# Noise Study Technical Report

**I-29 from Tea Interchange to Skunk Creek**

Sioux Falls, South Dakota

*November 16, 2005*

HDR Project No. 27893

*Prepared by*

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## EXECUTIVE SUMMARY

On behalf of South Dakota Department of Transportation (SDDOT), HDR Engineering, Inc. (HDR) performed a traffic noise analysis on the proposed improvements to I-29 from Tea Interchange to Skunk Creek. The analysis included traffic noise monitoring and modeling. To determine the loudest traffic hour, HDR performed a 24-hour noise measurement at a residence immediately adjacent to the I-29 right-of-way (ROW). Average noise levels (expressed as Leq) were measured and stored continuously for 24 hours. The loudest hours occurred between the hours of 3:00 p.m. and 6:00 p.m. Short-term traffic noise measurements were subsequently performed during the loudest hours at locations that are representative of residences adjacent to the ROW throughout the project area.

HDR used the Federal Highway Administration (FHWA) Traffic Noise Model (TNM) Version 2.5 to evaluate future noise traffic noise levels under both the “Build” and “No-build” alternatives. Traffic noise impacts were identified in accordance with the SDDOT Noise Analysis and Abatement Policy and FHWA Noise Abatement Criteria (NAC). A total of 150 residences are predicted to experience traffic noise impacts under the “Build” alternative. Therefore, HDR performed a traffic noise mitigation analysis.

Quiet pavement options were reviewed and summarized for this report. Quiet pavements provide noise reduction at the noise source – the tire/pavement interaction, and may be included in the final design of this project as a noise abatement measure.

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# 1.0 Introduction

The South Dakota Department of Transportation (SDDOT) proposes to add auxiliary lanes to I-29 from Tea Interchange to 41st Street (Project). Figure 1 shows the Project area, and the location of the proposed auxiliary lanes are shown in the Construction Plans diagram in Appendix A. This Project is classified as a Type I project because it proposes to increase the number of through-traffic lanes in the Project area. As a Type I project, a noise analysis is required because potentially impacted noise-sensitive receivers exist in the Project area.

HDR Engineering, Inc. (HDR) performed a highway traffic noise analysis for SDDOT in support of the Project. The analysis is based on SDDOT Noise Analysis and Abatement Policy (December 1999) and Federal Highway Administration (FHWA) Traffic Noise Analysis and Abatement Policy and Guidance (FHWA 1995). Where future predicted traffic noise levels approach or exceed the SDDOT Noise Abatement Criteria (NAC), noise mitigation was evaluated. Results of the analysis are presented in this report.

# 2.0 Nature of Noise

Noise is defined as unwanted sound and is measured in decibels (dB) - a logarithmic scale. Because human hearing is not equally sensitive to all frequencies of sound, certain frequencies are given more "weight". The A-weighted scale corresponds to the sensitivity range for human hearing. Therefore, noise levels are measured in dBA, the A-weighted sound level in decibels. When noise levels change 3-dBA, the change is considered to be barely perceptible to human hearing. However, a 5-dBA change in n oise level is clearly noticeable. A 10-dBA change in noise levels is perceived as a doubling or halving of noise loudness, while a 20-dBA change is considered a dramatic change in loudness. Table 1 shows noise levels associated with common, everyday sources and helps the reader more fully understand the magnitude of noise levels discussed in this report.



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**Table 1**
**Common Noise Sources and Levels**

| Sound Pressure Level (dB) | Typical Sources |
|---|---|
| 120 | Jet aircraft takeoff at 100 feet |
| 110 | Same aircraft at 400 feet |
| 90 | Motorcycle at 25 feet |
| 80 | Garbage disposal |
| 70 | City street corner |
| 60 | Conversational Speech |
| 50 | Typical office |
| 40 | Living room (without TV) |
| 30 | Quiet bedroom at night |

Source: Environmental Impact Analysis Handbook, ed. by Rau and Wooten, 1980

# 3.0 SDDOT Noise Analysis and Abatement Policy

The SDDOT Noise Analysis and Abatement Policy (Policy), upon which this analysis is based, is intended to supplement FHWA traffic noise analysis and abatement regulations and guidance. The Policy provides procedures for noise studies and noise abatement measures to help protect the public health and welfare, to supply noise abatement criteria and to establish requirements for traffic noise information to be given to those officials who have planning and zoning authority in the Project area.

The Policy contains noise abatement criteria that are based on the Leq(h) which is used to analyze traffic noise levels and identify noise impacts. The Leq(h) is defined as the equivalent steady-state sound level that, in a stated period of time, contains the same acoustic energy as the time-varying sound level during the same period. Therefore, for the purposes of this analysis, Leq can be considered the average sound level and Leq(h) can be considered the average sound level occurring over a one-hour period. It is representative of the overall (average) traffic-generated noise level expressed on an hourly basis.

Land uses are assigned to an activity category based on the type of activities occurring in each respective land use (i.e. picnic areas, churches, commercial land and undeveloped land). Activity categories are then ordered based on their sensitivity to traffic noise levels. NAC are assigned to each activity category. These NAC represent the maximum traffic noise levels that allow uninterrupted land use within each activity category. Table 2 lists the five land use categories included in the SDDOT NAC and the Leq(h) associated with each activity category. Traffic noise impacts are identified relative to the NAC and the Policy.

The federal (23 Code of Federal Regulations (CFR) 772) and SDDOT definition of a traffic noise impact contains three criteria of which only one has to be met. Traffic noise impacts are defined as impacts that occur when the predicted traffic noise levels:

- approach or equal the noise abatement criteria given on Table 2; or,
- exceed the noise abatement criteria given on Table 2; or,
- substantially exceed the existing noise levels.

**Table 2**
**Noise Abatement Criteria**

| Activity Category | $L_{eq}$ (h) | Description of Activity Category |
|---|---|---|
| A | 57-dBA (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-dBA (Exterior) | Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries and hospitals. |
| C | 72-dBA (Exterior) | Developed lands, properties or activities not included in Categories A or B above. |
| D | No Limit | Undeveloped Lands |
| E | 52-dBA (Interior) | Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums. |

SOURCE: Federal-Aid Highway Program Manual 7-7-3, "Procedures for Abatement of Highway Traffic Noise and Construction Noise", dated August 1982.

The SDDOT Policy defines "approach the NAC" as being within one dBA of the NAC, therefore traffic noise levels of 66-dBA are considered a traffic noise impact (for land use category B), a noise level greater than 67-dBA exceeds the NAC (for category B) and a 15-dBA increase in existing noise levels is a substantial increase.

# 4.0 Noise Prediction Method

Future "Build" traffic noise levels were determined by using the FHWA Traffic Noise Model (TNM) Version 2.5. The Basic model inputs are:

- Preliminary project concept and geometry.
- 2025 Traffic volumes for I-29 in the Study area (Appendix A).
- The operational speed for I-29: 65 miles per hour (mph).

The traffic volume used for this hour time period is the Peak Hourly Volume (PHV) traffic. Traffic noise levels for the existing condition were determined from noise monitoring data collected near the Project area (Section 8). Traffic volumes for the future "No-build" condition were assumed to be the same as the "Build" levels.

# 5.0 Traffic Parameters

The traffic volumes and vehicle mix used on this Project were obtained from the SDDOT Office of Planning and Engineering (Appendix A). Vehicle classifications used in this analysis include cars (86-88 percent) and heavy trucks (12-14 percent).

# 6.0 Adjacent Land Use

Land use adjacent to this Project is primarily residential on the west side of I-29 and commercial on the east side, with some variability on both sides. Figure 1 (page 2) includes an aerial view of the project area.

# 7.0 Noise Measurements

HDR performed noise measurements at representative receptors in the Project area to determine the existing peak hour traffic noise levels. The sources of I-29 noise included vehicle exhaust, motor noise and tire noise, in fairly even proportions.

## 7.1 Field Testing Procedure

On July 20, 21 and 28 and August 4, 2005, HDR staff measured noise levels in the Project area. HDR performed a 24-hour measurement during which noise monitoring data was stored each hour for the continuous 24-hour period. This data identified the loudest traffic period of the day;

short-term traffic noise measurements were performed during this period on subsequent days. The 24-hour measurement was performed in the back yard of a residence located immediately adjacent to the I-29 right-of-way (ROW). Table 3 presents the 24-hour noise monitoring data. The loudest periods occurred between the hours of 3:00p.m. to 6:00p.m.

**Table 3**
**24-Hour Noise Monitoring Data**

| Hour | Hourly Leq (dBA) |
|---|---|
| 5:00p.m. | 72 |
| 6:00p.m. | 71 |
| 7:00p.m. | 70 |
| 8:00p.m. | 71 |
| 9:00p.m. | 70 |
| 10:00p.m. | 67 |
| 11:00p.m. | 66 |
| 12:00a.m. | 64 |
| 1:00a.m. | 62 |
| 2:00a.m. | 62 |
| 3:00a.m. | 63 |
| 4:00a.m. | 64 |
| 5:00a.m. | 65 |
| 6:00a.m. | 69 |
| 7:00a.m. | 71 |
| 8:00a.m. | 71 |
| 9:00a.m. | 71 |
| 10:00a.m. | 70 |
| 11:00a.m. | 71 |
| 12:00p.m. | 70 |
| 1:00p.m. | 71 |
| 2:00p.m. | 70 |
| 3:00p.m. | 72 |
| 4:00p.m. | 72 |

Traffic noise measurements were conducted in accordance with the FHWA-PD-96-046 Measurement of Highway-Related Noise (May 1996). The average meteorological conditions are reported in Table 4.

**Table 4**
**Meteorological Conditions**

| | |
|---|---|
| **TEMPERATURE** | July 20-21 = 73-90° F<br>July 28 = 83° F<br>August 4 = 79° F |
| **HUMIDITY** | July 20-21 ≅ 70 percent<br>July 28 ≅ 44 percent<br>August 4 ≅ 44 percent |
| **WIND** | July 20-21 ≅ 8 -18 mph<br>July 28 ≅ 8 mph<br>August 4 ≅ 8 mph |
| **CONDITIONS** | July 20-21: variably cloudy<br>July 28: partly cloudy<br>August 4: partly cloudy |
| **BAROMETRIC PRESSURE** | July 20-21 = 29.85 - 30.03 inches<br>July 28 = 30.01 inches<br>August 4 = 30.22 inches |

## 7.2 INSTRUMENTATION

The 24-hour noise monitoring was done utilizing a Larson-Davis model 824 Type I Sound Level Meter whose microphone was set at a height of approximately 5 feet above the ground. Short-term noise monitoring was conducted using a Larson-Davis model 820 Type I Sound Level Meter. The meter and microphone were set at a height of approximately 5 feet for all measurements.

## 7.3 FIELD MEASUREMENT METHODS

The sound level meter was programmed to compute the hourly equivalent sound level Leq(h). As mentioned previously (Section 2.0), Leq(h) is the steady-state, A-weighted sound level that contains the same amount of acoustic energy as the actual time varying, A-weighted sound level over a 1-hour period. Leq(h) is measured in A-weighted decibels (dBA), which closely approximates the range of frequencies a human ear can hear.

The following procedures were used for noise monitoring:

- The duration of the short term measurements was approximately 15 minutes.
- The meter was calibrated before and after monitoring. No significant calibration drifts were detected during the duration of the study.

- The height of the microphone was 5 feet above the ground.
- The microphone was covered with a windscreen and wire bird spikes (24-hour test only).
- For the 24-hour measurement, a cable connected the microphone to the noise meter which was preprogrammed to start and stop the measurements at the selected times.

### 7.4 FIELD MEASUREMENT LOCATIONS AND RESULTS

Monitoring locations are shown on Figure 1 (page 2) and are as follows:

Site #1 – Residence: 4801 St. James Dr.

Site #2 – Apartment complex: 3000 Westwood.

Site #3 – Apartment/townhouse complex: Carrington Court Townhouse Apartments.

Site #4 – Residence: 5909 S. Mandy Ave.

Table 5 identifies the locations of each of the monitoring sites relative to the I-29 centerline and the respective noise levels measured at each location. Note that the existing noise levels exceed the NAC at three of the four locations.

**Table 5**
**Noise Monitoring Results**

| Measurement Location | Duration | Distance to I-29 Centerline (feet) | NAC (dBA) | Measured $L_{eq}$ During Peak Hour |
|---|---|---|---|---|
| 1 (R) | 24 hr. | 169 | 66 | 72 dBA |
| 2 (R) | 15 min. | 120 | 66 | 70 dBA |
| 3 (R) | 15 min. | 194 | 66 | 67 dBA |
| 4 (R) | 15 min. | 573 | 66 | 59 dBA |

Note: (R) is residential receptor.

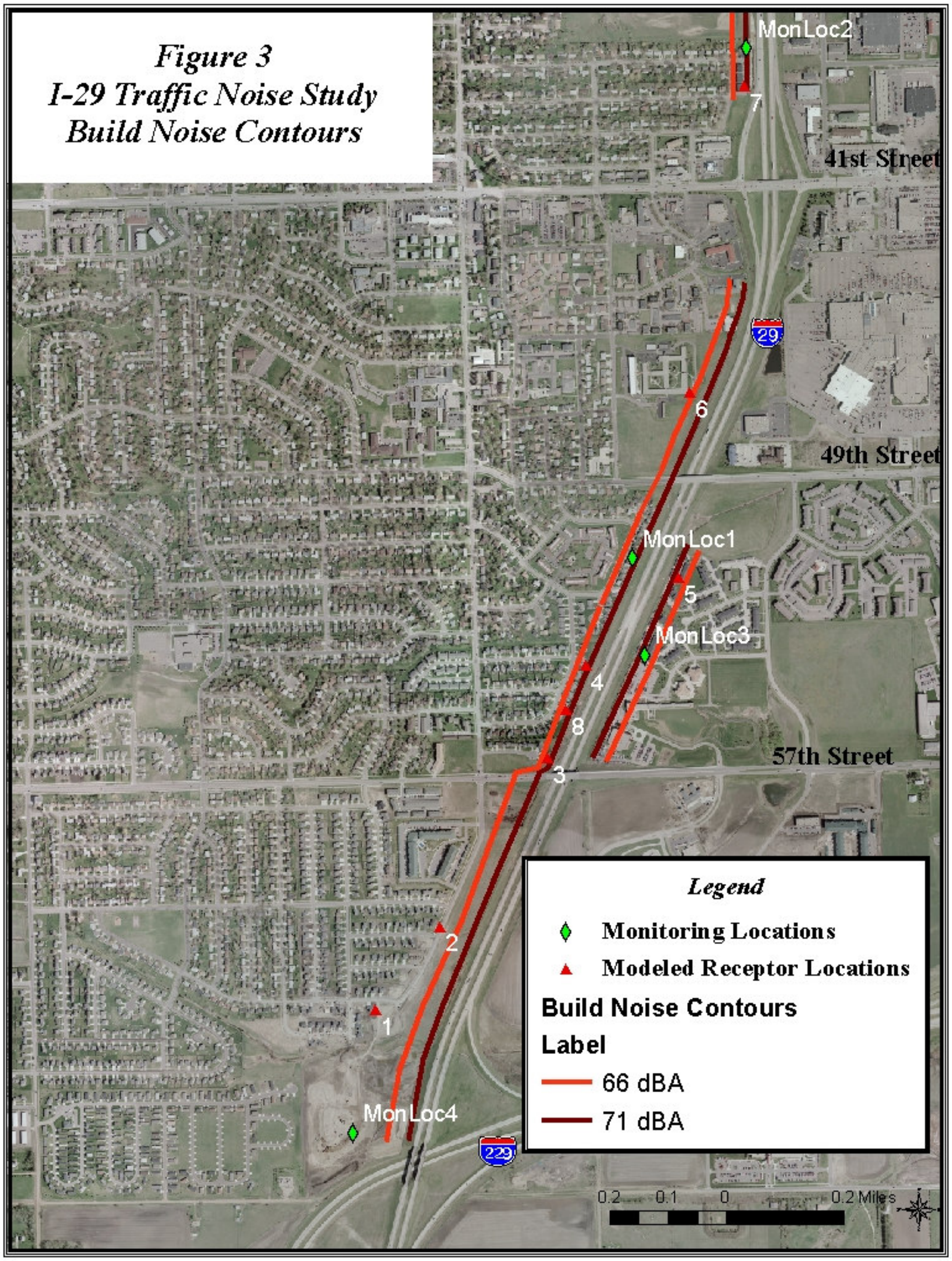
## 8.0 Traffic Noise Prediction

HDR used the FWHA Traffic Noise Model (TNM) Version 2.5 to evaluate future traffic noise levels at noise sensitive receptors within the limits of this Project. The predicted traffic noise levels reflect the elevation differences and the proposed roadway alignment in relation to the noise sensitive sites. Table 6 lists the NAC, existing Leq, and the future (2025) predicted Leq for both the "Build" and "No-build" alternatives. Receptors with a "MonLoc" designation refer to locations where actual noise measurements were made; "Receiver" designations refer to locations along the corridor that were used in the modeling process to better define the noise environment. Existing noise levels at "Receiver" locations were determined by adjusting the measured noise level at the closest monitoring location based on relative distance from I-29.

**Table 6**
**Predicted Noise Levels ($L_{eq}$) at Receptors**

| Receptor ID | Land Use | NAC (dBA) | Hourly Leq(h) dBA | | | | Approaches or Exceeds Standards in 2025 Build |
|---|---|---|---|---|---|---|---|
| | | | 2005 | 2025 | | Difference Between Existing/ Build | |
| | | | Existing | "No-build" | "Build" | | |
| MonLoc1 | Residential (B) | 67 | 70 | 70 | 70 | 0 | Yes |
| MonLoc2 | Residential (B) | 67 | 70 | 72 | 72 | +2 | Yes |
| MonLoc3 | Residential (B) | 67 | 67 | 69 | 69 | +2 | Yes |
| MonLoc4 | Residential (B) | 67 | 59 | 60 | 60 | +1 | No |
| Receiver1 | Residential (B) | 67 | 59 | 59 | 59 | 0 | No |
| Receiver2 | Residential (B) | 67 | 59 | 63 | 63 | +4 | No |
| Receiver3 | Residential (B) | 67 | 68 | 69 | 69 | +1 | Yes |
| Receiver4 | Residential (B) | 67 | 69 | 69 | 70 | +1 | Yes |
| Receiver5 | Residential (B) | 67 | 67 | 68 | 69 | +2 | Yes |
| Receiver6 | Residential (B) | 67 | 65 | 65 | 66 | +1 | Yes |
| Receiver7 | Residential (B) | 67 | 70 | 70 | 70 | 0 | Yes |
| Receiver8 | Residential (B) | 67 | 68 | 69 | 69 | +1 | Yes |

Future 66-dBA and 71-dBA "Build" and "No-build" contour lines are depicted in Figures 2 and 3.



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# 9.0 Noise Abatement Measures

Noise abatement measures are considered where predicted traffic noise levels approach or exceed the NAC or when the predicted traffic noise levels substantially exceed the existing noise levels. As shown in Table 6, three of the four monitored receptors and six of the eight modeled receptors have predicted noise levels which exceed the NAC, and therefore, noise abatement measures need to be evaluated.

## 9.1 IMPACTS

The difference between the existing 2005 and predicted 2025 "Build" noise levels range from 0 to +4 dBA. Results of this analysis indicate that traffic noise impacts are predicted to occur at MonLoc1-3 and Receiver3-8 under the "Build" alternative, eight of which currently experience traffic noise impacts as defined by the NAC under existing conditions. Under the "Build" alternative, traffic noise levels are predicted to change between 0 and 1 dBA over the future "No-build" noise levels. The difference in noise levels can be accounted for by the difference in roadway widths. The "Build" alternative is proposed to be 12 feet wider in each direction compared to the "No-build" alternative. As the roadway widens, the source of noise moves closer to receptors, though the volume of traffic itself is not changing.

## 9.2 ABATEMENT MEASURES

Potential traffic noise abatement measures that can be considered for a particular project are listed below. Also, the reasons some were not considered for the Project are explained.

1. Modifying the proposed horizontal and/or vertical alignments of the roadway.

   *Impractical based on logistics and cost.*

2. Traffic management measures (e.g. modify speed limits and restrict truck traffic).

   *Impractical given the type of road in question.*

3. Construction of noise barriers along or within the ROW.

   *Possible, options include walls, berms, and vegetation. Berms and vegetation would require more space than is available.*

4. Acquisition of property rights for construction of noise barriers.

   *Not necessary because walls from Item 3, above, can be utilized.*

5. Acquisition of property to serve as a buffer zone.

   *Prohibitively expensive.*

6. Noise insulation of public use or nonprofit institutional structures.

   *Does not apply to privately owned structures, so none of the existing residences would qualify for public funding of noise insulation.*

7. Modify the roadway pavement type.

   *The use of different pavement types to reduce noise from vehicle tires is a growing trend. A balance must be met between safety (enough texture to facilitate stopping on wet pavement and/or reduce road spray), maintainability (especially in cold climates where freeze/thaw is an issue), and noise reduction (also dependent on pavement age). Please see Appendix B for further discussion.*

## 9.3 DISCUSSION OF NOISE BARRIERS

The SDDOT Policy, dated April 1996, requires that SDDOT consider two criteria when evaluating whether noise barriers should be incorporated into a project: feasibility and reasonableness. Feasibility deals primarily with engineering considerations (e.g., can a barrier be built given the topography of the location, can a substantial noise reduction be achieved given certain access, drainage, snow, safety or maintenance requirements? and are other noise sources in the area?).

The Policy also states “Reasonableness is a more subjective criterion than feasibility. It implies that common sense and good judgment were applied in arriving at a decision.”

To comply with the Policy, SDDOT’s determination of reasonableness for noise barriers must be based upon a number of factors, including the following:

Amount of noise reduction provided

Number of people/residences benefited

Cost of abatement

Views of impacted residents

The timing and consideration of development along the highway

The noise policy states that substantial noise reduction should be made (7-dBA or greater) by the barrier and that the test for cost reasonableness is calculated by dividing the number of benefited residential units (those that receive a minimum of 5-dBA reduction in noise level) into the estimated total cost of the noise barrier. If the cost is $15,000 per residence or less, the barrier is deemed economically reasonable.

It should be noted that noise barriers could have their own negative impacts. Barriers may interfere with the passage of air, interrupt scenic views, create objectionable shadows, contribute to increased road icing and reduce or eliminate visibility of a business from the roadway. Barriers could also create snow removal problems, cause maintenance access problems, make it difficult to maintain landscaping, create drainage problems and provide pockets for trash and garbage to accumulate. Depending on location, noise barriers could also compromise traffic safety by reducing stopping or merging sight distance or by reducing errant vehicle recovery room.

HDR modeled noise walls along the ROW in three locations where noise impacts were determined to occur. These locations were chosen because they are adjacent to receptor locations where future noise levels were predicted to approach, equal or exceed the NAC (i.e. Receptors MonLoc1-3, Receiver3-8) under the "Build" alternative. The barriers attempted to provide a substantial noise reduction (at least a 7-dBA reduction) at all of the impacted receptors and to reduce future "Build" noise levels to less than 65 dBA. *Noise walls are typically effective only for ground level structures, they will have little to no impact on noise at second or third story apartments or townhomes, unless they are built tall enough to do so.* Figures 4 and 5 show the three walls located on the edge of the ROW superimposed on aerial views along with the receptors used in the noise wall evaluations. The construction cost estimation for each of the three barriers (assuming $57.50 per square foot, as provided by the SDDOT, for colored, textured, pre-cast concrete walls, included in Appendix C) indicates that none of the locations were determined to meet the cost reasonableness criteria. SDDOT determined that wooden walls are infeasible due to long term maintenance costs. When calculating cost reasonableness, only those receivers that were predicted to experience reductions of 5 dBA or more (benefited receivers) were included in those calculations.

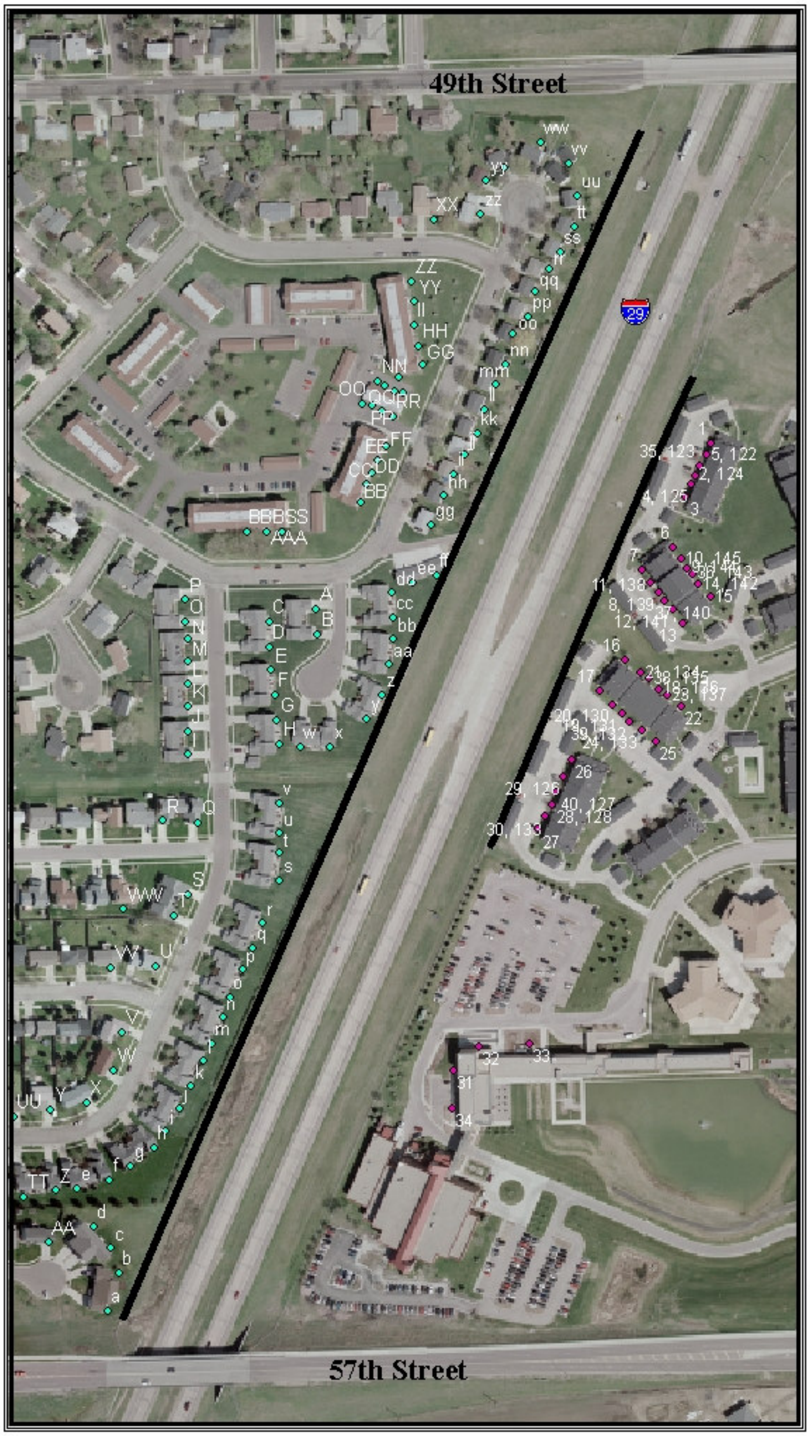


*Figure 4*

*I-29 Traffic Noise Study*

*South & East Noise Barriers*

**Legend**

- East Receivers
- South Receivers
- Noise Barrier

150 75 0 150 Feet

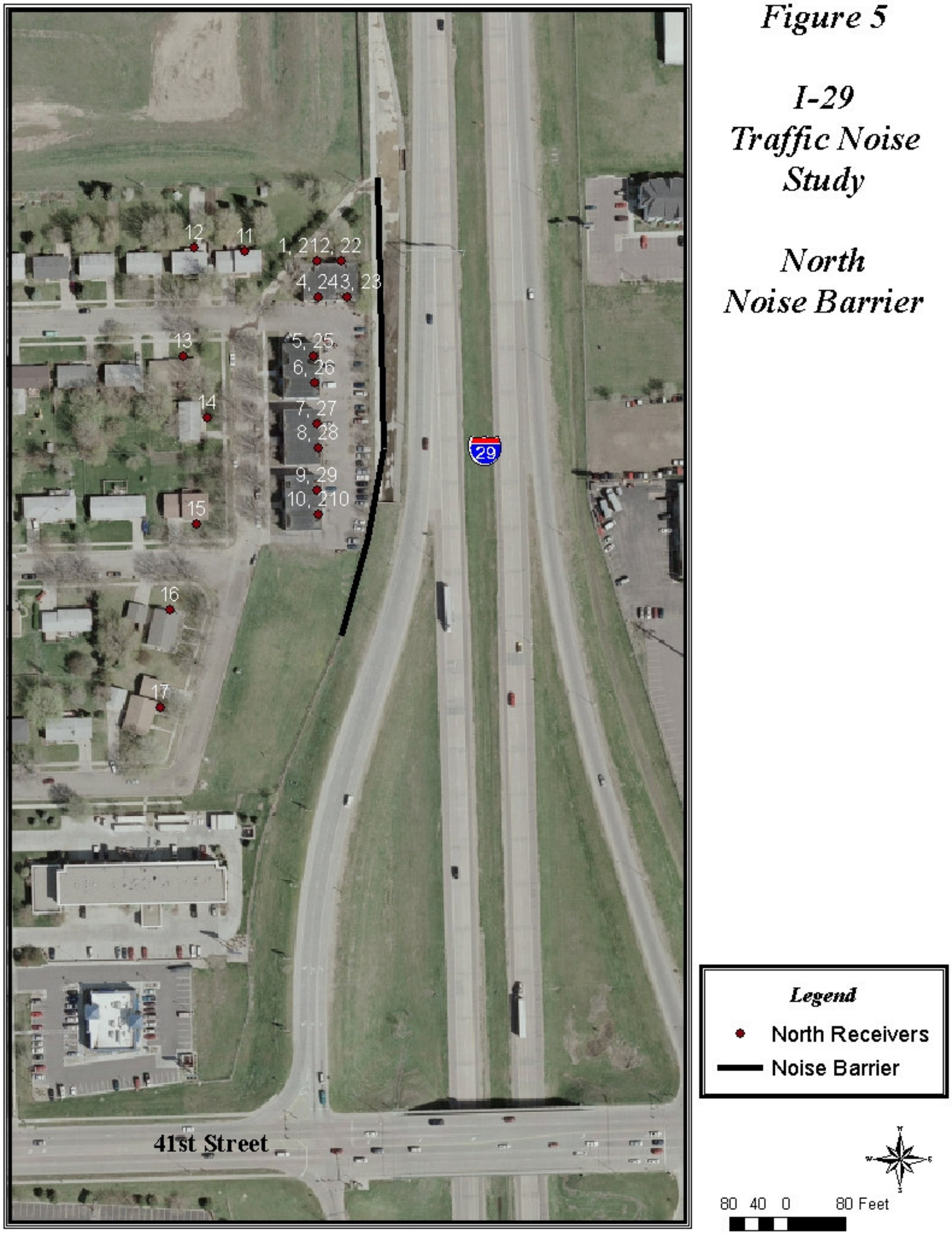


*Figure 5*

*I-29 Traffic Noise Study*

*North Noise Barrier*



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## 9.4 EAST BARRIER

HDR evaluated a noise barrier (East Barrier) approximately 1,039-feet in length. The wall is located along the highway ROW west of the Carrington Court Townhouse and Apartment complex. The height of the barrier is 16 feet. The barrier height modeled is the minimum wall height necessary to provide at least a 7-dBA noise reduction and reduce noise levels to less than 65-dBA for the first floor apartments/townhomes, it was also able to provide a 5 to 8-dBA noise reduction for the second floor residences.

Fifty-eight modeled receptors receive a noise level reduction of at least 5-dBA from this noise barrier. Table 7 summarizes the noise barrier modeled for this area. Appendix C presents the predicted noise levels at each receptor with and without noise walls. Given the calculated cost of the wall ($955,862 for concrete) and the number of benefited receptors (58), this barrier is not considered cost reasonable based on SDDOT policy ($16,480 per household).

**Table 7**
**Summary of Noise Barrier Analysis (East Barrier)**

| Barrier | Barrier Length (ft) | Average Barrier Height (ft) | Insertion Loss (dBA) | Total Number of Shielded Receptors | Total Number of Impacted Receptors | Number of Benefited Receptors [1] |
|---|---|---|---|---|---|---|
| East Barrier | 1,039 | 16 | 4-8 | 60 | 52 | 58 |

[1] Receptors where the noise level reduction from the barrier is at least 5 dBA.

## 9.5 NORTH BARRIER

HDR evaluated a second noise barrier (North Barrier) approximately 624-feet in length. The wall is located along the highway ROW north of 41st Street and east of a residential area that includes four 12-plexes. The height of the barrier is 16 feet. The barrier height modeled is the minimum wall height necessary to provide at least a 7-dBA noise reduction for the first floor apartments, it was also able to provide a 6 to 7-dBA noise reduction for the second floor apartments. Ten third floor apartments are impacted, but not modeled or screened by the barrier. Table 8 summarizes the noise barrier modeled for this area. Appendix C presents the predicted noise levels at each receptor with and without noise walls. Given the calculated cost of the wall ($586,704 for concrete) and the number of benefited receptors (20), this barrier is not considered cost reasonable based on SDDOT policy ($29,335 per household).

**Table 8**
**Summary of Noise Barrier Analysis (North Barrier)**

| Barrier Wall/ Receptor | Barrier Length (ft) | Average Barrier Height (ft) | Insertion Loss (dBA) | Total Number of Shielded Receptors | Total Number of Impacted Receptors | Number of Benefited Receptors [1] |
|---|---|---|---|---|---|---|
| North Barrier | 624 | 16 | 1-9 | 27 | 31 | 20 |

[1] Receptors where the noise level reduction from the barrier is at least 5 dBA.

## 9.6 South Barrier

HDR evaluated a third noise barrier (South Barrier) approximately 2,671-feet in length. The wall is located along the highway ROW east of the residential area between 49th Street and 57th Street. The height of the barrier is 19 feet. The barrier height modeled is the minimum wall height necessary to provide at least a 7-dBA noise reduction at the majority of first row receptors and reduce noise levels to less than 65-dBA.

A detailed model of the first and second row receptors predicted that 103 receptors would receive a noise level reduction of at least 5-dBA from this noise barrier. An additional 3 receptors would receive less than a 5-dBA reduction. Table 9 summarizes the noise barrier modeled for this area. Appendix C presents the predicted noise levels at each receptor with and without noise walls. Given the calculated cost of the wall ($2,918,238) and the number of benefited receptors (103), this barrier is not considered cost reasonable based on SDDOT policy ($28,332 per household).

**Table 9**
**Summary of Noise Barrier Analysis (South Barrier)**

| Barrier | Barrier Length (ft) | Average Barrier Height (ft) | Insertion Loss (dBA) | Total Number of Shielded Receptors | Total Number of Impacted Receptors | Number of Benefited Receptors [1] |
|---|---|---|---|---|---|---|
| South Barrier | 2,671 | 19 | 4-13 | 106 | 48 | 103 |

[1] Receptors where the noise level reduction from the barrier is at least 5 dBA.

Appendix C contains tables from TNM showing the actual dimensions of the barriers modeled for this analysis and is intended as a guide for potential noise wall design and construction. The minimum dimensions noted in the table may be increased to create a smoother, more aesthetically pleasing wall profile.

# 10.0 Construction Noise and Vibration

Construction of the Project would result in temporary noise and vibration increases within the Project area. The evaluation and control of construction noise and vibration must be considered as well as traffic noise. This Project is bordered by scattered residential receptors and these receptors are also a concern for impacts caused by construction noise and vibration.

The following are basic categories for mitigation measures for construction noise. Due to the interrelatedness of construction noise and vibration, some of these measures will also apply for vibration resulting from construction activities.

*Design Considerations*: Design considerations include measures in the plans and specifications to minimize or eliminate adverse impacts. The design for this Project includes the construction of auxiliary lanes along I-29. The proposed changes and their proximity to noise sensitive receptors were factors during design considerations.

*Community Awareness*: It is important for people to be made aware of the possible inconvenience and to know its approximate duration so they can plan their activities accordingly. It is the policy of the SDDOT that information concerning the Project be submitted to all local news media.

*Source Control*: Source control involves reducing noise impacts from construction by controlling the noise emissions at their source. This can be accomplished by specifying proper muffler systems, either as a requirement in the plans and specifications on this Project or through an established local noise ordinance requiring mufflers. Contractors generally maintain proper muffler systems on their equipment to ensure efficient operation and to minimize noise for the benefit of their own personnel as well as the adjacent receptors.

*Site Control*: Site control involves the specification of certain areas where extra precautions should be taken to minimize construction noise. One way to reduce construction noise impacts at sensitive receptors is to operate stationary equipment, such as air compressors or generators, as far away from the sensitive receptors as possible. Another method might be placing a temporary noise barrier in front of the equipment. As a general rule, good coordination between the project engineer, the contractor and the affected receptors are less confusing, less likely to increase the cost of the project and is a more personal approach to work out ways to minimize construction noise impacts in the more noise-sensitive areas. No specific construction-noise, site-control specifications will be included in the plans.

*Time and Activity Constraints*: Limiting working hours on a construction site can be very beneficial during the hours of sleep or on Sundays and holidays. However, most construction activities do not occur at night and usually not on Sundays. Exceptions due to weather, schedule and a time-related phase of construction work could occur. No specific constraints will be incorporated in the plans of this improvement. Enforcement of these constraints could be handled through a general city or county ordinance, either listing the exceptions or granting them on a case-by-case basis.

# 11.0 Conclusion

A total of 131 residences are predicted to be impacted with noise levels that approach or exceed the NAC within the Study area of this Project. Noise mitigation, in the form of noise walls along the interstate ROW adjacent to these residences, would result in a greater than 5-dBA reduction in noise levels at 181 of the residences and reduce the noise to below 65-dBA at all ground floor residences (an additional 50 residences received benefits from the noise walls, but were not predicted to experience traffic noise impacts).

# 12.0 References

South Dakota Department of Transportation, "Noise Analysis and Abatement Guidelines/Policy," December 1999.

Federal Highway Administration (FHWA) Traffic Noise Analysis and Abatement Policy and Guidance, 1995.

Methods for evaluation and control of construction noise were taken from the FHWA Special Report – "Highway Construction Noise: Measurement, Prediction and Mitigation".

# Appendix A
# Project Information

# DATA FOR NOISE ANALYSIS

## Traffic Data

| Peak Hour Traffic Volumes for the Following Roadways | | | | | | |
|---|---|---|---|---|---|---|
| I-29 2005 | AM Peak | PM Peak | ADT | Peak * | Trucks | Truck Percent |
| Tea to I-229 NB | 1650 | 940 | 26700 | 1455.15 | 202 | 14 |
| Tea to I-229 SB | 890 | 1740 | 26700 | 1455.15 | 202 | 14 |
| I-229 to 41st Street NB | 1315 | 1060 | 25500 | 1389.75 | 164 | 12 |
| I-229 to 41st Street SB | 875 | 1345 | 25500 | 1389.75 | 164 | 12 |
| 41st St to 26th St NB | 1570 | 1245 | 29200 | 1591.4 | 188 | 12 |
| 41st St to 26th St SB | 985 | 1490 | 29200 | 1591.4 | 188 | 12 |
| 26th St to 12th St NB | | | 16353 | 1782.5 | 210 | 12 |
| 26th St to 12th St SB | | | 16353 | 1782.5 | 210 | 12 |
| I-29 2025 | AM Peak | PM Peak | ADT | Peak * | Trucks | Truck Percent |
| Tea to I-229 NB | 3000 | 2100 | 58100 | 3166.45 | 440 | 14 |
| Tea to I-229 SB | 1900 | 3400 | 58100 | 3166.45 | 440 | 14 |
| I-229 to 41st Street NB | 2400 | 2200 | 48500 | 2643.25 | 312 | 12 |
| I-229 to 41st Street SB | 1900 | 2700 | 48500 | 2643.25 | 312 | 12 |
| 41st St to 26th St NB | 2720 | 2500 | 63800 | 3477.1 | 410 | 12 |
| 41st St to 26th St SB | 2060 | 2850 | 63800 | 3477.1 | 410 | 12 |
| 26th St to 12th St NB | | | 28257 | 3080 | 363 | 12 |
| 26th St to 12th St SB | | | 28257 | 3080 | 363 | 12 |

* Peak is assuming 50% Directional Split

Build (2007) – Not available

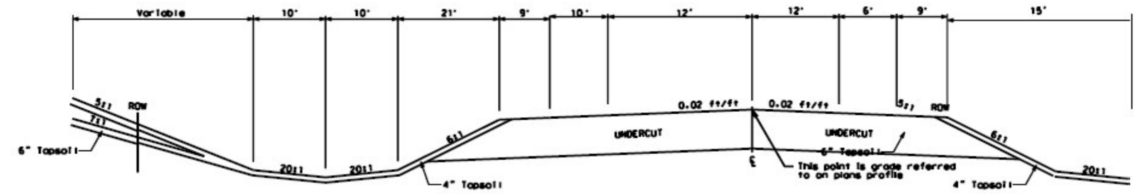
Build & No Build 2025 – Same

Percent Medium Trucks – Not available

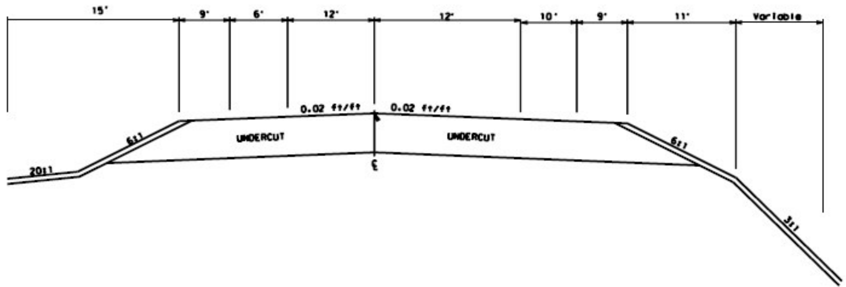
Percent Motorcycles – Not available

# EXISTING TYPICAL SECTION

SB LANES I-29

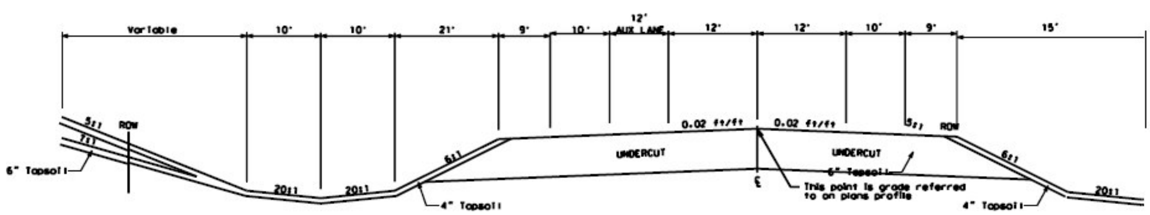



NB LANES I-29

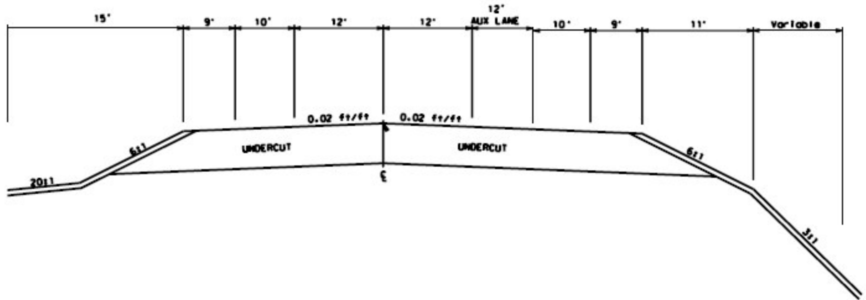



# PROPOSED TYPICAL SECTION

SB LANES I-29

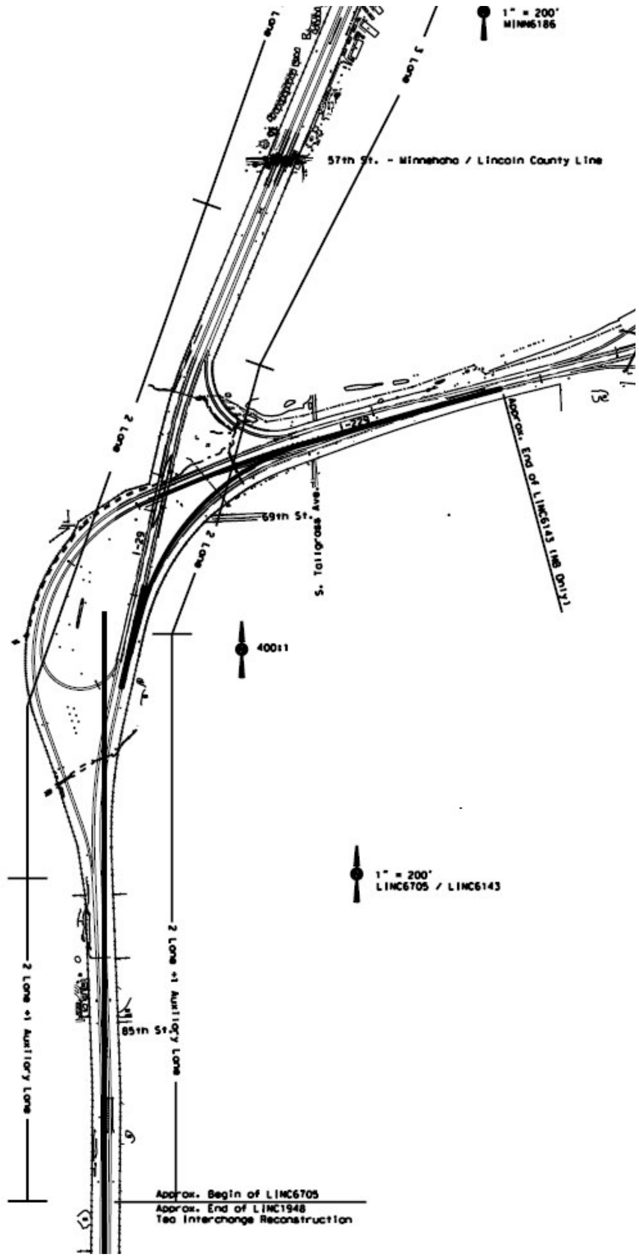



NB LANES I-29



# CONSTRUCTION PLANS

An additional lane will be added on I-29 southbound from near the I-229 Structure to 41st Street Interchange.



# Appendix B
# Pavement Noise Discussion

# PAVEMENT NOISE DISCUSSION

## Pavement Basics

Basically, all hard surfaced pavement types can be categorized into two groups, flexible and rigid. Flexible pavements are those that are surfaced with asphalt materials in the surface (or wearing) course. Hot Mix Asphalt (HMA) surface courses are generally used on higher volume roads such as the Interstate highway network. HMA is a high quality, thoroughly controlled hot-mixture of asphalt binder and aggregate that can be compacted into a uniform dense mass. These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads.

Rigid pavements are composed of a portland cement concrete (PCC) surface course. Such pavements are substantially "stiffer" than flexible pavements. In addition, these pavements can have reinforcing steel, which is generally used to reduce or eliminate "joints". PCC joints are a design detail, which can vary greatly between the various State Highway Agencies. Some states use joints (transverse across the lane) which are closely spaced (12 to 15 feet) and others use reinforcing steel to increase the allowable distance between joints to 40 feet or more or to eliminate them completely.

### HMA Mix Types [1]

The objective of HMA mix design is to determine the combination of asphalt binder and aggregate that will give long-lasting pavement performance while minimizing life cycle costs. In hot-mix, the component materials – aggregate, asphalt binder, and other additives – must be heated prior to mixing to obtain sufficient fluidity for mixing and workability. Mix design involves laboratory procedures developed to establish the necessary proportion of materials for use in the HMA. A sample paving mixture is prepared in the laboratory and can be analyzed to determine its probable performance in a pavement structure. Several characteristics of the mix influence mix behavior: mix density, air voids, voids in the mineral aggregate, and asphalt content.

There are three primary HMA mix types: dense-graded, open-graded, and gap-graded.

***Dense-Graded Mix***

A dense-graded mix is a well-graded (even distribution of aggregate particles from coarse to fine), dense HMA mixture consisting of aggregates and asphalt binder. Properly designed and constructed mixtures are relatively impermeable. This mixture provides a nearly impermeable surface to minimize the potential of surface moisture from entering the underlying pavement layers, which if allowed, weakens the pavement structure.

***Open-Graded Mix***
This is a type of asphalt mixture that has a special aggregate size, which creates a very open texture in the final pavement surface. The open surface texture characteristic of this type of pavement provides benefits in the form of decreased spray from vehicles under wet conditions.

***Gap-Graded Mix***
A gap-graded mix contains aggregate that is not continuously graded for all size fractions, typically missing one or two of the fines sizes.

**PCC Textures**
In its simplest form, concrete is a mixture of paste and aggregates. The paste, composed of portland cement and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. A properly designed concrete mixture will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, a mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may also take up another 5 to 8 percent. [(2)] Variability in the size of the materials used for the cement and aggregate help define its texture.

There are two types of texture that are of most importance in this discussion: microtexture and macrotexture.

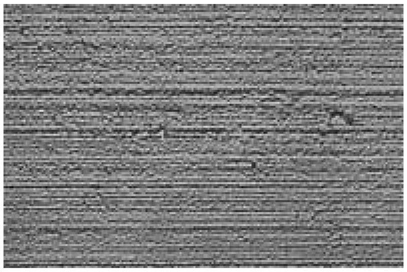
***Microtexture***
Microtexture is defined as the fine-scale roughness contributed by the fine aggregate in the cement which are less than 0.5mm (0.02 in) in size.

***Macrotexture***

Macrotexture, while also being a function of the size of the concrete's aggregate (0.5 mm to 50 mm or 0.02 in to 2.0 in), is most commonly described based on the small surface channels, grooves, or indentations that are intentionally formed (plastic concrete) or cut (hardened concrete) on the surface of the concrete.

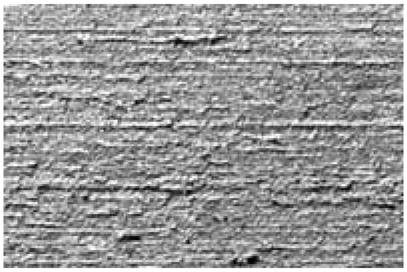
The following sections are short descriptions of the different texturing techniques used with PCC pavements (Source: www.pavement.com).

## Drag Textures



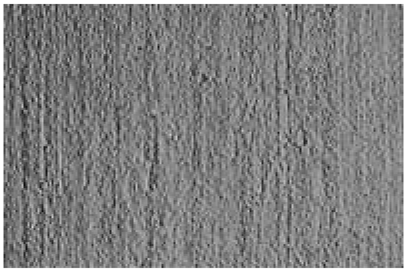
### Broomed Surface

Obtained using either a hand broom or mechanical broom device that lightly drags the stiff bristles across the surface. Produces 1.5-3 mm (1/16-1/8 in.) deep striations. Can be oriented either longitudinally or transversely to centerline of roadway.



### Turf Drag Surface

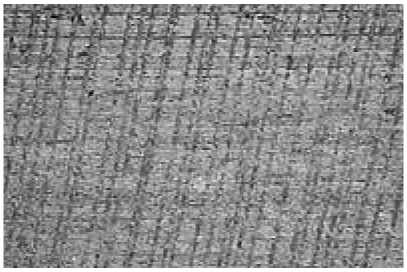
Produced by trailing an inverted section of artificial turf from a device that allows control of the time and rate of texturing - usually a construction bridge that spans the pavement. Produces 1.5-3 mm (1/16-1/8 in.) deep striations when using turf with 77,500 blades/m3 (2,736,887 blades ft3).



### Burlap Drag Surface

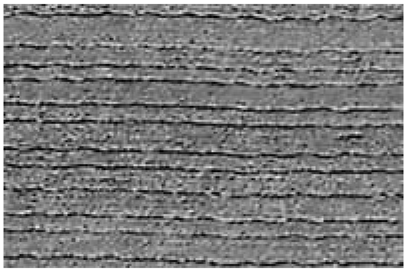
Produced by trailing moistened coarse burlap from a device that allows control of the time and rate of texturing - usually a construction bridge that spans the pavement. Produces 1.5-3 mm (1/16-1/8 in.) deep striations.

## Tine Textures



### Transverse Tine

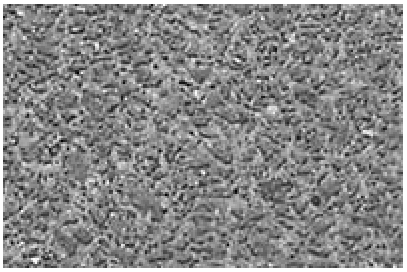
Achieved by a mechanical device equipped with a tining head (metal rake) that moves laterally across the width of the paving surface. Optimal dimensions are: random tine spacing 10 to 40-mm (1/2 to 1-1/2 in.) with no more than 50% above 25 mm (1 in.), 3-6 mm (1/8-1/4 in.) tine depth, and 3 mm (1/8 in.) tine width. Skewing (as shown) has been found to reduce tire/road noise.



### Longitudinal Tine

Achieved in similar manner as transverse tining, except that tines are pulled in a line parallel to the pavement centerline. Optimal dimensions are: 20-mm (3/4-in.) uniform tine spacing, 3-6 mm (1/8-1/4 in.) tine depth, and 3 mm (1/8 in.) tine width.

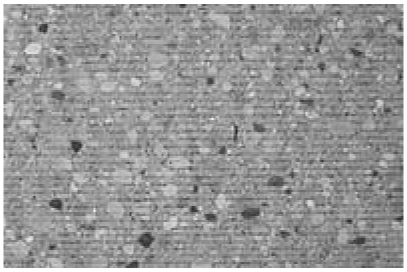
## Exposed Aggregate



### Exposed Aggregate

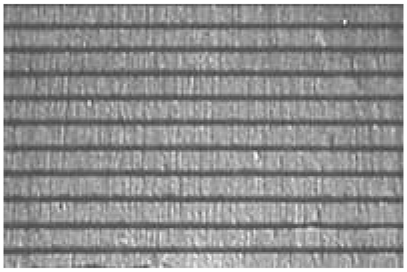
Mostly European practice of applying a set retarder to the new concrete surface, and then washing away surface mortar to expose durable chip-size aggregates. Requires uniformly applying chips to fresh surface and mechanically abrading surface to wash away still-wet mortar.

## Hardened Concrete Textures



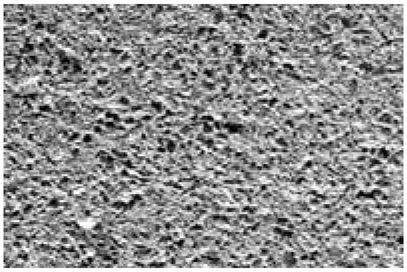
### Diamond Ground

Longitudinal, corduroy-like surface made by equipment using diamond saw blades gang-mounted on a cutting head. The cutting head produces 164-197 grooves/meter (50-60 grooves/foot) and can remove 3-20 mm (1/8-3/4 in.) from the pavement surface.



### Diamond Groove

Grooves sawed into surface longitudinally for highways and transversely for airports. Made by same equipment for diamond grinding. Typically, the grooves are 6 mm (1/4 in.) deep, 3 mm (1/8 in.) wide and spaced 20 mm (3/4 in.) apart. On airports grooves are 6 mm (1/4 in.) deep, 6 mm (1/4 in.) wide and spaced 40 mm (1-1/2 in.) apart.



**Abraded (Shot Blasted)**

Etched surface produced by equipment that hurls abrasive media within an enclosed housing. The abrasive media impacts the surface and removes a thin layer of mortar and aggregate. The depth of the removal is controllable and the dust is vacuumed into a baghouse.

The goal of all roadway pavements is to provide a long lasting surface that provides adequate traction for stopping during all conditions at the posted speed limit. Until relatively recently, the attempt to increase roadway safety through increasing or adding macrotexture has also increased roadway noise levels.

FHWA's Traffic Noise Model (TNM) utilizes an "average pavement type". The average pavement type is defined as a combination of both dense-graded asphaltic concrete (DGAC) and Portland cement concrete (PCC). This combination is made up of approximately 75% DGAC pavement and 25% PCC pavement.

## Macrotexture and Noise

The need for speed on highways, starting around 1950, brought about the need for roadway pavements that were able to provide traction and drainage during wet conditions, both of these are controlled by the pavement macrostructure.

Early methods of surface texturing of new PCC pavements primarily consisted of the use of broom finishing or burlap dragging to impart relatively shallow textures. Research results from this time period indicated that while these shallow texturing techniques resulted in a very quiet riding surface, they did not provide adequate skid resistance at high speeds. Subsequent research demonstrated that improved traction characteristics were provided by the use of transverse tining, which remains the most common texturing technique in use in the United States today. [(3)] Unfortunately, this texture also results in the loudest pavement because of the whine associated with uniform tining.

Extensive research efforts in many countries have examined various compositions and textures of pavement in the search for quieter roadways that are cost effective and, most importantly, provide traction under wet conditions. A small sampling is presented below.

A multi-state research project done by Marquette University and HNTB Corporation [(4)] compared pavement noise measurements ($L_{MAX}$) at 10 new PCC pavement test sites in Wisconsin and 57 locations in Colorado, Iowa, Michigan, Minnesota, North Dakota, and Wisconsin. They found that the longitudinally tined PCC and the "asphaltic concrete" pavements were the quietest, with a 4 to 7-dBA noise reduction over uniform, transversely tined

PCC pavement. Randomly skewed, tined PPC was next quietest with a 4-dBA reduction, and random, transversely tined was last with a 1 to 3-dBA reduction.

In another study, eighteen pavement surfaces were tested for noise in Colorado at the request of the Colorado DOT (5). A total of 12 HMA and 6 PCC pavements of varying ages are represented in the study. The transversely tined PCC pavement had the highest noise level (and was significantly older than the other pavements). The other PCC pavements (with textures of longitudinally tined, ground, and dragged) were about 4-dBA quieter. Noise levels measured for the HMA pavements had a strong age dependence, with the oldest (6 years) being only about 1.5-dBA quieter than the transversely tined PCC pavement. The youngest HMA pavements (1 year) averaged 7-dBA quieter than the transversely tined PCC pavement. This noise/age relationship with HMA pavements was not found in a four year California study which found open graded HMA to be about 4-dBA quieter than dense graded HMA (6).

The Utah Department of Transportation looked at the noise benefit from grinding a longitudinal texture on to a ten year old transversely tined PCC pavement (7). Their conclusion was that because of the heavy truck engine stack noise contribution only a 1 to 2-dBA noise reduction could be expected. The study did report that the pavement whine had been removed by the new texturing.

A study funded by the Texas Department of Transportation measured noise levels from 15 different types of pavement in Texas (8). The transversely tined PCC pavement (here called CRCP, or continuously reinforced concrete pavement) did not rank the noisiest, based on roadside measurements, that honor fell to two types of grooved pavements. The quietest pavement was a proprietary form of aged open graded asphalt that was about 4-dBA quieter than the transversely tined PCC pavement.

Climate can play a significant role in alternative pavement options, as well. An example of potentially climate sensitive material is rubberized pavement. Rubberized pavement is composed of an asphalt that uses recycled rubber from tires in the form of pellets as part of its mix. The city of Phoenix, Arizona, utilizes it as an overlay for pre-existing pavement and reports a noise reduction of up to10-dBA. However, the material must be placed when the underlying pavement surface temperature is between 85º and 145º F (9), which significantly reduces the window of opportunity in northern climates. Additionally, a pamphlet from the Colorado Department of Transportation states that asphalt pavement "has not been proven to ensure a safe riding surface for Colorado's extreme winters and variable temperatures resulting in numerous freeze-thaw cycles." (10)

## REFERENCES

(1) Baker, T., et al., "Evaluation of the Use of Scrap Tires in Transportation Related Applications in the State of Washington," Report to the Legislature as Required by SHB 2308, Washington State Department of Transportation, August 2003.
(2) www.cement.org
(3) Hoerner, T., et al., "Current Practice of PCC Pavement Texturing," Transportation Research Board 2003 Annual Meeting CD-ROM.
(4) Kuemmel, D., et al., "Noise and Texture on PCC Pavements – Results of a Multi-State Study," Wisconsin Department of Transportation Report WI/SPR-08-99, May 2000.
(5) Hanson, D., and James, R., "Colorado DOT Tire/Pavement Noise Study," Colorado Department of Transportation Report CDOT-DTD-R-2004-5, April 2004.
(6) Illingworth & Rodkin, Inc., "Traffic Noise Levels Associated with an Aging Open Grade Asphalt Concrete Overlay," California Department of Transportation, December 2002.
(7) Parsons Brinckerhoff Quade & Douglas, Inc., "I-215 Pavement Grinding Noise Study," Utah Department of Transportation, November 2000.
(8) McNerney, M., et al., "Comparative Field Measurements of Tire Pavement Noise of Selected Texas Pavements," Transportation Research Record No. 1626, 1998.
(9) Broviak, P., "The Sound of Traffic," PublicWorks Magazine, September 2005.
(10) "Highway Traffic Noise: Effect of Pavement Types," Colorado Department of Transportation website http://www.dot.state.co.us/Publications/Brochures, July 2005.

# Appendix C
# Barrier Analysis Results

RESULTS: SOUND LEVELS 27893

HDR, Inc.
A. Gowan

3 October 2005
TNM 2.5
Calculated with TNM 2.5

RESULTS: SOUND LEVELS
PROJECT/CONTRACT: 27893
RUN: I-29 Noise Analysis Build
BARRIER DESIGN: UpperEast

ATMOSPHERICS: 75 deg F, 55% RH

Average pavement type shall be used unless a State highway agency substantiates the use of a different type with approval of FHWA.

| Receiver | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | No. | #DUs | Existing LAeq1h | No Barrier | | | | | With Barrier | | | | |
| | | | | LAeq1h | | Increase over existing | | Type | Calculated LAeq1h | Noise Reduction | | | |
| | | | | Calculated | Crit'n | Calculated | Crit'n Sub'l Inc | Impact | | Calculated | Goal | | Calculated minus Goal |
| | | | dBA | dBA | dBA | dB | dB | | dBA | dB | dB | | dB |
| 1 | 26 | 1 | 0.0 | 69.1 | 66 | 69.1 | 10 | Snd Lvl | 63.7 | 5.4 | 1 | 8 | -2.6 |
| 2 | 27 | 1 | 0.0 | 69.1 | 66 | 69.1 | 10 | Snd Lvl | 62.7 | 6.4 | 2 | 8 | -1.6 |
| 3 | 28 | 1 | 0.0 | 68.9 | 66 | 68.9 | 10 | Snd Lvl | 61.9 | 7.0 | 3 | 8 | -1.0 |
| 4 | 29 | 1 | 0.0 | 69.0 | 66 | 69.0 | 10 | Snd Lvl | 62.2 | 6.8 | 4 | 8 | -1.2 |
| 5 | 30 | 1 | 0.0 | 69.1 | 66 | 69.1 | 10 | Snd Lvl | 63.1 | 6.0 | 5 | 8 | -2.0 |
| 6 | 31 | 1 | 0.0 | 68.3 | 66 | 68.3 | 10 | Snd Lvl | 61.5 | 6.8 | 6 | 8 | -1.2 |
| 7 | 32 | 1 | 0.0 | 69.7 | 66 | 69.7 | 10 | Snd Lvl | 61.4 | 8.3 | 7 | 8 | 0.3 |
| 8 | 33 | 1 | 0.0 | 67.6 | 66 | 67.6 | 10 | Snd Lvl | 61.1 | 6.5 | 8 | 8 | -1.5 |
| 9 | 34 | 1 | 0.0 | 66.5 | 66 | 66.5 | 10 | Snd Lvl | 61.0 | 5.5 | 9 | 8 | -2.5 |
| 10 | 35 | 1 | 0.0 | 67.5 | 66 | 67.5 | 10 | Snd Lvl | 61.3 | 6.2 | 10 | 8 | -1.8 |
| 11 | 36 | 1 | 0.0 | 68.6 | 66 | 68.6 | 10 | Snd Lvl | 61.3 | 7.3 | 11 | 8 | -0.7 |
| 12 | 37 | 1 | 0.0 | 66.5 | 66 | 66.5 | 10 | Snd Lvl | 60.7 | 5.8 | 12 | 8 | -2.2 |
| 13 | 38 | 1 | 0.0 | 65.6 | 66 | 65.6 | 10 | ---- | 60.3 | 5.3 | 13 | 8 | -2.7 |
| 14 | 39 | 1 | 0.0 | 65.7 | 66 | 65.7 | 10 | ---- | 60.6 | 5.1 | 14 | 8 | -2.9 |
| 15 | 40 | 1 | 0.0 | 64.8 | 66 | 64.8 | 10 | ---- | 60.1 | 4.7 | 15 | 8 | -3.3 |
| 16 | 41 | 1 | 0.0 | 68.2 | 66 | 68.2 | 10 | Snd Lvl | 61.3 | 6.9 | 16 | 8 | -1.1 |
| 17 | 42 | 1 | 0.0 | 69.0 | 66 | 69.0 | 10 | Snd Lvl | 61.4 | 7.6 | 17 | 8 | -0.4 |
| 18 | 43 | 1 | 0.0 | 65.6 | 66 | 65.6 | 10 | ---- | 60.5 | 5.1 | 18 | 8 | -2.9 |
| 19 | 44 | 1 | 0.0 | 66.3 | 66 | 66.3 | 10 | Snd Lvl | 60.9 | 5.4 | 19 | 8 | -2.6 |
| 20 | 45 | 1 | 0.0 | 67.6 | 66 | 67.6 | 10 | Snd Lvl | 61.3 | 6.3 | 20 | 8 | -1.7 |
| 21 | 46 | 1 | 0.0 | 66.8 | 66 | 66.8 | 10 | Snd Lvl | 61.0 | 5.8 | 21 | 8 | -2.2 |
| 22 | 47 | 1 | 0.0 | 64.0 | 66 | 64.0 | 10 | ---- | 59.9 | 4.1 | | 8 | -3.9 |
| 23 | 48 | 1 | 0.0 | 64.9 | 66 | 64.9 | 10 | ---- | 60.3 | 4.6 | 22 | 8 | -3.4 |

**RESULTS: SOUND LEVELS** **27893**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 49 | 1 | 0.0 | 65.3 | 66 | 65.3 | 10 | ---- | 60.6 | 4.7 | 23 | 8 | -3.3 |
| 25 | 50 | 1 | 0.0 | 64.6 | 66 | 64.6 | 10 | ---- | 60.4 | 4.2 | | 8 | -3.8 |
| 26 | 51 | 1 | 0.0 | 69.0 | 66 | 69.0 | 10 | Snd Lvl | 62.0 | 7.0 | 24 | 8 | -1.0 |
| 27 | 52 | 1 | 0.0 | 69.3 | 66 | 69.3 | 10 | Snd Lvl | 64.8 | 4.5 | 25 | 8 | -3.5 |
| 28 | 53 | 1 | 0.0 | 69.5 | 66 | 69.5 | 10 | Snd Lvl | 63.0 | 6.5 | 26 | 8 | -1.5 |
| 29 | 54 | 1 | 0.0 | 69.2 | 66 | 69.2 | 10 | Snd Lvl | 62.3 | 6.9 | 27 | 8 | -1.1 |
| 30 | 55 | 1 | 0.0 | 69.4 | 66 | 69.4 | 10 | Snd Lvl | 63.9 | 5.5 | 28 | 8 | -2.5 |
| 35 | 114 | 1 | 0.0 | 69.0 | 66 | 69.0 | 10 | Snd Lvl | 62.5 | 6.5 | 29 | 8 | -1.5 |
| 36 | 115 | 1 | 0.0 | 67.0 | 66 | 67.0 | 10 | Snd Lvl | 61.1 | 5.9 | 30 | 8 | -2.1 |
| 37 | 116 | 1 | 0.0 | 67.0 | 66 | 67.0 | 10 | Snd Lvl | 60.9 | 6.1 | 31 | 8 | -1.9 |
| 38 | 117 | 1 | 0.0 | 66.2 | 66 | 66.2 | 10 | Snd Lvl | 60.7 | 5.5 | 32 | 8 | -2.5 |
| 39 | 118 | 1 | 0.0 | 66.9 | 66 | 66.9 | 10 | Snd Lvl | 61.1 | 5.8 | 33 | 8 | -2.2 |
| 40 | 119 | 1 | 0.0 | 69.2 | 66 | 69.2 | 10 | Snd Lvl | 62.5 | 6.7 | 34 | 8 | -1.3 |
| Receiver122 | 122 | 1 | 0.0 | 72.7 | 66 | 72.7 | 10 | Snd Lvl | 67.6 | 5.1 | 35 | 8 | -2.9 |
| Receiver123 | 123 | 1 | 0.0 | 72.7 | 66 | 72.7 | 10 | Snd Lvl | 67.0 | 5.7 | 36 | 8 | -2.3 |
| Receiver124 | 124 | 1 | 0.0 | 72.7 | 66 | 72.7 | 10 | Snd Lvl | 66.6 | 6.1 | 37 | 8 | -1.9 |
| Receiver125 | 125 | 1 | 0.0 | 72.8 | 66 | 72.8 | 10 | Snd Lvl | 66.2 | 6.6 | 38 | 8 | -1.4 |
| Receiver126 | 126 | 1 | 0.0 | 72.8 | 66 | 72.8 | 10 | Snd Lvl | 66.4 | 6.4 | 39 | 8 | -1.6 |
| Receiver127 | 127 | 1 | 0.0 | 72.8 | 66 | 72.8 | 10 | Snd Lvl | 66.6 | 6.2 | 40 | 8 | -1.8 |
| Receiver128 | 128 | 1 | 0.0 | 72.9 | 66 | 72.9 | 10 | Snd Lvl | 67.0 | 5.9 | 41 | 8 | -2.1 |
| Receiver129 | 129 | 1 | 0.0 | 72.9 | 66 | 72.9 | 10 | Snd Lvl | 67.8 | 5.1 | 42 | 8 | -2.9 |
| Receiver130 | 130 | 1 | 0.0 | 71.7 | 66 | 71.7 | 10 | Snd Lvl | 65.1 | 6.6 | 43 | 8 | -1.4 |
| Receiver131 | 131 | 1 | 0.0 | 70.9 | 66 | 70.9 | 10 | Snd Lvl | 64.7 | 6.2 | 44 | 8 | -1.8 |
| Receiver132 | 132 | 1 | 0.0 | 70.2 | 66 | 70.2 | 10 | Snd Lvl | 64.6 | 5.6 | 45 | 8 | -2.4 |
| Receiver133 | 133 | 1 | 0.0 | 69.1 | 66 | 69.1 | 10 | Snd Lvl | 64.1 | 5.0 | 46 | 8 | -3.0 |
| Receiver134 | 134 | 1 | 0.0 | 70.8 | 66 | 70.8 | 10 | Snd Lvl | 64.5 | 6.3 | 47 | 8 | -1.7 |
| Receiver135 | 135 | 1 | 0.0 | 70.1 | 66 | 70.1 | 10 | Snd Lvl | 64.2 | 5.9 | 48 | 8 | -2.1 |
| Receiver136 | 136 | 1 | 0.0 | 69.4 | 66 | 69.4 | 10 | Snd Lvl | 63.9 | 5.5 | 49 | 8 | -2.5 |
| Receiver137 | 137 | 1 | 0.0 | 68.7 | 66 | 68.7 | 10 | Snd Lvl | 63.6 | 5.1 | 50 | 8 | -2.9 |
| Receiver138 | 138 | 1 | 0.0 | 72.6 | 66 | 72,6 | 10 | Snd Lvl | 65.0 | 7.6 | 51 | 8 | -0.4 |
| Receiver139 | 139 | 1 | 0.0 | 71.9 | 66 | 71.9 | 10 | Snd Lvl | 64.6 | 7.3 | 52 | 8 | -0.7 |
| Receiver140 | 140 | 1 | 0.0 | 71.1 | 66 | 71.1 | 10 | Snd Lvl | 64.3 | 6.8 | 53 | 8 | -1.2 |
| Receiver141 | 141 | 1 | 0.0 | 70.4 | 66 | 70.4 | 10 | Snd Lvl | 63.9 | 6.5 | 54 | 8 | -1.5 |
| Receiver142 | 142 | 1 | 0.0 | 69.5 | 66 | 69.5 | 10 | Snd Lvl | 63.9 | 5.6 | 55 | 8 | -2.4 |
| Receiver143 | 143 | 1 | 0.0 | 70.4 | 66 | 70.4 | 10 | Snd Lvl | 64.4 | 6.0 | 56 | 8 | -2.0 |
| Receiver144 | 144 | 1 | 0.0 | 71.0 | 66 | 71.0 | 10 | Snd Lvl | 64.8 | 6.2 | 57 | 8 | -1.8 |
| Receiver145 | 145 | 1 | 0.0 | 71.5 | 66 | 71.5 | 10 | Snd Lvl | 65.1 | 6.4 | 58 | 8 | -1.6 |

| Dwelling Units | # DUs | Noise Reduction | | |
|---|---|---|---|---|
| | | Min | Avg | Max |
| | | dB | dB | dB |

**RESULTS: SOUND LEVELS** **27893**

| | | | | | |
|---|---|---|---|---|---|
| All Selected | 60 | 4.1 | 6.0 | 8.3 | |
| All Impacted | 52 | 4.5 | 6.2 | 8.3 | |
| All that meet NR Goal | 1 | 8.3 | 8.3 | 8.3 | |

HDR, Inc. 16 November 2005
A. Gowan TNM 2.5

RESULTS: BARRIER DESCRIPTIONS
PROJECT/CONTRACT: 27893
RUN: I-29 Noise Analysis Build
BARRIER DESIGN: UpperEast

| Barriers | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | Type | Heights along Barrier | | | Length | If Wall | If Berm | | | Cost |
| | | Min | Avg | Max | | Area | Volume | Top Width | Run:Rise | |
| | | ft | ft | ft | ft | sq ft | cu yd | ft | ft:ft | $ |
| East | W | 16.00 | 16.00 | 16.00 | 1039 | 16624 | | | | 955862 |
| | | | | | | | | | Total Cost: | 955862 |

58 benefitted receptors (b.r.)
$16,480/b.r.

RESULTS: SOUND LEVELS 27893

HDR, Inc. 30 September 2005
A. Gowan TNM 2.5
Calculated with TNM 2.5

RESULTS: SOUND LEVELS
PROJECT/CONTRACT: 27893
RUN: I-29 Noise Analysis Build
BARRIER DESIGN: UpperNorth

ATMOSPHERICS: 75 deg F, 55% RH

Average pavement type shall be used unless a State highway agency substantiates the use of a different type with approval of FHWA.

| Receiver Name | No. | #DUs | Existing LAeq1h | No Barrier LAeq1h Calculated | Crit'n | Increase over existing Calculated | Crit'n Sub'l Inc | Type Impact | With Barrier Calculated LAeq1h | Noise Reduction Calculated | Goal | Calculated minus Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dBA | dBA | dBA | dB | dB | | dBA | dB | dB | dB |
| 1 | 2 | 1 | 70.1 | 69.6 | 66 | -0.5 | 10 | Snd Lvl | 63.4 | 6.2 | 1 8 | -1.8 |
| 2 | 3 | 1 | 70.1 | 71.2 | 66 | 1.1 | 10 | Snd Lvl | 63.2 | 8.0 | 2 8 | 0.0 |
| 3 | 4 | 1 | 70.1 | 71.5 | 66 | 1.4 | 10 | Snd Lvl | 62.5 | 9.0 | 3 8 | 1.0 |
| 4 | 6 | 1 | 70.1 | 69.6 | 66 | -0.5 | 10 | Snd Lvl | 62.7 | 6.9 | 4 8 | -1.1 |
| 5 | 7 | 1 | 70.1 | 69.4 | 66 | -0.7 | 10 | Snd Lvl | 62.4 | 7.0 | 5 8 | -1.0 |
| 6 | 17 | 1 | 70.1 | 69.4 | 66 | -0.7 | 10 | Snd Lvl | 62.3 | 7.1 | 6 8 | -0.9 |
| 7 | 18 | 1 | 70.1 | 69.4 | 66 | -0.7 | 10 | Snd Lvl | 62.1 | 7.3 | 7 8 | -0.7 |
| 8 | 19 | 1 | 70.1 | 69.5 | 66 | -0.6 | 10 | Snd Lvl | 62.0 | 7.5 | 8 8 | -0.5 |
| 9 | 20 | 1 | 70.1 | 69.3 | 66 | -0.8 | 10 | Snd Lvl | 61.7 | 7.6 | 9 8 | -0.4 |
| 10 | 22 | 1 | 70.1 | 69.3 | 66 | -0.8 | 10 | Snd Lvl | 61.6 | 7.7 | 10 8 | -0.3 |
| 11 | 23 | 1 | 69.0 | 66.2 | 66 | -2.8 | 10 | Snd Lvl | 62.7 | 3.5 | 8 | -4.5 |
| 12 | 24 | 1 | 69.0 | 64.1 | 66 | -4.9 | 10 | ---- | 61.3 | 2.8 | 8 | -5.2 |
| 13 | 25 | 1 | 69.0 | 64.0 | 66 | -5.0 | 10 | ---- | 60.8 | 3.2 | 8 | -4.8 |
| 14 | 26 | 1 | 69.0 | 64.9 | 66 | -4.1 | 10 | ---- | 61.1 | 3.8 | 8 | -4.2 |
| 15 | 27 | 1 | 69.0 | 64.3 | 66 | -4.7 | 10 | ---- | 61.0 | 3.3 | 8 | -4.7 |
| 16 | 28 | 1 | 69.0 | 63.2 | 66 | -5.8 | 10 | ---- | 61.3 | 1.9 | 8 | -6.1 |
| 17 | 29 | 1 | 69.0 | 62.5 | 66 | -6.5 | 10 | ---- | 61.6 | 0.9 | 8 | -7.1 |
| 21 | 30 | 1 | 0.0 | 75.3 | 66 | 75.3 | 10 | Snd Lvl | 68.4 | 6.9 | 11 8 | -1.1 |
| 22 | 31 | 1 | 0.0 | 75.6 | 66 | 75.6 | 10 | Snd Lvl | 67.9 | 7.7 | 12 8 | -0.3 |
| 23 | 32 | 1 | 0.0 | 73.8 | 66 | 73.8 | 10 | Snd Lvl | 67.3 | 6.5 | 13 8 | -1.5 |
| 23 | 33 | 1 | 0.0 | 73.8 | 66 | 73.8 | 10 | Snd Lvl | 68.2 | 5.6 | 14 8 | -2.4 |
| 25 | 34 | 1 | 0.0 | 73.4 | 66 | 73.4 | 10 | Snd Lvl | 67.0 | 6.4 | 15 8 | -1.6 |
| 26 | 35 | 1 | 0.0 | 73.2 | 66 | 73.2 | 10 | Snd Lvl | 66.7 | 6.5 | 16 8 | -1.5 |

**RESULTS: SOUND LEVELS** **27893**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | 36 | 1 | 0.0 | 73.4 | 66 | 73.4 | 10 | Snd Lvl | 66.6 | 6.8 | 17 | 8 | -1.2 |
| 28 | 37 | 1 | 0.0 | 73.4 | 66 | 73.4 | 10 | Snd Lvl | 66.6 | 6.8 | 18 | 8 | -1.2 |
| 29 | 38 | 1 | 0.0 | 73.2 | 66 | 73.2 | 10 | Snd Lvl | 66.3 | 6.9 | 19 | 8 | -1.1 |
| 210 | 39 | 1 | 0.0 | 73.3 | 66 | 73.3 | 10 | Snd Lvl | 66.4 | 6.9 | 20 | 8 | -1.1 |

| Dwelling Units | # DUs | Noise Reduction | | |
|---|---|---|---|---|
| | | Min | Avg | Max |
| | | dB | dB | dB |
| All Selected | 27 | 0.9 | 6.0 | 9.0 |
| All Impacted | 21 | 3.5 | 6.9 | 9.0 |
| All that meet NR Goal | 1 | 9.0 | 9.0 | 9.0 |

HDR, Inc. 16 November 2005
A. Gowan TNM 2.5

**RESULTS: BARRIER DESCRIPTIONS**
**PROJECT/CONTRACT:** 27893
**RUN:** I-29 Noise Analysis Build
**BARRIER DESIGN:** UpperNorth

| Barriers | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | Type | Heights along Barrier | | | Length | If Wall | If Berm | | | Cost |
| | | Min | Avg | Max | | Area | Volume | Top Width | Run:Rise | |
| | | ft | ft | ft | ft | sq ft | cu yd | ft | ft:ft | $ |
| North | W | 16.00 | 16.00 | 16.00 | 638 | 10204 | | | | 586704 |
| | | | | | | | | | Total Cost: | 586704 |

20 b.r.
$29,335/b.r.

RESULTS: SOUND LEVELS 27893

HDR, Inc. 3 October 2005
A. Gowan TNM 2.5
Calculated with TNM 2.5

RESULTS: SOUND LEVELS
PROJECT/CONTRACT: 27893
RUN: I-29 Noise Analysis Build
BARRIER DESIGN: South2

Average pavement type shall be used unless a State highway agency substantiates the use of a different type with approval of FHWA.

ATMOSPHERICS: 75 deg F, 55% RH

| Receiver | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | No. | #DUs | Existing LAeq1h | No Barrier LAeq1h Calculated | Crit'n | Increase over existing Calculated | Crit'n Sub'l Inc | Type Impact | With Barrier Calculated LAeq1h | Noise Reduction Calculated | Goal | Calculated minus Goal |
| | | | dBA | dBA | dBA | dB | dB | | dBA | dB | dB | dB |
| a | 26 | 1 | 0.0 | 69.7 | 66 | 69.7 | 10 | Snd Lvl | 64.9 | 4.8 | 8 | -3.2 |
| b | 27 | 1 | 0.0 | 69.7 | 66 | 69.7 | 10 | Snd Lvl | 59.6 | 10.1 | 8 | 2.1 |
| c | 28 | 1 | 0.0 | 68.3 | 66 | 68.3 | 10 | Snd Lvl | 59.6 | 8.7 | 8 | 0.7 |
| d | 29 | 1 | 0.0 | 66.4 | 66 | 66.4 | 10 | Snd Lvl | 59.1 | 7.3 | 8 | -0.7 |
| e | 30 | 1 | 0.0 | 64.6 | 66 | 64.6 | 10 | ---- | 58.2 | 6.4 | 8 | -1.6 |
| f | 31 | 1 | 0.0 | 66.4 | 66 | 66.4 | 10 | Snd Lvl | 59.0 | 7.4 | 8 | -0.6 |
| g | 32 | 1 | 0.0 | 67.5 | 66 | 67.5 | 10 | Snd Lvl | 59.6 | 7.9 | 8 | -0.1 |
| h | 33 | 1 | 0.0 | 68.6 | 66 | 68.6 | 10 | Snd Lvl | 59.9 | 8.7 | 8 | 0.7 |
| i | 34 | 1 | 0.0 | 69.1 | 66 | 69.1 | 10 | Snd Lvl | 60.2 | 8.9 | 8 | 0.9 |
| j | 35 | 1 | 0.0 | 69.8 | 66 | 69.8 | 10 | Snd Lvl | 60.7 | 9.1 | 8 | 1.1 |
| k | 36 | 1 | 0.0 | 70.0 | 66 | 70.0 | 10 | Snd Lvl | 61.0 | 9.0 | 8 | 1.0 |
| l | 37 | 1 | 0.0 | 70.0 | 66 | 70.0 | 10 | Snd Lvl | 60.7 | 9.3 | 8 | 1.3 |
| m | 38 | 1 | 0.0 | 70.3 | 66 | 70.3 | 10 | Snd Lvl | 60.9 | 9.4 | 8 | 1.4 |
| n | 39 | 1 | 0.0 | 70.4 | 66 | 70.4 | 10 | Snd Lvl | 61.2 | 9.2 | 8 | 1.2 |
| o | 40 | 1 | 0.0 | 70.2 | 66 | 70.2 | 10 | Snd Lvl | 61.1 | 9.1 | 8 | 1.1 |
| p | 41 | 1 | 0.0 | 70.2 | 66 | 70.2 | 10 | Snd Lvl | 61.1 | 9.1 | 8 | 1.1 |
| q | 42 | 1 | 0.0 | 70.5 | 66 | 70.5 | 10 | Snd Lvl | 61.4 | 9.1 | 8 | 1.1 |
| r | 43 | 1 | 0.0 | 70.4 | 66 | 70.4 | 10 | Snd Lvl | 61.3 | 9.1 | 8 | 1.1 |
| s | 44 | 1 | 0.0 | 70.4 | 66 | 70.4 | 10 | Snd Lvl | 61.5 | 8.9 | 8 | 0.9 |
| t | 45 | 1 | 0.0 | 69.4 | 66 | 69.4 | 10 | Snd Lvl | 61.1 | 8.3 | 8 | 0.3 |
| u | 46 | 1 | 0.0 | 68.8 | 66 | 68.8 | 10 | Snd Lvl | 61.0 | 7.8 | 8 | -0.2 |
| v | 47 | 1 | 0.0 | 67.8 | 66 | 67.8 | 10 | Snd Lvl | 60.5 | 7.3 | 8 | -0.7 |
| w | 48 | 1 | 0.0 | 67.6 | 66 | 67.6 | 10 | Snd Lvl | 60.5 | 7.1 | 23 8 | -0.9 |

RESULTS: SOUND LEVELS 27893

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x | 49 | 1 | 0.0 | 69.7 | 66 | 69.7 | 10 | Snd Lvl | 61.2 | 8.5 | 8 | 0.5 |
| y | 50 | 1 | 0.0 | 71.6 | 66 | 71.6 | 10 | Snd Lvl | 61.0 | 10.6 | 8 | 2.6 |
| z | 51 | 1 | 0.0 | 72.3 | 66 | 72.3 | 10 | Snd Lvl | 60.2 | 12.1 | 8 | 4.1 |
| aa | 52 | 1 | 0.0 | 71.6 | 66 | 71.6 | 10 | Snd Lvl | 61.1 | 10.5 | 8 | 2.5 |
| bb | 53 | 1 | 0.0 | 70.4 | 66 | 70.4 | 10 | Snd Lvl | 60.6 | 9.8 | 8 | 1.8 |
| cc | 54 | 1 | 0.0 | 69.6 | 66 | 69.6 | 10 | Snd Lvl | 60.5 | 9.1 | 8 | 1.1 |
| dd | 55 | 1 | 0.0 | 68.3 | 66 | 68.3 | 10 | Snd Lvl | 59.8 | 8.5 | 8 | 0.5 |
| ee | 56 | 1 | 0.0 | 69.4 | 66 | 69.4 | 10 | Snd Lvl | 59.8 | 9.6 | 8 | 1.6 |
| ff | 57 | 1 | 0.0 | 70.9 | 66 | 70.9 | 10 | Snd Lvl | 58.2 | 12.7 | 8 | 4.7 |
| gg | 58 | 1 | 0.0 | 69.0 | 66 | 69.0 | 10 | Snd Lvl | 60.0 | 9.0 | 8 | 1.0 |
| hh | 59 | 1 | 0.0 | 69.1 | 66 | 69.1 | 10 | Snd Lvl | 60.2 | 8.9 | 8 | 0.9 |
| ii | 60 | 1 | 0.0 | 69.2 | 66 | 69.2 | 10 | Snd Lvl | 60.2 | 9.0 | 8 | 1.0 |
| jj | 61 | 1 | 0.0 | 69.6 | 66 | 69.6 | 10 | Snd Lvl | 60.5 | 9.1 | 8 | 1.1 |
| kk | 62 | 1 | 0.0 | 69.9 | 66 | 69.9 | 10 | Snd Lvl | 60.6 | 9.3 | 8 | 1.3 |
| ll | 63 | 1 | 0.0 | 69.7 | 66 | 69.7 | 10 | Snd Lvl | 60.6 | 9.1 | 8 | 1.1 |
| mm | 64 | 1 | 0.0 | 69.7 | 66 | 69.7 | 10 | Snd Lvl | 60.5 | 9.2 | 8 | 1.2 |
| nn | 65 | 1 | 0.0 | 69.9 | 66 | 69.9 | 10 | Snd Lvl | 60.6 | 9.3 | 8 | 1.3 |
| oo | 66 | 1 | 0.0 | 69.6 | 66 | 69.6 | 10 | Snd Lvl | 60.7 | 8.9 | 8 | 0.9 |
| pp | 67 | 1 | 0.0 | 70.2 | 66 | 70.2 | 10 | Snd Lvl | 60.8 | 9.4 | 8 | 1.4 |
| qq | 68 | 1 | 0.0 | 70.1 | 66 | 70.1 | 10 | Snd Lvl | 61.0 | 9.1 | 8 | 1.1 |
| rr | 69 | 1 | 0.0 | 70.6 | 66 | 70.6 | 10 | Snd Lvl | 61.1 | 9.5 | 8 | 1.5 |
| ss | 70 | 1 | 0.0 | 70.9 | 66 | 70.9 | 10 | Snd Lvl | 61.3 | 9.6 | 8 | 1.6 |
| tt | 71 | 1 | 0.0 | 71.3 | 66 | 71.3 | 10 | Snd Lvl | 61.4 | 9.9 | 8 | 1.9 |
| uu | 72 | 1 | 0.0 | 70.2 | 66 | 70.2 | 10 | Snd Lvl | 61.2 | 9.0 | 8 | 1.0 |
| vv | 73 | 1 | 0.0 | 67.9 | 66 | 67.9 | 10 | Snd Lvl | 61.0 | 6.9 | 8 | -1.1 |
| ww | 74 | 1 | 0.0 | 65.0 | 66 | 65.0 | 10 | ---- | 59.7 | 5.3 | 8 | -2.7 |
| xx | 75 | 1 | 0.0 | 63.9 | 66 | 63.9 | 10 | ---- | 58.6 | 5.3 | 8 | -2.7 |
| yy | 76 | 1 | 0.0 | 63.5 | 66 | 63.5 | 10 | ---- | 58.2 | 5.3 | 8 | -2.7 |
| zz | 77 | 1 | 0.0 | 64.1 | 66 | 64.1 | 10 | ---- | 58.4 | 5.7 | 8 | -2.3 |
| A | 78 | 1 | 0.0 | 64.7 | 66 | 64.7 | 10 | ---- | 58.5 | 6.2 | 8 | -1.8 |
| B | 79 | 1 | 0.0 | 65.4 | 66 | 65.4 | 10 | ---- | 58.8 | 6.6 | 8 | -1.4 |
| C | 80 | 1 | 0.0 | 63.1 | 66 | 63.1 | 10 | ---- | 57.7 | 5.4 | 8 | -2.6 |
| D | 81 | 1 | 0.0 | 63.6 | 66 | 63.6 | 10 | ---- | 58.1 | 5.5 | 8 | -2.5 |
| E | 82 | 1 | 0.0 | 64.2 | 66 | 64.2 | 10 | ---- | 58.6 | 5.6 | 8 | -2.4 |
| F | 83 | 1 | 0.0 | 64.9 | 66 | 64.9 | 10 | ---- | 59.1 | 5.8 | 8 | -2.2 |
| G | 84 | 1 | 0.0 | 65.5 | 66 | 65.5 | 10 | ---- | 59.5 | 6.0 | 8 | -2.0 |
| H | 85 | 1 | 0.0 | 66.3 | 66 | 66.3 | 10 | Snd Lvl | 59.8 | 6.5 | 8 | -1.5 |
| I | 86 | 1 | 0.0 | 62.3 | 66 | 62.3 | 10 | ---- | 57.4 | 4.9 | 8 | -3.1 |
| J | 87 | 1 | 0.0 | 62.0 | 66 | 62.0 | 10 | ---- | 57.2 | 4.8 | 8 | -3.2 |
| K | 88 | 1 | 0.0 | 61.6 | 66 | 61.6 | 10 | ---- | 56.9 | 4.7 | 8 | -3.3 |
| L | 89 | 1 | 0.0 | 61.4 | 66 | 61.4 | 10 | ---- | 56.7 | 4.7 64 | 8 | -3.3 |

C:\I29\I29 Build\I29Buildbarriers\SouthBarrier 2 3 October 2005

**RESULTS: SOUND LEVELS** 27893

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M | 90 | 1 | 0.0 | 61.0 | 66 | 61.0 | 10 | ---- | 56.5 | 4.5 | 65 | 8 | -3.5 |
| N | 91 | 1 | 0.0 | 60.7 | 66 | 60.7 | 10 | ---- | 56.3 | 4.4 | | 8 | -3.6 |
| O | 92 | 1 | 0.0 | 60.3 | 66 | 60.3 | 10 | ---- | 55.9 | 4.4 | | 8 | -3.6 |
| P | 93 | 1 | 0.0 | 60.0 | 66 | 60.0 | 10 | ---- | 55.6 | 4.4 | | 8 | -3.6 |
| Q | 94 | 1 | 0.0 | 63.8 | 66 | 63.8 | 10 | ---- | 58.5 | 5.3 | 66 | 8 | -2.7 |
| R | 95 | 1 | 0.0 | 62.4 | 66 | 62.4 | 10 | ---- | 57.5 | 4.9 | 67 | 8 | -3.1 |
| S | 96 | 1 | 0.0 | 64.6 | 66 | 64.6 | 10 | ---- | 58.8 | 5.8 | 68 | 8 | -2.2 |
| T | 97 | 1 | 0.0 | 64.3 | 66 | 64.3 | 10 | ---- | 58.5 | 5.8 | 69 | 8 | -2.2 |
| U | 98 | 1 | 0.0 | 64.6 | 66 | 64.6 | 10 | ---- | 58.9 | 5.7 | 70 | 8 | -2.3 |
| V | 99 | 1 | 0.0 | 64.2 | 66 | 64.2 | 10 | ---- | 58.5 | 5.7 | | 8 | -2.3 |
| W | 100 | 1 | 0.0 | 64.4 | 66 | 64.4 | 10 | ---- | 58.4 | 6.0 | | 8 | -2.0 |
| X | 101 | 1 | 0.0 | 63.7 | 66 | 63.7 | 10 | ---- | 58.0 | 5.7 | | 8 | -2.3 |
| Y | 102 | 1 | 0.0 | 62.2 | 66 | 62.2 | 10 | ---- | 57.1 | 5.1 | | 8 | -2.9 |
| Z | 103 | 1 | 0.0 | 63.5 | 66 | 63.5 | 10 | ---- | 57.8 | 5.7 | | 8 | -2.3 |
| AA | 104 | 1 | 0.0 | 64.5 | 66 | 64.5 | 10 | ---- | 59.7 | 4.8 | | 8 | -3.2 |
| BB | 105 | 1 | 0.0 | 64.5 | 66 | 64.5 | 10 | ---- | 58.4 | 6.1 | | 8 | -1.9 |
| CC | 106 | 1 | 0.0 | 64.7 | 66 | 64.7 | 10 | ---- | 58.6 | 6.1 | | 8 | -1.9 |
| DD | 107 | 1 | 0.0 | 64.7 | 66 | 64.7 | 10 | ---- | 58.6 | 6.1 | | 8 | -1.9 |
| EE | 108 | 1 | 0.0 | 64.7 | 66 | 64.7 | 10 | ---- | 58.6 | 6.1 | 80 | 8 | -1.9 |
| FF | 109 | 1 | 0.0 | 64.7 | 66 | 64.7 | 10 | ---- | 58.7 | 6.0 | | 8 | -2.0 |
| GG | 110 | 1 | 0.0 | 64.7 | 66 | 64.7 | 10 | ---- | 58.7 | 6.0 | | 8 | -2.0 |
| HH | 111 | 1 | 0.0 | 64.2 | 66 | 64.2 | 10 | ---- | 58.5 | 5.7 | | 8 | -2.3 |
| II | 112 | 1 | 0.0 | 63.8 | 66 | 63.8 | 10 | ---- | 58.4 | 5.4 | | 8 | -2.6 |
| JJ | 113 | 1 | 0.0 | 64.0 | 66 | 64.0 | 10 | ---- | 58.4 | 5.6 | | 8 | -2.4 |
| KK | 114 | 1 | 0.0 | 64.3 | 66 | 64.3 | 10 | ---- | 58.4 | 5.9 | | 8 | -2.1 |
| LL | 115 | 1 | 0.0 | 64.0 | 66 | 64.0 | 10 | ---- | 58.3 | 5.7 | | 8 | -2.3 |
| MM | 116 | 1 | 0.0 | 63.5 | 66 | 63.5 | 10 | ---- | 58.0 | 5.5 | | 8 | -2.5 |
| NN | 117 | 1 | 0.0 | 63.2 | 66 | 63.2 | 10 | ---- | 57.9 | 5.3 | | 8 | -2.7 |
| OO | 118 | 1 | 0.0 | 63.0 | 66 | 63.0 | 10 | ---- | 57.7 | 5.3 | 90 | 8 | -2.7 |
| PP | 119 | 1 | 0.0 | 63.3 | 66 | 63.3 | 10 | ---- | 57.9 | 5.4 | | 8 | -2.6 |
| QQ | 120 | 1 | 0.0 | 63.8 | 66 | 63.8 | 10 | ---- | 58.2 | 5.6 | | 8 | -2.4 |
| RR | 121 | 1 | 0.0 | 64.3 | 66 | 64.3 | 10 | ---- | 58.4 | 5.9 | | 8 | -2.1 |
| SS | 122 | 1 | 0.0 | 62.0 | 66 | 62.0 | 10 | ---- | 56.9 | 5.1 | | 8 | -2.9 |
| TT | 123 | 1 | 0.0 | 62.1 | 66 | 62.1 | 10 | ---- | 57.4 | 4.7 | | 8 | -3.3 |
| UU | 124 | 1 | 0.0 | 60.9 | 66 | 60.9 | 10 | ---- | 56.3 | 4.6 | | 8 | -3.4 |
| VV | 125 | 1 | 0.0 | 62.7 | 66 | 62.7 | 10 | ---- | 57.5 | 5.2 | | 8 | -2.8 |
| WW | 126 | 1 | 0.0 | 62.3 | 66 | 62.3 | 10 | ---- | 57.4 | 4.9 | | 8 | -3.1 |
| XX | 127 | 1 | 0.0 | 62.3 | 66 | 62.3 | 10 | ---- | 57.3 | 5.0 | | 8 | -3.0 |
| YY | 128 | 1 | 0.0 | 63.3 | 66 | 63.3 | 10 | ---- | 58.0 | 5.3 | 100 | 8 | -2.7 |
| ZZ | 129 | 1 | 0.0 | 62.8 | 66 | 62.8 | 10 | ---- | 57.7 | 5.1 | | 8 | -2.9 |
| AAA | 130 | 1 | 0.0 | 61.6 | 66 | 61.6 | 10 | ---- | 56.6 | 5.0 | 102 | 8 | -3.0 |

**RESULTS: SOUND LEVELS** **27893**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BBB | 131 | 1 | 0.0 | 60.9 | 66 | 60.9 | 10 | ---- | 56.2 | 4.7 | 103 | 8 | -3.3 |

| Dwelling Units | # DUs | Noise Reduction | | |
|---|---|---|---|---|
| | | Min | Avg | Max |
| | | dB | dB | dB |
| All Selected | 106 | 4.4 | 7.0 | 12.7 |
| All Impacted | 48 | 4.8 | 8.9 | 12.7 |
| All that meet NR Goal | 39 | 8.3 | 9.4 | 12.7 |

HDR, Inc. 16 November 2005
A. Gowan TNM 2.5

**RESULTS: BARRIER DESCRIPTIONS**
**PROJECT/CONTRACT:** 27893
**RUN:** I-29 Noise Analysis Build
**BARRIER DESIGN:** South2

| Barriers | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | Type | Heights along Barrier | | | Length | If Wall | If Berm | | | Cost |
| | | Min | Avg | Max | | Area | Volume | Top Width | Run:Rise | |
| | | ft | ft | ft | ft | sq ft | cu yd | ft | ft:ft | $ |
| SouthBarrier | W | 19.00 | 19.00 | 19.00 | 2671 | 50752 | | | | 2918238 |
| | | | | | | | | | Total Cost: | 2918238 |

103. b.r.
$28,332/b.r.