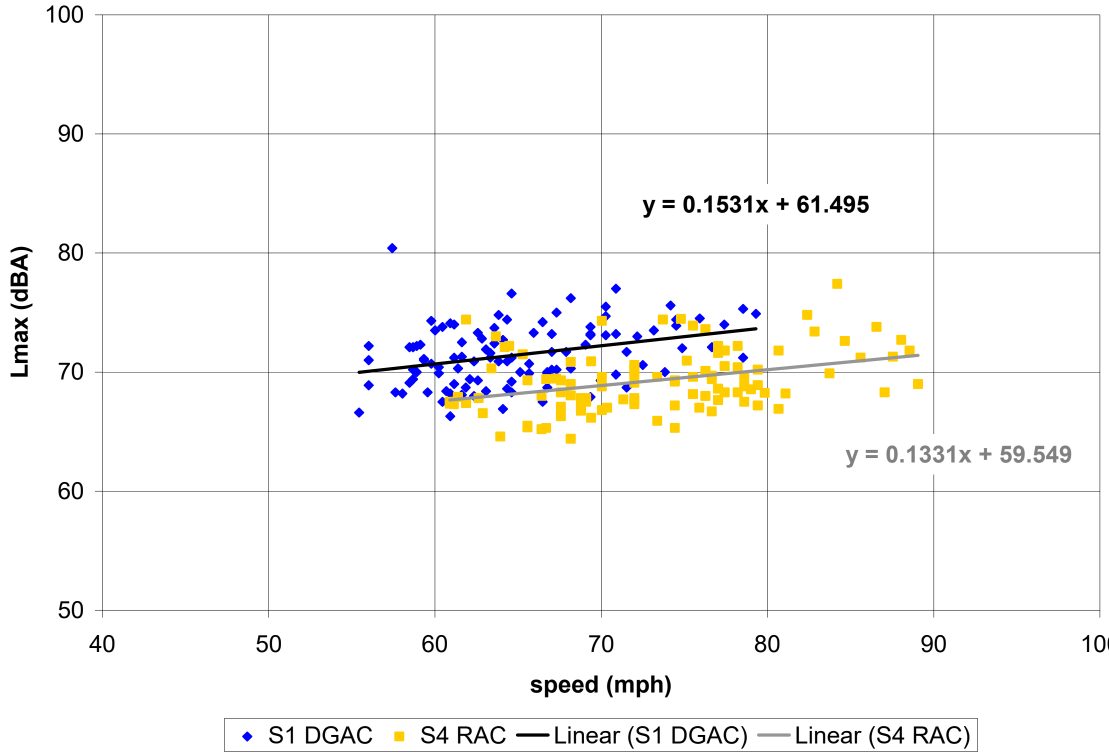
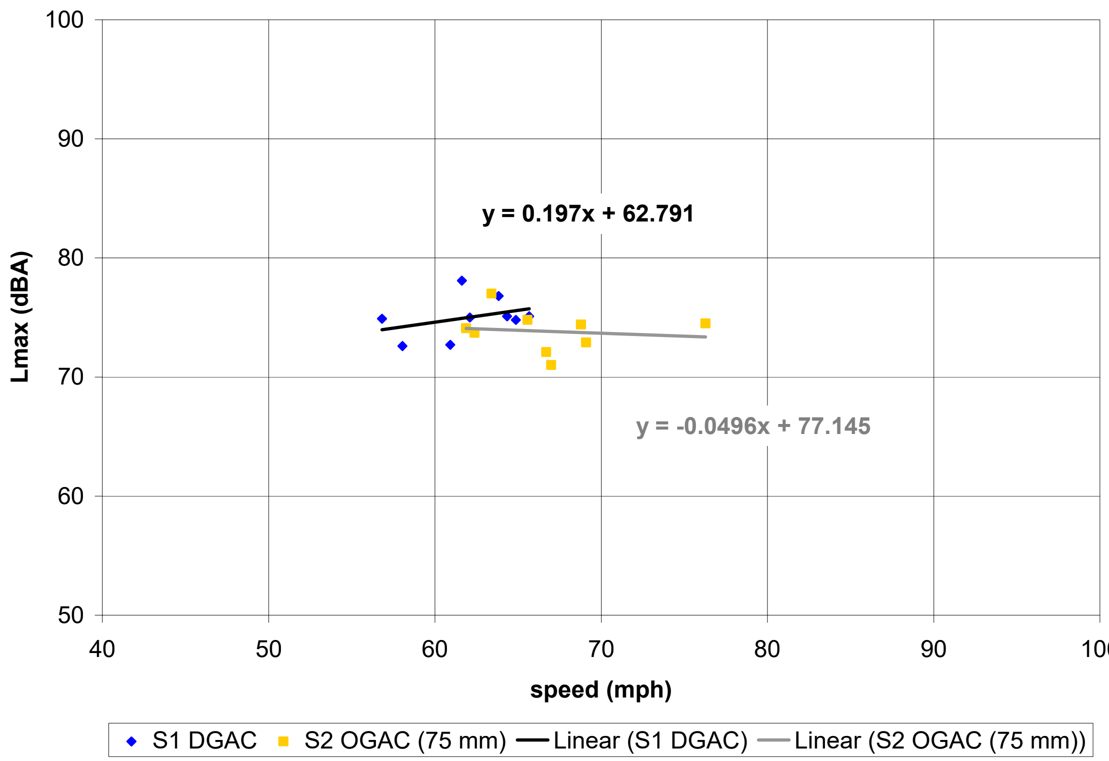


Figure C-19. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1531x + 61.495
y = 0.1331x + 59.549
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.197x + 62.791
y = -0.0496x + 77.145
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

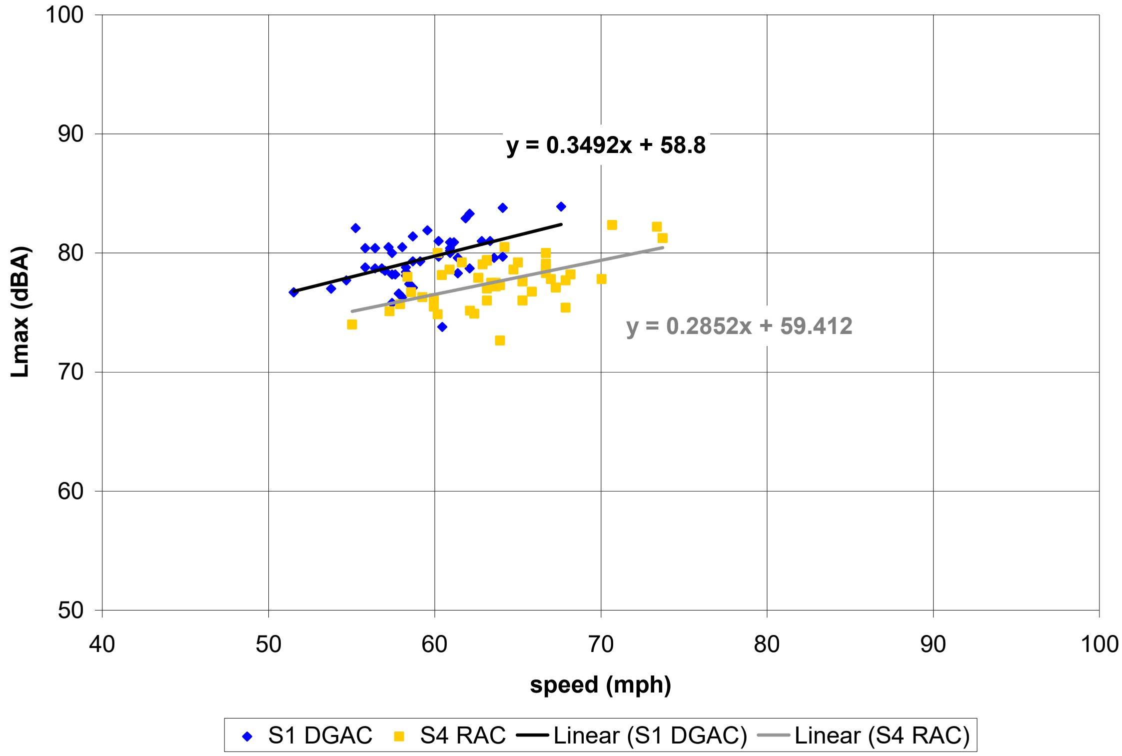
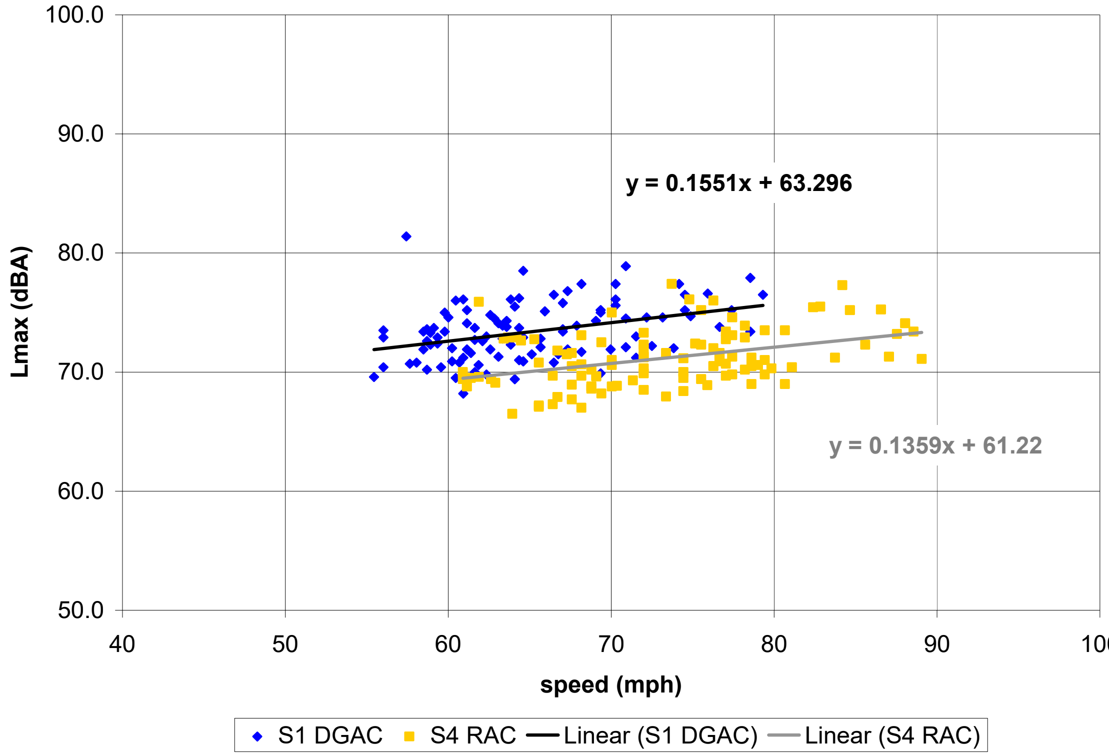
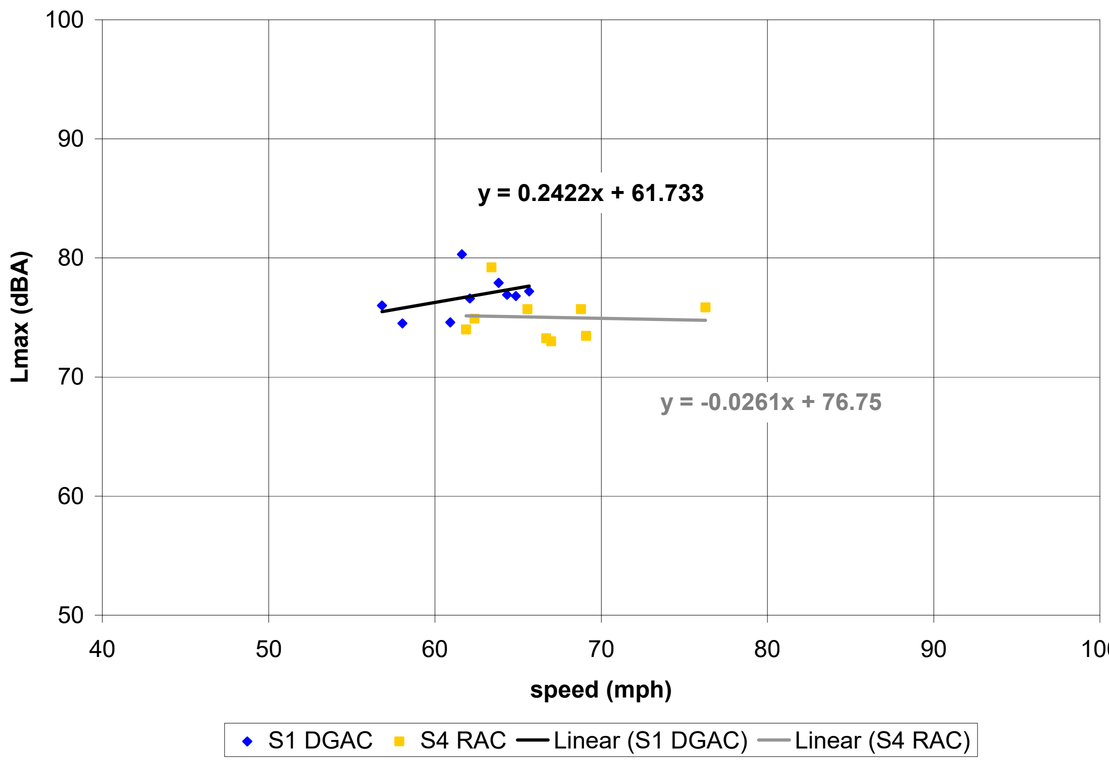


Figure C-20. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100.0
90.0
80.0
70.0
60.0
50.0
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1551x + 63.296
y = 0.1359x + 61.22
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2422x + 61.733
y = -0.0261x + 76.75
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

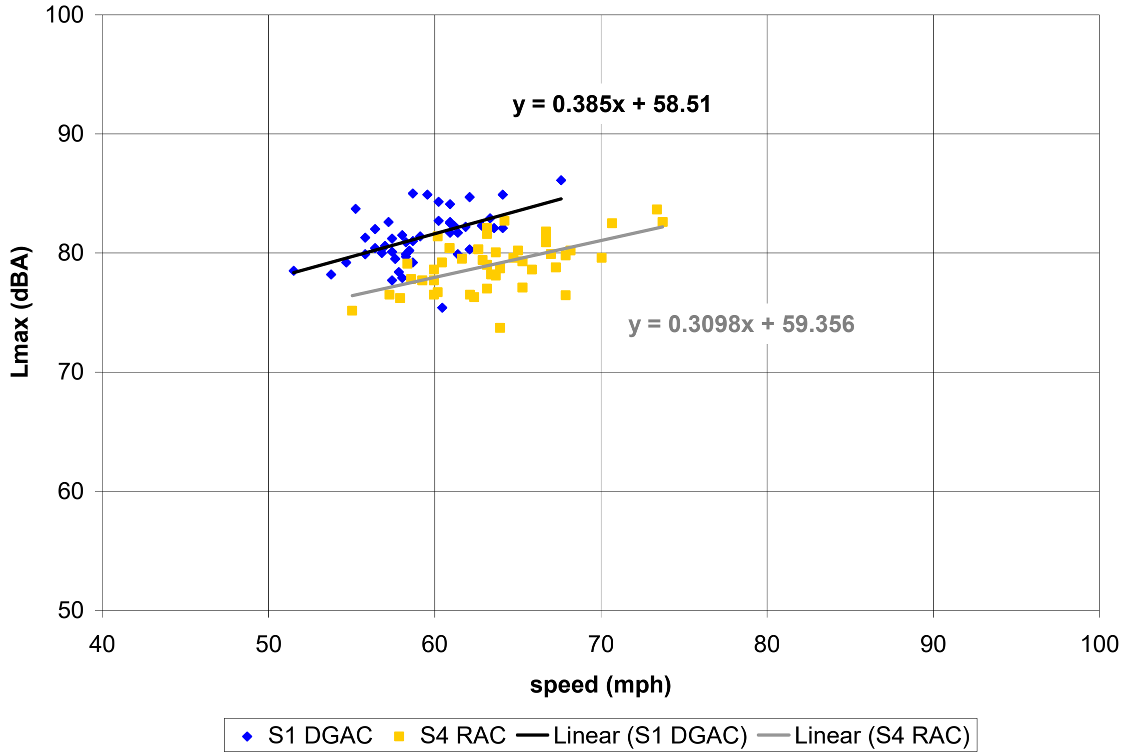
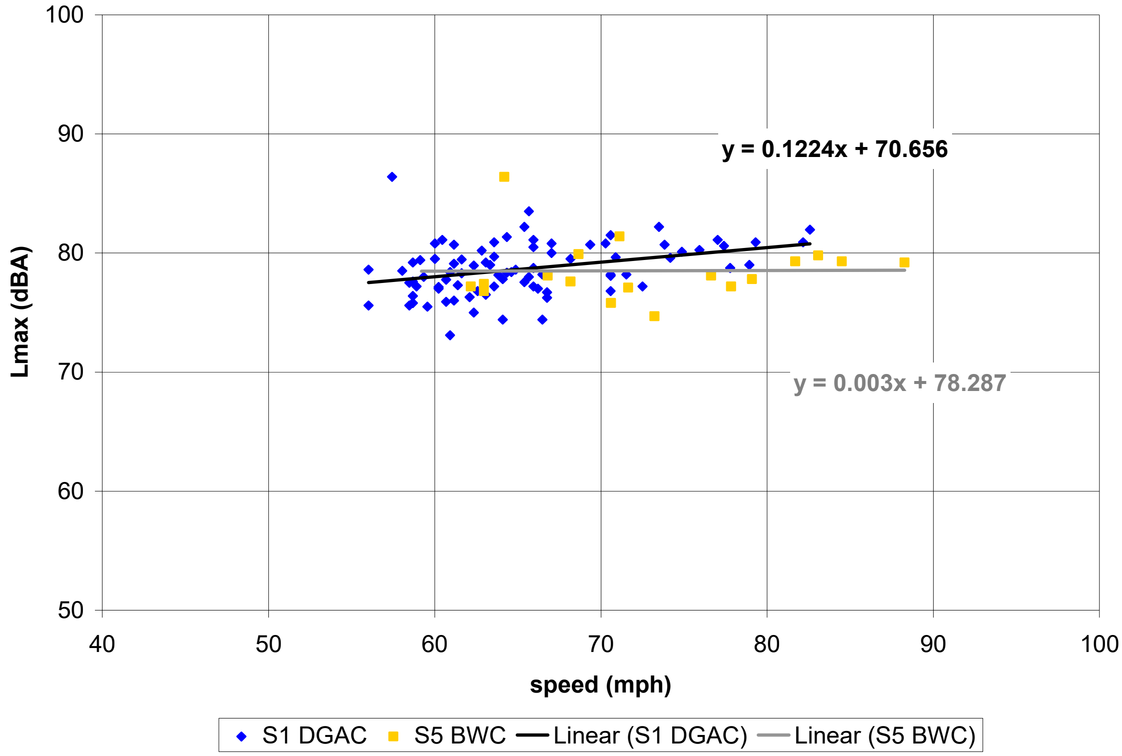
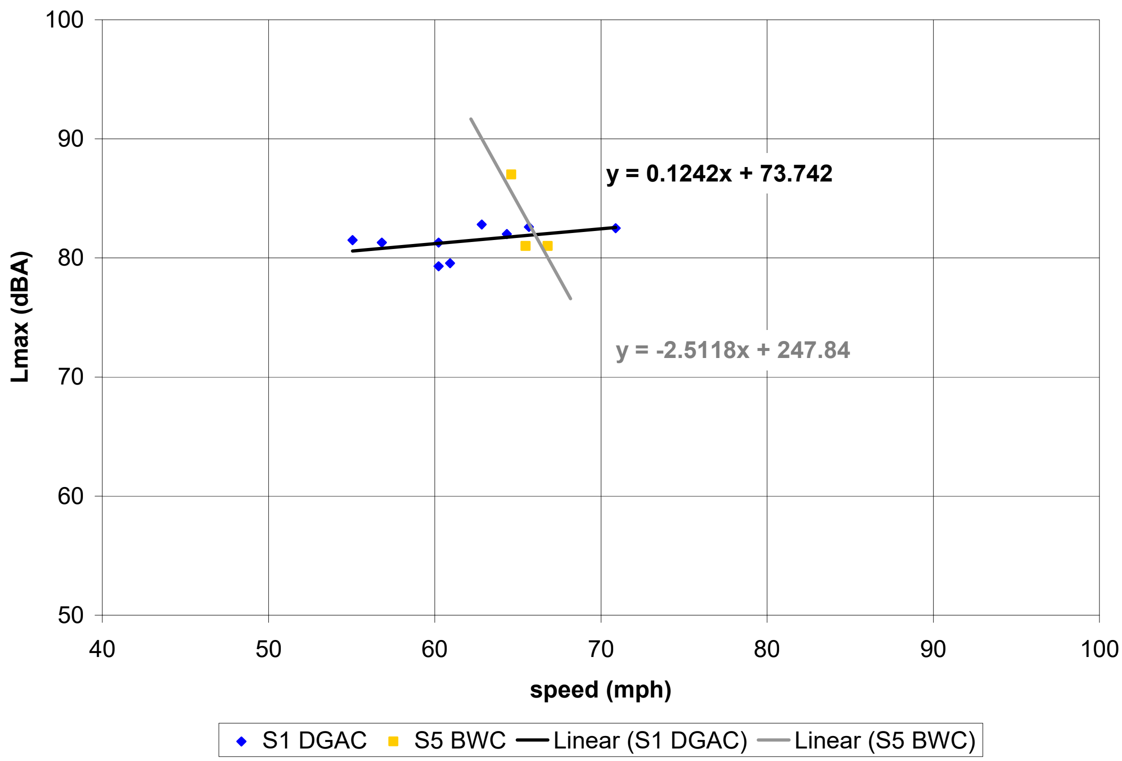


Figure C-21. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1224x + 70.656
y = 0.003x + 78.287
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1242x + 73.742
y = -2.5118x + 247.84
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

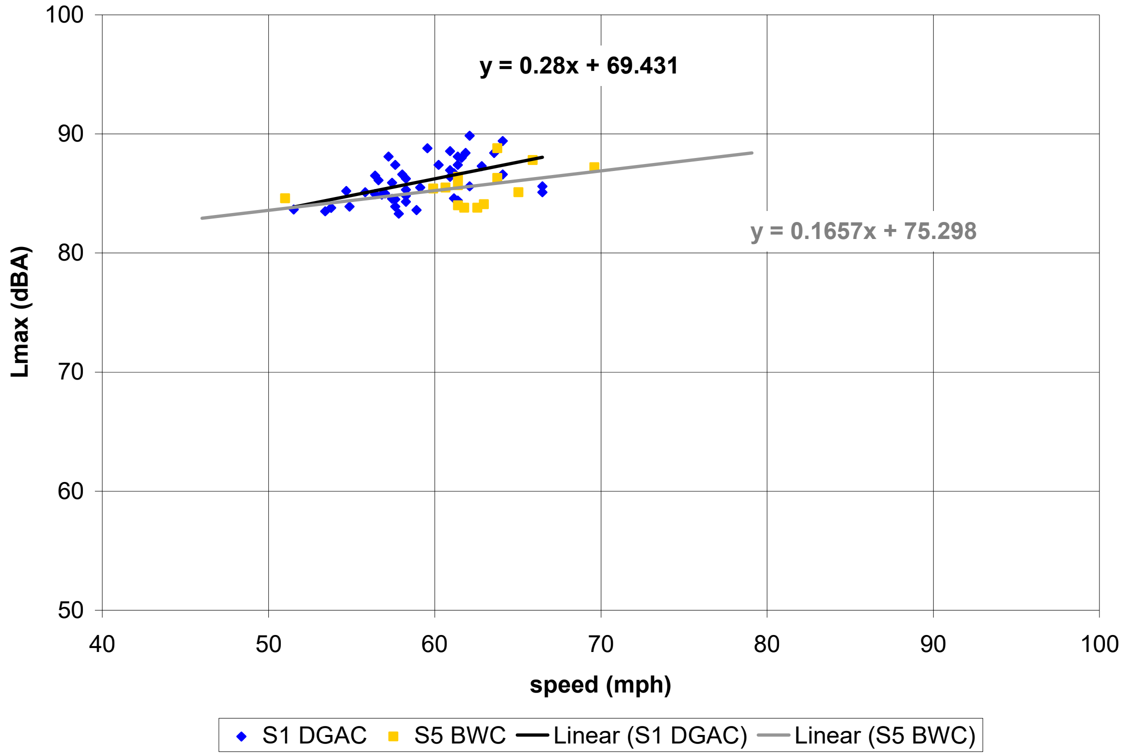
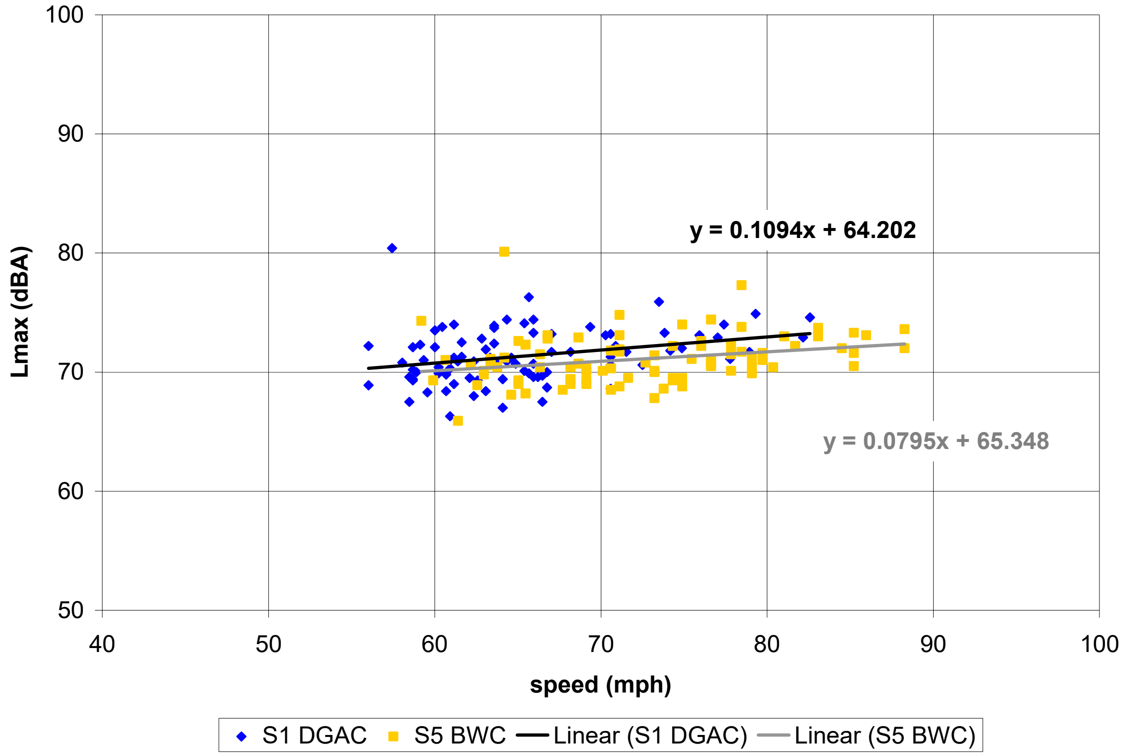
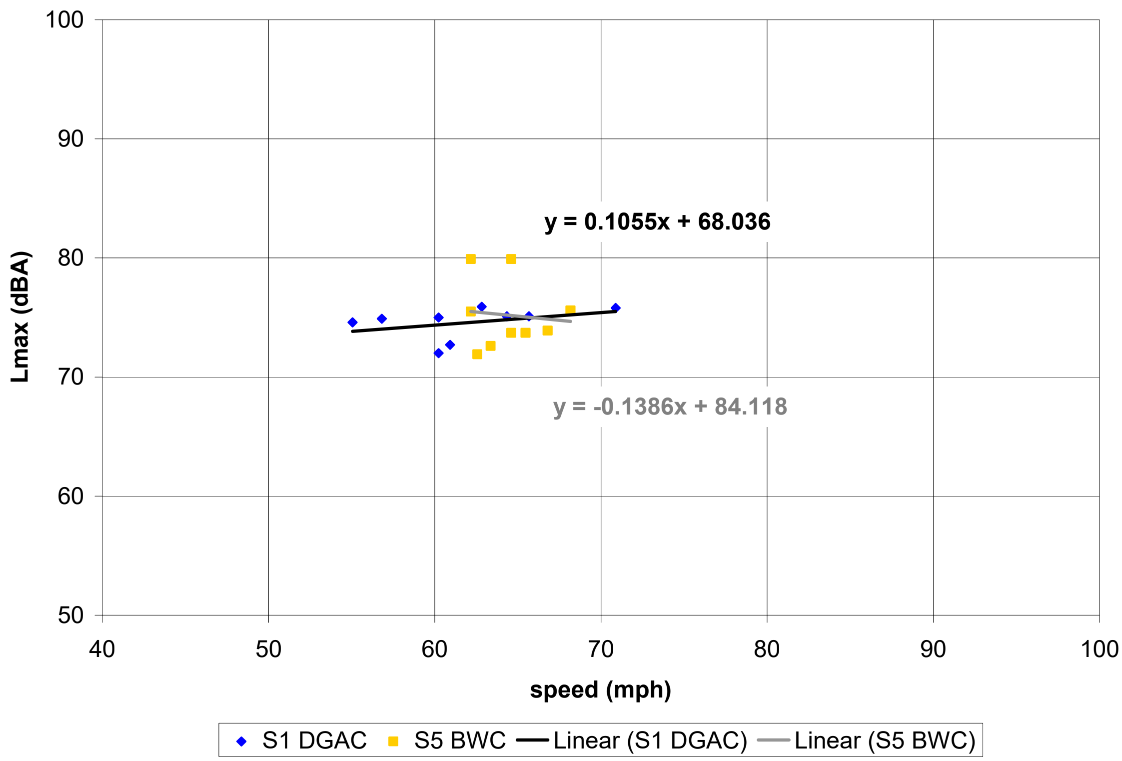


Figure C-22. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



y = 0.1094x + 64.202
y = 0.0795x + 65.348
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



y = 0.1055x + 68.036
y = -0.1386x + 84.118
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

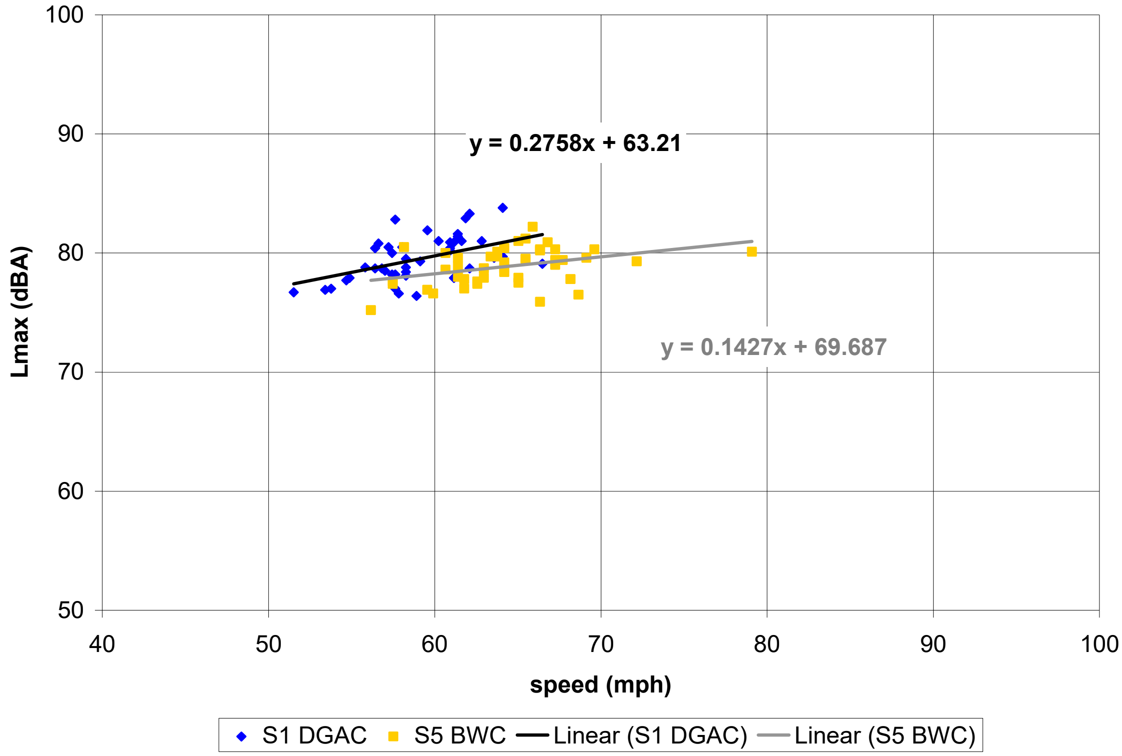
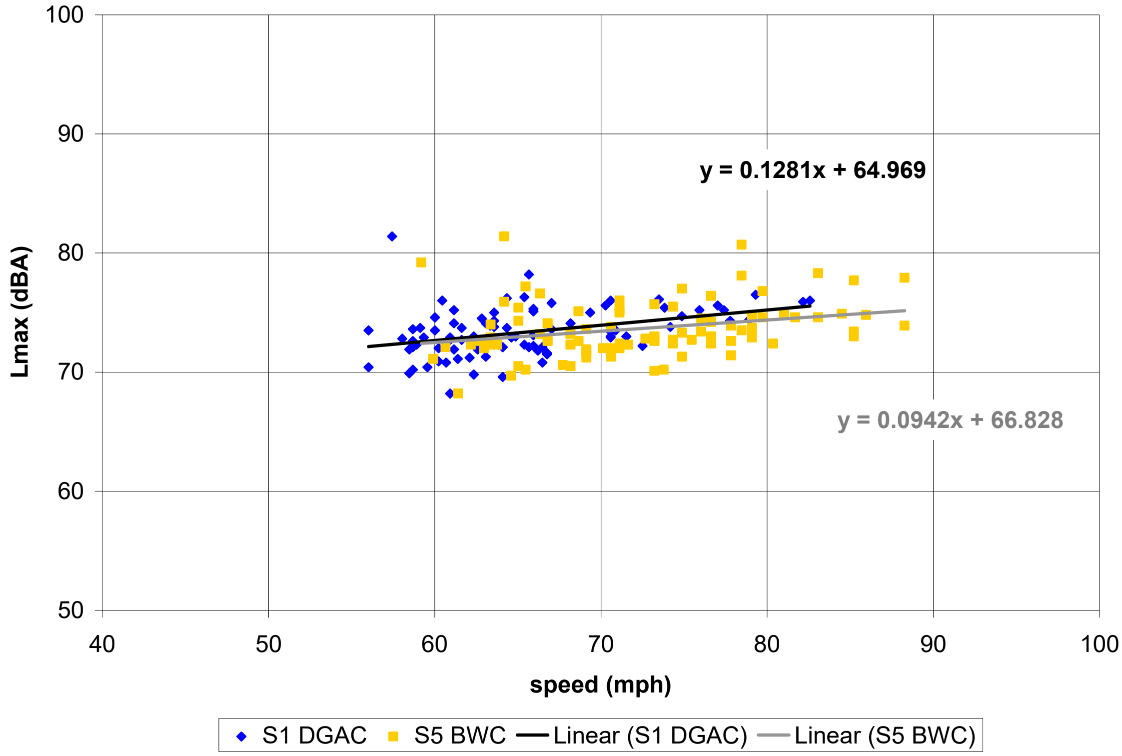
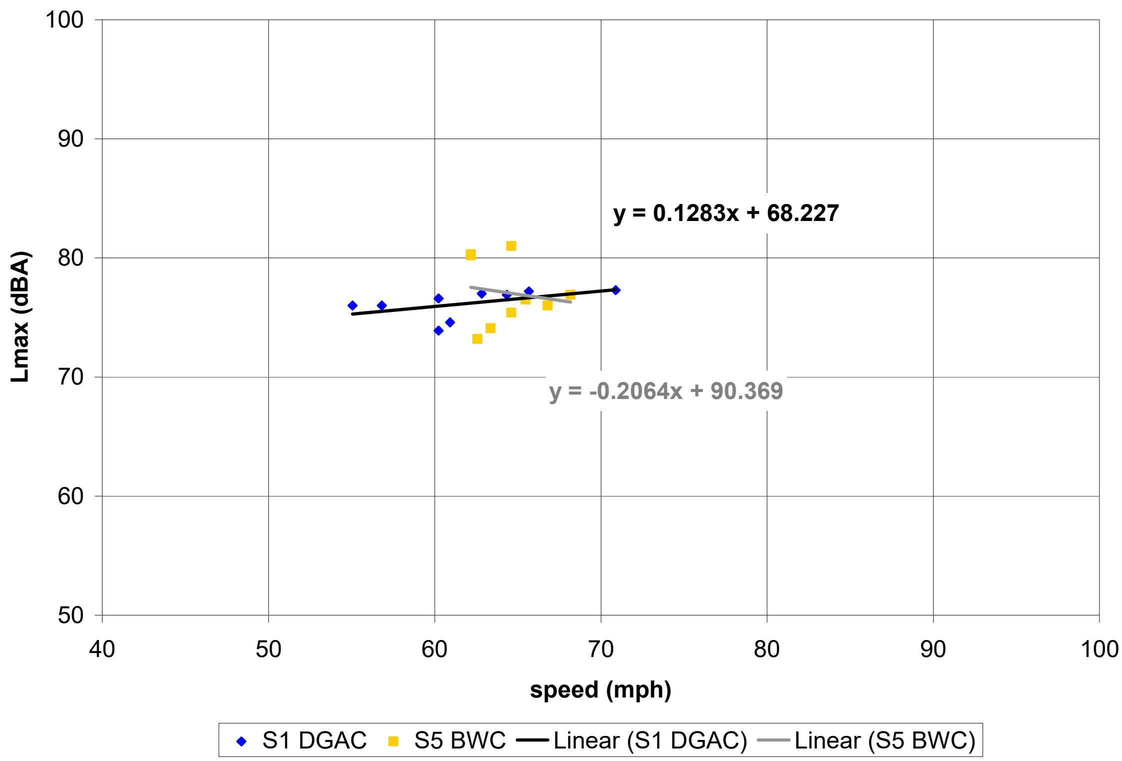


Figure C-23. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1281x + 64.969
y = 0.0942x + 66.828
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1283x + 68.227
y = -0.2064x + 90.369
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

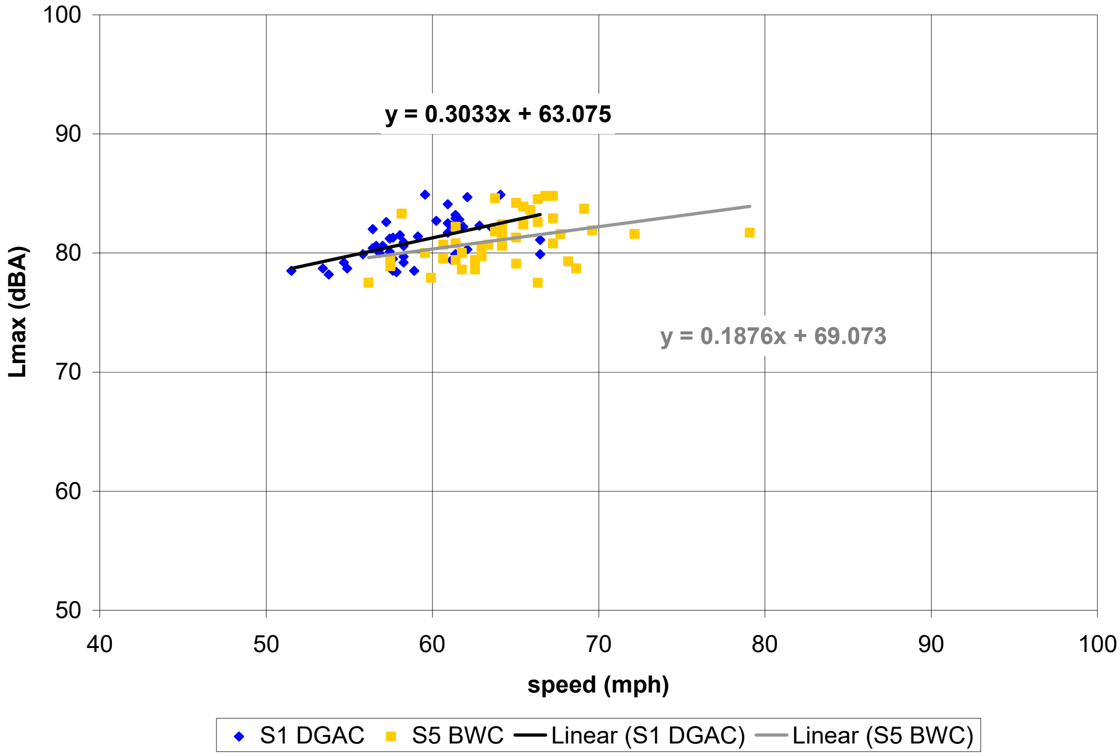
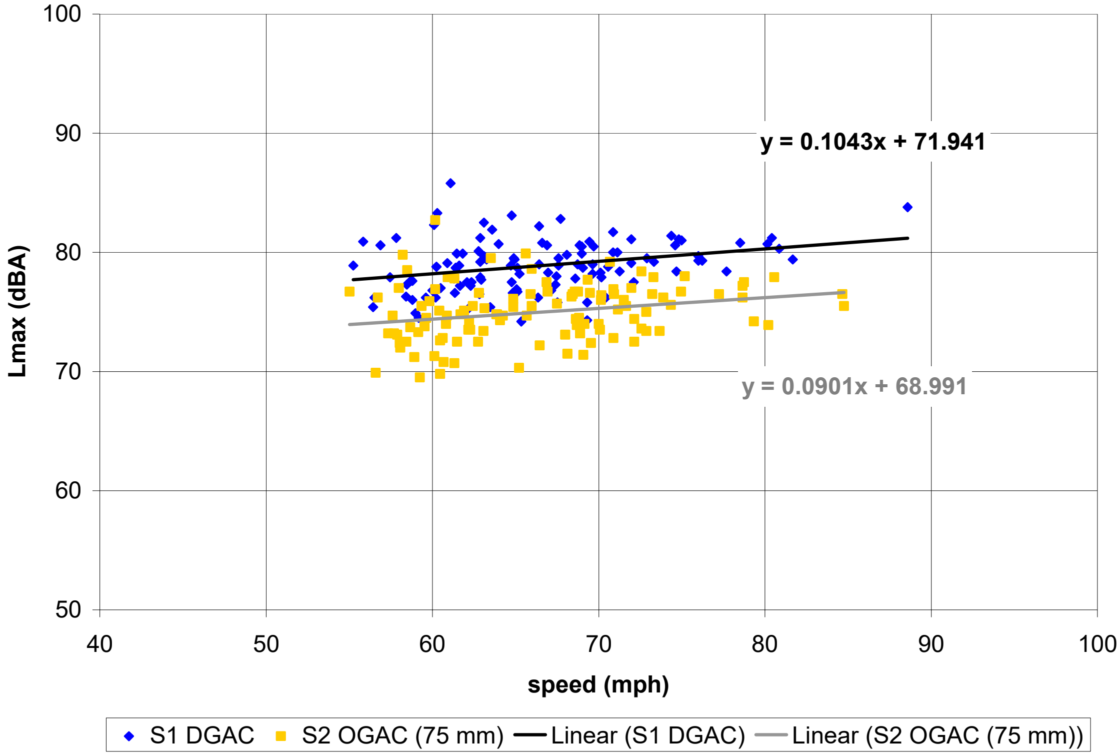
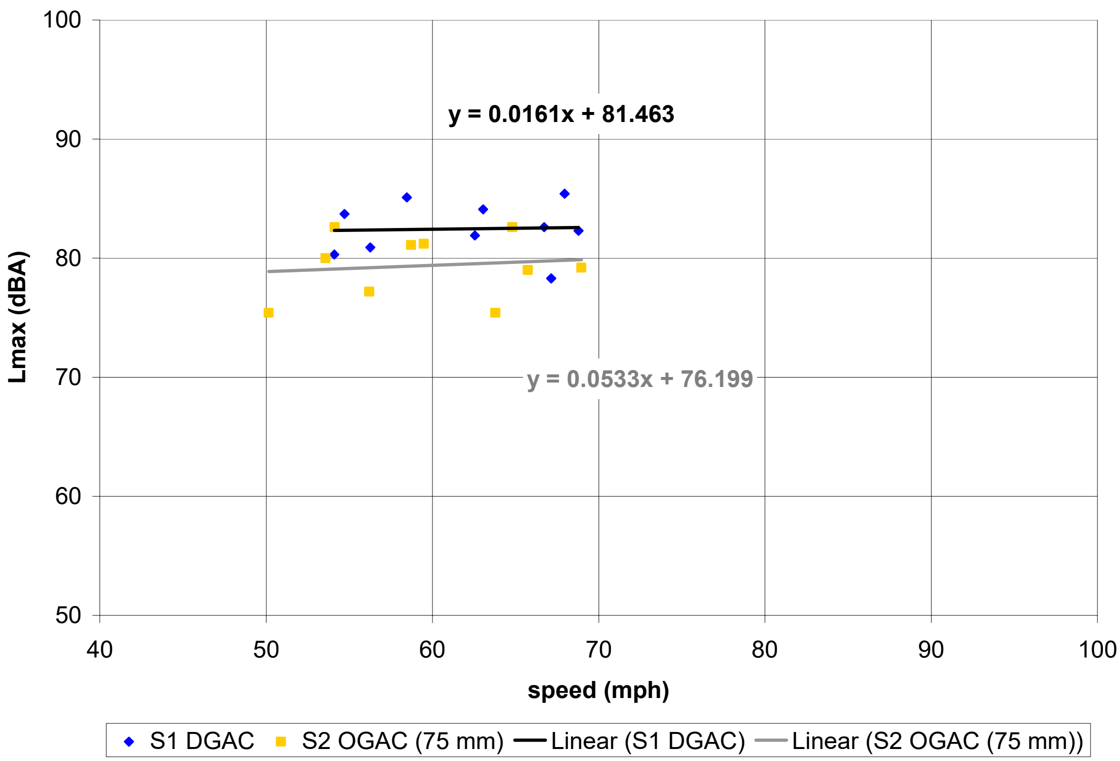


Figure C-24. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.4 Post-Overlay – Pavement Age: 10 months





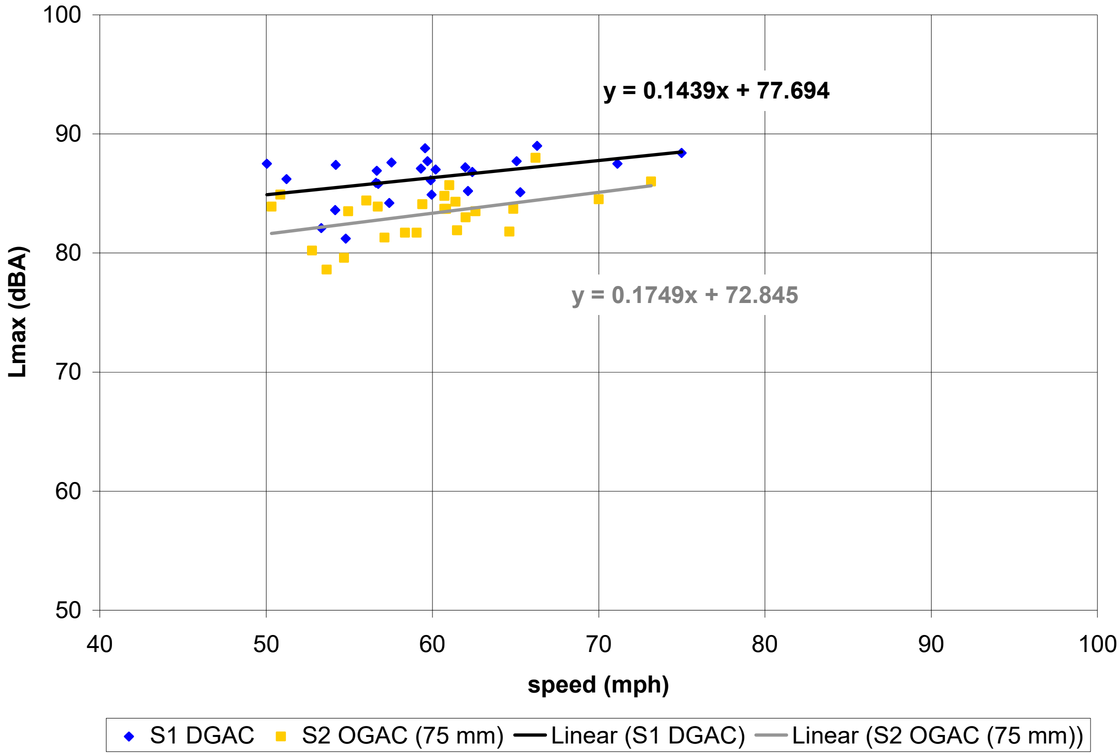
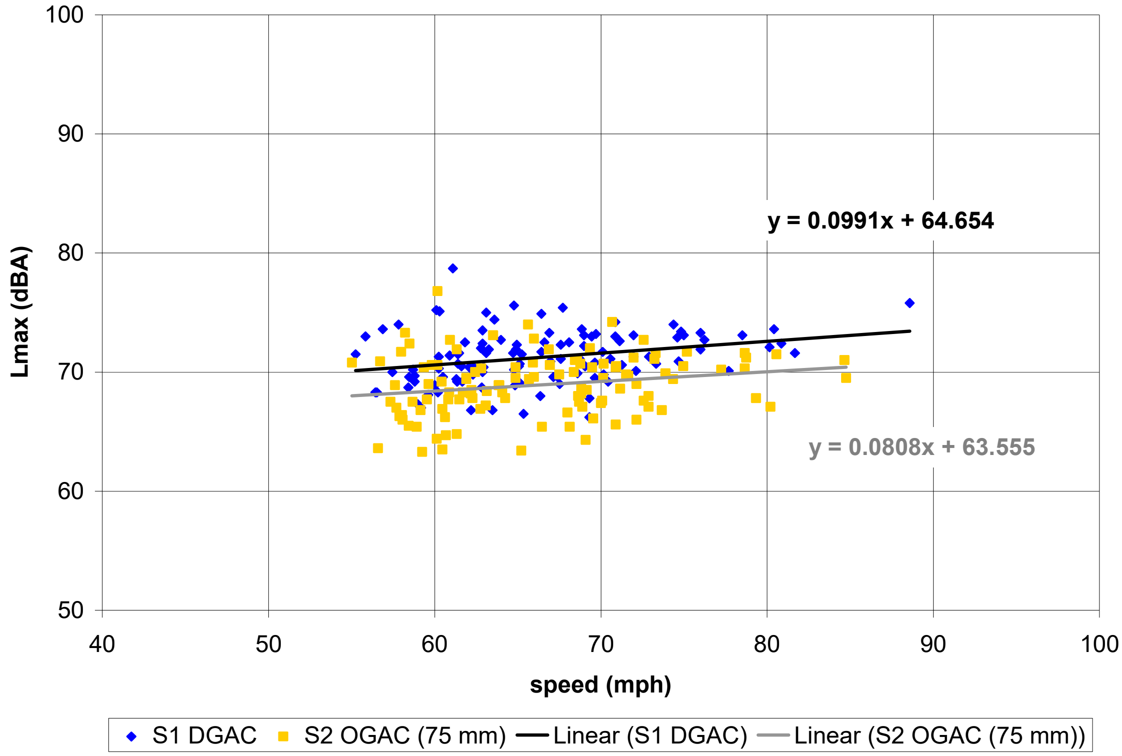
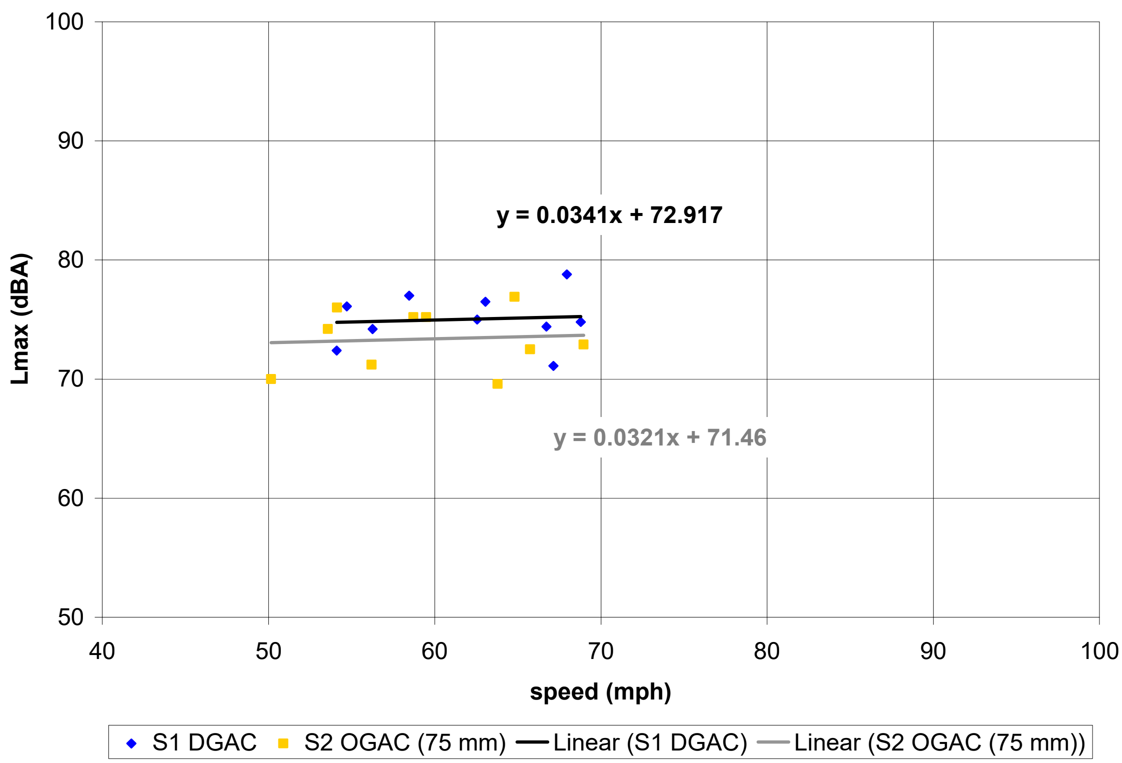


Figure C-25. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


y = 0.0991x + 64.654
y = 0.0808x + 63.555
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))


y = 0.0341x + 72.917
y = 0.0321x + 71.46
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

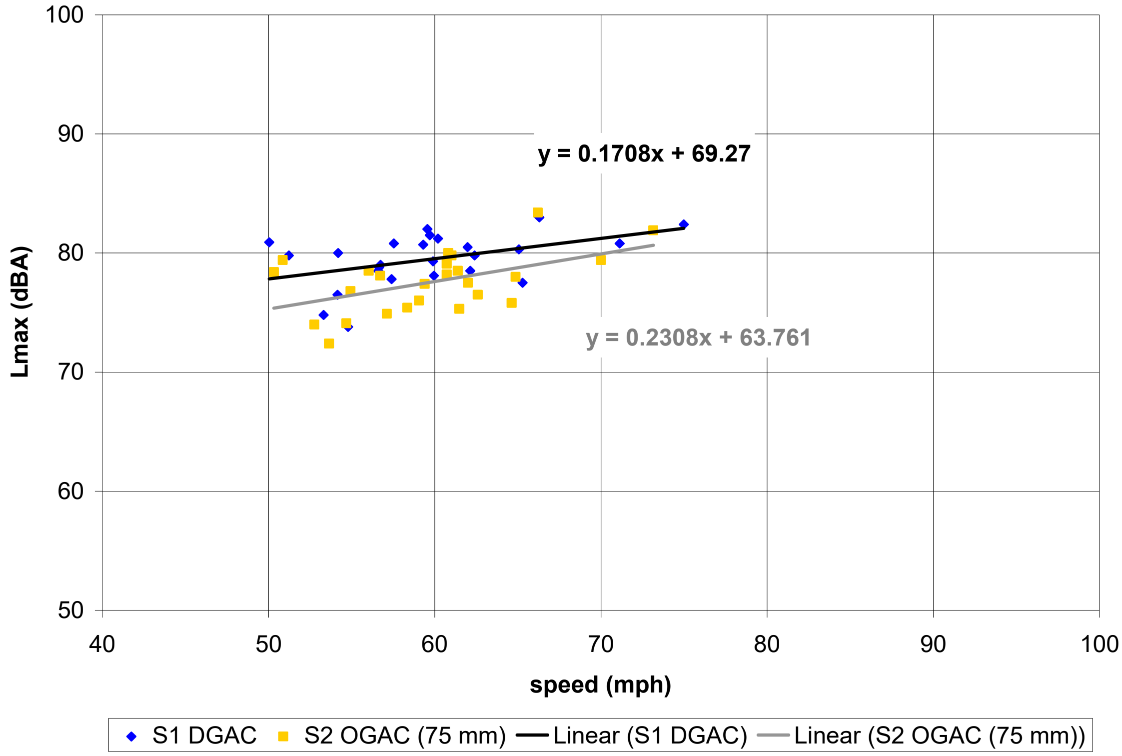
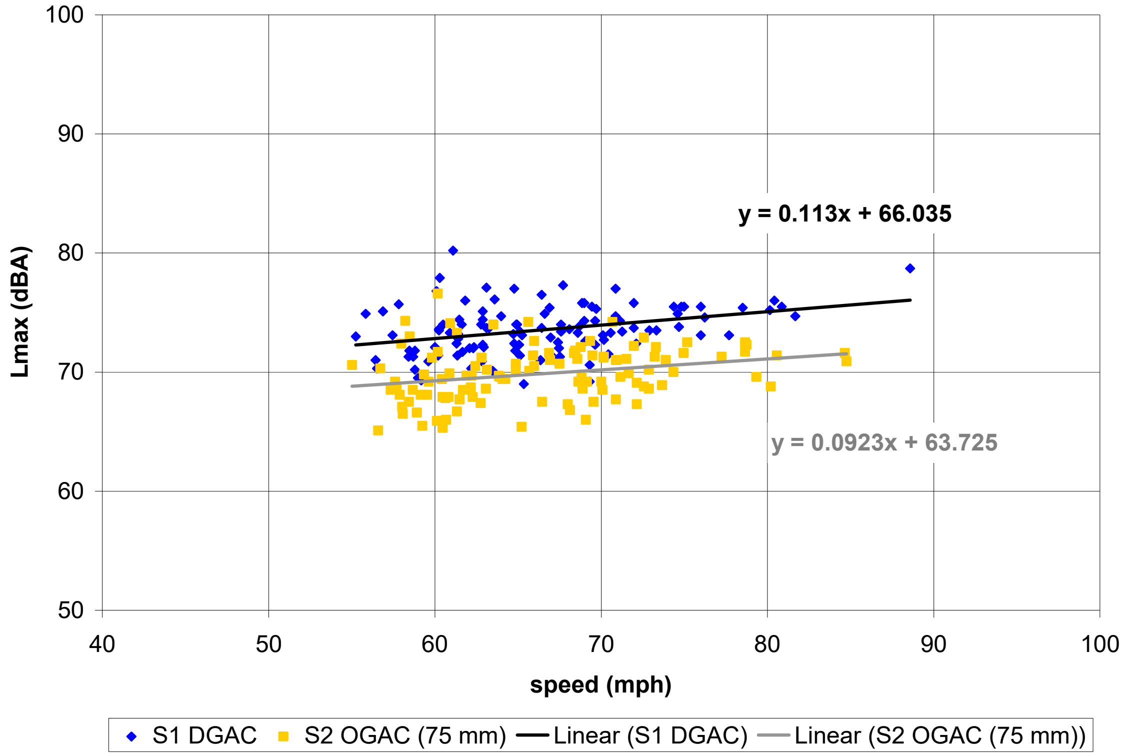
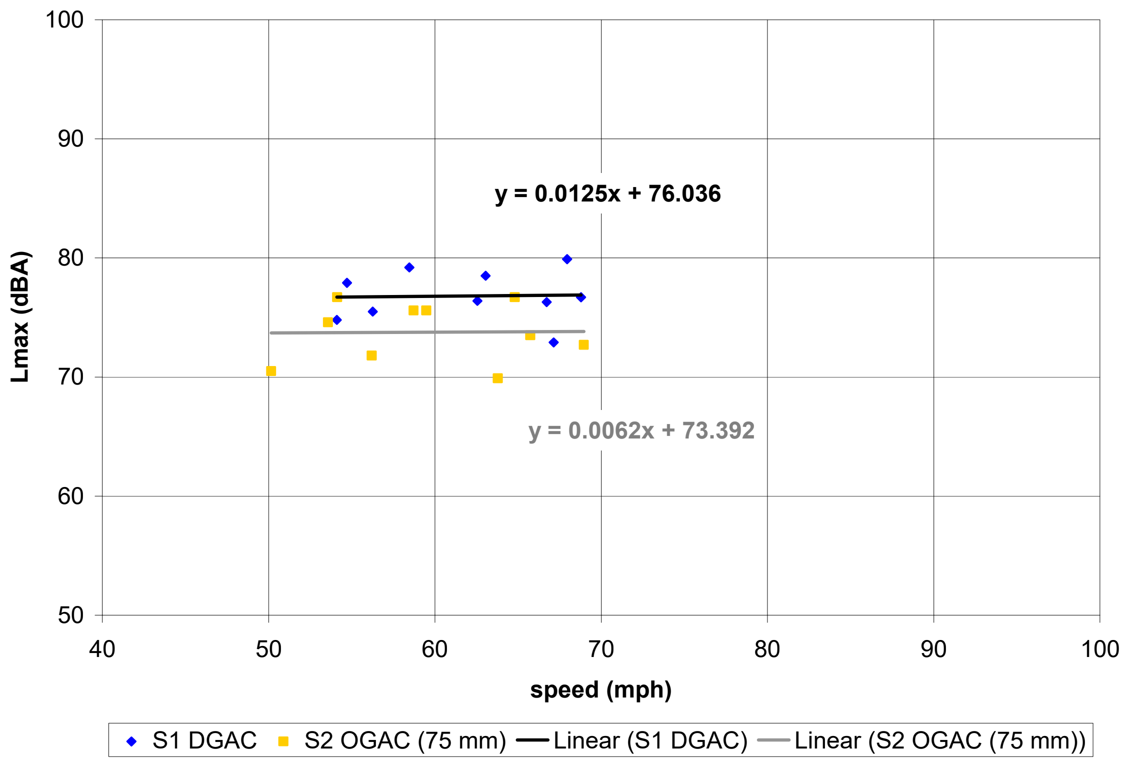


Figure C-26. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



y = 0.113x + 66.035
y = 0.0923x + 63.725
Lmax (dBA)
speed (mph)
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



y = 0.0125x + 76.036
y = 0.0062x + 73.392
Lmax (dBA)
speed (mph)
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

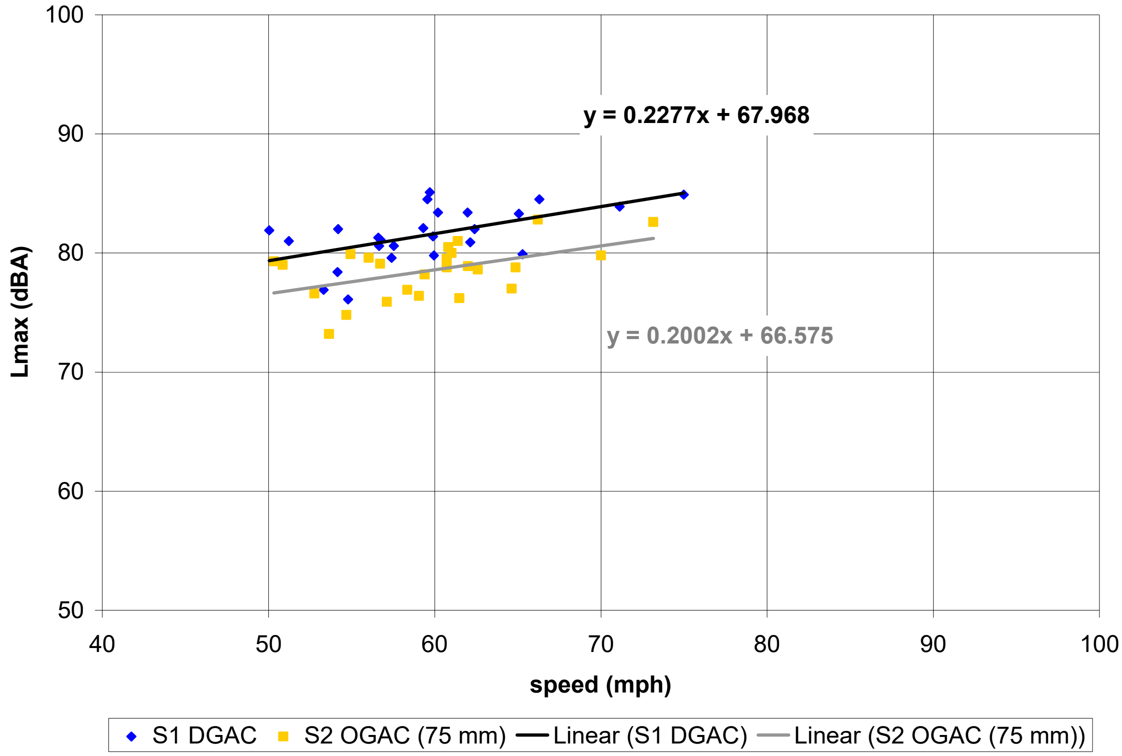
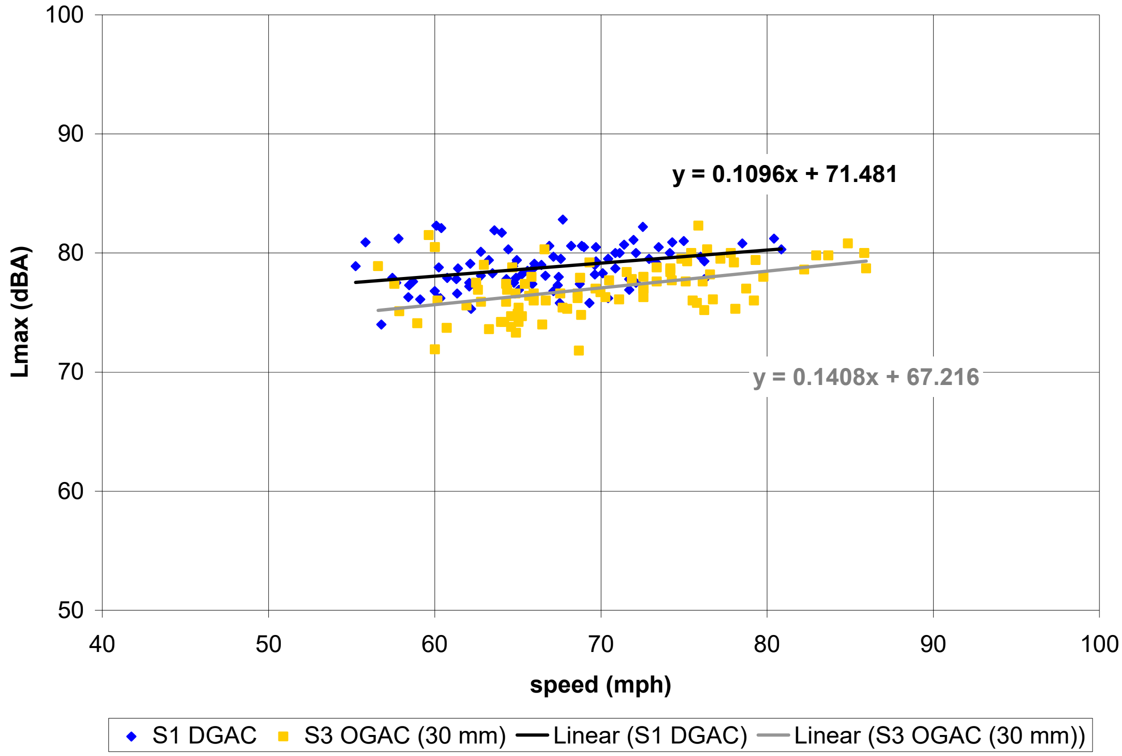
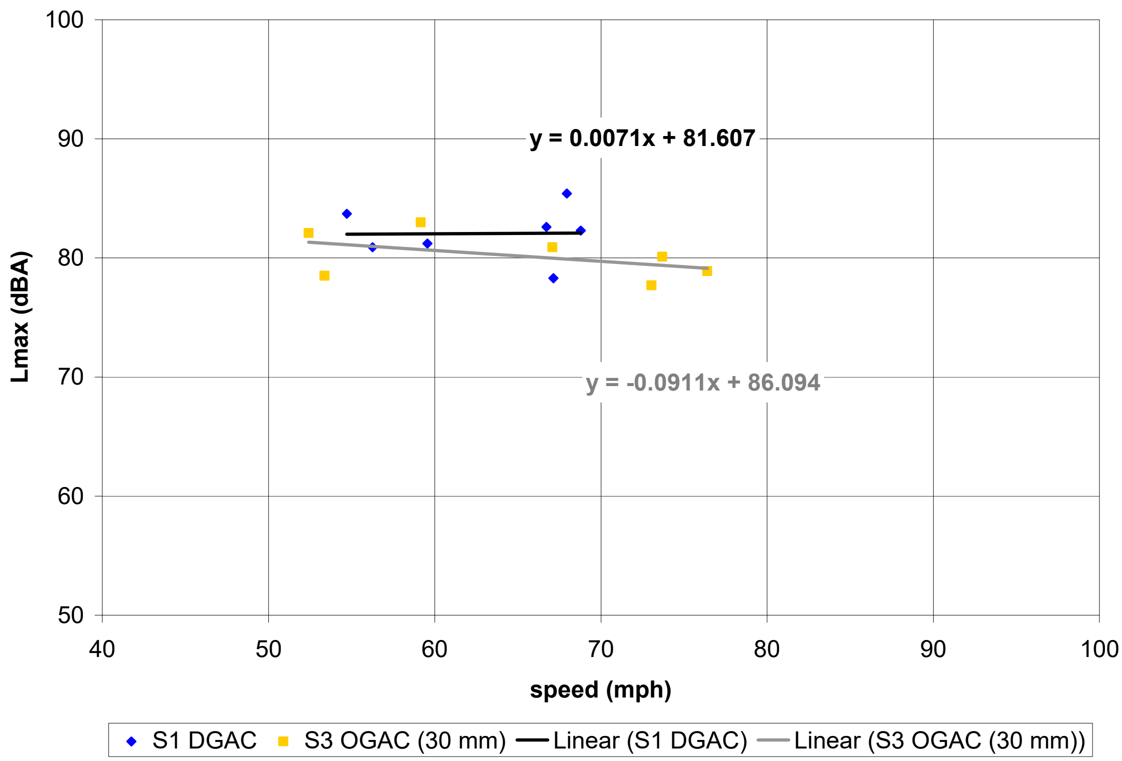


Figure C-27. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1096x + 71.481
y = 0.1408x + 67.216
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0071x + 81.607
y = -0.0911x + 86.094
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

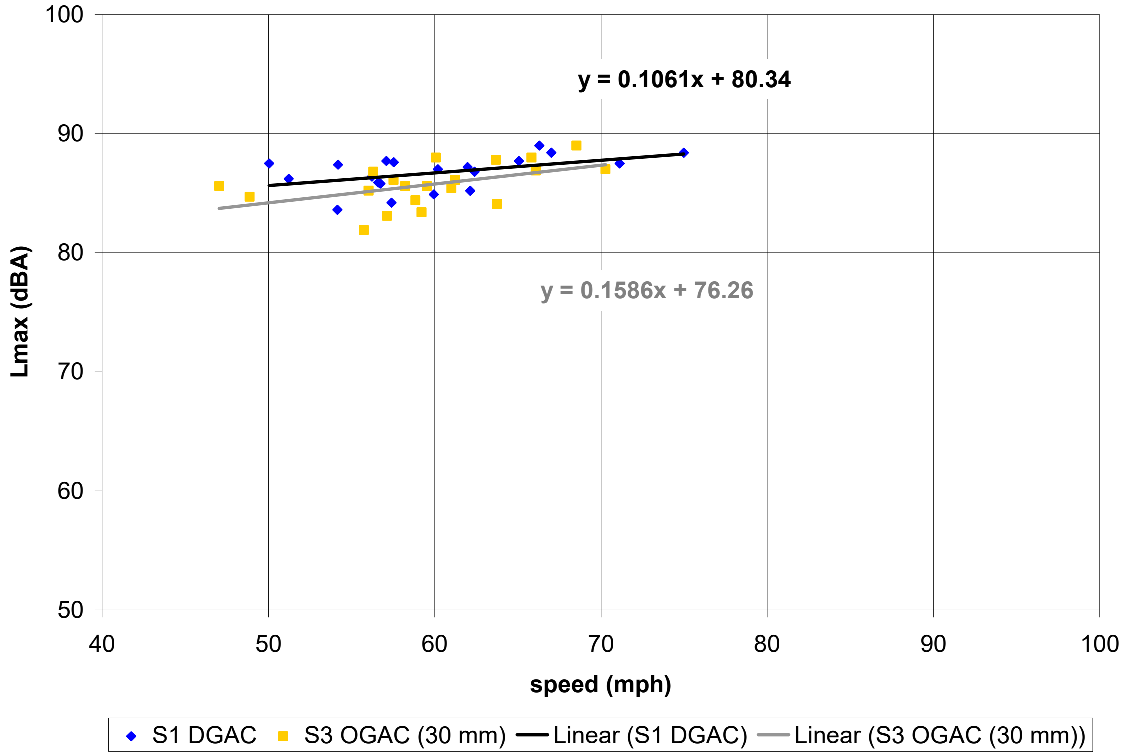
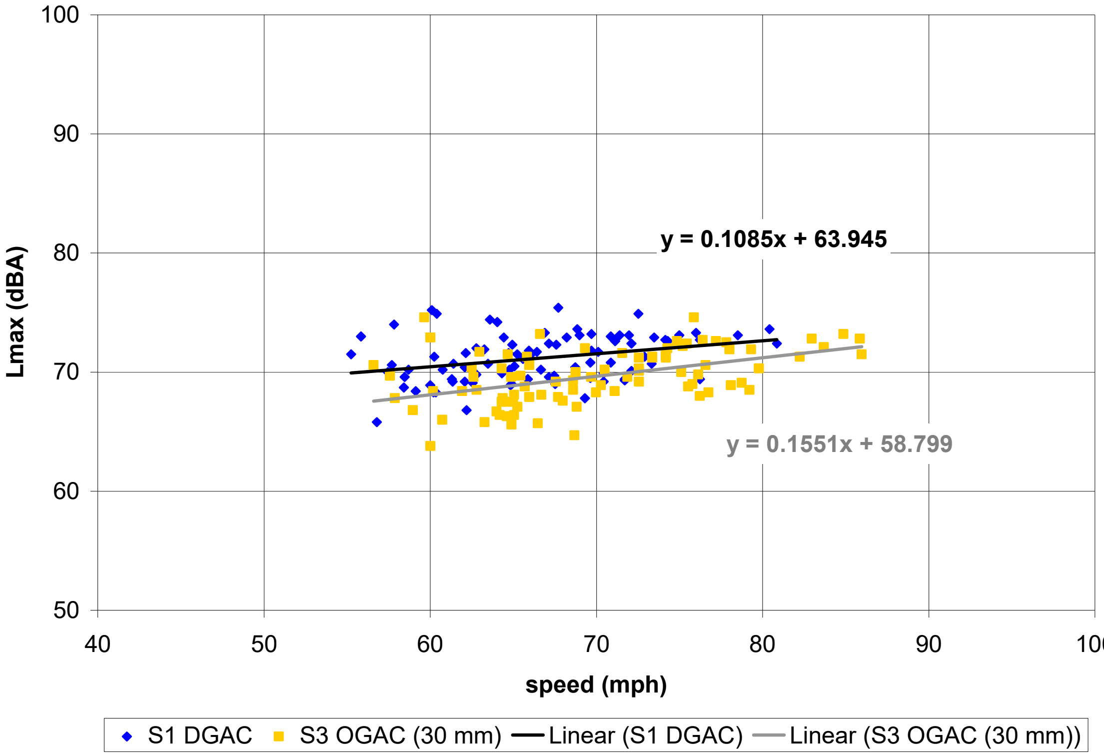
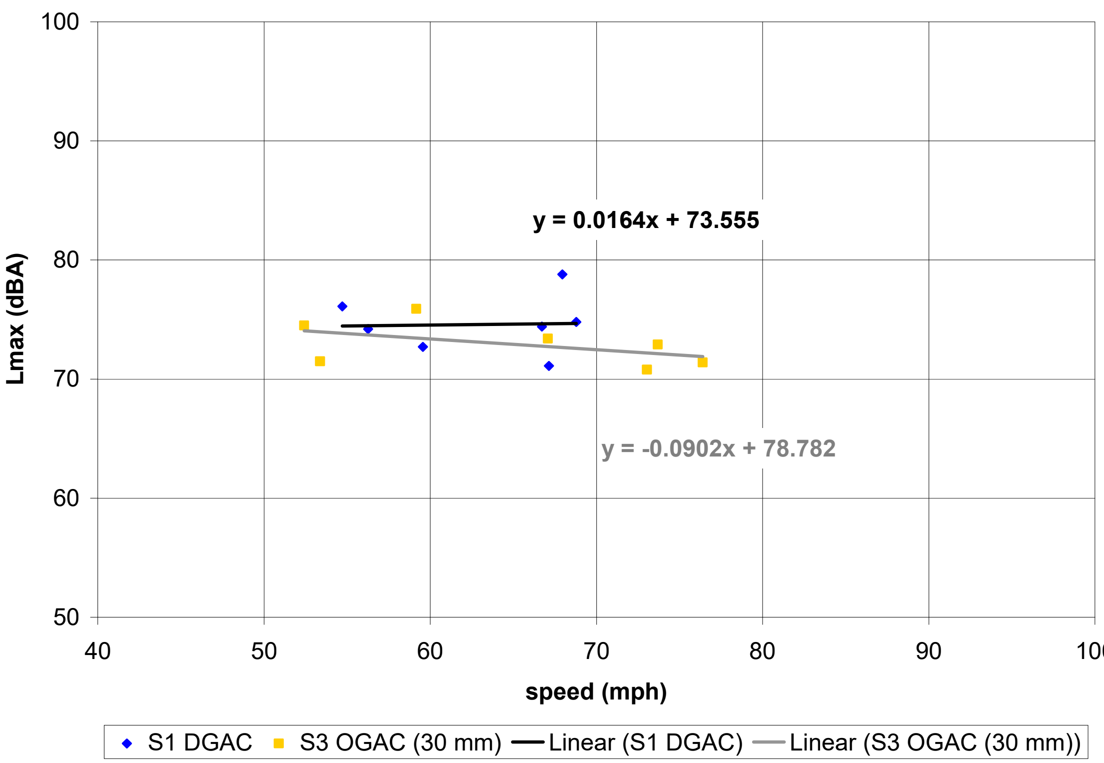


Figure C-28. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1085x + 63.945
y = 0.1551x + 58.799
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0164x + 73.555
y = -0.0902x + 78.782
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

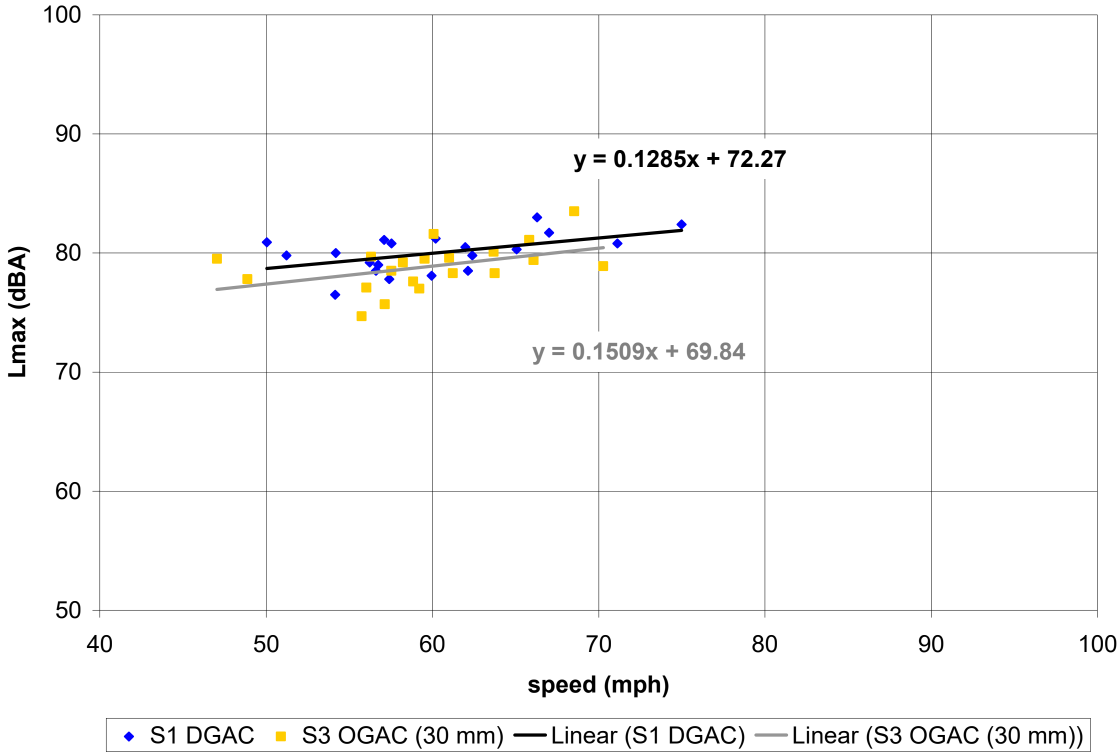
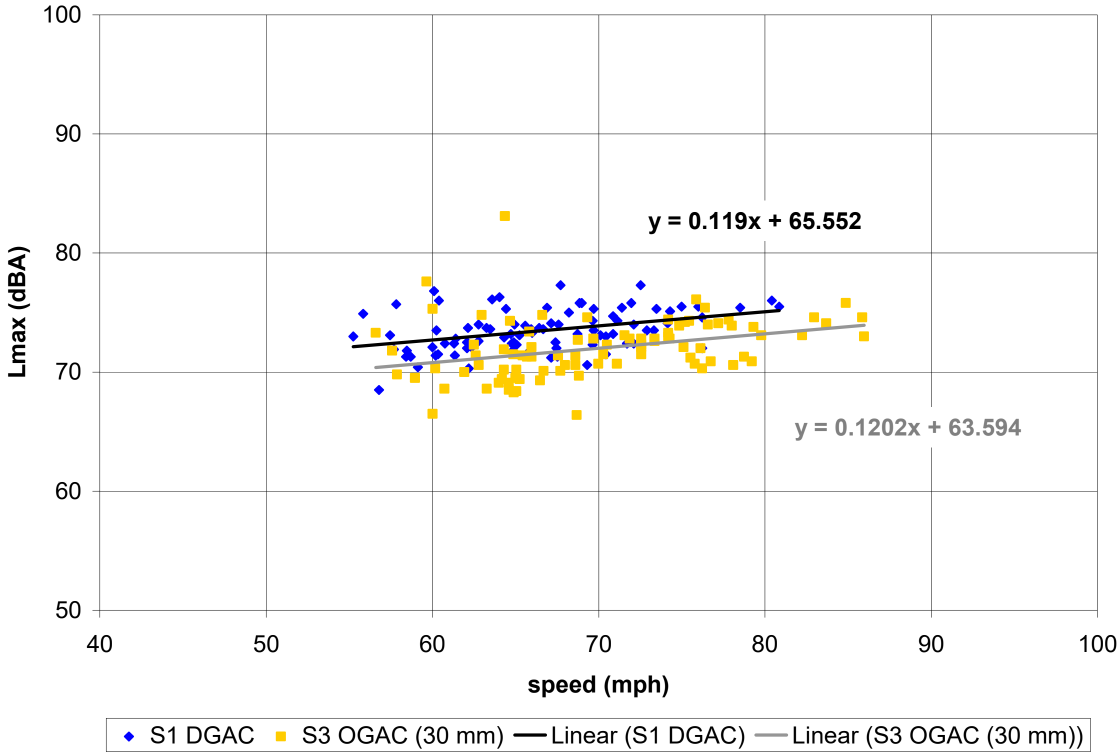
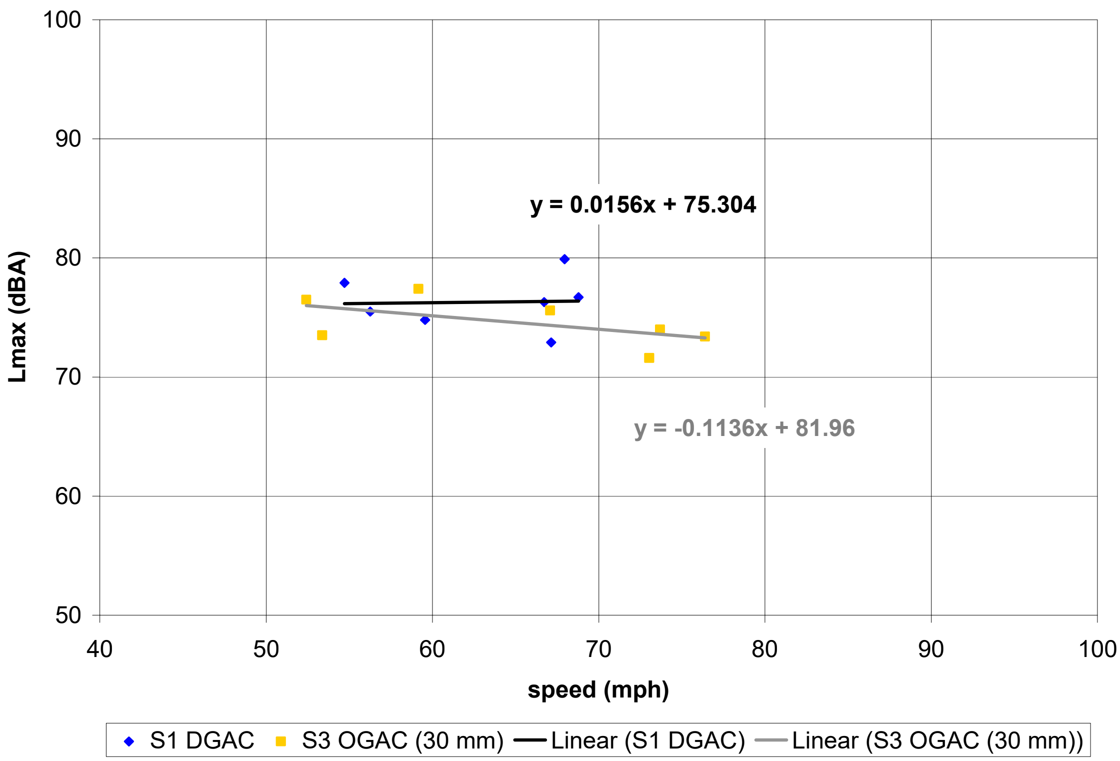


Figure C-29. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.119x + 65.552
y = 0.1202x + 63.594
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0156x + 75.304
y = -0.1136x + 81.96
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

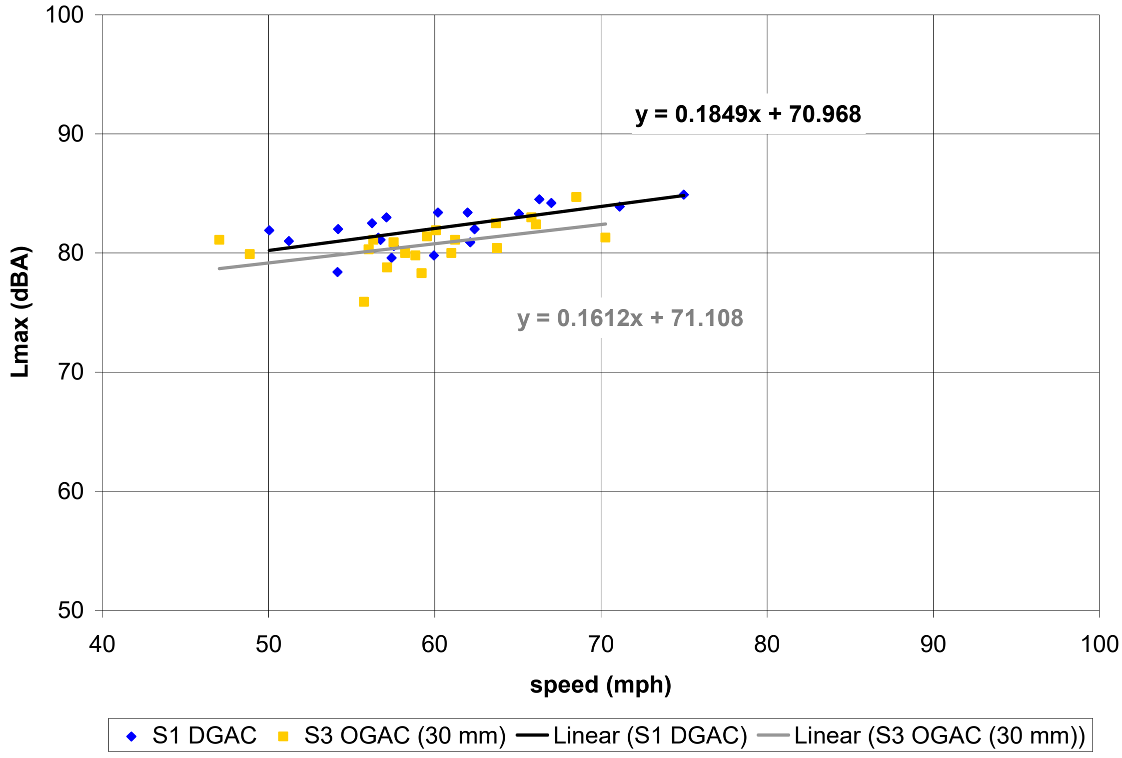
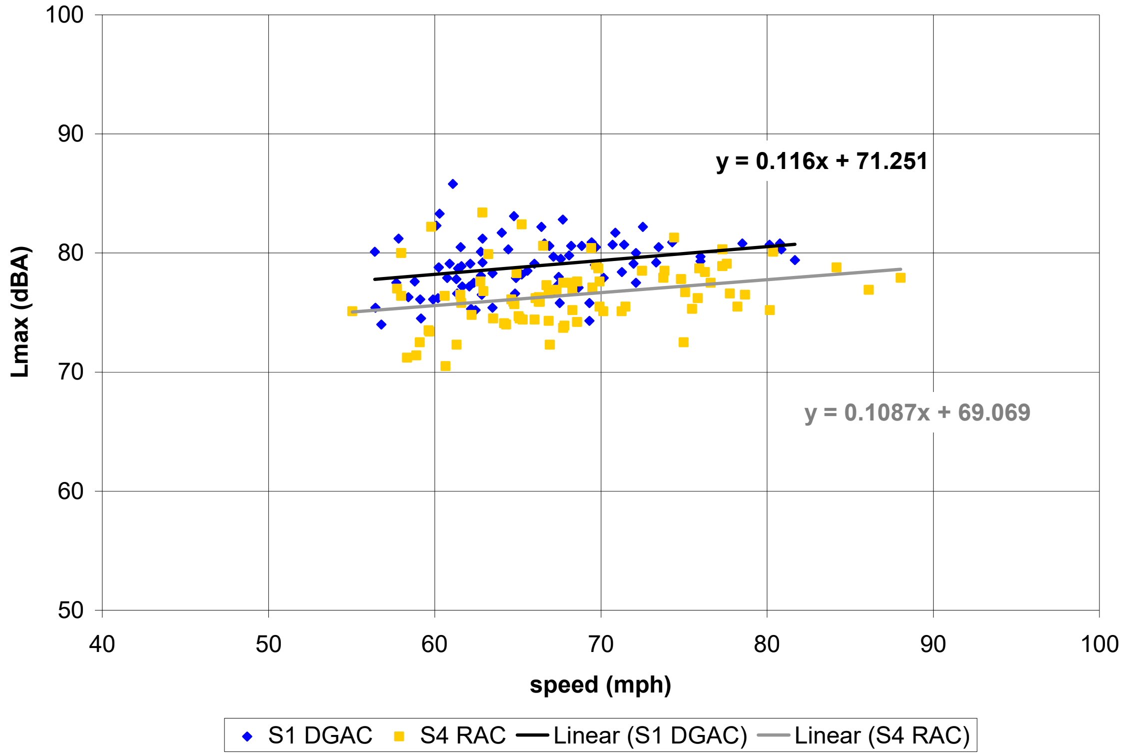
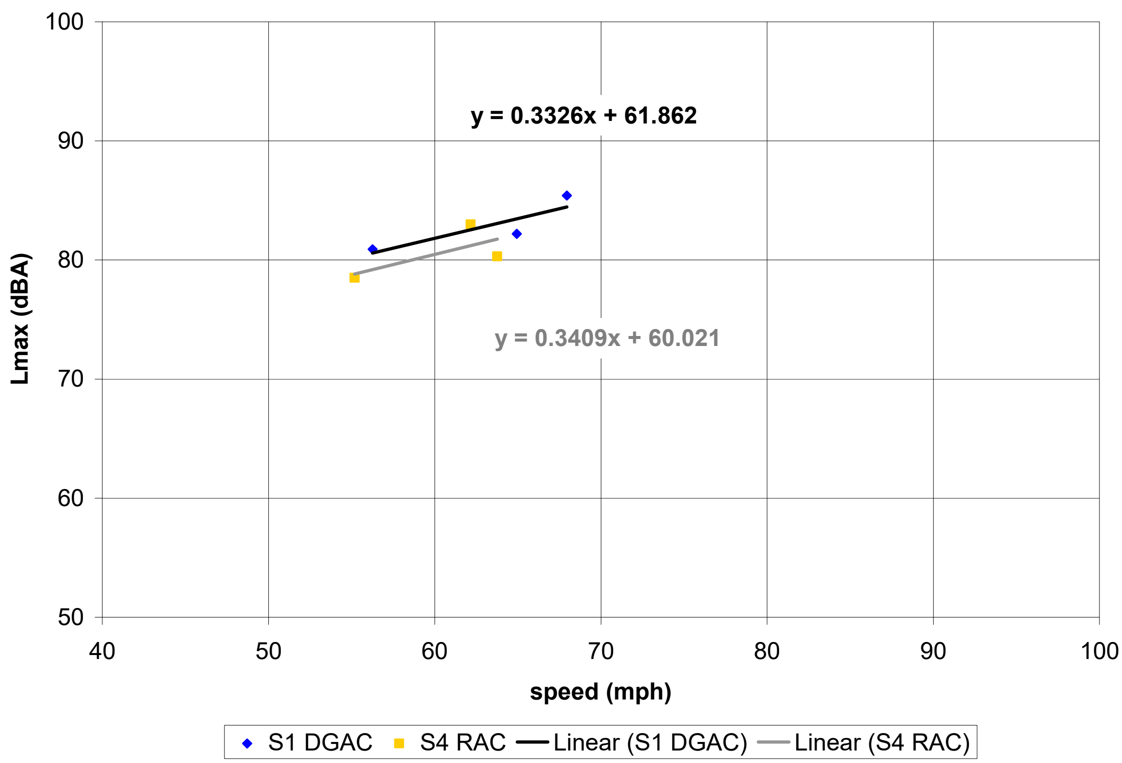


Figure C-30. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.116x + 71.251
y = 0.1087x + 69.069
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.3326x + 61.862
y = 0.3409x + 60.021
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

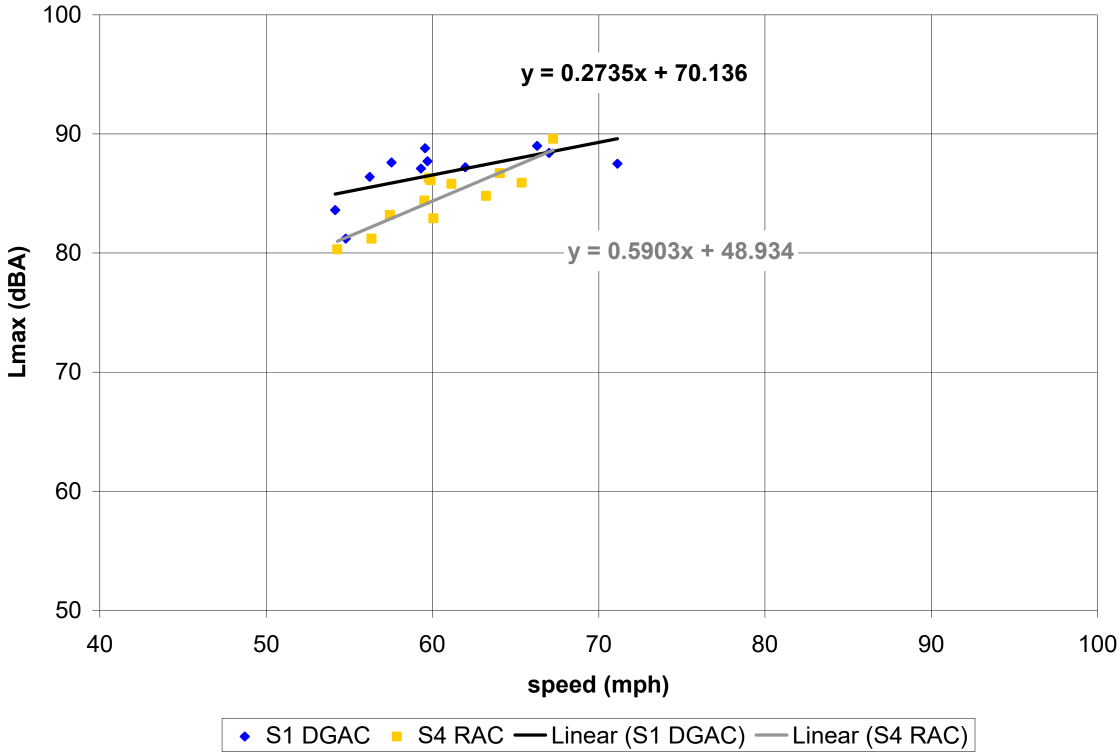
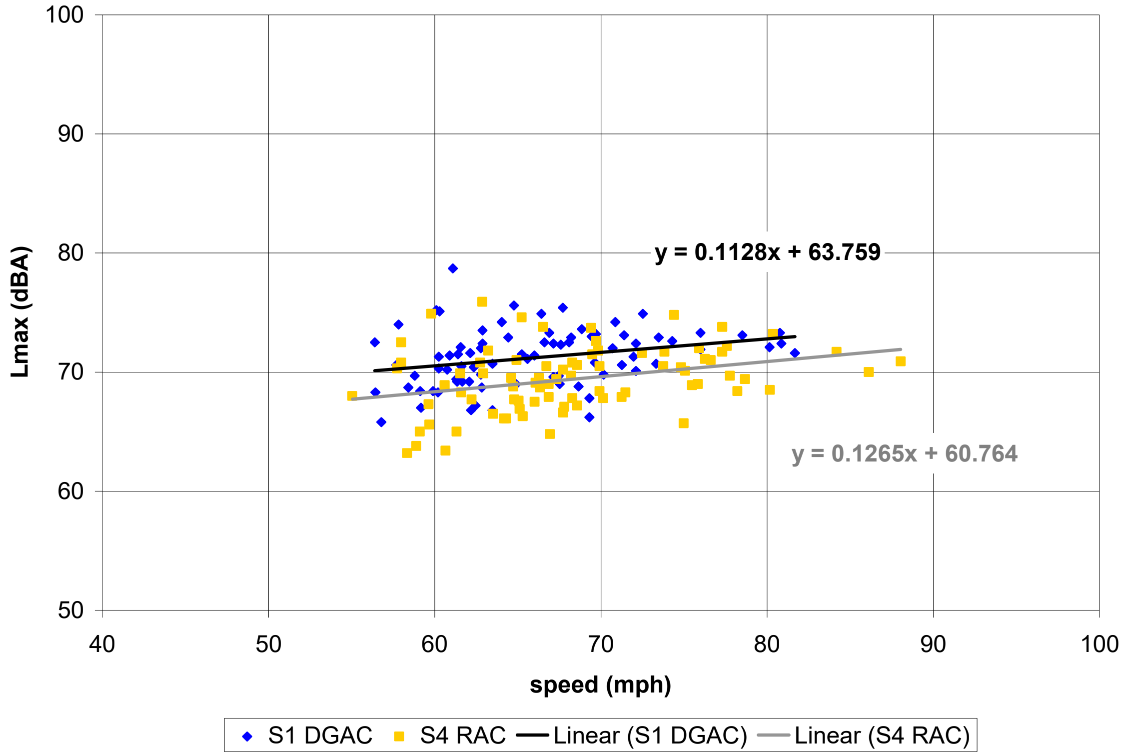
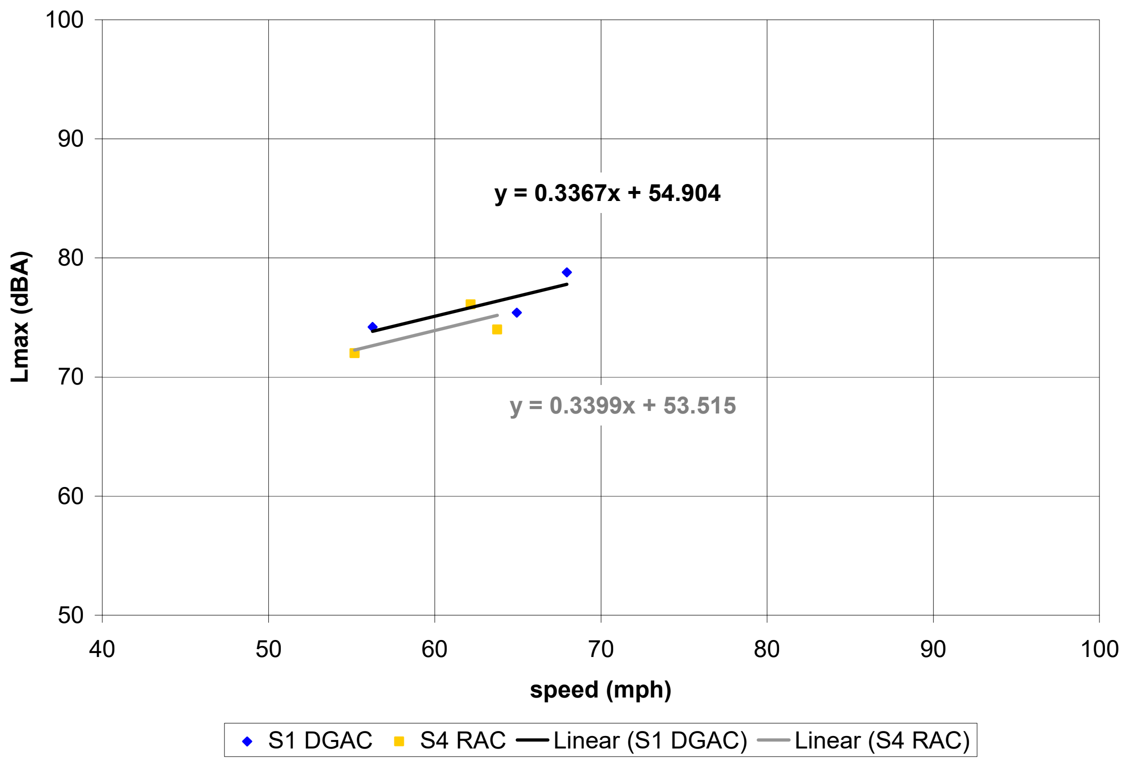


Figure C-31. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1128x + 63.759
y = 0.1265x + 60.764
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.3367x + 54.904
y = 0.3399x + 53.515
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

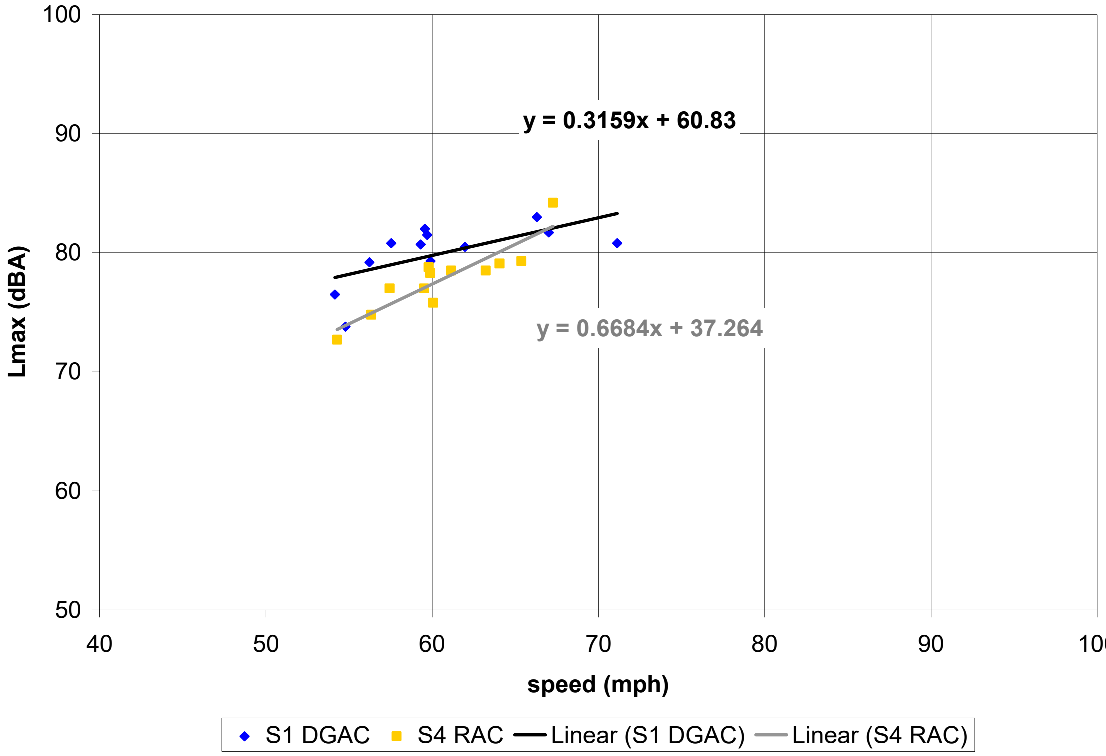
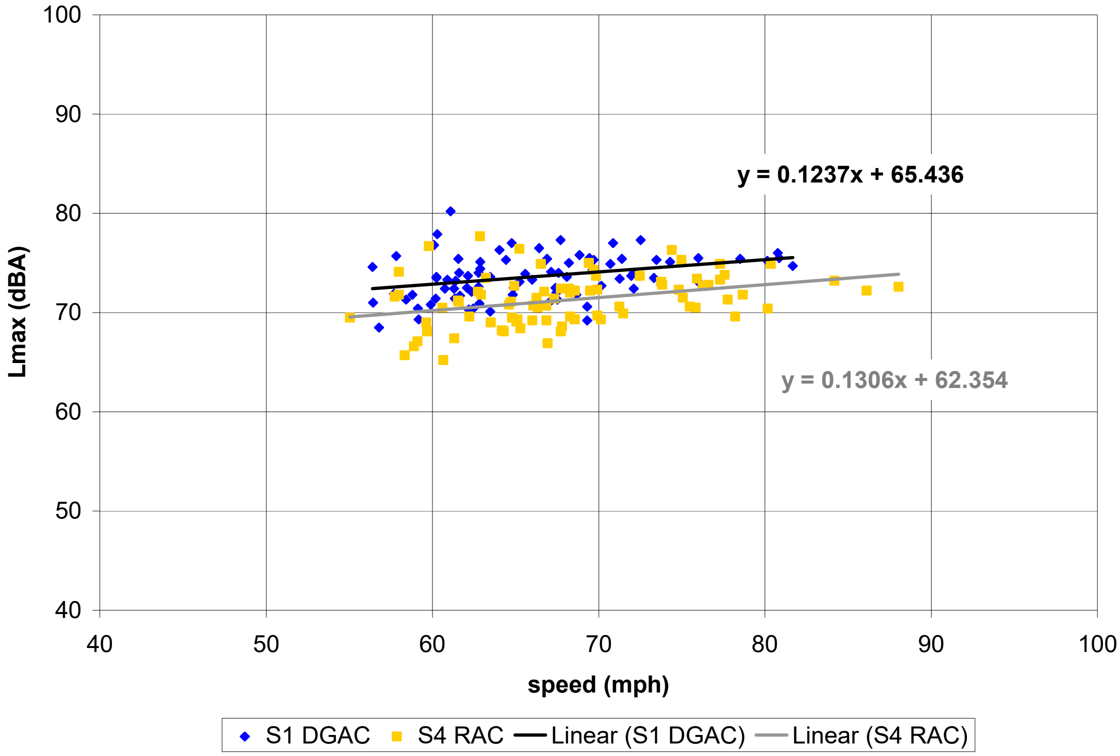
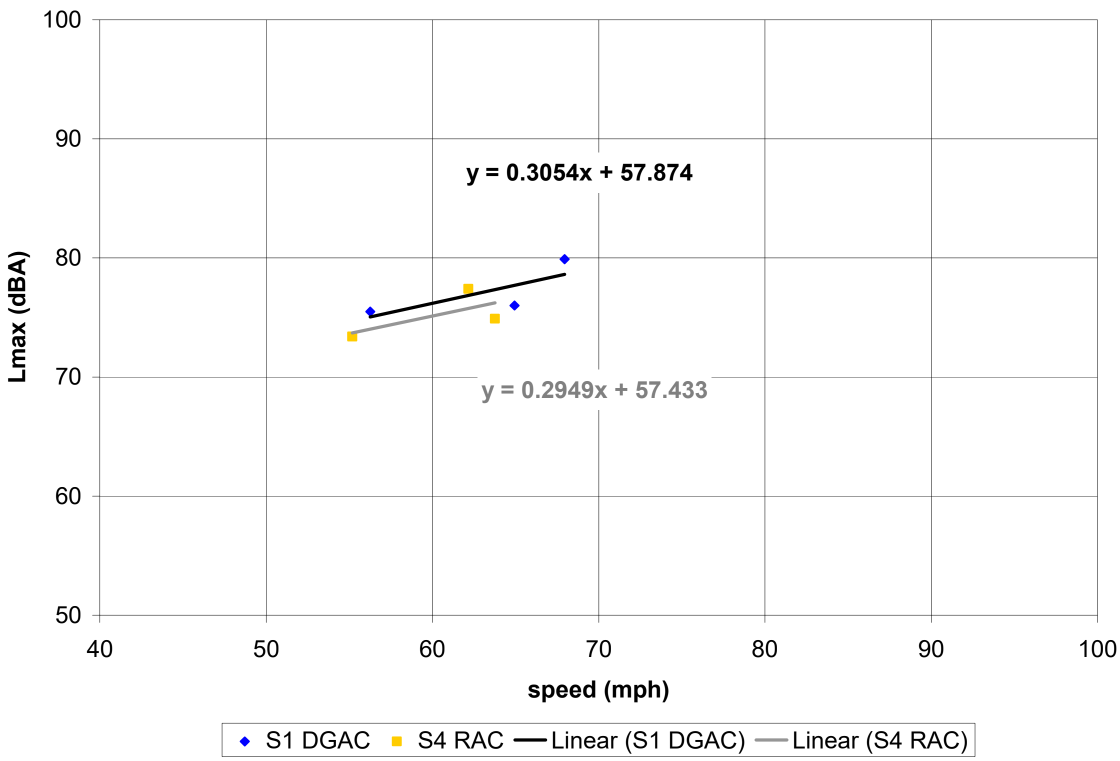


Figure C-32. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



y = 0.1237x + 65.436
y = 0.1306x + 62.354
Lmax (dBA)
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



y = 0.3054x + 57.874
y = 0.2949x + 57.433
Lmax (dBA)
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

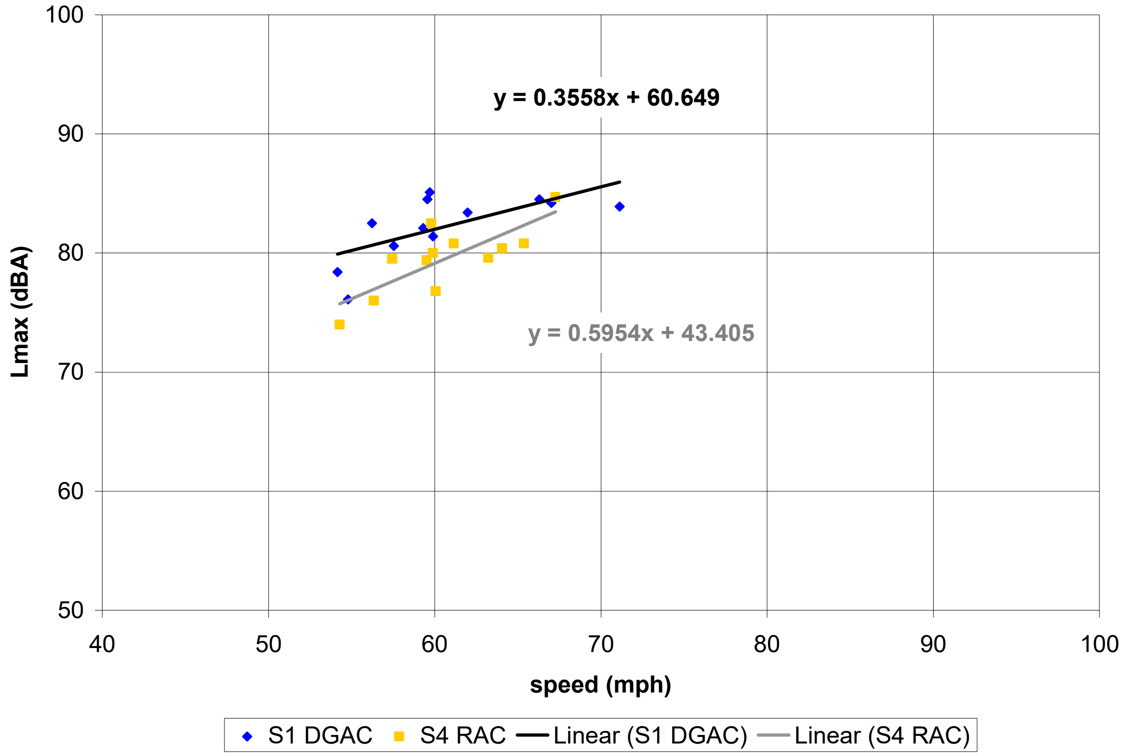
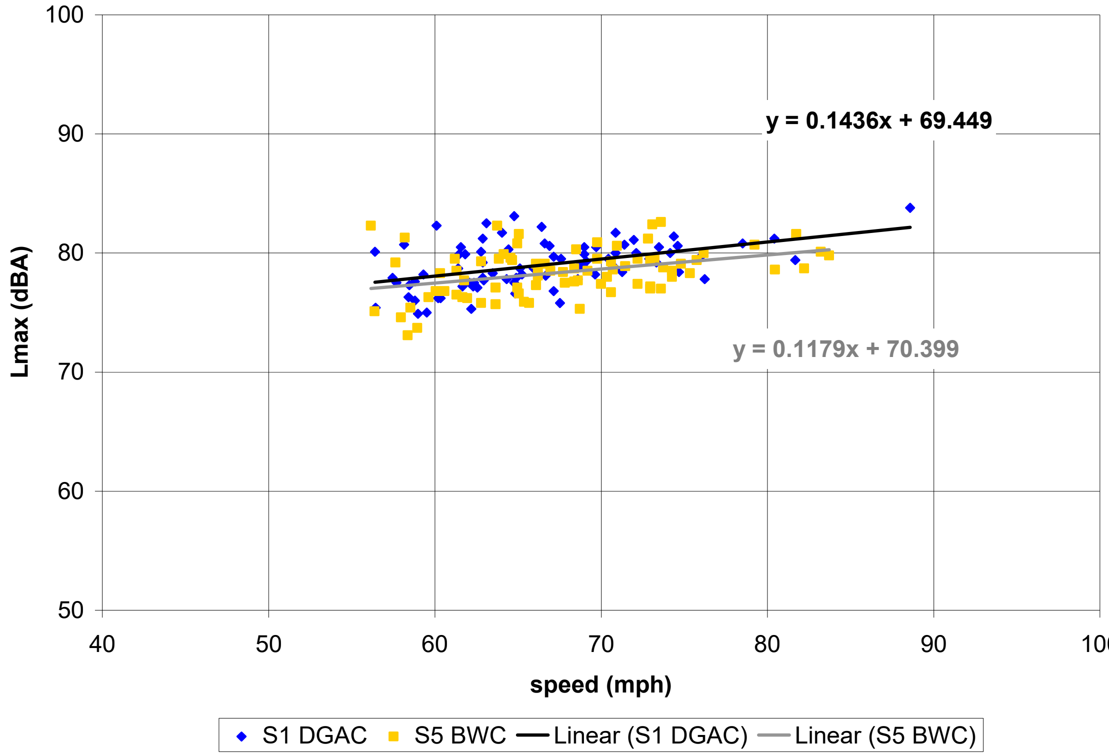
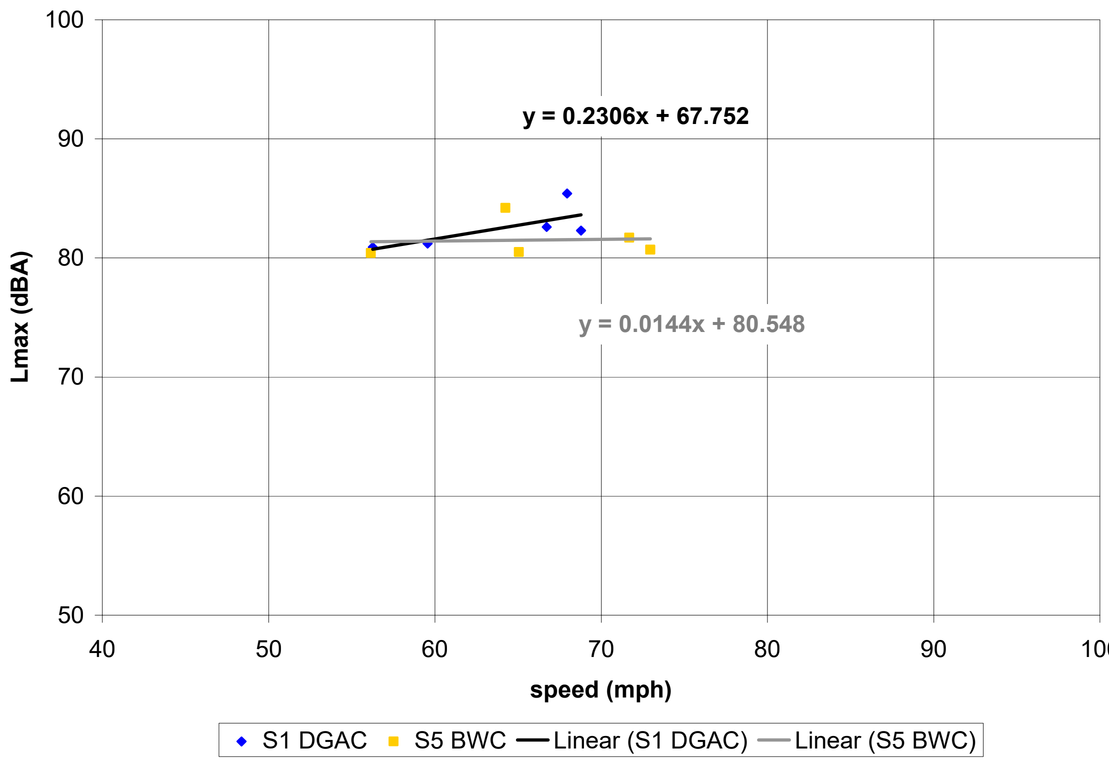


Figure C-33. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1436x + 69.449
y = 0.1179x + 70.399
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2306x + 67.752
y = 0.0144x + 80.548
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

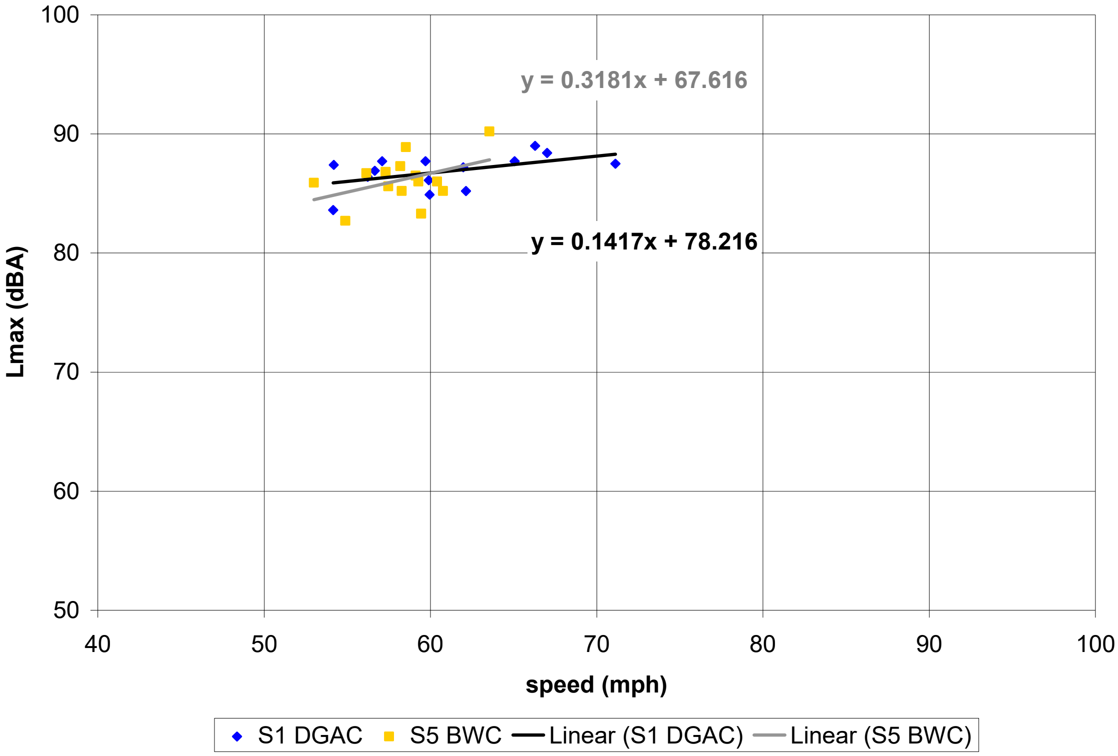
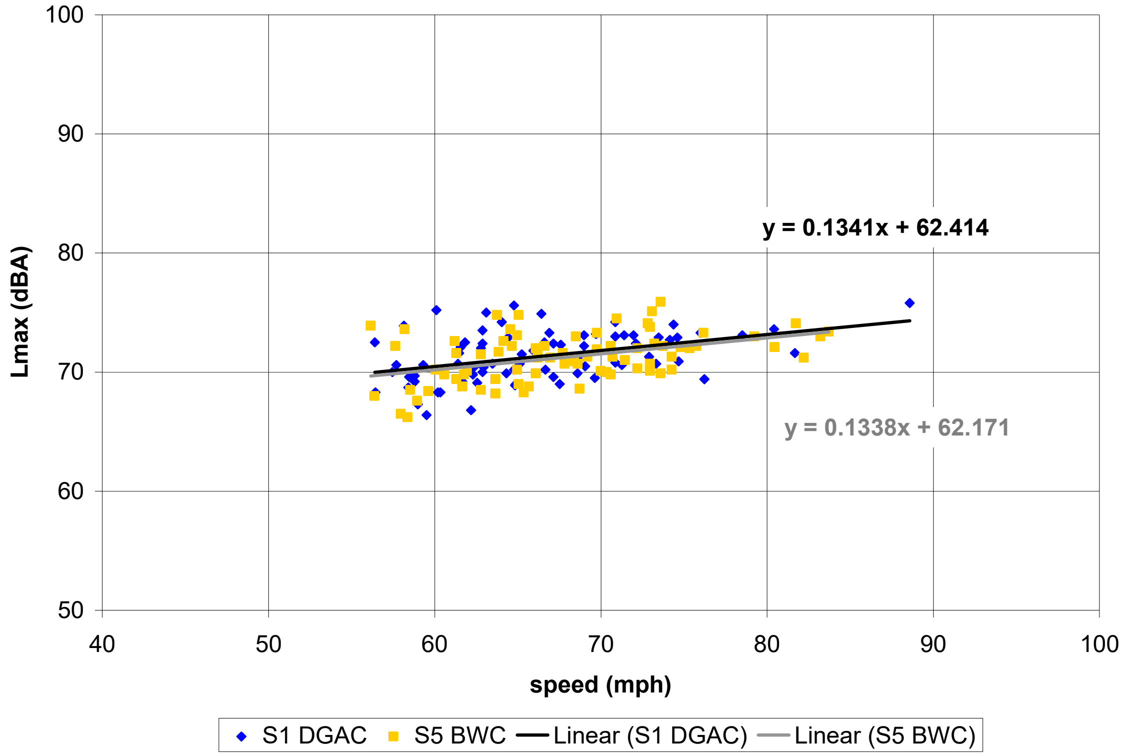
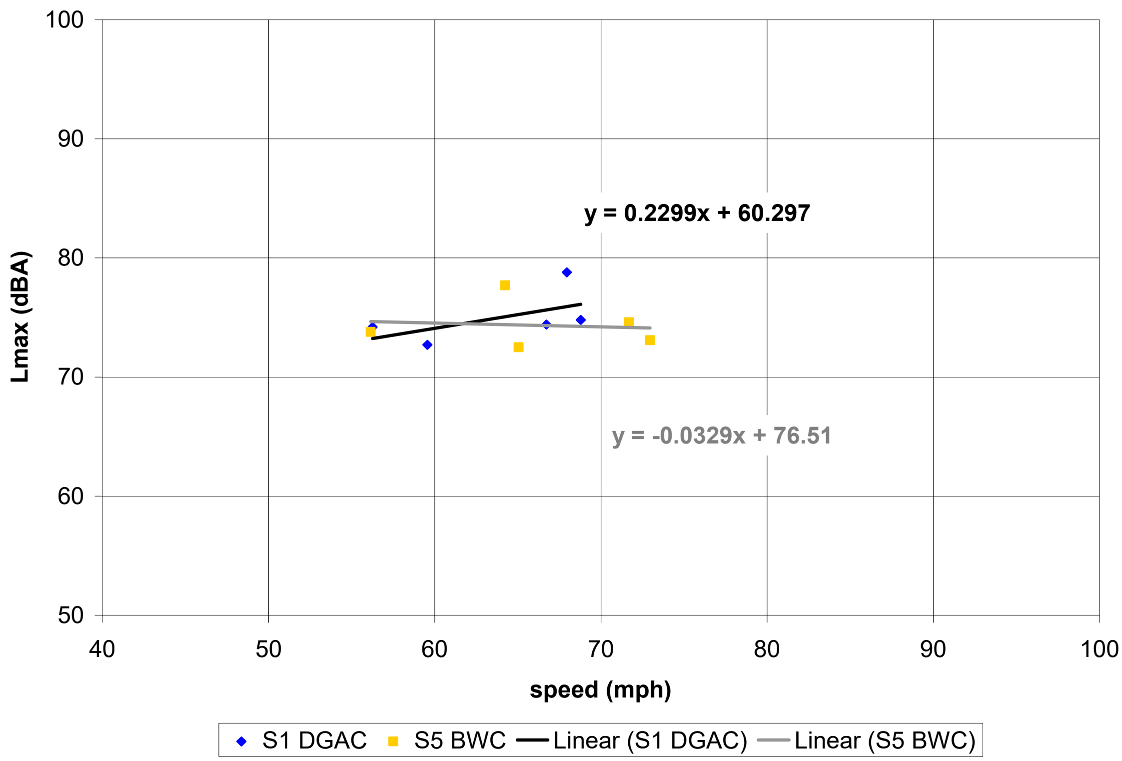


Figure C-34. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
y = 0.1341x + 62.414
y = 0.1338x + 62.171
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
y = 0.2299x + 60.297
y = -0.0329x + 76.51
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

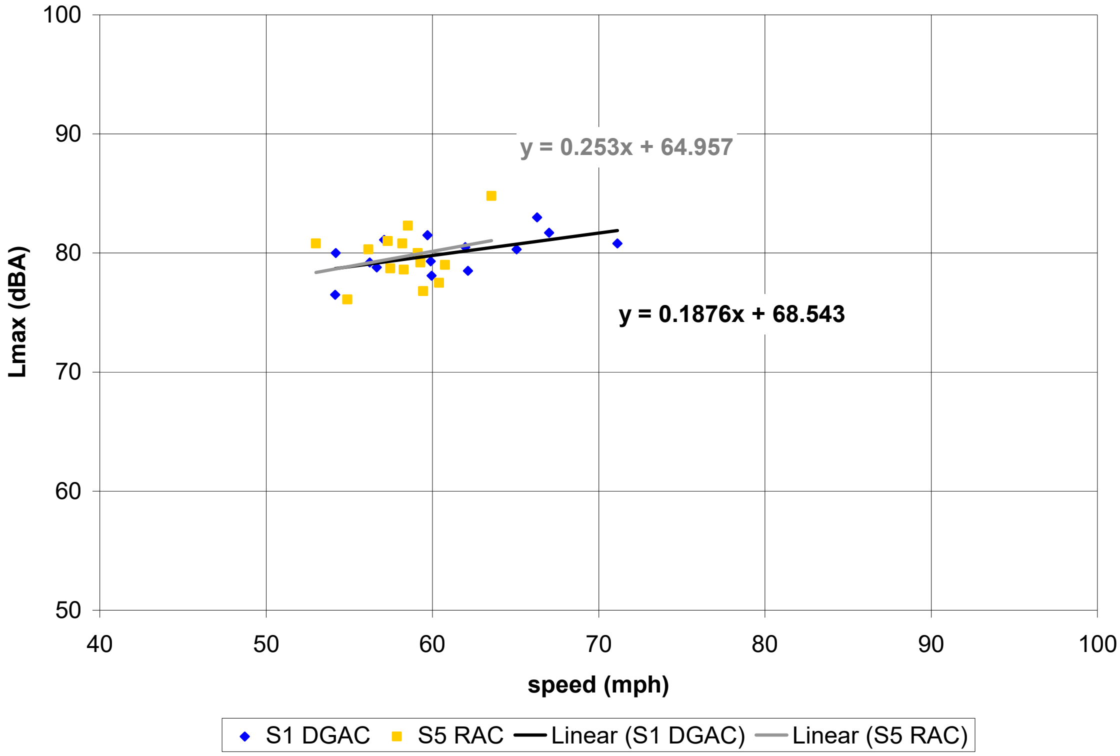
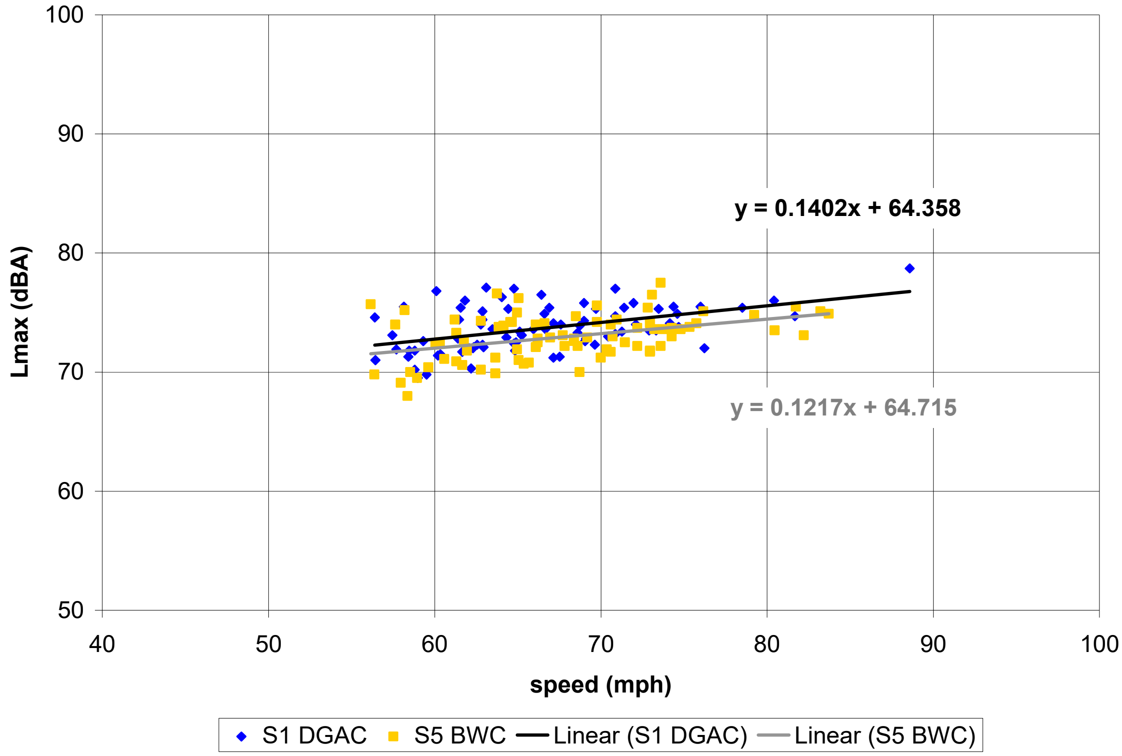
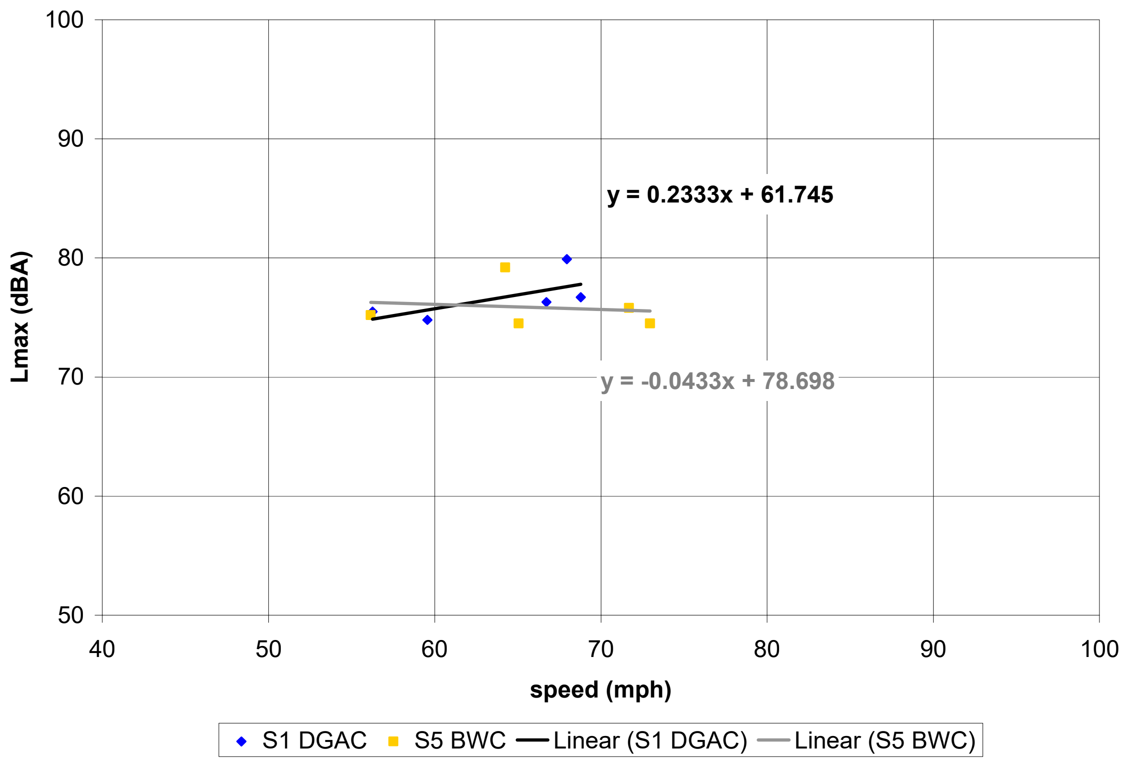


Figure C-35. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1402x + 64.358
y = 0.1217x + 64.715
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2333x + 61.745
y = -0.0433x + 78.698
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

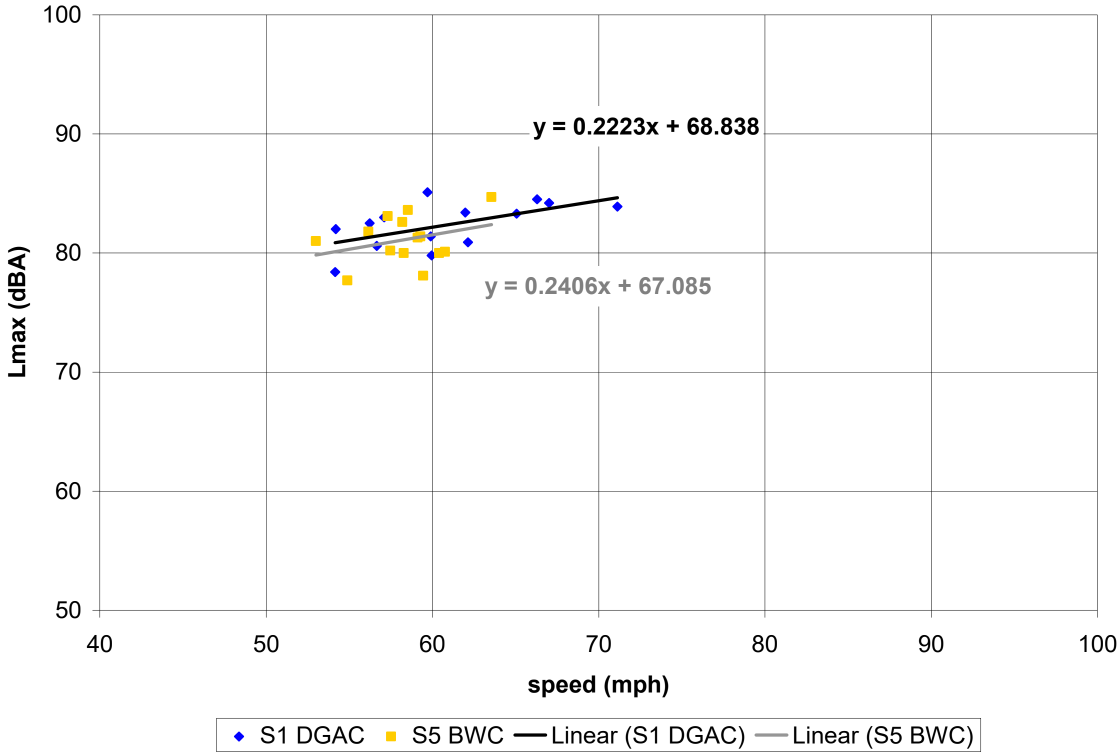
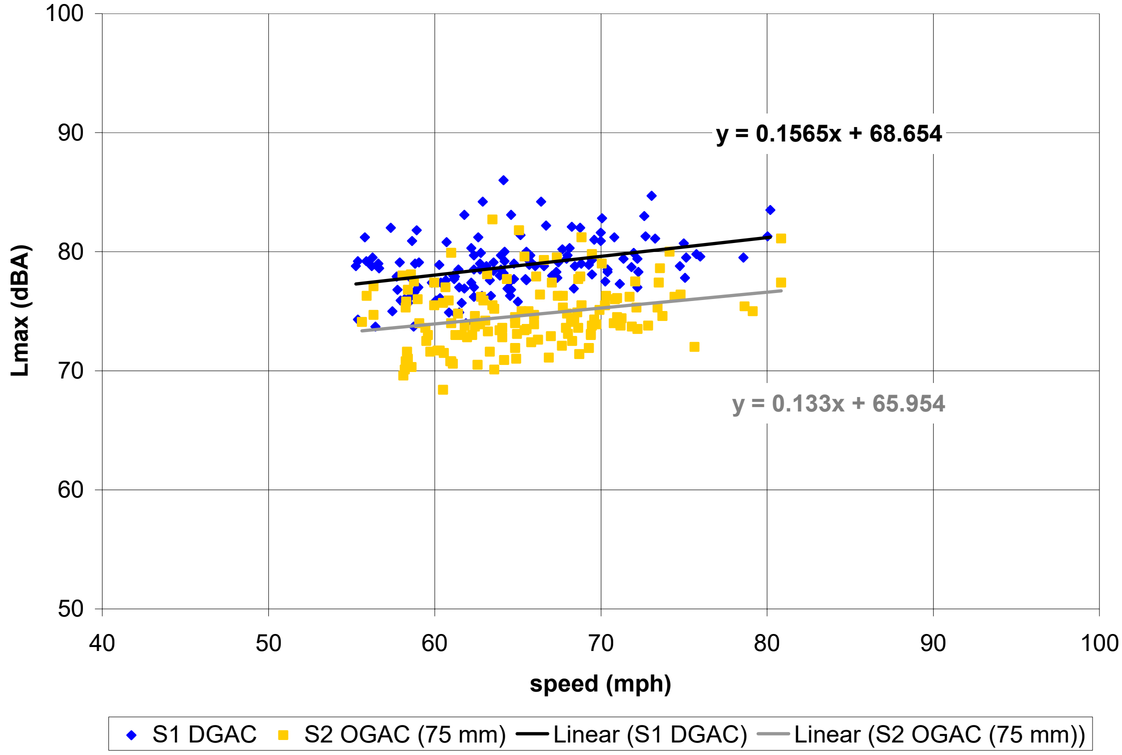
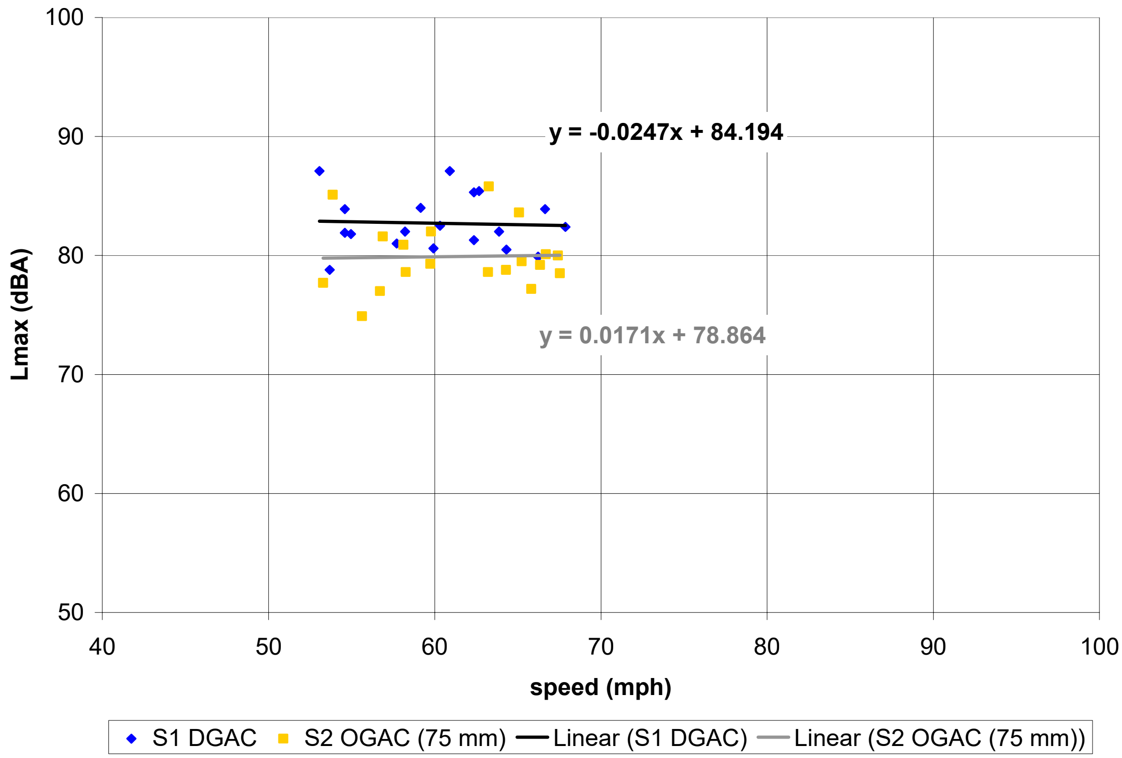


Figure C-36. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.5 Post-Overlay – Pavement Age: 16 months





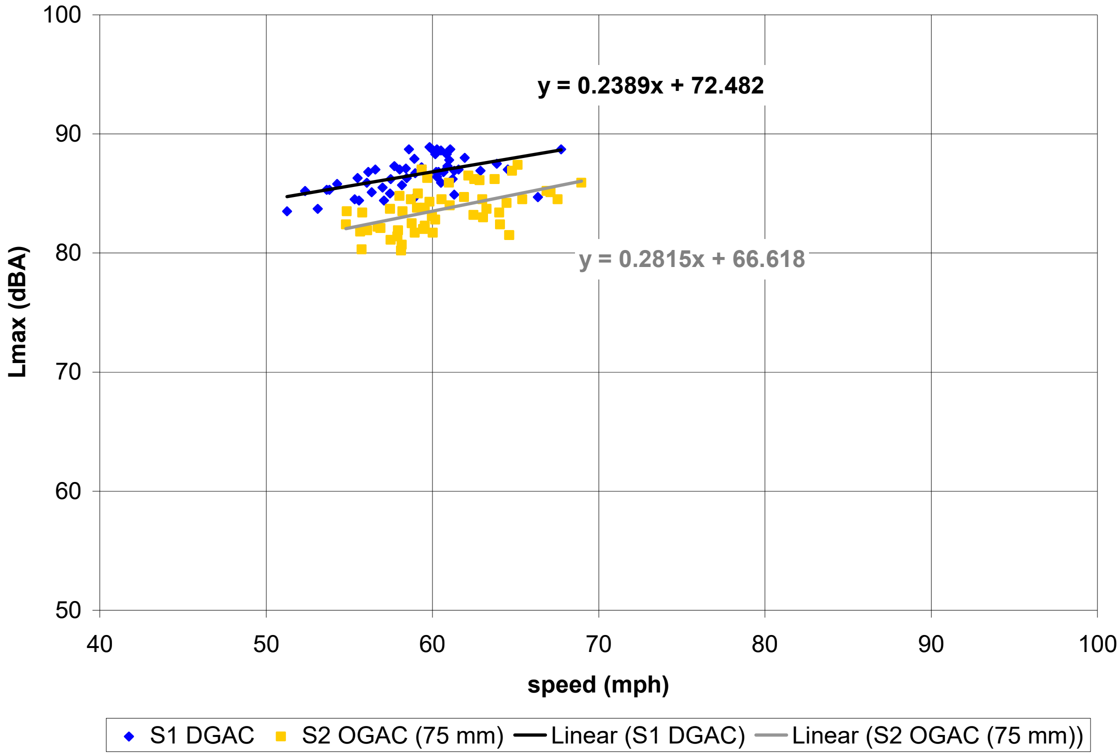
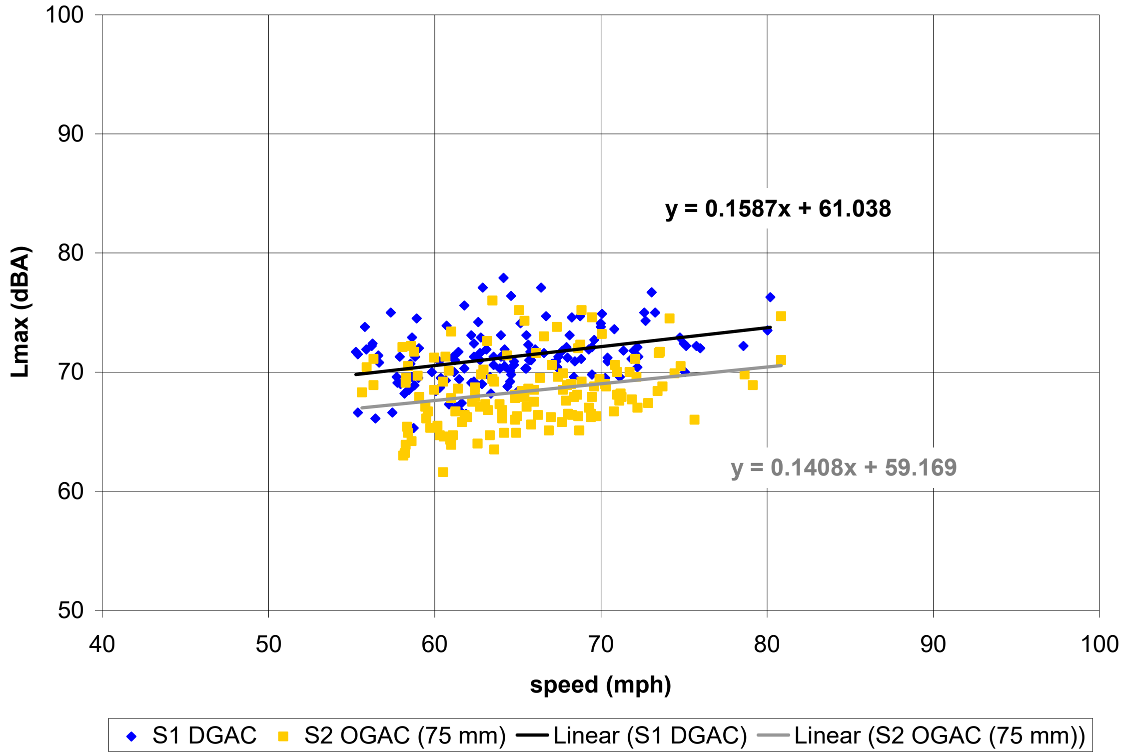
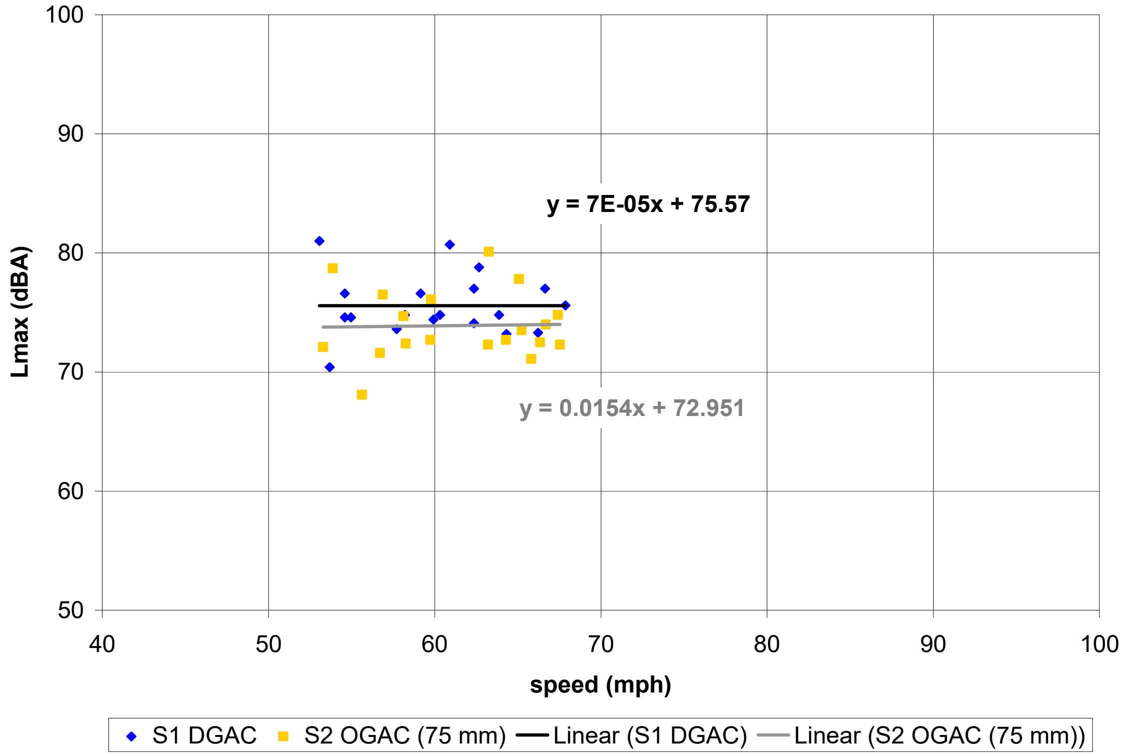


Figure C-37. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1587x + 61.038
y = 0.1408x + 59.169
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 7E-05x + 75.57
y = 0.0154x + 72.951
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

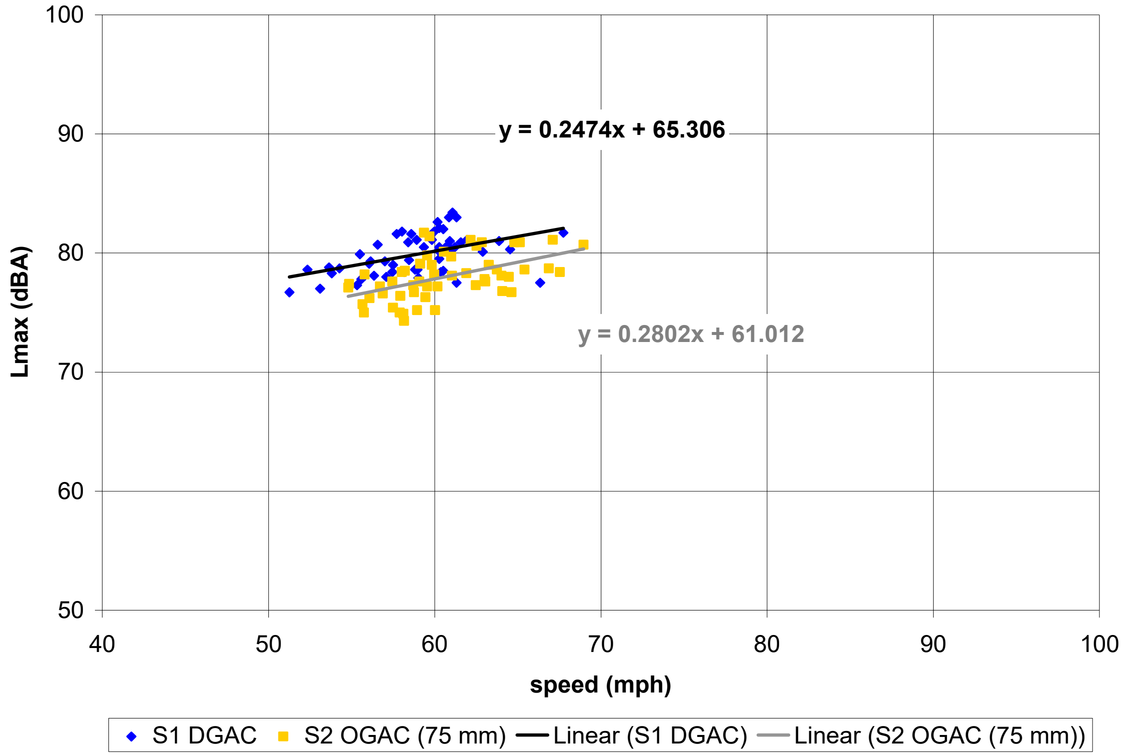
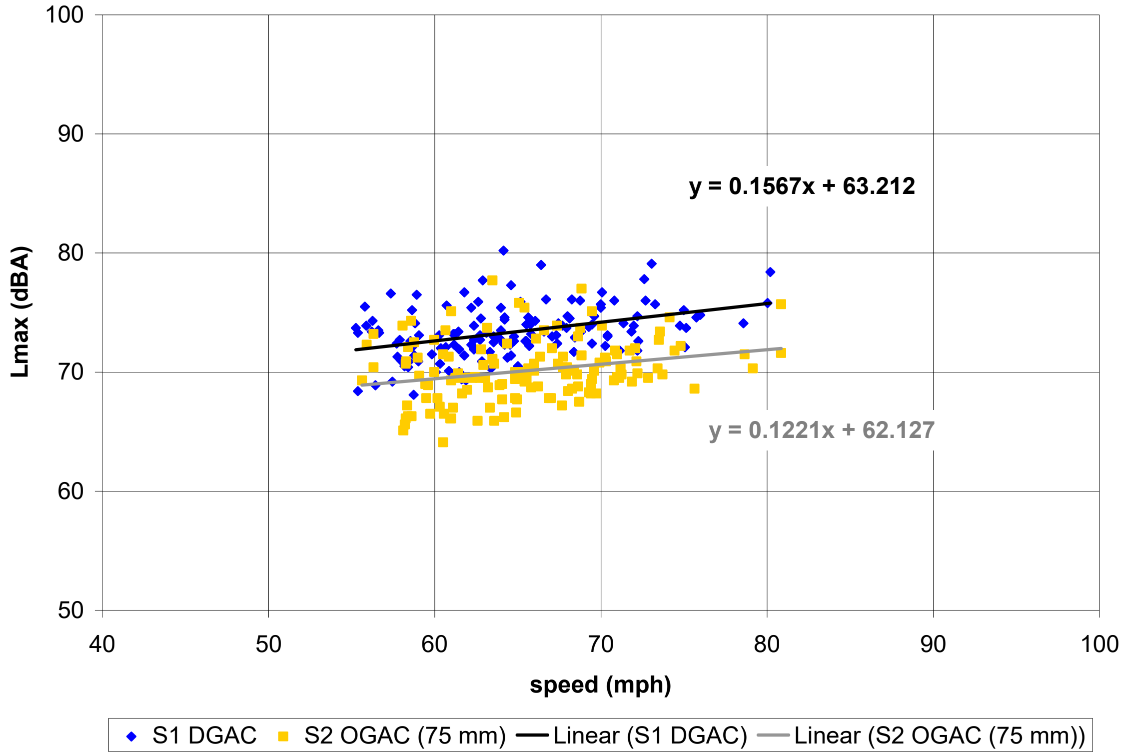
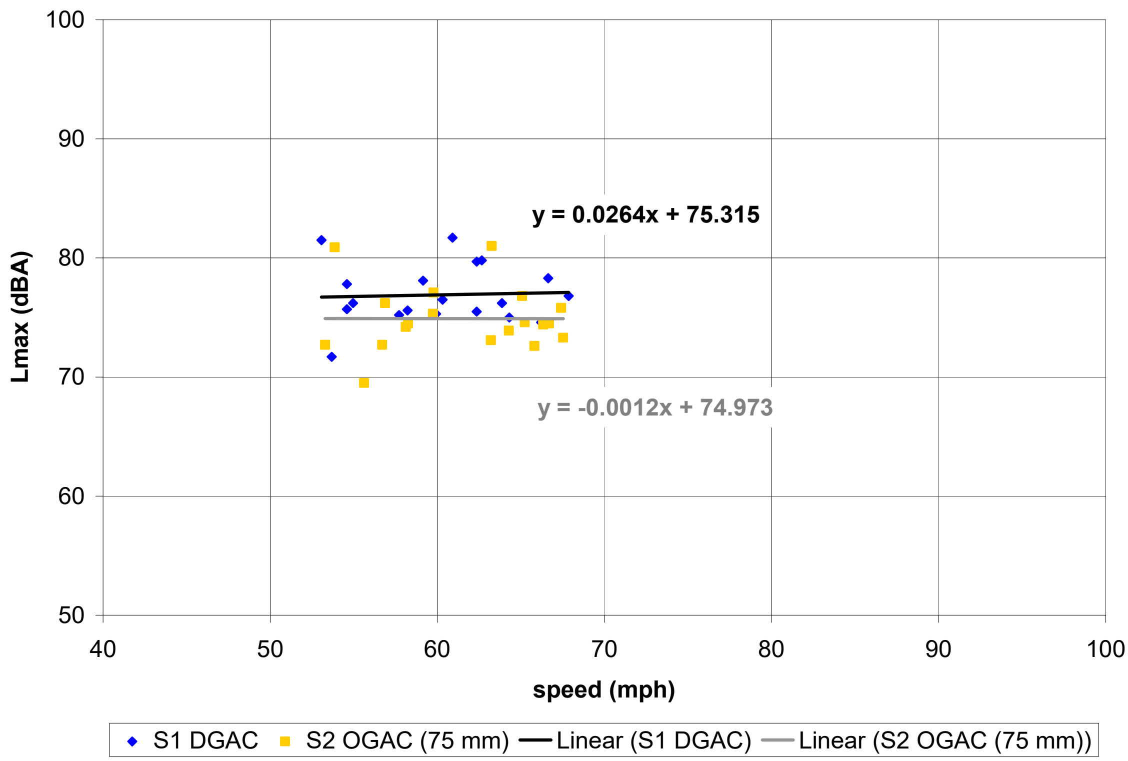


Figure C-38. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1567x + 63.212
y = 0.1221x + 62.127
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0264x + 75.315
y = -0.0012x + 74.973
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

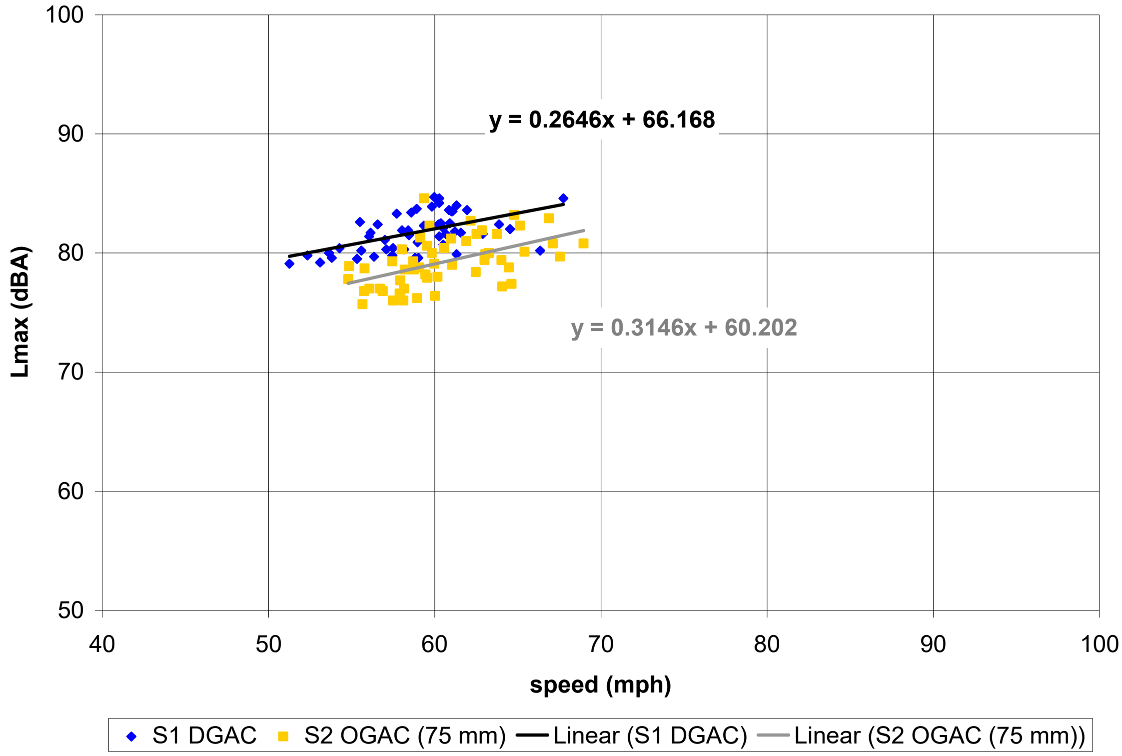
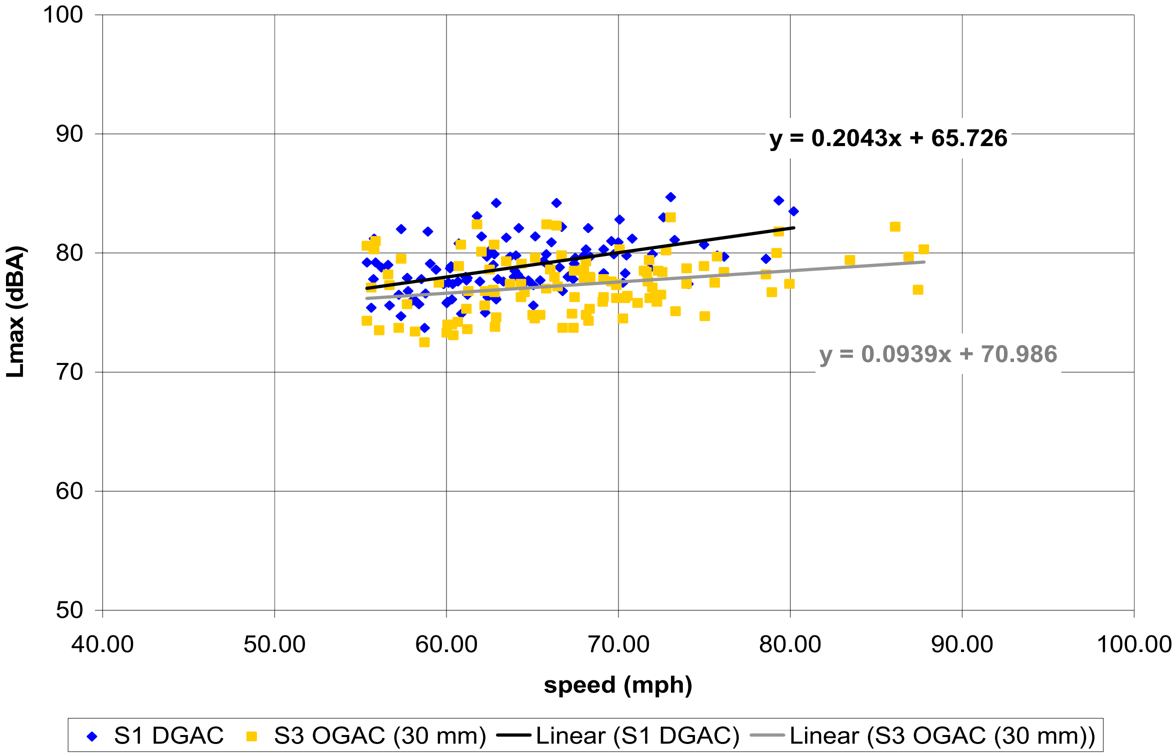
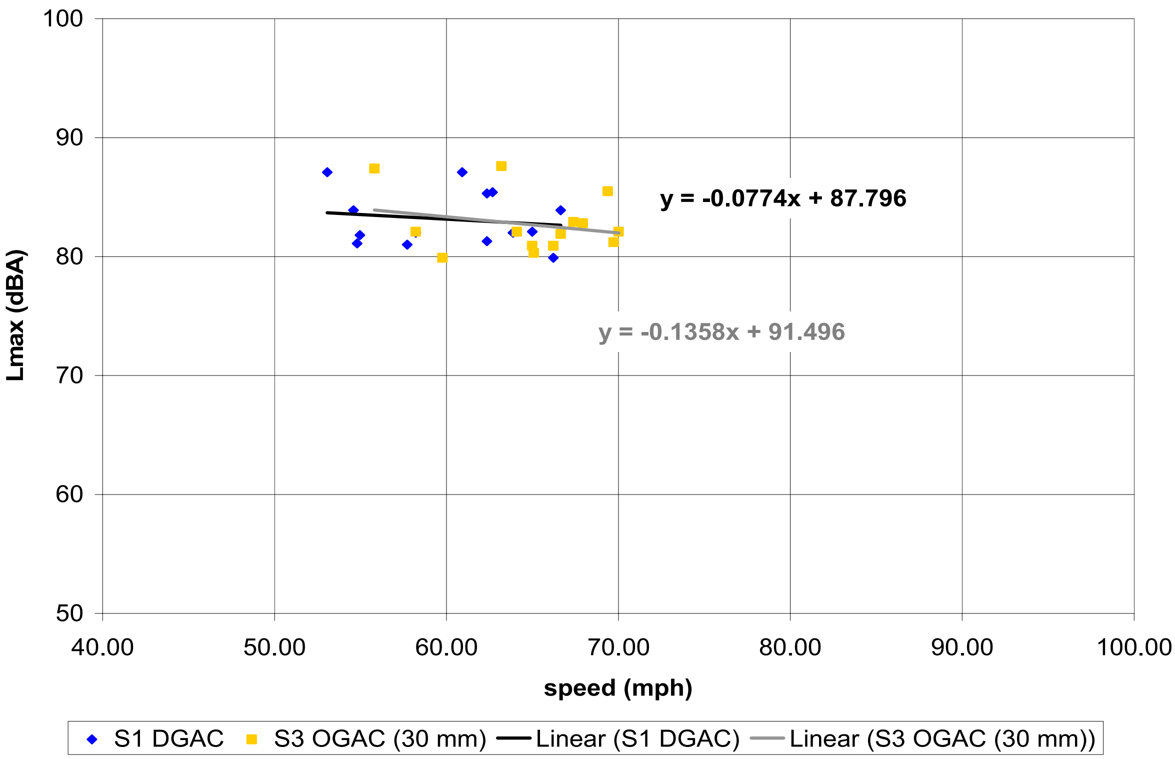


Figure C-39. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Lmax (dBA)
speed (mph)
y = 0.2043x + 65.726
y = 0.0939x + 70.986
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Lmax (dBA)
speed (mph)
y = -0.0774x + 87.796
y = -0.1358x + 91.496
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

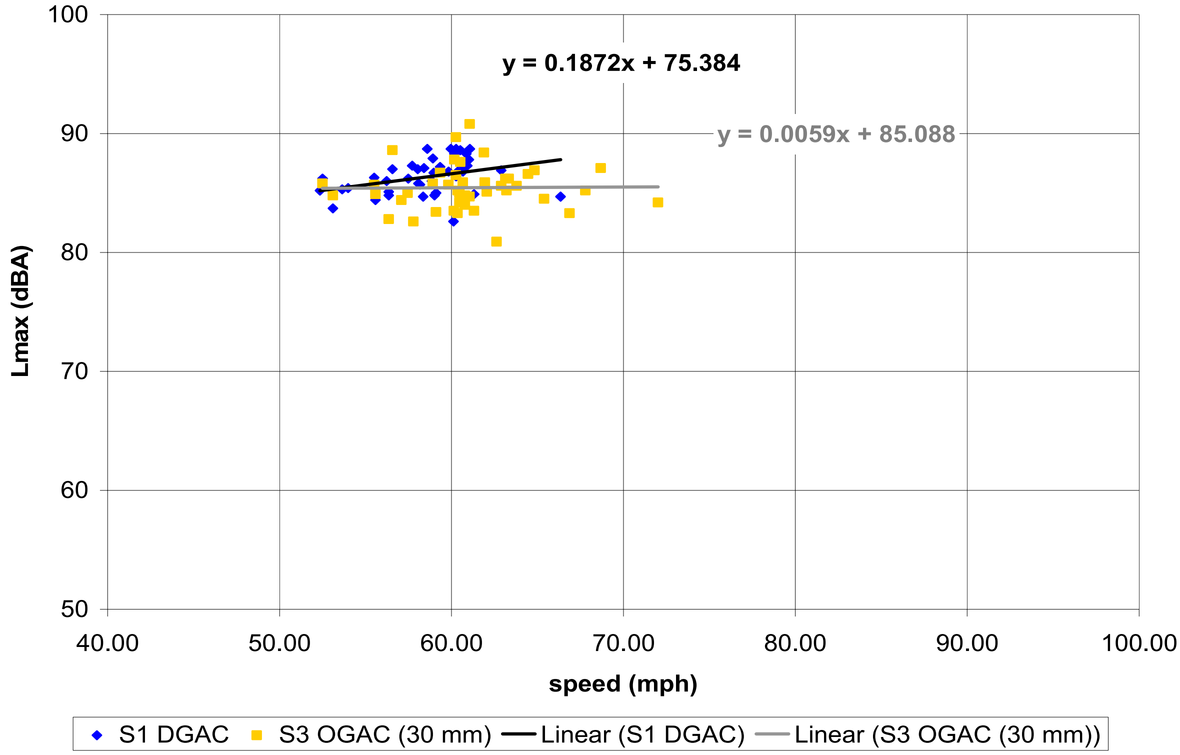
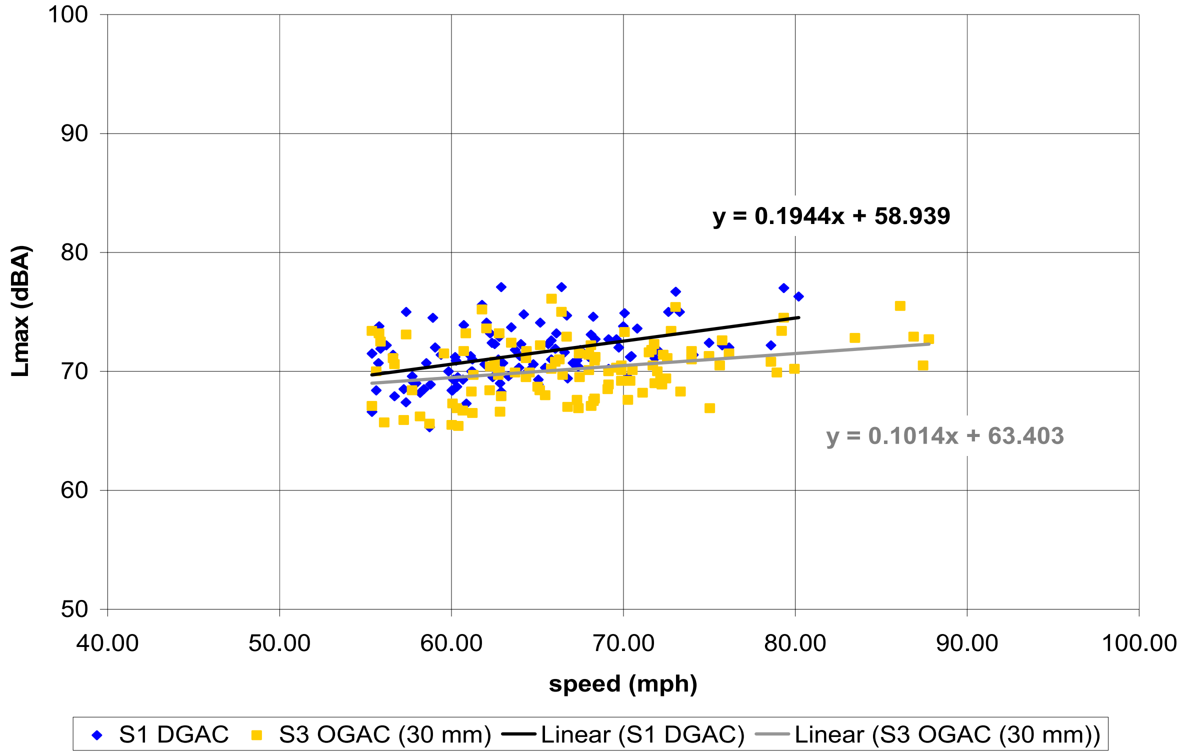
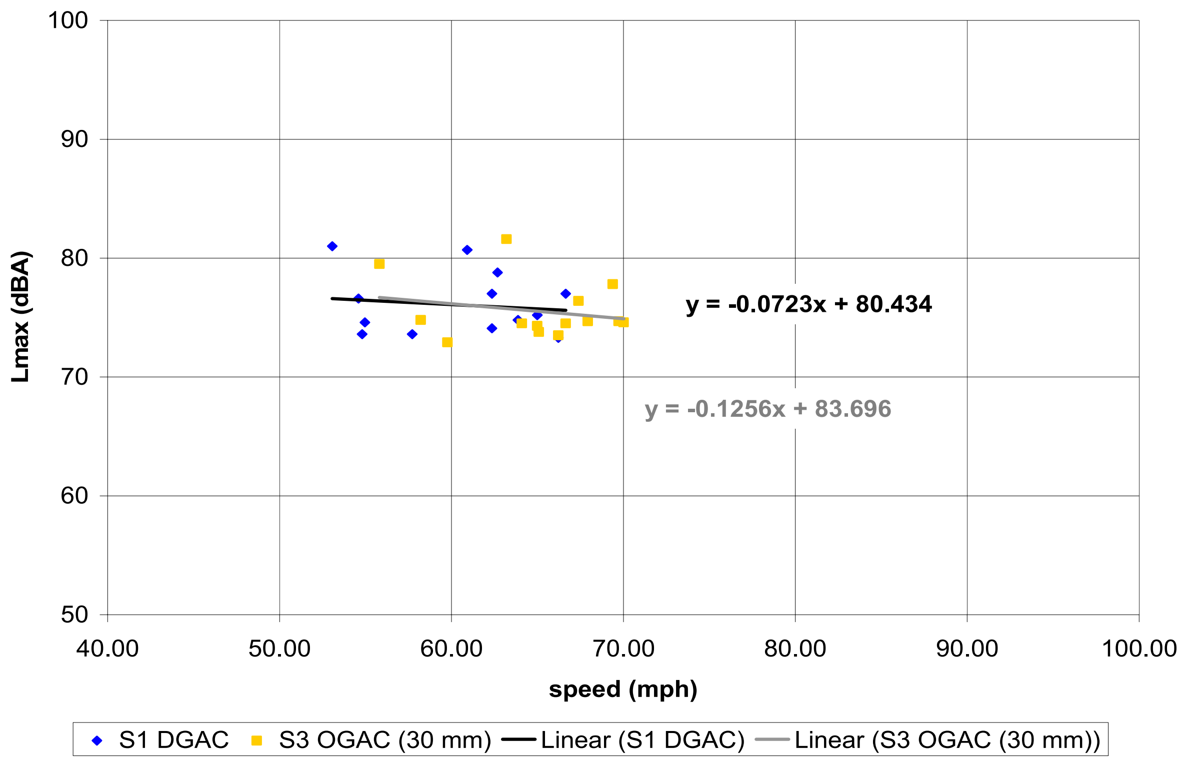


Figure C-40. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
y = 0.1944x + 58.939
y = 0.1014x + 63.403
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
Lmax (dBA)
y = -0.0723x + 80.434
y = -0.1256x + 83.696
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

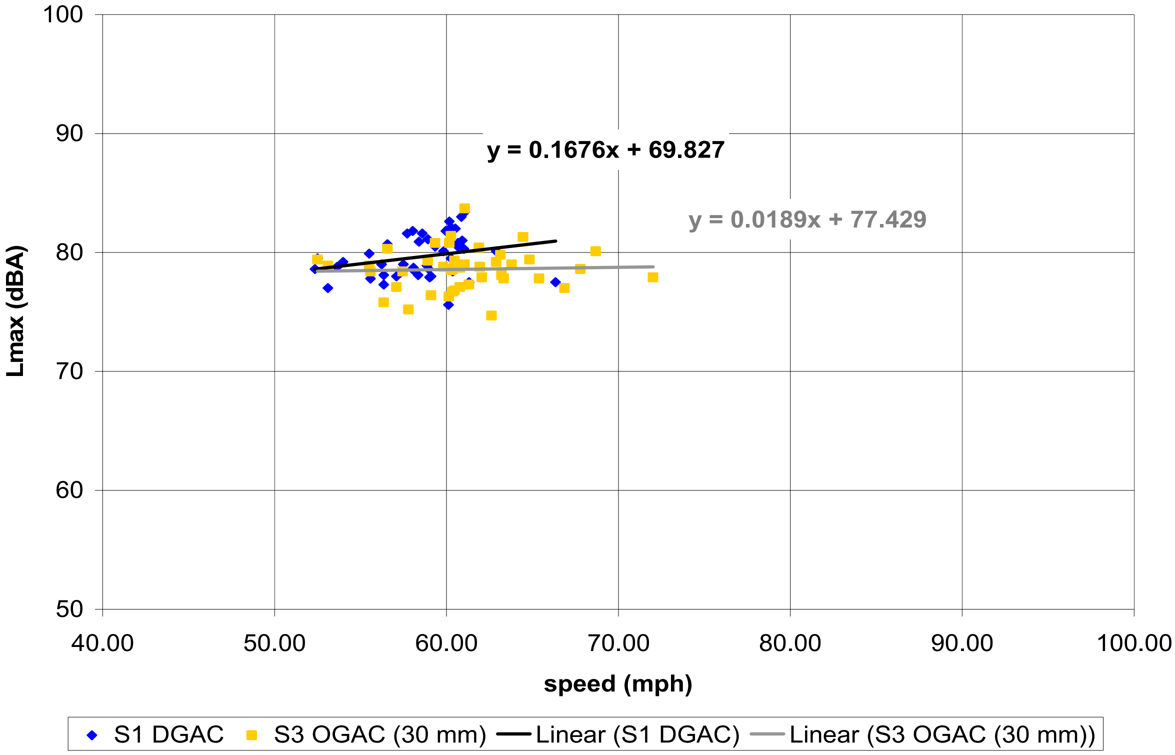
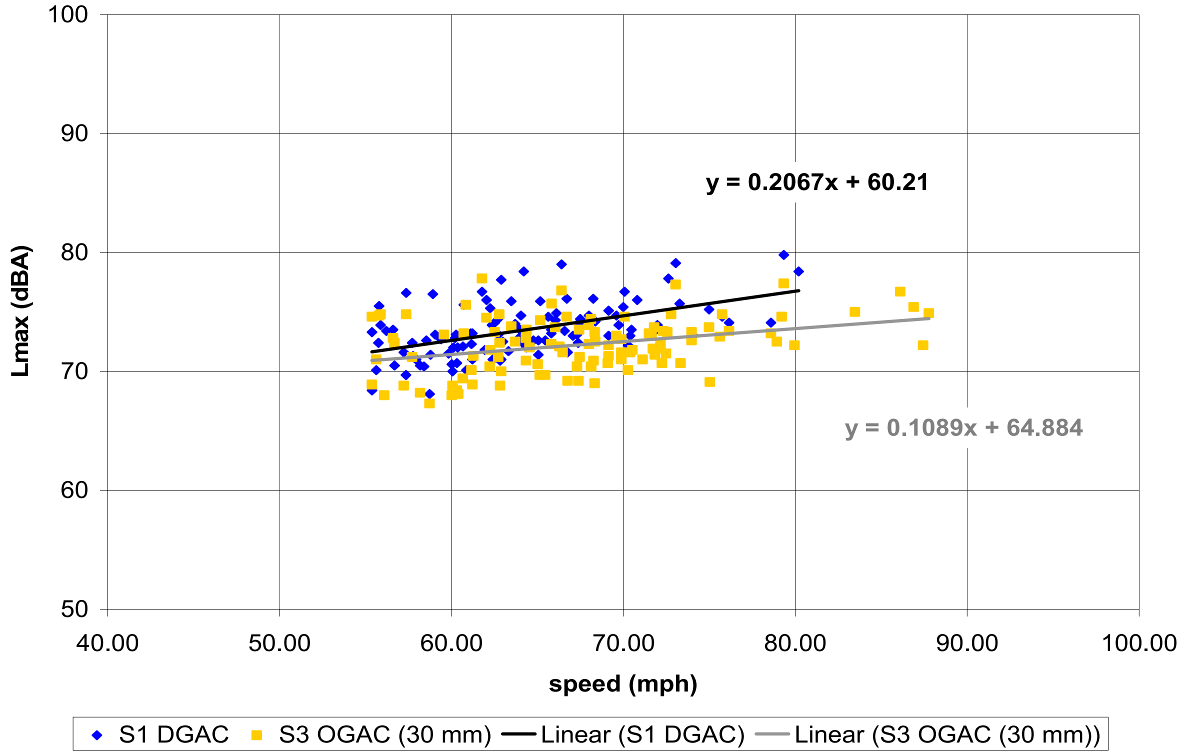
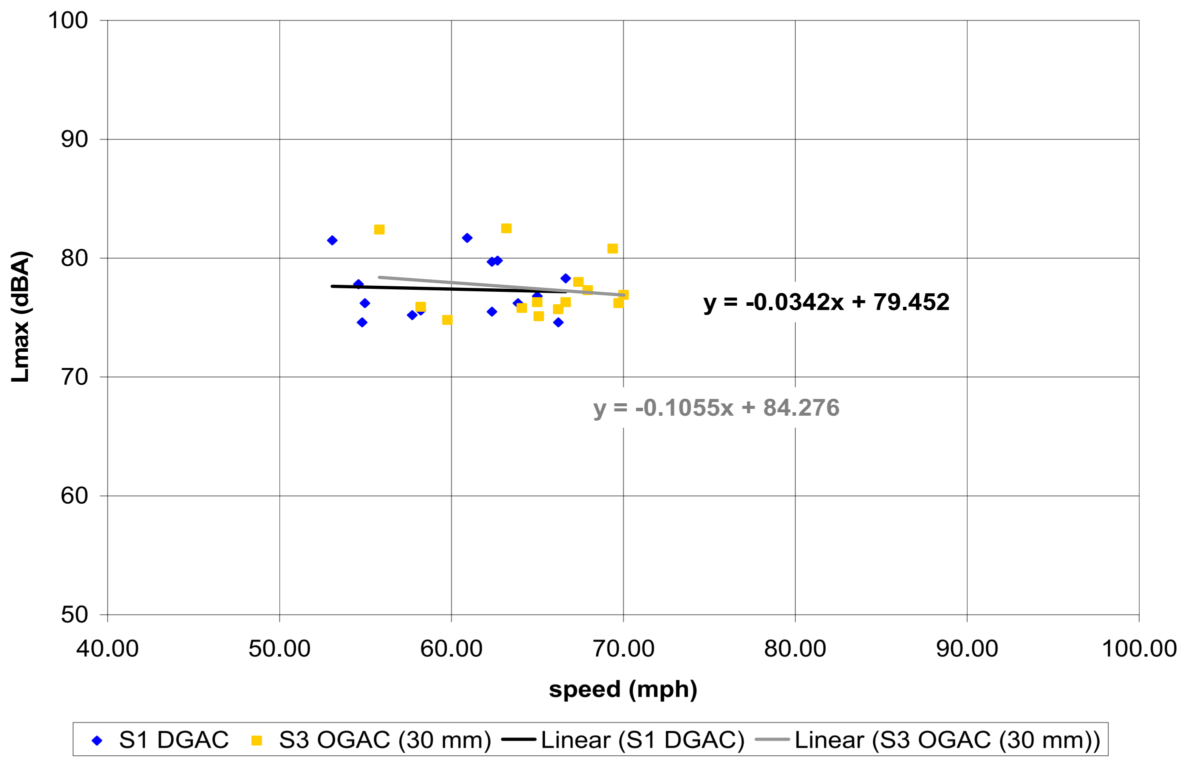


Figure C-41. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
y = 0.2067x + 60.21
y = 0.1089x + 64.884
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
Lmax (dBA)
y = -0.0342x + 79.452
y = -0.1055x + 84.276
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

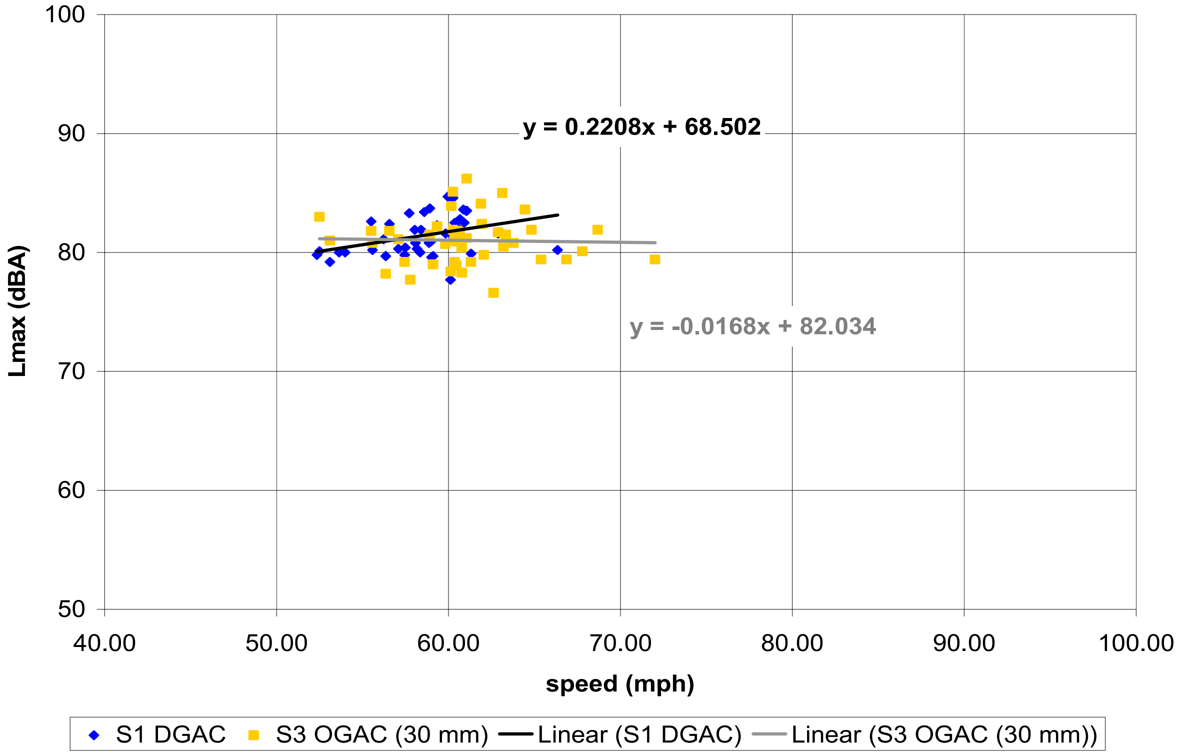
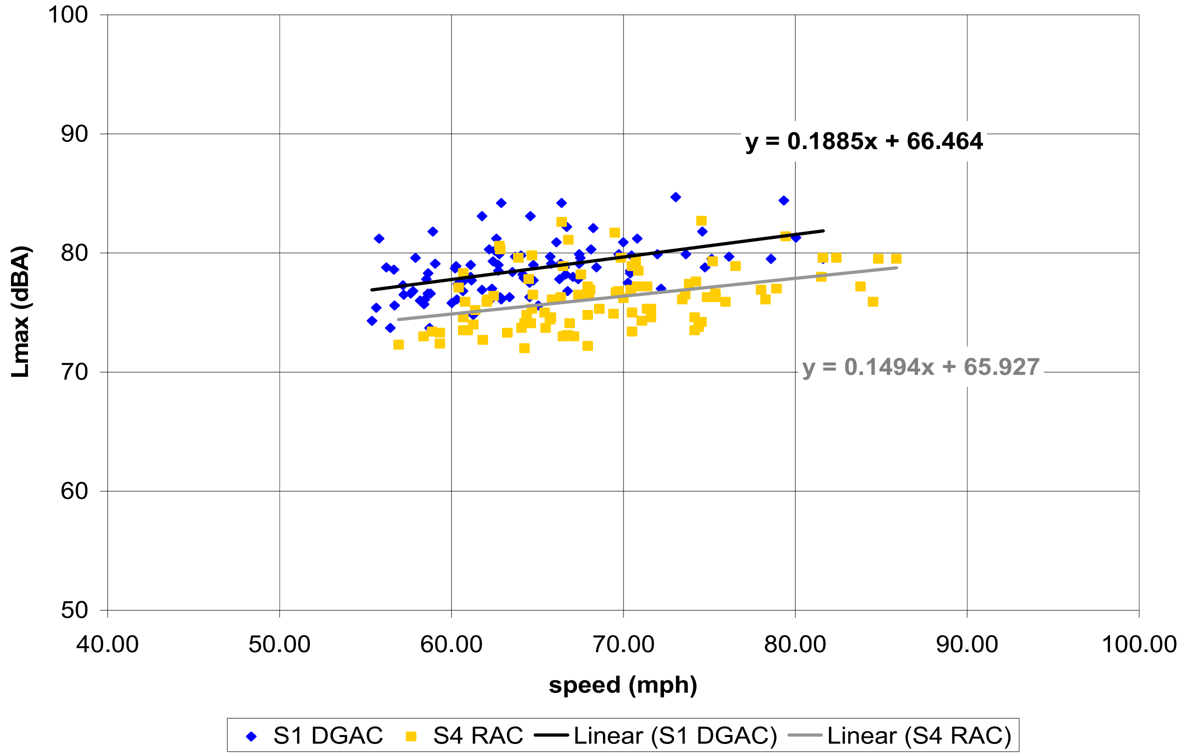
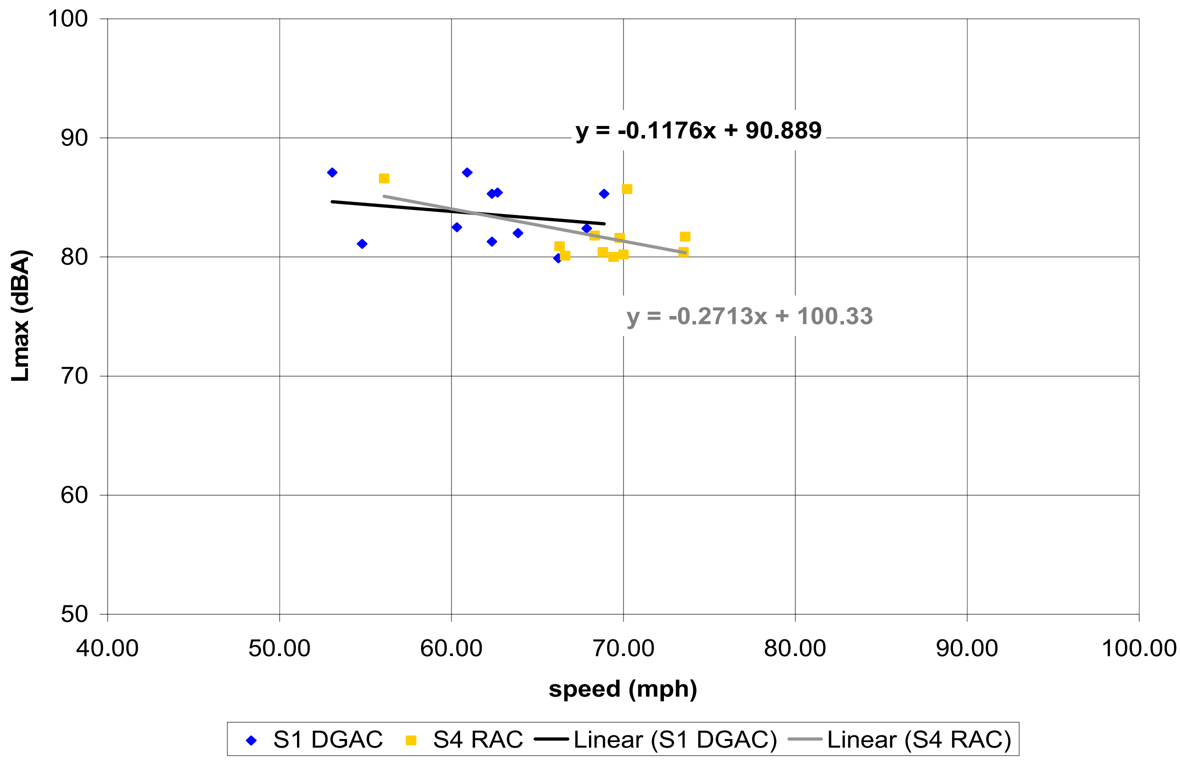


Figure C-42. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
Lmax (dBA)
y = 0.1885x + 66.464
y = 0.1494x + 65.927
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



100
90
80
70
60
50
Lmax (dBA)
y = -0.1176x + 90.889
y = -0.2713x + 100.33
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

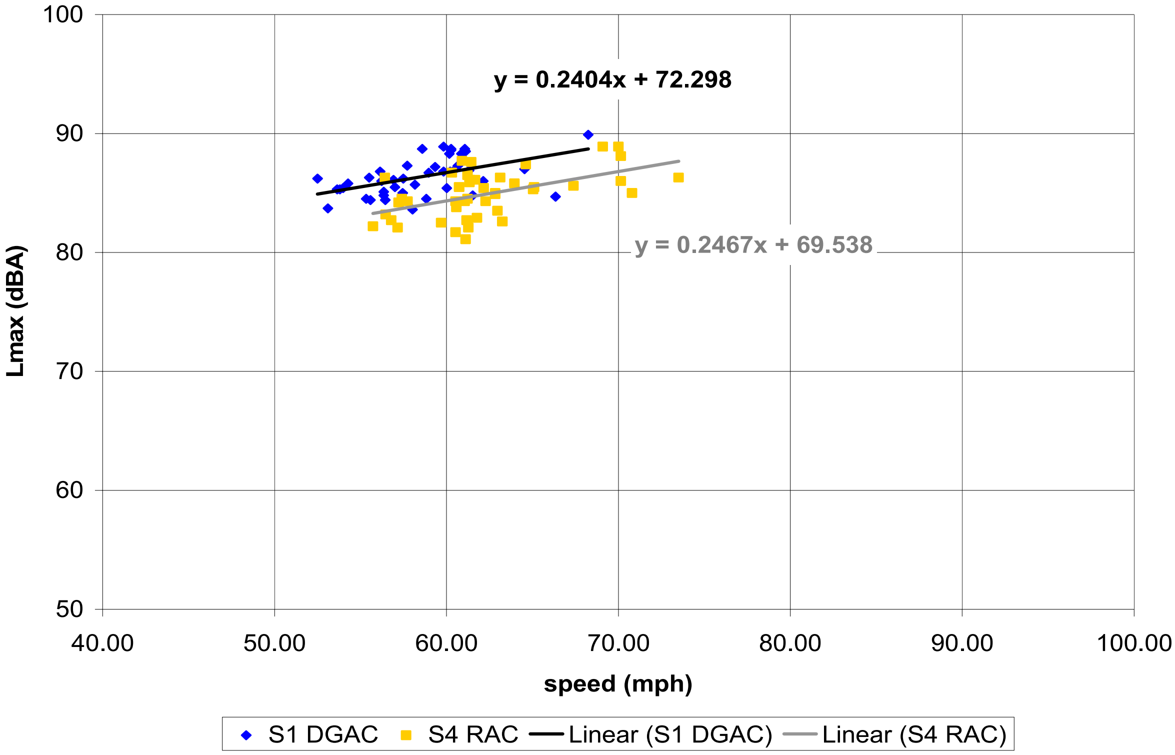
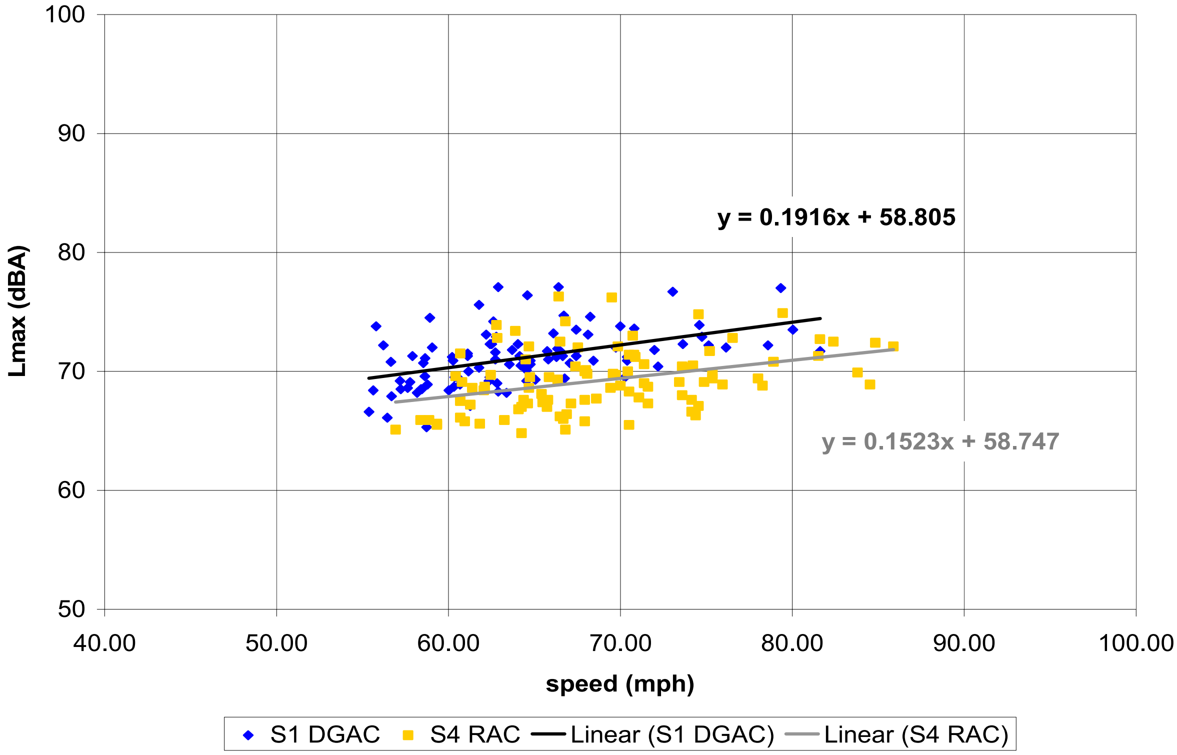
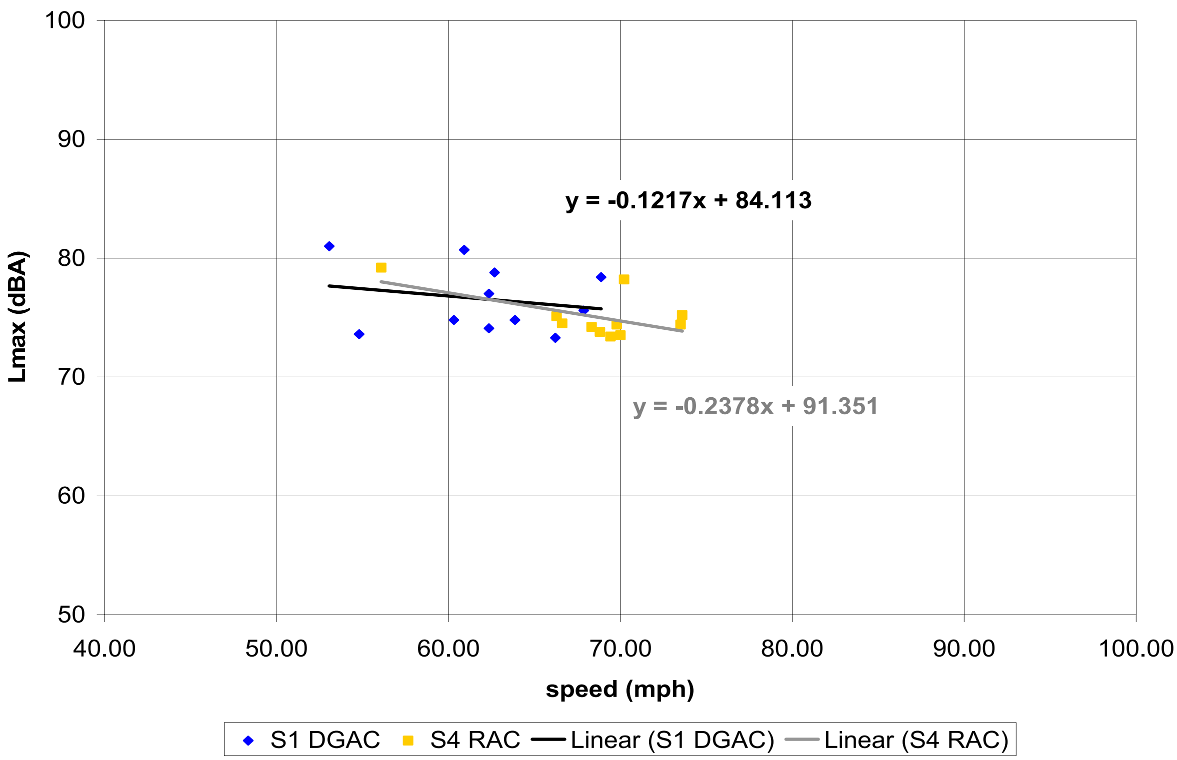


Figure C-43. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
y = 0.1916x + 58.805
y = 0.1523x + 58.747
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



100
90
80
70
60
50
Lmax (dBA)
y = -0.1217x + 84.113
y = -0.2378x + 91.351
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

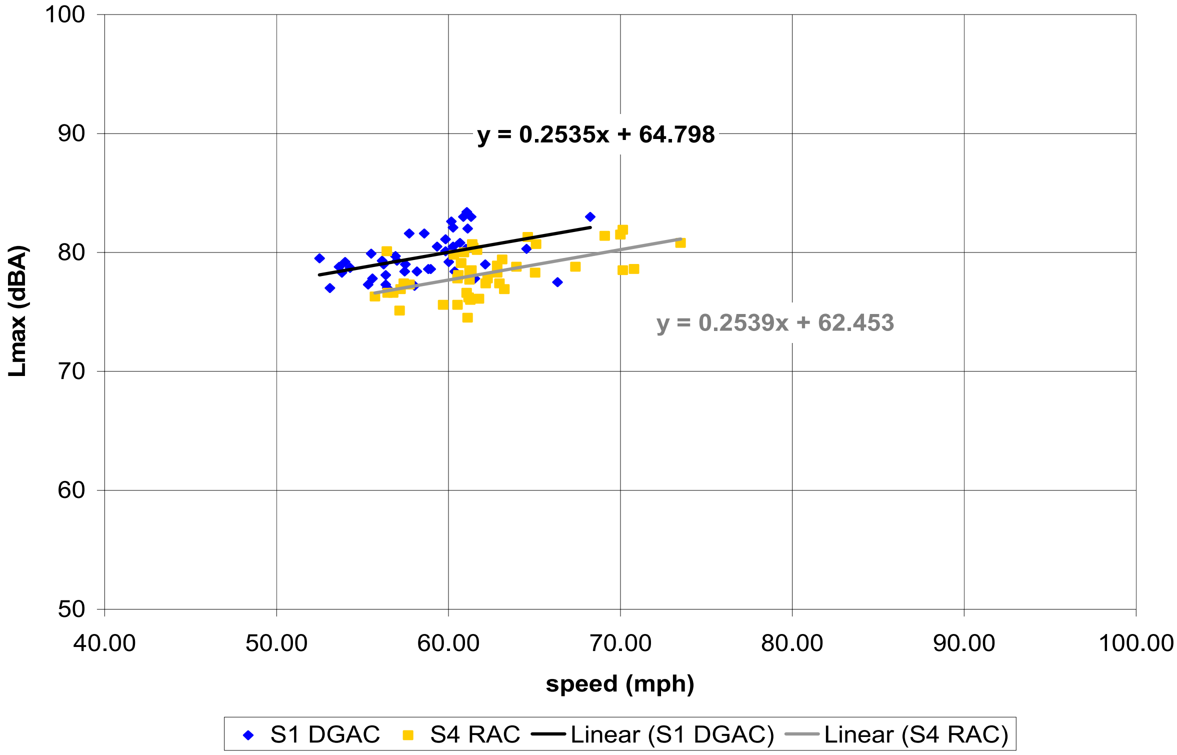
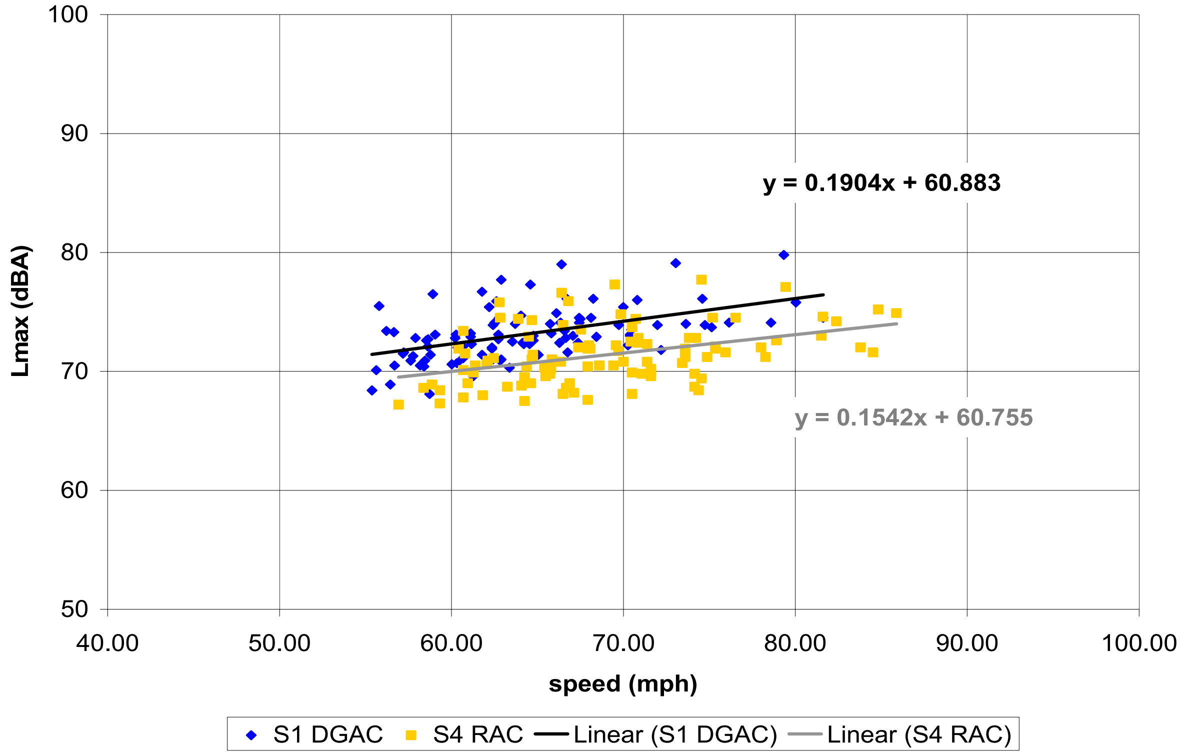
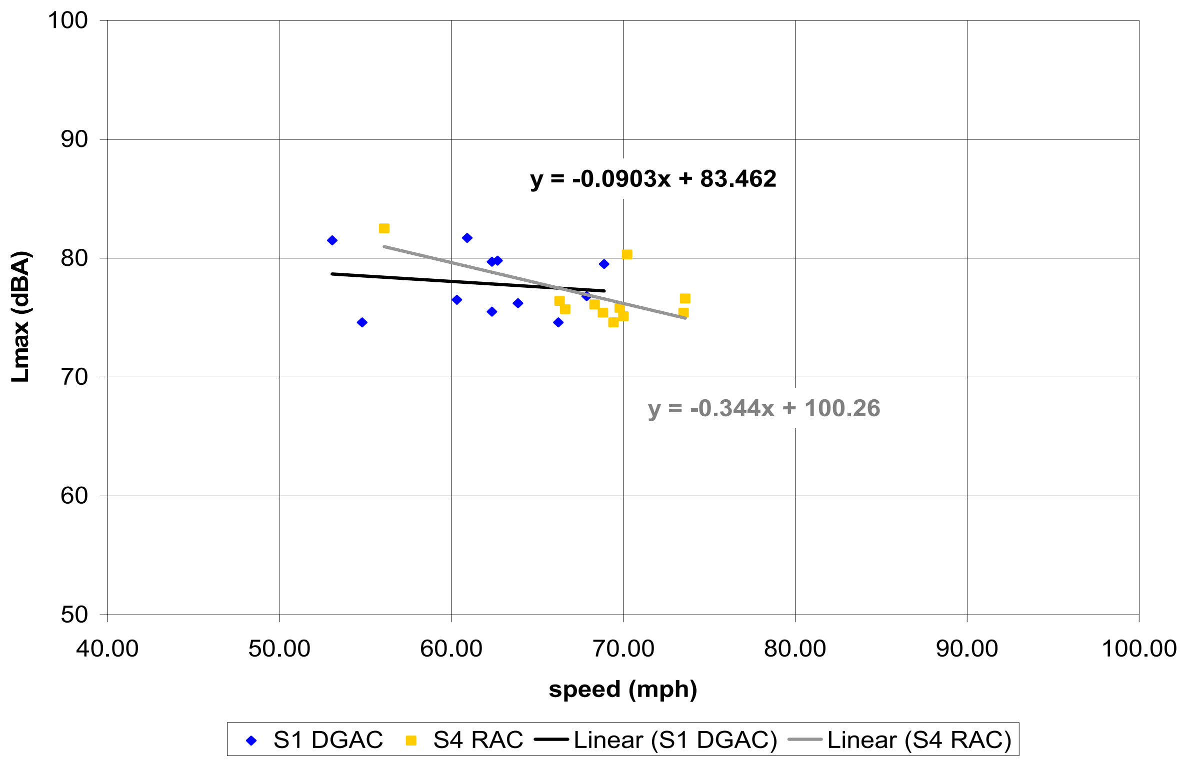


Figure C-44. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
y = 0.1904x + 60.883
y = 0.1542x + 60.755
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
Lmax (dBA)
y = -0.0903x + 83.462
y = -0.344x + 100.26
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

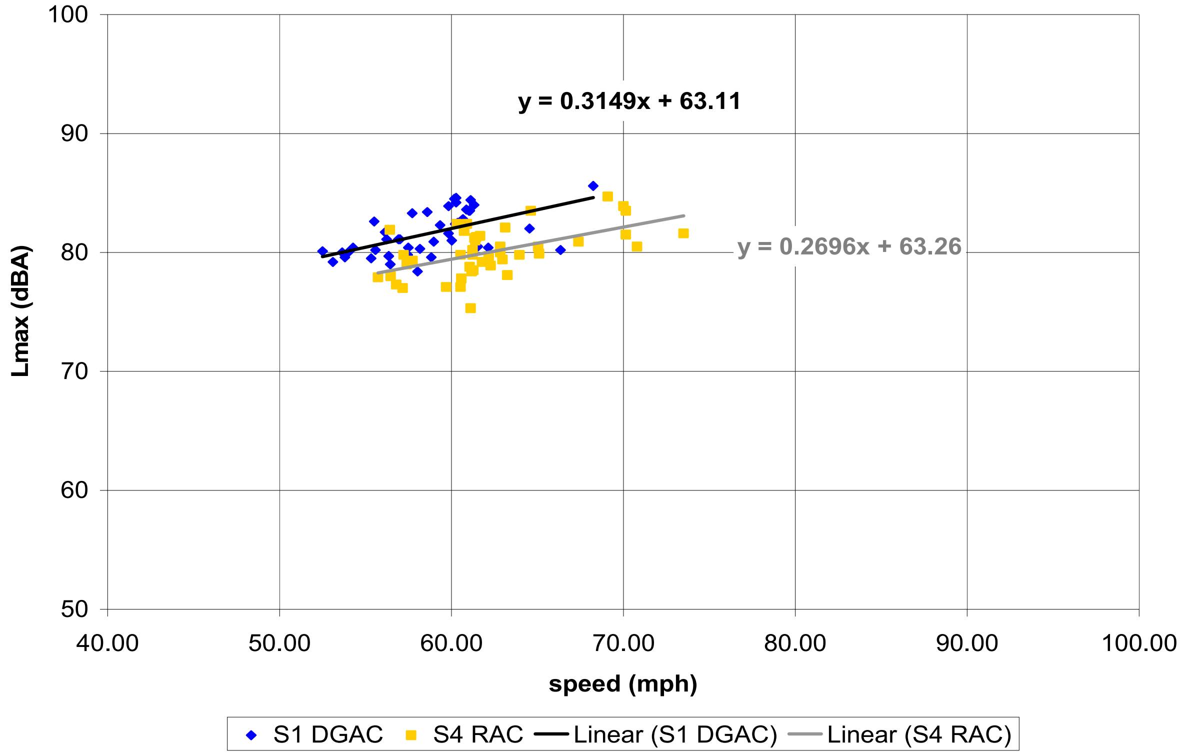
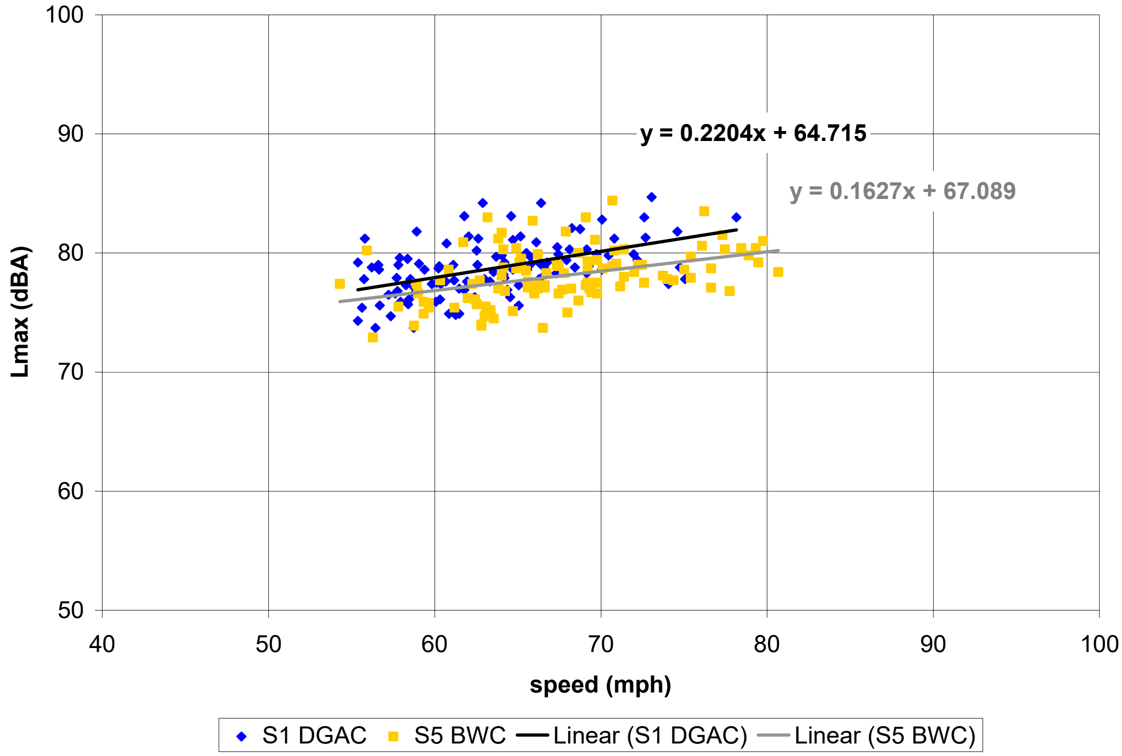
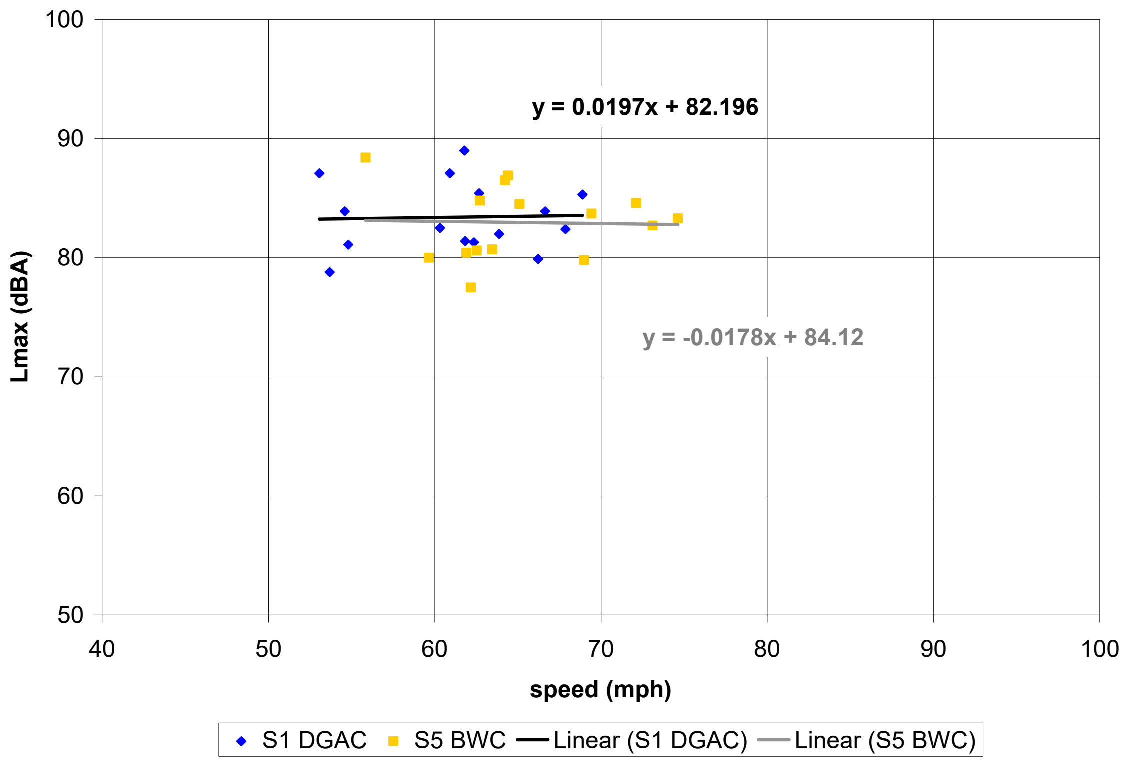


Figure C-45. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2204x + 64.715
y = 0.1627x + 67.089
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.0197x + 82.196
y = -0.0178x + 84.12
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

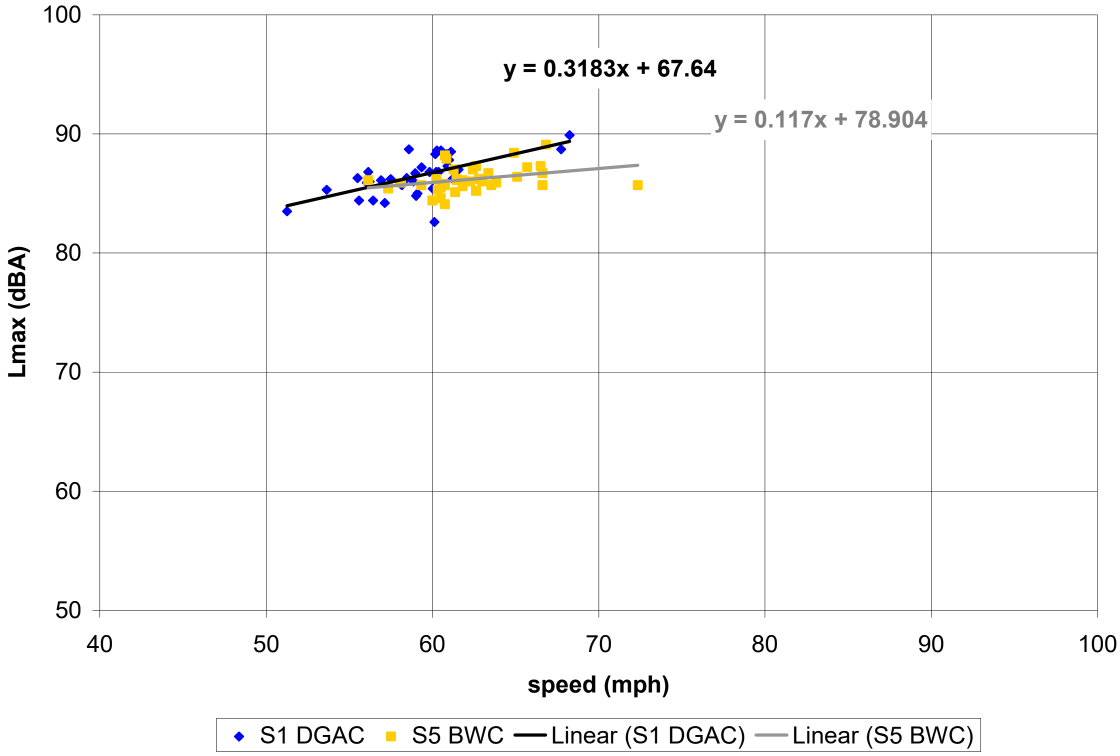
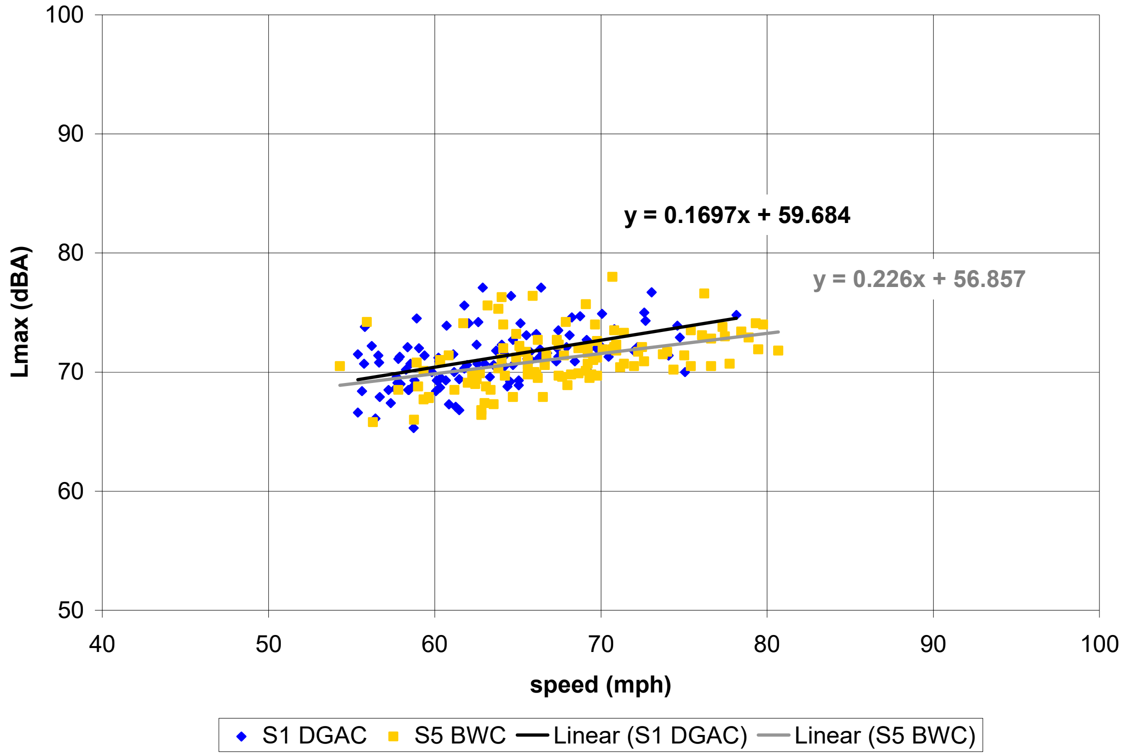
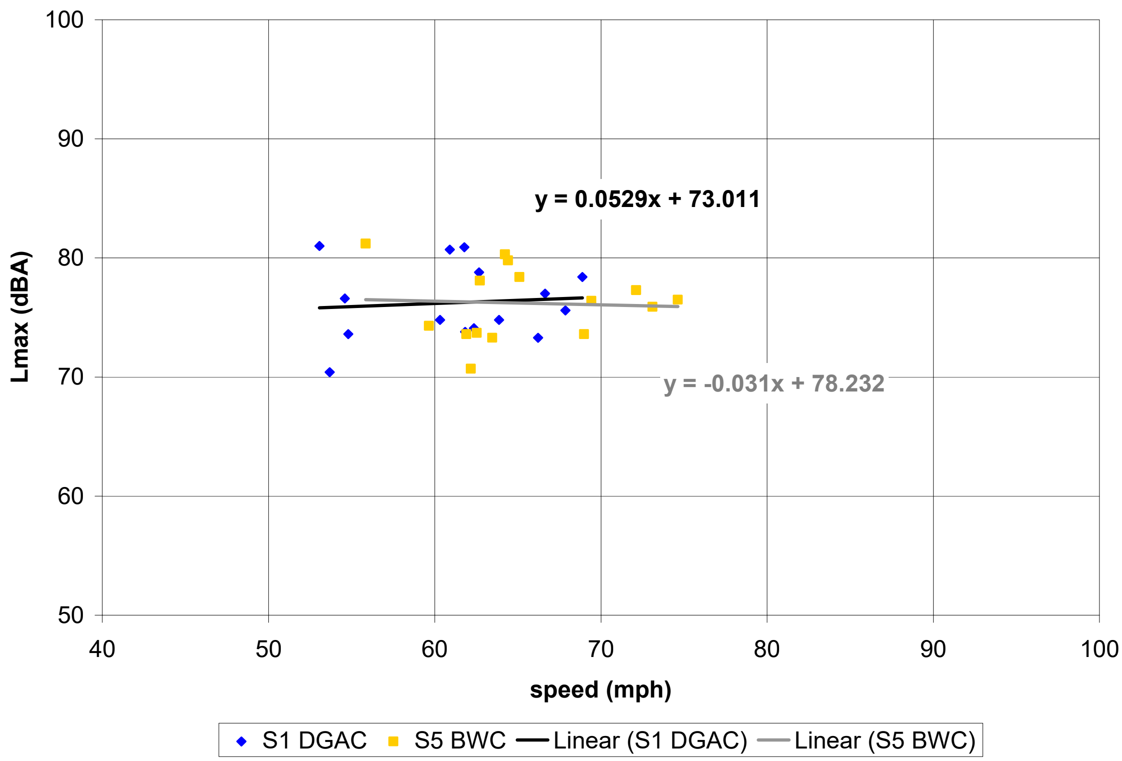


Figure C-46. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1697x + 59.684
y = 0.226x + 56.857
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0529x + 73.011
y = -0.031x + 78.232
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

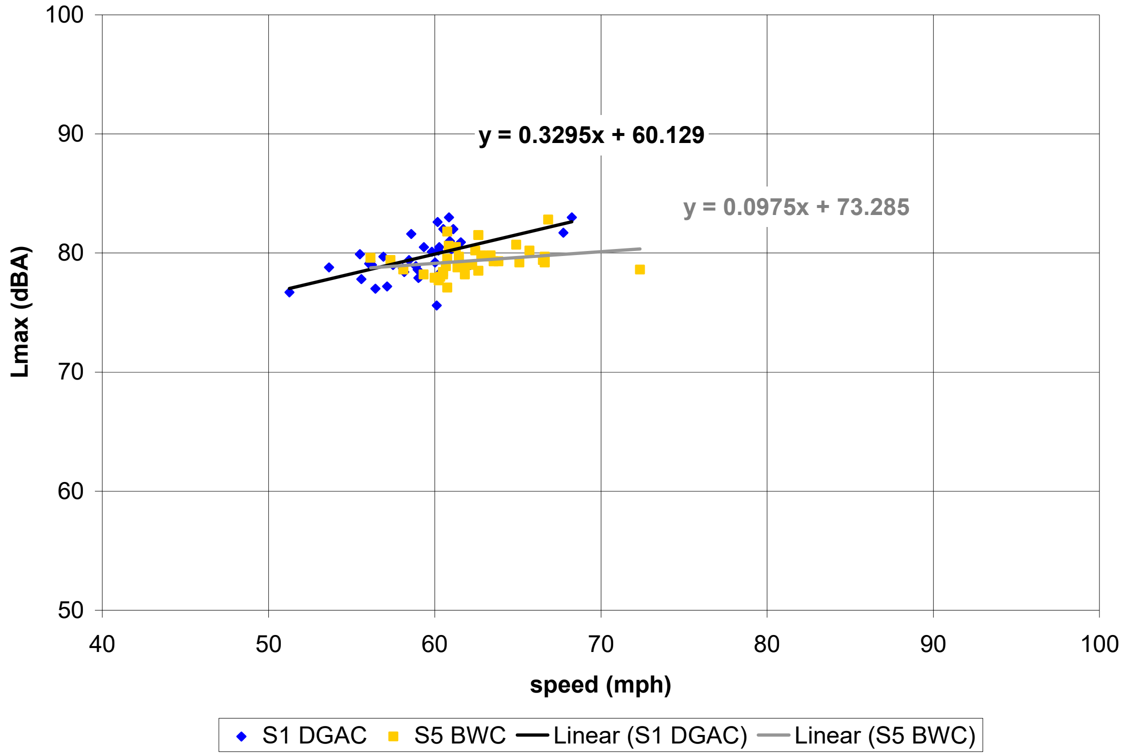
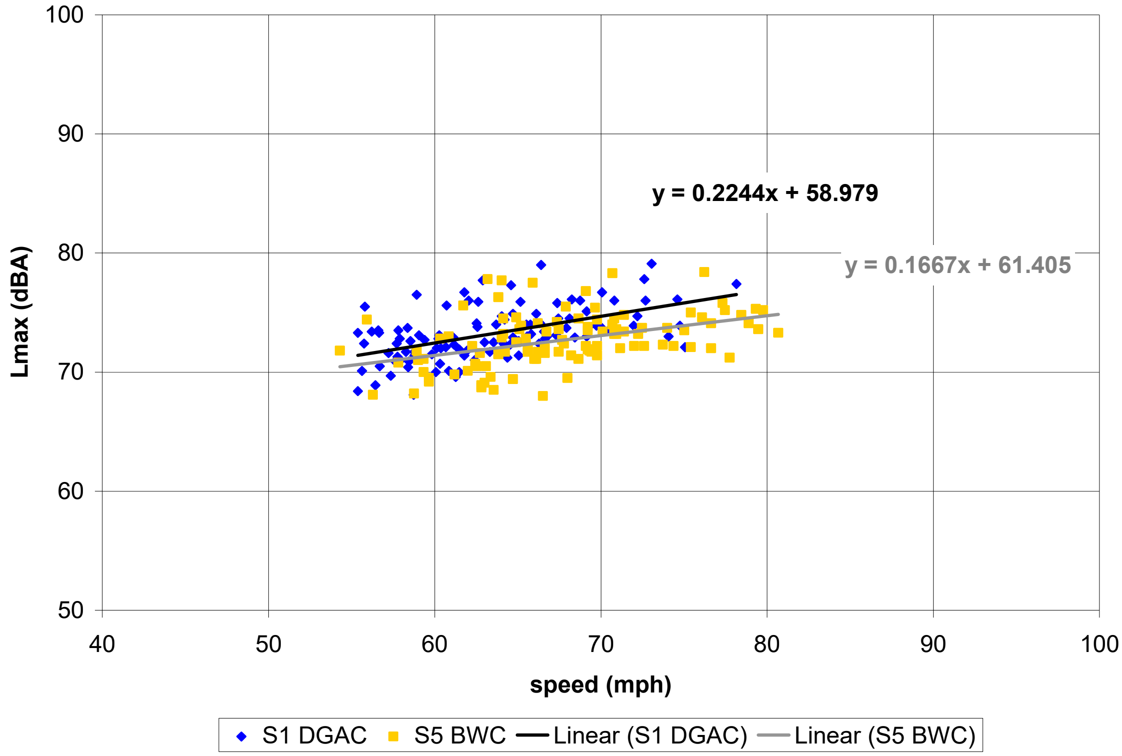
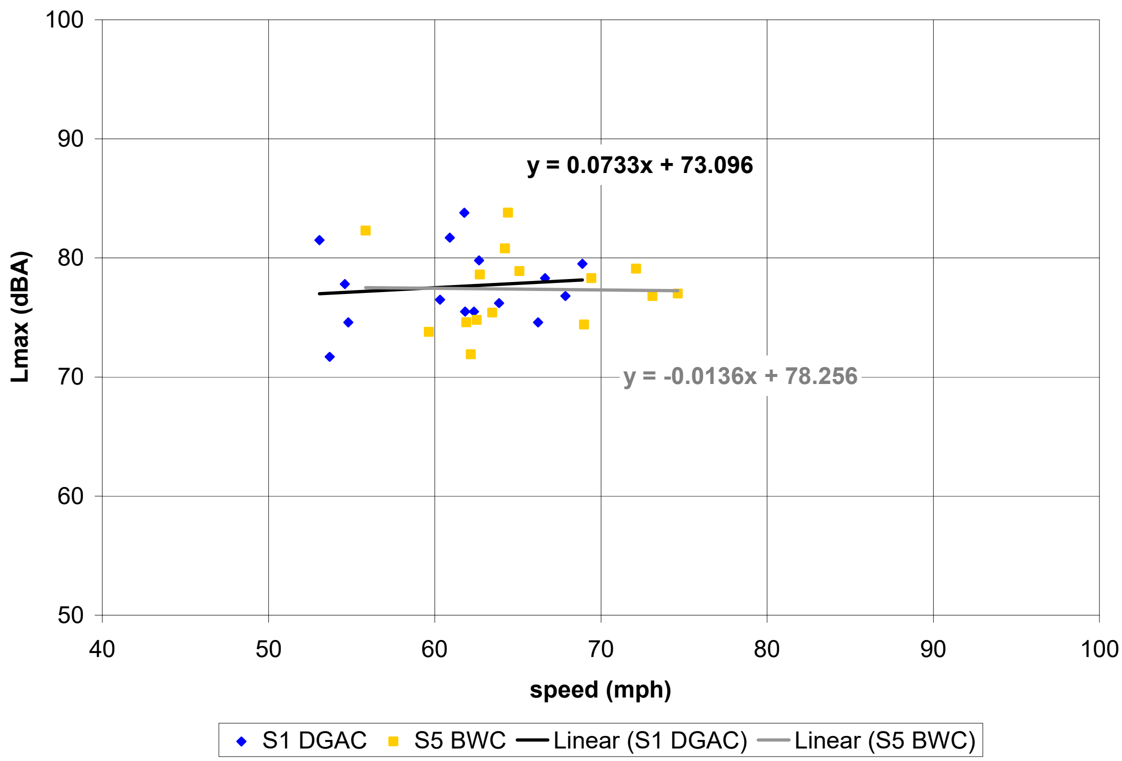


Figure C-47. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2244x + 58.979
y = 0.1667x + 61.405
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0733x + 73.096
y = -0.0136x + 78.256
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

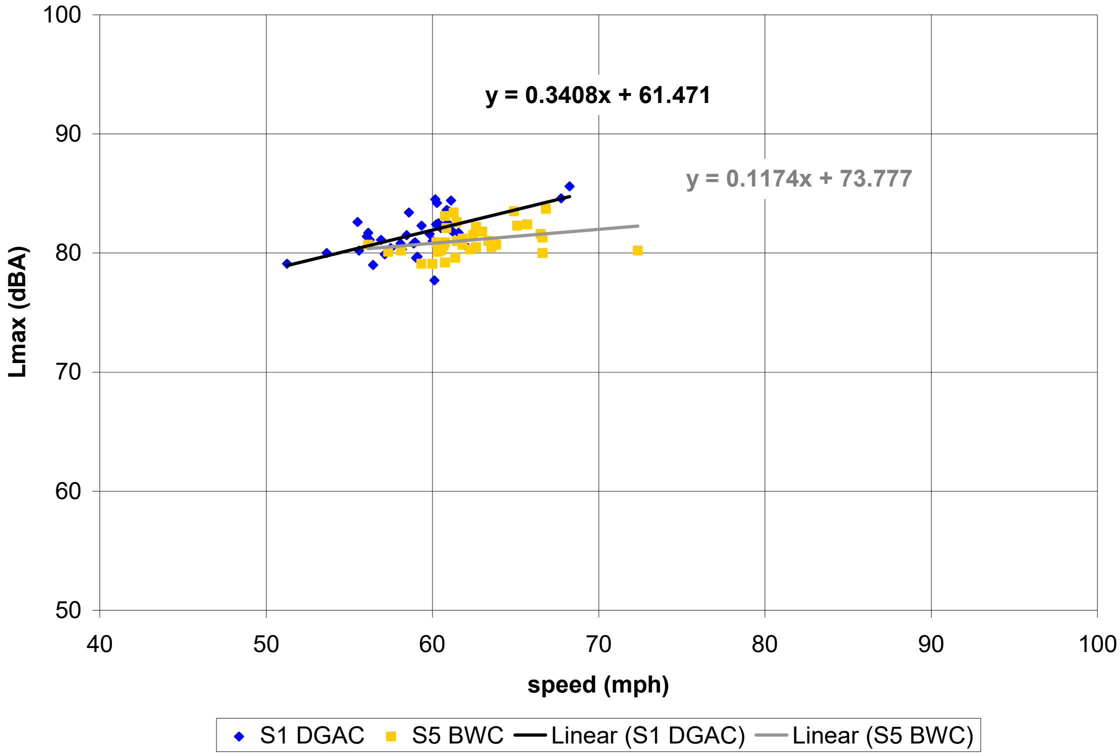
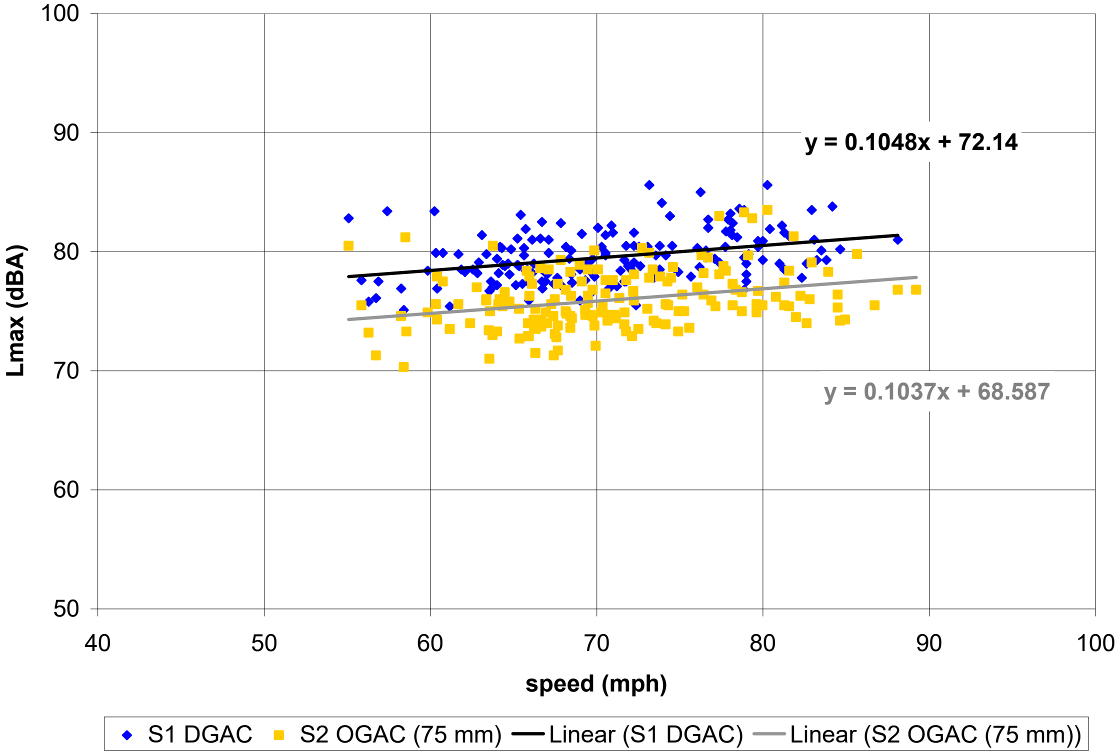
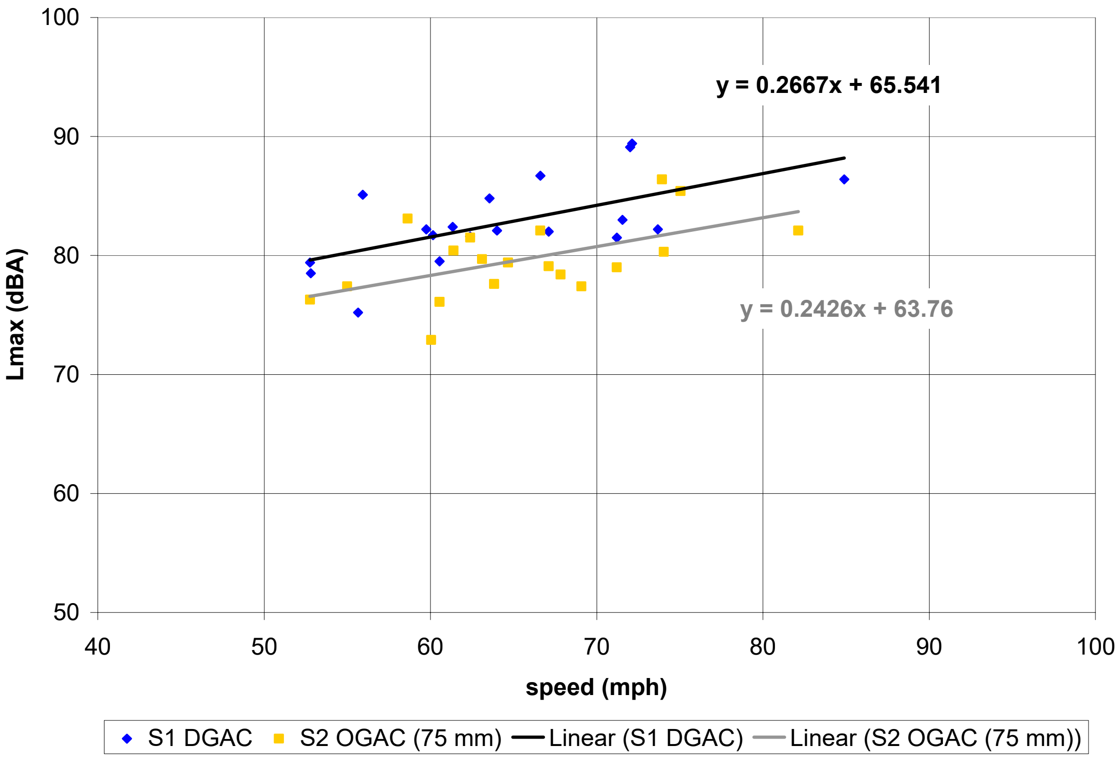


Figure C-48. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.6 Post-Overlay – Pavement Age: 52 months





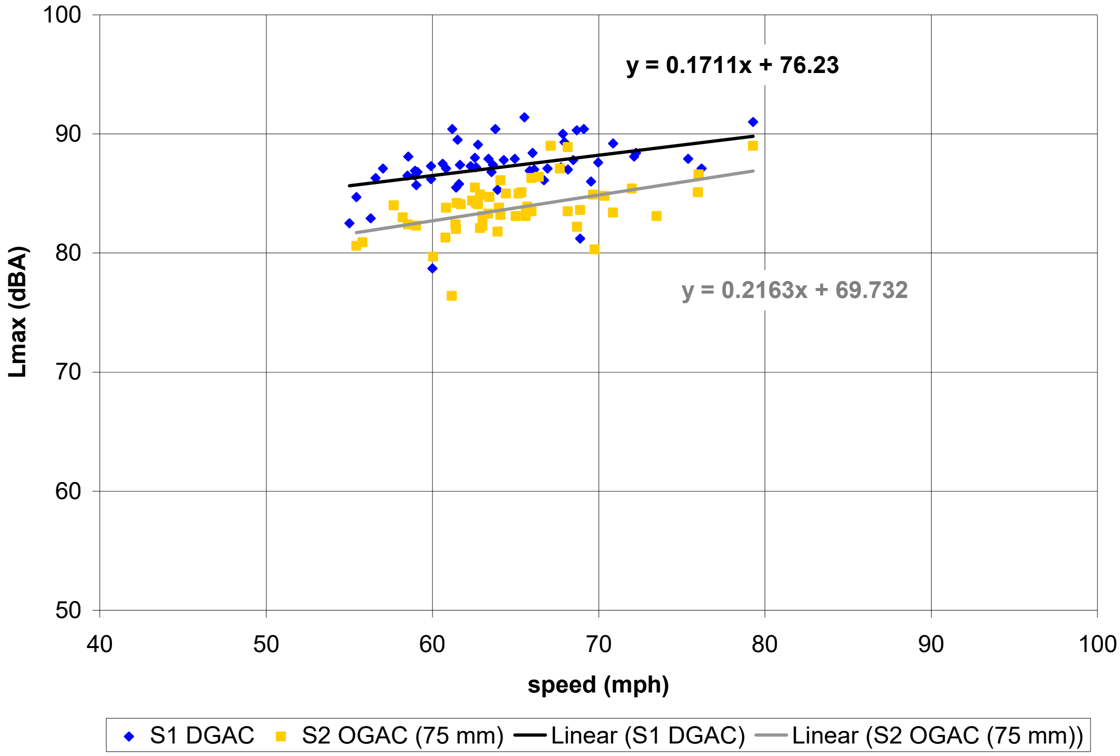
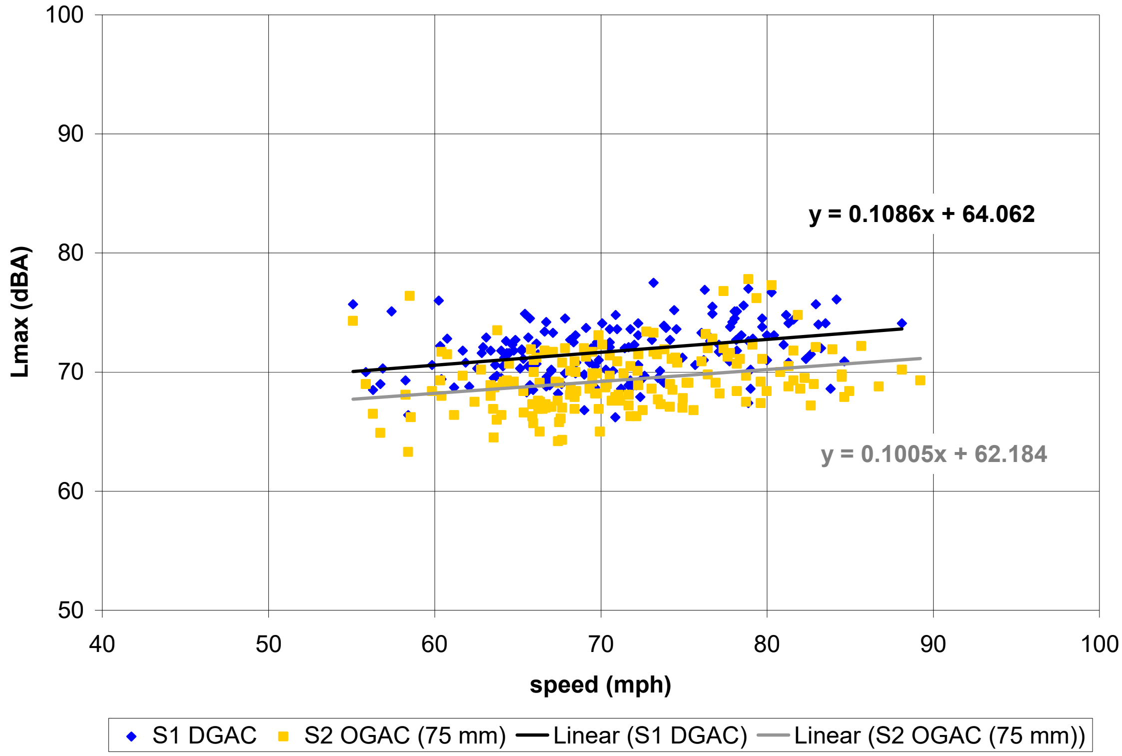
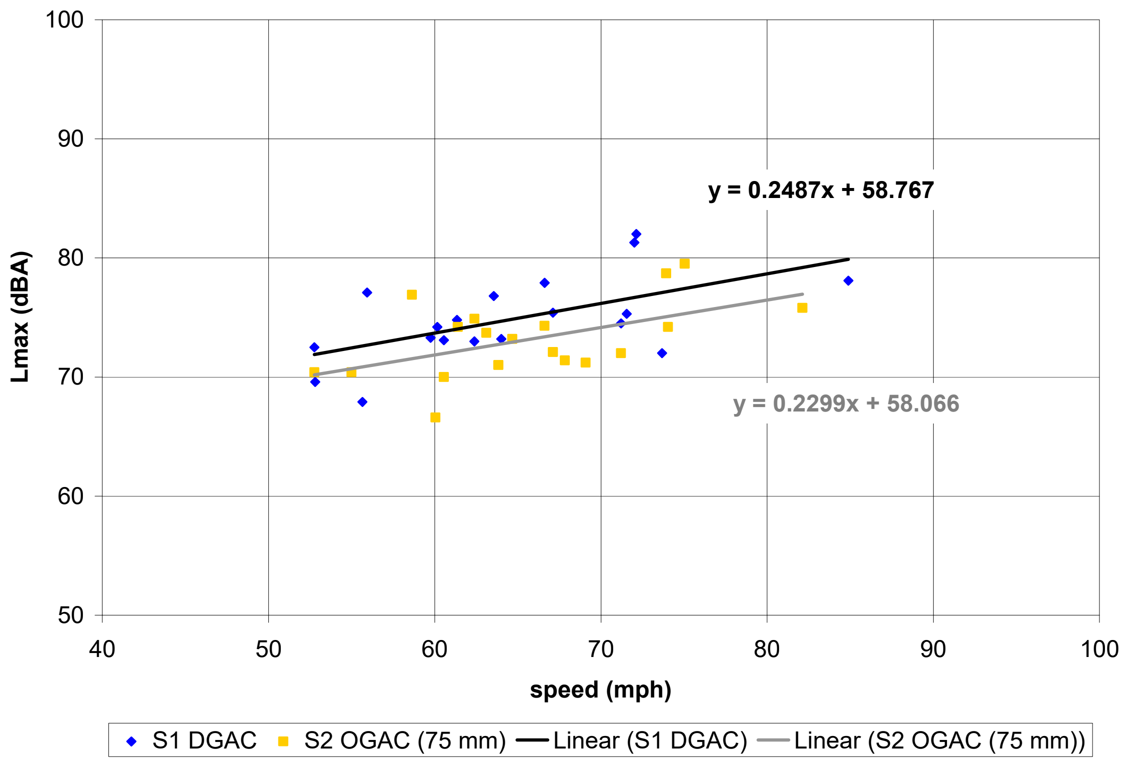


Figure C-49. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



y = 0.1086x + 64.062
y = 0.1005x + 62.184
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



y = 0.2487x + 58.767
y = 0.2299x + 58.066
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

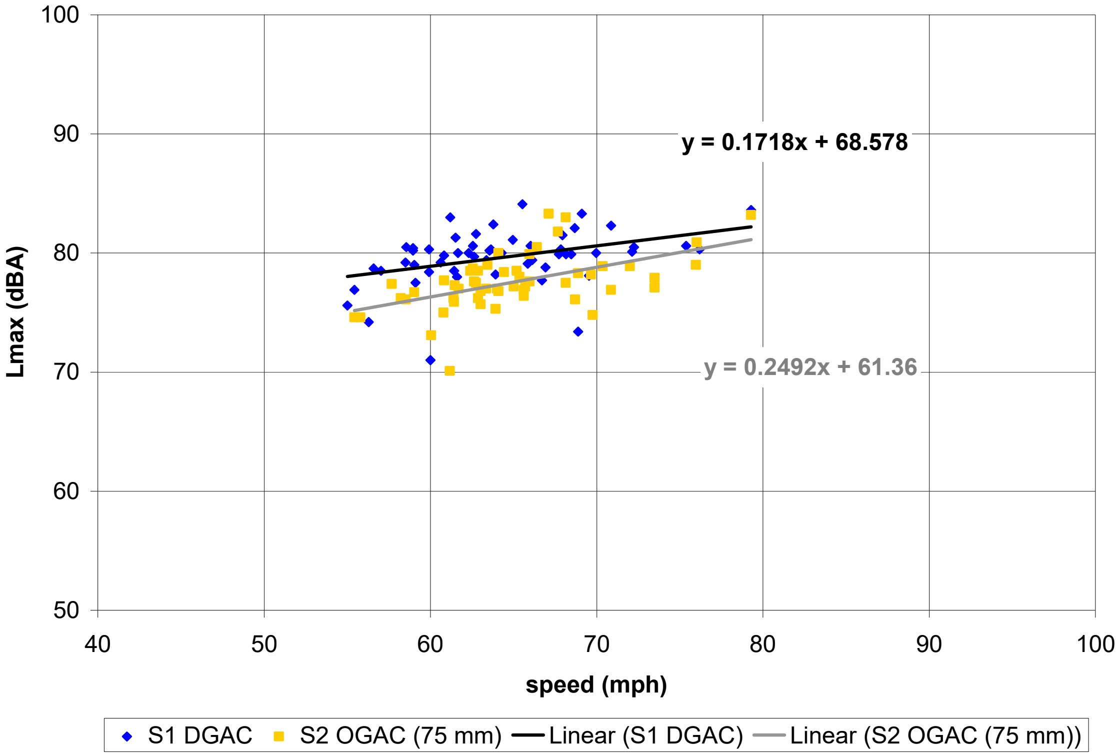
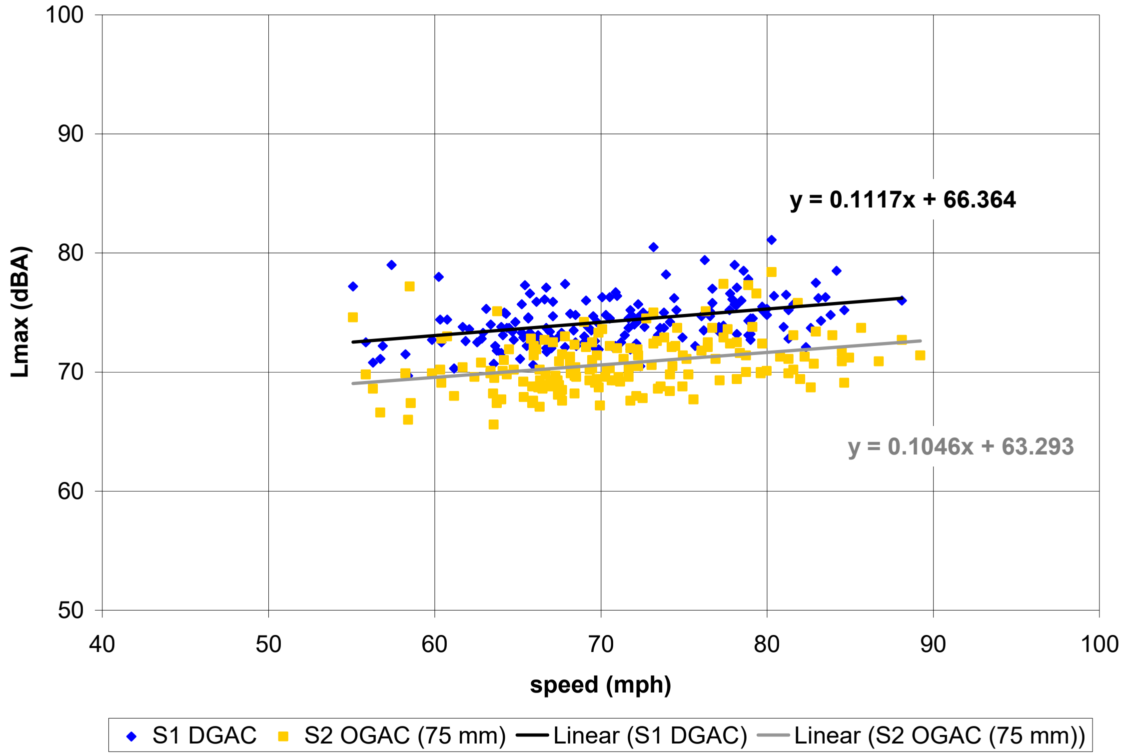
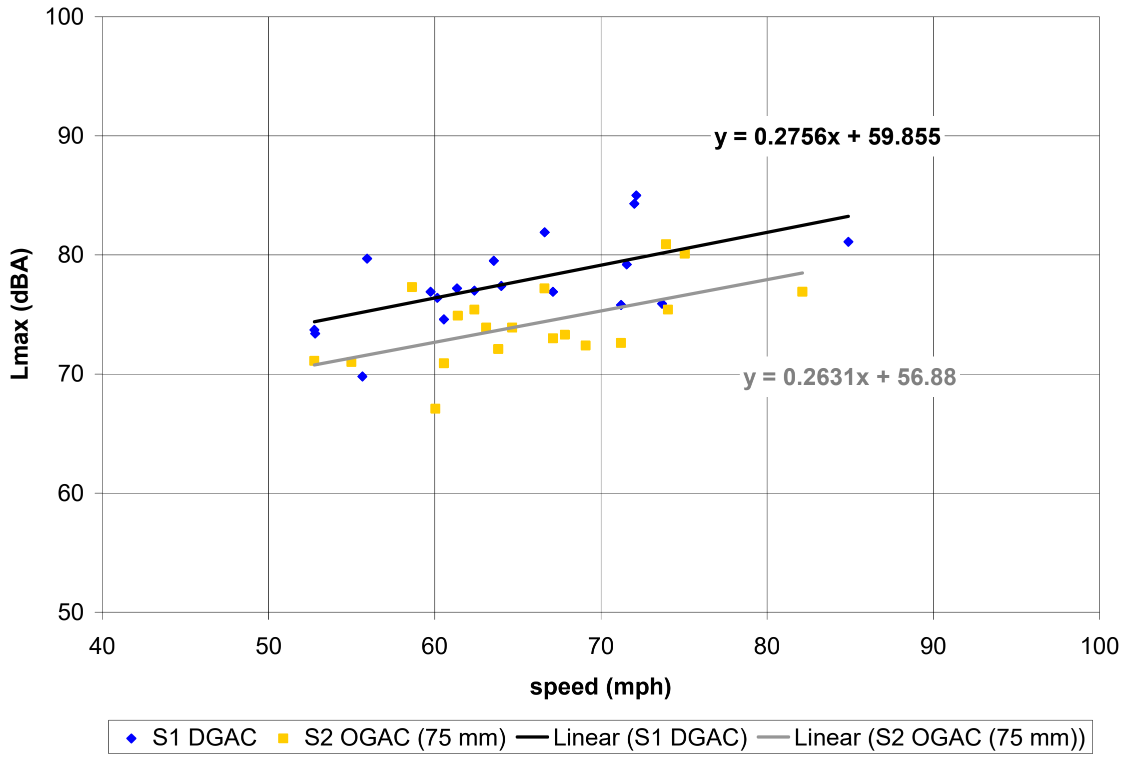


Figure C-50. Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1117x + 66.364
y = 0.1046x + 63.293
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2756x + 59.855
y = 0.2631x + 56.88
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

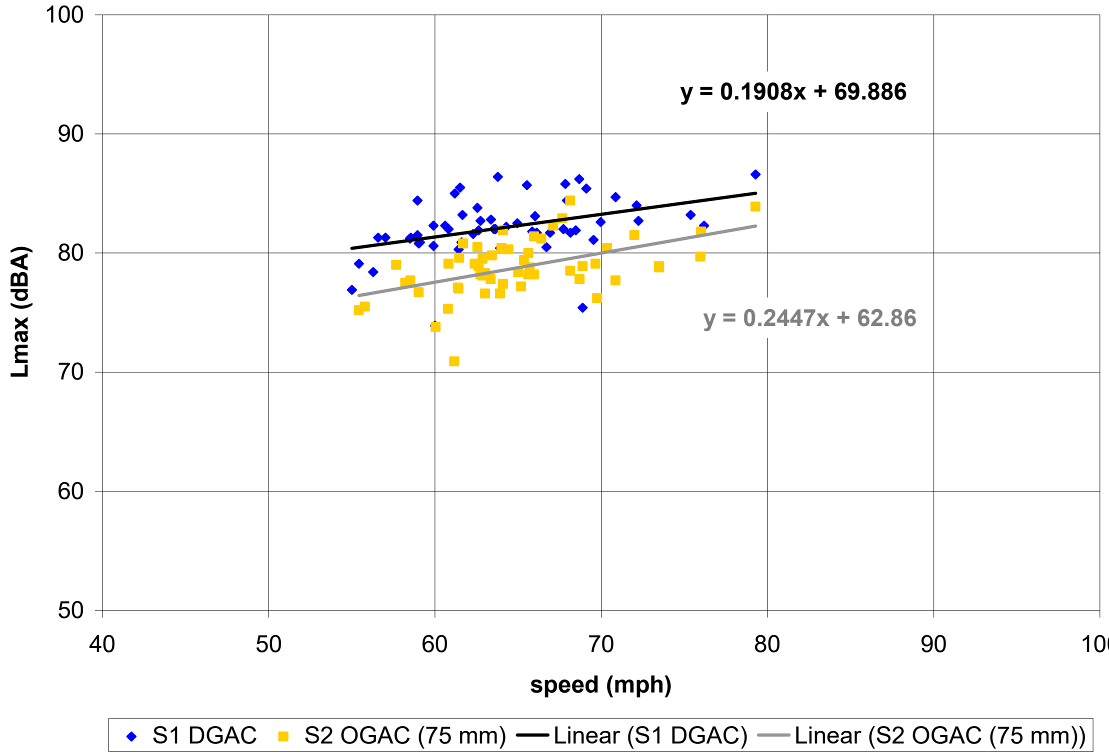
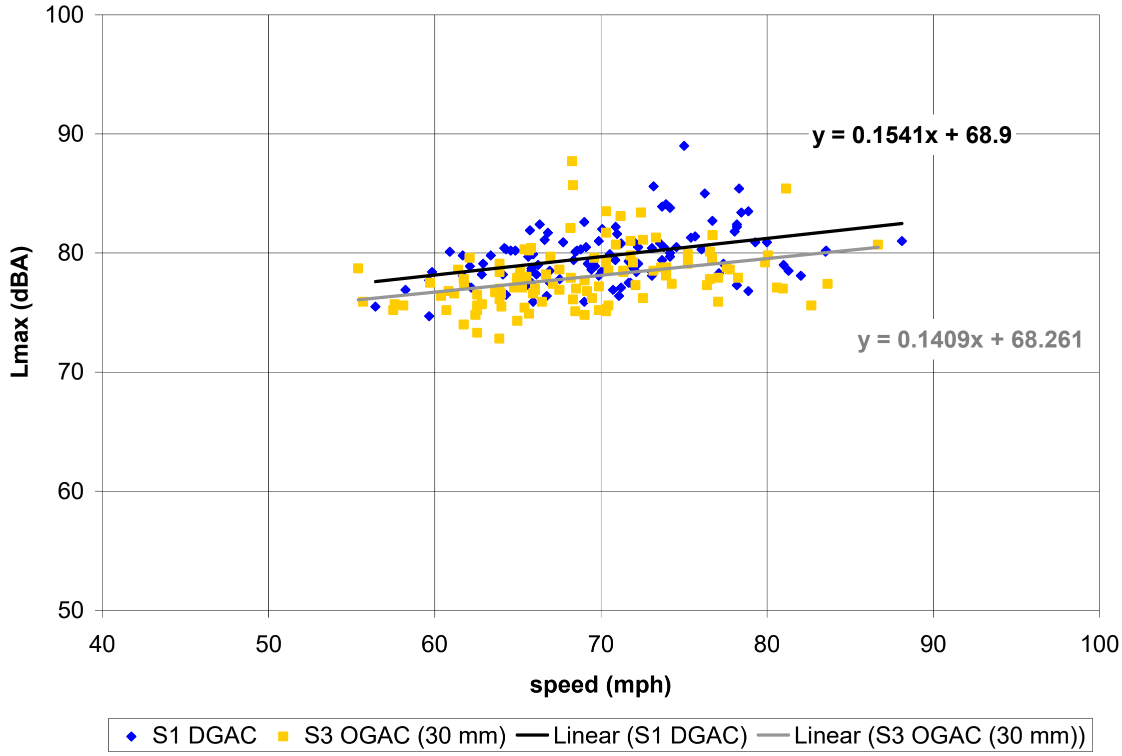
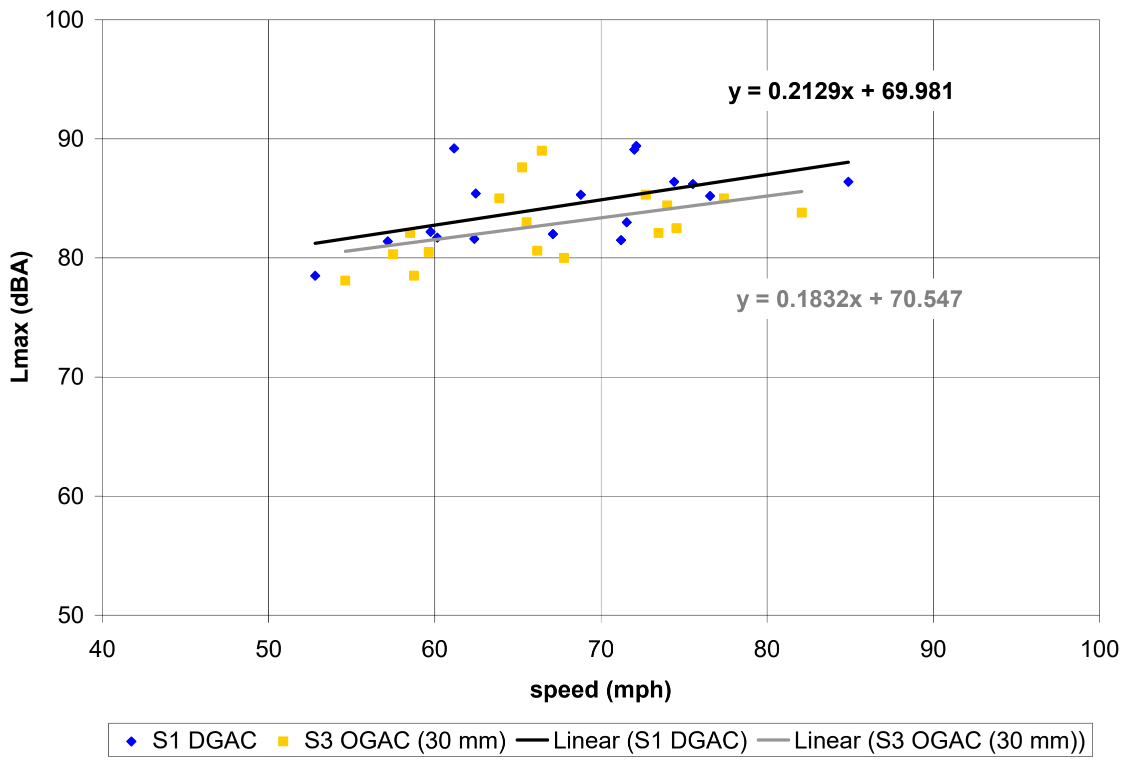


Figure C-51. Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1541x + 68.9
y = 0.1409x + 68.261
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2129x + 69.981
y = 0.1832x + 70.547
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

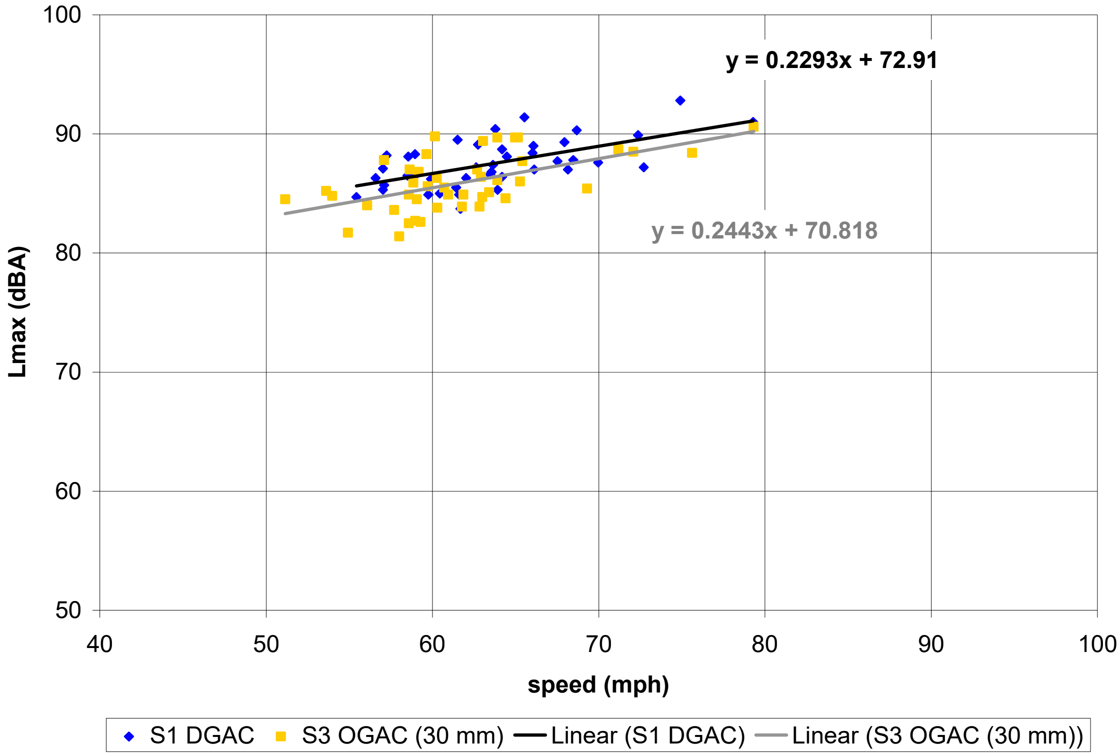
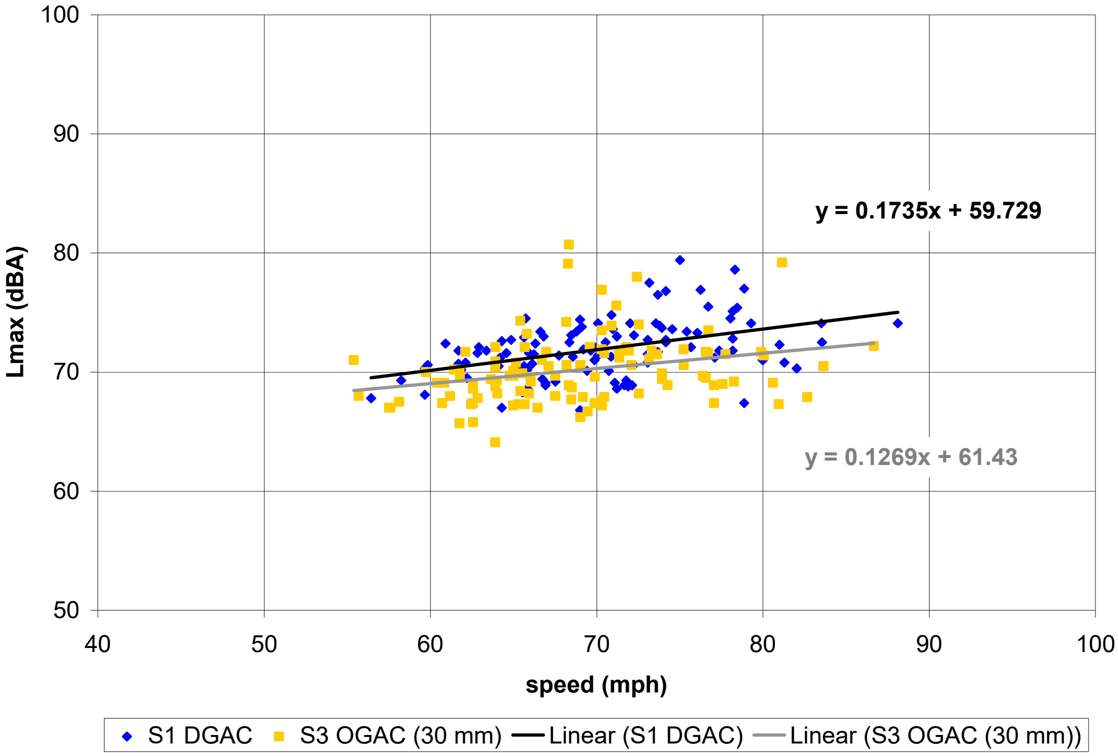
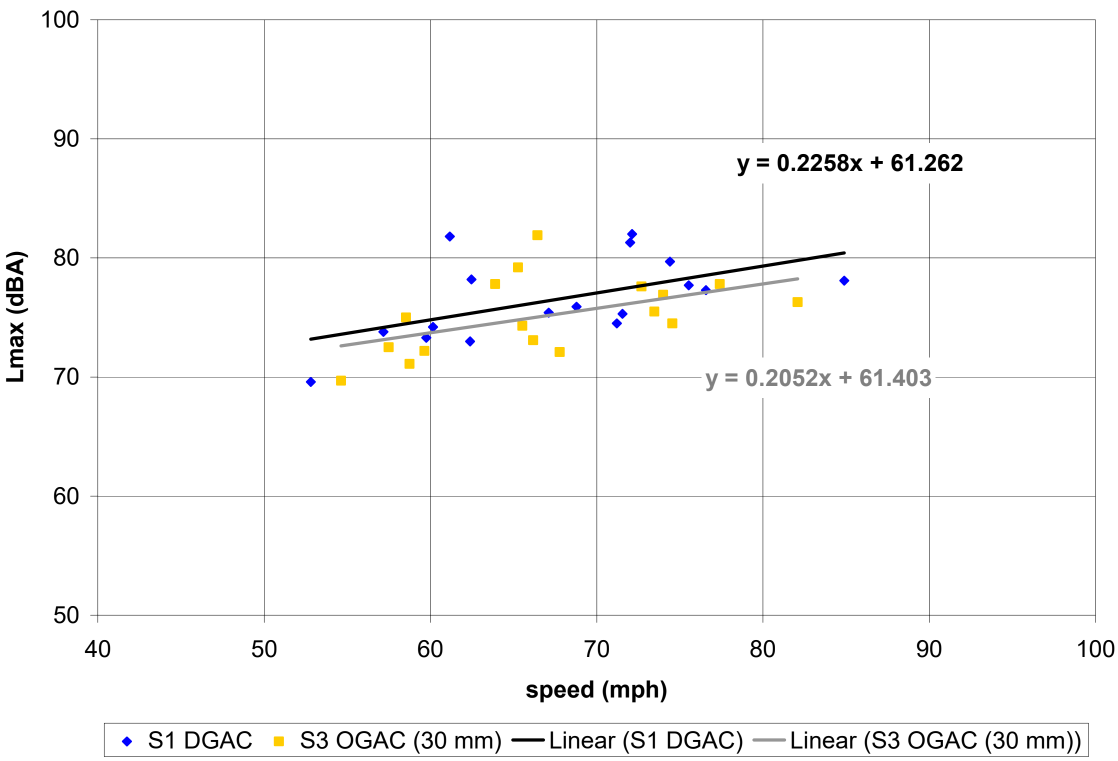


Figure C-52. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



y = 0.1735x + 59.729
y = 0.1269x + 61.43
Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



y = 0.2258x + 61.262
y = 0.2052x + 61.403
Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

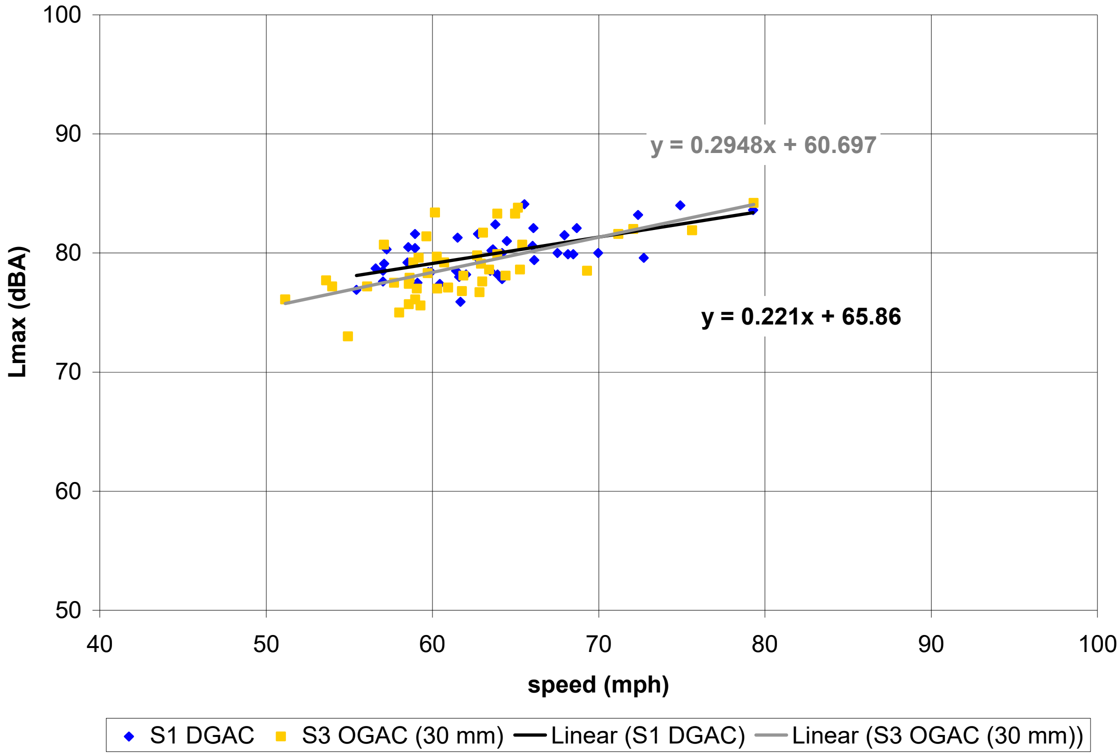
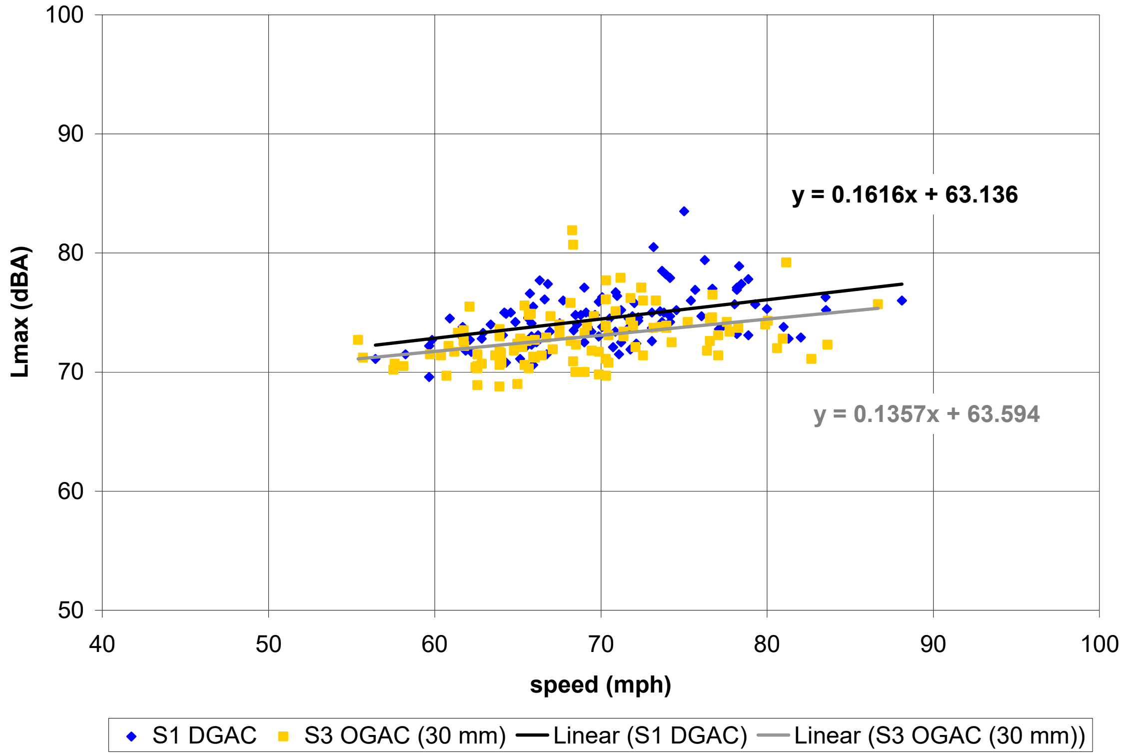
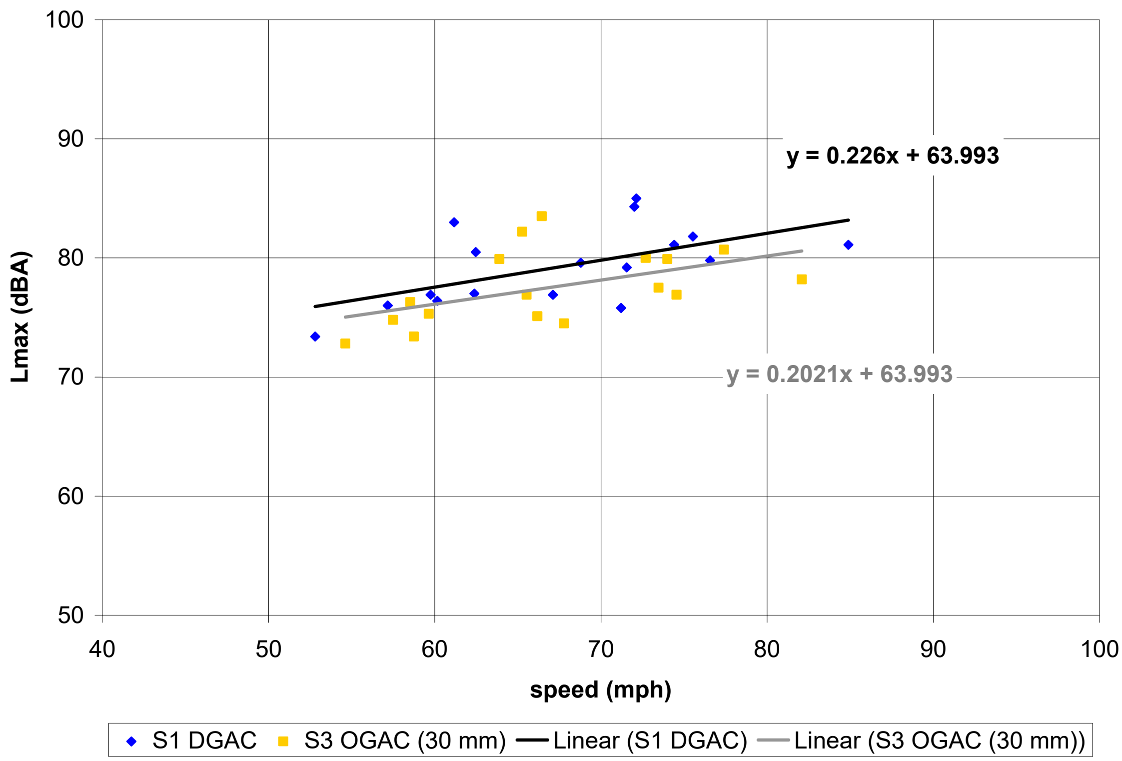


Figure C-53. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1616x + 63.136
y = 0.1357x + 63.594
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.226x + 63.993
y = 0.2021x + 63.993
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

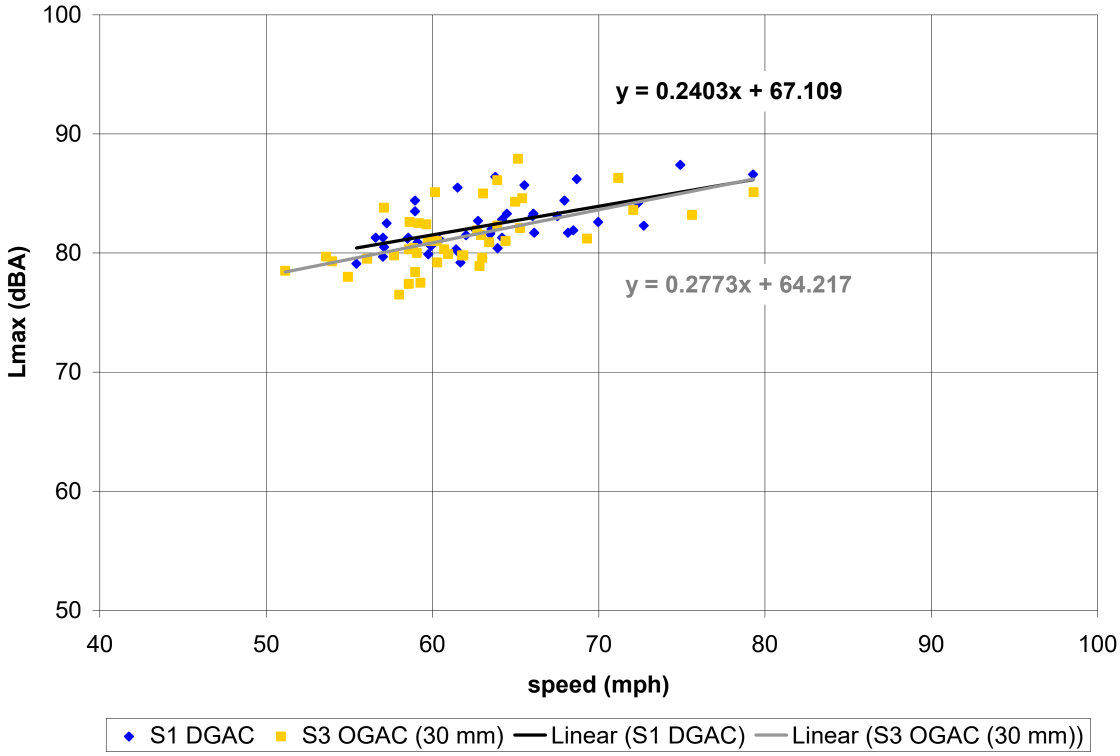
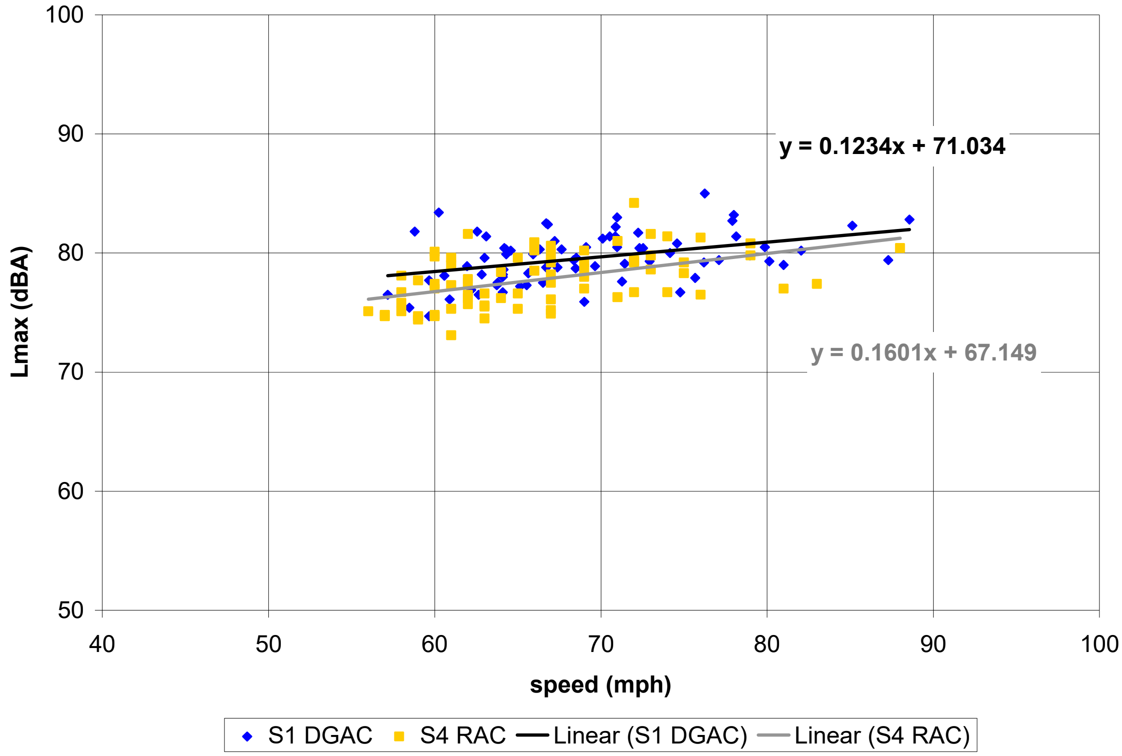
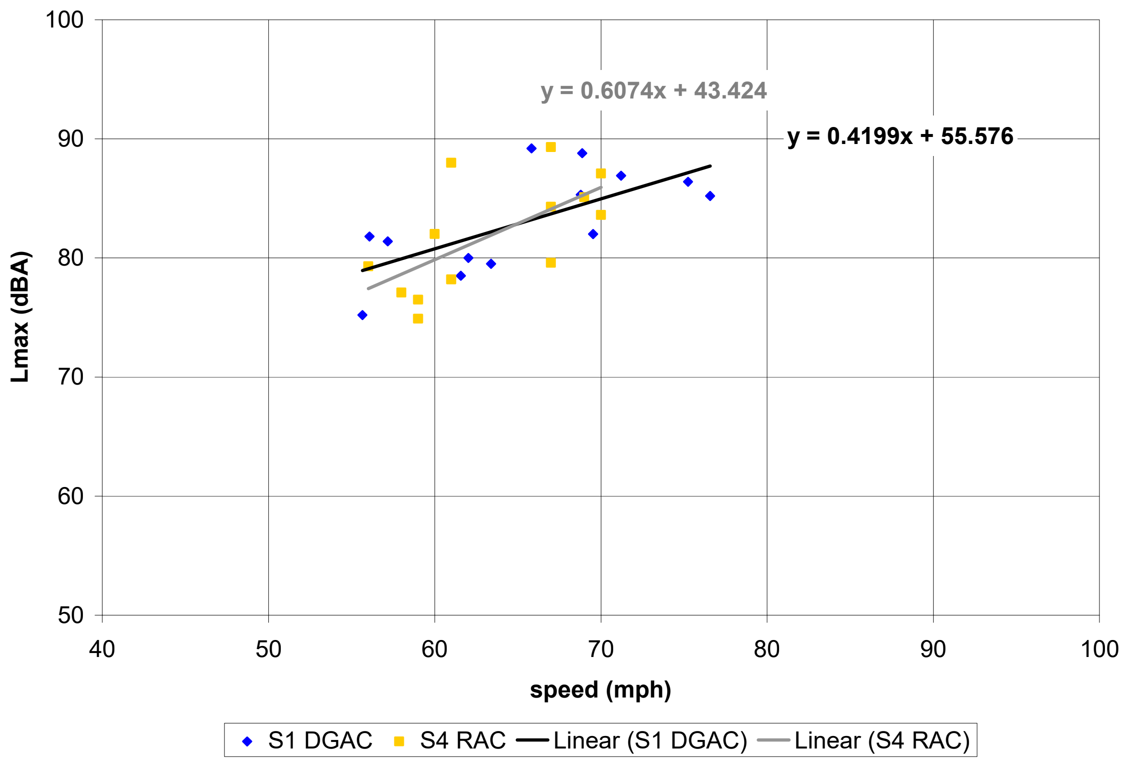


Figure C-54. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


y = 0.1234x + 71.034
y = 0.1601x + 67.149
Lmax (dBA)
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


y = 0.6074x + 43.424
y = 0.4199x + 55.576
Lmax (dBA)
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

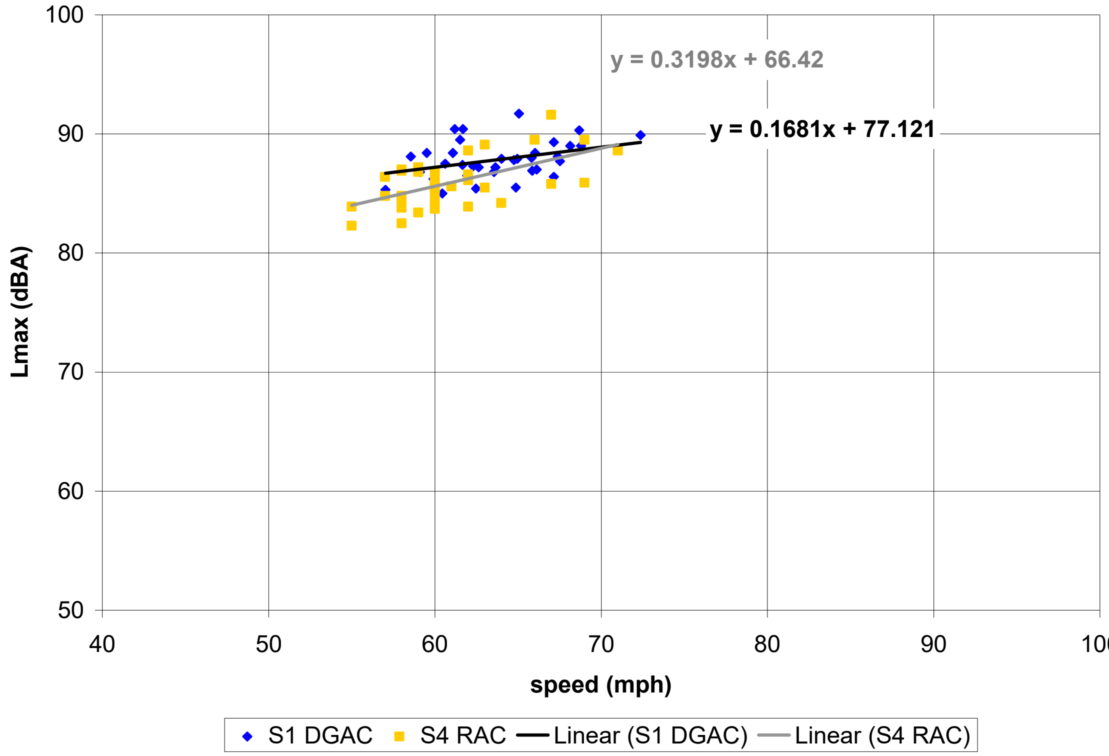
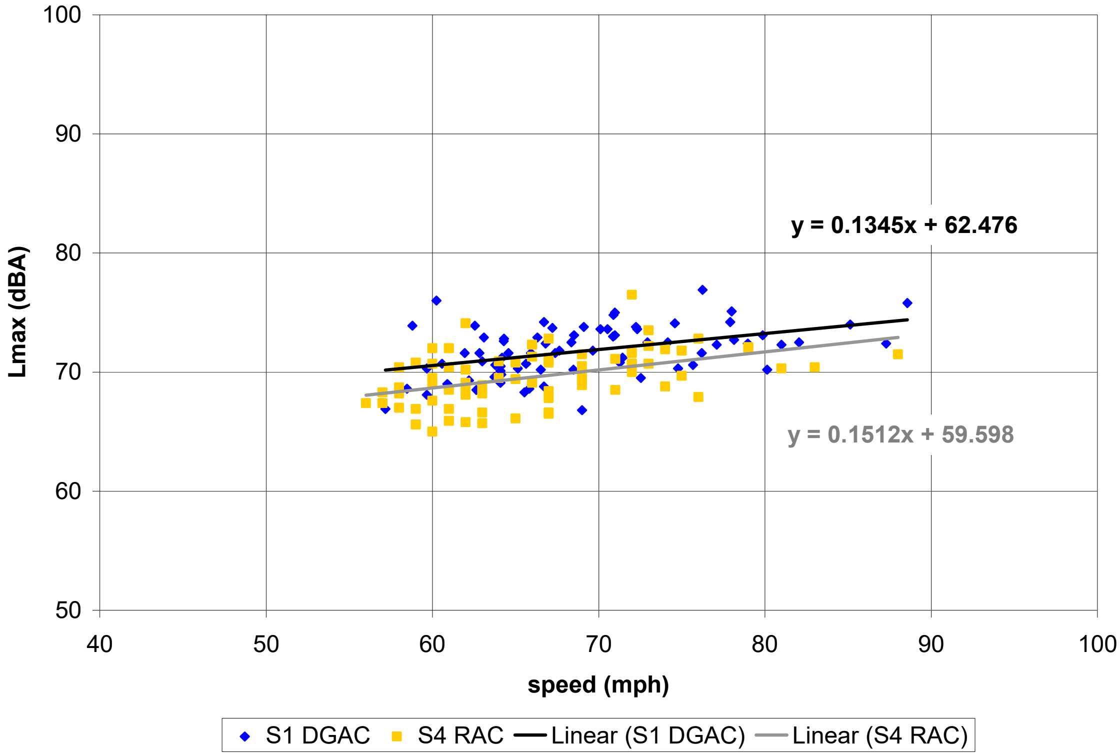
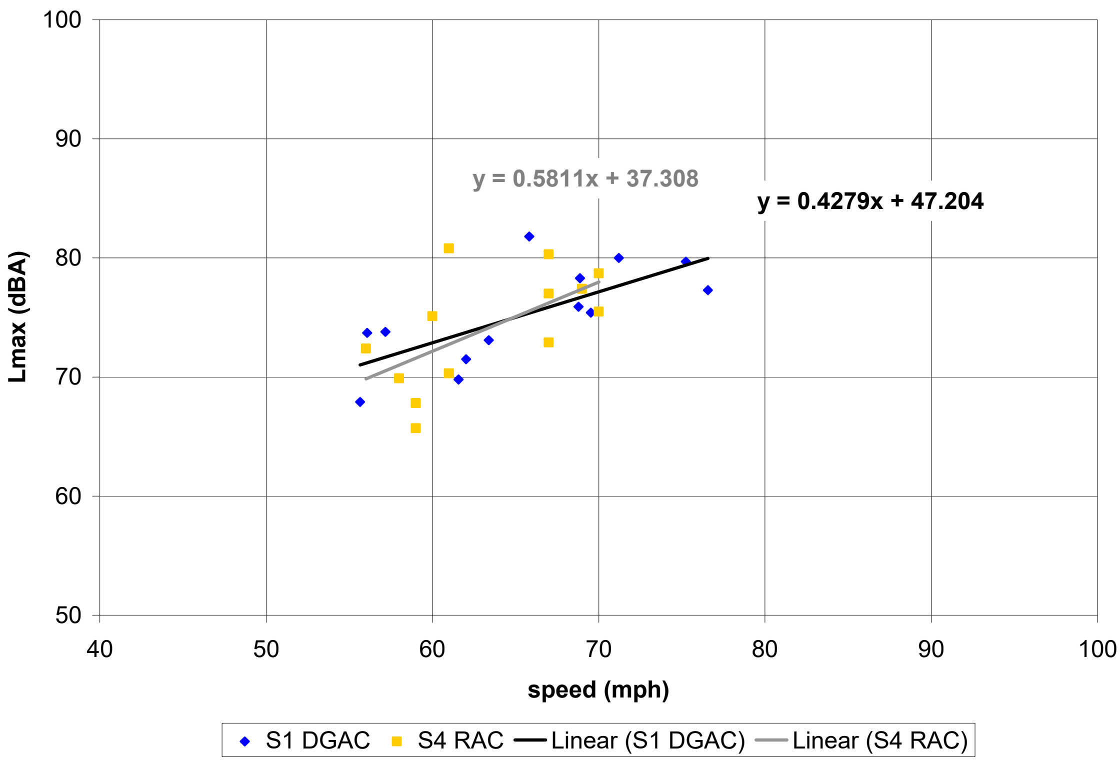


Figure C-55. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1345x + 62.476
y = 0.1512x + 59.598
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.5811x + 37.308
y = 0.4279x + 47.204
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

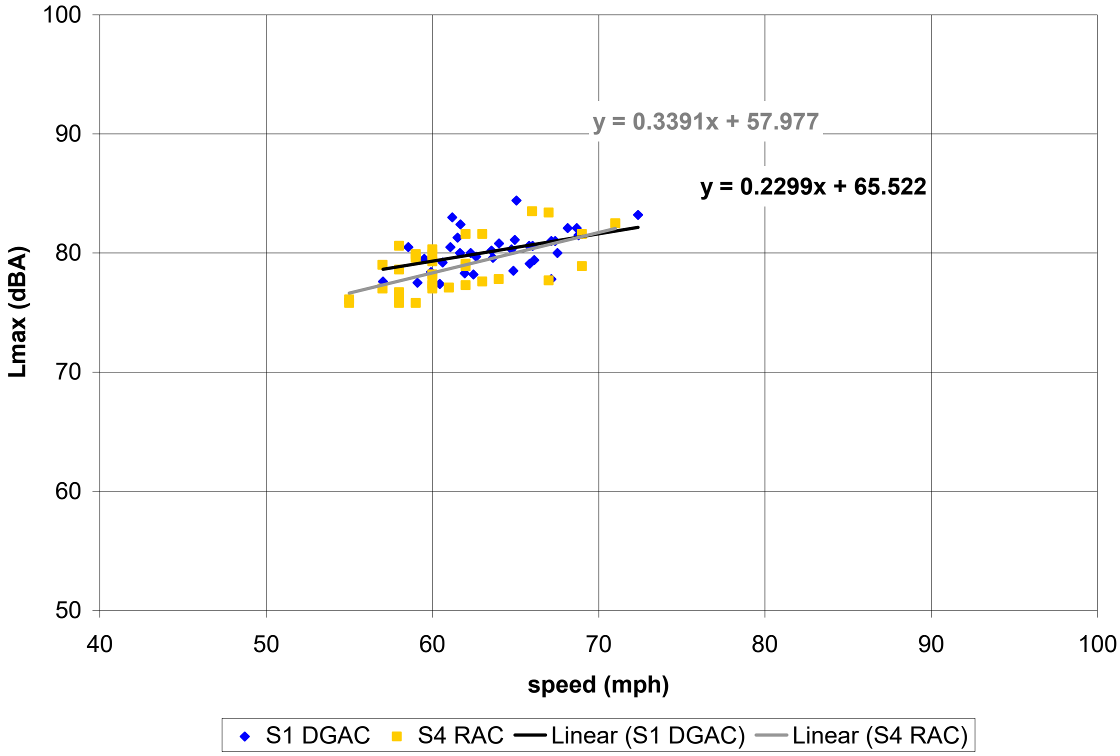
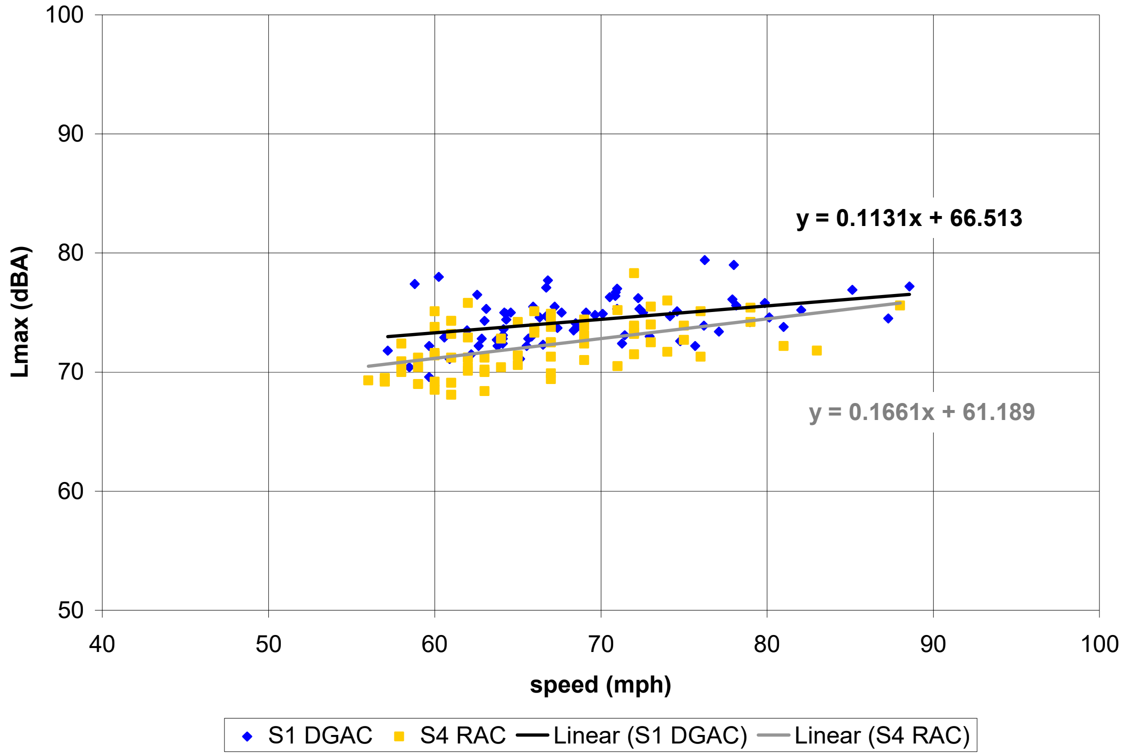
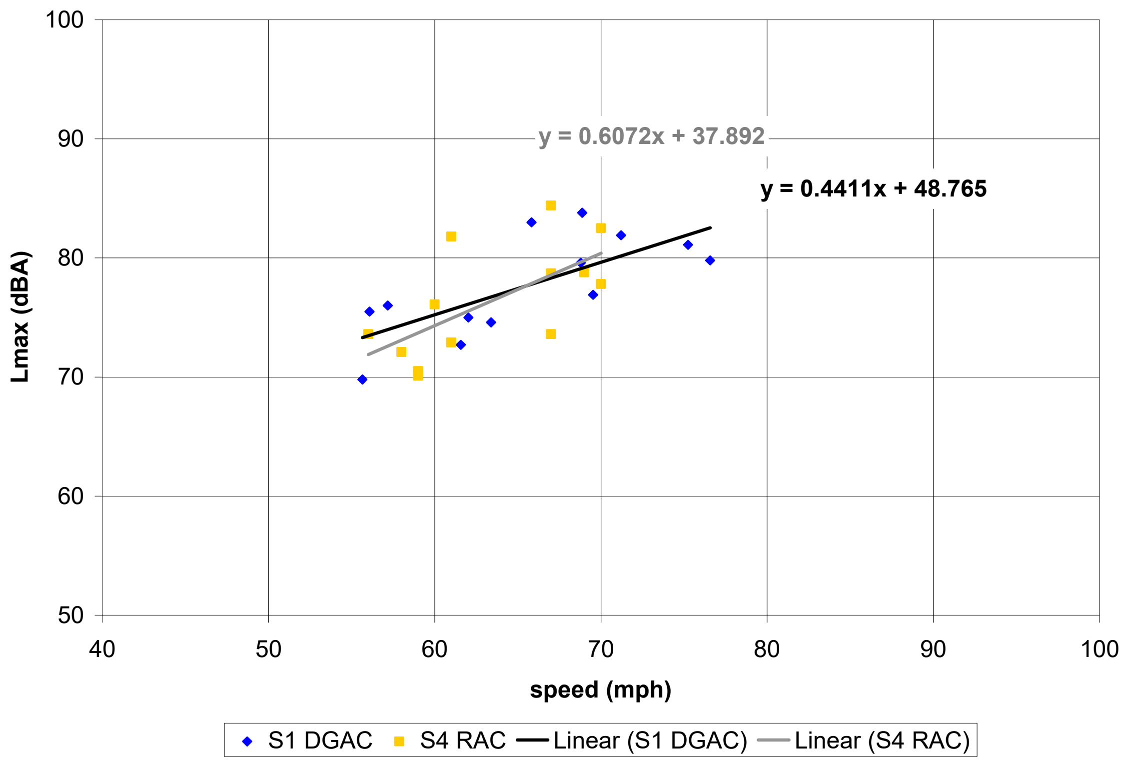


Figure C-56. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1131x + 66.513
y = 0.1661x + 61.189
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.6072x + 37.892
y = 0.4411x + 48.765
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

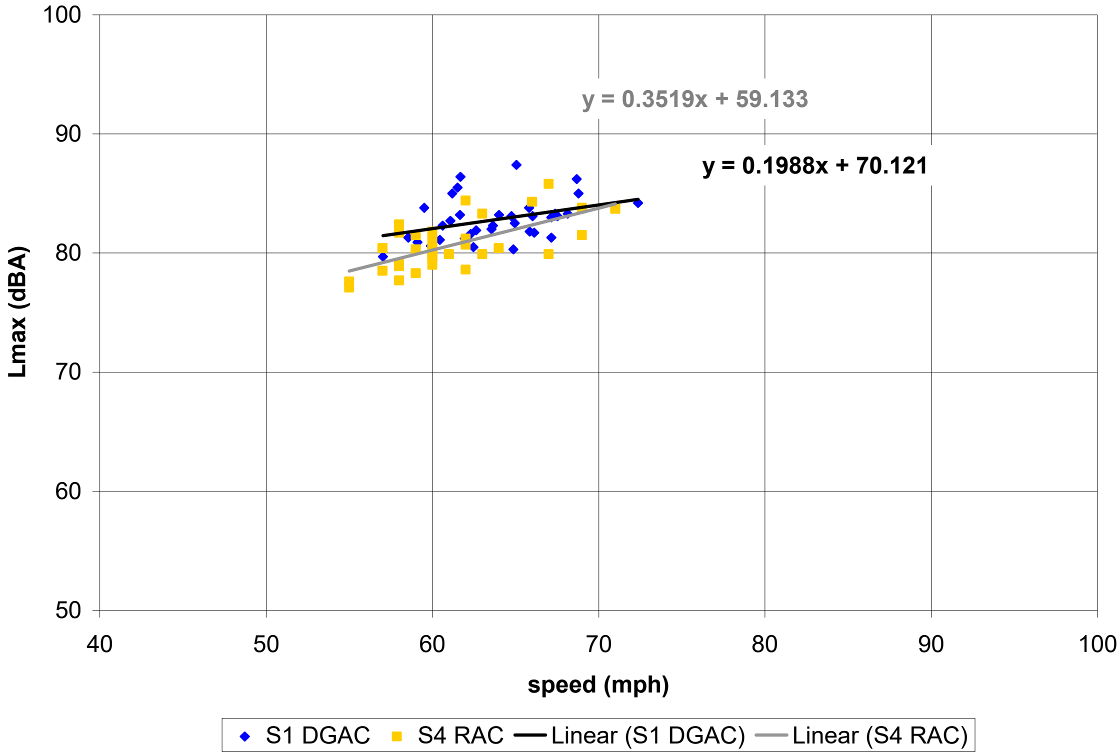


Figure C-57. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

APPENDIX D. OVERALL PAVEMENT PERFORMANCE

This appendix shows the following:

- tables and plots of the modified SPBI **values** for each pavement pair, age, and microphone position;
- tables and plots of the modified SPBI **deltas** (comparing each of the other pavements to DGAC) for each pavement pair, age, and microphone position; and
- tables and discussion of the site bias decibel adjustment values.

D.1 SPBI Values

Tables show values with and without site bias being removed. All plots show only values with the site bias removed.

Table D-1. Post-overlay measurements: sound levels for each pavement type (SPBI*) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months. Site bias removed.**

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* (dBA)							
		Site 1 (DGAC, 30 mm)	Site 2 (OGAC, 75 mm)	Site 1 (DGAC, 30 mm)	Site 3 (OGAC, 30 mm)	Site 1 (DGAC, 30 mm)	Site 4 (RAC Type O, 30 mm)	Site 1 (DGAC, 30 mm)	Site 5 (BWC, 30 mm)
baseline	7.5 m (25 ft) low	80.1	80.1	79.8	79.8	79.3	79.3	80.1	80.1
	15m (50 ft) low	73.3	73.3	72.9	72.9	72.4	72.4	73.2	73.2
	15m (50 ft) high	73.5	73.5	72.9	72.9	74.3	74.3	77.7	77.7
4 months	7.5 m (25 ft) low	82.1	78.9	82.0	80.6	82.1	79.7	na	na
	15m (50 ft) low	75.3	72.7	75.3	73.6	75.3	72.7	75.3	75.5
	15m (50 ft) high	77.1	73.8	77.1	75.4	77.2	75.1	76.9	76.2
10 months	7.5 m (25 ft) low	82.3	78.7	82.6	80.6	82.7	80.0	82.7	80.6
	15m (50 ft) low	75.2	72.4	75.5	73.8	75.7	72.9	75.6	76.0
	15m (50 ft) high	77.4	73.7	77.7	75.8	77.8	75.4	77.9	75.9
16 months	7.5 m (25 ft) low	82.5	79.0	82.4	80.7	82.4	80.2	82.5	80.7
	15m (50 ft) low	75.6	72.6	75.5	73.9	75.5	73.3	75.4	75.9
	15m (50 ft) high	77.5	74.4	77.3	76.2	77.3	75.9	77.4	75.9
52 months	7.5 m (25 ft) low	83.2	79.4	83.5	81.2	83.6	81.3	na	na
	15m (50 ft) low	75.5	72.5	75.9	74.1	75.9	73.6	na	na
	15m (50 ft) high	78.0	74.2	78.4	76.7	78.5	76.5	na	na

Table D-2. Post-overlay measurements: sound levels for each pavement type (SPBI*) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	SPBI* (dBA)							
		Site 1 (DGAC, 30 mm)	Site 2 (OGAC, 75 mm)	Site 1 (DGAC, 30 mm)	Site 3 (OGAC, 30 mm)	Site 1 (DGAC, 30 mm)	Site 4 (RAC Type O, 30 mm)	Site 1 (DGAC, 30 mm)	Site 5 (BWC, 30 mm)
baseline	7.5 m (25 ft) low	80.1	80.5	79.8	80.6	79.3	79.8	80.1	81.6
	15m (50 ft) low	73.3	74.1	72.9	73.4	72.4	73.0	73.2	72.6
	15m (50 ft) high	73.5	73.9	72.9	73.4	74.3	74.2	77.7	78.6
4 months	7.5 m (25 ft) low	82.1	79.3	82.0	81.3	82.1	80.2	na	na
	15m (50 ft) low	75.3	73.6	75.3	74.1	75.3	73.4	75.3	74.8
	15m (50 ft) high	77.1	74.3	77.1	75.8	77.2	75.0	76.9	77.2
10 months	7.5 m (25 ft) low	82.3	79.1	82.6	81.3	82.7	80.6	82.7	82.1
	15m (50 ft) low	75.2	73.2	75.5	74.3	75.7	73.6	75.6	75.4
	15m (50 ft) high	77.4	74.2	77.7	76.3	77.8	75.3	77.9	76.9
16 months	7.5 m (25 ft) low	82.5	79.3	82.4	81.4	82.4	80.7	82.5	82.1
	15m (50 ft) low	75.6	73.5	75.5	74.5	75.5	74.0	75.4	75.3
	15m (50 ft) high	77.5	74.8	77.3	76.7	77.3	75.8	77.4	76.9
52 months	7.5 m (25 ft) low	83.2	79.7	83.5	81.9	83.6	81.8	na	na
	15m (50 ft) low	75.5	73.3	75.9	74.6	75.9	74.2	na	na
	15m (50 ft) high	78.0	74.6	78.4	77.1	78.5	76.4	na	na

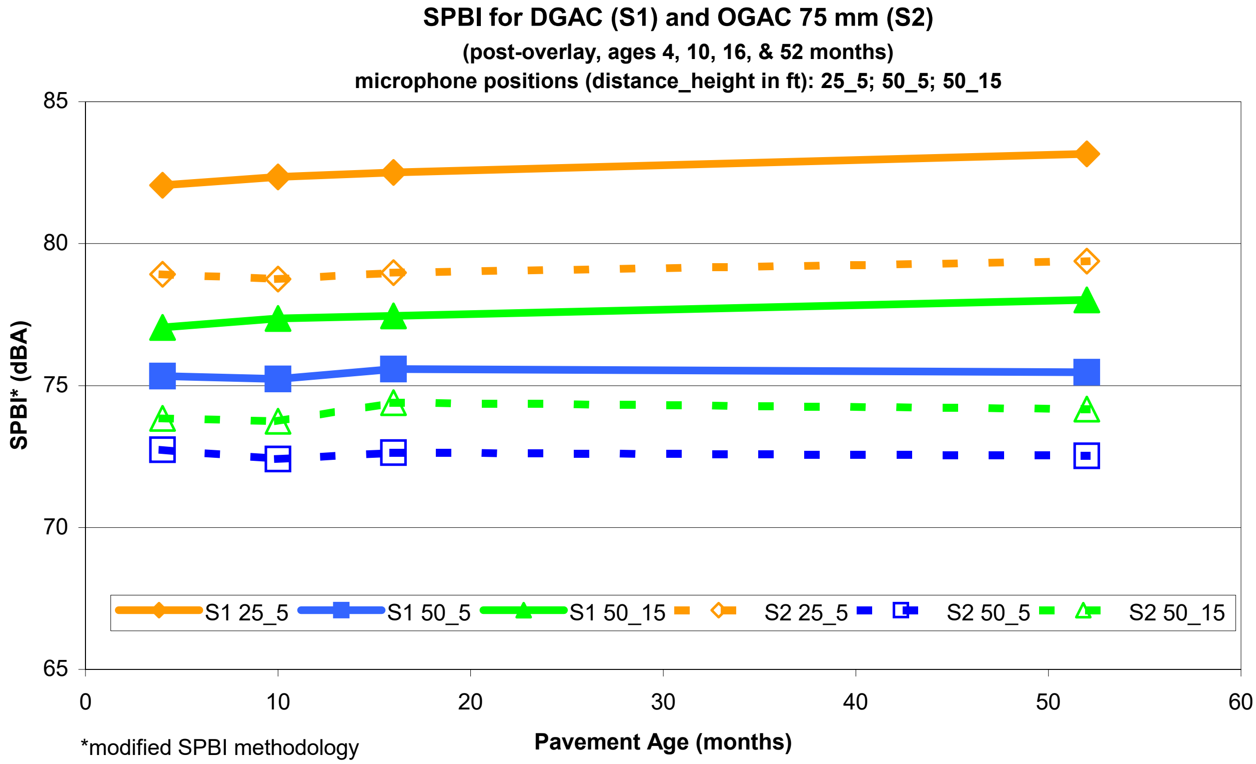


Figure D-1. SPBI* values over time for pavement pair DGAC 30mm (S1) and OGAC 75mm (S2). Overlay pavements aged 4, 10, 16, and 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

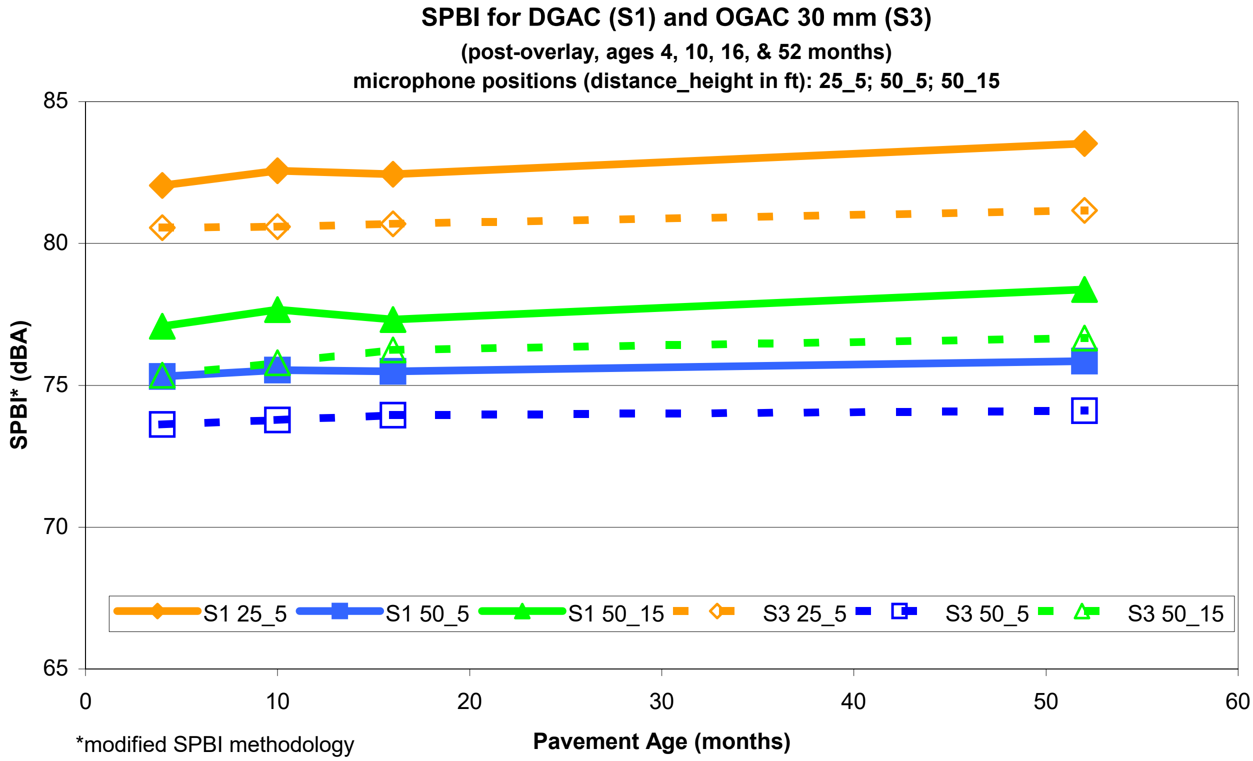


Figure D-2. SPBI* values over time for pavement pair DGAC 30mm (S1) and OGAC 30mm (S3). Overlay pavements aged 4, 10, 16, and 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

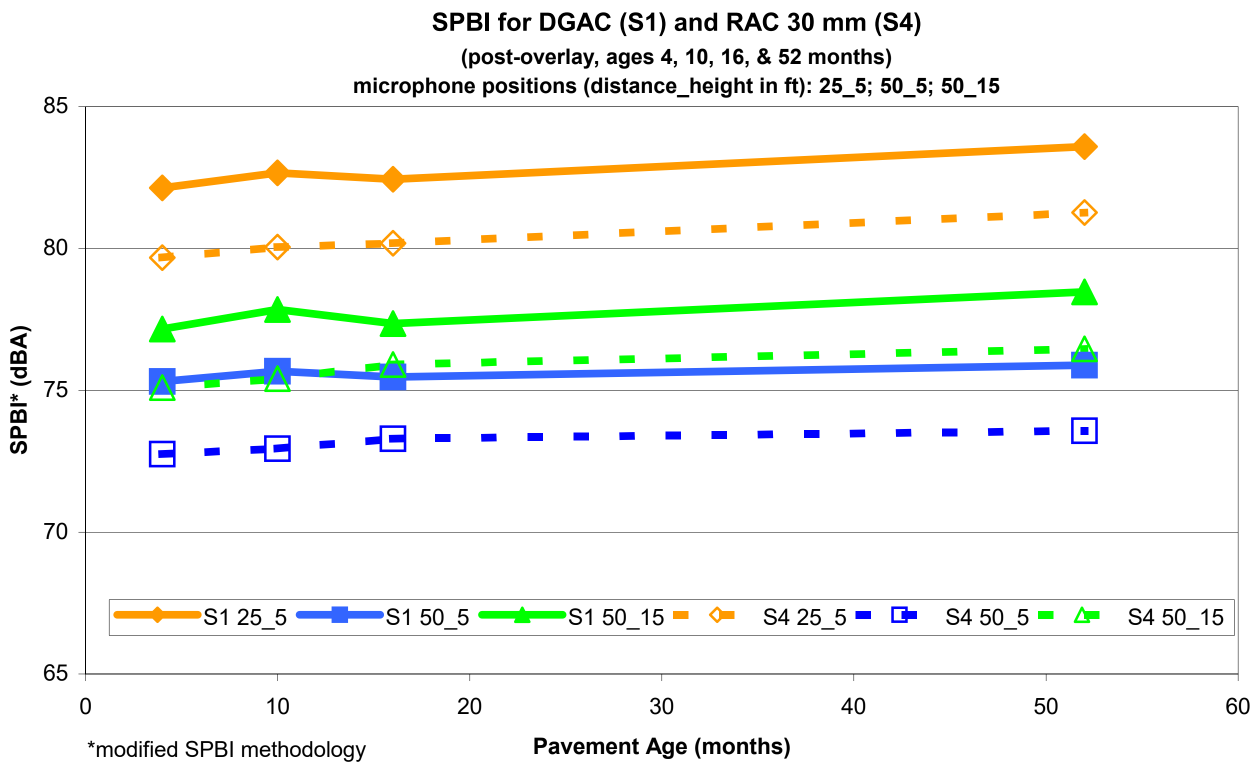


Figure D-3. SPBI* values over time for pavement pair DGAC 30mm (S1) and RAC Type O 30mm (S4). Overlay pavements aged 4, 10, 16, and 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

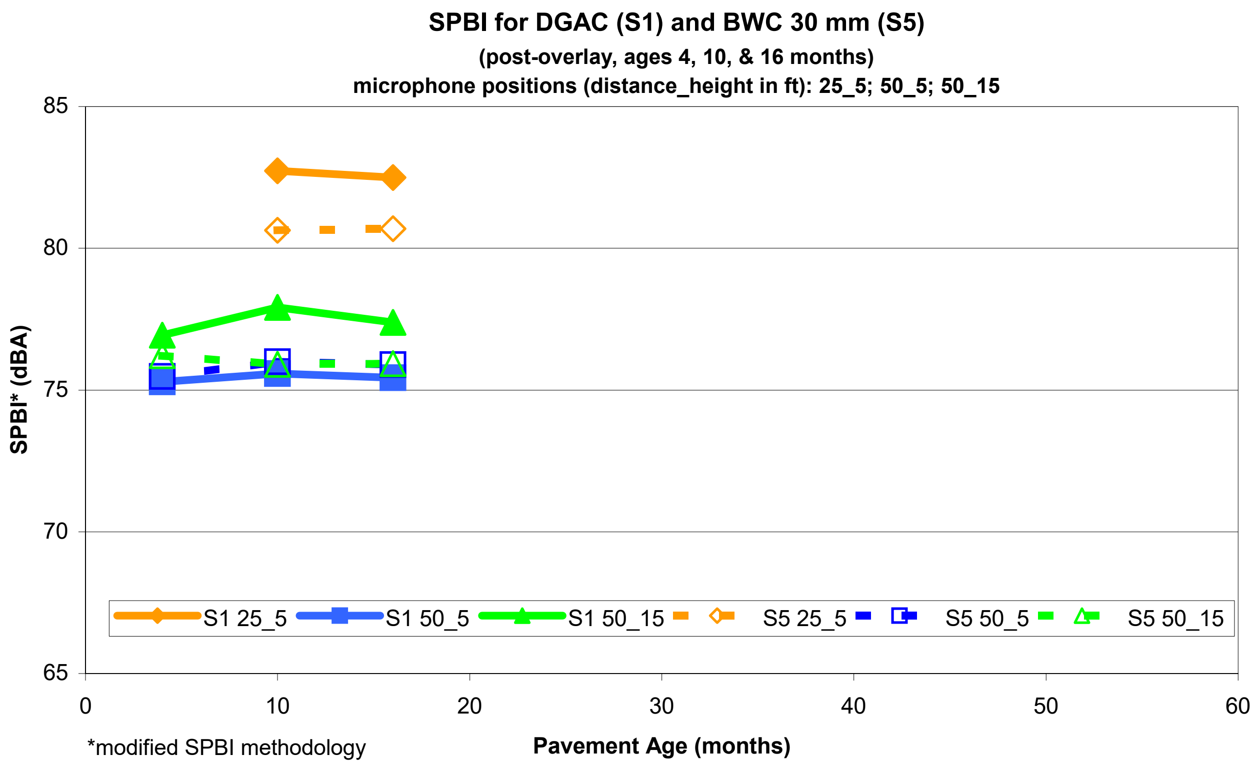


Figure D-4. SPBI* values over time for pavement pair DGAC 30mm (S1) and BWC 30mm (S5). Overlay pavements aged 4, 10, and 16 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

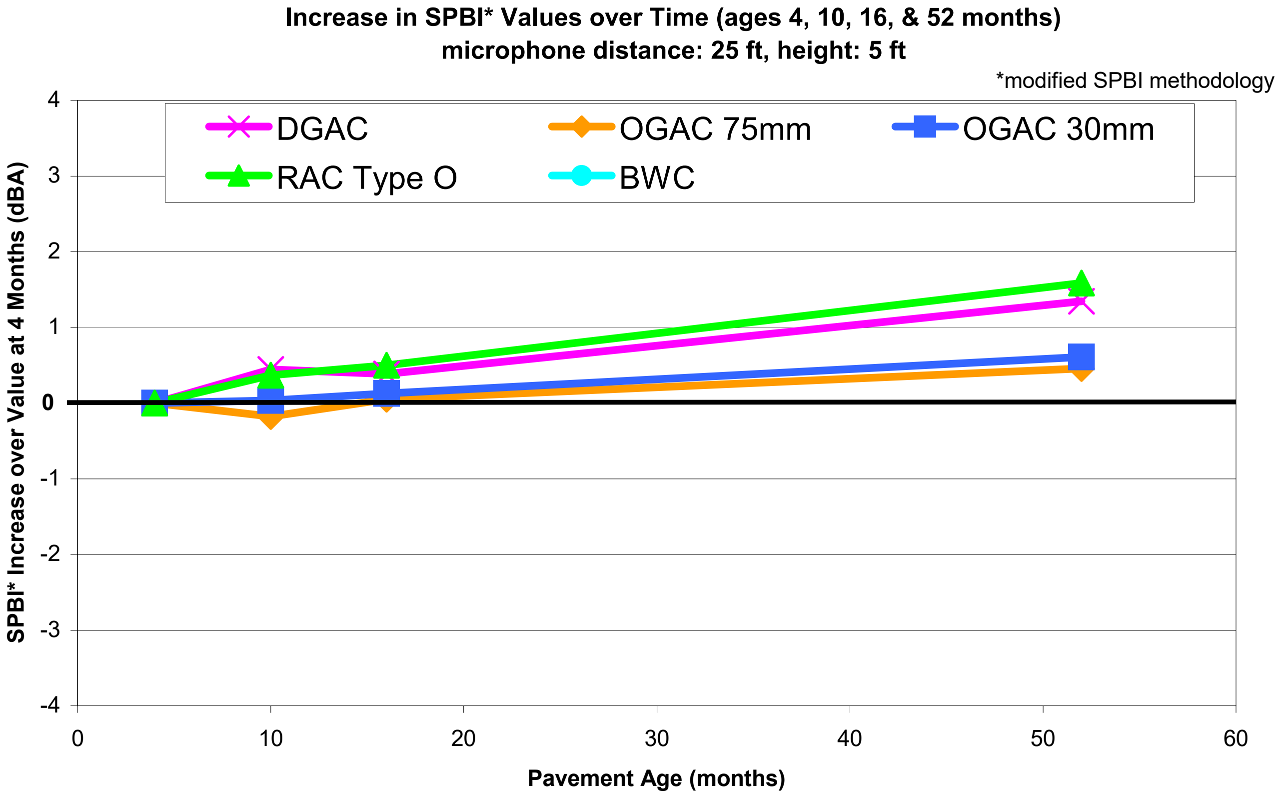


Figure D-5. Increase in SPBI* values over time, as compared to values at 4 months. Post-overlay results, all pavements (except BWC – no data available), including DGAC, aged 4, 10, 16, and 52 months. Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

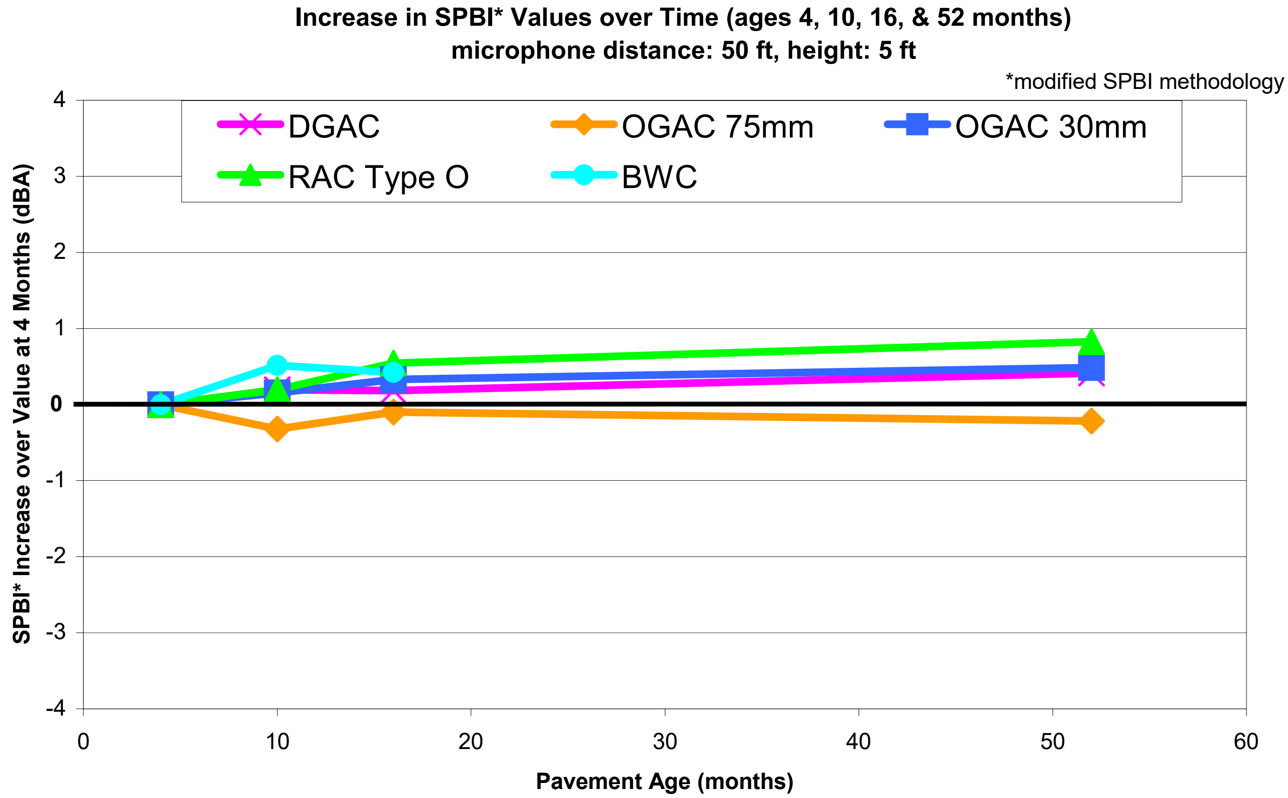


Figure D-6. Increase in SPBI* values over time, as compared to values at 4 months. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 1.5 m (5 ft).

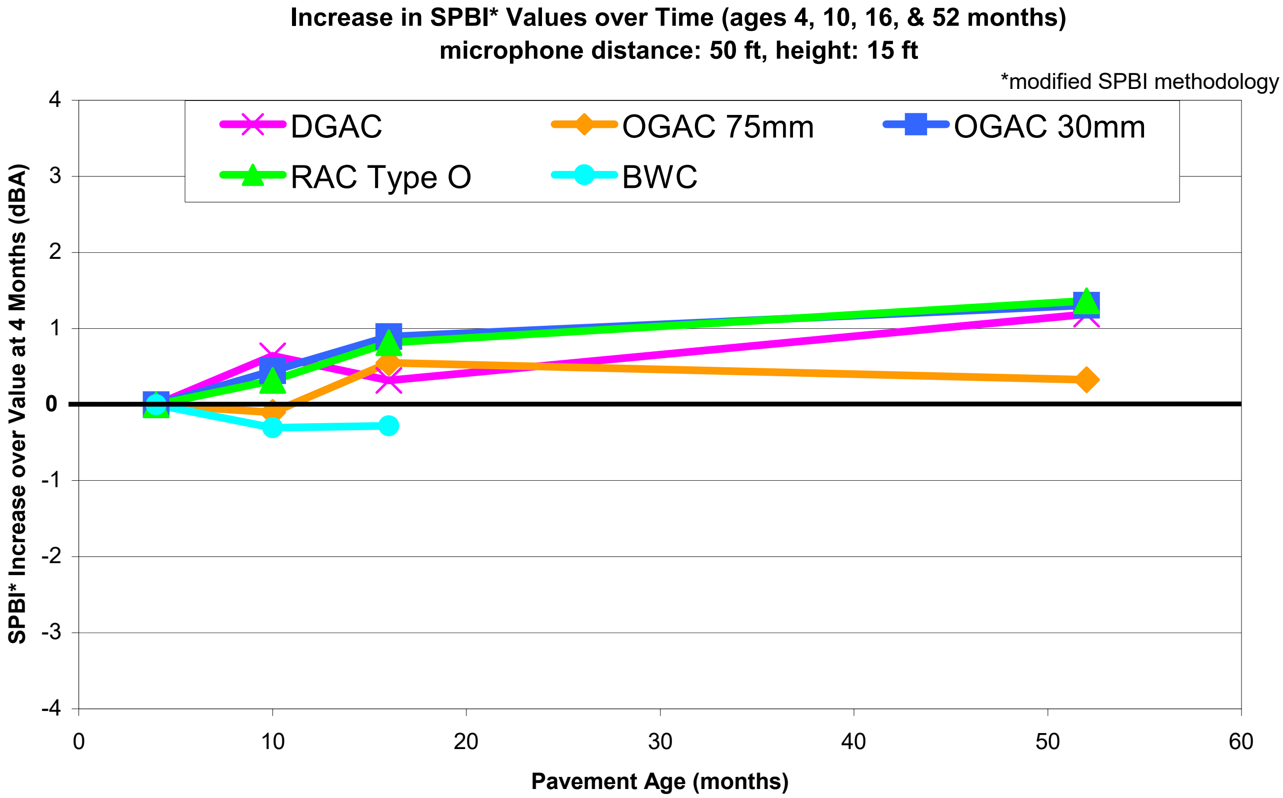


Figure D-7. Increase in SPBI* values over time, as compared to values at 4 months. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 4.5 m (15 ft).

D.2 SPBI Deltas

Tables show values with and without site bias being removed. All plots show only values with the site bias removed.

Table D-3. Post-overlay measurements: site differences due to type of pavement (SPBI* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months. Site bias removed.**

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* delta (dBA)			
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)	Site 3 – Site 1 (OGAC, 30 mm – DGAC)	Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)	Site 5 – Site 1 (BWC, 30 mm – DGAC)
baseline	7.5 m (25 ft) low	0.0	0.0	0.0	0.0
	15m (50 ft) low	0.0	0.0	0.0	0.0
	15m (50 ft) high	0.0	0.0	0.0	0.0
4 months	7.5 m (25 ft) low	-3.1	-1.5	-2.5	na
	15m (50 ft) low	-2.6	-1.7	-2.6	0.2
	15m (50 ft) high	-3.2	-1.7	-2.1	-0.7
10 months	7.5 m (25 ft) low	-3.6	-2.0	-2.6	-2.1
	15m (50 ft) low	-2.8	-1.8	-2.7	0.4
	15m (50 ft) high	-3.6	-1.9	-2.4	-2.0
16 months	7.5 m (25 ft) low	-3.5	-1.7	-2.3	-1.8
	15m (50 ft) low	-2.9	-1.5	-2.2	0.5
	15m (50 ft) high	-3.1	-1.1	-1.4	-1.5
52 months	7.5 m (25 ft) low	-3.8	-2.4	-2.3	na
	15m (50 ft) low	-3.0	-1.7	-2.3	na
	15m (50 ft) high	-3.8	-1.7	-2.0	na

Table D-4. Post-overlay measurements: site differences due to type of pavement (SPBI* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	SPBI* delta (dBA)			
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)	Site 3 – Site 1 (OGAC, 30 mm – DGAC)	Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)	Site 5 – Site 1 (BWC, 30 mm – DGAC)
baseline	7.5 m (25 ft) low	0.3	0.7	0.5	1.4
	15m (50 ft) low	0.8	0.5	0.7	-0.6
	15m (50 ft) high	0.4	0.5	-0.1	1.0
4 months	7.5 m (25 ft) low	-2.8	-0.8	-1.9	na
	15m (50 ft) low	-1.8	-1.2	-1.9	-0.4
	15m (50 ft) high	-2.8	-1.3	-2.2	0.2
10 months	7.5 m (25 ft) low	-3.3	-1.2	-2.1	-0.7
	15m (50 ft) low	-2.0	-1.3	-2.1	-0.2
	15m (50 ft) high	-3.2	-1.4	-2.5	-1.1
16 months	7.5 m (25 ft) low	-3.2	-1.0	-1.7	-0.4
	15m (50 ft) low	-2.1	-1.0	-1.5	-0.2
	15m (50 ft) high	-2.6	-0.6	-1.5	-0.5
52 months	7.5 m (25 ft) low	-3.4	-1.6	-1.8	na
	15m (50 ft) low	-2.1	-1.2	-1.6	na
	15m (50 ft) high	-3.4	-1.2	-2.1	na

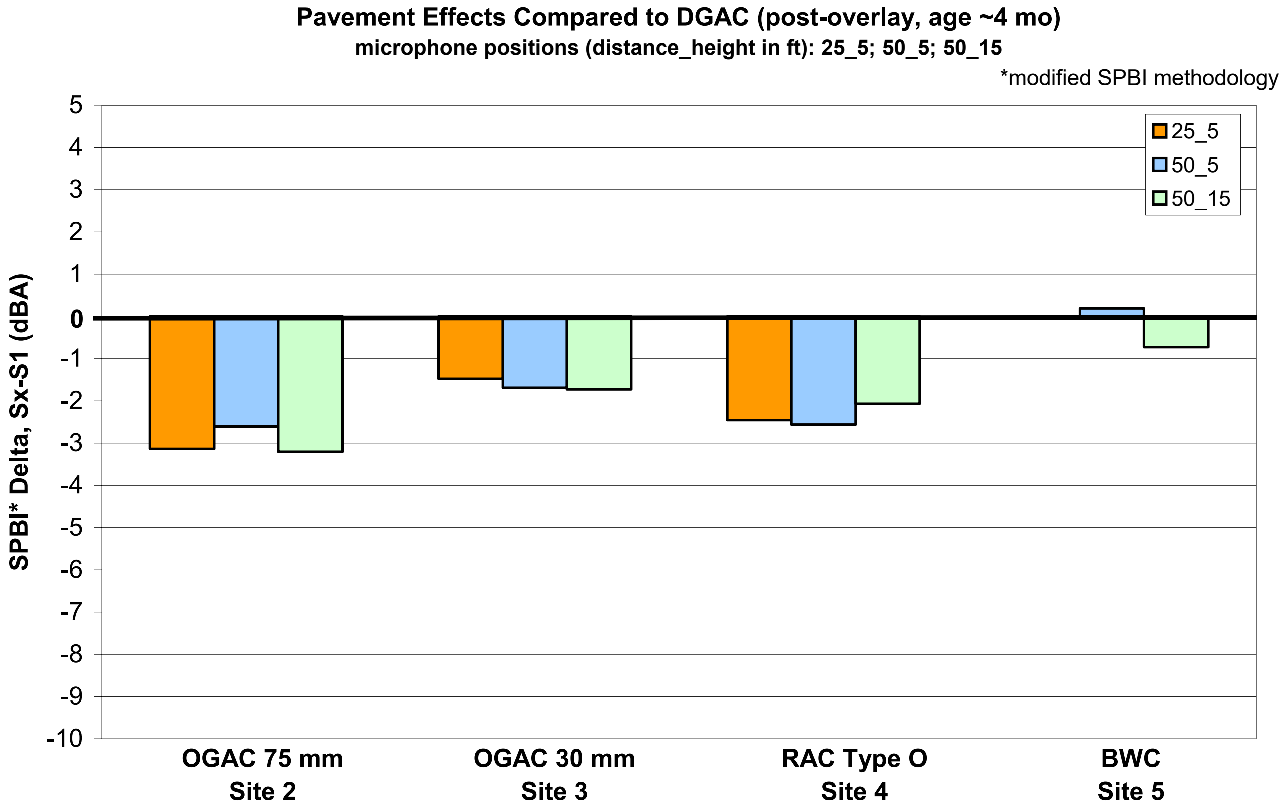


Figure D-8. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

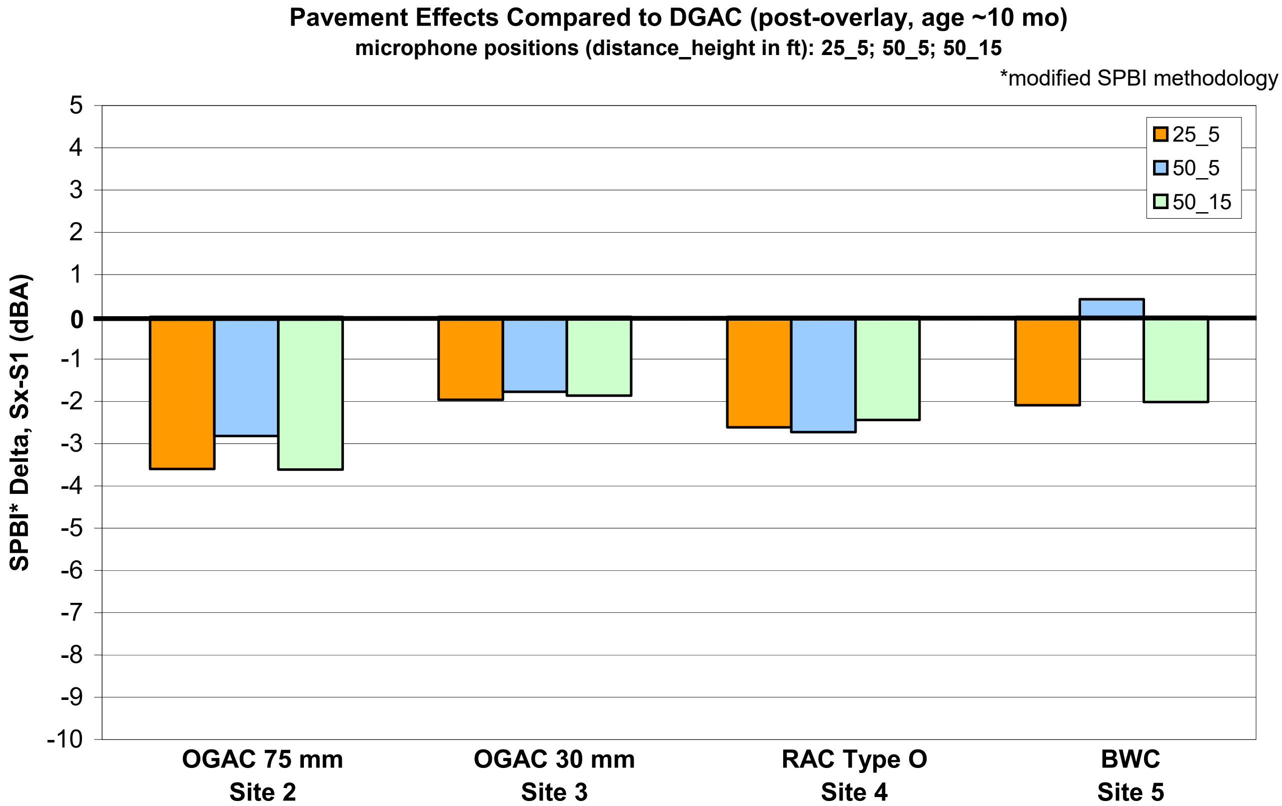


Figure D-9. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 10 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

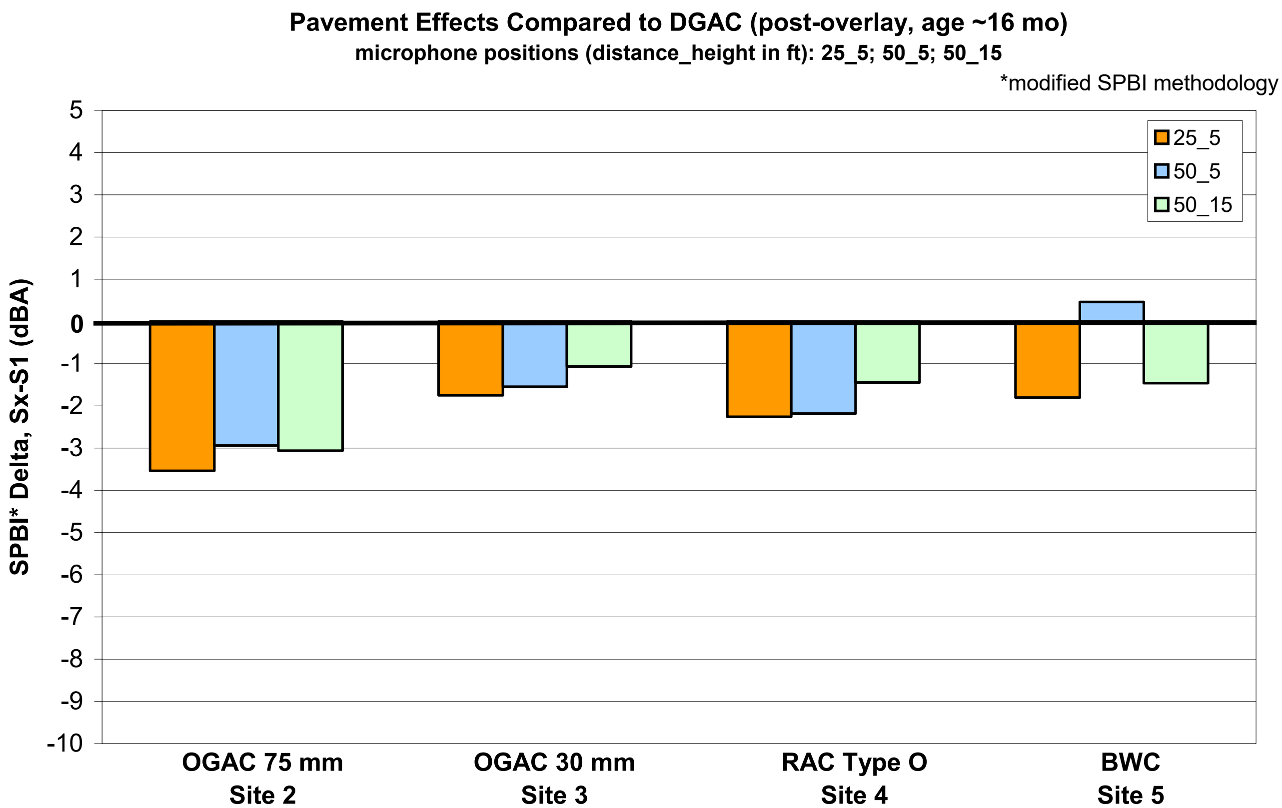


Figure D-10. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 16 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

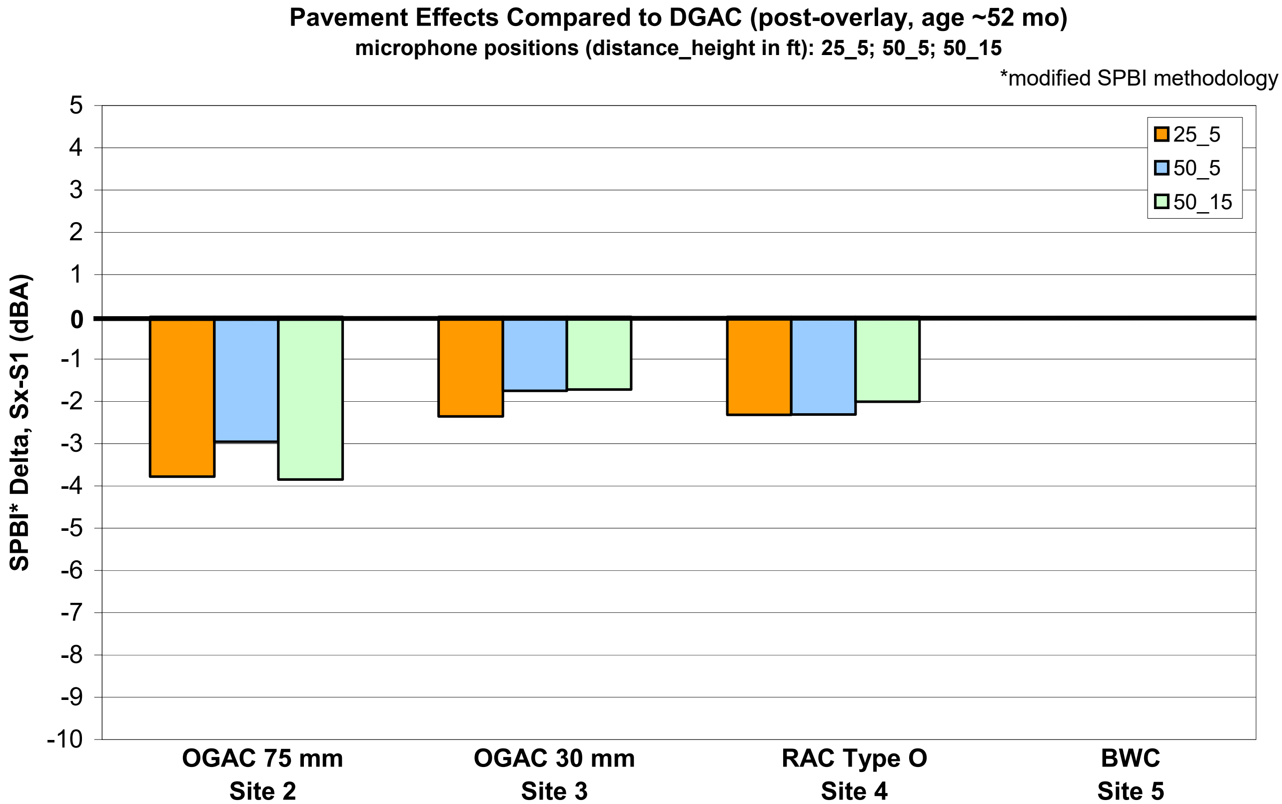


Figure D-11. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

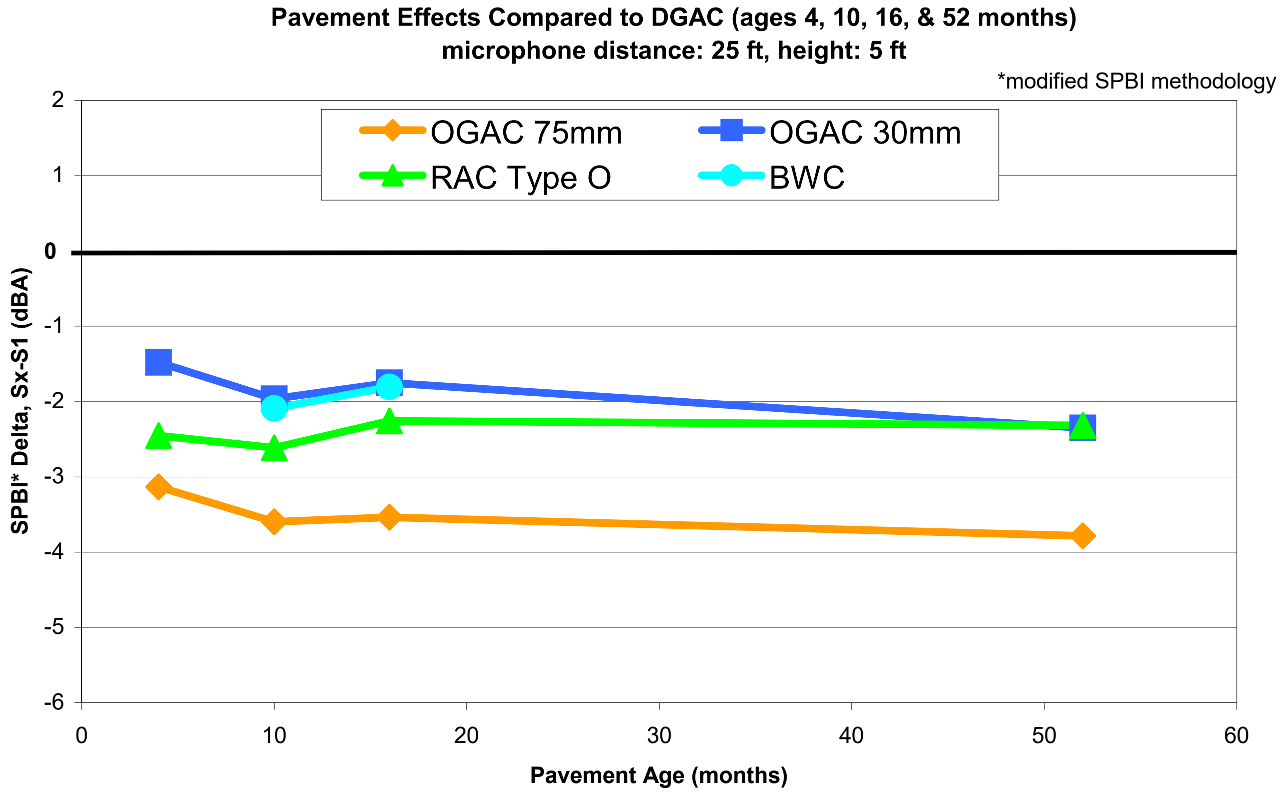


Figure D-12. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

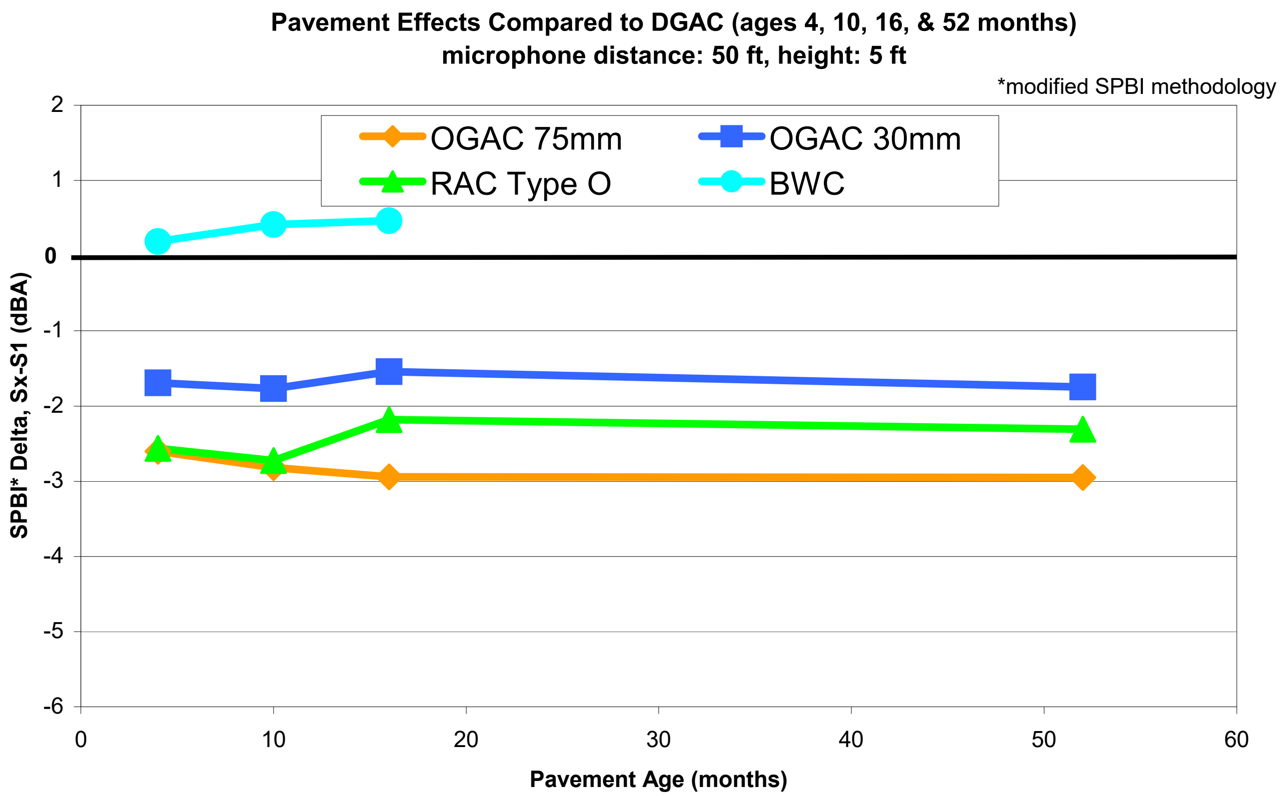


Figure D-13. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 1.5 m (5 ft).

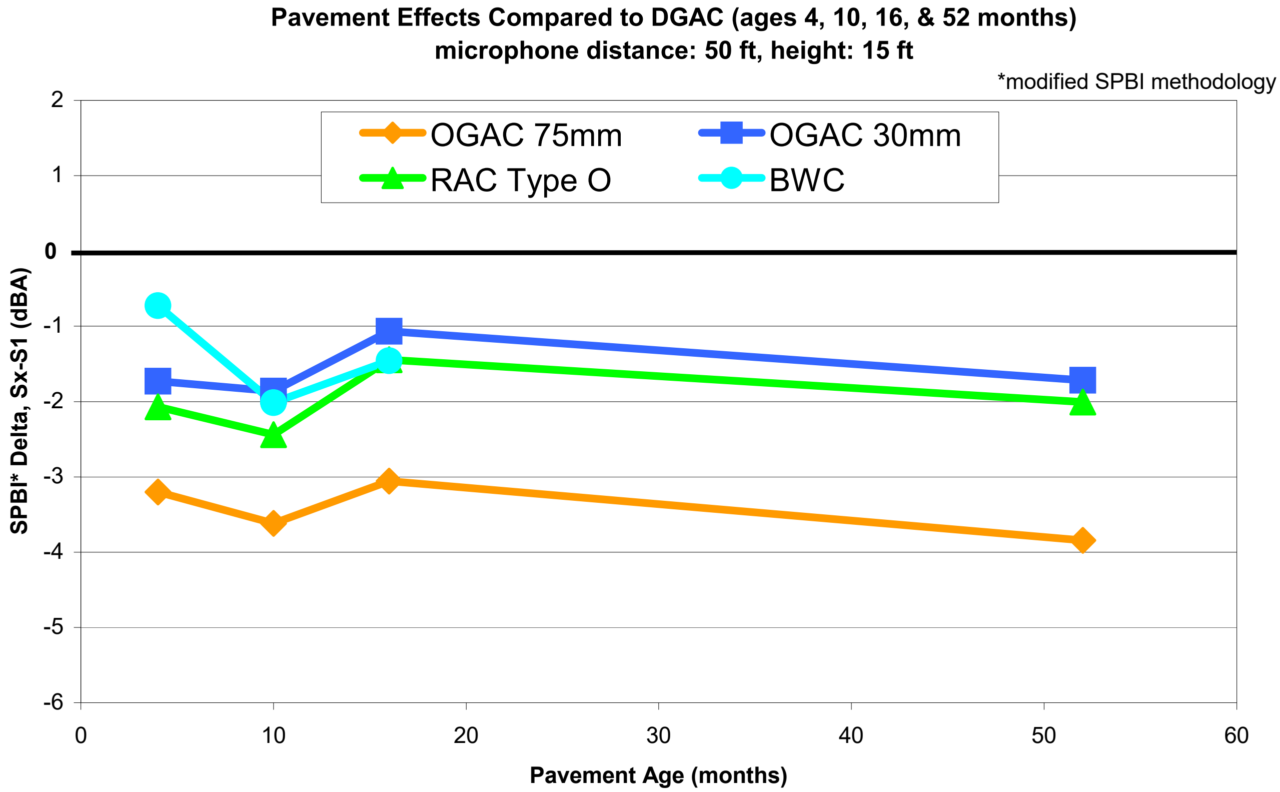


Figure D-14. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 4.5 m (15 ft).

D.3 Site Bias Decibel Adjustment Values

The baseline data collected in March 2002, with pavement at all sites being new DGAC, allow for the determination of site differences unrelated to the type of pavement. Data from Sites 2-5 are compared to data from Site 1. Because the terrain is not identical for each site, some differences are found. These differences are applied after the pavement overlays are in place in order to remove site bias (calibrate to Site 1).

The differences (Site x minus Site 1) range from -0.6 to 1.4 dB(A) and can be seen in Table 1; these differences are applied directly to (subtracted from) the SPBI results for post-overlay measurements for each Site x.

Table D-5. Baseline measurements: Site differences unrelated to type of pavement (SPBI* deltas).

*modified SPB methodology

	SPBI delta (dB(A))			
Microphone location	Site 2 – Site 1 (DGAC)	Site 3 – Site 1 (DGAC)	Site 4 – Site 1 (DGAC)	Site 5 – Site 1 (DGAC)
25 ft (7.5 m) low	0.3	0.7	0.5	1.4
50 ft (15 m) low	0.8	0.5	0.7	-0.6
50 ft (15 m) high	0.4	0.5	-0.1	1.0

APPENDIX E. PAVEMENT PERFORMANCE BY VEHICLE TYPE

This appendix shows the following:

- tables and plots of the modified-SPB Lveh **values** for each pavement pair, age, and microphone position;
- tables and plots of the modified-SPB Lveh **deltas** (comparing each of the other pavements to DGAC) for each pavement pair, age, and microphone position; and
- plots of spectral data averaged over several vehicle pass-by events, shown with varying parameter configurations.

E.1 Lveh Values

Tables show only values with site bias.

Table E-1. Post-overlay measurements: sound levels for each pavement type (Lveh*) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	Modified Lveh (or average L_{AFmx}) (dBA)																							
		Site 1 (DGAC, 30 mm)			Site 2 (OGAC, 75 mm)			Site 1 (DGAC, 30 mm)			Site 3 (OGAC, 30 mm)			Site 1 (DGAC, 30 mm)			Site 4 (RAC Type O, 30 mm)			Site 1 (DGAC, 30 mm)			Site 5 (BWC, 30 mm)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
baseline	7.5 m (25 ft) low	76.5	83.6	83.4	76.5	83.9	84.0	76.4	81.0	83.6	77.5	81.6	84.1	76.6	81.9	82.2	77.8	82.3	82.1	76.4	81.3	84.0	77.5	81.9	85.7
	15m (50 ft) low	69.3	76.4	76.9	70.0	77.3	77.7	69.1	74.4	76.8	70.1	74.3	77.2	69.4	75.0	75.5	71.2	76.2	74.9	69.2	74.9	77.2	68.5	74.5	76.5
	15m (50 ft) high	71.1	78.0	75.1	71.6	78.9	75.1	71.0	75.7	75.1	72.1	75.9	74.7	71.3	77.1	77.4	72.4	77.0	76.3	71.3	74.8	82.8	71.5	75.4	83.9
4 months	7.5 m (25 ft) low	78.6	82.8	85.9	74.8	80.2	83.5	78.4	82.4	86.0	77.3	82.3	85.3	78.6	82.0	86.1	76.3	80.5	84.3	na	na	na	na	na	na
	15m (50 ft) low	71.2	75.9	79.5	68.9	74.5	77.9	71.3	75.5	79.5	69.9	74.9	78.3	71.5	75.0	79.5	69.3	73.8	77.6	71.4	74.6	79.5	71.1	75.2	78.9
	15m (50 ft) high	73.3	77.3	81.1	69.8	74.8	78.6	73.3	77.1	81.2	71.8	76.8	79.9	73.4	76.8	81.3	71.2	75.0	79.1	73.4	76.2	81	73.7	77.1	81.1
10 months	7.5 m (25 ft) low	78.9	82.5	86.3	75	79.4	83.3	78.8	82.1	86.7	77.1	80.2	85.7	78.9	82.8	86.7	76.5	80.6	84.8	79	82.5	86.8	78.4	81.5	86.2
	15m (50 ft) low	71.2	75	79.5	68.9	73.4	77.6	71.2	74.6	80	69.7	72.9	78.9	71.2	76.1	80.0	69.4	74.0	77.8	71.3	75.0	80.0	71.2	74.3	79.7
	15m (50 ft) high	73.5	76.8	81.5	69.9	73.8	78.5	73.5	76.3	82.1	72	74.6	80.7	73.6	77.1	82.2	71.3	75.2	79.5	73.7	76.6	82.4	73.0	75.8	81.1
16 months	7.5 m (25 ft) low	78.8	82.7	86.6	74.7	79.9	83.7	78.9	83.1	86.3	77.3	82.7	85.4	78.6	83.6	86.4	76.2	81.8	84.9	78.7	83.4	86.5	78.1	83.0	86.2
	15m (50 ft) low	71.3	75.6	79.9	68.4	73.9	78.0	71.4	76.1	79.6	70.2	75.5	78.6	71.2	76.6	79.6	69.3	75.1	78.3	71.2	76.3	79.6	71.2	76.2	79.4
	15m (50 ft) high	73.3	76.9	81.8	70.1	74.9	79.3	73.5	77.4	81.4	72.2	77.4	81.0	73.2	77.9	81.6	71.4	76.7	80.1	73.2	77.6	81.6	72.7	77.4	81.1
52 months	7.5 m (25 ft) low	79.6	82.8	87.2	76.0	79.7	83.8	79.7	84.4	87.5	78.0	82.8	85.9	79.6	83.1	87.8	77.8	81.9	85.9	na	na	na	na	na	na
	15m (50 ft) low	71.7	74.8	79.6	69.3	73.2	77.6	71.9	76.5	79.9	70.2	75.1	78.9	71.8	75.2	80.2	69.7	74.1	78.7	na	na	na	na	na	na
	15m (50 ft) high	74.3	77.7	82.1	70.7	74.2	78.8	74.5	79.3	82.4	72.9	77.5	81.4	74.3	77.7	82.8	72.2	76.4	80.6	na	na	na	na	na	na

E.2 Lveh Deltas

Tables show values with and without site bias being removed. All plots show only values with the site bias removed.

Table E-2. Post-overlay measurements: for each vehicle type, site differences due to type of pavement (Lveh* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months. Site bias removed.**

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	Modified Lveh* (or average L_{AFmx}) delta (dBA)											
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)			Site 3 – Site 1 (OGAC, 30 mm – DGAC)			Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)			Site 5 – Site 1 (BWC, 30 mm – DGAC)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
baseline	25 ft (7.5 m) low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	50 ft (15 m) low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	50 ft (15 m) high	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 months	25 ft (7.5 m) low	-3.7	-2.9	-3.0	-2.2	-0.6	-1.2	-3.5	-2.0	-1.7	na	na	na
	50 ft (15 m) low	-3.1	-2.4	-2.4	-2.3	-0.5	-1.6	-4.0	-2.3	-1.3	0.5	1.0	0.0
	50 ft (15 m) high	-4.0	-3.4	-2.5	-2.7	-0.6	-0.9	-3.3	-1.7	-1.1	0.0	0.4	-1.0
10 months	25 ft (7.5 m) low	-3.9	-3.3	-3.6	-2.8	-2.4	-1.5	-3.6	-2.6	-1.8	-1.7	-1.6	-2.3
	50 ft (15 m) low	-3.0	-2.6	-2.7	-2.4	-1.6	-1.5	-3.6	-3.2	-1.6	0.7	-0.3	0.4
	50 ft (15 m) high	-4.2	-3.9	-3.0	-2.6	-2.0	-0.9	-3.4	-1.8	-1.6	-0.9	-1.3	-2.3
16 months	25 ft (7.5 m) low	-4.1	-3.0	-3.4	-2.7	-1.0	-1.4	-3.6	-2.2	-1.4	-1.8	-1.1	-1.9
	50 ft (15 m) low	-3.6	-2.7	-2.7	-2.1	-0.4	-1.4	-3.7	-2.6	-0.8	0.7	0.3	0.4
	50 ft (15 m) high	-3.7	-2.9	-2.5	-2.4	-0.2	0.0	-2.8	-1.0	-0.4	-0.8	-0.8	-1.6
52 months	25 ft (7.5 m) low	-3.6	-3.3	-4.0	-2.9	-2.1	-2.1	-3.0	-1.6	-1.8	na	na	na
	50 ft (15 m) low	-3.1	-2.6	-2.9	-2.7	-1.3	-1.4	-3.9	-2.2	-1.0	na	na	na
	50 ft (15 m) high	-4.0	-4.4	-3.4	-2.8	-2.0	-0.6	-3.1	-1.2	-1.1	na	na	na

Table 3. Post-overlay measurements: for each vehicle type, site differences due to type of pavement (Lveh* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	Modified Lveh* (or average L_{AFmx}) delta (dBA)											
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)			Site 3 – Site 1 (OGAC, 30 mm – DGAC)			Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)			Site 5 – Site 1 (BWC, 30 mm – DGAC)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
baseline	25 ft (7.5 m) low	0.0	0.3	0.6	1.1	0.5	0.5	1.2	0.4	-0.1	1.2	0.6	1.7
	50 ft (15 m) low	0.7	1.0	0.8	0.9	-0.1	0.4	1.8	1.1	-0.5	-0.7	-0.3	-0.7
	50 ft (15 m) high	0.5	0.9	0.0	1.2	0.3	-0.4	1.0	-0.1	-1.1	0.3	0.5	1.1
4 months	25 ft (7.5 m) low	-3.7	-2.6	-2.4	-1.1	-0.1	-0.7	-2.3	-1.6	-1.8	na	na	na
	50 ft (15 m) low	-2.4	-1.4	-1.6	-1.3	-0.6	-1.2	-2.2	-1.2	-1.9	-0.3	0.6	-0.7
	50 ft (15 m) high	-3.5	-2.5	-2.5	-1.5	-0.3	-1.3	-2.2	-1.8	-2.2	0.3	0.9	0.1
10 months	25 ft (7.5 m) low	-3.9	-3.1	-3.0	-1.7	-1.9	-1.0	-2.4	-2.2	-1.9	-0.6	-1.0	-0.7
	50 ft (15 m) low	-2.3	-1.7	-1.9	-1.5	-1.7	-1.1	-1.8	-2.1	-2.2	-0.1	-0.6	-0.2
	50 ft (15 m) high	-3.7	-3.1	-3.0	-1.5	-1.7	-1.3	-2.3	-1.9	-2.7	-0.7	-0.8	-1.2
16 months	25 ft (7.5 m) low	-4.1	-2.8	-2.9	-1.5	-0.4	-0.9	-2.4	-1.8	-1.5	-0.6	-0.4	-0.3
	50 ft (15 m) low	-2.9	-1.7	-1.9	-1.2	-0.5	-1.0	-1.9	-1.5	-1.4	-0.1	0.0	-0.2
	50 ft (15 m) high	-3.2	-2.0	-2.5	-1.3	0.0	-0.4	-1.8	-1.1	-1.5	-0.6	-0.2	-0.5
52 months	25 ft (7.5 m) low	-3.6	-3.1	-3.4	-1.8	-1.6	-1.6	-1.8	-1.2	-1.9	na	na	na
	50 ft (15 m) low	-2.4	-1.7	-2.0	-1.8	-1.4	-1.0	-2.1	-1.1	-1.5	na	na	na
	50 ft (15 m) high	-3.5	-3.5	-3.4	-1.6	-1.8	-1.0	-2.1	-1.3	-2.2	na	na	na

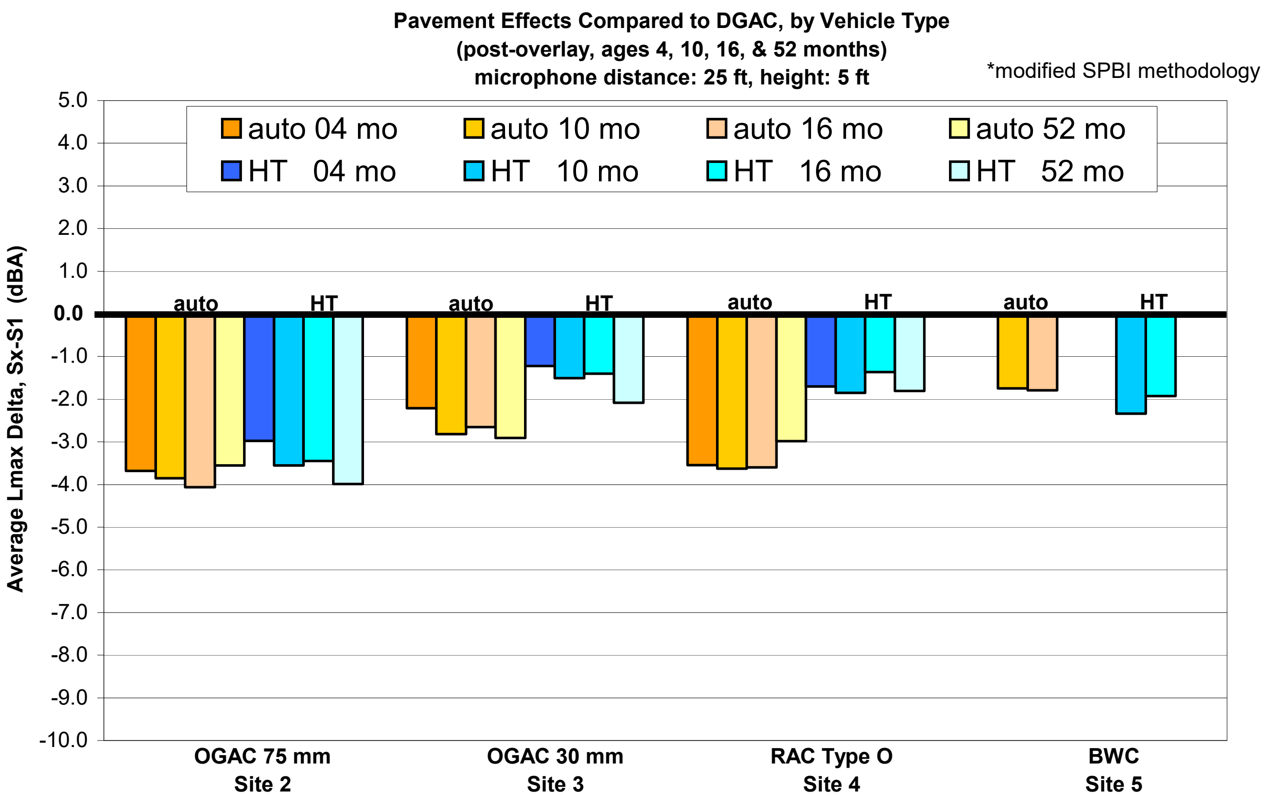


Figure E-1. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

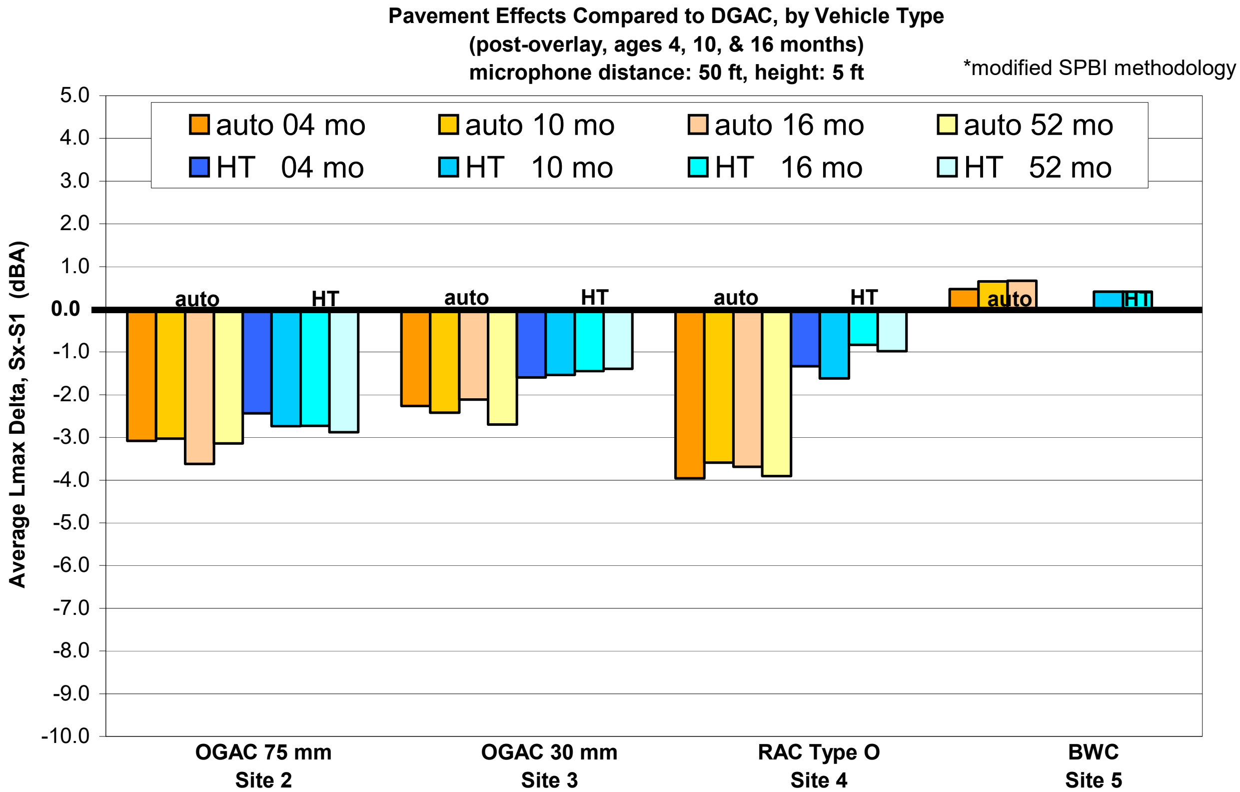


Figure E-2. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 1.5 m (5 ft).

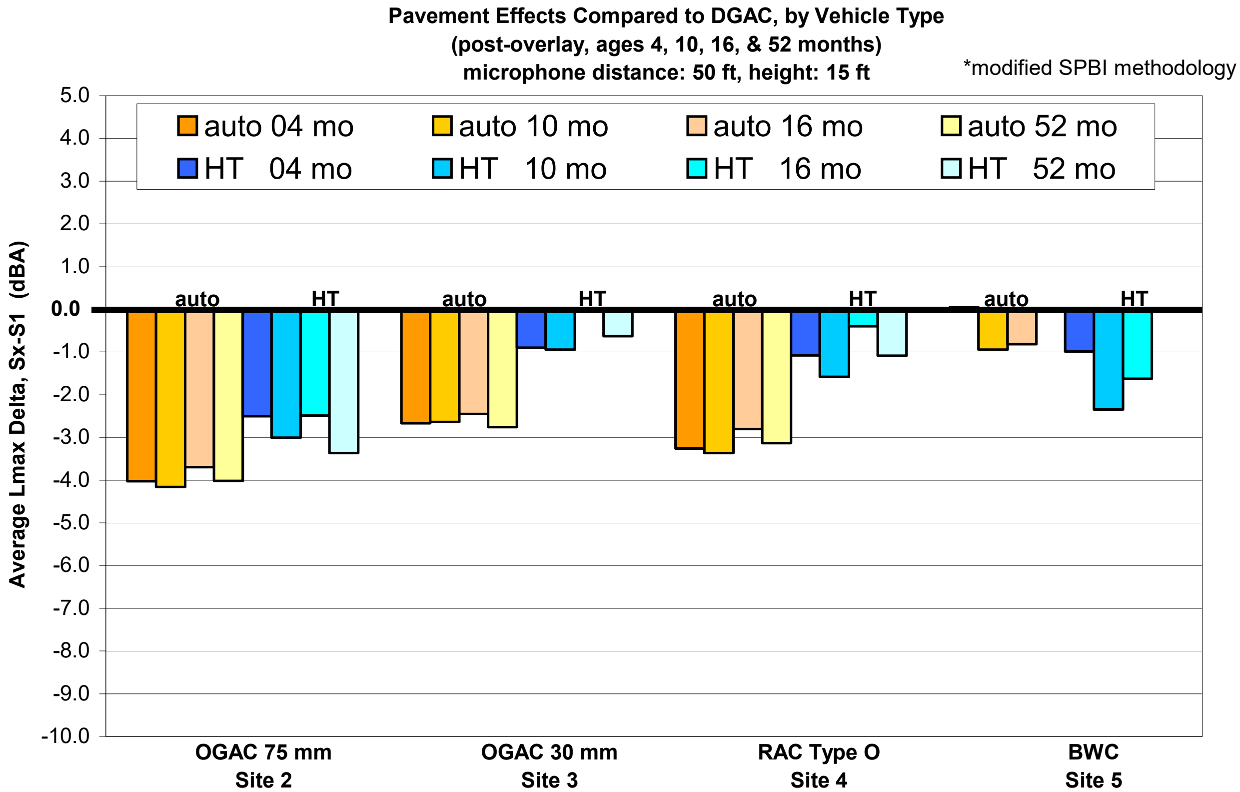


Figure E-3. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 4.5 m (15 ft).

E.3 Spectral Results

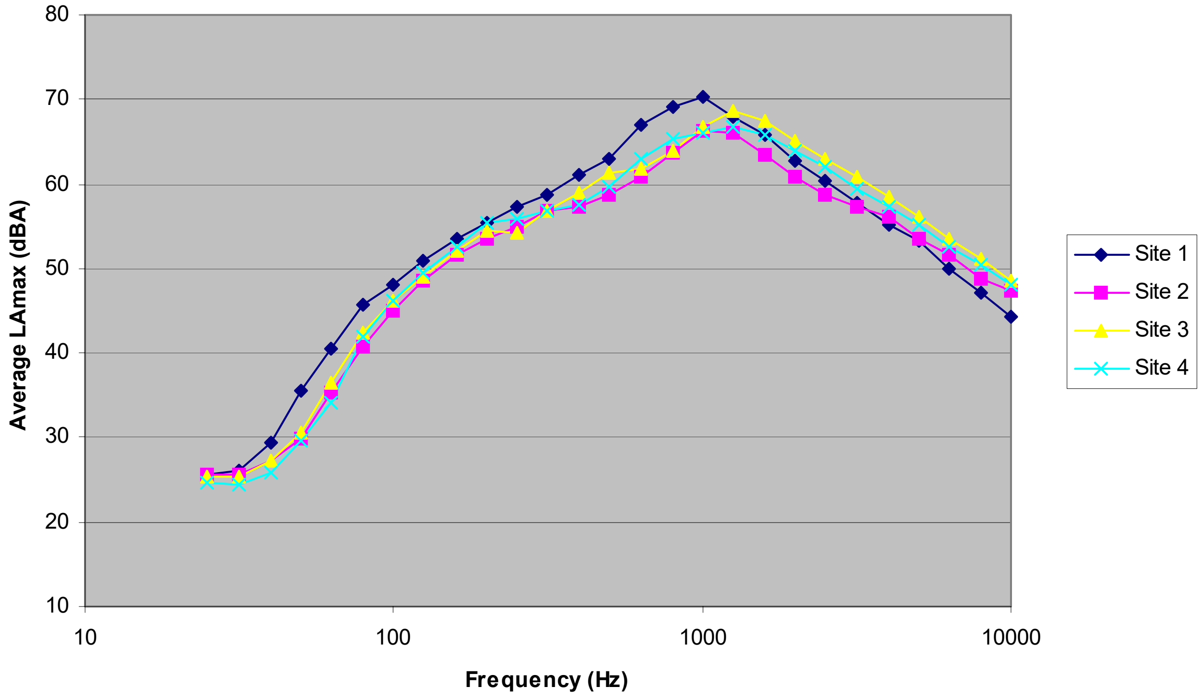
All plots show values where site bias has not been removed. Results are shown for various combinations of parameters:

- Figures E-4 through E-18 compare results for the different pavements for one age and a single microphone location; this includes results for both automobiles and heavy trucks. These plots highlight the spectral differences among pavements.
- Figures E-19 through E-23 compare results for different ages of a single pavement for a single microphone location; this includes results for automobiles only (heavy truck results show no trends). These plots highlight the age-related spectral differences among microphone locations.
- Figures E-24 through E-28 compare results for different microphone locations for a single pavement for one age (16 months only); this includes results for both automobiles and heavy trucks. These plots highlight the spectral differences among microphone locations.

Note: Data are not available for some data sets in Figures 4-28; results shown are those available.

As a reminder …

Site Information		Microphone Locations	
site name	pavement type	distance (ft)	height (ft)
Site 1 (S1)	DGAC 30 mm	25	5
Site 2 (S2)	OGAC 75 mm	50	5
Site 3 (S3)	OGAC 30 mm	50	15
Site 4 (S4)	RAC Type O 30 mm	200	5
Site 5 (S5)	BWC 30 mm		



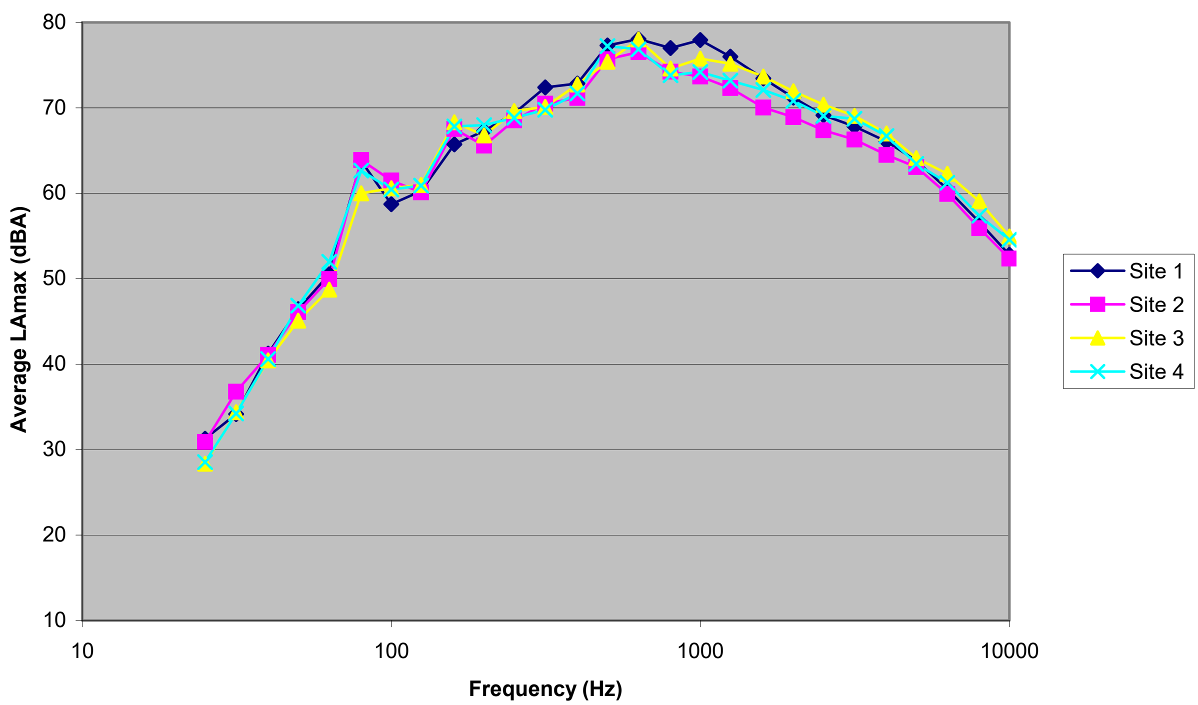
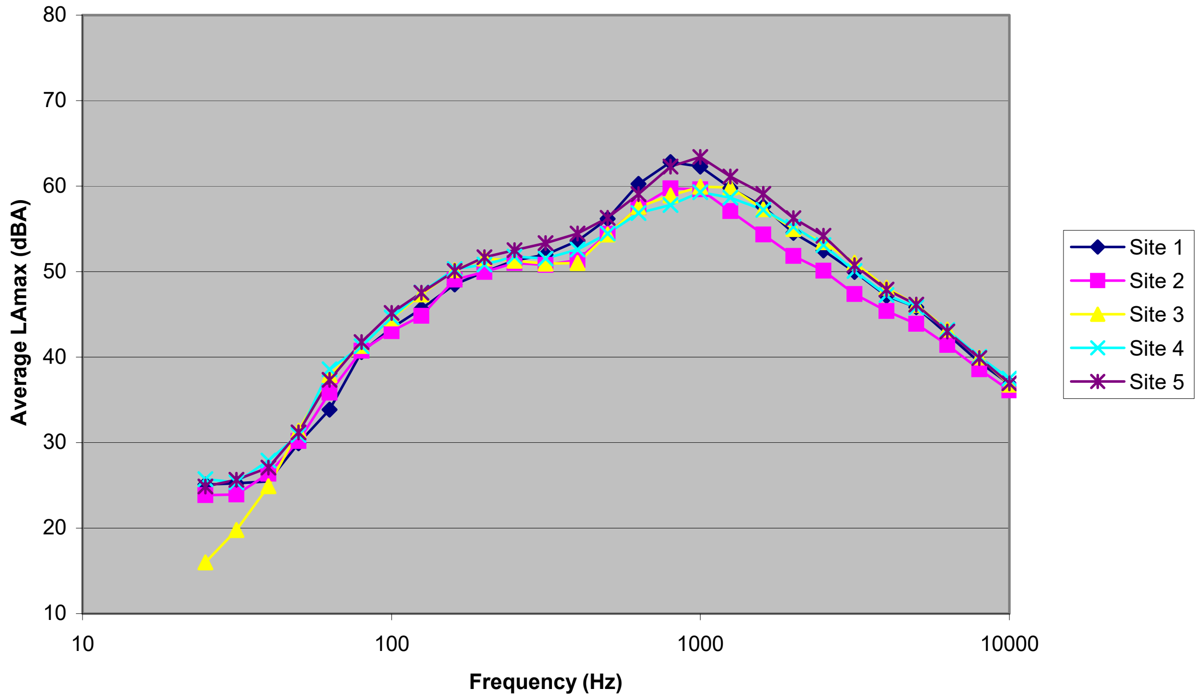


Figure E-4. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 25 ft, height 5 ft.



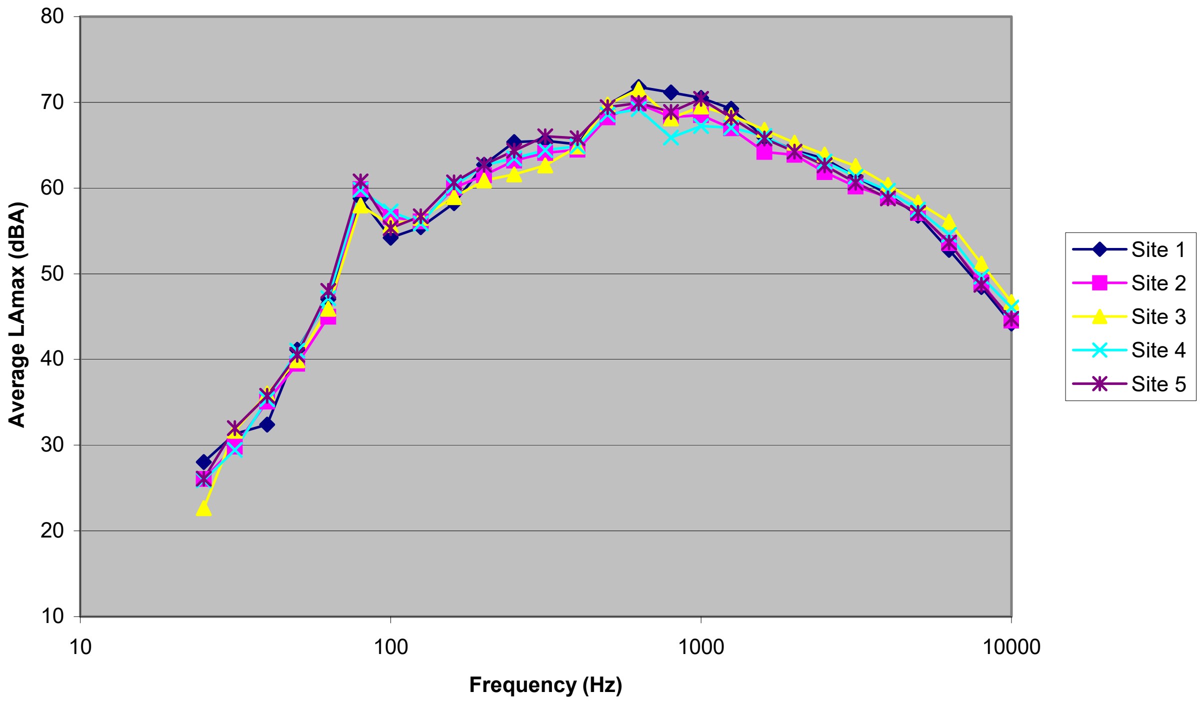
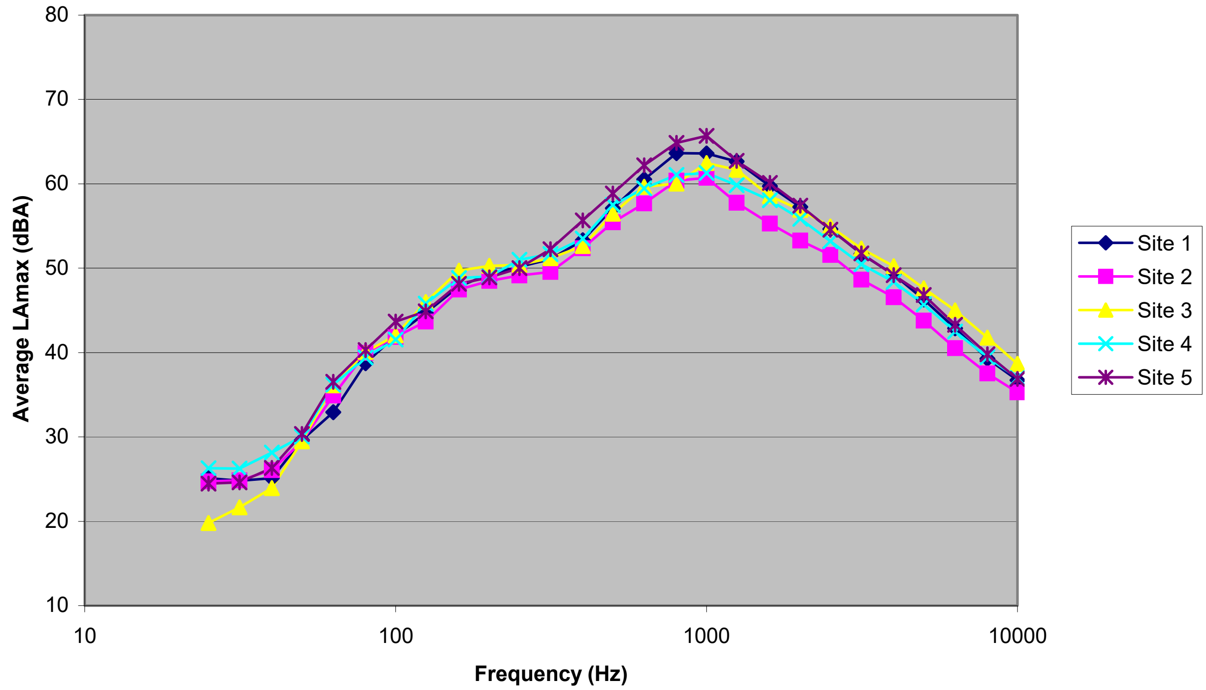


Figure E-5. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 50 ft, height 5 ft.



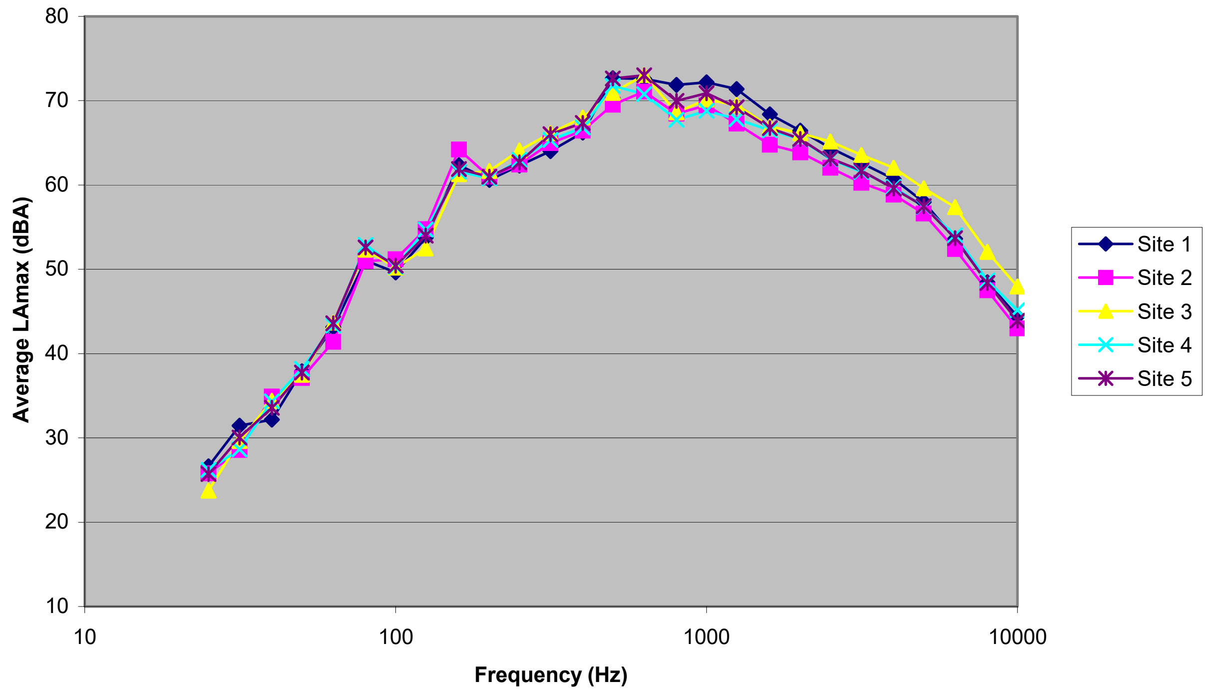
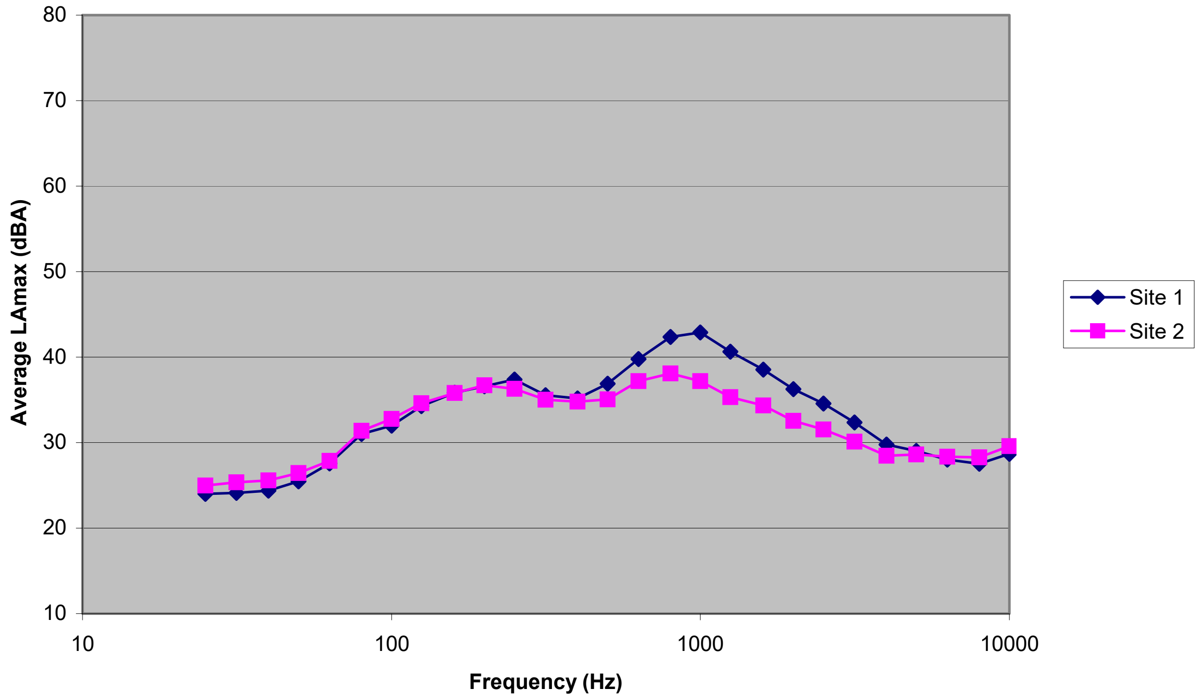


Figure E-6. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 50 ft, height 15 ft.



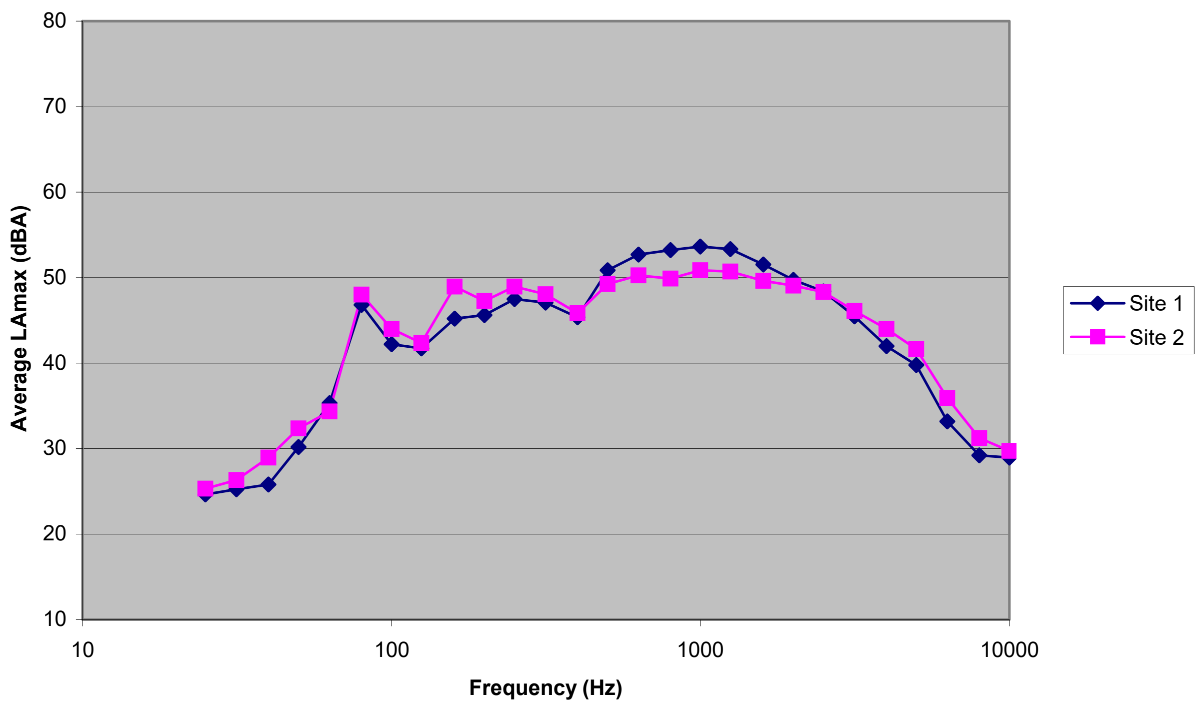
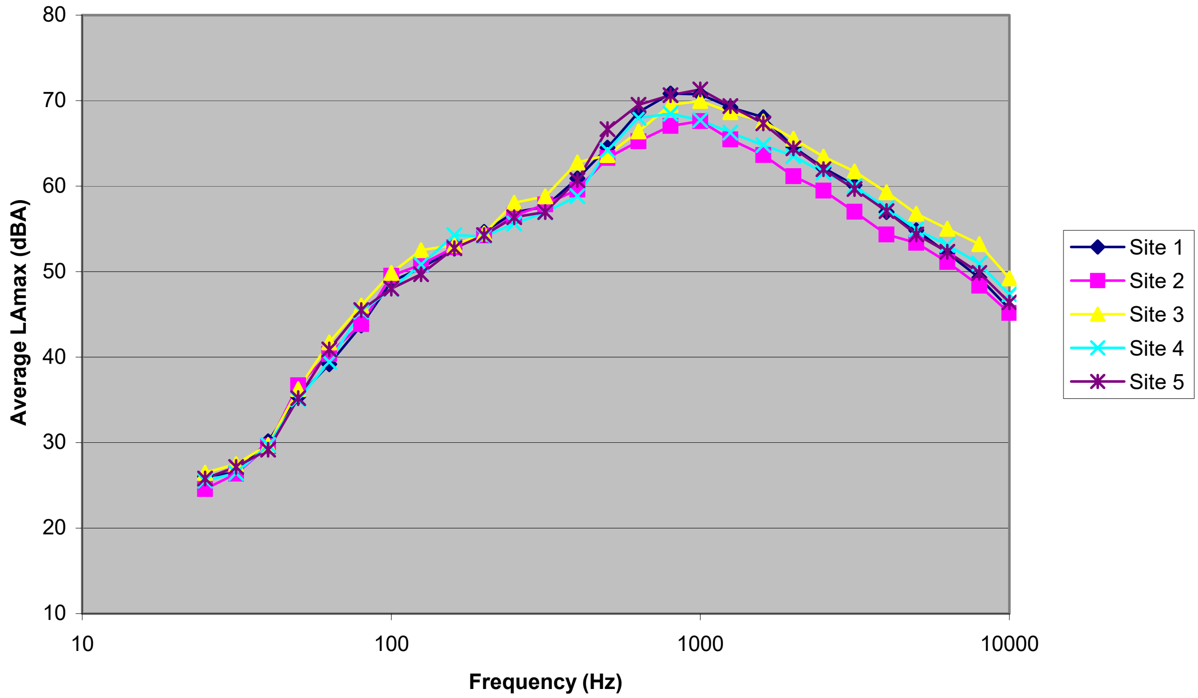


Figure E-7. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 200 ft, height 5 ft.



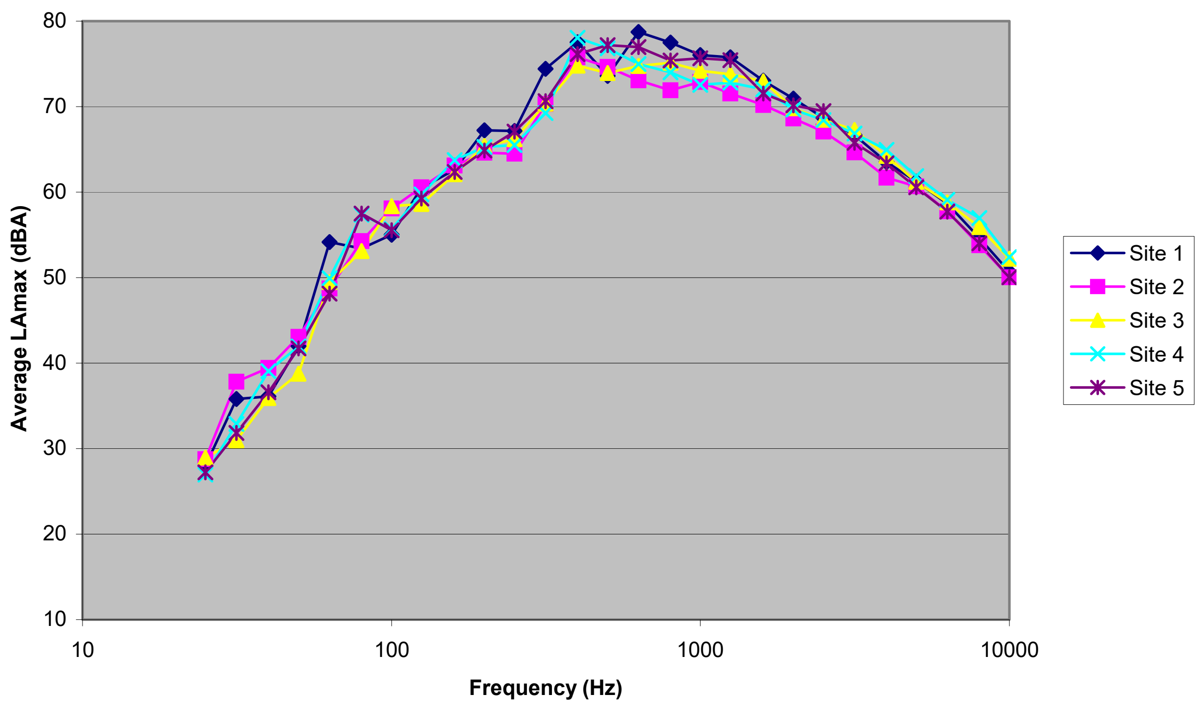
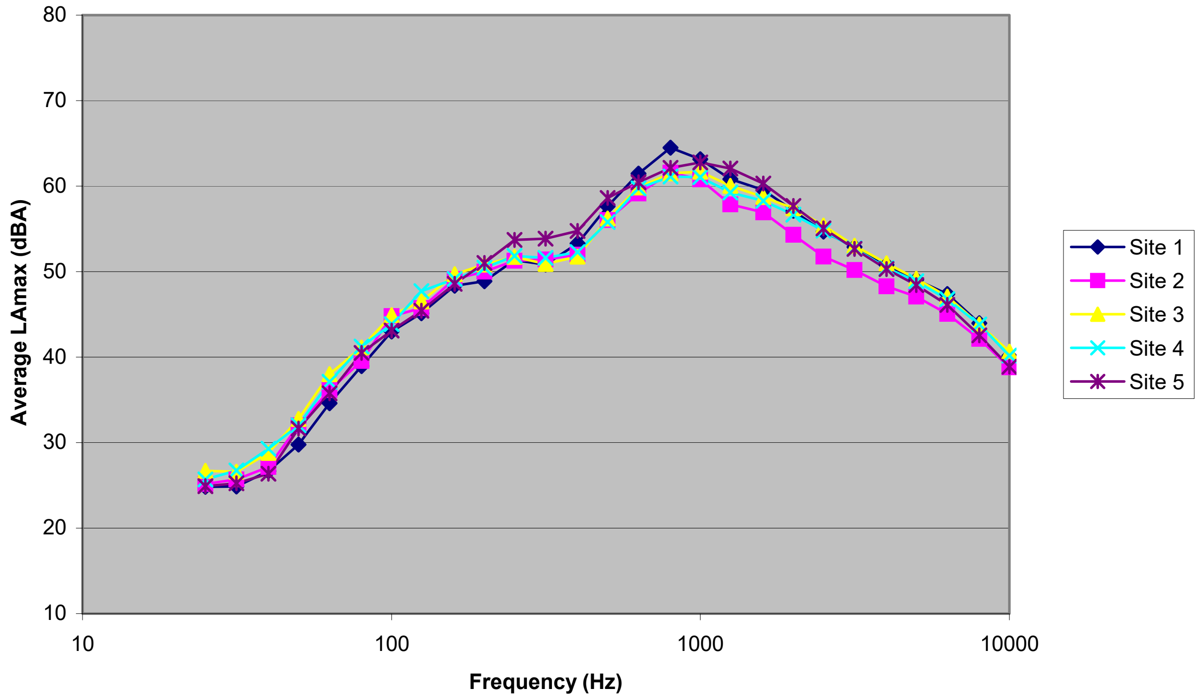


Figure E-8. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10 months. Microphone location: distance 25 ft, height 5 ft.



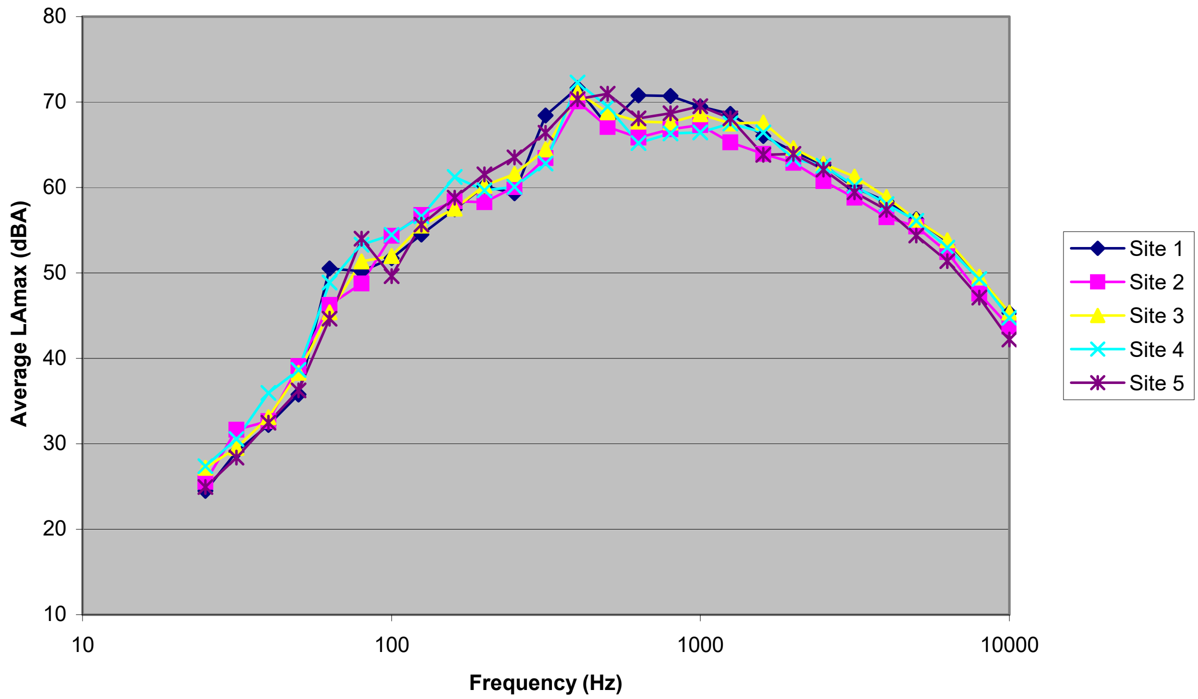
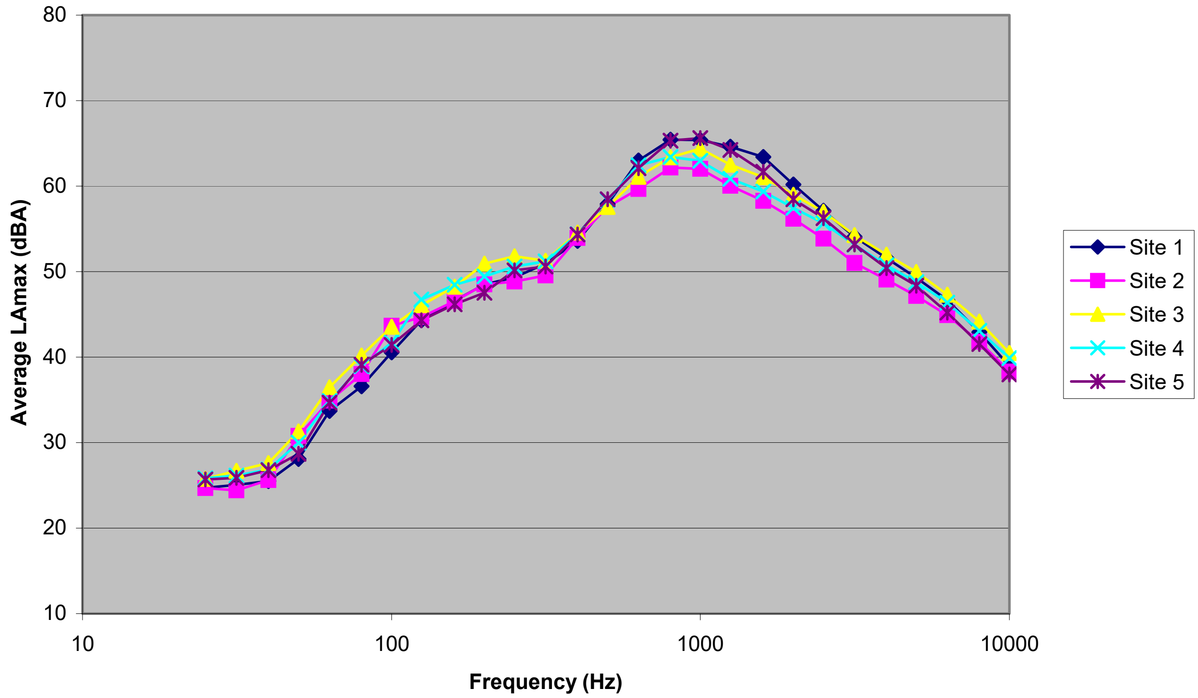


Figure E-9. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10 months. Microphone location: distance 50 ft, height 5 ft.



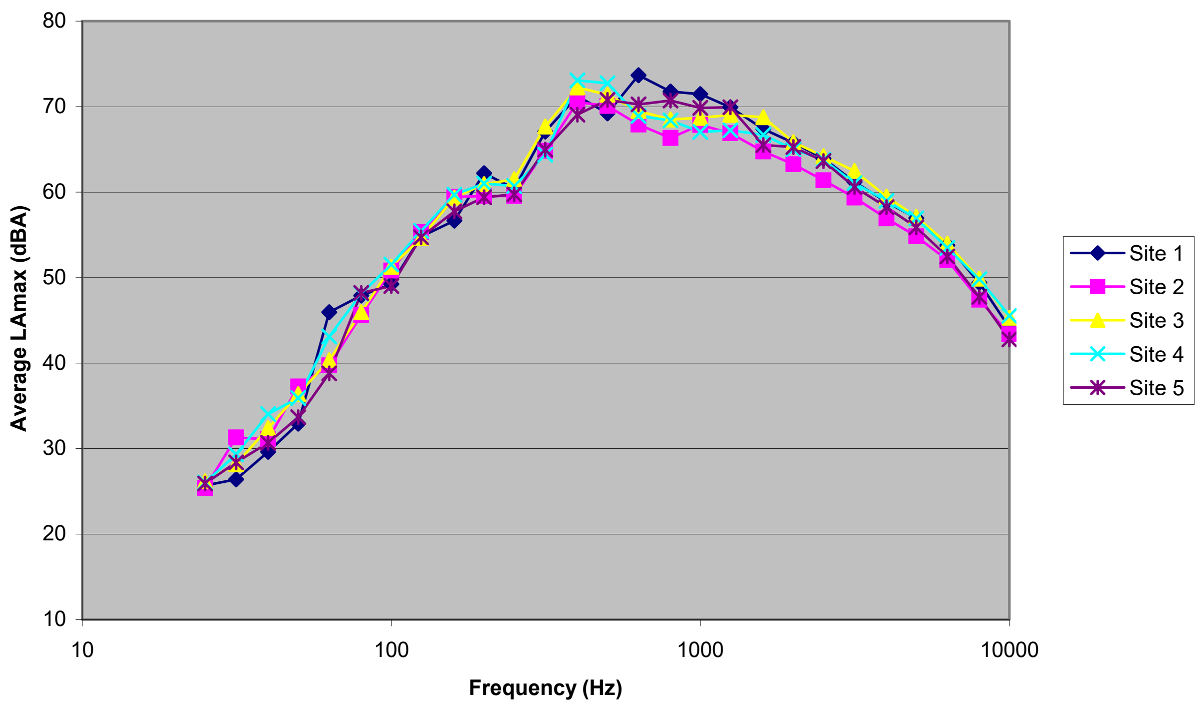
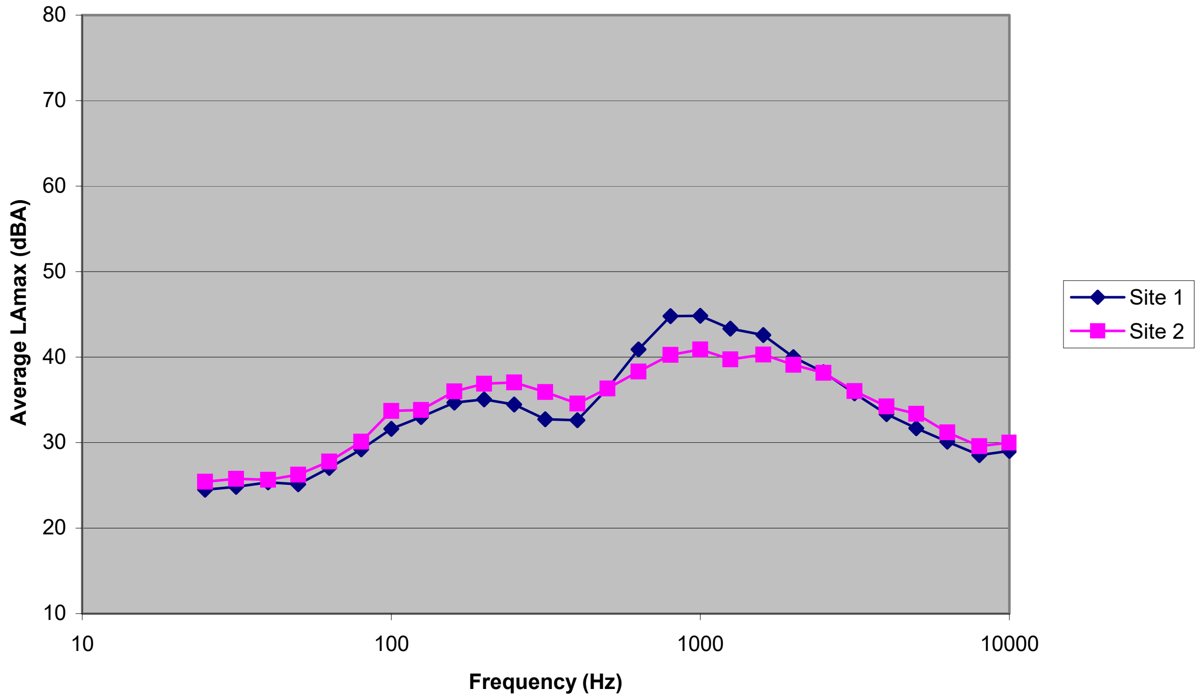


Figure E-10. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10 months. Microphone location: distance 50 ft, height 15 ft.



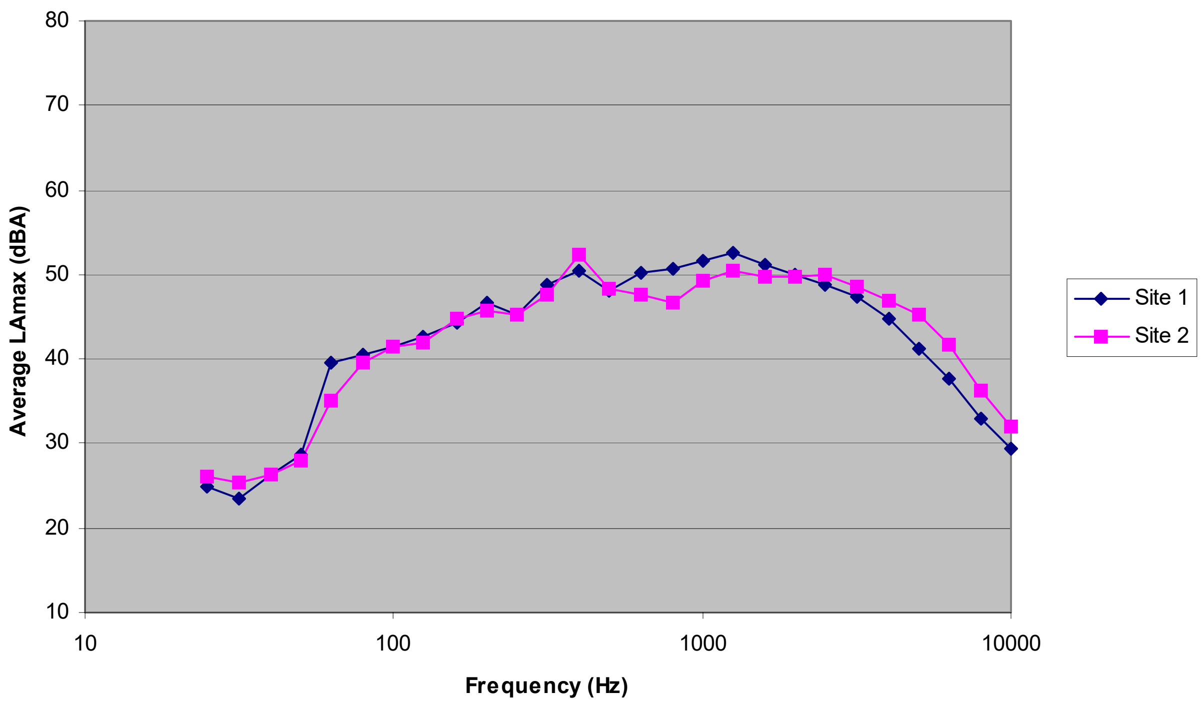
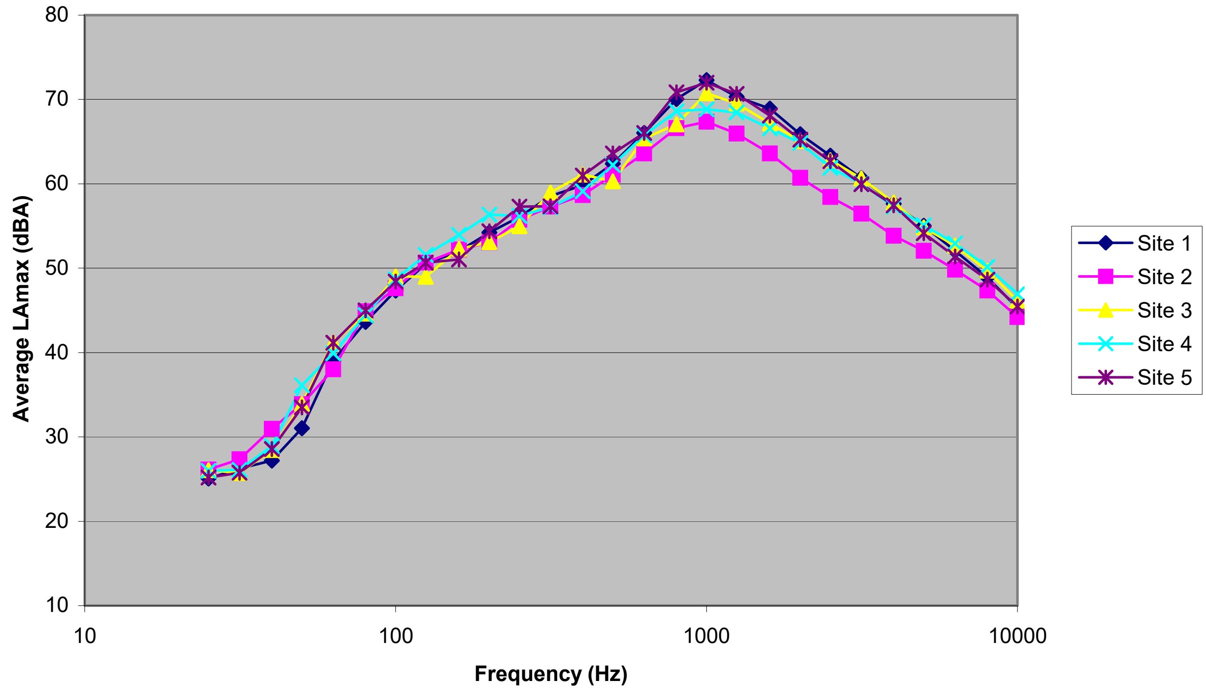


Figure E-11. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10months. Microphone location: distance 200 ft, height 5 ft.



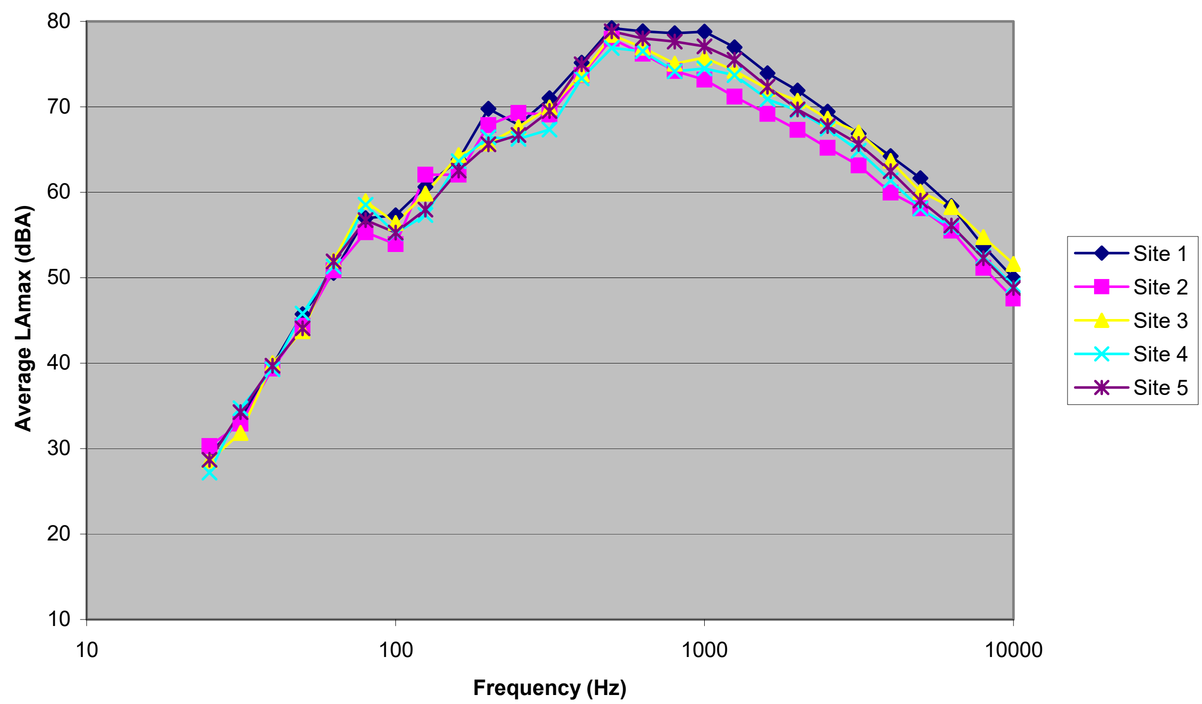


Figure E-12. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 25 ft, height 5 ft.

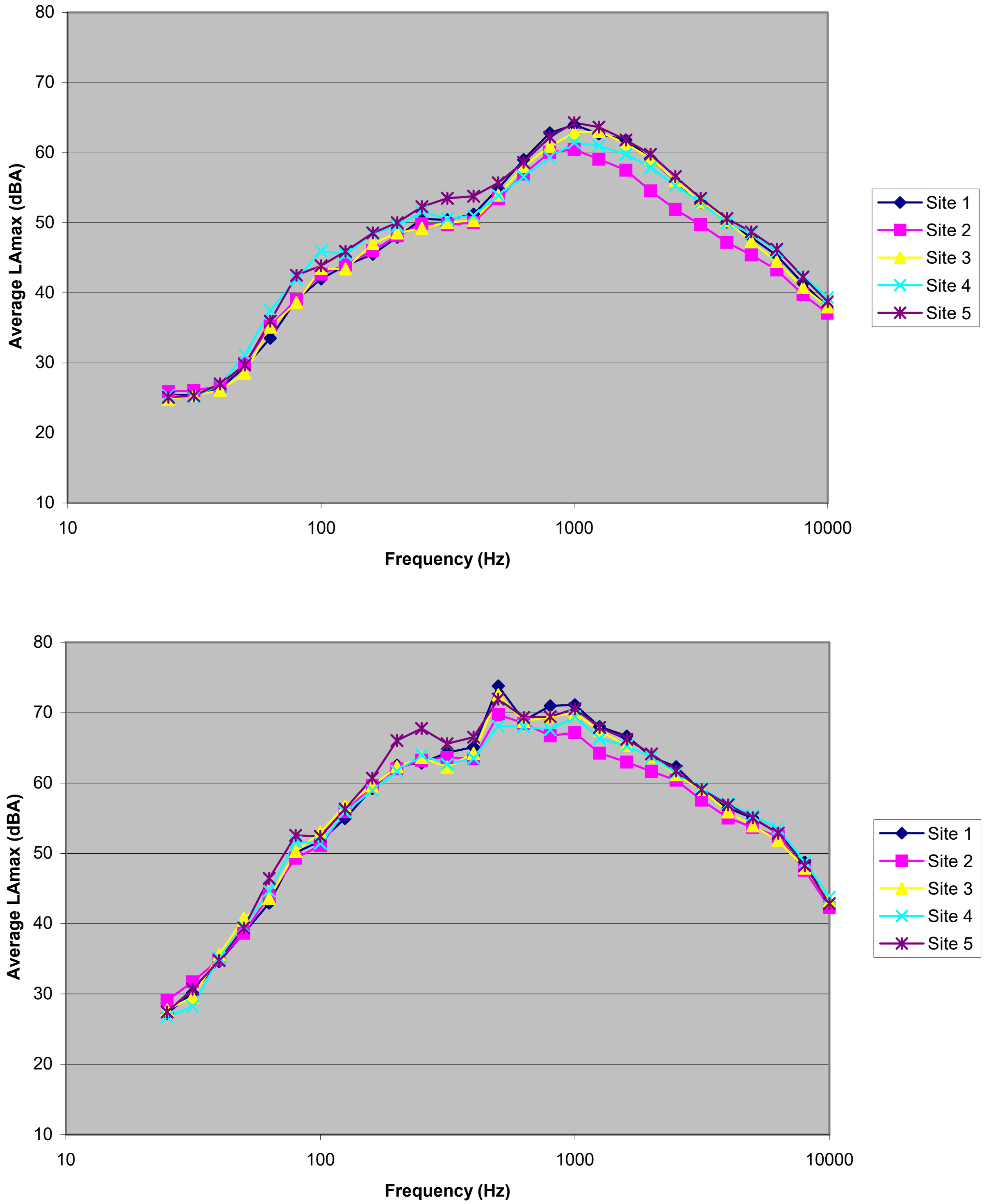
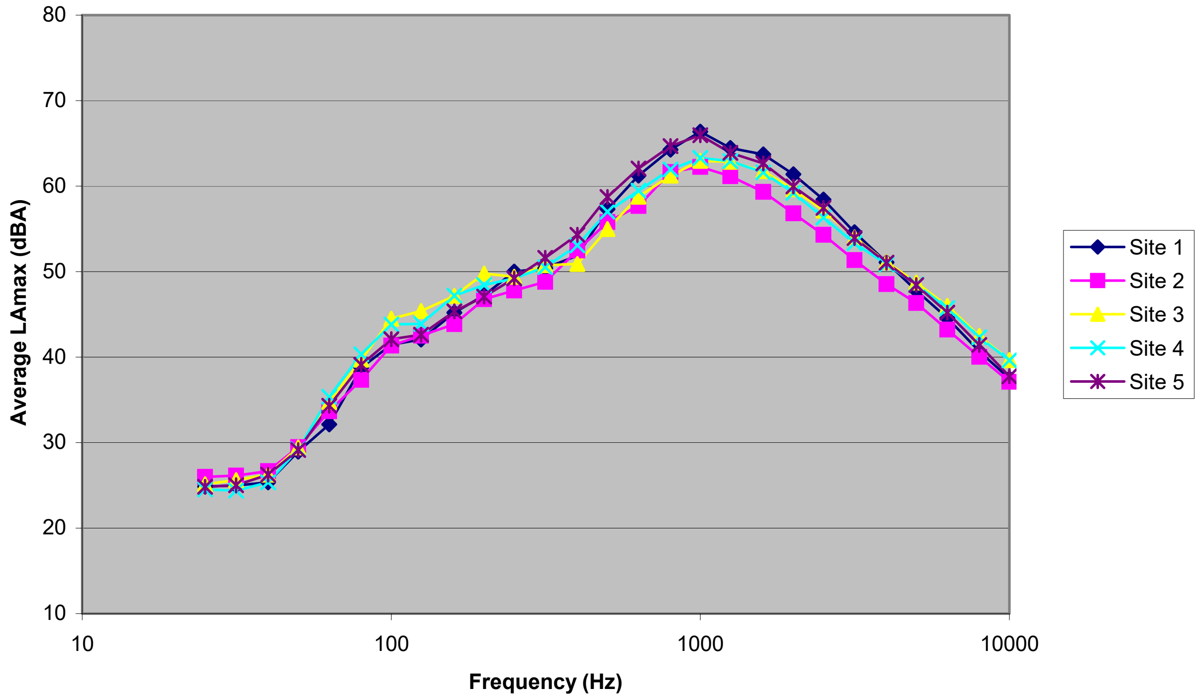


Figure E-13. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 50 ft, height 5 ft.



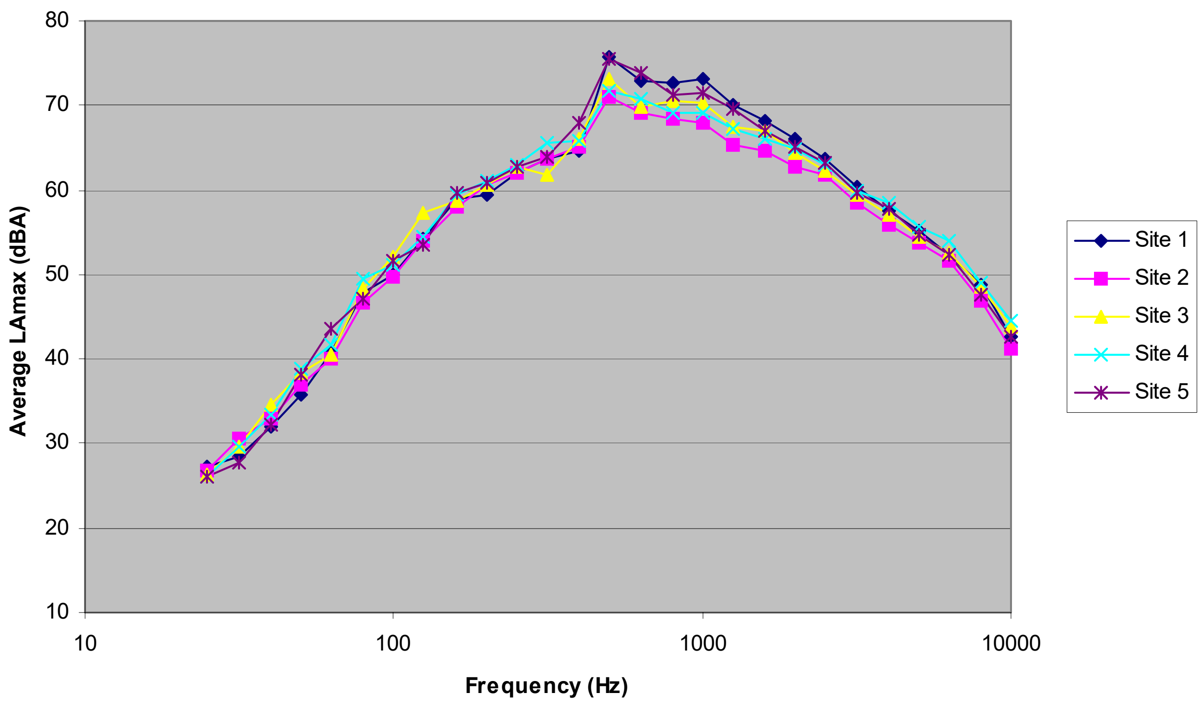
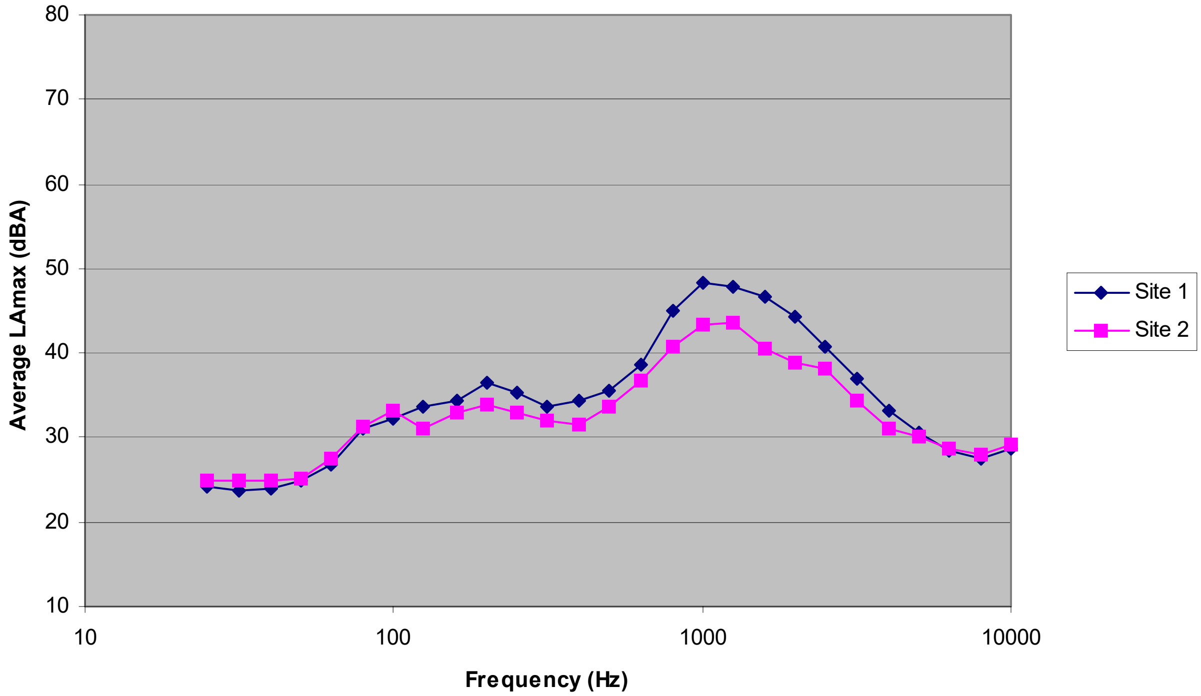


Figure E-14. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 50 ft, height 15 ft.



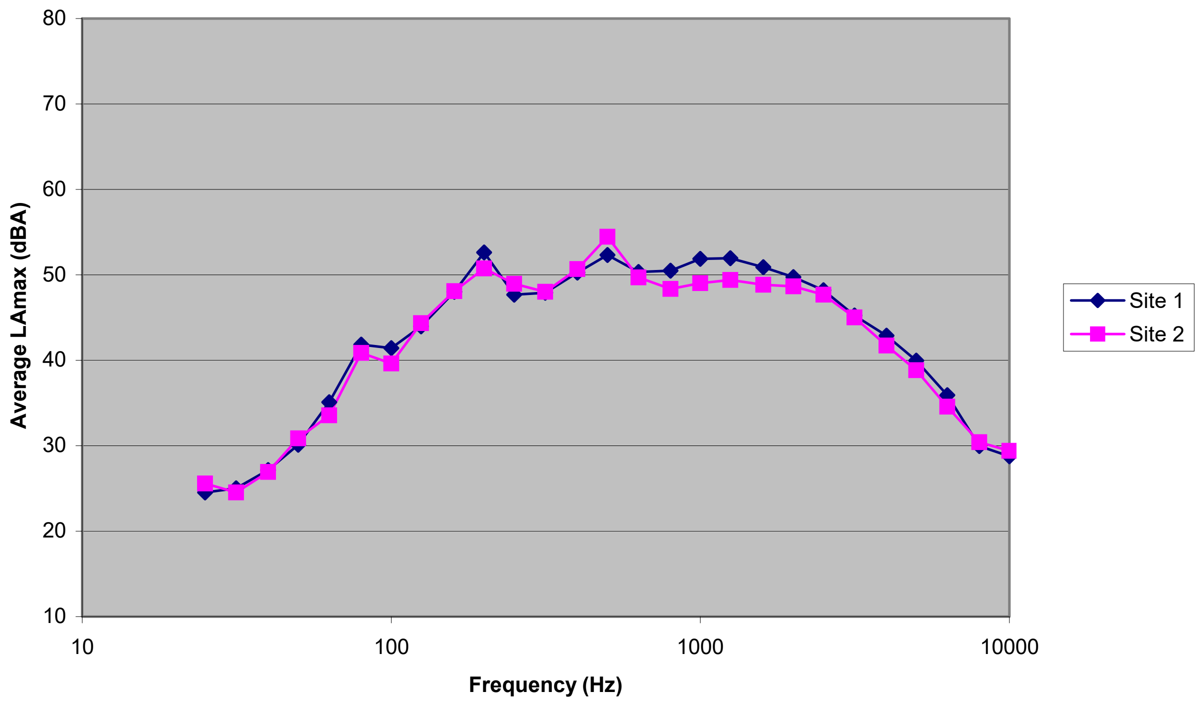
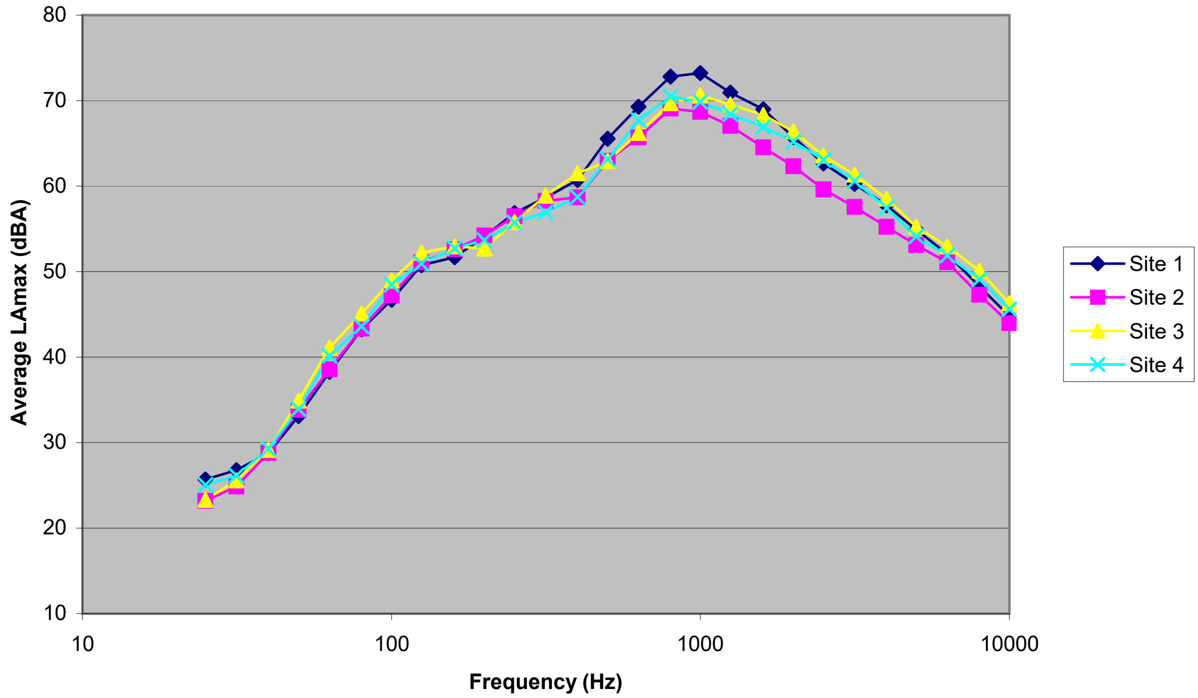


Figure E-15. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 200 ft, height 5 ft.



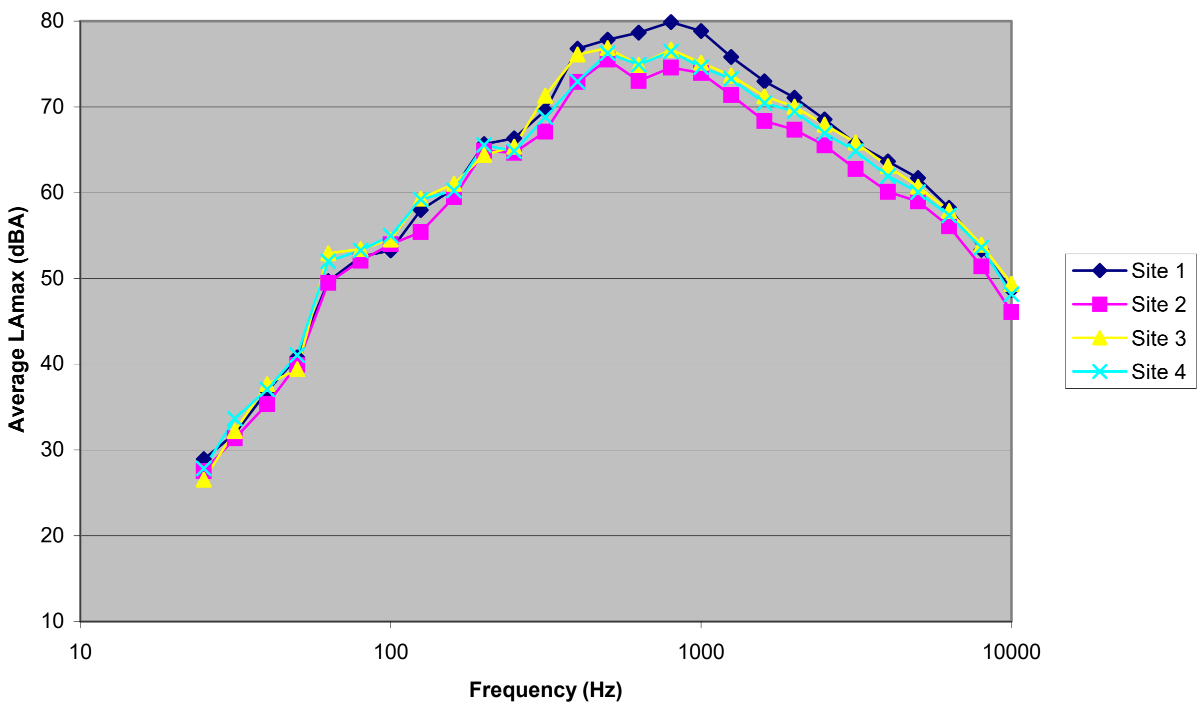
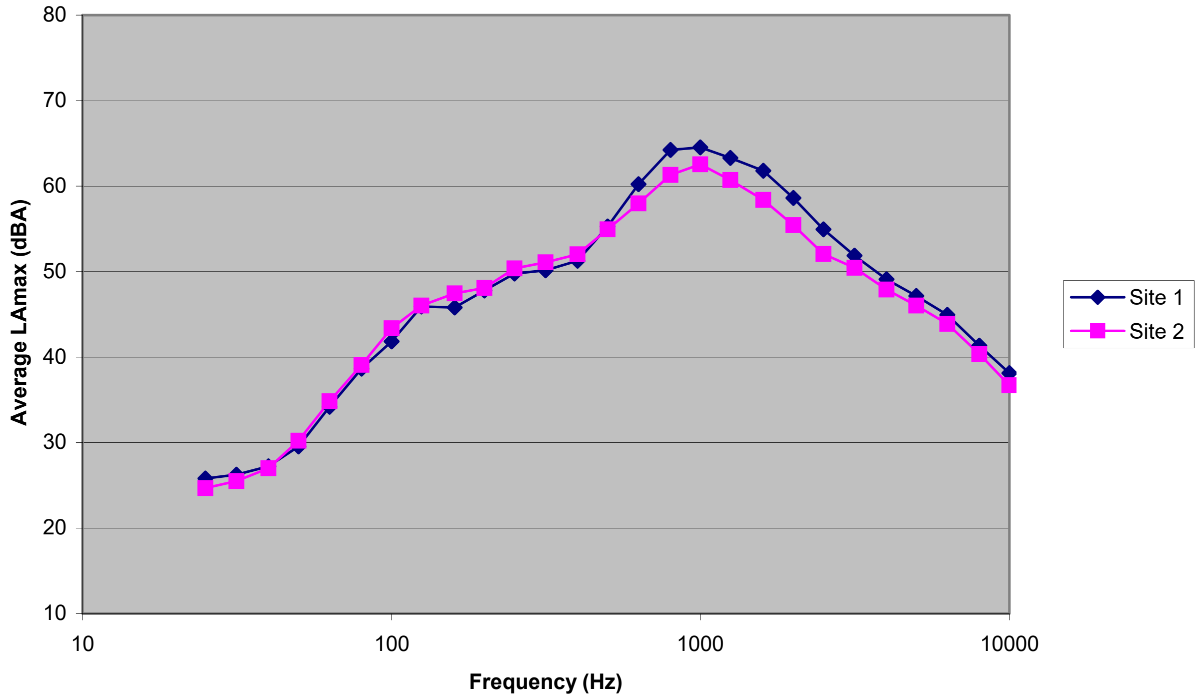


Figure E-16. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 52 months. Microphone location: distance 25 ft, height 5 ft.



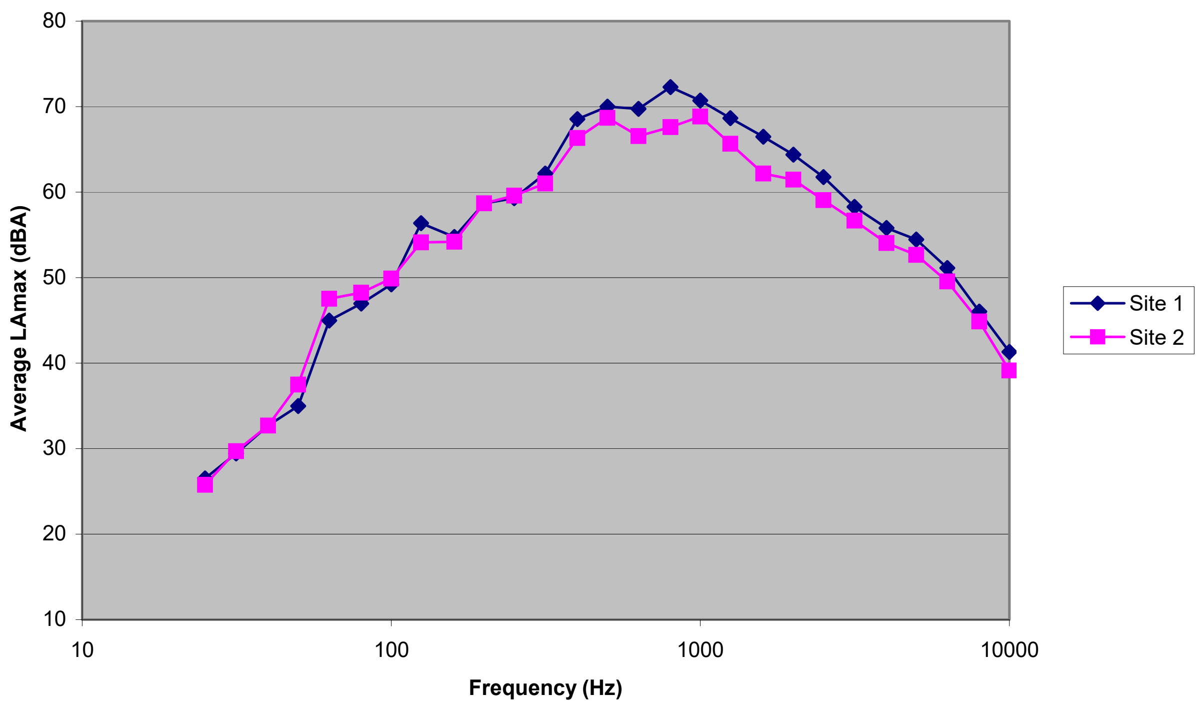
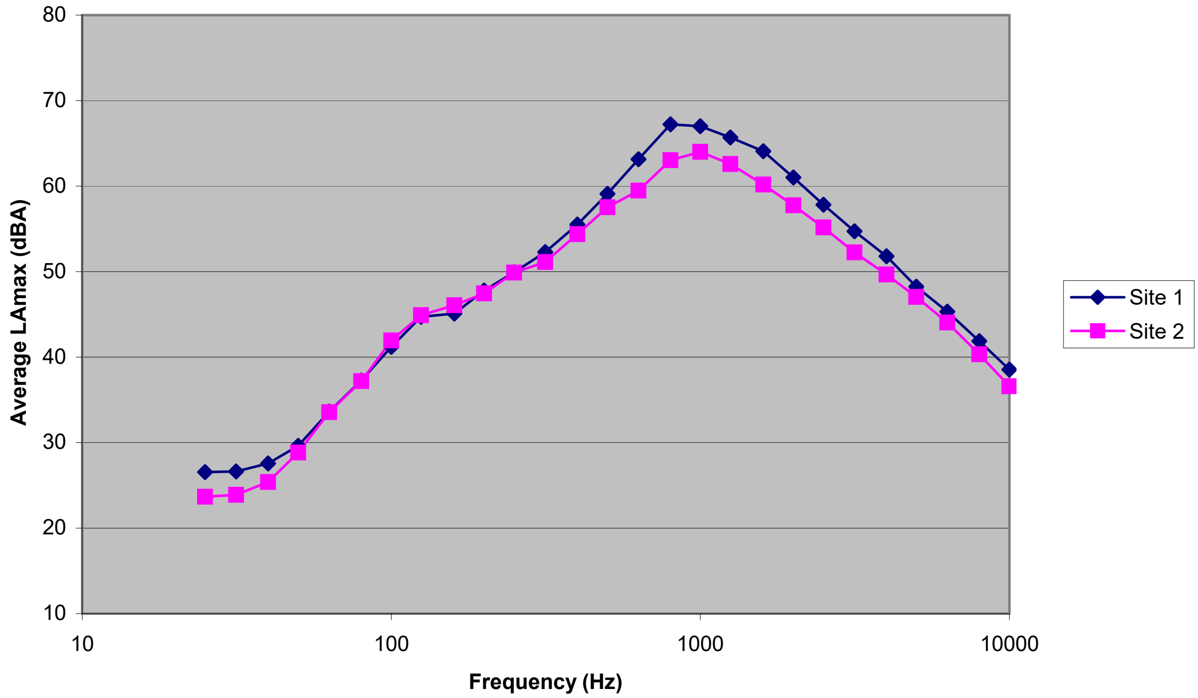


Figure E-17. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 52 months. Microphone location: distance 50 ft, height 5 ft.



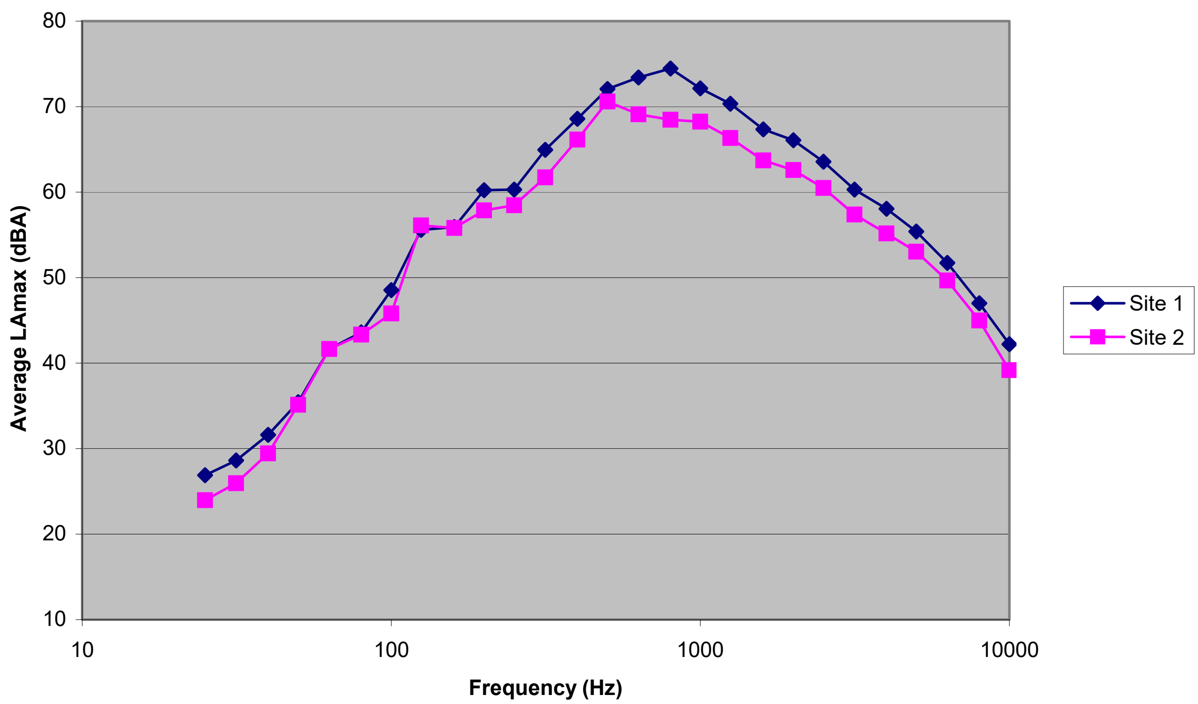


Figure E-18. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 52 months. Microphone location: distance 50 ft, height 15 ft.

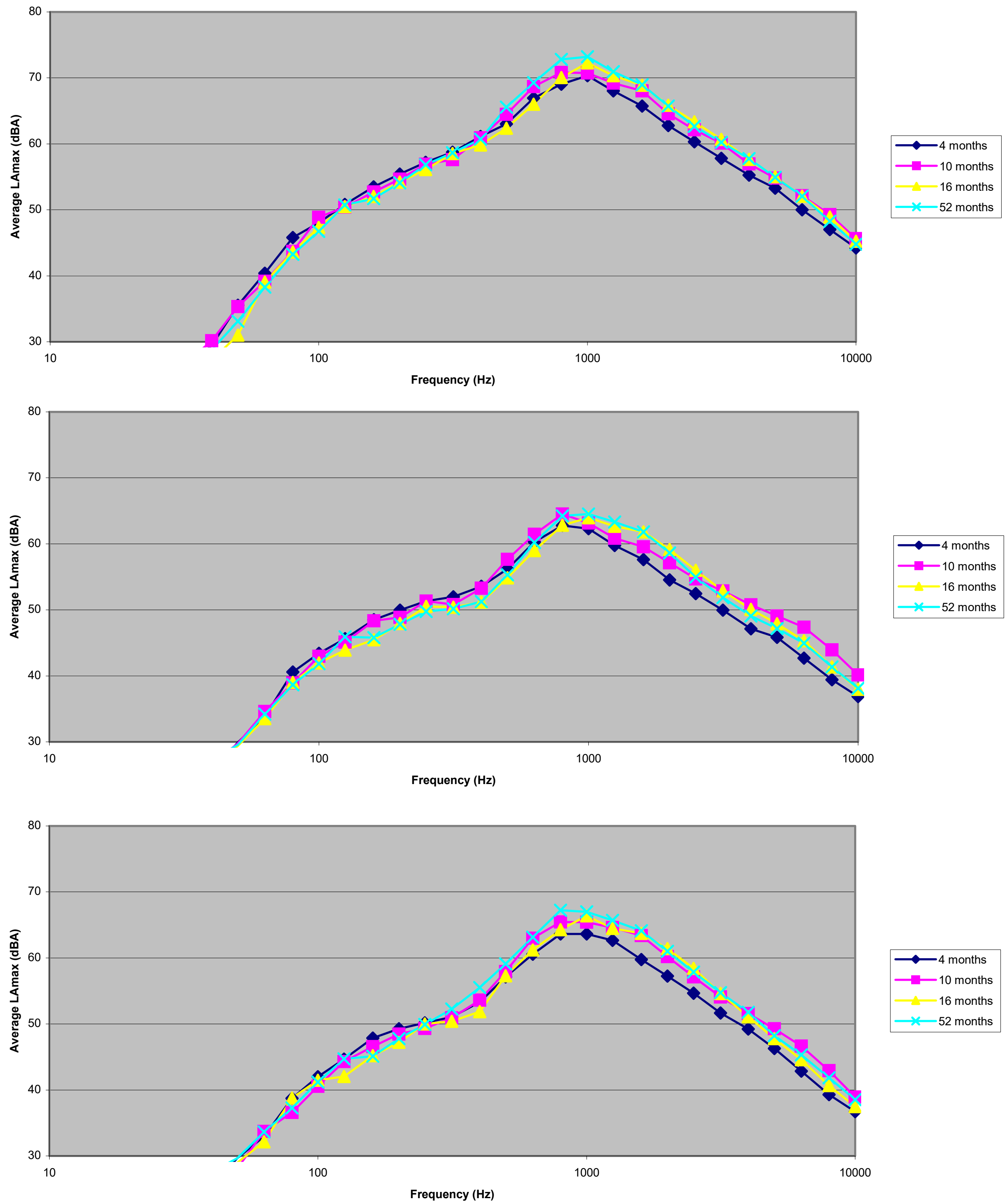


Figure E-19. Spectral data for automobiles; post-overlay results for Site 1 (DGAC 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).

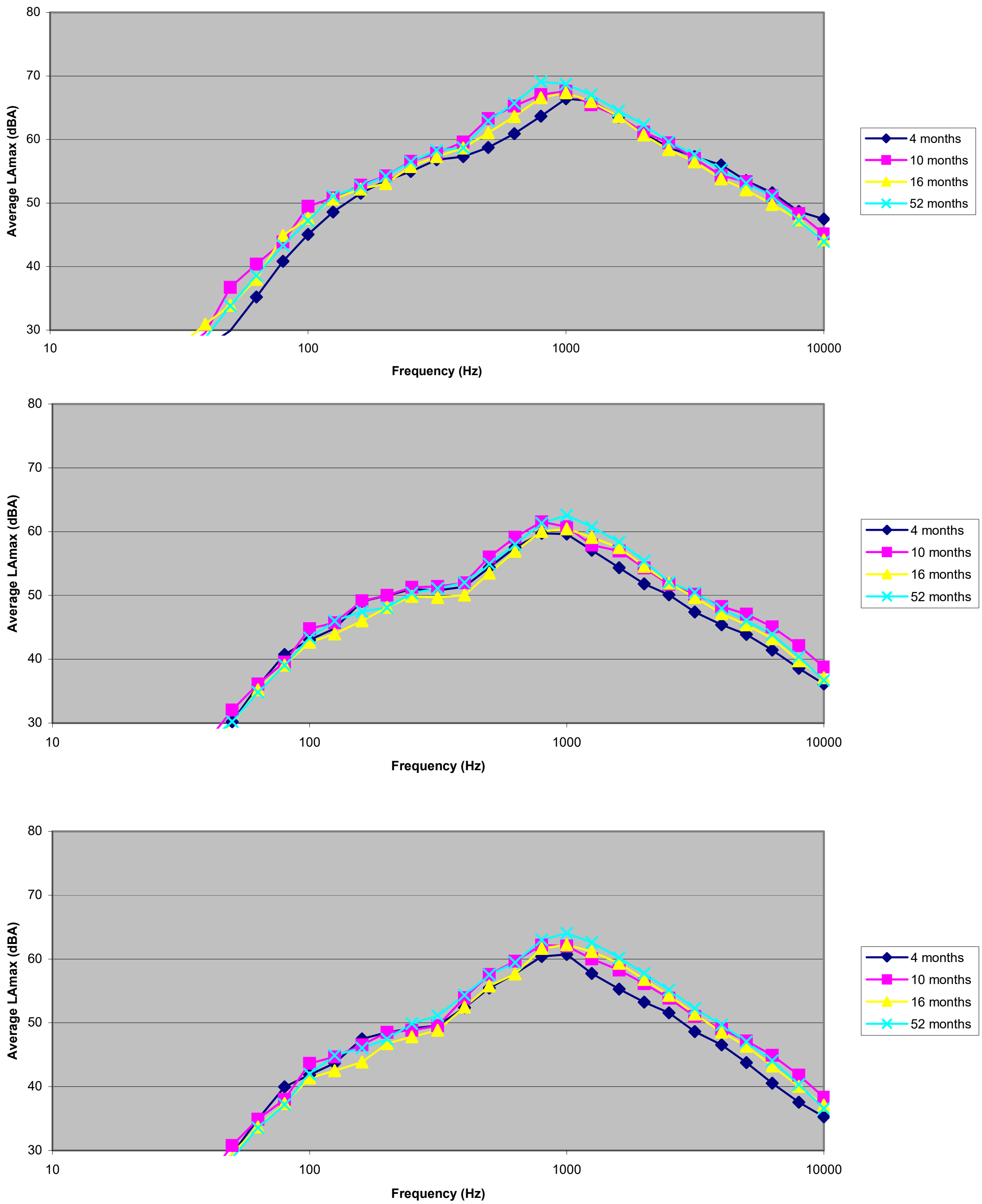


Figure E-20. Spectral data for automobiles; post-overlay results for Site 2 (OGAC 75 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).

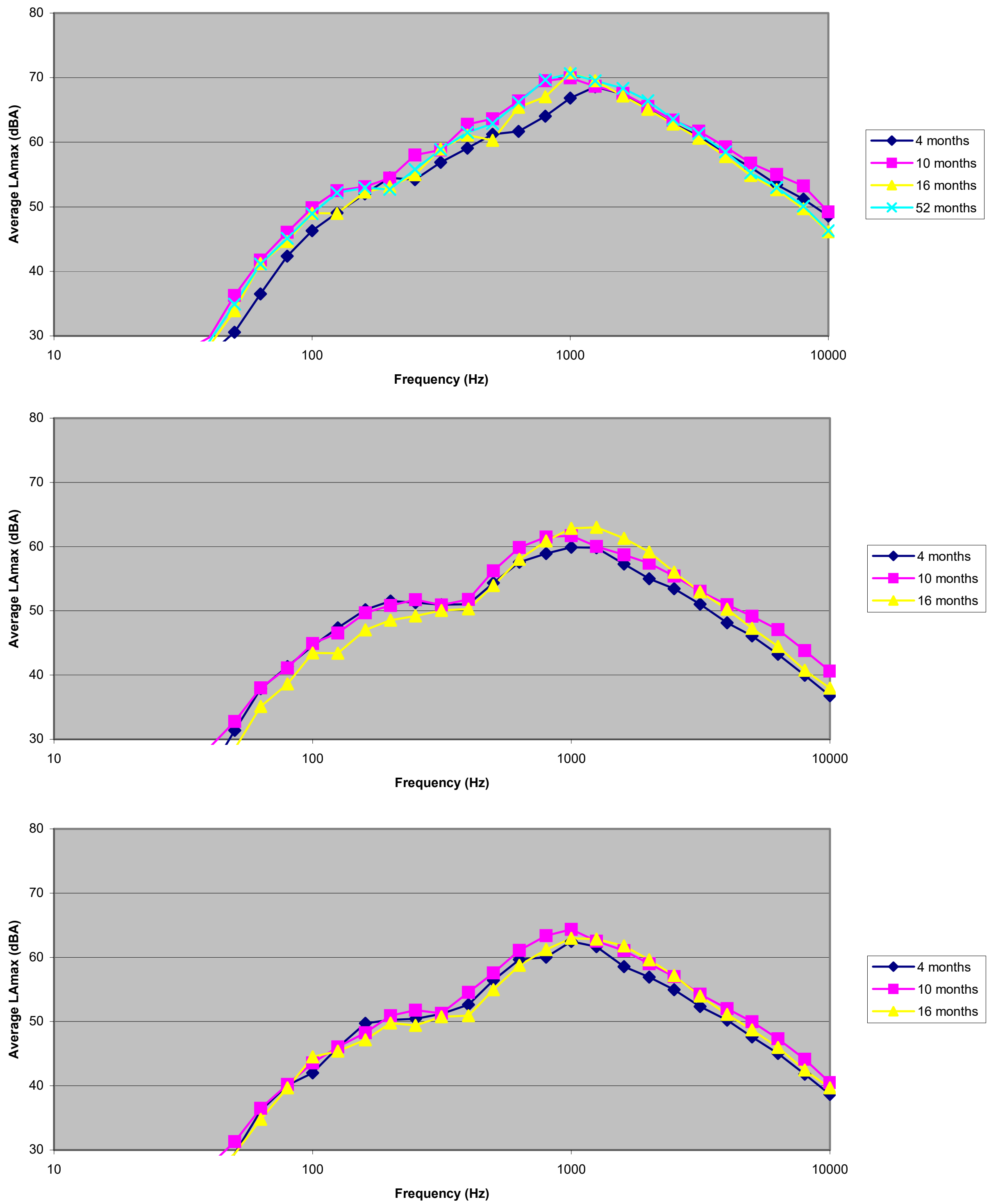
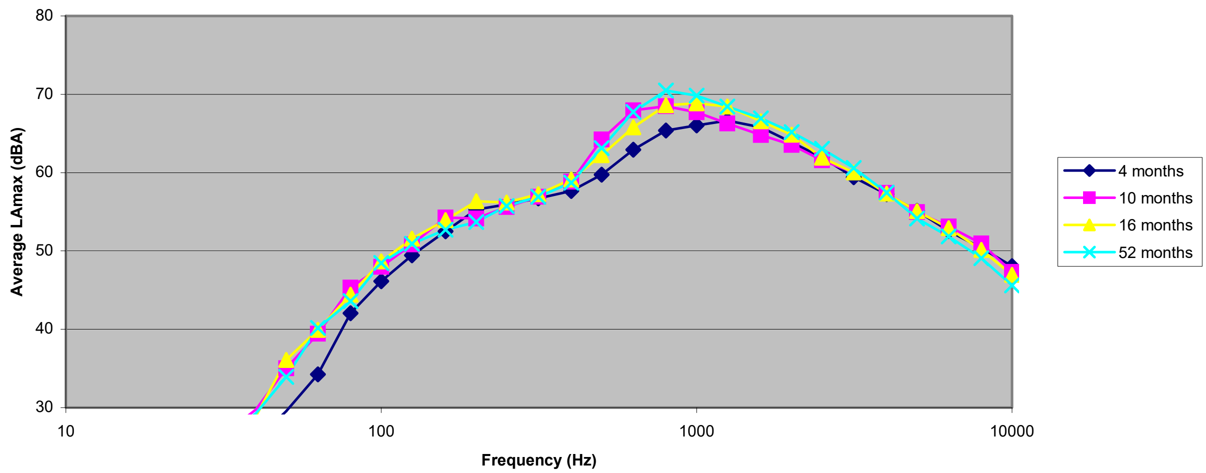
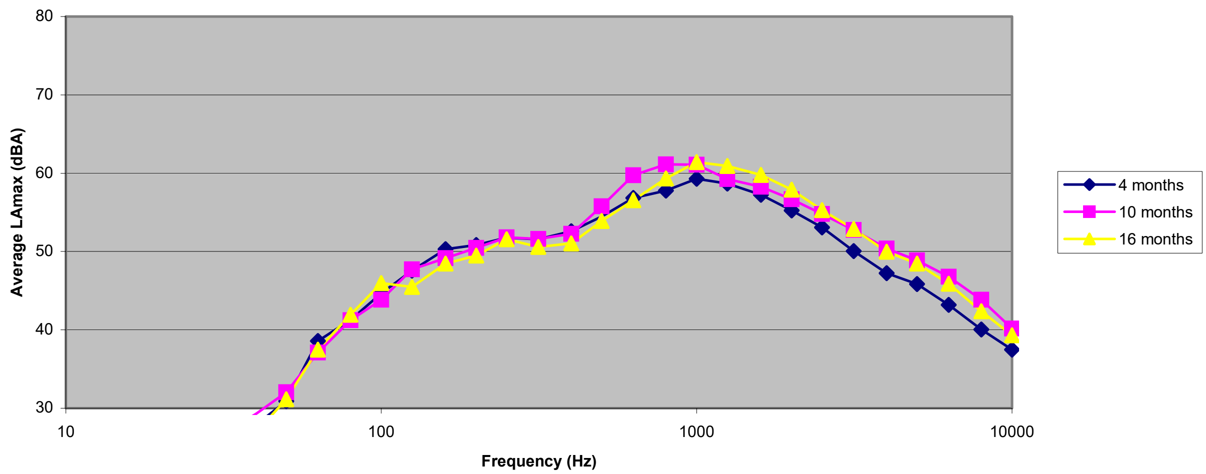


Figure E-21. Spectral data for automobiles; post-overlay results for Site 3 (OGAC 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).





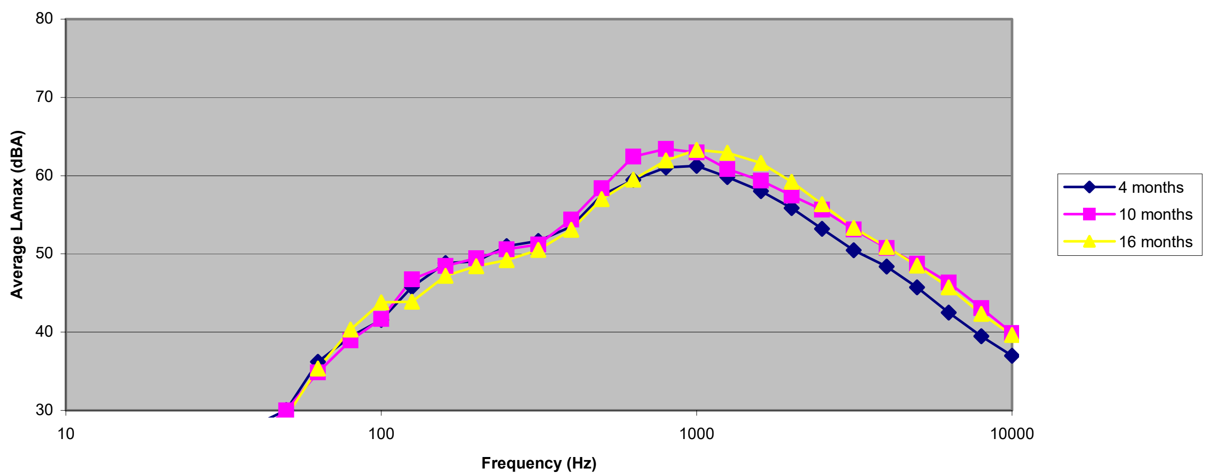


Figure E-22. Spectral data for automobiles; post-overlay results for Site 4 (RAC Type O 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).

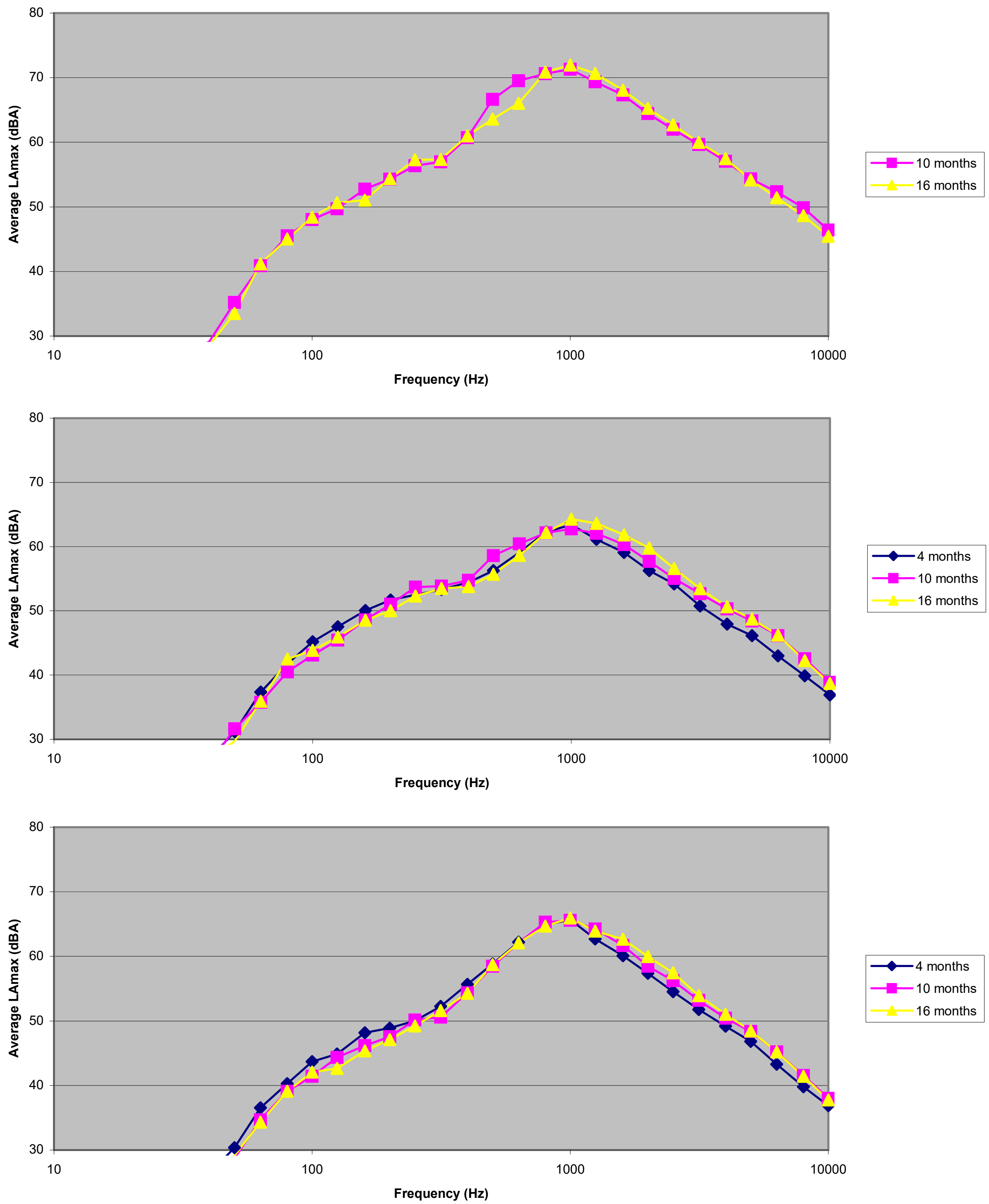
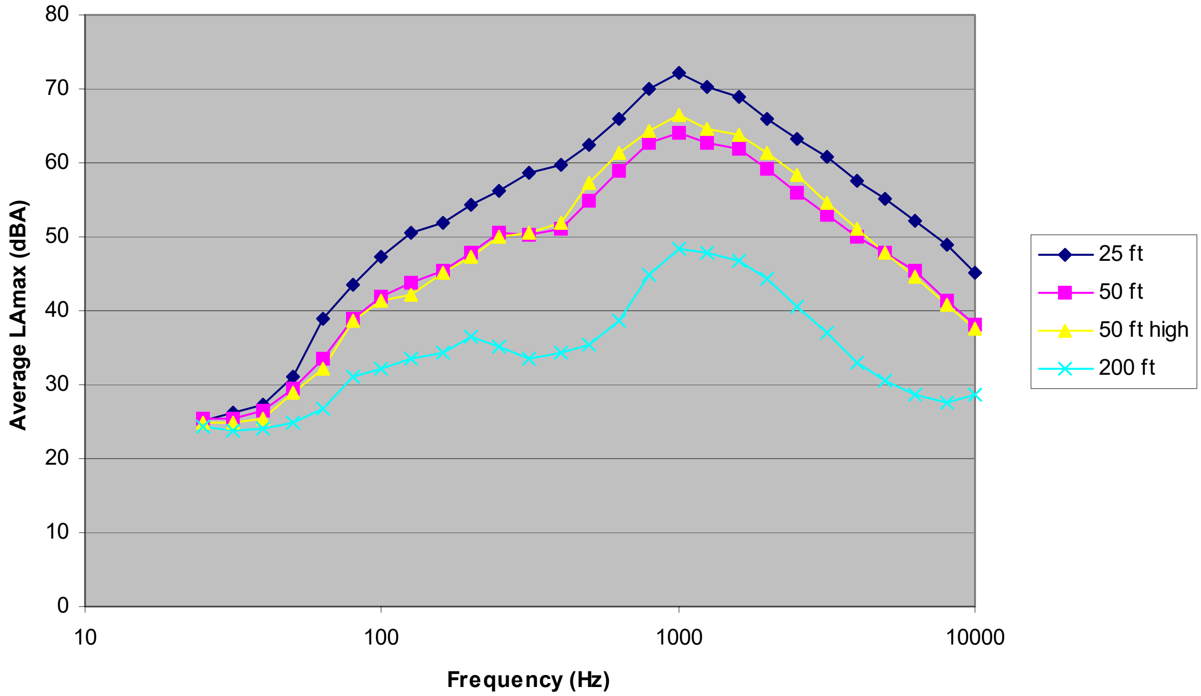


Figure E-23. Spectral data for automobiles; post-overlay results for Site 5 (BWC 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).



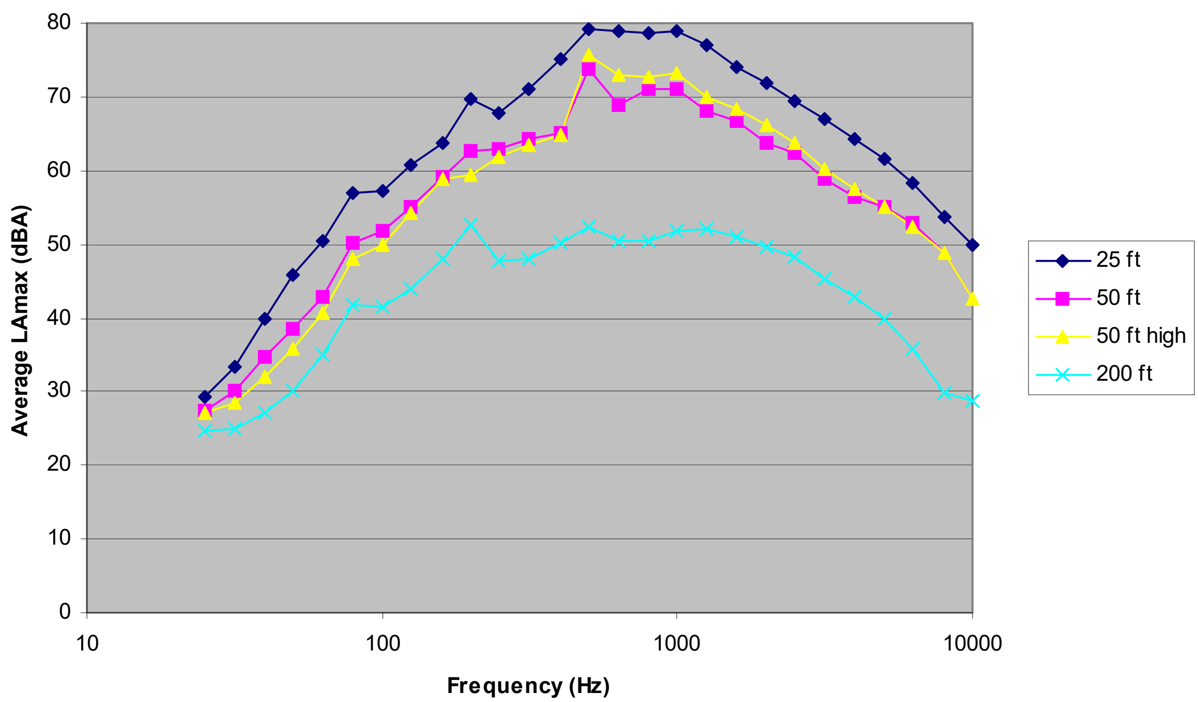
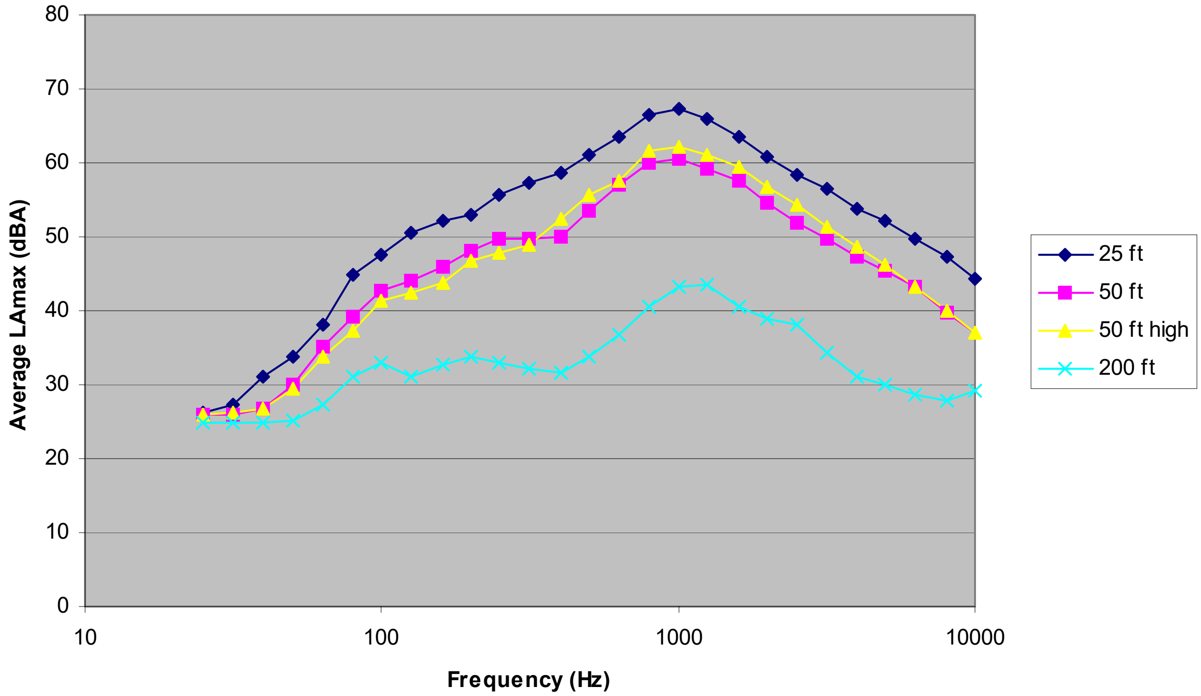


Figure E-24. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 1 (DGAC 30 mm) aged 16 months; all microphone positions.



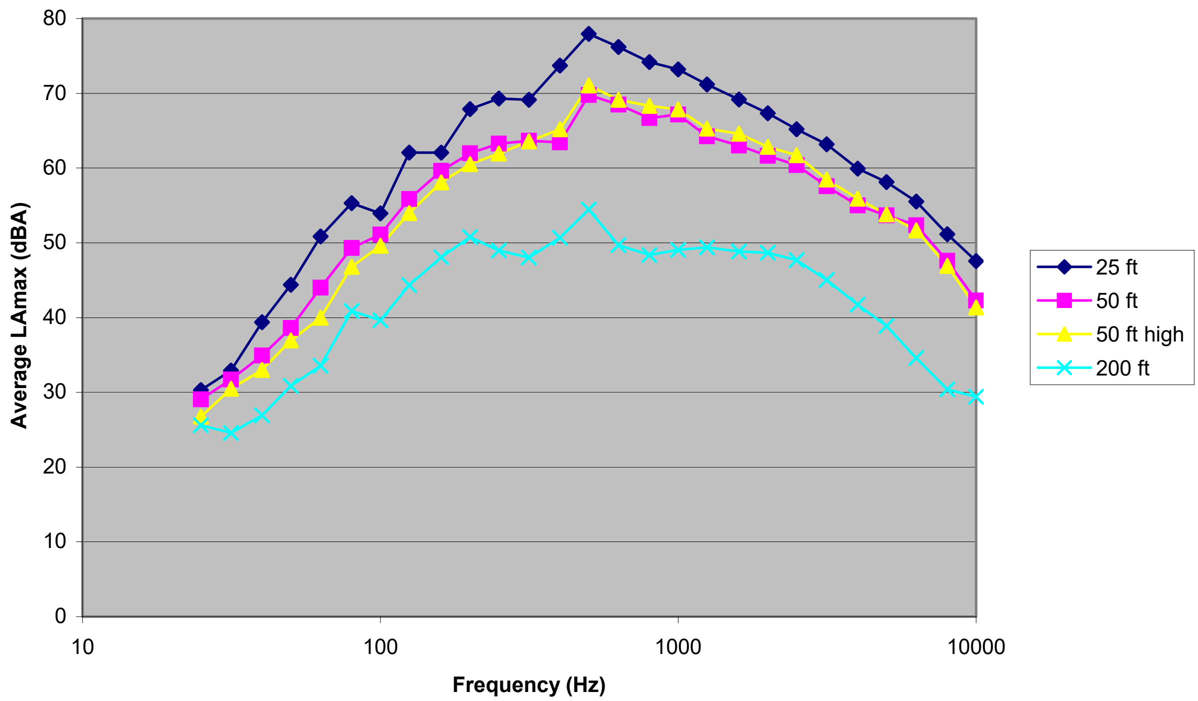


Figure E-25. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 2 (OGAC 75 mm) aged 16 months; all microphone positions.

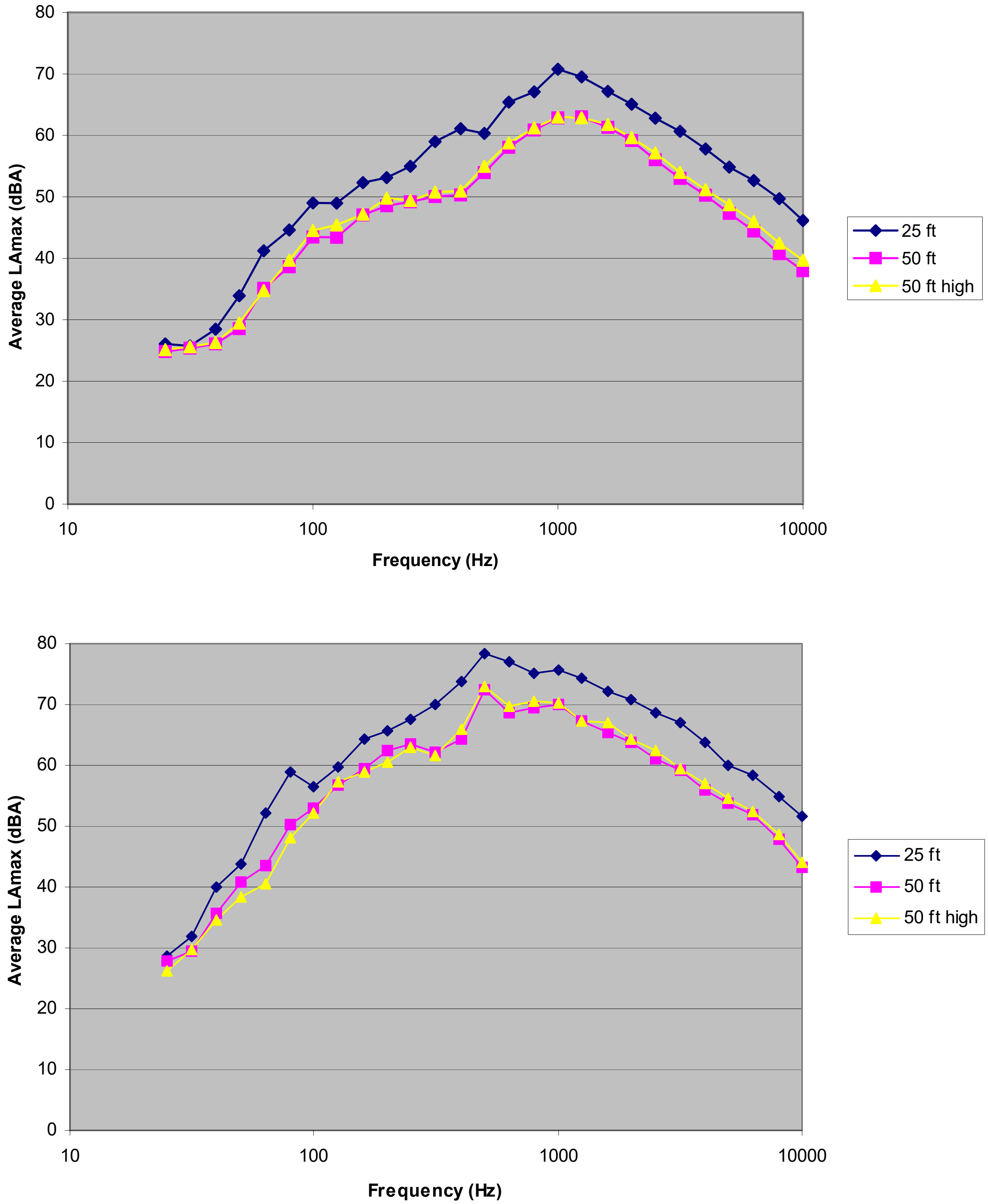
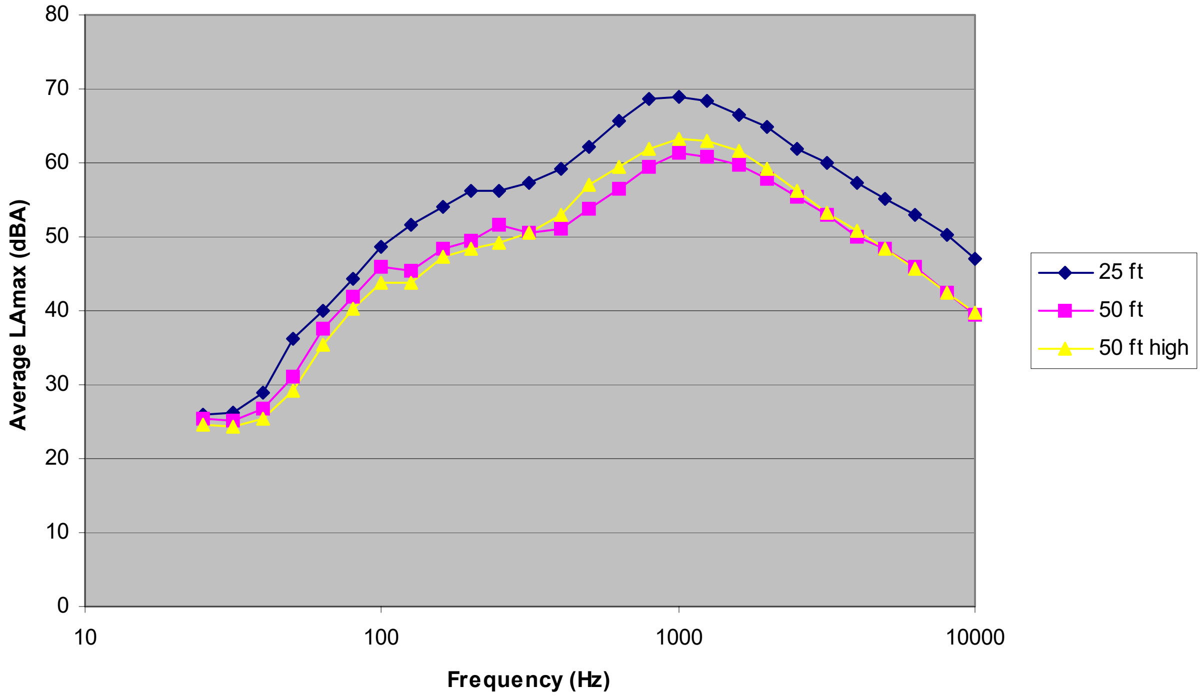


Figure E-26. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 3 (OGAC 30 mm) aged 16 months; all microphone positions.



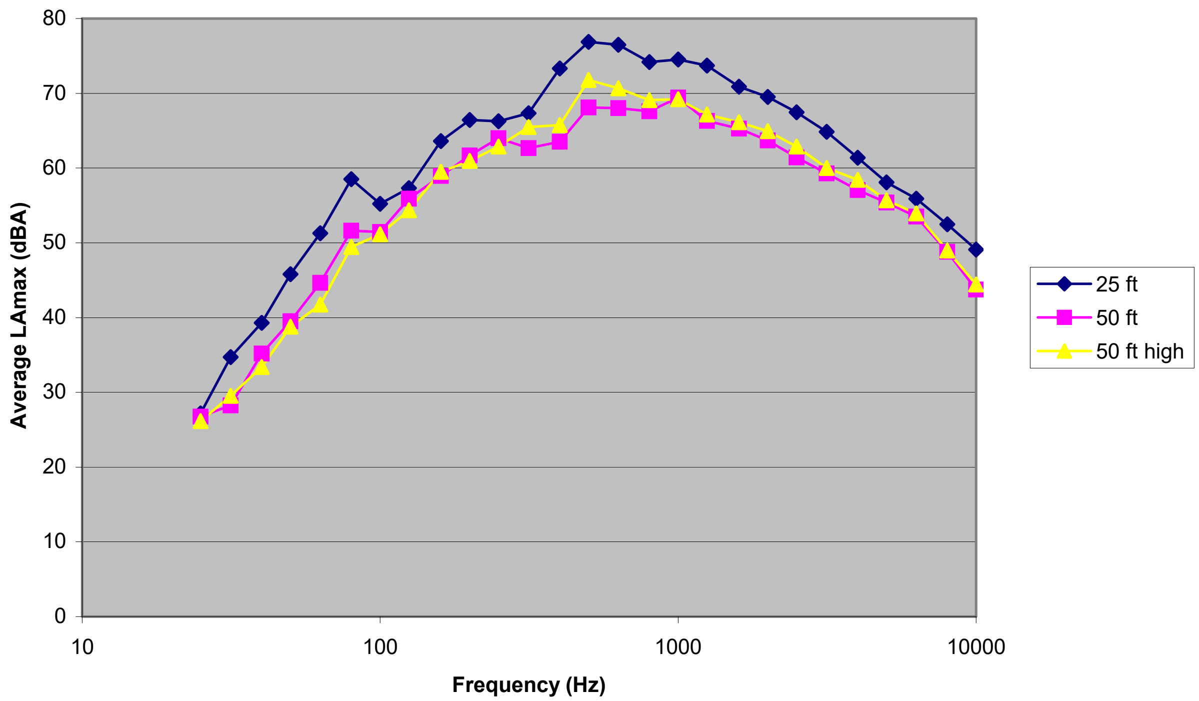
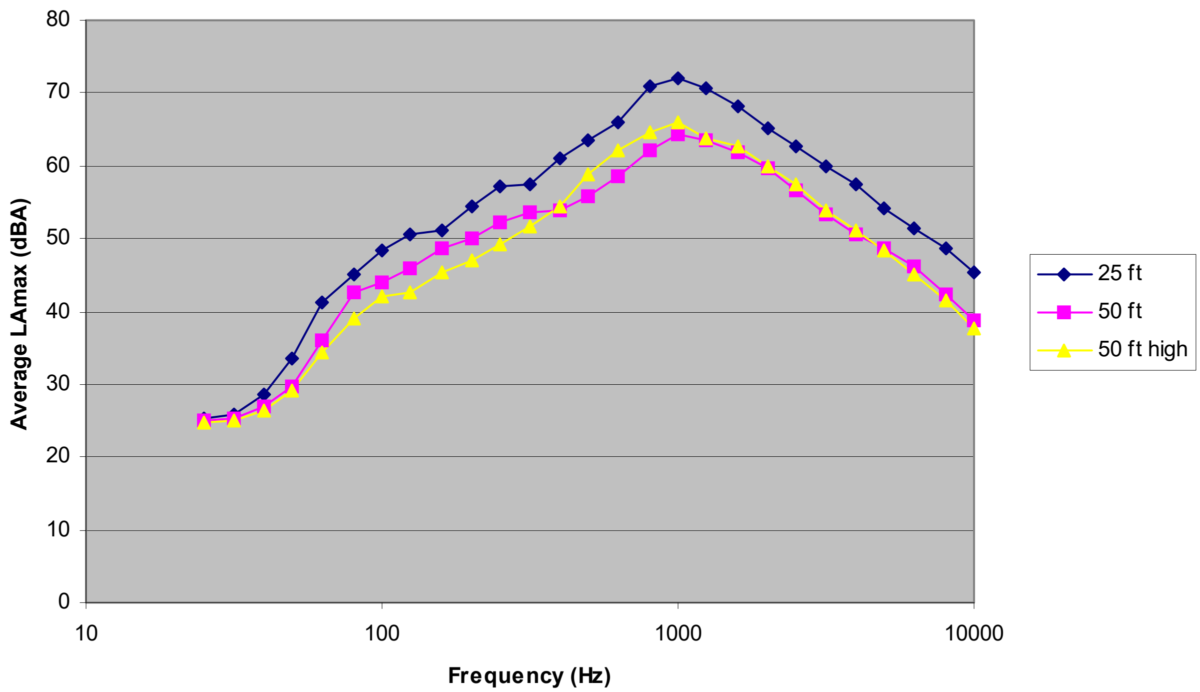


Figure E-27. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 4 (RAC Type O 30 mm) aged 16 months; all microphone positions.



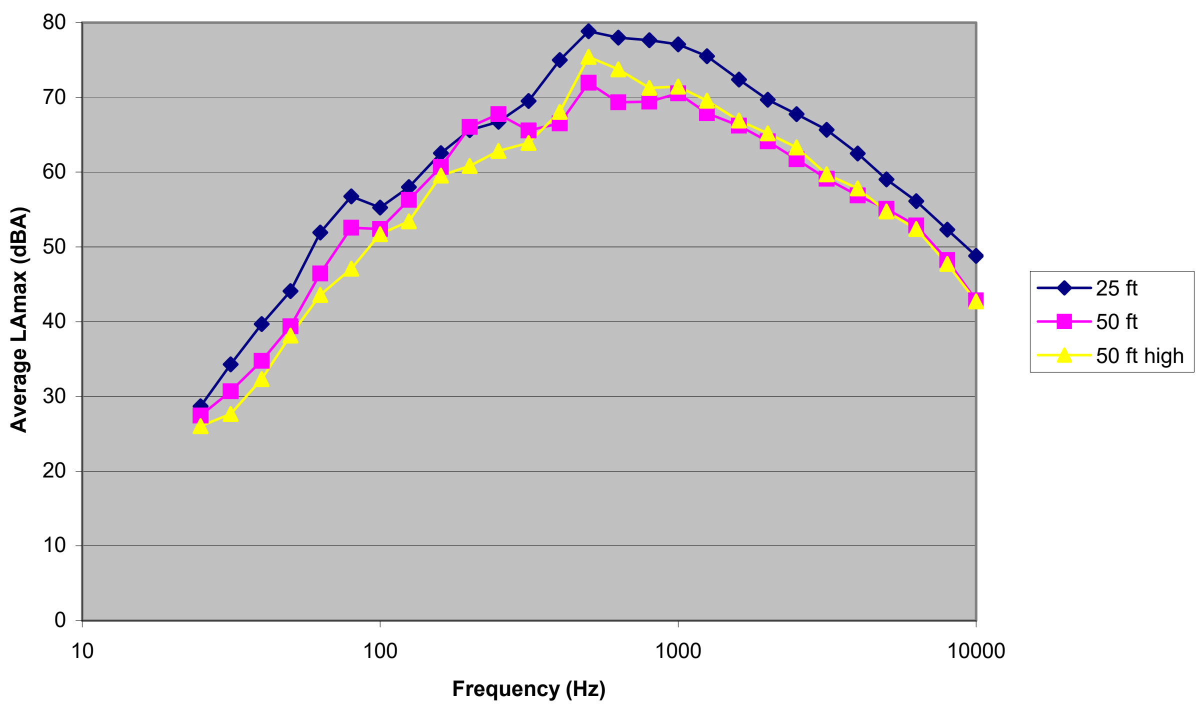


Figure E-28. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 5 (BWC 30 mm) aged 16 months; all microphone positions.

APPENDIX F. TEST VEHICLE RESULTS

This appendix shows the following:

- tables and plots of the average L_{AFmx} values for the test vehicle for each pavement, age (except 52 months), and microphone position; and
- tables and plots of the average L_{AFmx} deltas (comparing each of the other pavements to DGAC) for each pavement pair, age (except 52 months), and microphone position**.**

F.1 Average L_{AFmx} for Test Vehicle

Table F-1 shows the average L_{AFmx} for the test vehicle with site bias removed and Table F-2 shows the values with site bias not removed. The figures following the tables show plots of the site-bias-removed data (each plot shows multiple vehicle speeds and represents a different pavement age and microphone position).

Table F-1. Post-overlay measurements: sound levels for each pavement type (average L_{AFmx} for test vehicle). Post-overlay pavements, including DGAC, aged 4, 10, and 16 months. Site bias removed.*

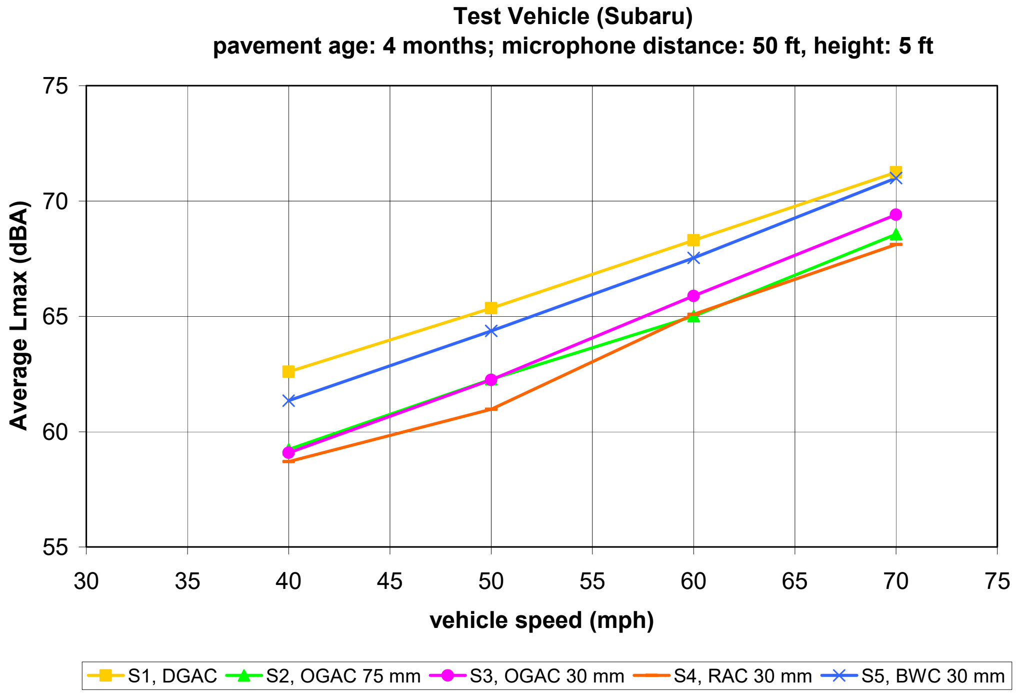
*other sites **calibrated to Site 1 to remove site bias** unrelated to pavement type (based on baseline measurements of test vehicle)

Pave-ment age	Microphone location	Test vehicle Average L_{AFmx} (dBA)																			
		Site 1 (DGAC)				Site 2 (OGAC, 75 mm)				Site 3 (OGAC, 30 mm)				Site 4 (RAC type O, 30 mm)				Site 5 (BWC, 30 mm)			
		Speed (mph)																			
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
4 months	50 ft (15 m) low	62.6	65.4	68.3	71.3	59.2	62.3	65.0	68.6	59.1	62.3	65.9	69.4	58.7	61.0	65.1	68.1	61.4	64.4	67.5	71.0
	50 ft (15 m) high	64.1	67.2	70.2	72.8	60.5	63.3	65.4	68.6	61.6	65	67.3	71	60.1	63.8	66.2	68.8	63.2	66.6	69.4	72.6
10 months	50 ft (15 m) low	62.3	66.0	68.0	71.0	58.9	62.5	64.4	67.4	59.9	63.1	66.9	69.2	59.5	61.8	65.5	67.7	61.0	64.6	67.7	70.9
	50 ft (15 m) high	65.1	68.3	70.5	73.6	61.4	63.8	65.8	68.7	63.1	65.9	68.7	70.8	61.1	64.8	67.0	68.6	63.7	67.5	69.8	72.8
16 months	50 ft (15 m) low	62.2	65.7	68.5	71.3	58.0	61.3	64.6	67.5	59.9	63.6	66.8	69.5	59.1	62.5	65.4	68.1	62.2	65.5	67.4	71.5
	50 ft (15 m) high	64.6	67.9	70.5	73.2	60.9	63.4	66.0	68.9	62.8	65.9	68.3	71.2	60.8	65.2	66.7	68.8	64.0	68.0	69.0	72.7

Table F-2. Post-overlay measurements: sound levels for each pavement type (average L_{AFmx} for test vehicle). Post-overlay pavements, including DGAC, aged 4, 10, and 16 months.*

*other sites ***not*** **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pave-ment age	Microphone location	Test vehicle Average L_{AFmx} (dBA)																			
		Site 1 (DGAC)				Site 2 (OGAC, 75 mm)				Site 3 (OGAC, 30 mm)				Site 4 (RAC type O, 30 mm)				Site 5 (BWC, 30 mm)			
		Speed (mph)																			
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
Base-line	50 ft (15 m) low	60.3	63.7	67.0	69.9	60.8	63.7	67.4	69.6	60.5	63.9	66.8	69.5	60.7	64.8	67.1	70.1	61.2	64.7	67.6	69.3
	50 ft (15 m) high	62.5	65.9	68.7	71.0	62.5	66.0	69.4	71.2	62.4	65.8	68.9	71.0	63.4	66.1	69.3	71.9	62.8	66.0	68.8	70.3
4 months	50 ft (15 m) low	62.6	65.4	68.3	71.3	59.7	62.3	65.4	68.3	59.3	62.5	65.7	69.1	59.1	62.1	65.1	68.3	62.3	65.5	68.1	70.4
	50 ft (15 m) high	64.1	67.2	70.2	72.8	60.5	63.4	66.1	68.8	61.5	64.9	67.5	71.0	61.0	64.0	66.8	69.7	63.5	66.7	69.5	71.9
10 months	50 ft (15 m) low	62.3	66.0	68.0	71.0	59.4	62.5	64.8	67.1	60.1	63.3	66.7	68.9	59.9	62.9	65.5	67.9	61.9	65.7	68.3	70.3
	50 ft (15 m) high	65.1	68.3	70.5	73.6	61.4	63.9	66.5	68.9	63.0	65.8	68.9	70.8	62.0	65.0	67.6	69.5	64.0	67.6	69.9	72.1
16 months	50 ft (15 m) low	62.2	65.7	68.5	71.3	58.5	61.3	65.0	67.2	60.1	63.8	66.6	69.2	59.5	63.6	65.4	68.3	63.1	66.6	68.0	70.9
	50 ft (15 m) high	64.6	67.9	70.5	73.2	60.9	63.5	66.7	69.1	62.7	65.8	68.5	71.2	61.7	65.4	67.3	69.7	64.3	68.1	69.1	72.0



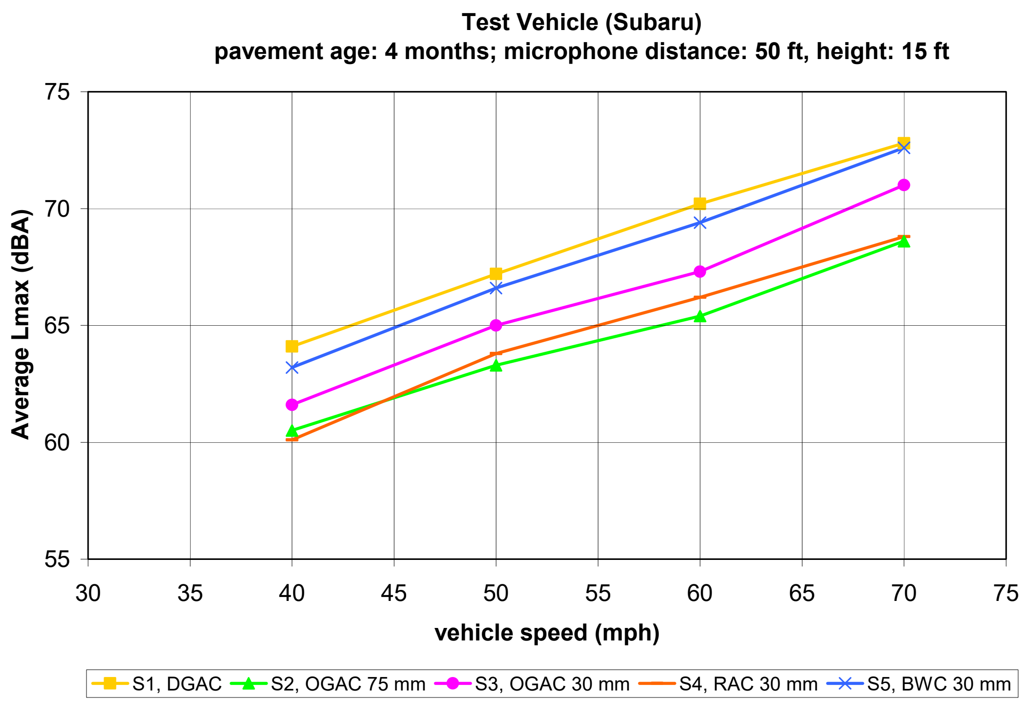
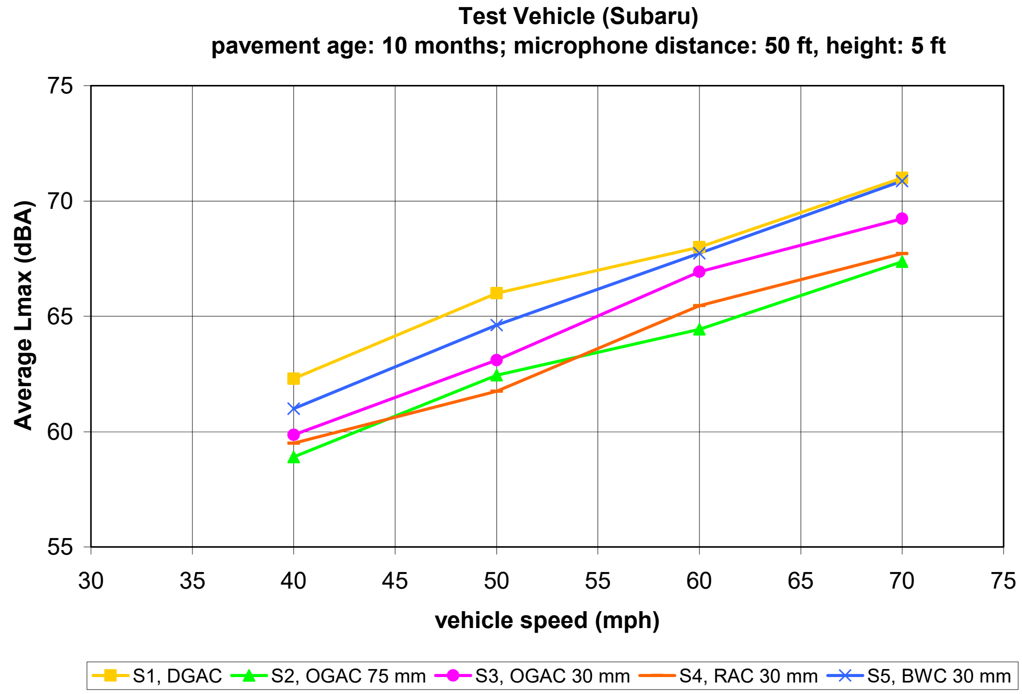


Figure F-1. Test vehicle average L_{AFmx} values for pavement aged 4 months, multiple speeds. Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.



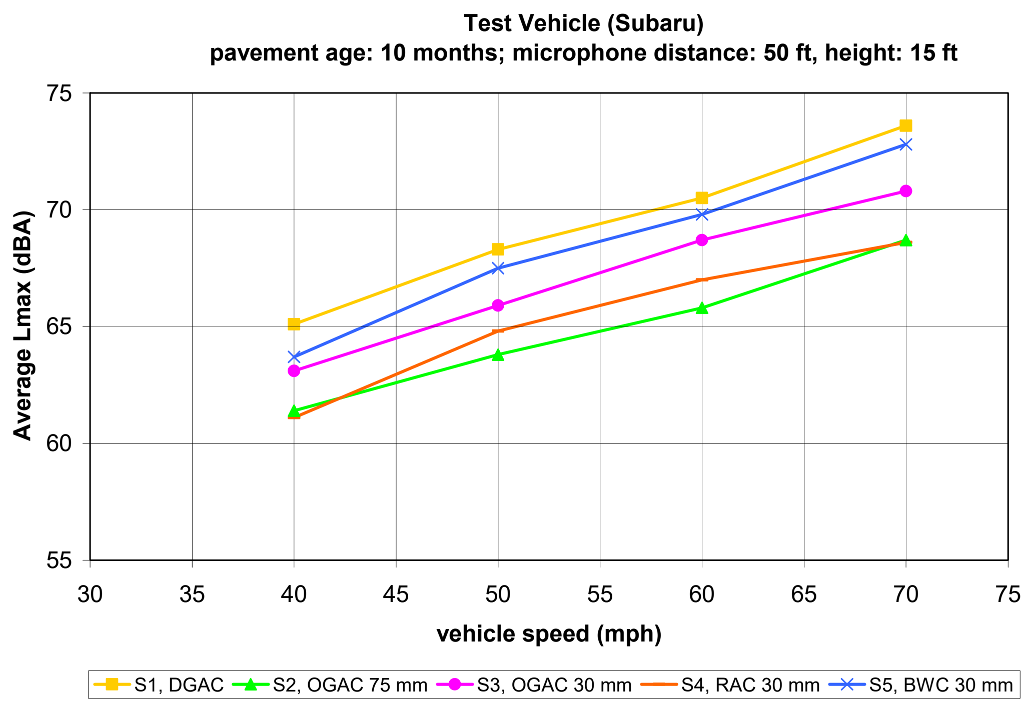
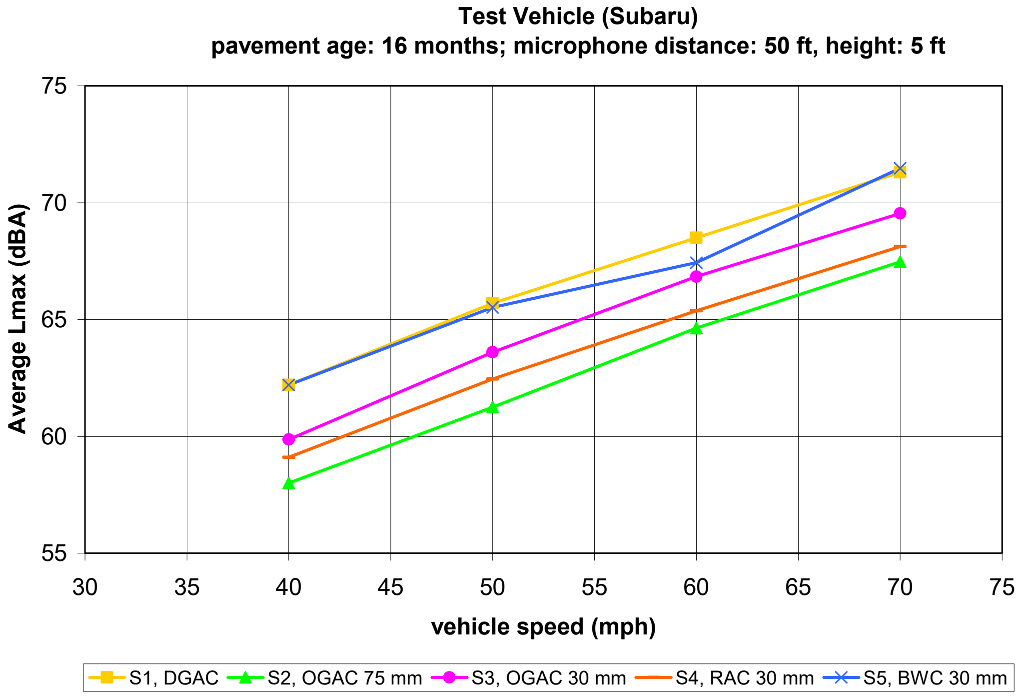


Figure F-2. Test vehicle average L_{AFmx} values for pavement aged 10 months, multiple speeds. Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.



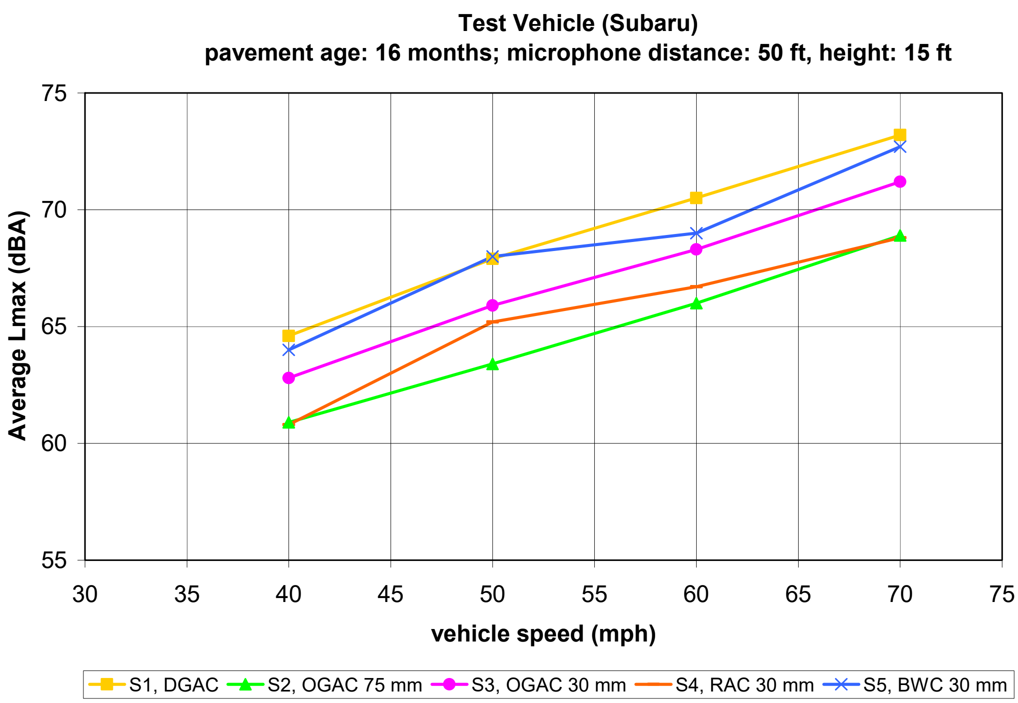


Figure F-3. Test vehicle average L_{AFmx} values for pavement aged 16 months, multiple speeds. Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.

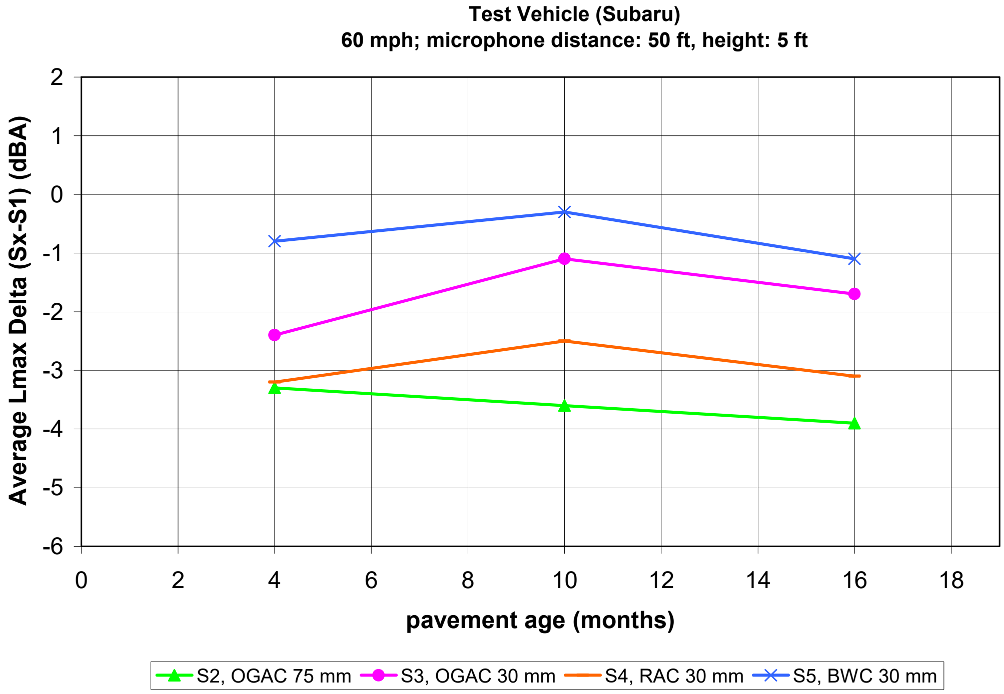
F.2 Average L_{AFmx} Deltas for Test Vehicle

Table F-3 shows the average L_{AFmx} deltas (Site 1 minus Site x) for the test vehicle with site bias removed. The figures following the tables show plots of the data (each plot representing a different microphone position for a single vehicle speed).

Table F-3. Post-overlay measurements: for the test vehicle, site differences due to type of pavement (average L_{AFmx} deltas). Post-overlay pavements, including DGAC, aged 4, 10, and 16 months. Site bias removed.*

other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements of test vehicle)

Pave-ment age	Micro-phone location	Average L_{AFmx} delta (dBA)															
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)				Site 3 – Site 1 (OGAC, 30 mm – DGAC)				Site 4 – Site 1 (RAC type O, 30 mm – DGAC)				Site 5 – Site 1 (BWC, 30 mm – DGAC)			
		Speed (mph)															
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
base-line	50 ft (15 m) low	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	50 ft (15 m) high	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 months	50 ft (15 m) low	-3.4	-3.1	-3.3	-2.7	-3.5	-3.1	-2.4	-1.8	-3.9	-4.4	-3.2	-3.1	-1.3	-1.0	-0.8	-0.3
	50 ft (15 m) high	-3.6	-3.9	-4.8	-4.2	-2.5	-2.2	-2.9	-1.8	-4.0	-3.4	-4.0	-4.0	-0.9	-0.6	-0.8	-0.2
10 months	50 ft (15 m) low	-3.4	-3.6	-3.6	-3.6	-2.4	-2.9	-1.1	-1.8	-2.8	-4.3	-2.5	-3.3	-1.3	-1.4	-0.3	-0.1
	50 ft (15 m) high	-3.7	-4.5	-4.7	-4.9	-2.0	-2.4	-1.8	-2.8	-4.0	-3.5	-3.5	-5	-1.4	-0.8	-0.7	-0.8
16 months	50 ft (15 m) low	-4.2	-4.5	-3.9	-3.8	-2.3	-2.1	-1.7	-1.8	-3.1	-3.3	-3.1	-3.2	0.0	-0.2	-1.1	0.2
	50 ft (15 m) high	-3.7	-4.5	-4.5	-4.3	-1.8	-2.0	-2.2	-2.0	-3.8	-2.7	-3.8	-4.4	-0.6	0.1	-1.5	-0.5
Average (both locations, all time)		-3.7	-4.0	-4.1	-3.9	-2.4	-2.5	-2.0	-2.0	-3.6	-3.6	-3.4	-3.8	-0.9	-0.7	-0.9	-0.3
Average (both locations, all time, all speeds)		-3.9				-2.2				-3.6				-0.7			



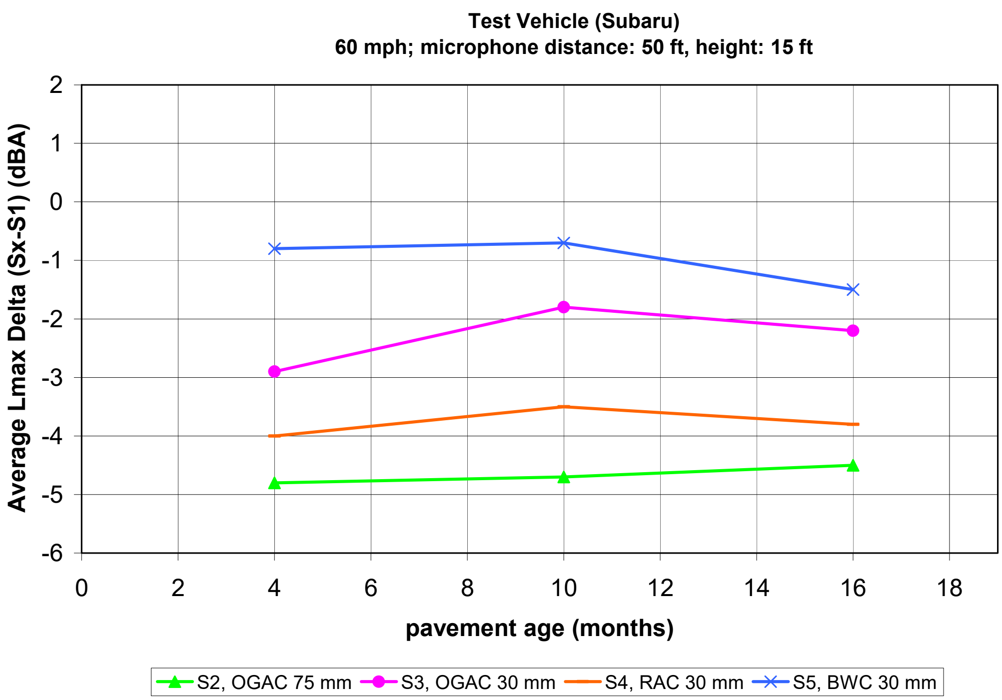


Figure F-4. Test vehicle average L_{AFmx} deltas (Site x minus Site 1) for pavement ages 4 months, 10 months, and 16 months, 100 km/h (60 mph). Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.