Memo

To:	Wayne Belzer		
From:	Tim Casey, Elliott Dick, and Gina Jarta	Project:	USIBWC Floodgate Noise Study
cc:	Patrick Solomon		
Date:	12/2/2013	Job No:	000000000210009

Re: Country Club Road Bridge Post-Construction Noise Study

INTRODUCTION

The International Boundary and Water Commission, U.S. Section (USIBWC), installed flood control gates on Country Club Road Bridge in El Paso, Texas, to manage the flow of flood waters upstream from the bridge. After the installation of the flood control measures, residents in the areas raised concerns about noise, particularly from the sound caused by vehicles passing over floodgate panels embedded into the bridge deck. In response to those concerns, USIBWC hired HDR Engineering, Inc. (HDR) to conduct a post-construction noise study.

The post-construction noise study included environmental noise monitoring and baseline noise modeling at a neighborhood in the vicinity of the bridge. Environmental noise levels at residences near to the floodgates on the Country Club Road Bridge were measured to determine the amount of noise exposure outside residences during daytime, nighttime, weekday, and weekend periods. Baseline noise modeling and hour-long noise monitoring was performed to assess traffic-related noise levels at residences near the floodgates and determine the noise contribution attributable to vehicles traveling over floodgates. Measured environmental noise levels, which include the influence of floodgates, were compared to traffic noise modeling, which does not include noise associated with traffic traveling over floodgates. The difference between measured noise levels and modeled noise levels is assumed to represent noise from vehicles traveling over the floodgate panels.

INTRODUCTION TO ENVIRONMENTAL ACOUSTICS

Sound is made up of tiny fluctuations in air pressure. Sound, within the range of human hearing, can vary in intensity by more than 1 million units. Therefore, a logarithmic scale, known as the decibel scale (dB), is used to quantify sound intensity and to compress the scale to a more manageable range.

Sound is characterized by both its amplitude (how loud it is) and frequency (or pitch). The human ear does not hear all frequencies equally. The human hearing organs of the inner ear deemphasize very low and very high frequencies. The A-weighted scale (dBA) is used to reflect this selective sensitivity of human hearing. This scale puts more weight on the range of frequencies that the average human ear perceives, and less weight on those frequencies we do not hear as well. For traffic noise purposes, the A-weighted scale is used.

Table 1 shows a range of typical noise levels from common activities.

Table 1. Typical Noise Levels

Common Outdoor Activities	Noise Level dB(A)	Common Indoor Activities
	-110-	Rock Band
Jet Fly-over at 1,000 feet		
	-100-	
Gas Lawn Mower at 3 feet		
	-90-	
Diesel Truck at 50 feet, at 50 mph		Food Blender at 3 feet
	-80-	Garbage Disposal at 3 feet
Noisy Urban Area (Daytime)		
Gas Lawn Mower at 100 feet	**-70-**	Vacuum Cleaner at 10 feet
Commercial Area		Normal Speech at 3 feet
Heavy Traffic at 300 feet	**-60-**	
		Large Business Office
Quiet Urban Daytime	**-50-**	Dishwasher Next Room
Quiet Urban Nighttime	**-40-**	Theater, Large Conference Room
Quiet Suburban Nighttime		(Background)
	-30-	
Quiet Rural Nighttime		Library
	-20-	Bedroom at Night, Concert Hall
		(Background)
	-10-	Broadcast/Recording Studio
Lowest Threshold of Human Hearing	**-0-**	Lowest Threshold of Human Hearing

Source: California Department of Transportation Technical Noise Supplement, Oct. 1998, Page 18.

Using the decibel scale, sound levels from two or more sound sources cannot be arithmetically added together to determine the overall sound level. Rather, the combination of two sounds at the same level yields an increase of 3 dB. On average, a 3 dB change in the A-weighted sound level is generally considered a noticeable change in loudness, whereas a 5 dB increase is clearly noticeable. A 10 dB change is perceived by most people as a doubling or halving of the perceived loudness based on human sensitivity to sound in the mid-range frequencies.

Environmental noise is often expressed as a sound level occurring over a stated period of time, typically 1 hour. When the acoustic energy is averaged over the stated period of time, the resulting equivalent sound level represents the energy-based average sound level. This is called the equivalent level, or L_{eq}. Therefore, the L_{eq} represents a constant sound that, over the specified period, has the same acoustic energy as the time-varying sound. The noise level descriptor used by the Federal Highways Administration (FHWA) and the Texas Department of Transportation (TxDOT) is the L_{eq}.

ENVIRONMENTAL NOISE MONITORING

The purpose of this project is to assess environmental noise levels at residences near the floodgates on the Country Club Road Bridge in El Paso. HDR deployed noise monitoring instrumentation at two residences near the bridge from Tuesday, June 18, through Sunday, June 23, 2013. This method of noise monitoring was generally guided by national and international standards and good practice for noise monitoring projects.

Monitoring Setup

HDR selected monitoring locations by reviewing aerial photographs of the areas around the bridge and identifying residences where the ambient acoustical environment is representative of residential areas in close proximity to the floodgates. Measurement locations were also selected based on landowner coordination and resident feedback from the public information meeting with residents of the neighborhoods in the project area held on June 17, 2013. The noise monitoring data represent the ambient acoustic environment at residences in close proximity to Country Club Road Bridge.

HDR performed two different measurements in the study area. Instrumentation used to measure noise levels included equipment to measure and record continuous acoustical data and audio recordings. HDR used two sets of monitoring systems: one for the 24-hour monitoring activities and one handheld system for the short-term calibration measurements. All components of the acoustical instrumentation for long-term monitoring were Type 1/Class 1 precision or better. The Type 1/Class 1 level is generally described as precision-grade and is suitable for laboratory or field measurements.

For short-term (hour-long) calibration measurements, a sound level meter was used to determine the hourly L_{eq}. Additional data collected during the calibration measurements included vehicular counts, classifications, and speed. All components of the acoustical instrumentation for calibration measurements were Type 2/Class 2 precision or better. The Type 2/Class 2 level of precision is generally described as engineering-grade and is suitable for field measurements.

Measurement equipment was placed on residential properties in yards nearest to the floodgates. Equipment was contained in waterproof cases. Equipment was sited at least 20 feet from the residence. Microphones were mounted on masts at an approximate height of 5 feet, or ear level. **Figure 1** depicts the typical long-term monitoring location.

Figure 1. Typical Monitoring Equipment Setup

The instrumentation was configured to log several different noise measurements simultaneously gathered on a daily, hourly, and 1-second basis. One-second data over the span of 6 days are not presented but are available in HDR's project files for as-needed review. Additional data collected on site included continuous audio recordings, which were selectively reviewed as necessary. This memorandum summarizes several selected noise measurements from the daily and hourly interval periods. An explanation of the selected noise metrics and measurement results follows.

- ***L_{eq}* –** The equivalent continuous sound level in A-weighted decibels (dBA) over a measurement period. In any measurement interval, the instantaneous sound pressure level can vary. This is a level average, obtained by averaging the sound pressure.
- ***L_{min}*** – The lowest sound level occurring within a measurement interval in dBA.
- ***L_{max}* –** The highest sound level occurring within a measurement period in dBA.
- ***L_{10}*, *L_{50}*,** and ***L_{90}*** – Statistical noise descriptors that represent sound level exceeded during the stated percent of a measurement interval in dBA. The L_{50} is the sound level exceeded 50 percent of the time (the median sound level during the measurement interval). The L_{10}

is the level exceeded 10 percent of the time during the interval, and is often higher where intermittent sounds occur during the measurement interval. The L_{90} is the level exceeded 90 percent of the time during the interval, and is near the lowest noise level.

- ***L_{day}*** **–** The average equivalent sound level in dBA during daytime hours (15 hours between 7 a.m. and 10 p.m.).
- ***L_{night}*** **–** The average equivalent sound level in dBA during nighttime hours (9 hours between 10 p.m. and 7 a.m.).
- ***L_{dn}*** **–** The day-night average sound level in dBA, which is the average equivalent sound level where 10 decibels are added to nighttime hours (10 p.m. to 7 a.m.). This is intended to represent a heightened sensitivity to noise disturbance during sleep. The abbreviation "DNL" is also used to describe this noise metric.

The L_{min}, L_{max}, L_{10}, L_{50}, and L_{90} metrics were measured with the standardized exponential time averaging characteristic and A-weighting characteristic; therefore, they are identified by the instrumentation as L_{AFmin}, L_{AFmax}, L_{AF10}, L_{AF50}, and L_{AF90}, respectively. Similarly, average equivalent sound levels were measured with the standardized A-weighting characteristic and are identified by the instrumentation as L_{Aeq}.

Tables and graphs showing the hourly interval measurements results for each monitoring location are provided as a part of this memorandum.

Monitoring Location 1

Monitoring Location 1 (ML1) is northeast of Country Club Road Bridge at 5130 Willow Creek Road in El Paso. Noise measurement equipment was placed in the side yard of the residential property, approximately 20 feet from the residence and 10 feet from the property fence line.

Sound sources observed on site included local vehicular traffic traveling on Willow Creek Road, distant traffic noise from Country Club Road, and animals. The monitoring location had direct line of sight to the Country Club Road Bridge. **Table 2** shows the overall results during the entire measurement period for ML1.

Figure 2 shows ML1 hourly measurement results through the entire period, except for the first and last measurements, which were partial hours. The shaded area in the graphs represents the highest and lowest sound levels in each hour (the hourly L_{max} is represented at the top and the hourly L_{min} is at the bottom of the shaded area). The bars represent the hourly statistical measurements. The top of the bar is the L_{10}, the bottom of the bar is the L_{90}, and the diamond in the middle is the L_{50} or median sound level. The solid dots connected by a thick line are the hourly L_{eq}.

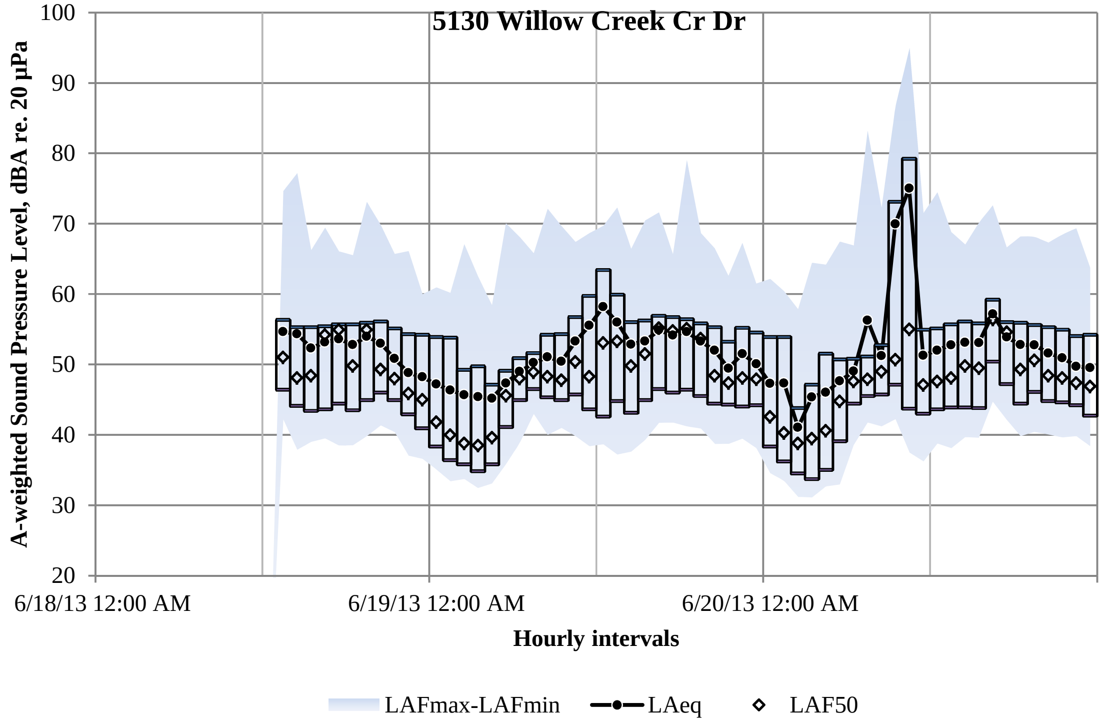
Table 2. Overall Measurement Period Results for ML1

Measure	Value (dBA)
L_{min}	30
L_{max}	95
L_{90}	40
L_{50}	47
L_{10}	55
L_{eq}	57
L_{day}	58
L_{night}	48
L_{dn}	58

Table 3 shows the same hourly results in rounded whole-decibel values. This table shows that for 80 percent of the measurement period at ML1, the measured level was between 40 dBA and 55 dBA, a range of 15 dBA (based upon the difference of the L_{90} and the L_{10}), and ML1 experienced a range of levels from 30 dBA to 95 dBA through the entire measurement period. However, upon examining the hourly data in **Figure 2** and **Table 3**, the sound levels exceeded 90 dBA during only one hour of the entire measurement period, and only a few other hours exceeded 80 dBA.

The hourly summaries (**Figure 2** and **Table 3**) show that noise levels followed an expected diurnal pattern where ambient noise levels were quieter overnight (generally 12 a.m. through 4 or 5 a.m.) and noisier during the day (generally 6 or 7 a.m. through 9 or 10 p.m.). The median ambient noise level (the L_{50}) generally decreased in the evening and then increased in the early morning. Median noise levels (the L_{50}) increased slightly during the morning and evening commuting hours. These are common daily patterns in urban and suburban noise environments.

At ML1 in particular, a nearby air conditioning unit affected the measured noise levels, sometimes with greater effect than at other times. Review of the 1-second data and audio data revealed the level of the air conditioner was 55 dBA. During the hot afternoon hours the air conditioner ran for half an hour or more. Therefore, the L_{50} (median sound level) would be elevated to this level, but it did not significantly affect the L_{10} because the air conditioner was off for more than 10 percent of the hour. In addition, there were a few hourly results where the statistical measurements are relatively stable, but the maximum and the equivalent-average sound levels jump much higher. This suggests that strong intermittent sounds that affected the L_{max} and the L_{eq} measurements occurred during these hours. However, these sounds generally did not occur frequently enough or for a long enough duration to affect the L_{10} significantly.



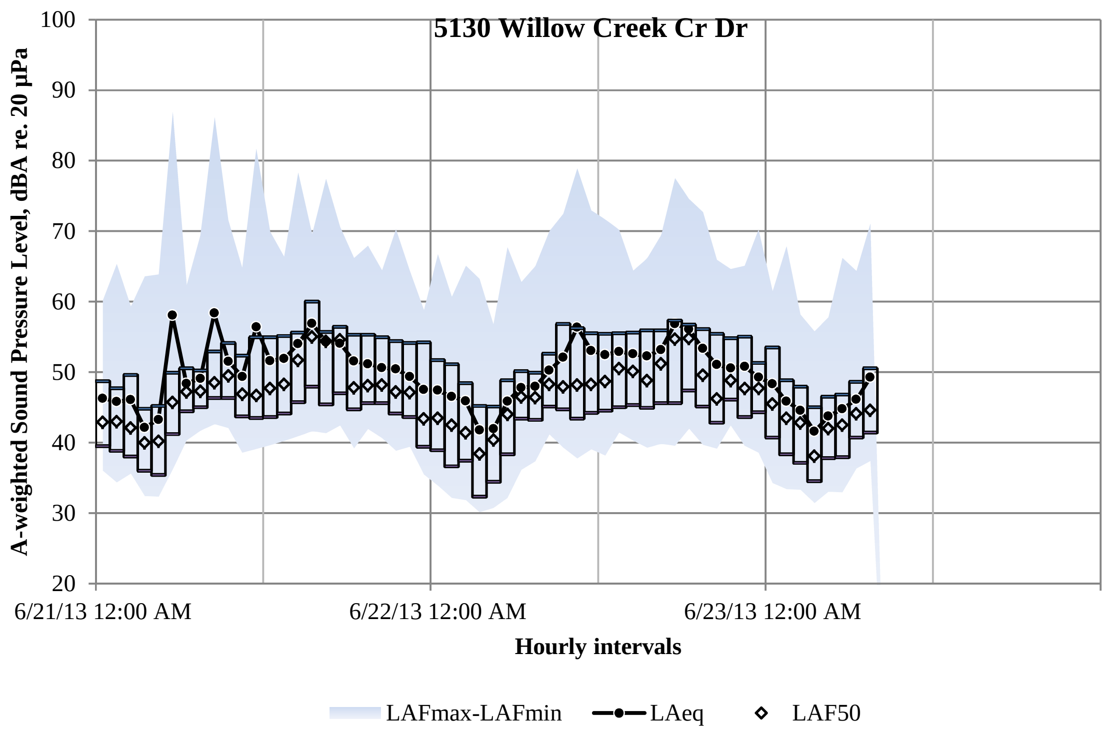


Figure 2. ML1 Hourly Results

Table 2. Hourly Results for ML1

Time	Sunday, June 23, 2013						Monday, June 24, 2013						Tuesday, June 25, 2013					
	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}
0:00							35	61	38	42	54	47	35	62	38	43	54	47
1:00							33	60	36	40	54	46	33	60	36	40	54	47
2:00							34	67	36	39	49	46	31	58	35	39	44	41
3:00							32	63	35	39	50	45	31	64	34	40	47	45
4:00							33	58	36	40	47	45	33	64	35	41	52	46
5:00							36	70	41	46	49	47	33	67	39	45	51	48
6:00							39	68	45	48	51	49	39	67	44	48	51	49
7:00							43	66	47	49	52	50	42	83	46	48	51	56
8:00							40	72	45	48	54	51	41	72	46	49	53	51
9:00							41	70	45	48	54	50	42	87	47	51	73	70
10:00							40	67	46	50	57	53	37	95	44	55	79	75
11:00							38	69	44	48	60	56	36	72	43	47	55	51
12:00							39	70	43	53	63	58	39	74	44	48	55	52
13:00	42	75	46	51	56	55	37	72	45	53	60	56	38	69	44	48	56	53
14:00	38	77	44	48	55	54	38	66	43	50	56	53	40	67	44	50	56	53
15:00	39	66	43	48	55	52	39	70	45	52	56	53	40	70	44	50	56	53
16:00	40	69	44	54	55	53	42	72	47	55	57	55	45	73	50	56	59	57
17:00	38	66	44	55	56	54	42	66	46	55	57	54	42	67	47	55	56	54
18:00	38	66	44	50	56	53	41	79	46	55	56	55	40	68	44	49	56	53
19:00	40	73	45	55	56	54	41	69	46	54	56	53	40	68	46	51	56	53
20:00	41	70	46	49	56	53	39	66	44	48	55	52	40	67	45	48	55	52
21:00	40	66	45	48	55	51	39	63	44	47	53	49	40	68	45	48	55	51
22:00	37	66	43	46	54	49	39	67	44	48	55	52	40	69	44	47	54	50
23:00	37	60	41	45	54	48	38	61	44	48	55	50	38	64	43	47	54	50
Daily	38	77	44	49	56	53	32	79	40	48	56	53	31	95	40	48	56	63
					L_{day}	53					L_{day}	54					L_{day}	65
					L_{night}	49					L_{night}	48					L_{night}	48
					L_{dn}	56					L_{dn}	56					L_{dn}	63

Table 3. Hourly Results for ML1 (continued)

Time	Wednesday, June 26, 2013						Thursday, June 27, 2013						Friday, June 28, 2013					
	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}
0:00	36	60	40	43	49	46	34	67	39	44	52	47	34	61	41	46	54	48
1:00	34	65	39	43	48	46	32	61	37	43	51	47	33	68	38	44	49	46
2:00	36	59	38	42	50	46	32	65	37	41	48	46	33	58	37	43	48	45
3:00	32	64	36	40	45	42	30	63	32	38	45	42	31	56	35	38	45	42
4:00	32	64	35	40	45	43	31	57	34	40	45	42	33	58	38	42	47	44
5:00	36	87	41	46	50	58	32	68	38	44	49	46	33	66	38	43	47	45
6:00	40	62	44	47	51	48	36	63	43	47	50	48	36	64	41	44	49	46
7:00	42	70	45	47	50	49	37	65	43	46	50	48	37	71	41	45	51	49
8:00	43	86	46	49	53	58	41	70	45	48	53	50	38	85	42	48	56	54
9:00	42	72	46	50	54	52	39	72	45	48	57	52						
10:00	39	65	44	47	52	49	38	79	43	48	56	56						
11:00	39	82	44	47	55	56	39	73	44	48	56	53						
12:00	40	70	44	48	55	52	38	72	45	49	55	52						
13:00	40	66	44	48	55	52	41	70	45	51	56	53						
14:00	41	78	46	52	56	54	40	64	45	50	56	53						
15:00	42	70	48	55	60	57	39	66	45	49	56	52						
16:00	41	77	45	54	56	54	40	69	46	51	56	53						
17:00	42	71	47	55	56	54	40	77	46	55	57	57						
18:00	39	66	45	48	55	52	42	75	47	55	57	56						
19:00	42	68	46	48	55	51	40	73	45	50	56	53						
20:00	41	64	46	48	55	51	39	66	43	46	55	51						
21:00	39	70	44	47	54	50	42	65	46	49	55	51						
22:00	39	64	44	47	54	49	40	65	44	48	55	51						
23:00	35	59	39	43	54	48	39	70	44	48	51	49						
Daily	32	87	41	47	55	53	30	79	41	47	55	52	31	85	38	44	50	46
					L_{day}	54					L_{day}	53					L_{day}	52
					L_{night}	50					L_{night}	47					L_{night}	45
					L_{dn}	58					L_{dn}	55					L_{dn}	54

In other words, during some hours there were some significant noise events, but the durations of these intermittent events occurred for less than 10 percent of the hour.

Figure 3 shows the measured frequency spectrum over the entire measurement period. Daily frequency spectrum measurements are shown in colors, behind the overall period frequency spectrum (black line), to show whether the frequency spectrum varied much from day to day.

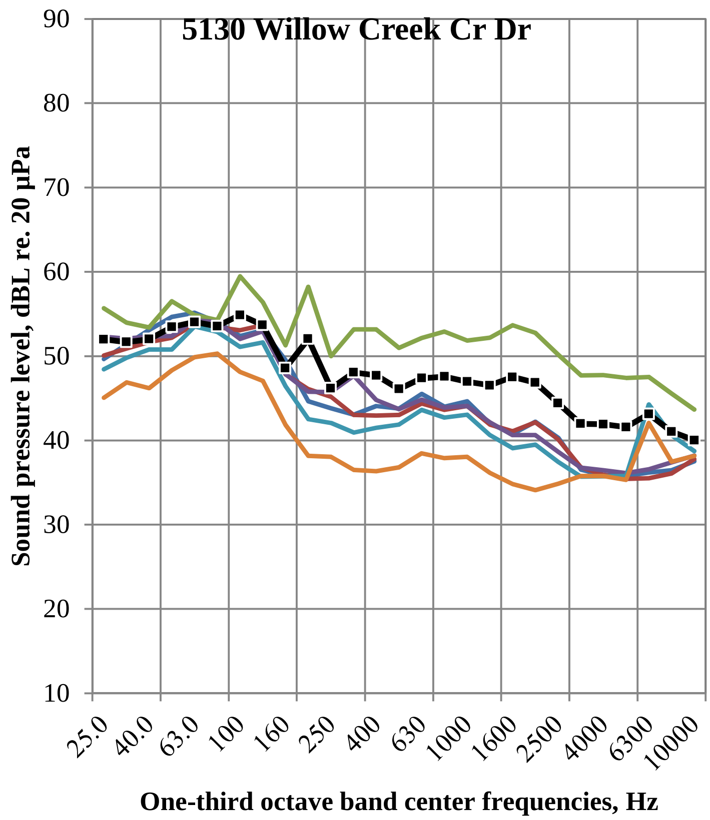


Figure 3. Overall Frequency Spectrum for ML1

One daily frequency spectrum measurement can influence the overall average, so most daily frequency spectra averages between 500 Hz and 5,000 Hz are 5 dB to 10 dB below the overall average frequency spectrum. The frequency spectra do not seem to be dominated by any one particular frequency band; therefore, source identification is not practical based solely on the frequency spectrum. Selective audio review did not reveal any particular dominant or unusual noise sources other than the air conditioner and local street traffic noise.

Monitoring Location 2

Monitoring Location 2 (ML2) is north of Country Club Road Bridge at 5125 Willow Creek Road in El Paso. The measurement equipment was placed in the backyard of the residential property, approximately 40 feet from the residential structure and 30 feet from the property's privacy wall.

Monitoring equipment was placed in the backyard to maintain direct line of sight to Country Club Road Bridge and out of the shadow zone of the privacy wall. Sound sources observed at ML2 included traffic noise from Country Club Road and local vehicular traffic traveling on Willow Creek Road.

Table 4 shows the overall results during the entire measurement period for ML2.

Table 4. Overall Measurement Period Results for ML2

Measure	Value (dBA)
L_{min}	29
L_{max}	80
L_{90}	40
L_{50}	51
L_{10}	55
L_{eq}	52
L_{day}	53
L_{night}	49
L_{dn}	56

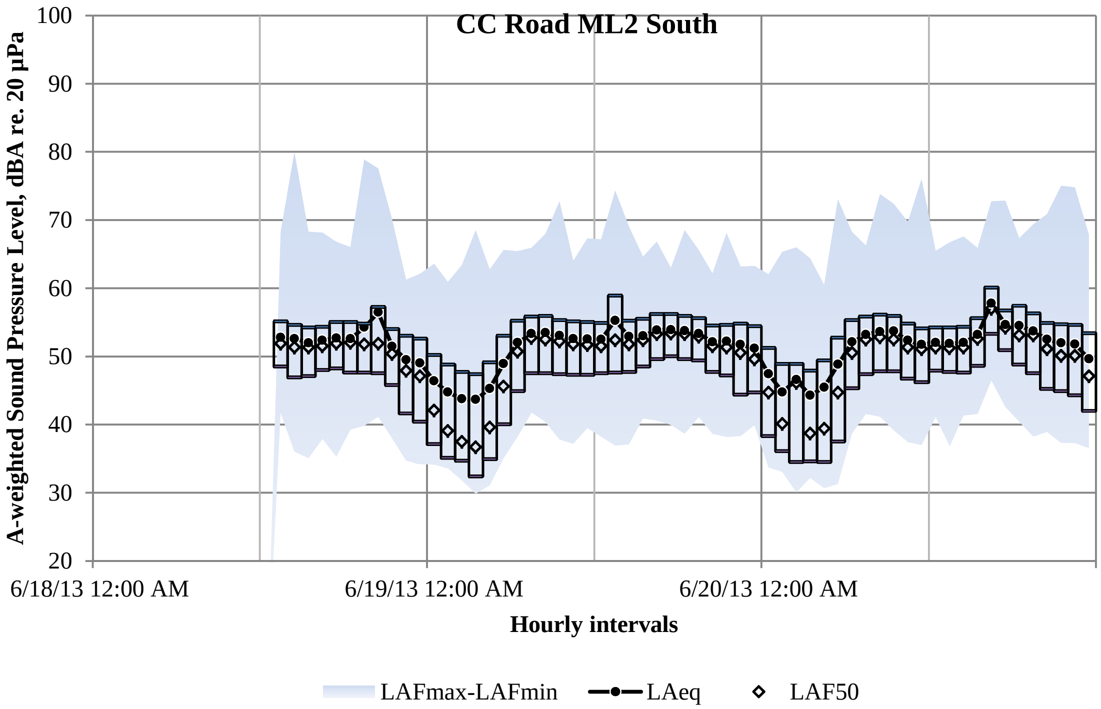
Table 4 shows that ML2 experienced a relatively narrow range of ambient noise levels. For 80 percent of the measurement period at ML2, the measured level was between 40 dBA and 55 dBA, a range of 15 dBA (based upon the difference of the L_{90} and the L_{10}), and ML2 experienced a range of levels from 29 dBA up to 80 dBA through the entire measurement period.

Figure 4 shows ML2 hourly measurement results through the entire period, except for the first and last measurements, which were partial hours. A description of the data presented in the graph was provided under ML1. **Table 5** shows the same hourly results in rounded whole-decibel values.

The hourly data in **Figure 4** and **Table 5** indicate that the sound levels at ML2 only reached a level of 80 dBA once.

Similar to ML1, the hourly summaries for ML2 (**Figure 4** and **Table 5**) show that noise levels followed an expected diurnal pattern where ambient noise levels were quieter overnight and noisier during the day, and median noise levels increased slightly during the morning and evening commuting hours. These are common daily patterns in urban and suburban noise environments.

At ML2, there was also an air conditioner that generated a noise level of approximately 45 dBA based upon 1-second and audio data review. This did not affect ambient noise levels to the extent that the air conditioner at ML1 did.



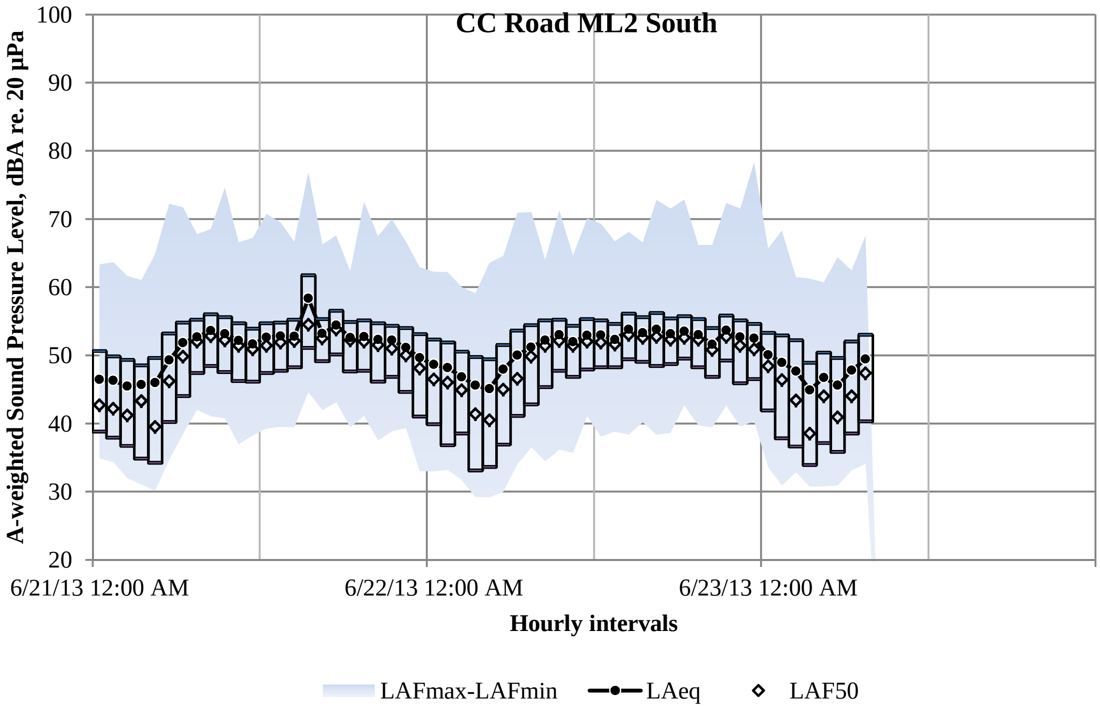


Figure 4. ML2 Hourly Results

Table 5. Hourly Results for ML2

Time	Sunday, June 23, 2013						Monday, June 24, 2013						Tuesday, June 25, 2013					
	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}
0:00							34	64	37	42	50	46	34	62	38	45	51	47
1:00							34	61	35	39	49	45	33	65	36	40	49	45
2:00							32	63	35	38	48	44	30	66	35	46	49	47
3:00							30	69	32	37	47	44	32	64	35	39	48	44
4:00							31	63	35	40	49	45	31	61	35	39	49	45
5:00							35	66	40	46	53	49	31	73	38	45	53	49
6:00							38	65	45	51	55	52	39	68	45	51	55	52
7:00							42	66	48	53	56	53	42	66	47	53	56	53
8:00							40	68	48	53	56	53	41	74	48	53	56	54
9:00							38	73	47	52	55	53	39	72	48	53	56	54
10:00							37	64	47	52	55	53	37	70	47	51	55	52
11:00							39	67	47	52	55	53	37	76	46	51	54	52
12:00							38	67	48	52	55	52	41	66	48	51	54	52
13:00	42	68	49	52	55	53	37	74	48	52	59	55	37	67	48	51	54	52
14:00	36	80	47	51	55	53	37	69	48	52	55	53	41	68	48	51	54	52
15:00	35	68	47	51	54	52	41	65	49	52	56	53	42	66	49	53	56	53
16:00	38	68	48	52	54	52	41	67	50	53	56	54	46	73	53	57	60	58
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18:00	39	66	48	52	55	53	39	69	50	53	56	54	40	67	49	53	57	54
19:00	40	79	48	52	55	54	41	66	49	53	56	53	38	69	48	53	56	54
20:00	41	78	48	52	57	56	39	62	48	52	55	52	39	71	45	51	55	53
21:00	38	70	46	50	54	51	38	68	47	51	55	52	37	75	45	50	55	52
22:00	35	61	42	48	53	50	38	63	44	51	55	52	37	75	44	50	55	52
23:00	34	62	40	47	53	49	40	63	45	50	54	51	37	68	42	47	53	50
Daily	35	80	45	51	55	53	30	74	39	51	55	52	30	76	40	51	56	52
					L_{day}	53					L_{day}	53					L_{day}	54
					L_{night}	49					L_{night}	49					L_{night}	49
					L_{dn}	57					L_{dn}	56					L_{dn}	56

Table 5. Hourly Results for ML2 (continued)

Time	Wednesday, June 26, 2013						Thursday, June 27, 2013						Friday, June 28, 2013					
	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}	L_{Fmin}	L_{Fmax}	L_{F90}	L_{F50}	L_{F10}	L_{eq}
0:00	35	63	39	43	51	46	33	62	40	47	52	49	34	66	42	48	53	50
1:00	34	64	38	42	50	46	33	62	37	46	52	48	31	68	38	46	53	49
2:00	32	62	37	41	49	45	32	60	39	45	51	47	33	61	37	43	52	48
3:00	31	61	35	43	49	46	29	59	33	41	50	46	31	61	34	39	49	45
4:00	30	65	34	40	50	46	29	64	34	41	49	45	31	61	37	44	50	47
5:00	35	72	40	46	53	49	30	65	37	45	52	48	31	64	36	41	50	46
6:00	38	72	44	50	55	52	34	71	41	47	54	50	33	62	39	44	52	48
7:00	42	68	47	52	55	53	37	71	43	50	54	51	34	68	40	47	53	49
8:00	41	69	48	53	56	54	34	64	45	51	55	52	33	73	41	48	53	50
9:00	41	75	48	52	56	53	36	71	48	52	55	53						
10:00	37	67	46	51	55	52	36	65	47	51	54	52						
11:00	38	67	46	51	54	52	41	70	48	52	55	53						
12:00	39	71	47	51	55	53	38	69	48	52	55	53						
13:00	40	70	48	52	55	53	39	67	48	52	55	52						
14:00	39	67	48	52	55	53	38	68	49	53	56	54						
15:00	45	77	51	55	62	58	40	67	49	53	56	53						
16:00	42	66	49	53	55	53	38	73	48	53	56	54						
17:00	43	68	50	54	57	54	39	72	49	52	55	53						
18:00	39	62	48	52	55	53	43	73	50	53	56	54						
19:00	41	73	48	52	55	53	40	66	48	52	55	53						
20:00	38	67	46	52	55	52	39	66	47	51	54	52						
21:00	39	70	47	51	54	52	43	72	49	53	56	54						
22:00	39	67	45	50	54	51	40	72	46	51	55	53						
23:00	33	63	41	48	53	50	40	78	47	51	55	52						
Daily	30	77	41	51	55	52	29	73	42	51	55	52	31	73	37	45	52	48
					L_{day}	54					L_{day}	53					L_{day}	50
					L_{night}	49					L_{night}	49					L_{night}	48
					L_{dn}	56					L_{dn}	56					L_{dn}	54

Figure 5 shows the measured frequency spectrum over the entire measurement period. Daily frequency spectrum measurements are shown in colors, behind the overall period frequency spectrum (black line), to show whether the frequency spectrum varied much from day to day.

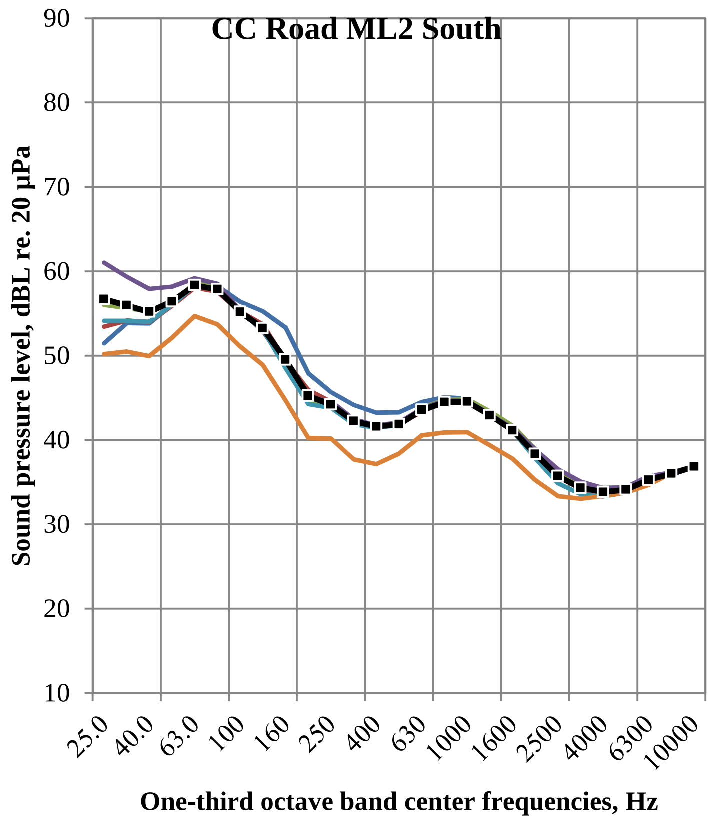

Figure 5. Overall Frequency Spectrum for ML2

Based upon selective audio review and the experienced judgment of HDR's noise analysts, the mid-frequency hump around 1,000 Hz could be attributable to vehicle noise on the roadway. The low-frequency hump centered at 63 Hz might be attributable to a combination of wind-microphone interference and the sound of vehicle tires running over the floodgate panels.

BASELINE NOISE MODELING

The purpose of the baseline noise modeling and monitoring is to assess traffic-related noise levels at residences near the floodgates. Modeled noise levels represent noise conditions without the influence of floodgates, or noise conditions before flood control measures were installed. The measured environmental noise levels presented in the previous section represent sound levels that include the influence of floodgates. The difference between measured noise levels and modeled sound levels is assumed to be attributed to vehicles traveling over the floodgates.

HDR modeled noise from vehicular traffic using the FHWA Traffic Noise Model (TNM 2.5). The TNM was developed based on vehicular traffic counts, classifications, and speeds measured on site. Attended measurements near the roadway were conducted 50 feet from the Country Club Road Bridge. **Table 6** summarizes the vehicular counts and classifications used in the TNM model as observed onsite. All traffic was modeled at a speed of approximately 39 miles per hour (mph), based on the average travel speed measured over the observation period.

Table 6. Observed Traffic Volume

Direction of Travel	Vehicle Classification				
	Automobiles	Medium Trucks	Heavy Trucks	Motorcycles	Buses
Eastbound	659	26	5	0	1
Westbound	590	17	4	1	1

The scenario developed for the Project accounts for site-specific terrain features and sound barriers such as privacy walls between the roadway and homes. The TNM developed for this project does not account for noise caused by vehicles passing over the floodgate and is therefore representative of noise conditions without flood control measures. Noise measurements were made concurrently with traffic counts at a distance of 50 feet and at the nearest residence. Measured noise levels, which include the influence of vehicles traveling over floodgates, were then compared against the model results to determine the increase in traffic noise due to traffic on the floodgates.

Evaluation Criteria

The flood control measures installed on Country Club Road Bridge are not subject to state or local noise regulation. Traffic noise impact thresholds established by the FHWA and TxDOT do not apply to the bridges in this study because this is not a TxDOT-sponsored project. In lieu of applicable noise regulations, the FHWA and TxDOT noise abatement criteria were used as evaluation criteria to assess traffic-related noise at the nearest residential land uses.

FHWA and TxDOT define a traffic noise impact as occurring when the predicted traffic noise level approaches, equals or exceeds the FHWA Noise Abatement Criteria (NAC). The NAC is 67 dBA (L_{eq}) for residential land uses. FHWA and TxDOT also use the following definitions for determining when traffic noise impacts occur.

- Noise Levels Approach the NAC: 1 dBA below the FHWA Noise Abatement Criteria (i.e., 66 dBA L_{eq}).
- Substantial noise increase: when the predicted noise level exceeds the existing level by more than 10 dBA.

Model Validation Measurements

On June 18, 2013, HDR staff measured noise levels at representative sites near Country Club Road Bridge. Traffic noise measurements were conducted in accordance with the FHWA-PD-96-046 Measurement of Highway Related Noise (May 1996). Existing traffic noise levels were measured in the field at a distance of 50 feet and at the nearest residence.

Instrumentation. Noise monitoring was conducted using a Larson Davis 831 Sound Level Meter (SLM). The SLM and microphone were set at a height of approximately 5 feet for all measurements. The microphone was covered with a windscreen. Refer to the *Monitoring Setup* section for details on the instruments used to collect the monitoring data for this noise analysis report.

Field Measurement Methods. The SLM was programmed to compute the L_{eq}, spectral noise levels, and capture audio recordings during the measurement period. The following procedures were used for noise monitoring:

- The duration of the L_{eq} measurements was 1 hour.
- The SLM was calibrated before and after monitoring. No significant calibration drifts were detected during the study.
- The microphone was approximately 5 feet above the ground.
- The microphone was covered with a windscreen.
- Traffic was counted manually, classified by vehicle type, and used as input in the FHWA Traffic Noise Model.
- Vehicle speeds were determined in the field using a radar gun.

RESULTS

The results of the Country Club Bridge baseline noise modeling analysis are presented in **Table 7**. The predicted (modeled) noise levels reflect the existing field conditions, noise barriers, elevation differences, and the roadway alignment in relation to the noise-sensitive sites.

Table 7. Noise Modeling Results

Measurement Location	L_{Aeq1h}, dBA		
	Measured	Predicted	Difference
1	63.0	63.5	+0.5
2	52.6	52.8	+0.2

As shown in **Table 7**, the measured and modeled noise levels for each of the monitoring locations are within an acceptable ±0.5 dBA tolerance. Generally, a ±3 dBA tolerance is allowed in model validation. The similarities between the measured and modeled traffic noise levels indicates that hourly A-weighted average sound levels, with the influence of floodgates, are comparable to the national average traffic noise level for a roadway of similar speed and traffic.

For informational purposes, measured and modeled noise levels at the nearest residence were also compared with FHWA and TxDOT NAC. An outdoor noise level of 66 dBA L_{eq} is considered to be approaching the NAC for residential land uses. As shown in **Table 7**, the modeled noise levels at the nearest residential land use is more than 13 dB below the NAC; therefore, traffic-related noise levels at the nearest residence, ML2, are not predicted to approach or exceed the FHWA NAC.

Spectral Analysis Results

In addition to evaluating noise levels on an overall A-weighted basis, traffic noise levels were also examined on a spectral basis. The FHWA published a database of spectral traffic noise measurements, called Reference Energy Mean Emission Levels (REMELS). Traffic noise levels measured in the project area were compared to the "typical" traffic noise spectrum for the vehicle speed and mix measured on site as calculated using the FHWA REMELS. **Figure 6** depicts a comparison of traffic noise levels measured at 50 feet and the calculated typical traffic noise spectrum. Spectral noise levels are shown by 1/3 octave band.

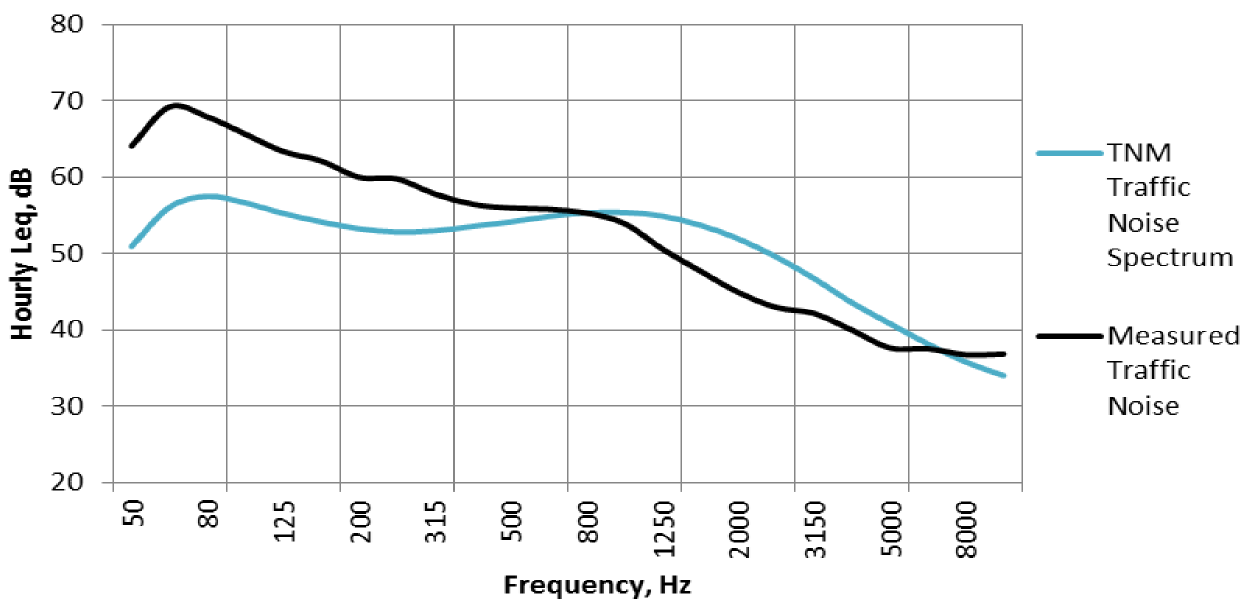

Figure 6. Spectral Noise Analysis

It should be noted that measured and calculated traffic noise levels as shown in **Figure 6** represent noise levels at a distance of 50 feet from the roadway edge. A summary of measured noise levels at the nearest residences were presented in the *Environmental Noise Monitoring* section. As shown in **Figure 6**, measured traffic noise levels, at a distance of 50 feet, exceeded calculated traffic noise spectra in the lower frequencies but were lower than typical traffic noise levels in the middle and high frequencies. Measured traffic noise levels exceed typical (modeled) traffic noise levels by as much as 14 dB in lower frequency bands. This indicates that noise from traffic driving over the floodgates has greater low-frequency noise than typical (modeled) vehicular traffic as evidenced by the sound made when vehicles drive over the floodgates. The 7 to 14 dB increase in the lower frequencies of the measured traffic noise, particularly in the 63 to 250 Hz range, would be perceived as more than a doubling of loudness due to human sensitivity to changes in lower frequencies. This increase in lower frequencies is likely to be perceived by residents as a change in the character of the noise environment. In the A-weighted scale, low-frequency sounds are not as heavily counted; therefore, it is likely that this increase in low-frequency sound level does not significantly increase A-weighted sound pressure levels in the study area.

Typical (modeled) traffic noise levels exceeded measured traffic noise levels by as much as 6 dB in the mid- to high-frequency bands. This indicates that noise levels with the influence of the floodgates, has quieter mid- and high-frequency noise than typical vehicular traffic. This is likely due to a decrease in tire-pavement noise (i.e., the pavement surface on the bridge is quieter than the national average pavement surface contained in the TNM). The overall character of traffic noise using the bridge is not dramatically louder than typical traffic noise, but it has a low-frequency character that is different from typical traffic noise. While the total A-weighted average sound levels, with the influence of floodgates, are comparable to national average traffic noise levels, residences near the floodgates are likely to experience an audible change in the noise environment due to the increase in low-frequency noise.

CONCLUSIONS AND RECCOMENDATIONS

Baseline noise modeling results demonstrate that measured A-weighted noise levels and TNM-predicted noise levels are within an acceptable ±0.5 dBA tolerance. Therefore, overall A-weighted average noise levels as measured at Country Club Road Bridge, with the influence of floodgates, are comparable to the national average traffic noise level for a roadway of similar speed and traffic. In addition, baseline noise modeling and monitoring show that noise levels following installation of floodgates on Country Club Bridge are not predicted to approach or exceed the FHWA NAC.

While overall A-weighted noise levels in the study area were in agreement with the FHWA traffic noise model, an analysis of the noise spectrum revealed a difference in the spectral distribution of traffic noise in the study area. Noise from traffic driving over the bridges in this study area exhibited an increase in low-frequency noise and decrease in mid- and high-frequency noise in comparison to the national average. The shift in the spectral distribution of noise levels supports the TNM results and onsite observation. Elevated sound levels in lower frequencies supports the onsite observation that vehicles traveling over the floodgate created a discrete noise event which is distinctly audible through background traffic noise. The sound is distinctly audible due to its short duration and distinct sound spectra.

The A-weighting scale weighs mid-range frequencies greater than low-frequency sounds, which corresponds with human sensitivity to noise at moderate sound pressure levels. Due to the nature of A-weighting, it is likely that this increase in low-frequency sound level measured in the vicinity of the floodgates does not significantly increase A-weighted sound levels in the study area despite being distinctly audible. The increase in low-frequency noise level is also offset by a decrease in mid- and high-frequency noise that might have resulted in strong similarities between calculated and measured noise levels.

Potential noise mitigation measures to decrease noise from vehicles traveling over floodgate structures are fairly limited as the floodgate manufacturer does not offer noise reduction attachments or sound dampening material. Source-based noise mitigation options include the replacement or removal of the floodgates. Removal of the floodgates would eliminate the new noise source. Alternative flood control options which would not impact the roadway surface and therefore reduce traffic related noise levels include floodgates with rolling gates or sectional stop logs.

Additional potential noise mitigation measures include the construction of a noise wall and receiver based modifications. The construction of a noise wall is limited by topography, noise wall continuity, and nature of the noise source. In order for noise walls to be effective, they should be continuous and break the line of sight between the residence and roadway. Due to driveways and access roads, it may be difficult to build a continuous noise wall in this location. Onsite measurement also exhibited an increase in low frequency noise versus mid-range and high frequencies. Noise walls are generally more effective and reducing noise levels from higher frequency sounds and would not prevent low frequency ground-borne vibration.

During the public meeting through correspondence with USIBWC, it has been noted that residences in the vicinity of the floodgates have noticed low-frequency noise or vibration within residences. All noise measurements performed by HDR in the floodgate post-construction noise study occurred outside of residences in areas of frequent outdoor use and are representative of outdoor sound levels. It is possible that ground-borne vibration caused by vehicles traveling over the floodgate, or low-frequency noise entering residences, is interacting with building structures to cause audible noise or vibration. Future studies might include an examination of interior noise and vibration levels.