**Arizona Department of Transportation**

**Environmental Planning**

# Noise Analysis Technical Report for the Proposed Ivanhoe Traffic Interchange Environmental Impact Statement Reevaluation

## Loop 202 – South Mountain Freeway

**Federal Project No. NH-202-D(ADY)**
**ADOT Project No. 202L MA 054 H5764 01D (H8827 01C)**

**8/27/2018**

**Submittal 2**

# Noise Analysis Technical Report for the Proposed Ivanhoe Traffic Interchange Environmental Impact Statement Reevaluation

FOR

Loop 202 – South Mountain Freeway

**Federal Project No. NH-202-D(ADY)**
**ADOT Project No. 202L MA 054 H5764 01D (H8827 01C)**

**Prepared by:**
Arizona Department of Transportation
Environmental Planning
1611 West Jackson Street, EM02
Phoenix, Arizona 85007

8/27/2018

## Contents

## Tables

## Figures

## EXECUTIVE SUMMARY

### Project Objectives

The State Route 202L (SR 202L) South Mountain Freeway Project (Project) is a new 22-mile traffic corridor that connects Interstate 10 (I-10) in west Phoenix (Papago Freeway) with I-10 in Chandler (Maricopa Freeway), thereby allowing long-distance travelers to avoid congestion in downtown Phoenix and reducing traffic congestion during peak travel hours. To reduce the financial burden and ensure timely completion of the freeway, the Arizona Department of Transportation (ADOT) entered into a public-private partnership (P3) agreement with Connect 202 Partners for the design, construction, and maintenance phases of the Project. The Connect 202 Partners have divided the Project into four design and construction segments: Pecos, Center, Salt River, and Papago.

This noise report addresses the proposed Ivanhoe Street traffic interchange (TI) within the Center segment. A noise report dated June 2014 evaluated the projected noise impacts from the various alternatives and options for the South Mountain Transportation Corridor (SMTC). Based on computer modeling, impacts were identified and noise mitigation was evaluated to reduce impacts at selected noise-sensitive receivers throughout the project corridor. It was stated in the report that “*As the proposed design of the SMTC further develops, additional noise analyses would need to be conducted*”. Furthermore, it said “*The results of this analysis and the recommendations contained in this report should not be considered final*” and “would need to be verified and refined as the SMTC design progresses.” In Appendix C of the report, Table C-1 states, “*The determination of benefited receptors and cost calculations would be made during final design of the Selected Alternative.*” In line with these stipulations, in 2016, the potential barrier at the general location, as presented in support of the Environmental Impact Statement at the Ivanhoe Street location near the Dusty Lane community, was evaluated based upon the available information but the barrier was not recommended because criteria had not been met on ADOT’s established policy. However, during the Project’s final design, the horizontal and vertical alignments of SR 202L were updated and a potential design for the proposed TI at Ivanhoe Street was developed. To reflect these changes, noise models were rebuilt and the dimensions of potential noise barriers were reevaluated. This noise reevaluation was based on updated noise analysis requirements and information obtained from public coordination that was not previously known in order to determine the most effective and optimal location of a noise barrier while meeting all regulatory required feasibility and reasonableness criteria.

ADOT considers mitigation for receivers predicted to experience traffic noise impacts associated with a proposed transportation improvement project. This analysis determined the traffic noise impacts based on the Federal Highway Administration (FHWA) Noise Abatement Criteria (NAC), which are referred to in ADOT’s 2011 Noise Abatement Policy (NAP), the policy applicable at the Date of Public Knowledge.

While the FHWA traffic noise regulations do not define the point at which a noise level "approaches" the NAC, each state highway agency is required to establish a definition that is at least 1 A-weighted decibel (dBA) less than the NAC for that land use category. The point at which noise levels approach the NAC is defined by ADOT as 3 dBA for Categories A, B, C, D, and E. Therefore, for Category B, ADOT will consider mitigation for receivers, under the ADOT 2011 NAP, when predicted traffic noise levels are 66 dBA or higher, or for Category E when predicted traffic noise levels are 69 dBA or higher. Additionally, ADOT will consider mitigation if noise levels from the transportation project are predicted to increase substantially. A substantial noise level increase is equal to or greater than 15 dBA.

Mitigation was evaluated for receivers with modeled future unmitigated noise levels equal to or greater than 64 dBA, for residences, or 69 dBA, for other developed lands, properties, or activities not included in Categories A to D or F. The ADOT 2011 NAP addresses noise abatement measures based on feasibility and reasonableness. Some key considerations in the assessment for abatement measures include:

- Barrier height should not normally be higher than 20 feet for a stand-alone structure.
- 50 percent of affected receptors must achieve a noise reduction of at least 5 dBA for highway traffic noise.
- The barriers should reduce predicted unmitigated noise levels by at least 7 dBA for benefited receptors closest to the transportation facility.
- The maximum cost of the abatement is $49,000 per benefited receptor, with barrier costs calculated at $35 per square foot or $55 per square foot if constructed on a structure.

## Current Noise Environment

Existing noise-sensitive land uses in the study area were identified using online land use data, aerial imagery, and site reconnaissance.

Land ownership within the Ivanhoe TI evaluation area is private east of the Project and Gila River Indian Community (GRIC) west of the Project. The private land is bordered by the City of Phoenix's South Mountain Park and Preserve (SMPP). Existing land uses within the private land are rural residential and undeveloped. Land uses on the GRIC are commercial and undeveloped. Noise levels are generally low in this rural area because of the minimal traffic and undeveloped land on the SMPP and GRIC. The NAC land use Categories B (residential) and E (other developed lands, properties, or activities not included in Categories A to D or F) on the eastern side of the Project are the focus of this study. In total, 41 noise receivers were modeled and evaluated to determine the most effective potential noise barrier locations. The modeled noise receivers represent single-family homes and/or property lots with outdoor activity areas near the Project. Modeled noise receiver locations were assigned a unique identifying designation.

## Noise Impacts and Noise Abatement Measures Determination

Table S-1 summarizes the results of the noise mitigation/barriers determined in accordance with the ADOT NAP for the proposed Ivanhoe TI location within the Project. The noise barrier locations/limits for the proposed Ivanhoe TI location are shown in Appendix A. The noise barrier locations, heights, and termini described in this report are subject to minor adjustments by final designers to accommodate final design features and considerations in association with this noise analysis.

### Table S-1. Recommended Noise Abatement Summary

| Barriers | Height | Length | Area | Cost per sqft | Barrier cost | Benefited receptors | CPBR |
|---|---|---|---|---|---|---|---|
| | (ft) | (ft) | (sqft) | ($/sqft) | ($) | Unit | ($) |
| System of 3 barriers | 10-12-14 | 4536 | 52734 | 35 | 1845690 | 39 | 47325 |
| Mainline Barrier | 10-12-14 | 4202 | 51593 | 35 | 1805755 | 41 | 44043 |

CPBR – cost-per-benefited-receptor

The barriers meet all feasibility and reasonableness criteria, including a cost-per-benefited-receptor below the ADOT NAP threshold of $49,000. During the public involvement process, it was evident the residents were overwhelmingly in favor of constructing a noise barrier; coordination with the affected community incorporates resident input into the final solution. The agreement to provide a 14-foot-high barrier for the community has been reached for visual (line-of-sight) and aesthetic purposes for noise barriers that are feasible and meet cost-effectiveness criteria. As per the agreement reached with the community, the barrier shall be 14 feet in height throughout, including the safety barrier.

# INTRODUCTION

## Project Description

The State Route 202L (SR 202L) South Mountain Freeway Project (Project), first proposed in 1985, will complete the Loop 202 and Loop 101 freeway systems in Phoenix, Maricopa County (Figure 1). The Project will result in a new 22-mile traffic corridor that connects Interstate 10 (I-10) in west Phoenix (Papago Freeway) with I-10 in Chandler (Maricopa Freeway), thereby allowing long-distance travelers to avoid congestion in downtown Phoenix and reducing traffic congestion during peak travel hours.

The Connect 202 Partners have divided the Project into four design and construction segments: Pecos, Center, Salt River, and Papago (Figure 2). Construction is currently underway on the Pecos, Salt River, and Papago segments, with initial stages of construction beginning in the Center segment. The overall plan is to design and construct both northbound and southbound sides simultaneously and meet in the middle at the Center segment.

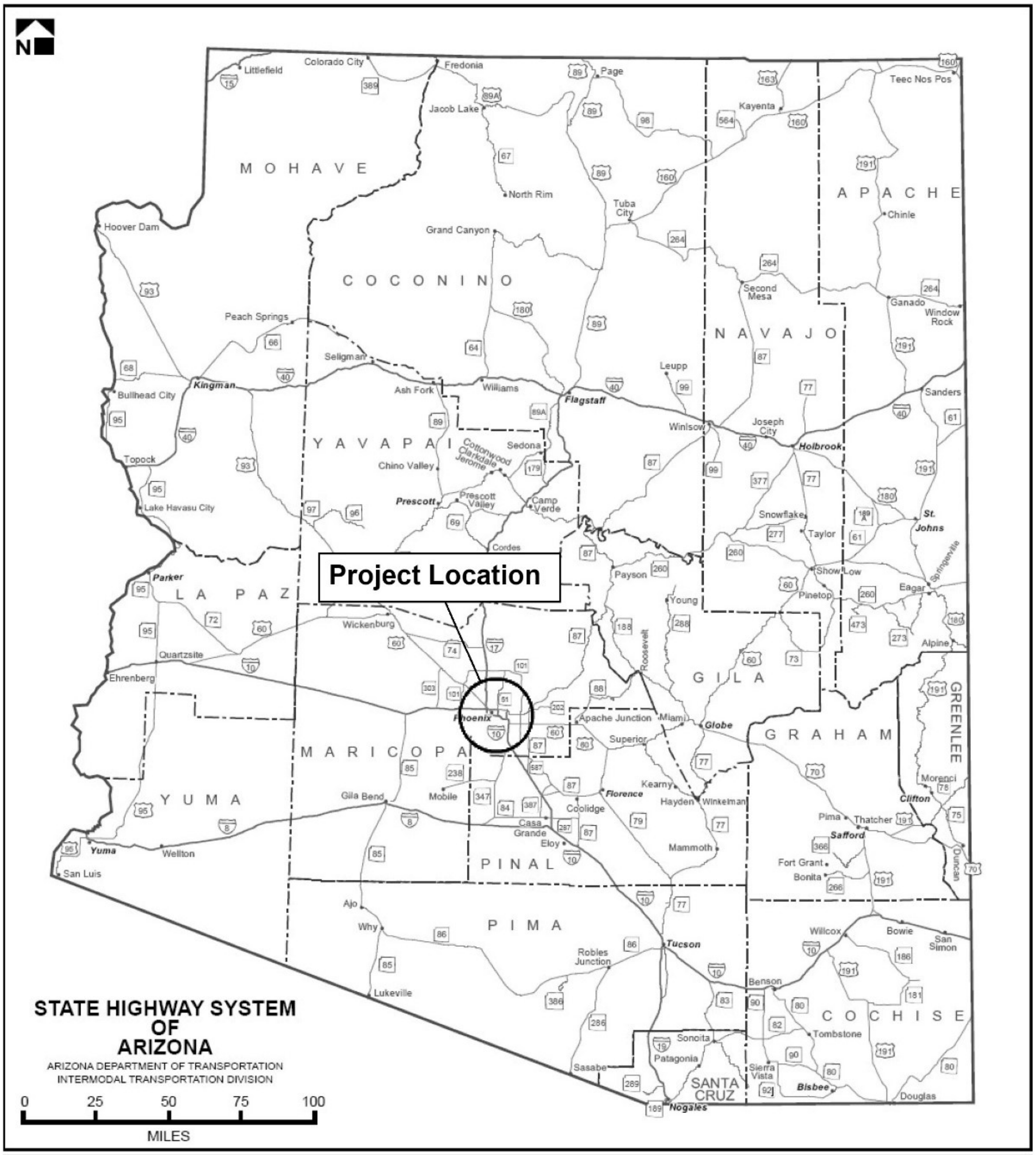
Based on stakeholder interest, a proposed traffic interchange (TI) is being evaluated at the Project’s intersection with Ivanhoe Street in the Center segment (Figure 3). The purpose of the TI is to improve traffic efficiency and operations by providing traffic relief at the Estrella Drive TI and improve transportation access and mobility for the Dusty Lane Community and the Gila River Indian Community. A noise report dated June 2014 was prepared that identified general locations of potential noise barriers in support of the Environmental Impact Statement. During the Project final design, the horizontal and vertical alignments of the SR 202L freeway were updated and a potential design for the proposed TI at Ivanhoe Street was developed.

The roadway typical section consists of eight lanes, with three general-purpose lanes and one high-occupancy vehicle (HOV) lane in each direction. The median is closed with a concrete median barrier dividing the directions of travel. Entrance and exit ramps are designed using a parallel-type configuration coupled with auxiliary lanes between service TIs, as warranted. The freeway main line design primarily features a rolling profile with minimized elevation above grade to cross over crossroads.

In accordance with 23 Code of Federal Regulations 772 and the Arizona Department of Transportation (ADOT) 2011 Noise Abatement Policy (NAP), a traffic noise analysis is required for any projects that receive federal-aid funds or are otherwise subject to Federal Highway Administration (FHWA) approval. They include federal projects that are administered by ADOT. To reflect the proposed TI at Ivanhoe Street, the noise analysis needed to be reevaluated and was based on updated noise analysis requirements.

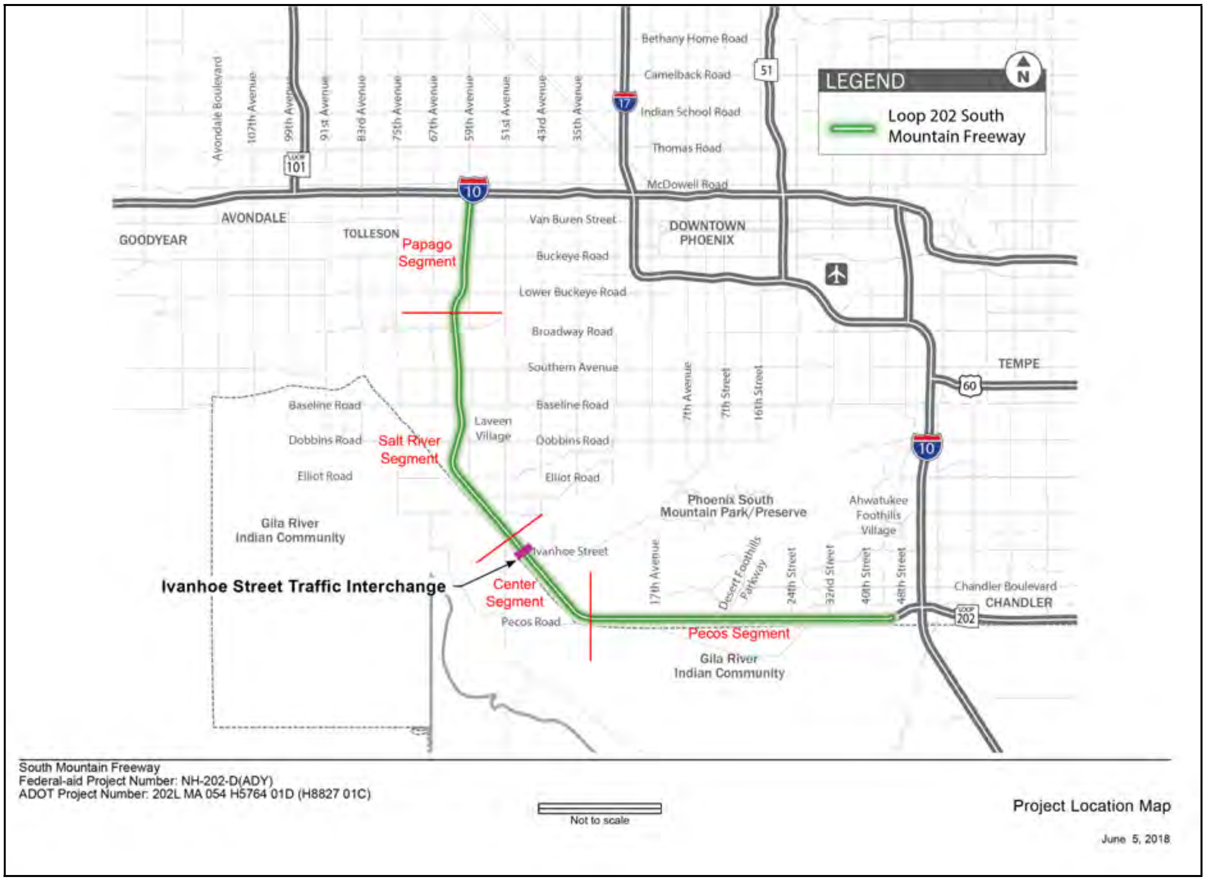
The noise-level analysis presented in this report focused on the proposed Ivanhoe Street TI location in the Center segment. The proposed TI features a

**Figure 1. Project Location**



Loop 202-South Mountain Freeway
NH-202-D(ADY)
202L MA 054 H5764 01D (H8827 01C)
Proposed Ivanhoe Traffic Interchange

**Figure 2. South Mountain Freeway Segments**



tight diamond configuration with on- and off-ramps on both sides of the freeway that would remain within the current Project right-of-way (ROW). Ivanhoe Street would be widened and realigned within the current project ROW to tie in to the TI and accommodate turning movements (Figure 4). The study was performed in accordance with 23 Code of Federal Regulations (CFR) 772, Procedures for Abatement of Highway Traffic Noise and Construction Noise, providing procedures for conducting noise analyses to protect the public health and welfare.

Existing noise-sensitive land uses in the study area were identified using online land use data, aerial imagery, and site reconnaissance.

Land ownership within the Ivanhoe TI evaluation area is private east of the Project and Gila River Indian Community (GRIC) west of the Project. The private land is bordered by the City of Phoenix's South Mountain Park and Preserve (SMPP). Existing land uses within the private land are rural residential and undeveloped.[1]

---

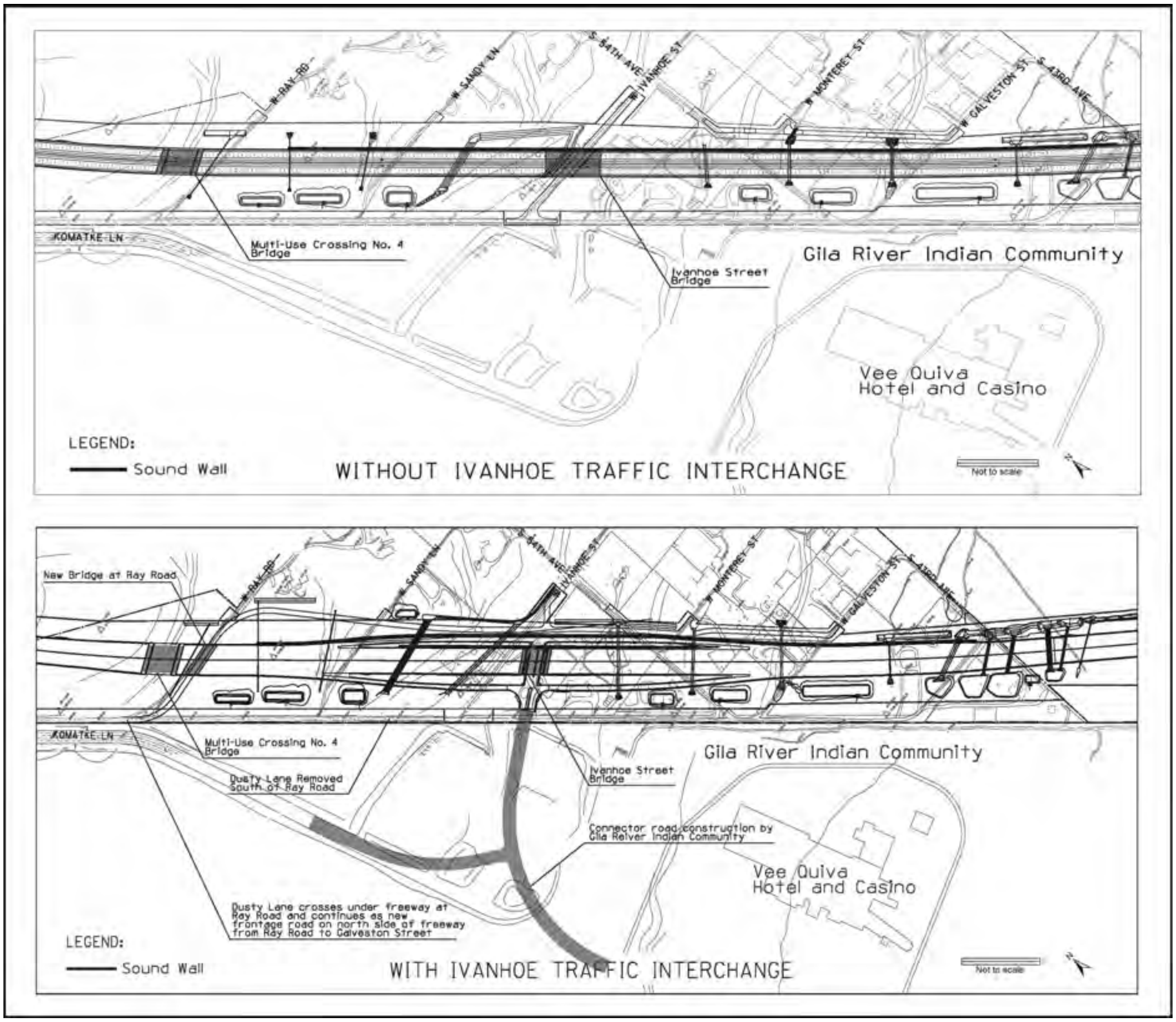
[1] The zoning definition of "developed" is any human-made change to a property, including, *but not limited to*, buildings or other structures, mining, dredging, filling, grading, landscaping, paving, excavating, or drilling.

**Figure 3. Project Vicinity**

| | |
|---|---|
| ADOT | Loop 202-South Mountain Freeway<br>NH-202-D(ADY)<br>202L MA 054 H5764 01D (H8827 01C)<br>Proposed Ivanhoe Traffic Interchange Location |

Land uses on the GRIC are commercial and undeveloped. Noise levels are generally low in this rural area because of the minimal traffic and undeveloped lands on the SMPP and GRIC. The FHWA Noise Abatement Criteria (NAC) land use Categories B (residential) and E (other developed properties or activities) on the eastern side of the Project were the focus of this study.

**Figure 4. Proposed[2] Ivanhoe Traffic Interchange**



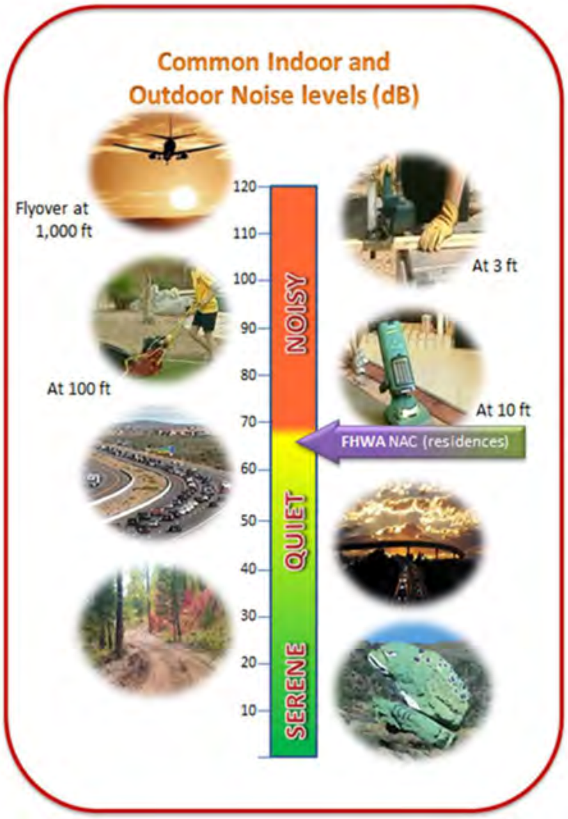
---

[2] See Appendix C for other versions.

## FUNDAMENTALS OF TRAFFIC NOISE

*Sound* is the sensation produced by stimulation of the hearing organs produced by continuous and regular vibrations of a longitudinal pressure wave that travels through an elastic medium (air, water, metal, wood) and can be heard when they reach a person's or animal's ear. When sound travels through air, the atmospheric pressure wave variations occur periodically. It travels in air at a speed of approximately 1,087 feet per second at sea level and a temperature of 32 degrees Fahrenheit. *Noise* is usually defined as any "unwanted sound," and consists of sounds that are perceived as interfering with communication, work, rest, and recreation. It is characterized as a non-harmonious or discordant group of sounds.

**Figure 5. Common Noise Levels**



### Sound Pressure Levels, Decibels, Frequencies, and A-Weighted Decibels

Noise can be measured in pascals (Pa). A healthy human ear can detect a pressure variation of 20 micropascals (μPa), and it is referred to as the threshold of hearing. A logarithmic scale is useful for handling numbers on a wide scale, but for a smaller span, the decibel (dB) scale is used. Sound pressure level is calculated using the measured sound level and the hearing threshold of 20 μPa or 20 x $10^{-6}$ Pa as the reference level; this level can also be defined as 0 dB. The decibel alone is insufficient to describe how the human ear responds to sound pressures at all frequencies. The human ear has a peak response in the range of 2,500 to 3,000 Hertz and has a somewhat low response at low or even high frequencies. In response to the human ear's sensitivity, the A-weighted noise level, referenced in units of dBA, was determined to better resemble people's perception of sound levels. This dBA unit of measurement is used in noise studies and reporting. Changes in sound level under 3 dBA are not noticed by human ear, while the human ear perceives a 10-dBA increase in sound level as a doubling of sound.

### Noise Descriptors

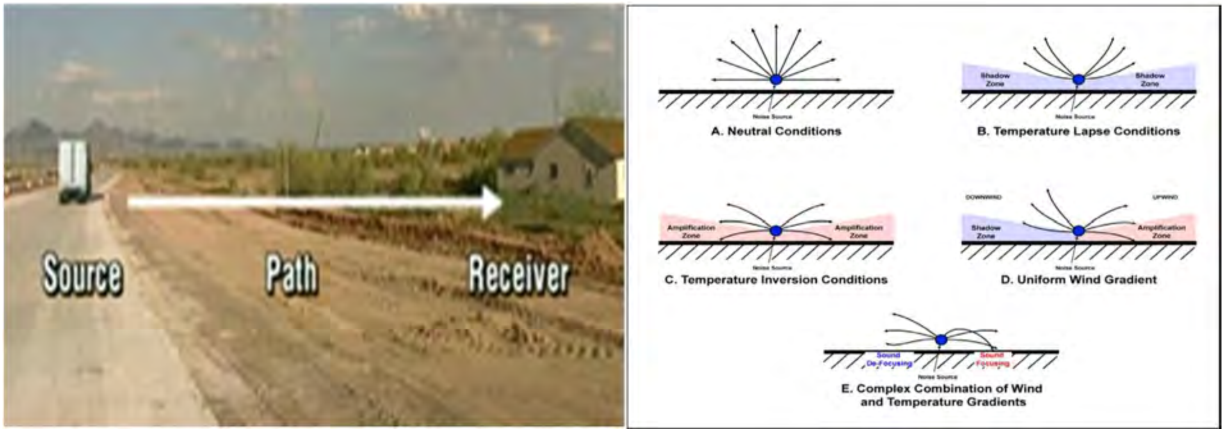
The most commonly used noise descriptor in traffic noise analyses is the equivalent sound level ($L_{eq}$). $L_{eq}$ represents an average of the sound energy occurring over a specified period. In effect, $L_{eq}$ is the steady-state sound level containing the same acoustical energy as the time-varying sound that actually occurs during the same period. The 1-hour A-weighted equivalent sound level [$L_{Aeq(h)}$] is the energy average of A-weighted sound levels occurring during a 1-hour period, and is the basis for noise criteria used by ADOT.

### What are source, receiver, receptor, and path when talking about traffic noise?

*Traffic noise* is a combination of the noises produced by vehicle engines, exhaust, and tires. The source of highway traffic noise comes from vehicles traveling on highways. The noise level at the *source* depends on pavement type, number of heavy trucks, traffic volumes, and traffic speeds. The predominant noise sources in vehicles at speeds less than 30 miles per hour (mph) are the engine and exhaust. At speeds greater than 30 mph, tire noise becomes the dominant noise source.

As shown in Figure 6, the *receptor* is any location where people are affected by the traffic noise. It can be a residence, park, school, playground, and any other place where frequent human use occurs. An area between the source and the receptor (*receiver* represents a receptor or receptors when modeled in the FHWA Traffic Noise Model) is considered a path. Depending on the path surface, propagation of sound may be reduced—such is the case for the soft ground and fresh snow. Doubling the distance between the source and receptor reduces noise by 3 dBA, depending on the ground.

**Figure 6. Source, Propagation Path, Receptor**



Air changes its density as a result of variations in humidity and temperature, and wind influences the refraction of sound waves. Wind, humidity, and temperature may have a significant impact, but only influence the receptors located a long distance away from source.

For more information on noise, please visit the ADOT Environmental Planning Noise webpage.

## METHODOLOGY OF ANALYSIS – INTRODUCTION

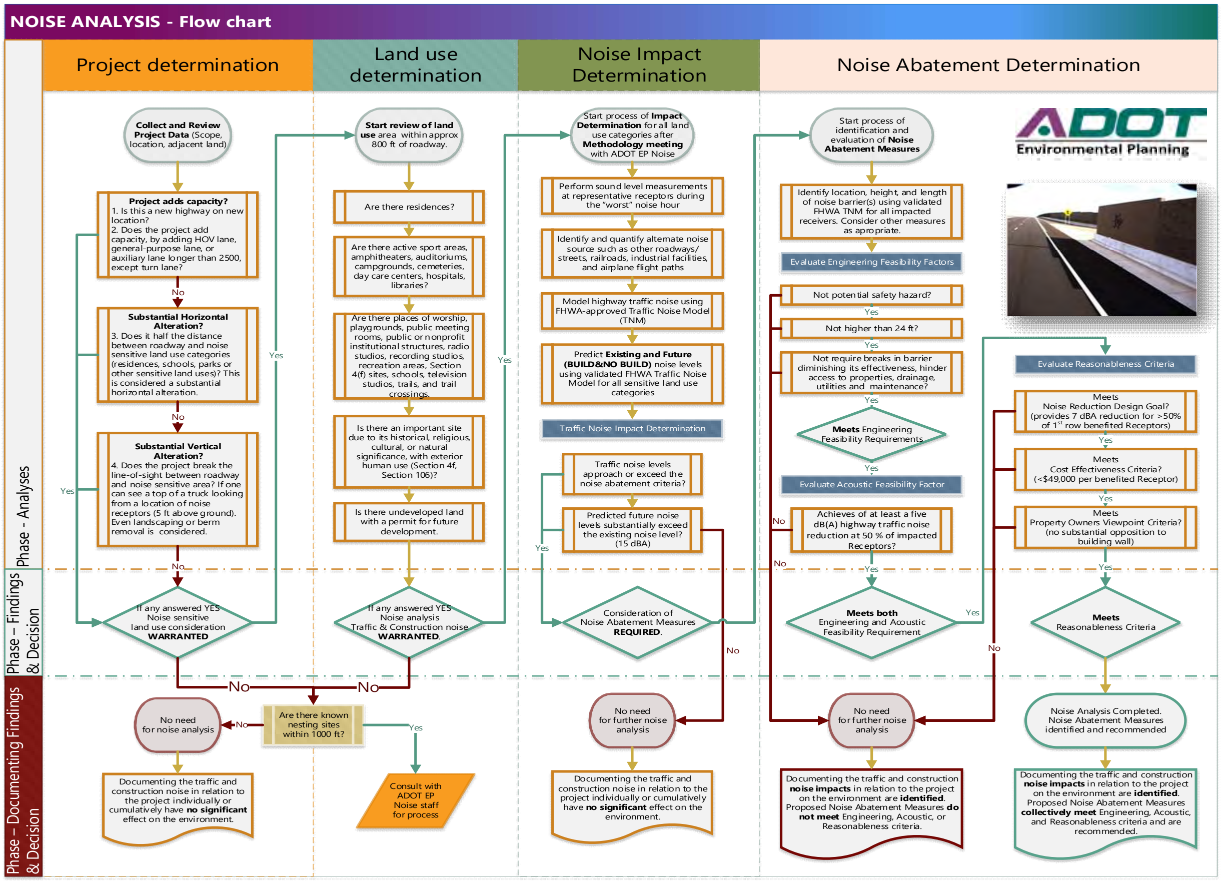
The procedure for conducting a noise analysis is exhibited in Figure 7. In principle, once the project is identified as Type I in line with 23 CFR 772.5, the next three major steps are:

1. Land use determination, answering the question of whether there are noise-sensitive areas, and pertinent Activity Category. If noise-sensitive areas are within approximately 800 to 1,000 feet of the highway, the analysis continues with a noise impact determination.

2. Noise impact determination, answering the question of whether there are any noise-sensitive areas affected by the project. If any of the noise-sensitive areas are determined to be affected, a consideration of noise abatement measures is required.

3. Noise abatement measures, answering the question of whether there are measures that meet all feasibility and reasonableness criteria, in accordance with the ADOT 2011 NAP.

**Figure 7. Noise Analysis Flow Chart**



## APPLICABLE REGULATIONS AND POLICIES

### National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires a "hard look" at the environmental consequences of a decision, and requires that the agencies have genuinely engaged in reasoned decision making. However, agencies are not required to consider in detail alternatives that do not meet the project's purpose or that are infeasible or impractical. Therefore, assumptions must be spelled out, inconsistencies explained, methodologies disclosed, contradictory evidence rebutted, record references solidly grounded, guesswork eliminated, and conclusions supported in a "*manner capable of judicial understanding*."

### National Environmental Policy Act and 23 Code of Federal Regulations 772

NEPA provides broad authority and responsibility for evaluating and mitigating adverse environmental effects, including highway traffic noise. In any environmental study required by NEPA, the Federal-Aid Highway Act of 1970 is an important federal law that specifically involves abatement of highway traffic noise. This law mandated that FHWA develop noise standards for mitigating highway traffic noise. The law required promulgation of traffic noise-level criteria for various land use activities, and further provided that FHWA cannot approve the plans and specifications for a federally aided highway project unless the project includes adequate noise abatement measures to comply with the standards. FHWA regulations for mitigation of highway traffic noise in the planning and design of federally aided highways are contained in 23 CFR 772. It is FHWA's view that the noise analysis performed to satisfy the requirements of 23 CFR 772 generally satisfies the requirements under NEPA.

The regulations require the following steps during the planning and design of a highway project:

- Identification of traffic noise impacts,
- Examination of potential mitigation measures,
- Incorporation of reasonable and feasible noise mitigation measures into the highway project, and
- Coordination with local officials to provide helpful information on compatible land use planning and control.

The regulations contain noise abatement criteria, which represent the upper limit of acceptable highway traffic noise for different types of land uses and human activities.

Compliance with the noise regulations is a prerequisite for the granting of federal-aid highway funds for construction or reconstruction of a highway.

## ADOT Noise Abatement Policy

The federal-aid highway program has always been based on a strong state-federal partnership. At the core of that partnership is a philosophy of trust and flexibility, and a belief that the states are in the best position to make investment decisions that are based on the needs and priorities of their citizens.[3] The FHWA noise regulations give each state department of transportation flexibility in determining the reasonableness and feasibility of noise abatement and, thus, in balancing the benefits of noise abatement against the overall adverse social, economic, and environmental effects and costs of the noise abatement measures. The state department of transportation must base its determination on the interest of the overall public good, keeping in mind all the elements of the highway program (need, funding, environmental impacts, public involvement, etc.).

ADOT has developed the NAP in coordination with FHWA, Arizona Division, in compliance with the noise regulation at 23 CFR 772. In addition to federal projects, the ADOT 2011 NAP[4] applies to other ADOT-funded projects that involve:

- Construction of a highway on a new alignment, or
- A significant change in the horizontal or vertical alignment of an existing highway, or
- Addition of new through lanes to an existing highway.

## Applicable Local Land Use Ordinance

The Zoning Ordinance for the Unincorporated Area of Maricopa County (the Ordinance) is used to appropriately interpret definitions and land use categories, in particular those pertinent to the noise analysis. The Ordinance is designed to promote the public health, peace, safety, comfort, convenience, and general welfare of the citizens of Maricopa County and, among other issues:

- To guide, control, and regulate future growth and development in order to promote orderly and appropriate use of land in the entire unincorporated area of said county;
- To protect the character and the stability of residential, business, and industrial areas of Maricopa County; and
- To facilitate existing or potential traffic movements.

The Ordinance provides definition of terms referred to in the analysis, such as *dwelling unit* and *family*.

---

[3] https://www.fhwa.dot.gov/environMent/noise/regulations_and_guidance/polguide/polguide05.cfm

[4] In 2017, ADOT developed the Noise Abatement Requirements (NAR) in coordination with FHWA, Arizona Division, along with a number of instructions on the processes and phases of noise analyses. Noise abatement measures proposed are also in compliance with the NAR.

## NOISE IMPACT CRITERIA

In developing the NAC contained in the noise regulations, FHWA attempted to strike a balance between that which is most desirable and that which is feasible.

Factors such as technical feasibility, the unique characteristics of highway-generated noise, cost, overall public interest, and other agency objectives were important elements in the process of setting a standard.

Establishing values for the NAC was approached by attempting to balance the control of future increases in highway noise levels and the economic, physical, and aesthetic considerations related to noise abatement measures. Numerous approaches were considered in establishing the criteria, including (1) hearing impairment; (2) annoyance, sleep, and task interference or disturbance; and (3) interference with speech communication. The first deals with very loud noises seldom encountered for a highway project beyond the roadway proper. The second approach was desirable in principle but was insufficiently researched to be useful in practice. The third approach—speech interference—was usefully applied to the problem of highway traffic noise.

Thus, it should be remembered that the NAC are based on noise levels associated with interference of speech communication and that the NAC are a compromise between noise levels that are desirable and those that are achievable. FHWA believes that its regulations provide a well-balanced approach to the problem of highway traffic-generated noise.

The NAC (Table 1) are not magical numbers, and should only be used as absolute values which, when approached or exceeded, require the consideration of traffic noise abatement measures.

As required by 23 CFR 772.5, ADOT defines a substantial increase in noise levels as an increase in noise levels of 15 dBA in the predicted noise level over the existing noise level. As required by 23 CFR 772.11(e), the point at which the noise levels "approach" the NAC is defined by ADOT as 3 dBA for Categories A, B, C, D, and E. There is no noise impact threshold for Category F or Category G locations.

## Table 1. FHWA Noise Abatement Criteria[1]

| Activity Category | dBA, $L_{eq1h}$[2] | Activity Description |
|---|---|---|
| A | 57<br>(exterior) | Land 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<br>(exterior) | Residential |
| C | 67<br>(exterior) | Active sports areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings |
| D | 52<br>(interior) | Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio structures, recording studios, schools, and television studios |
| E | 72<br>(exterior) | Hotels, motels, offices, restaurants/bars, and *other developed lands, properties, or activities* not included in Categories A–D or F |
| F | — | Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing |
| G | — | Undeveloped lands that are not permitted |

[1] Sources: Federal Highway Administration (2011); 23 Code of Federal Regulations 772

[2] The 1-hour equivalent loudness in A-weighted decibels, which is the logarithmic average of noise over a 1-hour period

## DETERMINATION OF EXISTING NOISE LEVELS

The methodology used for the highway noise level measurement is to comply with procedures specified in Section 4, *Existing Noise Measurements in the Vicinity of Highways,* of the FHWA document FHWA-PD-96-046/DOT-VNTC-FHWA-96-5, *Measurement of Highway-Related Noise* (1996), or any other subsequently FHWA-approved methodology.

Measurements are to be taken under meteorologically acceptable conditions, with winds less than 12 mph and dry pavement. All measurement equipment shall have a valid calibration certificate at the time of measurements, in line with the ADOT NAR and *Instruction on Determination of Existing Noise Levels and Noise Measurement Data Form*.

In general for all activity categories, existing noise levels should be established by:

- Field measurements alone during the *worst noise hour*, or
- Field measurements in combination with the FHWA Traffic Noise Model (TNM) and, if necessary, other noise prediction models depending on the existence of background noise sources.

Field measurements are required because existing background noise is usually a composite from many sources, and noise prediction models are applicable only to noise originating from a specific source.

The noise levels within the project area were taken in 2015 and were in a range of 48 to 52 dBA, and those levels are similar to noise levels in nearby parks.

## FUTURE PREDICTED NOISE LEVELS

Future predicted traffic noise analysis relies on project-specific traffic data, provided by the Maricopa Association of Governments (MAG) for 2040 (see Appendix B).

According to the ADOT 2011 NAP, when predicting noise levels for the design year, a “worst-case” approach should be used, wherein the traffic characteristics that produce the worst traffic noise impact should be used in the analysis. In general, this should reflect level of service (LOS) C traffic conditions during the peak noise hour, with traffic moving at 5 mph above the posted speed limit; however, if future traffic volumes are less than maximum LOS C volumes, then future traffic volumes will be utilized. If no other information is available, the peak hourly volume should be 10 percent of the predicted daily volume, which was used in the analysis.

It is important to understand that the noise levels established in this way are unlikely to occur but are required in the analysis to ensure the potential noise abatement measures would perform even under these conditions.

### Roadway Geometry, Topographic Data, and Ground Type

The roadway geometry data used for the noise modeling effort, such as roadway and lane width and horizontal and vertical coordinates, were based on the electronic roadway geometry data and plans provided. The main line was modeled as 40-foot, two-lane roadways in each direction with lateral distribution of traffic volumes and mix. On and off ramps were modeled as 24-foot, one-lane roadways.

Terrain lines determined the elevation of sound propagation-interfering features between the source and the noise receiver. The ground type for modeling purposes was assumed as hard soil, as in the other areas in the Project, although loose soil would better correspond to the field assessment.

### Traffic Volumes and Mix

Different vehicle types have different noise emission levels, with trucks producing higher noise levels than passenger automobiles. Furthermore, trucks with higher cargo weight capacity produce higher noise levels than trucks of lower cargo weight capacity. Vehicles are categorized as follows:

- Automobiles are categorized as vehicles with two axles and four wheels designed primarily for passenger or cargo (light trucks) transportation. Generally, the gross weight of an automobile is less than 10,000 pounds.
- Medium trucks are categorized as vehicles having two axles. Generally, the gross weight of a medium truck is greater than 10,000 pounds but less than 26,400 pounds.
- Heavy trucks are categorized as vehicles having three or more axles and designed for the transportation of cargo. Generally, the gross weight of a heavy truck is greater than 26,400 pounds.

Traffic projections for 2040, with and without the proposed TI, are shown in Table 2 and Appendix B.

**Table 2. Traffic Projections**

| 2040 | NORTHBOUND TRAFFIC DISTRIBUTION | | | | SOUTHBOUND TRAFFIC DISTRIBUTION | | | |
|---|---|---|---|---|---|---|---|---|
| Scenario | BUILD | | NO BUILD | | BUILD | | NO BUILD | |
| Lateral distribution | Lane 1 | Lane 2 | Lane 1 | Lane 2 | Lane 1 | Lane 2 | Lane 1 | Lane 2 |
| Auto | 2381 | 1654 | 2323 | 1614 | 2233 | 1552 | 2328 | 1618 |
| Medium Truck | 274 | 59 | 273 | 59 | 264 | 60 | 271 | 60 |
| Heavy Truck | 699 | 150 | 706 | 150 | 424 | 96 | 427 | 96 |
| Total | 5217 | | 5125 | | 4629 | | 4800 | |

### Vehicle Speed

The modeled vehicle speeds on the main line were 70 mph, which is 5 mph above the posted speed limit (65 mph). On and off ramps were modeled in line with Table 1 of NCHRP Report 311, Guidelines for Modeling Deceleration Roadways.

### Atmospheric Variables

Noise level is affected by temperature and humidity, particularly at longer distances and with uninterrupted noise propagation conditions. For noise modeling purposes, FHWA recommends the default values for temperature of 68 degrees Fahrenheit and for humidity of 50 percent.

### Receptor and Receiver Locations

The ADOT 2011 NAP define a "receptor" as a discrete or representative location of a noise-sensitive area(s) for any of the land uses in the project area. The "receiver" is defined as a location used in noise modeling to represent the measured and predicted noise level at a particular point. The noise-sensitive receptors are located in the backyard or common outdoor areas of residential and other noise-sensitive areas and properties.

23 CFR 772.11(c)(3) stipulates that a traffic noise analysis shall be completed for each activity category of the NAC listed in Table A-1 (Appendix A) that is present in the study area.

A team composed of experts with appropriate background in legal aspects of land use, roadway construction, and traffic noise ensured the most appropriate process was followed for all the properties and other land use categories within the Project area affected by the construction.

An integral part of that process was receiving information from the property owners and their representatives as to the use of their properties, and eventual exceptional circumstances. It has been established that certain areas of their properties, outside of the residential areas, were frequently used for human activities for recreational purposes, such as running or bicycle paths and trails, picnic areas, and playgrounds including autistic children.

The community has a very developed sense of belonging and, in the absence of similar infrastructure, relies on using its own properties regularly for these activities that would normally be readily available within urban residential areas. It has been decided that simple "roof-counting" would not constitute the hard look and further scrutiny of the land use that is essential for ensuring genuine engagement in a reasoned decision-making process.

Furthermore, the Ordinance provided definitions of terms and their application.

Land use category identification was performed pursuant to 23 CFR 772.11(c)(3), whereby it is stipulated that a traffic noise analysis shall be completed for each activity category of the NAC listed in Table A-1 (Appendix A) that is present in the study area. An inventory of all receptors within 2,000 feet was completed to address concerns of the community (normally, the analysis would focus on the area within 1,000 feet; however, after initial modeling, and due to noise propagation conducive topography, the area was expanded to account for all potentially affected properties and was subsequently incorporated into FHWA's TNM).

The area under analysis was represented by Categories B, E, and F, as applicable. Category F was not included in the analysis.

All considered lots were zoned as RU-43.

The first step was to account for residential buildings/dwelling units. Properties with residential buildings received a single receptor for every residence on their property, and were considered as activity Category B or as a multifamily dwelling, if applicable. Lots larger than 43,560 square feet, and with a residence, or residences, were evaluated if the remainder of the lot has an outdoor activity corresponding to the activity of Category F or, potentially, E, because it was determined that representing the entire lot as a residential area, activity Category B, was not in line with the understanding of Article 503 of the Ordinance—1 acre per dwelling unit, and the definition of terms provided therein. Other properties zoned as RU-43 were considered as activity Category F or E, depending on the frequent human use determination after closely looking into individual properties and aerial imagery available at the Maricopa County Assessor's Office. All properties, or their respective areas, that had activities identified as farms, parking lots, agriculture, industrial, logging, maintenance facilities, manufacturing, mining, retail facilities, utilities (water resources, water treatment, electrical), and warehousing were considered as activity Category F and were not included in the impact analysis.

For a lot area of at least 7,500 square feet, an average size of a residential lot in Arizona, that was potentially being used by the community as recreational, closely resembling the listed activities of, but not categorized as, Category C, a receiver was placed under the definition of activity Category E: "other developed lands, properties or activities not included in A–D or F."

ADOT NAP 4.b.1 says "*For other non-residential areas such as many of the Category C, D, and **E locations** listed in where the number of Receptors is not easily defined, the number and placement of receivers should consider the size of the area as well as the amount and intensity of use…*"

Furthermore, the process continues as "*(a) Determine the base number of Receptors in the area: divide the total land area of the receiver by 7,500 sqft, roughly the average size of a residential lot in Arizona.*
*(b) Considering the intensity of use, assign one of the following values to each activity area:*

> *(i) • 0.5 – Low Intensity Area. **A part of an area that receives limited use**, or which is used primarily during non-peak traffic hours. Possible Examples: A general use section of a park, an overflow section of a camping ground, etc.*

> *(ii) • 1 – Moderate Intensity Area. A part of an area that receives use comparable to a standard residence. Possible Examples: a small youth activity center, a designated picnic area, etc.*
>
> *(iii) • 2 – High Intensity Area. An area which is used by either a moderate amount of people constantly or by a large number of people at one time.*

*(c) Multiply the number of receivers from a) by the intensity of use determined in b) and place those receivers where the activity is most likely to occur. If this can't be determined, then the receivers should be distributed evenly across the area.*

*(d) Similar approach is to be used for land-development areas, where a lot of approx. 7500 sqft is to be considered as a single family residential facility, unless other facility is stated in the land use documents."*

In this case, the area was identified predominantly as a Low Intensity Area, with a factor of 0.5. Areas that met the definition of activity Category E were represented by the number of receivers as mentioned previously.

### Shielding Effects

TNM 2.5 can account for the noise shielding effects created by existing noise barriers, privacy walls, buildings, and terrain changes that are an obstruction between noise sources and receptors. Cut-and-fill slopes and corresponding elevation changes were modeled as terrain lines.

Based on the assumptions stated in this report, FHWA TNM 2.5 predicts noise levels along the project route in the design year after construction of the project has occurred. Actual noise levels in the future may differ somewhat due to a number of factors outside the scope of this modeling effort.

This analysis determines the traffic noise impacts based upon the FHWA NAC, which are referred to in the ADOT 2011 NAP.

## IMPACT DETERMINATION AND CONSIDERATION OF ABATEMENT

ADOT considers mitigation for receivers predicted to be affected by traffic noise associated with a proposed transportation improvement project. For a mitigation measure, such as a noise barrier, to be proposed in the project it must meet both feasibility and reasonableness criteria.

Pursuant to 23 CFR 772.13(d)(1), the initial consideration for each potential abatement measure should be both the engineering and acoustic factors that determine whether it is possible to design and construct the measure.

According to ADOT NAP, some of the engineering feasibility factors are:

- Safety, barrier height, curvature, and breaks in barriers
- Topography, drainage, and utilities
- Maintenance requirements, access to adjacent properties
- Overall project purpose

Barrier height should not normally be higher than 20 feet for a stand-alone structure.

For a noise abatement measure to be acoustically feasible, ADOT requires achievement of at least a 5-dBA highway traffic noise reduction at 50 percent of affected receptors. In some instances, the noise level at a particular location may be affected by another noise source, such as other roadways/streets, railroads, industrial facilities, and airplane flight paths. In such locations, noise abatement for the proposed transportation project may not be acoustically feasible, since a substantial overall noise reduction cannot be achieved because of other noise sources.

According to ADOT 2011 NAP, three reasonableness factors or "tests" must be achieved in order for a noise abatement measure to be deemed reasonable. These are:

- Viewpoints or preferences of property owners and residents,
- Noise reduction design goal, and
- Cost-effectiveness.

Noise barriers should be designed to reduce projected unmitigated noise levels by at least 7 dBA for benefited receptors *closest to the transportation facility*. To be considered reasonable, at least half of the benefited receptors in the first row shall achieve this level of noise reduction. The maximum reasonable cost of abatement is $49,000 per benefited receptor (cost-per-benefited-receptor), with barrier costs calculated at $35 per square foot, or $55 per square foot if constructed on a structure.

Although the cost of wall per square foot in the project area is $25, as established by previous similar contract details, it has been determined that using $35 per square foot would be appropriate to ensure uniform and consistent application of the ADOT 2011 NAP at the environmental phase of the transportation project development.

In the course of establishing the most appropriate noise barrier locations and characteristics, every effort was made to find a common denominator between maximum achievable noise reduction while achieving and maintaining its cost effectiveness.

The existing noise levels, future-not-mitigated noise levels, and future-mitigated noise levels, including the benefit determination and rounded up to the nearest value, are shown in Table A-1 in Appendix A. Table 3 shows the estimated cost of the proposed noise barriers.

## Table 3. Cost of Noise Barriers

| Barriers | Height | Length | Area | Cost per sqft | Barrier cost | Benefited receptors | CPBR |
|---|---|---|---|---|---|---|---|
| | (ft) | (ft) | (sqft) | ($/sqft) | ($) | Unit | ($) |
| System of 3 barriers | 10-12-14 | 4536 | 52734 | 35 | 1845690 | 39 | 47325 |
| Mainline Barrier | 10-12-14 | 4202 | 51593 | 35 | 1805755 | 41 | 44043 |

CPBR – cost-per-benefited-receptor

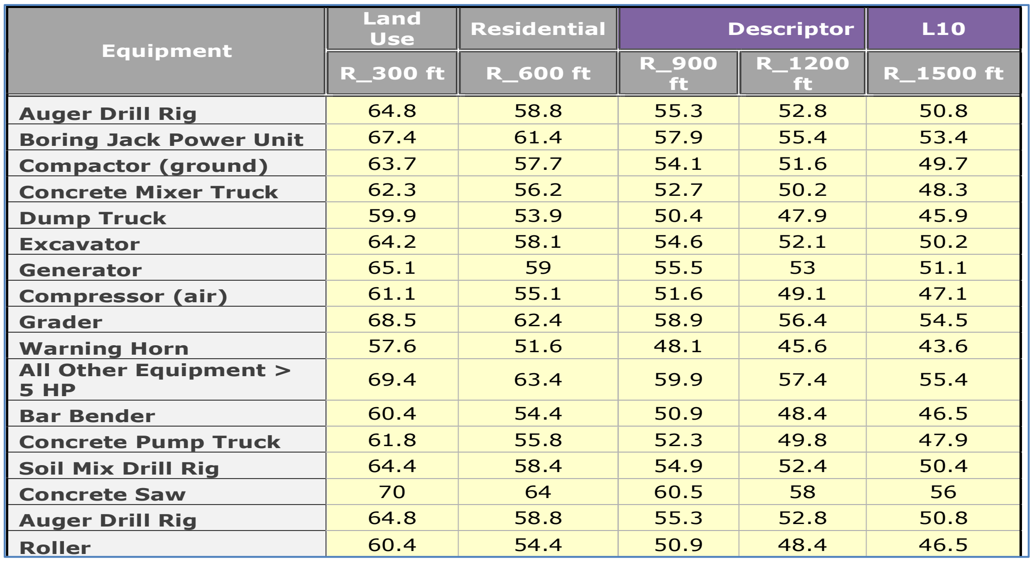
The barriers meet all feasibility and reasonableness criteria, including a cost-per-benefited-receptor below the ADOT NAP threshold of $49,000. During the public involvement process, it was evident the residents were overwhelmingly in favor of constructing a noise barrier; coordination with the affected community incorporates resident input into the final solution. The agreement to provide a 14-foot high barrier for the community has been reached for visual (line-of-sight) and aesthetic purposes for noise barriers that are feasible and meet cost-effectiveness criteria. As per the agreement reached with the community, the barrier shall be 14 feet in height throughout, including the safety barrier.

## CONSTRUCTION NOISE AND VIBRATION

Depending on the nature of construction operations, the duration of the noise could last from seconds (e.g., a truck passing a customer) to months (e.g., constructing a bridge). Construction noise is also intermittent and depends on the type of operation, location, and function of the equipment and the equipment usage cycle. Construction equipment is typically considered as a point source, as opposed to traffic, which is considered as a line source; therefore, the noise level decreases, theoretically, by 6 dBA per doubling the distance from it, as opposed to 3 dBA for a line source.

Noise levels at various distances, using listed equipment, are shown in Table 4. ADOT has set forth guidelines for construction noise in the *Standard Specifications for Road and Bridge Construction*, 2008. According to ADOT specification 104.08, Prevention of Air and Noise Pollution: "The contractor shall comply with all local sound control and noise rules, regulations and ordinances which apply to any work pursuant to the contract. Each internal combustion engine used for any purpose on the work or related to the work shall be equipped with a muffler or a type recommended by the manufacturer. No internal combustion engine shall be operated on the work without its muffler being in good working condition."

### Table 4. Construction Noise Levels at Various Distances from the Equipment



| Equipment | Land Use | Residential | Descriptor | | L10 |
|---|---|---|---|---|---|
| | R_300 ft | R_600 ft | R_900 ft | R_1200 ft | R_1500 ft |
| Auger Drill Rig | 64.8 | 58.8 | 55.3 | 52.8 | 50.8 |
| Boring Jack Power Unit | 67.4 | 61.4 | 57.9 | 55.4 | 53.4 |
| Compactor (ground) | 63.7 | 57.7 | 54.1 | 51.6 | 49.7 |
| Concrete Mixer Truck | 62.3 | 56.2 | 52.7 | 50.2 | 48.3 |
| Dump Truck | 59.9 | 53.9 | 50.4 | 47.9 | 45.9 |
| Excavator | 64.2 | 58.1 | 54.6 | 52.1 | 50.2 |
| Generator | 65.1 | 59 | 55.5 | 53 | 51.1 |
| Compressor (air) | 61.1 | 55.1 | 51.6 | 49.1 | 47.1 |
| Grader | 68.5 | 62.4 | 58.9 | 56.4 | 54.5 |
| Warning Horn | 57.6 | 51.6 | 48.1 | 45.6 | 43.6 |
| All Other Equipment > 5 HP | 69.4 | 63.4 | 59.9 | 57.4 | 55.4 |
| Bar Bender | 60.4 | 54.4 | 50.9 | 48.4 | 46.5 |
| Concrete Pump Truck | 61.8 | 55.8 | 52.3 | 49.8 | 47.9 |
| Soil Mix Drill Rig | 64.4 | 58.4 | 54.9 | 52.4 | 50.4 |
| Concrete Saw | 70 | 64 | 60.5 | 58 | 56 |
| Auger Drill Rig | 64.8 | 58.8 | 55.3 | 52.8 | 50.8 |
| Roller | 60.4 | 54.4 | 50.9 | 48.4 | 46.5 |

Ground vibration and groundborne noise can also be a source of annoyance to individuals who live or work close to vibration-generating activities. Pile driving, demolition activity, blasting, and crack-and-seat operations are the primary sources of vibration, while the impact pile driving can be the most significant source of vibration at construction sites. It is recommended to apply methods that may be practical and appropriate in specific situations, to reduce vibration to an acceptable level. Such measures may be:

- Jetting
- Predrilling
- Cast-in-place or auger cast piles
- Non-displacement piles
- Pile cushioning
- Using alternative non-impact drivers
- Scheduling activities to minimize disturbance at near-construction sites

## COORDINATION WITH LOCAL OFFICIALS

At the time of the preparation of this noise analysis technical report, results had not been presented to local officials. Upon request of the local land use planning agency or local public agency, noise contour lines may be produced during the noise analysis process for Project alternative screening and planning purposes only, in accordance with the ADOT NAP.

## STATEMENT OF LIKELIHOOD

In accordance with 23 CFR 772.13(g)(3), the noise analysis was completed to the extent of design information that is available at this time. A statement of likelihood is included since feasibility and reasonableness determinations may change due to changes in Project design subsequent to the approval.

## REFERENCES

1. Arizona Department of Transportation, *Noise Abatement Policy*, 2011.
2. Arizona Department of Transportation, *Standard Specifications for Road and Bridge Construction*, 2008.
3. Federal Highway Administration, *FHWA Traffic Noise Model, Version 1.0: Technical Manual and Addendums* (FHWA PD-96-010,) February 1998.
4. Federal Highway Administration, *Highway Traffic Noise Analysis and Abatement Policy and Guidance*, June 1995.
5. Federal Highway Administration, *Recommended Best Practices for the Use of the FHWA Traffic Noise Model (TNM)*, FHWA-HEP-16-018, December 2015.
6. Federal Highway Administration, *Measurement of Highway Related Noise* (FHWA PD-96-010), May 1996.
7. Federal Highway Administration, *FHWA Construction Noise Handbook*, FHWA-HEP-06-015, August 2006.
8. U.S. Code of Federal Regulations, Title 23, Part 772. Procedures for Abatement of Highway Traffic Noise and Construction Noise.

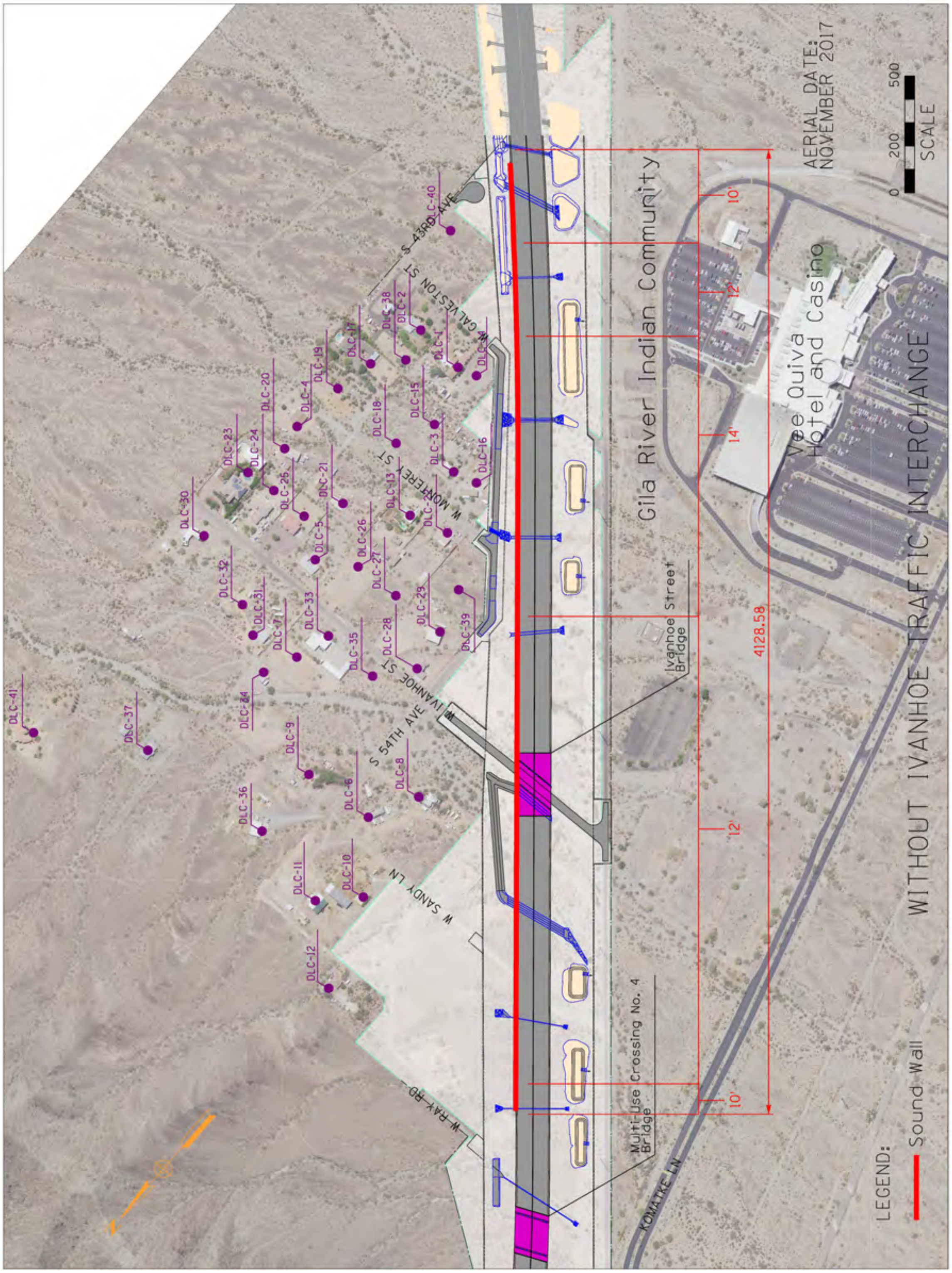
## APPENDIX A

### Table A-1. Existing, Future-Not-Mitigated, and Future-Mitigated Noise Levels

| ID | Receiver | Dwelling Units (equivalent) | Existing | BUILD (WITH TI) | | | NO BUILD | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Unmitigated | Mitigated | Noise Reduction | Unmitigated | Mitigated | Noise Reduction |
| Receiver | Description | Units | (dBA) | (dBA) | (dBA) | (dBA) | (dBA) | (dBA) | (dBA) |
| DLC-1 | R1-B-300-04-018A | 1 | 48-52 | 76 | 67 | **9** | 76 | 66 | **10** |
| DLC-2 | R2-B-300-04-019 | 2 | 48-52 | 73 | 67 | **6** | 73 | 65 | **8** |
| DLC-3 | R1-B-300-04-017N | 1 | 48-52 | 76 | 65 | **11** | 76 | 65 | **11** |
| DLC-4 | R3-B-300-04-023 | 1 | 48-52 | 69 | 63 | **6** | 69 | 62 | **7** |
| DLC-5 | R3-B-300-04-041A | 1 | 48-52 | 70 | 63 | **7** | 70 | 62 | **8** |
| DLC-6 | R2-B-300-04-022E(2) | 1 | 48-52 | 70 | 63 | **7** | 71 | 63 | **8** |
| DLC-7 | R3-E-300-04-004S | 0.5 | 48-52 | 68 | 62 | **6** | 69 | 61 | **8** |
| DLC-8 | R1-B-300-04-022E(1) | 1 | 48-52 | 72 | 64 | **8** | 73 | 64 | **9** |
| DLC-9 | R3-B-300-04-004Q | 1 | 48-52 | 68 | 62 | **6** | 68 | 62 | **6** |
| DLC-10 | R2-B-300-04-003N | 1 | 48-52 | 70 | 63 | **7** | 70 | 63 | **7** |
| DLC-11 | R2-B-300-04-003M | 1 | 48-52 | 69 | 64 | **5** | 69 | 63 | **6** |
| DLC-12 | R3-B-300-04-003F | 1 | 48-52 | 70 | 65 | **5** | 70 | 65 | **5** |
| DLC-13 | R2-B-300-04-017M | 1 | 48-52 | 74 | 65 | **9** | 73 | 64 | **9** |
| DLC-14 | R1-E-300-04-018A | 1 | 48-52 | 77 | 67 | **10** | 77 | 66 | **11** |
| DLC-15 | R1-E-300-04-002W | 1 | 48-52 | 77 | 67 | **10** | 77 | 66 | **11** |
| DLC-16 | R1-B-300-04-017Z | 1 | 48-52 | 79 | 68 | **11** | 79 | 66 | **13** |
| DLC-17 | R2-B-300-04-002V | 1 | 48-52 | 72 | 65 | **7** | 72 | 64 | **8** |
| DLC-18 | R2-E-300-04-002W | 1 | 48-52 | 74 | 66 | **8** | 74 | 64 | **10** |
| DLC-19 | R3-E-300-04-002V | 0.5 | 48-52 | 71 | 65 | **6** | 71 | 64 | **7** |
| DLC-20 | R3-B-300-04-002Z | 1 | 48-52 | 69 | 63 | **6** | 69 | 62 | **7** |
| DLC-21 | R3-B-300-04-002U | 2 | 48-52 | 71 | 64 | **7** | 71 | 63 | **8** |
| DLC-22 | R1-B-300-04-017L | 1 | 48-52 | 76 | 65 | **11** | 76 | 65 | **11** |
| DLC-23 | R3-B-300-04-031A | 1 | 48-52 | 67 | 62 | **5** | 68 | 61 | **7** |
| DLC-24 | R3-B-300-04-032A | 1 | 48-52 | 68 | 62 | **6** | 68 | 62 | **6** |
| DLC-25 | R3-B-300-04-040A | 1 | 48-52 | 69 | 63 | **6** | 69 | 62 | **7** |
| DLC-26 | R2-E-300-04-017T | 1 | 48-52 | 70 | 63 | **7** | 70 | 62 | **8** |
| DLC-27 | R2-E-300-04-017W | 0.5 | 48-52 | 72 | 64 | **8** | 72 | 63 | **9** |
| DLC-28 | R1-B-300-04-042A | 1 | 48-52 | 73 | 64 | **9** | 74 | 64 | **10** |
| DLC-29 | R1-B-300-04-043A | 1 | 48-52 | 74 | 65 | **9** | 75 | 64 | **11** |
| DLC-30 | R3-B-300-04-004K | 1 | 48-52 | 66 | 61 | **5** | 66 | 60 | **6** |
| DLC-31 | R3-B-300-04-046 | 1 | 48-52 | 67 | 61 | **6** | 67 | 61 | **6** |
| DLC-32 | R3-E-300-04-047 | 1 | 48-52 | 67 | 61 | **6** | 67 | 61 | **6** |
| DLC-33 | R2-B-300-04-004T | 1 | 48-52 | 70 | 62 | **8** | 70 | 62 | **8** |
| DLC-34 | R3-B-300-04-044 | 1 | 48-52 | 67 | 61 | **6** | 68 | 61 | **7** |
| DLC-35 | R1-E-300-04-004P | 0.5 | 48-52 | 71 | 63 | **8** | 71 | 63 | **8** |
| DLC-36 | R2-B-300-04-004V | 1 | 48-52 | 67 | 62 | **5** | 68 | 62 | **6** |
| DLC-37 | R4-B-300-04-004Y | 1 | 48-52 | 64 | 60 | 4 | 65 | 60 | **5** |
| DLC-38 | R2-E-300-04-020 | 1 | 48-52 | 74 | 66 | **8** | 74 | 65 | **9** |
| DLC-39 | R1-E-300-04-052A | 1 | 48-52 | 78 | 67 | **11** | 78 | 66 | **12** |
| DLC-40 | R2-E-300-04-048A | 1 | 48-52 | 73 | 67 | **6** | 72 | 67 | **5** |
| DLC-41 | R5-B-300-04-004Z | 1 | 48-52 | 62 | 59 | 3 | 63 | 58 | **5** |

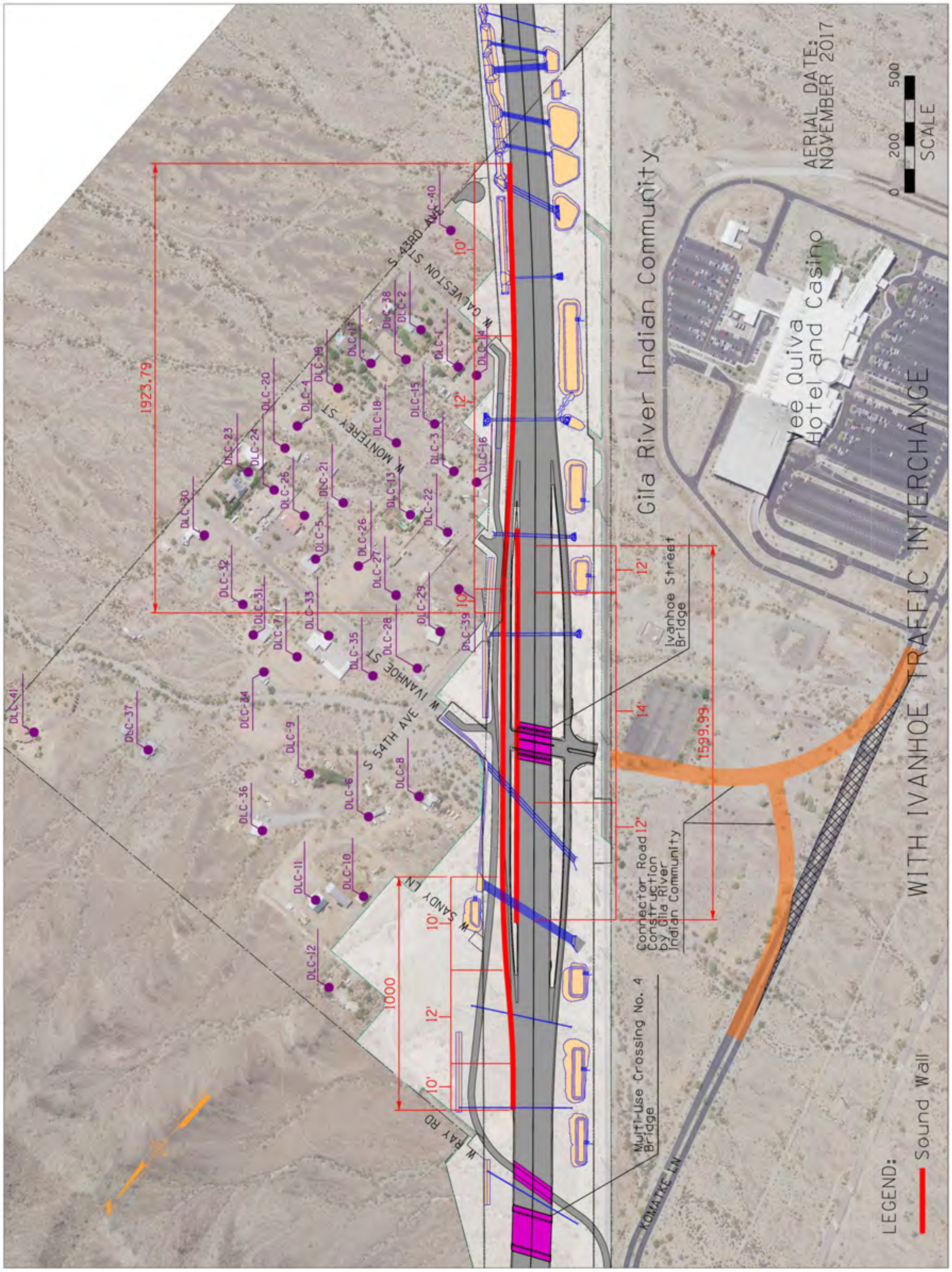
Note: Under Receiver Description, R1 and R2 receivers are closest to the roadway and were used to meet the noise reduction design goal and E = Activity Category E and B = Activity Category B from Table 1. Bold numbers in the Noise Reduction column are benefited receptors included in the cost-per-benefited-receptor calculation.

## Figure A-1. Recommended Noise Barrier Without Traffic Interchange



Note: Receiver locations are approximate

## Figure A-2. Recommended Noise Barrier With Traffic Interchange



Note: Receiver locations are approximate

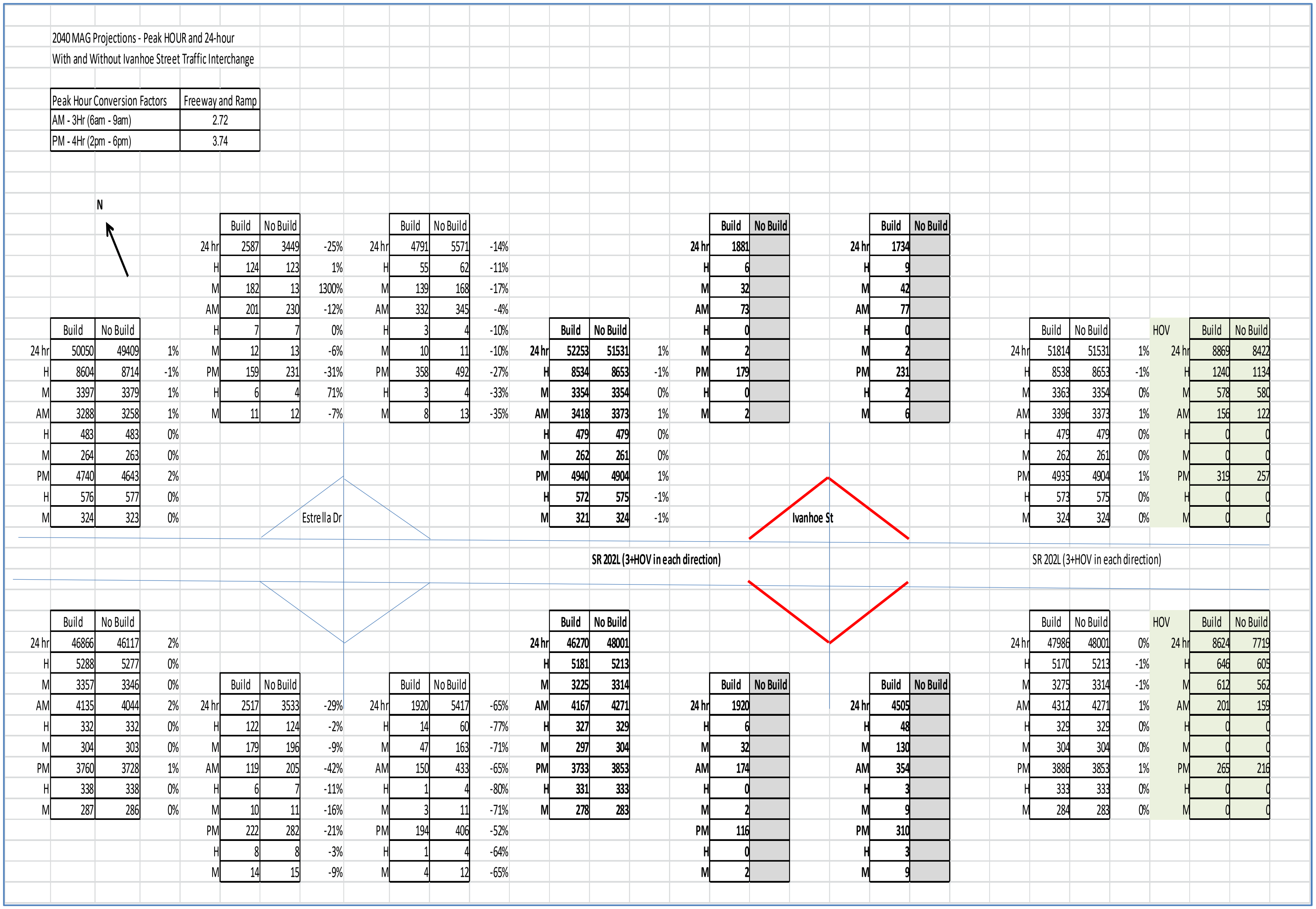
## Table A-2. Recommended Noise Barriers Heights, With and Without Proposed Traffic Interchange

| WITH TI | | | | | | WITHOUT TI | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MainLine NB-12 ft | Station | X | Y | Z | ft | Mainline NB 10-12-14 ft | Station | X | Y | Z | ft |
| | 2601+00.00 | 627,067.40 | 841,938.70 | 1,144.20 | 12 | | 2584+00.00 | 628,202.20 | 840,671.40 | 1,155.30 | 10 |
| | 2602+00.00 | 627,001.60 | 842,016.00 | 1,145.10 | 12 | | 2588+00.00 | 627,924.70 | 840,970.00 | 1,151.70 | 12 |
| | 2603+00.00 | 626,935.80 | 842,093.30 | 1,146.00 | 12 | | 2592+00.00 | 627,658.50 | 841,260.70 | 1,148.10 | 14 |
| MainLine NB-12-14 ft | | | | | | | 2596+00.00 | 627,394.20 | 841,562.10 | 1,144.50 | 14 |
| | 2603+00.00 | 626,935.80 | 842,093.30 | 1,146.00 | 14 | | 2600+00.00 | 627,136.80 | 841,862.40 | 1,143.30 | 14 |
| | 2604+00.00 | 626,869.90 | 842,170.60 | 1,146.90 | 14 | | 2604+00.00 | 626,874.40 | 842,169.90 | 1,146.90 | 12 |
| | 2608+00.00 | 626,610.10 | 842,471.30 | 1,152.10 | 14 | | 2608+00.00 | 626,614.60 | 842,470.70 | 1,152.10 | 12 |
| | 2612+00.00 | 626,348.50 | 842,778.60 | 1,151.70 | 12 | | 2612+00.00 | 626,353.00 | 842,777.90 | 1,151.70 | 12 |
| | 2616+00.00 | 626,090.40 | 843,080.30 | 1,144.90 | 12 | | 2616+00.00 | 626,094.90 | 843,079.70 | 1,144.90 | 12 |
| | 2617+00.00 | 626,024.60 | 843,156.40 | 1,142.95 | 12 | | 2620+00.00 | 625,831.60 | 843,384.10 | 1,137.10 | 12 |
| Off Ramp NB on mainline 10-12 ft | | | | | | | 2624+00.00 | 625,573.70 | 843,682.80 | 1,137.30 | 10 |
| | 2584+00.00 | 628,212.20 | 840,678.90 | 1,155.30 | 10 | | 2626+00.00 | 625,441.70 | 843,837.40 | 1,138.75 | 10 |
| | 2588+00.00 | 627,934.90 | 840,976.00 | 1,151.70 | 10 | | | | | | |
| | 2592+00.00 | 627,679.00 | 841,271.40 | 1,148.10 | 10 | | | | | | |
| Off Ramp NB 10-12 ft | | | | | | | | | | | |
| | 2592+00.00 | 627,679.00 | 841,271.40 | 1,148.10 | 12 | | | | | | |
| | 16+00.00 | 627,473.60 | 841,516.90 | 1,146.30 | 12 | | | | | | |
| | 17+00.00 | 627,405.30 | 841,608.90 | 1,144.30 | 12 | | | | | | |
| | 18+00.00 | 627,347.10 | 841,687.60 | 1,144.77 | 12 | | | | | | |
| | 19+00.00 | 627,288.30 | 841,766.30 | 1,144.51 | 12 | | | | | | |
| | 20+00.00 | 627,225.00 | 841,845.80 | 1,144.26 | 12 | | | | | | |
| | 21+00.00 | 627,162.60 | 841,925.10 | 1,143.63 | 12 | | | | | | |
| | 22+00.00 | 627,099.70 | 842,004.40 | 1,142.59 | 12 | | | | | | |
| | 23+00.00 | 627,036.80 | 842,083.60 | 1,141.54 | 10 | | | | | | |
| | 24+00.00 | 626,973.10 | 842,162.50 | 1,140.50 | 10 | | | | | | |
| On Ramp NB-10-12-10 ft | | | | | | | | | | | |
| | 16+00.00 | 626,234.30 | 843,017.90 | 1,137.40 | 10 | | | | | | |
| | 17+00.00 | 626,165.50 | 843,092.30 | 1,138.20 | 10 | | | | | | |
| | 18+00.00 | 626,098.40 | 843,163.20 | 1,140.00 | 10 | | | | | | |
| | 19+00.00 | 626,027.50 | 843,237.60 | 1,139.60 | 10 | | | | | | |
| | 20+00.00 | 625,958.40 | 843,311.00 | 1,139.20 | 12 | | | | | | |
| | 21+00.00 | 625,887.80 | 843,383.70 | 1,138.80 | 12 | | | | | | |
| | 22+00.00 | 625,820.90 | 843,456.10 | 1,138.40 | 12 | | | | | | |
| | 23+00.00 | 625,755.60 | 843,528.90 | 1,138.00 | 12 | | | | | | |
| | 24+00.00 | 625,687.80 | 843,601.40 | 1,137.60 | 10 | | | | | | |
| | 25+00.00 | 625,623.20 | 843,676.10 | 1,137.20 | 10 | | | | | | |
| | 26+00.00 | 625,556.80 | 843,751.20 | 1,137.00 | 10 | | | | | | |

As per the agreement reached with the community the barrier shall be 14 feet in height throughout.

## APPENDIX B

## Table B-1. Project Traffic Projections – MAG 2040



2040 MAG Projections - Peak HOUR and 24-hour
With and Without Ivanhoe Street Traffic Interchange

| Peak Hour Conversion Factors | Freeway and Ramp |
|---|---|
| AM - 3Hr (6am - 9am) | 2.72 |
| PM - 4Hr (2pm - 6pm) | 3.74 |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 50050 | 49409 | 1% |
| H | 8604 | 8714 | -1% |
| M | 3397 | 3379 | 1% |
| AM | 3288 | 3258 | 1% |
| H | 483 | 483 | 0% |
| M | 264 | 263 | 0% |
| PM | 4740 | 4643 | 2% |
| H | 576 | 577 | 0% |
| M | 324 | 323 | 0% |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 2587 | 3449 | -25% |
| H | 124 | 123 | 1% |
| M | 182 | 13 | 1300% |
| AM | 201 | 230 | -12% |
| H | 7 | 7 | 0% |
| M | 12 | 13 | -6% |
| PM | 159 | 231 | -31% |
| H | 6 | 4 | 71% |
| M | 11 | 12 | -7% |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 4791 | 5571 | -14% |
| H | 55 | 62 | -11% |
| M | 139 | 168 | -17% |
| AM | 332 | 345 | -4% |
| H | 3 | 4 | -10% |
| M | 10 | 11 | -10% |
| PM | 358 | 492 | -27% |
| H | 3 | 4 | -33% |
| M | 8 | 13 | -35% |

| | **Build** | **No Build** | |
|---|---|---|---|
| **24 hr** | **52253** | **51531** | 1% |
| **H** | **8534** | **8653** | -1% |
| **M** | **3354** | **3354** | 0% |
| **AM** | **3418** | **3373** | 1% |
| **H** | **479** | **479** | 0% |
| **M** | **262** | **261** | 0% |
| **PM** | **4940** | **4904** | 1% |
| **H** | **572** | **575** | -1% |
| **M** | **321** | **324** | -1% |

| | **Build** | **No Build** |
|---|---|---|
| **24 hr** | **1881** | |
| **H** | **6** | |
| **M** | **32** | |
| **AM** | **73** | |
| **H** | **0** | |
| **M** | **2** | |
| **PM** | **179** | |
| **H** | **0** | |
| **M** | **2** | |

| | **Build** | **No Build** |
|---|---|---|
| **24 hr** | **1734** | |
| **H** | **9** | |
| **M** | **42** | |
| **AM** | **77** | |
| **H** | **0** | |
| **M** | **2** | |
| **PM** | **231** | |
| **H** | **2** | |
| **M** | **6** | |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 51814 | 51531 | 1% |
| H | 8538 | 8653 | -1% |
| M | 3363 | 3354 | 0% |
| AM | 3396 | 3373 | 1% |
| H | 479 | 479 | 0% |
| M | 262 | 261 | 0% |
| PM | 4935 | 4904 | 1% |
| H | 573 | 575 | 0% |
| M | 324 | 324 | 0% |

| HOV | Build | No Build |
|---|---|---|
| 24 hr | 8869 | 8422 |
| H | 1240 | 1134 |
| M | 578 | 580 |
| AM | 156 | 122 |
| H | 0 | 0 |
| M | 0 | 0 |
| PM | 319 | 257 |
| H | 0 | 0 |
| M | 0 | 0 |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 46866 | 46117 | 2% |
| H | 5288 | 5277 | 0% |
| M | 3357 | 3346 | 0% |
| AM | 4135 | 4044 | 2% |
| H | 332 | 332 | 0% |
| M | 304 | 303 | 0% |
| PM | 3760 | 3728 | 1% |
| H | 338 | 338 | 0% |
| M | 287 | 286 | 0% |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 2517 | 3533 | -29% |
| H | 122 | 124 | -2% |
| M | 179 | 196 | -9% |
| AM | 119 | 205 | -42% |
| H | 6 | 7 | -11% |
| M | 10 | 11 | -16% |
| PM | 222 | 282 | -21% |
| H | 8 | 8 | -3% |
| M | 14 | 15 | -9% |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 1920 | 5417 | -65% |
| H | 14 | 60 | -77% |
| M | 47 | 163 | -71% |
| AM | 150 | 433 | -65% |
| H | 1 | 4 | -80% |
| M | 3 | 11 | -71% |
| PM | 194 | 406 | -52% |
| H | 1 | 4 | -64% |
| M | 4 | 12 | -65% |

| | **Build** | **No Build** |
|---|---|---|
| **24 hr** | **46270** | **48001** |
| **H** | **5181** | **5213** |
| **M** | **3225** | **3314** |
| **AM** | **4167** | **4271** |
| **H** | **327** | **329** |
| **M** | **297** | **304** |
| **PM** | **3733** | **3853** |
| **H** | **331** | **333** |
| **M** | **278** | **283** |

| | **Build** | **No Build** |
|---|---|---|
| **24 hr** | **1920** | |
| **H** | **6** | |
| **M** | **32** | |
| **AM** | **174** | |
| **H** | **0** | |
| **M** | **2** | |
| **PM** | **116** | |
| **H** | **0** | |
| **M** | **2** | |

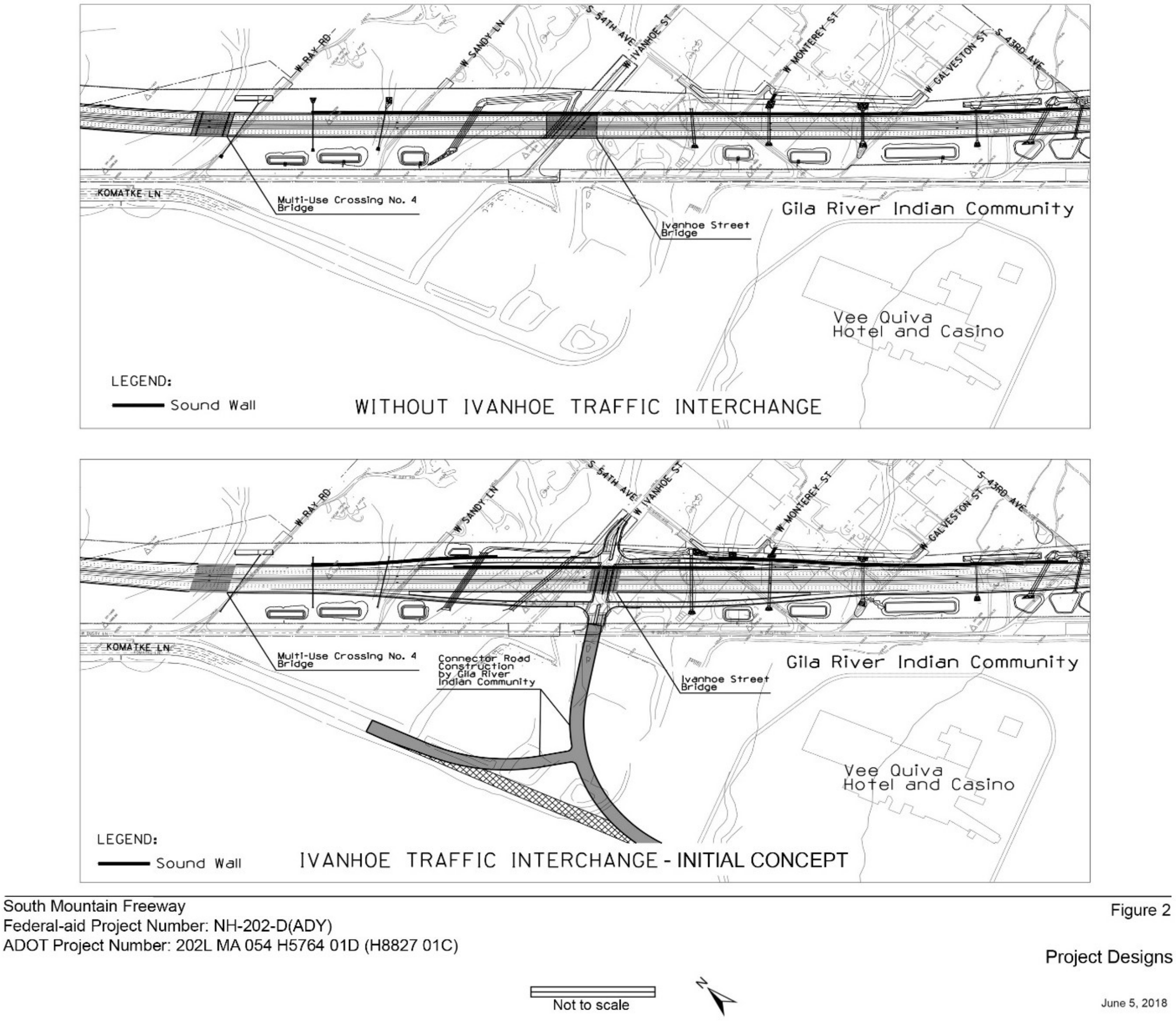
| | **Build** | **No Build** |
|---|---|---|
| **24 hr** | **4505** | |
| **H** | **48** | |
| **M** | **130** | |
| **AM** | **354** | |
| **H** | **3** | |
| **M** | **9** | |
| **PM** | **310** | |
| **H** | **3** | |
| **M** | **9** | |

| | Build | No Build | |
|---|---|---|---|
| 24 hr | 47986 | 48001 | 0% |
| H | 5170 | 5213 | -1% |
| M | 3275 | 3314 | -1% |
| AM | 4312 | 4271 | 1% |
| H | 329 | 329 | 0% |
| M | 304 | 304 | 0% |
| PM | 3886 | 3853 | 1% |
| H | 333 | 333 | 0% |
| M | 284 | 283 | 0% |

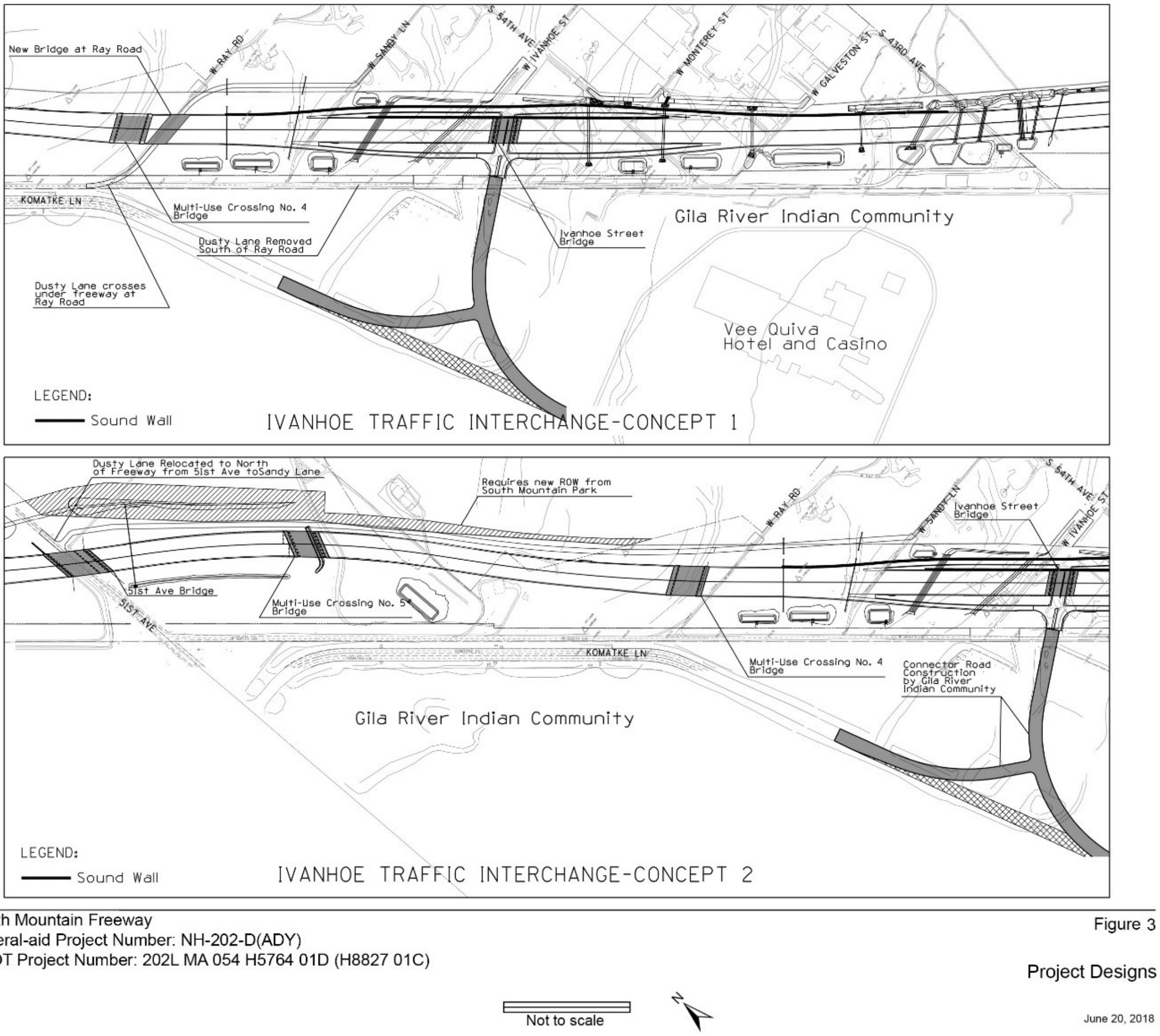
| HOV | Build | No Build |
|---|---|---|
| 24 hr | 8624 | 7719 |
| H | 646 | 605 |
| M | 612 | 562 |
| AM | 201 | 159 |
| H | 0 | 0 |
| M | 0 | 0 |
| PM | 265 | 216 |
| H | 0 | 0 |
| M | 0 | 0 |

## APPENDIX C

## Figure C-1. Traffic Interchange Configuration Concepts



## Figure C-2. Traffic Interchange Configuration Concepts



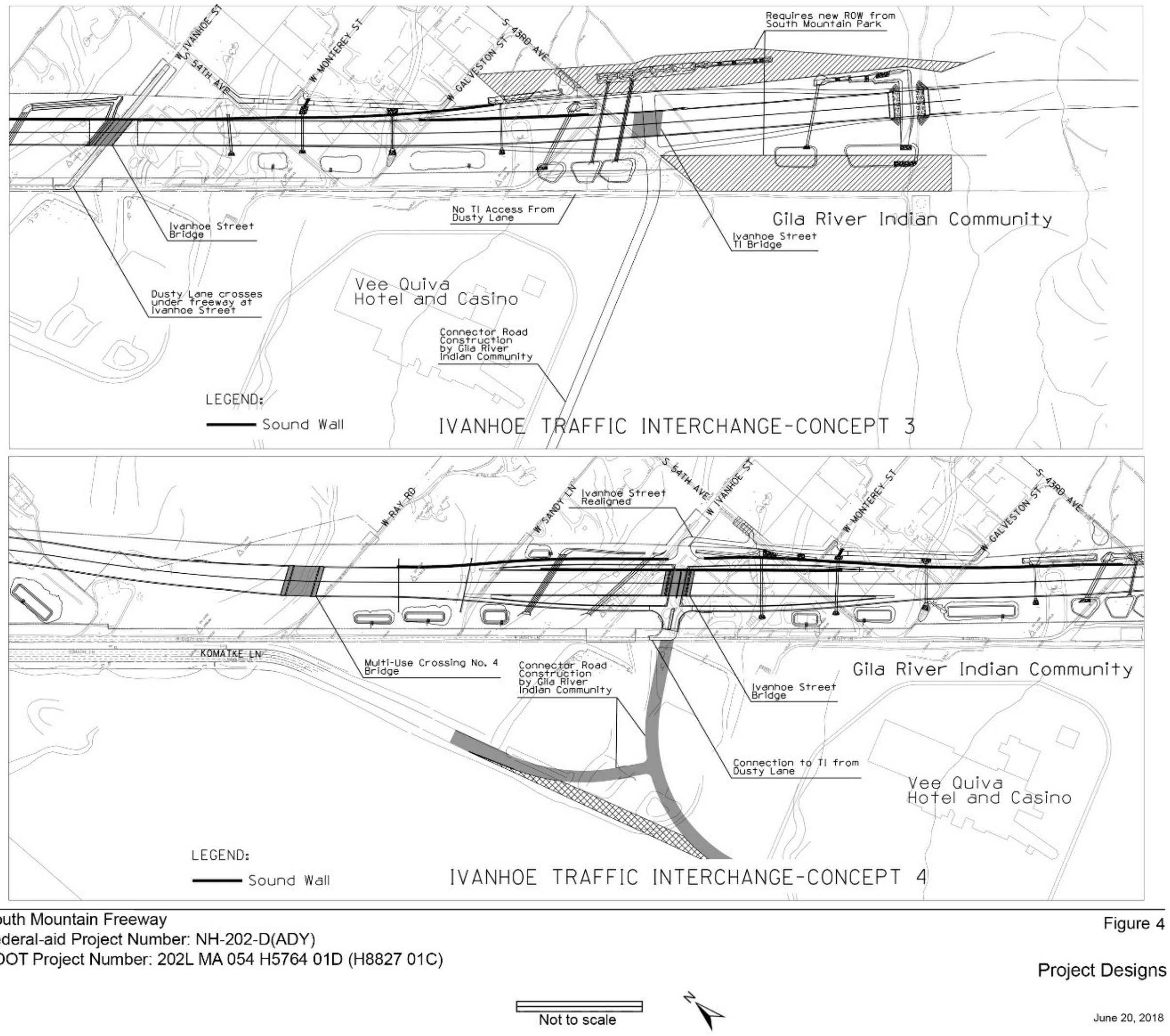
South Mountain Freeway
Federal-aid Project Number: NH-202-D(ADY)
ADOT Project Number: 202L MA 054 H5764 01D (H8827 01C)

Figure 3

Project Designs

June 20, 2018

## Figure C-3. Traffic Interchange Configuration Concepts



South Mountain Freeway
Federal-aid Project Number: NH-202-D(ADY)
ADOT Project Number: 202L MA 054 H5764 01D (H8827 01C)

Figure 4

Project Designs

June 20, 2018