

**US 36 Managed Lane Project:
Federal Boulevard To Interlocken Loop With A
Potential Extension To McCaslin Boulevard**

***Attachment F:
Noise Technical Report***

January 25, 2012

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INTRODUCTION

The purpose of this report is to document the noise barrier analysis conducted for the Madison Hills Townhomes and Tuscany Trails subdivision portions of the US 36 Managed Lanes Project. This current analysis only focuses on the noise barriers for the residences in the Madison Hills Townhomes and Tuscany Trails subdivision as a result of design changes since the ROD. There were no significant changes in traffic or the design which would warrant further analysis of noise barriers recommended in the ROD. For these reasons, this re-evaluation focused on recent changes made to the design. The analysis was conducted to determine the length and height of the proposed noise barrier based on the preliminary design developed for the Design-Build Request for Proposals (RFP). The goal is to optimize the noise barrier and determine feasible and reasonable mitigation based on the Colorado Department of Transportation (CDOT) 2002 Noise Analysis and Abatement Guidelines.

A Noise Technical Report was prepared by Hankard Environmental in October 2009 to support Phase I of the Record of Decision (ROD) for the US 36 Final Environmental Impact Statement (FEIS). The report recommended several noise barriers throughout the project corridor.

The ROD recommended a noise barrier approximately 2,400 feet in length and 15 feet tall to mitigate for noise impacts to these residences. The average noise decibel reduction was 9 dBA, and the cost per decibel per benefited receiver was \$1,200.

This technical memorandum summarizes the noise barrier results for the 2035 Preferred Alternative and 2015 interim improvements.

PROJECT LOCATION AND DESCRIPTION

The US 36 Managed Lane Project is a multimodal, toll-integrated project that will include reconstruction of the US 36 mainline pavement from Federal Boulevard to Interlocken Loop. The Project will also include widening to accommodate a new buffer-separated Managed Lane in each direction of travel along US 36, replacement of the Wadsworth Parkway, Wadsworth Boulevard, Lowell Boulevard bridges, construction of retaining walls and sound walls, installation of Intelligent Transportation Systems, and construction of portions of a commuter bikeway.

The typical section for the Managed Lane Project interim improvements consists of two general purpose lanes, one Managed Lane to the inside, and shoulders.

Noise Standards

The Federal Highway Administration's (FHWA) Noise Abatement Criteria (NAC) has defined noise levels for land activity categories. CDOT has adopted these NAC and defines noise levels that, if approached or exceeded, require noise abatement consideration (see **Table 1** for various land use categories). FHWA guidelines also state that noise abatement should be considered when the noise levels substantially exceed the existing noise levels (23 CFR 772.5(g)). This criterion is defined by CDOT as increases in the Leq of 10.0 dBA or more above existing noise levels.

Table 1: Noise Abatement Criteria, Hourly A-Weighted Sound Level Decibels (dBA)

Activity Category	Leq(h)	Description of Activity Category
A	56 (exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	66 (exterior)	Picnic area, recreational areas, playgrounds, active sport areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C	71 (exterior)	Developed lands, properties, or activities not included in Categories A or B above.
D	None	Undeveloped lands.
E	51 (interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

Source: Colorado Department of Transportation, Noise Analysis and Abatement Guidelines, December 2002.

Methodology

The noise analysis was conducted in accordance with the CDOT’s Noise Analysis and Abatement Guidelines (December 2002), which is consistent with FHWA’s 23 Code of Federal Regulations 772. The 2002 Noise Analysis and Abatement Guidelines were used to be consistent with those used for the 2009 FEIS and ROD.

The Traffic Noise Model 2.5 (TNM 2.5) was used to assess noise abatement for the impacted residences.

The Managed Lane Project roadway model was developed based on the design plans of two general purpose lanes and one managed lane in each direction of travel. A noise barrier for Managed Lane Project was modeled in two different locations for Madison Hills Townhomes: along the right-of-way line and along the bike path berm. The bike path is proposed in the area between the residences at Madison Hills Townhomes and US 36. The bike path will be built up on a berm to tie into 92nd Avenue. The berm ranges in heights up to 25 feet. This berm was included. A noise barrier was also modeled along the proposed roadway shoulder (Preferred Alternative location) for the Tuscany Trail residences. There are existing eight-foot-tall concrete walls surrounding the residences of Tuscany Trails subdivision which were included in the models, as well as building rows and terrain. **Figure 1 (Appendix B)** depicts the proposed noise barriers and existing walls.

The 2035 Preferred Alternative model was based on Hankards model, which is generally consistent with the preliminary design plans of three general purpose lanes and one Managed Lane in each direction of travel. The proposed noise barrier for the 2035 Preferred Alternative (same barrier described in the noise technical report prepared for Phase I of the ROD) was modeled along the proposed roadway and ramp shoulders adjacent to the residences at Madison Hills Townhomes and Tuscany Trail subdivisions. The existing eight-foot tall concrete walls were included in the 2035 Preferred Alternative model. Additional features, such as building rows and terrain, were also included. **Figure 2 (Appendix B)** depicts the proposed noise barrier and existing walls.

All x, y, and z coordinates for all TNM data inputs (roadways, noise barriers, receivers, building rows, and terrain) were input into both TNMs (see **Appendix A**). Only first-floor receivers were included in this analysis since there are no balconies (frequent outdoor use) on the second floor.

The noise barriers were optimized to provide at least a 5 dBA or more noise reduction for at least one receiver and a 3 dBA noise reduction for additional receivers.

Traffic Data

Traffic volumes for this analysis were taken from the Traffic Engineering Technical Report, prepared by URS in October 2009 for the ROD. However, if the peak hour volumes summarized in this report exceeded CDOT’s suggested maximum traffic volumes for worst noise hour (summarized in the 2011 noise policy), then the suggested volumes were used. The suggested volumes were used for the segment from 92nd Avenue to Federal Boulevard. The 2035 PM peak hour volumes and suggested volumes were used for both TNMs (see **Table 2**).

Traffic distribution is 97 percent vehicles, 2 percent medium trucks, and 1 percent heavy trucks, which was used for the October 2009 noise analysis and is consistent with CDOT’s traffic data.

The future posted speed limit will be 65 miles per hour (mph) for US 36 and 35 mph for 92nd Avenue and the associated ramps. The future posted speed limits were input into the TNMs.

Table 2: US 36 Traffic Report, 2035 PM Peak Hour Traffic Volumes

Roadway Segment	Vehicle	Westbound	Eastbound	Speed
104 th Avenue to 92 nd Avenue GP	Automobiles	5,112	5,306	65 mph
	Medium trucks	105	109	
	Heavy trucks	53	55	
104 th Avenue to 92 nd Avenue ML	Automobiles	504	611	65 mph
	Medium trucks	10	13	
	Heavy trucks	5	6	
92 nd Avenue to Federal Boulevard GP	Automobiles	5,733	6,286 (5,820)	65 mph
	Medium trucks	118	130 (120)	
	Heavy trucks	59	65 (60)	
92 nd Avenue to Federal Boulevard ML	Automobiles	611	660	65 mph
	Medium trucks	13	14	
	Heavy trucks	6	7	
Ramps		Westbound	Eastbound	Speed
WB 92 nd Avenue on-ramp	Automobiles	825	n/a	35 mph
	Medium trucks	17	n/a	
	Heavy trucks	9	n/a	
EB 92 nd Avenue off-ramp	Automobiles	n/a	1,474	35 mph
	Medium trucks	n/a	30	
	Heavy trucks	n/a	15	
WB 92 nd Avenue off-ramp	Automobiles	1,436	n/a	35 mph
	Medium trucks	30	n/a	
	Heavy trucks	15	n/a	
EB 92 nd Avenue on-ramp	Automobiles	n/a	1,746	35 mph
	Medium trucks	n/a	36	
	Heavy trucks	n/a	18	
Roadway Segment		Westbound	Eastbound	Speed
92 nd Avenue	Automobiles	2,008	1,833	35 mph
	Medium trucks	41	38	
	Heavy trucks	21	19	

GP = general purpose

ML = managed lanes

Numbers in parentheses = traffic volumes from CDOT’s 2011 noise policy

Noise Analysis for Managed Lane Project

Madison Hills Townhomes

There are 62 impacted residences in the Madison Hills Townhomes as a result of the Managed Lane Project roadway improvements. Therefore, noise barriers were considered for these impacted residences.

A noise barrier (Barrier 1) was modeled along the right-of-way line that ranges in height from 10 feet to 16 feet (see **Appendix B, Figure 1**). The proposed bike path berm, which ranges in heights up to 25 feet, was included in the model. The results in **Table 3** demonstrate the noise reduction provided by the berm. **Table 3** summarizes the noise mitigation analysis for the representative receivers. Each receiver represents multiple units in each building. **Table 4** summarizes the noise barrier analysis.

Table 3: Noise Mitigation Analysis for Madison Hills Townhomes along the Right-of-Way

Receiver Number	# of Units per Building	Interim (2015) Build (dBA)	Interim with 10-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Interim with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Interim with Optimized Mitigation (10 – 16 feet) (dBA)	Noise Reduction (dBA)
Receiver1	6	65.3	63.8	-1.5	62.1	-3.2	62.3	-3.0
Receiver2	6	66.8	65.0	-1.8	62.8	-4.0	63.2	-3.6
Receiver3	6	68.5	66.0	-2.5	63.1	-5.4	63.9	-4.6
Receiver4	6	69.8	66.6	-3.2	63.4	-6.4	64.5	-5.3
Receiver5	4	71.4	67.4	-4.0	63.7	-7.7	64.9	-6.5
Receiver6	6	70.7	68.3	-2.4	64.4	-6.3	66.0	-4.7
Receiver7	6	71.2	68.5	-2.7	64.7	-6.5	66.5	-4.7
Receiver8	6	76.4	67.6	-8.8	63.2	-13.2	66.2	-10.2
Receiver9	4	74.7	68.8	-5.9	65.7	-9.0	68.5	-6.2
Receiver10	6	74.1	67.3	-6.8	64.5	-9.6	66.9	-7.2
Receiver11	4	70.7	65.5	-5.2	63.1	-7.6	65.4	-5.3
Receiver12	6	71.9	65.0	-6.9	63.4	-8.5	65.0	-6.9
Receiver13	2	66.0	66.0	0.0	65.6	-0.4	65.8	-0.2
Receiver14	6	65.0	64.9	-0.1	64.5	-0.5	64.7	-0.3
Receiver15	6	63.4	63.7	0.3	63.6	0.2	63.4	0.0
Receiver16	6	62.0	63.2	1.2	61.7	-0.3	62.8	0.8
Receiver17	6	62.8	63.3	0.5	61.9	-0.9	63.3	0.5
Receiver18	6	64.9	63.5	-1.4	62.1	-2.8	63.1	-1.8
Receiver19	6	65.0	63.4	-1.6	60.8	-4.2	62.3	-2.7
Receiver20	6	64.4	62.7	-1.7	60.7	-3.7	62.4	-2.0
Receiver21	4	62.0	61.2	-0.8	60.0	-2.0	61.2	-0.8
Receiver22	6	64.0	61.9	-2.1	61.4	-2.6	61.9	-2.1
Receiver23	4	59.4	58.5	-0.9	57.7	-1.7	58.6	-0.8
Receiver24	6	60.5	58.9	-1.6	57.5	-3.0	58.7	-1.8

Note: Noise levels were left in decibel form to show exact noise reduction. Noise levels include the noise reduction provided by the proposed berm. The numbers in bold represent an impact and a benefitted noise reduction.

Table 4: Summary of Reasonableness: Madison Hill Townhomes along US 36 Right-of-Way

Barrier	Total Length of Barrier (feet)	Height of Barrier (Feet)	Total Cost of Barrier*	Total Decibel Reduction (dBA)	# of Benefited Receivers	Cost/ Receiver/ dBA
1	1,360	10	\$408,000	-238.4	34	\$1,711
1	1,360	15	612,000	-563.2	78	\$1,087
1	1,360	10 – 16	\$496,320	-392.6	62	\$1,264

*The cost of materials is based on \$30 per square foot.

As shown in **Table 3**, the proposed noise barriers that range in height from 10 to 16 feet would meet the feasible criteria of 5 dBA or more for at least one receiver and 3 dBA for additional receivers. In addition, the cost per benefited receiver per decibel meets the cost reasonableness criteria (see **Table 4**). Therefore, noise abatement along the right-of-way line would be feasible and reasonable for the residences at Madison Hills Townhomes for interim conditions in several mitigation scenarios.

A noise barrier (Barrier 2) was also modeled along the right-of-way line between receptors 7 and 12 (on Figure 1) and the proposed bike path berm south of receptor 7 that ranges in heights from 10 feet to 15 feet (see Appendix B, Figure 1). **Table 5** summarizes the noise mitigation analysis. **Table 6** summarizes the noise barrier analysis.

Table 5: Noise Mitigation Analysis for Madison Hills Townhomes along the Bike Path Berm

Receiver Number	# of Units	Interim (2015) Build (dBA)	Interim with 10-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Interim with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)
Receiver1	4	65.3	62.8	-2.5	62.1	-3.2
Receiver2	6	66.8	63.1	-3.7	62.2	-4.6
Receiver3	6	68.5	63.2	-5.3	61.7	-6.8
Receiver4	4	69.8	63.5	-6.3	61.6	-8.2
Receiver5	6	71.4	64.2	-7.2	61.9	-9.5
Receiver6	6	70.7	64.6	-6.1	61.7	-9.0
Receiver7	6	71.2	65.6	-5.6	62.3	-8.9
Receiver8	6	76.4	65.7	-10.7	62.0	-14.4
Receiver9	6	74.7	67.4	-7.3	63.8	-10.9
Receiver10	6	74.1	66.2	-7.9	63.1	-11.0
Receiver11	6	70.7	64.5	-6.2	61.6	-9.1
Receiver12	6	71.9	65.0	-6.9	61.5	-10.4
Receiver13	6	66.0	65.4	-0.6	65.2	-0.8
Receiver14	6	65.0	64.2	-0.8	64.0	-1.0
Receiver15	2	63.4	61.9	-1.5	61.3	-2.1
Receiver16	4	62.0	60.4	-1.6	59.0	-3.0
Receiver17	4	62.8	60.8	-2.0	58.9	-3.9
Receiver18	6	64.9	60.8	-4.1	58.8	-6.1
Receiver19	6	65.0	60.8	-4.2	58.7	-6.3

Table 5: Noise Mitigation Analysis for Madison Hills Townhomes along the Bike Path Berm

Receiver Number	# of Units	Interim (2015) Build (dBA)	Interim with 10-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Interim with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)
Receiver20	4	64.4	60.5	-3.9	58.3	-6.1
Receiver21	6	62.0	59.8	-2.2	57.8	-4.2
Receiver22	6	64.0	61.4	-2.6	58.3	-5.7
Receiver23	6	59.4	57.0	-2.4	55.7	-3.7
Receiver24	6	60.5	57.4	-3.1	55.6	-4.9

Note: Noise levels were left in decibel form to show exact noise reduction. The numbers in bold represent an impact and a benefitted noise reduction.

Table 6: Summary of Reasonableness: Madison Hills Townhomes along the Bike Path Berm

Barrier	Total Length of Barrier (feet)	Height of Barrier (Feet)	Total Cost of Barrier*	Total Decibel Reduction (dBA)	# of Benefited Receivers	Cost/ Receiver/ (dBA)
2	1,325	10	\$397,500	-510.6	86	\$779
2	1,325	15	\$596,250	-850.6	116	\$701

*The cost of materials is based on \$30 per square foot.

As shown in **Table 5**, the proposed noise barriers would meet the feasible criteria of 5 dBA or more for at least one receiver and 3 dBA for additional receivers. In addition, the cost per benefitted receiver per decibel meets the cost reasonableness criteria (see **Table 6**). Therefore, noise abatement along the right-of-way line and the proposed bike path berm would be feasible and reasonable for the residences at Madison Hills Townhomes for the Managed Lane Project.

Tuscany Trails

There are 10 impacted residences in the Tuscany Trails subdivision. Therefore, noise abatement was considered for these impacted residences.

A noise barrier (Barrier 3) was modeled along the roadway shoulder in the location of the Preferred Alternative improvements (see **Appendix B, Figure 1**). There are existing eight foot tall concrete walls surrounding the subdivision of Tuscany Trails which was included in the model. The results in **Table 7** demonstrate the noise reduction provided by the existing walls. **Table 7** summarizes the noise mitigation analysis for the residences at Tuscany Trails subdivision. **Table 8** summarizes the noise barrier analysis.

Table 7: Noise Mitigation Analysis for Tuscany Trails

Receiver Number	Interim (2015) Build (dBA)	Interim with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Interim with 17-foot-tall Mitigation (dBA)	Noise Reduction (dBA)
Receiver25	64.1	63.1	-1.0	62.4	-1.7
Receiver26	62.8	61.6	-1.2	60.9	-1.9
Receiver27	61.5	60.4	-1.1	59.7	-1.8
Receiver28	59.9	58.6	-1.3	57.9	-2.0
Receiver29	63.8	62.0	-1.8	60.8	-3.0
Receiver30	62.5	60.6	-1.9	59.5	-3.0
Receiver31	61.1	59.1	-2.0	57.9	-3.2
Receiver32	59.1	57.1	-2.0	56.2	-2.9
Receiver33	58.1	56.3	-1.8	55.5	-2.6
Receiver34	57.5	55.8	-1.7	55.1	-2.4
Receiver35	62.8	60.3	-2.5	58.9	-3.9
Receiver36	62.1	59.6	-2.5	58.3	-3.8
Receiver37	60.1	57.7	-2.4	56.6	-3.5
Receiver38	59.0	56.9	-2.1	55.9	-3.1
Receiver39	58.4	56.5	-1.9	55.7	-2.7
Receiver40	62.2	59.0	-3.2	57.7	-4.5
Receiver41	61.7	58.4	-3.3	57.0	-4.7
Receiver42	61.0	58.0	-3.0	56.8	-4.2
Receiver43	60.2	57.4	-2.8	56.5	-3.7
Receiver44	59.4	57.0	-2.4	56.0	-3.4
Receiver45	62.8	59.2	-3.6	58.1	-4.7
Receiver46	62.1	58.7	-3.4	57.9	-4.2
Receiver47	61.6	58.7	-2.9	57.6	-4.0
Receiver48	60.6	58.0	-2.6	57.1	-3.5
Receiver49	64.1	60.5	-3.6	59.7	-4.4
Receiver50	63.4	60.2	-3.2	59.3	-4.1
Receiver51	62.3	59.4	-2.9	58.4	-3.9
Receiver52	66.5	62.8	-3.7	61.8	-4.7
Receiver53	64.6	61.5	-3.1	60.3	-4.3
Receiver54	70.8	65.8	-5.0	64.8	-6.0
Receiver55	72.6	67.3	-5.3	66.1	-6.5
Receiver56	73.6	68.4	-5.2	67.3	-6.3
Receiver57	70.9	65.9	-5.0	64.5	-6.4
Receiver58	68.7	66.0	-2.7	65.9	-2.8
Receiver59	66.9	64.3	-2.6	64.0	-2.9
Receiver60	65.6	63.1	-2.5	62.6	-3.0

Table 7: Noise Mitigation Analysis for Tuscany Trails

Receiver Number	Interim (2015) Build (dBA)	Interim with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Interim with 17-foot-tall Mitigation (dBA)	Noise Reduction (dBA)
Receiver61	63.3	59.9	-3.4	59.0	-4.3
Receiver62	62.1	59.0	-3.1	58.1	-4.0
Receiver63	66.1	61.7	-4.4	60.8	-5.3
Receiver64	67.3	62.9	-4.4	61.8	-5.5
Receiver65	62.1	59.1	-3.0	58.4	-3.7
Receiver66	62.9	59.8	-3.1	59.2	-3.7

Note: Noise levels were left in decibel form to show exact noise reduction. Noise levels include the noise reduction provided by the existing walls.

The numbers in bold represent an impact and a benefitted noise reduction.

Table 8: Summary of Reasonableness: Tuscany Trails

Barrier	Total Length of Barrier (feet)	Height of Barrier (Feet)	Total Cost of Barrier*	Total Decibel Reduction (dBA)	# of Benefitted Receivers	Cost/ Receiver/ (dBA)
3	1,185	13	\$462,150	-72	19	\$6,419
3	1,185	15	\$533,250	-136.5	32	\$3,907

*The cost of materials is based on \$30 per square foot.

As shown in **Table 7**, the proposed noise barriers would meet the feasible criteria of 5 dBA or more for at least one receiver and 3 dBA for additional receivers. In addition, the cost per benefitted receiver per decibel for a 15 foot tall noise barrier meets the cost reasonableness criteria (see **Table 8**). Therefore, noise abatement along the roadway shoulder of Preferred Alternative improvements would be feasible and reasonable for the residences at Tuscany Trails subdivision.

Noise Analysis for Preferred Alternative

Madison Hills Townhomes and Tuscany Trails

There are 19 impacted residences in the Madison Hills Townhomes and Tuscany Trails subdivision as a result of the Preferred Alternative roadway improvements. Therefore, noise abatement was considered for these impacted residences.

A noise barrier (Barrier 4) was modeled along the proposed roadway and ramp shoulders adjacent to the residences at Madison Hills Townhomes and Tuscany Trail subdivisions (see **Appendix B, Figure 2**). There are existing eight-foot-tall concrete walls surrounding the subdivision of Tuscany Trails, which was included in the model. The results in **Table 9** demonstrate the noise reduction provided by the walls. There are four residential buildings that would be acquired as a result of the Preferred Alternative. Therefore, these receivers were not included in the noise mitigation and barrier analyses. **Table 9** summarizes the noise mitigation analysis. **Table 10** summarizes the noise barrier analysis.

Table 9: Noise Mitigation Analysis for Madison Hills and Tuscany Trails

Receiver Number	# of Receivers per Building	Preferred Alternative Build (dBA)	Preferred Alternative with 10-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Preferred Alternative with 13-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Preferred Alternative with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)
Madison Hills								
Receiver1	6	62.1	58.7	-3.4	58.5	-3.6	58.3	-3.8
Receiver2	6	61.1	58.0	-3.1	57.7	-3.4	57.4	-3.7
Receiver3	6	61.0	58.2	-2.8	57.7	-3.3	57.3	-3.7
Receiver4	6	61.5	58.4	-3.1	57.8	-3.7	57.4	-4.1
Receiver5	4	62.2	58.7	-3.5	58.1	-4.1	57.7	-4.5
Receiver6	6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Receiver7	6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Receiver8	6	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Receiver9	4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Receiver10	6	74.8	66.6	-8.2	64.5	-10.3	63.4	-11.4
Receiver11	4	71.1	65.2	-5.9	62.8	-8.3	61.6	-9.5
Receiver12	6	72.9	67.4	-5.5	64.2	-8.7	62.4	-10.5
Receiver13	2	63.1	61.3	-1.8	61.3	-1.8	61.3	-1.8
Receiver14	6	62.1	59.8	-2.3	59.8	-2.3	59.7	-2.4
Receiver15	6	60.3	57.3	-3.0	57.0	-3.3	56.9	-3.4
Receiver16	6	60.1	56.8	-3.3	56.1	-4.0	55.8	-4.3
Receiver17	6	61.0	57.0	-4.0	56.2	-4.8	55.8	-5.2
Receiver18	6	62.5	57.8	-4.7	56.9	-5.6	56.5	-6.0
Receiver19	6	63.4	58.7	-4.7	57.6	-5.8	56.9	-6.5
Receiver20	6	63.6	60.1	-3.5	58.9	-4.7	58.3	-5.3
Receiver21	4	62.0	58.7	-3.3	57.0	-5.0	56.1	-5.9
Receiver22	6	64.2	60.7	-3.5	58.1	-6.1	56.8	-7.4
Receiver23	4	59.6	54.0	-5.6	53.3	-6.3	52.9	-6.7

Table 9: Noise Mitigation Analysis for Madison Hills and Tuscany Trails

Receiver Number	# of Receivers per Building	Preferred Alternative Build (dBA)	Preferred Alternative with 10-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Preferred Alternative with 13-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Preferred Alternative with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)
Receiver24	6	60.4	55.9	-4.5	54.6	-5.8	53.9	-6.5
Tuscany Trails								
Receiver25	1	64.0	60.9	-3.1	57.9	-6.1	59.5	-4.5
Receiver26	1	62.9	60.0	-2.9	57.1	-5.8	56.5	-6.4
Receiver27	1	61.8	59.0	-2.8	56.5	-5.3	57.7	-4.1
Receiver28	1	60.3	57.8	-2.5	55.3	-5.0	55.4	-4.9
Receiver29	1	63.5	61.1	-2.4	57.8	-5.7	54.3	-9.2
Receiver30	1	62.5	59.8	-2.7	56.7	-5.8	56.4	-6.1
Receiver31	1	61.8	58.7	-3.1	55.8	-6.0	55.2	-6.6
Receiver32	1	59.9	57.2	-2.7	54.8	-5.1	54.3	-5.6
Receiver33	1	59.1	56.0	-3.1	53.7	-5.4	53.7	-5.4
Receiver34	1	58.5	55.1	-3.4	53.1	-5.4	52.9	-5.6
Receiver35	1	62.8	60.2	-2.6	57.0	-5.8	52.4	-10.4
Receiver36	1	62.2	59.5	-2.7	56.4	-5.8	55.1	-7.1
Receiver37	1	60.5	57.6	-2.9	55.1	-5.4	54.6	-5.9
Receiver38	1	59.1	56.6	-2.5	54.4	-4.7	54.1	-5.0
Receiver39	1	58.8	55.9	-2.9	54.1	-4.7	53.6	-5.2
Receiver40	1	62.7	59.7	-3.0	56.6	-6.1	53.3	-9.4
Receiver41	1	62.1	59.0	-3.1	56.0	-6.1	54.6	-7.5
Receiver42	1	61.6	58.4	-3.2	55.6	-6.0	54.1	-7.5
Receiver43	1	60.5	57.6	-2.9	55.3	-5.2	54.4	-6.1
Receiver44	1	59.5	56.7	-2.8	55.1	-4.4	54.8	-4.7
Receiver45	1	62.5	60.0	-2.5	57.0	-5.5	54.4	-8.1
Receiver46	1	62.4	59.3	-3.1	56.7	-5.7	55.8	-6.6

Table 9: Noise Mitigation Analysis for Madison Hills and Tuscan Trails

Receiver Number	# of Receivers per Building	Preferred Alternative Build (dBA)	Preferred Alternative with 10-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Preferred Alternative with 13-foot-tall Mitigation (dBA)	Noise Reduction (dBA)	Preferred Alternative with 15-foot-tall Mitigation (dBA)	Noise Reduction (dBA)
Receiver47	1	61.6	58.8	-2.8	57.0	-4.6	55.8	-5.8
Receiver48	1	60.5	57.8	-2.7	56.4	-4.1	56.2	-4.3
Receiver49	1	63.7	60.9	-2.8	58.7	-5.0	55.5	-8.2
Receiver50	1	63.0	60.4	-2.6	58.8	-4.2	58.1	-4.9
Receiver51	1	62.1	59.2	-2.9	58.1	-4.0	58.1	-4.0
Receiver52	1	64.2	62.9	-1.3	61.8	-2.4	57.3	-6.9
Receiver53	1	63.5	61.2	-2.3	60.4	-3.1	60.9	-2.6
Receiver54	1	69.4	67.0	-2.4	65.1	-4.3	57.8	-11.6
Receiver55	1	71.8	69.3	-2.5	66.9	-4.9	64.0	-7.8
Receiver56	1	72.2	71.1	-1.1	68.6	-3.6	65.9	-6.3
Receiver57	1	64.7	68.4	3.7	65.2	0.5	67.4	2.7
Receiver58	1	62.6	66.6	4.0	65.2	2.6	63.6	1.0
Receiver59	1	61.4	65.1	3.7	64.0	2.6	64.7	3.3
Receiver60	1	60.5	63.8	3.3	62.8	2.3	63.5	3.0
Receiver61	1	61.3	59.3	-2.0	58.5	-2.8	55.8	-5.5
Receiver62	1	59.6	58.3	-1.3	57.5	-2.1	60.8	1.2
Receiver63	1	61.6	62.2	0.6	60.7	-0.9	57.4	-4.2
Receiver64	1	61.9	64.0	2.1	62.0	0.1	59.6	-2.3
Receiver65	1	59.6	58.7	-0.9	57.8	-1.8	56.6	-3.0
Receiver66	1	59.9	59.7	-0.2	58.5	-1.4	56.9	-3.0

Note: Noise levels were left in decibel form to show exact noise reduction. Noise levels include the noise reduction provided by the existing walls. The numbers in bold represent an impact and a benefitted noise reduction.

As shown in **Table 9**, the proposed noise barriers would meet the feasible criteria of 5 dBA or more for at least one receiver and 3 dBA for additional receivers. In addition, the cost per benefited receiver per decibel meets the cost reasonableness criteria (see **Table 10**). Therefore, a noise barrier along the roadway and ramp shoulders would be feasible and reasonable for the residences at Madison Hills Townhomes and Tuscany Trails subdivision.

Table 10: Summary of Reasonableness: Madison Hills and Tuscany Trails (for Preferred Alternative)

Barrier	Total Length of Barrier (feet)	Height of Barrier (Feet)	Total Cost of Barrier*	Total Decibel Reduction (dBA)	# of Benefited Receivers	Cost/ Receiver/ (dBA)
4	2,400	10	720,000	-415.3	120	\$1,734
4	2,400	13	936,000	-684.8	149	\$1,367
4	2,400	15	1,080,000	-808.8	153	\$1,335

*The cost of materials is based on \$30 per square foot.

RECOMMENDATIONS

Based on this noise analysis, noise abatement is feasible and reasonable to mitigate for noise impacts to the residences at Madison Hills Townhomes and Tuscany Trails subdivision.

A noise barrier was modeled in two different locations for the residences at Madison Hills Townhomes. It is recommended that a 10-foot-tall noise barrier (Barrier 2) be placed along the right-of-way line and the proposed bike path berm to mitigate for noise impacts to the residences at Madison Hills Townhomes for the Managed Lane Project. This noise barrier provides a noise reduction for majority of the residences and reduces the cost of the barrier compared to a noise barrier (Barrier 1) along the right-of-way. However, only portions of the 10-foot-tall noise barrier would break the line of sight between the residences at Madison Hills Townhomes and the roadway.

It is also recommended that a 15-foot-tall noise barrier (Barrier 3) be placed along the roadway shoulder of the ultimate right-of-way adjacent to the Tuscany Trails subdivision for the Managed Lane Project. However, only portions of the 15-foot-tall noise barrier would break the line of sight between the residences at Tuscany Trails subdivision and the roadway.

For the Preferred Alternative, it is recommended that a 13-foot-tall noise barrier (Barrier 4) be placed along the roadway and ramp shoulders since this barrier provides a noise reduction for majority of the residences in both the Madison Hills Townhomes and Tuscany Trails subdivision. However, the northern section of the 13-foot-tall noise barrier would not break the line of sight between the residences at Tuscany Trails subdivision and the roadway. A 15-foot-tall noise barrier would also be sufficient for the ultimate build condition. The panels used to construct the noise barrier for the Managed Lane Project can also be used for the Preferred Alternative. However, the northern section of the 15-foot-tall noise barrier would also not break the line of sight between the residences at Tuscany Trails subdivision and the roadway. Further assessment of this noise barrier will be conducted during final design.

**Appendix A:
Traffic Noise Models (TNMs)
(Please see enclosed CD)**

Appendix B: Noise Barrier Maps

Figure 1: Noise Barrier Map

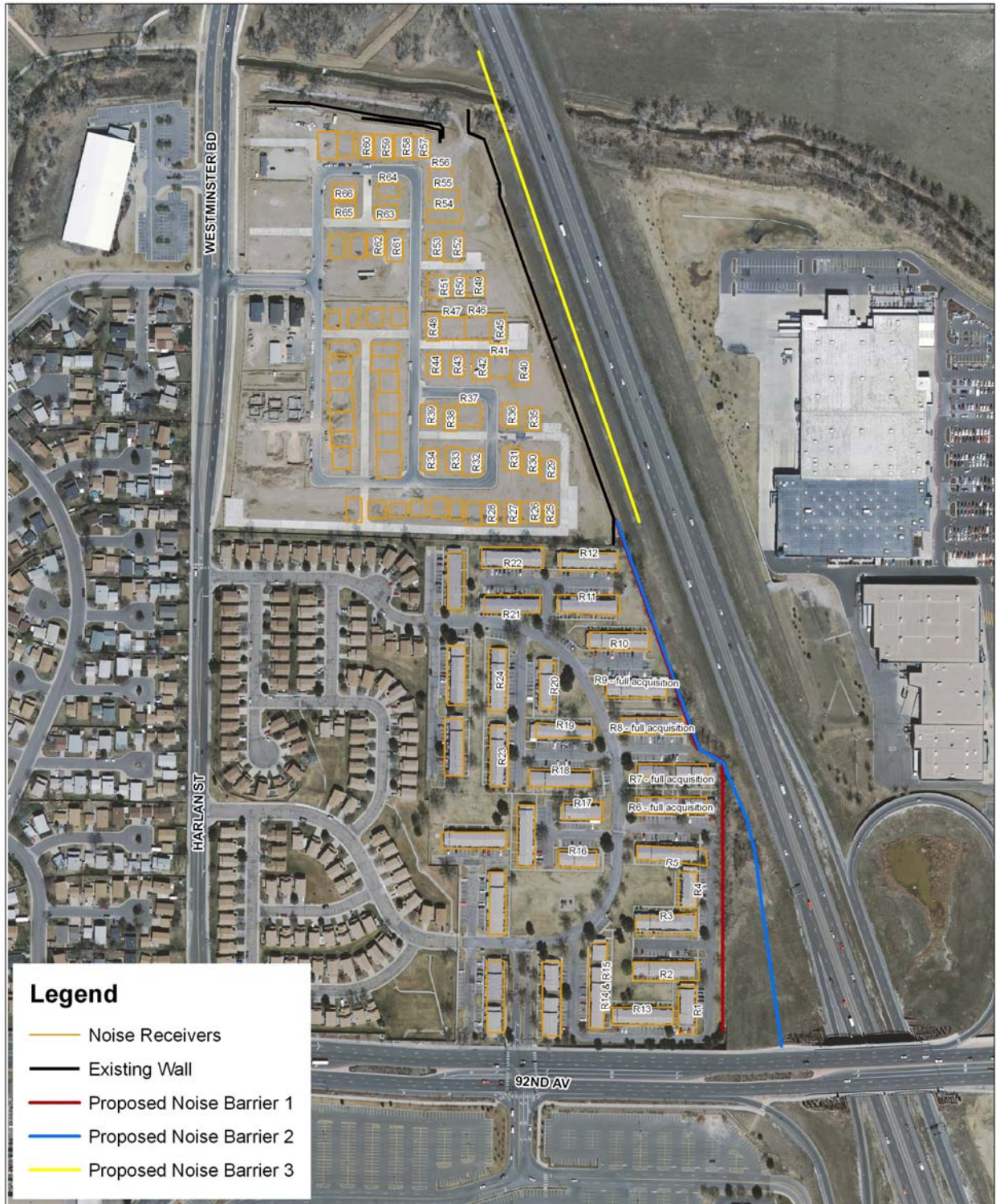
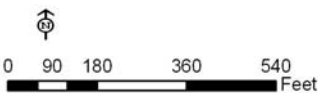


Figure 2: Noise Barrier Map (Tuscany Trail)



US 36 Preferred Alternative

JACOBS