4-YEAR SUMMARY REPORT

I-80 DAVIS OGAC PAVEMENT NOISE STUDY

TRAFFIC NOISE LEVELS ASSOCIATED WITH AN AGING OPEN GRADE ASPHALT CONCRETE OVERLAY

December 1, 2002

Prepared for:

California Department of Transportation
Environmental Program – Noise and Vibration Studies
1120 N St. 4th Floor
Sacramento, California 95814

Prepared by:

ILLINGWORTH & RODKIN, INC.
Acoustics • Air Quality

505 Petaluma Blvd South
Petaluma, CA 94952

EXECUTIVE SUMMARY

Traffic noise level changes associated with an open grade asphalt concrete (OGAC) overlay along Interstate 80 near Davis, California are currently being measured by the California Department of Transportation. The OGAC overlay, which was placed over a dense grade asphalt concrete (DGAC) surface, is now 4 years old. Traffic noise levels measurements were made prior to the overlay, just after, and 3 times per year (spring, early summer and late fall) since the overlay was applied. The roadway baseline condition prior to the overlay consisted of aged asphalt concrete. Results through June 2002 are reported herein This study is continuing into the 5th year and those results should be available in the later part of 2003.

Measurements are made at reference locations situated 20 meters from the edge of the nearest travel way. During the first two years of this study, measurements have been made at more distant locations (140 meters from the edge of the nearest travel way). Distant measurements were also made during the 4th year of measurements. Meteorological conditions, which influence traffic noise levels at distant locations substantially, were carefully monitored. Traffic conditions were monitored during all noise measurements. This allowed reference location noise levels to be normalized for changing traffic conditions. All measurements were made on weekdays from about 9:00am to 1:00pm during free-flowing traffic conditions.

Conclusions – Reference Sites

Measurements at the Reference sites were made one month prior to the OGAC overlay and then at least three separate times per year since the overlay occurred in July of 1998. The A-weighted noise levels measured at the reference sites on each side of the road indicate that substantial decreases in traffic noise occurred after the placement of the new OGAC overlays. DGAC measurements were made, but they only represent the conditions after a very recent application of this pavement type (within 3 weeks of the pavement placement). This study did not collect any data that would indicate the acoustical characteristics of DGAC as it ages. Noise measurements associated with the OGAC overlay that were made in the first 4 years provide some indications of the trends in acoustical characteristics of the pavement. Traffic noise levels were substantially lower following application of the OGAC:

Calculated Change in Traffic Noise Level – Reference Sites (20m)

Meas. Baseline	Very New DGAC	New OGAC	1-Mo. AUG	11-Mo. JUN	23-Mo. JUN	35-Mo. JUN	47-Mo. JUN
78.6	**-3.9**	**-5.6**	**-6.1**	**-6.0**	**-5.5**	**- 6.4**	**-5.8**

Important findings developed from this data set are as follows:

1. Noise levels decreased by 6 dBA from baseline conditions just after application of the OGAC overlay and continue to show this same reduction after 4 years. *Note: I-80 is a major trans-continental Interstate freeway with an average of nearly 140,000 vehicles daily- including almost 10% trucks.*

2. Noise levels decreased by almost 4 dBA from baseline conditions right after application of the DGAC.

3. Spectral data, shown in Figure E-1, indicate distinct tonal changes in traffic noise with decreases in noise levels at frequencies between about 1000 Hz and 4000 Hz. A decrease of about 3 to 5 dB occurred over this frequency range with the new DGAC and a decrease of up to 10 dB occurred with the new OGAC overlay. The aged OGAC overlay showed slightly higher noise levels than the new OGAC overlay at frequencies above 2000 Hz. Traffic noise levels over the range of 1000 to 2000 Hz that contribute most to the overall A-weighted noise levels were reduced substantially.

4. The TNM model, using average pavement conditions, over-predicted baseline traffic noise levels at the reference sites by about one dBA. With the new pavement conditions, the model over-predicted traffic noise levels by about 5 to 7 dBA.

5. There appears to be some variation in the noise level associated with the aged OGAC overlay measurements that are apparently attributable to changes in seasonal temperature. Noise levels normalized for traffic conditions were about 1 – 2 dBA louder during the colder months.

6. While it is clear that the application of the new OGAC overlay reduced traffic noise levels substantially (at least for the first 4 years), findings of this study are so far limited to conditions on I-80. This included a large amount of traffic with a relatively high percentage of trucks (about 2-3% medium-duty and 7% heavy-duty trucks), and high traffic speeds (e,g., 110kph or 70 mph). Effects, such as vehicle mix, vehicle speed, baseline pavement condition, and shielding effects, could effect potential noise level reductions attributable to OGAC overlays.

7. Meteorological conditions or subtle effects of traffic are suspected to have affected measured noise levels by about one dBA. It appears that increasing traffic on the frontage road adjacent to the Eastbound Reference site affects the reference noise levels slightly. We estimate this affect to currently be on the order of 0.5 to 1.5 dBA. Therefore, the data collected at the Westbound Reference site appears to be most reliable for evaluating the noise level reductions from the OGAC overlay. Findings in this study are primarily based on the Westbound Reference data set.

Conclusions – Distant Sites

Measurements at the distant sites (145 meters or 475 feet from the near lane) were made one month prior to the OGAC overlay (baseline conditions) and then twice each year for the two years since the overlay occurred in July of 1998. Additional measurements were made in this fourth year. The effect of pavement on noise levels at the distant sites was difficult to assess. Several factors, besides pavement type, affected noise levels at these sites. While changes in traffic conditions could be accounted to some extent by evaluating the change in the delta (difference between simultaneous reference and distant measurements), the effects due to changes in ground cover and subtle changes in meteorological conditions cannot be eliminated from the data. However, the data indicate noise levels decreased at these sites after the new pavement was applied. Findings developed from this data set are as follows:

1. An examination of the A-weighted noise levels under different meteorological conditions indicates that the new pavement provided a substantial decrease in noise levels at the distant sites. The decrease appears to be about 4 to 5 dBA after the application of the new OGAC. The reduction was evaluated under downwind conditions, when freeway traffic noise is loudest. The noise level decrease was still evident 4 years following the OGAC overlay. A more-thorough review is planned for the 2003 data report.

2. The finding above is based on an assessment that relied upon a limited amount of baseline data. There was substantial variation in levels at the distant site and the corresponding deltas that could not be directly accounted for by changes in measured meteorological parameters or variations in traffic .

3. The 1/3-octave band frequency data collected at the distant sites show that traffic noise levels decreased by about 5 dB over the frequencies of 1000 to 4000 Hz. This reinforces the finding that A-weighted noise levels decreased at the distant sites.

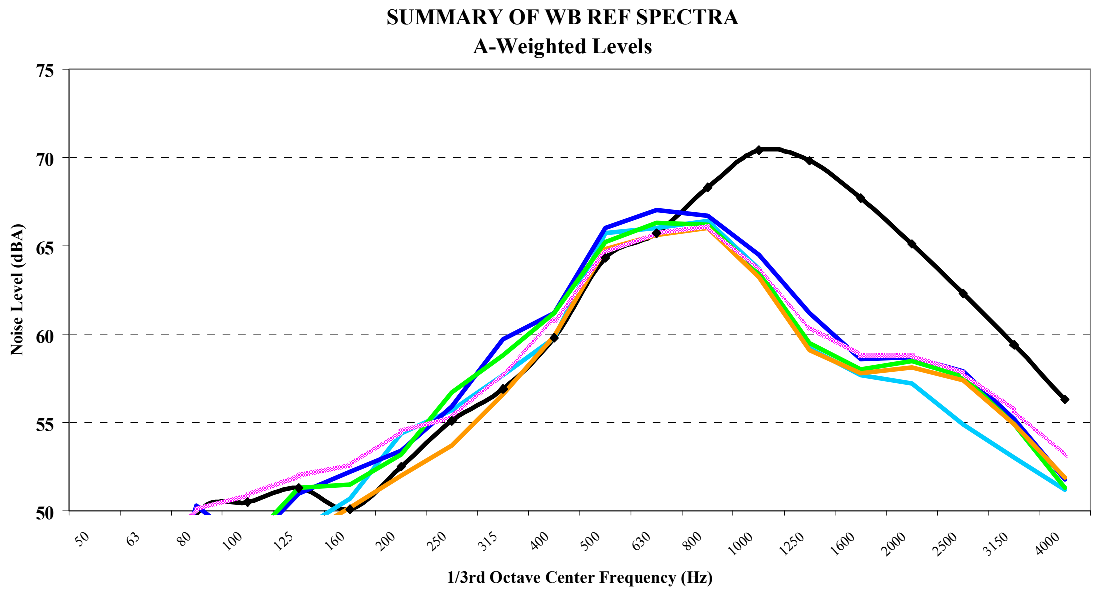
4. Wind had a substantial effect on noise attenuation. It was common to measure a difference of up to 10 dBA between eastbound and westbound distant sites. To a casual observer, this would be the difference between having some difficulty communicating with others at one side of the freeway and barely being able to hear the traffic noise at the other equally distant site.

5. Attended (clean) samples from each measurement day were modeled using TNM (with average pavement conditions) at the distant locations. Results for all wind conditions indicate an average over prediction of 4 dBA for baseline conditions and 8 dBA for OGAC conditions. There was considerable variation that was due mostly (but not entirely) to wind conditions:

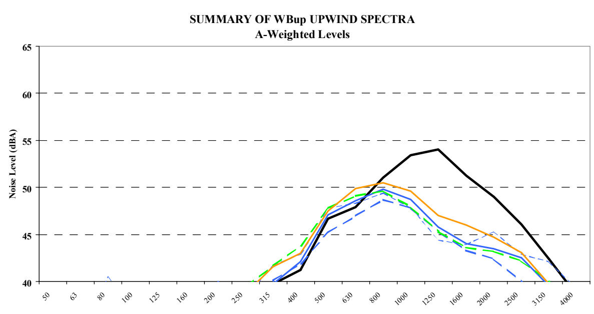
   a. Under downwind conditions (louder), TNM, on average, over predicted noise levels by –2 to +2 for baseline conditions and +3 to +5 dBA for OGAC conditions.
   b. Under upwind conditions (quieter), TNM had an average over prediction of +9 to +10 dBA for baseline conditions and +10 to +14 dBA for OGAC conditions.

   Comparison of these results for baseline and OGAC conditions indicate that the OGAC resulted in noise level reductions of 4 dBA at distant sites and 5 to 6 dBA at the reference sites. As mentioned above, a more thorough analysis is planned for the 2003 report.

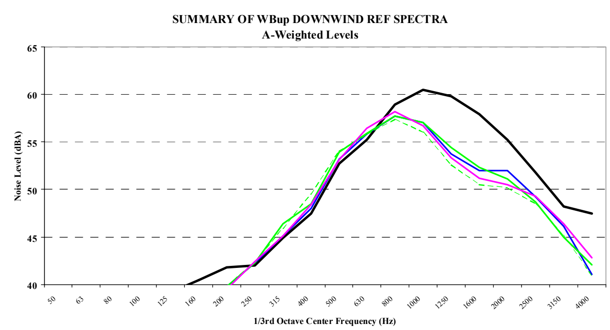
Fig E-1 Frequency Spectra



WB REFERENCE



WB Distant - Upwind



WB Distant - Downwind

Baseline	1st Month	1st Year	2nd Year	3rd Year	4th Year

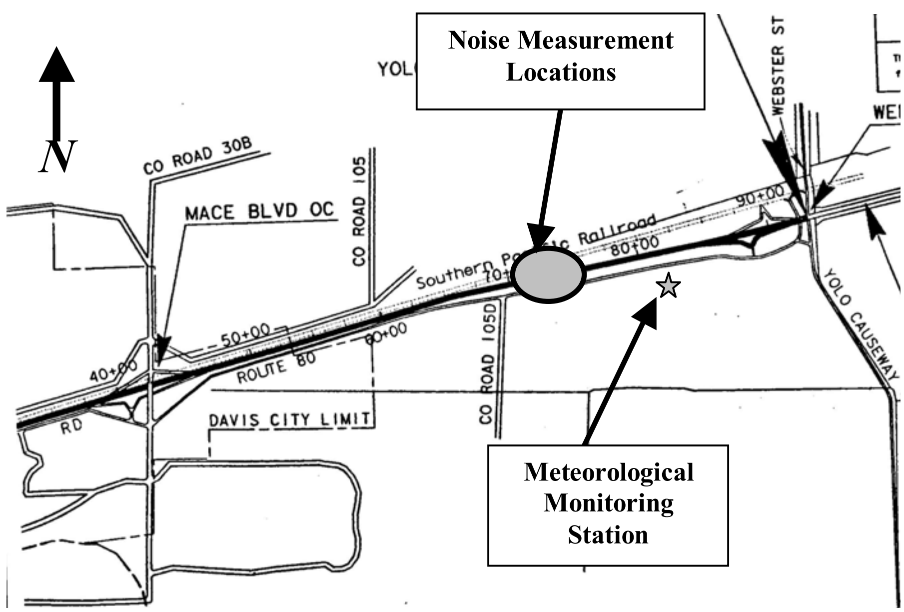
1.0 INTRODUCTION

The California Department of Transportation (Caltrans) is evaluating the effect of highway pavement types on traffic noise. Pavement overlays were applied to a 9-kilometer stretch of Interstate 80 (just east of Davis, California) in June and July of 1998. This provided an opportunity to carefully collect noise data associated with a new overlay of open-graded asphalt concrete (OGAC) and to evaluate noise levels as the pavement overlay ages. The purpose of this study is to evaluate noise conditions associated with the application of new open grade asphalt concrete along a California freeway. This report presents a summary of noise and traffic data collected at various times over the period from June 1998 through June 2002. The primary purpose of this report is to present data collected during the first four years of the study, including baseline data that represents noise conditions associated with the old pavement prior to the overlay. The study is continuing into the 5th year.

2.0 METHODOLOGY

The project study corridor is Interstate 80 from the Yolo County Line at Richards Boulevard (Yolo County Post Kilometer 0.0) to the Yolo Causeway (Yolo County Post Kilometer 9.3). The roadway segment studied was between Mace Boulevard and the Yolo Causeway. Figure 2-1 shows the study area and approximate measurement locations.

Figure 2-1. Study Area



Description of Pavement

Interstate 80 and adjoining lands are flat through the study area. Prior to the pavement rehabilitation project, the roadway bed consisted of 120 to 160 millimeters (mm) of asphalt concrete (AC). The pavement project consisted of the removal of the existing AC surfacing and replacement with the new AC. In some spots, the underlying base was removed and replaced. The new AC surfacing included placement of 60 mm of dense-graded asphalt concrete (DGAC) in June and early July 1998, which was subsequently covered with 25 mm of open-graded asphalt concrete

(OGAC) in July 1998. Existing and project pavement overlay information were obtained from project plans[1]. Measurements of noise conditions occurred before removal of the existing AC (baseline condition), after application of DGAC, after application of OGAC and then periodically during the OGAC pavement aging process.

Asphalt material pavement types are described in Chapter 600 of the Highway Design Manual and summarized as follows:

> **DGAC** consists of a mixture of bituminous material (paving asphalt) and a close graded aggregate ranging from coarse to very fine particles. DGAC is designated as Type A or Type B, depending on the specified aggregate quality and mix design criteria appropriate for the job conditions. Type A DGAC was used for this project.
>
> **OGAC** is a surface course used primarily over DGAC. The primary benefit of using OGAC is the reduction of wet pavement accidents by improving wet weather skid resistance, minimizing hydroplaning, reducing water splash and spray, and reducing nighttime wet pavement glare. Secondary benefits include better wet-night visibility of traffic stripes and markers, better wet weather (day and night) delineation between the traveled way and DGAC shoulders, and increased safety through reduced driver stress during rainstorms. OGAC surfacing is also known as an "open graded friction course".

Measurement Dates

Measurements were made for the following dates and roadway pavement conditions:

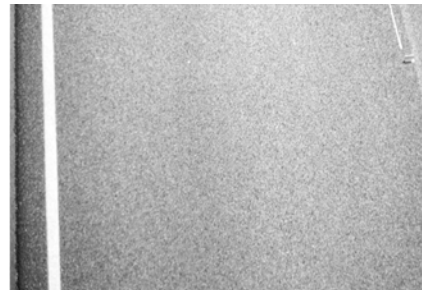
June 13-15, 1998 – Baseline Condition (original AC condition):

July 13-15, 1998 – New Dense Grade application (just after application of DGAC):

---

1 1997. State of California Department of Transportation (Caltrans). Project Plans for Construction on State Highway in Yolo County in and near Davis from the Solano County Line to Yolo Causeway West. Contract No. 03-444904. July 14.

August 11-13, 1998 – New OGAC Overlay (just after application of OGAC):



August 26, 1998 – 1 mo. OGAC

November 18-19, 1998 – 4 mo. OGAC

April 13 and 15, 1999 – 9 mo. OGAC

June 15,16, 1999 – 11-mo. OGAC:

December 8 and 15, 1999 – 17 mo. OGAC

April 5 and 6, 2000 – 21 mo. OGAC:

June 6 and 9, 2000 – 23-mo. OGAC

December 7 and 8, 2000 – 29 mo. OGAC

April 17 and 18, 2001 – 33 mo. OGAC:

June 5 and 6, 2001 – 35 mo. OGAC:

November 27 and December 19, 2001 – 40 mo. OGAC

April 24 and 25, 2001 45 mo. OGAC:

June 19 and 20, 2002 – 47 mo. OGAC

Measurement Locations

Noise measurements were conducted between the Mace Boulevard over crossing and the Yolo Causeway. Two measurement sites ("reference" and "distant") were used for the westbound side and two locations for the eastbound side of I-80. In addition to noise measurements, meteorological conditions were monitored and traffic counts and speed measurements were conducted. Exact measurement locations were determined prior to the first measurement and documented by photographs, video, and field notes.

On each side of the freeway, noise measurements were conducted at a location 20 meters from the edge of the nearest travel way (reference measurements) and at a distance of about 140 meters from the edge of the nearest travel lane (distant measurements). The reference measurements were made at a height of 3 meters above the roadway and the distant measurements were made at heights of 1.5 meters and 4.5 meters above the surrounding ground. Meteorological monitoring occurred near I-80 (about 50 meters from the roadway) during most noise measurement activities. Traffic observations were made from the Mace Boulevard over crossing. Measurement locations are shown in Figure 2-2.

Figure 2-2. Photographs of Measurement Locations

Eastbound Reference Location 	Westbound Reference Location 
Eastbound Distant Location 	Westbound Distant Location 
Meteorological Monitoring Location 	Traffic Observation Location 

Measurement Methods

To avoid substantial interference from noise sources other than the freeway, noise levels were measured continuously in 5-minute intervals. Observers attended the distant noise measurement locations and recorded noise levels associated with non-I-80 traffic events (e.g., aircraft, local truck traffic, etc.). These observations were recorded on data monitoring forms developed for this project. This allowed for editing of non-highway noise events from the data record.

Intervals affected by non-freeway noise sources were eliminated from the data set. The exception was the distant westbound site, which were periodically affected by large trucks accessing the landfill. Although these trucks were infrequent, they resulted in loud single-events, which affected the data considerably. In the cases of the westbound distant sites, the L_{50} noise level was used (i.e., noise level exceeded 50 percent of the time).

Sound level meters were utilized to collect these noise measurements. The sound level meters were programmed to continuously measure the A-weighted noise level and store the energy-equivalent noise level (L_{eq}) and the noise level exceeded 50 percent of the time (L_{50}). The L_{eq} and L_{50} noise levels were stored in consecutive 5-minute intervals during the measurement periods. A real-time analyzer (RTA) was used to collect 1/3-octave band data periodically during measurement periods.

Traffic monitoring was conducted by making manual vehicle counts and traffic radar speed measurements taken from the nearest overpass. The traffic counts were made almost continuously and separated into 5-minute intervals that correlate with noise and meteorological measurements. The traffic counts and speed measurements were further separated into vehicle classification for uses in the Federal Highway Administration/ Traffic Noise Model (TNM).

These vehicle classifications include light-duty vehicles (e.g., passenger autos and pickup trucks), medium-duty trucks (e.g., delivery trucks with two axles and six wheels), heavy-duty trucks (e.g., trucks with separated trailers and more than two axles and dump trucks), buses, and motorcycles.

3.0 DATA PRESENTATION

Noise Data

Noise data were collected in continuous 5-minute periods. Included with these data are the calculated average, minimum and maximum L_{eq} and L_{50} noise levels along with the ±95 percent confidence interval limits. Raw data are not included as part of this summary report.

The WB reference locations was mostly unaffected by noise sources other than freeway traffic. When the WB reference noise levels were suspected of being affected by non-freeway sources, the data were eliminated. This occurred infrequently, but there were weed control or freeway incidents that lead to interferences with the noise data. The eastbound reference location was infrequently affected by trucks using the adjacent frontage road (East Chiles Road). Traffic on this roadway is very light, but appears to be increasing slightly due to development further west. In addition, construction of the new Mace Avenue interchange has directed some traffic by the EB reference location. This construction is now complete.

For evaluating noise levels at distant locations, differences between the reference data and the distant data were evaluated (rather than the L_{eq}) to normalize for changes in traffic. At times, the distant sites were affected by noise from other sources. The eastbound site, located in farmland (a cornfield) south of the freeway, was affected by infrequent farming activities and occasional aircraft or distant train passages. Tall corn during the summers of 1998 (July and August), 2000 (June) and 2001 (June) appeared to affect freeway traffic noise levels at this location, especially the microphone position 1.5 meter above the ground. The L_{eq} for a small amount of the 5-minute intervals measured at the eastbound distant sites were affected by noise sources other than the freeway.

The westbound site was affected by traffic on the frontage road, as well as occasional aircraft and train passages. Although westbound side frontage road traffic was infrequent, there were a high percentage of trucks that access the nearby landfill, and vehicle speeds were about 70 to 80 kph. Although infrequent, this traffic affected the measured L_{eq} at the westbound distant sites substantially. Careful analysis was performed to evaluate the WB distant noise data. Almost all westbound distant L_{eqs} were affected by local traffic. Because L_{eqs} at the westbound SLMs were contaminated by non-freeway noise, the L_{50} at these sites along with the L_{50} at the westbound reference site were used to describe noise attenuation. Periodically at the westbound distant sites, simultaneous freeway-only noise measurements were made by pausing the meter when other sources were significant. These data were compared with corresponding continuous L_{50s} measured at the sites and found to be within one dBA agreement. *While the delta (or noise attenuation) is described for eastbound sites using the L_{eq}, the deltas for the westbound sites are described using the L_{50}.* Data for any 5-minute interval that was substantially affected by non-freeway sources were discarded from the data set.

A summary of the noise data collected during the measurement periods are presented in Table 3-1. Note that L_{eq} noise levels for the westbound distant up and westbound distant down locations are much greater than the L_{50} levels. This is because of local traffic, and therefore, the L_{eq} was not used in the data evaluation.

Meteorological Data

Meteorological data collected during some spring (April) and summer measurements are not included as part of this summary report. The data were also reported as 5-minute averages. The magnitude of the vector component of wind velocity that crosses the roadway (cross vector component) was calculated using a roadway bearing of 80º relative to truth north. The cross vector component is calculated in relation to the eastbound side. The cross-vector wind component for the westbound side would simply be the opposite. A summary of the measured meteorological conditions for each measurement period is in Table 3-2.

Most measurements were conducted during daytime hours (between 9:00 AM and 1:00 PM) under mostly clear skies (sun obscured by clouds less than 30% of each measurement period). The temperatures varied by about 15ºC at most between measurement periods. However, some measurements were conducted in late fall under colder conditions (5 to 10ºC) to evaluate any seasonal changes that might be attributable to pavement temperature. Temperatures in late fall were typically in the range of 7 to 12ºC while summer temperatures were typically 20 to 30ºC. Spring measurements were around 15 to 20ºC.Except for late fall, all periods had a normal low-level temperature lapse of about -0.10ºC/m present. For comparison of spring and summer conditions, these meteorological conditions, with the exception of wind, were considered equivalent (in terms of the effect on noise attenuation) for all of the measurement periods.

Wind conditions varied considerably. Measurements were avoided when winds exceeded about 5.5 m/s. Because the study area topography is flat and open, a wind flow is usually present during spring through fall. Winds tend to flow from either northerly or southerly directions. This was usually the case and can be seen in the crosswind vector component data averaged for each period. However, wind direction and strength also changed considerably during some measurement periods; therefore, the average cross-vector component for each period does not describe wind flow accurately. These data indicate that wind was the measured meteorological variable that likely had the greatest effect on traffic noise attenuation to the distant measurement locations.

Traffic Data and Traffic Noise Modeling

Traffic counts and speed measurements were adjusted to one-hour averages and used as input to the Traffic Noise Model (TNM) to predict noise levels at the reference locations. These modeled data were then compared with measured reference noise levels. Hourly average vehicle counts are shown in Table 3-3.

Interstate 80 through the study area is a busy freeway with a considerably large amount of truck traffic. Average Annual Daily Truck Traffic reports for 2000 indicate daily traffic of 138,000[2] vehicles. Trucks are reported to make up 7.4% of the volume on a daily basis. Truck volumes counted in this study and shown in Table 3-3 make up almost 10% of the volume. Because the measurements were conducted during off-peak travel periods, a higher percentage of trucks was present (compared to those reported above).

The numbers of buses and motorcycles were insignificant compared to auto and truck volumes, and therefore, are not reported in the Table 3-3. Traffic speeds appeared to be constant throughout the study. Typical auto speeds were consistently in the range of 108 to 115 kph, while truck speeds were in the range of 95 to 105 kph. According to TNM, the typical variations in traffic speeds encountered result in about a one-dBA variation in the noise level. Because the LeqV2 and SOUND32 traffic noise models have upper speed limits of 105 kph, the TNM model was used. It should be noted that LeqV2 was used in the baseline data modeling, but under predicted traffic noise levels by one dBA.

Inputs to TNM included only those that are required for traffic noise studies by FHWA. The purpose of this study was not to validate the TNM model, but to use the model to normalize traffic conditions for evaluating the noise levels changes at the reference locations attributable to pavement. Default meteorological conditions and "average" pavement type were used in the model. A dense vegetation median, 2.4 meters high was used to simulate the landscaped median (oleander bushes). Field grass ground type was used to describe the default ground (the selection of different ground types had little effect on the reference location model predictions). We noted that temperature and humidity had up to a 0.1 dBA effect on the results at the reference locations (up to 0.3 dBA at the distant locations). As indicated above, free-flowing traffic speeds did not vary much during the measurements. Slowed traffic conditions were rarely encountered in this study and always occurred during the 9am to 10am hour. All data for slowed traffic (or traffic congestion) were discarded. Some TNM predictions were performed for the distant locations using a small sample of results from each measurement day. The presence of the cornfield, which was there for some of the measurements, was modeled as a tree zone.

Traffic noise modeling results for the reference locations are presented in Table 3-4. TNM over-predicted traffic noise levels by about 0 to 1.5 dBA for the test baseline cases. At the WB Reference location, TNM over predicted

[2] West of the I-80 and US 50 junction, which is about 3 kilometers or 5 miles east of the study area.

traffic noise levels by 5 to 7 dBA after placement of the OGAC. TNM model results were 6 to 7 dBA higher than measured levels in summer and about 5 dBA higher during late fall (colder months). At the EB reference location, TNM had over predictions of about 5 to 6 dBA for spring and summer conditions and 4 to 5 dBA during late fall months (there was one over prediction of 3 dBA). A summary of measured and TNM modeled reference noise levels are presented in Table 3-4.

During each measurements day, at least two clean 5-minute samples were collected at each location using a real time analyzer to measure sound levels at 1/3rd octave bands. Clean, means that the samples were representative of free-flowing traffic conditions and do not include any interferences from other sources. These data were compared to TNM model results (using the monitored traffic conditions). This involved the modeling of 170 different conditions. The model inputs included soft ground conditions (i.e., field grass). The exception was on the eastbound side for 9 out of 22 days when corn was present across much of the sound propagation path (about 100meters of the 145-meter path). Data for the distant sites were categorized as *Upwind, Downwind*, or *Calm* using measured and observed meteorological conditions. TNM was found to over predict noise levels at the distant sites in almost all cases. A summary of the differences between TNM-modeled and measured levels, based on averages for each condition, is shown in Table 3-5.

On average, TNM over predicted **baseline** conditions at the distant sites by +4 dBA. With the **OGAC**, the over prediction increased to +8 dBA. There was considerable variation that was due mostly (but not entirely) to wind conditions. For downwind conditions, TNM, on average, over predicted noise levels by –2 to +2 for **baseline** conditions and +3 to +5 dBA for **OGAC** conditions. Under *Upwind* conditions, TNM had an average over prediction of +9 to +10 dBA for **baseline** conditions and +10 to +14 dBA for **OGAC** conditions. *Calm* conditions, which were only encountered for the **OGAC** conditions, had over predictions of +7 to +9 dBA at eastbound locations and +7 to +11 dBA at westbound locations.

The comparison of predictions for **baseline** and **OGAC** conditions indicate that there was an average reduction of 4 dBA at distant sites. The same type of analysis conducted for the reference sites indicates a reduction of 5 to 6 dBA. The findings of this study for the reference sites (discussed later in this report) are based on the far more extensive database that includes continuous data measured from 9:00am to 1:00pm on 32 separate days (about 1,500 samples). As mentioned above, a more thorough analysis is planned for the 2003 report.

1/3-Octave Band Data

As mentioned above, spectral (1/3-octave band) noise data were collected periodically at each site during the measurement periods. Typically, three samples were collected at each location for each measurement day. Each of the samples were collected over 5-minute periods, simultaneous with the collection of continuous A-weighted data.

Table 3-1. Summary of Average Noise Levels for Each Measurement Period

Date	Measured Noise Level (dBA)											
	ER L_{eq}	ER L_{50}	EU L_{eq}	EU L_{50}	ED L_{eq}	ED L_{50}	WR L_{eq}	WR L_{50}	WU L_{eq}	WU L_{50}	WD L_{eq}	WD L_{50}
6/12/98 – Baseline	78	77	58	57	55	54	79	79	69	68	67	65
6/15/98 – Baseline	78	78	66	65	62	61	78	77	63	60	58	53
7/13/98 – New DGAC	75	74	54	na	50	50	74	74	66	63	62	58
7/14/98 – New DGAC	75	73	59	59	54	53	74	73	64	58	61	52
8/11/98 – New OGAC	73	72	61	60	53	52	73	72	62	55	58	47
8/12/98 – New OGAC	73	72	60	60	51	51	72	71	64	58	60	50
8/13/98 – New OGAC	73	72	57	56	51	50	72	71	64	59	58	51
8/26/98 – 1-Mo. OGAC	74	72	58	57	54	53	73	72	64	56	59	49
11/18/98 – 4-Mo. OGAC	75	74	na	na	na	na	74	73	na	na	na	na
11/19/98 – 4-Mo. OGAC	75	74	na	na	na	na	74	73	na	na	na	na
4/13/99 – 9-Mo. OGAC	74	73	63	62	59	59	74	73	57	57	50	50
4/15/99 – 9-Mo. OGAC	74	73	64	64	62	62	na	na	na	na	na	na
6/15/99–11-Month OGAC	74	72	57	56	53	52	73	73	65	64	60	61
6/16/99–11-Month OGAC	74	73	61	60	56	55	73	72	58	60	50	53
12/08/99–17-Month OGAC	74	73	na	na	na	na	74	73	na	na	na	na
12/15/99–17-Month OGAC	75	74	na	na	na	na	74	73	na	na	na	na
4/05/00–21-Month OGAC	74	72	61	60	56	55	73	72	57	59	49	51
4/06/00–21-Month OGAC	74	72	58	57	53	52	73	72	60	62	54	54
6/06/00–23-Month OGAC	74	72	54	54	51	50	73	72	61	60	54	51
6/09/00-23-Month OGAC	74	73	52	52	50	49	74	73	65	65	58	60
12/07/00-29-Month OGAC	75	74	na	na	na	na	74	73	na	na	na	na
12/08/00-29-Month OGAC	75	74	na	na	na	na	74	73	na	na	na	na
4/17/01–33-Month OGAC	75	73	61	na	56	na	74	73	62	na	54	na
4/18/01–33-Month OGAC	75	74	57	na	53	na	74	73	67	na	64	na
6/05/01–35-Month OGAC	74	73	61	na	54	na	73	73	58	na	50	na
6/06/01-35-Month OGAC	75	74	63	na	56	na	73	72	53	na	45	na
11/27/01-40-Month OGAC	76	75	na	na	na	na	74	74	na	na	na	na
12/19/01-40-Month OGAC	76	75	na	na	na	na	75	74	na	na	na	na
4/24/02-45-Month OGAC	74	73	54	54	52	51	75	74	67	65	na	na
4/25/02-45-Month OGAC	75	74	60	59	55	54	75	74	64	60	58	52
6/19/02-47-Month OGAC	75	74	na	na	na	na	73	73	na	na	na	na
6/20/02-47-Month OGAC	74	73	na	na	na	na	74	73	na	na	na	na

na = data not available.

Notes:

1. ER = eastbound reference, EU = eastbound distant upper, ED = eastbound distant down, WR = westbound reference, WU = westbound distant upper, WD = westbound distant down.

2. EU levels for 11/18-19/98 and 12/8 and 15/99 based on small data set.

3. WU and WD L_{eqs} affected by local traffic, except for 4/13/99, 6/15/1999 and on.

Table 3-2. Summary of Meteorological Data for Each Measurement Period

Date	Measured Meteorological Conditions				
	Wind Speed (m/s)	Cross-Vector Wind Comp. [1] (m/s)	Temperature (ºC)	Temperature Gradient (ºC/m)	Sky Conditions
6/12/98 – Baseline	3.7	-3.1	21	-0.12 Lapse	Scattered Clouds
6/15/98 – Baseline	2.4	+2.0	27	-0.11 Lapse	Scattered Clouds
7/13/98 – New DGAC	2.7	-2.0	25	-0.12 Lapse	Clear
7/14/98 – New DGAC	1.9	0.5	24	-0.10 Lapse	Clear
8/11/98 – New OGAC	2.2	+2.0	29	-0.10 Lapse	Clear
8/12/98 – New OGAC	1.6	+1.1	30	-0.08 Lapse	Clear
8/13/98 – New OGAC	1.6	0.4	28	-0.08 Lapse	Clear
8/26/98 – 1-Mo. OGAC	2.0	+1.9	20	-0.10 Lapse	Clear
11/18/98 – 4-Mo. OGAC	NA	NA	16	NA	Clear
11/19/98 – 4-Mo. OGAC	NA	NA	16	NA	Clear
4/13/99 – 9-Mo. OGAC	2.3	+1.8	15	-0.09 Lapse	Clear
4/15/99 – 9-Mo. OGAC	4.5	+4.4	22	-0.09 Lapse	Clear
6/15/99–11-Month OGAC	4.0	-4.0	18	-0.12 Lapse	Clear
6/16/99–11-Month OGAC	1.6	0.4	20	-0.10 Lapse	Clear
12/08/99–17-Month OGAC	NA	NA	16	NA	Clear
12/15/99–17-Month OGAC	NA	NA	16	NA	Clear
4/05/00–21-Month OGAC	1.4	0.4	14	-0.08 Lapse	Clear
4/06/00–21-Month OGAC	1.6	-0.9	15	-0.08 Lapse	Clear
6/06/00–23-Month OGAC	1.3	-0.4	25	~*-0.10* Lapse	Clear
6/09/00-23-Month OGAC	2.5	-2.1	22	~*-0.10* Lapse	Scattered Clouds
12/07/00-29-Month OGAC	NA	NA	*~10*	NA	Partly Cloudy
12/08/00-29-Month OGAC	NA	NA	*~15*	NA	Clear
4/17/01–33-Month OGAC	NA	NA	~20	Lapse	Clear
4/18/01–33-Month OGAC	NA	NA	~20	Lapse	Partly Cloudy
6/05/01–35-Month OGAC	NA	NA	~25	Lapse	Clear
6/06/01-35-Month OGAC	NA	NA	~25	Lapse	Clear
11/27/01-40-Month OGAC	NA	NA	10	Lapse	Clear
12/19/01-40-Month OGAC	NA	NA	7	Lapse	Fog/Overcast
4/24/02-45-Month OGAC	~ 4	~ -2	~ 19	Lapse	Clear
4/25/02-45-Month OGAC	2.1	-0.5	19	Lapse	Partly Cloudy
6/19/02-47-Month OGAC	4-5	~ +3	~30	Lapse	Clear
6/20/02-47-Month OGAC	2-4	~ -1	~30	Lapse	Clear

Note: Meteorological data was not monitored for measurements made for 1st 2 year then at 3rd year (April 2002)

NA = data not available.
[1]Calculated relative to eastbound side of I-80.
Note: Vertical temperature gradient typically negative (lapse condition) during April and June due to solar heating.

Table 3-3. Average Hourly Traffic for Each Measurement Period

Date	Eastbound Direction			Westbound Direction		
	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks
6/12/98 – Baseline	2765	75	195	2815	123	202
6/15/98 – Baseline	2772	61	223	2453	102	200
7/13/98 – New DGAC	2425	106	178	2461	89	201
7/14/98 – New DGAC	2611	78	200	2365	80	213
8/11/98 – New OGAC	2662	102	164	2458	89	194
8/12/98 – New OGAC	2727	83	235	2693	84	191
8/13/98 – New OGAC	2593	99	188	2719	87	173
8/26/98 – 1-Mo. OGAC	2975	111	249	3102	63	278
11/18/98 – 4-Mo. OGAC	2325	90	210	1944	49	240
11/19/98 – 4-Mo. OGAC	2496	108	197	1635	52	202
4/13/99 – 9-Mo. OGAC	2423	82	200	2221	104	186
4/15/99 – 9-Mo. OGAC	2341	128	183	2303	105	205
6/15/99–11-Month OGAC	2859	59	219	2457	135	338
6/16/99–11-Month OGAC	2992	42	250	2526	78	280
12/08/99–17-Month OGAC	2594	89	219	2361	88	223
12/15/99–17-Month OGAC	2522	93	198	2409	102	214
4/05/00–21-Month OGAC	2680	50	253	2386	97	238
4/06/00–21-Month OGAC	2764	38	260	2540	112	228
6/06/00–23-Month OGAC	2804	43	262	2508	63	222
6/09/00-23-Month OGAC	2666	99	199	2954	54	215
12/07/00-29-Month OGAC	2809	64	252	2379	126	245
12/08/00-29-Month OGAC	3228	50	288	2511	119	214
4/17/01–33-Month OGAC	3165	135	209	3141	112	238
4/18/01–33-Month OGAC	3331	136	195	3256	100	214
6/05/01–35-Month OGAC	2883	117	213	3203	75	263
6/06/01-35-Month OGAC	3038	132	204	3137	87	246
11/27/01-40-Month OGAC	2862	127	184	2994	81	268
12/19/01-40-Month OGAC	3203	133	185	3039	84	222
4/24/02-45-Month OGAC	3031	144	226	3104	155	193
4/25/02-45-Month OGAC	3188	108	236	3373	98	210
6/19/02-47-Month OGAC	3234	47	292	3455	144	229
6/20/02-47-Month OGAC	3185	163	228	3557	111	189

Table 3-4. Hourly Average Modeled and Measured Noise Levels at Reference Locations

Date	EB Reference Noise Levels (in dBA)			WB Reference Noise Levels (in dBA)		
	EB Ref Measured	EB Ref Modeled	Diff (Mod.-Meas.)	WB Ref Measured	WB Ref Modeled	Diff (Mod.-Meas.)
6/12/98 – Baseline	**78.0**	**79.2**	**1.2**	**79.1**	**79.2**	**0.1**
6/15/98 – Baseline	**78.2**	**79.5**	**1.3**	**77.9**	**79.4**	**1.5**
7/13/98 – New DGAC	**74.7**	**78.8**	**4.1**	**74.4**	**79.1**	**4.7**
7/14/98 – New DGAC	**74.6**	**79.0**	**4.4**	**74.1**	**79.1**	**5.0**
8/11/98 – New OGAC	**73.3**	**79.0**	**5.7**	**73.2**	**79.1**	**5.9**
8/12/98 – New OGAC	**73.3**	**79.2**	**5.9**	**72.2**	**79.3**	**7.1**
8/13/98 – New OGAC	**73.5**	**79.0**	**5.5**	**72.4**	**79.2**	**6.8**
8/26/98 – 1-Mo. OGAC	**74.3**	**79.8**	**5.5**	**72.9**	**80.0**	**7.1**
11/18/98 – 4-Mo. OGAC	**75.2**	**78.8**	**3.6**	**74.4**	**78.9**	**4.5**
11/19/98 – 4-Mo. OGAC	**74.7**	**78.9**	**4.2**	**74.1**	**78.6**	**4.5**
4/13/99 – 9-Mo. OGAC	**74.4**	**78.8**	**4.4**	**73.7**	**78.8**	**5.1**
4/15/99 – 9-Mo. OGAC	**73.8**	**78.8**	**5.2**	**NA**	**NA**	**NA**
6/15/99–11-Month OGAC	**73.7**	**80.0**	**6.3**	**73.4**	**80.2**	**7.0**
6/16/99–11-Month OGAC	**73.8**	**80.0**	**6.2**	**73.2**	**79.8**	**6.6**
12/08/99–17-Month OGAC	74.2	79.5	5.4	73.8	79.6	5.9
12/15/99–17-Month OGAC	74.9	79.3	4.4	73.9	79.7	5.8
4/05/00–21-Month OGAC	73.5	79.8	6.3	73.3	79.8	6.5
4/06/00–21-Month OGAC	73.6	79.9	6.3	73.2	80.0	6.8
6/06/00–23-Month OGAC	73.5	79.8	6.3	73.3	79.8	6.5
6/09/00-23-Month OGAC	74.3	79.7	5.3	74.0	80.0	6.0
12/07/00-29-Month OGAC	**74.6**	**79.9**	**5.3**	**74.1**	**79.9**	**5.8**
12/08/00-29-Month OGAC	**74.7**	**80.0**	**5.3**	**73.8**	**79.7**	**5.9**
4/17/01–33-Month OGAC	**74.5**	**79.4**	**4.9**	**74.0**	**79.7**	**5.7**
4/18/01–33-Month OGAC	**74.7**	**79.4**	**4.7**	**73.8**	**79.6**	**5.8**
6/05/01–35-Month OGAC	**74.4**	**80.1**	**5.7**	**73.4**	**80.4**	**7.0**
6/06/01-35-Month OGAC	**74.7**	**80.2**	**5.5**	**73.2**	**80.3**	**7.1**
11/27/01-40-Month OGAC	76.2	79.3	3.1	74.4	79.7	5.3
12/19/01-40-Month OGAC	75.6	79.6	4.0	74.9	79.7	4.8
4/24/02-45-Month OGAC	74.4	79.8	5.4	74.6	79.9	5.3
4/25/02-45-Month OGAC	74.8	80	5.2	74.6	80.1	5.5
6/19/02-47-Month OGAC	75.1	80.1	5.0	73.4	80.3	6.9
6/20/02-47-Month OGAC	74.3	80.0	5.7	74.0	80.2	6.2

Table 3-5. Summary of TNM Over Predictions at Distant Sites

Measurement Condition	Average (in dBA)	
	Baseline	OGAC
Upwind		
WB up	7	11
WB down	10	14
EB up	--	10
EB down	9	10
Downwind		
WB up	0	3
WB down	-2	4
EB up	2	5
EB down	1	4
Calm		
WB up	--	7
WB down	--	11
EB up	--	9
EB down	--	7
Overall		
All data	3.9	7.8
WB data only	4.0	8.3

Wind conditions are characterized by the magnitude of the cross-vector wind component with respect to the roadway: *Upwind* is less than +1.2m/s; *Calm* is between -1.2m/s and +1.2m/s; *Downwind* is greater than 1.2m/s. Conditions greater than $\pm$3.2m/s are not included. All measurement conditions occurred when the temperature was between 15° and 30° C and there was a temperature lapse.

Eastbound data (especially the EB down data) was affected by corn on some of the days. This was accounted in the modeling by including a tree zone.

4.0 REFERENCE NOISE LEVEL FINDINGS

This section presents findings based on data collected from June 1998 through June 2002. A draft report was submitted in June 1999 that reported results for the period June 1998 through April 1999. A second draft report was issued in June 2000 that reported results for measurements conducted up to 2 years after the OGAC pavement overlay was applied and this was followed up with a report summarizing results through June 2001.

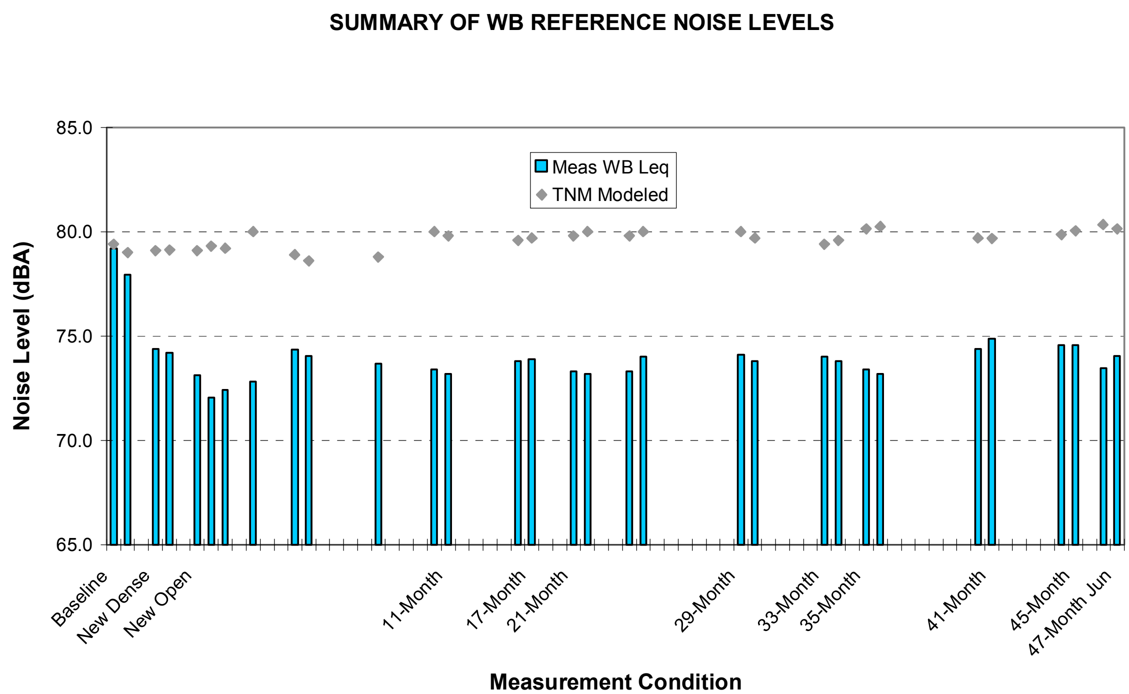
Noise levels were measured at locations on each side of I-80, approximately 20 meters from the edge of the near travel lane. These were considered reference locations (EB Ref for eastbound and WB Ref for westbound reference). During noise measurements, traffic conditions were observed through almost continuous vehicle counts and periodic vehicle speed measurements (using a hand-held traffic radar). All noise and traffic data were compiled into hourly averages. Observed traffic conditions were modeled using TNM to predict noise levels at each of the reference noise measurement locations. These data were used to provide a measure of the acoustical strength for each roadway condition to account for the effects of variations in traffic volume and speed. Spectral (1/3-octave band) data were collected at random times during each measurement period.

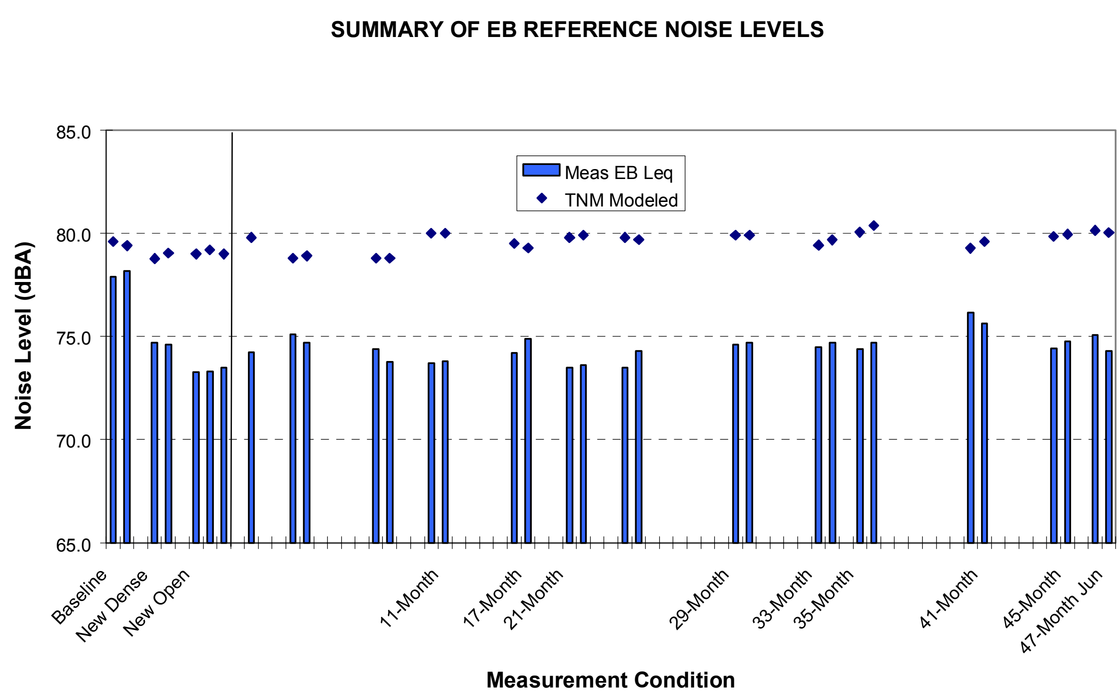
A-Weighted Noise Levels

A summary of measured and modeled A-weighted noise levels for both the EB Ref and WB Ref noise levels are shown graphically in Figure 4-1. Note that TNM modeled levels were about one dBA higher than measured baseline levels. TNM predicted that a majority of the acoustical energy was produced by automobiles. Heavy-duty trucks contributed almost 2 dBA to the overall modeled noise level, while medium-duty trucks had very little effect. An obvious decrease (from baseline conditions) in measured noise levels associated with different pavement conditions occurred, while modeled noise levels varied by about one dBA. EB Ref and WB Ref noise levels changed similarly. However, the changes with EB Ref noise levels were slightly less. Obvious decreases in measured noise levels from the baseline condition are apparent for both EB Ref and WB Ref.

EB Ref noise levels were usually about one dBA higher than WB Ref. This difference in noise levels was not reflected in the traffic noise modeling results. A 1 dBA difference is typically ignored during routine noise studies. However, an explanation is warranted for this study where 3 to 7 dBA changes in overall levels are evaluated. The primary cause for higher noise levels at the EB Ref site is due to the effects of local traffic on East Chiles Road. When the study began with the older pavement in place, noise levels were higher and local traffic noise levels had no affect on the overall Leq noise level. The local traffic appears to be affecting the overall noise levels with the quieter pavement. Also, traffic has increased along this local roadway over the course of the study. During the second year of measurements, traffic on this frontage road was noted to be slightly higher with a higher percentage of equivalent medium-duty trucks (mostly recreational vehicles from the new dealership located about 3 kilometers west). New growth in the area appears to have added traffic. A comparison of Leqs measured with and without pauses for local traffic indicated the effect is now (in 2002) about 0.5 to 1 dBA. Wind also appears to have a slight effect on noise levels. In just about all cases, slightly lower noise levels occurred at the upwind reference location. A third, but likely minor cause, would be subtle changes in traffic conditions that could not be accounted for in traffic observations. Although the roadway is relatively flat and at-grade, eastbound traffic is approaching a slight rise (about 0.5 Km to the east) on to the Yolo Causeway. Eastbound trucks may be “somewhat” accelerating in anticipation of this slight grade. Conversely, westbound traffic has just come off this rise and large trucks may be “somewhat” coasting.

Figure 4-1. Trends in Measured and Modeled Noise Levels at Reference Locations





Average baseline noise levels were used to normalize the effects of variations in traffic volume and speed. The difference in average measured noise levels between each measured pavement condition and the baseline is adjusted (or normalized) by applying the difference between the modeled baseline condition and the modeled level for a pavement condition of interest. Differences between modeled noise levels were small, typically less than one dBA.

The changes to traffic noise levels, from the baseline condition,

$$\Delta_i = [Lmea_i - Lmea_b] - [Lmod_i - Lmod_b]$$

where:

Δ_i is the normalized change in the average noise level for a given pavement condition; *i*;
$Lmea_i$ is the average measured noise level for a given pavement condition (*i*);
$Lmea_b$ is the average measured noise level for the baseline condition; and
$Lmod_i$ is the average modeled noise level for a given pavement condition (*i*); and
$Lmod_b$ is the average modeled noise level for the baseline condition.

Changes to noise levels at reference locations are shown in Table 4-1. The data shown in the table and the previous graphs clearly indicate that noise levels decreased after the application of both new DGAC and OGAC.

Noise levels at EB Ref decreased about 3 dBA after application of the new DGAC. Noise levels decreased another 1.5 dBA after application of the new OGAC overlay (4.5 dBA quieter than baseline conditions). Noise levels were about one dBA higher during the 4- to 9-month old OGAC measurements. The second year measurements (11- to 23-month old OGAC) indicate that the EB Ref noise levels are 4 to 5 dBA lower than baseline levels. The third and fourth year noise measurements indicate that the noise reduction from OGAC is about 4 dBA. The actual reduction is probably 0.5 to 1.5 dBA greater than reported due to the interferences from local traffic.

At WB Ref, noise levels decreased by almost 4 dBA with application of the new DGAC. Noise levels were about 5 to 6 dBA lower for the new and 1-month old OGAC pavement. The newly aged (4- and 9-month old) OGAC pavement is about 4 dBA quieter than the baseline pavement condition. The second year measurements indicate that noise levels were about 5 to 6 dBA quieter than baseline conditions. The third year noise measurements indicate that the noise reduction from OGAC is over 5 dBA, similar to the 2nd year measurements. The fourth year measurements indicate that the reduction is about 5 to 6 dBA; in other words, unchanged from previous years.

The greater reduction in noise levels shows up at the WB Ref location for two suspected reasons. First, the baseline noise levels at the EB Ref locations were about 0.5 dBA lower than the WB Ref location. Second, interferences from local traffic appear to increase noise levels with the OGAC by 0.5 to 1.5 dBA.

Overall, the noise measurement and traffic modeling data indicate that the OGAC pavement reduced noise levels by 4 to 6 dBA. This reduction is still readily apparent 47 months after application. Another related finding regards the traffic noise modeling. Use of the TNM model over-predicted baseline noise levels by about one dBA. A 1-dBA difference between measured and modeled is usually considered acceptable for routine traffic noise studies. However, with the new pavement conditions, the model over predicted traffic noise levels at the nearby reference locations by about 4 to 7 dBA. This is a substantial over prediction.

1/3-Octave Band Data

Spectral or 1/3-octave band frequency data were collected at each of the reference sites. These data were collected over 5-minute periods, while simultaneously collecting A-weighted data at the sites. A sample of the spectral data collected at reference sites are shown graphically in Figure 4-2a for the WB Ref data and Figure 4-2b for the EB Ref data. The 1/3-octave band center frequencies are shown on the horizontal axis and the noise level is shown on the vertical axis.

The graphs show noise levels that are similar at each reference site. Noise levels at both reference sites were similar for all conditions for frequencies less than about 1000 Hz. For frequencies between 1000 Hz and 4000 Hz, noise levels associated with the OGAC overlay were 5 to 10 dB lower. The new DGAC exhibited a slight decrease over these frequencies also. The newly worn OGAC overlay exhibited a slight increase in noise levels at about 2000 Hz to 2500 Hz. The new pavement clearly changed the tonal characteristics of traffic noise at this location, decreasing the mid- to high-frequency traffic noise. The 2nd year (11- to 23-month aged OGAC), 3rd year (29- to 35-month), and 4th year frequency noise data show little change from the new OGAC condition. Noise levels continue to be about 5 to 10 dB lower (than baseline conditions) at frequencies above 1000 Hz.

Prior to the OGAC overlay, most A-weighted acoustical energy occurred between 500 and 2500 Hz. Following the OGAC overlay, most A-weighted energy is contained within about 500 to 1000 Hz. Again, noise levels were reduced by over 5 dBA at frequencies centered around 1000 Hz.

Conclusions – Reference Sites

The A-weighted noise levels measured at both reference sites indicate that substantial decreases in traffic noise occurred after the placement of the new DGAC and new OGAC overlays. The new DGAC measurements are representative of only the conditions after a very recent application of this pavement overlay type. This study did not measure traffic noise levels associated with aging of this DGAC pavement. Several measurements of OGAC overlay were made over the first four years, which provide some indications of the trends in acoustical characteristics of the pavement. The newly applied OGAC resulted in substantially lower noise levels than the baseline condition. After 4 years of aging, the noise levels continue to be lower than the baseline condition. Important findings developed from this data set are as follows:

1. Based on the data collected to date, it can be concluded that traffic noise levels decreased by 5 to 6 dBA with the application of an OGAC overlay to a roadway bed that contained aged dense graded asphalt. This reduction remains apparent after 4 years of aging on a busily traveled Interstate freeway with a relatively large volume of trucks. Visual observations indicate that the roadway surface is in good shape (i.e., no cracking or significant pavement patches).

2. A reduction of 3 to 4 dBA from baseline conditions occurred *just* after application of the DGAC. Traffic noise levels decreased further by 2 to 3 dBA just after application of the OGAC overlay to the DGAC or leveling coarse.

3. There appears to be a seasonal variation in the traffic noise levels that appears to be associated with pavement temperature. Normalized traffic noise levels appear to be slightly higher in the colder seasons then summer months.

4. 1/3rd Octave Band data indicate distinct spectral changes in traffic noise with decreases in noise levels at frequencies between about 1000 Hz and 4000 Hz. A decrease of about 3 to 5 dB occurred over this frequency range with the new DGAC and a decrease of up to 10 dB occurred with the new OGAC overlay. The aged OGAC overlay showed slightly higher noise levels than the new OGAC overlay at frequencies above 2000 Hz. Traffic noise levels over the range of 1000 to 2000 Hz that contribute most to the overall A-weighted noise levels were reduced substantially.

5. The TNM model over-predicted baseline traffic noise levels at the reference sites by about one dBA. With the new pavement conditions, the model over-predicted traffic noise levels by about 6 dBA.

6. While it is clear that the application of the new OGAC overlay reduced traffic noise levels substantially, findings of this study are so far limited to conditions on I-80. This included a relatively high percentage of trucks (about 2-3% medium-duty and 7% heavy-duty trucks), and high traffic speeds (110+kph or 70+ mph). Effects, such as vehicle mix, vehicle speed, baseline pavement condition, and shielding effects, could effect the magnitude of noise level reductions attributable to OGAC overlays. This portion of I-80 does not experience snow and freezing conditions with moisture are rare.

8. Meteorological conditions or subtle effects of traffic are suspected to have affected measured noise levels by up to one dBA. It appears that increasing traffic on the frontage road adjacent to the Eastbound

Reference site affects the reference noise levels slightly. We estimate this affect to currently be on the order of 0.5 to 1.5 dBA. Therefore, the data collected at the Westbound Reference site appears to be most reliable for evaluating the noise level reductions from the OGAC overlay. Findings in this study are primarily based on the Westbound Reference data set.

Table 4-1. Noise Level Changes at Reference Sites

Ref Site	Calculated Change in Traffic Noise Level Normalized for Traffic Conditions															
	Base-line	DGAC	New OGAC	1-Mo. AUG	4-Mo. NOV	9-Mo. APR	11-Mo. JUN	17-Mo. DEC	21-Mo. APR	23-Mo. JUN	29-Mo. DEC	33-Mo. APR	35-Mo. JUN	40-Mo. Dec	45-Mo. APR	47-Mo. JUN
EBRef	78.1	-3.0	-4.5	-4.3	-2.7	-3.5	-4.9	- 3.5	-5.0	-4.6	-4.0	-3.5	-4.3	-2.1	-3.8	-3.9
WBRef	78.6	-3.9	-5.6	-6.1	-3.5	-4.1	- 6.0	-5.1	-5.9	-5.5	-5.2	-5.1	-6.4	-4.4	-4.8	-5.9

Figure 4-2a Westbound Reference Traffic Noise Spectra

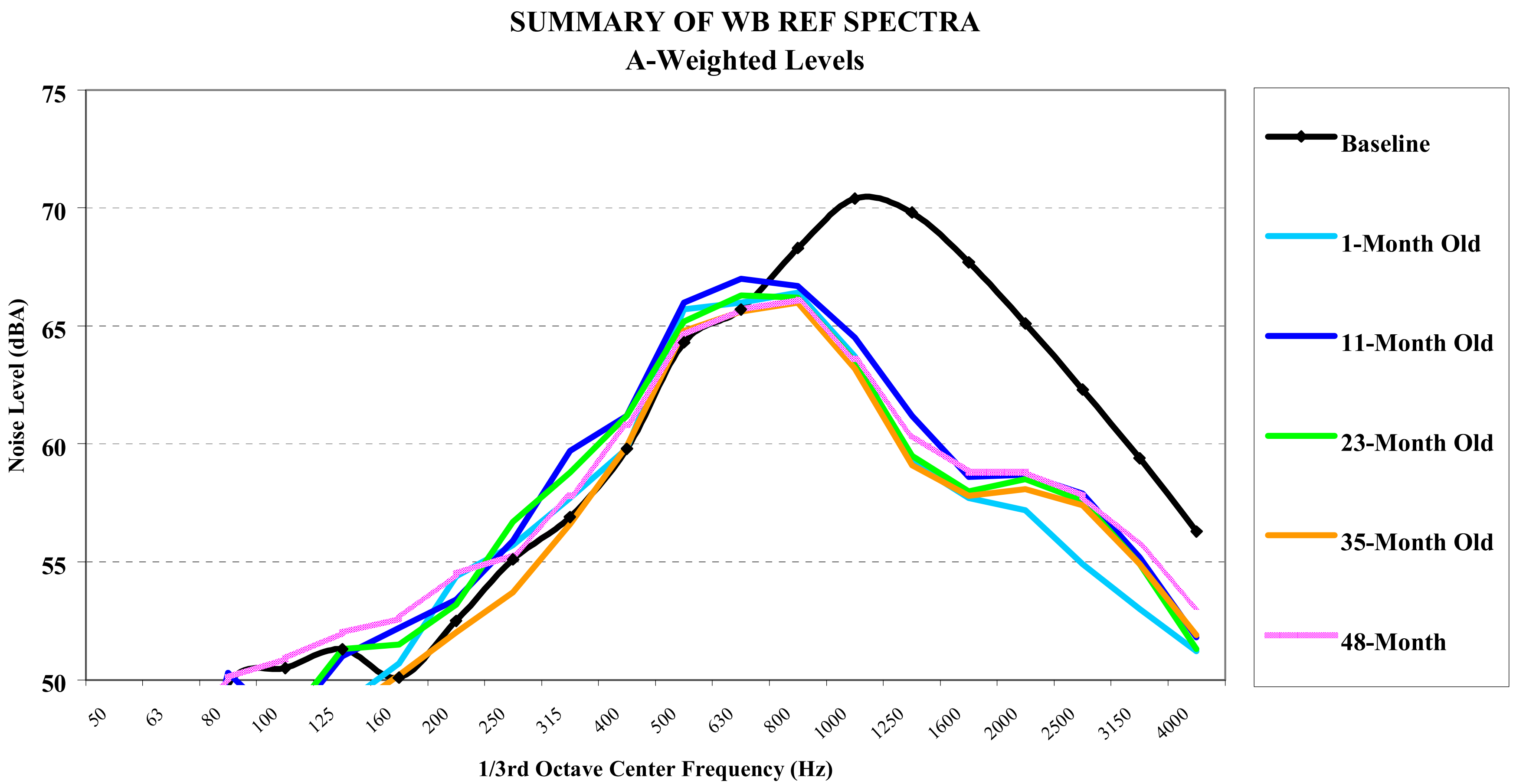
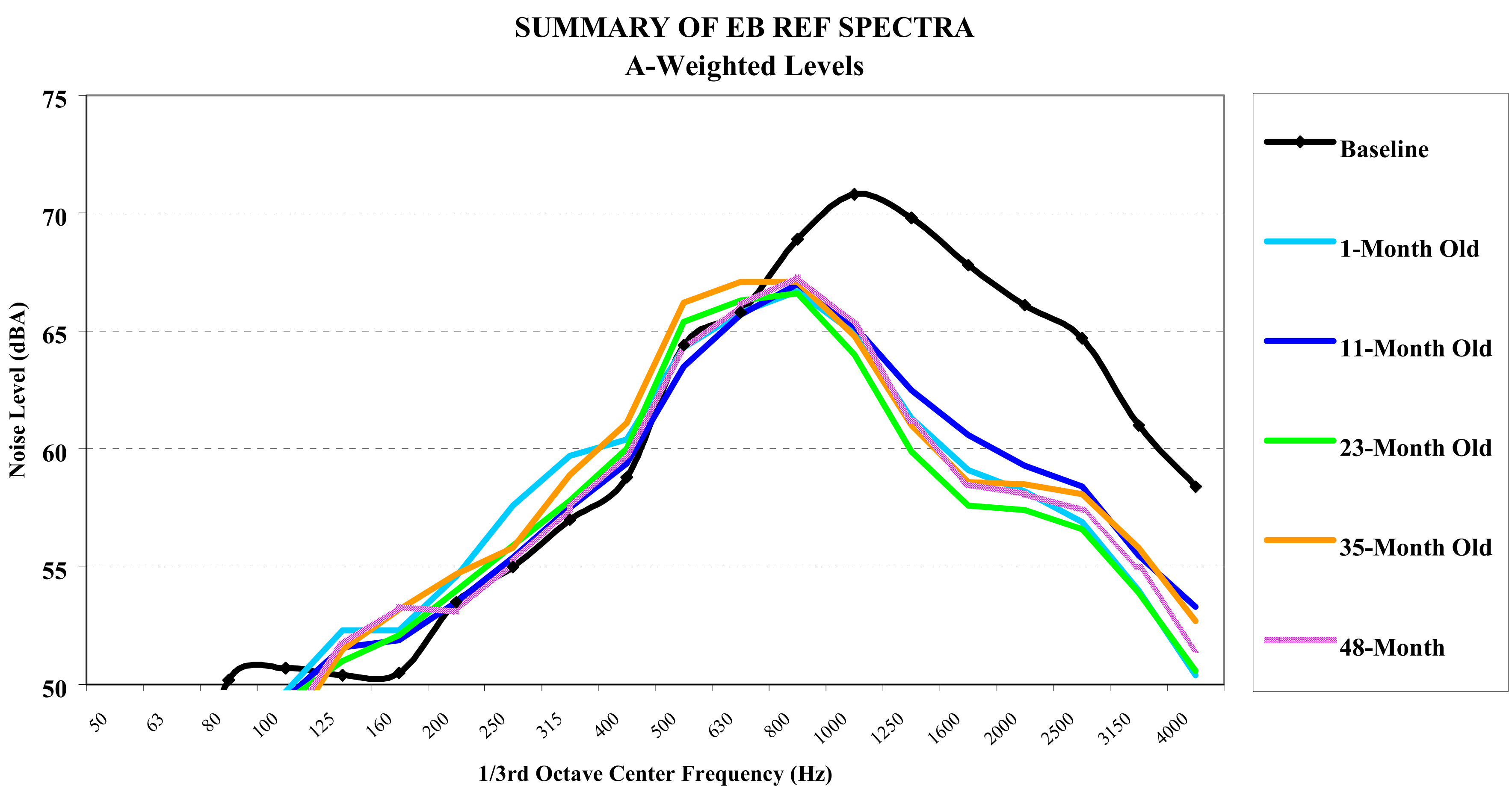


Figure 4-2b Eastbound Reference Traffic Noise Spectra



5.0 DISTANT LOCATION NOISE LEVEL FINDINGS

Data at distant sites were not targeted for collection during the third year and only one day of measurements were made in the fourth year of monitoring. Some spot measurements were made during all years. This summary report focused on the results for the reference locations. Results for distant locations were evaluated previously (Woodward-Clyde 2000) and those results are assumed valid as long as reference location results do not change substantially. An updated analysis based on samples from each measurements day combined with model results for those samples was conducted for this report.

The measured noise level at each site (shown in Table 5-5) illustrates the evidence that noise levels decreased after application of the new pavement. These measured levels are not normalized for changing traffic conditions; however, it should be noted that the TNM model indicated an increase about one dBA over baseline conditions that are due to changes in traffic conditions. These data are categorized by upwind or downwind conditions. However, it should be noted there is variability within these classes that cannot easily be accounted.

Table 5-1. Summary of Noise Levels Measured at Distant Measurement Sites

Site	Measured Noise Level at Distant Locations (in dBA)								
	Baseline	New DGAC	New OGAC	1-Mo. OGAC	9-Mo. OGAC	11-Mo. OGAC	21-Mo. OGAC	23-Mo. OGAC	45-Mo. OGAC
EB Up (Downwind)	66	59	61*	58*	63	--	--	--	61
EB Up (Upwind)	58	54	--	--	--	57	58	52*	57
EB Down (Downwind)	62	54*	53*	54*	59	--	--	--	56
EB Down (Upwind)	55	50*	--	--	--	53	53	51*	52
WB Up (Downwind)	68	63	--	--	--	64	62	65	62
WB Up (Upwind)	60	58	55	56	57	--	--	--	56
WB Down (Downwind)	65	58	--	--	--	61	54	60	55
WB Down (Upwind)	53	52	47	49	50	--	--	--	49

* Noise measurements likely affected by tall corn growing in field on EB side

Attended (clean) samples from each measurement day were modeled at the distant locations. On average, TNM over predicted **baseline** conditions at the distant sites by 4 dBA. With the **OGAC**, the over prediction increased to 8 dBA. There was considerable variation that was due mostly (but not entirely) to wind conditions. For downwind conditions, TNM, on average, over predicted noise levels by –2 to +2 for **baseline** conditions and +3 to +5 dBA for **OGAC** conditions. Under *Upwind* conditions, TNM had an average over prediction of +9 to +10 dBA for **baseline** conditions and +10 to +14 dBA for **OGAC** conditions. *Calm* conditions, which were only encountered for the **OGAC** conditions, had over predictions of +7 to +9 dBA at eastbound locations and +7 to +11 dBA at westbound locations. The comparison of predictions for **baseline** and **OGAC** conditions indicate that there was an average reduction of 4 dBA at distant sites. Calm conditions (i.e., magnitude of cross-wind vectors exceed ±1.2 m/s) were not encountered during the baseline measurements; and therefore, they are not examined in this report.

1/3-Octave Band Data

Representative 1/3-octave band data collected at the distant sites (EBup, EBdown, WBup and WBdown) showed the similar decrease in noise levels (between 1000 and about 4000 Hz) that occurred at the reference sites. The data for the westbound sites were most representative since eastbound distant sites were affected by changes in ground cover. For all distant sites, baseline conditions always had the highest noise levels, especially around 1000 to 2000 Hz. Decreases to noise levels occurred at both the upper and lower sites. The decrease is most important for downwind conditions that are 5 to 8 dB louder than the barely audible upwind conditions (at 1000 to 2000 Hz). However, decreases are apparent for upwind conditions also. Although the overall noise level varied between measurements, the spectral shape at these distant locations was clearly changed after application of the new pavement surfaces. These data support a finding that noise levels decreased at both upper and lower distant sites after application of the OGAC and the reduction was evident when the pavement had aged 47 months.

Conclusions – Distant Sites

The effect of pavement on noise levels at the distant sites was difficult to assess. Several factors, besides pavement type, affected noise levels at these sites. While changes in traffic conditions could be accounted to some extent by evaluating the change in the delta (difference between simultaneous reference and distant measurements), the effects due to changes in ground cover and subtle changes in meteorological conditions cannot be eliminated from the data. However, with these complications in the analysis, the data do show an indication that noise levels decreased at distant sites after the new pavement was applied. Specific findings developed from this data set are as follows:

1. A careful examination of the A-weighted noise levels under different meteorological conditions indicates that the new pavement provided a substantial decrease in noise levels at the distant sites. The decrease was about 4 to 5 dBA just after the application of the new OGAC. The reduction was evaluated under downwind conditions, when freeway traffic noise is loudest. The noise level decrease was still evident after almost 4 years since the OGAC overlay.

2. The finding above is based on an assessment that relied upon a limited amount of baseline data. There was considerable variation in the delta that could not be directly accounted for by changes in measured meteorological parameters. Wind had a substantial effect on noise attenuation. It was common to measure a difference of up to 10 dBA between eastbound and westbound distant sites. To a casual observer, this would be the difference between having some difficulty communicating with others at one side of the freeway and barely being able to hear the traffic noise at the other equally distant site.

3. The 1/3-octave band frequency data collected at the distant sites show that traffic noise levels decreased substantially over the frequencies of 1000 to 4000 Hz. This reinforces the finding that A-weighted noise levels decreased at the distant sites.

4. Attended (clean) samples from each measurement day were modeled at the distant locations. Results for all wind conditions indicate an average over prediction of 4 dBA for baseline conditions and 8 dBA for OGAC conditions. There was considerable variation that was due mostly (but not entirely) to wind conditions. For *Downwind* conditions, TNM, on average, over predicted noise levels by –2 to +2 for baseline conditions and 3 to 5 dBA for OGAC conditions. Under *Upwind* conditions, TNM had an average over prediction of 9 to 10 dBA for baseline conditions and 10 to 14 dBA for OGAC conditions. Comparison of measurement and modeling data for Baseline and OGAC conditions would indicate that the OGAC resulted in noise level reductions of 4 dBA at distant sites and 5 to 6 dBA at the reference sites. As mentioned above, a more thorough analysis is planned for the 2003 report.

6.0 PERSONNEL

The Principal Investigator for this report was Mr. James Reyff of Illingworth & Rodkin, Inc. Technical direction and oversight was provided by Mr. Richard Rodkin, P.E. of Illingworth & Rodkin, Inc. Field support was provided by Mr. Mike Thill and Joe McGloin (noise measurements), and Mr. Phil Williams (traffic measurements) of Illingworth & Rodkin. Additional field staff was provided from Denise Duffy and Associates and in previous years by Haygood & Associates and Woodward Clyde. Technical and management oversight by Caltrans was provided by Mr. Keith Jones, P.E, James Andrews, P.E., and Mr. Rudy Hendriks. This work was begun under task orders issued through the statewide “on-call” noise and vibration contract (Contract No. 43A0009) managed by Mr. Rob Greene of URS (formerly Woodward Clyde Consultants) and is now conducted under the current contract managed by Mr. James Reyff of Illingworth & Rodkin, Inc. (Contract No. 43A0063).