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16. Abstract

Current procedures for setting ramp advisory speeds in the state of Texas are outlined in the Texas Department of Transportation's official procedures for establishing speed zones. For ramps, these procedures suggest using exit speed or ramp speed signing where an engineering investigation shows the necessity of advising drivers of the maximum recommended speed on a ramp. Research conducted under this investigation involved speed studies of ramps with a broad range of horizontal and vertical curvatures, frontage road to freeway speed differentials and distances between the ramp and the downstream cross street in order to create a predictive model of ramp speed. Utilizing the degree of curvature (if any) found along the ramp and the distance along the ramp from the freeway exit ramp gore to the downstream intersection along the ramp or frontage road, analysts use the predictive model to identify the expected mean truck speed along the ramp. Based on the difference in speed between the freeway and the mean truck speed expected along the ramp, a ramp advisory speed signing scheme is recommended.

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ESTABLISHING ADVISORY SPEEDS ON NON DIRECT-CONNECT RAMPS: TECHNICAL REPORT

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DISCLAIMER

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CHAPTER 1. STUDY BACKGROUND

INTRODUCTION

The available literature on advisory speeds on exit ramps yields a number of works regarding curves and turns; however, there is very little information available on procedures and policies for establishing advisory speeds for ramps that do not have horizontal curvature. As an example, the *Texas Manual on Uniform Traffic Control Devices* (TMUTCD) (*1*) provides this information about the location of the exit speed sign: *"The Exit Speed (W13-2) or Ramp Speed (W13-3) signs shall be used where engineering judgment indicates the need to advise road users of the recommended speed on an exit or a ramp.*" Figure 1 illustrates the referenced signs. However, this document offers nothing relative to how to establish the recommended speed.

W13-2

W13-3

Figure 1. Exit Speed and Ramp Speed Signs (*1*).

The Texas Department of Transportation (TxDOT) has implemented procedures for establishing advisory speeds on horizontal curves and turns. The basic intent of these procedures is to warn motorists on the approach to each curve where the safe operating speed on the curve is five or more miles per hour (mph) below the posted, regulatory speed of the highway. Chapter 5, Section 2 of the *Procedures for Establishing Speed Zones* (*2*) clearly outlines a method of determining the "safe operating speed" for horizontal curves/turns, namely using a ball-bank indicator and a series of trial runs on a curve.

Chapter 5, Section 6 of the *Procedures for Establishing Speed Zones* (*2*) indicates, in a fashion similar to the TMUTCD (*1*), basic guidance on how to establish exit and/or ramp advisory speeds, stating: "*The Exit Speed or Ramp Speed signs (W13-2 and W13-3) are intended for use where engineering investigations of roadway, geometric, or operating conditions show the necessity of advising drivers of the maximum recommended speed on a ramp."* This language and guidance is obviously vague and leaves much to individual interpretation, and is clearly not as well represented as the procedures for horizontal curves in Section 2.

With regard to advisory exit speed signs, the *Signs and Markings Manual* (*3*) states only that W13-2 and W13-3 signs "are used to display the maximum recommended speed on expressway and freeway ramps." It also points the reader to the TMUTCD (*1*) and the *Procedures for Establishing Speed Zones* (*2*) for further information.

The federal *Manual on Uniform Traffic Control Devices* (MUTCD) (*4*) provides a graphical example of advisory speed signing for an exit ramp, as shown in Figure 2. In association with this figure, this document states, in Section 2C.36" "*The advisory speed may be the 85th-percentile speed of free-flowing traffic, the speed corresponding to a 16-degree ball-bank indicator reading, or the speed otherwise determined by an engineering study because of unusual circumstances.*" The example typifies the lack of information on advisory speed signing for non-direct connectors, i.e., regular slip ramps, where there are no obvious geometric features that would impact an advisory speed.

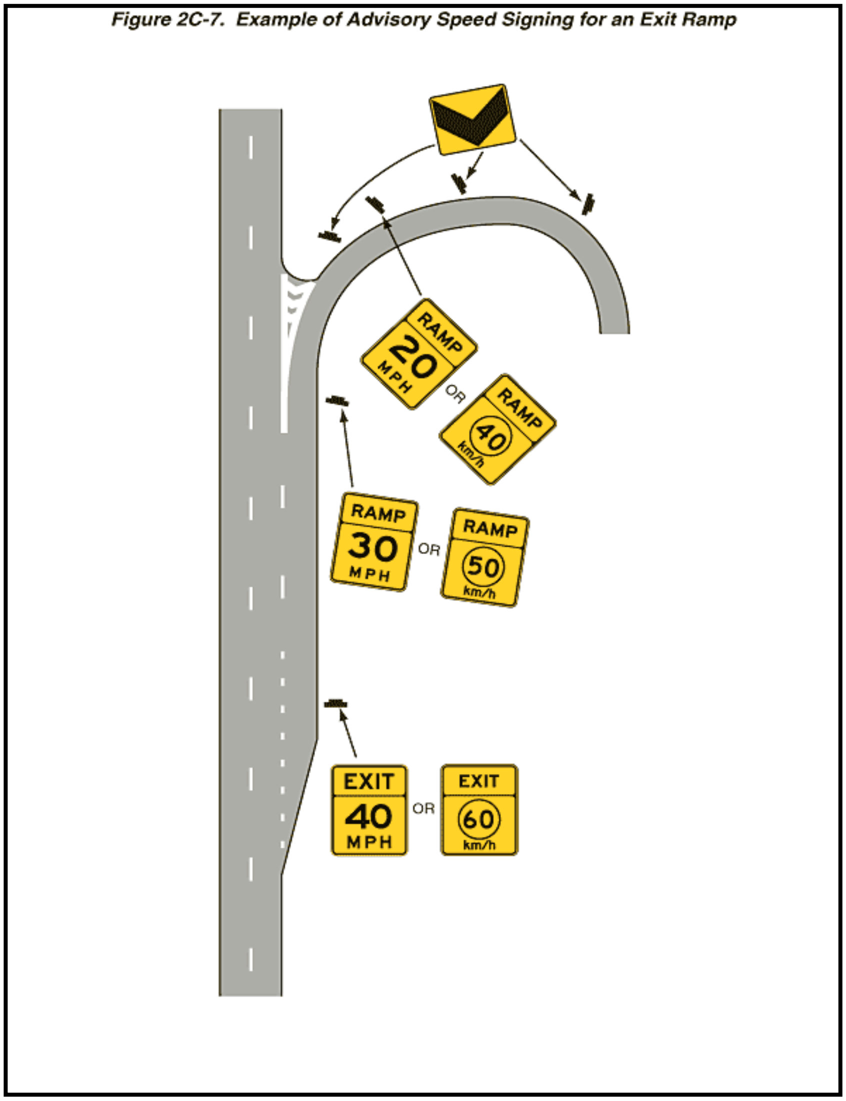


Figure 2. Example of Advisory Speed Signing for an Exit Ramp (*4*).

Researchers conducted numerous past studies in relation to establishing advisory speeds in curves and on direct connect ramps around the state of Texas and the country (*5*, *6* and *7*). In recent research on freeway-to-freeway connector ramps, researchers noted that there are likely several reasons why truck drivers exceed the posted advisory speed on a freeway-to-freeway ramp. The most prominent reasons include the desire of the driver to hold his speed for merging into freeway main lanes, and inadequate deceleration distance entering the connector. However, drivers may also lack understanding of the geometric limitations of many freeway connectors. Passenger vehicle drivers also typically exceed the posted advisory speeds on freeway-to-freeway connector curves, for some of the same reasons as truck drivers (*6*).

Historically, analysts have determined advisory speeds for curves in the field by making several trial runs through the curve at different speeds in a vehicle equipped with a ball-bank indicator. The ball-bank reading is a combined measure of centrifugal force, vehicle roll, and superelevation; as such, it indicates overturning forces on the vehicle. The generally accepted criteria for setting advisory speeds are ball-bank readings of 14 degrees for speeds below 20 mph, 12 degrees for speeds between 20 and 35 mph, and 10 degrees for speeds of 35 mph or greater (*8*). These criteria are based on tests conducted in the 1930's and are intended to represent the 85th to 90th percentile curve speed (*9*). These criteria still form the basis in the *Procedures for Establishing Speed Zones* (*2*). Ball-bank readings of 12 degrees for speeds above 40 mph, 16 degrees for speeds between 30 mph and 40 mph, and 20 degrees for speeds below 30 mph would better reflect observed or average curve speeds (*10*).

An alternative approach to determining safe curve speed would be to sample vehicular speeds. A sample of 10 vehicles could be used to estimate the average curve speed to within 3 mph. Researchers are currently investigating this approach as well as several other alternatives for recommending safe speeds on curves. These alternatives include prediction models of curve speed based on degree and length of curve and use of the G-analyst, an accelerometer that provides a direct measure of lateral acceleration (*10*).

Previous research on freeway-to-freeway connector ramps also found that the non-truck-driving motoring public (drivers in passenger cars, light trucks, and sport-utility vehicles, etc.) generally exceed the posted advisory speed on freeway-to-freeway connectors in great numbers (with violation rates from 95 to 99 percent) and often exceeded that speed by more than 10 mph (*7*). There is a 5 to 10 mph higher difference between a passenger car driver's maximum comfortable speed on a freeway-to-freeway connector ramp when compared to drivers of larger vehicles (*7*).

Researchers found little attention devoted to quantifying or identifying problems in current slip ramp operations (between freeways and frontage roads) or pointing to factors to consider in establishing speed advisory signing. However, the previously cited examples show that for most ramp operations, current speed advisories are significantly below operating speeds on these ramps.

Recent research on exit ramps attempts to address the phenomenon of vehicles exceeding the advisory speed signs, particularly for curved exit ramp sections. Speed is a significant factor in many crashes that occur on curves. Recent research investigating the use of experimental pavement markings to reduce speeds of freeway exit ramp vehicles was conducted in Fairfax County, Virginia and New York City, New York (*11*). Researchers employed an experimental pavement marking pattern to narrow the lane width of both the curve and a portion of the tangent section leading into the curve by use of a gradual inward taper of existing edge line or exit gore pavement markings or both. Analysts studied traffic speeds before and after installation of the pavement markings at four experimental ramps in New York and Virginia. Results indicated that the markings were generally effective in reducing speeds of passenger vehicles and large trucks. The markings resulted in significant reductions in the percentages of passenger vehicles and large trucks exceeding posted exit ramp advisory speeds (*11*).

STATE DOT INQUIRY

Since researchers were unable to identify guidance documents and practices on processes regarding the establishment of exit ramp advisory speeds in the literature, they distributed a questionnaire (see Appendix) to the departments of transportation of each state as well as each district of the Texas Department of Transportation. Twenty-six state DOTs and 9 TxDOT districts provided responses. Responses revealed the following findings:

- Ninety-five percent of respondents affirmed that their agency does post advisory speeds on freeway exit ramps.
- Sixty0seven percent responded that their agency has specific practices related to placement of the exit ramp advisory speed signs.

Respondents identified (indicated by percentage) the following items as factors used in selecting the advisory speeds on ramps:

- 94 percent - geometric characteristics of the ramp
- 86 percent - speed on the exit ramp
- 67 percent - speed on the freeway main lanes
- 64 percent - traffic control at the exit ramp terminal
- 52 percent - geometric characteristics of the freeway main lanes
- 46 percent - speed on the connecting surface facility
- 28 percent - geometric characteristics of the connecting surface facility

Several respondents indicated that they simply apply good engineering judgment and many pointed to horizontal curvature guidance, generally, and/or to ball-bank indicators, specifically. However, a few respondents provided insights with respect to advisory speeds that were not exclusively related to horizontal curvature, as listed below.

> "If the maximum recommended speed on a ramp, as it exits the main lane roadway, is less than, or equal to, 70 percent of the design speed of the main lane roadway, the exit ramp shall be signed with an Advisory Exit Speed sign." (Minnesota)

> "Advisory speed may be the 85th percentile of free-flowing traffic, the speed corresponding to 10-degree ball-bank indicator, or *other speed determined by engineering study*." (Missouri)

"If a ramp could not handle the posted speed on main lanes then an advisory speed is recommended for ramp." (Texas)

"The Advisory Exit Speed (W13-2) sign should . . . advise motorists of the speed at which the exit ramp can be comfortably negotiated. Consideration should also be given to the speed at which traffic can enter the surface street at the end of the ramp if a stop is not required. The W13-2 sign is not necessary for an exit ramp that has a tangent alignment and terminates at a stop sign or a signal." (California)

"All but 1 or 2 in our whole state approach stop conditions and do not transition onto other low speed facilities." (Idaho)

"Most of our ramps are approaching stopped condition." (Montana)

"Advisory exit speed signs should be used where the ramp design speed is 10 mph or more below the main lane design speed." (Montana)

"The speed is posted to help ensure motorists can stop or yield at the end of the ramp. A 30 or 35 mph (advisory) speed would be posted, even if the ramp alignment was nearly tangent." (New York)

"Install RAMP ADVISORY SPEED (W13-3) sign to inform motorists of the recommended speed, based on traffic engineering analysis, for negotiating a ramp alignment with curvature or *other unexpected conditions*. Illumination is warranted when . . . the exit advisory speed is more than 20 mph below the posted main lane speed." (Washington)

"Guidelines require consideration of *approach speeds*, geometry, truck rollovers, roadside hazards, surface conditions, crash history, driver expectancy." (New York)

From these contributions, it is evident that the processes used by analysts to select advisory speeds are largely based on judgment rather than on a documented rationale. Some of the questionnaire responses implied that the advisory speed for an exit ramp is simply the design speed and that if the differential between the ramp design speed and the main lane design speed is less than a particular threshold, then an advisory speed is not necessary and a sign is not posted.

CHAPTER 2. EXPERIMENTAL DESIGN

The intent of the analysis and development phases of this research investigation was to identify the absolute conditions under which agencies should deploy ramp advisory warning signing and establish better state-wide consistency in the conditions and posted ramp warning speed values where such signing is deployed. Through discussions with the TxDOT Project Monitoring Committee (PMC) and a survey of ramp advisory speed procedures in state departments of transportation across the country and TxDOT districts, the research team identified the following primary factors to consider when establishing ramp advisory warning speeds:

- Speed differential between (freeway) main lanes and frontage roads,
- Ramp horizontal and vertical geometry, and
- Proximity of ramp to downstream intersecting roadway.

Researchers structured the experimental design to study these factors for their contribution to ramp speed.

IDENTIFYING FACTOR RANGES

The PMC established an initial set of thresholds for each primary factor in order to frame the discussion and field site selection. Note that in each case the value selected was a compromise of a range of concerns whose intent was establishing a midpoint around which to choose field sites.

Fifteen (15) mph was selected as a potential threshold for main lane to ramp posted speed differential. At differentials above 15 mph, engineers typically posted a ramp advisory speed warning sign; below this speed the sign was not typically used.

The second criterion for potential ramp advisory speed placement was ramp geometry. Since this factor could involve either one or a combination of ranges of horizontal or vertical curvature, analysts selected broadly representative locations from the range of sites received from the PMC.

The final factor was proximity of the exit ramp gore of the freeway to the ramp/cross street intersection. The PMC identified a distance of 2000 ft as the threshold below which interactions between the cross street (frontage road queue) and freeway were possible. Researchers assembled each of these factors and their corresponding ranges into a ramp advisory speed warning sign threshold flowchart (see Figure 3).

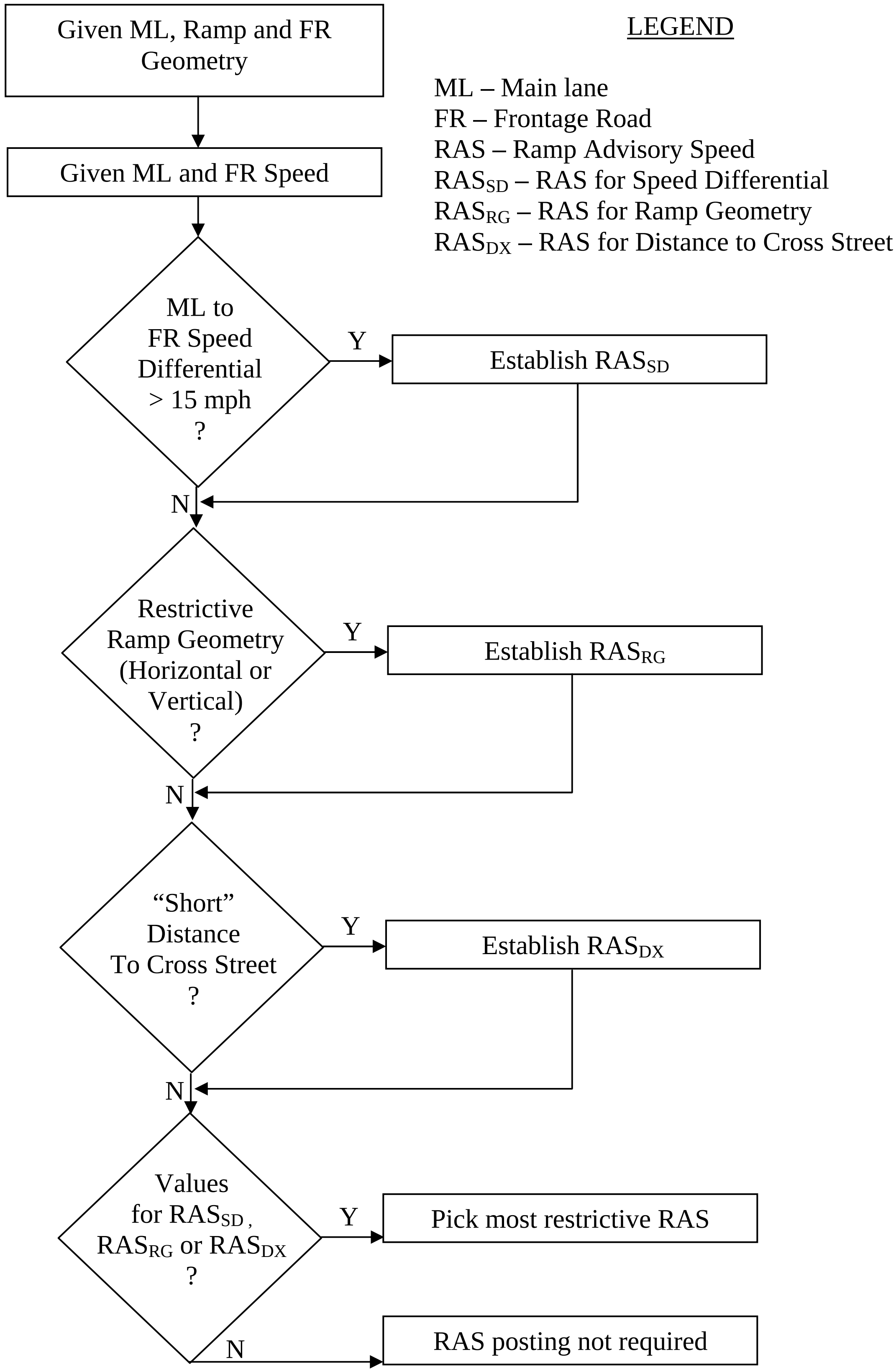


Figure 3. Decision-Making Logic for Determination of Ramp Advisory Speed.

In following the flowchart logic, if any of the factors at any given field site reaches a threshold value, either alone or in combination with other factors, it would "trip" the requirement to provide a ramp advisory speed warning sign. Comparison among the factors reaching their respective threshold is then made to establish the most restrictive conditions (i.e., lowest ramp advisory speed warning sign value) for implementation.

SELECTING SITES

Based on input from the Texas Transportation Institute's (TTI) internal statistics support staff, researchers devised a data collection plan based on studying a minimum of 15 sites to collect sufficient information to build a mathematical model that would enable the prediction of exit ramp speed. Inputs to the model would be the four ramp characteristics judged by the research team and PMC to be the most important contributors to ramp speed, namely:

- main lane to frontage speed differential,
- horizontal curvature,
- vertical curvature/grade, and
- distance from the ramp gore to the intersecting cross street.

Since the analysts did not know whether these characteristics would influence ramp speed in a linear fashion or what level of interaction occurred between each potential pair of characteristics (i.e., if ramps with significant grades tend to be farther from cross streets, etc.), they decided that a model capable of including linear effects, two-way interaction terms, and quadratic terms would be used, as follows:

$$y = a_o + a_1 x_1 + ... + a_4 x_4 + b_1 x_1 x_2 + b_2 x_1 x_3 + ... + b_6 + x_3 x_4 + c_1 x_1^2 + ... + c_4 x_4^2$$

Statistical analysis revealed the following variable combinations (Table 1) for data collection, where tabular cell values -1, 0, 1 represent the extent to which a site demonstrates that feature. For instance, Site 1 – which has the numerical value "1" in all columns, would be a field data collection site that featured:

- speed differential of greater than 15 mph between the freeway and frontage road,
- horizontal curve of greater than or equal to 14 degrees,
- uphill grade of greater than four (4) percent, and
- distance between the freeway to ramp gore area and the cross street intersection's stop bar of greater than 2000 ft.

Researchers translated the site requirements table into field sites through:

- an iterative process involving site recommendations from the PMC,
- review of suggested sites in the field and/or with aerial photography,
- verification of sites that met the requirements of a unique combination of features as set forth in the table, and
- a request for additional site suggestions from the PMC for site feature combinations that were not met in the previous request for study locations.

While most combinations of study site characteristics were eventually met in full, a few combinations could only be met with the relaxation of one of the four site characteristics. In these instances, the research team queried TTI and TxDOT staff not previously involved in the project for any ramps that had the required feature combinations. Ultimately, the research team selected the “best fit” site for each feature set combination.

Table 1. Desired Combinations of Study Site Characteristics.

Site	Speed Differential	Horizontal Curve	Vertical Curve/Grade	Distance to Cross Street
1	1	1	1	1
2	1	-1	-1	-1
3	-1	0	-1	-1
4	-1	-1	1	-1
5	0	-1	-1	1
6	1	0	1	-1
7	1	-1	1	1
8	-1	1	-1	1
9	1	1	-1	-1
10	-1	-1	0	1
11	-1	-1	-1	0
12	-1	1	1	-1
13	-1	0	1	1
14	1	0	-1	1
15	0	0	0	0

Note: A “1” indicates that the site characteristic is present and/or at its highest value, a “0” indicates the characteristic is either present at the middle value or not present, and a “-1” indicates the characteristic is either not present or present at its lowest value.

CHAPTER 3. FIELD STUDIES

In order to gain a better understanding of operating speeds on freeway exit ramps, researchers conducted a number of observational studies at freeway exit ramp facilities throughout the state. Studies were conducted at a total of 17 such sites across Texas. The TxDOT Districts where the sites were located include:

- Austin District (4 sites)
- Bryan District (1 site)
- Houston District (4 sites)
- San Antonio District (5 sites)
- Yoakum District(3 sites)

A total of 15 criteria combinations (see Chapter 2, Selecting Sites) were originally developed and matched to ramps for field investigation. The research team collected data at an additional two sites because of the unique characteristics at these ramps that might provide useful into to the study effort, and to increase the sample size for the statistical analysis that would produce a model for estimating ramp speed. Table 3 shows the various criteria and corresponding factor combinations, along with the freeway exit ramp site used for each combination. Due to the difficulties in locating sites that fit all the factor combinations for each criterion, some sites were selected as a best fit for a particular criteria combination.

DATA COLLECTION METHODOLOGY

Researchers used two primary speed data collection techniques to gather observational data in this study, using a combination of speed data and site characteristics to describe the nature of speeds and geometric alignment of each ramp. Table 2 lists all of the techniques used, and the following sections describe each technique in more detail.

Table 2. Data Collection Techniques Used in Observational Studies.

Technique	Equipment Used
Speed Data	• Portable on-pavement traffic analyzers • Pneumatic tube traffic counters
Site Characteristics	• Digital photographs • Design plans • Data collection sheet • Other observations

Speed Data

The research team wanted to collect speed data along each targeted ramp to determine the speed variation along the ramp. Researchers used two kinds of automated traffic data collection tools to collect speed data: portable on-pavement traffic analyzers and pneumatic tube traffic counters. At a minimum, members of the research team collected speed data during an entire 24-hour period in order to get a better data set of speeds on each ramp and to be able to correct any anomalies in speeds between peak and non-peak periods. Typically, data collection started around 12 midnight and ended just before 12 midnight the next day. For sites with low volumes (typically more rural sites), the data collection extended up to 72-hour spans.

Table 3. Data Collection Sites and Their Characteristics.

Site ID	Speed Differential[1]	Horizontal Curvature[2]	Vertical Grade[3]	Intersection Proximity[4]	Site Selected[5]
1	>= 30 mph	>= 14 degrees	> 4% Downgrade	<1000 ft	LP1 SB Exit to Windsor (AU1)
2	>= 30 mph	< 7 degrees	> 4% Upgrade	>= 2000 ft	IH35 SB Exit to 3009 (SA1)
3	< 20 mph	7-13 degrees	> 4% Upgrade	>= 2000 ft	IH37 SB Exit to Southcross (SA5)
4	< 20 mph	< 7 degrees	> 4% Downgrade	>= 2000 ft	US59 SB Exit to Kirby (HU2)
5	20 – 30 mph	< 7 degrees	> 4% Upgrade	<1000 ft	IH10 NB Exit to S. Alamo (SA2)
6	>= 30 mph	7-13 degrees	> 4% Downgrade	>= 2000 ft	SH6 SB Exit to Harvey Rd (BR1)
7	>= 30 mph	< 7 degrees	> 4% Downgrade	<1000 ft	IH35 NB Exit to 6th/8th Street (AU4)
8	< 20 mph	>= 14 degrees	> 4% Upgrade	<1000 ft	IH10 WB Exit to Beckendorff Rd (YK1)
9	>= 30 mph	>= 14 degrees	> 4% Upgrade	>= 2000 ft	IH10 EB Exit to Pyka Rd (YK2)
10	< 20 mph	< 7 degrees	~ 0	<1000 ft	IH35 SB Exit to Cesar Chavez (AU3)
11	< 20 mph	< 7 degrees	> 4% Upgrade	1000 - 2000 ft	IH35 NB Exit to O’Connor (SA3)
12	< 20 mph	>= 14 degrees	> 4% Downgrade	>= 2000 ft	LP610 EB Exit to Reveille (HU3)
13	< 20 mph	7-13 degrees	> 4% Downgrade	<1000 ft	US281 SB Exit to Mulberry (SA4)
14	>= 30 mph	7-13 degrees	> 4% Upgrade	<1000 ft	US59 SB Exit to SH185 (YK3)
15	20 – 30 mph	7-13 degrees	~ 0	1000 - 2000 ft	SH225 EB Exit to Shavers (HU4)
16	20 – 30 mph	< 7 degrees	> 4% Upgrade	>= 2000 ft	SH288 NB Exit to Binz (HU1)
17	>= 30 mph	< 7 degrees	> 4% Downgrade	>= 2000 ft	LP1 NB Exit to Enfield (AU2)

1. Posted speed difference between the main lanes (at the point of exit ramp lane departure) and the frontage road
2. Degree of curvature for “sharpest” curve
3. Percent vertical grade (specified for upgrade or downgrades)
4. Distance from ramp gore (on freeway main lanes) to the intersecting cross street
5. Best fitting ramp location, Site ID number shown in parentheses

Portable On-Pavement Traffic Analyzer

The design of portable on-pavement traffic analyzers allows them to provide accurate count, speed and vehicle classification data. The sensor is light-weight and has a rectangular shape measuring 4.5 inches by 7.25 inches. The units are self-contained in an aluminum housing (see Figure 4) designed to withstand the impact of heavy vehicles and damage from most chemicals such as oil or fuel. Technicians deploying the counters use a rugged sheet embedded with asphalt mastic to secure the sensor to the roadway surface, centered on a lane or ramp. The sensor determines vehicle count, speed, and classification data using magnetic imaging technology and is able to record data for each individual vehicle passing over the sensor.

A major advantage of this type of unit is that it is portable and does not require the installation of tubes, loops or devices to detect vehicles, thus reducing the potential for sensor detection by drivers and reducing artificial driver behavior changes. Because of their lower profile, the portable on-pavement traffic sensors were used when available.

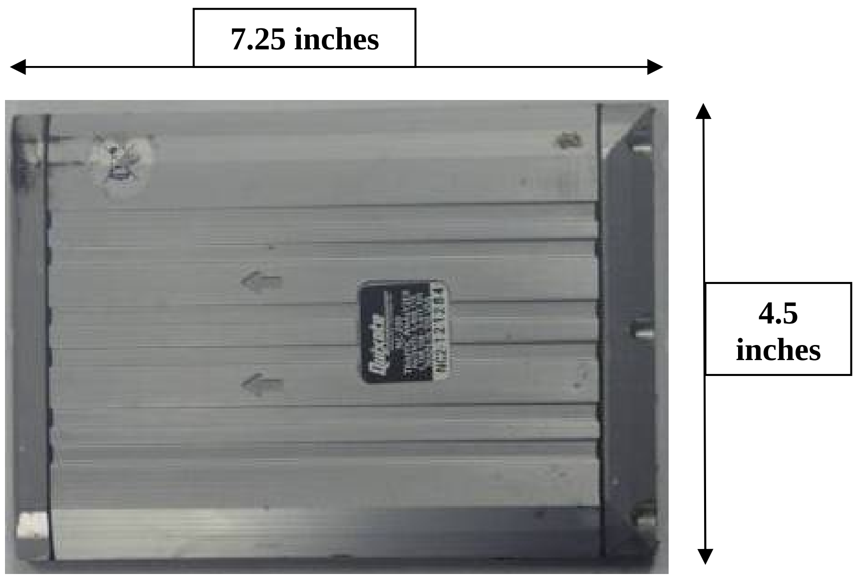


Figure 4. Portable On-Pavement Traffic Analyzer.

Pneumatic Tube Counters (Automatic)

In lieu of the portable on-pavement traffic analyzers, automated counters were utilized to collect speed data at some field study sites. The counter set-up consisted of pneumatic tubes connected to portable counters that automatically recorded information on vehicle count, classification, and speed, among other data. Technicians placed the tubes across the entire driving lane of each ramp and each approach to the ramp on the freeway and connected to the receivers on the counter unit, as shown in Figure 5. Traffic traversing the tubes trigger the counter and generate a reading, compiling a count of the number of vehicles. For this study, the tubes were set up to record speed data by placing two tubes across each exit ramp at a predetermined spacing. Based on the spacing of the vehicle's axles and the signals sent by the tubes to the counter unit, speeds were calculated and recorded and the vehicle's classification was determined. Data collected with the counters can be analyzed in a variety of ways using proprietary software from the manufacturer.

Figure 5. Installation of Pneumatic Tubes with Portable Counter.

Site Characteristics

As part of the data collection efforts, members of the research team observed and took photographs of operations and existing conditions on each freeway exit ramp being studied.

Digital Photographs

Researchers took photographs of freeway exit ramp approaches, showing the driver view as vehicles exit the freeway and drive on the exit ramp and approach the downstream intersection.

Design Maps

TxDOT's San Antonio, Houston and Austin Districts provided exit ramp design plans for the various ramps used for the study. Geometric information such as the horizontal curvature and vertical grades of the ramps were derived from such plans. For ramps with no readily available design plans, researchers measured such information manually at the site.

Data Collection Sheet

Observation information was recorded on the "Site Characteristics Worksheet" (see Appendix). The use of this data collection sheet allowed for consistency of information recording and detail across the various sites studied. The information gathered included:

- Freeway posted speed limit
- Exit ramp advisory speed limit
- Frontage road posted speed limit
- Distance from exit ramp gore on freeway to stop bar of intersection downstream

- Vertical grade (for ramps that had no available design plans)
- Lane and shoulder widths

Other Observations

Technicians documented other observations to provide a complete picture of potential impacts to speeds at the various sites. These observations included potential obstructions to driver line of sight to speed limit signs as well as frontage road-exit ramp merge area yield treatment.

COLLECTED DATA

The Appendix contains the exit ramp data for each site. A sample of the data is provided here for the first field site, southbound Loop 1 (MOPAC) at Windsor Road in Austin, Texas. Table 4 presents site speed limit data, types of curvature present, grades, the distance to the downstream intersection, and other details. Figure 6 provides an aerial view of the study site and, in some cases, provides details as to the geometry on the ramp and/or the type of downstream control present. A driver's view perspective of the exit ramp from the freeway is given in Figure 7. If exit ramp advisory speed warning signing is currently in use at the site, it is usually shown in this view. The speed data collected in the field are given in the last figure for each study site, and are presented here as Figure 8. This figure contains a best fit curve speed profile of both the average speed and the 85th percentile speed. The "y" axis, which gives speed in mph, is always shown at the freeway gore point where the exit ramp begins. Freeway speed limit, ramp advisory warning speed (if present), and frontage road speed are shown to readily compare the observed speeds with regulatory signing.

Table 4. Site Details for Southbound Loop1 Exit Ramp to Windsor Road.

Characteristic	Value
Freeway Posted Speed Limit (mph)	65 mph
Exit Ramp Advisory Speed Limit (mph)	25 mph
Frontage Road Speed Limit(mph)	Not applicable
Distance from Gore to Cross Street	635 ft
Horizontal Degree of Curvature (maximum)	~40
Grade (maximum)	5.1% downgrade
Notes	Ramp advisory speed sign has flashers Cloverleaf type ramp No frontage road present; ramp connects directly to signal on two-way cross street

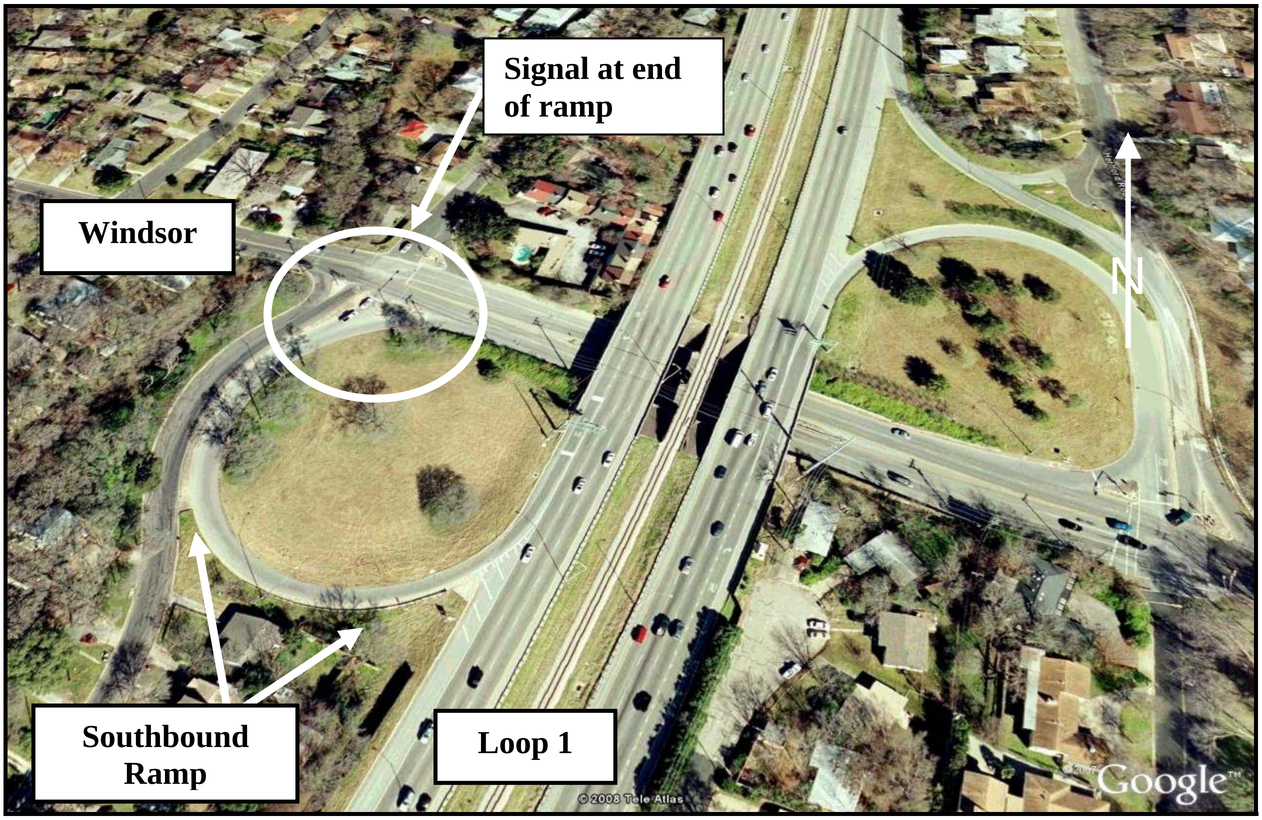


Figure 6. Loop 1 Southbound Exit to Windsor, Austin, Texas.
(Source: Google maps)

Figure 7. Exit Ramp to Windsor off Southbound Loop 1.

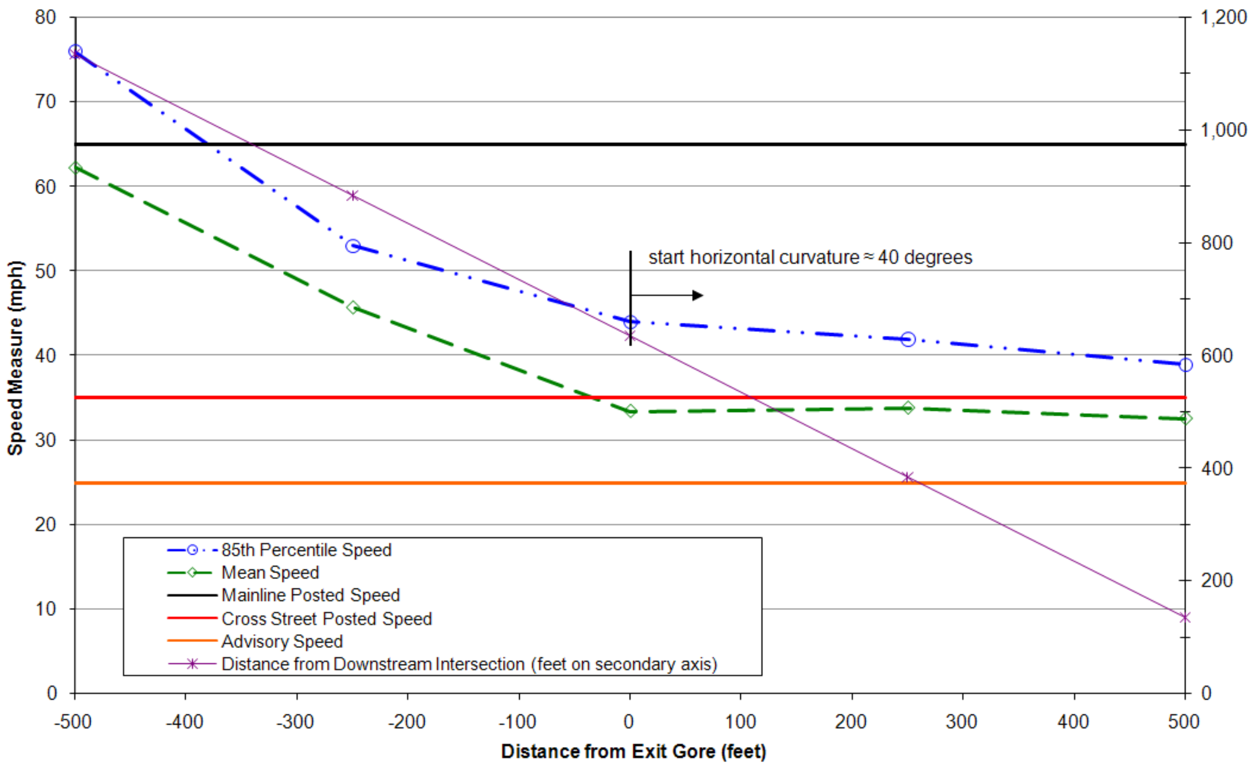


Figure 8. Speed Plot, AU1.

CHAPTER 4. DATA ANALYSIS AND RECOMMENDATIONS

DATA REDUCTION

More than one million vehicle speeds were observed at 102 locations on 17exit ramps; an average of over 10,000 vehicle speeds per location and over 61,000 vehicle speeds per ramp. Speeds are likely to vary with traffic levels, vehicle mix, weather, time of day, and a number of other roadway, driver and environmental characteristics. Data were screened to include only those points that yielded relevant information to establishing ramp advisory speeds.

Related advisory speed setting processes and research are based on free-flowing vehicle speeds (*4*, *5*). A number of criteria, mostly related to headways and hourly flow, have been used to define free-flow. The most recent and related work defined a free-flow vehicle as one with a leading headway greater than or equal to 7.0 seconds and a trailing headway greater than or equal to 7.0 seconds for cars and 3.0 seconds for trucks (based on the belief that truck drivers are less likely than passenger car drivers to be influenced by closely following vehicles) (*5*). Vehicles are less likely to be influenced by other vehicles as the leading and trailing headways increase. However, practical sample size needs often limits the upper bound of the headway screening criteria. Researchers investigated a number of options for this study. A leading and trailing headway greater than or equal to 10.0 seconds was used for passenger cars; a 7.0 second leading headway and a 3.0 second trailing headway were used for trucks.

Bonneson et al. found that mean and 85th percentile truck speeds were 1 to 2 mph slower than passenger cars on two-lane rural highway tangents and curves (*5*). Mean and 85th percentile speeds were approximately 1 mph slower during nighttime hours than during daytime hours in the same data set (*5*). Hassan also reported relatively small differences in operating speeds by ambient light conditions on two-lane rural Canadian highways (*12*). A preliminary analysis of the car and truck ramp speeds revealed some differences in speed behavior for each vehicle type. Differences were small enough that speeds for all vehicle types were combined for the descriptive comparisons as well as qualitative assessments of the speed profiles reported in the following two sections. The data were disaggregated by vehicle type for the in-depth exploratory analyses and regression modeling discussed in the final section. Both day and night observations were included in all analyses.

DATA SUMMARY

The final data set consisted of site and location characteristics as well as aggregate speed measures. Table 5 shows a representative illustration of the data. Descriptive statistics for aggregate speed measures as well as available site and location variables are also summarized in Table 6 through Table 8. The PMC and research team jointly identified the following four primary factors of interest at the beginning of the project:

- reduction in posted speed from the freeway main lane to the frontage road or cross street,
- horizontal curvature,
- vertical grade, and
- proximity to the first downstream signalized or stop-controlled intersection.

Although values for other variables were measured and recorded, these primary factors were the central focus of the exploratory and statistical analysis. All but two ramps had a posted ramp advisory speed. All but one frontage road had a posted speed limit.

QUALITATIVE ASSESSMENT OF SPEED PROFILES

Speed profiles are a useful visual aid for observing site relationships between different speed measures. Tarris et al. (*13*) first introduced the general concept and it was more recently demonstrated with field data from a number of facility types by Donnell et al. (*14*). Speed profiles were developed for all seventeen exit ramps. The profiles demonstrated relationships between 85th percentile speed, mean speed, main lane posted speed, frontage road or cross street posted speed, ramp advisory speed and distance from the first downstream signalized or stop-controlled intersection. Longitudinal locations of horizontal and vertical alignment features were also identified. The authors show two selected profiles here for discussion. The Appendix contains speed profiles for all 17 ramps.

The profiles were qualitatively examined to assess cases with good and poor agreement between ramp advisory speeds and operating speeds and to also identify speed-influencing ramp features. Figure 9 illustrates an example of a site with agreement between ramp advisory speed and operating speed. This site consisted of a loop exit ramp which merged directly onto the cross street. The primary speed dampening feature of the ramp was a 36 degree horizontal curve, which began shortly downstream of the gore. The 85th percentile speed decreased to a minimum of 25 mph at a location 750 ft downstream of the ramp gore; the ramp advisory speed was also 25 mph. Operating speeds increased as vehicles moved beyond the horizontal curve and merged onto the cross street. Figure 10 provides an example of a site without agreement between ramp advisory speed and operating speed. The exit ramp was a braided ramp with a pronounced crest vertical curve and relatively flat horizontal curvature. The 85th percentile speed steadily decreased from approximately 65 mph at the ramp gore to 50 mph at a point less than 1000 ft from the first downstream intersection. The ramp advisory speed was 35 mph.

Researchers developed the following conclusions after the qualitative assessment of all seventeen speed profiles:

- Operating speeds on exit ramps were higher than advisory speeds at many locations.
- Horizontal curvature and proximity to intersections appeared to be most influential on operating speeds.
- The presence of vertical geometric features did not appear to influence operating speeds.

With these observations in mind, the final step of the analysis was quantitative with a goal of modeling speed magnitudes and speed reductions as a function of exit ramp characteristics.

Table 5. Site Characteristics and Speed Statistics for All Vehicles.

Site ID	Location ID	Distance from ramp gore (ft)[1]	Distance from downstream intersection (ft)[2]	Main Lane Posted Speed (mph)	Frontage Road or Cross Street Posted Speed (mph)[3]	Ramp Advisory Speed (mph)	Degree of curve (per 100 ft of arc)	Average site grade (%)[4]	Mean Speed (mph)	85th Percentile speed (mph)	Mean Speed Differential (mph)[5]
AU1	1	-500	1135	65	35	25	0	-5.1	62	76	-3
AU1	2	-250	885	65	35	25	0	-5.1	46	53	-19
AU1	3	0	635	65	35	25	40	-5.1	33	44	-32
AU1	4	250	385	65	35	25	40	-5.1	34	42	-31
AU1	5	500	135	65	35	25	40	-5.1	33	39	-32
SA1	1	-500	5230	70	50	45	0	3.9	80	94	15
SA1	2	-250	4980	70	50	45	0	3.9	67	76	2
SA1	3	0	4730	70	50	45	0	3.9	65	79	0
SA1	4	250	4480	70	50	45	0.5	3.9	58	67	-7
SA1	5	500	4230	70	50	45	0	3.9	62	72	-3
SA1	6	750	3980	70	50	45	0	3.9	59	71	-6
SA1	7	1000	3730	70	50	45	0	3.9	59	70	-6
SA1	8	1250	3480	70	50	45	0	3.9	59	69	-6
SA1	9	1500	3230	70	50	45	0	3.9	51	61	-14
SA5	1	-250	2188	65	35	25	0	4.8	59	70	-6
SA5	2	0	1938	65	35	25	35.8	4.8	36	43	-29
SA5	3	250	1688	65	35	25	35.8	4.8	31	35	-34
SA5	4	500	1438	65	35	25	35.8	4.8	28	34	-37
SA5	5	750	1188	65	35	25	35.8	4.8	20	25	-45
SA5	6	1000	938	65	35	25	35.8	4.8	29	37	-36
SA5	7	1250	688	65	35	25	0	4.8	38	43	-27
SA5	8	1500	438	65	35	25	0	4.8	33	41	-32
HO2	1	-250	2455	60	45	35	0	-4.3	61	66	1
HO2	2	0	2205	60	45	35	0	-4.3	42	46	-18
HO2	3	250	1955	60	45	35	0.5	-4.3	52	58	-8
HO2	4	750	1455	60	45	35	0	-4.3	46	52	-14
HO2	5	1000	1205	60	45	35	0.5	-4.3	43	49	-17
HO2	6	1250	955	60	45	35	0	-4.3	40	45	-20
HO2	7	1750	455	60	45	35	0	-4.3	37	45	-23

Table 5 (continued). Site Characteristics and Speed Statistics for All Vehicles.

Site ID	Location ID	Distance from ramp gore (ft)[1]	Distance from downstream intersection (ft)[2]	Main Lane Posted Speed (mph)	Frontage Road or Cross Street Posted Speed (mph)[3]	Ramp Advisory Speed (mph)	Degree of curve (per 100 ft of arc)	Average site grade (%)[4]	Mean Speed (mph)	85th Percentile speed (mph)	Mean Speed Differential (mph)[5]
SA2	1	-250	800	60	30	40	0	3.6	63	71	3
SA2	2	0	550	60	30	40	0.5	3.6	49	65	-11
SA2	3	250	300	60	30	40	0.5	3.6	39	46	-21
SA2	4	500	50	60	30	40	0	3.6	15	20	-45
BCS	1	-250	2150	70	40	none	0	-4	60	66	-10
BCS	2	0	1900	70	40	none	0	-4	58	64	-12
BCS	3	250	1650	70	40	none	0	-4	55	62	-15
BCS	4	750	1150	70	40	none	6.24	-4	44	50	-26
BCS	5	1000	900	70	40	none	6.24	-4	39	44	-31
BCS	6	1250	650	70	40	none	0	-4	37	42	-33
AU4	1	-250	690	60	35	25	0	-10	46	58	-14
AU4	2	0	440	60	35	25	0	-10	41	49	-19
AU4	3	250	190	60	35	25	0.5	-10	33	41	-27
YK1	1	-250	2003	70	30	15	0	0.5	72	80	2
YK1	2	0	1753	70	30	15	0	0.5	52	59	-18
YK1	3	250	1503	70	30	15	0	0.5	46	53	-24
YK1	4	500	1253	70	30	15	18	0.5	41	48	-29
YK1	5	750	1003	70	30	15	18	0.5	29	33	-41
YK1	6	1000	753	70	30	15	18	0.5	23	31	-47
YK2	1	-250	2150	70	55	15	0	0	70	75	0
YK2	2	0	1900	70	55	15	0	0	60	68	-10
YK2	3	250	1650	70	55	15	0	0	50	58	-20
YK2	4	500	1400	70	55	15	18	0	47	56	-23
YK2	5	750	1150	70	55	15	18	0	32	37	-38
YK2	6	1000	900	70	55	15	18	0	23	27	-47
AU3	1	-250	660	60	35	20	0	-3.7	46	60	-14
AU3	2	0	410	60	35	20	0	-3.7	34	43	-26
AU3	3	250	160	60	35	20	0	-3.7	22	30	-38

Table 5 (continued). Site Characteristics and Speed Statistics for All Vehicles.

Site ID	Location ID	Distance from ramp gore (ft)[1]	Distance from downstream intersection (ft)[2]	Main Lane Posted Speed (mph)	Frontage Road or Cross Street Posted Speed (mph)[3]	Ramp Advisory Speed (mph)	Degree of curve (per 100 ft of arc)	Average site grade (%)[4]	Mean Speed (mph)	85^{th} Percentile speed (mph)	Mean Speed Differential (mph)[5]
SA3	1	-250	1510	65	35	40	0	4.1	61	77	-4
SA3	2	0	1250	65	35	40	0	4.1	59	67	-6
SA3	3	250	1010	65	35	40	0.5	4.1	57	65	-8
SA3	4	500	760	65	35	40	0	4.1	56	65	-9
SA3	5	750	510	65	35	40	0.5	4.1	49	62	-16
SA3	6	1000	260	65	35	40	0	4.1	26	36	-39
HO3	1	-250	2975	60	45	35	0	-2.5	58	66	-2
HO3	2	0	2725	60	45	35	0	-2.5	48	54	-12
HO3	3	250	2475	60	45	35	0	-2.5	53	59	-7
HO3	4	500	2225	60	45	35	0	-2.5	53	59	-7
HO3	5	750	1975	60	45	35	7.4	-2.5	39	43	-21
HO3	6	1000	1725	60	45	35	0	-2.5	43	49	-17
HO3	7	1250	1475	60	45	35	0	-2.5	43	48	-17
SA4	1	-250	1280	60	35	30	0	-3	68	81	8
SA4	2	0	1030	60	35	30	0	-3	53	63	-7
SA4	3	250	780	60	35	30	0	-3	49	56	-11
SA4	4	500	530	60	35	30	6.5	-3	35	46	-25
YK3	1	-250	1700	70	none	30	0	0	61	68	-9
YK3	2	0	1450	70	none	30	0	0	55	62	-15
YK3	3	250	1200	70	none	30	0	0	55	63	-15
YK3	4	500	950	70	none	30	7.1	0	36	42	-34
YK3	5	750	700	70	none	30	7.1	0	30	36	-40
HO4	1	-250	2714	65	40	35	0	2	52	58	-13
HO4	2	0	2464	65	40	35	0	2	47	52	-18
HO4	3	250	2214	65	40	35	5.3	2	36	40	-29
HO4	4	500	1964	65	40	35	5.3	2	41	47	-24
HO4	5	750	1714	65	40	35	0	2	37	43	-28

Table 5 (continued). Site Characteristics and Speed Statistics for All Vehicles.

Site ID	Location ID	Distance from ramp gore (ft)[1]	Distance from downstream intersection (ft)[2]	Main Lane Posted Speed (mph)	Frontage Road or Cross Street Posted Speed (mph)[3]	Ramp Advisory Speed (mph)	Degree of curve (per 100 ft of arc)	Average site grade (%)[4]	Mean Speed (mph)	85th Percentile speed (mph)	Mean Speed Differential (mph)[5]
HO1	1	-250	2410	60	35	35	0	2	58	64	-2
HO1	2	0	2160	60	35	35	0	2	58	64	-2
HO1	3	250	1910	60	35	35	0	2	56	61	-4
HO1	4	500	1660	60	35	35	0	2	51	56	-9
HO1	5	750	1410	60	35	35	2.5	2	48	54	-12
HO1	6	1000	1160	60	35	35	2.5	2	45	50	-15
HO1	7	1250	910	60	35	35	0	2	45	51	-15
AU2	1	-500	3390	65	25	none	0	0	51	62	-14
AU2	2	-250	3140	65	25	none	0	0	48	63	-17
AU2	3	0	2890	65	25	none	0.5	0	62	72	-3
AU2	4	250	2640	65	25	none	0.5	0	66	78	1
AU2	5	500	2390	65	25	none	0.5	0	59	66	-6
AU2	6	750	2140	65	25	none	0.5	0	59	67	-6
AU2	7	1000	1890	65	25	none	0.5	0	49	61	-16
AU2	8	1250	1640	65	25	none	0.5	0	45	55	-20
AU2	9	1500	1390	65	25	none	0	0	50	65	-15
AU2	10	1750	1140	65	25	none	0	0	43	54	-22
AU2	11	2000	890	65	25	none	0	0	41	49	-24

[1] The physical gore was used as the origin for all measurements. Negative numbers indicate the location is upstream of the physical ramp gore; positive numbers indicate the location is downstream.
[2] The distance from the data collection location to the first at-grade signalized or stop-controlled intersection.
[3] The posted speed of the first road or street that vehicles merge onto as they leave the exit ramp (usually either the frontage road or cross street)
[4] The average grade, weighted by length, for the entire site.
[5] Speed differentials are defined as the difference between individual vehicle speeds and the main lane posted speed.

Table 6. Descriptive Statistics for Aggregate Speed Measures (all vehicles).

Speed Measure	Number of Samples	Minimum	Maximum	Mean	Standard Deviation
Mean speed (mph)	102	15	80	47.3	12.7
Standard deviation of speed (mph)	102	4	14	8.2	2.5
85th percentile speed (mph)	102	20	94	55.3	14.0
Mean speed differential (mph)	102	-47	15	-17.10	13.1
Standard deviation of speed differential (mph)	102	4	14	8.3	2.5

Table 7. Descriptive Statistics for Categorical Site and Location Variables.

Variable	Values	Number of Observations	Percent of all Observations
Freeway Main Lane Posted Speed (mph)	60	35	34.3
	65	35	34.3
	70	32	31.4
Frontage Road or Cross Street Posted Speed (mph)	25	11	10.8
	30	10	9.8
	35	36	35.3
	40	11	10.8
	45	14	13.7
	50	9	8.8
	55	6	5.9
	none	5	4.9
Posted Speed Differential (mph)	15	29	28.4
	25	22	21.6
	30	29	28.4
	40	17	16.7
	Not applicable	5	4.9
Ramp Advisory Speed (mph)	15	12	11.8
	20	3	2.9
	25	16	15.7
	30	9	8.8
	35	26	25.5
	40	10	9.8
	45	9	8.8
	none	17	16.7
Ramp type	Braided	25	24.5
	Loop	13	12.7
	Slip	64	62.7
Area type	Rural commercial	11	10.8
	Rural undeveloped	6	5.9
	Suburban mix	6	5.9
	Urban commercial	28	27.5
	Urban mix	36	35.3
	Urban residential	15	14.7

Table 8. Descriptive Statistics for Continuous Site and Location Variables.

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Intersection proximity (ft)	102	50	5230	1659	1103
Degree of Horizontal Curvature (per 100 ft of arc)	102	0	40	4.6	10.6
Average Vertical Grade (%)	102	-10.0	+4.8	0	3.6
Lane width (ft)	102	12	16	13.5	1.2
Shoulder width (ft)	102	0	10	4.5	2.7

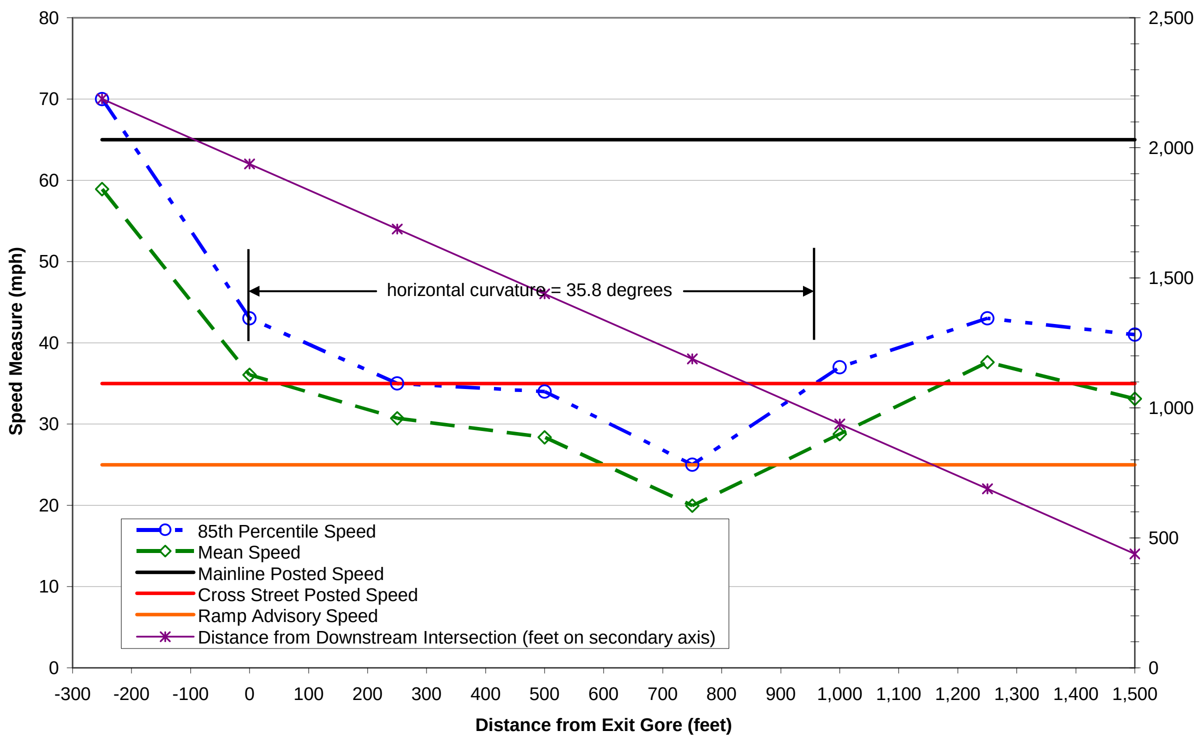


Figure 9. Agreement between Ramp Advisory Speed and Operating Speed (all vehicles).

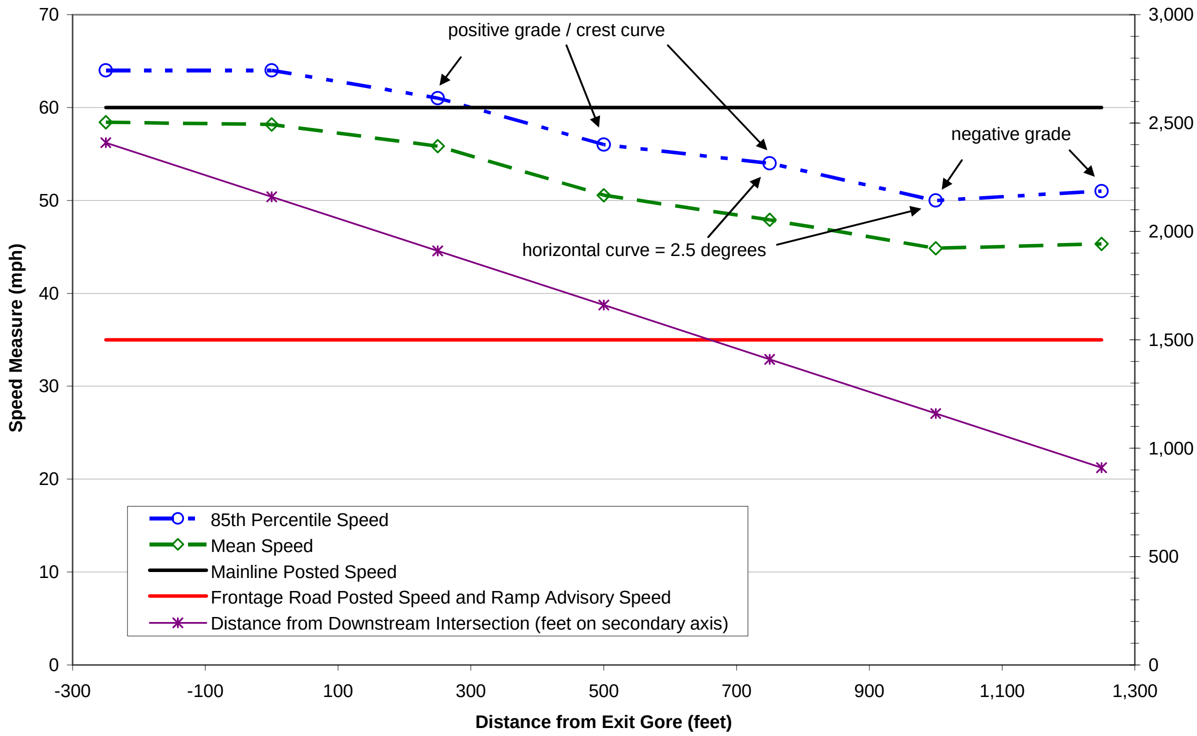
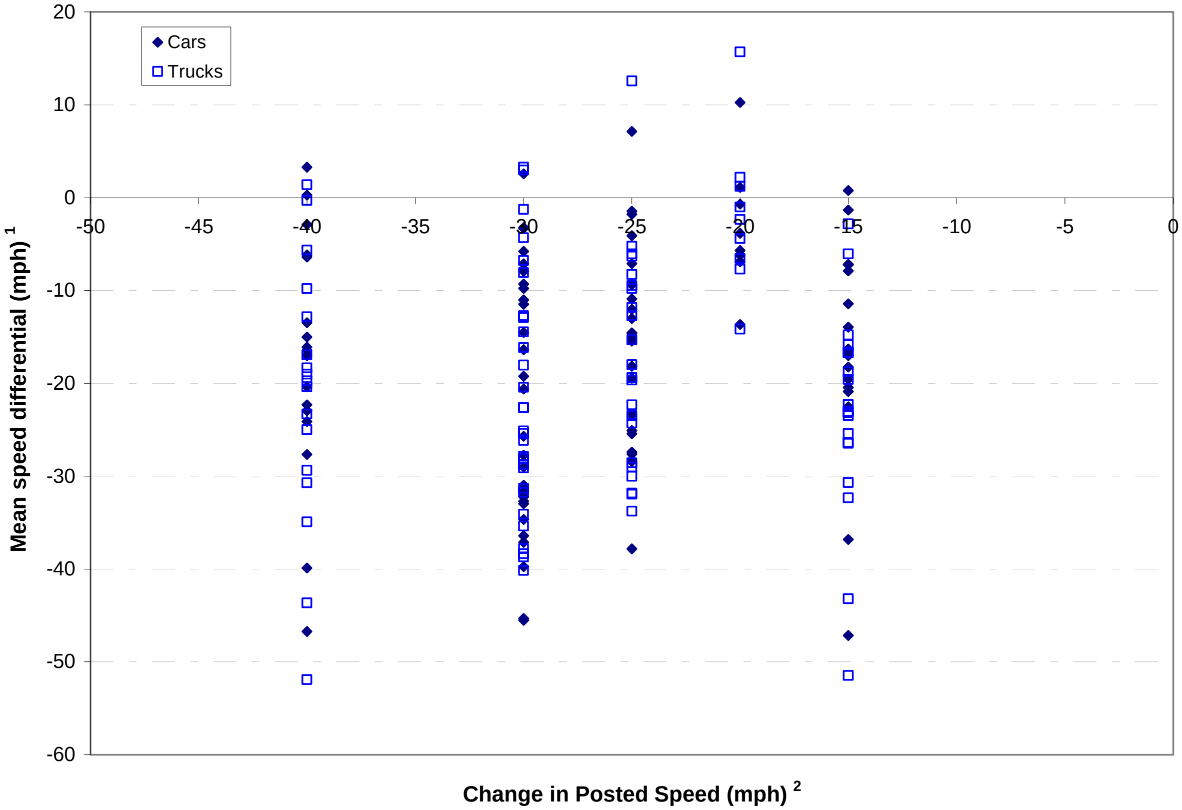


Figure 10. Disagreement between Ramp Advisory Speed and Operating Speed (all vehicles).

EXPLORATORY DATA ANALYSIS AND REGRESSION MODELING

Operating speed magnitudes and reductions are important considerations for setting advisory speeds. Common measures include 85th percentile speed and mean speed. Both measures were investigated in addition to a third measure, mean speed differential. This research defined speed differential as the difference between operating speed at any point along the ramp and the freeway main lane posted speed. As defined, speed differential is a surrogate for the change in operating speed observed from the freeway main lane to the exit ramp. Although vehicles may travel at speeds higher or lower that the posted speed on the freeway, the measure is potentially useful and would not require spot speed data collection.

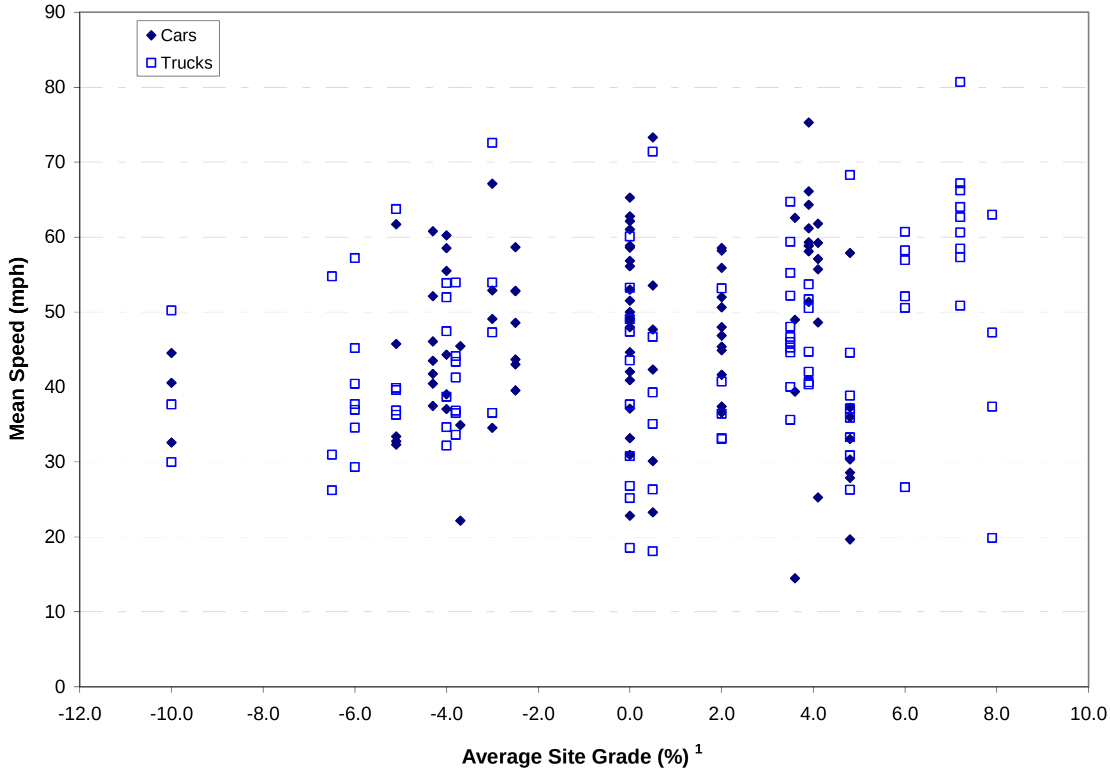
All three speed measures are related, and conclusions regarding speed behavior on exit ramps were consistent regardless of the modeled measure. The choice was ultimately related to the primary factors used to set advisory speeds. Mean speed differential is a more intuitive measure if the change in posted speed from the freeway main lane to the frontage road (or cross street) is a factor in setting ramp advisory speeds. For all other factors, mean speed is appropriate and consistent with recent research (*5*). Figure 11 shows observed speed differentials for different changes in posted speed. No relationships are evident, a conclusion that was confirmed during regression modeling. Since changes in posted speed did not appear to influence speed behavior, mean operating speed was used for the remainder of the analysis.



[1] Mean speed differential = ramp operating speed – freeway main lane posted speed
[2] Change in posted speed = frontage road or cross street posted speed - freeway main lane posted speed

Figure 11. Observed Speed Differentials for Different Changes in Posted Speed.

Qualitative assessments of the speed profiles revealed that vertical grade did not appear to influence vehicle speeds within the ranges observed. This observation was confirmed with more in-depth quantitative investigations. Figure 12 is a scatter plot of mean operating speed versus average vertical grade. No relationships are apparent for cars or trucks. Similar patterns exist for the maximum vertical grade at a site. The exact vertical grades at the data collection locations, including those within crest or sag vertical curves, were not available.



[1] The average grade, weighted by length, for the entire site.

Figure 12. Scatterplot of Mean Speed and Average Site Grade.

Figure 13 is a scatter plot of mean speed versus the degree of horizontal curvature. The estimated superlevation and side friction factor combinations required to navigate the horizontal curve at the observed speeds are also shown using a secondary axis. The relationship between friction, superelevation, curve radius and speed is commonly expressed as:

$$f + \frac{e}{100} = \frac{V^2}{15R}$$

where, f = side friction factor;

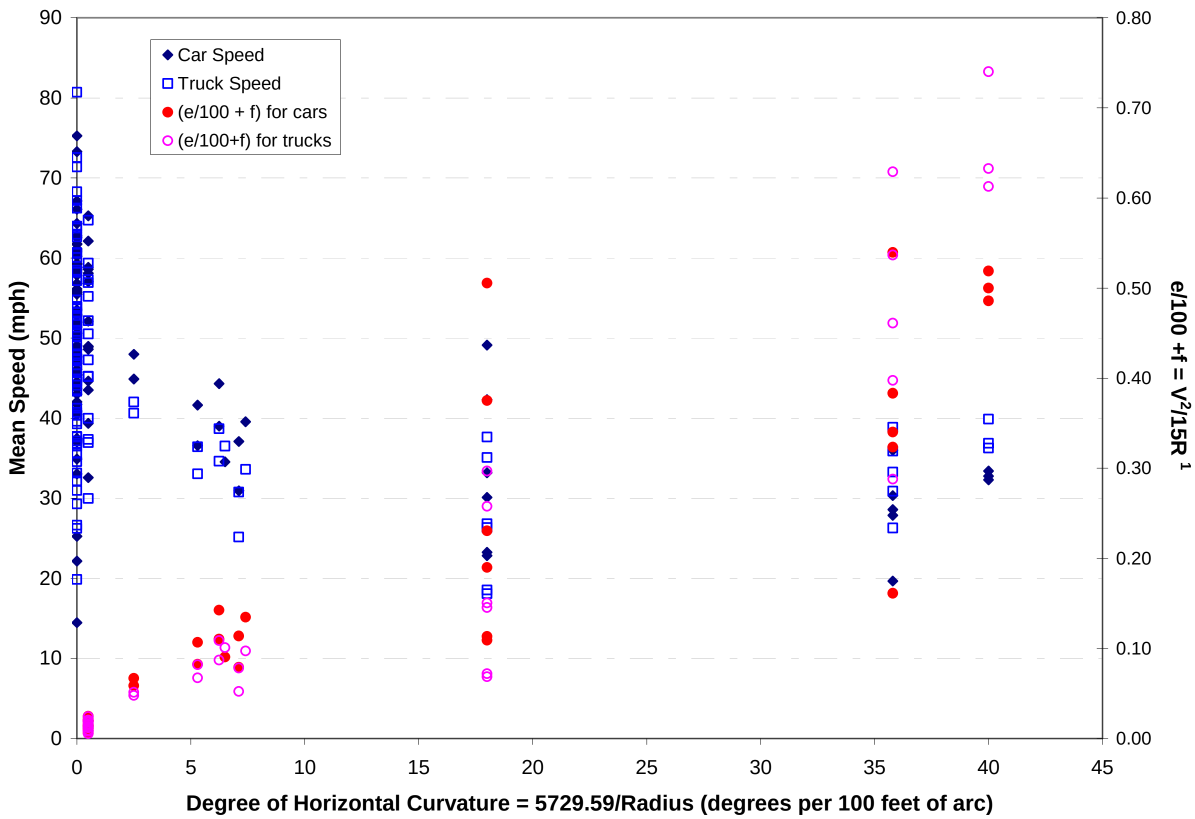
e = rate of superelevation (percent);

V = vehicle speed (mph); and

R = radius of horizontal curve (ft).

The cross slope at each data collection location was not available. Maximum superelevation rates in Texas generally range from 6 to 8 percent for high-speed facilities (*15*). Information regarding vehicle path through the horizontal curves as well as the position of the data collection location relative to the point of curvature and point of tangency was also not available. It was therefore important to evaluate outlying data points against realistic driver and vehicle capabilities. For example, operating speeds observed at a few locations on the two loop ramps coincided with superelevation and side friction factor combinations above 0.5 for cars and

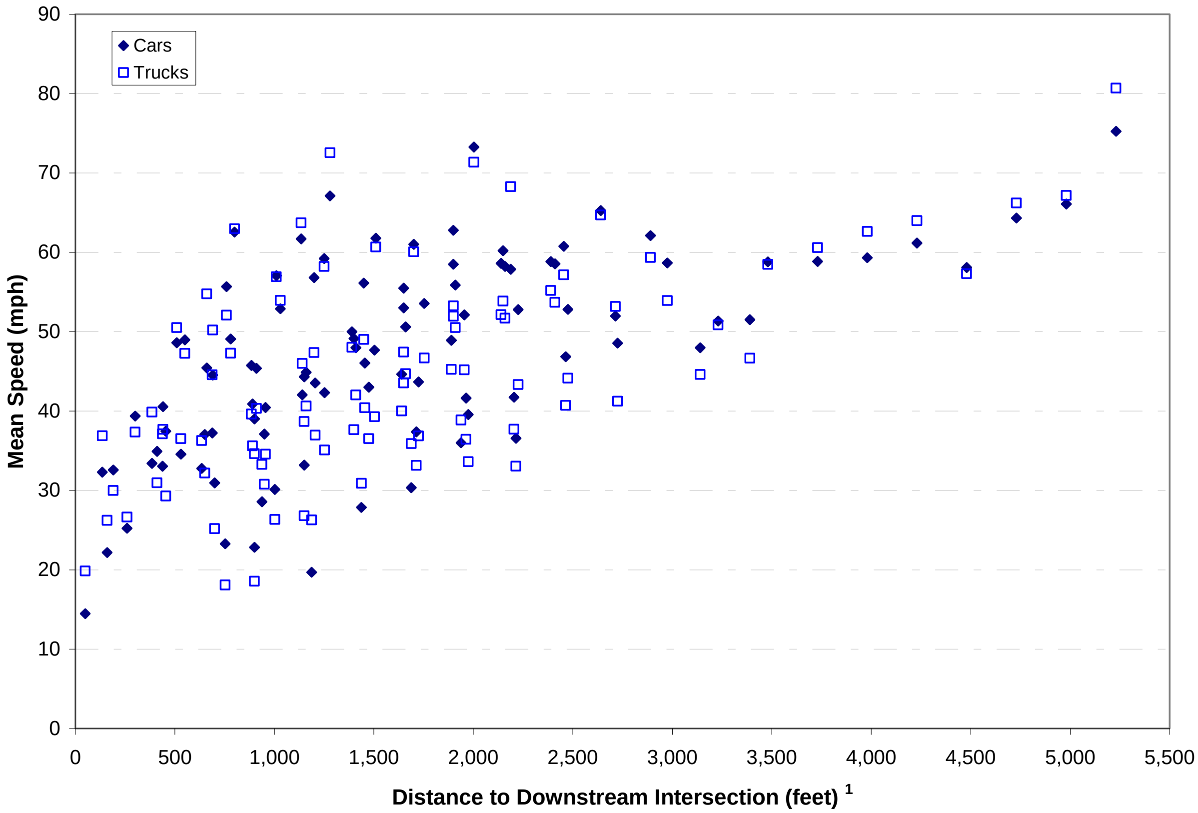
0.6 for trucks. The associated side friction factors (assuming maximum superlevation rates) are higher than values for similar speeds in the TxDOT *Roadway Design Manual* (*15*) and American Association of State Highway and Transportation Officials' *A Policy on Geometric Design of Highways and Streets* (*16*). Research shows that side friction factors as high as 0.4 to 0.5 are not unreasonable (*17*, *10*). Bonneson reported values between 0.3 and 0.4 for turning roadways (*18*). To decrease the likelihood of overestimating ramp speeds, the locations with estimated superelevation and side friction factor combinations above 0.4 were eliminated from the data set prior to model estimation. Data points at these locations were likely not capturing complex acceleration/deceleration and vehicle path behavior.



[1] The superlevation and side friction factor combination required to navigate the horizontal curve at the observed speed (computed as $V^2/15R$)

Figure 13. Scatterplot of Mean Speed, Degree of Horizontal Curvature and Lateral Acceleration.

Figure 14 is a scatter plot of mean speed versus the distance to the first downstream signalized or stop-controlled intersection. The plot shows a relationship in the direction expected; mean speeds are higher at distances further away from the intersection. Researchers found a linear-log functional form between mean speed and distance to intersection to be best from both a model fit and theoretical standpoint; one would not expect speed to increase at a constant rate throughout the range of distances observed.



[1] The distance from the data collection location to the first at-grade signalized or stop-controlled intersection.

Figure 14. Scatterplot of Mean Speed and Distance to Downstream Intersection.

The relationship between mean passenger car speed, degree of curve and distance to downstream intersection was estimated as:

$$v_c = -20.872 - 0.758DC + 9.864\ln(Z);\ R^2 = 0.653;\ S.E. = 7.17$$
$$0 \le DC \le 36$$
$$200 \le Z \le 5200$$

where: v_c = mean passenger car speed (mph);
DC = degree of horizontal curvature (degree per 100 ft of arc);
Z = distance to the first at-grade signalized or stop-controlled intersection (ft);
$\ln(\ )$ = natural logarithm; and
R^2 = the coefficient of determination for the estimated model.
$S.E.$ = standard error of estimate

The ranges of the data used for model estimation are shown. Prediction of speeds outside of these ranges is not recommended.

Figure 15 illustrates the relationship between average car speeds and average truck speeds. The following model structure fit the data best and was consistent with previous work (5):

$$v_t = b_0 v_c$$

where: v_t = mean truck speed (mph);

v_c = mean car speed (mph); and

b_0 = calibration coefficient.

A value of 0.95 was estimated for the calibration coefficient, indicating mean truck speeds 95 percent of mean cars speeds.

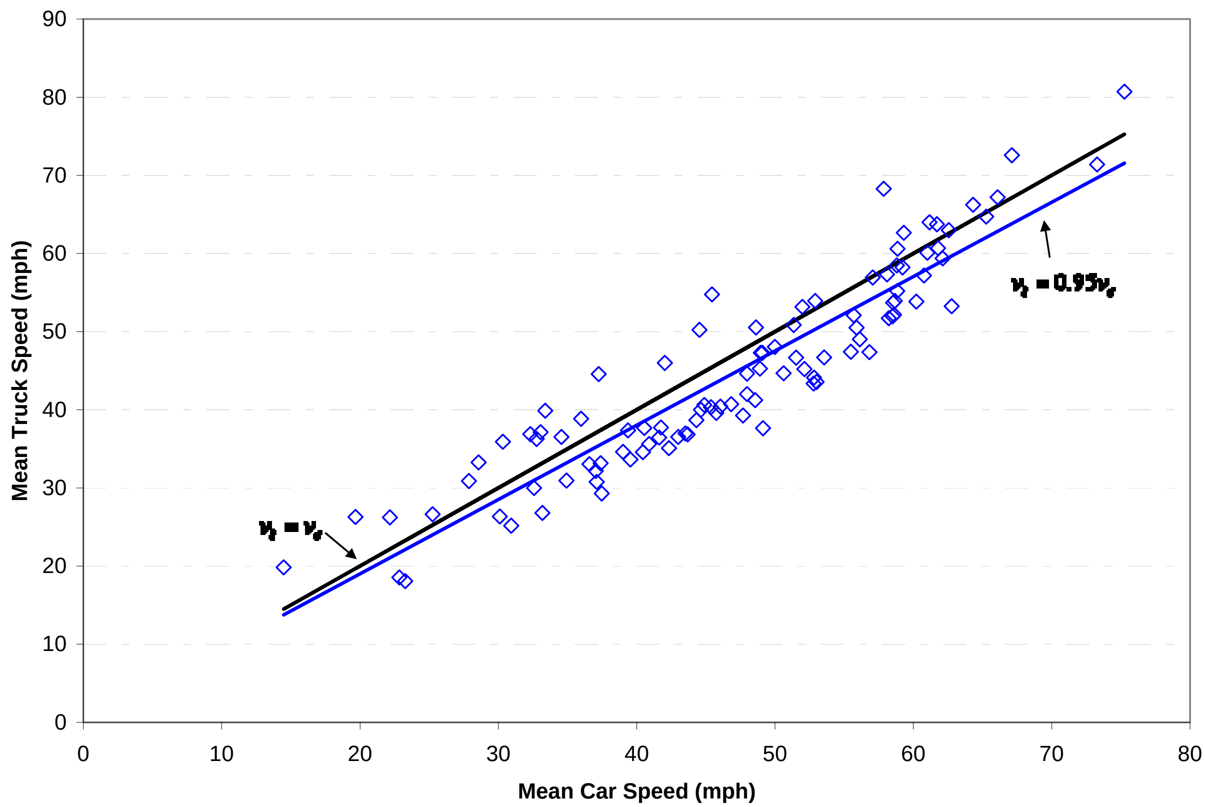


Figure 15. Relationship between Mean Car Speed Mean Truck Speed.

The model estimation results are graphically summarized in Figure 16. Curves are shown for 15, 25, 35, 45 and 55 mph car and truck speeds. The curves in Figure 16 represent expected values derived from a regression equation. The mean speeds are just as likely to be overestimated as underestimated. If a conservative estimate (i.e., underestimate) of curve speed is desired for setting ramp advisory speeds, the expected value minus a multiple of the standard error can be used (the multiple being the standard normal statistic for the percentile of interest).

Figure 17 shows an example, which graphically illustrates the 20th percentile estimates of mean speed computed by subtracting $0.84 * S.E.$ from the values in Figure 16.

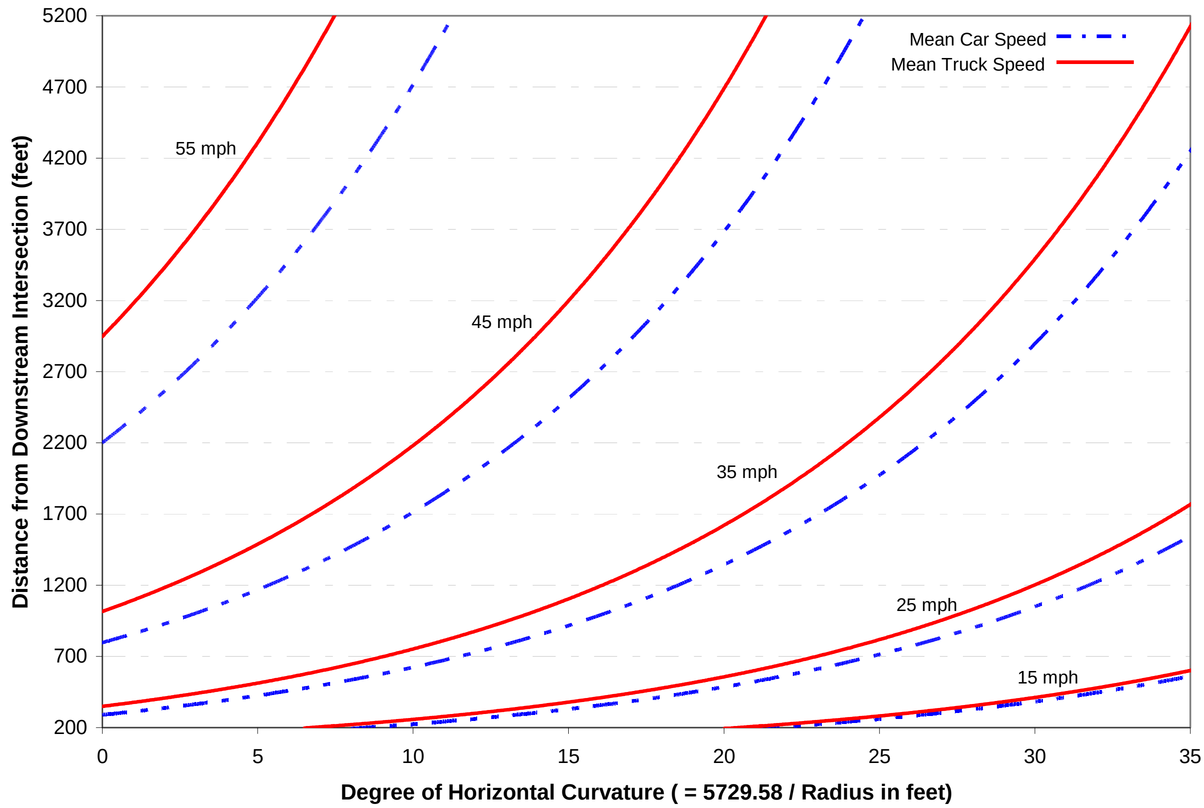


Figure 16. Graphical Representation of Model Estimation; Expected Mean Car and Truck Speeds.

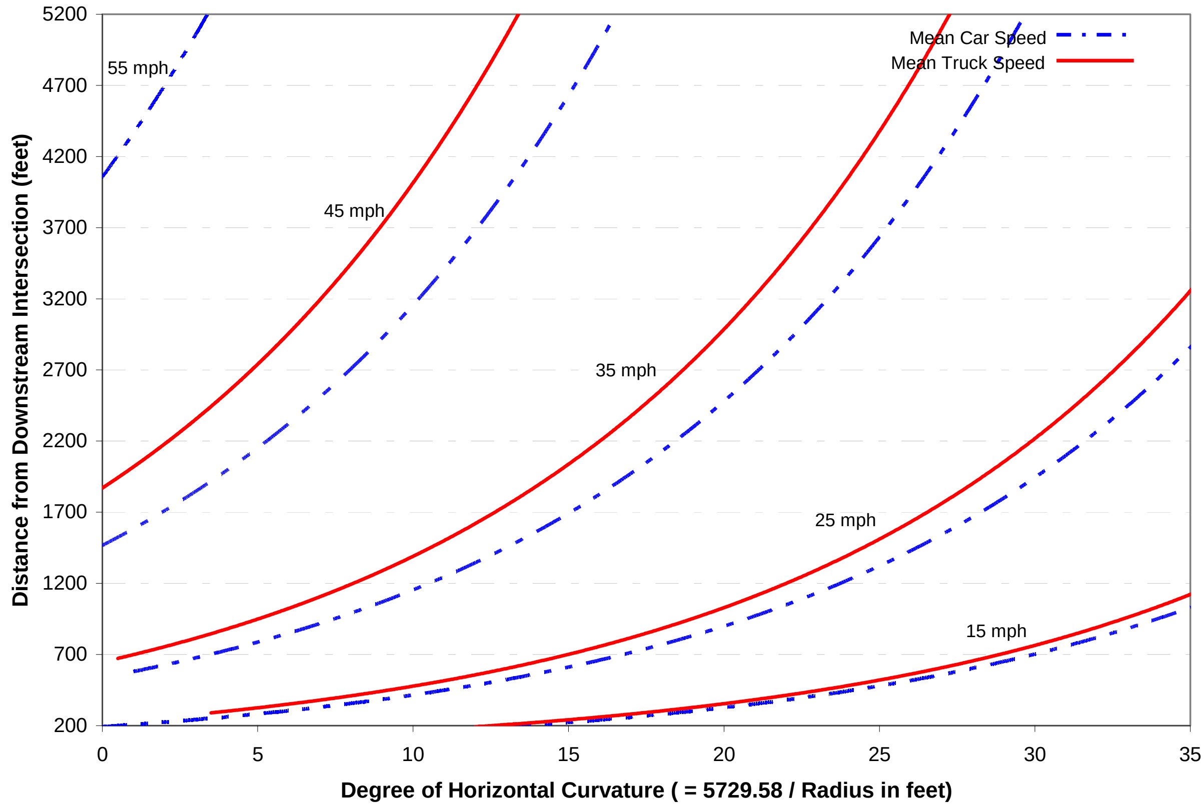


Figure 17. Graphical Representation of Model Estimation; 20th Percentile Estimates of Mean Car and Truck Speeds.

CHAPTER 5. RECOMMENDED PRACTICE

The final product of this multi-faceted investigation of freeway exit ramp speeds is a means of providing guidance to staff responsible for the establishment of ramp advisory speeds. Previous research in the area of curve advisory speed development and practices (*5*) resolved that mean truck speed is the desired value to post as the curve advisory speed. This research built on this concept for freeway exit ramps, incorporating the dimension of distance between the freeway exit ramp gore point and the downstream (signalized or stop-controlled) intersection and the degree of curvature found along the exit ramp as critical criteria for determining mean truck speed on freeway exit ramps (Figure 18).

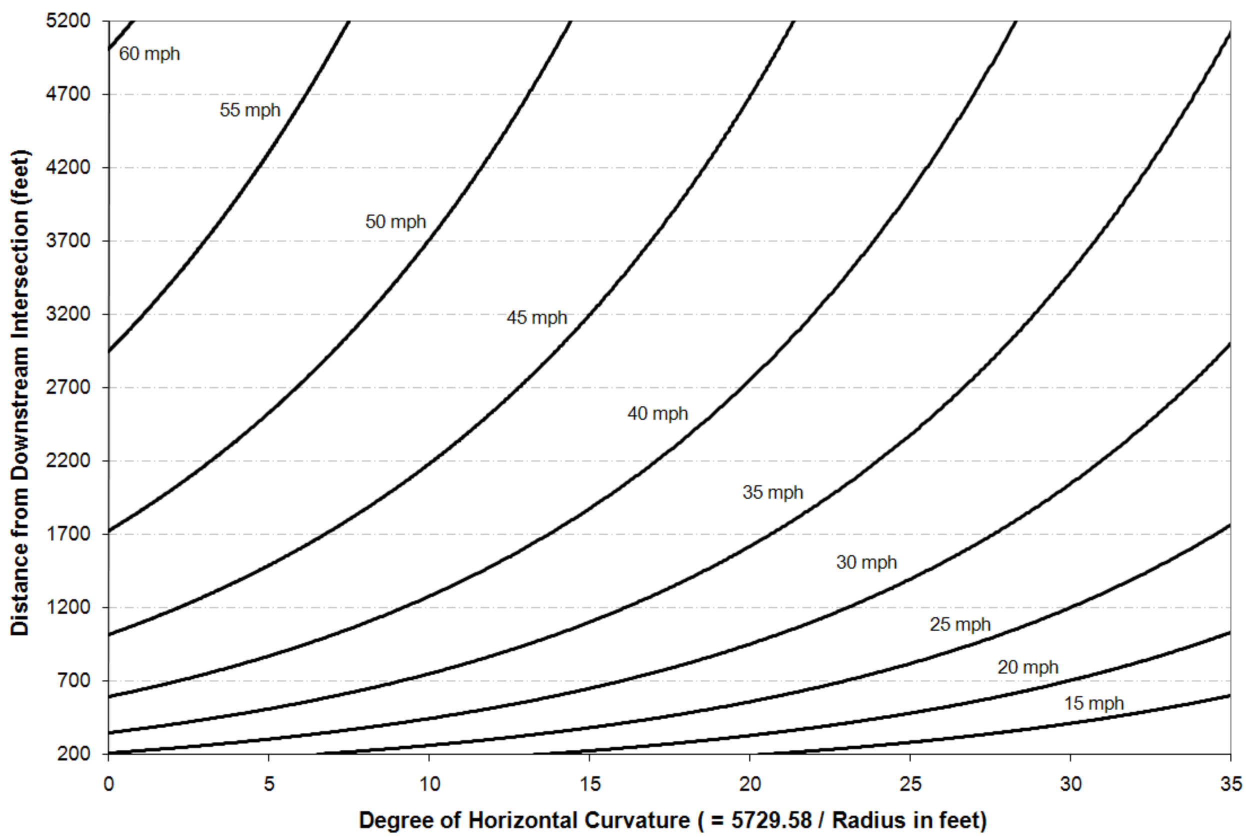


Figure 18. Mean Truck Ramp Speed – Speed Prediction Model.

In using the figure, it is necessary to identify the speeds along the entire ramp (i.e., several points along the ramp should be selected and their data entered on the figure), selecting the 5 mph curve to the right of the lowest speed point found for the ramp. The selected curve represents the ramp advisory speed for that ramp. A speed differential is next calculated as the difference between the freeway's posted speed limit and the ramp advisory speed from the figure. The speed differential is used with a look-up table (Table 9) to identify the signing scheme for the ramp. For speed differentials of 5 or 10 mph, ramp advisory speed signing is optional for straight ramps but recommended for ramps with curves to be consistent with

TUMTCD curve signing recommendations. For speed differentials of 15 or 20 mph, researchers recommend MUTCD/TMUCTD W13-2 or W13-3 ramp advisory speed signs. For speed differentials of 30 mph, researchers recommend W13-2 or W13-3 signing in addition to W1-8 chevron signing and raised pavement markers for ramps with curves (for consistency with TMUTCD curve signing and marking procedures). For speed differentials of 30 mph or more, researchers recommend that all signing and marking for 25 mph speed differentials be used and that supplemental signing or devices alerting freeway drivers to the ramp reduced speed condition be considered. The type of supplemental device will vary by site conditions, but examples include constant flashers on the ramp advisory speed sign (Figure 19) and a supplemental speed plaque or warning sign on the exit guide sign (Figure 20 and Figure 21).

Table 9. Ramp Advisory Speed Signing Selection Matrix.

Speed Differential (Freeway posted speed less Ramp Advisory Speed from Figure 18)	Ramp Advisory Signing
5 or 10 mph	Optional TMUTCD W13-2 or W13-3 for straight ramps; recommended for ramps with curves
15 or 20 mph	TMUTCD W13-2 or W13-3
25 mph	TMUTCD W13-2 or W13-3 and W1-8 (chevron signing) and raised pavement markers for ramps with curves
30 mph or greater	TMUTCD W13-2 or W13-3, W1-8 (chevron signing) and raised pavement markers for ramps with curves, and suggested supplemental freeway signing regarding reduced speed on ramp

Figure 19. Flashers Supplementing Ramp Advisory Speed Sign.

Figure 20. Overhead Ramp Advisory Speed Sign and Signal Ahead Sign on Guide Signing.

Figure 21. Ramp Warning Speed Plaque on Exit Guide Sign.

While applicable for most geometric designs utilized by TxDOT, the approach defined by this research is not applicable to ramps whose freeway exit gore point is greater than a mile from the downstream intersection. This approach is also not applicable to ramps with horizontal curves that have a degree of curvature greater than 35 degrees. For such ramps, it is recommended that the curve advisory speed procedures developed in previous research by Bonneson (*5*) be utilized to establish a ramp advisory speed. This restriction is likely to affect exit ramps to two-way frontage roads, as the curve from the ramp to the opposing direction on the frontage road is almost always in excess of 35 degrees. Also, the procedures documented here would not apply to ramps with unusual sight distance restrictions, potentially imposed by embankments or bridge structures, which would limit a driver's ability to perceive and respond to downstream conditions along the ramp or frontage road. Staff responsible for setting ramp advisory speeds should always use special precautions where the distance from the ramp gore to the downstream intersection is short, as queues that extended upstream to the ramp or freeway may require a queuing study and more detailed engineering investigation.

EXAMPLE APPLICATION

Researchers chose study site SA4, the US 281 southbound exit to Mulberry in San Antonio, Texas to provide an example of applying the recommended procedures. The exit ramp gore is 1,030 ft upstream from the traffic signal where the southbound US 281 frontage road and Mulberry intersect. The ramp is approximately 600 ft long, supplying 7, 100-foot "check points" (Figure 22) where both the distance to the signal and the curvature are entered into Figure 18. The values interpolated from the figure corresponding to each check point are found in Table 10.

Table 10. Check Point Values for US 281 Southbound to Mulberry Exit.

Check Point	Distance to Signal (ft)	Degree of Curvature (degrees)	Ramp Advisory Speed/ Mean Truck Speed from Figure 18 (mph)
1 (gore)	1030	0	45
2	930	0	44
3	830	0	43
4	730	6.5	37
5	630	6.5	36
6	530	6.5	34
7 (frontage road)	430	6.5	32

Notice that when the check point positions are plotted to the ramp advisory speed curve (see Figure 23) they tend to cluster vertically in regions where the ramp exhibits constant curvature. In the case of the Mulberry exit ramp, the first three hundred ft are straight and the last four hundred ft are along a 6.5-degree horizontal curve. For this ramp, the critical point is Point 7, which is both along the curve and most proximate to the signalized intersection. The 5-mph ramp advisory speed curve to the right of 32 mph is the 30 mph curve, resulting in a ramp advisory speed for this ramp of 30 mph.

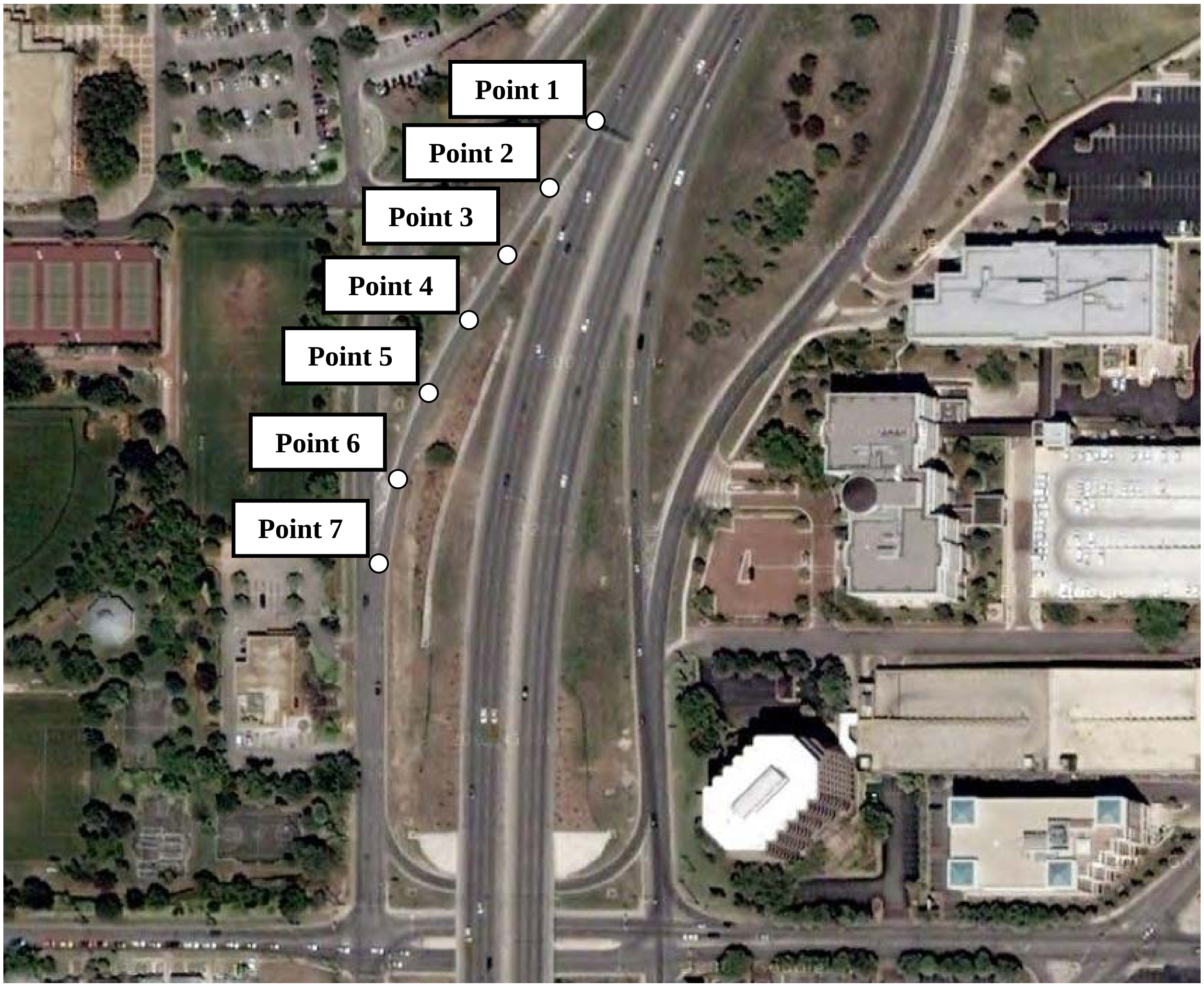


Figure 22. Exit Ramp Speed Check Points for US 281 Southbound Exit to Mulberry, San Antonio, Texas.

The difference between the freeway posted speed limit of 60 mph and the ramp advisory speed of 30 mph is 30 mph. From Table 9, the recommended ramp advisory signing scheme for this ramp is TMUTCD W13-2 or W13-3 ramp advisory speed signing plus W1-8 (chevron signing) and raised pavement markers in the curved section of the ramp. Because the speed differential is 30 mph or greater, this research also suggests that some form of supplemental freeway signing regarding reduced speed on the exit ramp be used, based on engineering judgment and site conditions.

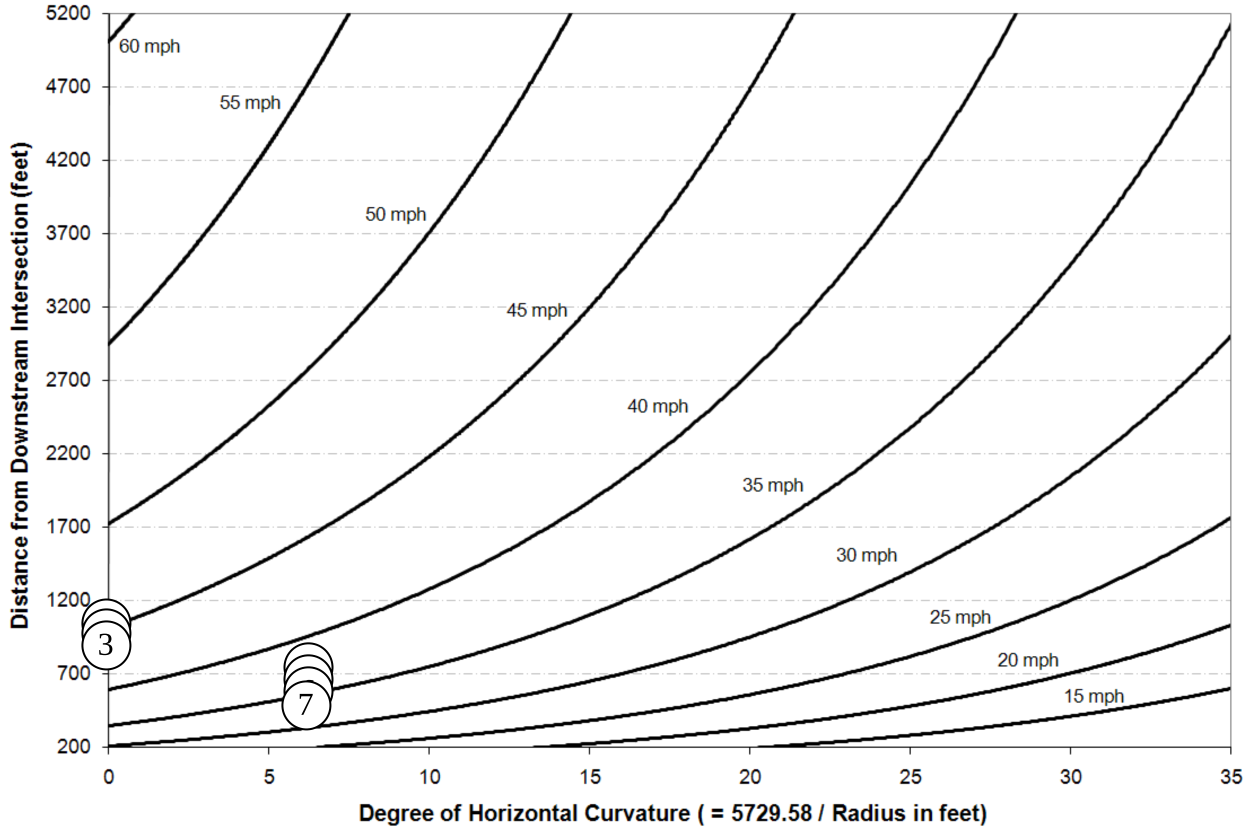


Figure 23. Plotting of Mulberry Exit Ramp Check Points to Ramp Advisory Speed Curves.

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2. *Procedures for Establishing Speed Zones*, Texas Department of Transportation, Austin, Texas. Revised, November 2006.

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5. Bonneson, J., M. Pratt, J. Miles and P. Carlson. *Development of Guidelines for Establishing Curve Advisory Speed*, Research Report No. FHWA/TX-07/0-5439-1, Texas Department of Transportation, Austin, Texas, October 2007.

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APPENDIX

This Appendix contains a sample exit ramp advisory speed questionnaire, a sample exit ramp site visit data collection form, and data from each of the 17 data collection sites visited during the research investigation.

Exit Ramp Advisory Speed Questionnaire

The Texas Transportation Institute, on behalf of the Texas Department of Transportation, is collecting and synthesizing information regarding posted advisory speeds practices on freeway exit ramps (excluding ramps that directly connect two freeways). Our focus is advisory speeds on exit ramps that transition from freeways to lower-speed frontage roads or surface facilities. We would appreciate your assistance in identifying how your agency addresses this issue.

If establishing advisory speeds is not a function of your office, please forward this request to the appropriate office within your agency.

1. Does your agency post advisory speeds on freeway exit ramps?

   ☐ Yes
   ☐ No

   If yes, can you provide access (e.g., online links, hardcopy mail, email, etc.) to standard detail sheets or documentation of your policies/practices related to selecting advisory speeds for exit ramps?

   ☐ Yes
   ☐ No

   Comments:

   Although a digital version is preferred (send to a-ballard@tamu.edu), a hardcopy may be mailed to the following address:

   Andrew Ballard, PE
   Research Engineer
   Texas Transportation Institute
   1100 NW Loop 410, Suite 400
   San Antonio, TX 78213

2. Identify (using the following table) factors that your agency considers when posting an advisory speed on an exit ramp:

Factor	Yes	No	Explanation
Speed (regulatory, operating) on the freeway main lane	☐	☐	
Speed (regulatory, operating) on the connecting surface facility	☐	☐	
Speed (operating) on the exit ramp			
Geometric characteristics of freeway main lane	☐	☐	
Geometric characteristics of exit ramp	☐	☐	
Geometric characteristics of surface facility	☐	☐	
Traffic control at exit ramp terminal	☐	☐	
Other:	n/a	n/a	
Other:	n/a	n/a	

3. Does your agency have specific practices related to advisory speed sign placement?

   ☐ Yes
   ☐ No

   If yes, can you provide access (e.g., online links, hardcopy mail, email, etc.) to standard detail sheets or documentation of your policies/practices related to advisory speed sign placement on exit ramps?

   ☐ Yes
   ☐ No

   Comments:

4. Do you have any additional information to share that you think might be applicable to this investigation?

   ☐ Yes
   ☐ No

   Comments:

Thank you for your assistance.

RMC 6035 SITE CHARACTERISTICS WORKSHEET

City	District	Site Number
Date	Type of Ramp: B S C Other (describe) ______________	
Area Type:	R U S	R C M U
Road Name:	Main Road/Freeway	Cross Street
Direction of Travel (NB-SB/EB-WB)	NB-SB EB-WB	NB-SB EB-WB
SPEED DIFFERENTIAL		
Freeway Regulatory Speed Limit (at point of departure from freeway to ramp)		Comment
Ramp Advisory Speed	Presence of Advisory Speed on Ramp Y N ______________________	Comment
Distance from exit gore on freeway to location of advisory speed sign(s)		Comment
Frontage Road Regulatory Speed Limit		Comment
RAMP GEOMETRY		
Horizontal Curve Degree		Comment
Vertical Grade Percent		Comment
Presence of Obstruction (e.g. barricades/other structure, high grass etc)	Y N (describe obstruction)	Comment
Number of Lanes on Ramp		Comment
DISTANCE MEASUREMENTS/FRONTAGE ROAD CHARACTERISTICS		
1. Distance from Freeway Gore to Yield Point Gore on frontage road (if applicable)*		Comment
2. Distance from Yield Point Gore to Downstream Intersection		Comment
Total Distance from Freeway gore to Downstream Intersection (sum 1 and 2 above)		
Frontage Road/Exit Ramp Yield Treatment Type	D DY NO NY FY DAL N/A	Comment

* - for certain locations this will just be distance from freeway gore to intersection (e.g. clover-leaf type ramps with signalized intersections immediately at end of ramp)

Show on sketch or printout:

- Signs and markings (include type and distance, note if in poor condition or needs replacing)
- Nature of ramp geometry
- Street names
- North arrow

Ramp Type (choose one from each column):

- **B**utton Hook
- **S**lip (regular)
- **C**loverleaf-type
- Other

Area Type (choose one from each column):

- **R**ural
- **U**rban
- **S**uburban
- **R**esidential
- **C**ommercial
- **M**ix
- **U**ndeveloped

Frontage Road Yield Treatment Type (choose one from each column):

- **D -** Double/Single solid line, ramp with own lane, no yield sign present on frontage road
- **DY –** Double/Single solid line, ramp with own lane, **y**ield sign present on Frontage road urban
- **NO –** No double/solid line, ramp with own lane, no yield sign
- **NY –** No double/solid white line, ramp with own lane, yield sign present
- **FY –** forced merge with yield sign
- **DAL –** Double/Single solid line, ramp with acceleration lane dropped
- **NA –** Non Applicable **-** No frontage road present (ramp feeds directly into cross street

FIELD CHECKLIST

- o Take MULTIPLE digital pictures of each location showing approach to ramp, location of posted and advisory speed signs, ramp geometry, and nature of yielding at junction with frontage road.
- o Complete worksheet
- o Draw sketch or make notes on printout
- o Update

OTHER COMMENTS:

Site Number: **Austin District Site 1 (AU1)**
Location: **Southbound Loop 1 Exit to Windsor, Austin, Texas**
Data Collected: **02/14/2008**

Characteristic	Value
Freeway Posted Speed Limit (mph)	65
Exit Ramp Advisory Speed Limit (mph)	25
Frontage Road Speed Limit(mph)	N/A
Distance from Gore to Cross Street (ft)	635
Horizontal Degree of Curvature (maximum)	~40
Grade (maximum)	5.1% downgrade
Notes	Ramp advisory speed sign has flashers Cloverleaf type ramp No frontage road present; ramp connects directly to signal on two-way cross street

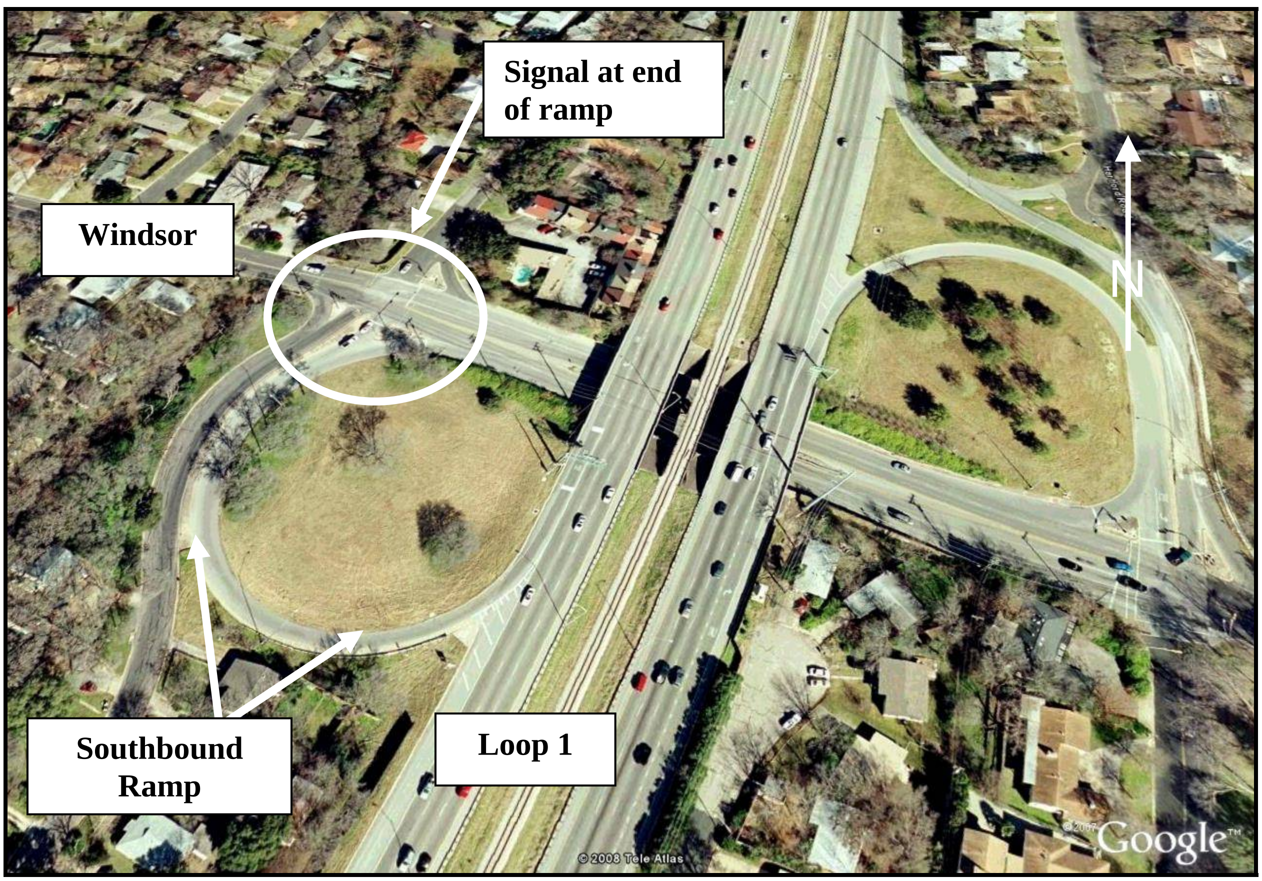

Figure 24. Loop 1 Southbound Exit to Windsor, Austin, Texas.
(Source: Google maps)

Figure 25. Exit Ramp to Windsor off Southbound Loop 1.

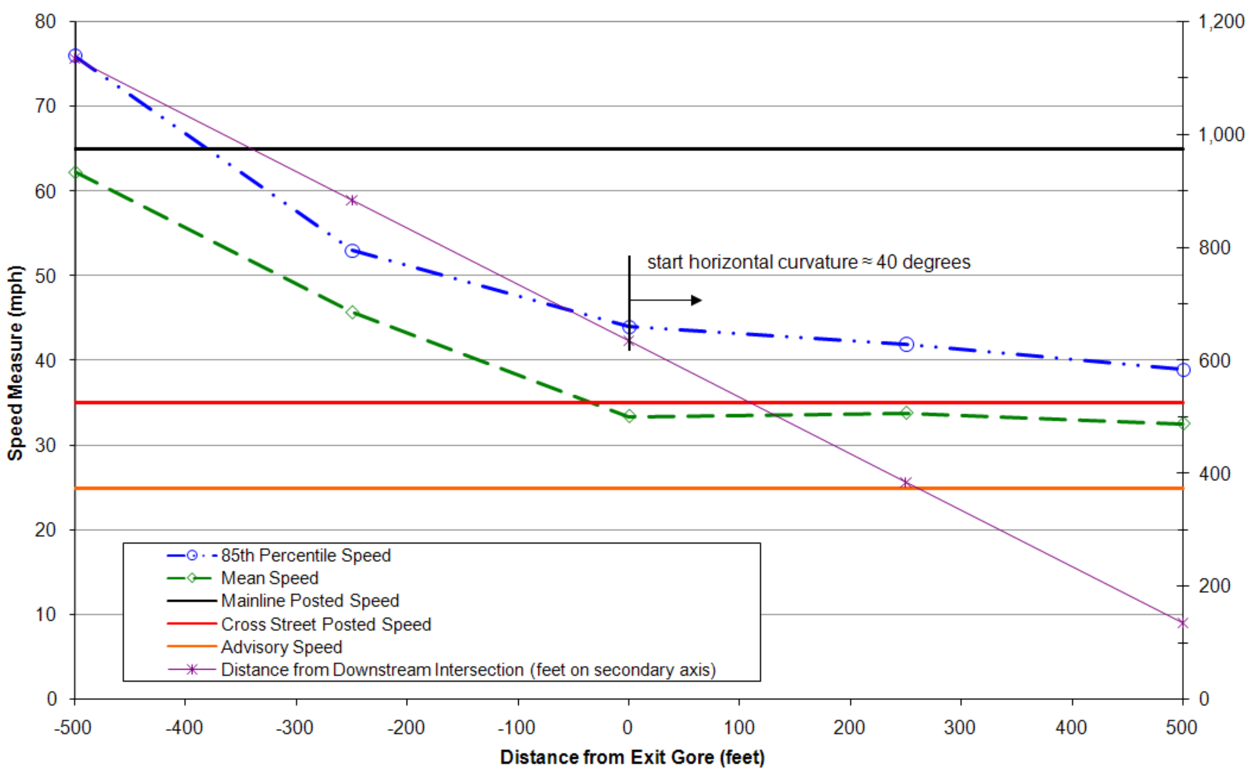

Figure 26. Speed Plot, AU1.

Site Number: Austin District Site 2 (AU2)
Location: Northbound Loop 1 Exit to Enfield, Austin, Texas
Data Collected: 04/01/2008

Characteristic	Value
Freeway Posted Speed Limit (mph)	65
Exit Ramp Advisory Speed Limit (mph)	None Posted
Frontage Road Speed Limit* (mph)	25
Distance from Gore to Cross Street (ft)	2890
Horizontal Degree of Curvature (maximum)	~0.5
Percent Grade (maximum)	3.5 % downgrade
*Notes	Regular/Slip ramp type, but with no frontage road connecting to ramp; Ramp becomes frontage road further downstream of exit point and another ramp joining from the left side

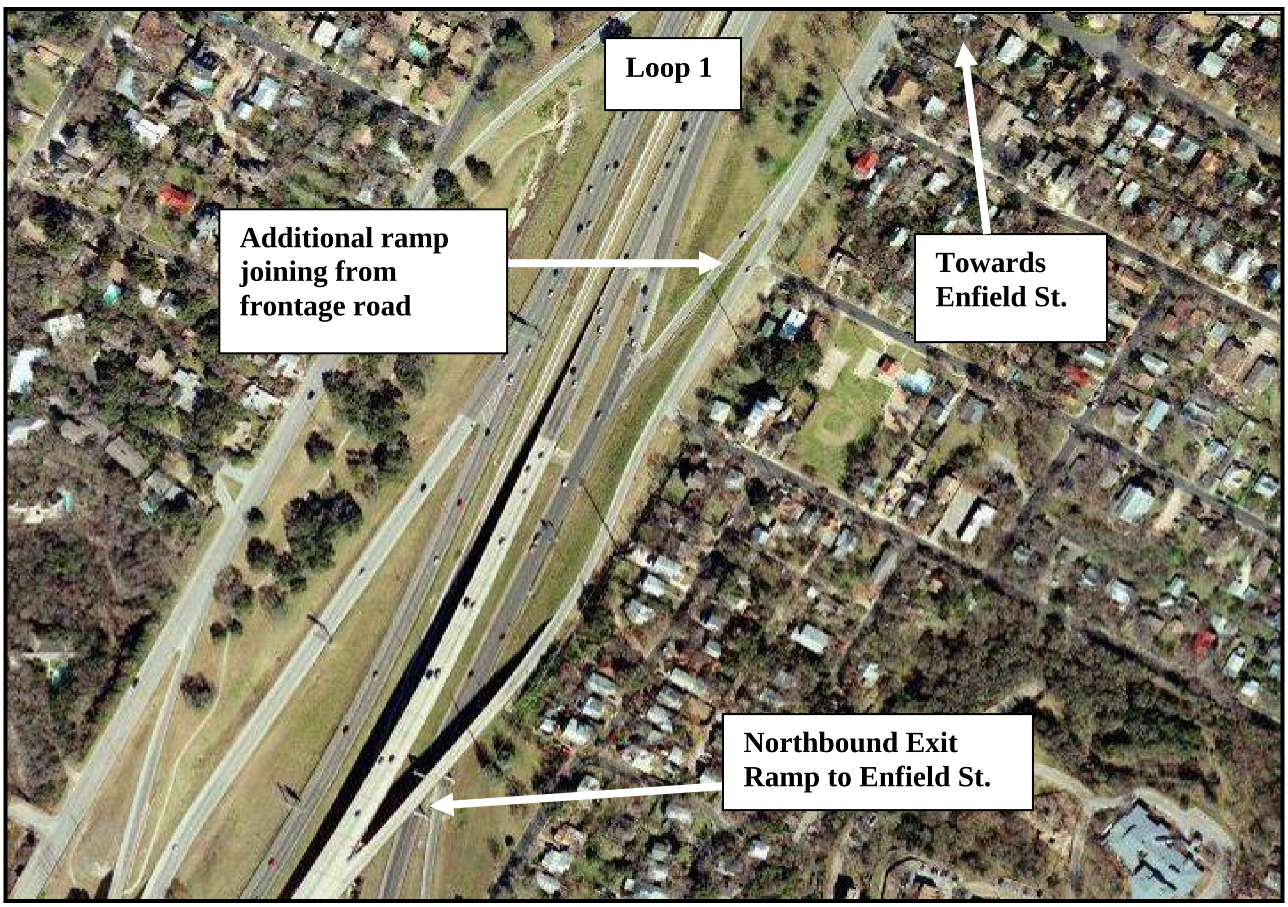

Figure 27. Loop 1 Northbound Exit to Enfield, Austin, Texas.
(Source: Google maps)

Figure 28. Exit Ramp to Enfield off Northbound Loop 1.

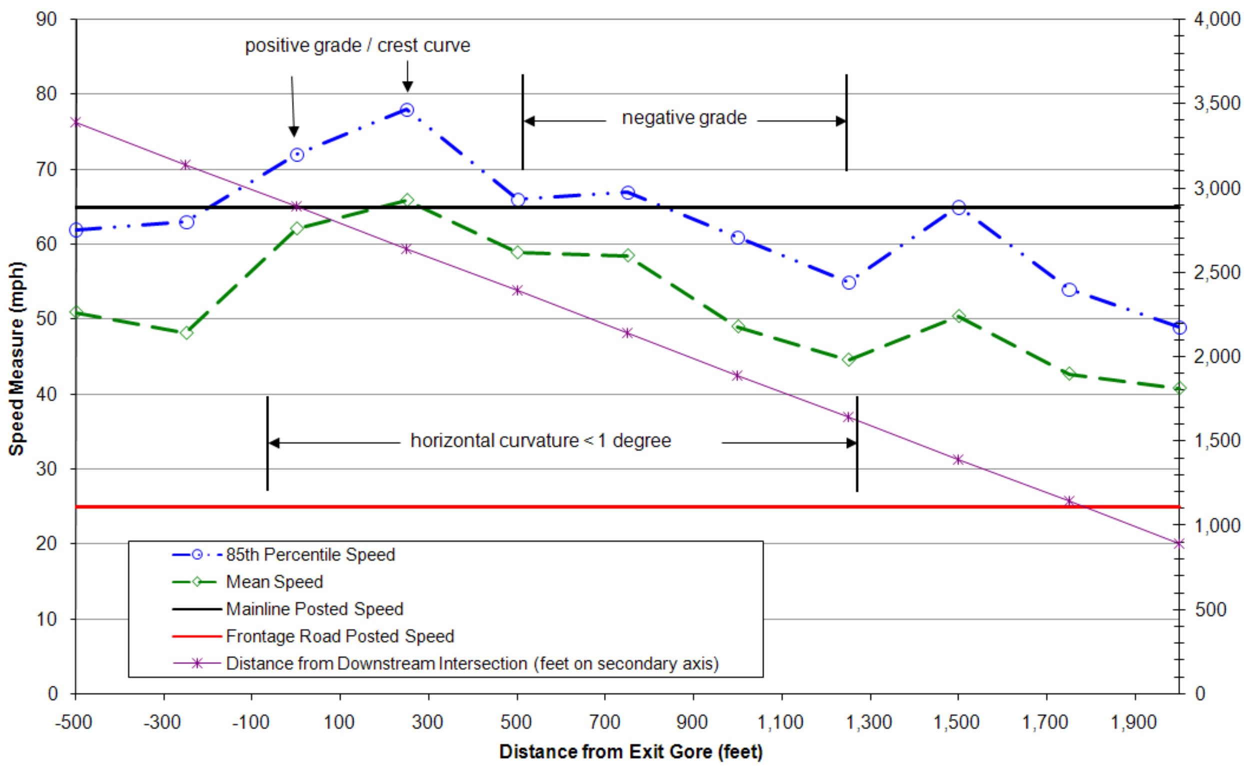

Figure 29. Speed Plot, AU2.

Site Number: **Austin District Site 3 (AU3)**
Location: **Southbound IH 35 Exit to Cesar Chavez, Austin, Texas**
Data Collected: **04/09/2008**

Characteristic	Value
Freeway Posted Speed Limit (mph)	60
Exit Ramp Advisory Speed Limit (mph)	20
Frontage Road Speed Limit (mph)	35
Distance from Gore to Cross Street (ft)	410
Horizontal Degree of Curvature (maximum)	~0.5
Percent Grade (maximum)	6.5% downgrade
Notes	None

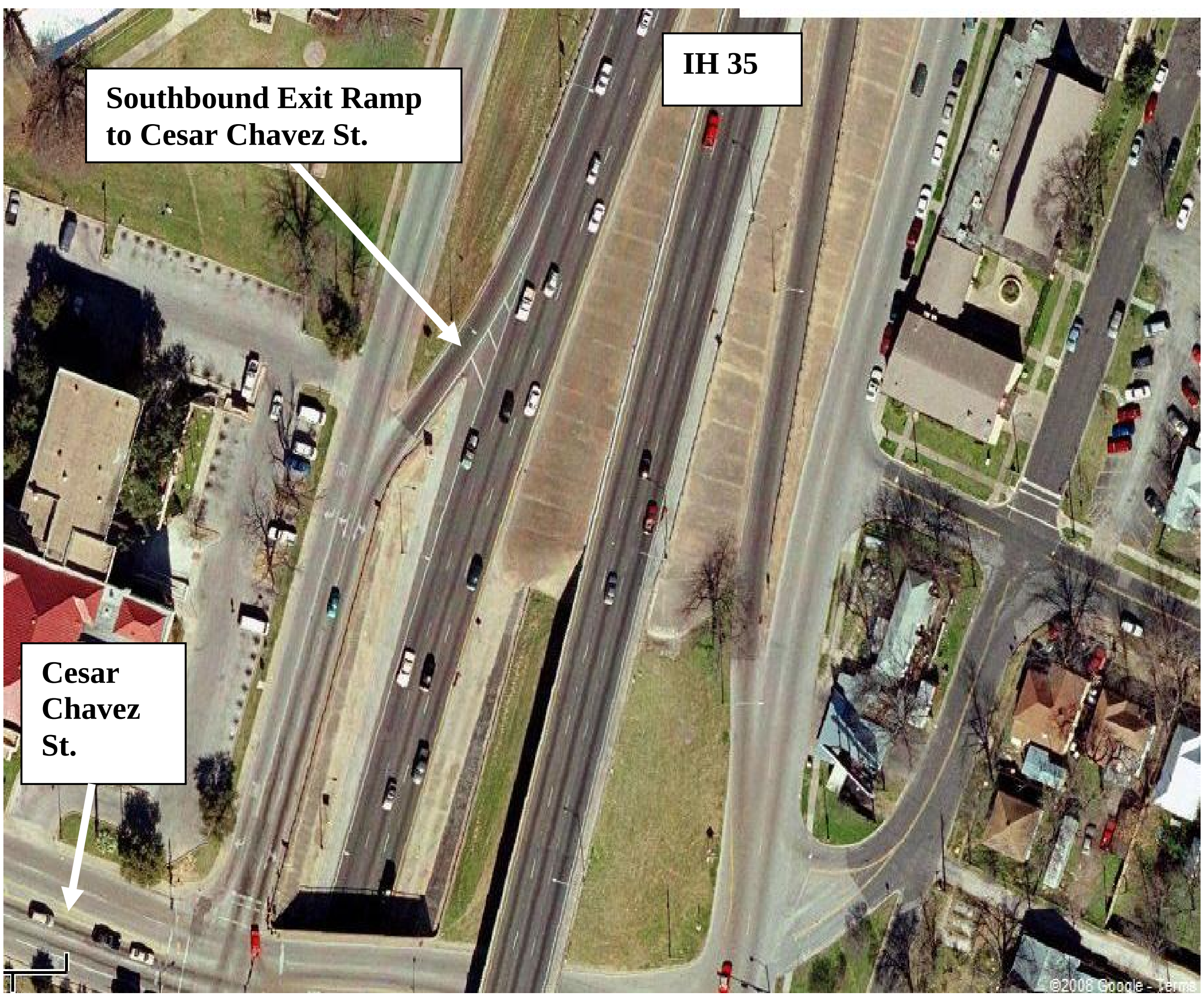

Figure 30. IH 35 Southbound Exit to Cesar Chavez, Austin, Texas.
(Source: Google maps)

Figure 31. Exit Ramp to Cesar Chavez off Southbound IH 35.

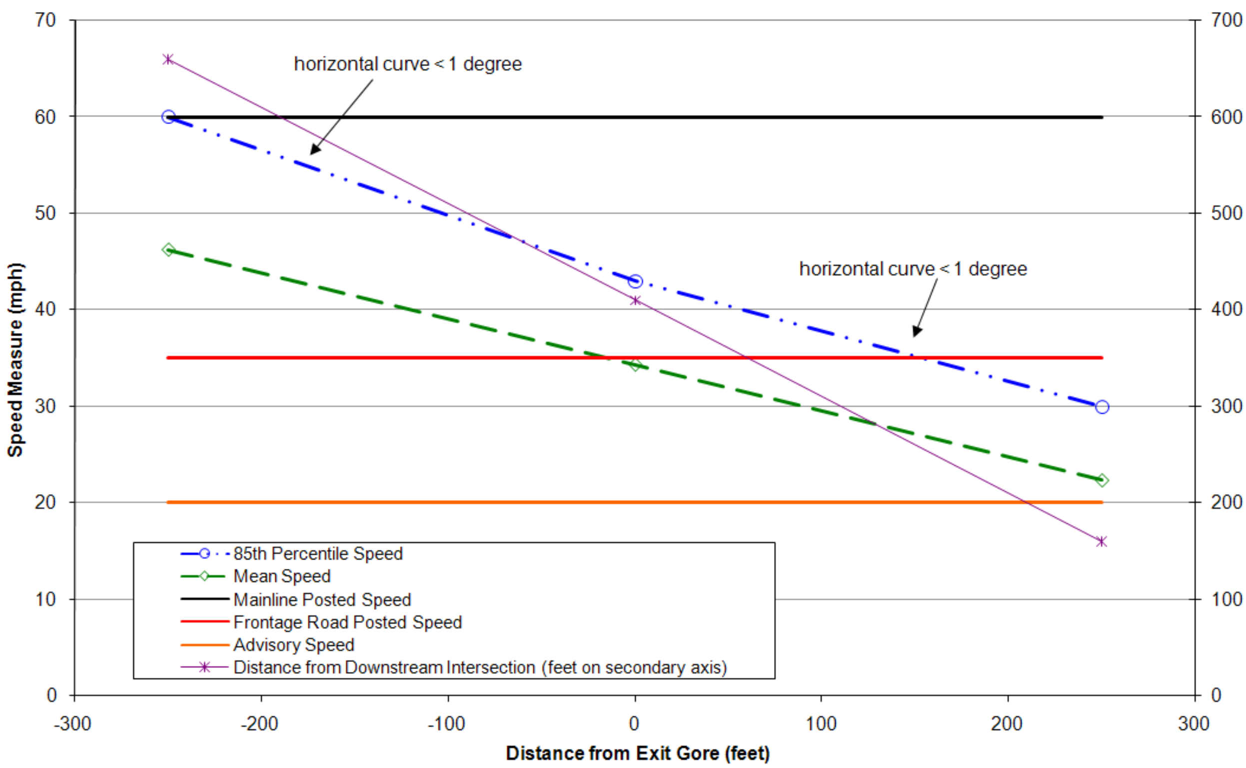

Figure 32. Speed Plot, AU3.

Site Number: Austin District Site 4 (AU4)
Location: Northbound IH 35 Exit to 6th Street, Austin, Texas
Data Collected: 04/09/2008

Characteristic	Value
Freeway Posted Speed Limit (mph)	60
Exit Ramp Advisory Speed Limit (mph)	25
Frontage Road Speed Limit (mph)	35
Distance from Gore to Cross Street (ft)	440
Horizontal Degree of Curvature (maximum)	~0.5
Percent Grade (maximum)	10% downgrade
Notes	Sharp downgrade, short distance from exit gore to downstream intersection.

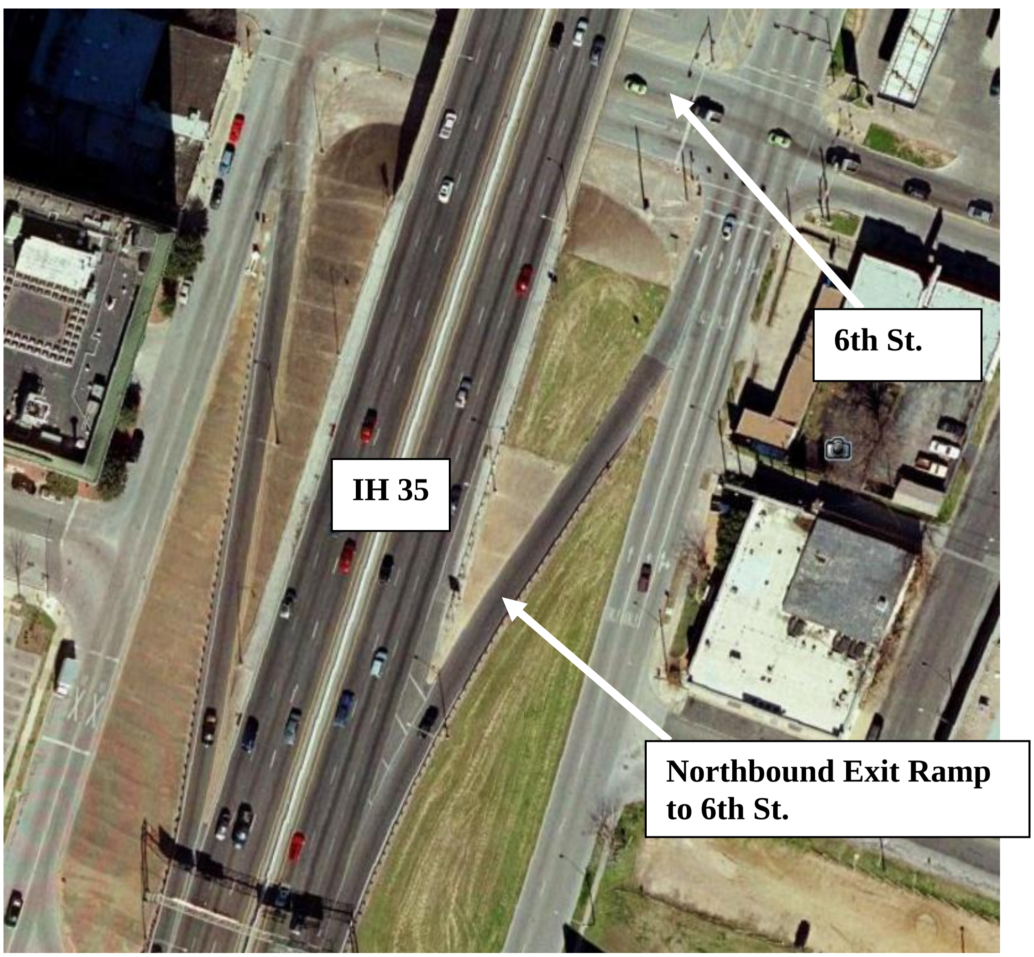

Figure 33. IH 35 Northbound Exit to 6th Street, Austin, Texas.
(Source: Google maps)

Figure 34. Exit Ramp to 6th Street off Northbound IH 35.

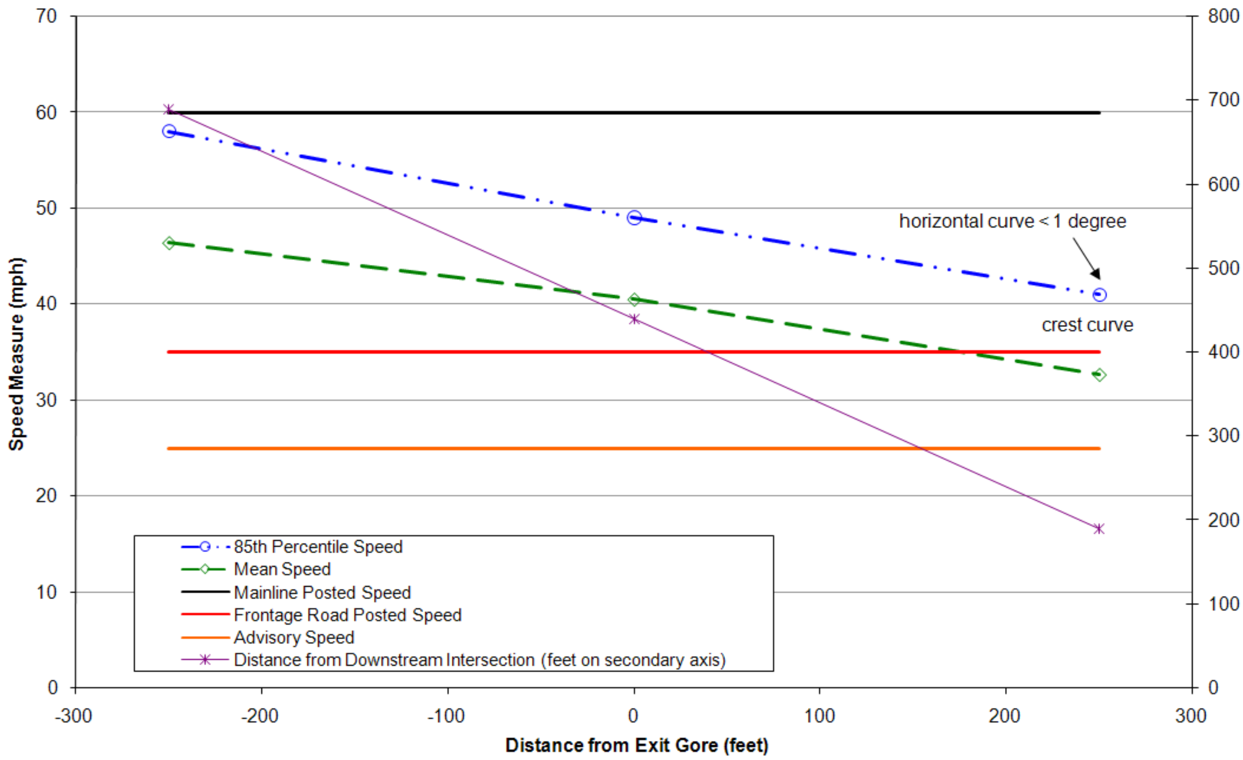

Figure 35. Speed Plot, AU4.

Site Number: **Bryan District Site 1 (BR1)**
Location: **Southbound SH 6 Exit to Harvey Road, College Station, Texas**
Data Collected: **05/27/2008**

Characteristic	Value
Freeway Posted Speed Limit (mph)	70
Exit Ramp Advisory Speed Limit (mph)	None Posted
Frontage Road Speed Limit (mph)	35
Distance from Gore to Cross Street (ft)	1900
Horizontal Degree of Curvature (maximum)	~6.2
Percent Grade (maximum)	~4% downgrade
Notes	No exit ramp advisory speed sign present

Figure 36. Southbound SH 6 Exit to Harvey Road, College Station, Texas.
(Source: Google maps)

Figure 37. Southbound SH 6 Exit Ramp to Harvey Road.

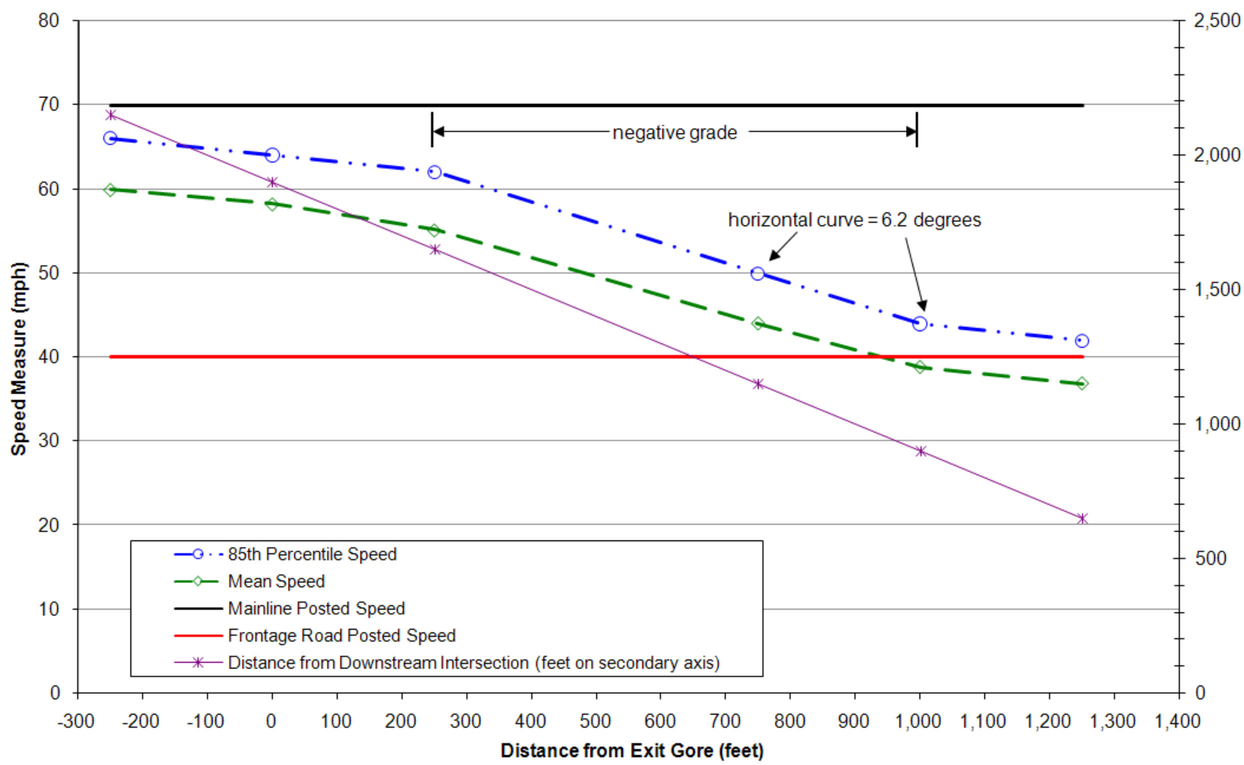

Figure 38. Speed Plot, BR1.

Site Number: **Houston District Site 1 (HU1)**
Location: **Northbound SH 288 Exit to Binz Street, Houston, Texas**
Data Collected: **04/24/2008**

Characteristic	Value
Freeway Posted Speed Limit (mph)	60
Exit Ramp Advisory Speed Limit (mph)	35
Frontage Road Speed Limit (mph)	35
Distance from Gore to Cross Street (ft)	2160
Horizontal Degree of Curvature (maximum)	~2.5
Percent Grade (maximum)	~3.9% upgrade
Notes	Braided ramp

Figure 39. Northbound SH 288 Exit to Binz Street, Houston, Texas.
(Source: Google maps)

Figure 40. Northbound SH 288 Exit Ramp to Binz Street.

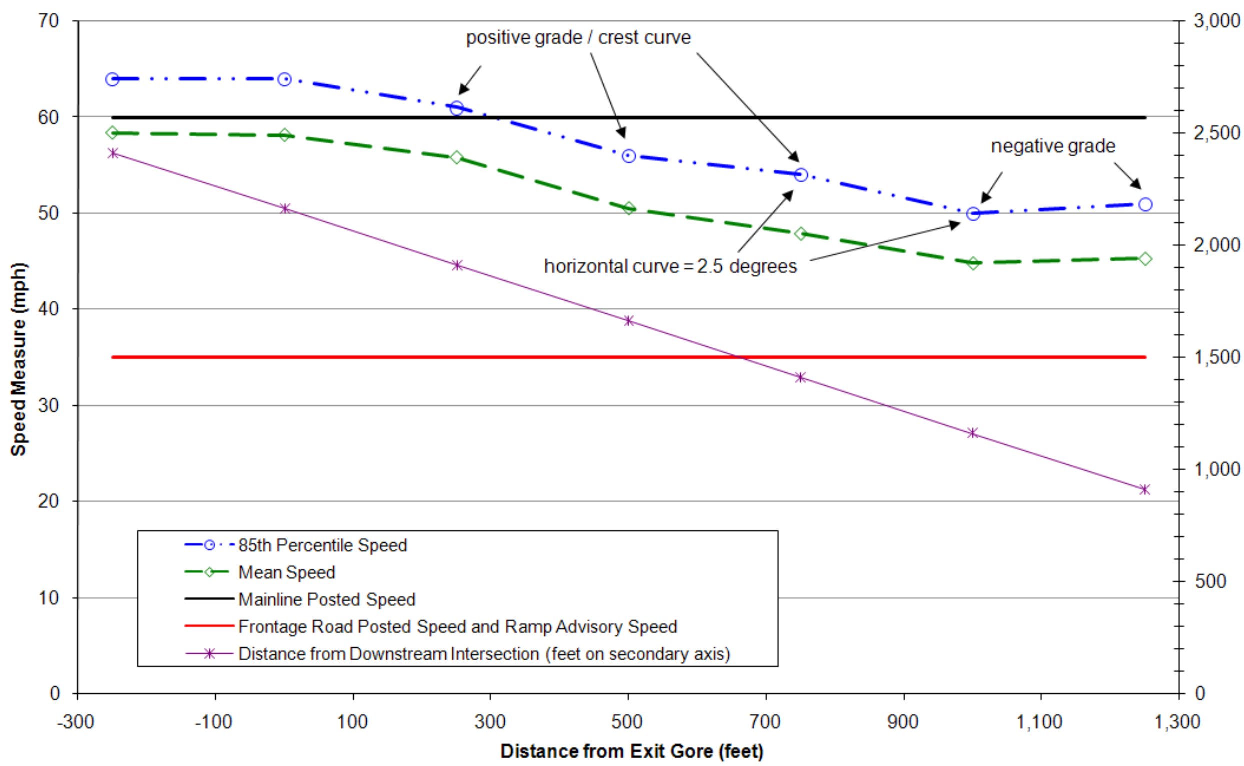

Figure 41. Speed Plot, HU1.

Site Number: Houston District Site 2 (HU2)
Location: Southbound US 59 Exit to Kirby Street, Houston, Texas
Data Collected: 05/06/2008

Characteristic	Value
Freeway Posted Speed Limit (mph)	60
Exit Ramp Advisory Speed Limit (mph)	35
Frontage Road Speed Limit (mph)	45
Distance from Gore to Cross Street (ft)	2205
Horizontal Degree of Curvature (maximum)	~0.5
Percent Grade (maximum)	~6% downgrade
Notes	Braided ramp, Some trees around advisory speed sign

Figure 42. Southbound US 59 Exit to Kirby Street, Houston, Texas.
(Source: Google maps)

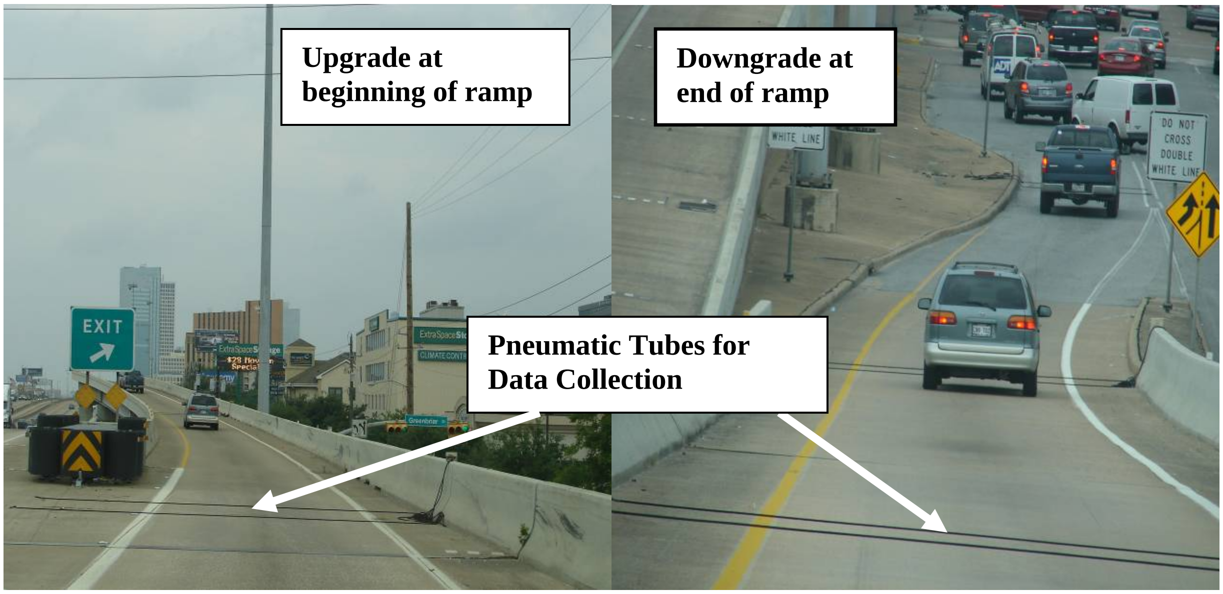

Figure 43. Exit Ramp to Kirby Street off Southbound US 59.

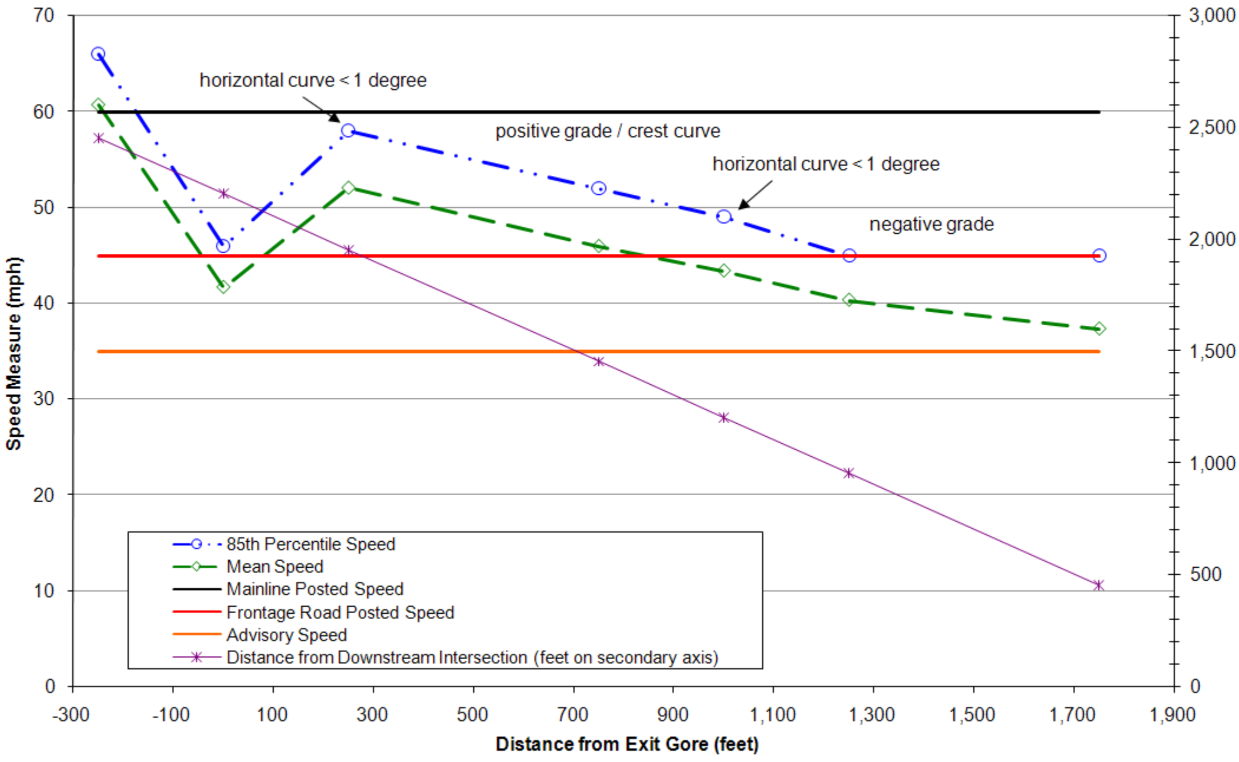

Figure 44. Speed Plot, HU2.

Site Number: Houston District Site 3 (HU3)
Location: Eastbound IH 610 Exit to Reveille Street (and IH 45 North), Houston, Texas
Data Collected: 05/06/2008

Characteristic	Value
Freeway Posted Speed Limit(mph)	65
Exit Ramp Advisory Speed Limit(mph)	35
Frontage Road Speed Limit(mph)	45
Distance from Gore to Cross Street (ft)	2725
Horizontal Degree of Curvature (maximum)	~7.4
Percent Grade (maximum)	~3.75% downgrade
Notes	Braided ramp; frontage road is on the left of ramp

Figure 45. Eastbound IH 610 Exit to Reveille Street, Houston, Texas.
(Source: Google maps)

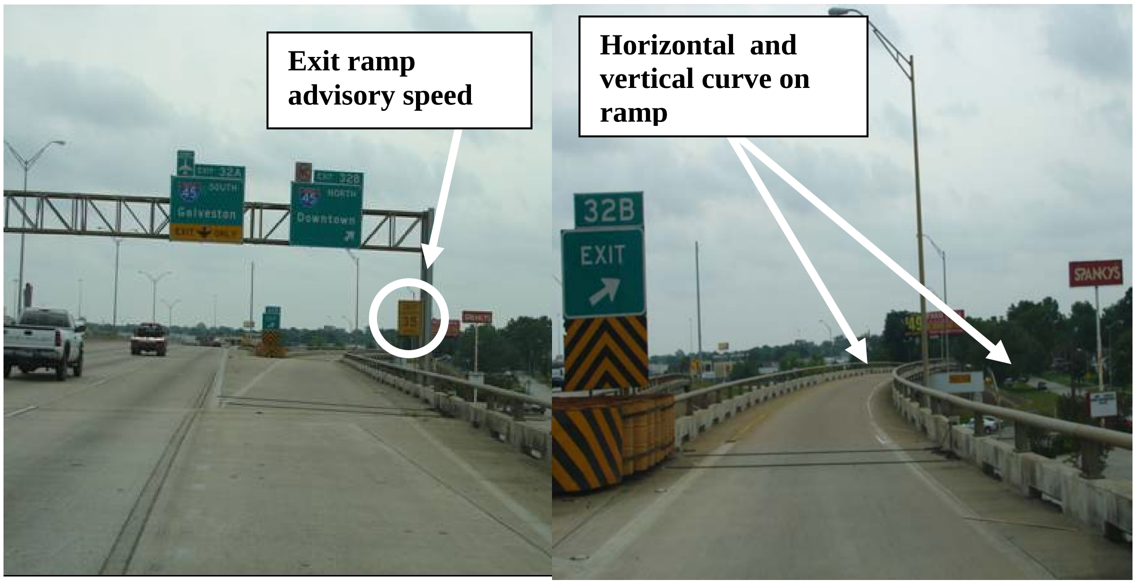

Figure 46. Exit Ramp to Reveille Street (and IH 45 North) off Eastbound IH 610.

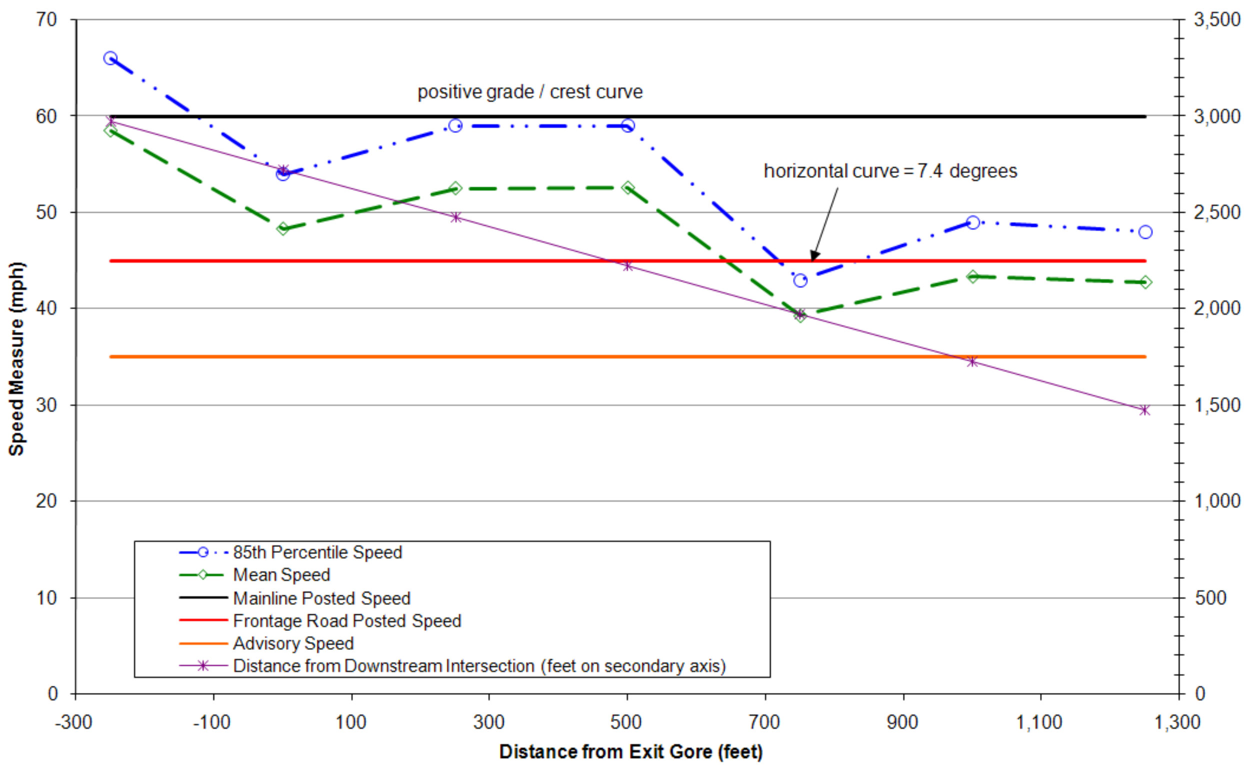

Figure 47. Speed Plot, HU3.

Site Number: **Houston District Site 4 (HU4)**
Location: **Eastbound SH 225 Exit to Shaver Street, Houston, Texas**
Data Collected: **05/13/2008**

Characteristic	Value
Freeway Posted Speed Limit(mph)	65
Exit Ramp Advisory Speed Limit(mph)	35
Frontage Road Speed Limit(mph)	40
Distance from Gore to Cross Street (ft)	2464
Horizontal Degree of Curvature (maximum)	~5.3
Percent Grade (maximum)	2% upgrade
Notes	Braided ramp

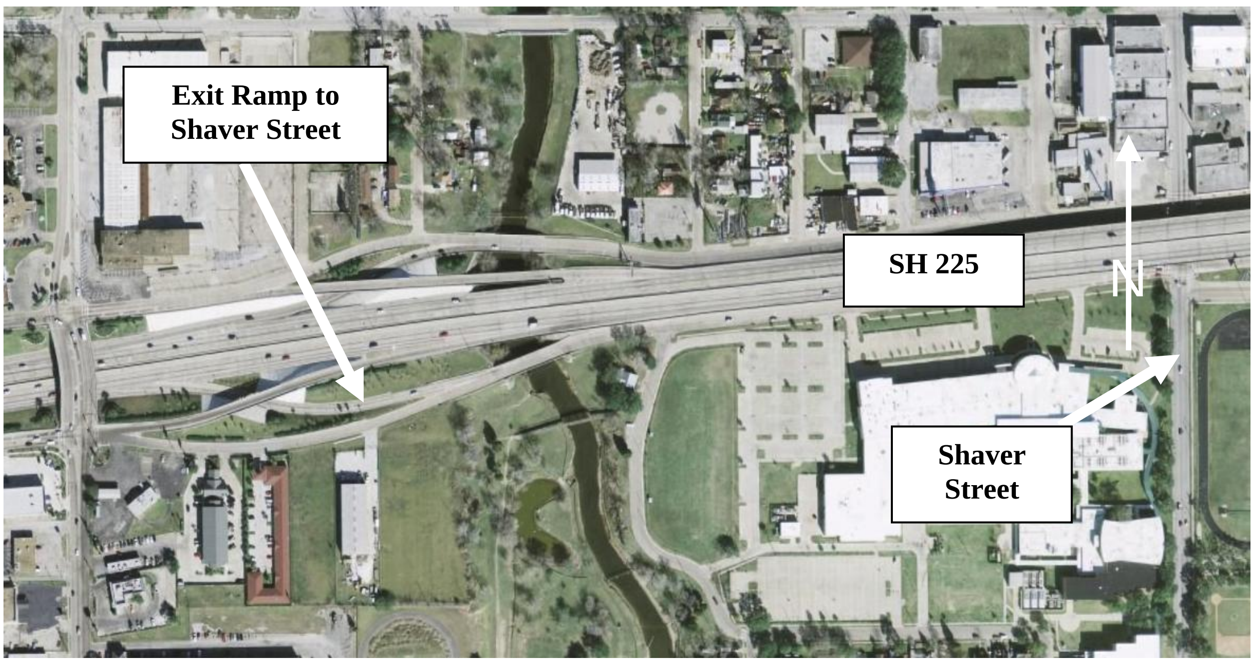

Figure 48. Eastbound SH 225 Exit to Shaver Street, Houston, Texas.
(Source: Google maps)

Figure 49. Exit Ramp to Shaver Street off Eastbound SH 225.

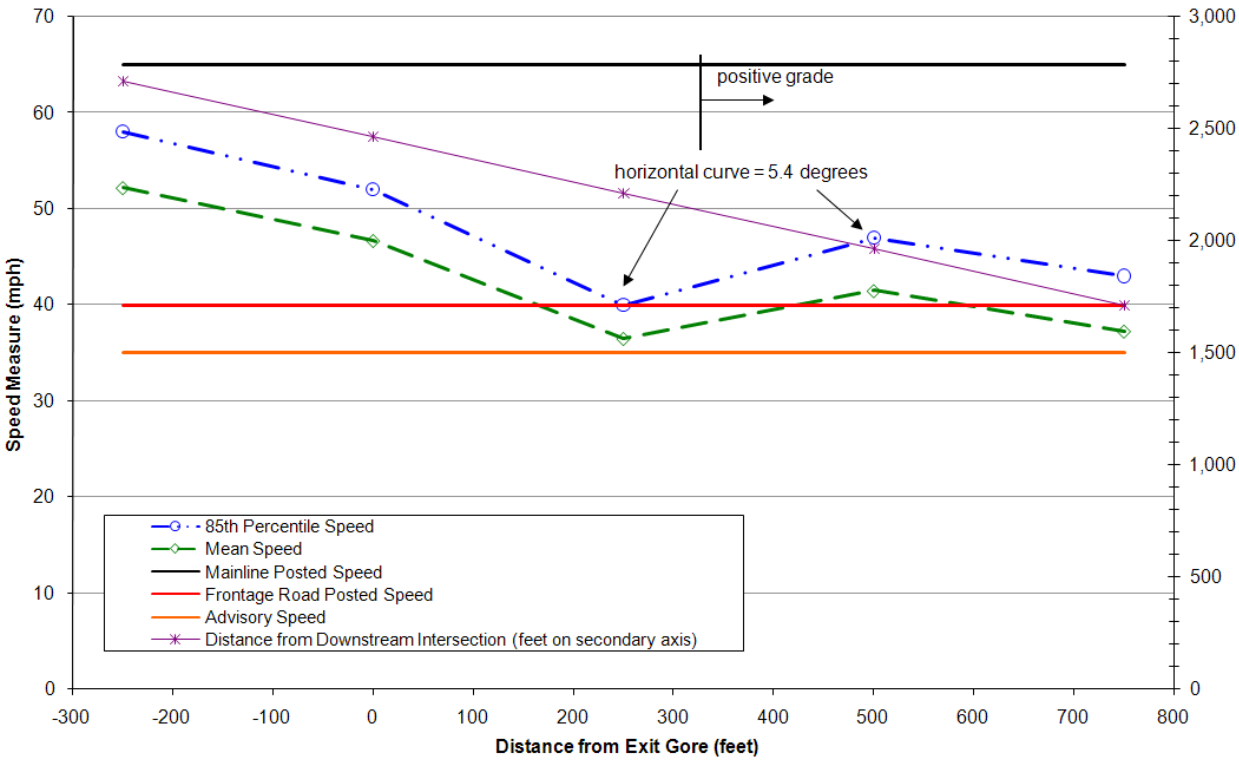

Figure 50. Speed Plot, HU4.

Site Number: **San Antonio District Site 1(SA1)**
Location: **Southbound IH 35 Exit to FM 3009, San Antonio, Texas**
Data Collected: 05/08/2008

Characteristic	Value
Freeway Posted Speed Limit(mph)	70
Exit Ramp Advisory Speed Limit(mph)	45
Frontage Road Speed Limit (mph)	50
Distance from Gore to Cross Street (ft)	4730
Horizontal Degree of Curvature (maximum)	~0.5
Percent Grade (maximum)	7.17% upgrade
Notes	None

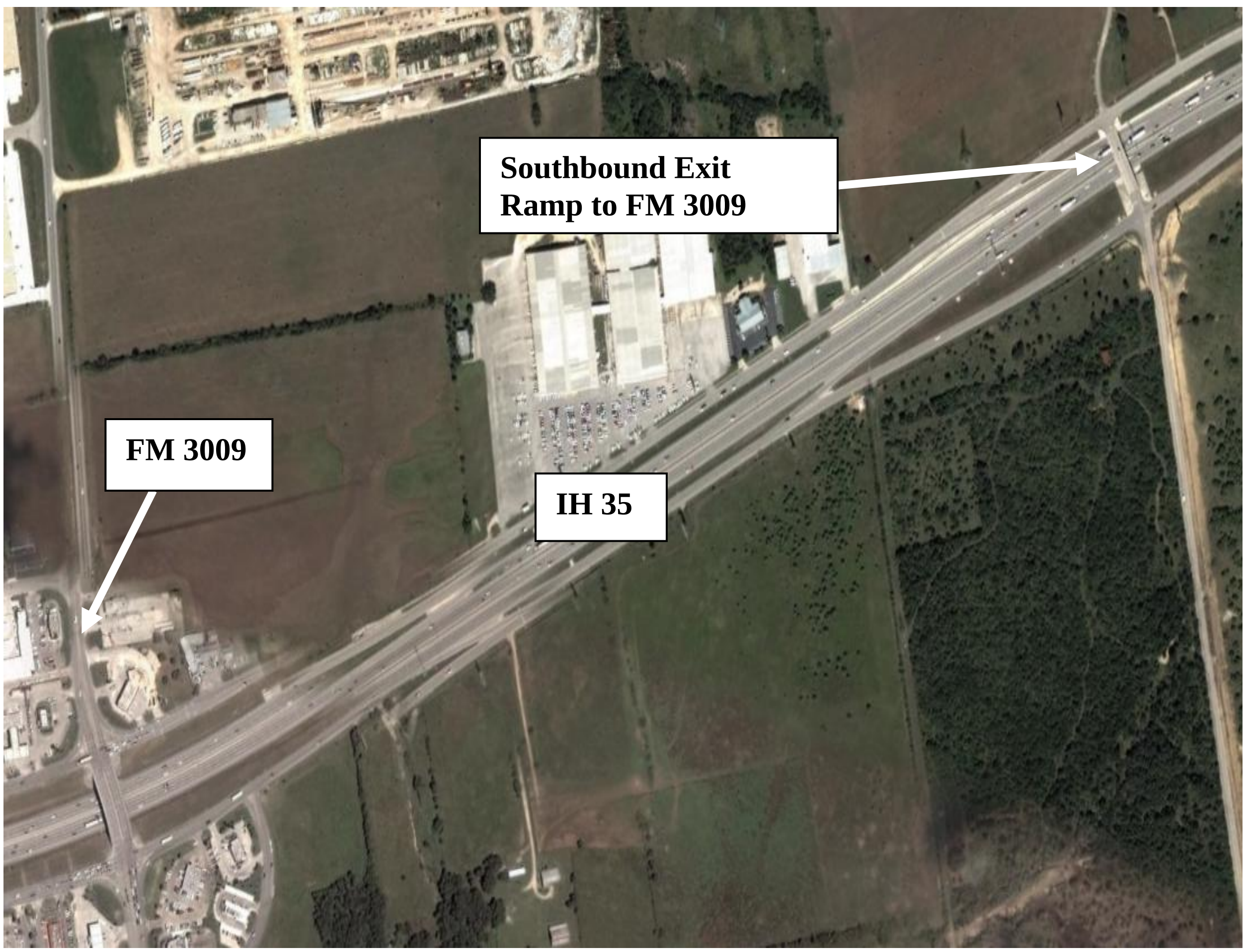

Figure 51. IH 35 Southbound Exit to FM 3009, San Antonio, Texas
(Source: Google maps)

Figure 52. Southbound IH 35 Exit Ramp to FM 3009

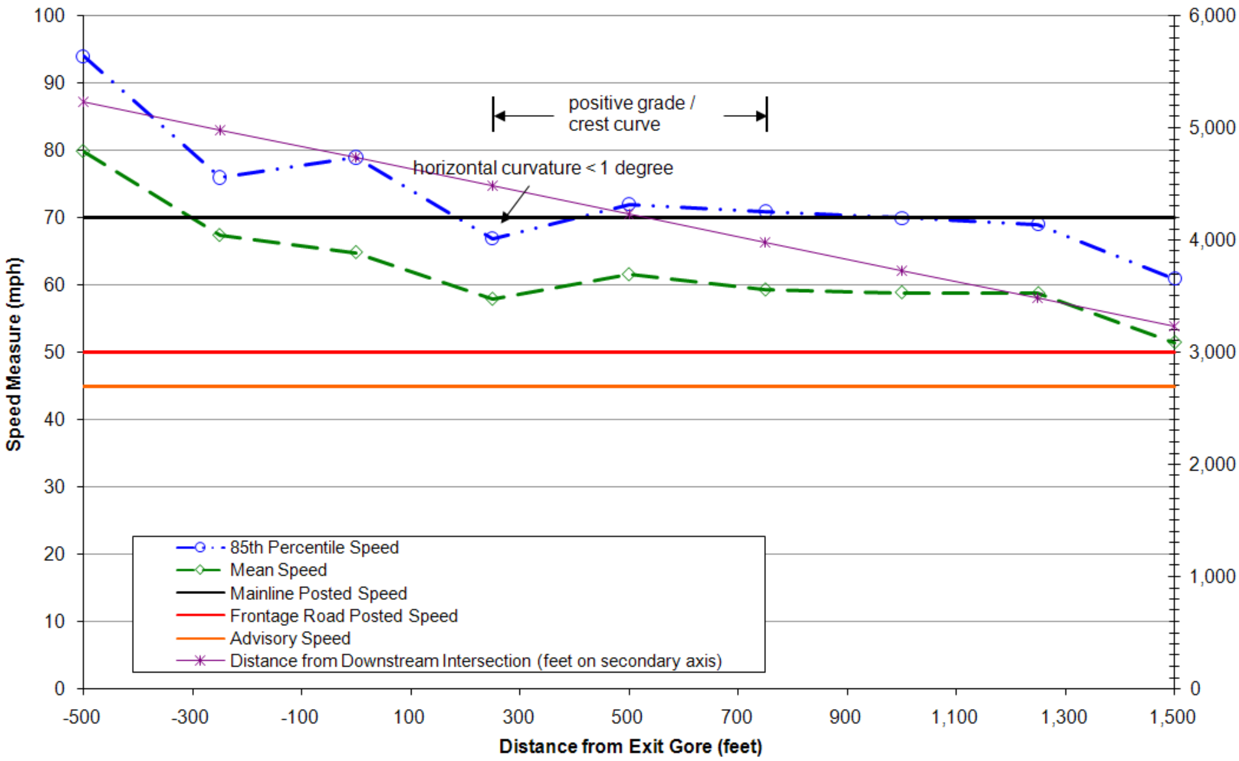

Figure 53. Speed Plot, SA1.

Site Number: San Antonio District Site 2(SA2)
Location: Westbound IH 10 Exit to South Alamo, San Antonio, Texas
Data Collected: 05/23/2008

Characteristic	Value
Freeway Posted Speed Limit(mph)	60
Exit Ramp Advisory Speed Limit(mph)	40
Frontage Road Speed Limit(mph)	30
Distance from Gore to Cross Street (ft)	550
Horizontal Degree of Curvature (maximum)	~0.5
Percent Grade (maximum)	~7.9 % upgrade
Notes	None

Figure 54. IH 10 Westbound Exit to South Alamo, San Antonio, Texas.
(Source: Google maps)

Figure 55. Westbound IH 10 Exit Ramp to South Alamo.

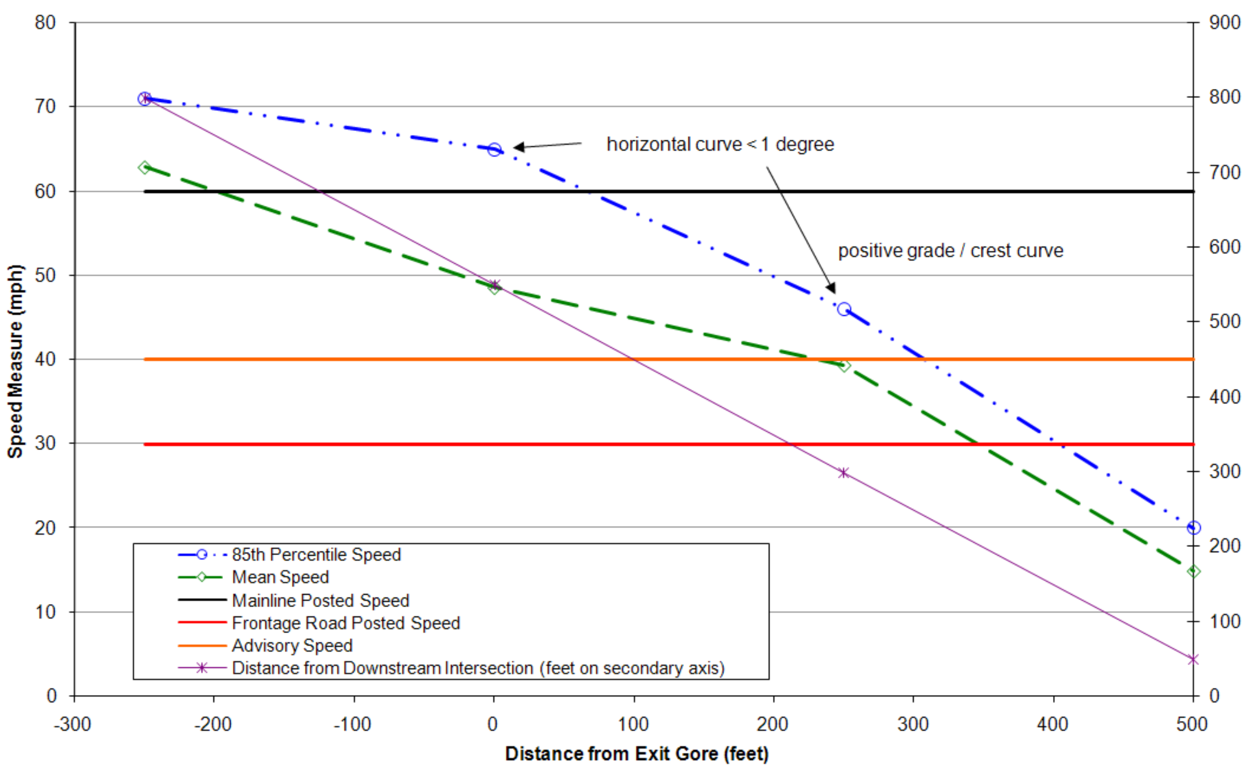

Figure 56. Speed Plot, SA2.

Site Number: **San Antonio District Site 3(SA3)**
Location: **Northbound IH 35 Exit to O'Connor Road, San Antonio, Texas**
Data Collected: **05/19/2008**

Characteristic	**Value**
Freeway Posted Speed Limit (mph)	65
Exit Ramp Advisory Speed Limit (mph)	40
Frontage Road Speed Limit* (mph)	35
Distance from Gore to Cross Street (ft)	1260
`Horizontal Degree of Curvature (maximum)	0.5
Percent Grade (maximum)	5.99% upgrade
Notes*	Frontage Road has a posted advisory speed limit of 35 mph due to sight distance limitation

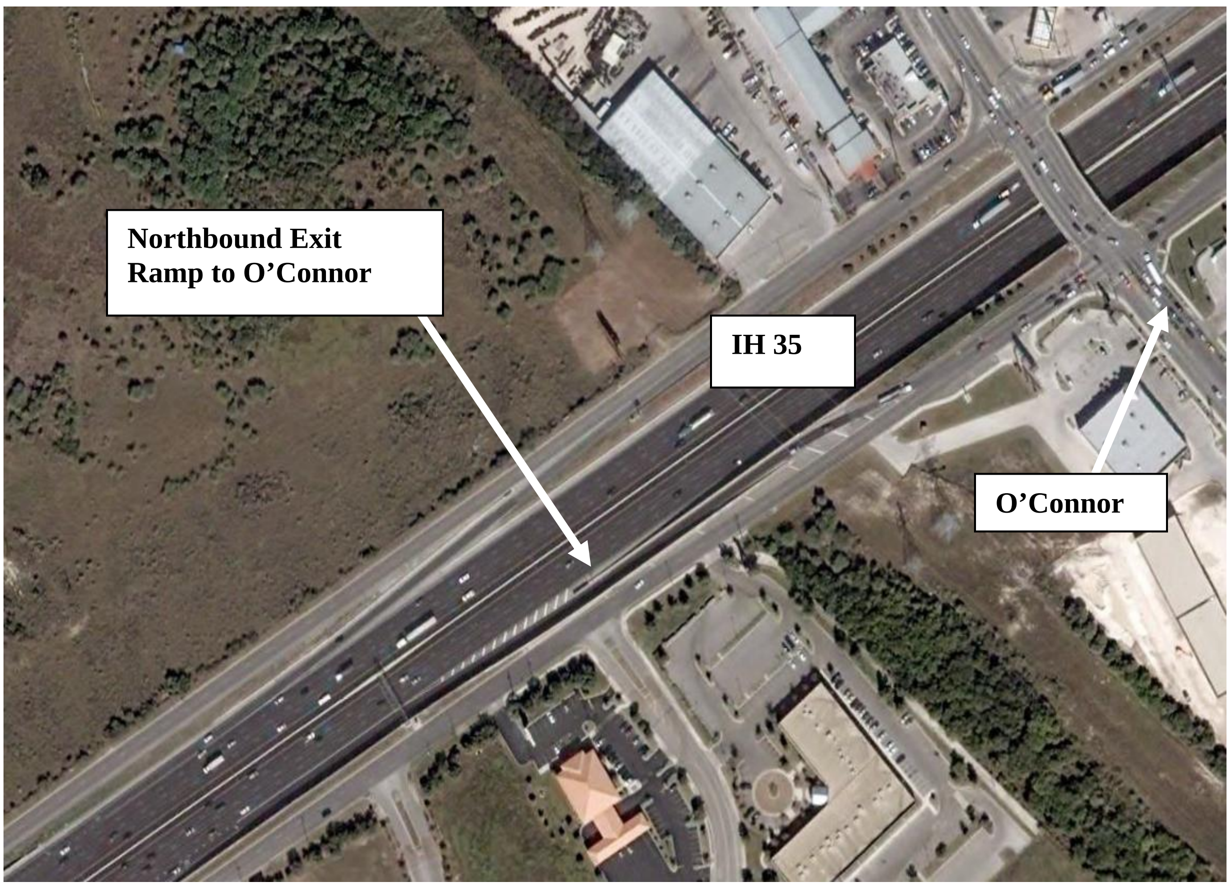

Figure 57. IH 35 Northbound Exit to O'Connor Road, San Antonio, Texas.
(Source: Google maps)

Figure 58. Northbound IH 35 Exit Ramp to O'Connor Road.

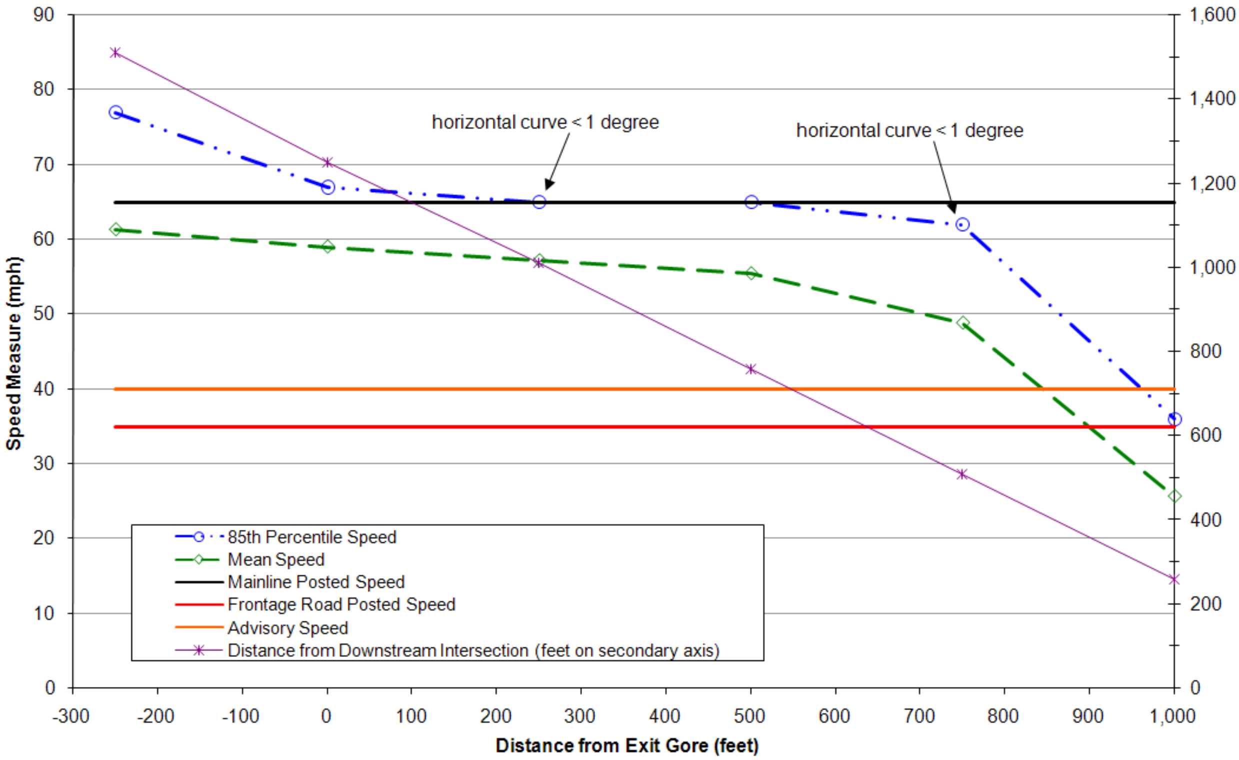

Figure 59. Speed Plot, SA3.

Site Number: San Antonio District Site 4(SA4)
Location: Southbound US 281 Exit to Mulberry Road, San Antonio, Texas
Data Collected: 06/09/2008

Characteristic	Value
Freeway Posted Speed Limit (mph)	60
Exit Ramp Advisory Speed Limit (mph)	30
Frontage Road Speed Limit (mph)	35
Distance from Gore to Cross Street (ft)	1030
Horizontal Degree of Curvature (maximum)	6.5
Percent Grade (maximum)	3% downgrade
Notes	None

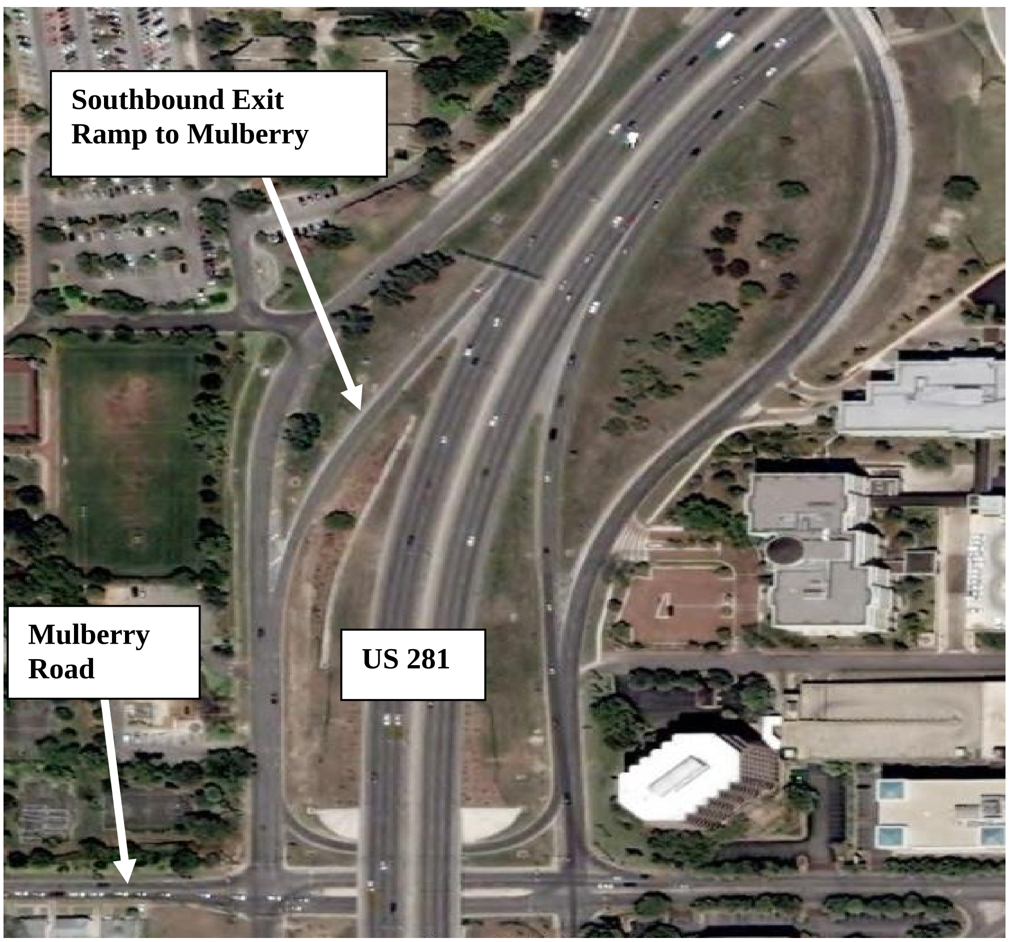

Figure 60. US 281 Southbound Exit to Mulberry Road, San Antonio, Texas.
(Source: Google maps)

Figure 61. Southbound US 281 Exit Ramp to Mulberry Road.

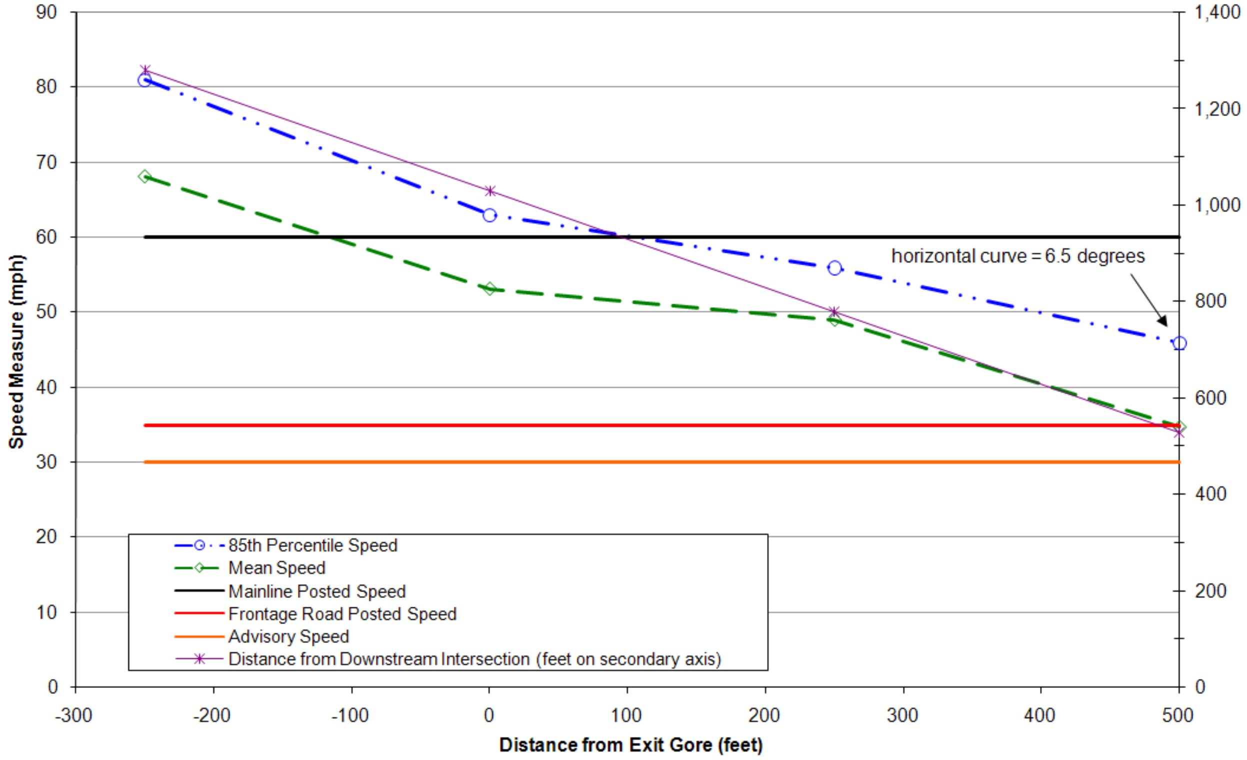

Figure 62. Speed Plot, SA4.

Site Number: San Antonio District Site 5 (SA5)
Location: Southbound IH 37 Exit to East Southcross Boulevard, San Antonio, Texas
Data Collected: 06/24/2008

Characteristic	Value
Freeway Posted Speed Limit (mph)	65
Exit Ramp Advisory Speed Limit (mph)	25
Frontage Road Speed Limit* (mph)	35
Distance from Gore to Cross Street (ft)	1938
Horizontal Degree of Curvature (maximum)	35.8
Percent Grade (maximum)	4.82 % upgrade
*Notes	Ramp connects directly to East Southcross Blvd. The posted speed on Southcross is assumed as the frontage road speed

Figure 63. IH 37 Southbound Exit to East Southcross, San Antonio, Texas.
(Source: Google maps)

Figure 64. Southbound IH 37 to East Southcross.

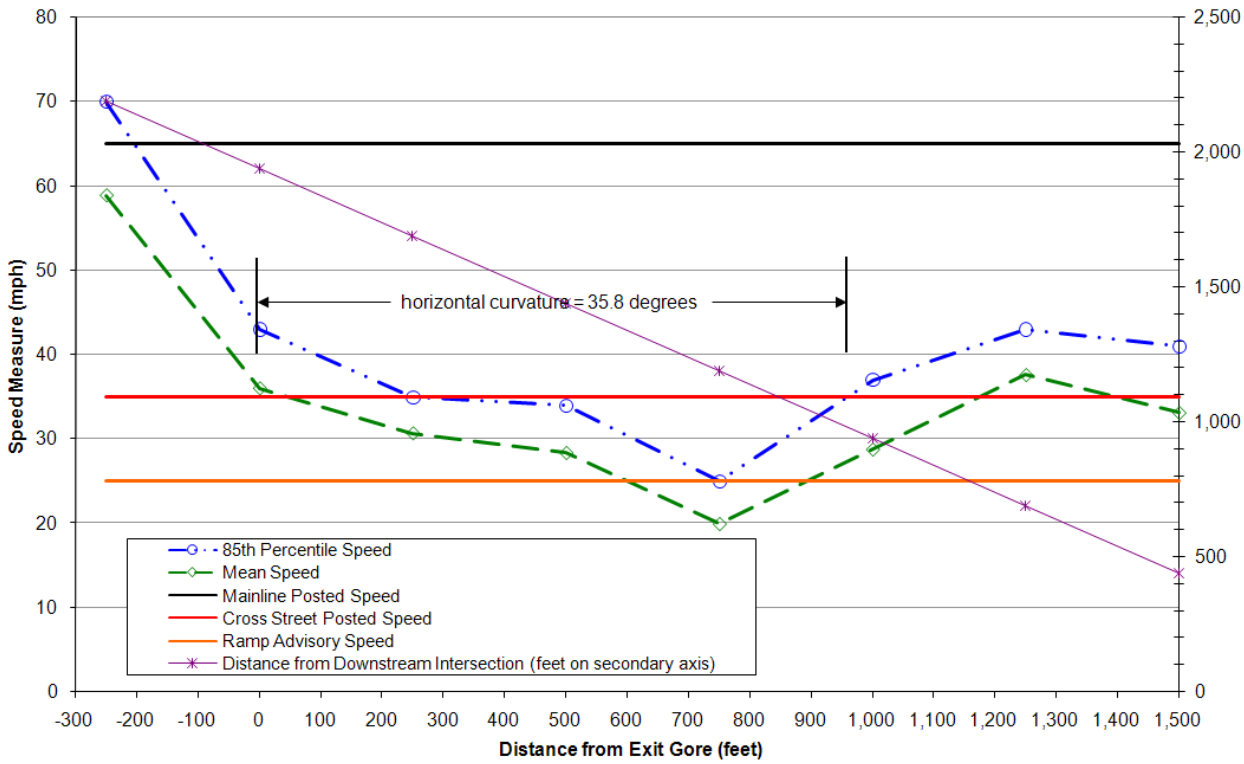

Figure 65. Speed Plot, SA5.

Site Number: **Yoakum District Site 1 (YK1)**
Location: **Westbound IH 10 Exit to Beckendorff Road, Sealy, Texas**
Data Collected: **06/03/2008**

Characteristic	Value
Freeway Posted Speed Limit (mph)	70
Exit Ramp Advisory Speed Limit(mph)	15
Frontage Road Speed Limit* (mph)	30 mph advisory (55 mph on other section of IH10)
Distance from Gore to Cross Street (ft)	1753
Horizontal Degree of Curvature (maximum)	~18
Percent Grade (maximum)	0.5% upgrade
*Notes	No posted speed limit on frontage road in immediate vicinity of exit ramp, only advisory speed present

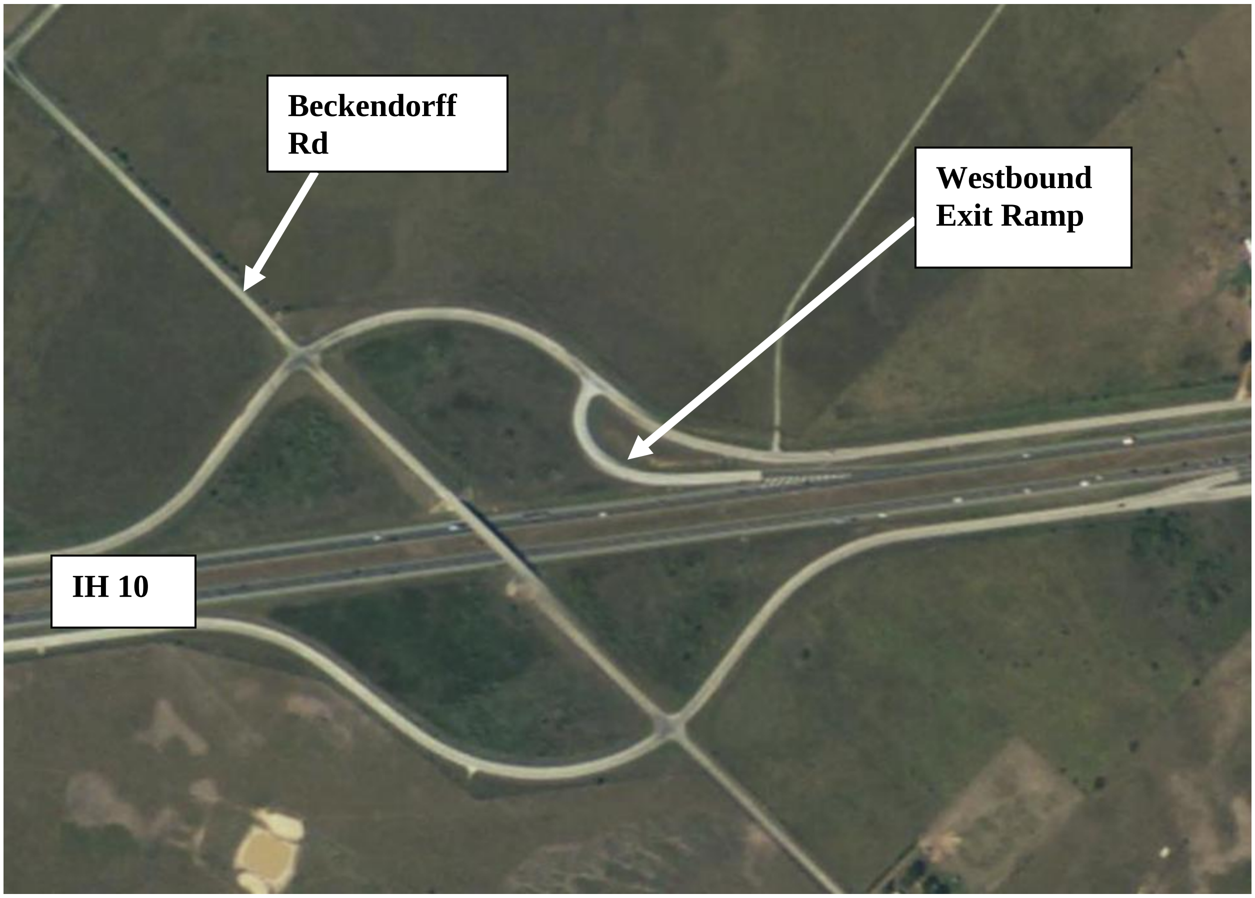

Figure 66. Westbound IH 10 Exit to Beckendorff Road, Sealy, Texas.
(Source: Google maps)

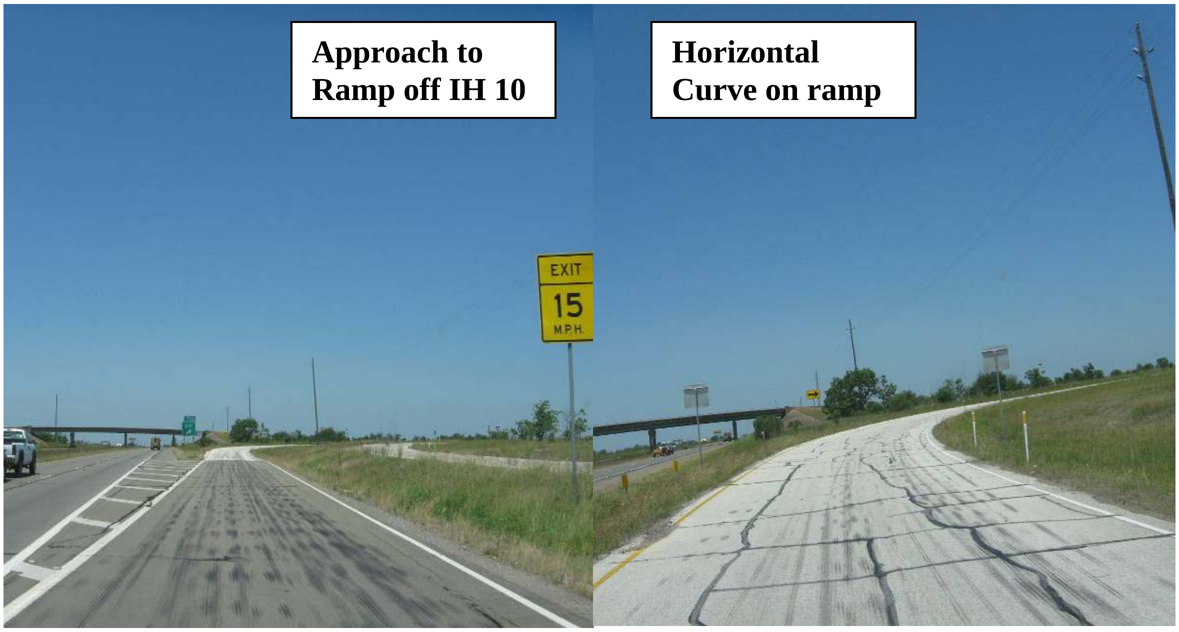

Figure 67. Westbound IH 10 Exit to Beckendorff Road.

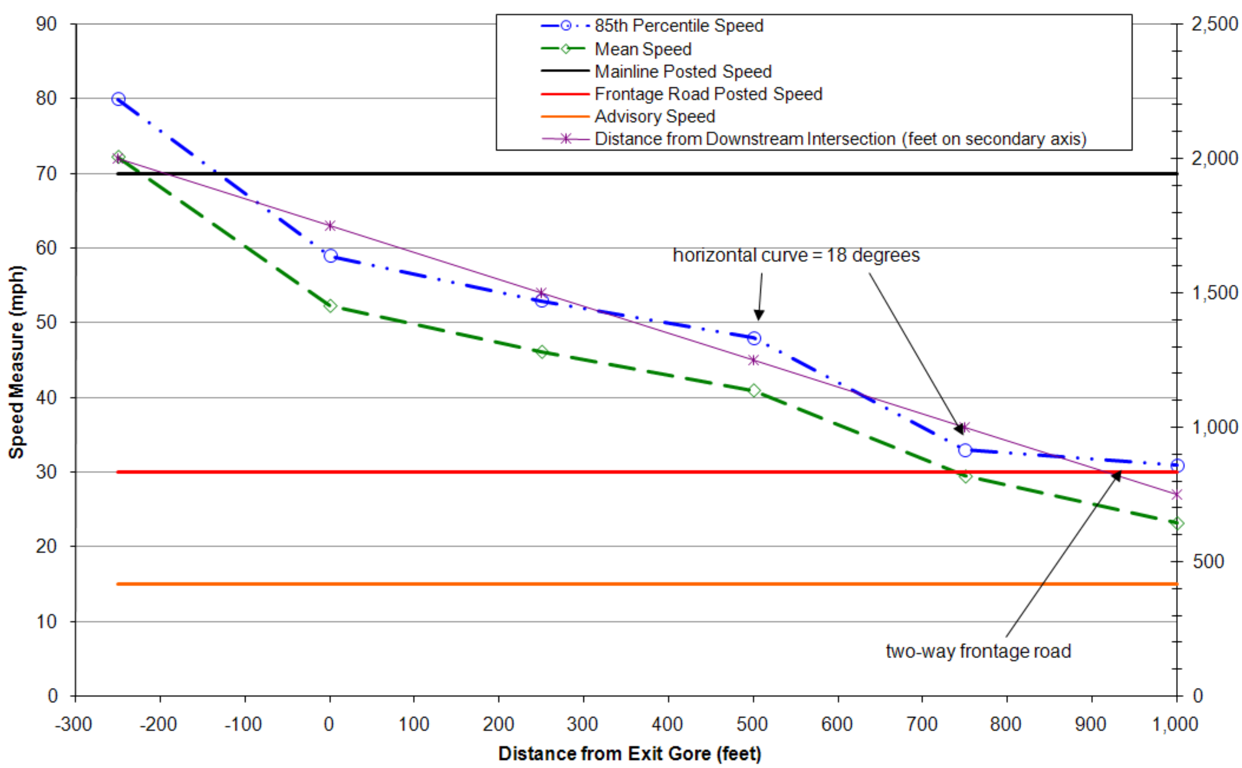

Figure 68. Speed Plot, YK1.

Site Number: Yoakum District Site 2(YK2)
Location: Eastbound IH 10 Exit to Pyka Road, Sealy, Texas
Data Collected: 06/03/2008

Characteristic	Value
Freeway Posted Speed Limit (mph)	70
Exit Ramp Advisory Speed Limit (mph)	15
Frontage Road Speed Limit*(mph)	55
Distance from Gore to Cross Street (ft)	1900
Horizontal Degree of Curvature (maximum)	~18
Percent Grade (maximum)	~0 (Level)
*Notes	No posted speed on frontage road near exit ramp – posted speed assumed to be similar to sections upstream of study site

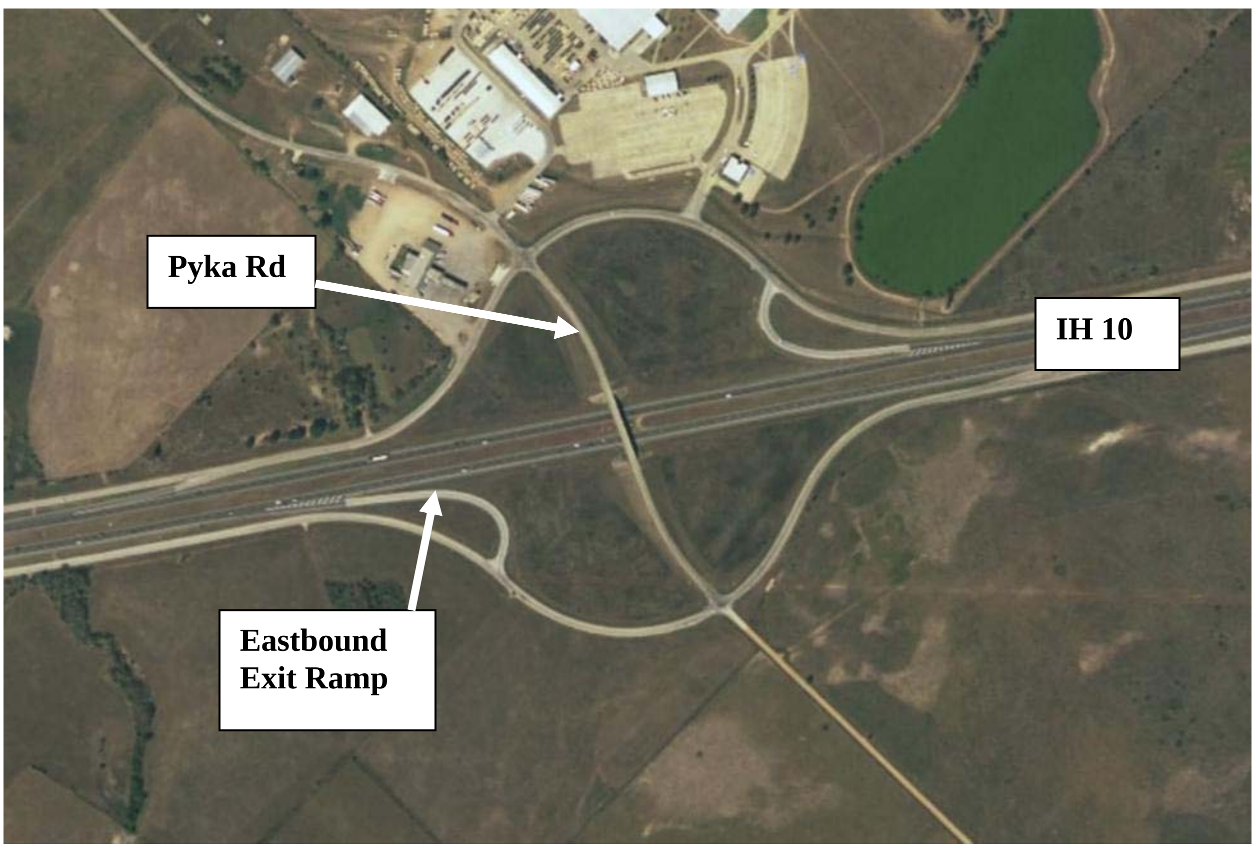

Figure 69. Eastbound IH 10 Exit to Pyka Road, Sealy, Texas.
(Source: Google maps)

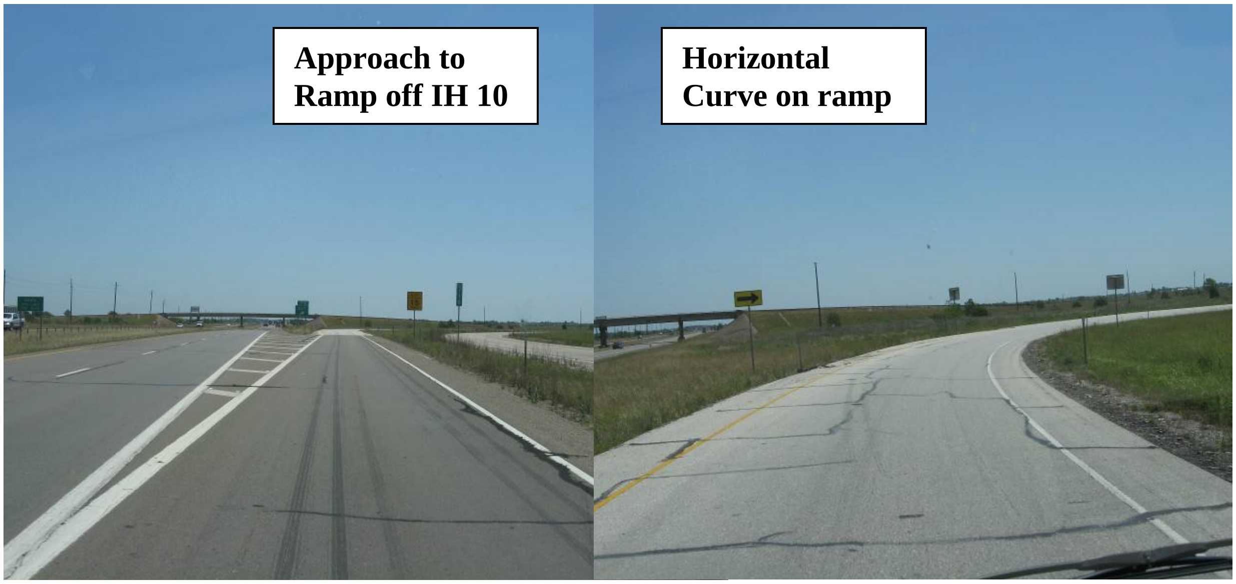

Figure 70. Eastbound IH 10 Exit to Pyka Road.

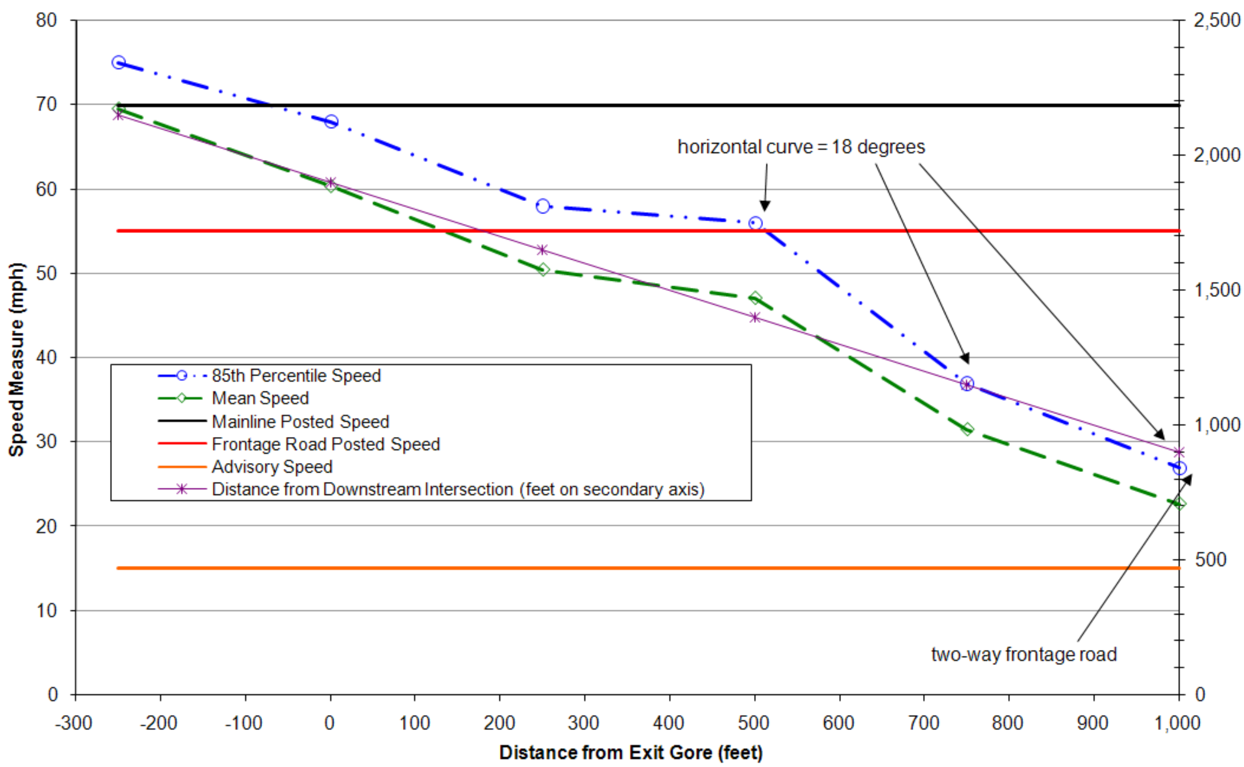

Figure 71. Speed Plot, YK2.

Site Number: **Yoakum District Site 3 (YK3)**
Location: **US 59 Southbound Exit to SH 185, Victoria, Texas**
Data Collected: **06/17/2008**

Characteristic	Value
Freeway Posted Speed Limit(mph)	70
Exit Ramp Advisory Speed Limit(mph)	30
Frontage Road Speed Limit(mph)	None Posted*
Distance from Gore to Cross Street (ft)	1450
Horizontal Degree of Curvature (maximum)	~7.1
Percent Grade (maximum)	~ 0 (level)
*Notes	Only short frontage road of about 400 ft exists at this site. Two-way frontage road with no posted speed limit

Figure 72. Southbound US 59 Exit to SH 185, Victoria, Texas.
(Source: Google maps)

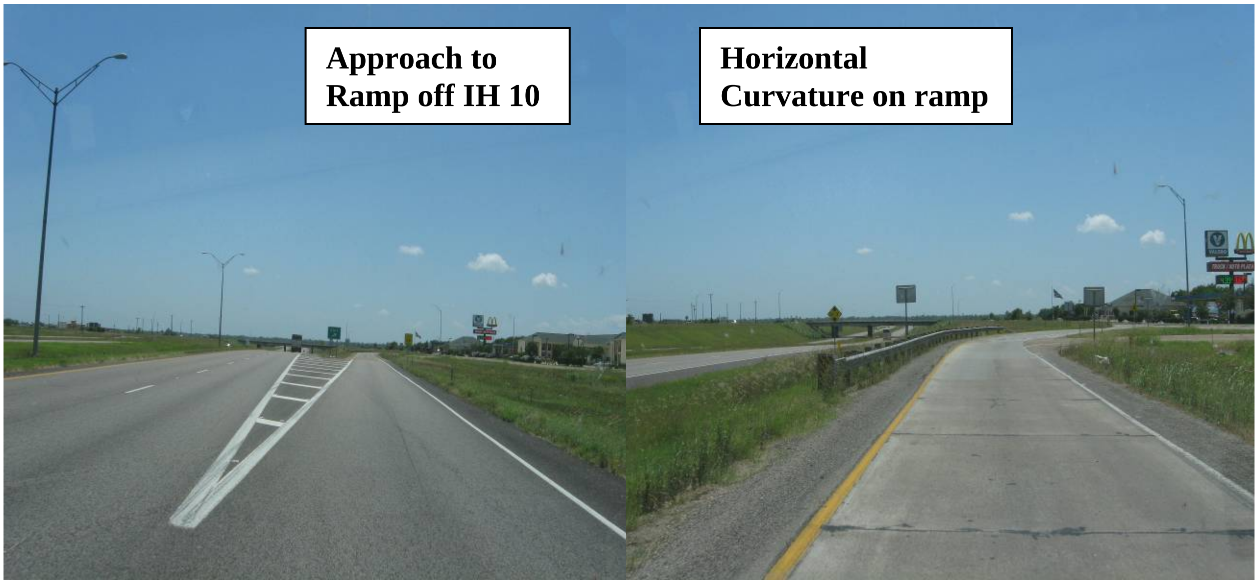

Figure 73. Southbound US 59 Exit to SH 185.

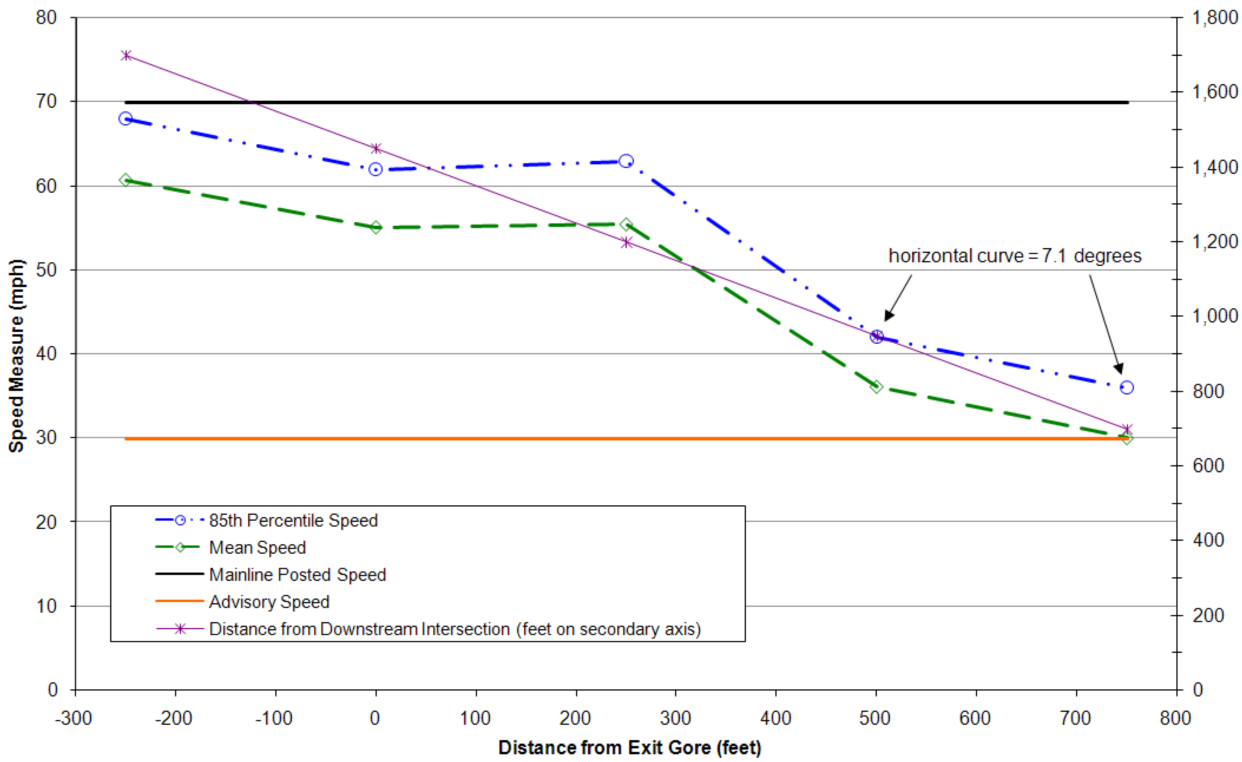

Figure 74. Speed Plot, YK3.