Noise Analysis

U.S. 287 at Lamar Environmental Assessment

CDOT Project No: C2871-026

CH2M HILL Project No: 172922

Hankard Environmental Inc. Report No: 4-16-1

Prepared for

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Table of Contents

1.0 Introduction

This report describes the results of a noise study conducted for the U.S. 287 at Lamar Project in Lamar, Colorado. The intent of the study was to determine and compare the increase in noise levels for the one design alternative and no-action alternative.

As shown in Figure 1-1, below, the existing alignment of U.S. 287 is located through the center of downtown Lamar. The Preferred Alternative (dashed line) would construct an alternate route east of town, which would significantly reduce the number of heavy trucks traveling through downtown. This Preferred Alternative includes the construction of three interchanges (south of town between County Road CC and County Road DD, east of town at U.S. 50, and north of town at S.H. 196 and U.S. 287/U.S. 50) as circled in Figure 1-1.

The noise study was conducted according to Colorado Department of Transportation (CDOT) guidelines. Pursuant to these guidelines, the main purpose of this study was twofold. First, noise levels were predicted along the corridor for both existing and design-year conditions, and these levels compared to CDOT's Noise Abatement Criteria and Increase Criterion. This is the process of determining impact. Second, the feasibility and reasonableness of providing noise mitigation was analyzed for areas where the criteria were exceeded.

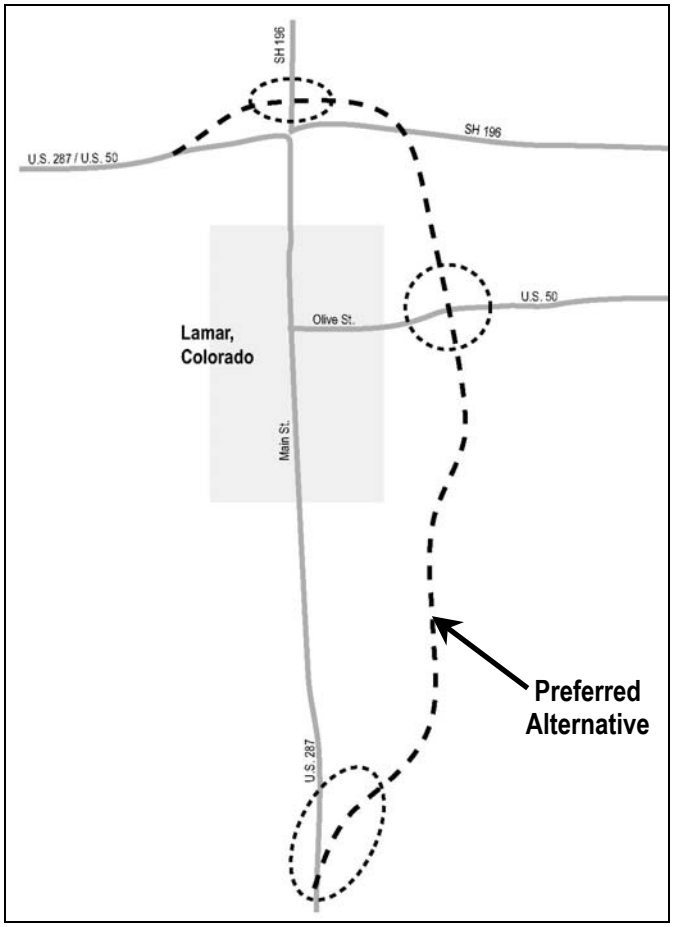


FIGURE 1-1: PROJECT LOCATION

2.0 Methodology

2.1 Noise Analysis Standards

This project, as it involves state and federal funds, is subject to CDOT noise guidelines, which are set forth in the document entitled *CDOT Noise Analysis and Abatement Guidelines*, February 1, 1995. The CDOT noise guidelines are consistent with those of the Federal Highway Administration (FHWA) (23 CFR 772) and have been approved by the FHWA for use on Federal-aid projects. CDOT's guidelines establish noise abatement criteria and design and cost requirements for noise mitigation. The guidelines state that noise mitigation should be considered for any receptor or group of receptors where predicted traffic noise levels, using future traffic volumes and roadway conditions, approach or exceed FHWA's Noise Abatement Criteria (NAC) shown in Table 2-1. Traffic noise is considered to "approach" a criterion at a level 1 dB(A) less than the criterion (e.g., 66 dB(A) for Category B receptors). The guidelines also state that noise mitigation should be considered for any receptors where predicted noise levels for future conditions are greater than existing noise levels by 10 dB(A) or more. This standard is referred to hereafter as the Increase Criterion.

CDOT guidelines also outline a method for determining the "feasibility and reasonableness" of proposed mitigation measures. Feasibility issues include:

- If a noise barrier is to be constructed, can it be constructed in a continuous manner (gaps in noise barriers, e.g., for driveways, significantly degrade their performance)?
- Can at least 5 dB(A) of noise reduction be achieved at front row receptors (minimum significant reduction)?
- Are there any "fatal flaw" maintenance or safety issues involved with the proposed measure?

Reasonableness issues include:

- Do existing and future noise levels exceed the aforementioned standards?
- Does the cost per affected receptor per decibel of noise reduction meet CDOT's $3,500 limit?
- Do a majority of the residents affected by the proposed measure approve of it?
- Is the majority of the development in the area Category B?

TABLE 2-1
FHWA Noise Abatement Criteria

Activity Category	L_{eq} [(1),(2)] (dB(A))	Description of Activity Category
A	57 (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	67 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries and hospitals.
C	72 (Exterior)	Developed lands, properties, or activities not included in Categories A or B above.
D	--	Undeveloped lands.
E	52 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums.

[(1)]Hourly A-weighted equivalent level for the "noisiest hour" of the day in the design year

[(2)]CDOT noise impact analyses use "approach criteria", which are 1 dB(A) less than the values in the table

2.2 Noise Level Prediction Methodology

A noise model of the site was needed to predict the noise levels for the Preferred Alternative. Existing noise levels were also predicted. Measured noise levels represent only the conditions present during the measurement itself, which may or may not be representative of the desired "loudest hour" condition, and it is not practical to measure at every residence and business located within a project area of this size. Short-term measurements (one-hour) were taken at four locations to validate the model, as described in Section 2.3. One long-term measurement (one 24 hour period) was taken adjacent to the existing county truck bypass on which the Preferred Alternative will be built. The purpose of this longer-term measurement was to determine the range of existing noise, as there is little to no existing traffic in this area. The longer-term measurement results are described in Section 3.1.

The noise model used to predict noise levels was STAMINA v2.0. The STAMINA model calculates the hourly, A-weighted L_{eq} at a receptor location given the noise emission level of automobiles, medium, and heavy trucks; the volume and speed of each of these vehicle types on each roadway of interest; the relative location of all roadways, receptors, and terrain features (i.e., natural and man-made barriers); and the type of terrain between each receptor and each roadway. See Attachment A for a description of the relevant noise terminology including L_{eq} and dB(A). The STAMINA input data used to predict noise levels for both existing (2002) and design-year (2025) conditions on this project are provided in Attachment B. All predicted levels correspond to loudest-hour (Level-of-Service (LOS) C) conditions.

2.3 Validation of Noise Prediction Procedures

To validate the above-described modeling procedures, noise levels were measured at four locations within the vicinity of the project for the duration of one-hour sometime between 8:00 a.m. and 12:15 p.m. on December 6, 2002. These locations (M1, M2, M3, and M5) were scattered throughout Lamar, and their general locations are shown in Figure 2-1. A more detailed location is shown in Figures D-1 to D-5. Note that M4 was the long-duration measurement not used for validation purposes. Traffic volumes, traffic speeds, and meteorological conditions were also measured and the data is provided in Table 2-2. Then, using the traffic conditions measured on-site, and accurate topographical data to model the physical aspects of each location, STAMINA 2.0 was used to predict noise levels at each measurement location. The measured and predicted noise levels were then compared, as shown in Table 2-3.

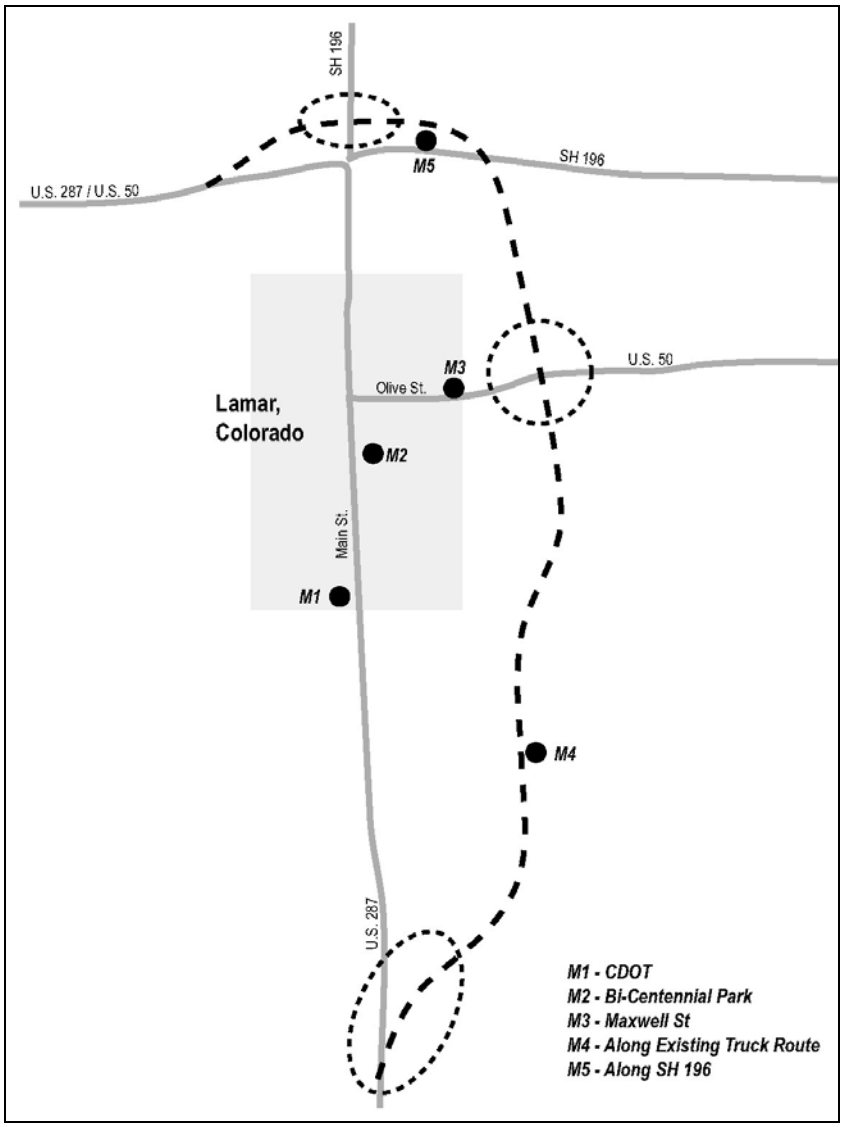


FIGURE 2-1: NOISE MEASUREMENT LOCATIONS

Table 2-2

Validation Measurement (12/6/2002) Traffic Volumes and Speeds

Measurement Location	Roadway	Autos	Medium Trucks	Heavy Trucks	Speed (mph)
M1	US 287 NB & SB	175	8	57	44
M2	US 287 NB & SB	175	8	57	25
M3	US 50 EB & WB	347	11	23	34
M5	SH 196 EB & WB	41	1	10	56

NOTE: M4 was a long-duration measurement and was not used for validation purposes.

Table 2-2

Measured and Predicted Noise Levels (L_{eq} dB(A))

Site	Time	Average Measured Level (dB(A))	Average Predicted Level (dB(A))	Avg Predicted Minus Avg Measured (dB(A))
M1 - CDOT	8:00 a.m. to 9:00 a.m.	66.1	64.1	-2
M2 - Bi-Centennial Park	8:00 a.m. to 9:00 a.m.	58.3	56.1	-2.2
M3 - Adjacent to Olive	9:15 a.m. to 10:15 a.m.	60.1	58.8	-1.3
M5 - Adjacent to SH 196	11:15 a.m. to 12:15 p.m.	50.4	54	3.6

NOTE: M4 was a long-duration measurement and was not used for validation purposes.

On average, STAMINA v2.0 predicted noise levels within 2.2 dB(A) of the measured levels, which is within the desired accuracy of ±3 dB(A). For all four measurements STAMINA v2.0 predicted noise levels between 2.2 dB(A) below and 3.6 dB(A) above measured levels. The reason that one location (M5) was predicted to be 3.6 dB(A) above the measured level is because the traffic volumes along this roadway (State Highway 196) were very low (52 vehicles per hour). This creates a problem for the STAMINA model as the average noise emission values used in the model were determined using a much larger vehicle sample size. Thus, a larger error is expected when measuring low traffic volumes because the average emission values of a small sample size compared to a much larger sample size may not be the same. This will result in a noise model that will over-predict noise levels for this area, and thus increase the probability that a noise mitigation analysis may be required.

3.0 Existing Noise Levels

Existing noise levels were both measured and predicted. The assessment of noise impacts per CDOT guidelines was conducted using peak-hour (loudest hour) noise levels. Because the truck bypass section of the Preferred Alternative is located where there is little to no existing traffic, a long-term noise level measurement was taken to determine the existing noise level (i.e. the model could not be used because there is no traffic there to model).

3.1 Measured Existing Noise Levels

Noise levels were measured at M4 over one 24-hour period (December 5 to 6, 2002) in which the average L_{eq} was recorded every hour adjacent (50 ft from centerline) to the existing alternate truck route (Figure 2-1). Attempts were made to measure noise at the residences in this area, but because nobody was home to give permission, the measurement was taken next to the roadway. The noise level trend during this measurement, with the corresponding average wind speed, is shown in Attachment B. The maximum hourly noise level measured was 58 dB(A) and the minimum was 35 dB(A). Average wind speeds were all below 5 m.p.h., which suggests that the noise levels measured were not too dependent on wind. The primary noise sources in this area are from distant roadways, the occasional heavy dump truck or other vehicle along the existing truck alternate route (dirt road), and noise caused by wind blowing through vegetation. The peak-hour noise levels for the residences adjacent to this low use roadway (~800 to 1,400 feet away) are estimated to be 43 dB(A). This estimation is based on the noise measured directly adjacent to the roadway (range of 35 to 58 dB(A)), the locations of the closest nearby residences (~800 feet), and the existing background noise level due to sources other than nearby traffic.

3.2 Predicted Existing Noise Levels

The predicted noise levels represent the existing (Year 2002) peak-hour noise level at each of the 48 noise receptor locations along existing U.S. 287 (Main St.), U.S. 50 (Olive St.), and the truck bypass section of the Preferred Alternative. Noise receptor locations for this area consist of residences, parks, and schools, and are described in Table B-4, and shown in Figures D-1 and D-2. Noise level predictions were calculated using STAMIMA v2.0 using the various input data as described in Section 2.1, above. The existing (Year 2002) peak-hour traffic volumes, speeds, and truck percentages were provided by CH2M HILL, and were limited to LOS C condition which is the loudest hour. The STAMINA input data can be found in Attachment B. The predicted existing noise levels are described along with the design year noise levels in Section 4.0, below. The maximum predicted existing peak-hour noise level is 63 dB(A), which occurred at three residences (Receptor 1 – near U.S. 287 and SH 196 interchange, Receptor 41 and 42 – adjacent to U.S. 50 (Olive St.)) and one city park (Receptor 17 – Bi-Centennial Park). The lowest peak-hour noise level of 43 dB(A) was predicted at locations adjacent to the truck bypass section of the Preferred Alternative where there is little to no existing traffic.

4.0 Design Year Noise Levels

Design Year (2025) noise levels were predicted at each of the 48 noise receptor locations described in Table B-4 and shown in Figures D-1 to D-5. While the Preferred Alternative represents the predicted noise levels with the new alternate route and interchanges, the No-Action Alternative represents the predicted noise levels with no changes to the existing alignment for the same Design Year 2025. Noise level predictions were made using STAMIMA v2.0 using the input data described in Section 2.1, above. Design-year (2025) peak-hour traffic volumes, speeds, and truck percentages were provided by CH2M HILL, and this data can be found in Attachment B. Table 4-1 lists the peak-hour noise levels for existing conditions, the Preferred Alternative, No-Action Alternative, and the corresponding increases in noise levels.

Table 4-1
Predicted Noise Level Increases between 2002 and 2025

Location	Existing 2002	Proposed Alt 2025	No-Action 2025	Change due to Proposed Alt (2025 - 2002)	Change due to No-Action Alt (2025 - 2002)
R1	63	57	64	-6	1
R2	61	57	62	-4	1
R3	55	58	55	3	0
R4	57	60	57	3	0
R5	58	61	59	3	1
R6	56	57	56	1	0
R7	55	57	56	2	1
R8	50	53	51	3	1
R9	49	54	49	5	0
R10	43	47	44	4	1
R11	55	56	56	1	1
R12	61	60	62	-1	1
R13	61	60	61	-1	0
R14	60	59	61	-1	1
R15	61	60	62	-1	1
R16	57	56	58	-1	1
R17	63	65	63	2	0
R18	59	61	60	2	1
R19	56	56	57	0	1
R20	58	58	59	0	1
R21	55	55	55	0	0
R22	52	51	52	-1	0
R23	51	54	52	3	1
R24	56	51	57	-5	1
R25	43	47	43	4	0
R26	43	46	43	3	0
R27	43	46	43	3	0
R28	43	49	43	6	0
R29	43	49	43	6	0

Table 4-1
Predicted Noise Level Increases between 2002 and 2025

Location	Existing 2002	Proposed Alt 2025	No-Action 2025	Change due to Proposed Alt (2025 - 2002)	Change due to No-Action Alt (2025 - 2002)
R30	43	50	43	7	0
R31	43	51	43	8	0
R32	43	48	43	5	0
R33	56	49	56	-7	0
R34	56	49	57	-7	1
R35	51	48	52	-3	1
R36	52	50	53	-2	1
R37	61	59	62	-2	1
R38	61	59	62	-2	1
R39	60	58	61	-2	1
R40	51	50	52	-1	1
R41	63	61	64	-2	1
R42	63	61	64	-2	1
R43	62	60	63	-2	1
R44	46	46	47	0	1
R45	49	49	50	0	1
R46	52	51	52	-1	0
R47	54	55	55	1	1
R48	54	54	55	0	1
Minimum	43	46	43	-7	0
Maximum	63	65	64	8	1
Average	54	54	55	0	1

The Preferred Alternative is predicted to increase noise levels by as much as 8 dB(A) at some locations and reduce noise levels by as much as 7 dB(A) at others. In downtown Lamar, noise levels are shown to generally decrease or remain the same by the design-year 2025 due to the relocation of traffic to the bypass. For areas adjacent to the proposed bypass and the respective interchanges, noise levels are predicted to increase by about 3 to 8 dB(A) by the design-year 2025. The largest noise level increases are found north of the proposed southern interchange and adjacent to the proposed bypass. The loudest future predicted noise level is 65 dB(A), and is located in Bi-Centennial Park downtown. The next loudest noise levels are around 60 to 61 dB(A) and are found near residences at the SH 196 and Main Street intersection, hotels along North Main Street, the high school across from Bi-Centennial Park, and the residences adjacent to Olive Street.

Because none of the design-year noise levels are predicted to meet or exceed the Noise Abatement Criteria (Table 2-1) or meet or exceed the 10 dB(A) increase criterion, none of the noise receptors analyzed are considered to be impacted by noise.

5.0 Noise Mitigation

A noise mitigation analysis is required for any noise receptors that meet or exceed the noise impact criteria described in Section 2.1. For this project, noise levels were analyzed at the 48 receptors locations identified within the project study area. For these receptors to be considered impacted by noise, their design-year noise levels must reach 66 dB(A) or have an increase over existing noise levels of at least 10 dB(A). As described in Section 4.0, the maximum design-year noise levels were 65 dB(A) for the downtown area, and 61 dB(A) for the areas near the Preferred Alternative. Additionally, the maximum increase in noise level was 8 dB(A). Because neither of the two noise impact criteria was met, no noise mitigation is recommended for this project according to CDOT policy.

ATTACHMENT A

Relevant Noise Terminology

Noise, often defined as unwanted sound, is the result of pressure fluctuations in the air. The range of sound pressures which the human ear is capable of detecting is very large (0.00002 to 200 Pa). To facilitate easier discussion, sound pressures are described on a decibel (dB) scale. Sound pressure level in dB is equal to $10Log_{10}(p^2/p_o^2)$ where p is the instantaneous sound pressure and p_o is the reference sound pressure of 0.00002 Pa. This results in a scale of 0 dB (threshold of audibility) to 120 dB (threshold of pain).

In addition to level or loudness, sound has both frequency and time components. The human ear is, in general, capable of detecting frequencies between 20 to 20,000 Hertz. The human ear is more sensitive to high frequency sounds than to low frequency sounds. Because of this, the A-weighting network was developed and is applied to either measured or predicted noise levels to mimic the ear's varying sensitivity to frequency. Resulting noise levels are expressed in dB(A). Table A1 shows the A-weighted noise levels of some common noise sources.

Different methods have been developed to quantify the time-varying nature of environmental noise levels (environmental noise levels are those found outdoors as the result of sources such as traffic, industry, and wind). The method used to describe noise levels along highways is the equivalent level (L_{eq}). The L_{eq} is essentially the average noise level over a given time period. Technically, it is called the energy-average noise level because of the fact that noise levels are expressed in decibels, which must be converted to absolute values of pressure before being averaged. The L_{eq} is a single level that has the same sound energy as the time-varying sound level over the stated time period. The time period used for highway noise analysis is one hour. All noise levels described in this report are hourly, A-weighted L_{eq}'s.

Locations at which noise is analyzed are typically known as noise receptors. Noise receptors are defined as areas in which people are typically located, which include places such as residences, hotels, commercial buildings, parks, etc. Usually, one noise receptor location is used to analyze an area unless the area is quite large and covers various distances from the roadway. The noise receptor is typically located on the façade of a structure that faces the noise source or roadway.

TABLE A1
Typical Noise Levels

Noise Source	Noise Level (dB(A))
Amplified rock band	115 – 120
Commercial jet takeoff at 200 feet	105 – 115
Community warning siren at 100 feet	95 – 105
Busy urban street	85 – 95
Construction equipment at 50 feet	75 – 85
Freeway traffic at 50 feet	65 – 75
Normal conversation at 6 feet	55 – 65
Typical office interior	45 – 55
Soft radio music	35 – 45
Typical residential interior	25 – 35
Typical whisper at 6 feet	15 – 25
Human breathing	5 – 15
Threshold of hearing	0 – 5

ATTACHMENT B

Noise Model Input Data

Vehicle Emission Levels

Vehicle emission levels refer to the noise level of vehicles measured at a reference distance and a reference speed. STAMINA requires separate emission levels for automobiles, medium trucks (trucks with two axles, six tires, and a gross vehicle weight greater than 9,900 lbs and less than 26,400 lbs), and heavy trucks (trucks with three or more axles and a gross vehicle weight greater than 26,400 lbs). The Colorado-specific Reference Energy Mean Emission Levels were used for all vehicle types in all of the predictions. These emission levels were developed by CDOT, approved by FHWA, and are published in the document entitled *Reference Energy Mean Emission Levels Used in STAMINA 2.0 for Highway Noise Prediction in the State of Colorado*, CDOT, February 1995.

Traffic Volumes and Speeds

Three conditions were modeled on this project: Existing (2002), Preferred Alternative (Year 2025), and No-Action (Year 2025). The traffic volumes and speeds used to model these three conditions are shown in Tables B-1, B-2, and B-3, below. The traffic volumes were provided by CH2M HILL. In order to model loudest-hour conditions, all of the volumes represent Level-of-Service (LOS) C conditions or better. That is, where traffic projections indicated that the LOS would be A, B, or C, all of which represent free-flowing conditions, the projected volumes were used directly. When traffic projections indicated that the LOS would be D, E, or F, which represents some degree of congestion and therefore lower speeds, then the volumes were reduced to replicate LOS C conditions. Free-flow speeds were used in all of the predictions, which range from 25 to 65 m.p.h. throughout the project area.

Table B-1

Existing (Year 2002) PM Traffic Volumes and Speeds

Roadway	Section	Autos	Medium Trucks	Heavy Trucks	Speed (mph)
US 287	Northwest to SH196 Interchange	306	17	90	55
	SH196 to Arkansas River	738	26	66	45
	Arkansas River to Lamar Canal	691	72	92	45
	Lamar Canal to US50/Olive	916	38	115	30
	US50/Olive to Savage Ave	1007	27	87	30
	Savage Ave to Existing Truck Alt.	1007	27	87	40
	Existing Truck Alt to South	113	8	67	55
US 50	East of Existing Truck Alt	247	5	35	55
	Existing Truck Alt to CR9	484	18	26	55
	CR9 to 1st Street	484	18	26	35
	1st Street to US287	484	18	26	30
SH 196	North to US287 Interchange	173	7	14	50
	US287 Interchange to East	53	3	16	55
Ramps	SH196 to NB&SB US287	215	11	9	30
	EB & WB US287 to SH196	23	1	7	25

Table B-2

Preferred Alternative (Year 2025) PM Traffic Volumes and Speeds

Roadway	Section	Autos	Medium Trucks	Heavy Trucks	Speed (mph)
US 287	SH196 to Arkansas River	611	14	85	45
	Arkansas River to Lamar Canal	611	14	85	45
	Lamar Canal to Maple St.	779	36	81	30
	Maple St. to US50/Olive	853	39	88	30
	US50/Olive to Savage Ave	927	43	96	40
	Savage Ave to Existing Truck Alt.	927	43	96	40
Northbound US 287 / Bypass	Southern Interchange to US 50	23	2	34	65
	US 50 to SH 196 Interchange	58	5	38	65
	SH 196 Interchange to West	363	5	92	55
Southbound US 287 / Bypass	Southern Interchange to US 50	26	2	33	65
	US 50 to SH 196 Interchange	60	2	40	65
	SH 196 Interchange to West	339	34	111	55
US 50	East to CR 9	261	3	40	55
	CR 9 to 1st Street	200	5	25	35
	1st Street to US 287/Main St.	365	8	46	30
SH 196	North to US287 Interchange	860	10	119	45
	Main St. to East	59	4	19	55
Ramps	US 287 Bypass - South Ramps	139	6	14	40
	KLMR Curve / Access Road	26	1	8	25

Table B-3

No-Action (Year 2025) PM Traffic Volumes and Speeds

Roadway	Section	Autos	Medium Trucks	Heavy Trucks	Speed (mph)
US 287	Northwest to SH196 Interchange	358	20	105	55
	SH196 to Arkansas River	864	31	77	45
	Arkansas River to Lamar Canal	808	84	108	45
	Lamar Canal to US50/Olive	1080	45	136	30
	US50/Olive to Savage Ave	1188	32	103	30
	Savage Ave to Existing Truck Alt.	1178	32	102	40
	Existing Truck Alt to South	132	9	78	55
US 50	East of Existing Truck Alt	291	6	41	55
	Existing Truck Alt to CR9	571	21	31	55
	CR9 to 1st Street	576	22	31	35
	1st Street to US287	576	22	31	30
SH 196	North to US287 Interchange	203	8	16	50
	US287 Interchange to East	62	4	19	55
Ramps	SH196 to NB&SB US287	251	13	10	30
	EB & WB US287 to SH196	27	2	8	25

Location of Roadways

For existing (2002) conditions, the locations of U.S. 287, U.S. 50, SH 196, and the truck bypass section of the Preferred Alternative were determined using CAD topographical maps. As this site is relatively flat, one elevation of 3,650 feet was used. For the Design Year conditions, this information was obtained from CAD design files provided by CH2M HILL.

Location of Receptors

To determine the magnitude of noise level increases along the corridor, noise levels were predicted at 48 locations. All of these locations are considered Noise Activity Category B types (residential, schools, hotels, etc.). The coordinates of these locations were determined from topographical plans. Elevation and topography were taken into account. A list of these receptor locations is provided in Table B-4, and a graphical representation is provided in Attachment D.

Table B-4

Type and Location of Noise Receptors

Number	Type	Location
1	sf	7405 US287
2	sf	74xx US287
3	sf	7425 US287
4	sf	7435 US287
5	museum	Big Timbers Museum
6	sf	adjacent to SH196
7	sf	8276 SH196
8	sf	8276 SH196
9	sf	8275 SH196
10	sf	adjacent to SH196
11	sf	9529 SH196
12	hotel	Best Western
13	hotel	Days Inn
14	hotel	Travelodge
15	hotel	Super 8
16	museum	Historic Lamar Depot
17	park	Bi-Centennial Park
18	school	High School
19	park	ballfields
20	school	community college
21	sf	adjacent to US287
22	sf	adjacent to CR DD
23	sf	across from R22
24	sf	near proposed bypass interchange (south)
25	sf	along proposed bypass
26	sf	along proposed bypass
27	sf	along proposed bypass
28	sf	along proposed bypass
29	sf	along proposed bypass
30	sf	along proposed bypass

Table B-4

Type and Location of Noise Receptors

Number	Type	Location
31	sf	9523 CR HH
32	sf	adjacent to SH50
33	sf	adjacent to SH50
34	sf	adjacent to SH50
35	sf	adjacent to SH50
36	sf	Hays Mobile Home Park north of Olive
37	sf	NE Corner Maxwell and Olive
38	sf	NE Corner Mullen and Olive
39	hotel	Golden Arrow Motel
40	sf	Homes to the NW of Golden Arrow Motel
41	sf	SE Corner Maxwell and Olive
42	sf	SE Corner Mullen and Olive
43	sf	SW Corner Mullen and Olive
44	sf	adjacent to Elm St
45	sf	adjacent to Elm St
46	school	NW Corner of 1st St and Elm St
47	sf	SE Corner of 2nd St and Olive
48	sf	SW Corner of 2nd St and Olive

sf = single family residence

Location of Terrain Features and Structures

Existing terrain features such as embankments, existing noise walls, the edge of the roadway itself, and structures can act as barriers that reduce noise propagation. The effects of these features were modeled when it was determined that they break the line-of-sight between the adjacent roadway and receptors and were of substantial mass.

Terrain Type

STAMINA allows the user to select one of two types of ground for each receiver-roadway pair: hard or soft. This selection is made using the alpha factor input variable. An alpha factor of zero represents hard ground such as pavement and water, as well as the case where either the source or the receptor are significantly elevated above the ground. An alpha factor of 0.5 represents acoustically soft terrain, which is representative of vegetated ground with both source and receiver located close to the ground. An alpha factor of 0.5 was used in all of the predictions on this project.

ATTACHMENT C

Measured Noise Levels

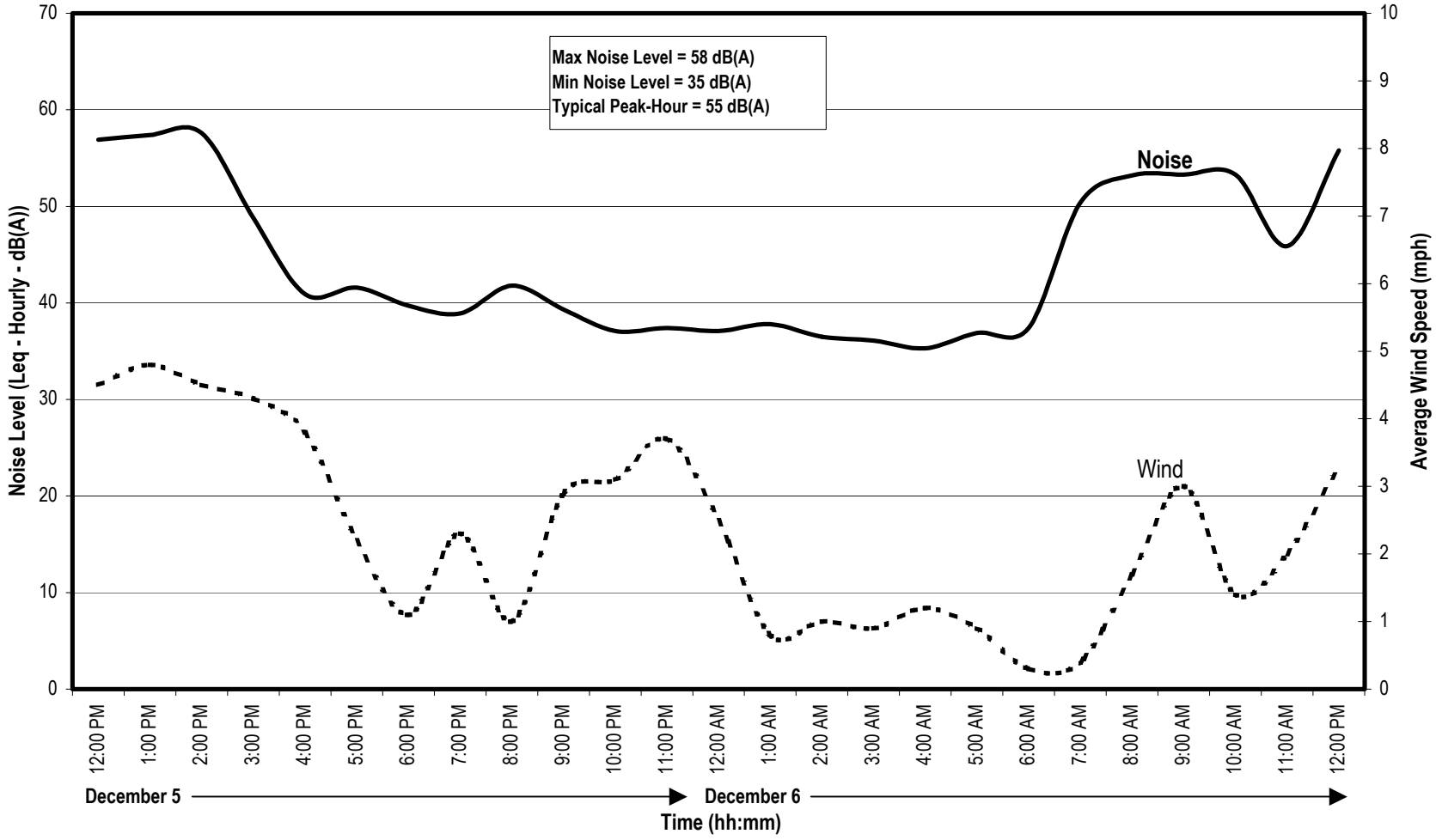


FIGURE C-1: EXISTING NOISE LEVELS AT M4

ATTACHMENT D

Noise Analysis Site Plans

NORTH

0 1000'

1 INCH = 1000 FEET

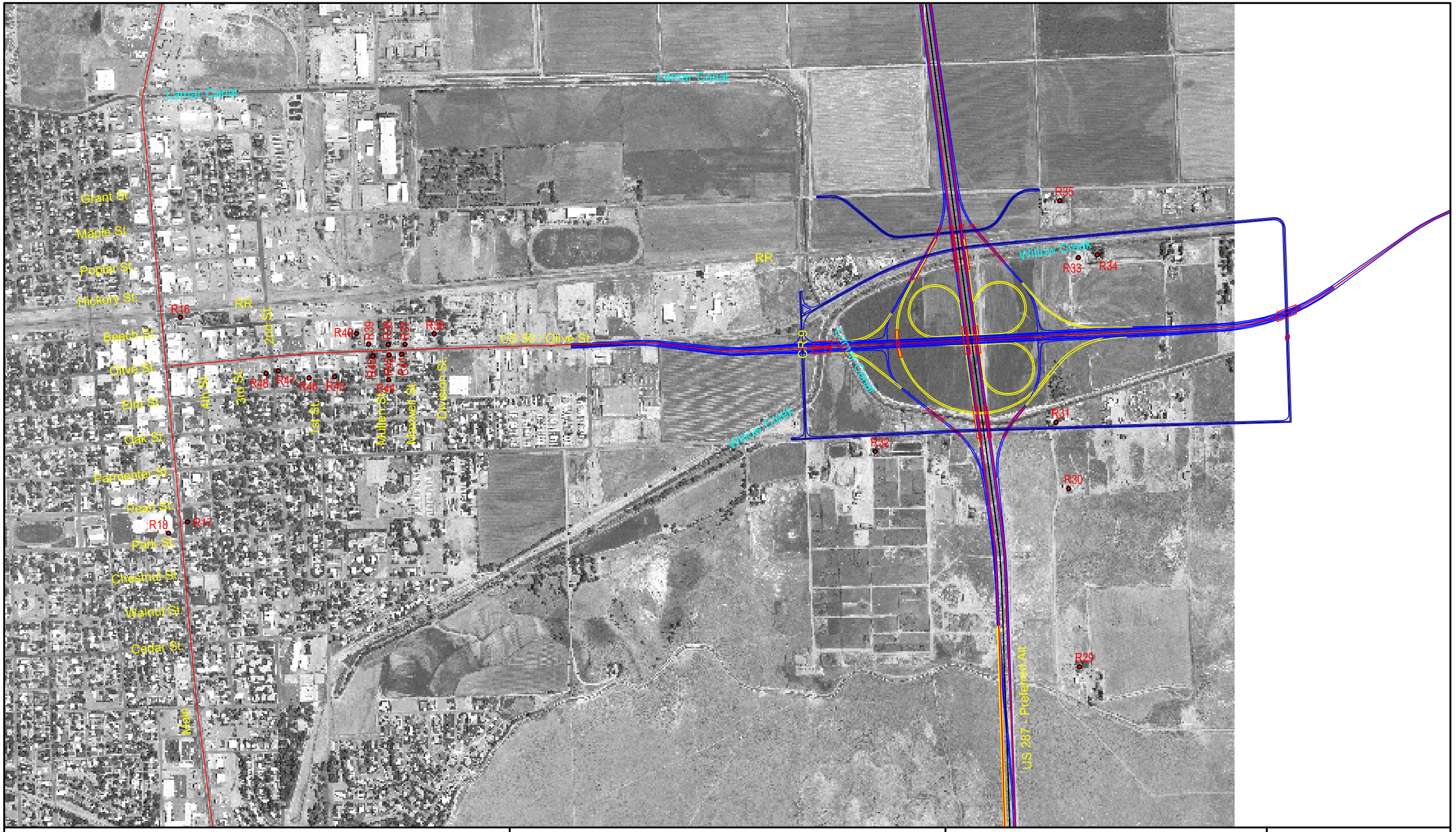
- Noise Receptor Locations

HANKARD ENVIRONMENTAL

19 Old Town Square, Suite 238
Fort Collins, Colorado 80524
Phone: (303) 666-0617

U.S. 287 at Lamar
Noise Analysis Site Plan

Figure D-1



NORTH

0 1000'

1 INCH = 1000 FEET

- Noise Receptor Locations

HANKARD ENVIRONMENTAL

19 Old Town Square, Suite 238
Fort Collins, Colorado 80524
Phone: (303) 666-0617

U.S. 287 at Lamar
Noise Analysis Site Plan

Figure D-2

NORTH

0 1000'

1 INCH = 1000 FEET

- Noise Receptor Locations

HANKARD ENVIRONMENTAL

19 Old Town Square, Suite 238
Fort Collins, Colorado 80524
Phone: (303) 666-0617

U.S. 287 at Lamar
Noise Analysis Site Plan

Figure D-3

NORTH

0 1000'

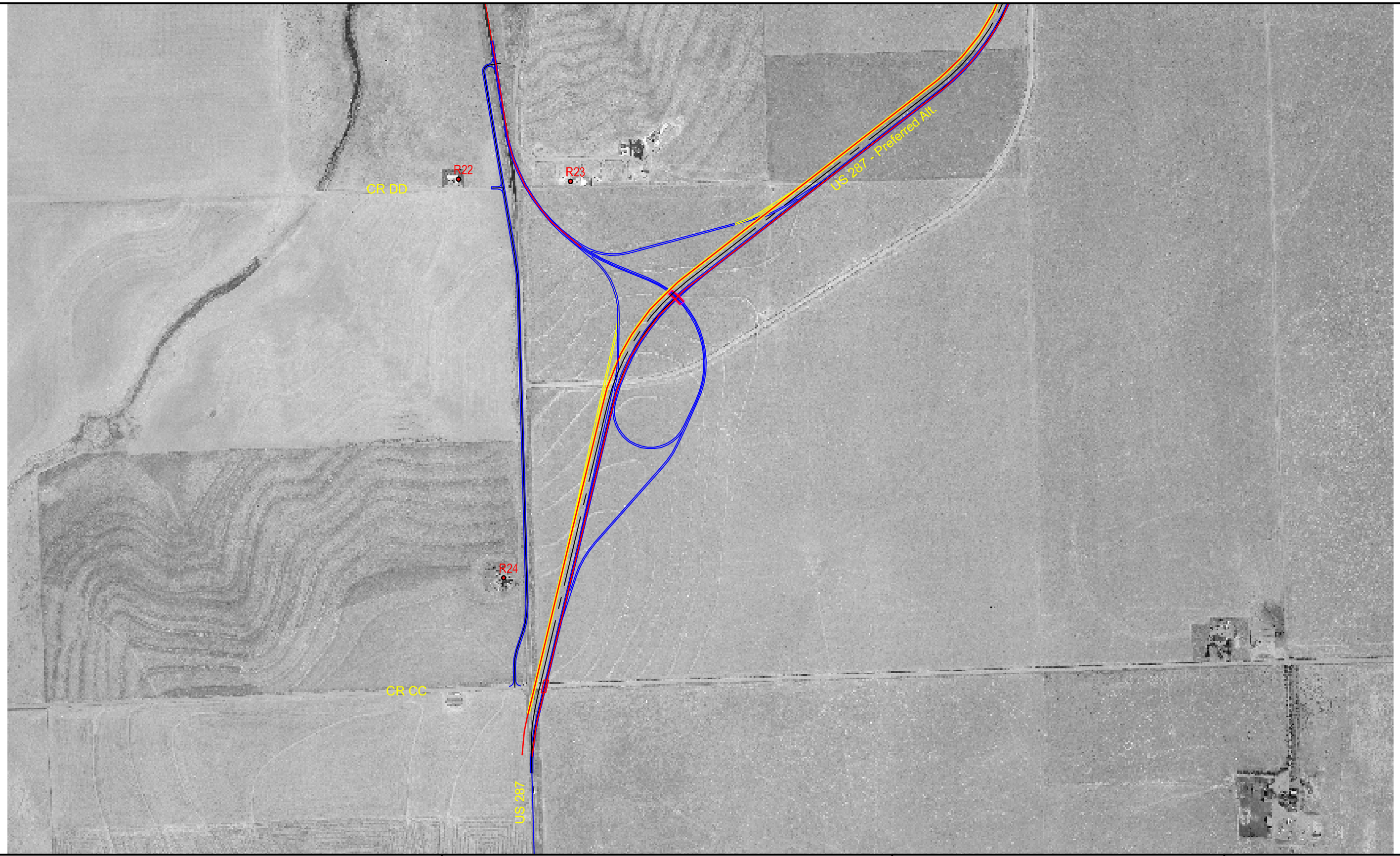
1 INCH = 1000 FEET

- Noise Receptor Locations

HANKARD ENVIRONMENTAL
19 Old Town Square, Suite 238
Fort Collins, Colorado 80524
Phone: (303) 666-0617

U.S. 287 at Lamar
Noise Analysis Site Plan

Figure D-4



NORTH

0 1000'

1 INCH = 1000 FEET

- Noise Receptor Locations

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Phone: (303) 666-0617

U.S. 287 at Lamar
Noise Analysis Site Plan

Figure D-5