GEORGIA DOT RESEARCH PROJECT 15-04

FINAL REPORT

DEVELOPING GEORGIA'S HIGH FRICTION SURFACE TREATMENT (HFST) PROGRAM – HFST SITE CHARACTERISTICS (HFST-SC) DATA COLLECTION AND ANALYSIS

Georgia Department of Transportation

OFFICE OF PERFORMANCE-BASED MANAGEMENT AND RESEARCH
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<tr><td colspan="4">16. Abstract:
The Georgia Department of Transportation (GDOT) has invested millions of dollars in the high friction surface treatment (HFST) and will continue investing more to reduce potential run-off-road (ROR) crashes on sharp curves. GDOT has taken the initiative to work with Georgia Tech's research team to improve its HFST program. An enhanced HFST-SS method was developed to systematically and proactively select HFST sites. The method consists of three steps: 1) analyze crash data and assign it to segments, 2) prioritize and select segments/corridors for application of HFST considering and balancing crash frequency, severity ratio, and wet crash conditions, and 3) use BBI values to select curve sites for HFST application. A procedure, including a geo-database and an HFST report card (HFST-RC), was developed for collecting, processing, integrating, visualizing, and analyzing the before and after HFST-Site Characteristics (HFST-SC); these characteristics were collected using emerging sensing technologies (including 2D imaging, lasers, 3D LiDAR, Inertial Measurement Units (IMU), and GPS/GIS technologies). The detailed-level, location-referenced HFST-SC data, including a) curve information, such as curve location, radius, point of curvature (PC), and point of tangent (PT), b) superelevation and vertical slope, c) posted speed, and d) the presence of other curve treatments, such as signs and chevrons, on 31 miles of State Route 2, were collected. The change in the site characteristics before and after HSFT-SC was analyzed using the developed procedure. A case study using the sensing data collected on State Route 2 has demonstrated the capability of the proposed procedure to collect, process, visualize, and analyze detailed, location- referenced HFST-SC data and to document the data changes, which will support subsequent analyses and safety studies. The preliminary study, using the detailed level location-referenced HFST-SC on State Route 2, was conducted, and results show that vertical grades (greater than 4%) play an important role on the ROC near a curve when the BBI values are the same; thus, a sharp vertical grade could be used as an additional factor for HFST site selection. Additional study using a large data set is recommended to support the preliminary findings.</td></tr>
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Final Report

DEVELOPING GEORGIA'S HIGH FRICTION SURFACE TREATMENT (HFST) PROGRAM - HFST SITE CHARACTERISTICS (HFST-SC) DATA COLLECTION AND ANALYSIS

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EXECUTIVE SUMMARY

The Georgia Department of Transportation (GDOT) has invested millions of dollars in the high friction surface treatment (HFST) and will continue investing more in HFST to reduce potential run-off-road (ROR) crashes on sharp curves. To take full advantage of HFST, it is essential to use a systematic approach to select HFST sites, lay the foundation for subsequent studies of Georgia's HFST crash reduction factors and calculation of HSFT's return on investment, and identify additional factors for selecting sites that can benefit from HFST. Thus, GDOT has partnered with Georgia Tech to 1) develop an enhanced systematic HFST site selection (HFST-SS) method; 2) collect detailed, location-referenced HSFT site characteristics (HFST-SC) data using emerging sensing technologies (including 2D imaging, 3D LiDAR, global positioning system (GPS)/geographic information system (GIS) technologies) to support subsequent studies of Georgia's HFST crash reduction factors and calculation of HSFT's return on investment; and 3) conduct a preliminary study to identify the site characteristics, besides Ball Bank Indicator (BBI) values, that contribute to ROR crash. It is noted that HFST-SC data was collected by using emerging sensing technologies and leveraging research outcomes, including automatic curve identification and sign detection, from previous research projects (including DTOS59-10-H-00003, RP 12-10, and RP 15-05) sponsored by the US Department of Transportation (DOT), the FHWA Every Day Counts (EDC), and GDOT. The outcomes of this research project are summarized below:

- A comprehensive literature review of existing HFST site-selection practices of state and local transportation agencies was conducted to identify the HFST site-selection criteria. The most common data used to screen and prioritize sites for HFST is crash data, especially ROR crashes; site characteristic data is rarely used due to its lack of availability. The most common criteria are the crash frequency, the severity, and sometimes, the number of fatalities. Some agencies, like the Kentucky Transportation Cabinet (KYTC), heavily consider pavement conditions, such as wet pavements.

- An enhanced HFST-SS method was developed to enable GDOT engineers to systematically, proactively, and flexibly identify and select HFST sites. The developed method consists of three steps: 1) analyze crash data by pavement segments, 2) prioritize and select segments/corridors for HFST application using the proposed criteria, which balances crash frequency, severity ratio, and wet crash conditions, and 3) select curve sites for HFST application by evaluating the site characteristics of the curves using BBI values.
    - The developed method provides a systematic procedure that uses step-by-step procedures to process and analyze crash data, including crash frequency, severity, and wet pavements, to identify curve sites for HFST application. The developed method, also, proactively evaluates the site characteristics of the curves, using BBI values to indirectly evaluate the roadway characteristics, including curvature, superelevation, and friction.
    - A case study using historical crash data in GDOT's District 1 was conducted to demonstrate the capability of the developed HFST-SS method. Results show the proposed prioritization criteria, in comparison to the count-based selection criteria, is able to determine the highest number of fatalities and serious injuries for the selected HFST segments. Transportation agencies can

adjust the weights they apply to the prioritization criteria (crash frequency, severity ratio, and wet crashes) based on their specific focus, such as reducing the number of crashes or reducing the number of fatalities/injuries.

- A procedure, including a relational database and an HFST report card (HFST-RC), was developed for collecting, processing, storing, integrating, reporting, and analyzing the detailed, location-referenced HFST-Site Characteristics (HFST-SC) data. The before and after data were collected on March 26th, 2016 and October 12th, 2017 using emerging sensing technologies, including 2D imaging, lasers, 3D LiDAR, inertial measurement units (IMU), and GPS/GIS technologies, to support the studies of Georgia-specific HFST crash reduction factors and calculation of return on investment.
    - A relational database was designed to store and integrate the detailed, location-referenced HFST-SC data, which are categorized into the following: 1) geometry property, including curve location, curve radius, superelevation, vertical grade, etc., 2) countermeasure property, including the presence (i.e., location or x-y coordinate) of various countermeasures, such as advanced curve warning signs, advisory speed signs, chevrons, etc., 3) roadway property, including posted speed, lane width, BBI values, and pavement friction (if available), and 4) traffic condition, including traffic and truck volume. In addition, an HFST-RC was developed to provide a means of integrating and reporting/visualizing all location-referenced information on each HFST curve site, so these site characteristics can be visualized and used to support studies of Georgia-specific HFST crash reduction factors and

calculation of HSFT's return on investment (ROI). Finally, the changes of the HFST-SC before and after HFST installation can be identified to objectively evaluate the effectiveness of different curve treatments.

  - A case study on State Route 2 using data collected by the Georgia Tech Sensing Van (GTSV) was conducted to demonstrate the capability of using the collected sensing data and the developed HFST-RC to obtain the detailed-level and location-referenced HFST-SC data and to effectively integrate and visualize this data for subsequent analyses. The GTSV was used to collect the sensor data on the approximately 31 miles of roadway on State Route 2 in Rabun and Towns Counties. Its curves have radii ranging between 183 ft. and 3235 ft., deflection angles between 3.0° and 63.0°, superelevations between 2.0% and 14.0%, and grades between -8.8% and 11.0%.

- A method was proposed to identify site characteristics that can be used in GDOT's HFST-SS process by leveraging the detailed, location-referenced site characteristic data collected using sensor data. A case study using data on State Route 2 was conducted to demonstrate the proposed method. Results show that a vertical grade greater than 4% plays an important role in ROR crashes on sharp curves when their site characteristics are comparable. Therefore, a vertical grade greater than 4% could be considered as an additional HFST site-selection decision criterion along with the current criterion (a BBI value equal to or greater than 12), especially in the presence of a sharp curve whose radius is less than 800 ft. Certainly, additional study with a large data set is recommended to support the preliminary findings.

The implementation of research outcomes are presented as follows:

- Training on the enhanced HFST-SS method is recommended at the district level to implement a systematic, proactive, and cost-effective HFST site-selection method.
- It is recommended that GDOT develop a statewide curve inventory (including curve location, curve radius, point of curve (PC), and point of tangent (PT)) so that the crashes can be clustered inside the curves rather than segments for more adequately selecting curves for HFST.
- To better support subsequent studies of Georgia-specific HFST crash reduction factors and calculation of HSFT's ROI, it is recommended that an HFST-SC inventory (such as curve radius, superelevation, vertical grade, posted speed, etc.) before and after HFST installation on new and incoming HFST curve sites be established using the developed procedure and the GTSV.
- It is recommended that the optimal segment size and segmentation method be studied to further improve the HFST-SS method. It is also recommended that the optimal values for the parameters (i.e., β in the prioritization strategy and various severity weights) in the segment prioritization and selection step be further studied.

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1. INTRODUCTION

1.1 Research Background and Need

In the United States (US), only 5% of highway miles contain horizontal curves; however, according to the Federal Highway Administration (FHWA, 2010), more than 25% of fatal crashes occur on horizontal curves, and over 80% of them are run-off-road (ROR) crashes. Excessive braking by vehicles on curves causes the pavement to be polished and leads to low pavement friction. When the friction is insufficient to balance the lateral force of a vehicle negotiating a curve, it causes the vehicle to slide and run off the road (Lord et al., 2011). The high friction surface treatment (HFST), part of the Every Day Counts (EDC) program by FHWA, is a particularly effective countermeasure that can effectively restore pavement friction to improve the safety of horizontal curves (McGee et al., 2006). HFST is usually composed of a layer of thin aggregates (i.e., basalt, calcine bauxite, emery, granite, steel slag, or taconite) on top of a special binder (i.e., epoxy-resin, rosin ester, polyurethane-resin, or acrylic-resin) laid either cold with a thermosetting resin or hot with thermoplastic resin (FHWA, 2014). HFST aggregates resist polish and abrasion and reduce hydroplaning on wet pavement surfaces (Roa, 2008; Brimley and Carlson, 2012). Studies have demonstrated that HFST is effective in reducing crashes at horizontal curve sites and highway ramps (FHWA, 2013).

The Georgia Department of Transportation (GDOT) has invested millions of dollars in HFST and will be investing more to reduce potential run-off-road (ROR) crashes on sharp curves. To take full advantage of HFST, it is essential to use a systematic approach to select HFST sites, lay the foundation for subsequent studies of Georgia's HFST crash reduction factors and calculation of HSFT's return on investment (ROI), and identify additional factors for selecting sites that can benefit from HFST. This detailed, location-referenced HFST-SC information/data will enable GDOT to understand the factors that relate to and contribute to ROR crashes, quantitatively study the effectiveness of HFST, and determine the effectiveness of different curve treatments, including HFST, signs, and others. Such HFST-SC data include but are not limited to curve location, radius, PC, and PT, superelevation, vertical grade, and the presence of other curve treatments, including signs, chevrons, etc. It is noted that the collection of HFST-SC data leverages research outcomes, including automatic curve identification and sign detection, from previous research projects (including DTOS59-10-H-00003, RP 12-10, and RP 15-05) sponsored by the US Department of Transportation (DOT), the FHWA Every Day Counts (EDC), and GDOT.

1.2 Research Objectives and Scope

The objectives of this project are: 1) to develop an enhanced HFST site selection (HFST-SS) method that will maximize the return on investment, 2) to collect detailed and location-referenced HSFT site characteristics data using emerging sensing technologies, including 2D imaging, 3D LiDAR, IMU, and GPS/GIS technologies, with artificial intelligence and machine learning, to support subsequent studies of Georgia's HFST crash reduction factors and calculation of HSFT's return on investment , and 3) to conduct a preliminary study to identify the detailed site characteristics data, besides Ball Bank Indicator (BBI) values, that impact the ROR crash rate.

1.3 Organization of This Report

With the objectives defined above, this project has accomplished the following results that have been organized into different chapters.

1) Chapter 1 introduces the background, objectives, and organization of this research project and final report.

2) Chapter 2 presents a comprehensive literature review of existing HFST site-selection practices of state and local transportation agencies to identify the criteria used for selecting HFST sites.

3) Chapter 3 presents the enhanced systematic HFST-SS method, which consists of three steps: 1) analyzing crash data and assign to segments, 2) prioritizing and selecting segments/corridors for HFST using the proposed criteria for considering and balancing crash frequency, severity ratio, and wet crash conditions, and 3) selecting curve sites for HFST application on selected pavement segments by evaluating the site characteristics of the curves, including use of a BBI value. A case study using the historical crash data in GDOT's District 1 was conducted to demonstrate the capability of the developed site-selection method and prioritization criteria.

4) Chapter 4 presents a procedure that includes a geo-database and an HFST report card (HFST-RC) for collecting, processing, integrating, visualize, and analyze the before and after HFST-site characteristics (HFST-SS);. The detailed level, location-referenced HFST-SC data on 31 miles of State Route 2 was collected, and the change of the site characteristics (i.e., before and after HSFT-SC) was analyzed using the developed procedure. The case study, using the sensing data

collected on State Route 2, demonstrated the capability of the proposed procedure to collect, process, visualize, and analyze the detailed, location-referenced HFST-SC and their changes, all in support of subsequent analyses and support of subsequent safety studies.

5) Chapter 5 presents a method to identify site characteristics that can be used in GDOT's HFST-SS process by leveraging sensor data and automatic roadway feature extraction. A case study using detailed, location-referenced data extracted from State Route 2 is presented to demonstrate the proposed method. Results and recommendations are also discussed.

6) Chapter 6 summarizes the conclusions and also provides recommendations for future research.

2. LITERATURE REVIEW

The high-friction surface treatment (HFST) has proven to be an effective means to improve pavement friction on curved roadways where insufficient friction causes crashes; it is a relatively new countermeasure on curves compared to other countermeasures, such as curve warning signs, rumble strips, etc. Although many transportation agencies have started to incorporate HFST as an effective countermeasure and have begun implementing it into their safety improvement practices, currently, there are no nationwide criteria for selecting HFST sites. Transportation agencies continue to develop and refine their site selection methods. This chapter presents a comprehensive review of the available HFST site selection method by state and local transportation agencies to identify the site selection criteria. Individual HFST-SS methods were briefly described and summarized in this chapter. The detailed steps for individual HSFT-SS method are described in Appendix A.

2.1. HFST Site Selection Methods by Transportation Agencies

There are very few studies that have focused on HFST site-selection methods, especially for statewide application of HFST. Therefore, guidelines are not readily available to instruct state and local transportation agencies on how to identify sites that can benefit from HFST the most to maximize the return on investment (ROI). Different HFST site-selection methods by state and local transportation agencies are summarized in Table 2-1. They include the Kentucky Transportation Cabinet (KYTC) (Quintus and Mergenmeier, 2015); the Texas Department of Transportation (TxDOT) (Pratt et al., 2014); Nevada

County and Placer County California (Holloway et al., 2013); Thurston County, Washington (Davis, 2014); the Department of Transport, United Kingdom (2006); and the Georgia Department of Transportation (GDOT). The HFST-SS method is briefly described in the following. The detailed steps for individual transportation agencies are described in Appendix A.

Table 2-1 Summary of the HFST-SS methods

Agency	**Data**	**Target Crashes**	**Criteria**	**Segment Length**
KYTC (30 Worst)	Crash data	ROR	Wet-to-dry >0.5	curve location
KYTC (2010 RWDIP)	Crash data	ROR	Wet crash > 8 Wet-to-dry > 0.35	3000-ft.
KYTC (After 2010)	Crash data	ROR	Crash reduction	0.3-mile
TxDOT	Road geometry Friction	ROR	Margin of Safety	Curve location
GDOT	Crash BBI	ROR	Severity index and BBI	5 mile
Nevada and Placer Counties, CA	Crash data	N/A	Wet and icy	No clustering
Thurston County, WA	Crash data	Skidding related crashes		0.2-mile segment
Department of Transport, UK	Road Category Traffic	N/A		Critical locations

- Kentucky Transportation Cabinet (KYTC)

  The Kentucky Transportation Cabinet (KYTC) has developed its own process for identifying potential HFST sites using crash data since 2009. KYTC initially used 3-year roadway departure crash data on curves, and sites with a wet-to-dry crash ratio greater than 50 percent (0.5) were identified as priority sites for HFST. In the

Roadway Departure Safety Implementation Plan (RwDIP), the criteria for identifying priority sites for HFST were a minimum of 8 wet-pavement crashes and a wet-to-total crash ratio greater than 0.35. According to KYTC (Quintus and Mergenmeier, 2015), "8 was selected due to data showing high return on investment," and its analysis shows the wet-to-total crash ratio of 0.35, which represented the targeted number of sections that can achieve crash reduction for the selected benefit/cost within the available funds dedicated to this countermeasure over a span of 5 years. KYTC is currently moving towards using the effectiveness (or benefit) of countermeasure to identify candidate sites for HFST. The effectiveness is approximated by estimated crash reduction, which is computed as the differences between the predicted number of crashes of a site in the same period of time under one of two conditions: with or without HFST.

- Texas Department of Transportation (TxDOT)

  TxDOT, in collaboration with the Texas A&M University and the Texas Transportation Institute (TTI), has recently developed a Texas Curve Margin of Safety (TCMS) tool to assess countermeasures, including HFST. Instead of crash data, the TCMS uses the "margin of safety" to determine the severity category, which is then used to suggest potential countermeasures (Pratt et al., 2014). The margin of safety is defined as the difference between the friction demand and the friction supply, in which it measures the friction insufficiency on the pavement. TCMS computes the friction demand at the point of curvature (PC), midpoint (MC), and point of tangent (PT) based on radius on the curve, vertical grade, superelevation, and the 85th percentile vehicle speed at these locations. It is noted that this tool relies heavily on the detailed, comprehensive roadway geometry data, and friction data. The margin of safety is combined with other guidelines for selecting the countermeasures. Bonneson et al. (2007) categorized the margin of safety into five severity categories, and suggested safety countermeasures based on advisory speed and severity category.

- Georgia Department of Transportation (GDOT)

  GDOT has developed a two-step procedure using crash data and BBI values to proactively identify curve sites that can benefit from HFST installation. The two steps, corridor selection and BBI-based site selection, were designed to incorporate GDOT's unique considerations for HFST application. GDOT considers the application of HFST on the sites along a corridor can reduce the mobilization cost and result in a lower unit cost for HFST application. Thus, the first step is to select candidate corridors. Second, GDOT uses BBI values to identify sites that may be prone to ROR crashes because of their site characteristics, regardless of the crash history. In corridor selection, the corridor is divided into fixed-length segments. A severity index defined in GDOT's Top 150 Sections (GDOT, 1980; Tsai, et al., 2011) is computed for each segment. The severity index represents the average damage (in terms of fatality and serious injury with different weights) resulting from the total number of crashes. The corridors that contain segments with a high severity index are then selected for further analysis. In BBI-based site selection, ball bank indicator (BBI) values that represent the combination of superelevation, unbalanced lateral acceleration (i.e., side friction), and vehicle body roll (Carlson et al., 2005; Carlson and Mason, 1999) and are used as a composite safety indicator for identifying HFST sites. The maximum BBI value is collected at the posted advisory speed on every curve along the selected corridor. The curves with a BBI value greater than or equal to 12 are then identified for HFST installation.

- Nevada County and Placer County, California

  Local agencies, such as Placer County and Nevada County in California, have also developed their own HFST-SS methods based on crash data analysis. They focus on curves with high ROR crashes on rural, two-lane, undivided roadways. The severity of the crashes is also taken into the consideration. The locations, where crashes occur repeatedly, regardless of the applications of different countermeasures, e.g., signing, striping, etc., were identified as candidate sites for HFST. A score that considers pavement condition, roadside hazards, type of crashes, posted speed, roadway characteristics, weather conditions, and primary collision factors is calculated for each site. The site with a score less than 20 is not recommended for HFST. Finally, the benefit-cost ratio is calculated to provide a quantitative measure for prioritizing HFST candidate sites while optimizing the return on investment.

- Thurston County, Washington

  Thurston County, Washington, has used its HFST-SS method since 2013 (Davis, 2014). It identified horizontal curve-related crashes using wet/icy surface conditions and skidding/out of control driver actions. For each 0.2-mile section, if there are more than three crashes in the section, the site will be recorded as a candidate site for potential HFST. A risk score is computed for each candidate site to rank/prioritize the sites. The risk score is a simple scoring system used to rank the candidate sites and is calculated from the risk factors. The risk factors include speed limit, roadway classification, the presence of intersections, roadway geometry, traffic volume, traffic control type, shoulder type, shoulder width, etc. (Davis, 2014). Finally, the candidate site with the highest score will be selected as the site for HFST.

- Department of Transport, United Kingdom

  The Department of Transport in the United Kingdom (UK) has been applying HFST (or, Anti-Skid Road Surfacing Treatment) since the 1980s. The Department of Transport considers the use of HFST based on site category, investigatory level (IL), and traffic to enhance safety and reduce accidents at sites (RSTA, 2011). Note that, in addition to curves (with a radius tighter than 500m on single carriageways), the following site categories are also considered for HFST application: 1) approaches to major junctions, 2) approaches to pedestrian crossings at which pedestrians or other vulnerable road users may misjudge the speed of the traffic, such as near schools or where children cross, near public houses, or where the approach speed is high, and 3) sites with gradients steeper than 10% if other hazards are present.

2.2. Summary

Although transportation agencies have developed HFST-SS methods using various criteria, systematic and comprehensive procedures to proactively identify and prioritize HFST curve sites for application of HFST is still lacking. The following points summarize the transportation agencies’ HFST curve site selection criteria and methods:

- Many transportation agencies, including KYTC, Nevada County and Placer County in California, and Thurston County in Washington, primarily rely on crash data to identify locations prone to certain types of crashes that can benefit from HFST application (Quintus and Mergenmeier, 2015; Holloway et al., 2013; Davis, 2014).

- The most common method to select (or screen) sites for HFST is using ROR crash frequency (Quintus and Mergenmeier, 2015; Holloway et al., 2013; Davis, 2014). Some transportation agencies, such as GDOT, prioritize by the severity of crashes by giving a higher weight to fatal crashes; others, like KYTC, heavily consider pavement conditions during a crash, such as wet pavement crashes (Quintus and Mergenmeier, 2015). Some transportation agencies, such as Nevada and Placer Counties in California, make final decisions to treat the site based on benefit/cost maximization (Holloway et al., 2013). In recent years, agencies like KYTC have used safety performance functions (SPF) to quantify the anticipated crash reduction rate before and after the HFST is applied to identify the sites to treat.
- Most transportation agencies, including KYTC, TxDOT, Nevada County and Placer County in California, and Thurston County in Washington, recommend conducting field surveys to evaluate the roadway characteristics (such as curvature, superelevation, and others) on the candidate sites in the field during the planning stage of HFST site selection (Quintus and Mergenmeier, 2015; Pratt et al., 2014; Holloway et al., 2013; Davis, 2014). However, only a limited number of transportation agencies, like GDOT, actually quantitatively assess the roadway characteristics in the curve section (e.g., using ball bank indicator (BBI) values), to make final HFST curve site selections. Most transportation agencies conduct a field survey in the HFST construction stage to determine the point of curve (PC) and point of tangent (PT) for HFST installation (Holloway et al., 2013; Davis, 2014).

- Few agencies use roadway characteristics to identify the need for HFST. In the United Kingdom, HFST is applied in critical locations, such as approaches to pedestrian crossings with high traffic and on steep roads (DMRB, 2006). GDOT has taken the proactive approach of using roadway characteristics measured by using a BBI to decide the final curve sites for HFST. A curve site will be treated proactively with HFST if it meets the BBI requirement, even when, currently, there are no ROR crashes or a limited number of ROR crashes on the curve.
- While high crash frequency and SPF-based prioritization approaches have been used by several agencies, the outcome of HFST site selection from these approaches may be biased by the quality of the crash report. These approaches may often miss promising sites for treatment where potential crashes may occur because they have an under-reported number of crashes. However, GDOT's proactive approach attempts to link the site characteristics to the likelihood of a crash occurrence at that site. Therefore, it is a more objective and, potentially, a more effective approach for selecting HFST sites. Moreover, several HFST site-selection criteria exist, such as crash frequency, crash severity, crash environment (like wet pavement), etc.; however, there is no method that combines all these with the roadway characteristics in the field (including curvature, super-elevation, etc.), such as using BBI values. GDOT and Georgia Tech have partnered to develop an enhanced HFST site-selection method and program.

3. ENHANCED HFST SITE SELECTION METHOD

In this project, the research team worked with the Office of Traffic Operations (OTO) to develop an enhanced HFST site-selection (HFST-SS) method that systematically and proactively selects HFST sites to improve safety at horizontal curves. This chapter presents the enhanced HFST-SS method, which consists of three steps: 1) analyze crash data and assign to segments, 2) prioritize and select segments/corridors for HFST using the proposed criteria of considering and balancing crash frequency, severity ratio, and wet crash conditions, and 3) select curve sites for HFST application on selected corridors by evaluating the site characteristics of curves using a ball bank indicator (BBI) value. A case study using 3 years of crash data in GDOT's District 1 was conducted to demonstrate the capability of the criteria used in a proposed method in comparison to other criteria, such as prioritization by crash count, to select the same number of segments. The proposed method selects those segments having the highest number of fatalities and serious injuries. Conclusions and the recommendations are, also, discussed.

3.1 Enhanced HFST Site Selection (HFST-SS) Method

This section presents an enhanced HFST-SS method that consists of the three steps shown in Figure 3-1. First, analyze target crash data and assign to segments; second, prioritize and select segments/corridors for HFST using the proposed criteria of balancing crash frequency, severity ratio, and wet crash condition; and third, select curve sites for HFST application on the selected corridors by evaluating the BBI value on the curves to consider site characteristics. An important feature of this procedure is that all the curve sites in the selected corridors that fail to meet the BBI requirement will be treated, regardless of the crash frequency. It optimizes resources by proactively treating all the curves failing the BBI requirement in the corridors and minimizes the mobilization cost.

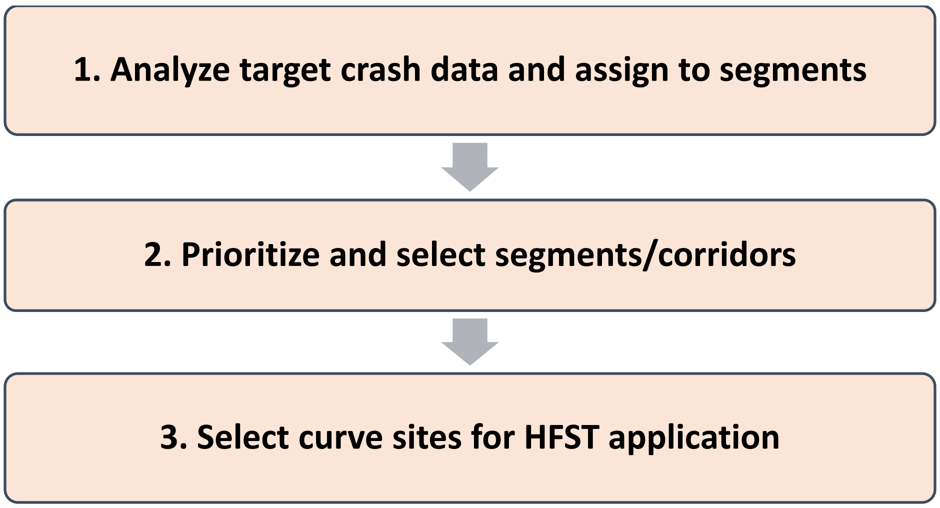


Figure 3-1 Steps of the enhanced HFST site selection method

Step 1: Analyze target crash data by segments

This step involves analyzing GDOT's crash data to identify target crash types and assigning them to road segments on the state route system. Prior to segmentation and analysis of the crash data, target crashes are identified from the crash database. Among run-off-road (ROR) crashes, single-vehicle ROR crashes are estimated to be over 76 percent of the curve-related fatal crashes in which the vehicle leaves the roadway and collides with a fixed object or gets overturned (Torbic et al., 2004). After the review of crash data and discussion with OTO, single-vehicle ROR crashes and on-road-lane-departure crashes were identified as the target crashes. Single-vehicle ROR crashes are defined as those crashes that involve a single vehicle; the location of the crashed vehicle is off the road; the crash involves either an overturned vehicle or a collision with guardrails, tree, pole, ditches, embankments, or other fixed and non-fixed objects;

potentially contributing factors include speeding or the driver's loss of control. On the other hand, lane departure crashes are defined as those crashes that involve any of the following: (1) one or more vehicles; (2) the crashed vehicles are on the road, on the shoulder, or in the opposite lane; (3) the vehicles are involved in on-road collisions, such as head-on, angular, or side-swiped collisions; (4) there are other non-collision situations, such as overturned vehicles; and (5) potentially contributing factors are speeding or the driver's loss of control. In this step, the corridors are segmented and the identified target crashes within each segment are analyzed. A corridor is defined as the roads with the same route number and route suffix, regardless of county. It is noted that this definition is different from the use of RCLINK, which considers the county (in addition to the route number and route suffix). This is to avoid the corridors stopping abruptly at county boundaries, which could cause the segmentation to miss crash clusters around the county boundaries. Segments are generated using a fixed window size (e.g., 5 miles). For example, Mile Post 0 to 5 on the corridor will be treated as one segment, Mile Posts 5 to 10 as next segment, and so on. This process is continued until the end of the corridor. The target crashes in each segment are summarized by injury type and separated into wet and dry pavement crashes.

Step 2: Prioritize and Select Segments/Corridors for HFST

This step prioritizes and selects segments by using the proposed new segment prioritization criterion that balances the crash frequency, severity ratio, and wet crash condition. The proposed prioritization criterion maximizes the number of fatal and serious injury crashes captured on the prioritized/selected segments. In addition, it is flexible and allows transportation agencies, based on their needs, to adjust their weights among crash frequency, severity ratio, and wet-related crashes. The development of the new prioritization criterion is discussed in the following; different prioritization criteria were developed and compared.

- Severe crashes have to be considered in the prioritization criterion because the social cost of severe/fatal crashes is over 100 times the non-injury crashes (Blincoe, et al., 2015). This means preventing a fatal crash is 100 times more beneficial than preventing one non-injury crash. A severity ratio is often used by transportation agencies to consider the crash severity. It is defined as the weighted ratio of fatal and injury crashes over a total number of crashes in the respective segment. The general form of segment severity is described as follows:

  Severity ratio, $$s = \frac{\sum_n w_i . x_i}{n} \qquad (3\text{-}1)$$

  where xi is the injury type (i.e. fatal, serious injury, visible injury, and compliant injury), wi is the corresponding weight, and n is the total number of crashes recorded in the segment. The weights represent the equivalent social cost of several injury levels in terms of the fatality/injury.

  However, using a severity ratio to prioritize segments cannot be the sole criteria. For example, when two locations, have the same severity ratio, one with 10 crashes (1 fatal crash) and the other with 100 crashes (10 fatal crashes), the severity ratios in both cases are both calculated as 0.1. In such a case, there should be a priority between the severity ratio and the number of crashes. This problem becomes significant if an agency evaluates thousands of segments using an algorithm based solely on severity.

- To overcome the problem, a linear function combining the count and the severity ratio is proposed. The combined prioritization criteria (CPC) is the combined prioritization criteria and is defined below:

$$\textit{Combined prioritization criteria (CPC)} = \textit{count} \times \textit{severity ratio} \qquad (3\text{-}2)$$

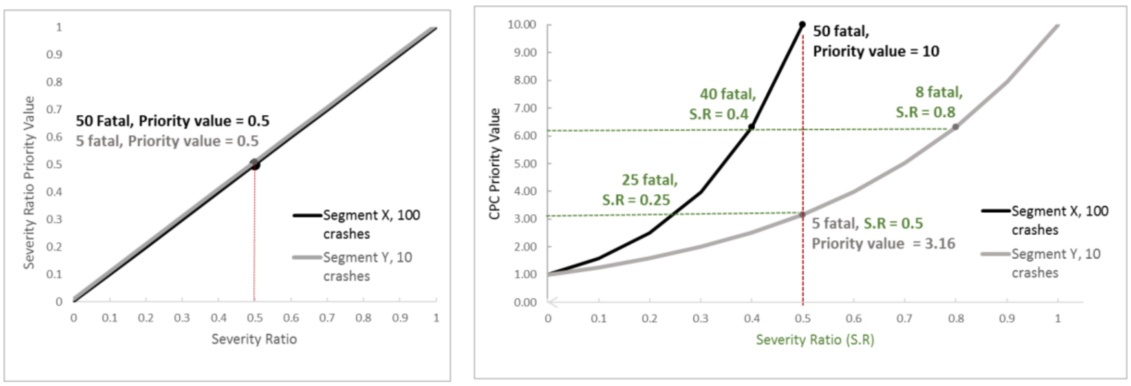
Unfortunately, segments with the same number of severe crashes cannot be differentiated. For example, consider two segments, one with 100 crashes of which 10 are fatal, and another with 10 crashes all of which are fatal. In this case, using this linear function will have a CPC = 10 for both cases, and there is no clear distinction.

- To overcome the limitation, the authors propose a CPC using an exponential function:

$$\text{CPC} = Count^{Severity\ ratio} \qquad (3\text{-}3)$$

where the severity ratio is non-zero. When the severity ratio is zero, it is assigned a very small value close to zero so that no two zero-severity segments have the same CPC.

To illustrate this function, consider two identical roadway segments, X and Y, at different locations. Segment X contains 100 crashes, and 50 of them are fatal. Segment Y contains 10 crashes, and five of them are fatal. Segments X and Y are prioritized using two prioritization strategies, as shown in Figure 3-2, one using the severity ratio (Figure 3-2 (a)) and the second using the combined prioritization criterion (Figure 3-2 (b)). If the severity ratio is used as the prioritization strategy, both segments will have the same priority ratio value (50/100 = 0.5; 5/10 = 0.5), and they cannot be distinguished, as represented in Figure 3-2 (a)). Moreover, if segment X contains one fatality less (priority value 0.49), segment Y will be prioritized over it, which is not reasonable. However, if the CPC is used, segment X (priority value 10) is prioritized over Segment Y (priority value 3.16), as shown in Figure 3-2 (b), for the same severity ratio. The difference between the CPC values of the two segments along the same severity ratio (shown by red line) is large enough to accommodate slightly fewer crashes in Segment X and will still be prioritized over segment Y, unlike prioritization only by the severity ratio.



(a) (b)

Figure 3-2 Comparison between (a) prioritization using severity ratio only and (b) prioritization using the combined prioritization criterion

- Besides using the above concept that involves severity ratio and total crash frequency, the authors have also considered the importance of wet pavement crashes. Research conducted by the National Transportation Safety Board and FHWA indicates that about 70% of wet pavement crashes can be prevented or minimized by improving pavement friction (FHWA, 2017). The underlying dilemma is that HFST is useful in segments containing a higher number of wet pavement crashes, and these segments have to be prioritized for treatment. By considering all these components, the crash frequency, severity ratio, and wet/dry conditions, the authors propose the following prioritization criterion combining them to prioritize the segments:

$$CPC = \alpha \, . nd^{Sd} + \beta \, . nw^{sw} \tag{3-4}$$

$$Sd = \frac{\sum_d w_i \, .x_i}{nd} \quad (3\text{-}5)$$

$$Sw = \frac{\sum_w w_i \, .x_i}{nw} \quad (3\text{-}6)$$

where

CPC - combined prioritization criteria,

α - modification factor for dry crashes, which is equal to 1 for the proposed method,

β - modification factor for wet crashes, in which it assigns a weight to the wet pavement crashes,

nd, nw- total numbers of dry and wet pavement crashes respectively,

Sd - severity ratio calculated only for dry pavement crashes,

Sw - severity ratio calculated only wet pavement crashes,

xi - injury type (i.e. fatal, serious injury, visible injury, and compliant injury), and

wi - corresponding weight for each injury type.

The main advantage of this method is that if a small number of segments need to be selected as candidates (because of, for example, funding being limited), prioritization using this function will capture segments that have relatively high crash counts and considerable severity, thereby selecting segments that will provide a higher benefit if given treatment. Thus, this criterion is particularly useful for justifying the benefit (reduction of social cost) of using HFST at particular segments. Second, this criterion is flexible enough to accommodate count-based prioritization without changing the form to meet different transportation agencies' needs and practices. Assigning 1 to α, β, and wi will transform the CPC into nw+ nd and can be used to prioritize segments based purely on the crash frequency. In addition to this transformation, assigning α = 0 allows the CPC to prioritize only wet pavement crashes. This is particularly helpful for agencies to analyze different options for prioritization based on their objectives. The segments are finally prioritized and selected in this step by using the proposed prioritization criteria. Note that the entire corridor will be selected if any of the segments in the corridor is selected.

<u>Step 3: Curve Site Selection</u>

In this step, field staff record the BBI values for each curve on the selected corridor. A BBI value is a combined impact of radius of curvature, superelevation, driving speed, and pavement friction. It is used to determine the advisory speed on the curves. Given the advisory speed, this procedure uses this principle to evaluate the available friction and the combined impact of curvature, superelevation, driving speed, and pavement friction. Based on the GDOT's practices, curves having a maximum BBI value greater than 12 measured at the advisory speed indicate that there is insufficient friction on them, so they need to be treated. Finally, to decide if HSFT is to be applied, the site characteristics are evaluated, along with the maximum BBI value, to select Yes/No for the segments selected in Step 2.

3.2 Case Study

This section demonstrates the capability of the proposed HFST-SS method to select curve sites for HFST. The proposed method can select segments that contain the maximum number of fatal and serious injury crashes using the proposed prioritization criteria. This case study uses three years of actual crash data from GDOT's District 1, which comprises 21 counties in the northeast of Georgia; the region is predominantly mountainous.

In this case study, three commonly used prioritization criteria are compared to the proposed prioritization criteria by prioritizing the Top 10 segments. The three prioritization criteria are as follows: prioritization by severity ratio (GDOT current method), prioritization by total crash count (Placer and Nevada Counties, California, and Thurston County, Washington), and prioritization by wet crash count (KYTC).

Prioritization by severity ratio

While most state agencies use either crash count or wet crashes to screen and prioritize segments in their network, GDOT considers only the severity ratio in its current method. The severity ratio of a segment is defined as the weighted ratio of fatal and injury ROR crashes over a total number of ROR crashes in the respective segment, as shown in Equation (3-1). The weights represent the equivalent social cost of several injury levels in terms of the fatality/injury. Table 3-1 shows the weights recommended by different references.

Table 3-1 Comparison of Severity Weights from Different References

Crash Type	**GDOT**	**Value of life** (Torbic et al., 2004)	**MnDOT** (MnDOT, 2016)	**HSM*** (AASHTO, 2010)
Fatal	1.0	1.00	1.000	1.000
Serious injury	0.6	0.20	0.500	0.020
Visible injury	0.4	0.05	0.150	0.020
Complaint injury	0.2	0.01	0.070	0.020
No Injury/Property damage only	0.0	0.00	0.007	0.002

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Different severity levels may be weighted differently based on the objectives of the transportation agency. For example, fatal crashes can be weighted very highly if the objective is to reduce curve-related fatal crashes using HFST. For a comparison of the severity ratio in this case study, GDOT's weights are used, and the segments are ranked according to their severity ratios.

Prioritization by total crash frequency

This type of prioritization, in which locations containing higher crash frequency are prioritized and selected for safety improvement, is the most widely used method in the United States (Torbic et al., 2004). In this case study, the segments are ranked in the order of highest to lowest number of ROR crash counts.

Prioritization by wet crash frequency

DOTs like KYTC prioritize segments based on the number of wet pavement ROR crashes, so the segment with the highest number of wet crashes is prioritized first.

3.2.1 Data

The data used in this analysis includes a) three years of crash data (2006-2008) for crashes that occurred on Georgia roadways; b) linear referenced state roads centerline shapefile data from GDOT; and c) a Georgia urban area shapefile developed by the Atlanta Regional Commission Research and Analytics Division. The police crash database contains the information of each crash location, crash date, driver, and passenger information (such as injury suffered), the number of vehicles involved, first harmful event, road condition, and maneuver code.

The first step in the proposed method is to identify the target crashes. For this case study, ROR crashes along the state routes in District 1 are identified and are plotted using ArcMap 10.3. The ROR crashes on interstates and on roadways within city limits are removed because the HFST's proactive approach is beneficial only on the non-interstate, non-urban roads managed by the state; curve-related roadway departure crashes are a minor concern on interstate highways. Under Step 1, the corridors are divided into 5-mile intervals based on current GDOT practices, using an ArcGIS add-in built by the authors, and the ROR crash details are summarized for each segment. The size of the interval can be modified more easily using the developed ArcGIS tool. Segments with zero crashes are removed, as the crash count forms the basis of the prioritization. Finally, 398 segments were generated for the prioritization. A section of the output from Step 1 is shown in Table 3-2.

Table 3-2 Examples of Segment ROR Crash Summary

Segment ID	Route No.	Total Crashes	Fatal Crashes	Serious Injury Crashes	Visible Injury Crashes	Compliant Injury Crashes	Crashes with No Injuries	Dry Pavement Crashes	Wet Pavement Crashes
1	0419	19	3	0	5	3	8	14	5
2	0052	15	1	2	7	0	5	7	8
3	0002	10	2	4	2	0	2	9	1
4	0052	9	2	1	3	1	2	5	4
5	0010	31	3	1	6	4	17	22	9
6	0136	15	2	1	6	2	4	11	4
7	0017	10	2	1	3	1	3	8	2
8	0330	24	2	3	6	1	12	17	7

3.2.2 Analysis parameters

In Step 2, after consulting with GDOT engineers, the Georgia Tech research team used weights similar to those applied by the Minnesota Department of Transportation (MnDOT, 2014) for the proposed prioritization criteria (1 for fatal crash; 0.6, 0.15 and 0.07 for serious, visible, and complaint injury crashes, respectively, and 0.007 for non-injury property damage only (PDO) crash). These weights give higher importance to fatal and serious injury crashes and sharply differentiate them from other severity levels. Identifying the appropriate β value is essential for achieving the objective of maximizing the number of severe wet pavement crashes using the proposed prioritization criteria (Equation 3). Therefore, a sensitivity analysis was performed for the given data to identify the optimal β value by plotting the fatal crash for various β values, as shown in Figure 3-3; β at 1.3 achieves the best combination of both dry and wet fatal crashes with 14 and 3 crashes, respectively, although the maximum number of fatal crashes possible is 18 (17 dry and 1 wet crash).

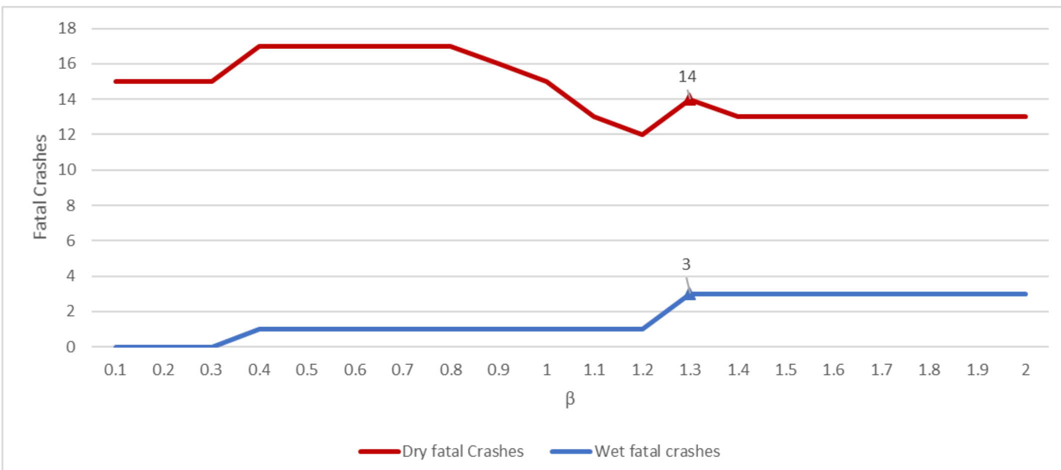


Figure 3-3 Dry and wet fatal crashes at different β values

Alternatively, Georgia's HFST crash modification factor (CMF) of dry and wet crashes on curves can be assigned to α and β once the values become available. This way, segments with the highest potential for crash reduction will be selected.

3.2.3 Results

Table 3-3 shows the number of crashes selected in the Top 10 segments for the three prioritization criteria discussed above and the proposed prioritization criteria. It would be cost-effective to treat the segments with more serious injuries and fatalities. It is clear that the number of serious injury and fatal crashes captured in the proposed criteria (total number = 38) is more than any other criteria. It is also seen that the proposed criteria perform better than GDOT's current prioritization criteria (i.e. severity ratio) in every category.

Table 3-3 Summary of crashes in the top 10 segments selected using different prioritization criteria

Prioritization Criteria	Number of crashes (Dry, Wet)				
	No Injury	Minor Injury	Serious Injury	Fatal	Serious Injury & Fatal
Severity ratio	9 (5, 4)	21 (18, 3)	14 (13, 1)	8 (7, 1)	22 (20,2)
Total crash requency	293 (156, 137)	183 (112, 71)	19 (14, 5)	9 (6, 3)	28 (20, 8)
Wet crash frequency	304 (138, 166)	158 (89, 69)	16 (12, 4)	5 (2, 3)	21 (14, 5)
Proposed criteria	52 (37, 21)	63 (46, 17)	21 (12, 9)	17 (14, 3)	38 (26, 12)

Table 3-3 shows that a very high number of crashes in the segments that are prioritized by count and are major non-injury or minor-injury crashes. It can be reasoned that such segments have a higher number of crashes, as they are located in urban areas that have high traffic volume and are more congested. ROR crashes in such situations may be attributed to drivers' evasive maneuvers to avoid vehicles in their lanes or while overtaking slow-moving vehicles. Such crashes may not lead to serious outcomes, such as fatalities, as noted in the NCHRP report (Preston et al., 2010), which states that severe outcome crashes are dispersed and occur mostly on non-urban roadways. Therefore, caution is advised when using count-only based prioritization to avoid considering high-crash/low- severity locations for application of HFST. Figure 3-4 compares the segments selected using the total count criteria and the proposed criteria. It is observed that many segments selected using the total count criteria occur in and around urban areas, while only one segment (top red) is completely in a rural region. On the other hand, five segments selected using the proposed criteria are in the rural region, and only one segment is selected by both sets of criteria. This specific segment, shown in green, is located in an urbanized area containing both a high number of crashes (45) and a high fatality/serious injury (3+3) count.

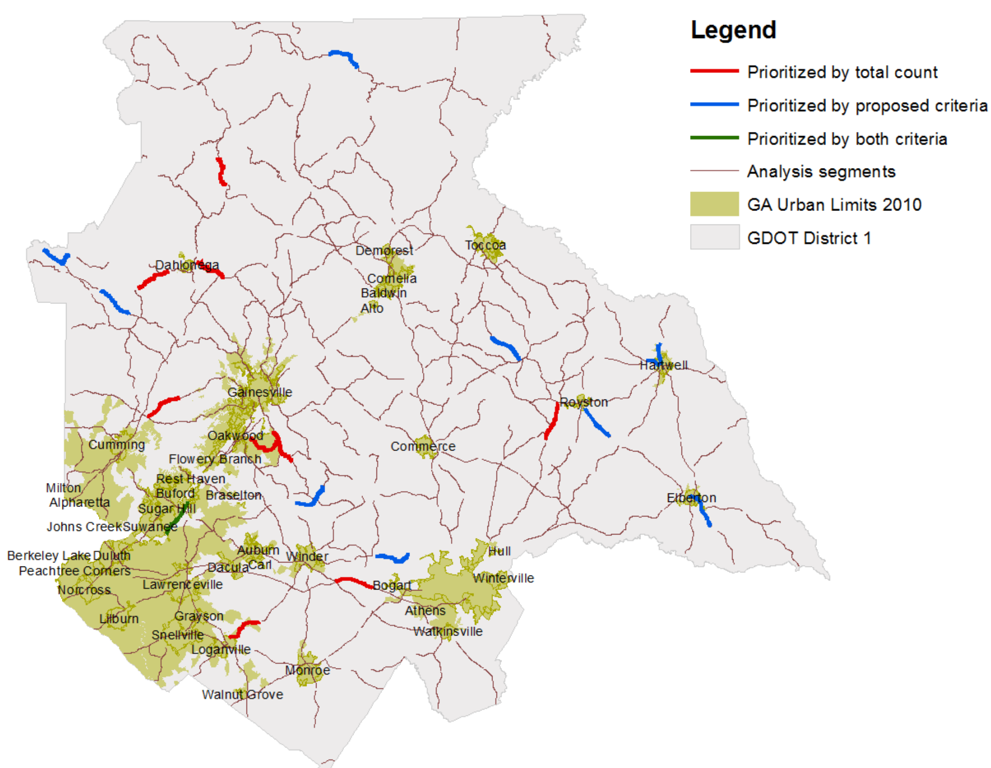


Figure 3-4 Spatial comparison of Top 10 roadway segments prioritized using the count based prioritization and the proposed prioritization criteria.

This case study has demonstrated that the proposed method, using its proposed prioritization criteria, is able to determine the highest number of fatalities and serious injuries on the selected roadway segments for HFST. In addition, the proposed prioritization criteria also provide the flexibility for transportation agencies to adjust the weights of crash frequency, severity ratio, and wet crashes to meet specific needs.

3.3 Summary

HFST is an effective countermeasure that reduces run-off-the-road (ROR) crashes related to low friction, especially on horizontal curves. Many transportation agencies have invested in HFST, so there is an urgent need for an enhanced HFST site-selection procedure to maximize the agencies' return on investment. GDOT has worked with Georgia Tech to actively develop a sharp curve improvement program by developing an enhanced and proactive HFST site-selection procedure. The contributions of this paper include the development of an enhanced, proactive HFST site-selection procedure for GDOT and includes the following benefits:

1. It is a systematic procedure to identify curve sites for HFST, as it provides step-wise directions from crash analysis to final curve site selection for HSFT.
2. It proactively evaluates the site characteristics of the curves, including curvature, superelevation, and friction, using a BBI value; also, it considers crashes and wet pavement conditions.
3. It has demonstrated that using the proposed prioritization criteria in the proposed method, in comparison to the count-based selection criteria, is able to obtain the highest number of fatalities and serious injury for the selected HFST segments.

4. The proposed prioritization criteria also provide flexibility for the transportation agencies to adjust the weights to crash frequency, severity ratio, and wet crashes based on their specific needs (e.g. focusing on the reduction of crash number or fatalities and injury).

It is recommended that a pilot study be performed using statewide data and the proposed HFST-SS method; then, the proposed HFST-SS method should be implemented. Although the proposed method can be implemented now, refinements are recommended. Currently, 5-mile segments are used and work adequately, but studying the optimal segment size and segmentation method is recommended. Studying the optimal values for the input parameters (i.e., β in the prioritization strategy and various severity weights) in the segments prioritization and selection step is also recommended.

A statewide curve inventory that includes the details of PC and PT so that the crashes can be clustered inside the curves rather than segments, which is more relevant to curve safety improvement, is recommended. Sensing technologies, such as mobile LIDAR and imaging, can be used to collect the detailed site characteristics data before and after HSFT installation, so the impact of HFST and other countermeasures, like signs, on crash reduction can be evaluated separately in future studies and can be used to support the study of accurate, location-based HFST Crash Reduction Factors.

4. COLLECTION AND PROCESSING OF HFST SITE CHARACTERISTICS (HFST-SC) DATA

In this project, detailed, location-referenced HSFT site characteristics (HFST-SC) data were collected by using emerging sensing technologies and leveraging the research outcomes from previous projects (e.g., RP 15-05, RP 13-15) sponsored by the US Department of Transportation (DOT), the FHWA Every Day Counts (EDC), and GDOT. This chapter presents a method, including a geo-database, and an HFST report card (HFST-RC), to collect, process, store, integrate, visualize, and analyze HFST-SC data before and after HFST installation. HFST-SC data on 31 miles of State Route 2 were collected, processed, spatially integrated and analyzed using the developed method to document changes in the HFST-SC data before and after HFST installation. The spatial and temporal changes of HFST-SC can be used to support subsequent safety analyses and studies.

4.1 HFST Site Characteristics (HFST-SC)

This section identifies the site characteristics to be collected on HFST sites. The horizontal curve is to provide a smooth transition for a change in direction between two tangent roadway sections, allowing a vehicle to negotiate the change at a gradual rate instead of a sharp rate. The design of the curves is based on the appropriate balancing of the designed speed, curve radius, superelevation, and pavement friction that will provide sufficient resistance against the centrifugal force to keep the vehicle on the curve at the designed speed. Based on the essential properties of curve design and communications with safety engineers in GDOT's Office of Traffic Operations (OTO), four categories of HFST-SC were identified as follows: 1) geometry properties, including curve location, curve radius, superelevation, vertical grade, etc.; 2) countermeasure properties, including the presence (i.e., location or x-y coordinate) of various countermeasures, such as advanced curve warning signs, advisory speed signs, chevrons, etc..; 3) roadway properties, including posted speeds, lane widths, BBI values, and pavement friction (if available); 4) traffic conditions, including traffic volume and truck percentage. Among various curve countermeasures, advanced curve warning signs, advisory speed signs, and chevrons were selected because they are the most common low-cost countermeasures and required by the Manual on Uniform Traffic Control Devices (MUTCD). Table 4-1 lists the selected HFST-SC.

Table 4-1 Key site characteristics considered in this study

Category	**Site Characteristic**	**Description**
Geometry	Curve location	Point of curve and point of tangent
	Curve radius	Curve radius in ft
	Curve length	Curve length in ft
	Degree of curvature	
	Superelevation	Measured in 15 ft. interval) and recorded, Max, Min
	Vertical grade	Measured at 15 ft. interval and recorded the maximum value
Countermeasure	Signs	Location and sign type
Roadway	Posted Speed	Speed on the nearest speed limit sign
	Pavement Friction	Friction number collected using DFT (if available)
	BBI	Maximum BBI on each curve
Traffic	Traffic volume	Average annual daily traffic (AADT)
	Truck percentage	

- Curve Location: Curve location is defined by the PC and PT of a horizontal curve. In addition to the coordinates, the PC and PT are also represented using a linear referencing system (RCLINK, Milepoint From/To, and direction).
- Curve Radius: The curve radius is defined as the radius of the circular shape that best fits a horizontal curve in ft.
- Curve Length: The curve length is defined as the arc length of a horizontal curve bounded by the PC and PT in ft.
- Degree of Curvature: The degree of curvature is defined as the central angle to the PC and the PT of a horizontal curve in degrees.
- Superelevation: The superelevation is defined as the amount by which the outer edge of a curve on a road is banked above the inner edge. The superelevation is measured by the tangent value of the lateral angle by percent.
- Vertical Grade: The vertical grade is defined as the amount by which a road inclines in the longitudinal direction. The vertical grade is measured by the tangent value of the longitudinal angle by percent.
- Traffic Sign: In this study, the traffic signs of interest include regulatory speed limit signs, advisory speed limit signs, and all related curve warning signs showing direction and warning features (e.g., chevrons) before and within curved sections.
- Posted Speed: The posted speed is defined as the speed (mph) on the speed limit sign closest to a curve.
- Ball Bank Indicator (BBI): The BBI value is a composite property of the curve geometry and pavement condition that is affected by the driving speed, roadway side friction, and superelevation. The maximum BBI value is recorded on each curve.

- Traffic Volume and Truck Percentage: In this study, traffic volume is represented using the average annual daily truck (AADT) load. Both AADT and truck percentage are obtained using GeoCount.

4.2 Data Collection

The Georgia Tech Sensing Vehicle (GTSV), equipped with high-resolution cameras, light detection and ranging (LiDAR) systems, a 3D pavement laser system, a global positing system (GPS), an inertial measurement unit (IMU), and a distance measuring instrument (DMI), was used to collect the sensing data used for extracting detail-level, location-referenced HFST-SC. The data was collected before and after HFST installation on March 26th, 2016 and October 12th, 2017, respectively. The GTSV, as shown in Figure 4-1, was sponsored by the US DOT and GDOT. It consists of the following: a) four high-resolution video cameras at 2448x2048 for generating a panoramic view of the roadway and a detailed, downward view of the pavement; b) two line-scanning LiDARs at 10kHz-15kHz with 3-cm ranging error for generating full 3D coverage of the roadway and roadside; c) a pair of high-frequency pavement profiling lasers at 5.6Hz with 0.5mm resolution of elevation measurement for generating a detailed 3D scan of the pavement; and 4) GPS, IMU, and DMI for synchronizing and location-referencing the data. The video cameras capture video log images at a 5m interval based on the DMI to avoid data redundancy while maintaining full coverage of the roadway. All the video cameras are synchronized with a high-accuracy GPS/IMU system at 100Hz and geometrically calibrated so that the features extracted from images can be geo-referenced with accurate position information. Using the collected sensing data, roadway data was acquired using

GPS in the GTSV, in the X, Y, Z format, while the actual locations (i.e., starting and ending points) of the HFST for each horizontal curve were extracted using the images taken by the high-resolution cameras. With high-frequency data acquisition capability, the GTSV can be operated at highway speed (up to 60 mph) and without interrupting the traffic. Figure 4-2 shows examples of the collected data, including video log images, a LiDAR point cloud, a GPS trajectory, and a 3D pavement scan.

Figure 4-1 The Georgia Tech’s Sensing Van (GTSV)

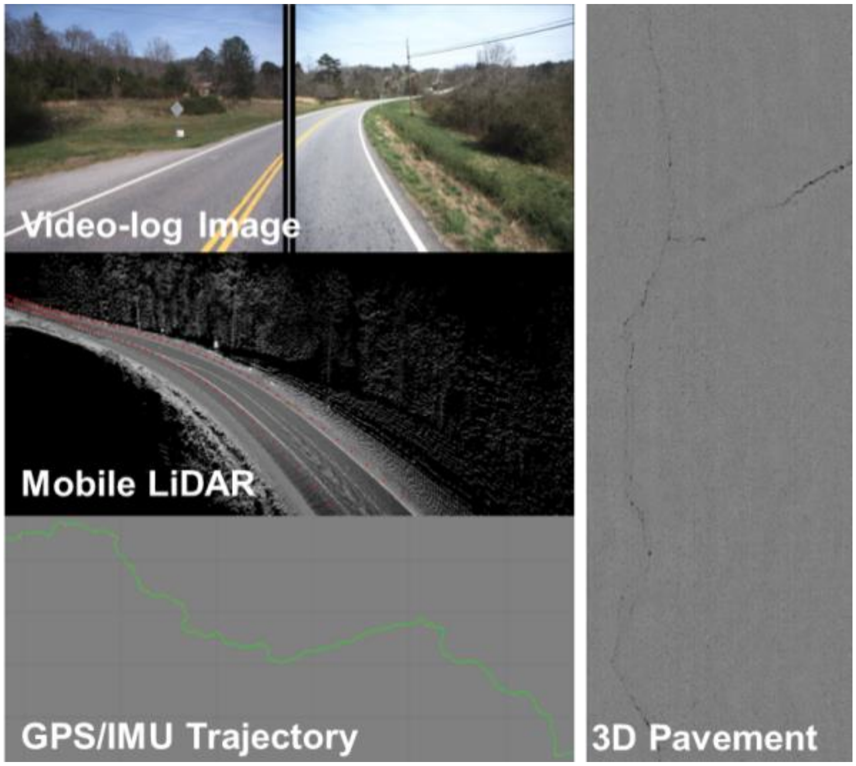


Figure 4-2 Data from the GTSV

In addition to sensing data from the GTSV, the BBI measurements surveyed by GDOT's field engineers and the crash data between 2006 and 2008 were also collected by the research team. The BBI measurements were also collected by the research team using a Rieker Digital BBI device. These data were further integrated with the site characteristics extracted from the sensing data by the research team using the proposed geodatabase and are presented in the following sections.

4.3 Data Processing

The collected sensing data, including 2D images, 3D Lidar, GPS/IMU, etc., were processed using the outcomes from previous research projects (Ai and Tsai, 2015a; Ai and Tsai, 2015b; Tsai et al., 2013; Tsai et al., 2017) to extract the detailed, location-referenced HFST-SC identified in Section 4.1. The following sections provide brief descriptions of selected algorithms and tools used for extracting HFST-SC. For comprehensive and detailed algorithms and tools used in this study, refer to the papers and reports.

4.3.1 GPS-Based Curve Information Extraction

The acquired GPS data was processed using the Smart Curve Information Extraction (Smart-CIE) tool develop under RP 15-05 (Tsai et al., 2017) to effectively identify curve locations along with accurate curve information, including PC and PT of the curve, radius of curvature, deviation angle, length, and direction of curve. The Smart-CIE tool implements an iterative process to identify the best-fitted curves along a route trajectory. The GPS data that represents the roadway is sequentially processed and segmented into delineated segments using an iterative circular fitting method. The iterative circular fitting method attempts to find the best fit using an exhaustive search by iteratively increasing the regression size. Then a map-based QA/QC operation was performed to review and edit the curves when necessary. The Smart-CIE tool allows users to update the curves by adding, deleting, or merging curves (when appropriate) interactively on a map. The corresponding curve information is automatically computed and updated in the table. Figure 4-3 shows an example the curves extracted using the Smart-CIE. The curves are listed in a grid, as shown in Figure 4-3 (a), with the information including Curve ID, status, coordinates of center of curve, curve radius, curve deflection angle, coordinates of PC and PT. The curves can be visualized on the map, as shown in Figure 4-3 (b).

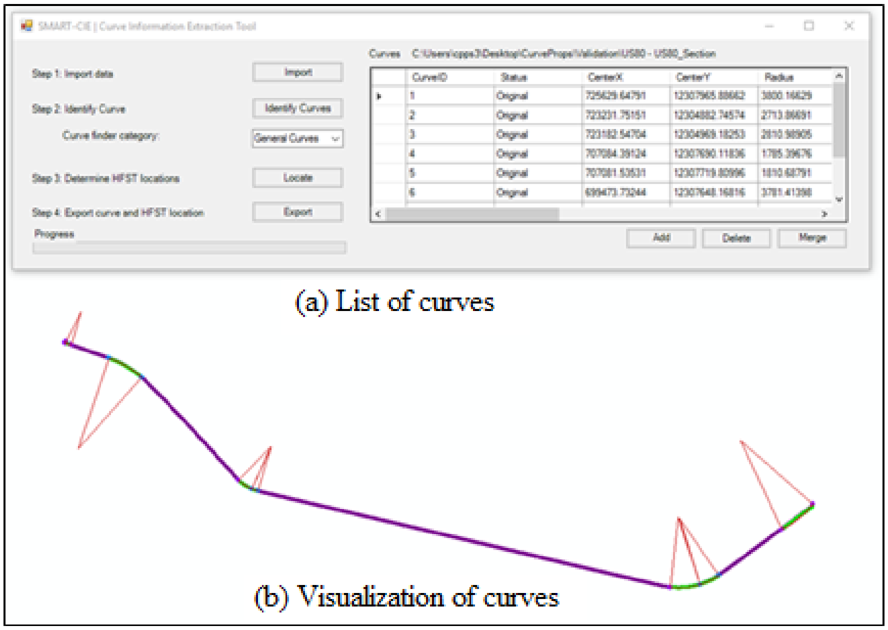


Figure 4-3 An example of the curves identified by the Smart-CIE tool (Tsai et al., 2017)

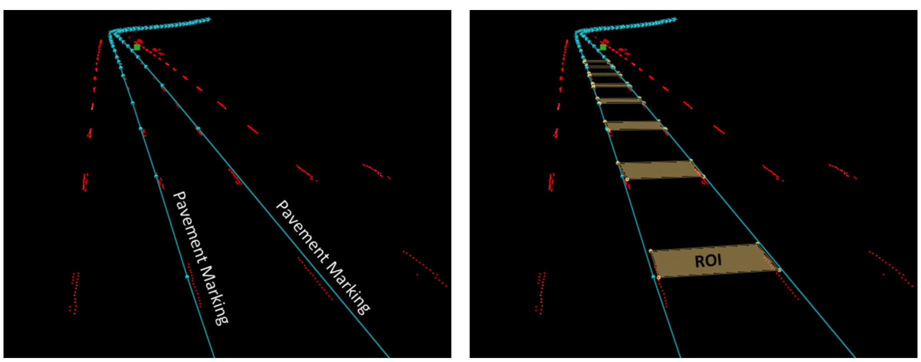
4.3.2 LiDAR-Based Superelevation and Vertical Grade Measurement

The acquired LiDAR data was processed using a superelevation (or cross-slope) measurement algorithm develop by Tsai et al. (2013) to automatically process the LiDAR point cloud, semi-automatically identify the road boundary, and measure the corresponding superelevation of the HFST sites (including both tangent and curved sections). The process consists of two primary steps, including region of interest (ROI) extraction and superelevation computation.

<u>STEP 1 - ROI Extraction</u>

ROI extraction is performed on the collected LiDAR point cloud to extract the rectangular region within a single lane between the pavement markings. Individual superelevation or cross-slope measurements will be conducted within each region of interest (ROI). Figure 4-4 shows an example of the ROI for individual superelevation or cross-slope measurements in this study. The ROI can be extracted in two sub-steps, which correspond to the two dimensions of the defined ROI:

- STEP 1.1: Pavement marking extraction (ROI width in the transverse direction). The width of the ROI is defined by the distance between the pavement markings. The pavement markings can be automatically or semi-automatically extracted from video log images based on the existing pavement marking extraction algorithm or from the LiDAR point cloud. In this study, the semi-automatic pavement marking extraction method using the LiDAR point cloud is used. Figure 4-4 (a) shows the pavement marking extraction result; the red dots are the extracted pavement markings from the LiDAR point cloud, and the blue line is the connected pavement markings.
- STEP 1.2: ROI interval determination (ROI length in the longitudinal direction). ROI interval is the key parameter that impacts the accuracy of superelevation or cross-slope computation because it determines the size of the buffer for the regression in the next step. Figure 4-4 (b) shows an example of the extracted ROI with an interval of 8ft.



(a) **(b)**

Figure 4-4 Example of the ROI extraction for individual cross-slope measurement (Tsai et al., 2013).

STEP 2 - Superelevation or Cross Slope Computation

For each extracted ROI, a small group of LiDAR points is extracted for superelevation computation. As each of the LiDAR points incorporates the accuracy of GPS information, including the elevation value in the z direction, a linear regression for the association between the extracted elevations and the transverse offset of the lane is conducted. Therefore, the slope of the regression result represents the superelevation within the corresponding ROI. Figure 4-5 shows an illustration of the extracted points from an extracted ROI and the corresponding elevation values for linear regression. Similar to cross-slope measurement, the vertical grade can be computed by conducting the regressing in the longitudinal direction.

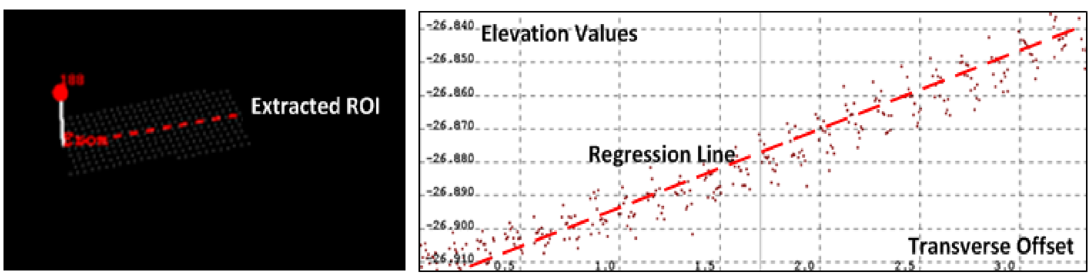


Figure 4-5 Illustration of the extracted point within an ROI for regression (Tsai et al., 2013)

Therefore, the horizontal slope (i.e., cross slope or superelevation) and vertical slope (i.e., vertical grade) can be computed automatically and continuously using the described method. In this study, a measurement interval of 5m was consistently used to measure both superelevations and vertical grades. Figure 4-6 shows the measurement results of the superelevations and the vertical grades on State Route 2.

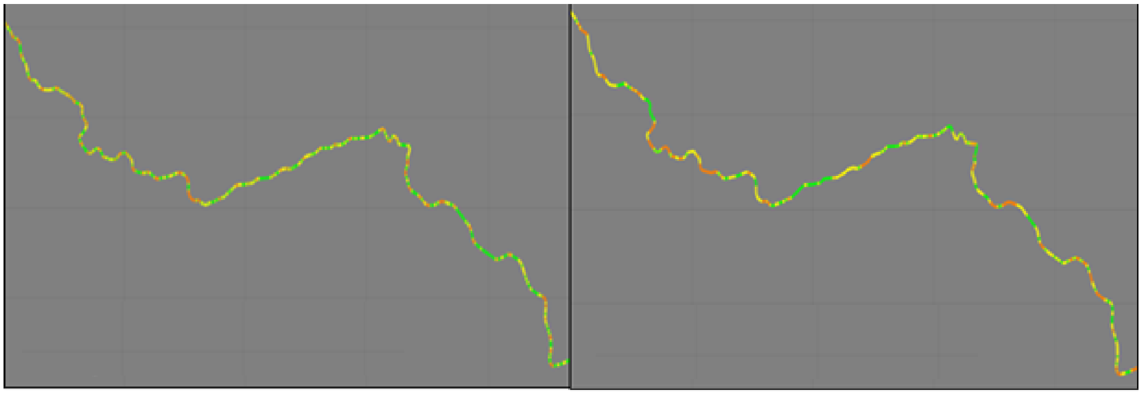


Figure 4-6 Examples of the computed superelevations and vertical grades on the State Route 2

4.3.3 LiDAR-Based Sign Detection and Image-based Sign Recognition

The acquired LiDAR data was processed using a traffic sign detection algorithm developed by the authors (Ai and Tsai, 2015b) to automatically identify traffic signs in the corresponding dataset, and the images were used for identifying the sign type. The LiDAR-based sign detection algorithm is aimed at effectively filtering the point cloud that is not associated with traffic signs by utilizing unique traffic features captured by mobile LiDAR. It consists of four primary steps, including retro-intensity filtering, elevation filtering, lateral offset filtering and LIDAR point regrouping, and hit-count filtering.

<u>STEP 1 - Retro-Intensity Filtering</u>

Retro-intensity is defined as the percentage of the redirected energy from the target divided by the emitted energy from the LiDAR, which is consistent with FHWA's definition of retroreflectivity (Carlson and Lupes, 2007). The range of retro-intensity is between 0 and 1. In the MUTCD, the traffic signs “shall be retroreflective or illuminated to show the same shape and similar color by both day and night” (FHWA, 2009).

Therefore, the threshold for retro-intensity parameter defines the lower bound of retroreflectivity. All the LiDAR points with retro-intensity values smaller than the threshold will be filtered out. The initial threshold can be determined by the reflectance reference of the of the LiDAR system. Based on the observation of the retro-intensity values that are associated with different roadside objects, the values associated with traffic signs are significantly greater than the values that are associated with other objects. Therefore, by setting an appropriate filter threshold, most of the non-traffic-sign roadside objects can be effectively rejected. The LiDAR points with high retro-intensity values (i.e. points of interests) will be further processed in the subsequent steps.

STEP 2 - Elevation Filtering

The elevation is defined as the height difference of the LiDAR point to the ground in the z direction. The elevation is computed by subtracting the z-coordinate of the estimated pavement plane from the z-coordinates of LiDAR points. As the height of the traffic signs is defined in the MUTCD for different road functions, all the LiDAR points of interest with small elevation values are unlikely to be traffic signs, and they will be effectively filtered out. This step can effectively reject some of the non-traffic-sign-associated LiDAR points with high retro-intensity values, e.g. vehicle license plates and temporary traffic control cones/drums/barricades.

STEP 3 - Lateral Offset Filtering

Lateral offset is defined as the lateral difference of the LiDAR points to the data collection trajectory. The lateral offset is computed as the absolute distance between the LiDAR points and the vehicle trajectory (continuously collected by GPS and IMU devices during vehicle movement) in the normal direction of the trajectory in the x-y plane. As the lateral offset of the traffic signs is defined in the MUTCD for different road functions, all the remaining LiDAR points of interest from STEP 2 with lateral offsets beyond the requirement are unlikely to be traffic signs, and they will be effectively filtered out. This step can effectively reject some of the remaining non-traffic-sign-associated LiDAR points that are too close or too far away from the vehicle, e.g. safety reflectors on semi-trucks in the adjacent lane and reflectors on utility poles.

STEP 4.4: LiDAR Point Regrouping and Hit Count Filtering.

LiDAR point regrouping clusters the remaining LiDAR points from STEP 1 to STEP 3 based on their proximity. Only the LiDAR points that are close enough will be clustered to the same object, i.e. traffic sign candidates. However, if the clustered object contains too few points (i.e. a small hit-count), the cluster could be too small to be a traffic sign. Therefore, such traffic sign candidates will be dropped from the detection results.

Figure 4-7 shows an example of the extracted traffic signs on State Route 2 in Rabun County.

Figure 4-7 An example of a detected traffic sign (W1-8) on the State Route 2

Following the sign detection, the 2D images around the detected signs are extracted based on sign location; sign type and corresponding MUTCD code are obtained by reviewing the images.

4.4 Data Storage, Integration and Visualization/Reporting

A relational database and an HFST report card (HFST-RC) were developed in this project to facilitate the storage, integration, visualization/reporting, and analysis of the detailed, location-referenced HFST-SC data extracted from the sensing data. A relational database with spatial and temporal information was designed to store and integrate the detailed, location-referenced HFST-SC data to support the analyses of the changes in space and time of HFST-SC data before and after HFST installation. Such data allow GDOT to understand the site characteristics that could relate to ROR crashes and the effectiveness (i.e., Georgia-specific crash reduction factors) of various curve countermeasures by considering their combinations and other conditions (e.g., curve radius, vertical grade, etc.). The HFST-SC, including 1) geometry properties (curve location, curve radius, etc.), 2) countermeasure properties, including the presence (i.e., location or x-y coordinate) of various countermeasures, such as advanced curve warning signs, advisory speed signs, chevrons, etc..), 3) roadway properties (posted speeds, lane widths, BBI values, superelevation, vertical grade, and pavement friction if available); and 4) traffic conditions (including traffic and truck volume), are stored in the geo-database. Figure 4-8 shows the schematic view of the designed geodatabase.

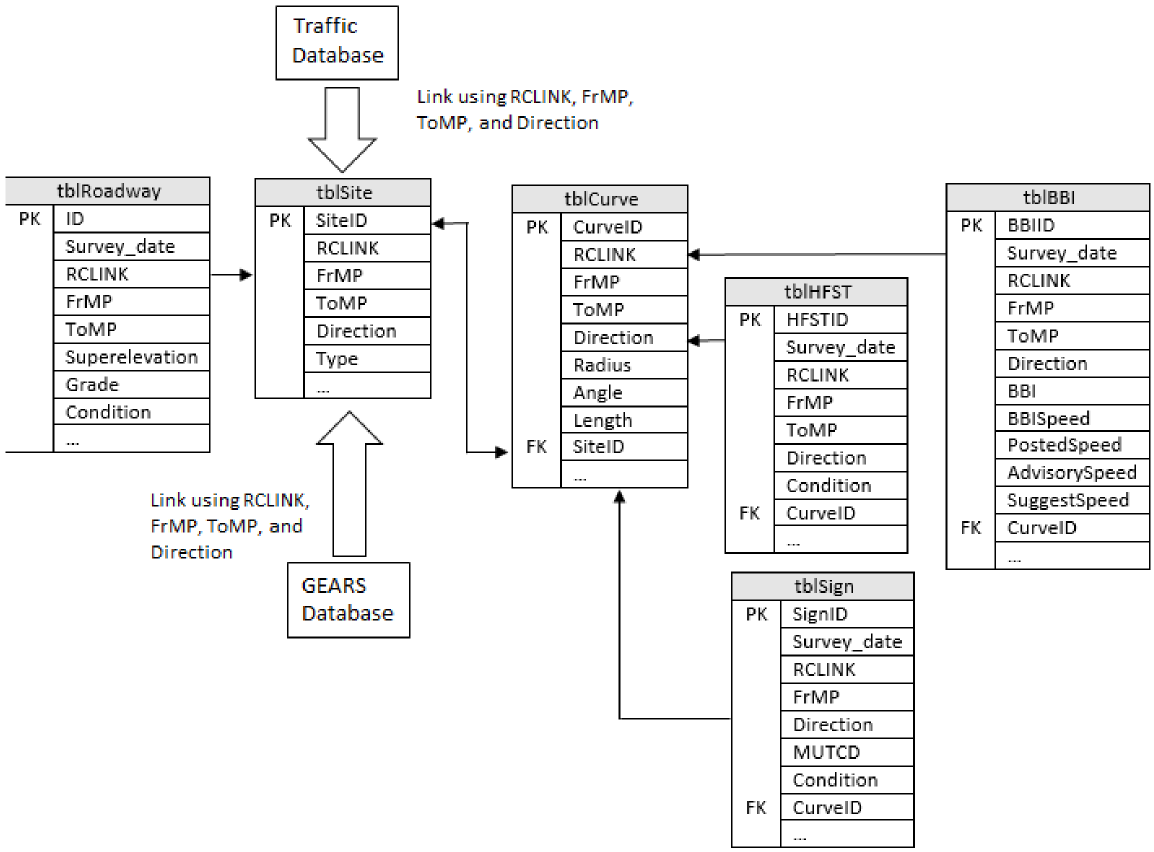


Figure 4-8 Schematic view of the proposed geodatabase for data integration

The designed database is structured based on curve site. A curve site is introduced to represent a cluster of individual curves that are close to each other (i.e., the length of the tangent section is less than 147 ft.). It is specially designed for compound curves and reversed curves, which consist of multiple curves, as illustrated in Figure 4-9. A curve site can also consist of clustered curves that have short tangents between curves. A curve site can be considered as a minimum unit for safety analysis and/or improvement. Within a curve site, the driver needs to continuously adjust steering control to negotiate curves with different curvature and changes in angles; thus, curves need to be analyzed in conjunction with driving behaviors and safety improvements. HFST-SC data are stored in individual schemas (e.g., geometry schema and sign schema) and related to a curve based on their spatial relationship. Each curve is related to a curve site. For a simple curve, a curve site only contains one curve member whose site characteristics are directly associated with its only member curve. For a compound curve, reversed curve, or continuous curves, a curve site may contain multiple curve members whose site characteristics can be further derived by summarizing all the site characteristics of its member curves. Each HFST-SC is associated with spatial information. Besides the coordinates, the designed relational database also implements GDOT's linear referencing system so that it can be seamlessly integrated with many existing data sources at GDOT, such as the GEARS (Georgia Electronic Accident Reporting System). By using the linear referencing system, various HFST-SC data can be spatially integrated and represented as a point (e.g., sign) or a line (e.g., curve). The date of the HFST-SC data collected is also stored in the schema to track the changes at different timestamps (e.g., before and after HFST installation).

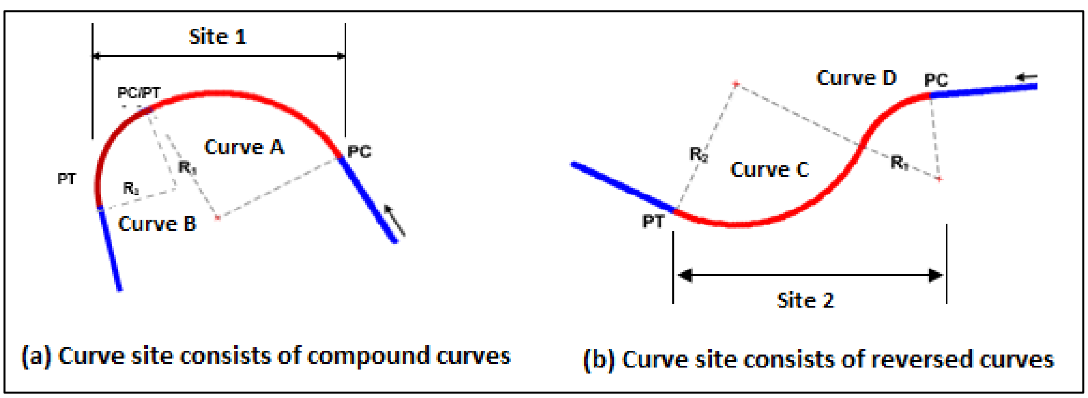


Figure 4-9 Illustration of curve sites with multiple curves

An HFST report card (HFST-RC) was developed to provide a means of integrating and visualizing detailed level, location-referenced HFST-SC data on each site so these characteristics can be visualized and analyzed by GDOT's engineers. Figure 4-10 shows a template of the reporting card. The template was designed to consist of a linear diagram with curve geometry and the countermeasures, a thumbnail map of the curve location, a screenshot of Google Street View, and, most importantly, the schematic of the curve. In the schematic of the curve, the shaded region indicates the HFST region (if it exists) together with the existing/proposed signage. The developed HFST-RC provides GDOT a convenient tool to visualize the critical HFST-SC data along a curve using the spatial data stored in the database.

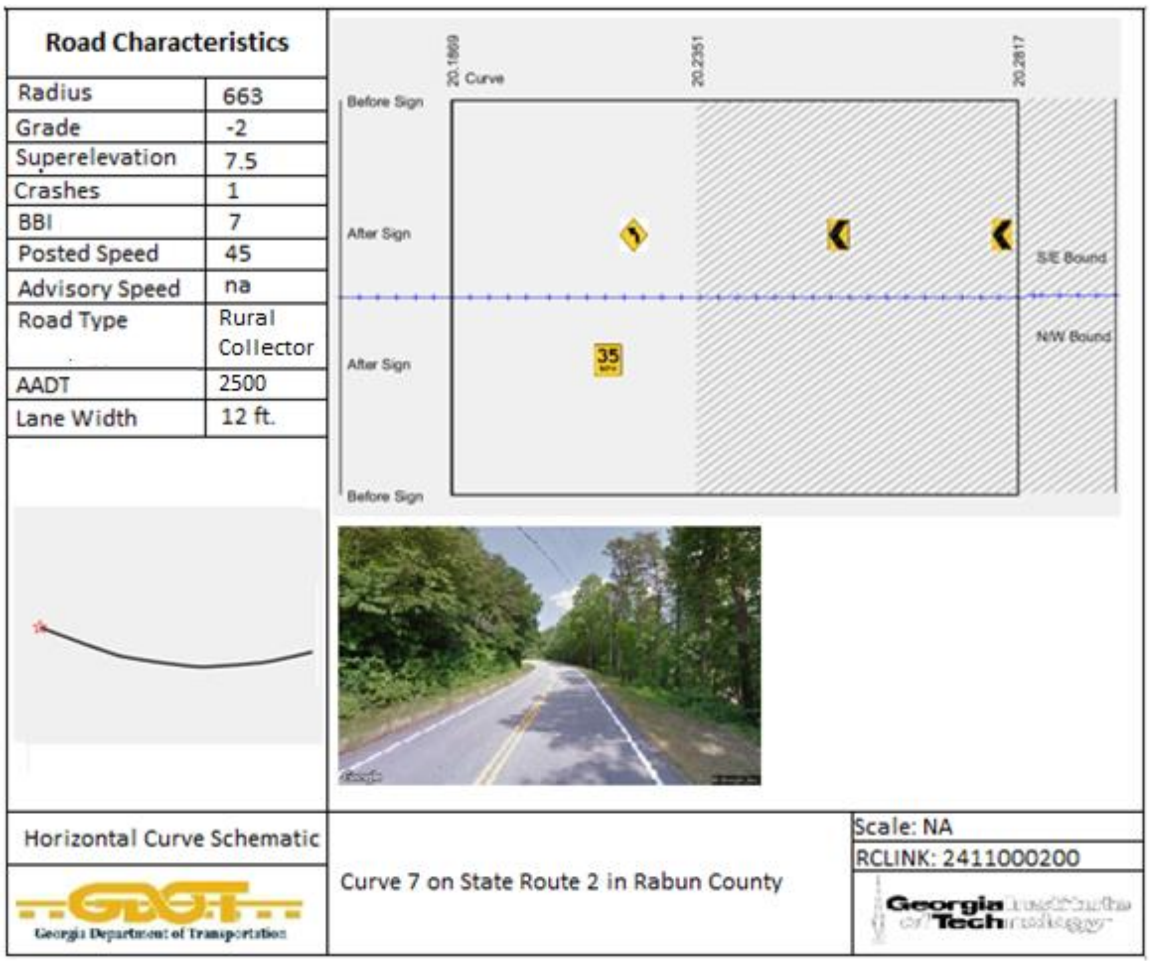


Figure 4-10 A template of a curve reporting card

4.5 Case Study on Data Integration and Visualization (State Route 2)

The research team worked closely with Mr. David Adams and Mr. Michael Turpeau of the Office of Traffic and Operations (OTO) at GDOT to select State Route 2 in Rabun and Towns Counties, shown in Figure 4-11**,** as the testing route for collecting the detailed location-referenced HFST-SC data using the developed method. This section of roadway was selected because a) there are 62 HFST sites that are installed under an HFST project PI #0009993 and b) there are diverse site characteristics and abundant sharp curves on this mountainous region's route. State Route 2 covers 31 miles in Rabun and Towns Counties and consists of different roadway characteristics, such as varied radii, several curve types, frequent vertical grades, etc.

Figure 4-11 Location of State Route 2 test section in North Georgia

Sensing data (2D images, 3D LiDAR, laser, GPS, and IMU data) on State Route 2 were collected using the GTSV on March 25th, 2016 before HFST installation and on October 12th, 2017 after HFST installation. The data was collected in two directions, but only the eastbound (EB) data was used in this case study. Figure 4-12 shows the locations of the curves on State Route 2; there are 140 curves on this route. For each curve, the detailed level, location HFST-SC data include 1) geometry properties (curve location, curve radius, superelevation, vertical grade, etc.); 2) countermeasure properties (the location or x-y coordinate of various countermeasures, such as advanced curve warning signs, advisory speed signs, chevrons, etc.; 3) roadway properties (posted speeds, lane widths, BBI values, and available pavement friction; and 4) traffic conditions (AADT and AADTT). All data were stored in the designed relational database. Figure 4-13 shows a screenshot of HFST-SC data stored in the database.

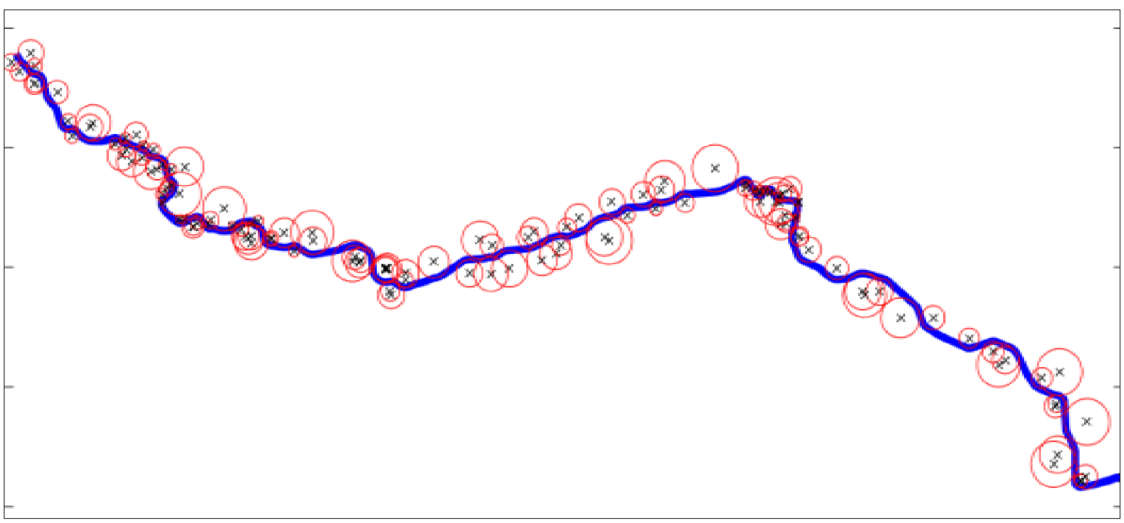
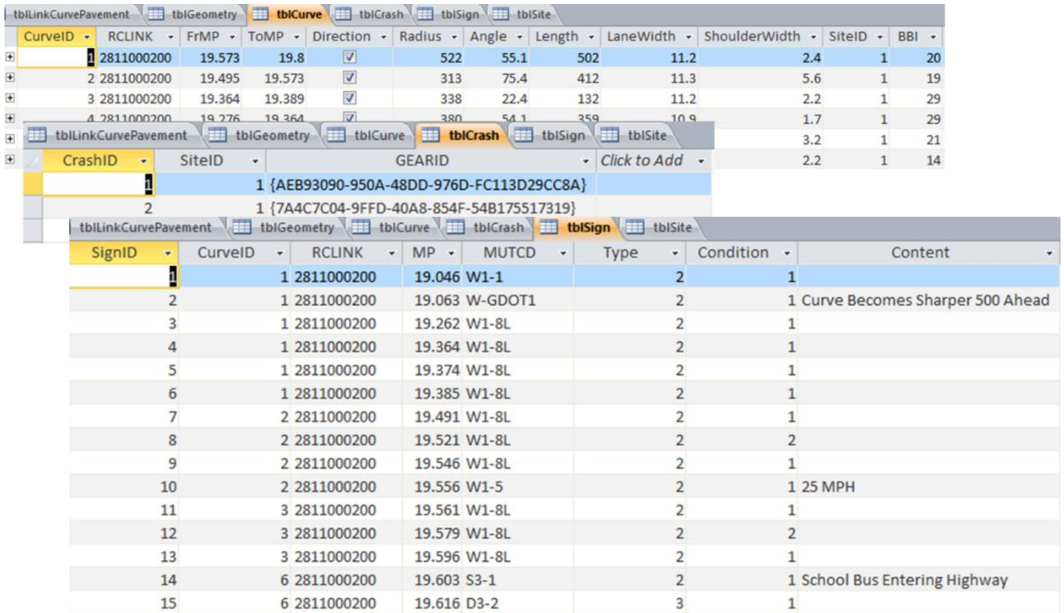


Figure 4-12 An example of curves on the State Route 2



CurveID	RCLINK	FrMP	ToMP	Direction	Radius	Angle	Length	LaneWidth	ShoulderWidth	SiteID	BBI
1	2811000200	19.573	19.8	☑	522	55.1	502	11.2	2.4	1	20
2	2811000200	19.495	19.573	☑	313	75.4	412	11.3	5.6	1	19
3	2811000200	19.364	19.389	☑	338	22.4	132	11.2	2.2	1	29
4	2811000200	19.276	19.364	☑	380	54.1	359	10.9	1.7	1	29
									3.2	1	21
									2.2	1	14

CrashID	SiteID	GEARID	Click to Add
1	1	{AEB93090-950A-48DD-976D-FC113D29CC8A}	
2	1	{7A4C7C04-9FFD-40A8-854F-54B175517319}	

SignID	CurveID	RCLINK	MP	MUTCD	Type	Condition	Content
1	1	2811000200	19.046	W1-1	2	1	
2	1	2811000200	19.063	W-GDOT1	2	1	Curve Becomes Sharper 500 Ahead
3	1	2811000200	19.262	W1-8L	2	1	
4	1	2811000200	19.364	W1-8L	2	1	
5	1	2811000200	19.374	W1-8L	2	1	
6	1	2811000200	19.385	W1-8L	2	1	
7	2	2811000200	19.491	W1-8L	2	1	
8	2	2811000200	19.521	W1-8L	2	2	
9	2	2811000200	19.546	W1-8L	2	1	
10	2	2811000200	19.556	W1-5	2	1	25 MPH
11	3	2811000200	19.561	W1-8L	2	1	
12	3	2811000200	19.579	W1-8L	2	2	
13	3	2811000200	19.596	W1-8L	2	1	
14	6	2811000200	19.603	S3-1	2	1	School Bus Entering Highway
15	6	2811000200	19.616	D3-2	3	1	

Figure 4-13 A screenshot of the HFST-SC on State Route 2

Using the relational database, the HFST-SC data can be queried and easily integrated for each curve. Table 4-2 shows examples of HFST-SC data, including curve radius, PC, PT, and vertical grade, at each curve. A complete list of all 140 curves is included in Appendix B. These curves have radii ranging from 183 ft. to 3235 ft., deflection angles from 3.0° to 63.0°, superelevations between 2.0% and 14.0%, and grades between -8.8% and 11.0%. It should be noted that many of the 140 curves are connected as reverse curves and compound curves because the selected road sections are located primarily in a mountainous area. There are 85 curves with vertical grades greater than 3%; the remaining curves have grades less than 3%. The BBI value collected by GDOT is available for 67 curves. The BBI values range from 11 to 29 with the majority of them less than 16.

In this study, a total of 100 unique curve sites were identified. A curve site may consist of one or more curves in which curves whose PC is less than 80 feet from the PT of the adjacent curve and are grouped under one site. Of the 100 curve sites, 23 curve sites contain more than one curve consisting of simple reverse curves, combined curves, and continuous reverse curve sites (i.e. 67 individual curves).

Table 4-2 Sample curve characteristics data from State Route 2

Site.No	RCLINK	Road Class	Curve Type	FrMP	ToMP	RADIUS (ft)	Deviation Angle (°)	Length (ft)	Direction	Lane Width (ft)	Superelevation (%)	Vertical Grade (%)	Max BBI	AADT (Truck Percentage)	Existing Signs	Existing Speed Limit (mph)	Existing Curve Advisory Speed
1	2811000200	Rural Arterial	S	14.248	14.310	877	10.6	326	1	3.8	7.0	0.6	9	2500 (10%)	None	45	N/A
2	2811000200	Rural Arterial	S	14.676	14.803	1158	16.5	667	-1	4.0	5.5	4.8	5	2500 (10%)	W1-2	45	N/A
3	2811000200	Rural Arterial	S	14.985	15.084	721	20.3	520	-1	4.1	9.0	-5.4	6	2500 (10%)	W13-1P	45	25
4	2811000200	Rural Arterial	S	15.141	15.231	459	29.0	474	1	3.7	11.0	0.9	8	2500 (10%)	W13-1P	45	25
5	2811000200	Rural Arterial	S	15.769	15.883	1992	8.6	599	-1	3.9	3.0	-5.0	5	2500 (10%)	None	45	N/A

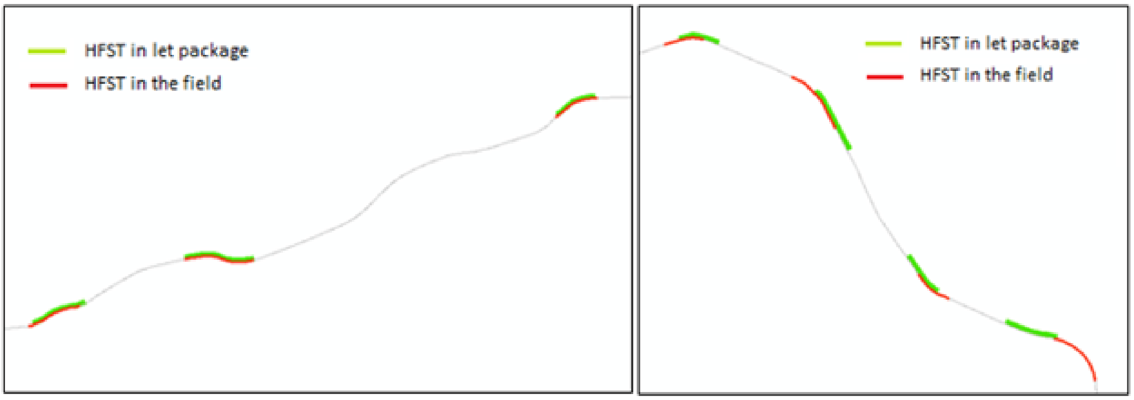
Based on the countermeasure data collected on State Route 2 in the eastbound direction, there are a total of 16 speed limit signs and 91 curve related traffic signs, including the advance curve warning signs (W1-1, W1-2, W1-3, W1-4, and W1-5), the advisory speed limit signs (W13-1), and the chevron signs (W1-8). The curve related signs are assigned to 83 curves. It is noted that many of curves do not have any curve warning signs, and advisory speed limit signs were posted only for 19 curves. Chevron signs (W1-8) and advisory speed limit signs (W13-1) were not present on many of the curves with a BBI greater than 12. This indicates a need for curve sign improvement. GDOT did includ sign improvement in the HFST project.

The HFST-SC data after the HFST installation were also collected, and an HFST-RC, as shown in Figure 4-10, was generated for each curve to help visualize the various data on the site with respect to their spatial relationship. Appendix C lists HFST-RC for each of the HFST sites; Appendix D includes the reporting card for each curve. The changes in HFST-SC data before and after HFST installation is discussed in the following section.

4.6 Change Analysis of Before and After HFST-SC

The before data collected on March 26th, 2016 was processed as the initial inventory of HFST-SC on curves; the HFST-SC was also obtained using the data collected after HFST installation on October 12th, 2017. By integrating the before and after HFST-SC data spatially, the detailed site characteristic changes can be identified to support the subsequent analysis. For example, by distinguishing the sites with HFST only and the sites with both HFST and signage improvement, the effectiveness of HFST on safety improvement can be more rigorously investigated and better understood. This section presents the HFST-SC data collected before and after HFST installation by the safety project PI #0009993.

Based on the after data, a total of 52 sites were installed with HFST. Most of the HFST sites are located near the mile points specified in the let packages (as shown in Figure 4-14 (a)). However, some sites are off from the locations in the let package, especially in Towns County and the actual location seems to align better with the curve (as shown in Figure 4-14 (b)). This indicates the need for collecting the after data to establish an accurate HFST inventory.



(a) HSFT sites in the field are near the locations in the let package

(b) HFST sites in the field are off from the locations in the let package

Figure 4-14 Examples of HFST sites in let package and in the field

By querying the relational database, the change in HFST-SC data, including geometry, countermeasures, etc., can be identified along with other detailed information, such as the date of the change and the location of the change. Table 4-3 shows examples of the changes in HFST-SC data before and after the safety project (PI #0009993). As expected, there was no change in the geometry, especially superelevation, because the geometry improvement was not included in the project. A total of 48 sites were identified with HFST after HFST installation. Although 7 HFST sites in Towns County were included in the let package, two sites were removed from HFST because of concerns about the existing pavement condition. Based on the project engineer, extensive cracking was observed on these two sites before HFST installation. There were concerns that 1) the life of HFST could be shortened because of the cracked pavement surface and 2) the curve might be resurfaced in the near future. Thus, it was decided to remove these two sites from HFST consideration. The exact HFST start and end points were also extracted from the sensing data. It is noted that some of the sites have HFST extending more than 175 ft.

beyond the PC and PT, while other sites have a shorter HFST. This allows GDOT engineers to compare the effectiveness of HFST by considering the start and end points and length of HFST.

Table 4-3 A sample of safety measures comparison before and after safety project (PI #0009993)

RCLINK	Beg_MP	End_MP	2016 Safety Measures		2017 Safety Measures		BBI Before 2016	BBI After 2017
			HFST	Signs	HFST	Signs		
2811000200	14.25	14.31	No	None	No	None	9	
2811000200	14.68	14.80	No	W1-2	No	None	5	
2811000200	14.99	15.08	No	W13-1P(25), W1-4	**Yes**	W13-1P(35), W1-4, W1-8#4	6	
2811000200	15.14	15.23	No	W13-1P(25), W1-4, W1-8#4	No	W13-1P(35), W1-4	8	
2811000200	15.77	15.88	No	None	No	None	5	
2811000200	15.95	16.11	No	W1-4	No	None	6	
2811000200	16.20	16.34	No	W1-4	No	None	8	
2811000200	16.47	16.56	No	None	No	None	8	
2811000200	16.58	16.71	No	W1-2	No	None	6	
2811000200	16.88	16.99	No	None	**Yes**	None	9	
2811000200	17.11	17.22	No	None	No	W13-1P(35), W1-4	9	
2811000200	17.23	17.32	No	None	No	W13-1P(35), W1-4	10	
2811000200	17.33	17.41	No	None	No	None	9	

In addition to HFST, curve warning signs were also installed on every one of these 48 HFST sites. An additional 212 curve warning signs were installed, including 24 advisory speed signs (W13-1P), 2 speed limit signs (R2-1), 16 curve warning signs (W1-2), 7 reverse curve warning signs (W1-4), 2 continuous reverse curve warning signs (W1-5), , and 161 chevron warning signs (W1-8). It is noted that chevron warning signs were installed on almost every one of the 48 HFST sites. Thus, it is important to take the chevron signs into the consideration when evaluating the effectiveness on these 48 HFST sites. These sites can be compared to the HFST sites to better understand the effectiveness of different combinations of curves countermeasures.

The detailed, location-referenced HFST-SC data, including curve geometry, countermeasures, roadway, and traffic, can facilitate safety engineers and field engineers' analysis in the office and in the field. By further integrating the site characteristic data collected after the HFST installation, the temporal data for each curve can be further incorporated to facilitate a more comprehensive analysis. For example, the curves with only HFST and the curves with both HFST and signage improvement can be clearly identified and differentiated so that the subsequent effectiveness analysis of the HFST can be conducted by eliminating the effect introduced by the improved signage or other site characteristic changes. The effectiveness of the low-cost countermeasures, e.g., improved signage, can also be identified and combined with the presence of HFST. It is recommended that GDOT collect HFST-SC data before and after HFST installation on all HFST sites to study Georgia-specific HFST crash reduction factors, the presence of other countermeasures, the HFST location (i.e., start and end points), roadway geometry (e.g., vertical grade), etc.

5. IDENTIFICATION OF SITE CHARACTERISTICS FOR PROACTIVE HFST SITE-SELECTION USING SENSOR-BASED, DETAILED, LOCATION-REFERENCED CURVE CHARACTERISTICS DATA

GDOT has partnered with Georgia Tech to identify additional factors for its HFST site-selection (HFST-SS) decision-making process by leveraging high-resolution, full-coverage sensor data (e.g., GPS, Lidar, and 2D images). This chapter presents a procedure to identify additional site characteristics, besides BBI, that can be used in GDOT's HFST-SS process by leveraging sensor data and automatic roadway feature extraction. For completeness, the proposed method consists of five steps: 1) roadway data collection using emerging sensing technologies, 2) automatic extraction of detailed site characteristics data and curve information, 3) curved-based roadway segmentation using the extracted curve information; 4) spatial integration of curve characteristics data (CCD); 5) analysis of CCD and ROR crashes to identify additional factors for HFST site selection. A case study using CCD extracted from State Route 2 demonstrates the proposed method. Results show that on sharp curves having radii of less than 800 feet and comparable site characteristics, vertical grades greater than 3% play an important role in ROR crashes. Therefore, a vertical grade greater than 3% could be considered as an additional HFST-SS factor along with the current BBI criterion. The proposed method, case study, and results are presented in the following sections.

5.1. Proposed Procedure

GDOT has partnered with Georgia Tech to leverage currently available, high-resolution, full-coverage sensor data (e.g., GPS, Lidar, 2D images, etc.) and identify additional curve characteristics that contribute to ROR crashes and could be used, in addition to BBI values, in its HFST-SS decision process. This section presents a procedure that effectively extracts, spatially integrates, and correlates CCD values to ROR crashes to identify the factor(s) that can be incorporated for effective HFST-SS decision-making process. The proposed method consists of the following steps: 1) collection of sensor data on curves, using emerging sensing technologies, including 2D imaging, lasers, 3D LiDAR, inertial measurement units (IMU), and GPS/GIS technologies; 2) automatic feature extraction of the detailed, location-referenced curve information, including curve radius, PC and PT, etc. and continuous site characteristics data such as superelevation, grade, BBI, etc.; 3) curved-based segmentation using the extracted PC and PT; 4) spatial integration of CCD; 5) analysis of correlation between CCD and ROR crashes to identify additional factors for HFST site selection. Figure 5-1 illustrates the steps of the proposed method.

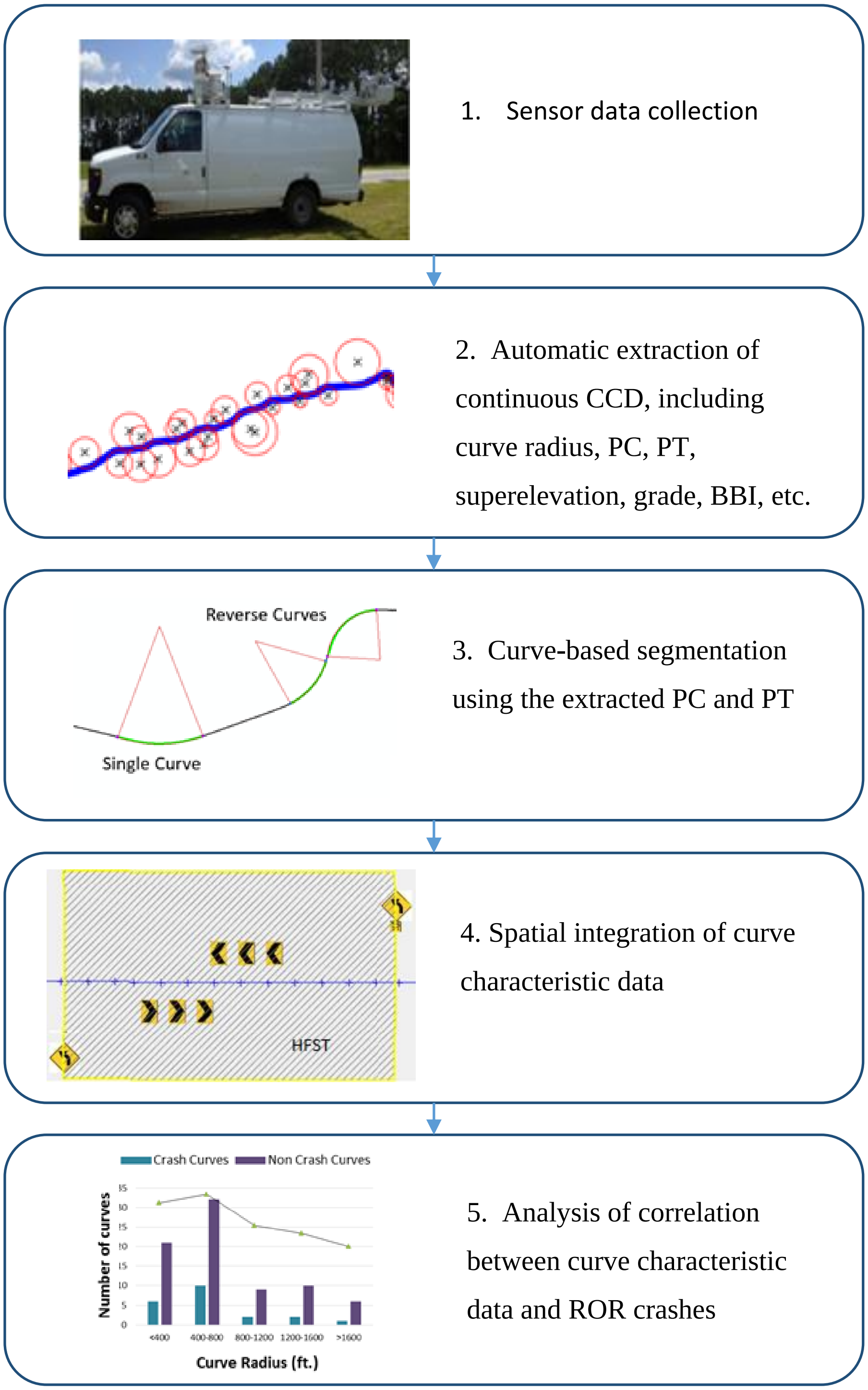


Figure 5-1 Illustration of the steps in the proposed procedure.

5.1.1 Sensor Data Collection

In this step, the Georgia Tech Sensing Vehicle (GTSV), equipped with high-resolution cameras, LiDAR, a 3D pavement laser system, GPS, an IMU, and a distance measuring instrument (DMI), was used to collect the sensor data for extracting detailed, location-referenced CCD. See Section 4.2 for details on the sensor data collection.

5.1.2 Automatic Extraction of Continuous CCD

In this step, the raw sensor data are processed to automatically extract the detailed, location-referenced, continuous roadway site characteristics data by leveraging the outcomes of previous research projects (Tsai et al., 2017; FHWA, 2015). Section 4.3 describes the methods used for automatic extraction of continuous CCD. First, the GPS trajectory is used to extract the curve information (foundation for CCD), including PC and PT of the curve, radius of curvature, deviation angle, length, and direction of curve, using the Smart-CIE (Smart Curve Information Extraction) tool developed by Tsai et al. (2017) and featuring a curve-identification algorithm developed by Ai and Tsai (2014a) and map-based QA/QC. Second, the LiDAR data is processed using an algorithm develop by Tsai et al. (2013) to automatically process the LiDAR point cloud, semi-automatically identify the road boundary, and measure the superelevation and vertical grade along the road. Third, the LiDAR data and 2D images are processed together to extract the location and type of signs (regulatory speed limit signs, advisory speed signs, advanced curve warning signs, and chevrons) using the algorithm developed by Ai and Tsai (2014b). The LiDAR-based, sign-detection algorithm uses a series of filters on the point cloud data to remove points that are not associated with traffic signs and locates the sign from the filtered data. This consists of five primary steps, including retro-intensity filtering, elevation filtering, lateral offset filtering, LIDAR point regrouping, and hit-count filtering. The sign type is determined from the video log images that are georeferenced to the sign location. The final output of processing the sensor data contains the curve characteristics data including PC and PT of the curve, the radius of curvature, deviation angle, length, the direction of curve; and continuous data including superelevation, grade, pavement width, curve sign (location and sign type), and BBI.

5.1.3 Curve-based Segmentation Using PC and PT

In this step, the road is first linear referenced to create a continuous linear measure along the road and then segmented into individual curves and tangents using the PC and PT. This curve-based segmentation allows transportation agencies to easily identify the exact curve locations and analyze crashes on curves to better identify the issues with regard to curve safety. Further, the curve segments are clustered into sites to allow transportation agencies to identify non-single curve sites that may require attention from a safety point of view. A site, which consists of one or more than one curve, can be categorized into a single curve, reversed curve, compound curve, or continuous curve (one with more than two curves). Figure 5-2 illustrates curve sites on a section of a road. Adjacent curves with a distance less than 80 ft. are clustered into the same sites; the underlying assumption to use 80 feet considers the fact that drivers have to respond to the changing alignment within 1.5 seconds when traveling at the typical curve speed (35 mph). Accordingly, if the adjacent curves are within 80 feet of each other, drivers do not have sufficient time to steering properly while entering the next curve.

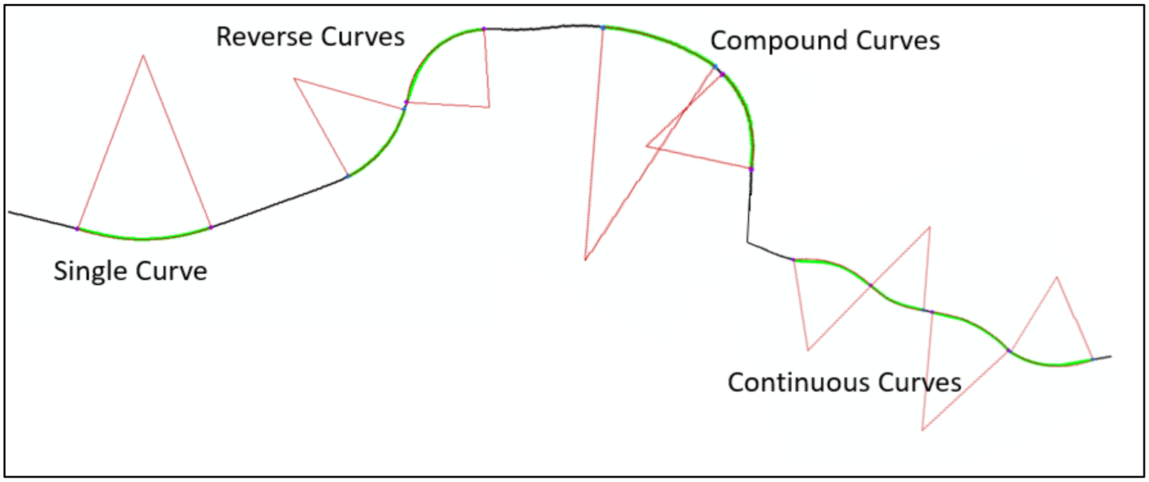


Figure 5-2 Illustration of sites consisting of a single curve, reversed curves, compound curves, and a continuous curve along a road section.

5.1.4 Spatial Integration of CCD

In this step, the extracted detail-level continuous data (e.g., grade and superelevation measured at 3-meter intervals, BBI, and sign locations) and crash data are spatially integrated with curve segments to support further analyses. A multi-level data model was designed to support the analyses at various levels. First, all the data extracted from sensor and crash data are linear referenced. All extracted continuous data falling within the limits of PC and PT of a particular curve are assigned to that curve, enhancing the curve characteristics data. At this level, there is no aggregation of data. Such CCD allows detailed analysis of individual curves in conjunction with crash location. Next, this data is aggregated into each individual curve to support the curve-level analysis, such as curve-to-curve comparisons and statistical analysis of site characteristics across multiple curves. In this case, each curve is assigned a single value for each of the continuous data points like curve BBI is assigned the maximum absolute BBI value falling within each curve. Similarly, the average value of the vertical grade points and the 90-percentile value for the superelevation points that fall within a curve is assigned as the curve's grade and superelevation, respectively. At the third level, the curves are aggregated into the sites, such as continuous curves, to support analysis at the site level. Table 5-1 shows an example of CCD integration at multiple levels. Site 11 in Table 5-1 is an example of curve aggregation in which curves 11, 12, 13, and 14 are grouped together.

Table 5-1 An Example of Integrated CCD at Curve and Site Levels

Site No.	1	2	3	4	5		6	7	8	9	10			
AADT, (Truck Percentage)	2500, (10%)	2500, (10%)	2500, (10%)	2500, (10%)	2500, (10%)		2500, (10%)	2500, (10%)	2500, (10%)	2500, (10%)	2500, (10%)			
Type of Curve Site	Single Curve	Single Curve	Single Curve	Single Curve	Reverse Curve*		Single Curve	Single Curve	Single Curve	Single Curve	Continuous Curves**			
Curve No.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
PC Mile Point	14.25	14.68	14.99	15.14	15.77	15.95	16.20	16.47	16.58	16.88	17.11	17.23	17.33	17.41
PT Mile Point	14.31	14.80	15.08	15.23	15.95	16.11	16.34	16.56	16.71	16.99	17.22	17.32	17.41	17.66
Radius (ft)	877	1158	721	459	1206	718	571	646	997	728	410	404	934	1448
Deviation Angle (°)	11	17	20	29	28	34	37	21	19	22	42	37	14	26
Length(ft)	326	667	520	474	599	858	743	472	660	562	582	508	442	1309
Direction (Left = -1 Right = 1)	1	-1	-1	1	-1	1	-1	-1	1	1	1	-1	-1	1
Avg. Lane Width (ft)	3.8	4.0	4.1	3.7	3.9	3.7	3.7	3.6	4.0	3.9	4.0	4.1	3.9	3.8
Super Elevation (%) - 90 percentile	7	5.5	9	11	9	11	12	11.5	7	12	14	12	10	7
Avg. Vertical Grade (%)	0.6	4.8	-5.4	0.9	-5.0	-0.2	7.3	-1.8	-3.8	-0.4	4.4	5.1	1.6	-1.7
Maximum BBI (°)	9	5	6	8	5	6	8	8	6	9	9	10	9	5
MUTCD code of Existing Signs	None	W1-2	W13-1P(25)	W13-1P(25)	None	W1-4	W1-4	None	W1-2	None	None	None	None	None
Existing Speed Limit (mph)	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Existing Curve Advisory Speed (mph)	N/A	N/A	25	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

5.1.5 Analysis of Correlation between CCD and ROR Crashes

In this step, a curve-level analysis is conducted to identify factors that correlate to ROR crashes so that it may be considered in HFST-SS criteria. Various CCD are categorized quantitatively to analyze if ROR crashes in any particular category stand out, suggesting the specific CCD category is prone to ROR crashes and can benefit from HFST. An over-representation analysis is conducted to qualitatively analyze each site characteristic that may be related to ROR crashes at horizontal curves; it studies the number of curves with and without crashes based on different ranges of site characteristics. Accordingly, site characteristics, including curve radius, cross slope (superelevation), and vertical grade, are analyzed in this study. In addition, BBI (the HFST-SS criterion GDOT uses) is analyzed. However, this analysis is not limited to the identified site characteristics alone. It may extend to other site characteristics, such as roadside hazards and pavement conditions (Davis, 2014), type of site (single curve, reversed curve, compound curve, and continuous curve), etc.

5.2. Case Study

A case study using the detailed, location-referenced CCD collected on a test section (31 miles of State Route 2), was conducted to demonstrate the proposed method to identify additional CCD factors that impact ROR crashes, besides BBI. The State Route 2 sections in Rabun and Towns Counties are located in northern Georgia, a mountainous terrain. They cover many curves with various radii and a wide range of grades and superelevations. Sensor data, including GPS, Lidar, video, and acceleration data, were collected by the GTSV in the eastbound direction for extracting detailed, location-referenced CCD. While it was not feasible to conduct a full-scale statistical analysis from which to draw final conclusions due to the limited number of crashes and the number of horizontal curves, this case study was conducted to demonstrate the feasibility of identifying additional CCD factors that could be used in HFST site selection.

5.2.1 CCD Data

After processing the sensor data collected on the test section, 140 horizontal curves were extracted from 31miles of the road. Figure 5-3 shows the 140 curves (with circle size indicating curve radii) automatically extracted using GPS data. In addition, the geometry properties of the curve, including curve radii, PC and PT, grade, and superelevation, were extracted and spatially integrated using linear referencing. Results are shown in Figure 5-4. Figure 5-4 (a) collectively represents the mile-point location of the curves along the test section, direction of turn, radius, and length of the curve. The height of the bar in Figure 5-4 (a) represents the radius of the curve; a positive radius implies that the curve turns in the right-hand direction, and a negative radius implies the curve is turning towards the left. The width of the bar represents the curve length. Figure 5-4 (b), Figure 5-4 (c), and Figure 5-4 (d) represent the detailed elevation, superelevation, and BBI of a 0.16-mile sub section containing a continuous curve site highlighted by red, green and blue. The elevation and superelevation are measured every 10 feet, while BBI is collected at 1 Hz frequency.

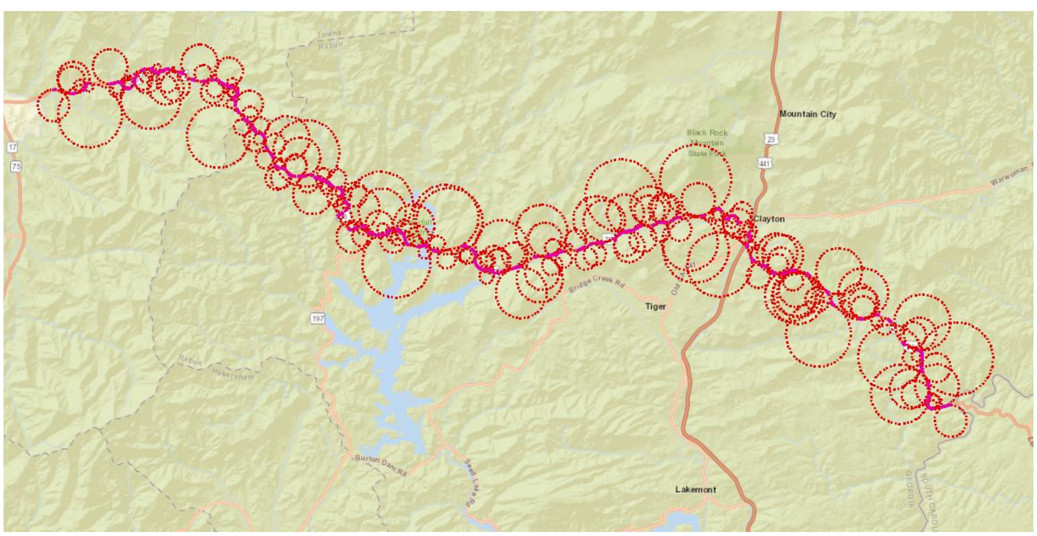


Figure 5-3 The curves extracted using SMART-CIE tool on State Route 2

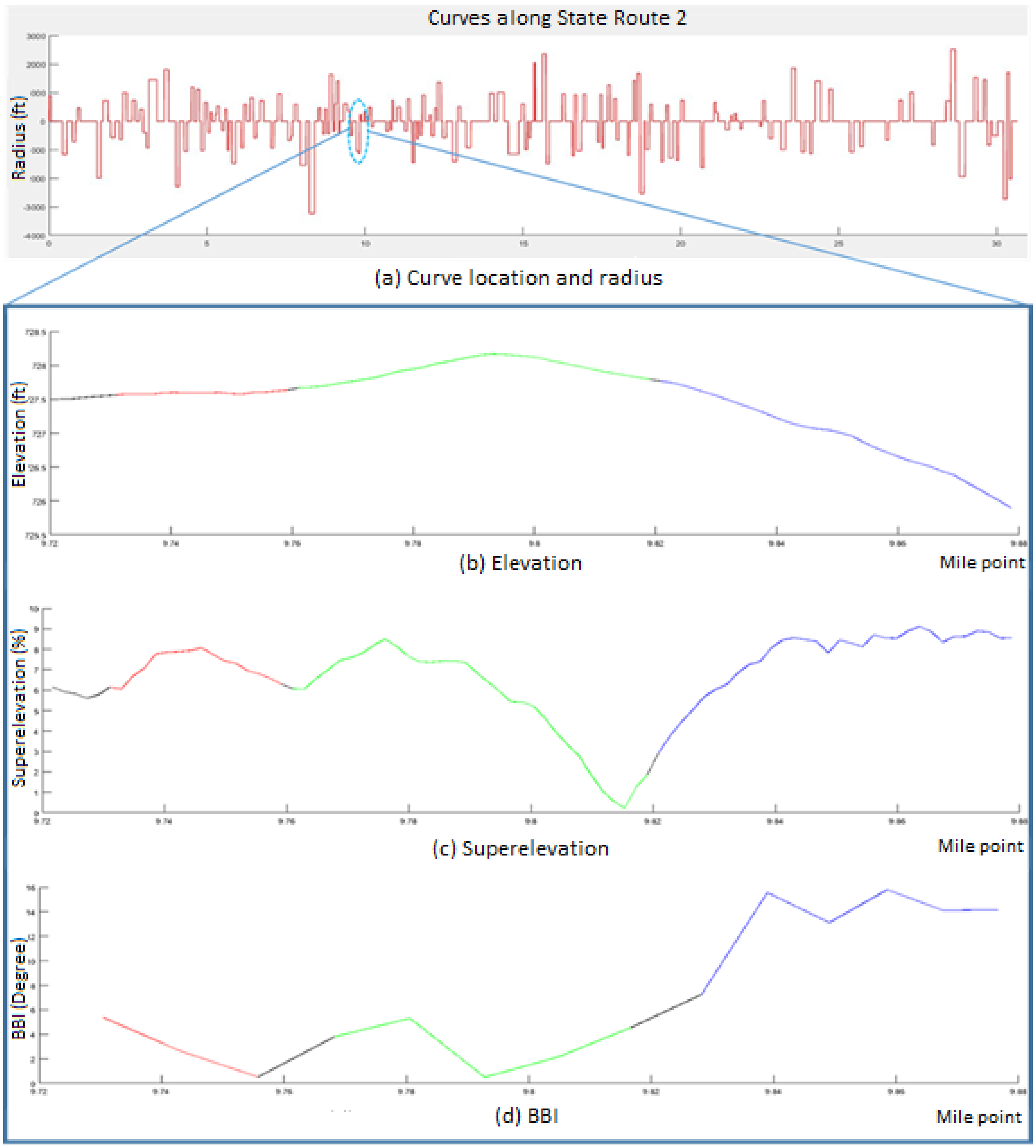


Figure 5-4 Visualization of curve location and radius on State Route 2, and an example of detailed, location-referenced CCD on three curves

Before further analysis, a few CCD were plotted against each other to verify whether or not the data follow the expected trends. A review of BBI values and curve radii shows a negative correlation, as shown in Figure 5-5 (a); that is, as radii decreases, BBI values increase, the superelevation and curve radii also have a negative correlation, as shown in Figure 5-5 (b). As the radii decreases, superelevation increases. The trends shown in Figure 5-5 (a) and Figure 5-5 (b) are as expected.

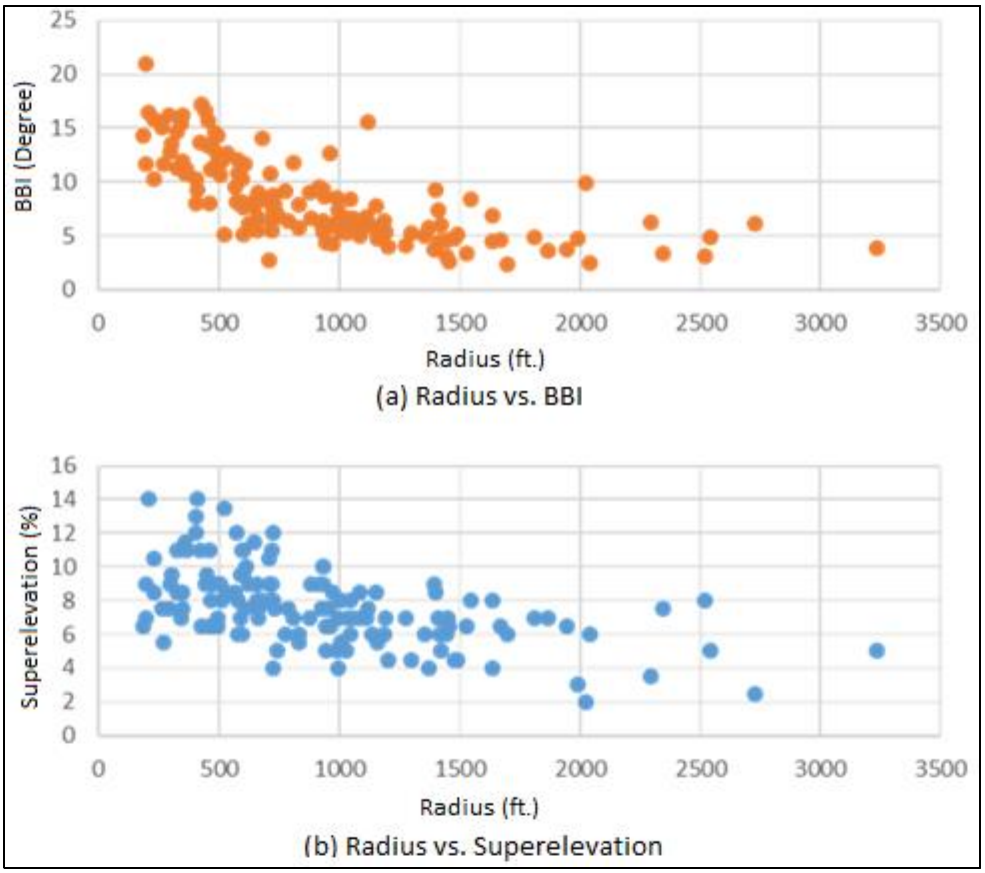


Figure 5-5 Relationship between (a) the radius and the BBI, and (b) the radius and the superelevation.

In addition to CCD, ROR crash data between 2010 and 2015 were extracted from the crash database (i.e., Georgia Electronic Accident Reporting System - GEARS) and spatially integrated with the curves to facilitate the subsequent analysis. There were 55

ROR crashes in the eastbound direction, 34 of which were located within curves. ROR crashes occurring within 50 feet from the PC of the curve were also assigned to the curve since the crash site in the database may not represent the true start of crash events In most cases, one or no crash per curve occurred; only five curves had more than one crash. After spatial integration, CCD and crash data were correlated and analyzed to identify additional CCD factors that affect ROR crashes.

5.2.2 Overrepresentation Analysis

An overrepresentation analysis is used in this section to identify additional site characteristics that contributing to ROR crashes on curves. The overrepresentation analysis is a simplified approach used by transportation agencies and researchers (Spainhour et al., 2015; Eustace and Indupuru, 2010; Parrish et al., 2013) to analyzing characteristics (or factors) contributing to certain types crashes or fatal injuries. An overrepresentation analysis divides the data into two subsets (the control set that is of interest and the complement set that is for comparison) and compares probability (or risks) of positive outcomes between the control and complement sets. Table 5-2 lists the variables for each subset for computing an overrepresentation factor. A and C represent the number of positive and negative outcomes in the control set that is of interest; B and D represent the number of positive and negative outcomes in the complement set. A factor is considered to be overrepresented if it occurs in the control set more frequently than it does in the complement of the set. On the other hand, it is underrepresented if it occurs less frequently in the set than its complement. An overrepresentation factor (ORF) is computed as the ratio of percent of positive responses in the control set to the percent of positive response to the complement set, as shown in Equation (5-1). An ORF greater than one indicates the factor occurs more frequently in the control set (being overrepresented); thus, there is a higher probability (or risk) of a positive outcome. An ORF less than 1 means it occurs less frequently in the control set than in the complement set. For example, to examine whether or not curves with a BBI greater than 12 have a higher risk of ROR crashes, the control set contains the curves with a BBI greater than 12 and the complement set contains the remaining curves. The positive outcomes are the number of curves with ROR crashes, while the negative outcomes are the number of curves without ROR crash.

Table 5-2 Subsets in Overrepresentation Analysis

	Control Set	Complement Set
Positive (success) outcome	A	B
Negative (failure) outcome	C	D

$$Overrepresentation\ Factor\ (ORF) = \frac{R1}{R2} = \frac{\frac{A}{(A+C)}}{\frac{B}{(B+D)}} \quad (5\text{-}1)$$

where A: number of positive (success) outcomes for the control set

B: number of positive outcomes for the complement set

C: number of negative (failure) outcomes for the control set

D: number of negative outcomes for the complement set

R1: proportion of positive (success) outcomes for the control

R2: proportion of negative (failure) outcomes for the complement set

An overrepresentation analysis was conducted for BBI, radius, grade, and superelevation. Each of these four characteristics was quantitatively categorized into subgroups; the positive and negative outcomes mean the number of curves with and without ROR crashes, respectively. An ORF was computed for each of the subgroups to assess whether or not a site characteristic with a certain range(s) is associated with a higher ROR. Results are shown in Table 5-3 and discussed as follows. Davis (2014) identified several site characteristics typically considered in such studies, including curve radius, cross slope (superelevation), and vertical grade. Based on the available data from State Route 2 in Rabun and Towns Counties, the research team conducted an overrepresented analysis on these three characteristics. In addition, as the BBI values are considered as another important characteristic by GDOT, the research team also included the BBI values in the analysis. Table 5-3 shows the ORFs for the four characteristics (curve radius, superelevation, vertical grade, and BBI) and the results are discussed as follows.

Table 5-3 ORF for Site Characteristics

Site Characteristics		ORF
BBI	<4	-
	4-8	1.12
	8-12	1.14
	12-16	0.55
	>16	4.08
Curve Radius	<200	1.67
	<300	1.51
	<400	1.13
	<500	0.88
	<600	0.97
	<700	0.94
	<800	1.03
	<900	1.19
	<1000	0.76
	<1200	0.93
Vertical Grade	< -4%	1.42
	-4%~4%	0.77
	> 4%	0.95
Superelevation	2%-4%	1.28
	4%-6%	1.15
	6%-8%	1.32
	>8%	0.61

BBI:

BBI values are currently used by GDOT as the single criterion to proactively identify curves for HFST application, regardless of the crash history. BBI "measures the overturning force (side friction), measured in degrees on a vehicle negotiating a horizontal curve"(Rieker, 2017). AASHTO's Geometric Design of Highways and Streets (2004) correlates the side friction demand with the BBI values. Accordingly, a high value of BBI indicates low friction and a higher possibility of ROR crash. ORFs were computed for different ranges of BBI values (i.e., <4, 4-8, 8-12, 12-16, >16) to estimate the risks of ROR crash related to BBI values. As shown in Table 5-3, the BBI greater than 16 is overrepresented in ROR crashes on curves with a 408% ROR crash risk compared to other BBI ranges. This result indicates the higher the BBI values, the higher the risks of ROR crashes. It supports GDOT's use of a BBI value as an important threshold for qualifying a HFST. However, the actual threshold needs to be verified with a large data set.

Curve Radius:

Elvik (2013) analyzed the effect of horizontal curve radius on highway crashes for 10 countries and concluded that the number of crashes typically increases as the radius decreases; the increase is significant when the radius of curvature is below 200 m (~656 feet). Although previous studies for crash-contributing factors considered curve radius for analysis, only one study confirmed that curve radius is a significant contributing factor (Khan et al., 2013). In this study, the curve radius was examined using different curve radii ranging from 200 meters to 1600 meters. ORFs were computed for each group. As shown in Table 5-3, the ORFs tend to decrease mildly with increasing radius. A fitted regression line shows the ORFs are greater than 1 when the radii are less than 800 ft. Again, the actual threshold needs to be verified with a large data set.

Superelevation:

The superelevation was grouped into six categories (each category varied by 2% increase). ORFs were computed for each superelevation category. No significant trend can be observed in Table 5-3, which implies the superelevation cannot be used in its absolute sense as a contributory factor. It is noted that the superelevation may be correlated with other HFST-SC data, such as advisory speed and curve radius. This may also be because of the presence of site characteristics such as advisory speed and/or the alert to the curve.

Vertical Grade:

The vertical grade was categorized into three categories (significant uphill, significant downhill, and no significant uphill or downhill). Strong positive or strong negative values (greater than 4%) indicate that the curve is located on an uphill or downhill slope. Table 5-3 shows the percentage of ROR crashes by vertical grade category. It was observed that there is a noticeable trend that indicates the percentage of ROR crashes on curves with steep downhill grades increases with each 2% increase in the grade. It was observed that the percentage curves with ROR crashes decrease noticeably on uphill slopes greater than 4.5%. Such a trend could be explained based on acceleration. On an uphill steep grade, drivers tend to have a lower speed due to the uphill deceleration and drivers having to apply throttle to maintain the speed; on a downhill steep grade, drivers tend to have a higher speed due to the downhill acceleration and drivers having to brake to decelerate.

The four qualitative results based on the over-representation of the curves with ROR crashes show that the vertical grade is one potential site characteristic (besides BBI) that indicates a ROR crash-prone curve, although a full-scale analysis of data is still needed to validate that a downhill steep grade is an additional indicator. The overrepresentation analysis can be applied to examine if curves with similar site characteristics would have less risks of ROR crashes when HFST is installed.

5.2.3 Analysis of Selected Curves

It is observed from the overrepresentation analysis that the vertical grade is a significant site characteristic that may be closely related to ROR crashes on horizontal curves. Therefore, the authors further explored the CCD of all the curves in the test section to identify comparable curves that contain different vertical grades, but which have site characteristics that are similar, such as curve radius, superelevation, BBI values, etc. Two cases were identified among the 140 curves. Both cases contain two curves whose curve radii, curve lengths, cross slopes, and BBI values are comparable; however, the vertical grades are different (flat vs. steep downhill). Figure 5-6 shows the two identified cases with the respective locations of the pair of curves and the perceptions of the curves from Google Street View. The green dot represents ROR crashes. It can be observed that no ROR crash occurred on the curve with a flat vertical grade, but ROR crashes occurred on the steep downhill vertical grade when approaching the curve. Drivers on a steep, downhill grade tend to have higher speeds due to additional acceleration on the downward slope, and they must apply brakes constantly to decelerate. Downhill is constantly in an acceleration condition, leading to the higher likelihood of increasing and excessive speed unless a driver deliberately tries to reduce speed. If the driver does not brake and decrease speed properly, a dangerous situation occurs. It is also observed that both cases show a small curve radius, which implies that the presence of a steep, downhill vertical grade is likely to synergize with sharp curves to create high friction demand, which eventually leads to potentially hazardous situations.

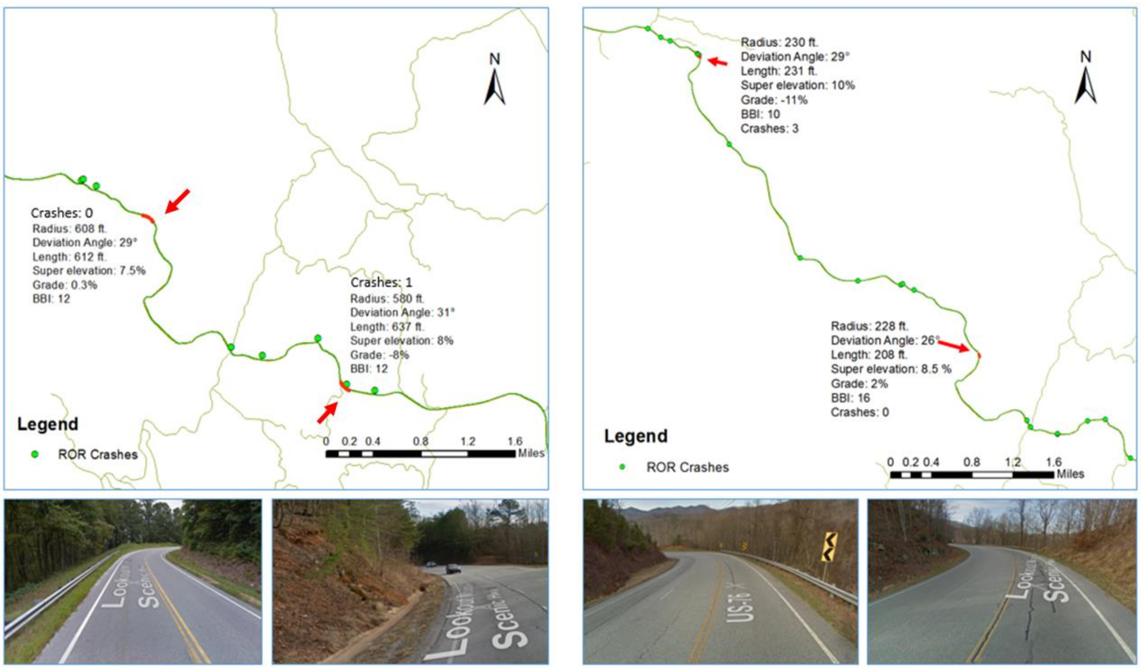


Figure 5-6 Sample curve pairs with similar site characteristics except for vertical grade

5.3. Summary

HFST is often applied at selected sites based on crash data. GDOT has adopted a proactive approach to identify curves for HFST application using BBI collected on selected segments/corridors. GDOT is partnering with Georgia Tech to identify additional site characteristics (besides BBI) that can be incorporated into its HFST-SS decision-making process to maximize its return on HFST investment by leveraging data from emerging sensing technologies. In this study, a procedure was proposed to integrate curve site characteristics data to perform curve safety analysis, and the proposed method was demonstrated by analyzing the data collected on 31 miles of State Route 2 and offers the preliminary findings. The proposed procedure consists of five steps: 1) collection of sensor data using emerging sensing technologies, 2) automatic feature extraction of the detailed, location-referenced, continuous curve characteristics data (CCD), 3) curve-based segmentation with the extracted curve information; 4) spatial integration of CCD; and 5) analysis of correlation between CCD and ROR crashes to identify additional factors for HFST site selection.

The preliminary findings show that a vertical grade greater than 4% plays an important role in ROR crashes on sharp curves when their site characteristics are comparable. Therefore, a vertical grade greater than 4% could be considered as an additional HFST site-selection decision criterion along with the current criterion (BBI value equal to or greater than 12), especially in presence of a sharp curve whose radius is small.

The following are recommendations for future research:

- Studying a larger data set using the proposed method is recommended to further confirm the preliminary findings.
- Transportation agencies can take advantage of the detailed, location-referenced continuous CCD to support various driver behavior studies and safety analyses on curves.

- The detailed, location-referenced continuous CCD collected at different times can be used to track detailed changes in CCD. For example, countermeasures, such as HFST and curve warning signs installed on each curve can be identified, and this allows safety engineers to objectively evaluate a countermeasure's effectiveness (i.e., crash reduction rate) by factoring other roadway conditions (such as superelevation and grade) to which the combined countermeasures have been applied.
- With the detailed, location-referenced, continuous CCD, transportation agencies can review and analyze safety issues on both individual curves and adjacent curves to gain an in-depth understanding of the combined CCD effects on curve safety. Since the design of the curves is based on the appropriate balancing of multiple factors, such as designed speed, curve radius, superelevation, and pavement friction, to provide sufficient resistance to safely and effectively keep a vehicle on a curve, engineers can simultaneously assess the multiple factors to proactively and systematically identify curves with safety issues.

6. CONCLUSIONS AND RECOMMENDATIONS

The high friction surface treatment (HFST) has proven to be an effective means to improve pavement friction on curved roadways to reduce run-off-road (ROR) crashes. The Georgia Department of Transportation (GDOT) has invested millions of dollars in HFST and will continue investing more reduce potential run-off-road (ROR) crashes on sharp curves. Thus, GDOT has partnered with Georgia Tech to enhance its HFST program. This project has three objectives: 1) develop an enhanced HFST site selection (HFST-SS) method to maximize the return on investment; 2) collect detailed-level and location-referenced HSFT site characteristics (HFST-SC) data (including curve radius, superelevation, vertical grade, posted speed, etc.) before and after HFST installation by using emerging sensing technologies (including 2D imaging, 3D LiDAR, GPS/GIS technologies) to support subsequent studies of Georgia-specific HFST crash modification factors and calculation of HFST's return on investment; and 3) conduct a preliminary study using collected HFST-SC data to identify the detailed site characteristics data, in addition to Ball Bank Indicator (BBI) values, that impact the ROR crash rate. This project leverages the outcomes, including automatic curve identification and sign detection, from previous research projects (including DTOS59-10-H-00003, RP 12-10, and RP 15-05) for detailed, location-referenced HFST-SC data collection. The outcomes of this study are summarized as follows:

- A comprehensive literature review of existing HFST site-selection practices of state and local transportation agencies was conducted to identify the HFST site-selection criteria. The most common data used to screen and prioritize sites for HFST are crash data, especially ROR crashes; site characteristic data is rarely used due to its lack of availability. The most common criteria are the crash frequency, the severity, and, sometimes, the number of fatalities. Some agencies, like the Kentucky Transportation Cabinet (KYTC), heavily consider pavement conditions, such as wet pavements.

- An enhanced HFST-SS method was developed to enable GDOT engineers to systematically, proactively, and flexibly identify and select HFST sites. The developed method consists of three steps: 1) analyze crash data by pavement segments, 2) prioritize and select segments/corridors for HFST application using the proposed criteria, which balances crash frequency, severity ratio, and wet crash conditions, and 3) select curve sites for HFST application by evaluating the site characteristics of the curves using BBI values.
    - The developed method provides a systematic procedure that uses step-by-step procedures to process and analyze crash data, including crash frequency, severity, and wet pavements, to identify curve sites for HFST application. The developed method, also, proactively evaluates the site characteristics of the curves, using BBI values to indirectly evaluate the roadway characteristics, including curvature, superelevation, and friction.
    - A case study using historical crash data in GDOT's District 1 was conducted to demonstrate the capability of the developed HFST-SS method. Results show the proposed prioritization criteria, in comparison to the count-based selection criteria, is able to determine the highest number of fatalities and serious injuries for the selected HFST segments. Transportation agencies can adjust the weights they apply to the prioritization criteria (crash frequency,

severity ratio, and wet crashes) based on their specific focus, such as reducing the number of crashes or reducing the number of fatalities/injuries.

- A procedure, including a relational database and an HFST report card (HFST-RC), was developed for collecting, processing, storing, integrating, reporting, and analyzing the detailed, location-referenced HFST-Site Characteristics (HFST-SC) data. The before data were collected using emerging sensing technologies, including 2D imaging, lasers, 3D LiDAR, inertial measurement units (IMU), and global positioning system (GPS) technologies, to support the studies of Georgia-specific HFST crash reduction factors and calculation of return on investment. Currently, the after data, including sign locations and HFST sites, are based on the information in the let package (PI#0009993).
    - A relational database was designed to store and integrate the detailed, location-referenced HFST-SC data, which are categorized into the following: 1) geometry property, including curve location, curve radius, superelevation, vertical grade, etc., 2) countermeasure property, including the presence (i.e., location or x-y coordinate) of various countermeasures, such as advanced curve warning signs, advisory speed signs, chevrons, etc., 3) roadway property, including posted speed, lane width, BBI values, and pavement friction (if available), and 4) traffic condition, including traffic and truck volume. In addition, an HFST-RC was developed to provide a means of integrating and reporting/visualizing all location-referenced information on each HFST curve site so these site characteristics can be visualized and used to support studies of Georgia-specific HFST crash reduction factors and

calculation of HSFT's return on investment. The changes of the HFST-SC before and after HFST installation can, also, be identified to objectively evaluate the effectiveness of different curve treatments.

  - A case study on State Route 2 using data collected by the Georgia Tech Sensing Van (GTSV) was conducted to demonstrate the capability of using the collected sensing data and the developed HFST-RC to obtain the detailed-level and location-referenced HFST-SC data and to effectively integrate and visualize this data for subsequent analyses. The GTSV was used to collect the sensor data on the approximately 31 miles of roadway on State Route 2 in Rabun and Towns Counties. Its curves have radii ranging between 183 ft. and 3235 ft., deflection angles between 3.0° and 63.0°, superelevations between 2.0% and 14.0%, and grades between -8.8% and 11.0%.

- A method was proposed to identify site characteristics that can be used in GDOT's HFST-SS process by leveraging the detailed, location-referenced site characteristic data collected using sensor data. A case study using data on State Route 2 was conducted to demonstrate the proposed method. Results show that a vertical grade greater than 4% plays an important role in ROR crashes on sharp curves when their site characteristics are comparable. Therefore, a vertical grade greater than 4% could be considered as an additional HFST site-selection decision criterion along with the current criterion (a BBI value equal to or greater than 12), especially in the presence of a sharp curve whose radius is less than 800 ft. Certainly, additional study with a large data set is recommended to support the preliminary findings.

The implementation of research outcomes are presented as follows:

- Training on the enhanced HFST-SS method is recommended at the district level to implement a systematic, proactive, and cost-effective HFST site-selection method.
- It is recommended that GDOT develop a statewide curve inventory (including curve location, curve radius, PC, and PT) so that the crashes can be clustered inside the curves rather than segments for more adequately selecting curves for HFST.
- To better support subsequent studies of Georgia-specific HFST crash reduction factors and calculation of HSFT's ROI, it is recommended that an HFST-SC inventory (such as curve radius, superelevation, vertical grade, posted speed, etc.) before and after HFST installation on new and incoming HFST curve sites be established using the developed procedure and the GTSV.
- It is recommended that the optimal segment size and segmentation method be studied to further improve the HFST-SS method. It is also recommended that the optimal values for the parameters (i.e., β in the prioritization strategy and various severity weights) in the segment prioritization and selection step be further studied.

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APPENDIX A HFST SITE SELECTION METHODS

Kentucky Transportation Cabinet (KYTC)

The Kentucky Transportation Cabinet (KYTC) has developed its own process for identifying potential HFST sites, using crash data analysis since 2009. KYTC first installed HFST in 2009 at two sites that had experienced a high number of road departure crashes (Julian and Moler, 2008; Moravec, 2013; Sheehan, 2015) and immediately observed a significant reduction in crashes on the sites. Thus, in late 2009, KYTC conducted a crash data analysis that identified 30 crash sites that could benefit from HFST. Within the same time frame, KYTC, in collaboration with FHWA, developed the Roadway Departure Safety Implementation Plan (RwDIP), which included a refined process for identifying potential HFST sites based on crash data. According to KYTC (Quintus and Mergenmeier, 2015), the process "*was designed to find sections that had a high probability of realizing benefits (i.e., crash reductions) in a short time frame as a means of continuing to gain support from KYTC personnel. Thus, it was a reactive type screening process*." Currently, KYTC is transitioning to a predictive approach using a safety performance function to predict crashes where there has been no treatment.

KYTC initially used 3-year roadway departure crash data on curves on two-lane, two-way rural state routes and ramps to identify the 30 sites in 2009. KYTC defined roadway departure crashes as single-vehicle, non-intersection, non-parking lot, non-private property, fixed object, non-fixed object, overturn/rollover, run off road left/right/straight, head-on, and sideswipe/opposite direction (Quintus and Mergenmeier, 2015). The roadway departure crashes were further categorized into wet- and dry-pavement crashes, and sites with a wet-to-dry crash ratio greater than 50 percent (0.5) were identified as priority sites for HFST.

In RwDIP, the roadways were segmented into 3000-ft sections, and 4-year roadway departure crash data (2004-2008) were summarized for each segment. The criteria for identifying priority sites for HFST were a minimum of 8 wet-pavement crashes and a wet-to-total crash ratio greater than 0.35. According to KYTC (Quintus and Mergenmeier, 2015): *"8 was selected due to data showing high return on investment,"* and its analysis shows the wet-to-total crash ratio of 0.35, which represented the targeted number of sections within the available funds dedicated to this countermeasure over a span of 5 years. Based on the criteria, 227 candidate sites were identified for HFST application. However, it is suggested that the wet-to-total crash ratio may significantly vary among different agencies depending on the available funding, agency goals, and number of roadway crashes.

KYTC is currently moving towards using the effectiveness (or benefit) of countermeasure to identify candidate sites for HFST. The effectiveness is approximated by estimated crash reduction, which is computed as the differences between the predicted number of crashes of a site in the same period of time under one of two conditions: with or without HFST. Safety performance functions were developed using the Empirical Bayes methodology to predict the number of wet-pavement crashes and serious wet-pavement crashes (fatal, incapacitating, and evident injuries) that would have occurred at an individual site if the after period had been treated or not (Srinivasan and Bauer, 2013).

After the candidate sites are identified, KYTC conducts a field site assessment to determine whether or not HFST is an appropriate treatment for the given site characteristics. Factors considered in the field assessment include but are not limited to the following:

- Geometry: superelevation, driveways, sight distances;
- Pavement condition: existing pavement condition has expected life of greater than about 3 years, drainage, ponding water conditions;
- Other: coordinate future, planned work on road section by the district, HFST treatment for one or both directions of the road, HFST limits, and constructability. (Quintus and Mergenmeier, 2005).

Texas Department of Transportation (TxDOT)

TxDOT, in collaboration with the Texas A&M University and the Texas Transportation Institute (TTI), has recently developed a Texas Curve Margin of Safety (TCMS) tool to assess countermeasures, including HFST, superelevation correction, etc., on each horizontal curve to maximize the benefit of safety improvement. Instead of crash data, the TCMS uses the "margin of safety" to determine the severity category, which is then used to suggest potential countermeasures (Pratt et al., 2014). The margin of safety is defined as the difference between the friction demand and the friction supply, that is, the friction insufficiency on the pavement. TCMS computes the friction demand (f_D) at the point of curvature (PC), midpoint (MC), and point of tangent (PT) based on radius on the curve (Rp,), vertical grade (G), superelevation (e), and the 85th percentile vehicle speed (v) at these locations. The equation for computing friction demand is shown below:

$$f_D = \frac{v^2}{gR_p}\cos\left(\frac{e}{100}\right) - \sin\left(\frac{e}{100}\right)\cos G$$

The 85th percentile vehicle speed is predicted using speed and travel distribution models developed using the data from 458 representative curve sites that are spread across Texas. The friction demand is then compared to the existing pavement friction values (skid number) at these points to calculate the margin of safety (Pratt et al., 2014). It is noted that this tool relies heavily on detailed, comprehensive roadway geometry data, and friction data.

The margin of safety is combined with other guidelines for selecting the countermeasures. Bonneson et al. (2007) categorized the margin of safety into five severity categories, and suggested safety countermeasures based on advisory speed and severity category. Figure A-1 shows the warning signs, delineation devices, and special treatments suggested based on advisory speed and severity category. For example, special treatments, such as oversize advance warning signs and profiled pavement markings, are suggested for severity category "E," regardless of speeds. In addition, it is recommended that the margin of safety be at least 0.08-0.12 along the entire length of the curve (Glennon and Weaver, 1971). Safety engineers may use other outputs (such as predicted crashes) to evaluate if a curve site needs HFST or not.

Advisory Speed, mph	Device Type	Device Name	Device Number	Severity Category (Friction Differential, *g*)				
				A (0.00)	B (0.03)	C (0.08)	D (0.13)	E (0.16)
35 mph or more	Warning Signs	Curve, Reverse Curve, Winding Road, Hairpin Curve [a]	W1-2, W1-4, W1-5, W1-11	✓	✓	✓	✓	✓
		Advisory Speed plaque	W13-1		✓	✓	✓	✓
		Combination Curve/ Advisory Speed	W1-2a			✓	✓	✓
		Chevrons [b]	W1-8				✓	✓
30 mph or less	Warning Signs	Turn, Reverse Turn, Winding Road, Hairpin Curve [a]	W1-1, W1-3, W1-5, W1-11	✓	✓	✓	✓	✓
		Advisory Speed plaque	W13-1		✓	✓	✓	✓
		Combination Turn/ Advisory Speed	W1-1a			✓	✓	✓
		Large Arrow sign	W1-6				✓	✓
Any	Delineation Devices	Raised pavement markers		✓	✓	✓	✓	✓
		Delineators [c]				✓	✓	✓
	Special Treatments [d]							✓

Notes:

a–Use the Curve, Reverse Curve, Turn, Reverse Turn, or Winding Road sign if the deflection angle is less than 135 degrees. Use the Hairpin Curve sign if the deflection angle is 135 degrees or more.

b–A Large Arrow sign may be used on curves where roadside obstacles prevent the installation of Chevrons.

c–Delineators do not need to be used if Chevrons are used.

d–Special treatments could include oversize advance warning signs, flashers added to advance warning signs, wider edgelines, and profiled pavement markings.

Figure A-1 Curve severity categories and recommended countermeasures (Pratt et al., 2014)

Georgia Department of Transportation (GDOT)

GDOT has developed a two-step procedure using crash data and BBI values to proactively identify curve sites that can benefit from HFST installation. The two steps, corridor selection, and BBI-based site selection were designed to incorporate GDOT's unique considerations for HFST application. First, GDOT considers the application of HFST on the sites along a corridor that can reduce the mobilization cost and result in a lower unit cost for HFST application. Thus, the first step is to select candidate corridors. Second, GDOT uses BBI values to identify sites that may be prone to ROR crashes because of their site characteristics, regardless of the crash history. The two steps are described as follows:

Step 1 - Corridor Selection

A corridor is defined as a section of roadway identified by a unique RCLINK, which is composed of county, route type, route number, and route suffix. In this step, GDOT divides corridors into segments, prioritizes segments using a severity index computed using ROR crashes injury levels; it selects the corridors with high severity segments. GDOT uses 3 years of ROR crash data to select corridors; here, a ROR crash is defined as a single vehicle roadway departure (i.e., the location of the crashed vehicle is off the road) crash. ROR crashes are first geo-referenced and matched to each corridor. Corridors are then segmented using a sliding window technique with a 5-mile fixed window. A fixed window of 5 miles is moved along the corridor, and when the window encompasses a minimum of 5 ROR crashes, the window is converted into a segment whose starting and ending points are defined by the limits of the window. This process is continued until the end of the corridor is reached.

A severity index defined in GDOT's Top 150 Sections (GDOT, 1980; Tsai et al., 2011) is computed for each segment. The severity index represents the average damage (in terms of fatality and serious injury with different weights) resulting from the total number of crashes and is computed as follows:

Severity Index =

(10 # of fatal ROR crashes + 6* # of serious injury ROR crashes) *10 / # of ROR crashes*

The segments are ranked by severity index, and the corridors that contain segments with high a severity index are then selected for further analysis. Note that the corridors with at least one segment and a severity index greater than 40 were selected in District 1 for further BBI-based site selection.

Step 2 – BBI-based site selection

Ball bank indicator (BBI) values represent the combination of superelevation, unbalanced lateral acceleration (i.e., side friction), and vehicle body roll (Carlson et al., 2005; Carlson and Mason, 1999) and are used as a composite safety indicator by transportation agencies. GDOT collects BBI values on every curve along the selected corridor using a Rieker BBI device. The maximum BBI is recorded for each curve by watching BBI values while driving a car at the posted speed through the curve. The curves with a BBI value greater than or equal to 12 are then identified for HFST installation. FHWA (2009) recommends that the BBI value is used for setting advisory speeds based on "driver discomfort" due to lateral acceleration, and 12 degrees of BBI is used for speeds of 35 mph and higher. Thus, a threshold value of 12 is used for identifying sites for HFST. It is noted that GDOT recommends all the curves with BBI values of 12 or more within the selected corridor for HFST installation, even though not all the curves within the corridor are top-ranked with high total ROR crash counts and/or more severe crashes. Such an approach could proactively identify some curves that may be prone to ROR crashes but have not reported any ROR crashes in the historical crash data.

The research team recognizes the value of such a proactive approach in Step 2 of the current BBI-based site selection. Therefore, the research team proposed an enhanced

HFST site selection method that takes advantage of the proactive strategy in Step 2 and improves the current corridor selection approach in Step 1.

Nevada County and Placer County, California

Local agencies, such as Placer County and Nevada County in California, have also developed their own HFST-SS methods based on crash data analysis. They focus on curves with high ROR crashes on rural, two-lane, undivided roadways. The severity of the crashes is also taken into the consideration. The following steps present the flow of the HFST site-selection process in Nevada County and Placer County.

- Step 1 – Serious Crash Mapping. This step is to geo-reference crashes and display them on a GIS map. Nevada and Placer Counties use the crash data collected between 2004 and 2010 and between 2003 and 2012, respectively. While fatal and severe injury crashes on major roadways were mapped by Nevada County, fatal, severe, and visible injury ROR crashes were mapped by the Placer County.
- Step 2 – Chronic Crash Location Identification. This step is to identify the locations where crashes occur repeatedly, regardless of the applications of different countermeasures, e.g., signing, striping, etc. These locations are identified based on the synthesis of the map generated from the Step 1 and the opinions of safety engineers and local law enforcement.
- Step 3 – HFST Checklist for Locals. This step is to determine a score for each location identified in Step 2 based on the site characteristics, including pavement condition, roadside hazards, type of crashes, posted speed, roadway characteristics, weather conditions, and primary collision factors. Table A-1shows the scores for each

site characteristic. For example, a location on a tangent, vertical curve, and horizontal curve (or intersection) will have a score of 0, 1, and 2, respectively. For each site, the sum of the scores will be used for HFST recommendation. The site with a score of less than 20 is not recommended for HFST. A site with a score between 21 and 35 is considered for HFST, while a site with a score greater than 36 is highly recommended for HFST.

Table A-1 The HFST checklist for locals

Pavement Condition	**Roadway Characteristics**
- Open/Gap Graded (1) - Dense Graded (2) - Pavement overlay < 3 years (2) - Pavement overlay > 3 years (4)	- Tangent (0) - Vertical Curve (1) - Horizontal Curve/Intersection (3)
Roadside Hazards	**Weather Conditions**
- Adequate Clear Recovery Area (0) - Embankment > 6:1 (2) - Trees/Utility Poles/Fixed Objects/Water (3)	- Dry (0) - Wet (2) - Icy (3)
Types of Crashes (add for each crash)	**Primary Collision Factor (add for each crash)**
- PDO (2) - Injury (4) - Fatal (6)	- Rear-ender (1) - Unsafe Speed (2) - Improper turning (overcorrecting) (2)
Posted Speed	**< 20 HFST not recommended** **21 - 35 HFST considered** **>36 HFST highly recommended**
- < 50 mph (0) - > 50 mph (3)	

- Step 4 – Benefit/Cost (B/C) Analysis. In this step, the B/C ratio is calculated to provide a quantitative measure for prioritizing HFST candidate sites while optimizing the return on investment. The benefits (i.e. reduction in fatality and injuries) are expressed in monetary terms and compared to the cost of implementing HFST. Nevada County and Placer County are currently calibrating the B/C calculation to gain a more reliable and consistent justification.

Thurston County, Washington

Thurston County, Washington, has used its HFST-SS method since 2013 (Davis, 2014); it uses seven steps, including network data collection, target crash type selection, critical facility type selection, candidate site selection, risk factor identification, risk factor analysis, and site rankings. Thurston County focuses on roadway departure crashes on horizontal curves on its arterial and collector roads because 43 % of its fatal and serious injury crashes occur on them. After the network data is collected (i.e. 5-year historical crash data between 2006 and 2010), Thurston County identified horizontal curve-related crashes using wet/icy surface conditions and skidding/out of control driver actions. The facility types, namely the arterial and collector roads, were identified as the critical facility types because 90% of the county's severe crashes occur on these facility types.

For each 0.2-mile section, if there are more than three crashes in the section, the site will be recorded as a candidate site for potential HFST. A risk score is computed for each candidate site to rank/prioritize the sites. The risk score is a simple scoring system used to rank the candidate sites and is calculated from the risk factors identified. The risk factors are those factors that contribute to a crash. The following are the risk factors considered by Thurston County: speed limit, roadway classification, the presence of intersections, roadway geometry, traffic volume, traffic control type, shoulder type, shoulder width, etc. (Davis, 2014).

Under the risk factor analysis step, two primary considerations are used to determine the confidence level of the critical risk factors, including the crash "over-representation" and the percentage of fatal/serious crashes. Accordingly, Thurston County identifies the risk factors with high confidence as those including a posted speed of 50mph, traffic volume between 5,000 and 8,000 per day, and the presence of horizontal curves, whereas the risk factors with low confidence include a paved shoulder of 4ft. and 8ft., a native shoulder of

2ft., 3ft., 7ft. or 8ft., a traffic volume ranging between 3,000 and 5,000 vehicles per day, and a horizontal curve on a grade. If the critical value (e.g. 50 mph) of the risk factor (e.g. speed limit) is over-represented and contains a high percentage of fatal and serious injuries, a risk score of 1 is assigned to the candidate site; if the risk factor of a particular value is over-represented and contains a lower percentage of fatal and serious injuries, a risk score of 0.5 is assigned to the candidate site. Finally, the candidate site with the highest score will be selected as the site for HFST.

Department of Transport, United Kingdom

The Department of Transport in the United Kingdom (UK) has been applying HFST (or, Anti-Skid Road Surfacing Treatment) since the 1980s. The Department of Transport considers the use of HFST based on site category, investigatory level (IL), and traffic to enhance safety and reduce accidents at sites, as shown in Table A-2 (RSTA, 2011). Note that, in addition to curves (with a radius tighter than 500m on single carriageways), the following site categories are also considered for HFST application:

- Approaches to major junctions;
- Approaches to pedestrian crossings at which pedestrians or other vulnerable road users may misjudge the speed of the traffic, such as near schools or where children cross, near public houses, or where the approach speed is high;
- Sites with gradients steeper than 10% if other hazards are present;

According to the *Design Manual for Road and Bridges* (RSTA, 2011), a site is first categorized into one of the ten site categories, as shown in Table A-2, based on their general characteristics; then, investigatory levels (IL) are determined based on site category. IL represents the skid resistance limit “above which the skid resistance is considered to be satisfactory but at or below which the road is judged to require an investigation of the skid resistance requirements” (RSTA, 2011). Sites with the same site category may have different ILs. The required polished stone value (PSV), which provides a measure of the resistance to skidding, is then specified based on traffic. HFST is recommended for the sites where the PSV requirement exceeds 70 (Robinson, 2013). Table A-1 shows HFST is recommended for a pedestrian crossing with a traffic count greater than 3000 (per lane per day). Also, a site with a gradient greater than 5% would need HFST when the IL is 0.55 and traffic is greater than 250. It is noted that instead of crash data, the PSV requirement, which is determined based on site category, IL, and traffic, is used for identifying HFST sites.

Table A-2 Minimum PSV of Chippings, or Coarse Aggregate in Unchipped Surfaces, for New Surface Courses (RSTA, 2011)

Site category	Site description	IL	Minimum PSV required for given IL, traffic level and type of site — Traffic (cv/lane/day) at design life									
			0-250	251-500	501-750	751-1000	1001-2000	2001-3000	3001-4000	4001-5000	5001-6000	Over 6000
A1	Motorways where traffic is generally free-flowing on a relatively straight line	0.30	50	50	50	50	50	55	55	60	65	65
		0.35	50	50	50	50	50	60	60	60	65	65
A2	Motorways where some braking regularly occurs (eg. on 300m approach to an off-slip)	0.35	50	50	50	55	55	60	60	65	65	65
B1	Dual carriageways where traffic is generally free-flowing on a relatively straight line	0.3	50	50	50	50	50	55	55	60	65	65
		0.35	50	50	50	50	50	60	60	60	65	65
		0.4	50	50	50	55	60	65	65	65	65	68+
B2	Dual carriageways where some braking regularly occurs (eg. on 300m approach to an off-slip)	0.35	50	50	50	55	55	60	60	65	65	65
		0.4	55	60	60	65	65	68+	68+	68+	68+	68+
C	Single carriageways where traffic is generally free-flowing on a relatively straight line	0.35	50	50	50	55	55	60	60	65	65	65
		0.4	55	60	60	65	65	68+	68+	68+	68+	68+
		0.45	60	60	65	65	68+	68+	68+	68+	68+	68+
G1/G2	Gradients >5% longer than 50m as per HD 28	0.45	55	60	60	65	65	68+	68+	68+	68+	HFS
		0.5	60	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
		0.55	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
K	Approaches to pedestrian crossings and other high risk situations	0.5	65	65	65	68+	68+	68+	HFS	HFS	HFS	HFS
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
Q	Approaches to major and minor junctions on dual carriageways and single carriageways where frequent or sudden braking occurs but in a generally straight line.	0.45	60	65	65	68+	68+	68+	68+	68+	68+	HFS
		0.5	65	65	65	68+	68+	68+	HFS	HFS	HFS	HFS
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
R	Roundabout circulation areas	0.45	50	55	60	60	65	65	68+	68+	HFS	HFS
		0.5	68+	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
S1/S2	Bends (radius <500m) on all types of road, including motorway link roads; other hazards that require combined braking and cornering	0.45	50	55	60	60	65	65	68+	68+	HFS	HFS
		0.5	68+	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
		0.55	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS

Notes:

1. Site categories are grouped according to their general character and traffic behaviour. The Investigatory Levels (IL) for specific categories of site are defined in HD 28 (DMRB 7.3.1). The IL to be used here must be that which has been allocated to the specific site on which the material is to be laid, as determined by following the procedures in HD 28.
2. Motorway or dual carriageway slip roads may fit in a number of groups depending on their layout. For example, a free-flowing section close to the main line would be in Group 1 whereas the end of an off-slip approaching a give way line or the point at which a queue develops would be in Group 3. Some slip roads with gradients may be in Group 4. Use the most appropriate Group depending upon the Site Category from HD 28 that was used to determine the IL.
3. Where '68+' material is listed in this Table, none of the three most recent results from consecutive PSV tests relating to the aggregate to be supplied must fall below 68. See paragraph 3.21.
4. Throughout this Table, HFS means specialised high friction surfacing, incorporating calcined bauxite aggregate and conforming to Clause 924 of the Specification (MCHW 1) will be required. Where HFS is required on the approaches to a hazard, the minimum treatment length must be 50m. This may be extended where queuing traffic or sightlines indicate that 50m may not be sufficiently long.
5. For site categories G1/G2, S1/S2 and R any PSV in the range given for each traffic level may be used for any IL and should be chosen on the basis of local experience of material performance. In the absence of this information, the values given for the appropriate IL and traffic level must be used.
6. Where designers are knowledgeable or have other experience of particular site conditions, an alternative psv value can be specified.

APPENDIX B CURVE INFORMATION

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#1	2811000200	14.248	14.310	877	11	6.53	326	1	7	0.6	None	9	45	N/A
#2	2811000200	14.676	14.803	1158	17	4.95	667	-1	5.5	4.8	W1-2	5	45	N/A
#3	2811000200	14.985	15.084	721	20	7.95	510	-1	9	-5.4	W13-1P(25), W1-4	6	45	25
#4	2811000200	15.141	15.231	459	29	12.49	464	1	11	0.9	W13-1P(25), W1-4, W1-8	8	45	25
#5	2811000200	15.769	15.883	1992	9	2.88	599	-1	3	-5.0	None	5	45	N/A
#6	2811000200	15.952	16.114	718	34	7.98	848	1	11	-0.2	W1-4	6	45	N/A
#7	2811000200	16.200	16.340	571	37	10.03	743	-1	12	7.3	W1-4	8	45	N/A
#8	2811000200	16.474	16.564	646	21	8.87	472	-1	11.5	-1.8	None	8	45	N/A
#9	2811000200	16.582	16.707	997	19	5.75	650	1	7	-3.8	W1-2	6	45	N/A
#10	2811000200	16.882	16.989	728	22	7.87	562	1	12	-0.4	None	9	45	N/A
#11	2811000200	17.112	17.222	410	42	13.96	592	1	14	4.4	None	9	45	N/A
#12	2811000200	17.226	17.322	404	37	14.17	518	-1	12	5.1	None	10	45	N/A
#13	2811000200	17.326	17.410	934	14	6.13	442	-1	10	1.6	None	9	45	N/A
#14	2811000200	17.412	17.660	1448	26	3.96	1319	1	7	-1.7	None	5	45	N/A
#15	2811000200	17.890	18.030	1808	12	3.17	747	1	7	-5.7	W13-1P(45)	5	45	N/A
#16	2811000200	18.259	18.360	2296	7	2.50	531	-1	3.5	0.6	None	6	45	N/A
#17	2811000200	18.523	18.626	1058	14	5.41	531	-1	7	-0.8	None	7	45	N/A
#18	2811000200	18.745	18.832	1193	11	4.80	473	1	7	0.8	None	5	45	N/A
#19	2811000200	18.920	19.010	1107	12	5.18	473	1	7	4.0	W13-1P(35), W1-5	7	35	30

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#20	2811000200	19.054	19.152	1033	14	5.55	517	-1	7	6.4	W13-1P(35), W1-5	7	35	30
#21	2811000200	19.165	19.253	657	21	8.73	475	1	9	6.9	W13-1P(35), W1-5	5	35	30
#22	2811000200	19.265	19.345	407	30	14.07	425	-1	13	8.0	W13-1P(35), W1-5	8	35	30
#23	2811000200	19.356	19.403	325	22	17.62	249	1	8.5	10.7	W13-1P(35), W1-5	11	45	35
#24	2811000200	19.505	19.547	230	29	24.87	231	1	10.5	11.1	None	10	45	N/A
#25	2811000200	19.551	19.638	521	26	11.00	468	1	13.5	6.4	None	5	45	N/A
#26	2811000200	19.714	19.786	326	34	17.59	382	-1	11	4.4	None	15	45	35
#27	2811000200	19.811	19.881	420	26	13.64	374	1	11	4.6	W13-1P(35), W1-5	14	35	N/A
#28	2811000200	19.894	19.945	1028	7	5.57	265	-1	5	2.1	W13-1P(35), W1-5	5	45	N/A
#29	2811000200	20.032	20.157	1476	13	3.88	658	-1	4.5	4.5	W1-2	5	45	N/A
#30	2811000200	20.317	20.402	935	14	6.13	442	-1	10	4.5	W1-4	6	N/A	N/A
#31	2811000200	20.410	20.496	595	21	9.63	444	1	11	5.5	W1-4	8	N/A	N/A
#32	2411000200	0.053	0.166	811	21	7.07	591	1	7	-5.9	W1-5	12	45	N/A
#33	2411000200	0.183	0.263	588	20	9.75	421	-1	9.5	-5.9	W1-5	10	45	N/A
#34	2411000200	0.369	0.492	714	26	8.02	650	1	8	-5.8	W1-5	11	45	N/A
#35	2411000200	0.721	0.808	940	14	6.09	462	-1	7.5	-4.4	None	9	45	N/A

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#36	2411000200	0.928	1.043	959	18	5.97	611	1	6.5	3.6	None	13	45	N/A
#37	2411000200	1.254	1.350	680	21	8.42	500	-1	8	5.3	W13-1P(35), W1-2	14	45	35
#38	2411000200	1.352	1.387	531	10	10.78	186	-1	8.5	5.1	W13-1P(35), W1-2	13	45	35
#39	2411000200	1.452	1.549	593	25	9.66	511	1	6	7.5	W13-1P(35), W1-4	10	45	35
#40	2411000200	1.651	1.832	1549	17	3.70	943	-1	8	2.9	W13-1P(35), W1-4	8	45	35
#41	2411000200	1.936	2.102	3235	8	1.77	874	-1	5	1.0	W1-2	4	45	N/A
#42	2411000200	2.215	2.285	463	24	12.37	380	1	9	-2.3	W13-1P(25), W1-5	13	45	25
#43	2411000200	2.366	2.419	455	18	12.59	284	-1	6.5	-1.0	W13-1P(25), W1-5	16	45	25
#44	2411000200	2.427	2.488	426	22	13.44	326	1	6.5	-4.7	W13-1P(25), W1-5	17	45	25
#45	2411000200	2.498	2.561	443	22	12.92	333	-1	9	-5.5	W13-1P(25), W1-5	17	45	25
#46	2411000200	2.572	2.677	1635	10	3.50	552	1	8	-5.8	W13-1P(25), W1-5	7	45	25
#47	2411000200	2.688	2.742	365	22	15.69	274	-1	11	-6.8	W13-1P(35), W1-5	11	45	35

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#48	2411000200	2.749	2.798	610	12	9.39	247	1	10	-6.0	W13-1P(35), W1-5	8	45	35
#49	2411000200	2.798	2.867	1402	7	4.09	354	1	8.5	-4.3	W13-1P(35), W1-5	9	45	35
#50	2411000200	2.867	2.898	469	10	12.22	156	-1	8	-5.0	W13-1P(35), W1-5	11	45	35
#51	2411000200	3.023	3.137	608	29	9.43	612	1	7.5	0.3	W13-1P(30), W1-5	12	45	30
#52	2411000200	3.141	3.229	351	39	16.35	475	1	7.5	0.6	W13-1P(30), W1-5	16	45	30
#53	2411000200	3.232	3.297	497	20	11.54	343	-1	6.5	0.2	W13-1P(30), W1-5	12	45	30
#54	2411000200	3.422	3.475	1043	8	5.49	277	-1	8	0.5	None	6	45	30
#55	2411000200	3.475	3.538	1117	8	5.13	324	-1	7.5	-0.8	None	16	45	30
#56	2411000200	3.538	3.579	228	26	25.15	208	1	8.5	-2.3	None	16	45	30
#57	2411000200	3.673	3.701	343	13	16.69	158	1	7	-7.7	None	15	45	N/A
#58	2411000200	3.812	3.887	480	24	11.94	405	1	6.5	-5.9	W13-1P(35), W1-5	13	45	35
#59	2411000200	3.891	3.968	195	63	29.31	419	-1	9	-3.5	W13-1P(35), W1-5	21	45	35
#60	2411000200	4.363	4.435	358	30	16.02	373	-1	11.5	2.0	W13-1P(35), W1-2	11	45	35

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#61	2411000200	4.498	4.547	302	25	18.99	264	-1	9.5	0.3	None	13	45	N/A
#62	2411000200	4.550	4.604	724	11	7.91	286	1	4	-4.6	None	9	45	N/A
#63	2411000200	4.714	4.822	493	33	11.61	571	1	7	-7.5	None	14	45	N/A
#64	2411000200	4.949	5.031	350	35	16.36	431	-1	8.5	4.0	W1-4	12	45	N/A
#65	2411000200	5.032	5.120	774	17	7.40	470	1	6	7.1	W1-4	9	45	N/A
#66	2411000200	5.192	5.258	1448	7	3.96	345	-1	6	5.2	None	3	45	N/A
#67	2411000200	5.330	5.381	625	12	9.17	268	-1	9	5.4	None	6	45	N/A
#68	2411000200	5.435	5.499	485	19	11.81	327	-1	9	2.5	None	14	45	N/A
#69	2411000200	5.506	5.596	915	15	6.27	464	1	9	-3.0	None	10	45	N/A
#70	2411000200	5.734	5.790	206	42	27.82	298	1	14	-4.8	None	16	45	N/A
#71	2411000200	5.800	5.887	514	26	11.15	461	-1	8	-4.8	W1-10d	12	45	N/A
#72	2411000200	5.896	5.973	451	26	12.69	414	1	9.5	-5.2	W1-10d	13	45	N/A
#73	2411000200	5.988	6.096	1355	12	4.23	561	1	6	-4.7	W1-10d	5	45	N/A
#74	2411000200	6.148	6.270	580	31	9.88	637	-1	8	-8.2	None	12	45	N/A
#75	2411000200	6.465	6.599	1414	14	4.05	706	-1	7	-8.8	None	7	45	N/A
#76	2411000200	6.632	6.727	501	28	11.43	493	1	9	-6.9	None	12	55	N/A
#77	2411000200	6.900	7.047	928	24	6.18	766	-1	7.5	2.2	None	6	55	N/A
#78	2411000200	7.647	7.775	975	19	5.88	663	1	8.5	5.1	None	4	55	N/A
#79	2411000200	7.901	8.098	1008	30	5.68	1040	1	8	1.8	None	5	55	N/A
#80	2411000200	8.238	8.564	1151	43	4.98	1719	-1	8.5	-5.1	None	8	55	N/A
#81	2411000200	8.644	8.746	602	26	9.52	553	1	9.5	-5.9	None	8	55	N/A
#82	2411000200	8.758	8.832	995	11	5.76	392	-1	4	-6.6	W13-1P(45)	7	55	45

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#83	2411000200	8.882	8.953	579	18	9.89	363	-1	6	0.7	W1-8#4	11	55	N/A
#84	2411000200	9.051	9.087	2041	3	2.81	197	1	6	5.1	None	2	55	N/A
#85	2411000200	9.318	9.420	2348	6	2.44	531	1	7.5	2.7	None	3	55	N/A
#86	2411000200	9.435	9.536	1489	10	3.85	530	-1	4.5	4.2	None	5	55	N/A
#87	2411000200	9.933	10.035	955	16	6.00	533	1	7.5	-1.8	W1-2	6	55	N/A
#88	2411000200	10.253	10.313	1204	8	4.76	324	-1	4.5	0.7	W1-5	4	55	N/A
#89	2411000200	10.317	10.397	925	13	6.19	434	1	7.5	0.8	W1-5	6	55	N/A
#90	2411000200	10.401	10.540	1043	20	5.49	737	-1	6	1.4	W1-5	8	55	N/A
#91	2411000200	10.600	10.688	945	14	6.06	464	1	6.5	-0.4	None	6	55	N/A
#92	2411000200	11.058	11.125	741	14	7.73	363	-1	5	3.4	W1-5	7	55	N/A
#93	2411000200	11.129	11.206	935	13	6.13	414	1	9	5.4	W1-5	5	55	N/A
#94	2411000200	11.209	11.259	947	8	6.05	265	-1	5	3.6	W1-5	4	55	N/A
#95	2411000200	11.377	11.470	1274	11	4.50	482	1	7	4.4	None	4	55	N/A
#96	2411000200	11.574	11.653	785	15	7.30	414	1	7.5	4.8	W1-4	6	55	N/A
#97	2411000200	11.653	11.744	661	21	8.67	480	-1	7	4.4	W1-4	9	55	N/A
#98	2411000200	12.012	12.077	1187	8	4.83	334	-1	6	-6.4	W1-4	6	55	N/A
#99	2411000200	12.186	12.252	1415	7	4.05	354	1	6	-5.9	W1-4	4	55	N/A
#100	2411000200	12.317	12.406	1671	8	3.43	463	1	6.5	-4.4	None	5	55	N/A
#101	2411000200	12.406	12.527	2540	7	2.26	639	-1	5	-4.3	None	5	55	N/A
#102	2411000200	12.585	12.682	991	15	5.78	521	-1	5	2.1	W1-4, W1-8#2	8	55	N/A

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#103	2411000200	12.712	12.794	591	21	9.69	424	1	7	-2.4	W1-4, W1-8#4	11	55	N/A
#104	2411000200	13.066	13.138	1422	8	4.03	393	-1	5	0.6	W13-1P(35), W1-4	6	55	35
#105	2411000200	13.230	13.299	569	18	10.07	365	1	8.5	2.5	W13-1P(35), W1-4	10	55	35
#106	2411000200	13.317	13.440	1297	14	4.42	648	-1	4.5	2.9	W13-1P(35), W1-4	5	55	35
#107	2411000200	13.550	13.615	1372	7	4.18	344	-1	4	-4.8	None	6	45	N/A
#108	2411000200	13.703	13.789	724	18	7.91	454	1	8	0.5	None	7	35	N/A
#109	2411000200	14.338	14.416	1637	7	3.50	413	-1	4	-2.5	None	5	35	N/A
#110	2411000200	14.748	14.811	658	15	8.71	345	1	8	0.5	W1-2, W1-8#3	9	35	N/A
#111	2411000200	14.815	14.869	295	29	19.41	296	1	9	0.5	W1-2, W1-8#3	13	35	N/A
#112	2411000200	15.110	15.224	292	58	19.64	596	-1	7.5	-2.2	W13-1P(15), W1-3, W1-8#7	16	35	15
#113	2411000200	15.275	15.319	197	35	29.11	236	1	7	-2.4	W13-1P(15), W1-3, W1-8#3	12	35	15
#114	2411000200	15.399	15.450	266	30	21.53	276	1	7.5	1.3	W1-2	15	35	N/A

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#115	2411000200	15.567	15.634	271	39	21.13	364	-1	5.5	5.7	None	12	35	N/A
#116	2411000200	16.200	16.253	183	45	31.36	280	-1	6.5	-4.0	None	14	35	N/A
#117	2411000200	16.283	16.367	711	18	8.06	444	1	9	2.2	None	3	45	N/A
#118	2411000200	16.494	16.596	602	26	9.52	540	-1	11	5.4	W13-1P(30), W1-2	5	45	30
#119	2411000200	16.862	17.008	1004	22	5.71	767	-1	8	-2.2	W1-2	6	45	N/A
#120	2411000200	17.198	17.323	1864	10	3.07	650	1	7	0.5	None	4	45	N/A
#121	2411000200	17.507	17.620	1083	16	5.29	599	-1	8.5	-6.3	W1-2	6	45	N/A
#122	2411000200	17.773	17.855	1136	11	5.05	442	-1	6	-4.0	W1-4	6	45	N/A
#123	2411000200	17.946	18.125	1397	19	4.10	934	1	9	-7.3	W1-4	4	45	N/A
#124	2411000200	18.393	18.495	1114	14	5.14	532	1	7	-2.8	None	7	45	N/A
#125	2411000200	19.047	19.170	1083	17	5.29	641	-1	7	2.2	W13-1P(45), W1-2	5	45	45
#126	2411000200	19.358	19.476	882	20	6.50	618	-1	9	-6.2	W1-2	7	45	N/A
#127	2411000200	20.187	20.282	663	22	8.65	501	-1	7.5	-2.0	None	7	45	N/A
#128	2411000200	20.611	20.697	730	18	7.85	463	1	7.5	-5.5	W1-2	8	45	N/A
#129	2411000200	20.945	21.057	1004	17	5.70	581	1	5.5	5.7	W1-2	6	45	N/A
#130	2411000200	21.645	21.730	834	15	6.87	450	-1	6	7.9	W1-2	6	45	N/A
#131	2411000200	22.083	22.244	708	34	8.10	839	1	10.5	-2.9	W1-2	8	45	N/A
#132	2411000200	22.248	22.382	2519	8	2.27	709	1	8	-1.5	W1-2	3	45	N/A
#133	2411000200	22.516	22.689	1945	14	2.95	924	-1	6.5	-3.4	W1-2	4	45	N/A
#134	2411000200	22.971	23.086	1530	11	3.74	601	1	6.5	-3.8	W1-2	3	45	N/A

Curve	RCLINK	Begin Milepoint	End Milepoint	Radius (ft)	Deviation Angle (°)	Degree of Curvature (°)	Length (ft)	Direction (EB) (Left: -1 Right: 1)	Superelevation (%)	Grade (%)	Before Signs (EB Mar 2016)	BBI	Posted Speed (Jan 2016)	Posted Advisory Speed (Jan 2016)
#135	2411000200	23.273	23.360	1454	9	3.94	463	1	6.5	-2.2	None	3	45	N/A
#136	2411000200	23.403	23.496	831	17	6.89	491	-1	5.5	-3.5	W1-2	8	45	N/A
#137	2411000200	23.557	23.719	508	49	11.28	852	-1	9	-6.2	None	11	45	N/A
#138	2411000200	23.911	24.013	2725	6	2.10	541	-1	2.5	-0.3	None	6	45	N/A
#139	2411000200	24.017	24.093	1699	7	3.37	413	1	6	-4.4	None	2	45	N/A
#140	2411000200	24.097	24.166	2026	5	2.83	363	-1	2	-7.2	None	10	45	N/A

APPENDIX C CURVE SITES INFORMATION

Site No	Curve	RCLINK	Curve Type	Begin Milepoint	End Milepoint	Radius (ft)	Length (ft)	Proposed HFST
1	#1	2811000200	Single Curve	14.2480	14.3097	877	326	No
2	#2	2811000200	Single Curve	14.6763	14.8027	1158	667	No
3	#3	2811000200	Single Curve	14.9851	15.0836	721	520	Yes
4	#4	2811000200	Single Curve	15.1413	15.2311	459	474	No
5	#5	2811000200	Single Curve	15.7692	15.8827	1992	599	No
6	#6	2811000200	Single Curve	15.9515	16.1140	718	858	No
7	#7	2811000200	Single Curve	16.1995	16.3403	571	743	No
8	#8	2811000200	Single Curve	16.4743	16.5636	646	472	No
9	#9	2811000200	Single Curve	16.5822	16.7072	997	660	No
10	#10	2811000200	Single Curve	16.8824	16.9889	728	562	Yes
11	#11	2811000200	Continuous Curves	17.1120	17.2222	410	582	No
	#12	2811000200		17.2260	17.3223	404	508	No
	#13	2811000200		17.3260	17.4097	934	442	No
	#14	2811000200		17.4116	17.6595	1448	1309	No
12	#15	2811000200	Single Curve	17.8903	18.0300	1808	737	No
13	#16	2811000200	Single Curve	18.2590	18.3595	2296	531	No
14	#17	2811000200	Single Curve	18.5232	18.6255	1058	540	No
15	#18	2811000200	Single Curve	18.7448	18.8324	1193	463	No
16	#19	2811000200	Single Curves	18.9200	19.0096	1107	473	Yes
17	#20	2811000200	Continuous Curves	19.0542	19.1522	1033	517	Yes
	#21	2811000200		19.1652	19.2533	657	466	Yes
	#22	2811000200		19.2645	19.3449	407	425	Yes
	#23	2811000200		19.3561	19.4033	325	249	Yes
18	#24	2811000200	Compound Curve	19.5054	19.5472	230	221	Yes
	#25	2811000200		19.5510	19.6378	521	458	Yes
19	#26	2811000200	Single Curve	19.7141	19.7864	326	382	No
20	#27	2811000200	Reverse Curve	19.8106	19.8814	420	374	No
	#28	2811000200		19.8944	19.9447	1028	265	No
21	#29	2811000200	Single Curve	20.0321	20.1567	1476	658	No
22	#30	2811000200	Reverse Curve	20.3169	20.4024	935	452	No
	#31	2811000200		20.4099	20.4958	595	453	No
23	#32	2411000200	Single Curve	0.0525	0.1662	811	600	Yes
24	#33	2411000200	Single Curve	0.1829	0.2626	588	421	Yes
25	#34	2411000200	Single Curve	0.3687	0.4918	714	650	No
26	#35	2411000200	Single Curve	0.7208	0.8083	940	462	No
27	#36	2411000200	Single Curve	0.9275	1.0432	959	611	Yes
28	#37	2411000200	Compound Curve	1.2536	1.3501	680	509	Yes
	#38	2411000200		1.3519	1.3871	531	186	Yes
29	#39	2411000200	Single Curve	1.4522	1.5490	593	511	Yes

Site No	Curve	RCLINK	Curve Type	Begin Milepoint	End Milepoint	Radius (ft)	Length (ft)	Proposed HFST
30	#40	2411000200	Single Curve	1.6514	1.8319	1549	953	No
31	#41	2411000200	Single Curve	1.9360	2.1015	3235	874	No
32	#42	2411000200	Single Curve	2.2153	2.2854	463	370	Yes
33	#43	2411000200	Continuous Curves	2.3655	2.4192	455	284	Yes
	#44	2411000200		2.4267	2.4884	426	326	Yes
	#45	2411000200		2.4977	2.5608	443	333	Yes
	#46	2411000200		2.5720	2.6765	1635	552	Yes
	#47	2411000200		2.6877	2.7415	365	284	Yes
	#48	2411000200		2.7490	2.7977	610	257	Yes
	#49	2411000200		2.7977	2.8666	1402	364	Yes
	#50	2411000200		2.8666	2.8981	469	166	Yes
	#51	2411000200	Continuous Curves	3.0229	3.1369	608	602	Yes
	#52	2411000200		3.1406	3.2286	351	465	Yes
	#53	2411000200		3.2324	3.2973	497	343	Yes
	#54	2411000200	Continuous Curves	3.4223	3.4748	1043	277	No
	#55	2411000200		3.4748	3.5381	1117	334	Yes
	#56	2411000200		3.5381	3.5793	228	218	Yes
36	#57	2411000200	Single Curve	3.6726	3.7007	343	148	Yes
37	#58	2411000200	Reverse Curve	3.8122	3.8869	480	395	Yes
	#59	2411000200		3.8906	3.9682	195	410	Yes
38	#60	2411000200	Single Curves	4.3625	4.4350	358	383	Yes
39	#61	2411000200	Reverse Curve	4.4983	4.5465	302	255	Yes
	#62	2411000200		4.5503	4.6044	724	286	Yes
40	#63	2411000200	Single Curve	4.7142	4.8224	493	571	Yes
41	#64	2411000200	Reverse Curve	4.9489	5.0305	350	431	Yes
	#65	2411000200		5.0324	5.1195	774	460	Yes
42	#66	2411000200	Single Curve	5.1921	5.2575	1448	345	No
43	#67	2411000200	Single Curve	5.3301	5.3808	625	268	No
44	#68	2411000200	Reverse Curve	5.4349	5.4986	485	337	Yes
	#69	2411000200		5.5061	5.5958	915	474	Yes
45	#70	2411000200	Continuous Curves	5.7337	5.7901	206	298	Yes
	#71	2411000200		5.7995	5.8867	514	461	Yes
	#72	2411000200		5.8960	5.9726	451	404	Yes
	#73	2411000200		5.9875	6.0957	1355	571	No
46	#74	2411000200	Single Curve	6.1477	6.2702	580	646	No
47	#75	2411000200	Single Curve	6.4650	6.5987	1414	706	No
48	#76	2411000200	Single Curve	6.6321	6.7273	501	502	Yes
49	#77	2411000200	Single Curve	6.9004	7.0474	928	776	No
50	#78	2411000200	Single Curve	7.6472	7.7746	975	673	No

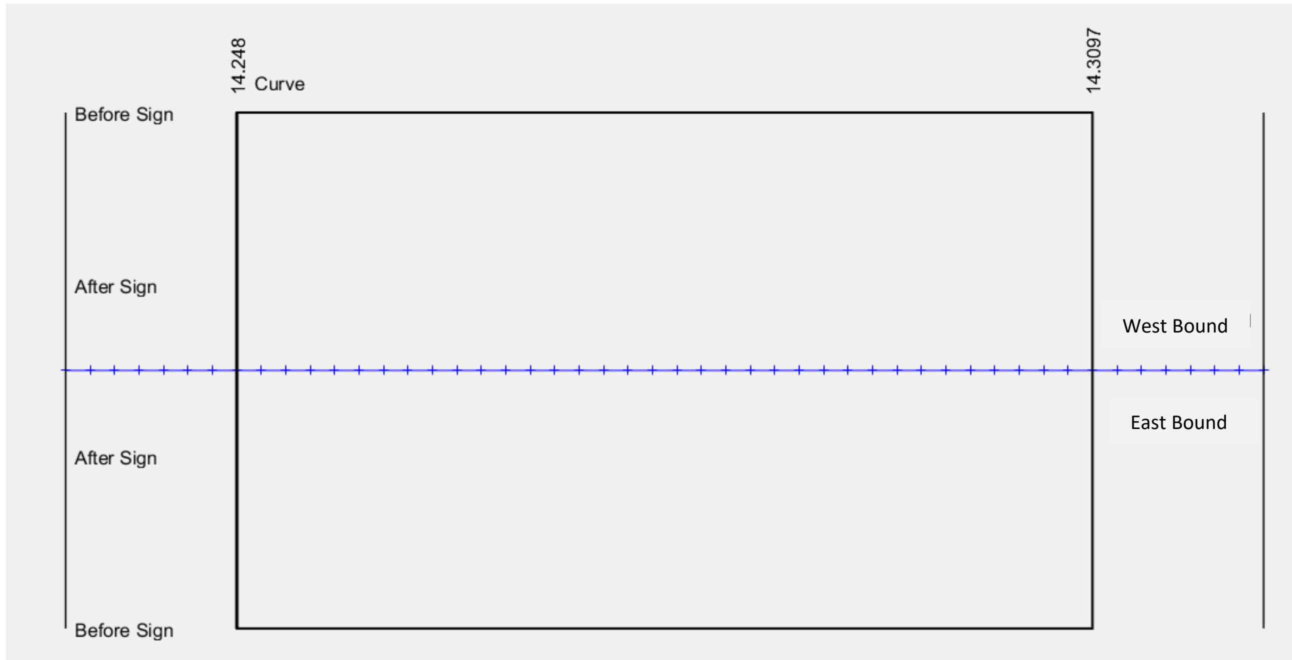
Site No	Curve	RCLINK	Curve Type	Begin Milepoint	End Milepoint	Radius (ft)	Length (ft)	Proposed HFST
51	#79	2411000200	Single Curve	7.9013	8.0983	1008	1040	No
52	#80	2411000200	Single Curve	8.2381	8.5635	1151	1719	No
53	#81	2411000200	Reverse Curve	8.6435	8.7464	602	543	Yes
	#82	2411000200		8.7575	8.8318	995	392	Yes
54	#83	2411000200	Single Curve	8.8821	8.9526	579	373	Yes
55	#84	2411000200	Single Curve	9.0514	9.0868	2041	187	No
56	#85	2411000200	Reverse Curve	9.3178	9.4204	2348	541	No
	#86	2411000200		9.4352	9.5356	1489	530	No
57	#87	2411000200	Single Curve	9.9326	10.0353	955	542	No
58	#88	2411000200	Continuous Curves	10.2534	10.3129	1204	314	Yes
	#89	2411000200		10.3166	10.3970	925	424	Yes
	#90	2411000200		10.4007	10.5402	1043	737	Yes
59	#91	2411000200	Single Curve	10.5999	10.6877	945	464	Yes
60	#92	2411000200	Continuous Curves	11.0584	11.1253	741	353	Yes
	#93	2411000200		11.1290	11.2055	935	404	Yes
	#94	2411000200		11.2092	11.2594	947	265	Yes
61	#95	2411000200	Single Curves	11.3767	11.4700	1274	492	No
62	#96	2411000200	Reverse Curve	11.5742	11.6526	785	414	Yes
	#97	2411000200		11.6526	11.7436	661	480	Yes
63	#98	2411000200	Single Curves	12.0115	12.0766	1187	343	No
64	#99	2411000200	Single Curves	12.1863	12.2515	1415	344	No
65	#100	2411000200	Reverse Curve	12.3167	12.4062	1671	473	No
	#101	2411000200		12.4062	12.5272	2540	639	No
66	#102	2411000200	Single Curve	12.5850	12.6817	991	511	No
67	#103	2411000200	Single Curve	12.7115	12.7936	591	434	Yes
68	#104	2411000200	Single Curve	13.0658	13.1384	1422	383	No
69	#105	2411000200	Single Curve	13.2296	13.2988	569	365	Yes
70	#106	2411000200	Single Curve	13.3174	13.4402	1297	648	No
71	#107	2411000200	Single Curve	13.5500	13.6151	1372	344	No
72	#108	2411000200	Single Curve	13.7026	13.7886	724	454	Yes
73	#109	2411000200	Single Curve	14.3379	14.4161	1637	413	No
74	#110	2411000200	Compound Curve	14.7477	14.8112	658	335	Yes
	#111	2411000200		14.8149	14.8692	295	287	Yes
75	#112	2411000200	Single Curve	15.1095	15.2243	292	606	Yes
76	#113	2411000200	Single Curve	15.2745	15.3192	197	236	Yes
77	#114	2411000200	Single Curve	15.3994	15.4498	266	266	Yes
78	#115	2411000200	Single Curve	15.5672	15.6343	271	354	No
79	#116	2411000200	Single Curve	16.2000	16.2531	183	280	No
80	#117	2411000200	Single Curve	16.2830	16.3671	711	444	No

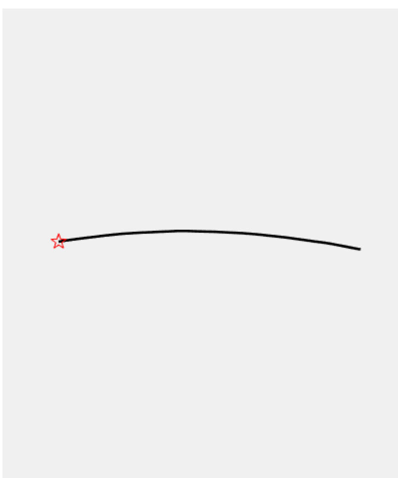
Site No	Curve	RCLINK	Curve Type	Begin Milepoint	End Milepoint	Radius (ft)	Length (ft)	Proposed HFST
81	#118	2411000200	Single Curve	16.4937	16.5959	602	540	No
82	#119	2411000200	Single Curve	16.8623	17.0075	1004	767	No
83	#120	2411000200	Single Curve	17.1975	17.3225	1864	660	No
84	#121	2411000200	Single Curve	17.5068	17.6202	1083	599	No
85	#122	2411000200	Single Curve	17.7729	17.8548	1136	432	No
86	#123	2411000200	Single Curve	17.9459	18.1247	1397	944	No
87	#124	2411000200	Single Curve	18.3927	18.4954	1114	542	No
88	#125	2411000200	Single Curve	19.0470	19.1702	1083	651	No
89	#126	2411000200	Single Curve	19.3584	19.4755	882	618	No
90	#127	2411000200	Single Curve	20.1869	20.2817	663	501	No
91	#128	2411000200	Single Curve	20.6113	20.6971	730	453	Yes
92	#129	2411000200	Single Curve	20.9447	21.0565	1004	591	Yes
93	#130	2411000200	Single Curve	21.6447	21.7299	834	450	Yes
94	#131	2411000200	Compound Curve	22.0833	22.2440	708	849	Yes
	#132	2411000200		22.2477	22.3821	2519	709	No
95	#133	2411000200	Single Curve	22.5162	22.6894	1945	914	No
96	#134	2411000200	Single Curve	22.9706	23.0862	1530	611	No
97	#135	2411000200	Single Curve	23.2725	23.3603	1454	463	No
98	#136	2411000200	Single Curve	23.4031	23.4961	831	491	Yes
99	#137	2411000200	Single Curve	23.5574	23.7188	508	852	Yes
100	#138	2411000200	Continuous Curves	23.9106	24.0130	2725	541	No
	#139	2411000200		24.0167	24.0932	1699	404	No
	#140	2411000200		24.0969	24.1656	2026	363	No

APPENDIX D CURVE REPORTING CARD

Road Characteristics

Radius	877
Grade	0.6
Superelevation	7
Crashes	0
BBI	9
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #1 on State Route 2 in Towns County

Scale: NA

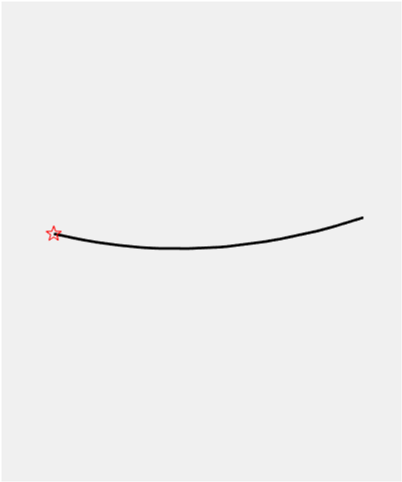
RCLINK:2811000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	1158
Grade	4.8
Superelevation	5.5
Crashes	1
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

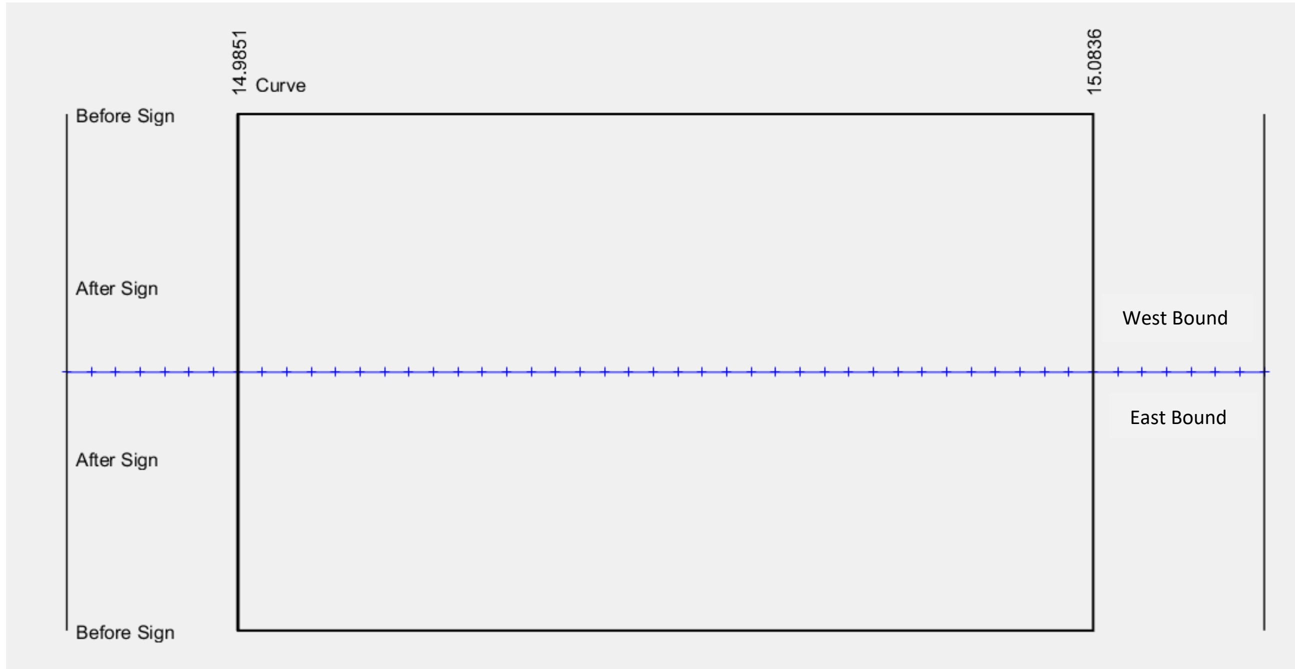
Curve #2 on State Route 2 in Towns County

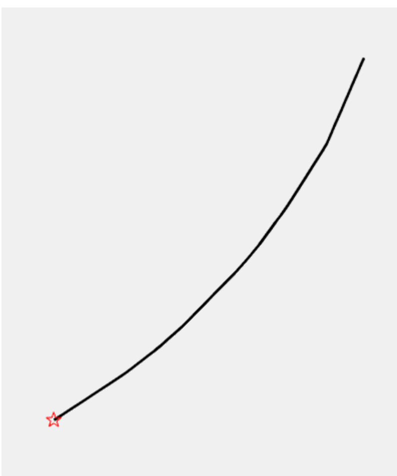
Scale: NA

RCLINK:2811000200

Road Characteristics

Radius	721
Grade	-5.4
Superelevation	9
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	25
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

Curve #3 on State Route 2 in Towns County

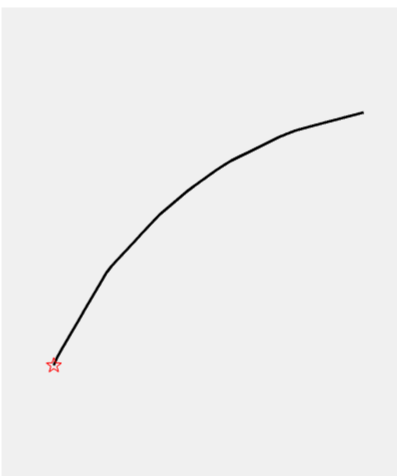
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics

Radius	459
Grade	0.9
Superelevation	11
Crashes	0
BBI	8
Posted Speed	45
Advisory Speed	25
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

Georgia Department of Transportation

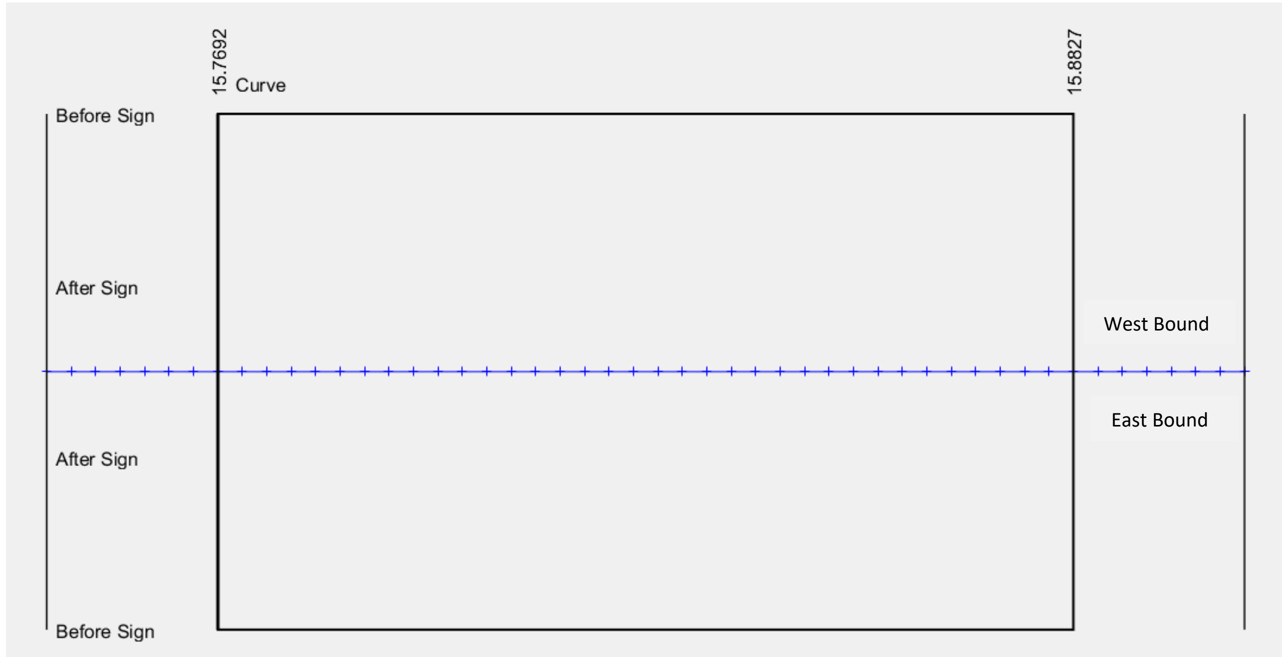
Curve #4 on State Route 2 in Towns County

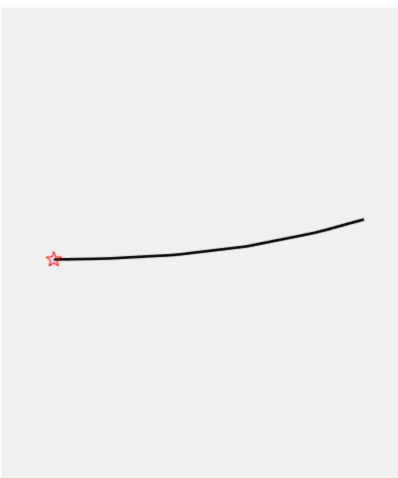
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	1992
Grade	-5
Superelevation	3
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #5 on State Route 2 in Towns County

Scale: NA

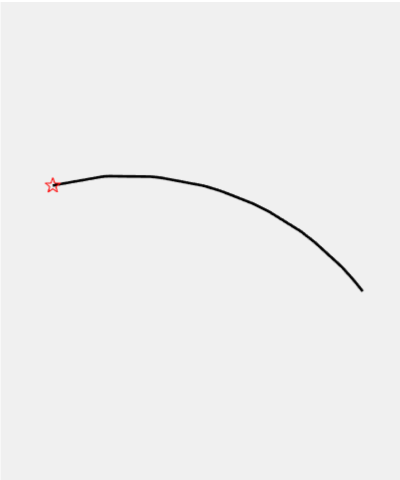
RCLINK:2811000200

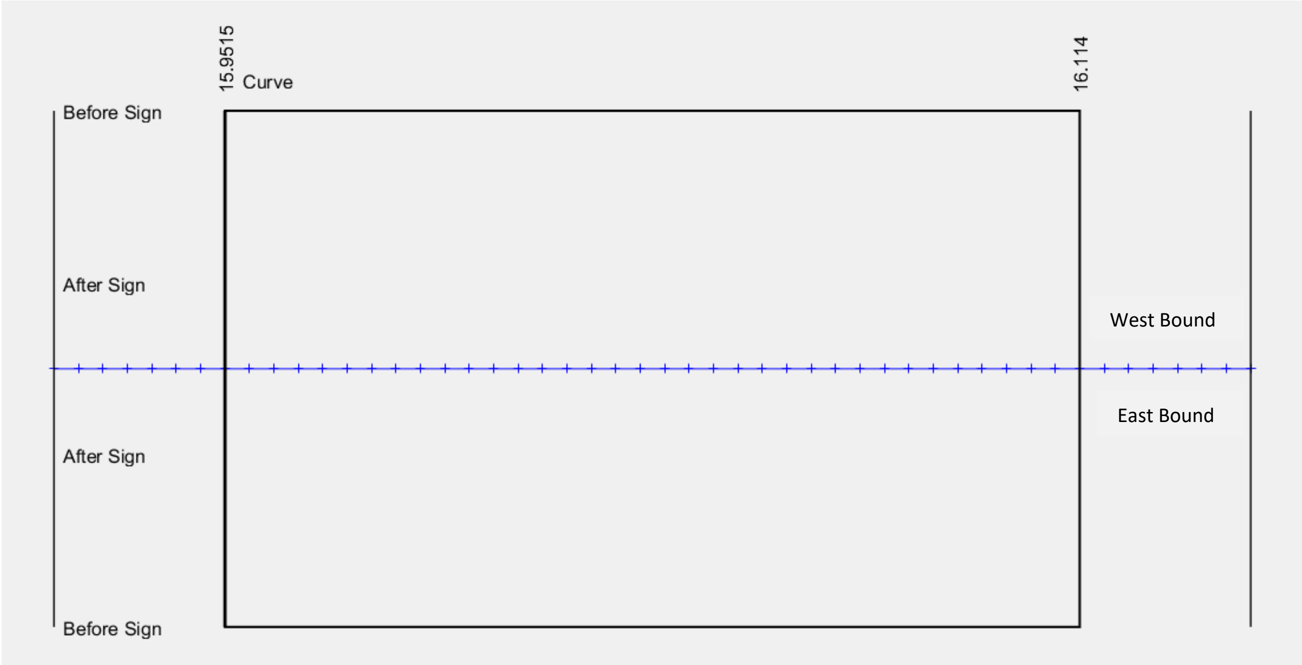
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	718
Grade	-0.2
Superelevation	11
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #6 on State Route 2 in Towns County

Scale: NA

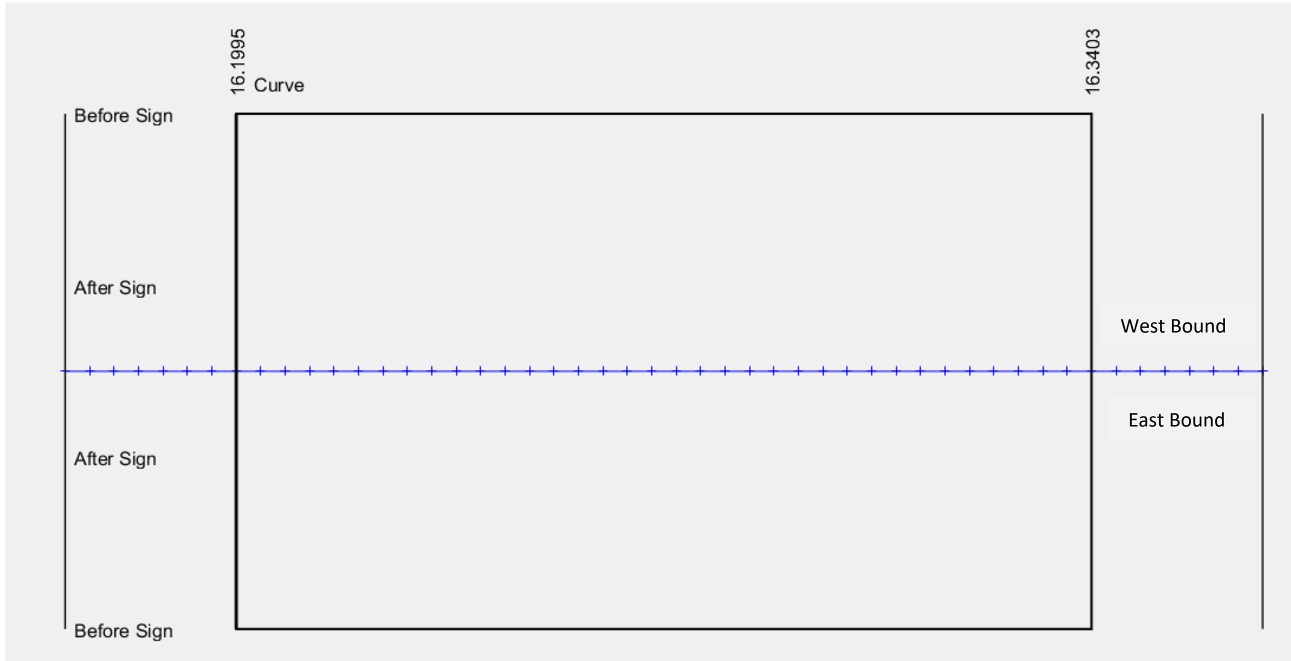
RCLINK:2811000200

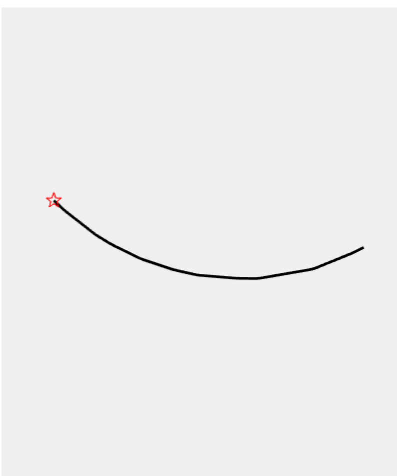
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	571
Grade	7.3
Superelevation	12
Crashes	0
BBI	8
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #7 on State Route 2 in Towns County

Scale: NA

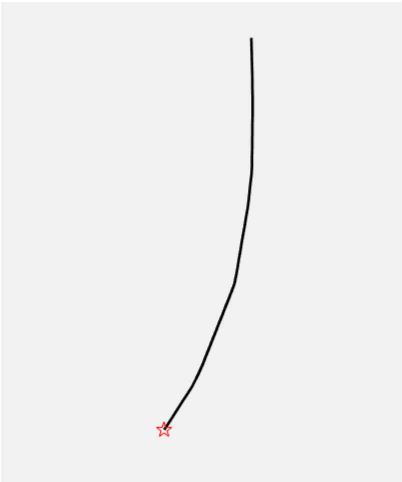
RCLINK:2811000200

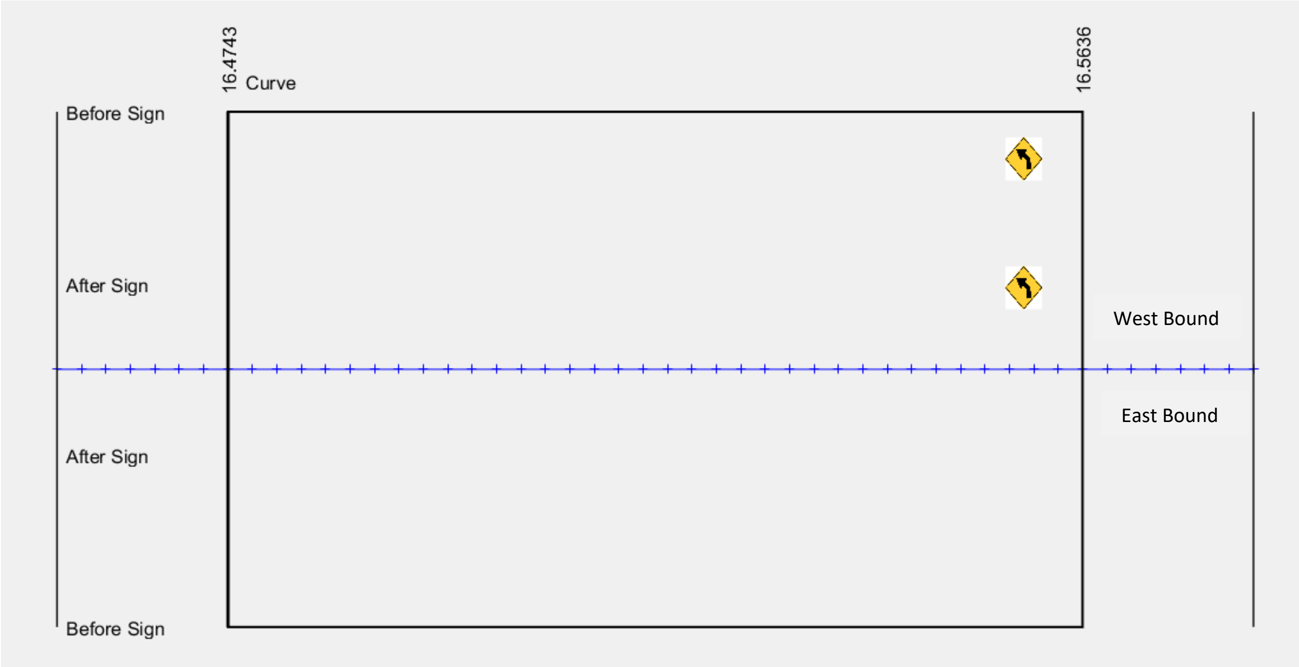
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	646
Grade	-1.8
Superelevation	11.5
Crashes	0
BBI	8
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #8 on State Route 2 in Towns County

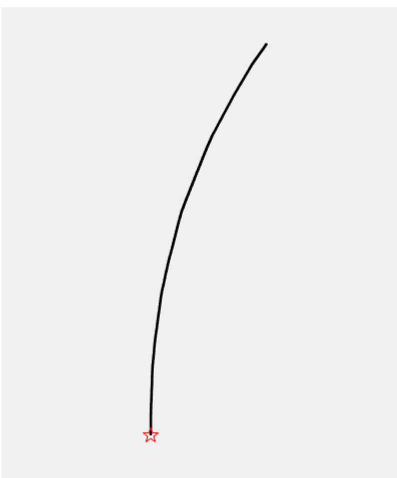
Scale: NA

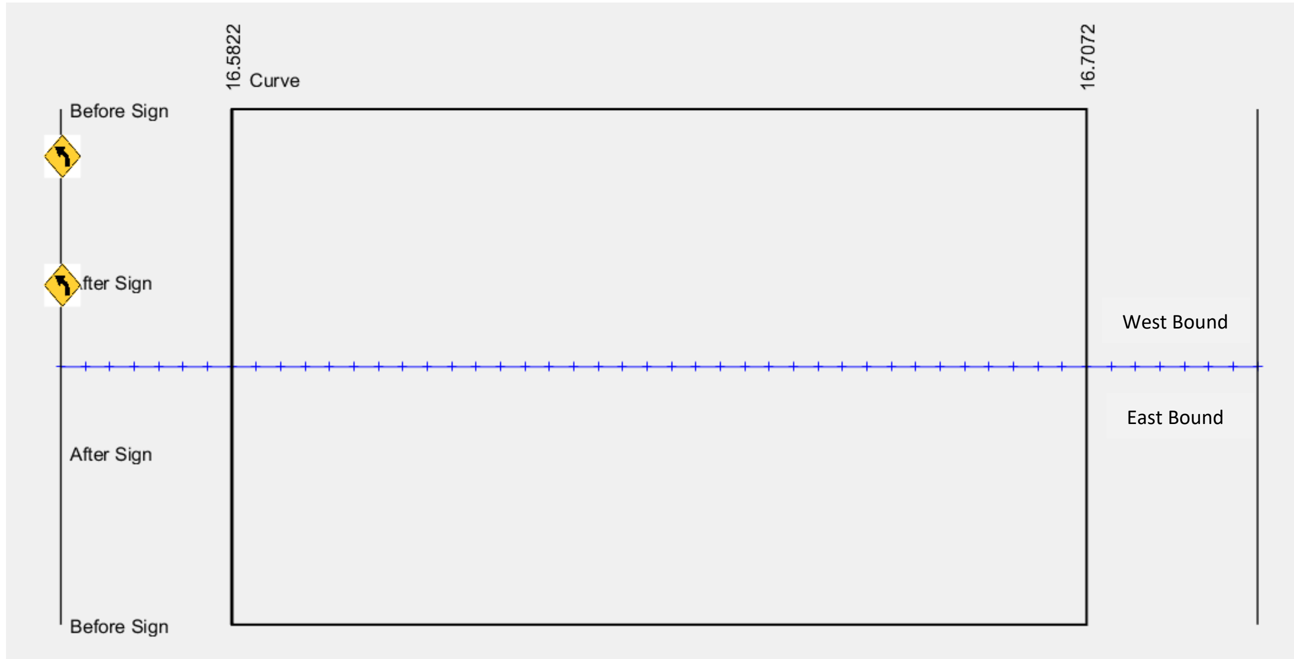
RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics

Radius	997
Grade	-3.8
Superelevation	7
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #9 on State Route 2 in Towns County

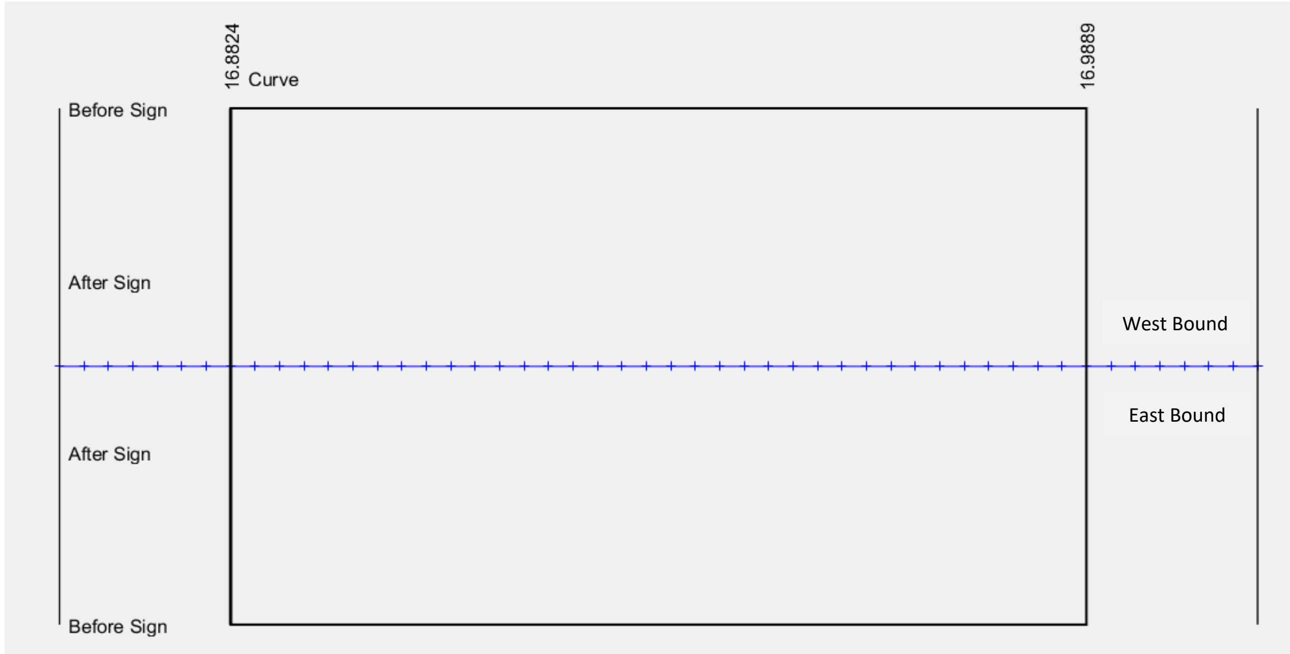
Scale: NA

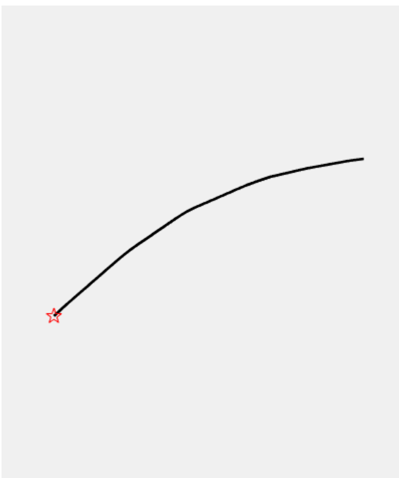
RCLINK:2811000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	728
Grade	-0.4
Superelevation	12
Crashes	1
BBI	9
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #10 on State Route 2 in Towns County

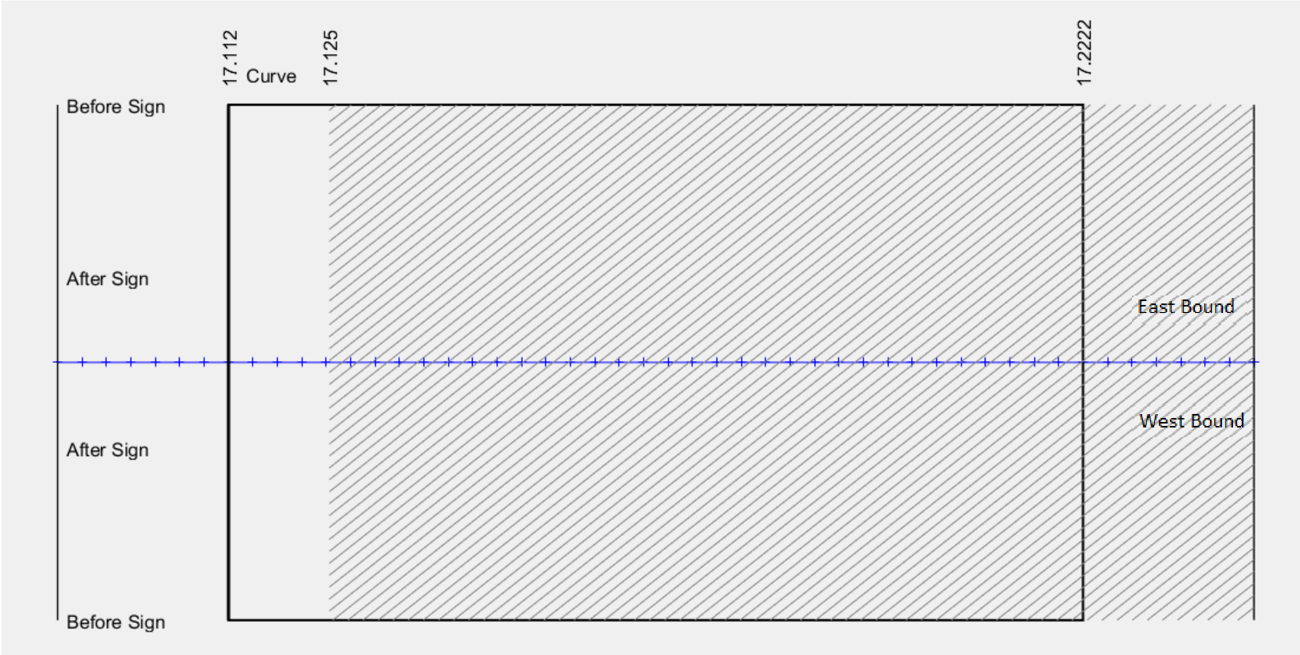
Scale: NA

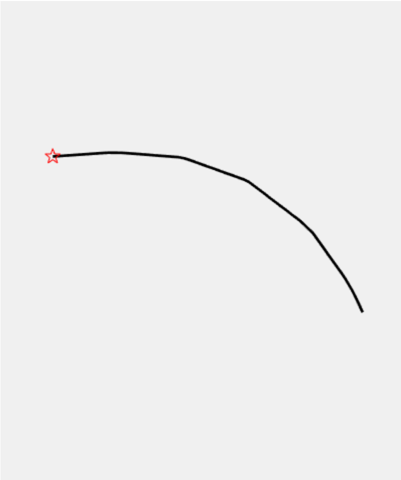
RCLINK:2811000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	410
Grade	4.4
Superelevation	14
Crashes	0
BBI	9
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

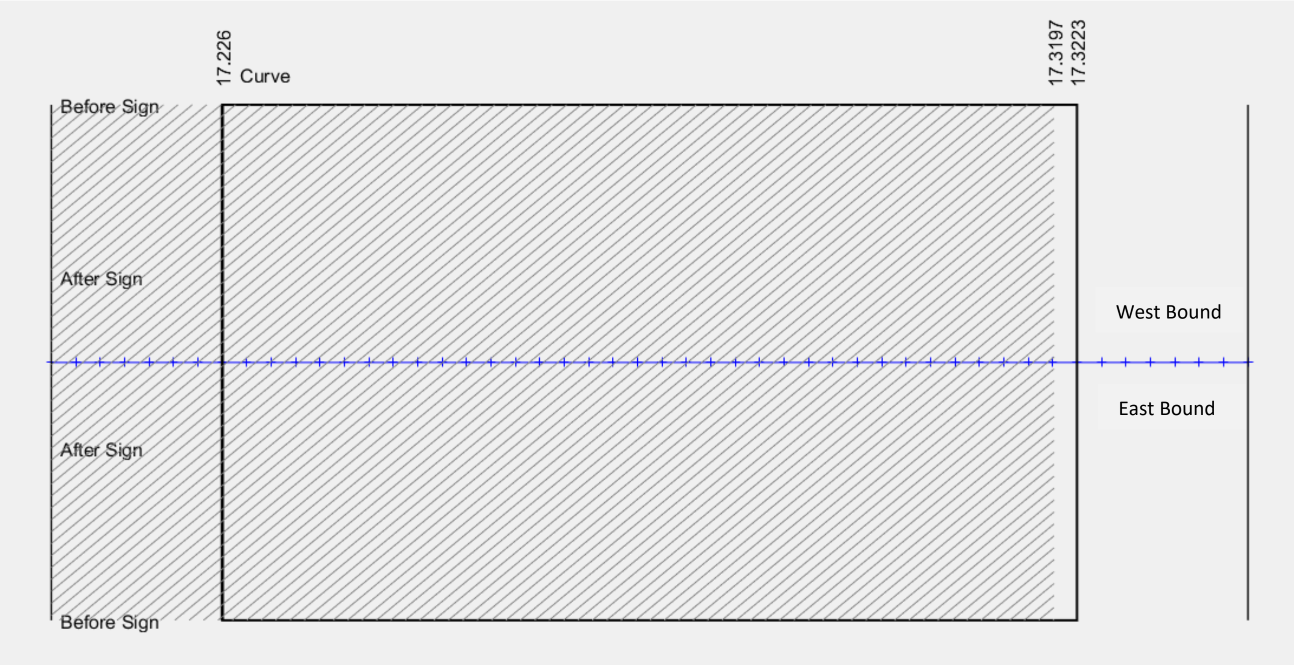
Curve #11 on State Route 2 in Towns County

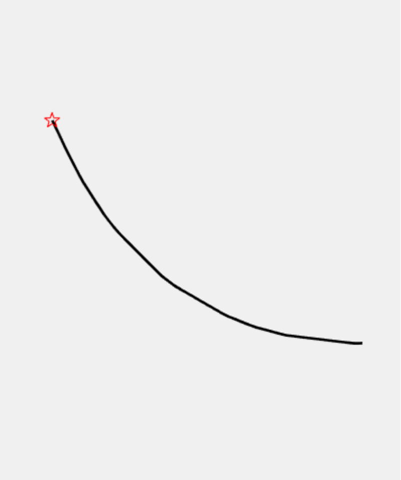
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	404
Grade	5.1
Superelevation	12
Crashes	1
BBI	10
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #12 on State Route 2 in Towns County

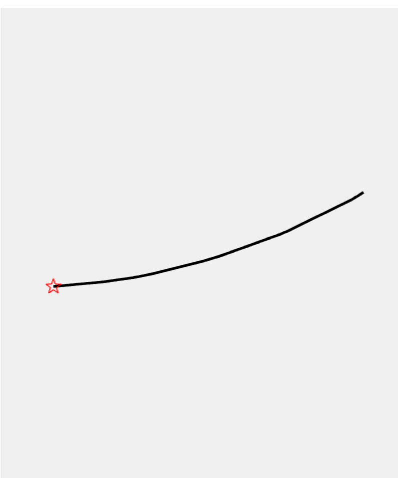
Scale: NA

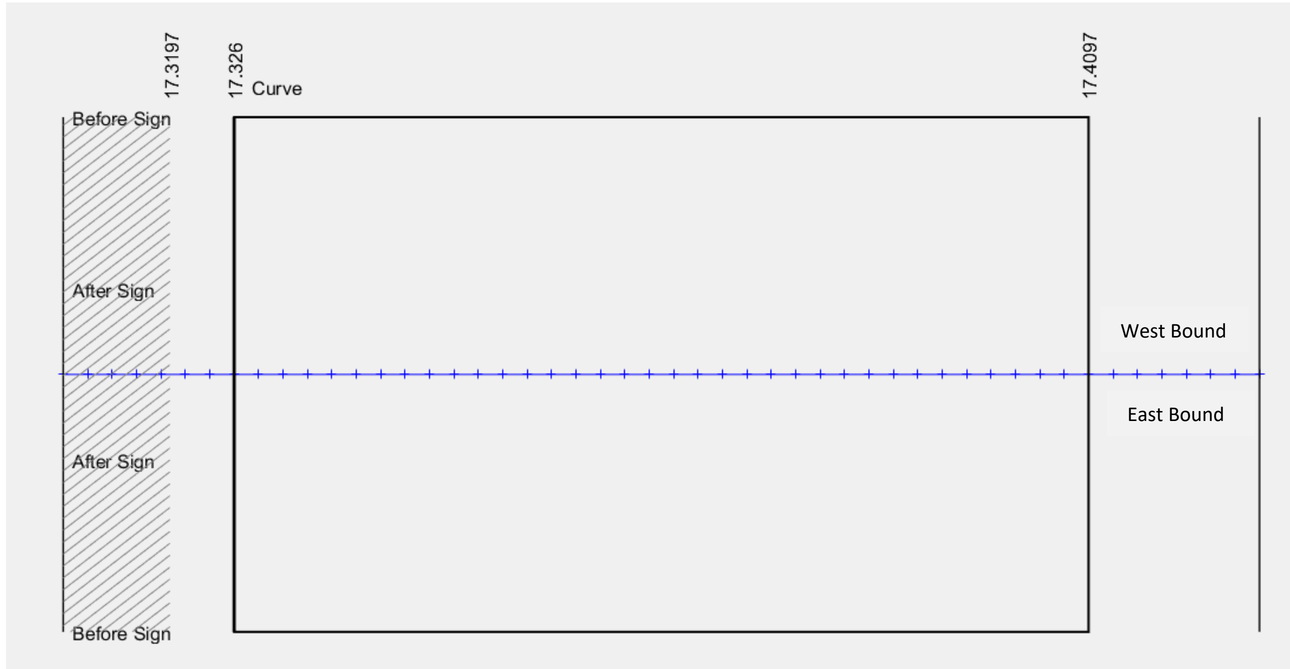
RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics

Radius	934
Grade	1.6
Superelevation	10
Crashes	0
BBI	9
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #13 on State Route 2 in Towns County

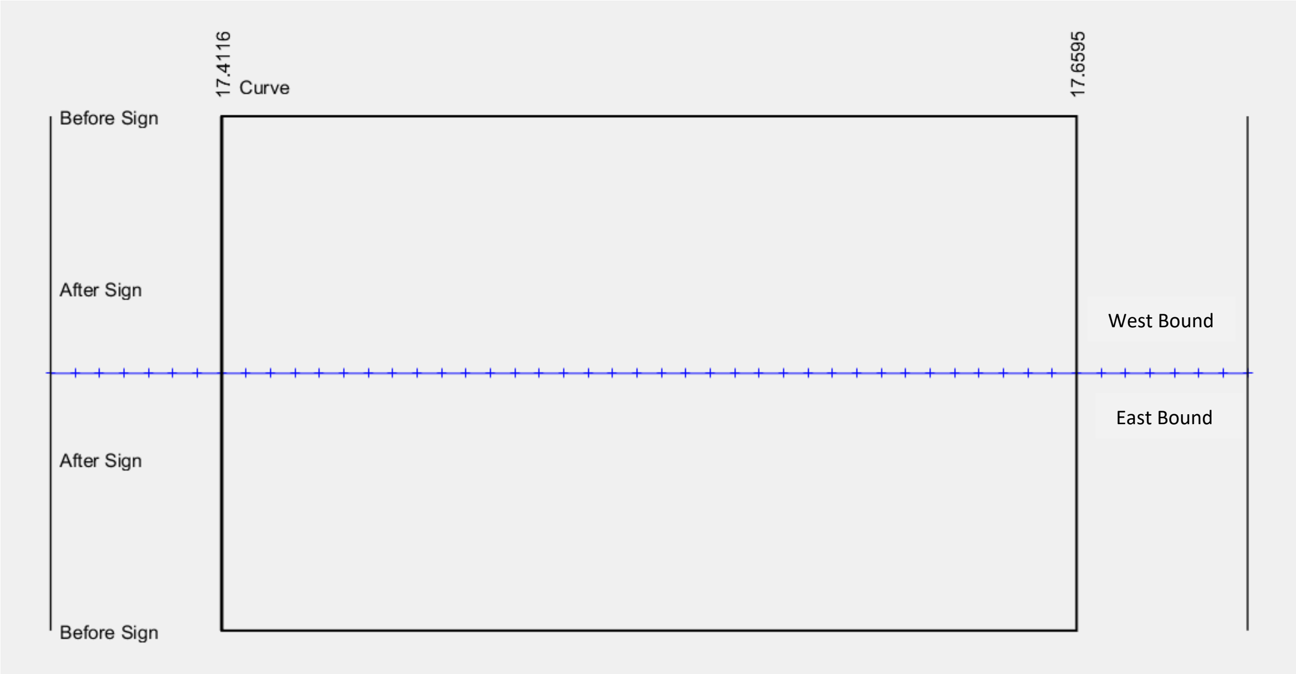
Scale: NA

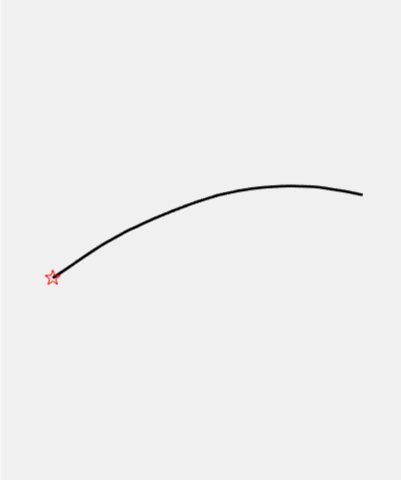
RCLINK:2811000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1448
Grade	-1.7
Superelevation	7
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

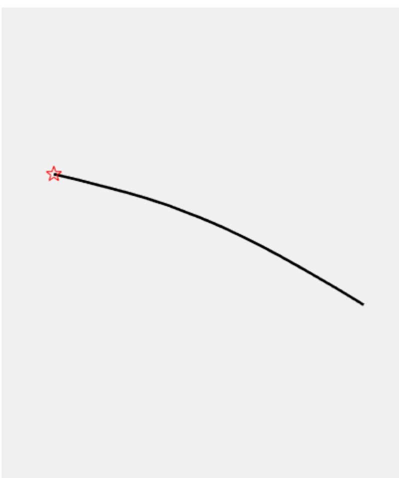
Curve #14 on State Route 2 in Towns County

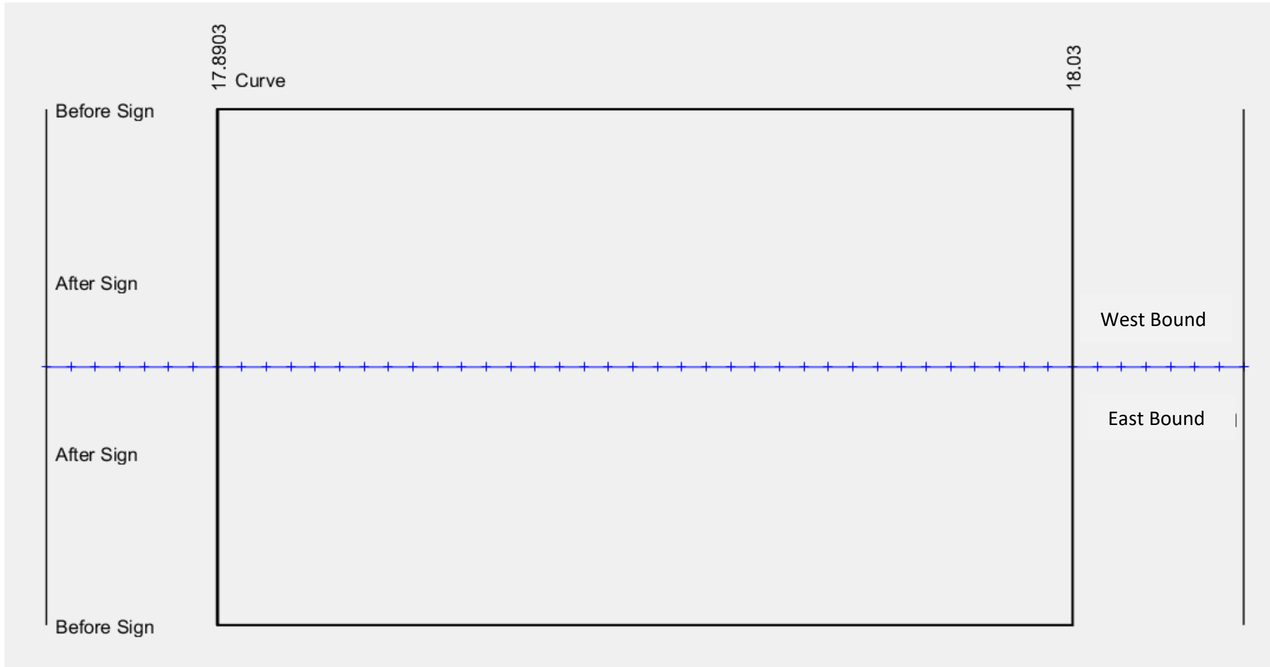
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	1808
Grade	-5.7
Superelevation	7
Crashes	1
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

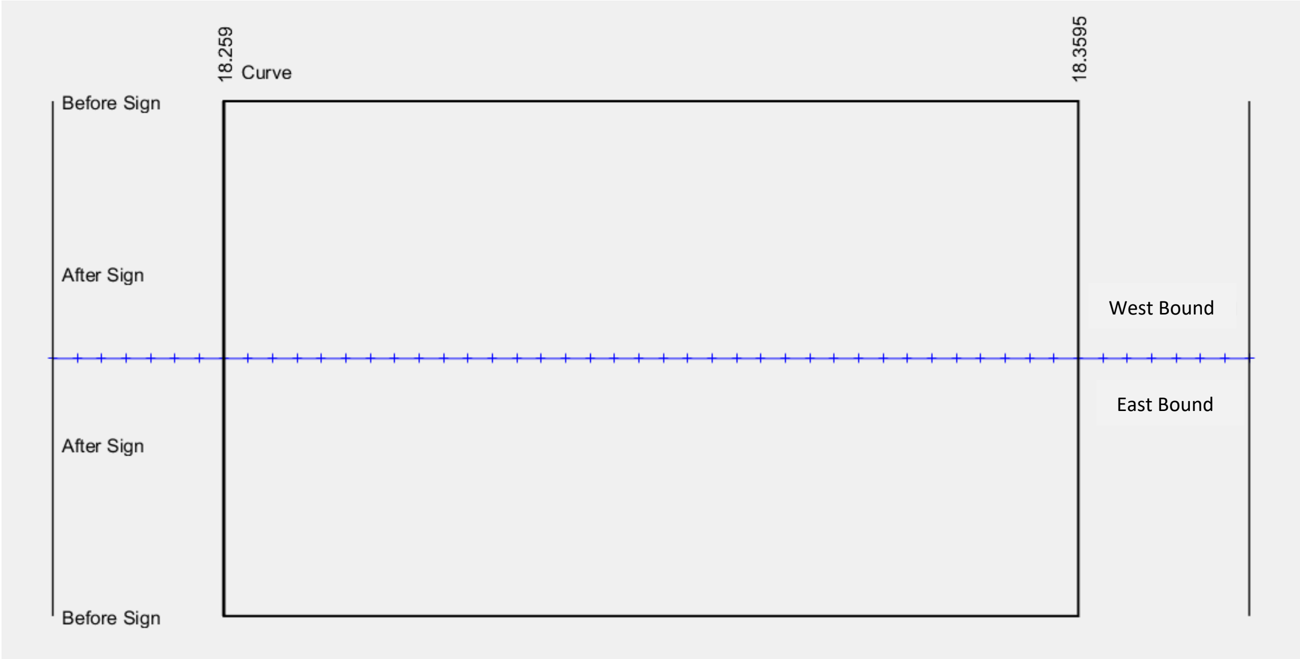
Curve #15 on State Route 2 in Towns County

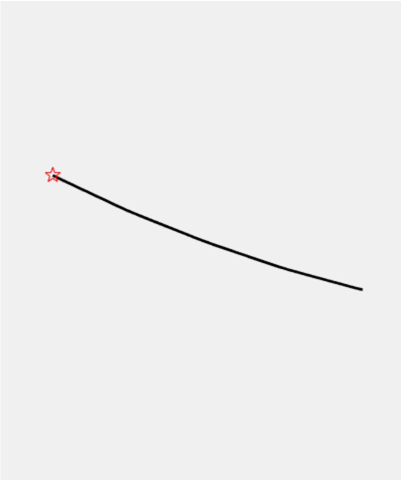
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	2296
Grade	0.6
Superelevation	3.5
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

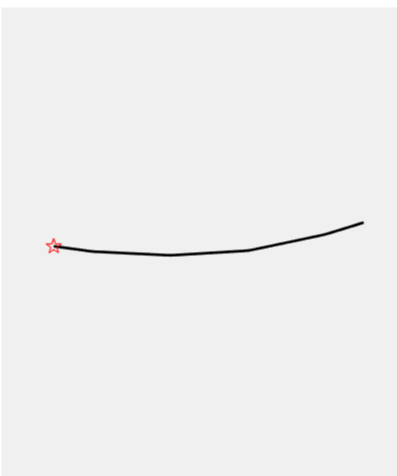
Curve #16 on State Route 2 in Towns County

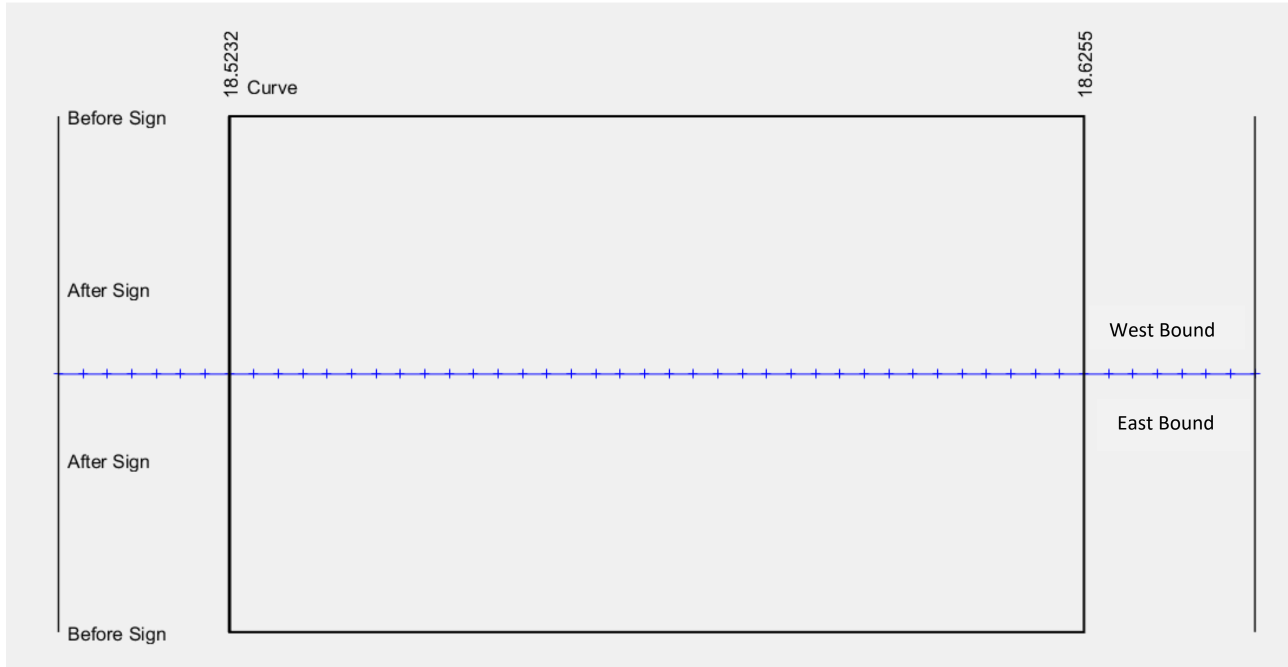
Scale: NA

RCLINK:2811000200

Road Characteristics

Radius	1058
Grade	-0.8
Superelevation	7
Crashes	0
BBI	7
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

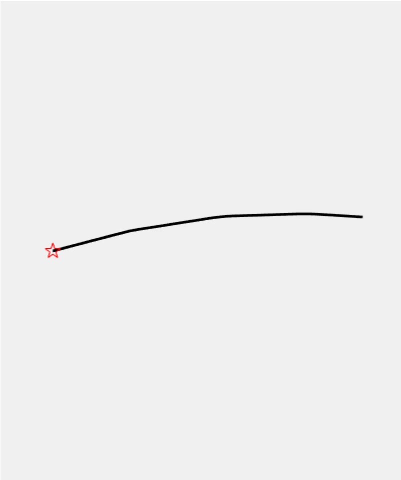
Curve #17 on State Route 2 in Towns County

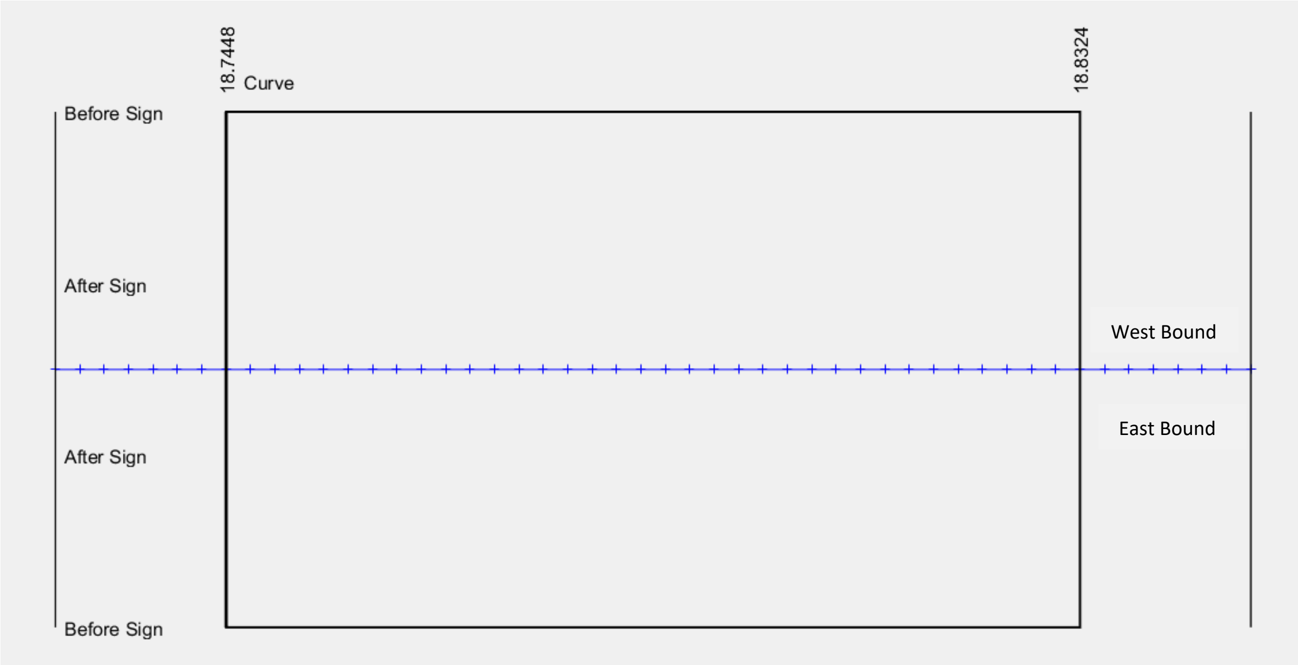
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	1193
Grade	0.8
Superelevation	7
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #18 on State Route 2 in Towns County

Scale: NA

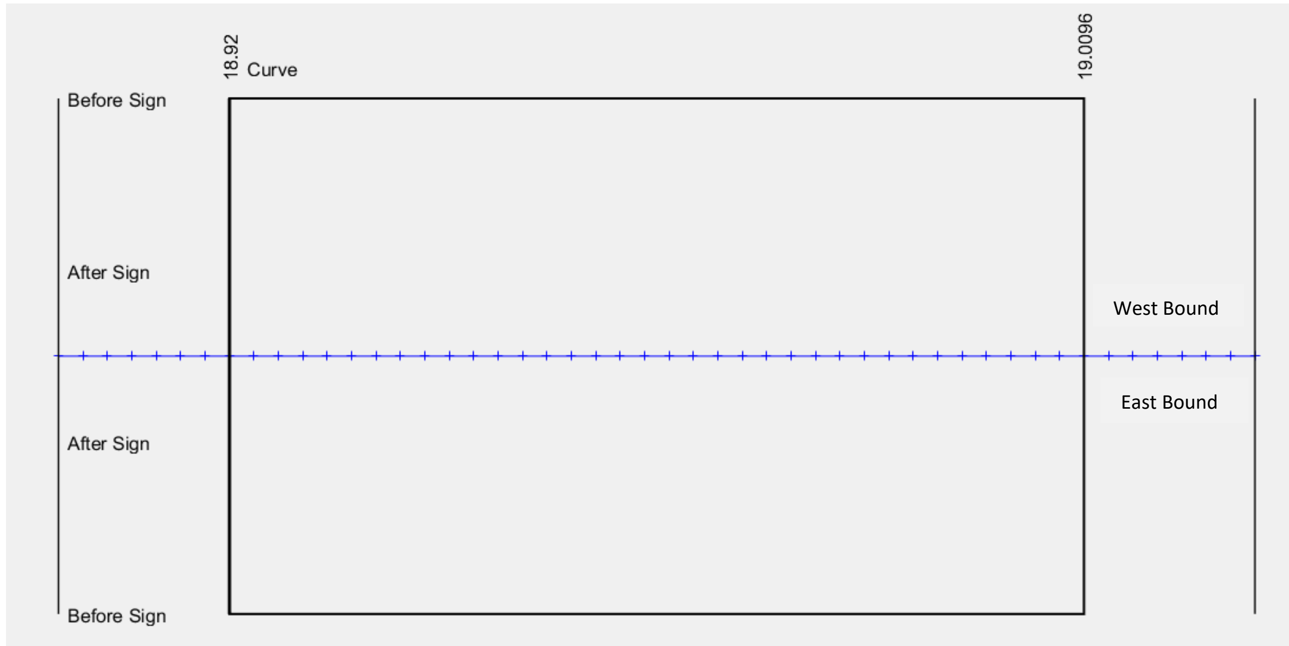
RCLINK:2811000200

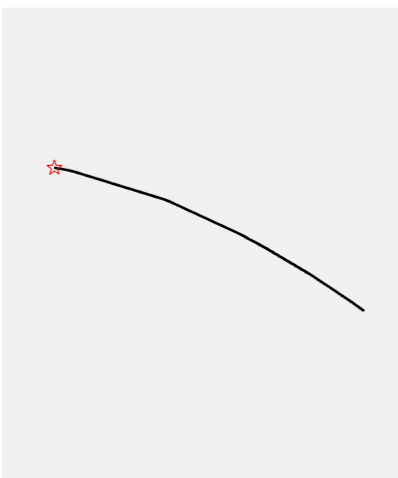
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	1107
Grade	4
Superelevation	7
Crashes	1
BBI	7
Posted Speed	35
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #19 on State Route 2 in Towns County

Scale: NA

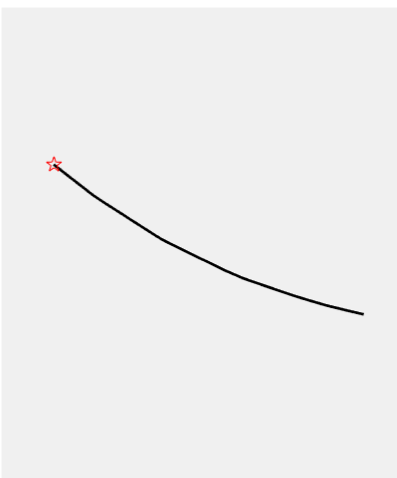
RCLINK:2811000200

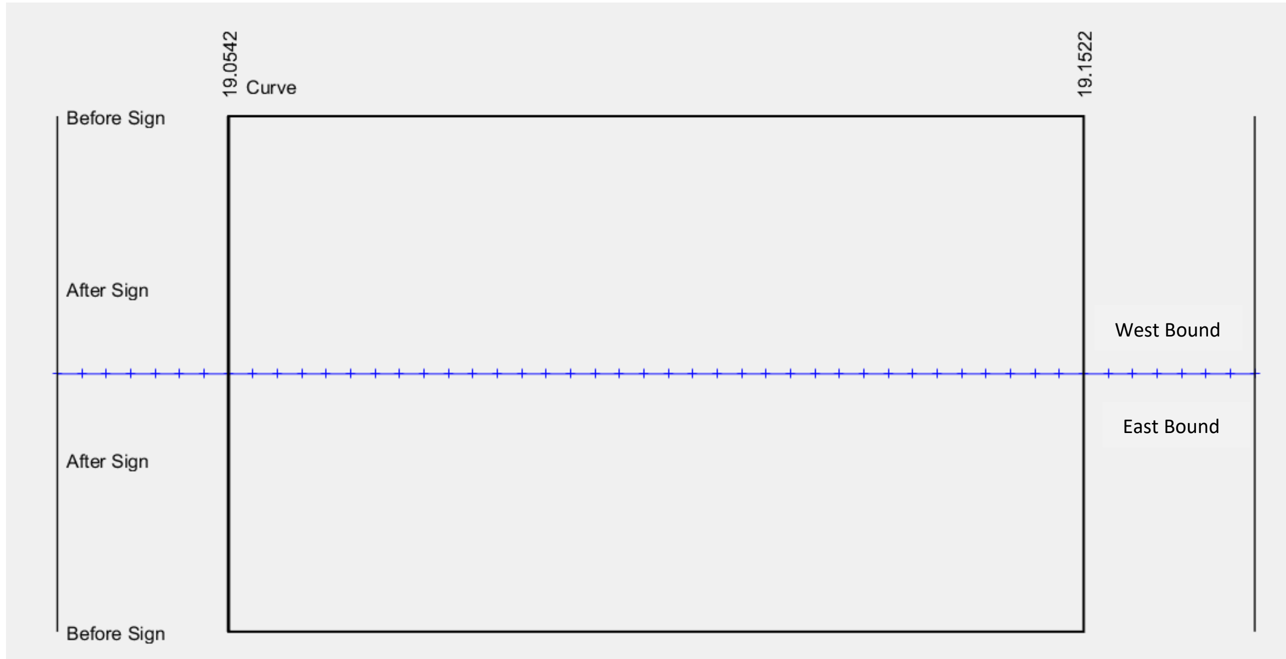
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	1033
Grade	6.4
Superelevation	7
Crashes	1
BBI	7
Posted Speed	35
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #20 on State Route 2 in Towns County

Scale: NA

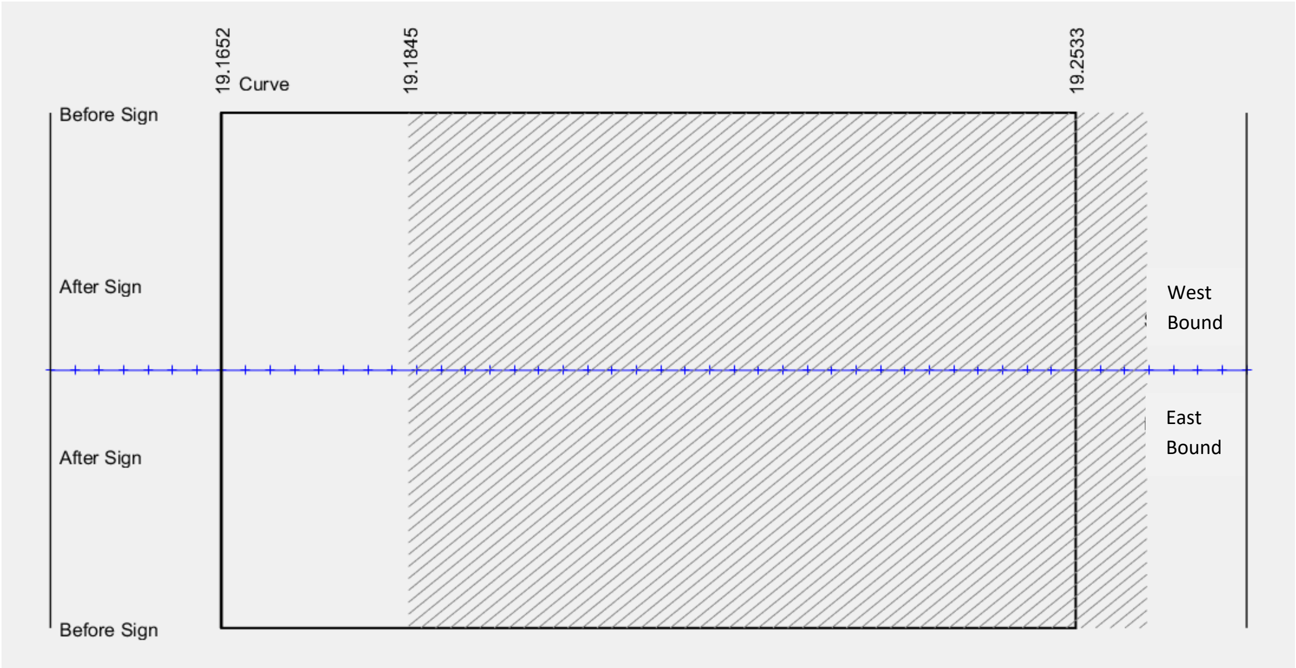
RCLINK:2811000200

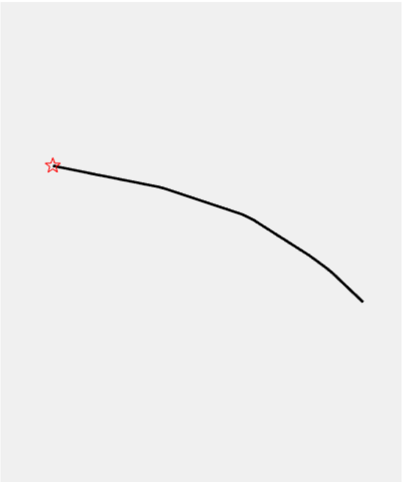
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	657
Grade	6.9
Superelevation	9
Crashes	0
BBI	5
Posted Speed	35
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

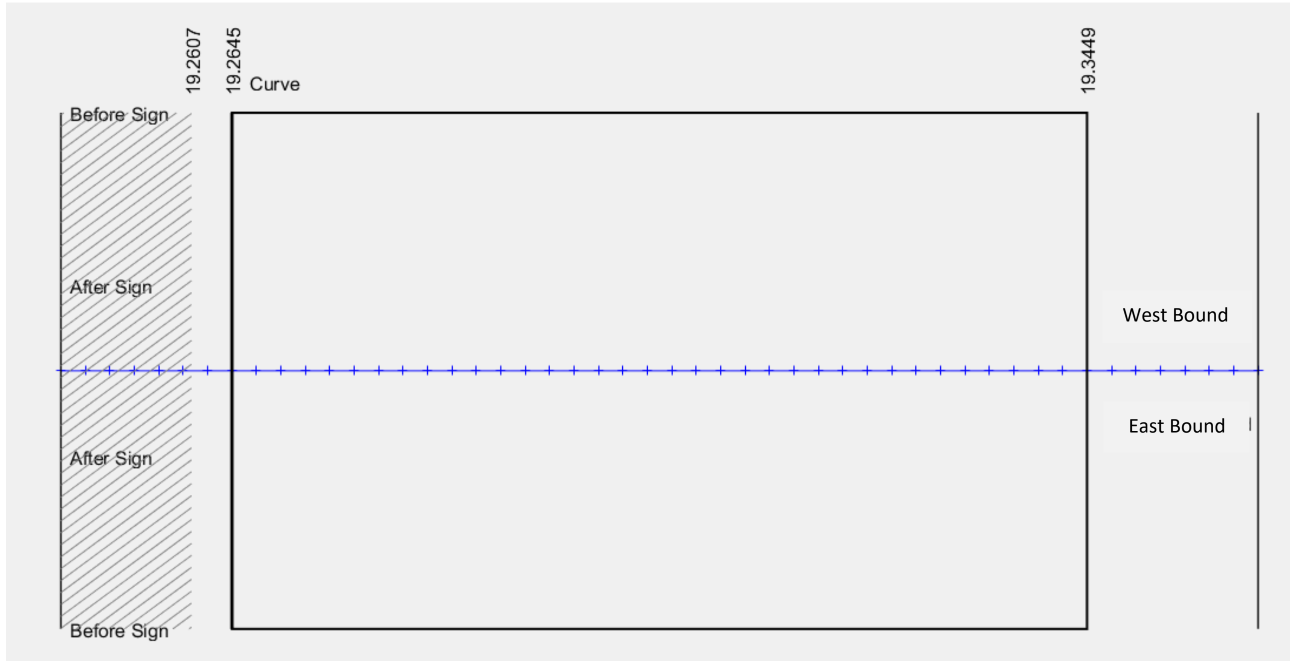
Curve #21 on State Route 2 in Towns County

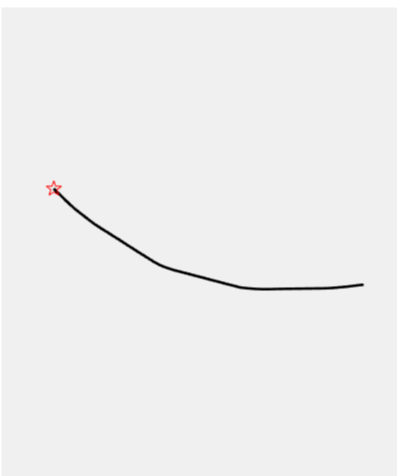
Scale: NA

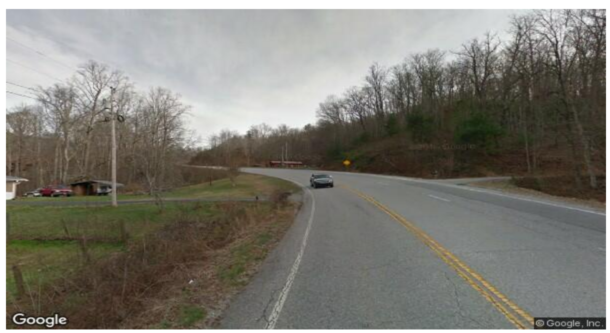
RCLINK:2811000200

Road Characteristics

Radius	407	
Grade	8	
Superelevation	13	
Crashes	0	
BBI	8	
Posted Speed	35	
Advisory Speed	30	
Road Type	Rural Collector	
AADT	2000	
	2016	
Lane Width	12 ft.	
Shoulder Width	NA	







Horizontal Curve Schematic

Curve #22 on State Route 2 in Towns County

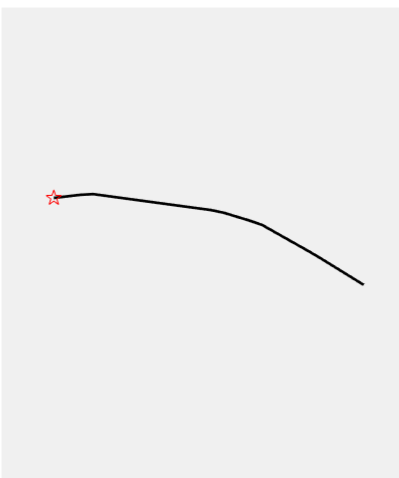
Scale: NA

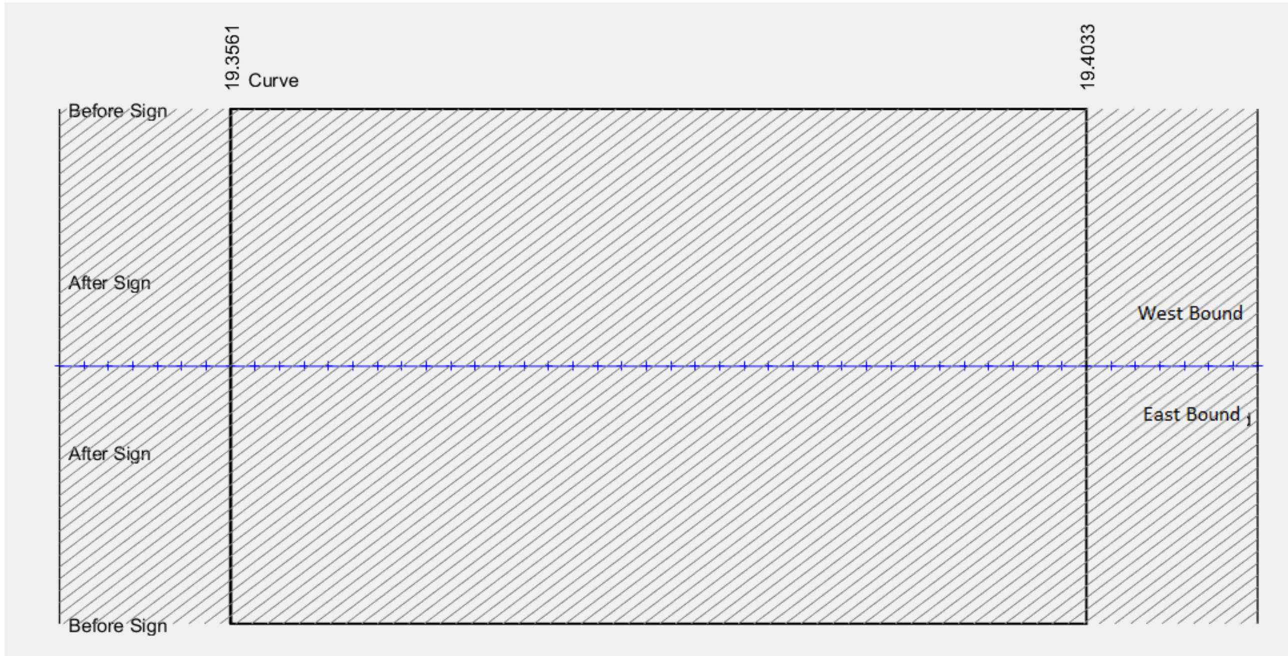
RCLINK:2811000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	325
Grade	10.7
Superelevation	8.5
Crashes	0
BBI	11
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #23 on State Route 2 in Towns County

Scale: NA

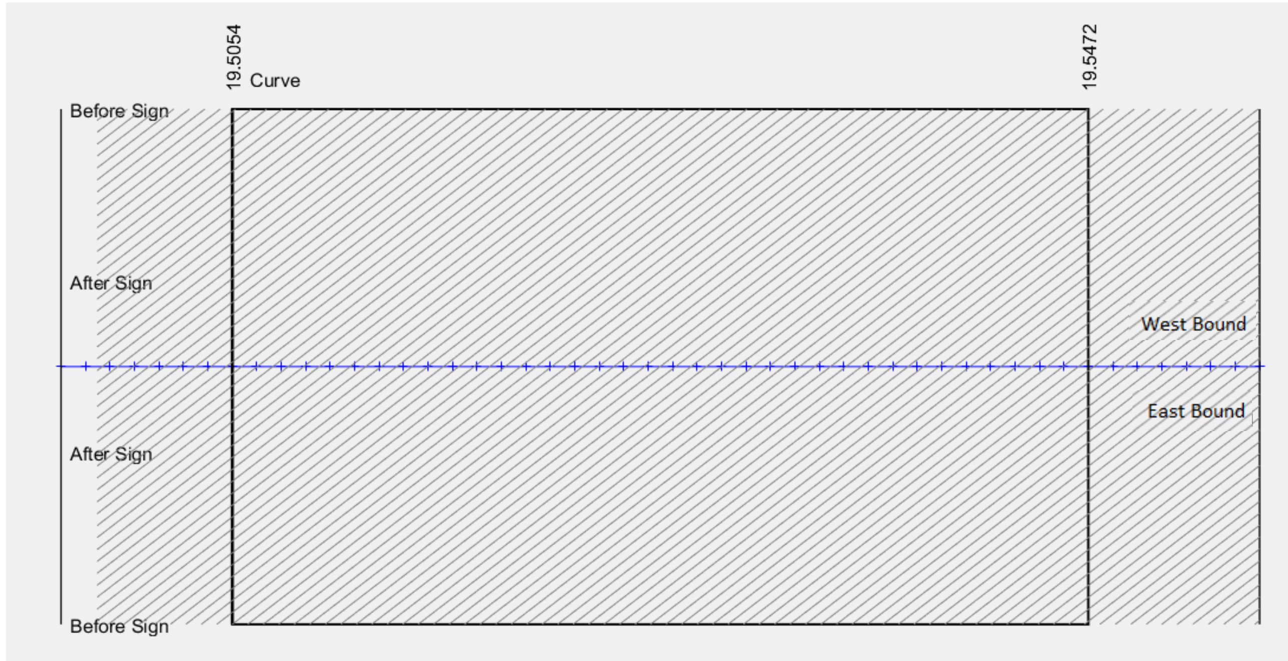
RCLINK:2811000200

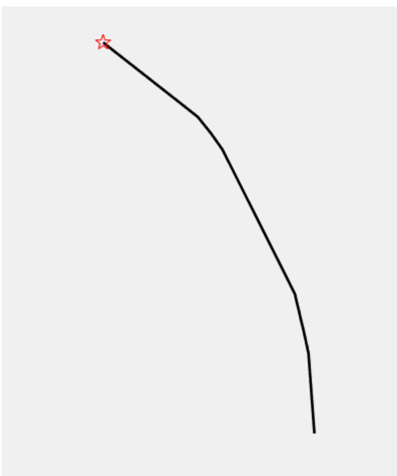
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	230
Grade	11.1
Superelevation	10.5
Crashes	0
BBI	10
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #24 on State Route 2 in Towns County

Scale: NA

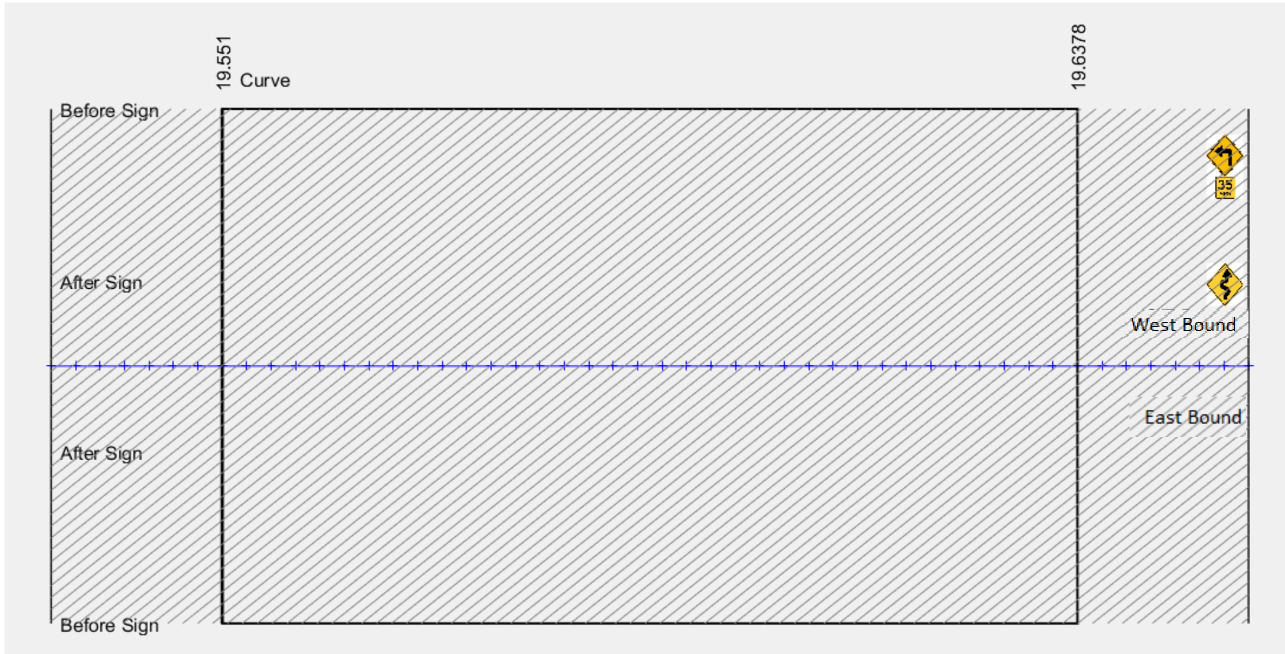
RCLINK:2811000200

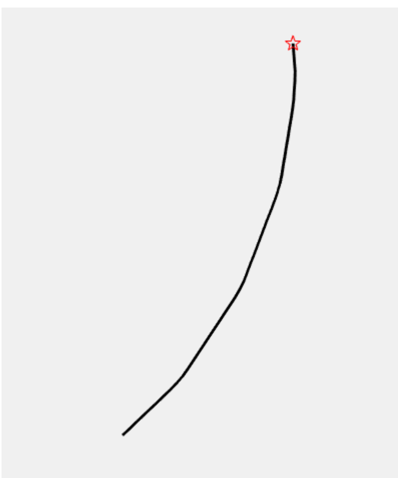
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	521
Grade	6.4
Superelevation	13.5
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #25 on State Route 2 in Towns County

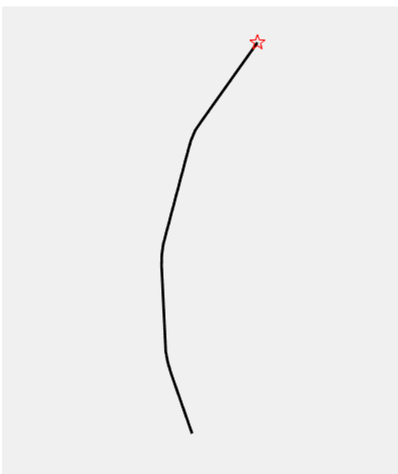
Scale: NA

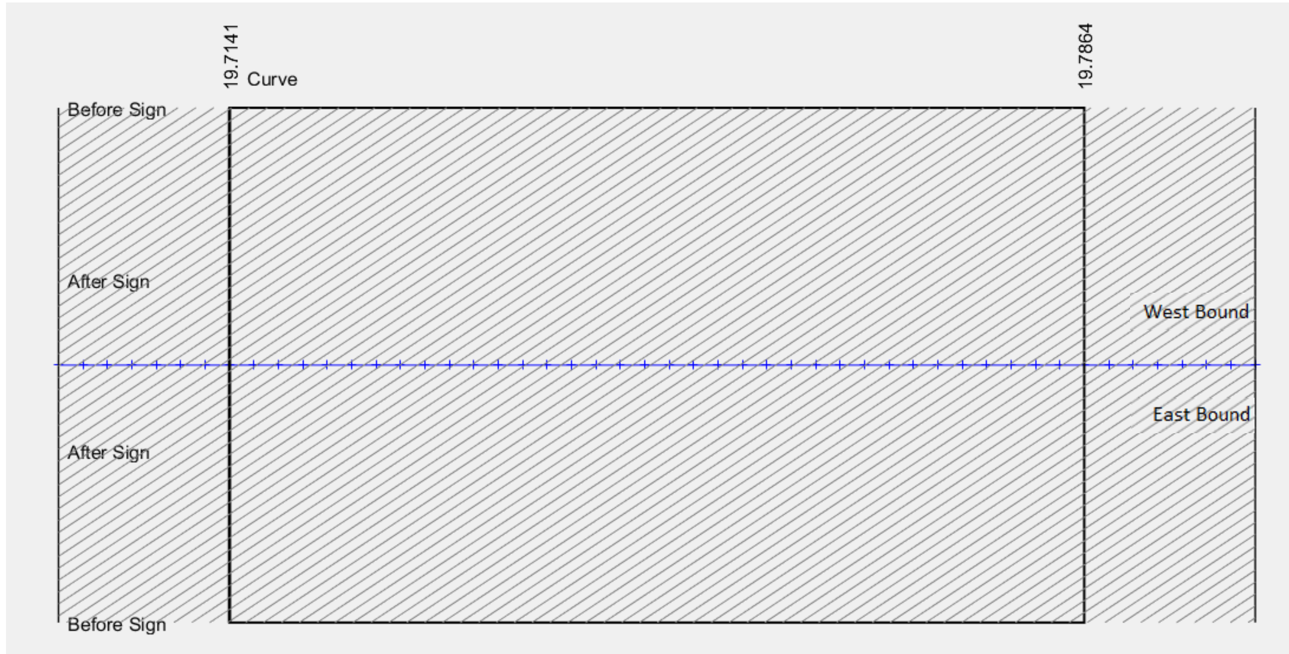
RCLINK:2811000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	326
Grade	4.4
Superelevation	11
Crashes	0
BBI	15
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #26 on State Route 2 in Towns County

Scale: NA

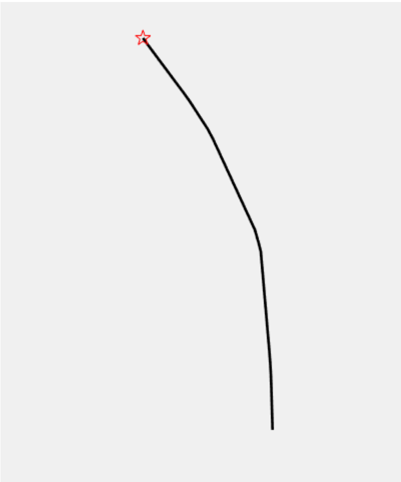
RCLINK:2811000200

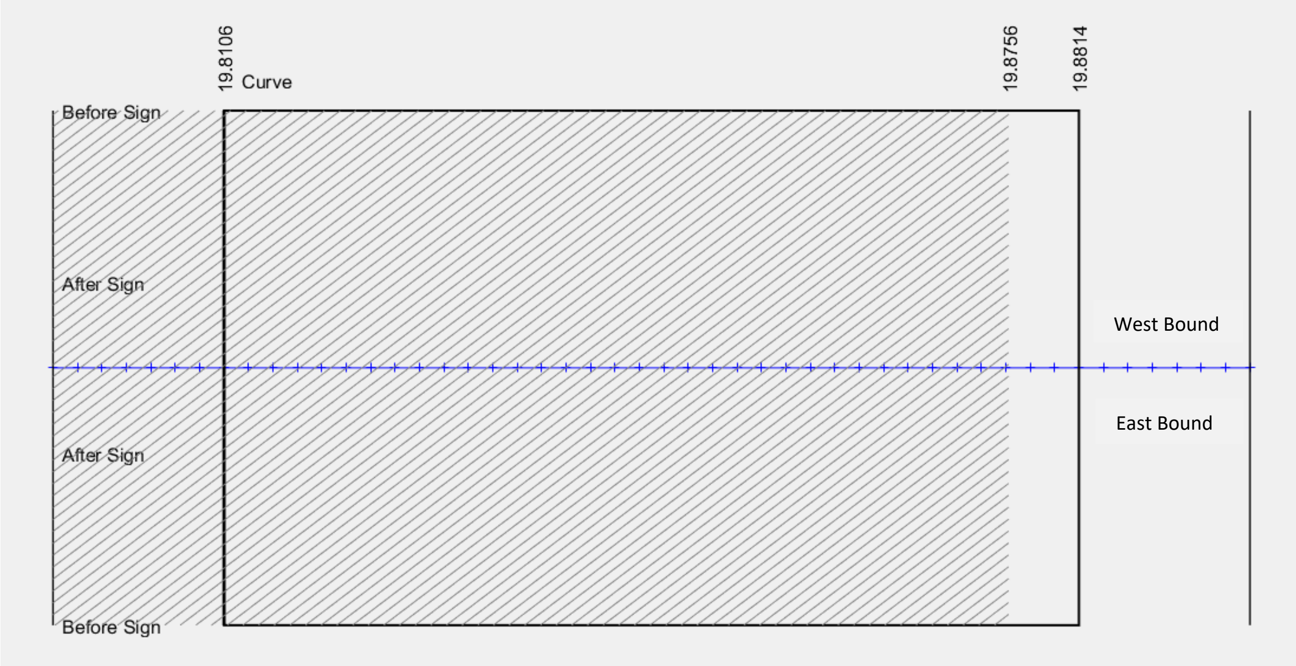
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	420
Grade	4.6
Superelevation	11
Crashes	0
BBI	14
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

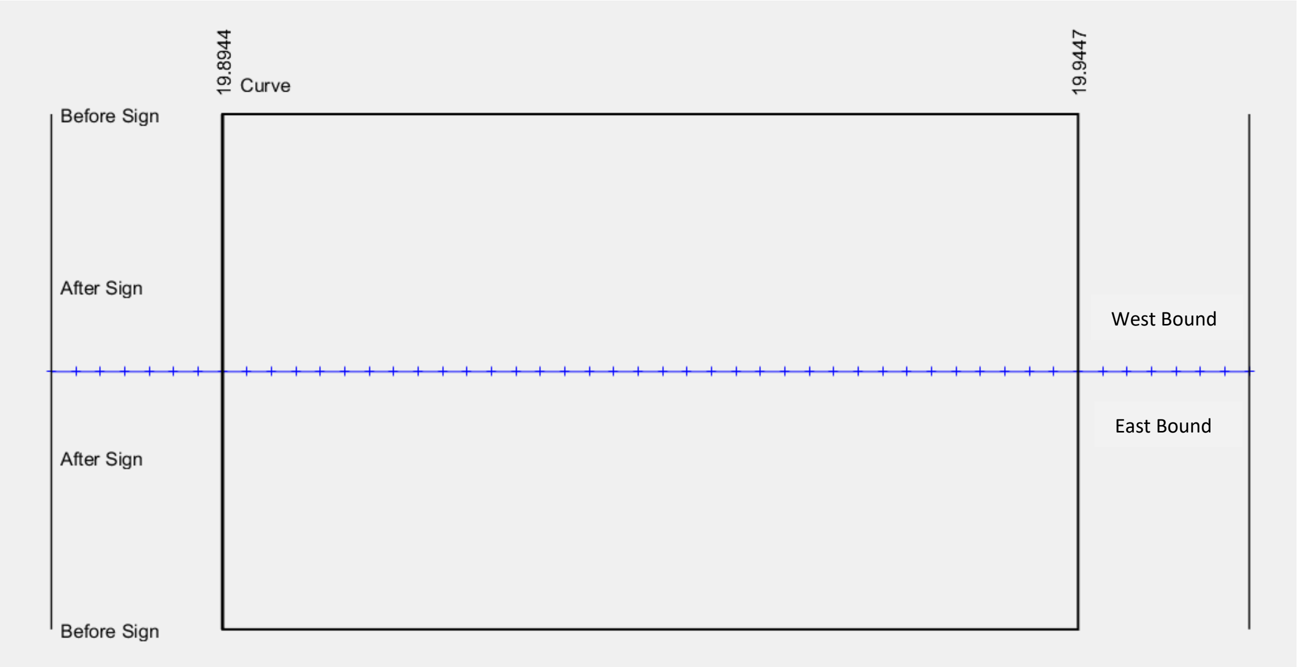
Curve #27 on State Route 2 in Towns County

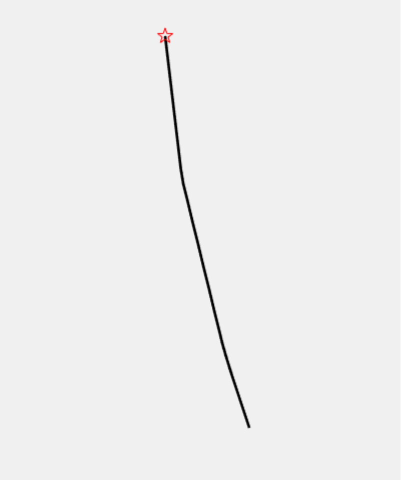
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	1028
Grade	2.1
Superelevation	5
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

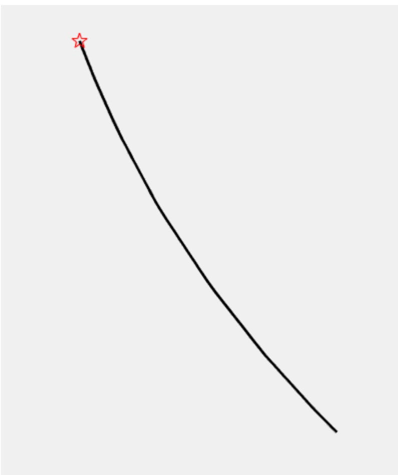
Curve #28 on State Route 2 in Towns County

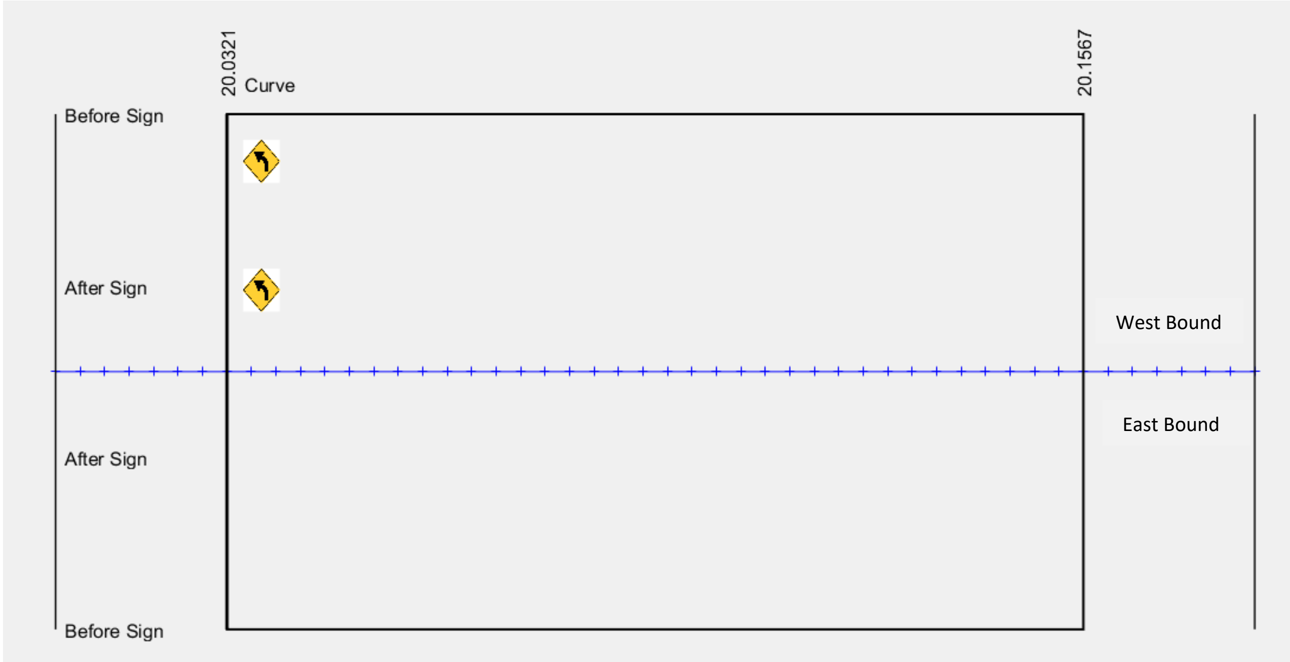
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	1476
Grade	4.5
Superelevation	4.5
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

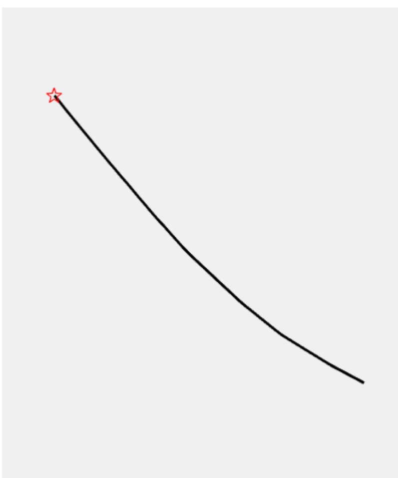
Curve #29 on State Route 2 in Towns County

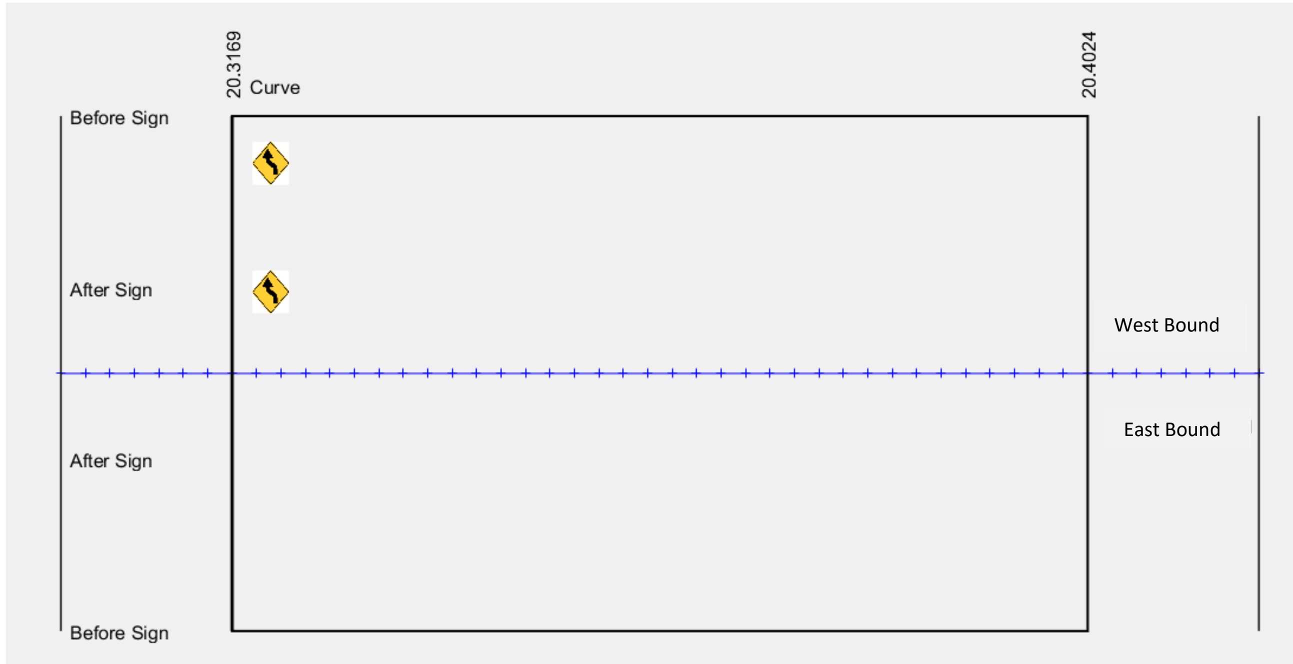
Scale: NA

RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	935
Grade	4.5
Superelevation	10
Crashes	0
BBI	6
Posted Speed	nan
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

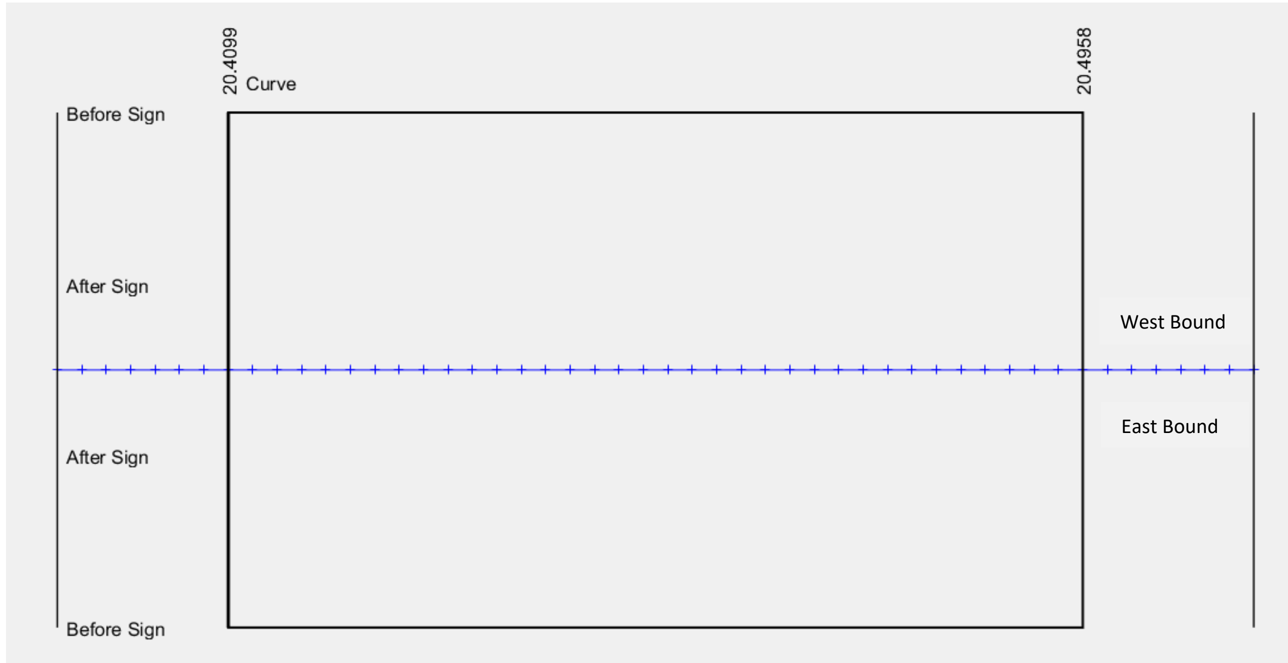
Curve #30 on State Route 2 in Towns County

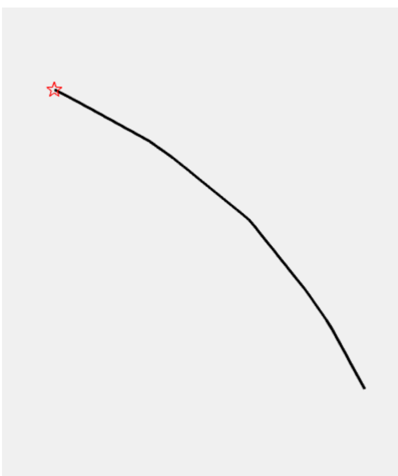
Scale: NA

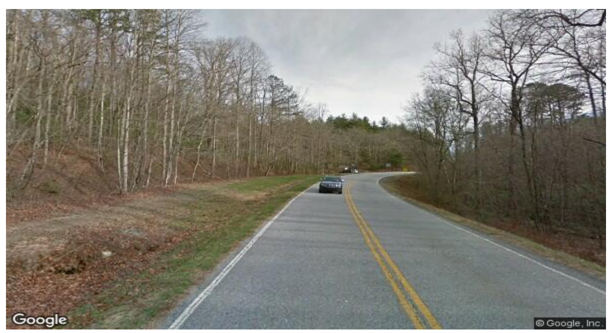
RCLINK:2811000200

Georgia Institute of Technology

Road Characteristics	
Radius	595
Grade	5.5
Superelevation	11
Crashes	0
BBI	8
Posted Speed	nan
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA







Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #31 on State Route 2 in Towns County

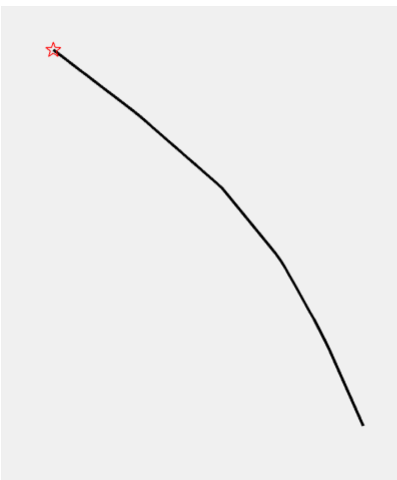
Scale: NA

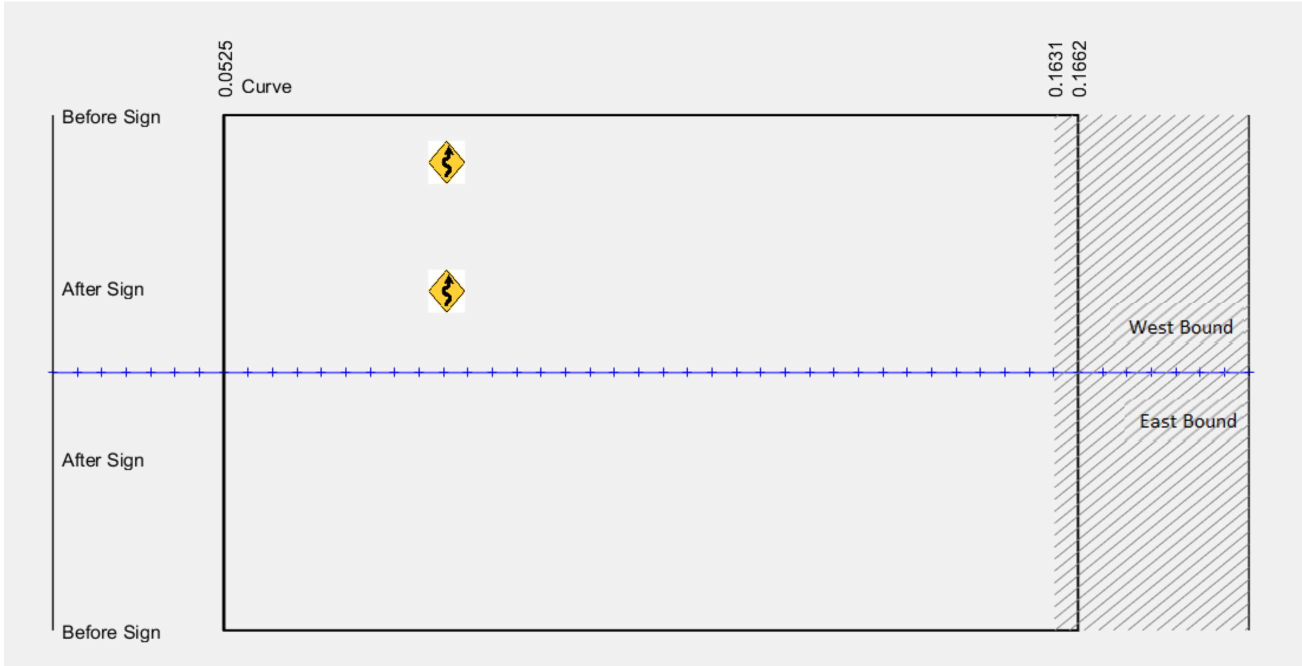
RCLINK:2811000200

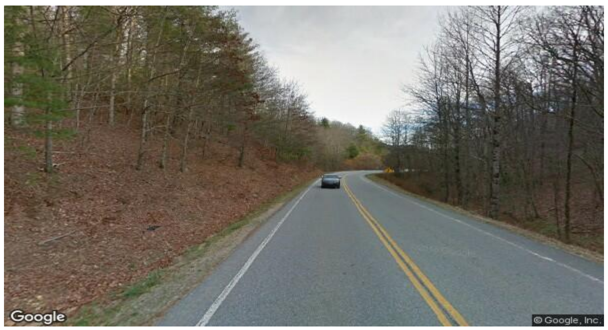
Georgia Institute of Technology

Road Characteristics

Radius	811
Grade	-5.9
Superelevation	7
Crashes	0
BBI	12
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA







Horizontal Curve Schematic

Curve #32 on State Route 2 in Rabun County

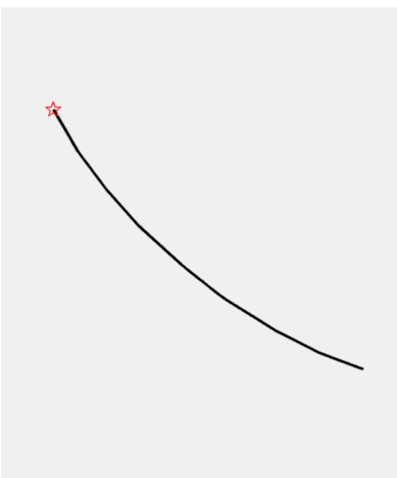
Scale: NA

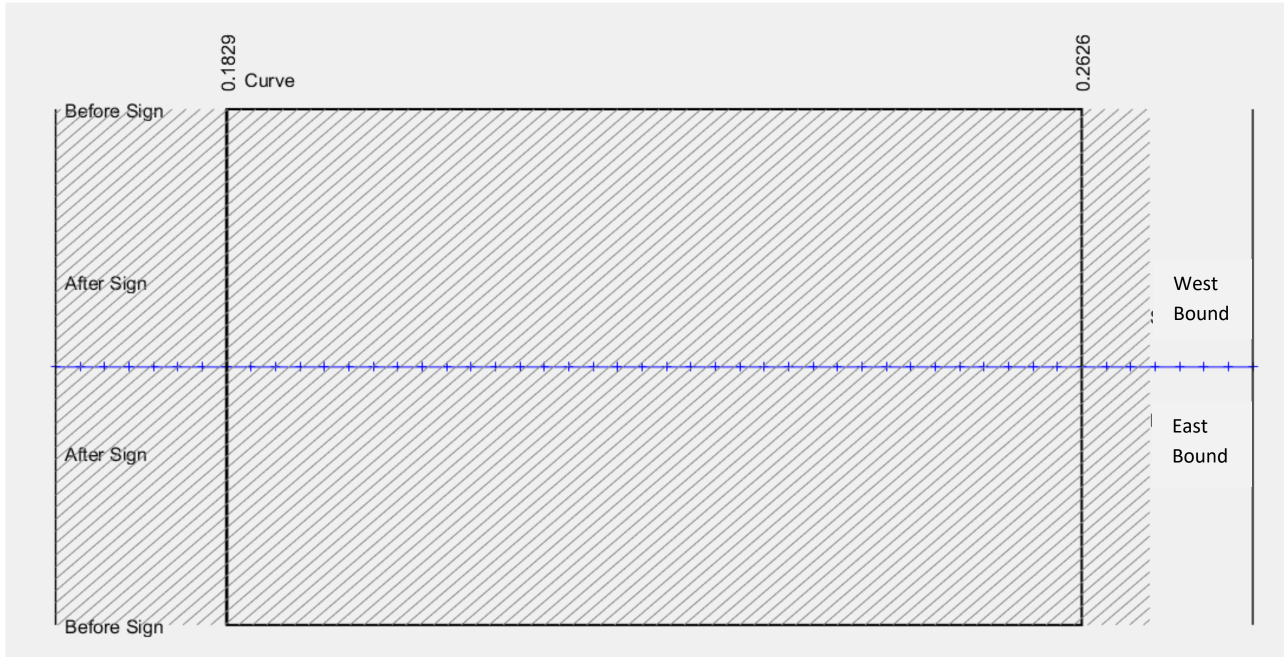
RCLINK:2411000200

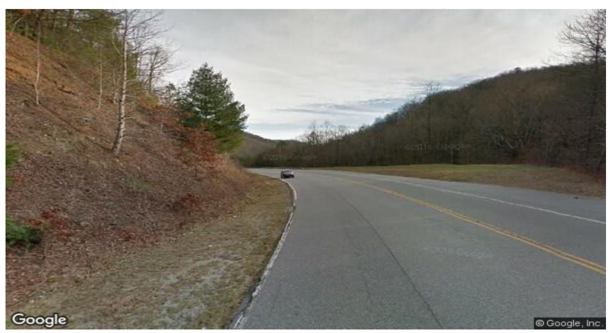
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	588
Grade	-5.9
Superelevation	9.5
Crashes	0
BBI	10
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA







Horizontal Curve Schematic

Georgia Department of Transportation

Curve #33 on State Route 2 in Rabun County

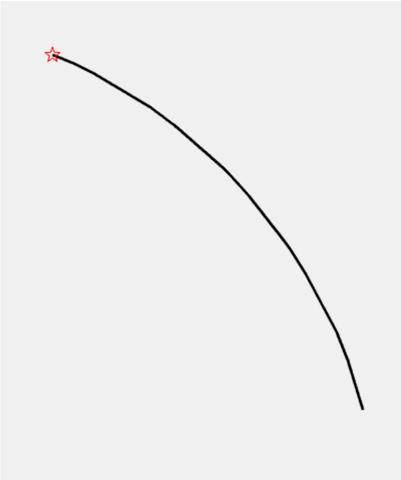
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	714
Grade	-5.8
Superelevation	8
Crashes	0
BBI	11
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

GDOT Georgia Department of Transportation

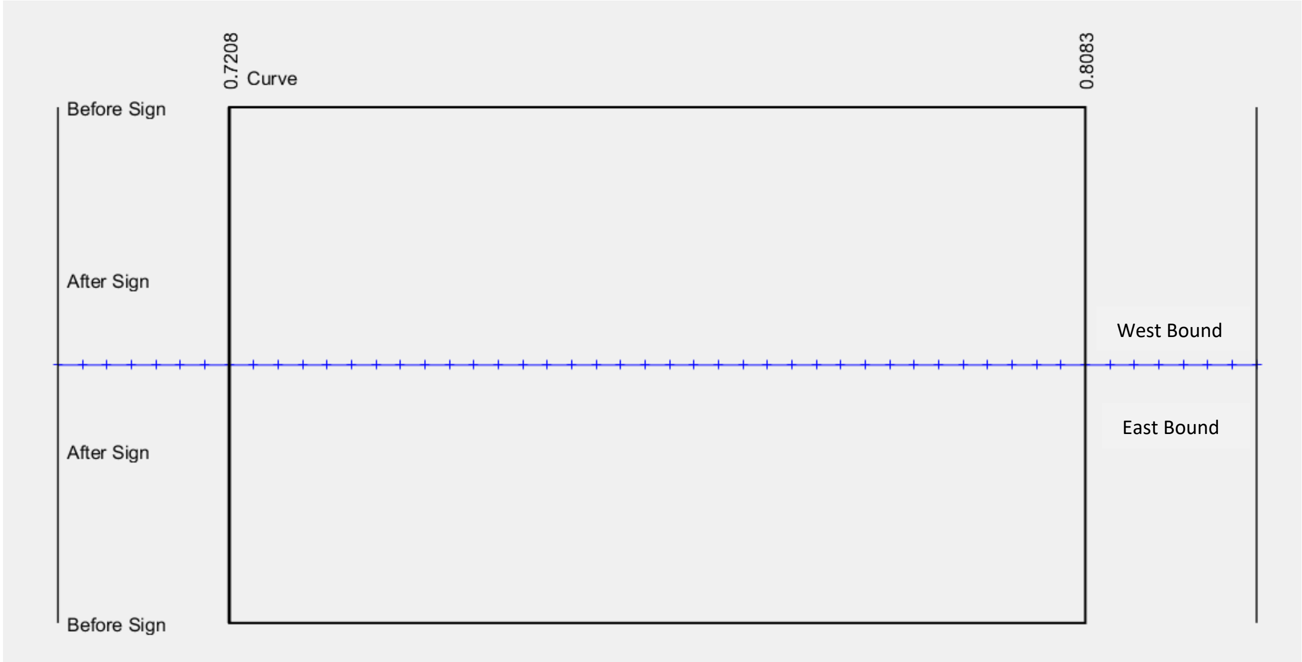
Curve #34 on State Route 2 in Rabun County

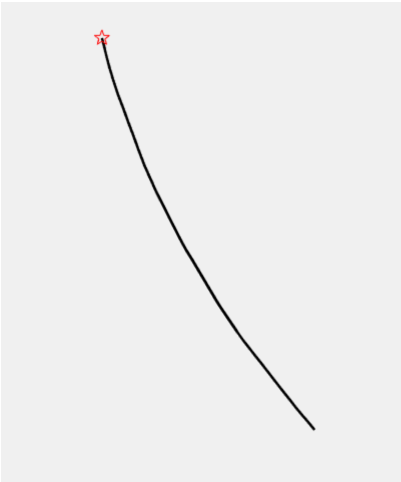
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	940
Grade	-4.4
Superelevation	7.5
Crashes	0
BBI	9
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #35 on State Route 2 in Rabun County

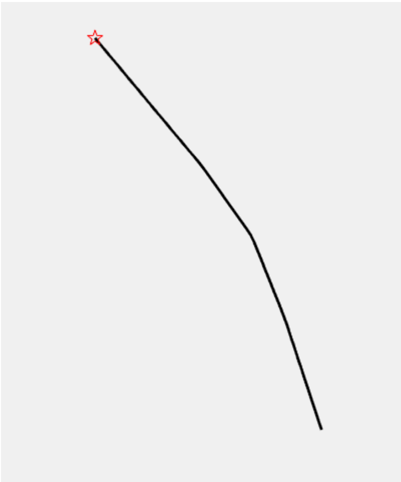
Scale: NA

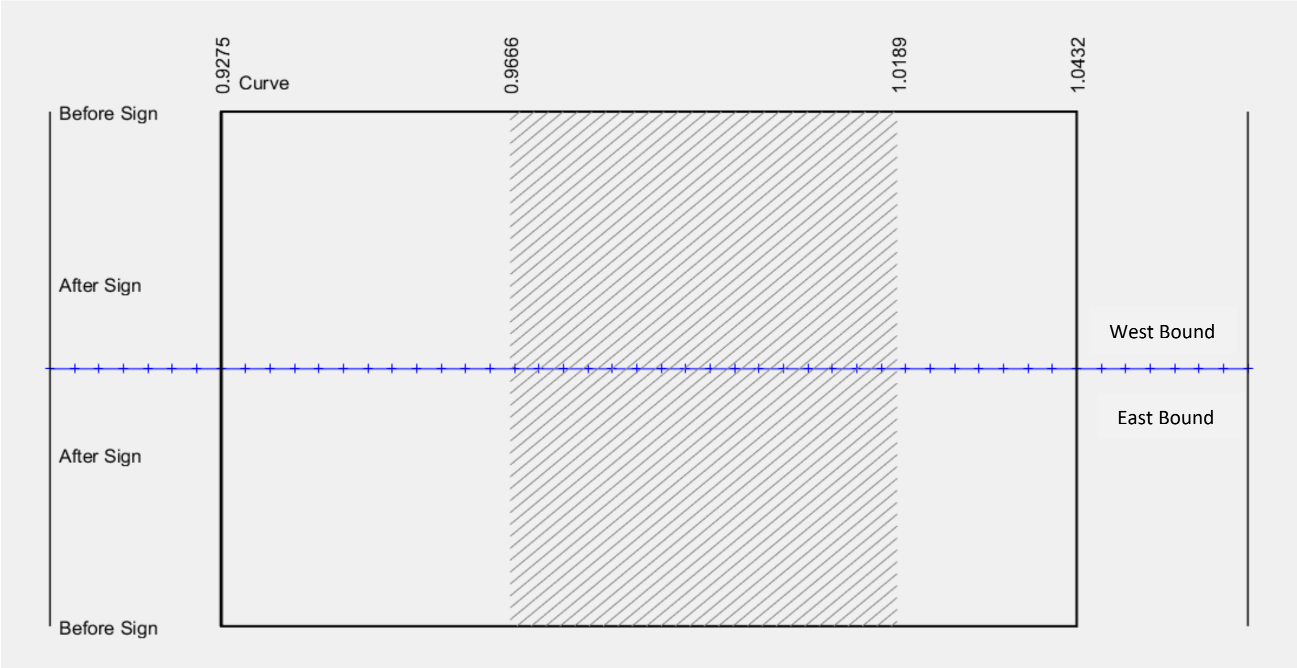
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	959
Grade	3.6
Superelevation	6.5
Crashes	0
BBI	13
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #36 on State Route 2 in Rabun County

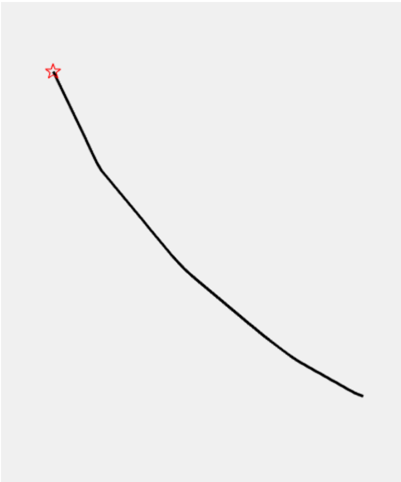
Scale: NA

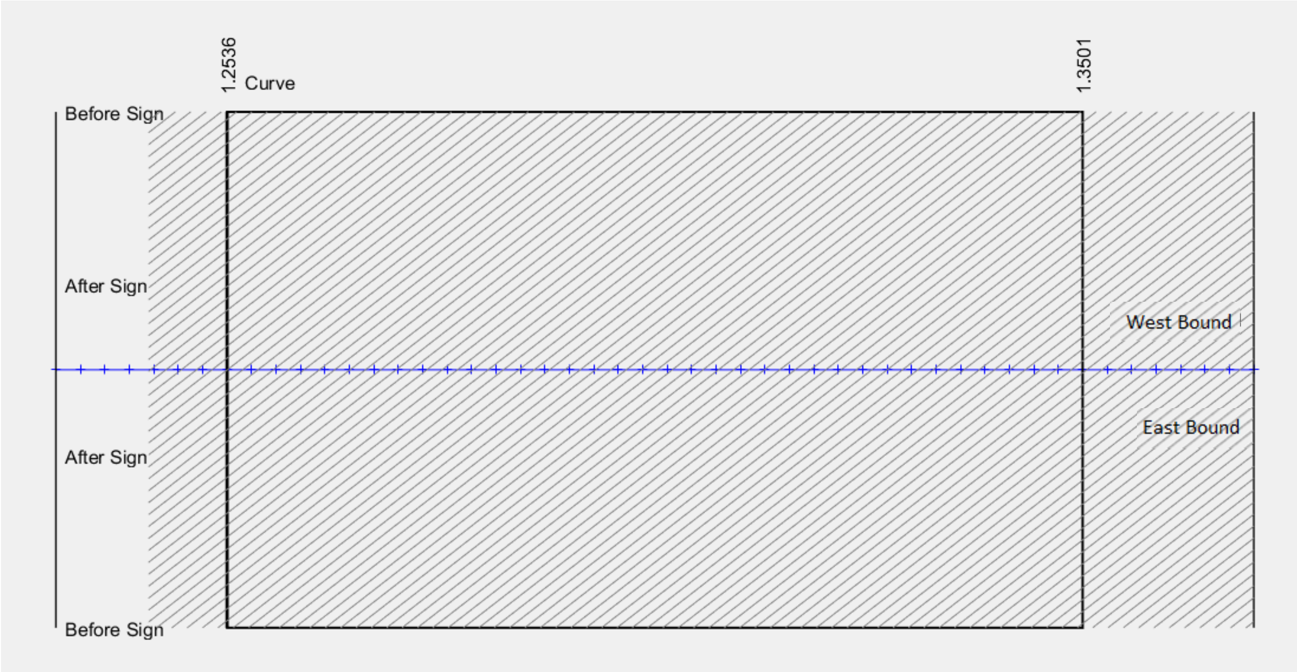
RCLINK:2411000200

Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	680
Grade	5.3
Superelevation	8
Crashes	0
BBI	14
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #37 on State Route 2 in Rabun County

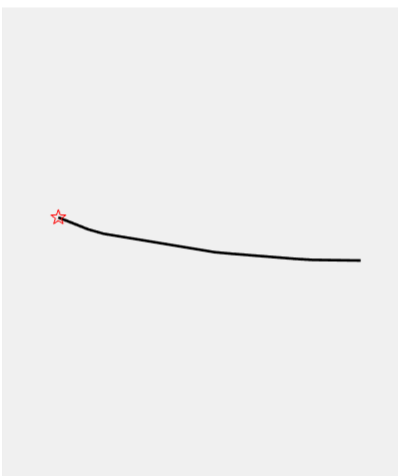
Scale: NA

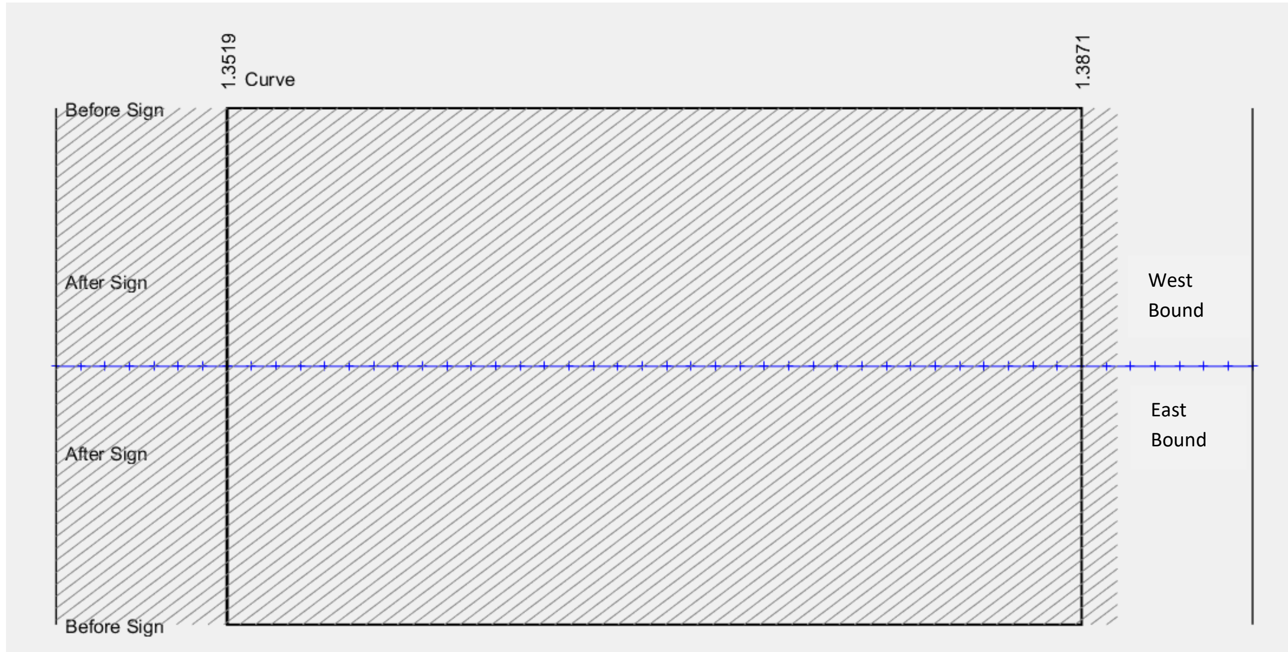
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	531
Grade	5.1
Superelevation	8.5
Crashes	0
BBI	13
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #38 on State Route 2 in Rabun County

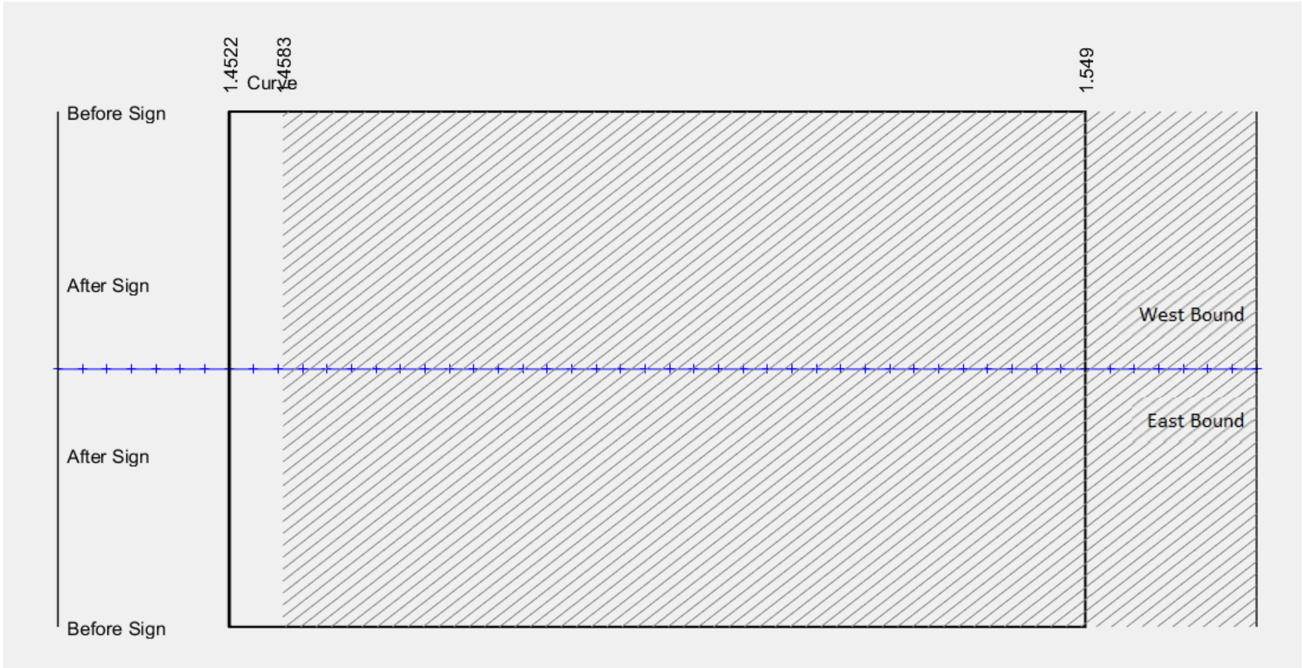
Scale: NA

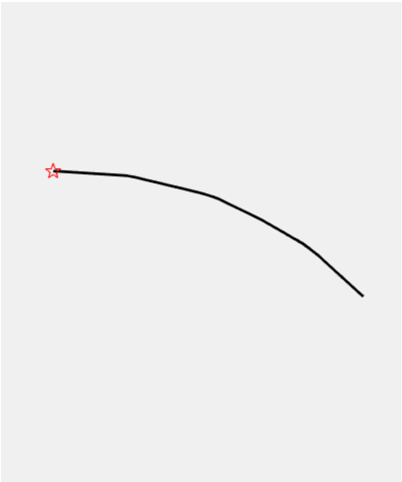
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	593
Grade	7.5
Superelevation	6
Crashes	0
BBI	10
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #39 on State Route 2 in Rabun County

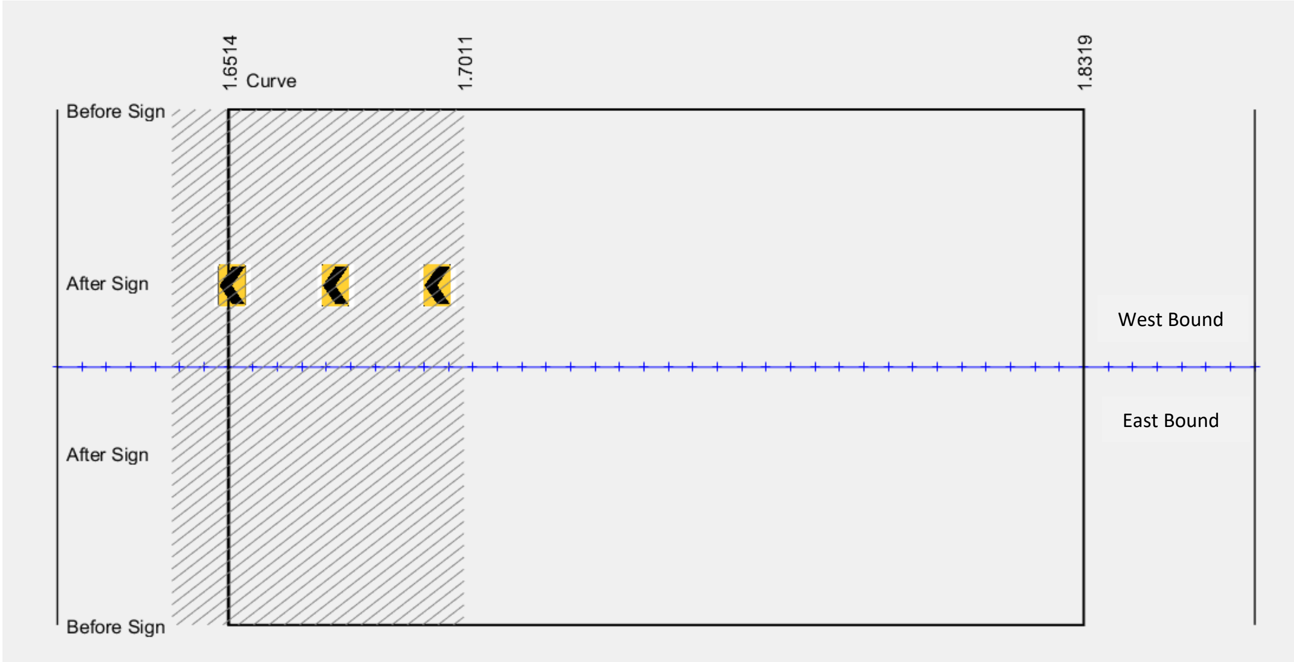
Scale: NA

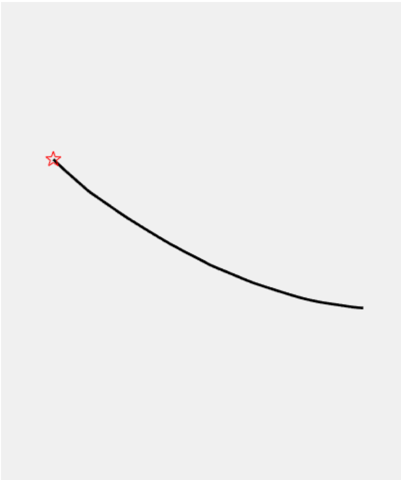
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1549
Grade	2.9
Superelevation	8
Crashes	0
BBI	8
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #40 on State Route 2 in Rabun County

Scale: NA

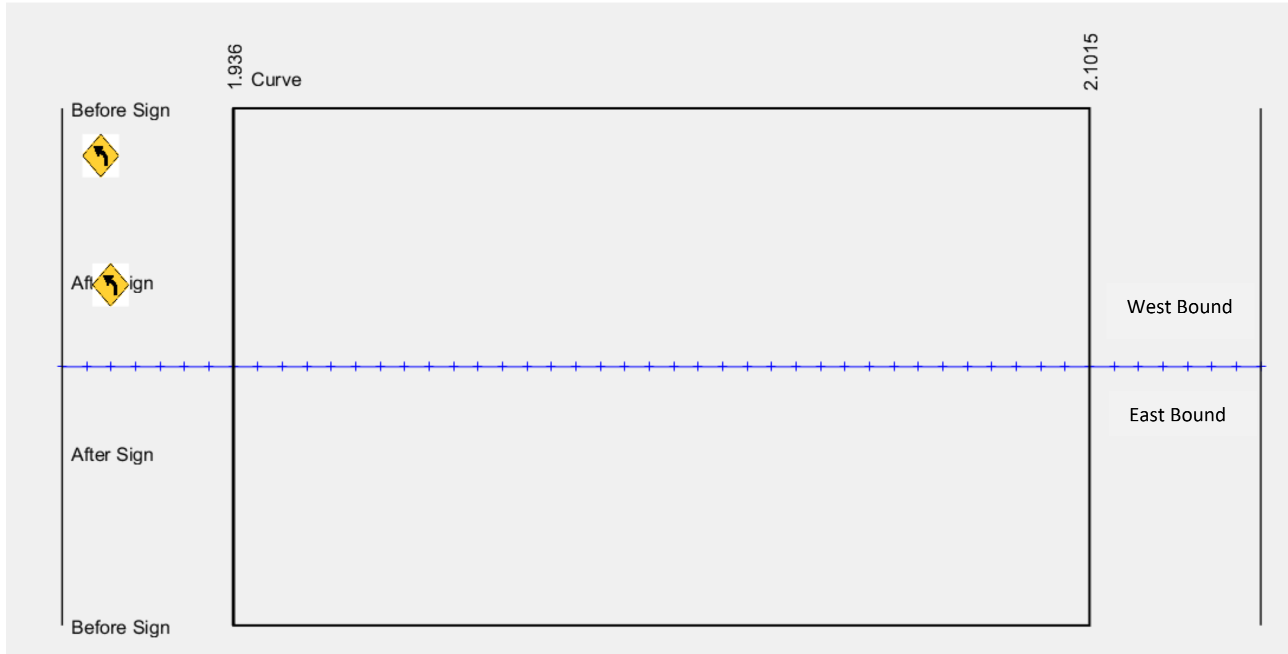
RCLINK:2411000200

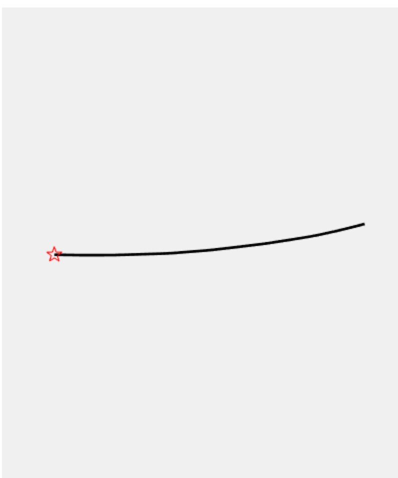
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	3235
Grade	1
Superelevation	5
Crashes	0
BBI	4
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





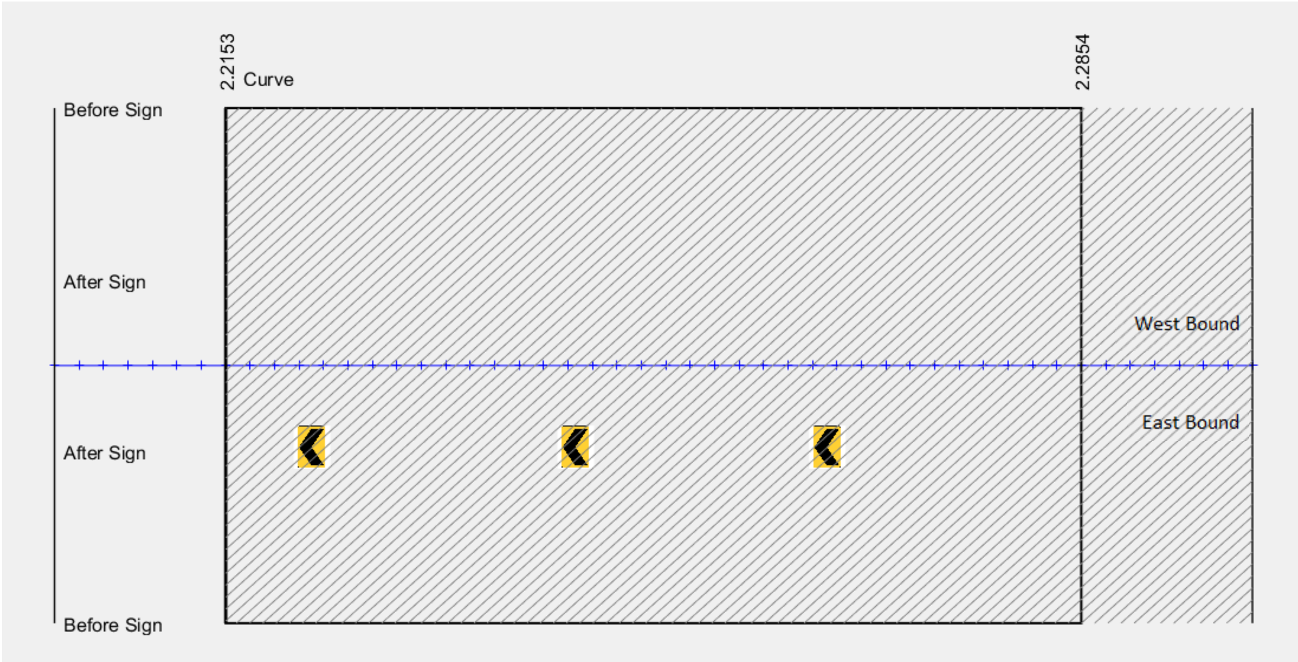
Horizontal Curve Schematic

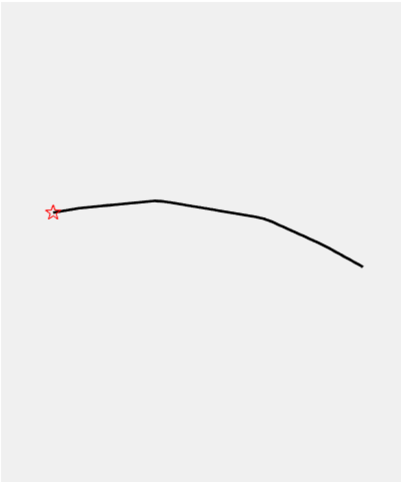
Curve #41 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	463
Grade	-2.3
Superelevation	9
Crashes	0
BBI	13
Posted Speed	45
Advisory Speed	25
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





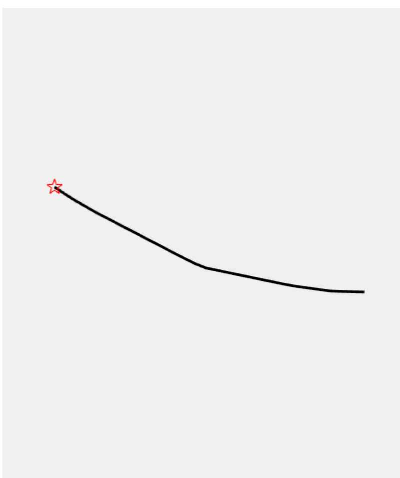
Horizontal Curve Schematic

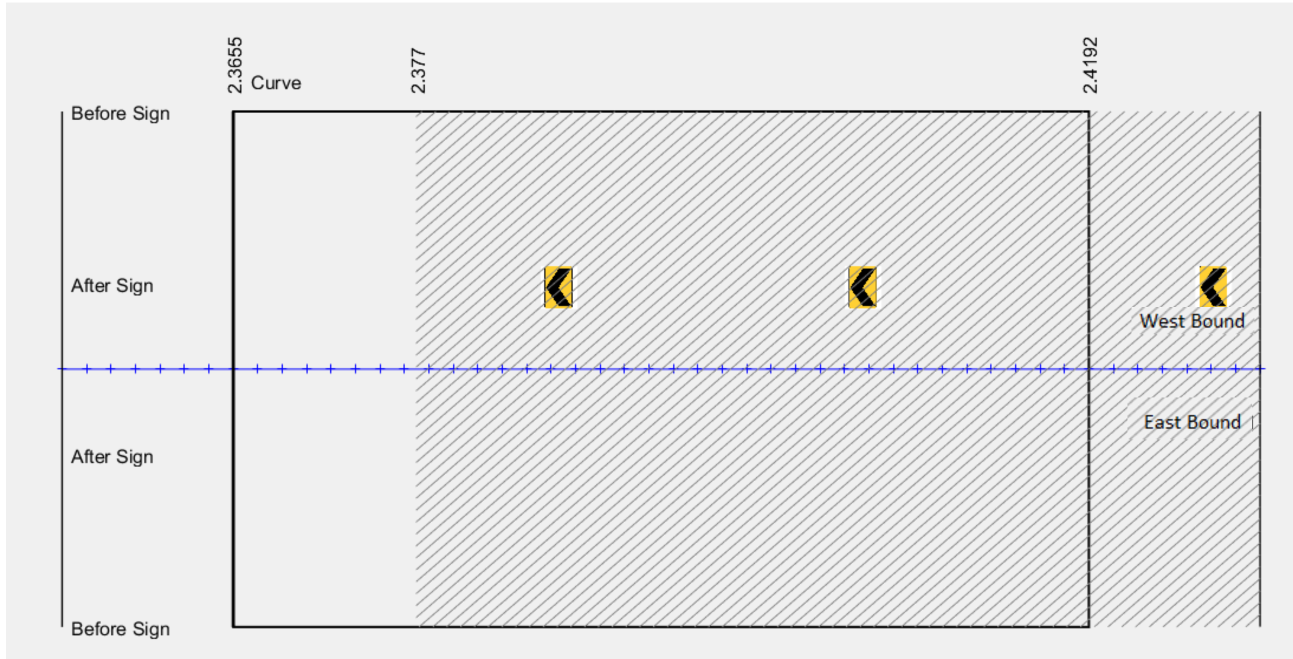
Curve #42 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	455
Grade	-1
Superelevation	6.5
Crashes	0
BBI	16
Posted Speed	45
Advisory Speed	25
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #43 on State Route 2 in Rabun County

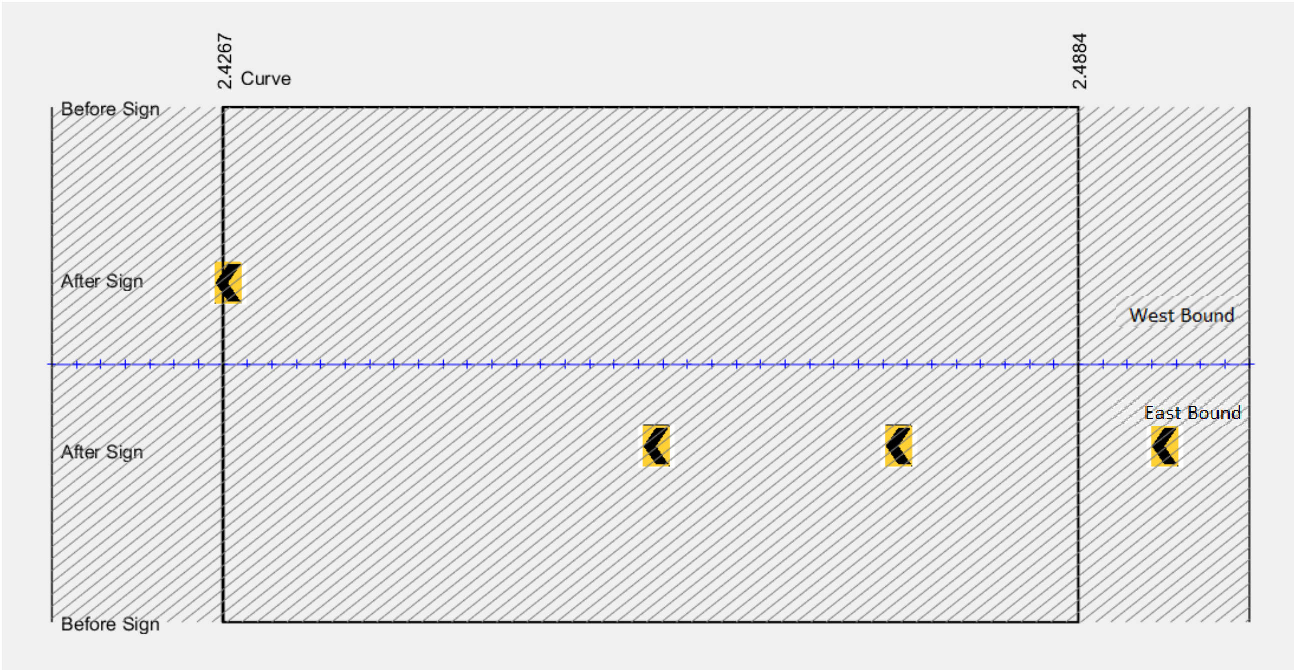
Scale: NA

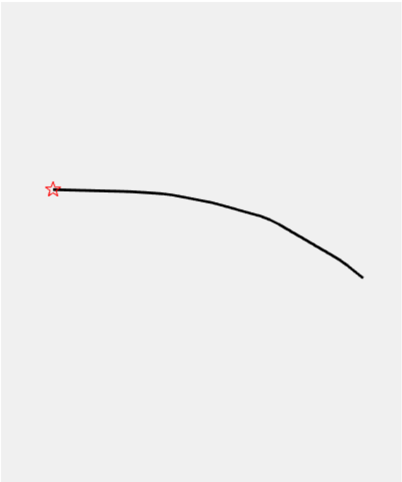
RCLINK:2411000200

Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	426
Grade	-4.7
Superelevation	6.5
Crashes	2
BBI	17
Posted Speed	45
Advisory Speed	25
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

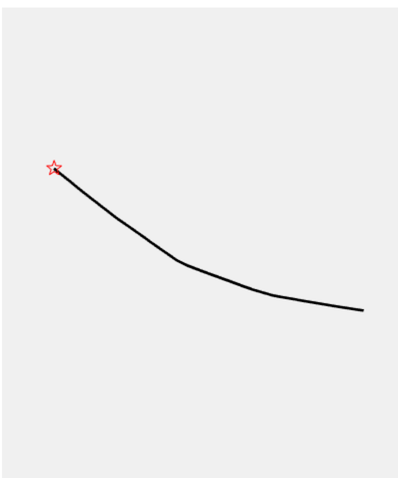
Curve #44 on State Route 2 in Rabun County

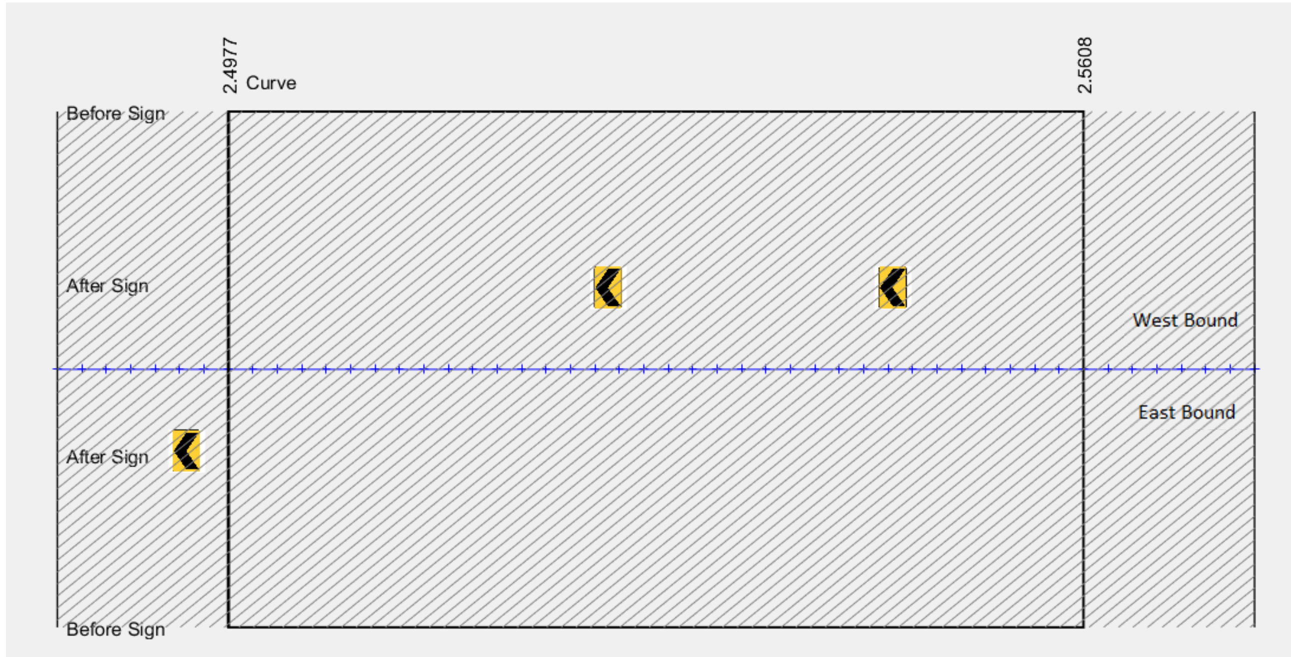
Scale: NA

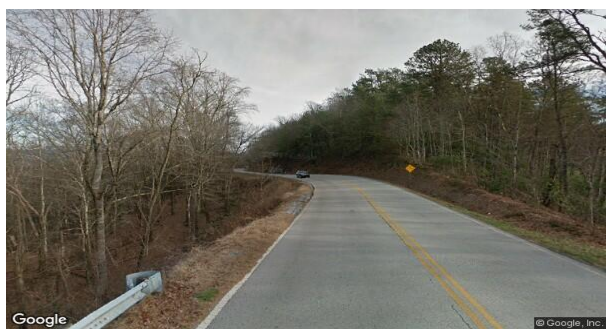
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	443
Grade	-5.5
Superelevation	9
Crashes	0
BBI	17
Posted Speed	45
Advisory Speed	25
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA







Horizontal Curve Schematic

Georgia Department of Transportation

Curve #45 on State Route 2 in Rabun County

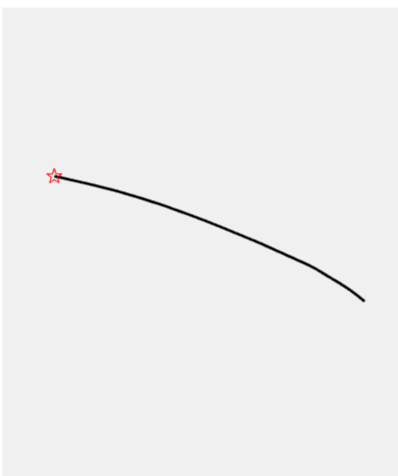
Scale: NA

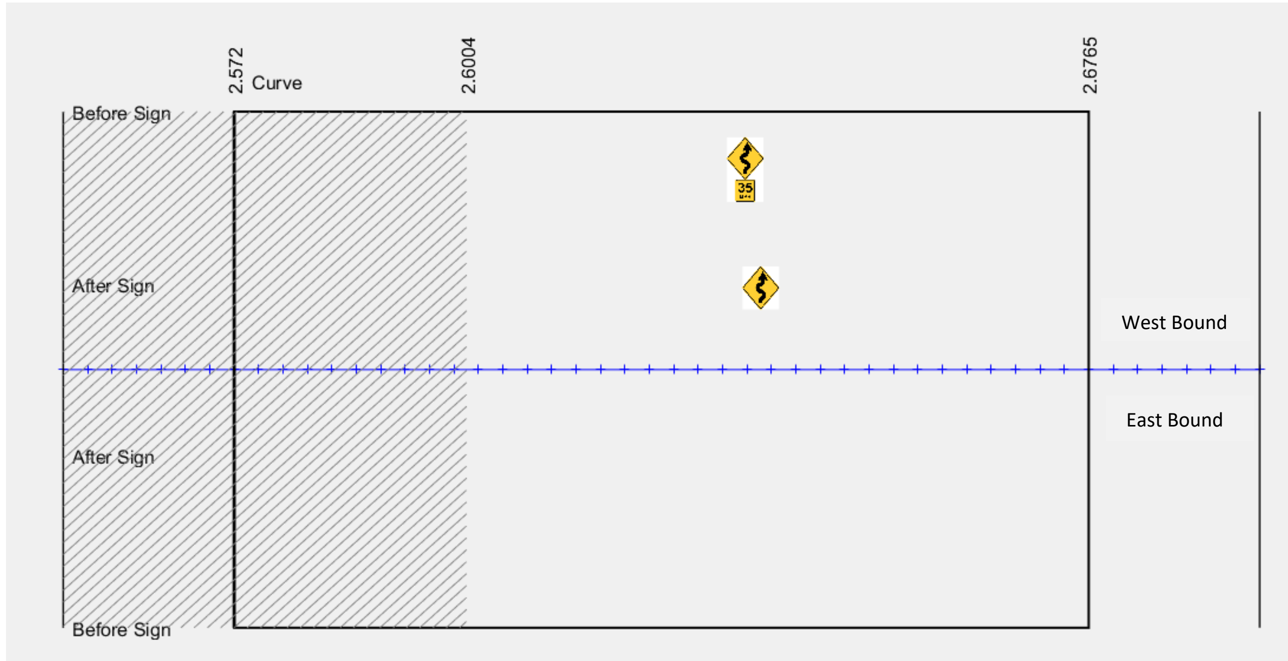
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1635
Grade	-5.8
Superelevation	8
Crashes	1
BBI	7
Posted Speed	45
Advisory Speed	25
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

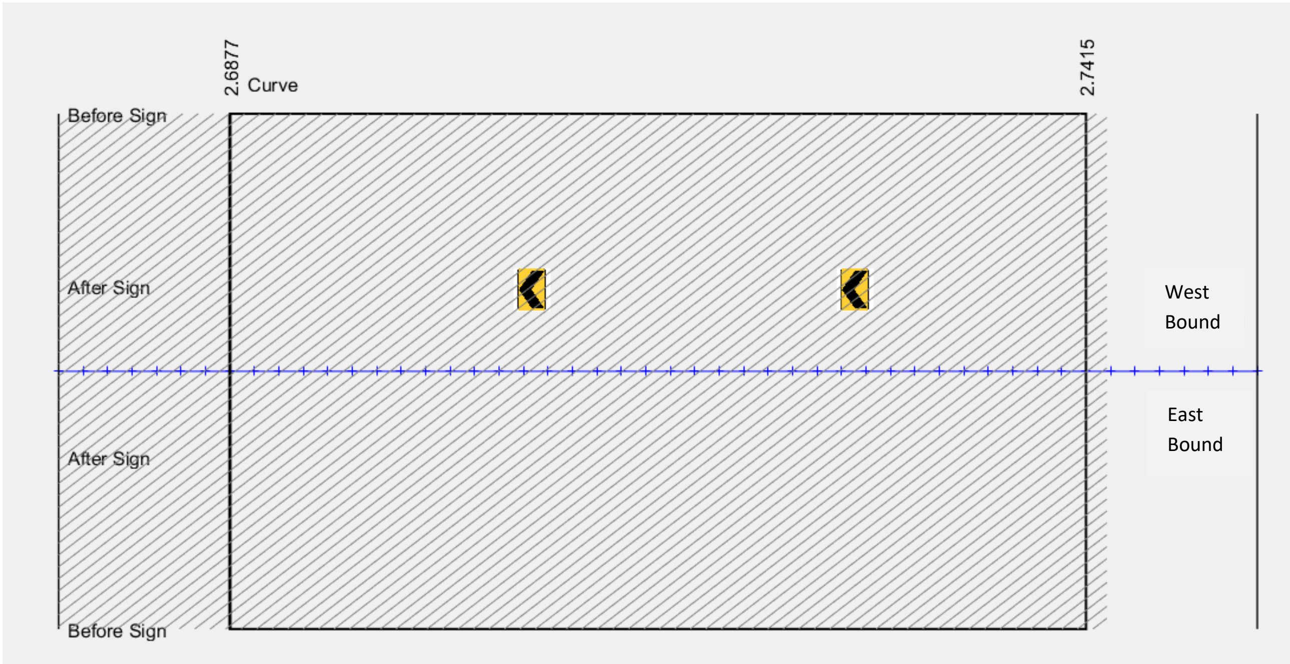
Curve #46 on State Route 2 in Rabun County

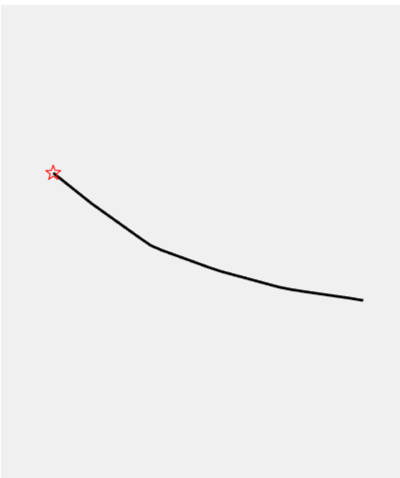
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	365
Grade	-6.8
Superelevation	11
Crashes	0
BBI	11
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

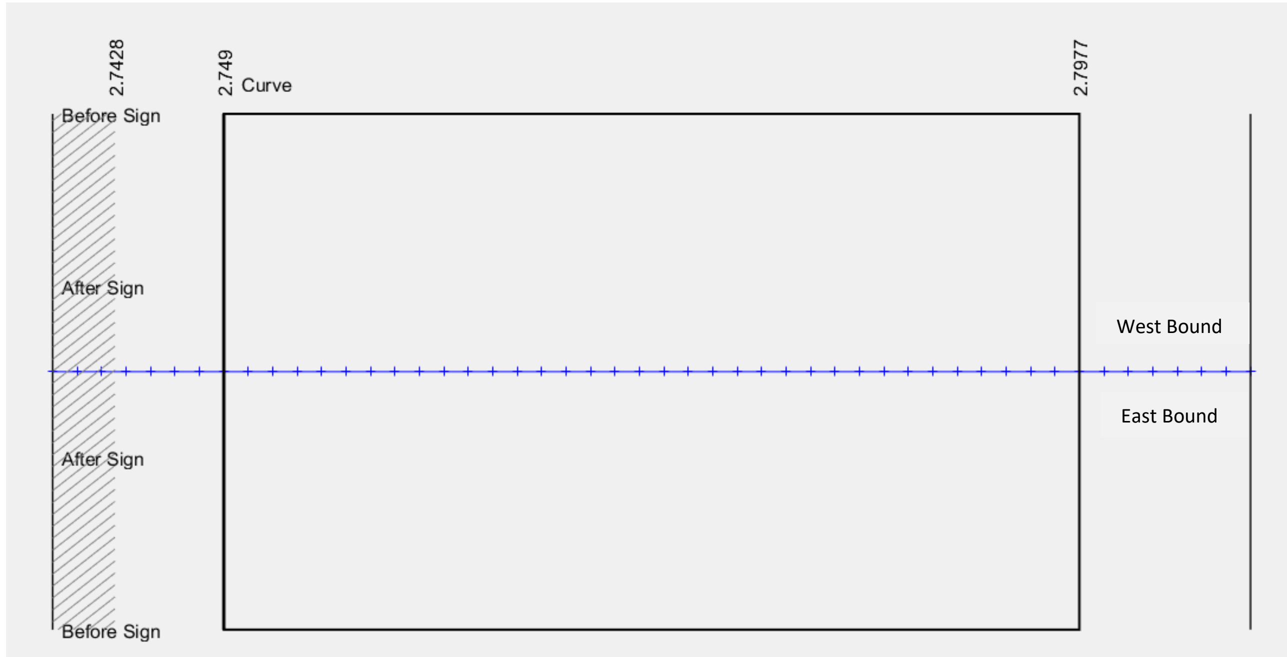
Curve #47 on State Route 2 in Rabun County

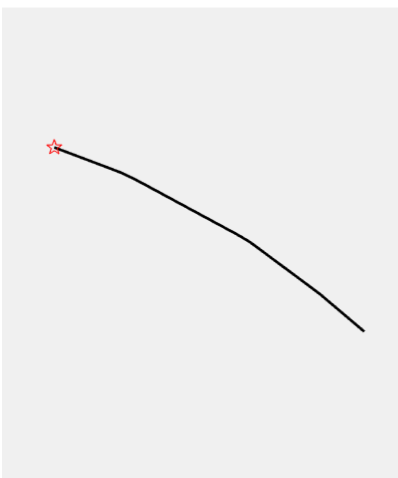
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	610
Grade	-6
Superelevation	10
Crashes	0
BBI	8
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #48 on State Route 2 in Rabun County

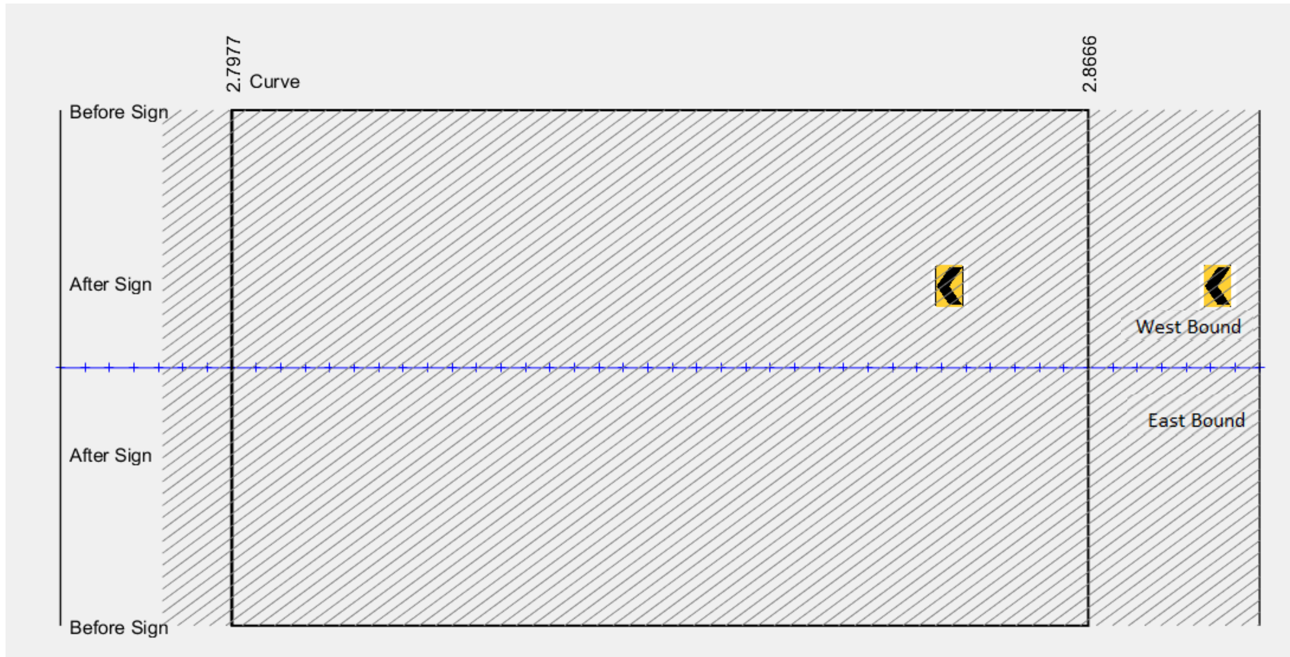
Scale: NA

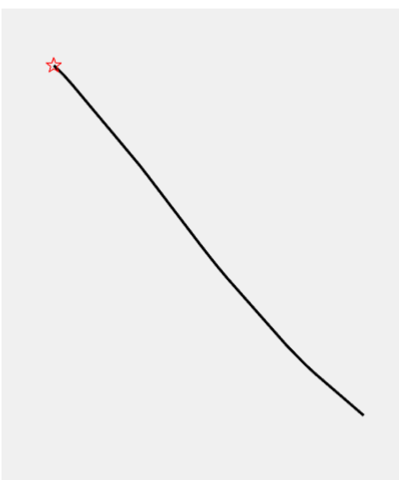
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1402
Grade	-4.3
Superelevation	8.5
Crashes	0
BBI	9
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #49 on State Route 2 in Rabun County

Scale: NA

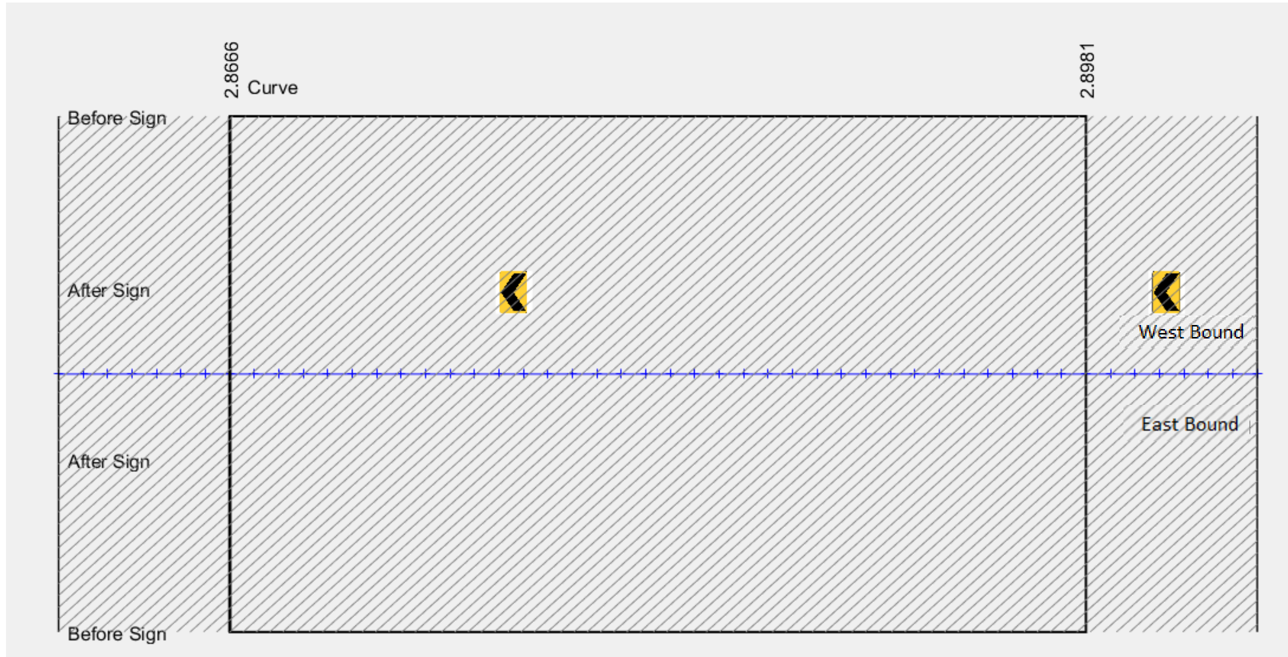
RCLINK:2411000200

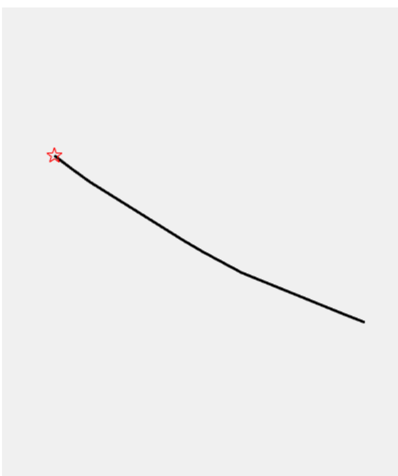
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	469
Grade	-5
Superelevation	8
Crashes	0
BBI	11
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #50 on State Route 2 in Rabun County

Scale: NA

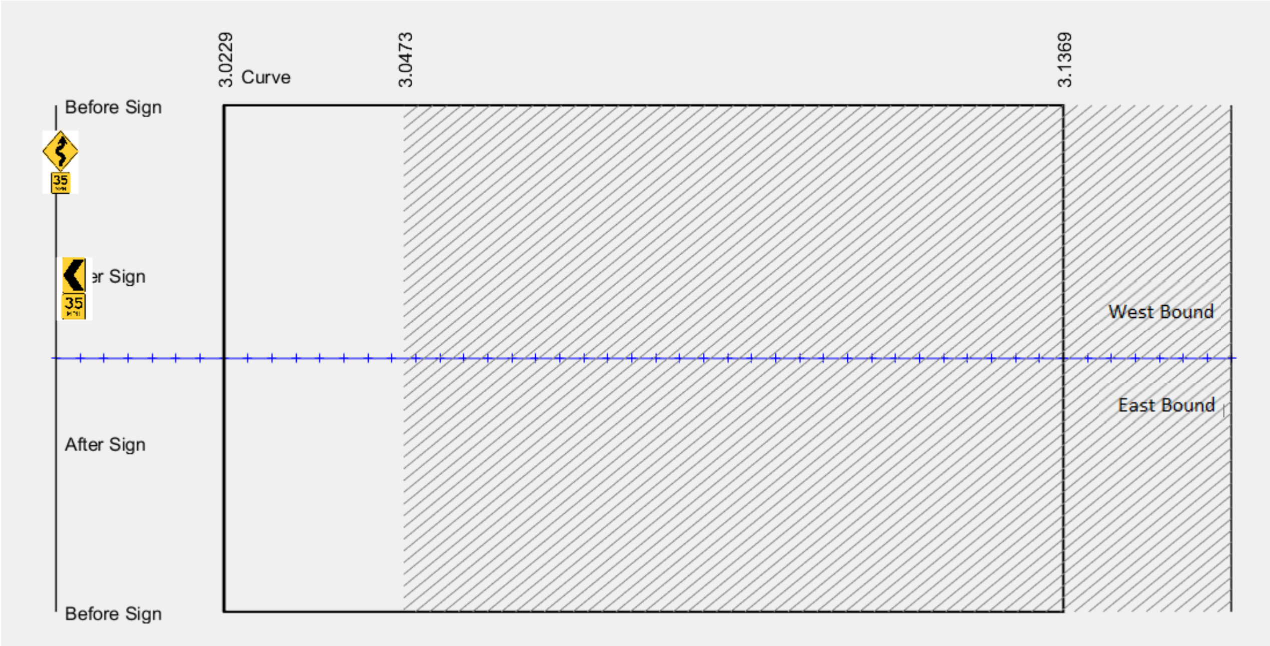
RCLINK:2411000200

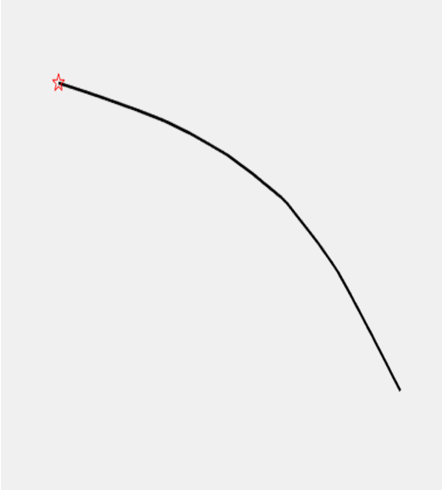
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	608
Grade	0.3
Superelevation	7.5
Crashes	0
BBI	12
Posted Speed	45
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #51 on State Route 2 in Rabun County

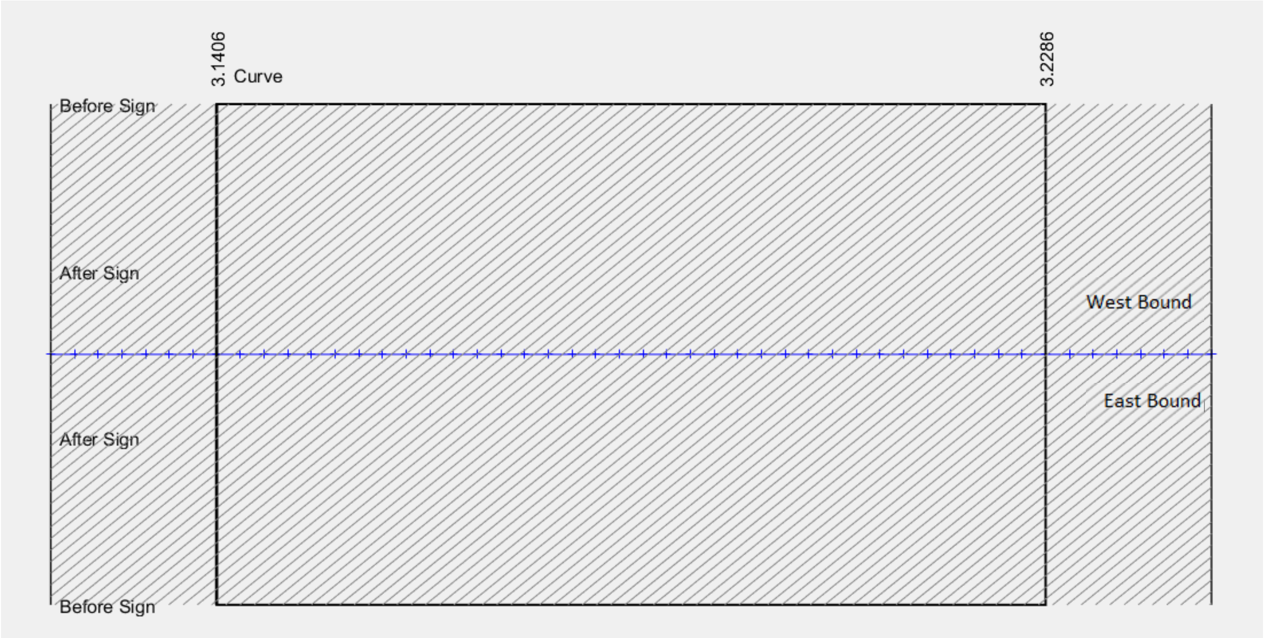
Scale: NA

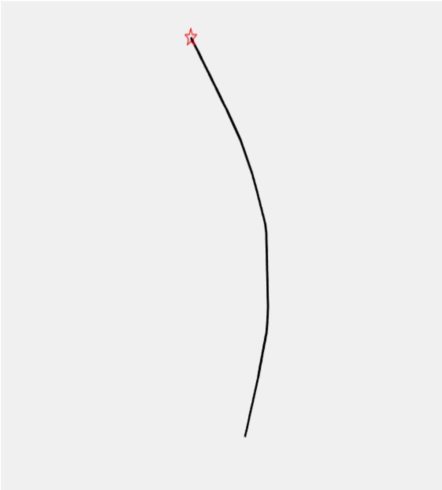
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	351
Grade	0.6
Superelevation	7.5
Crashes	0
BBI	16
Posted Speed	45
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #52 on State Route 2 in Rabun County

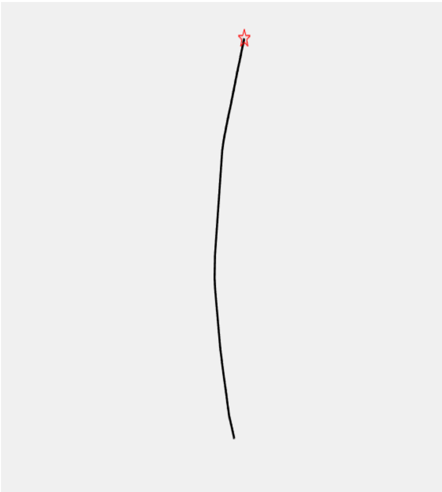
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	497
Grade	0.2
Superelevation	6.5
Crashes	0
BBI	12
Posted Speed	45
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

Georgia Department of Transportation

Curve #53 on State Route 2 in Rabun County

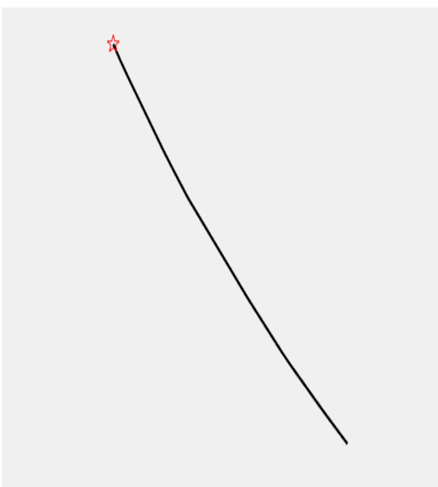
Scale: NA

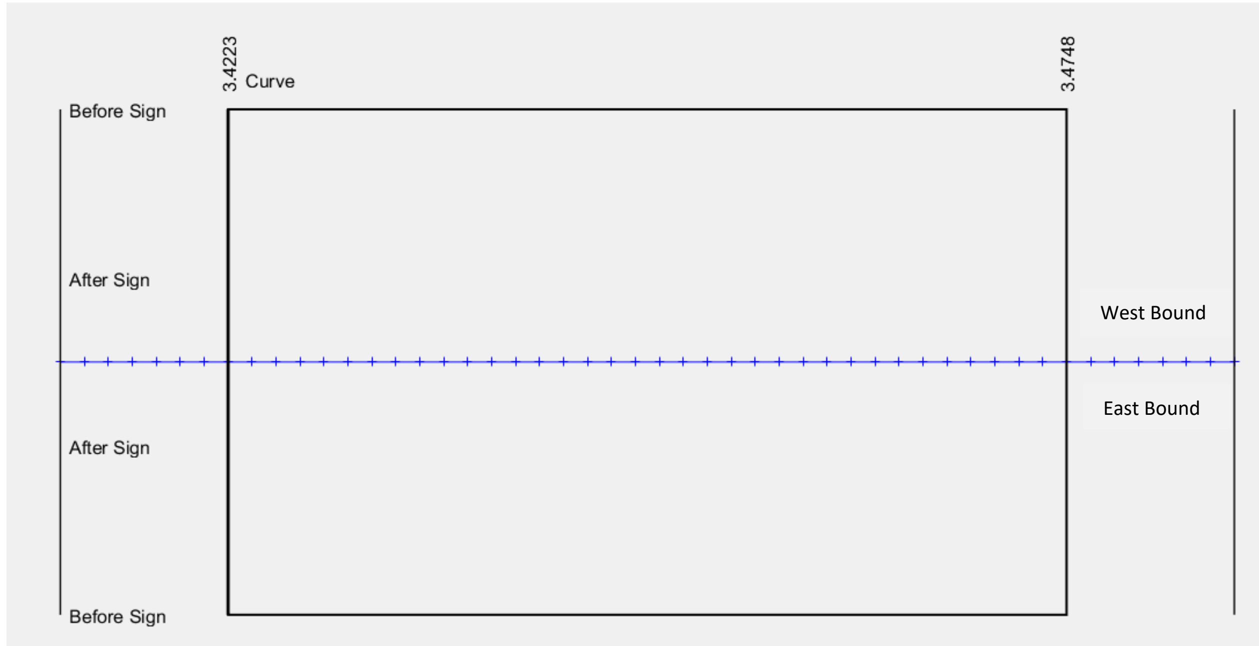
RCLINK:2411000200

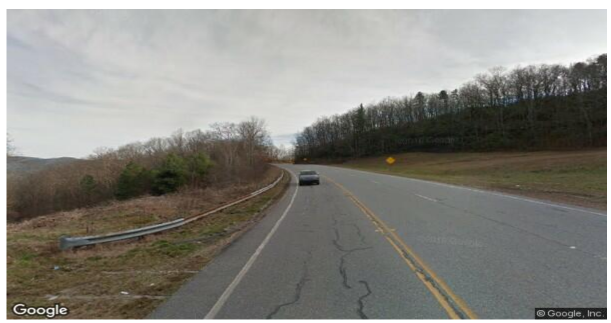
Georgia Institute of Technology

Road Characteristics

Radius	1043
Grade	0.5
Superelevation	8
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA







Horizontal Curve Schematic

Georgia Department of Transportation

Curve #54 on State Route 2 in Rabun County

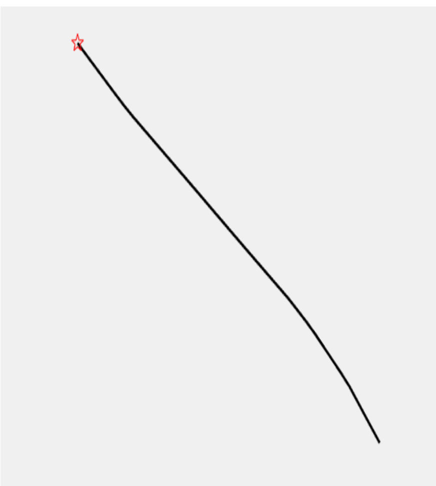
Scale: NA

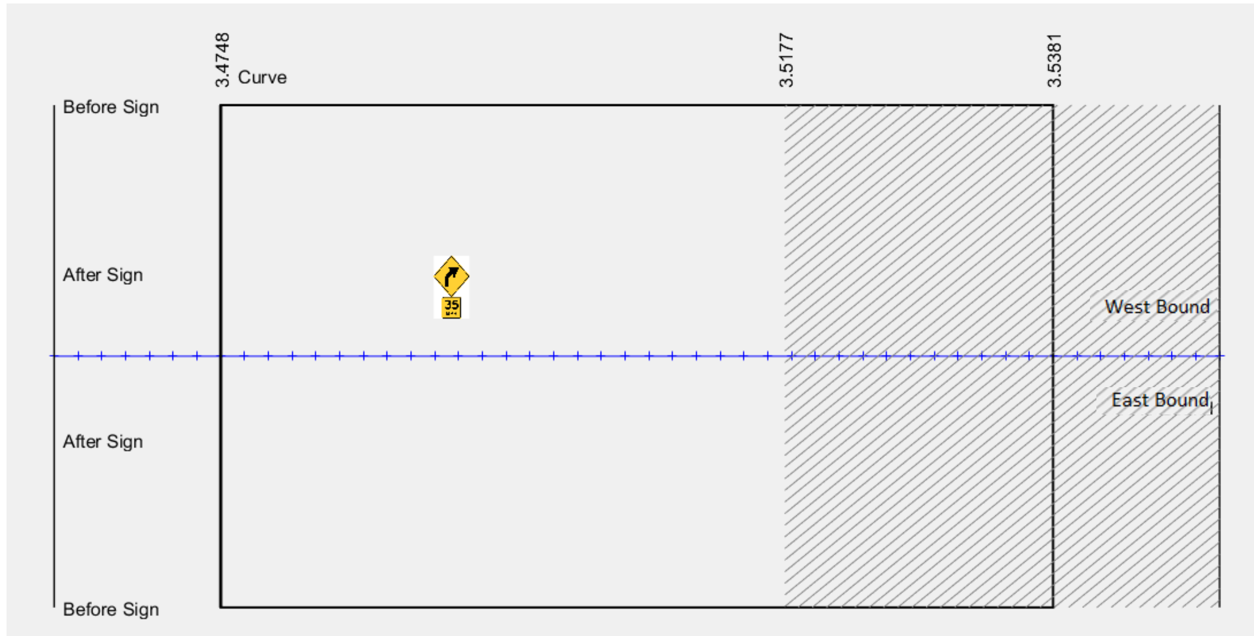
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1117
Grade	-0.8
Superelevation	7.5
Crashes	0
BBI	16
Posted Speed	45
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





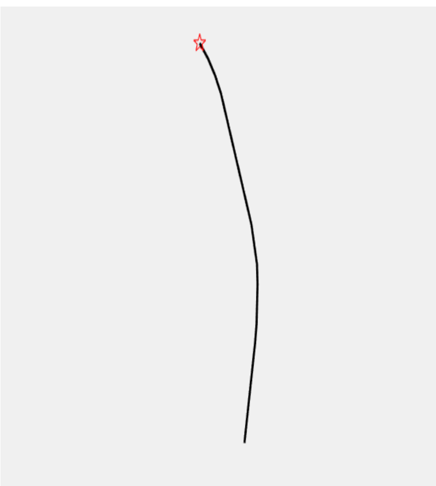
Horizontal Curve Schematic

Curve #55 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	228
Grade	-2.3
Superelevation	8.5
Crashes	0
BBI	16
Posted Speed	45
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

Curve #56 on State Route 2 in Rabun County

Scale: NA

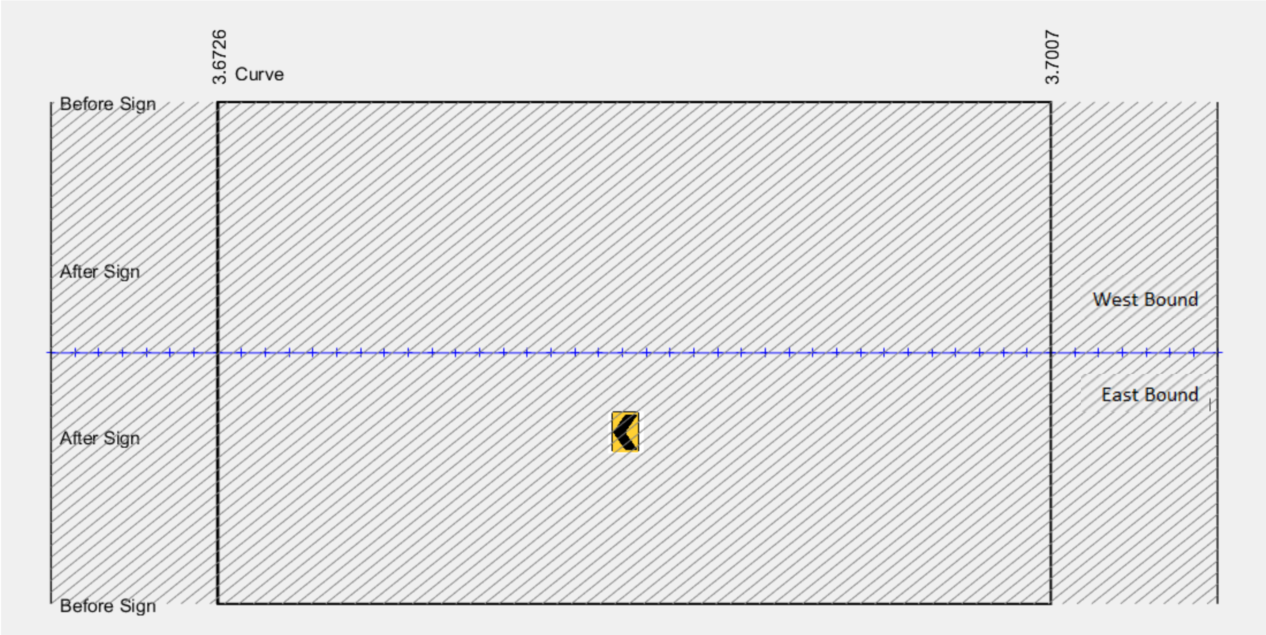
RCLINK:2411000200

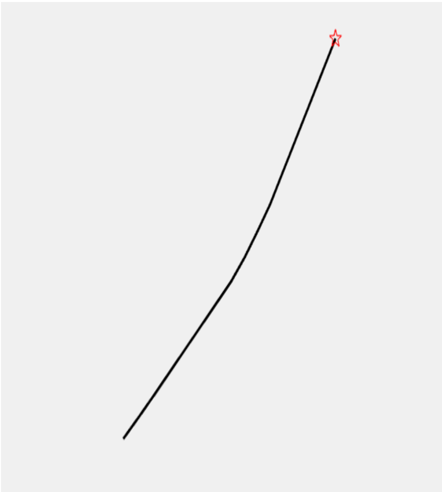
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	343
Grade	-7.7
Superelevation	7
Crashes	0
BBI	15
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

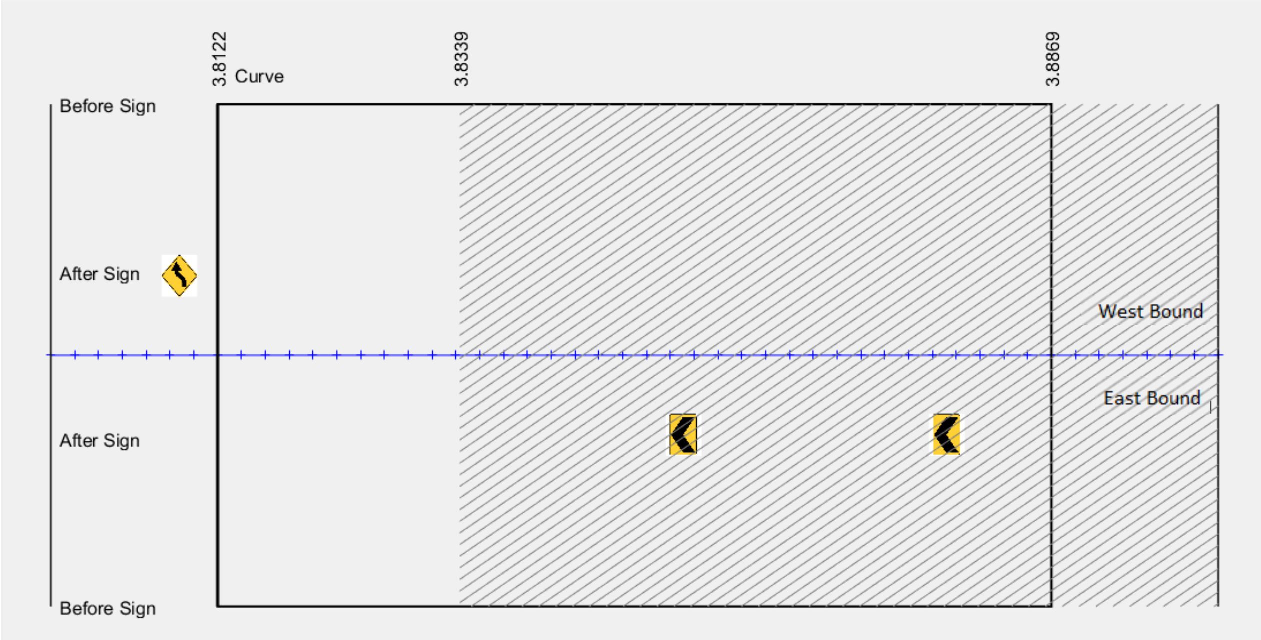
Curve #57 on State Route 2 in Rabun County

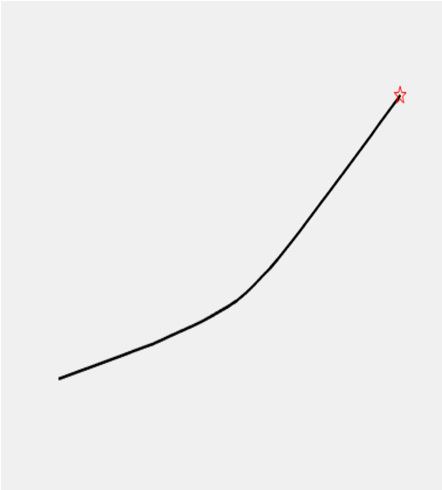
Scale: NA

RCLINK:2411000200

Road Characteristics

Radius	480
Grade	-5.9
Superelevation	6.5
Crashes	0
BBI	13
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

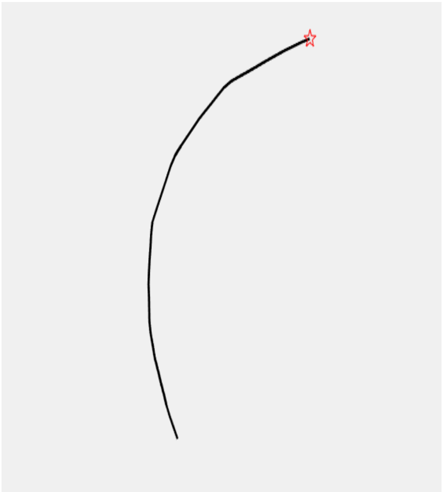
Curve #58 on State Route 2 in Rabun County

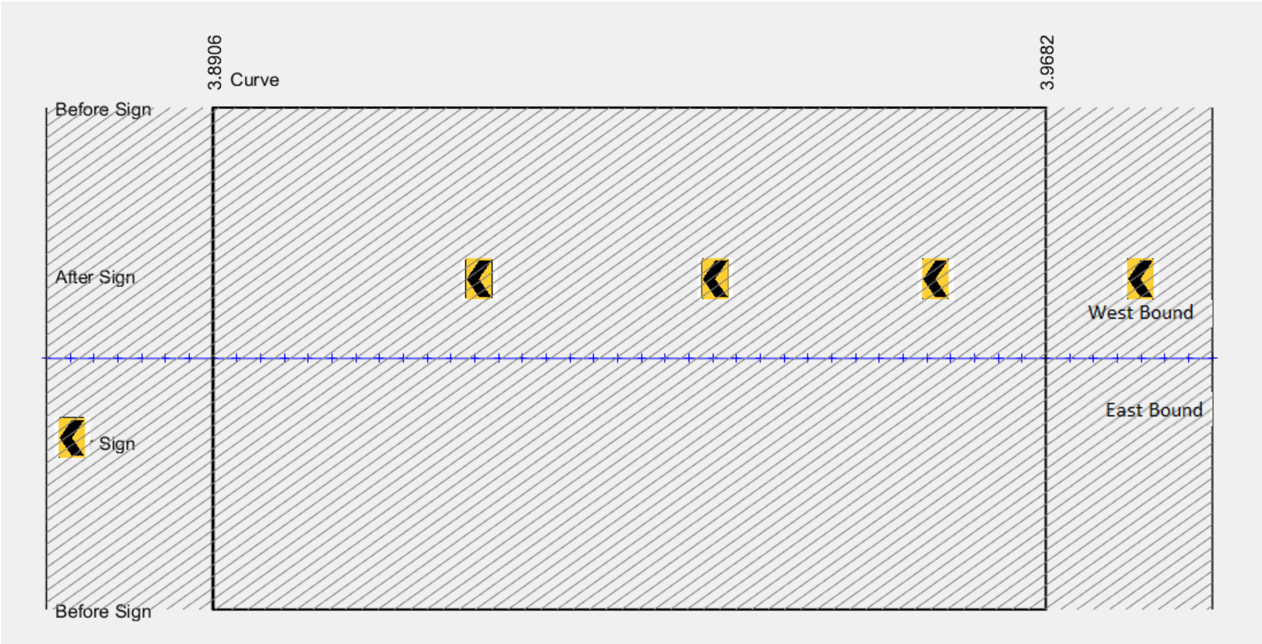
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	195
Grade	-3.5
Superelevation	9
Crashes	0
BBI	21
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #59 on State Route 2 in Rabun County

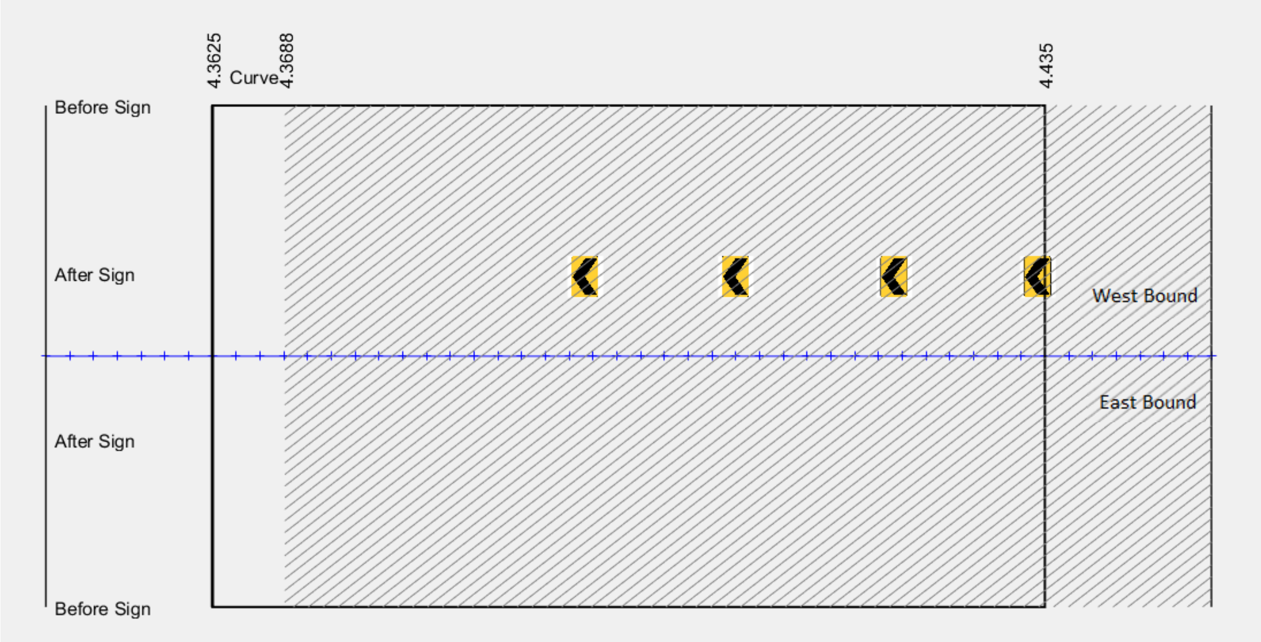
Scale: NA

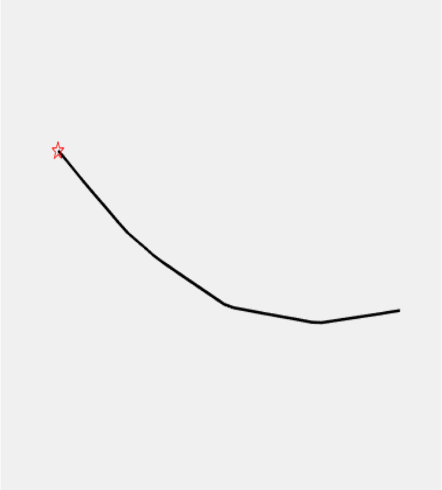
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	358
Grade	2
Superelevation	11.5
Crashes	0
BBI	11
Posted Speed	45
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #60 on State Route 2 in Rabun County

Scale: NA

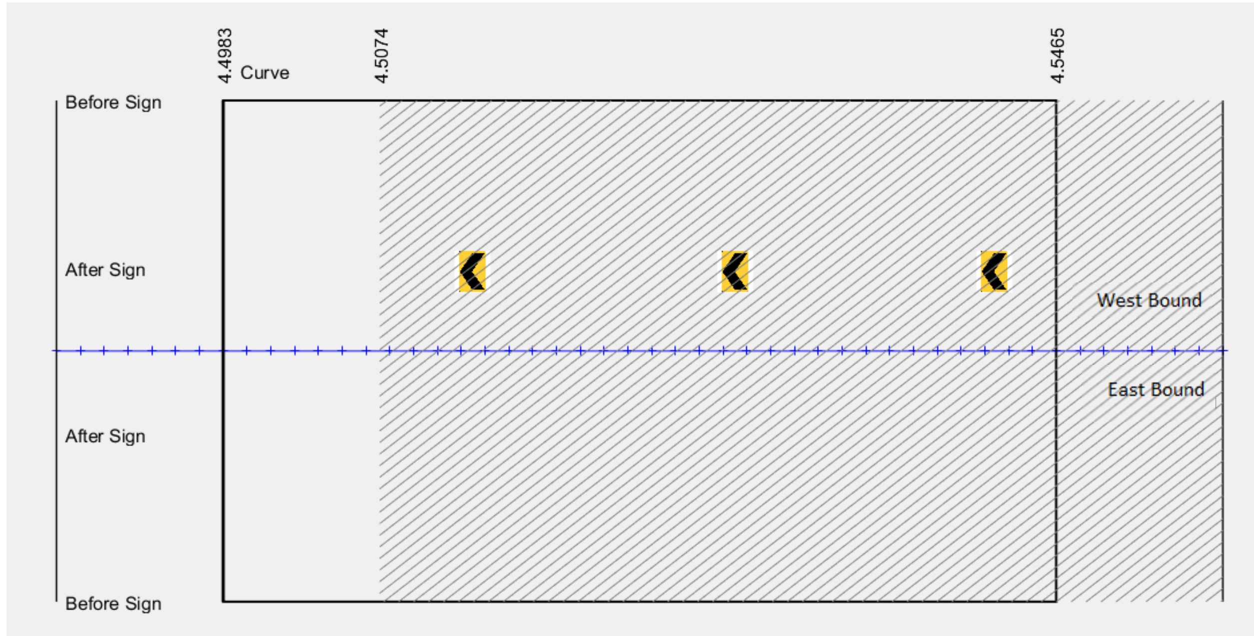
RCLINK:2411000200

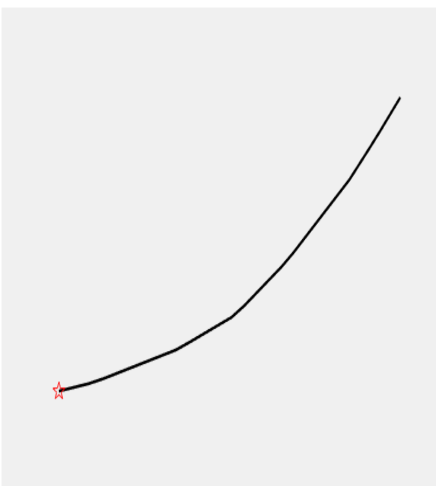
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	302
Grade	0.3
Superelevation	9.5
Crashes	0
BBI	13
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #61 on State Route 2 in Rabun County

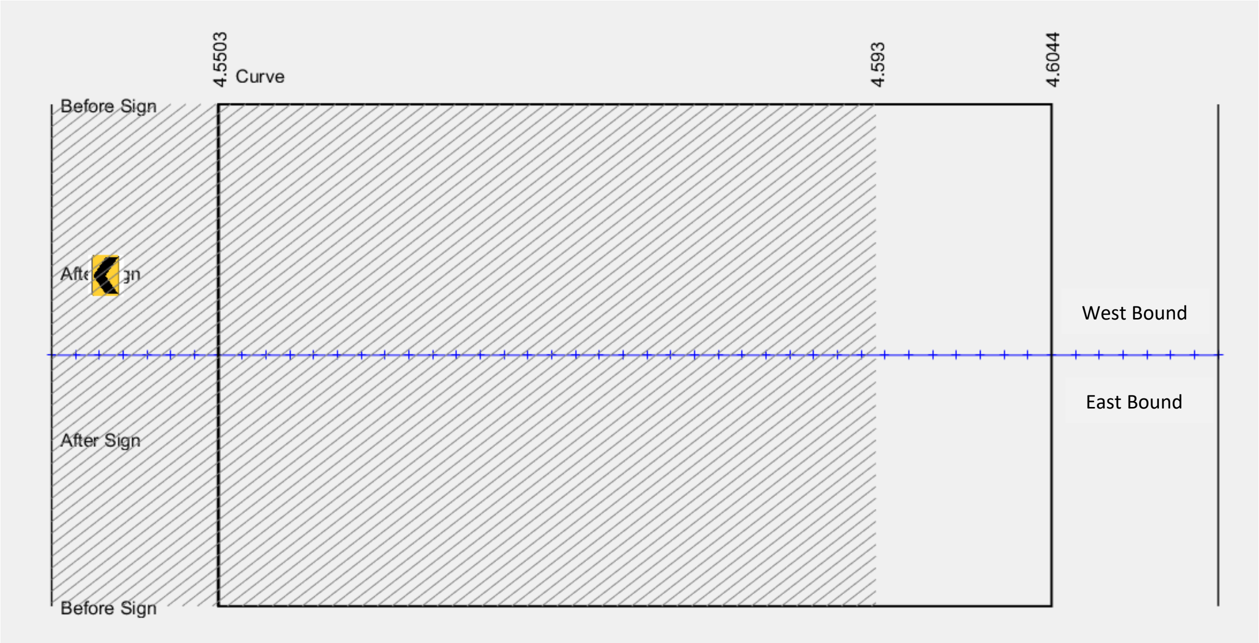
Scale: NA

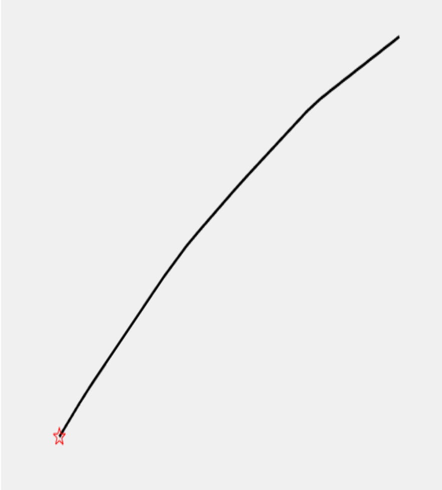
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	724
Grade	-4.6
Superelevation	4
Crashes	0
BBI	9
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

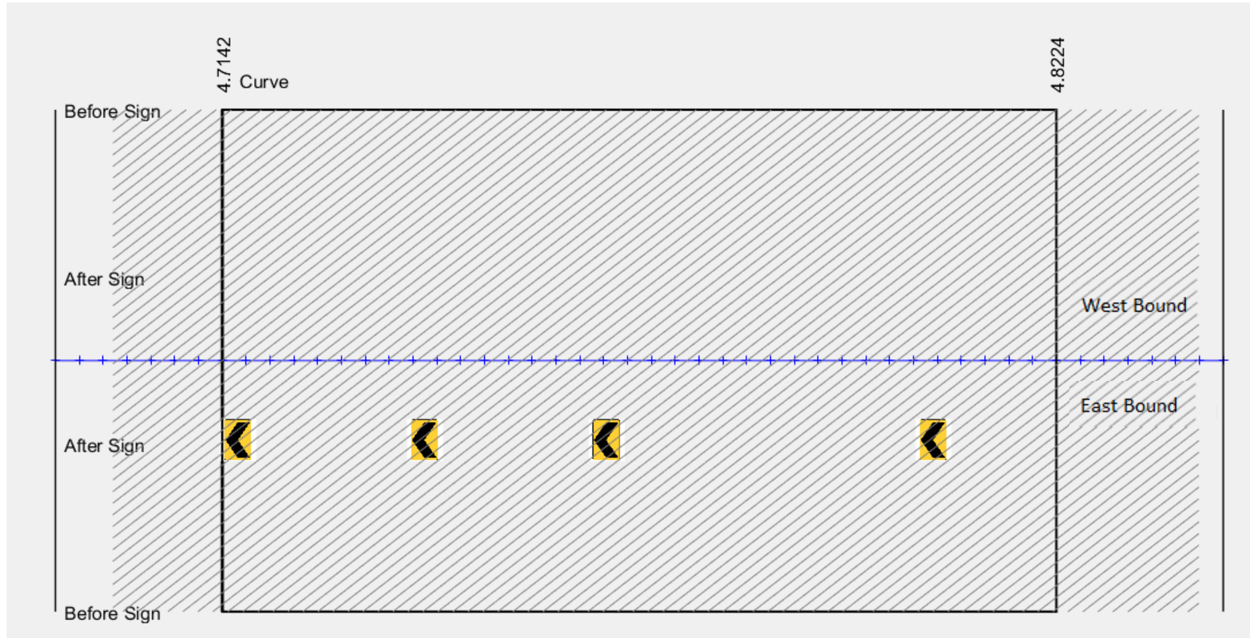
Curve #62 on State Route 2 in Rabun County

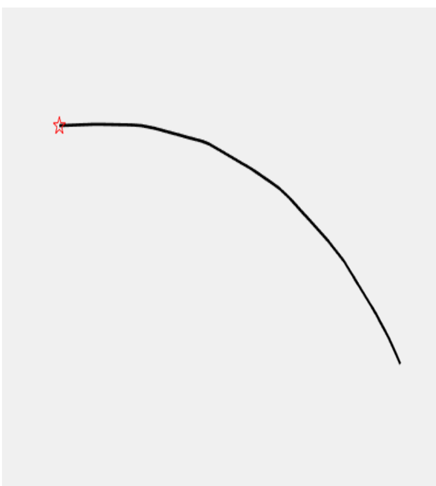
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	493
Grade	-7.5
Superelevation	7
Crashes	0
BBI	14
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #63 on State Route 2 in Rabun County

Scale: NA

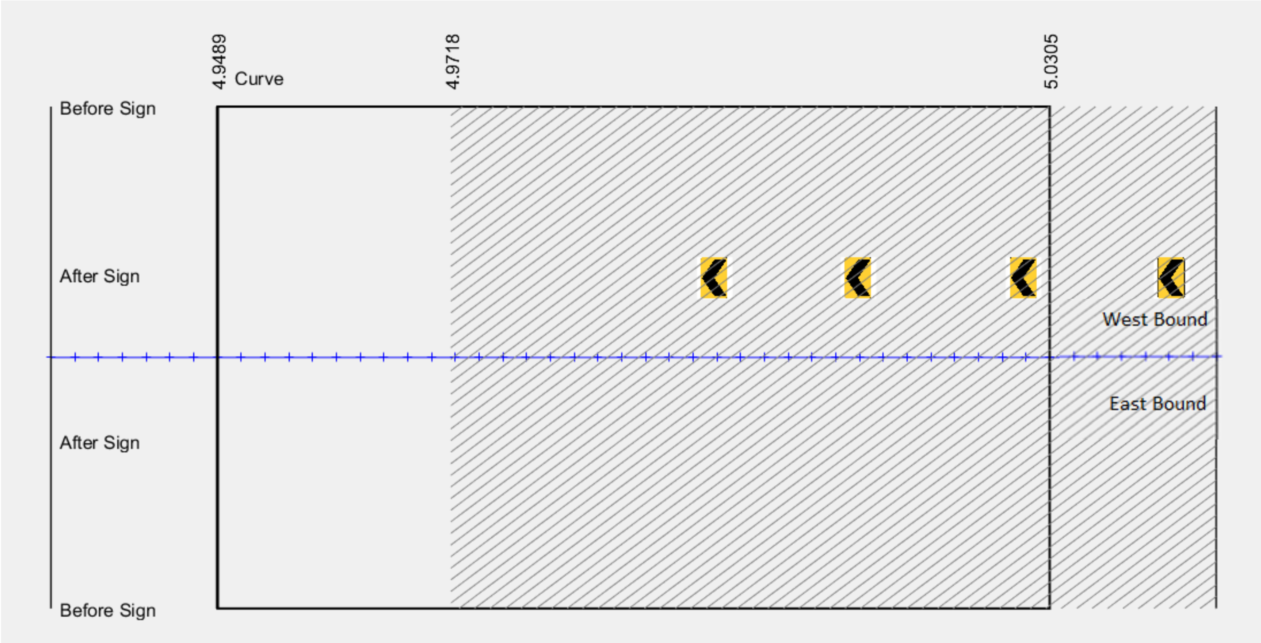
RCLINK:2411000200

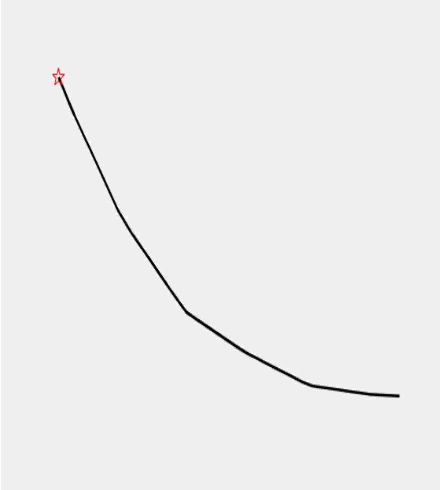
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	350
Grade	4
Superelevation	8.5
Crashes	2
BBI	12
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #64 on State Route 2 in Rabun County

Scale: NA

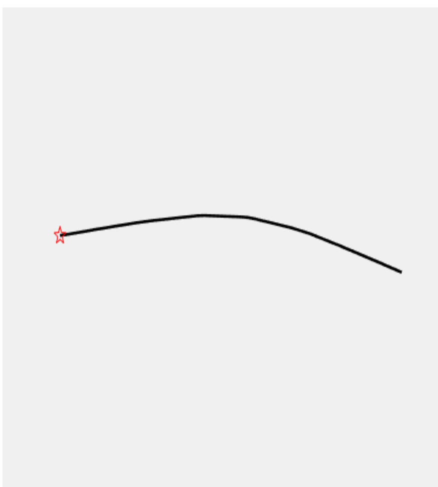
RCLINK:2411000200

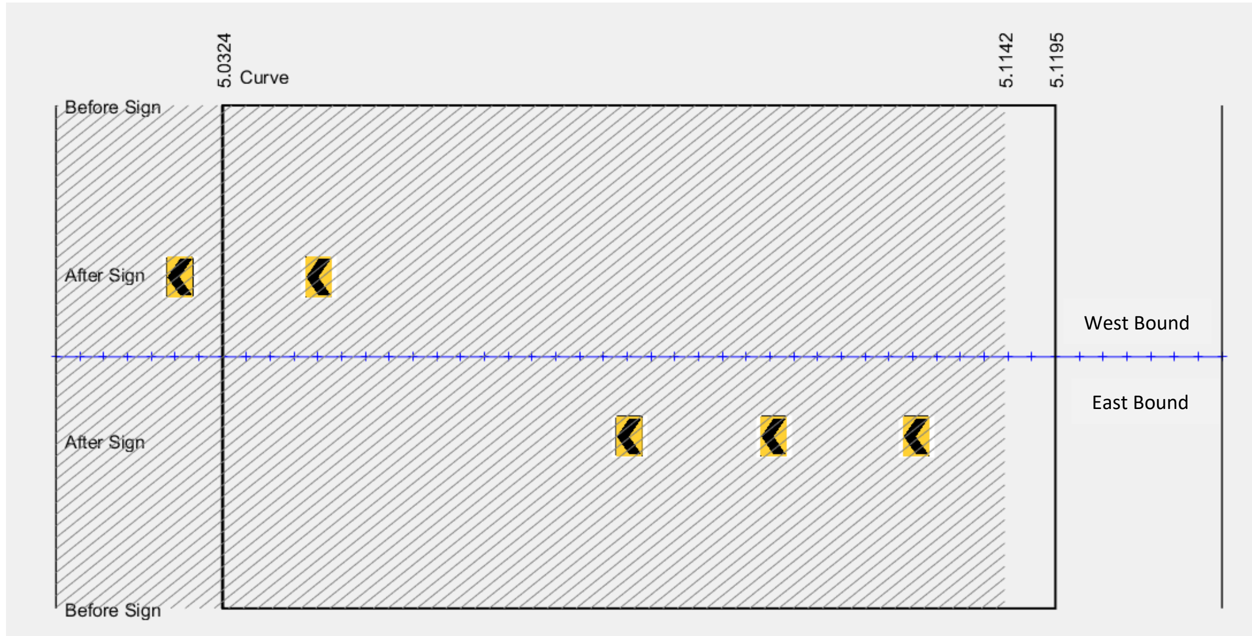
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	774
Grade	7.1
Superelevation	6
Crashes	0
BBI	9
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #65 on State Route 2 in Rabun County

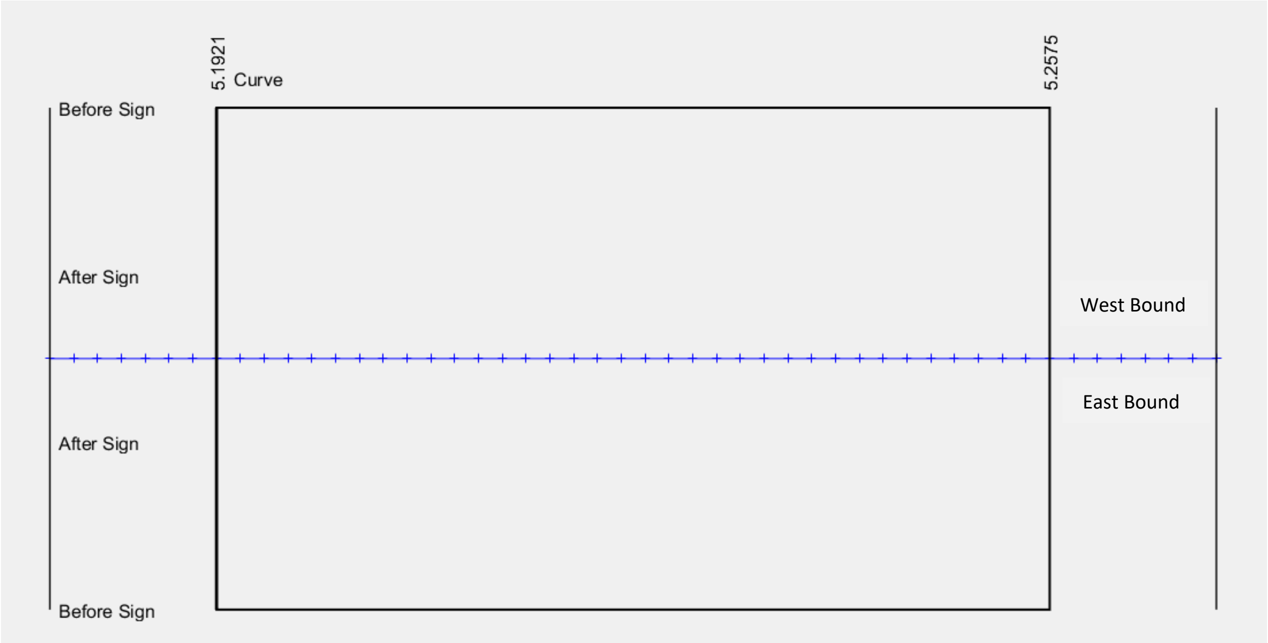
Scale: NA

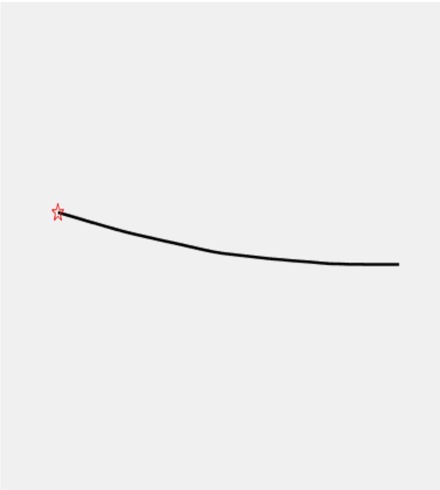
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1448
Grade	5.2
Superelevation	6
Crashes	1
BBI	3
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #66 on State Route 2 in Rabun County

Scale: NA

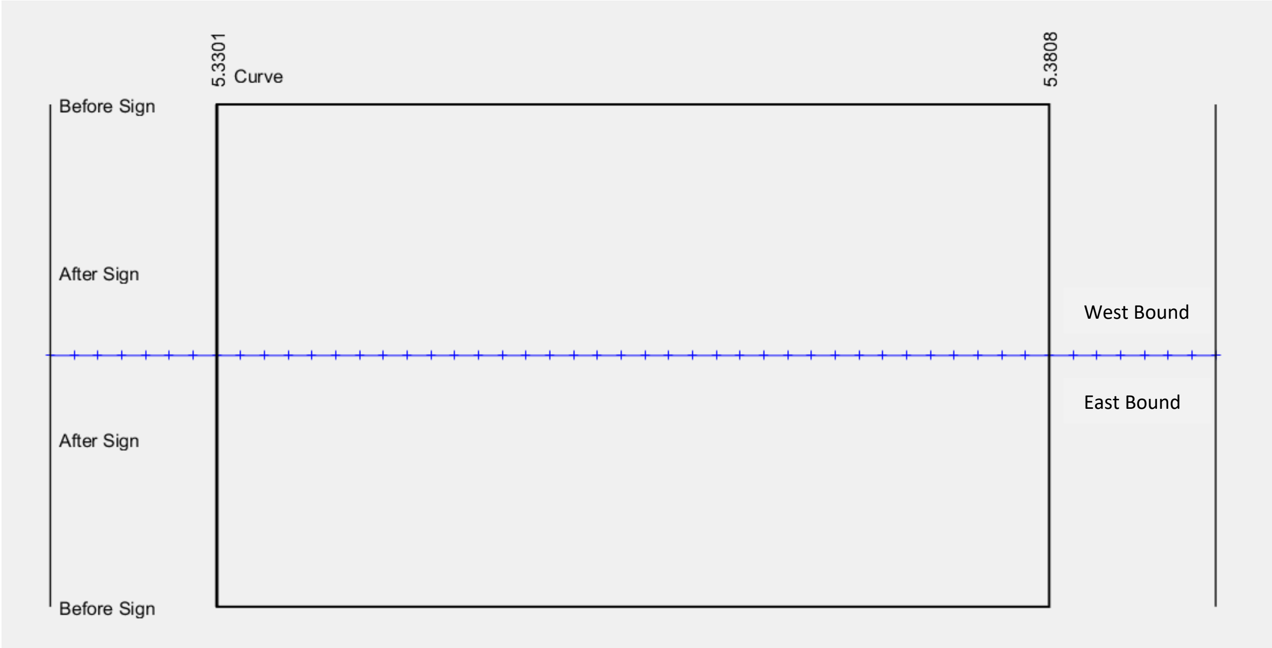
RCLINK:2411000200

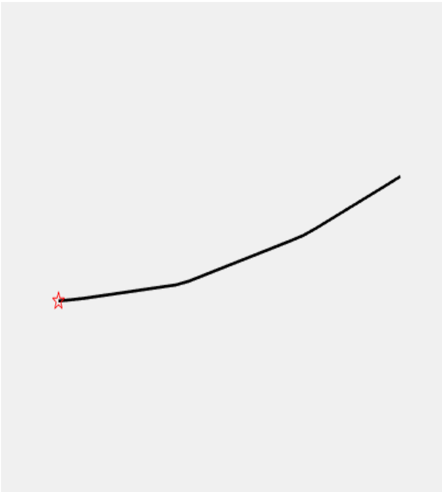
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	625
Grade	5.4
Superelevation	9
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #67 on State Route 2 in Rabun County

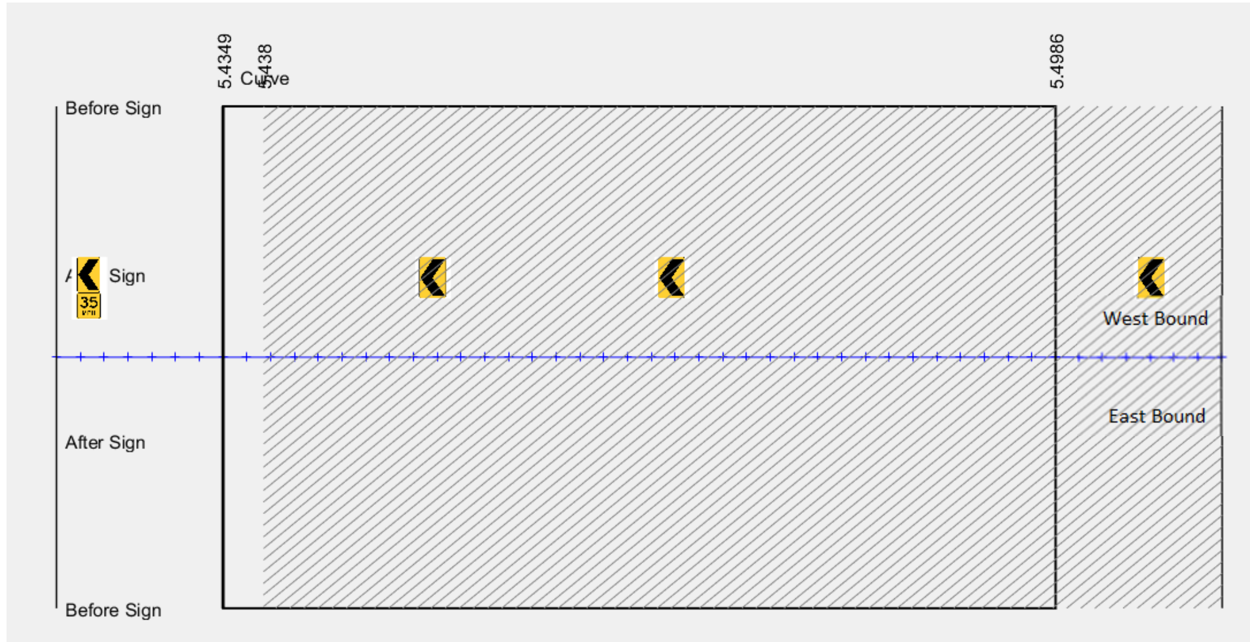
Scale: NA

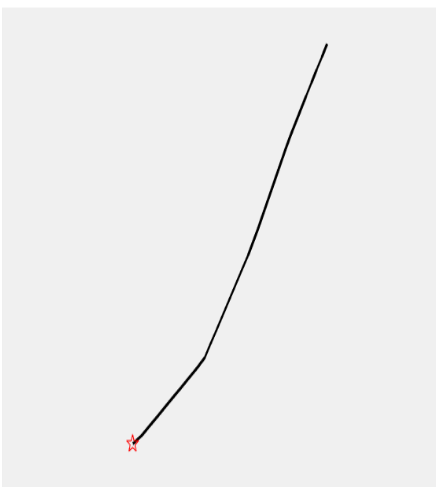
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	485
Grade	2.5
Superelevation	9
Crashes	0
BBI	14
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #68 on State Route 2 in Rabun County

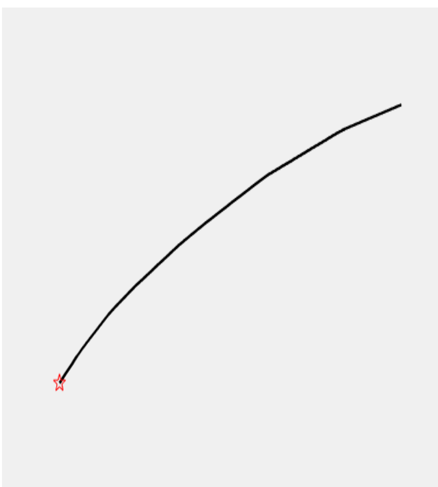
Scale: NA

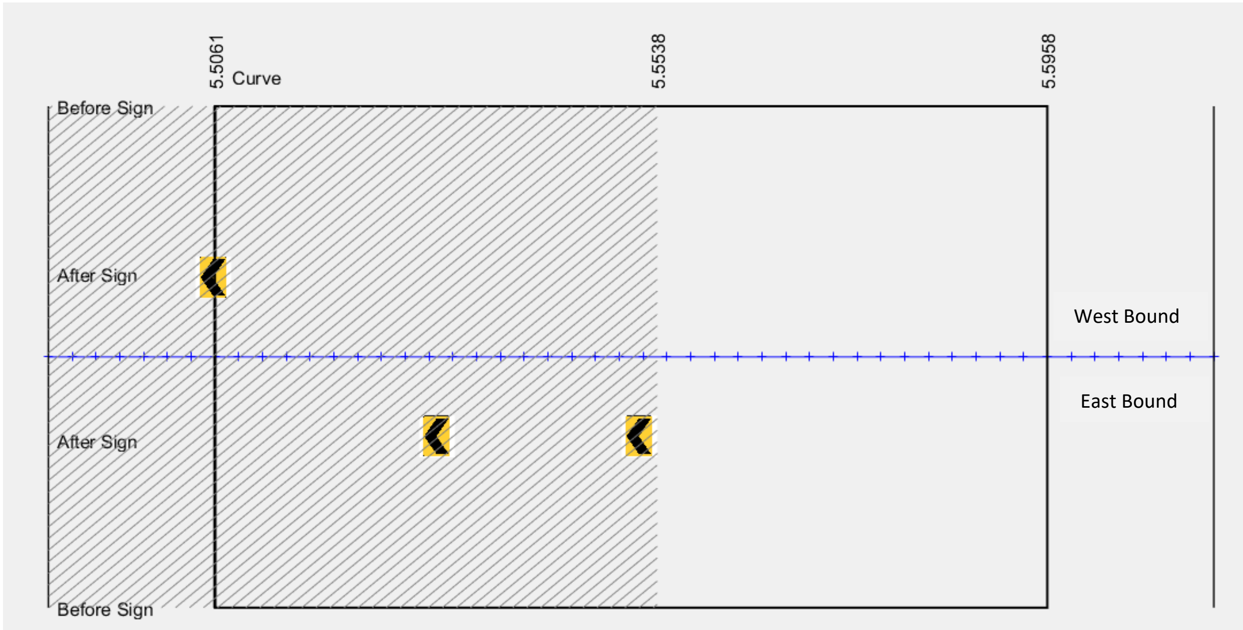
RCLINK:2411000200

Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	915
Grade	-3
Superelevation	9
Crashes	0
BBI	10
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #69 on State Route 2 in Rabun County

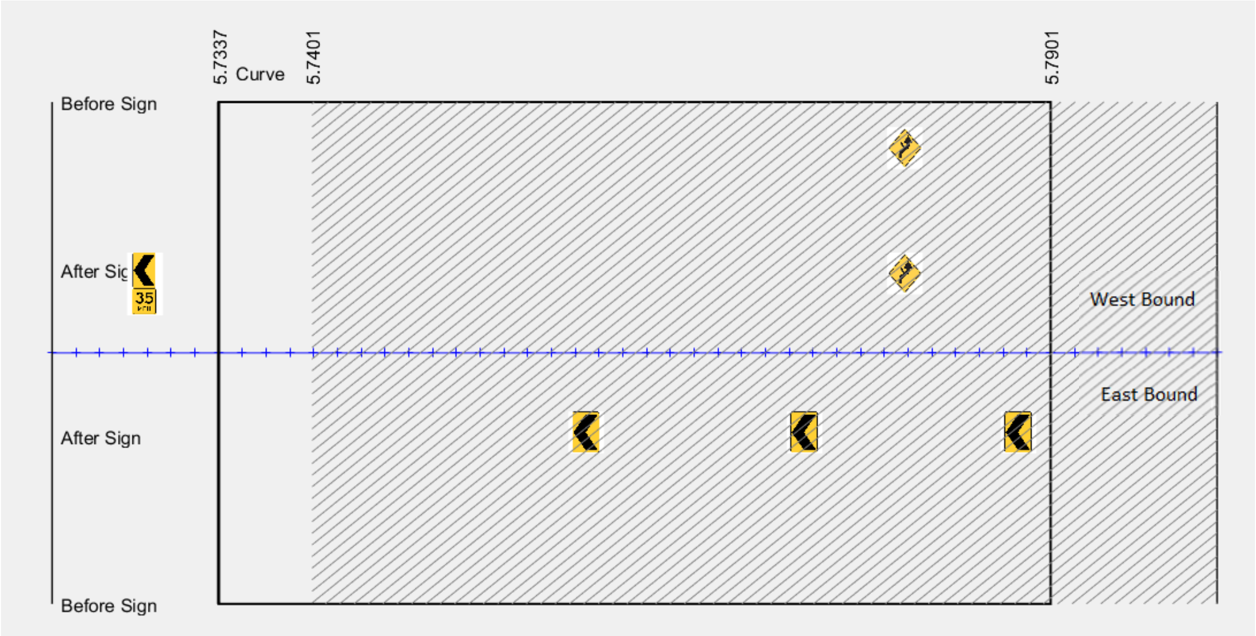
Scale: NA

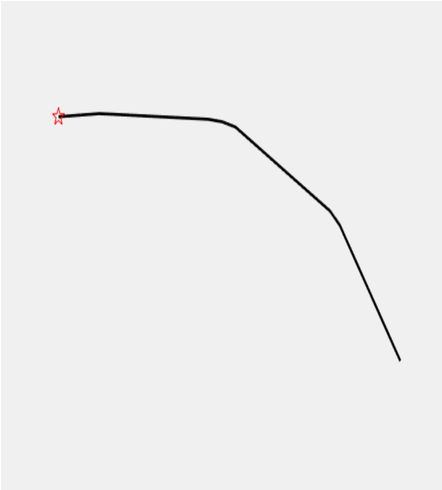
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	206
Grade	-4.8
Superelevation	14
Crashes	1
BBI	16
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #70 on State Route 2 in Rabun County

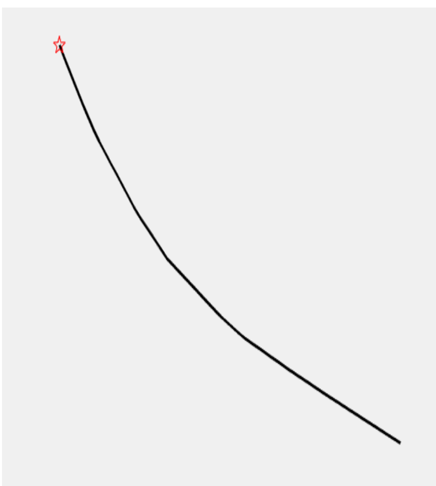
Scale: NA

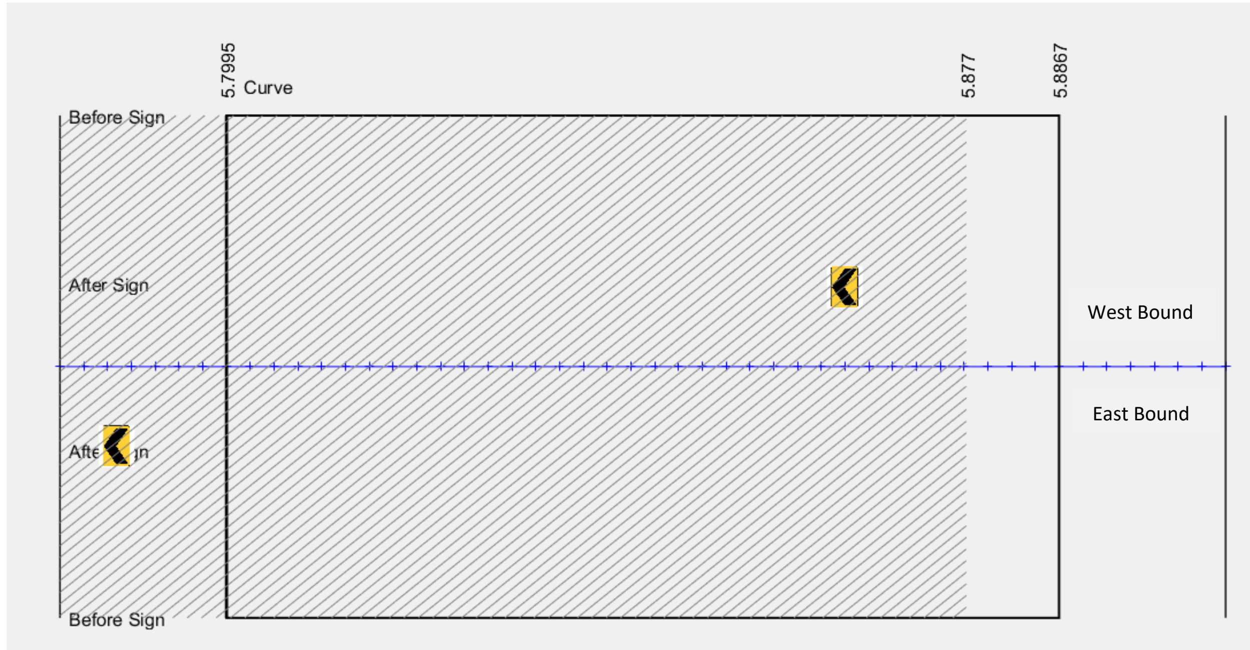
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	514
Grade	-4.8
Superelevation	8
Crashes	0
BBI	12
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

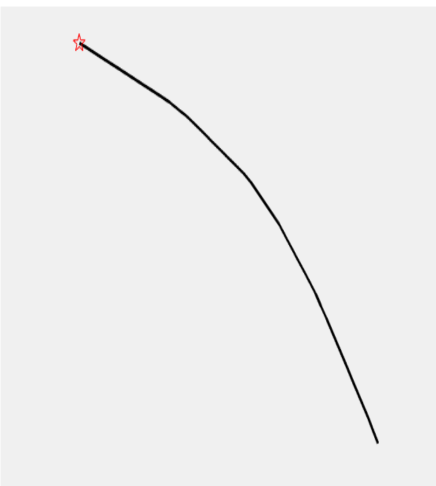
Curve #71 on State Route 2 in Rabun County

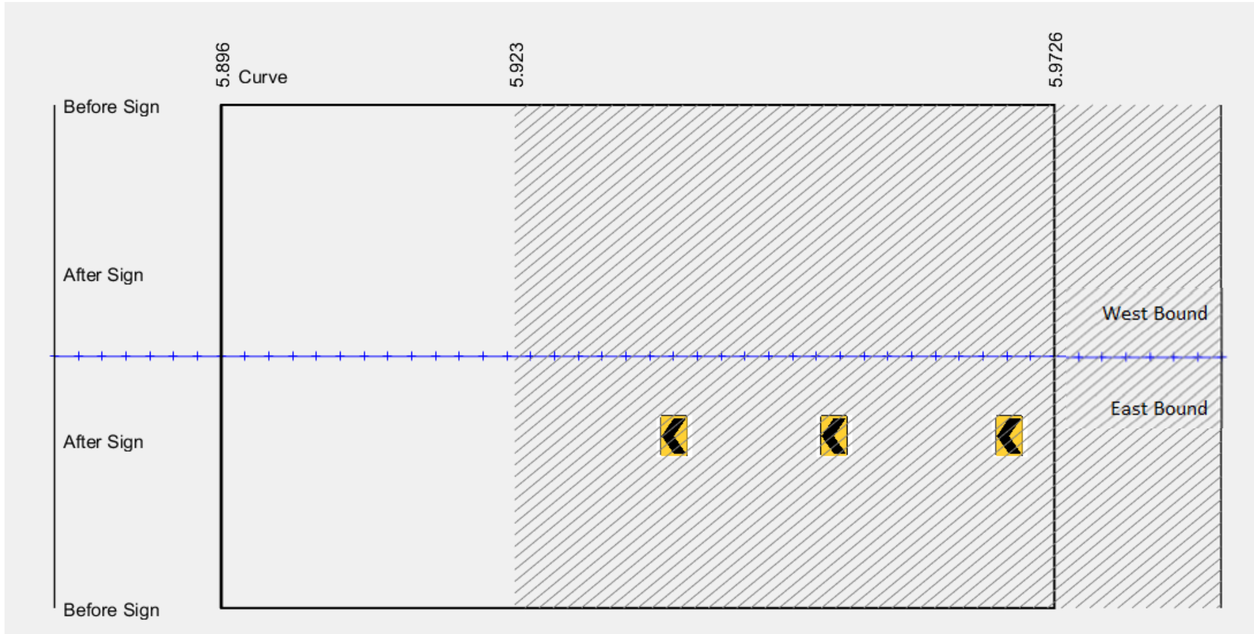
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	451
Grade	-5.2
Superelevation	9.5
Crashes	0
BBI	13
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #72 on State Route 2 in Rabun County

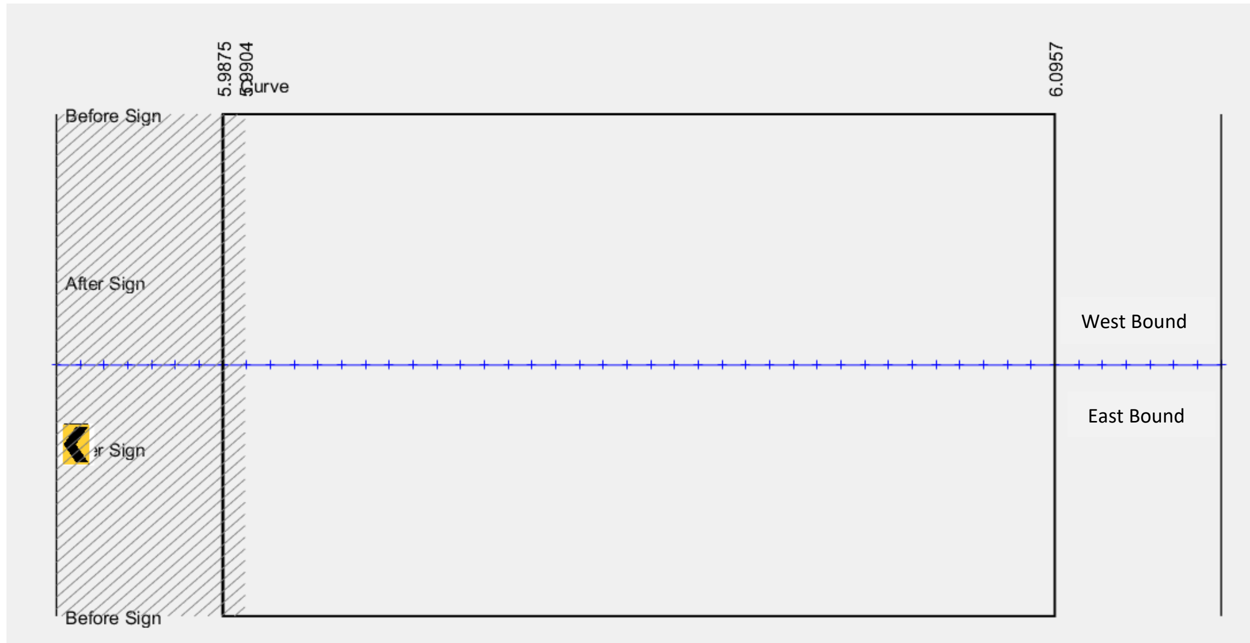
Scale: NA

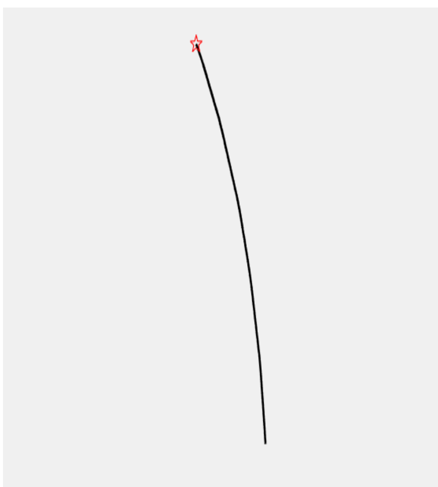
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1355
Grade	-4.7
Superelevation	6
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #73 on State Route 2 in Rabun County

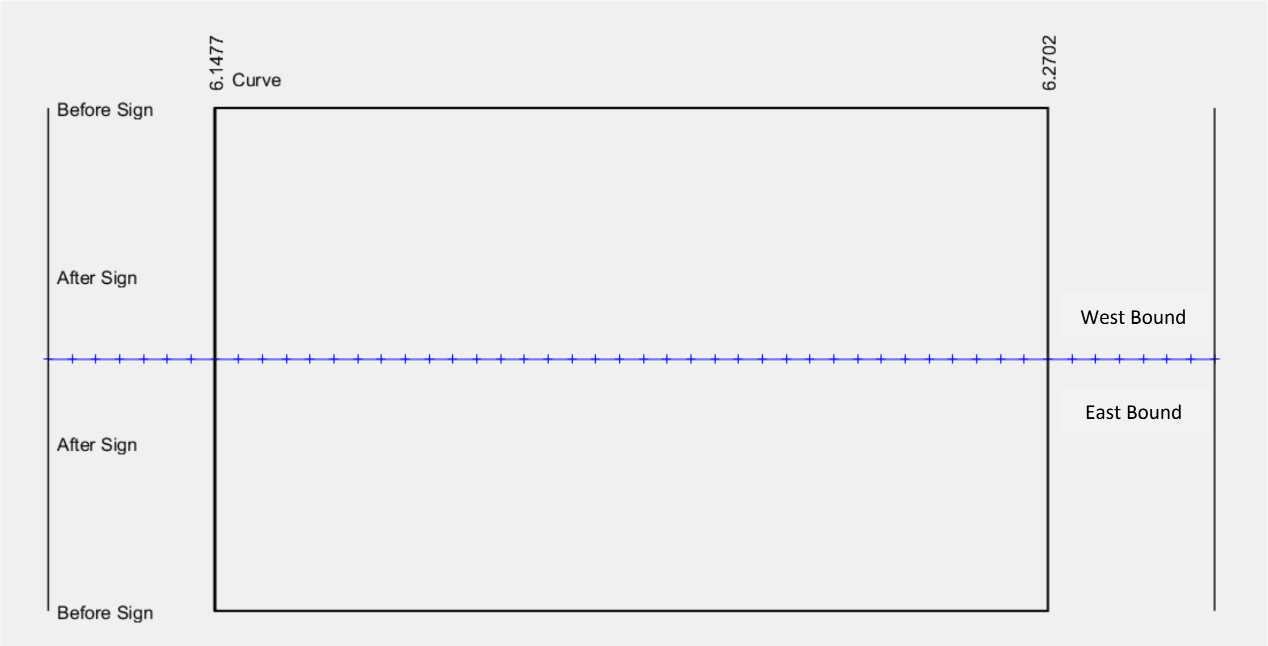
Scale: NA

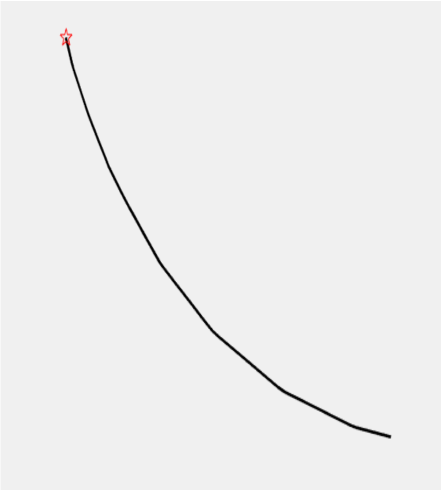
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	580
Grade	-8.2
Superelevation	8
Crashes	1
BBI	12
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #74 on State Route 2 in Rabun County

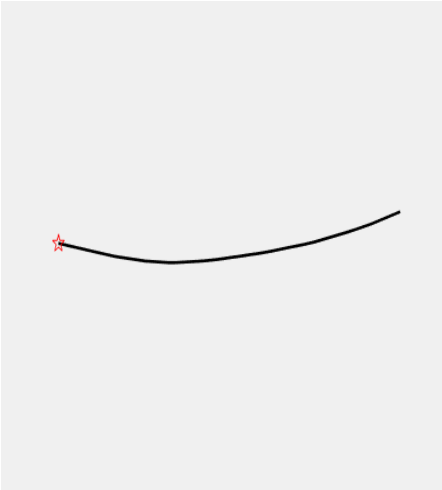
Scale: NA

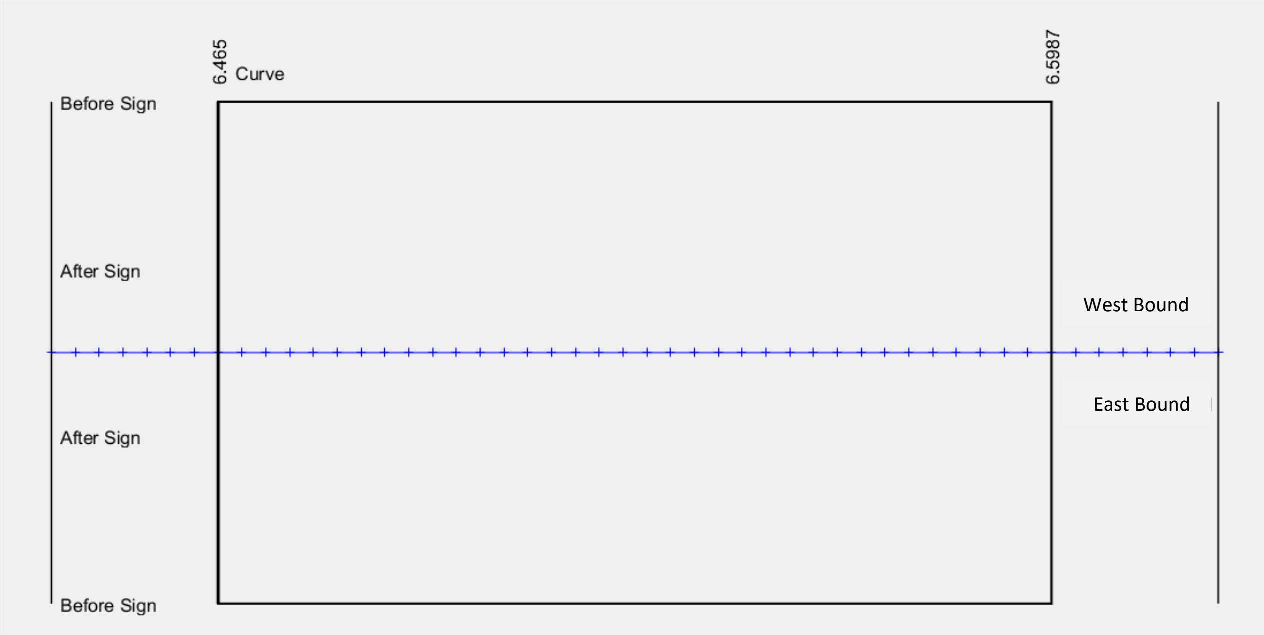
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1414
Grade	-8.8
Superelevation	7
Crashes	1
BBI	7
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #75 on State Route 2 in Rabun County

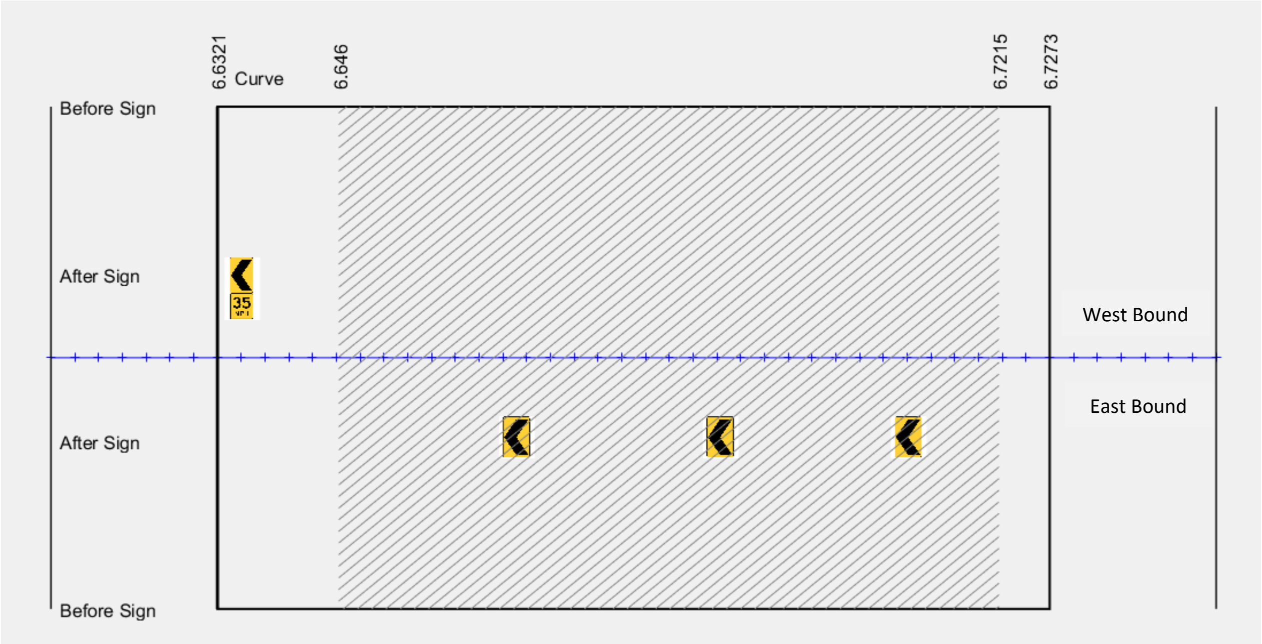
Scale: NA

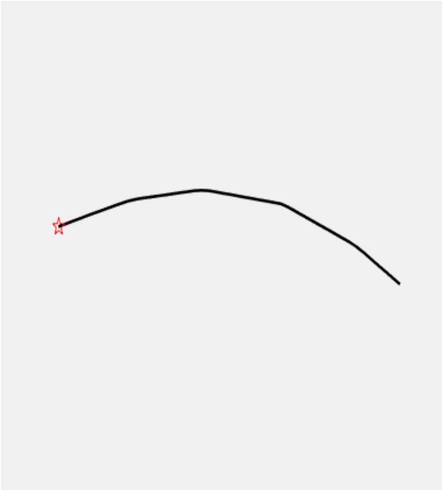
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	501
Grade	-6.9
Superelevation	9
Crashes	0
BBI	12
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

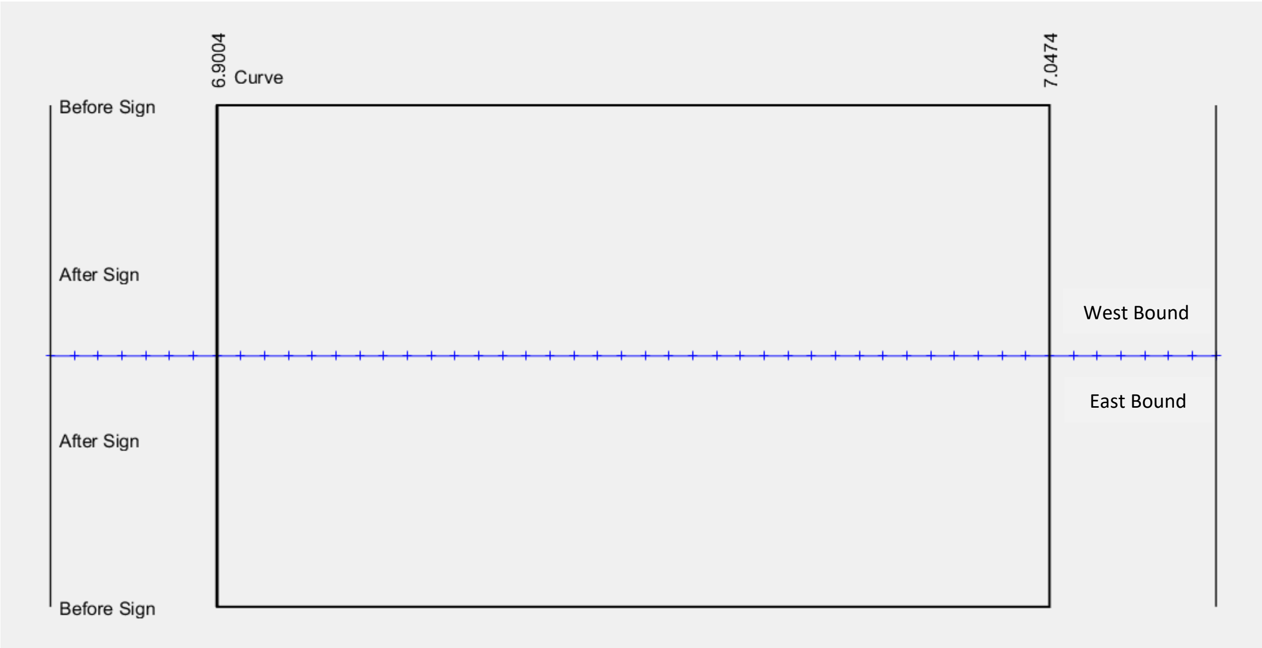
Curve #76 on State Route 2 in Rabun County

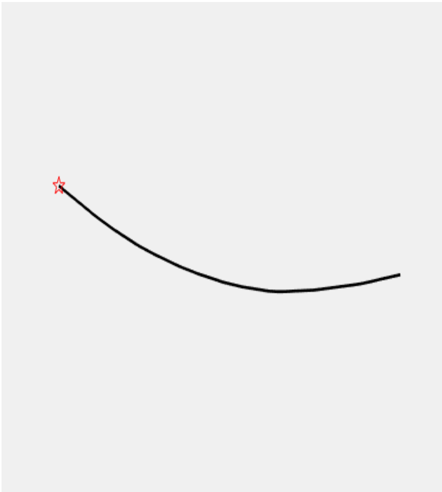
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	928
Grade	2.2
Superelevation	7.5
Crashes	0
BBI	6
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #77 on State Route 2 in Rabun County

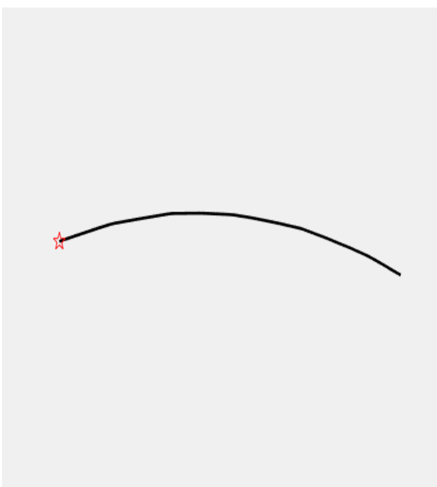
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	975
Grade	5.1
Superelevation	8.5
Crashes	0
BBI	4
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

Curve #78 on State Route 2 in Rabun County

Scale: NA

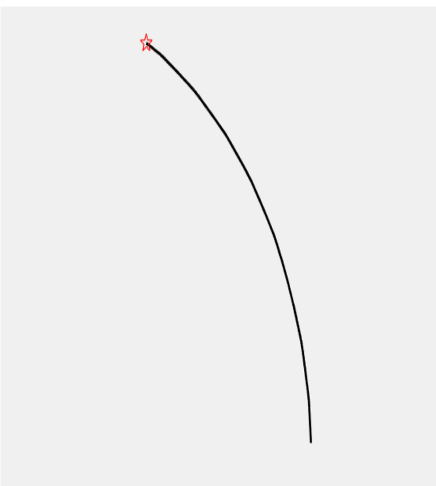
RCLINK:2411000200

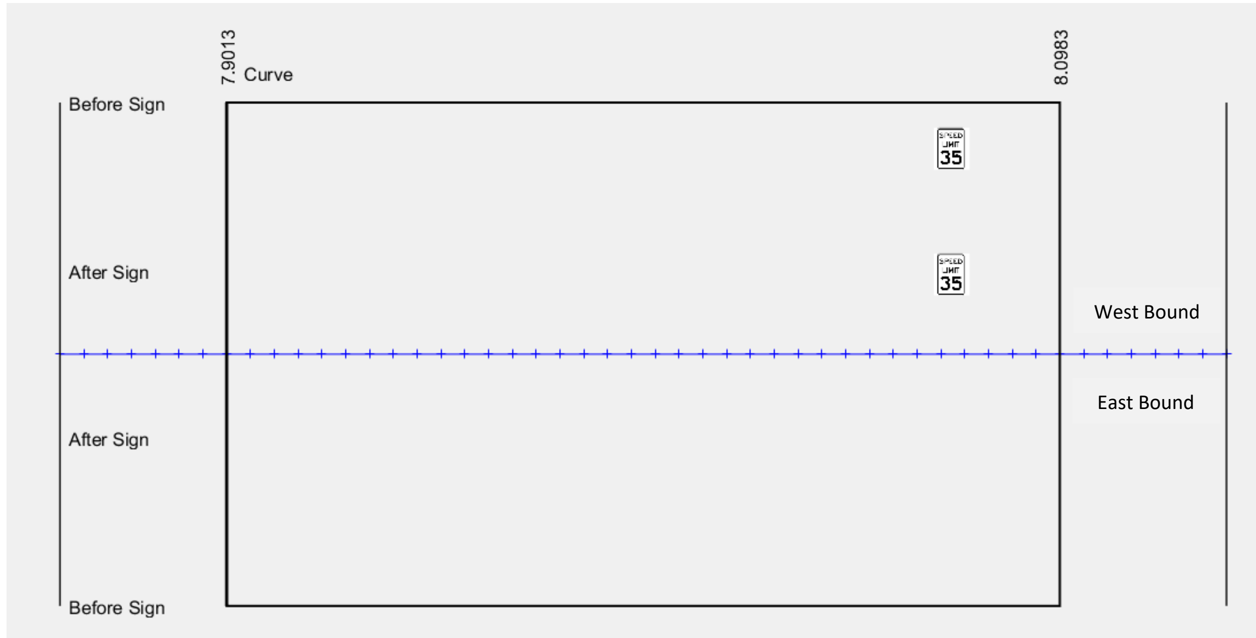
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	1008
Grade	1.8
Superelevation	8
Crashes	0
BBI	5
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #79 on State Route 2 in Rabun County

Scale: NA

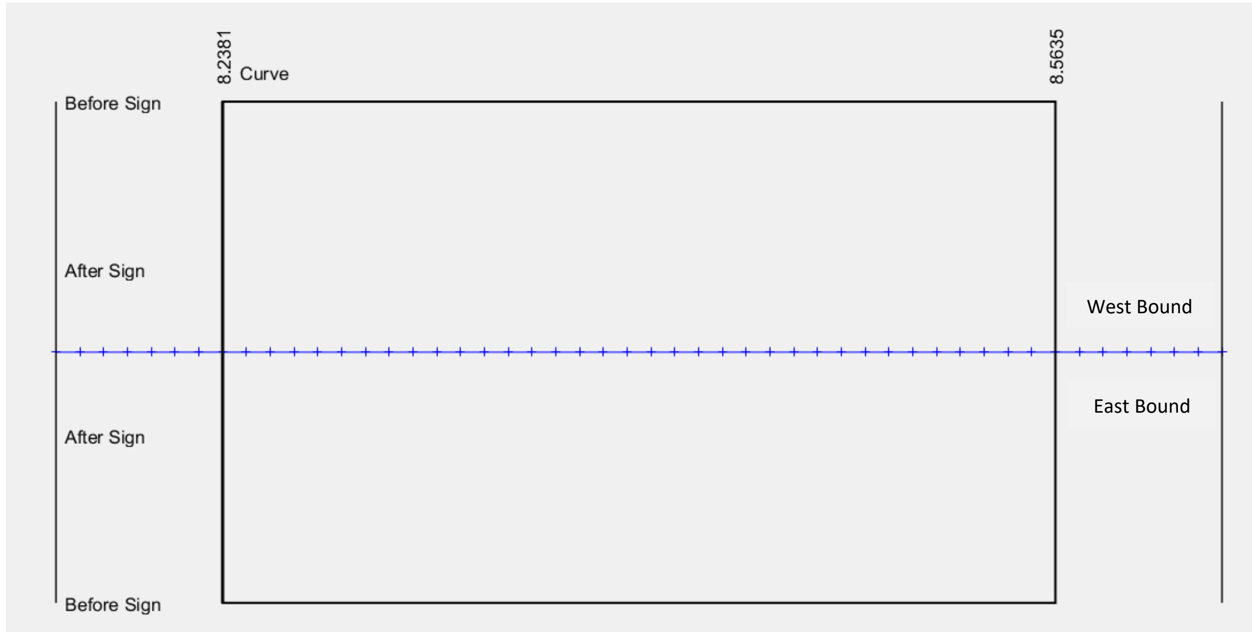
RCLINK:2411000200

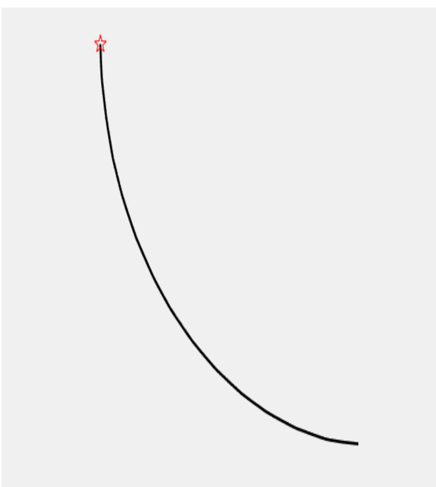
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	1151
Grade	-5.1
Superelevation	8.5
Crashes	0
BBI	8
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #80 on State Route 2 in Rabun County

Scale: NA

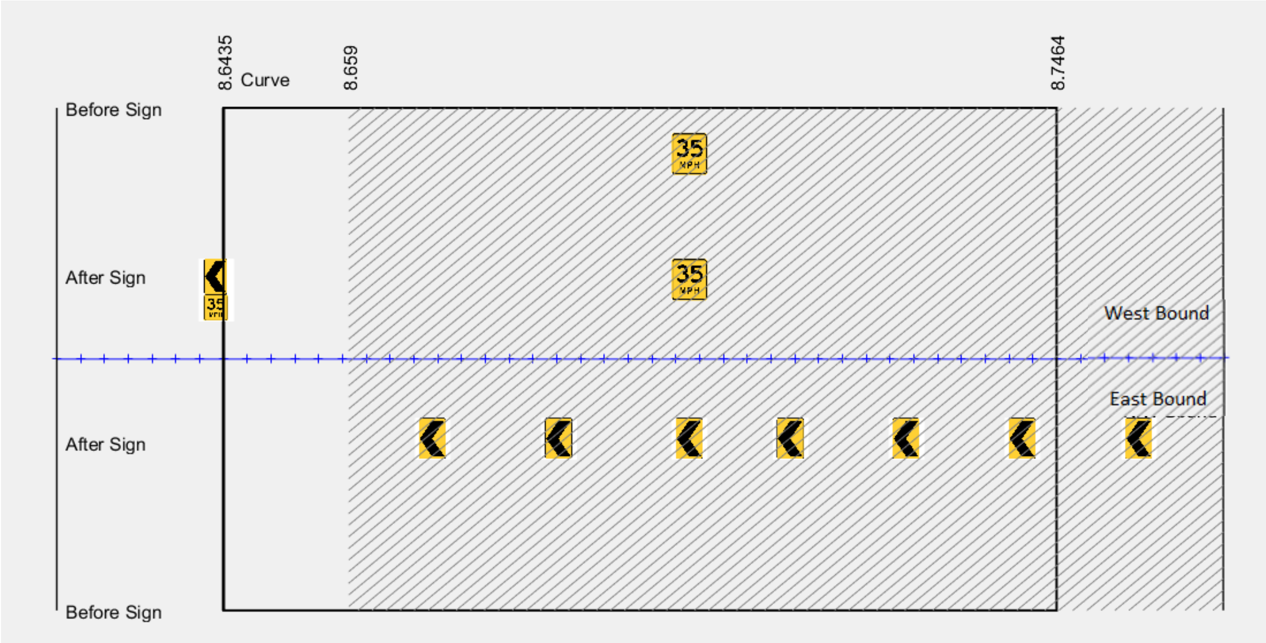
RCLINK:2411000200

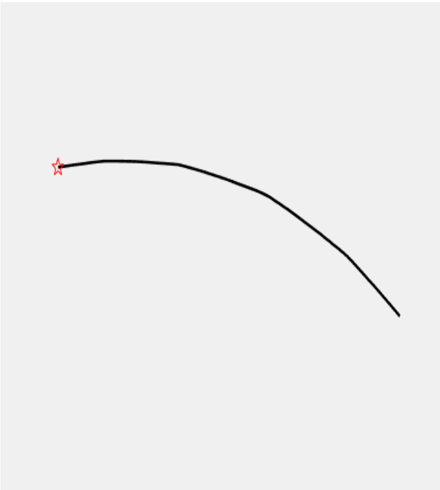
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	602
Grade	-5.9
Superelevation	9.5
Crashes	0
BBI	8
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

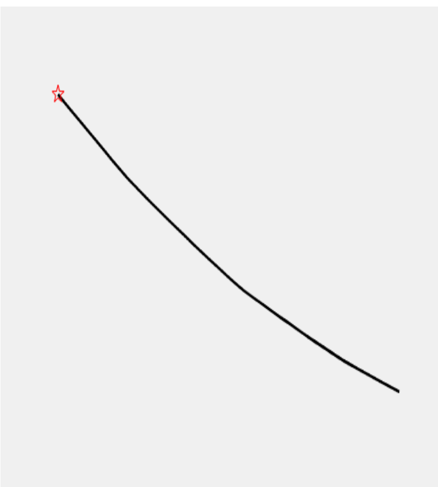
Curve #81 on State Route 2 in Rabun County

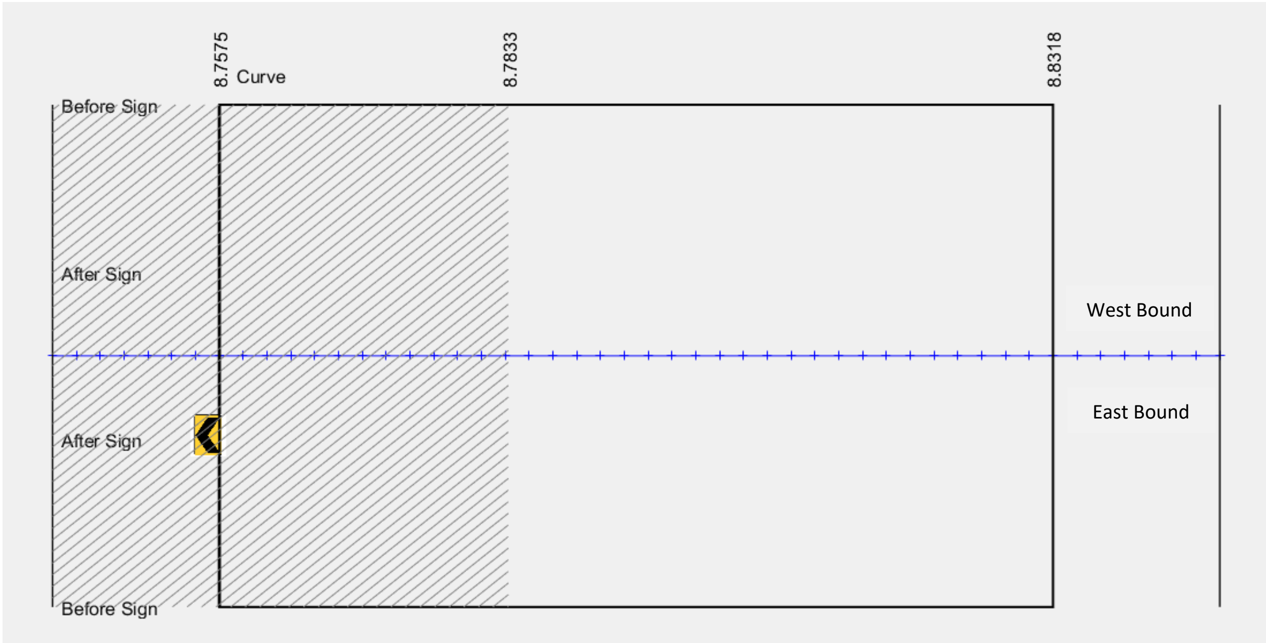
Scale: NA

RCLINK:2411000200

Road Characteristics

Radius	995
Grade	-6.6
Superelevation	4
Crashes	0
BBI	7
Posted Speed	55
Advisory Speed	45
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #82 on State Route 2 in Rabun County

Scale: NA

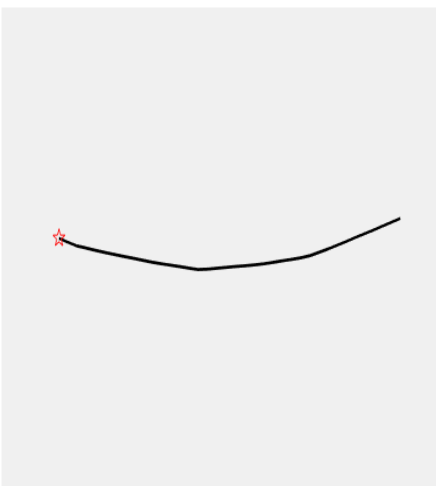
RCLINK:2411000200

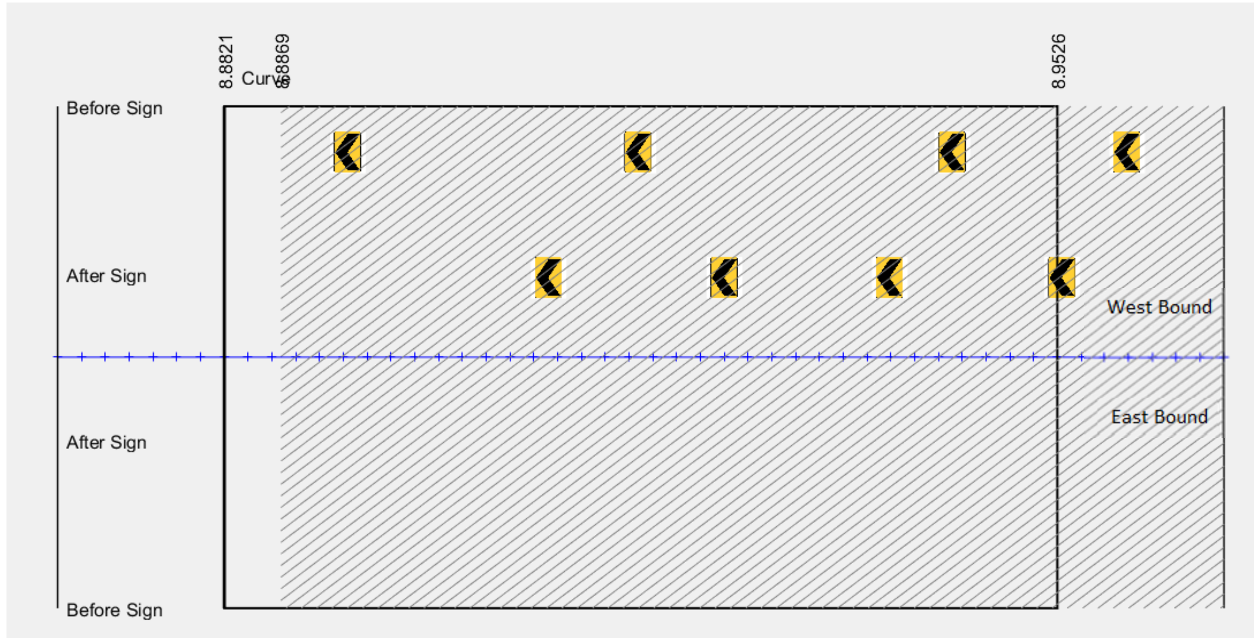
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	579
Grade	0.7
Superelevation	6
Crashes	0
BBI	11
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

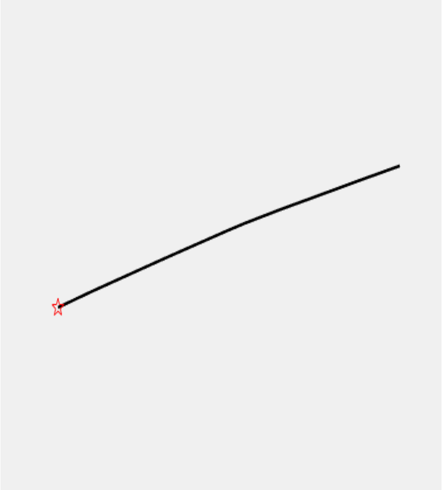
Curve #83 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	2041
Grade	5.1
Superelevation	6
Crashes	0
BBI	2
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

Curve #84 on State Route 2 in Rabun County

Scale: NA

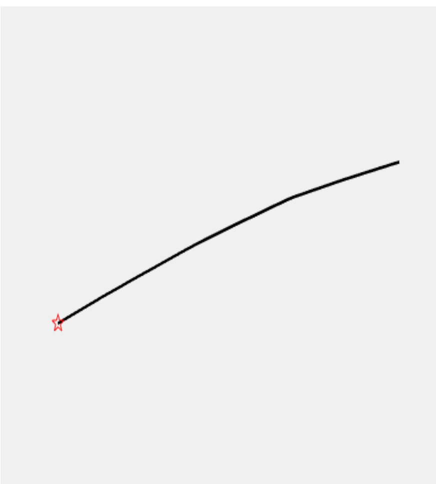
RCLINK:2411000200

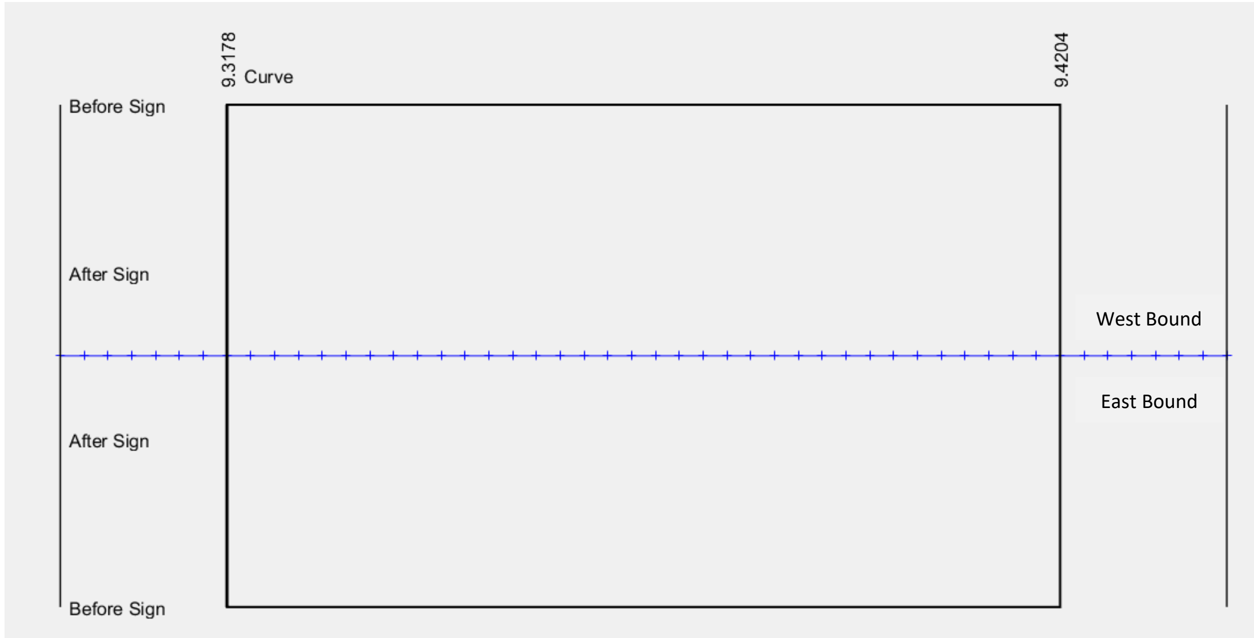
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	2348
Grade	2.7
Superelevation	7.5
Crashes	0
BBI	3
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #85 on State Route 2 in Rabun County

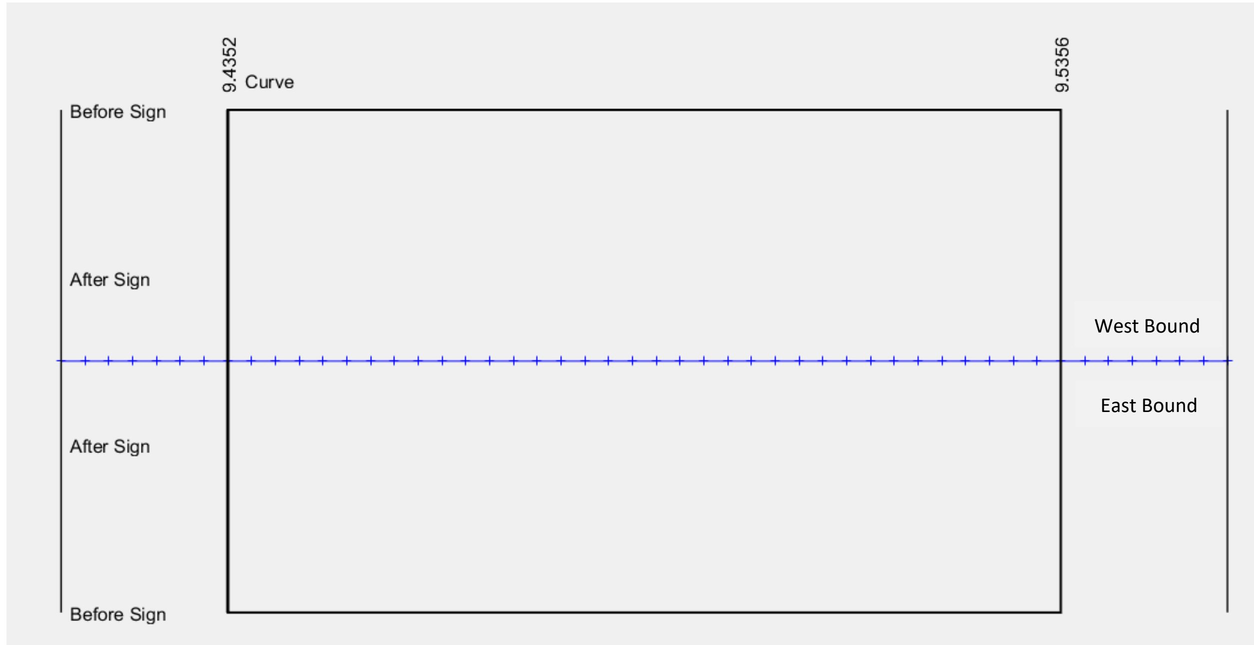
Scale: NA

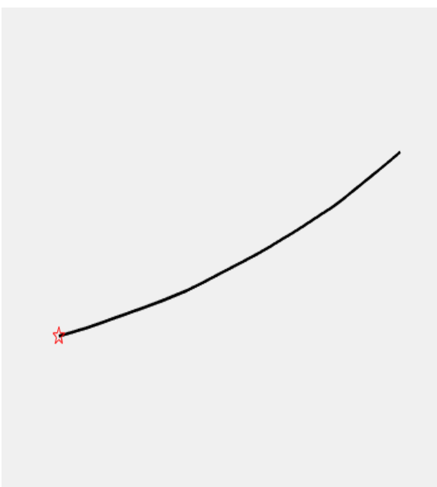
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1489
Grade	4.2
Superelevation	4.5
Crashes	0
BBI	5
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

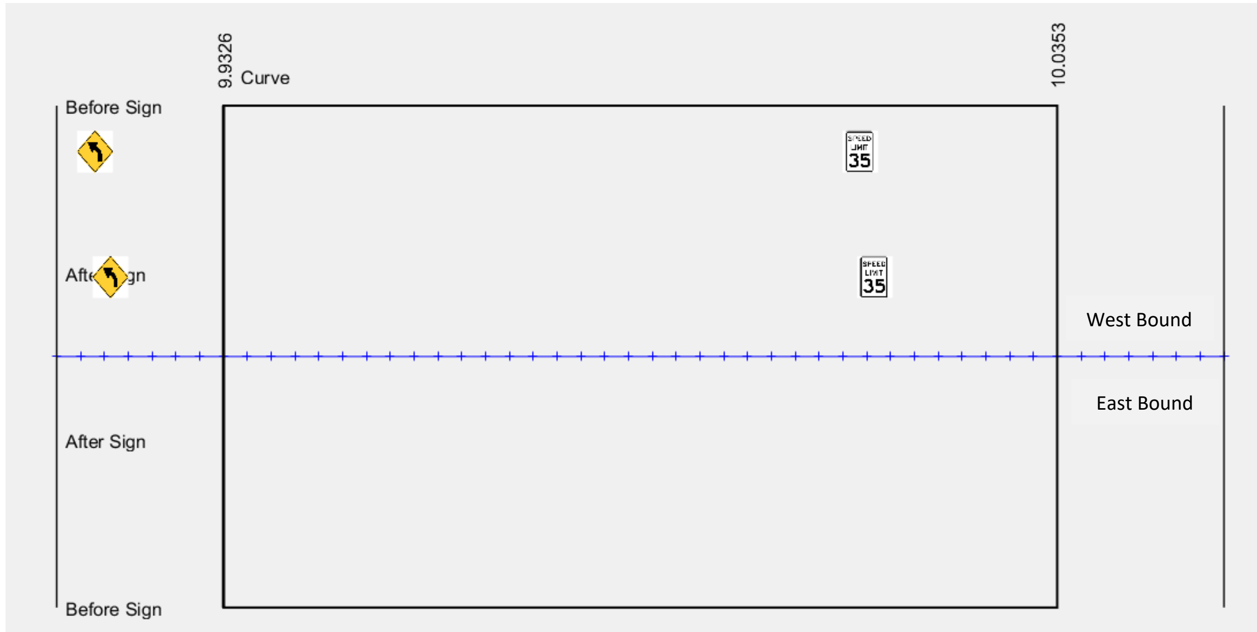
Curve #86 on State Route 2 in Rabun County

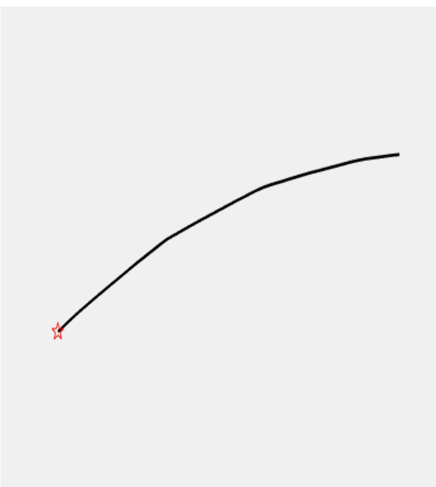
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	955
Grade	-1.8
Superelevation	7.5
Crashes	0
BBI	6
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #87 on State Route 2 in Rabun County

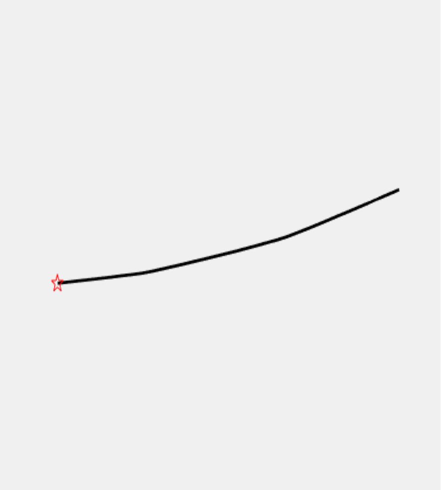
Scale: NA

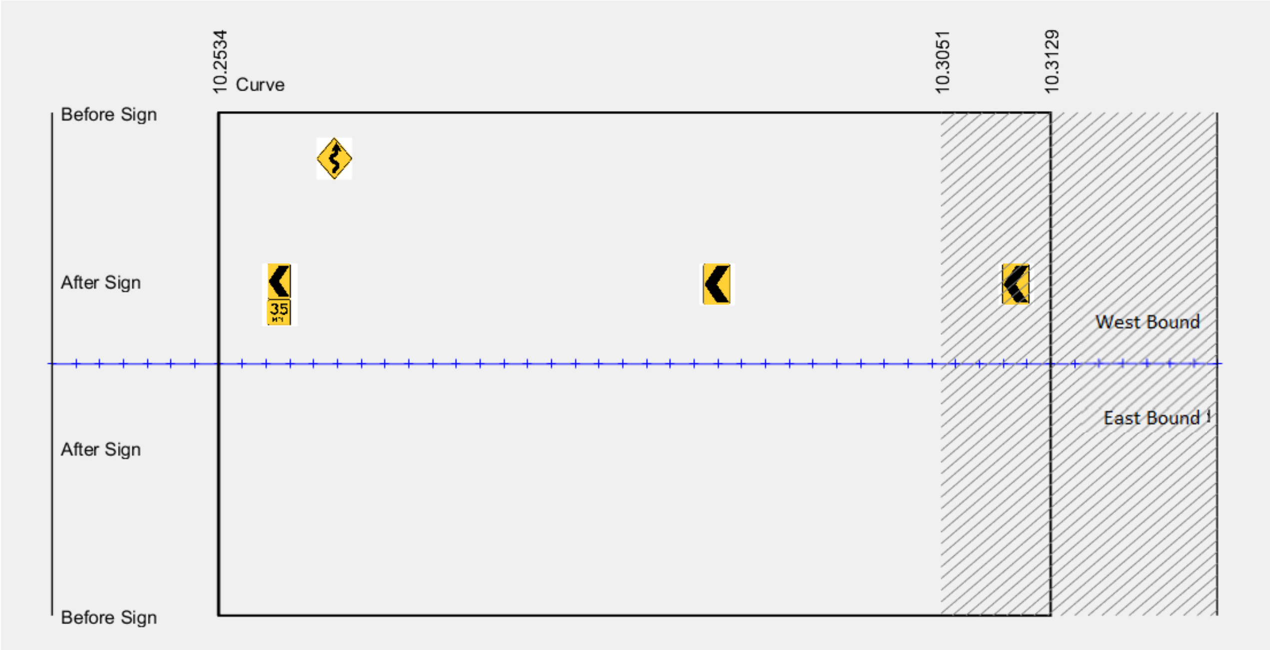
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1204
Grade	0.7
Superelevation	4.5
Crashes	0
BBI	4
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





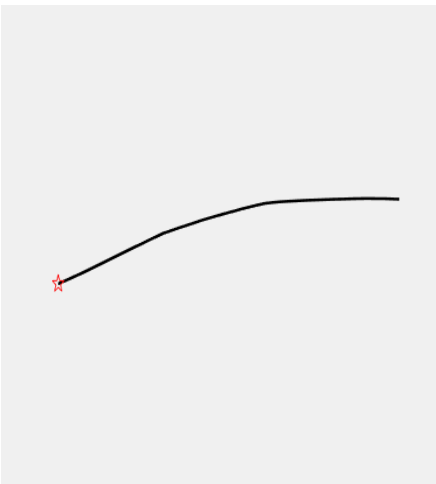
Horizontal Curve Schematic

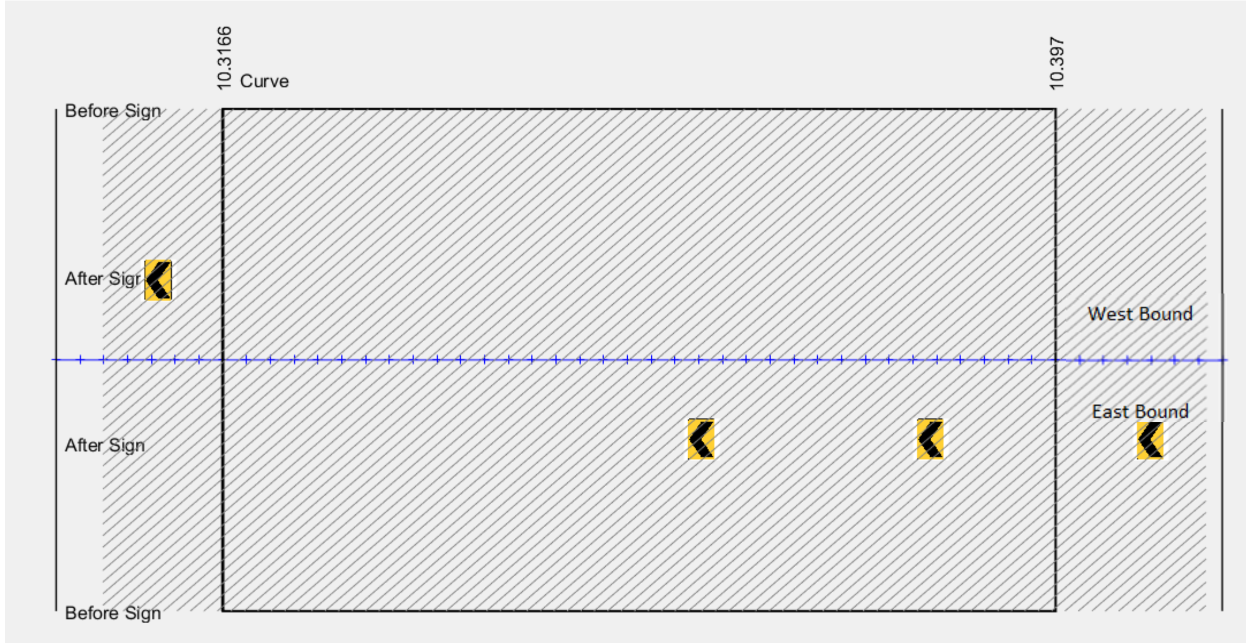
Curve #88 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	925
Grade	0.8
Superelevation	7.5
Crashes	0
BBI	6
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

Curve #89 on State Route 2 in Rabun County

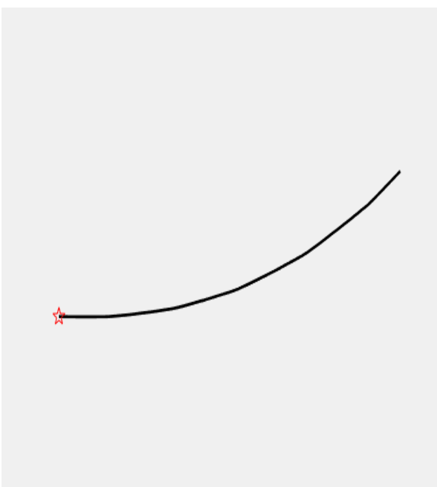
Scale: NA

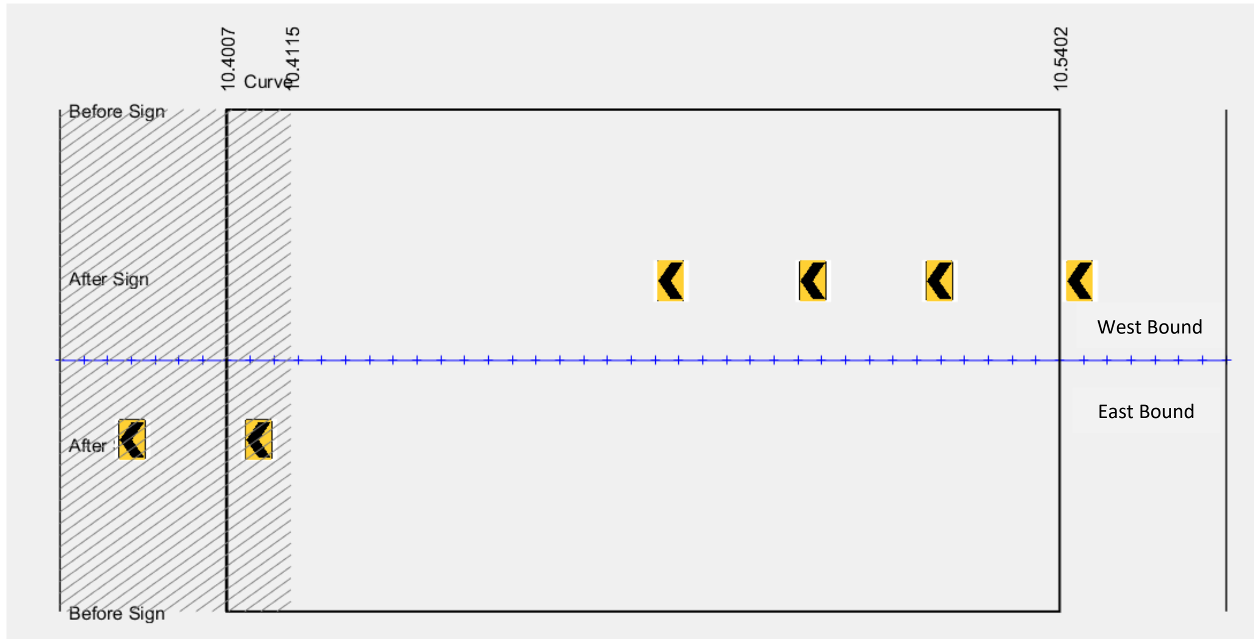
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1043
Grade	1.4
Superelevation	6
Crashes	1
BBI	8
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

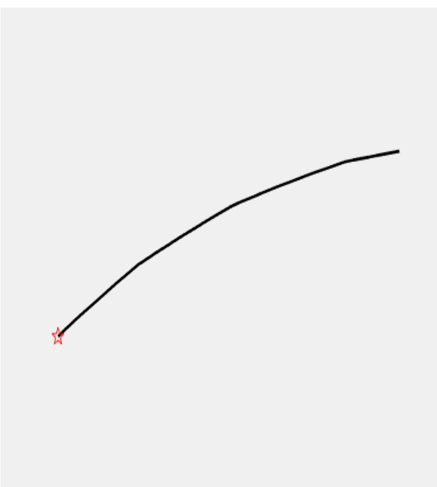
Curve #90 on State Route 2 in Rabun County

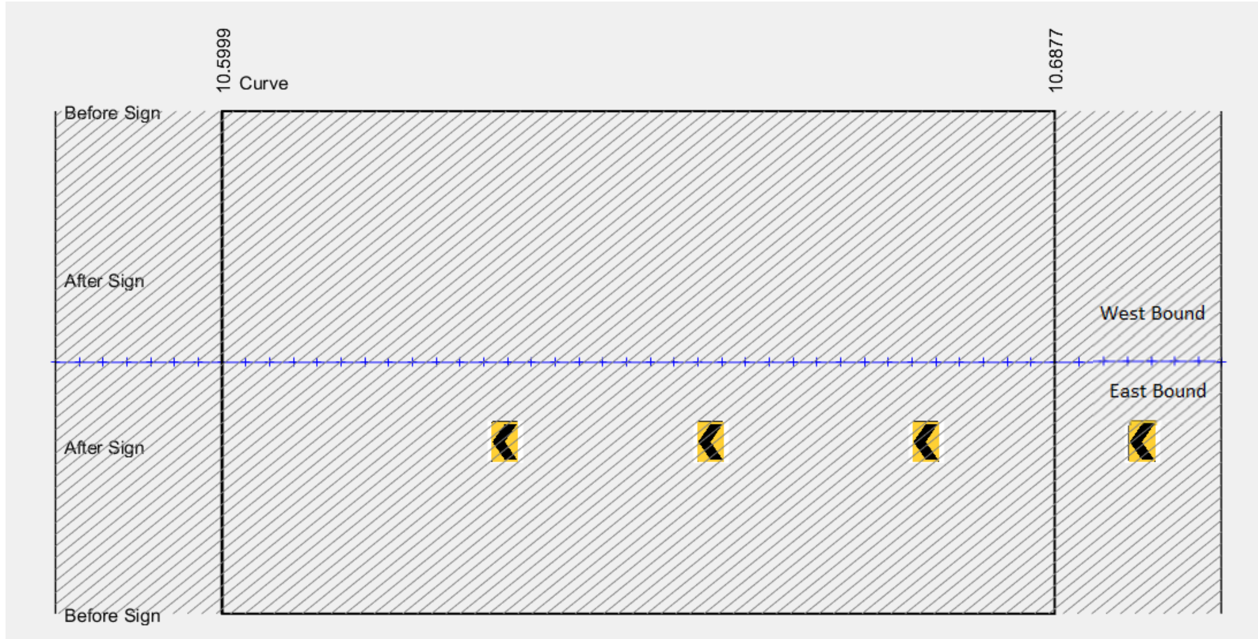
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	945
Grade	-0.4
Superelevation	6.5
Crashes	0
BBI	6
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #91 on State Route 2 in Rabun County

Scale: NA

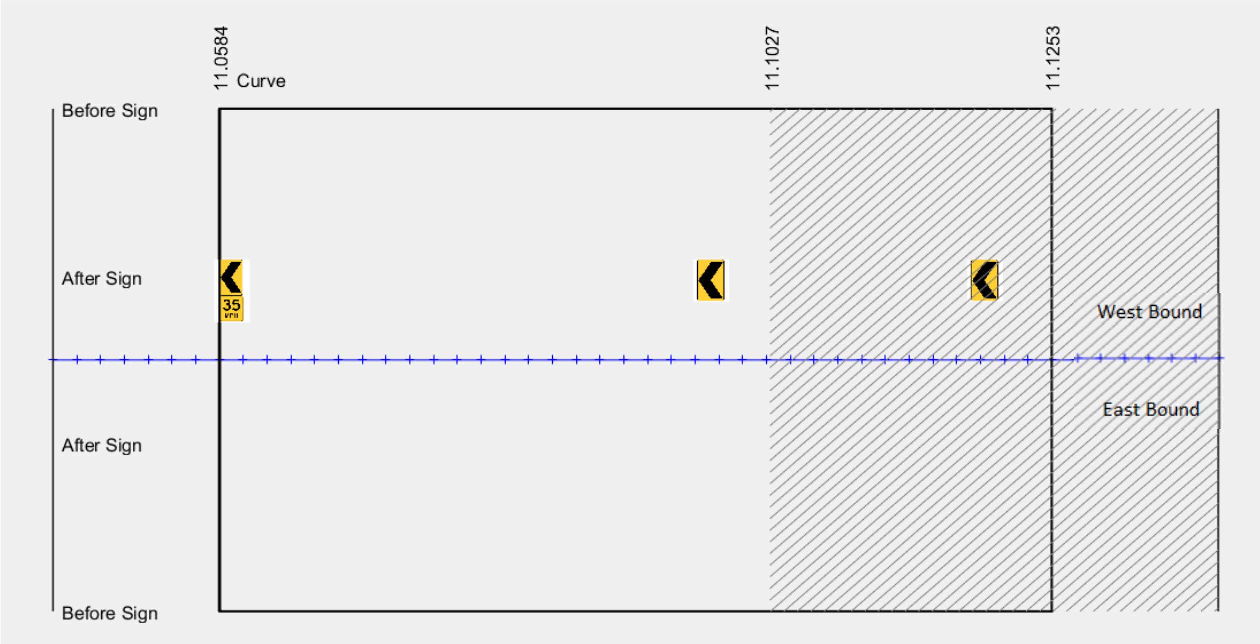
RCLINK:2411000200

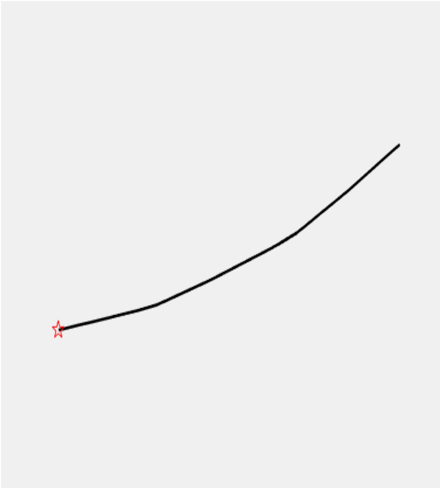
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	741
Grade	3.4
Superelevation	5
Crashes	1
BBI	7
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #92 on State Route 2 in Rabun County

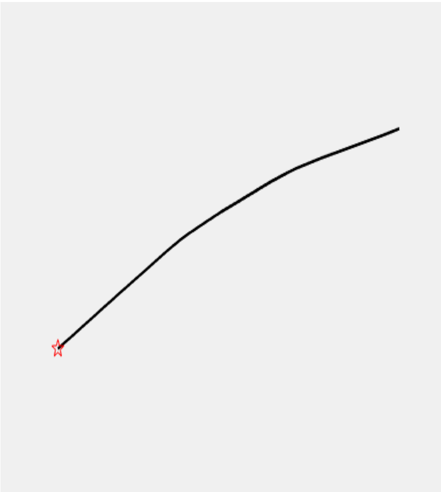
Scale: NA

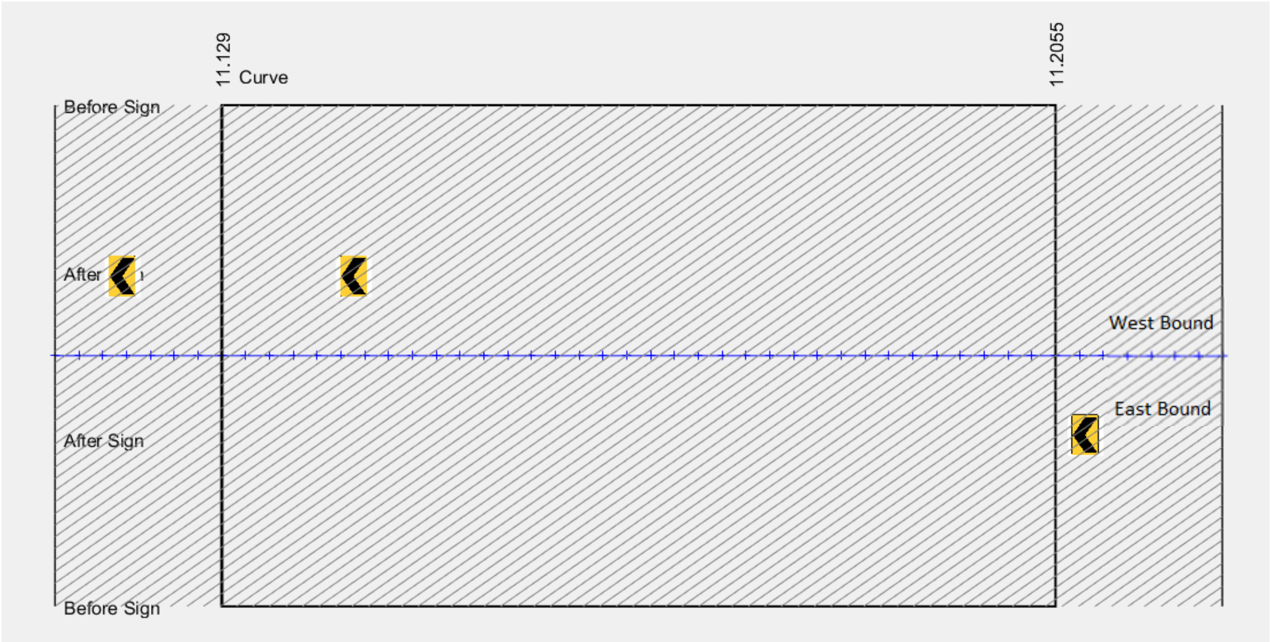
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	935
Grade	5.4
Superelevation	9
Crashes	0
BBI	5
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

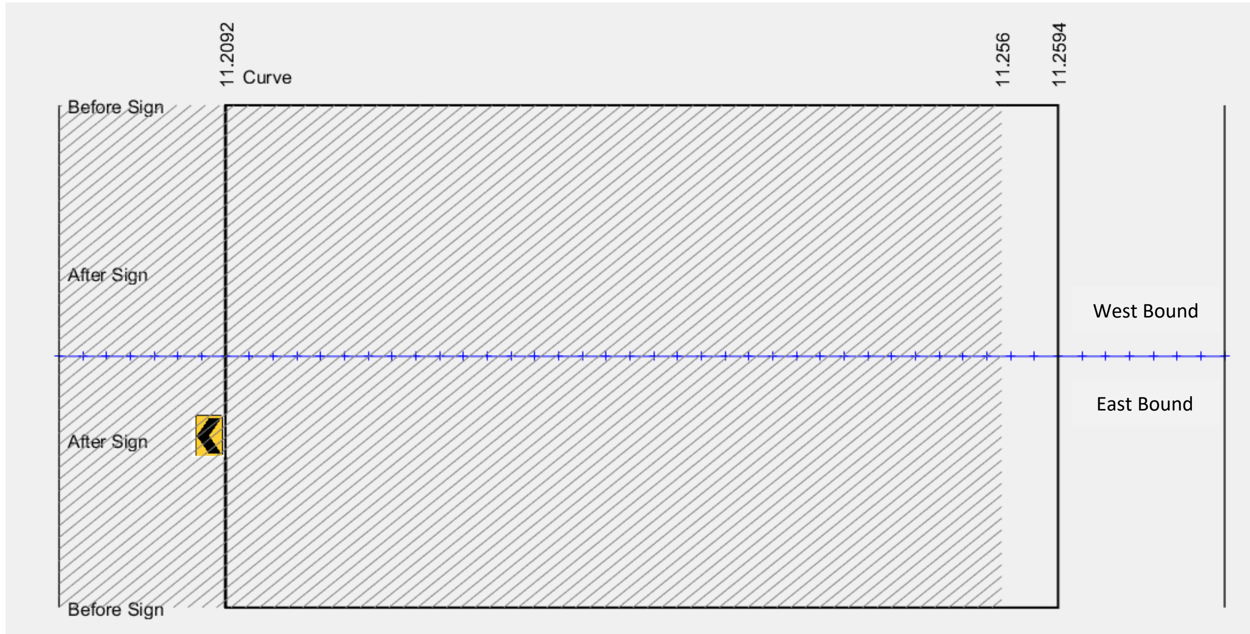
Curve #93 on State Route 2 in Rabun County

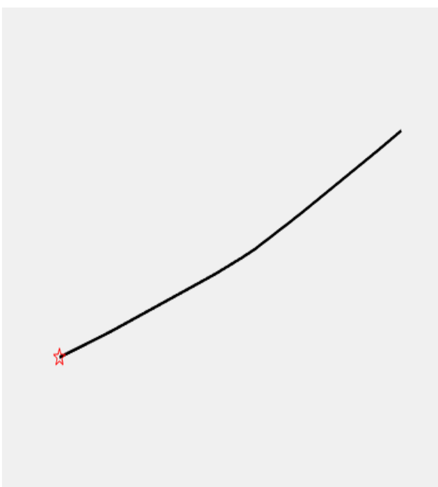
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	947
Grade	3.6
Superelevation	5
Crashes	0
BBI	4
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

Curve #94 on State Route 2 in Rabun County

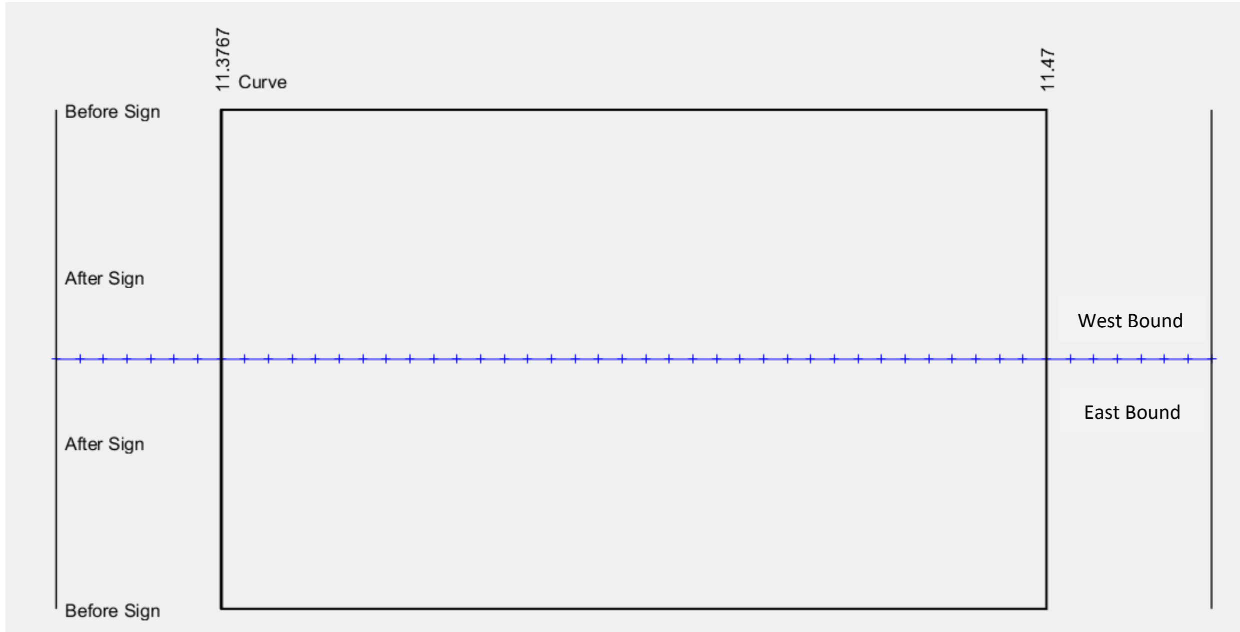
Scale: NA

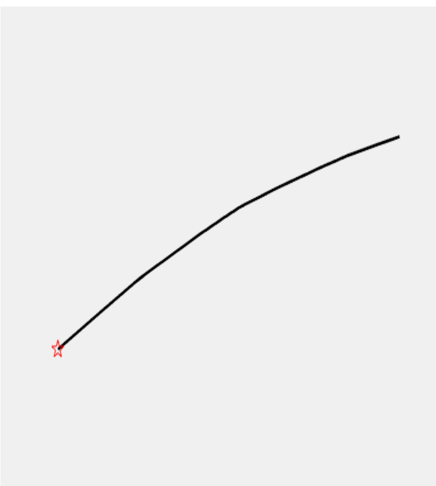
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1274
Grade	4.4
Superelevation	7
Crashes	0
BBI	4
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

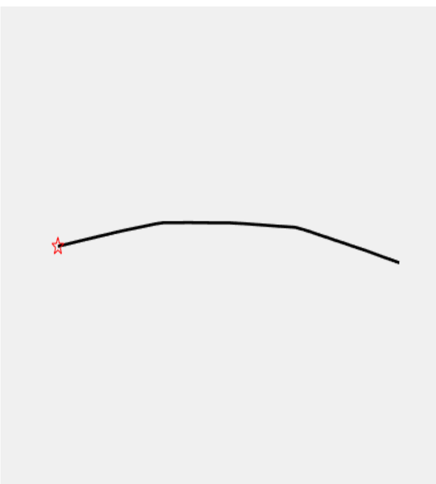
Curve#95 on State Route 2 in Rabun County

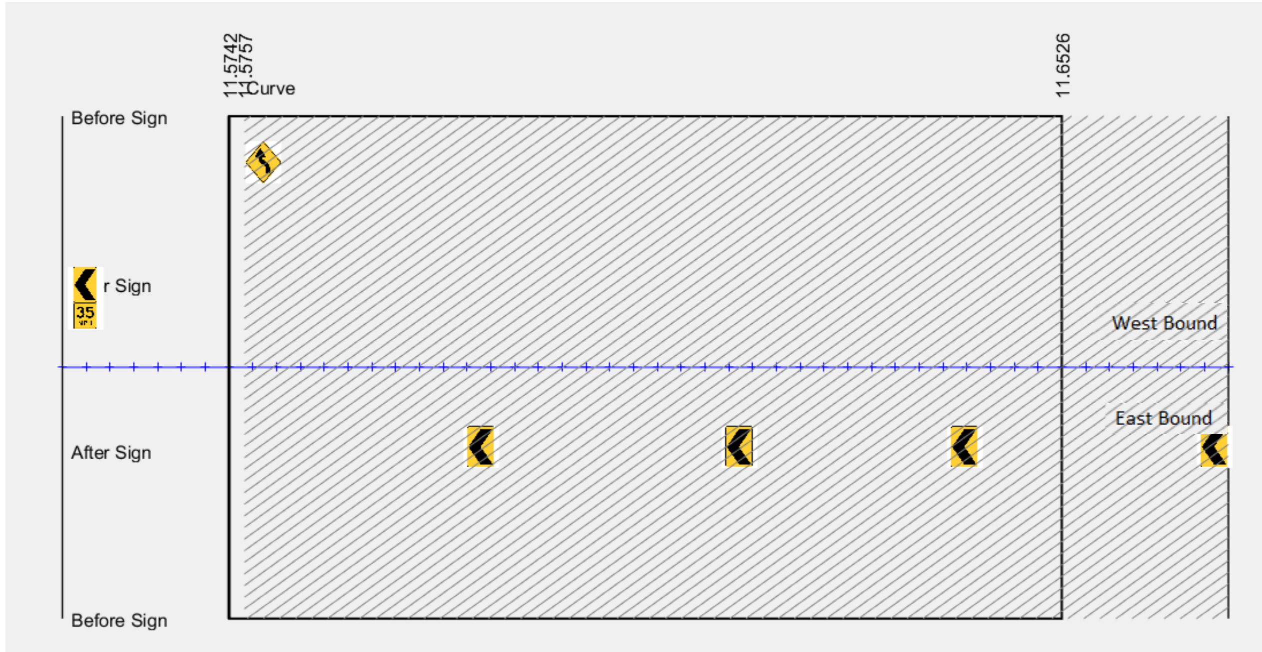
Scale: NA

RCLINK:2411000200

Road Characteristics

Radius	785
Grade	4.8
Superelevation	7.5
Crashes	0
BBI	6
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #96 on State Route 2 in Rabun County

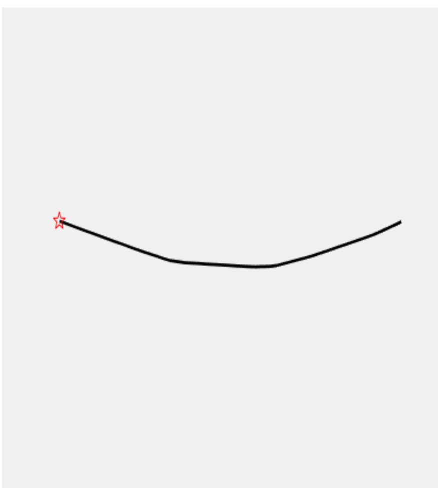
Scale: NA

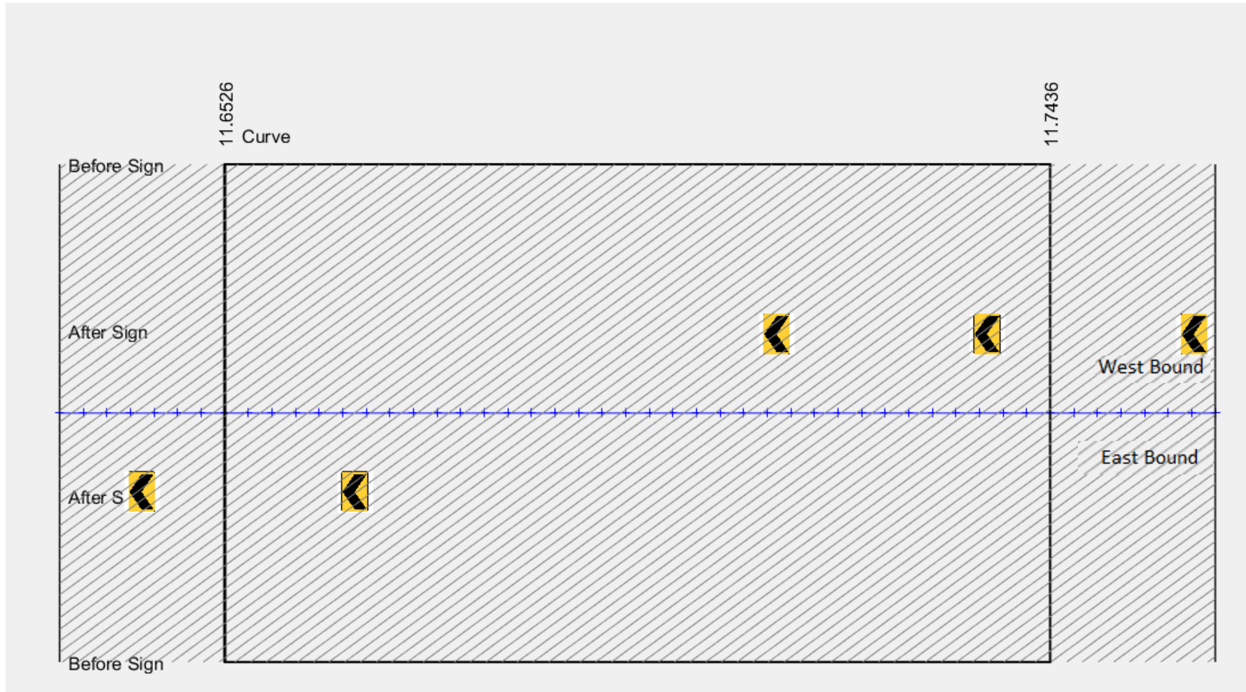
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	661
Grade	4.4
Superelevation	7
Crashes	1
BBI	9
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

Curve #97 on State Route 2 in Rabun County

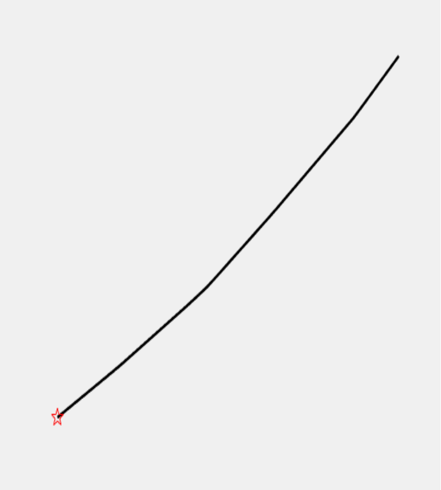
Scale: NA

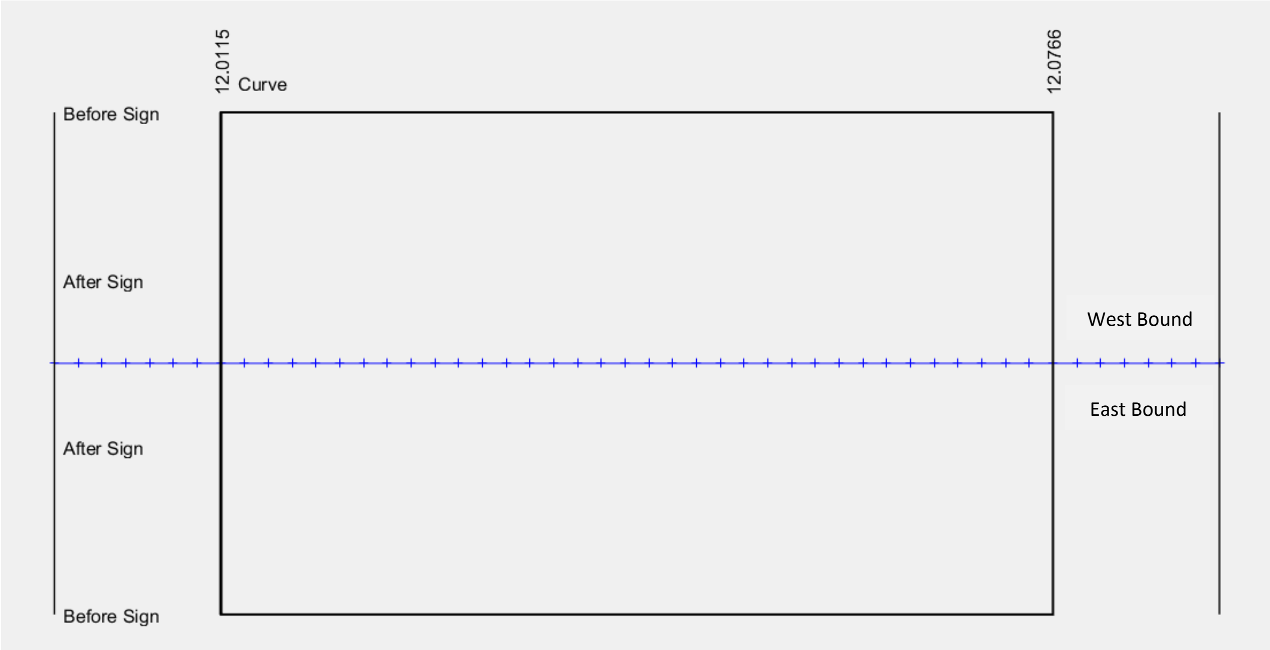
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1187
Grade	-6.4
Superelevation	6
Crashes	0
BBI	6
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #98 on State Route 2 in Rabun County

Scale: NA

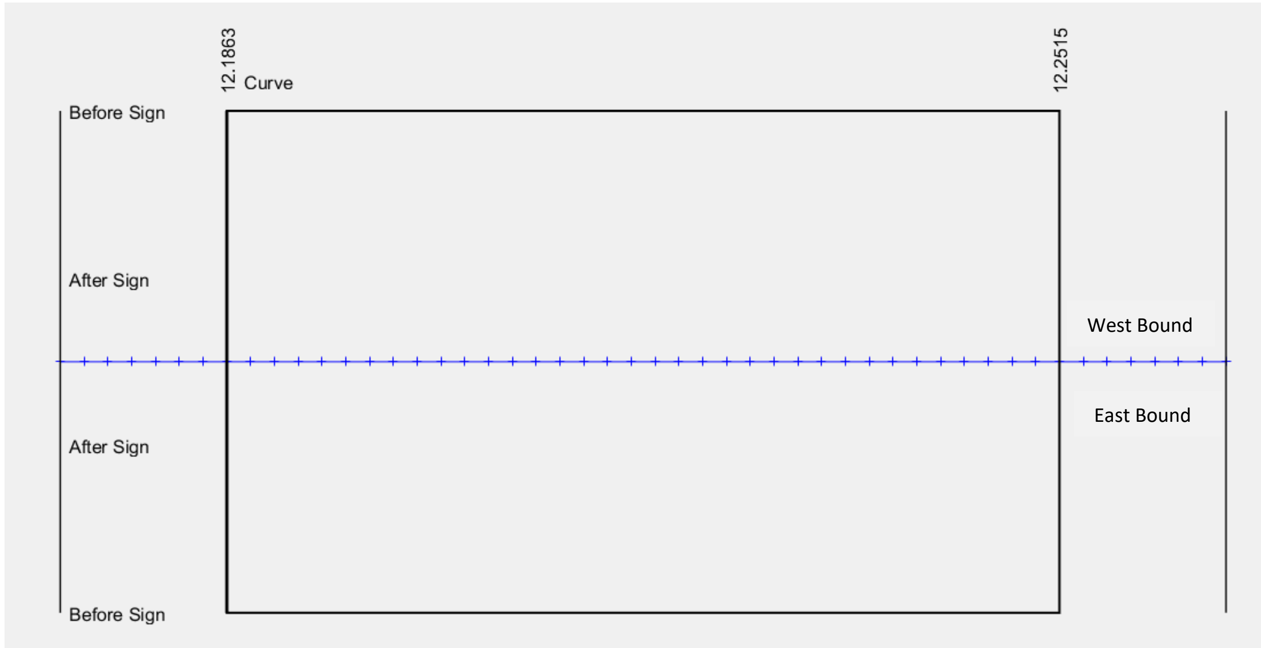
RCLINK:2411000200

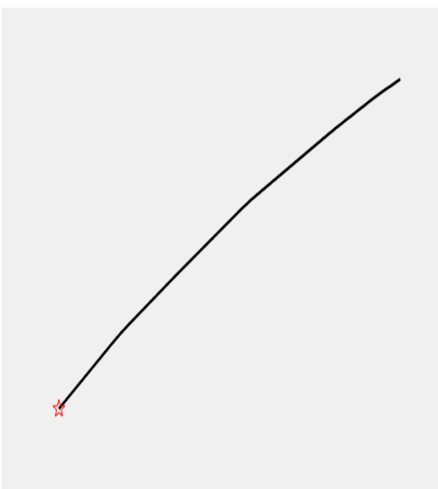
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	1415
Grade	-5.9
Superelevation	6
Crashes	0
BBI	4
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #99 on State Route 2 in Rabun County

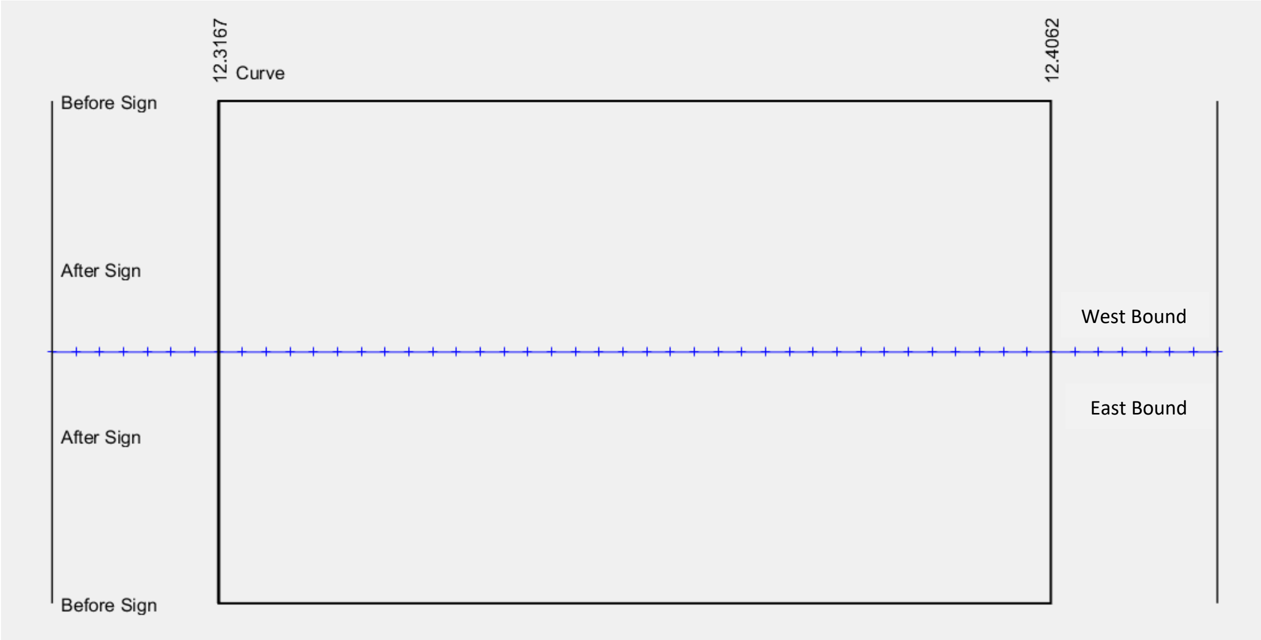
Scale: NA

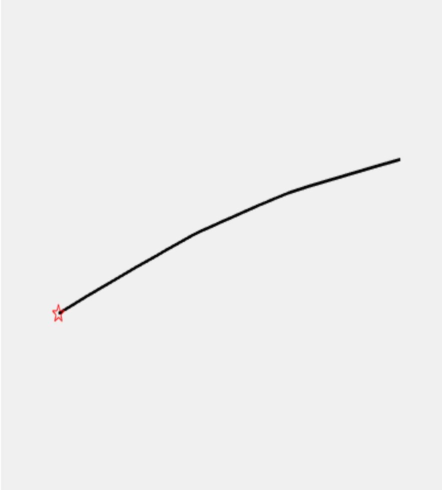
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1671
Grade	-4.4
Superelevation	6.5
Crashes	0
BBI	5
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

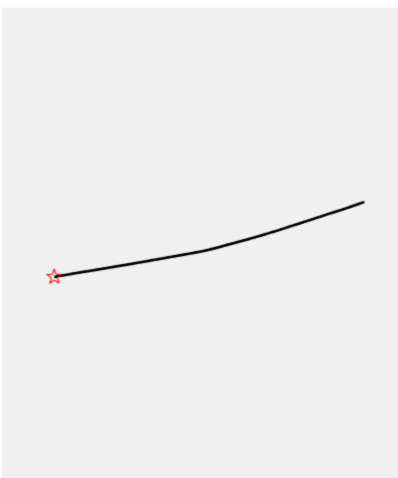
Curve #100 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	2540
Grade	-4.3
Superelevation	5
Crashes	0
BBI	5
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #101 on State Route 2 in Rabun County

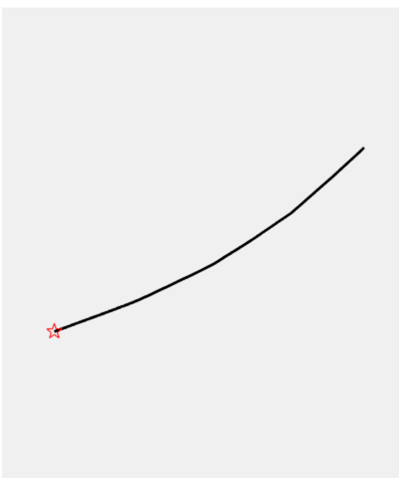
Scale: NA

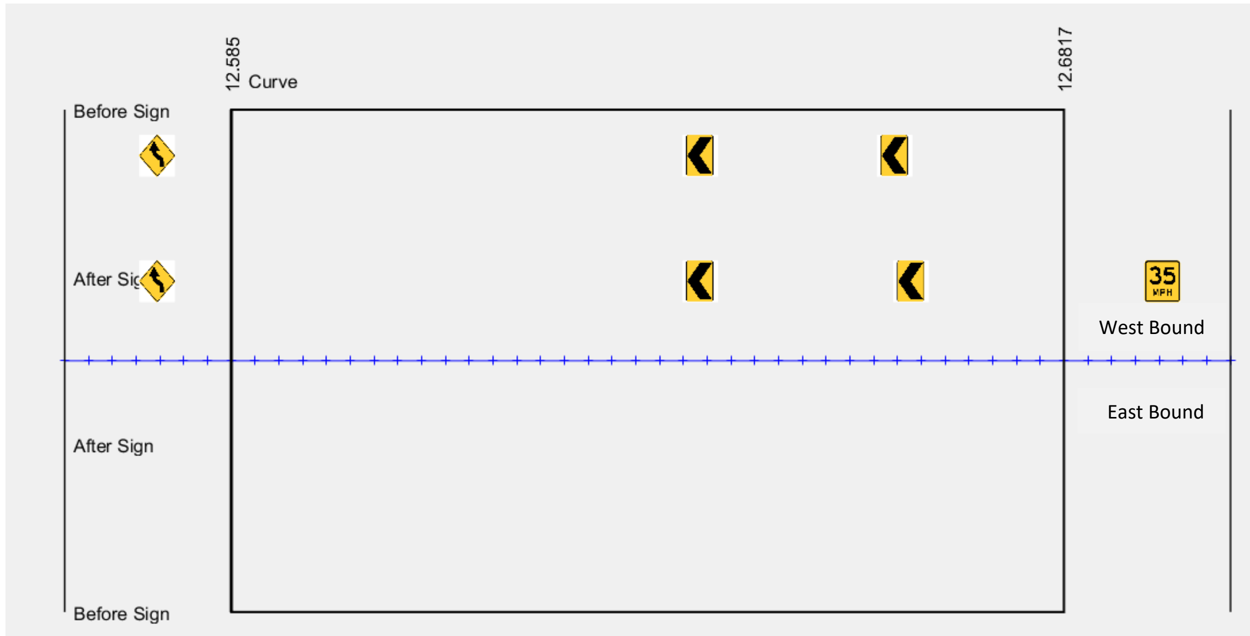
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	991
Grade	2.1
Superelevation	5
Crashes	0
BBI	8
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

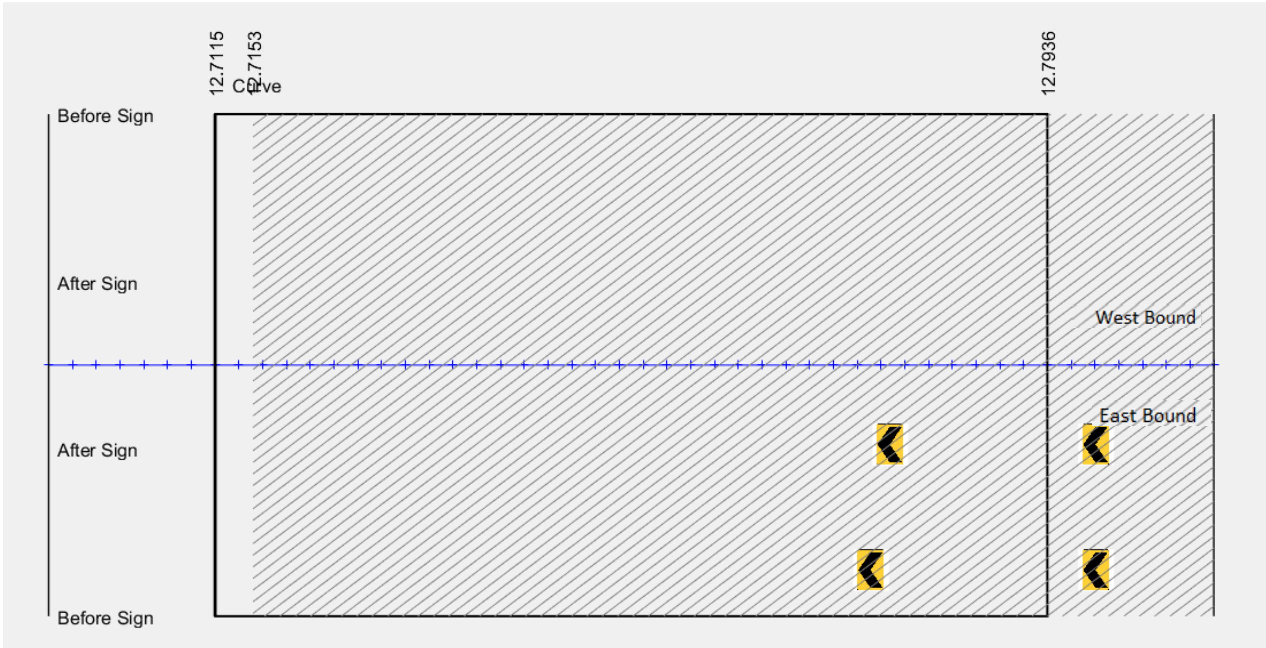
Curve #102 on State Route 2 in Rabun County

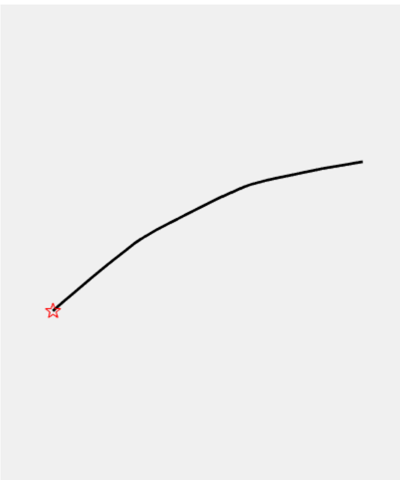
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	591
Grade	-2.4
Superelevation	7
Crashes	0
BBI	11
Posted Speed	55
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

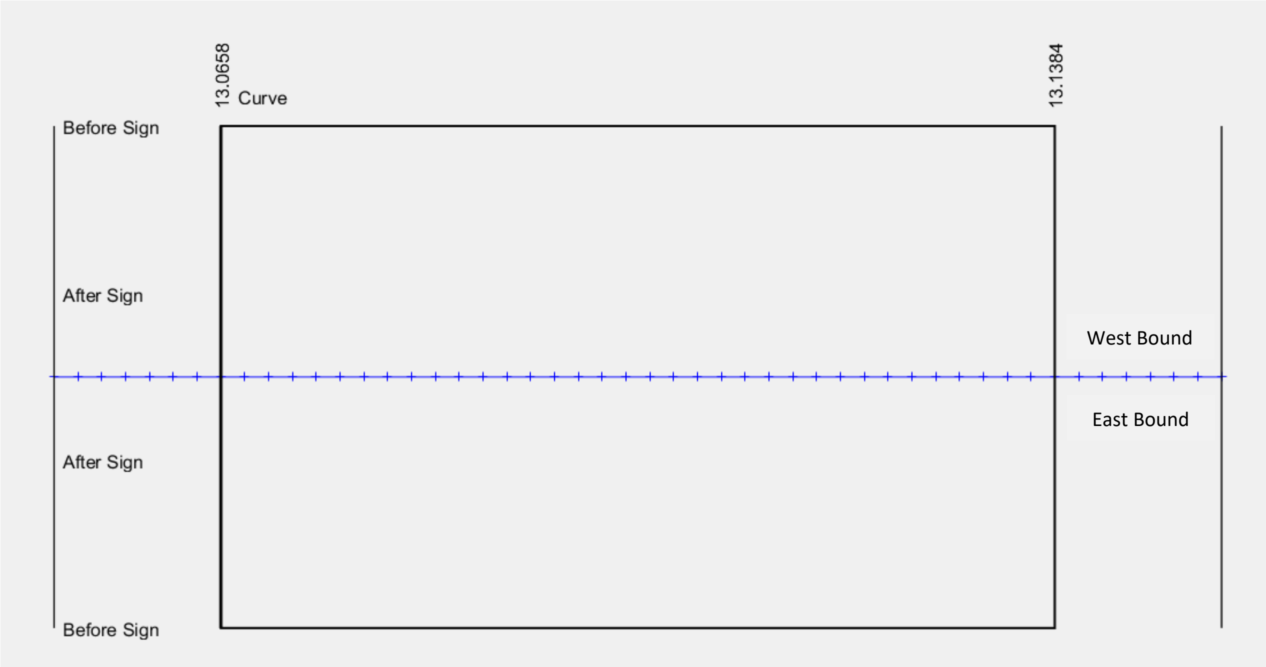
Curve #103 on State Route 2 in Rabun County

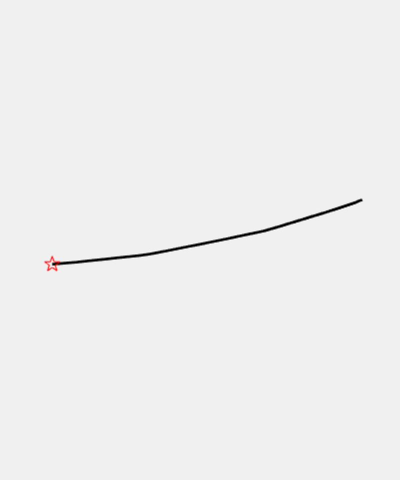
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	1422
Grade	0.6
Superelevation	5
Crashes	0
BBI	6
Posted Speed	55
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA

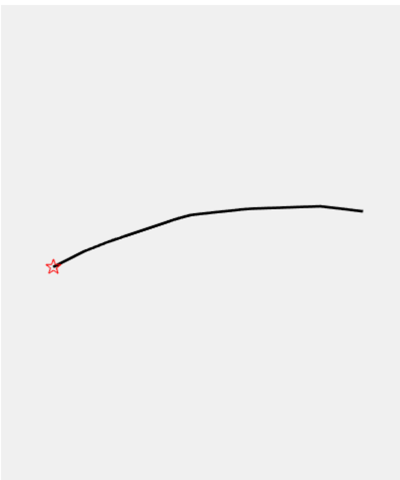


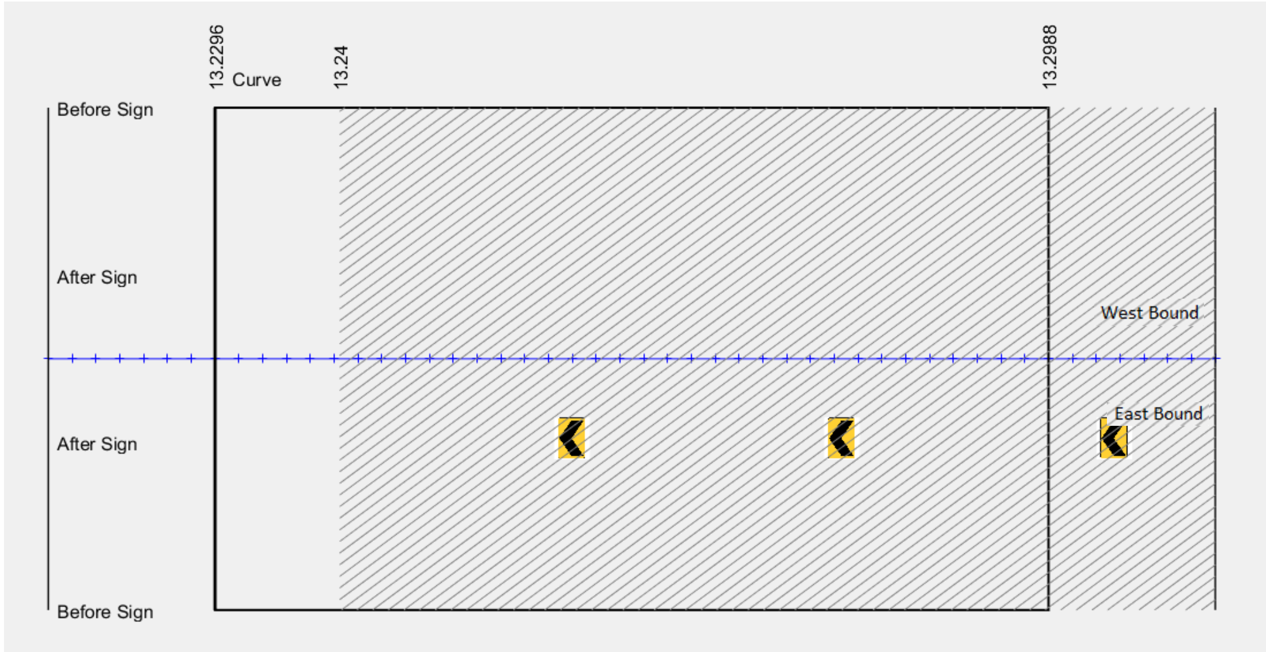


Horizontal Curve Schematic	Curve #104 on State Route 2 in Rabun County	Scale: NA
GDOT Georgia Department of Transportation		RCLINK:2411000200
		Georgia Institute of Technology

Road Characteristics

Radius	569
Grade	2.5
Superelevation	8.5
Crashes	1
BBI	10
Posted Speed	55
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #105 on State Route 2 in Rabun County

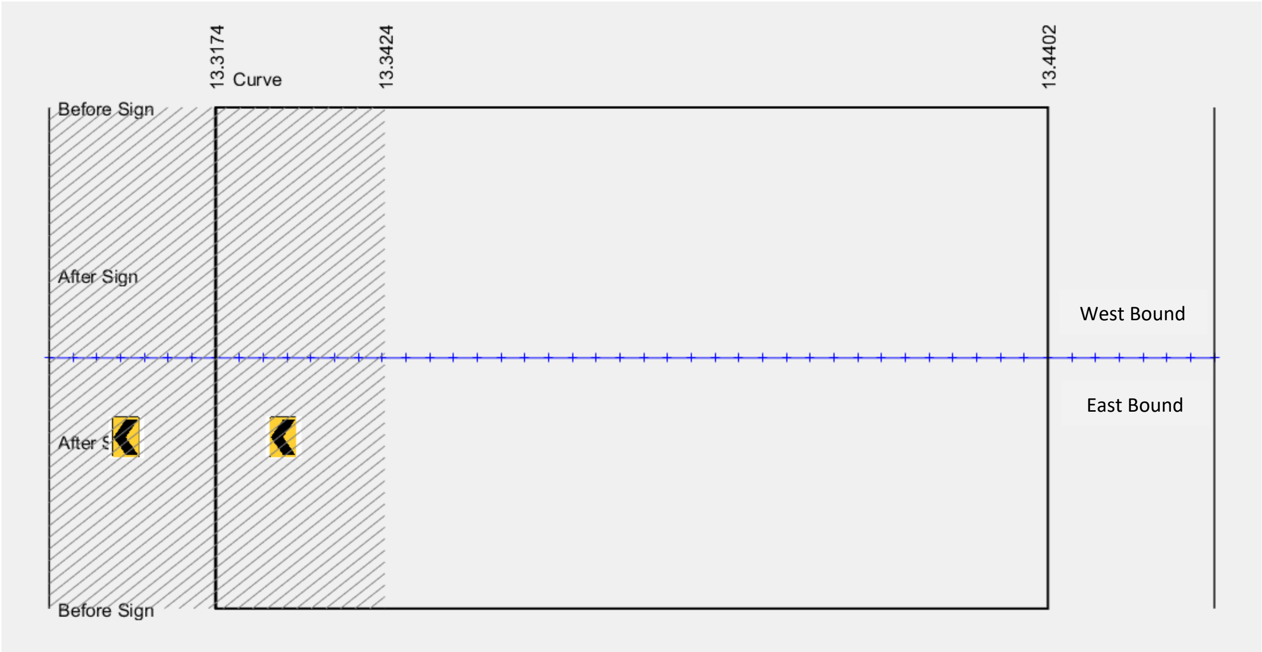
Scale: NA

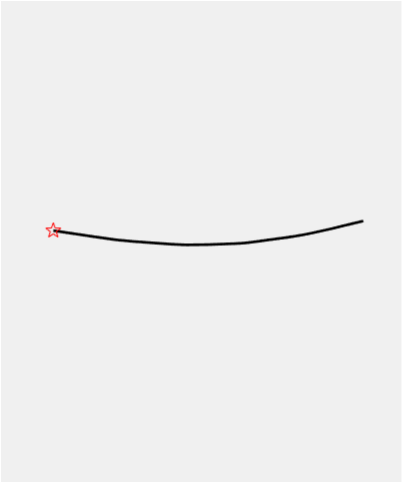
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1297
Grade	2.9
Superelevation	4.5
Crashes	0
BBI	5
Posted Speed	55
Advisory Speed	35
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #106 on State Route 2 in Rabun County

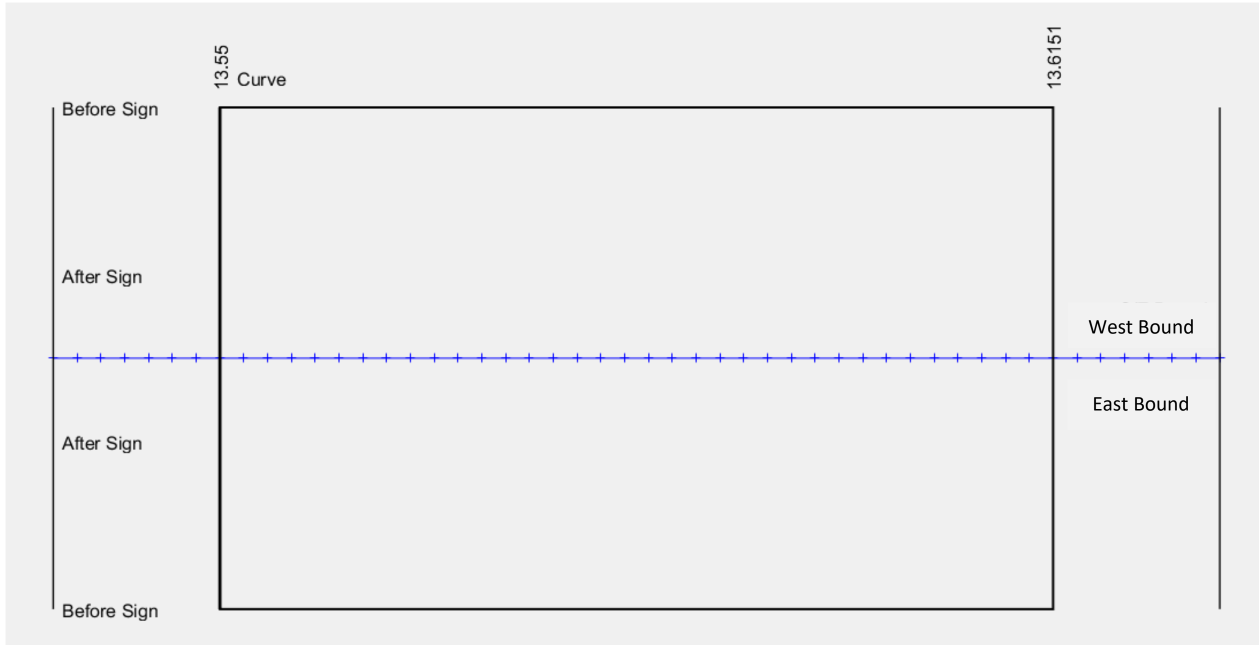
Scale: NA

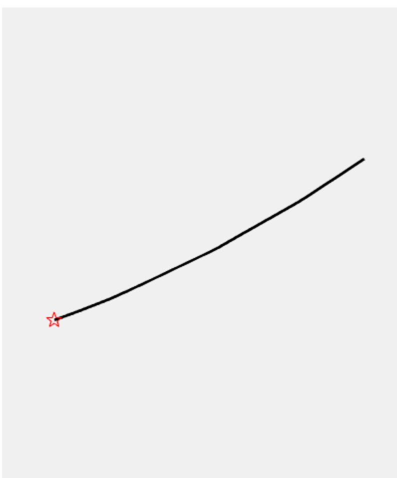
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1372
Grade	-4.8
Superelevation	4
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

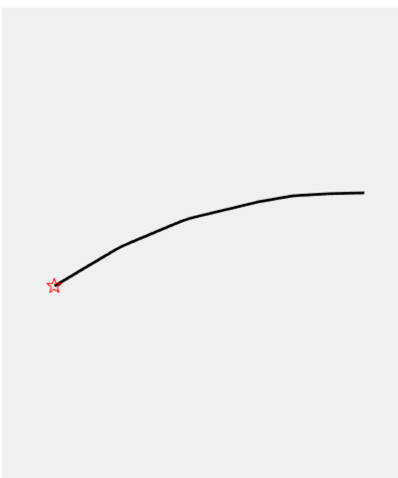
Curve #107 on State Route 2 in Rabun County

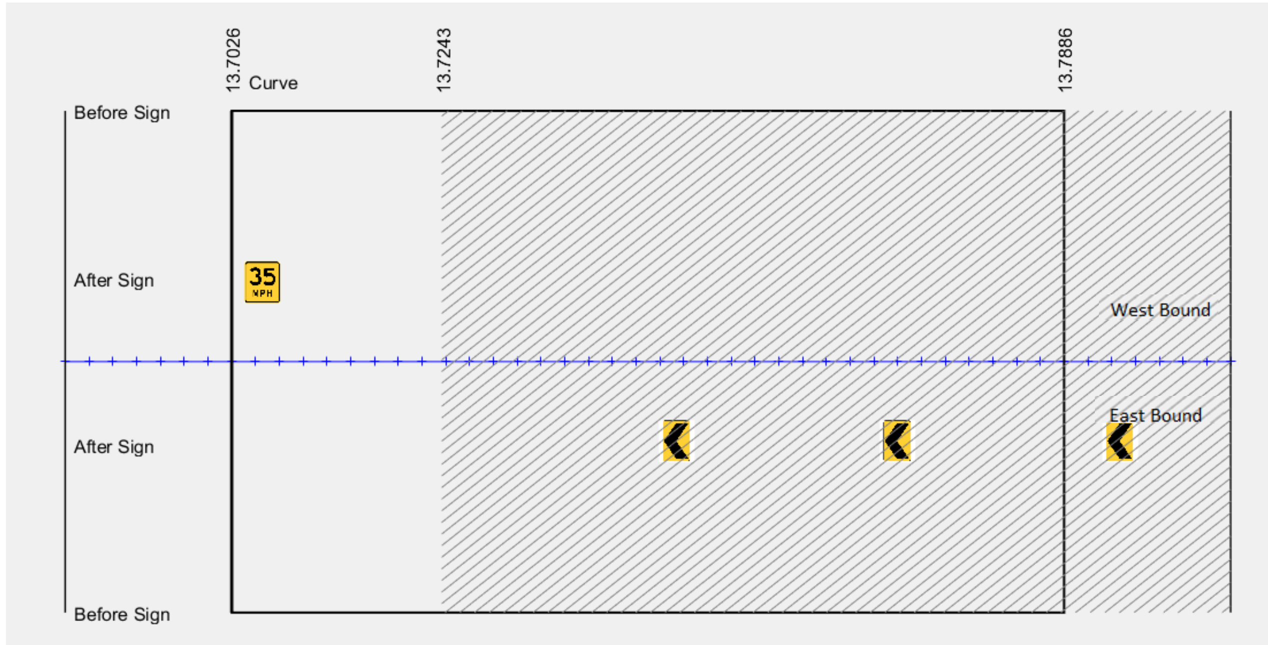
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	724
Grade	0.5
Superelevation	8
Crashes	0
BBI	7
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

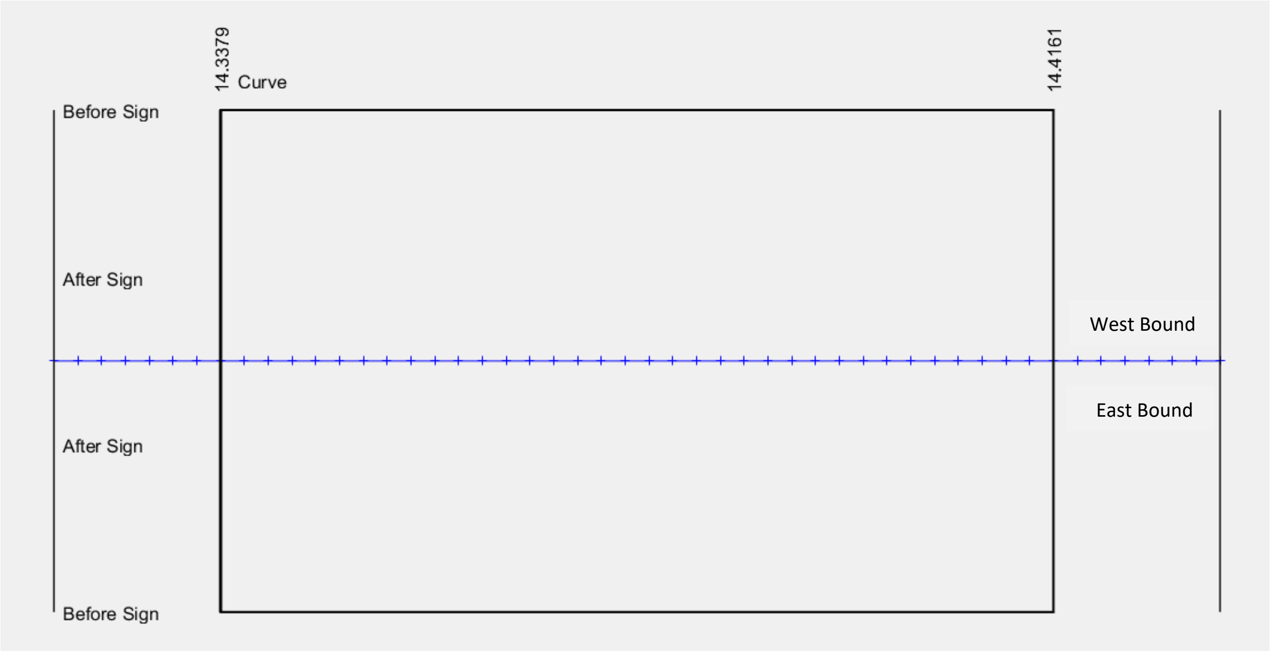
Curve #108 on State Route 2 in Rabun County

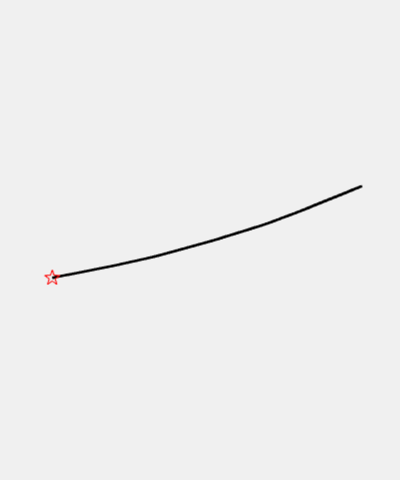
Scale: NA

RCLINK:2411000200

Road Characteristics

Radius	1637
Grade	-2.5
Superelevation	4
Crashes	1
BBI	5
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

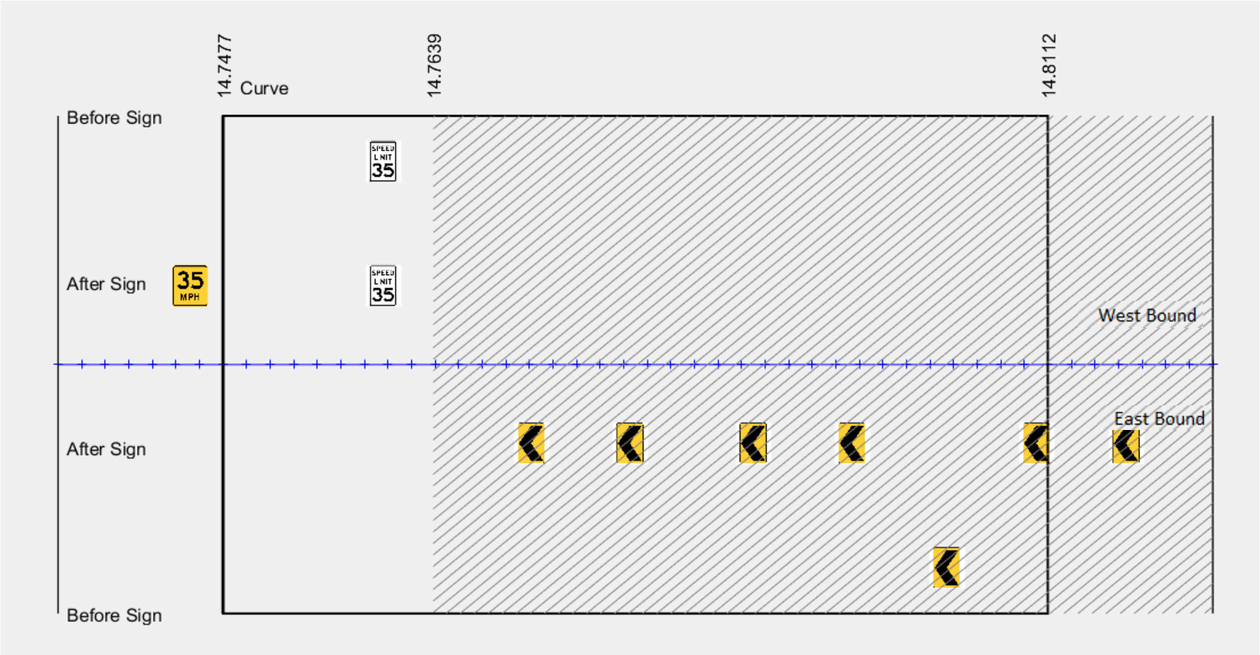
Curve #109 on State Route 2 in Rabun County

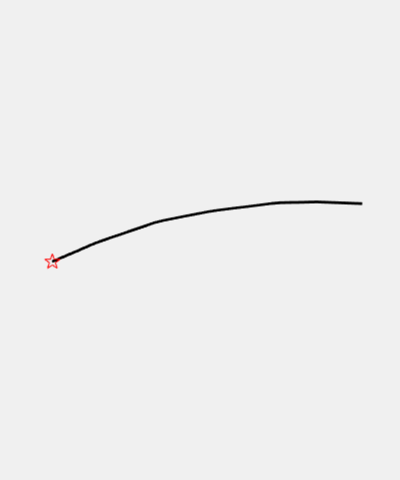
Scale: NA

RCLINK:2411000200

Road Characteristics

Radius	658
Grade	0.5
Superelevation	8
Crashes	0
BBI	9
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #110 on State Route 2 in Rabun County

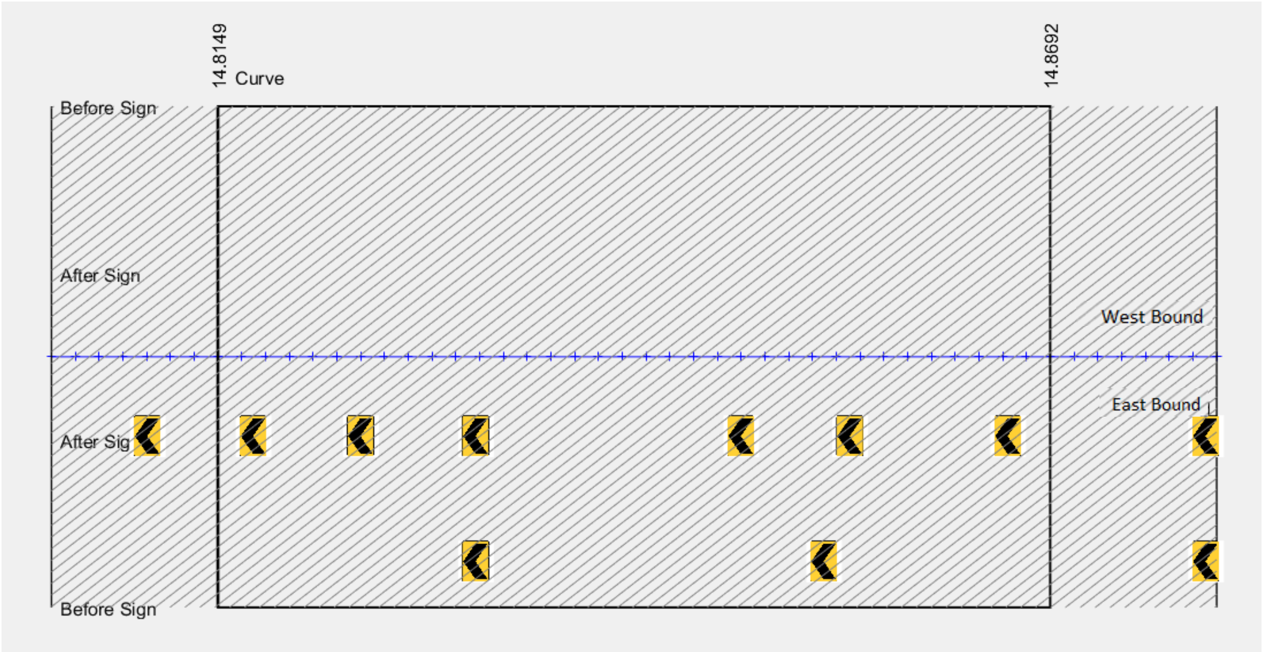
Scale: NA

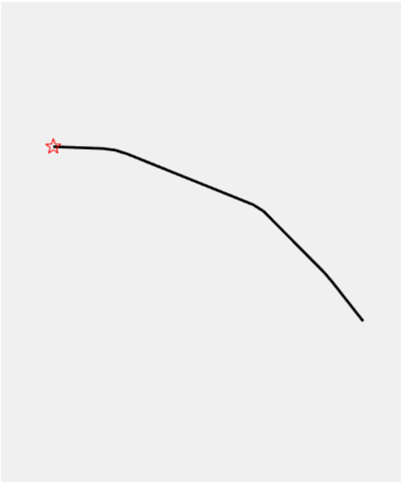
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

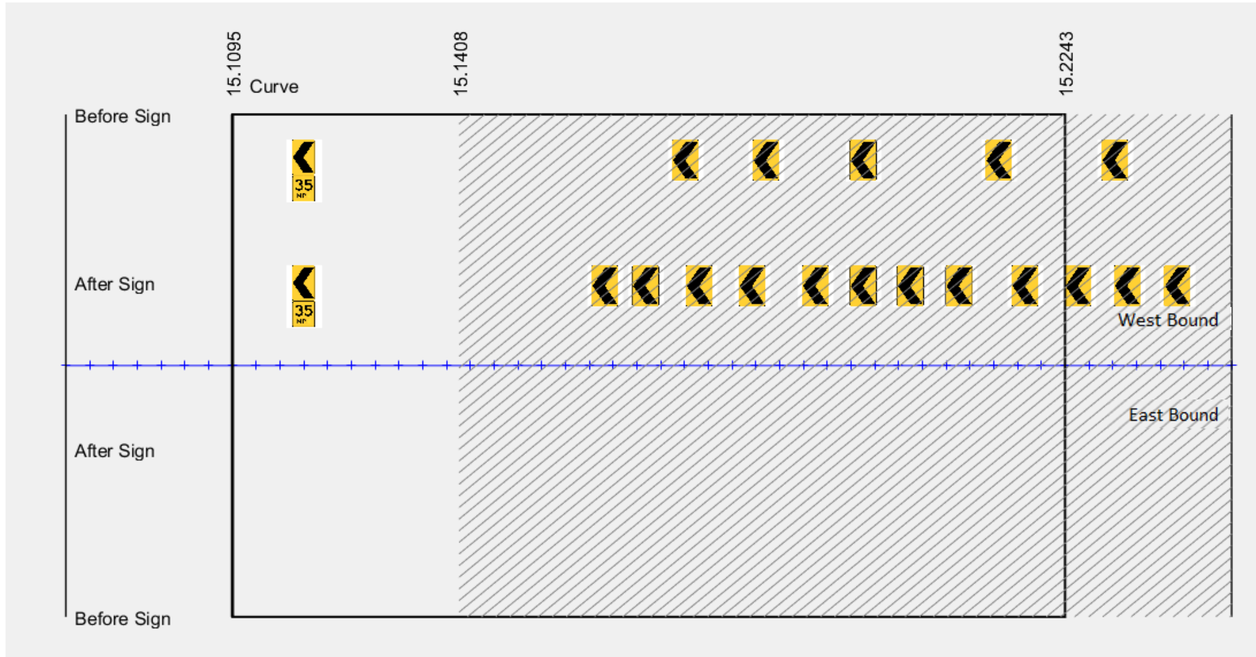
Road Characteristics	
Radius	295
Grade	0.5
Superelevation	9
Crashes	0
BBI	13
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA

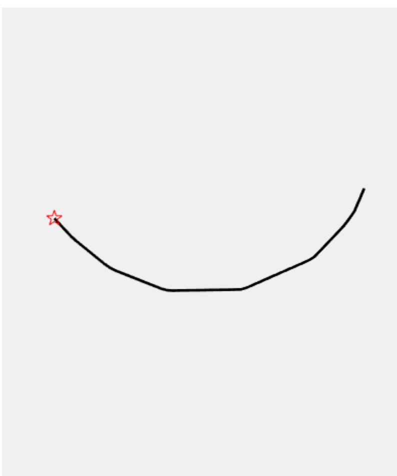




Horizontal Curve Schematic	Curve #111 on State Route 2 in Rabun County	Scale: NA
GDOT Georgia Department of Transportation		RCLINK:2411000200
		Georgia Institute of Technology

Road Characteristics	
Radius	292
Grade	-2.2
Superelevation	7.5
Crashes	1
BBI	16
Posted Speed	35
Advisory Speed	15
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

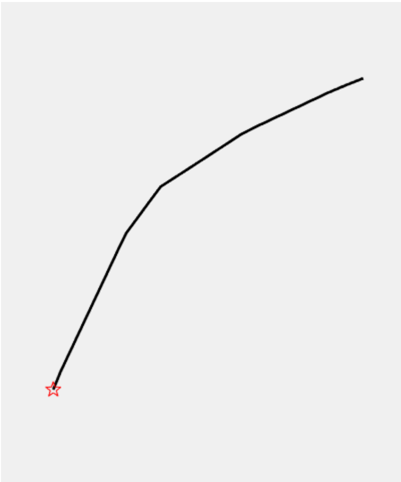
Curve #112 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	197
Grade	-2.4
Superelevation	7
Crashes	1
BBI	12
Posted Speed	35
Advisory Speed	15
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA



Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #113 on State Route 2 in Rabun County

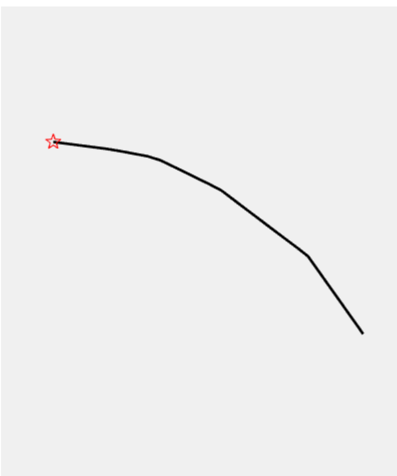
Scale: NA

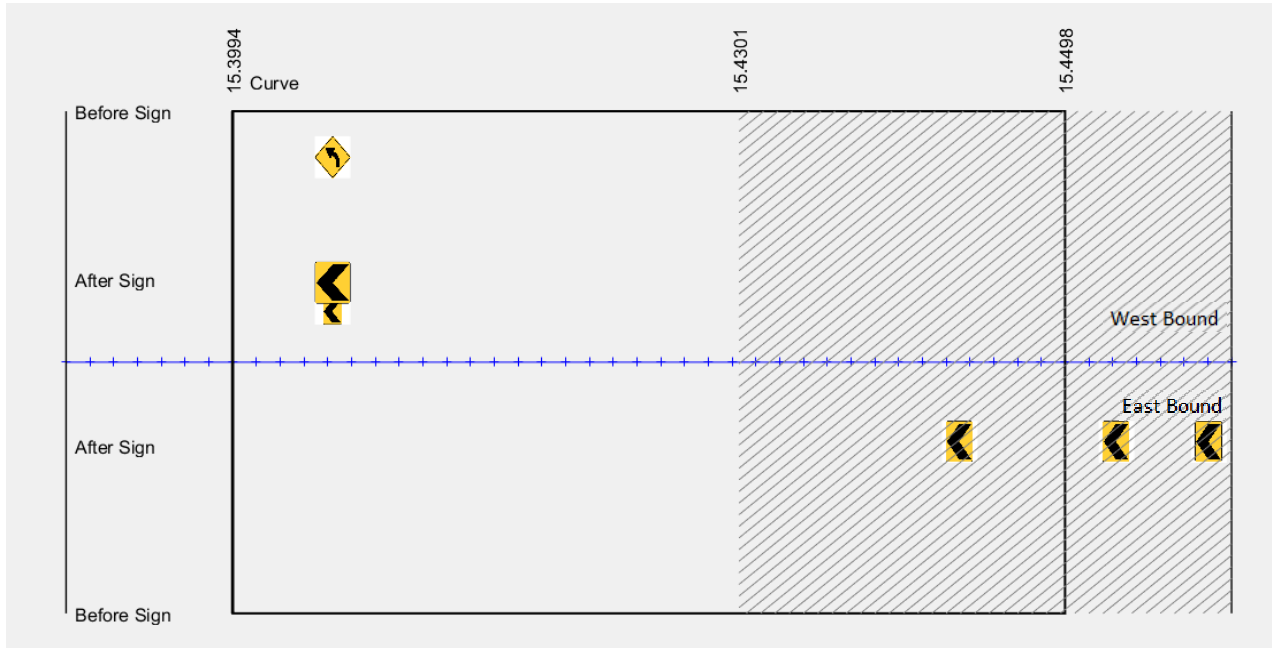
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	266
Grade	1.3
Superelevation	7.5
Crashes	0
BBI	15
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

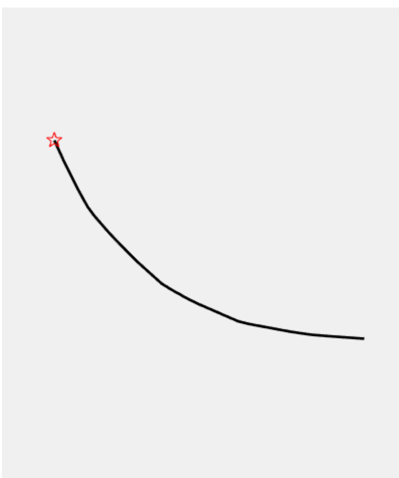
Curve #114 on State Route 2 in Rabun County

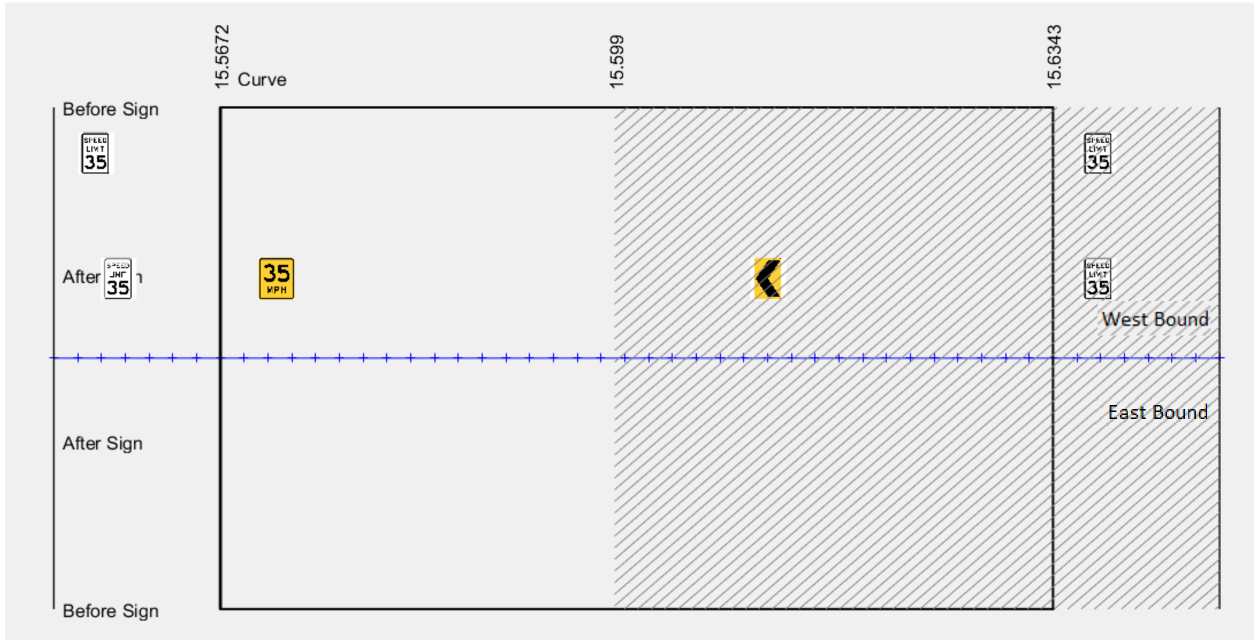
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	271
Grade	5.7
Superelevation	5.5
Crashes	0
BBI	12
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

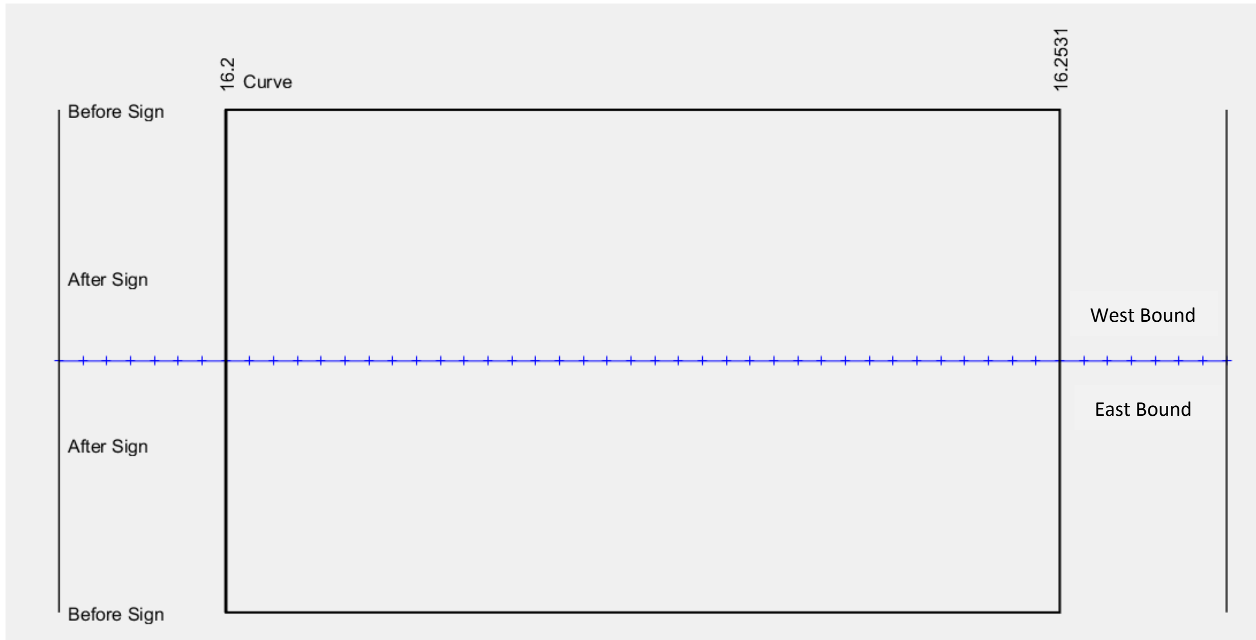
Curve #115 on State Route 2 in Rabun County

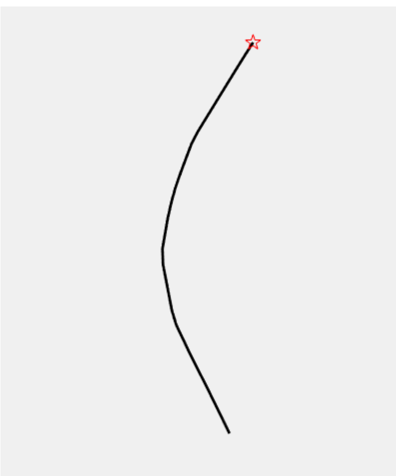
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	183
Grade	-4
Superelevation	6.5
Crashes	0
BBI	14
Posted Speed	35
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #116 on State Route 2 in Rabun County

Scale: NA

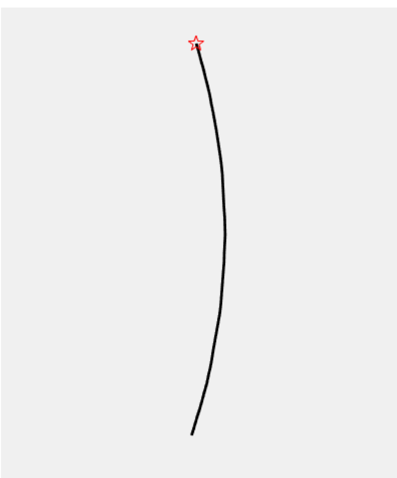
RCLINK:2411000200

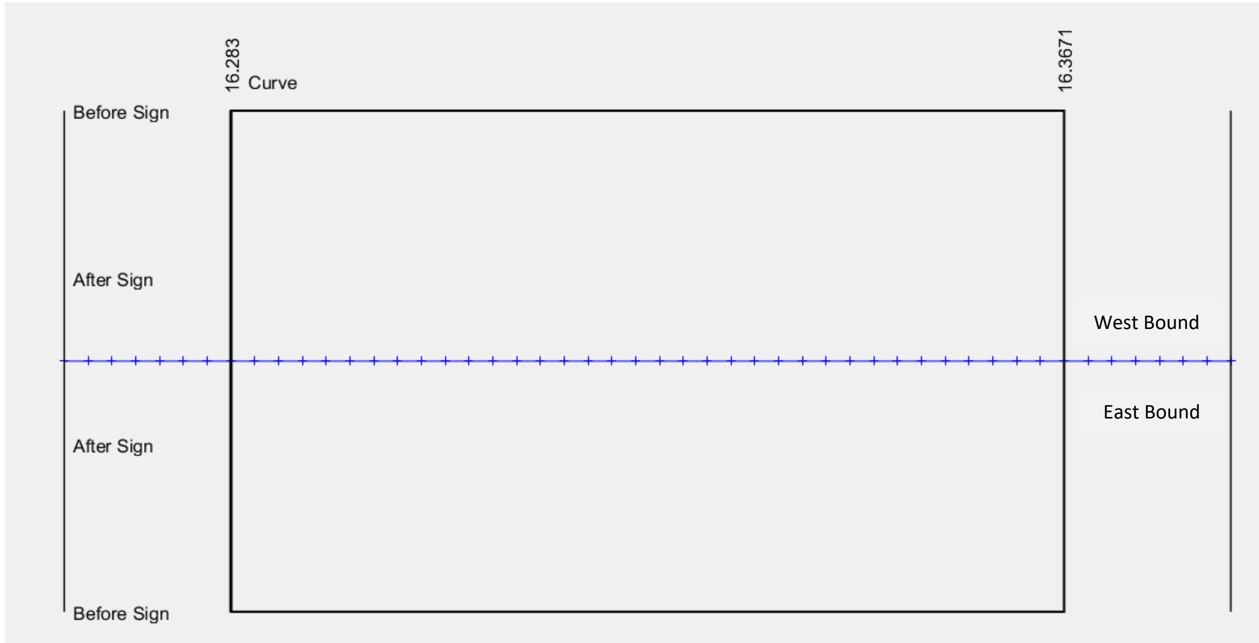
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	711
Grade	2.2
Superelevation	9
Crashes	0
BBI	3
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

Curve #117 on State Route 2 in Rabun County

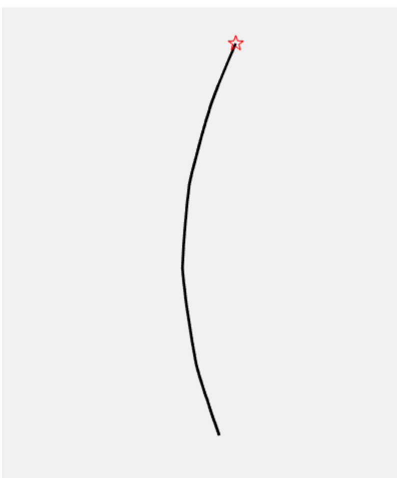
Scale: NA

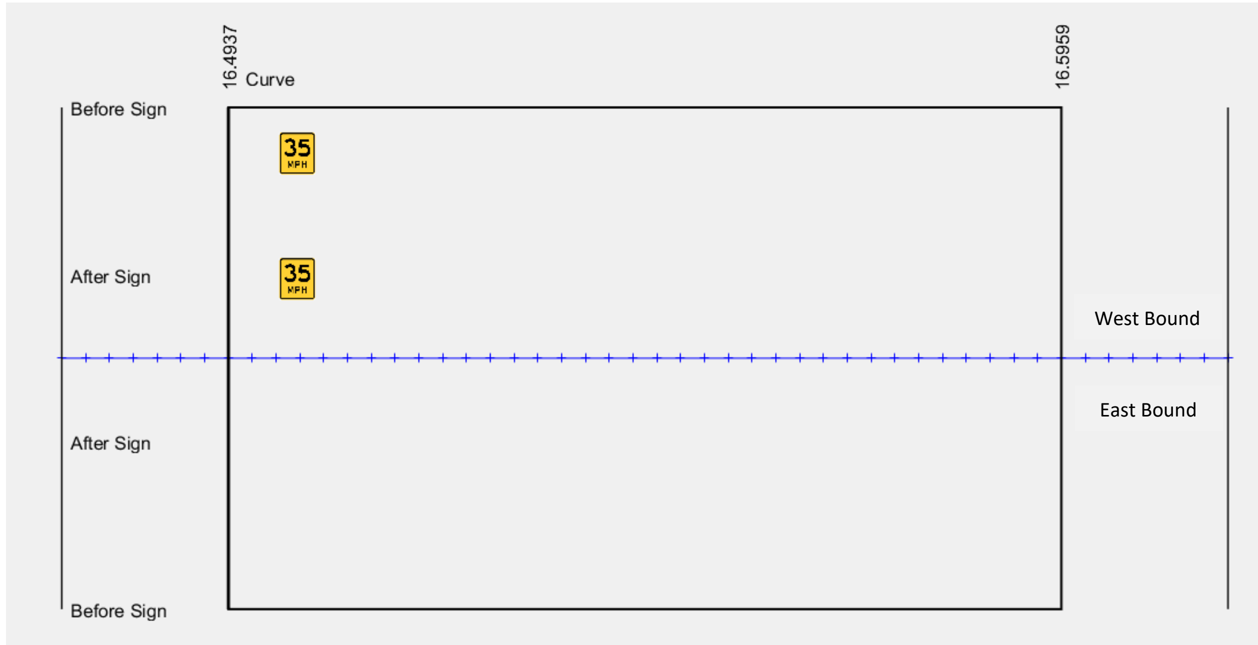
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	602
Grade	5.4
Superelevation	11
Crashes	0
BBI	5
Posted Speed	45
Advisory Speed	30
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

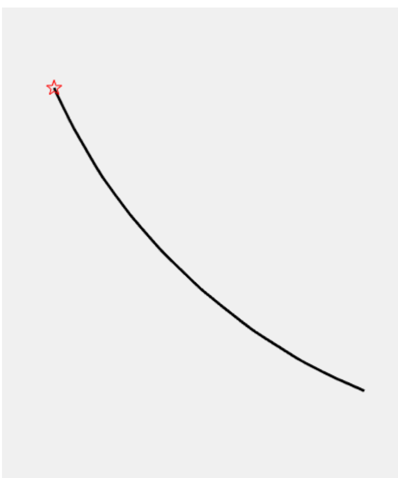
Curve #118 on State Route 2 in Rabun County

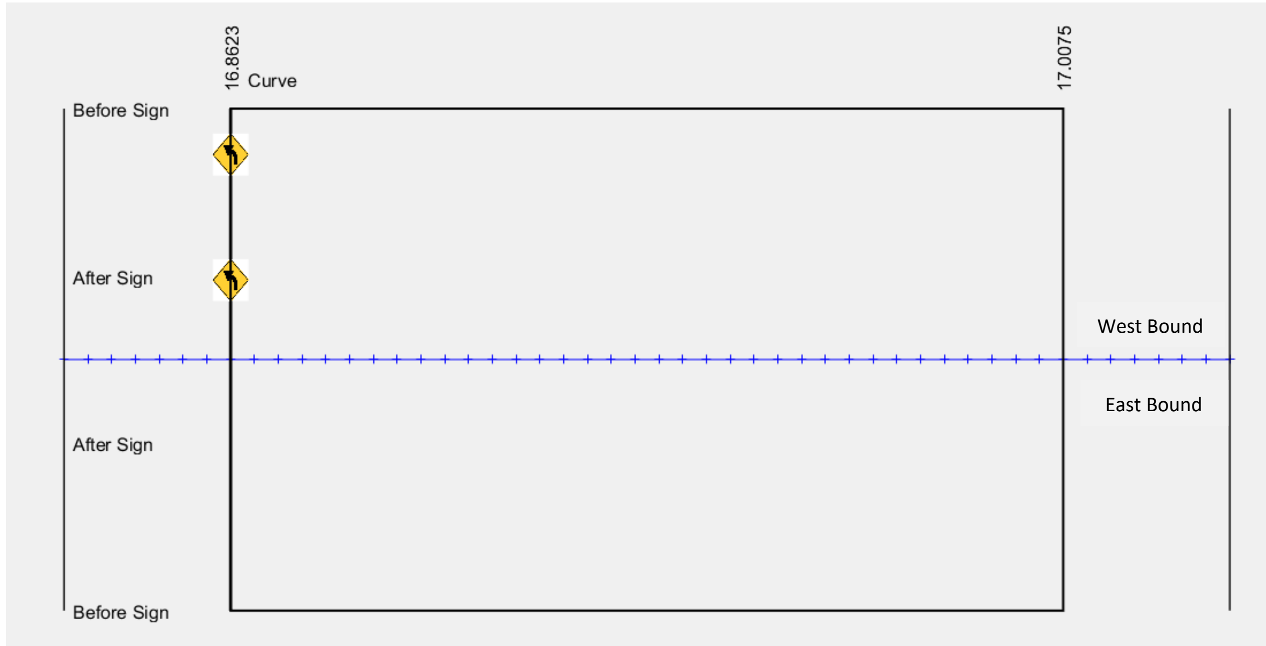
Scale: NA

RCLINK:2411000200

Road Characteristics

Radius	1004
Grade	-2.2
Superelevation	8
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

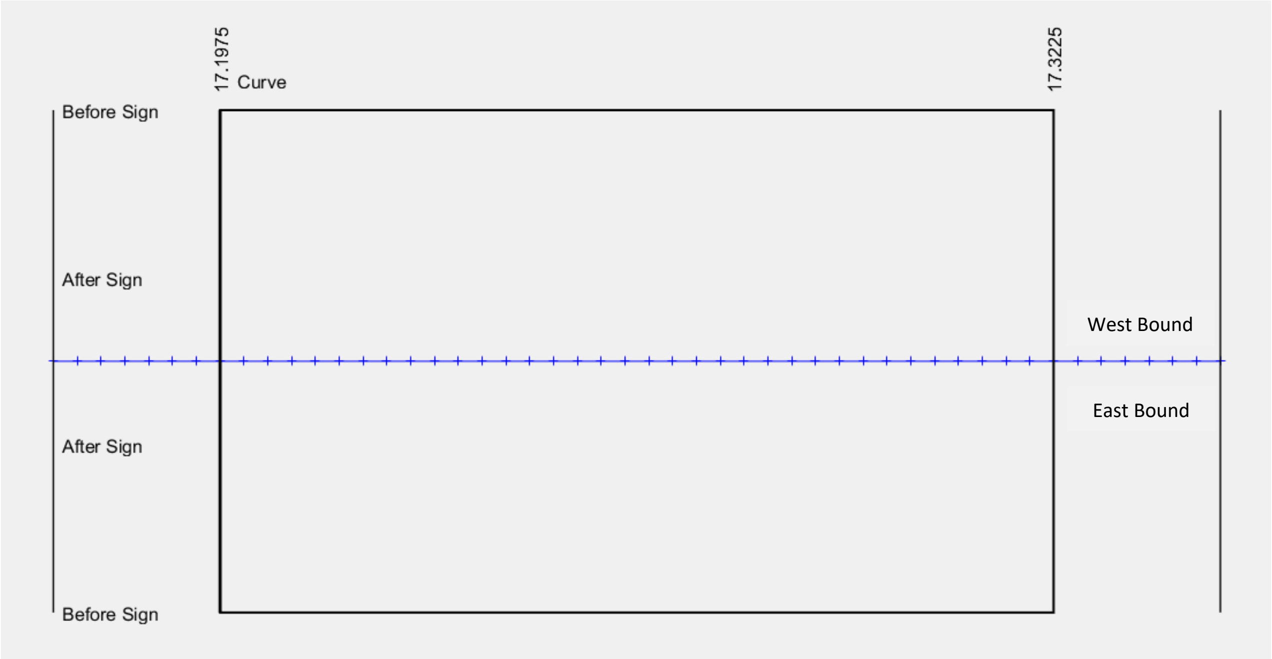
#119 Curve on State Route 2 in Rabun County

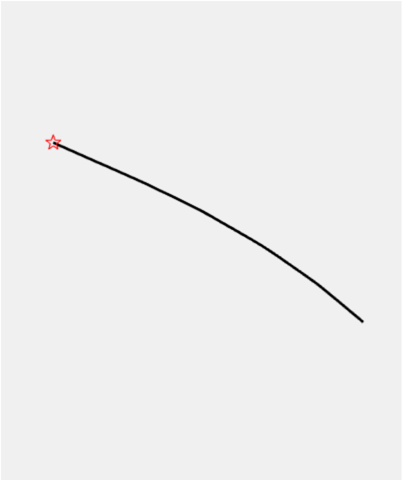
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	1864
Grade	0.5
Superelevation	7
Crashes	0
BBI	4
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #120 on State Route 2 in Rabun County

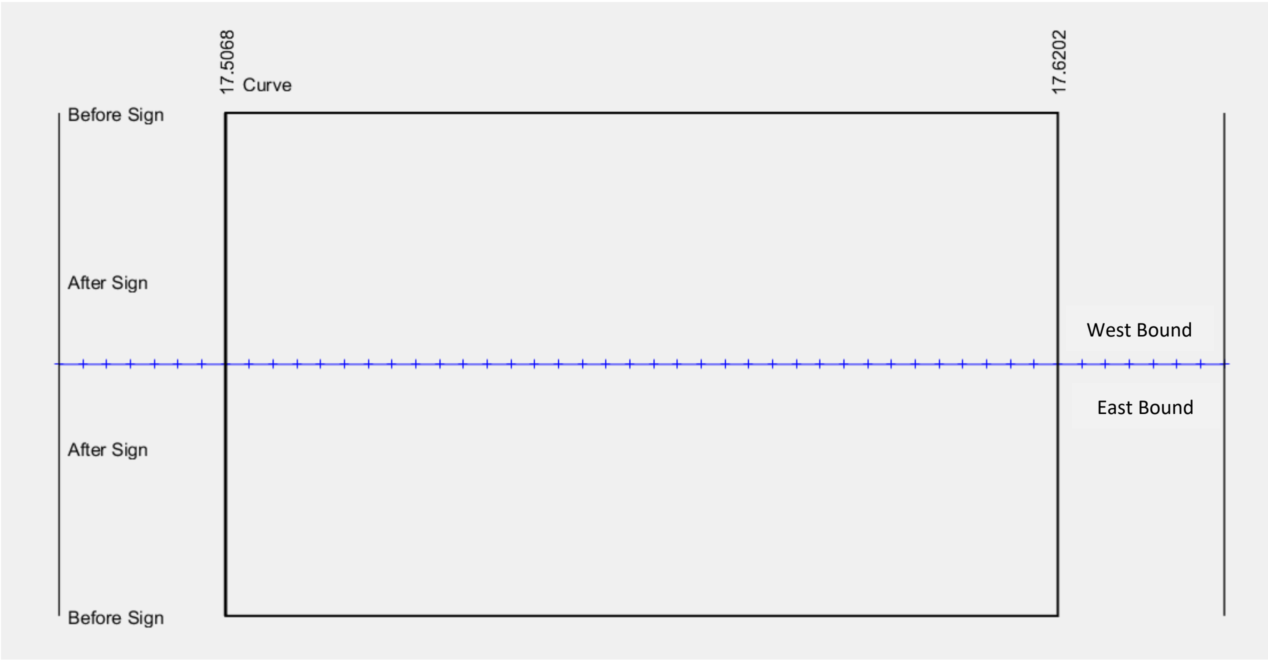
Scale: NA

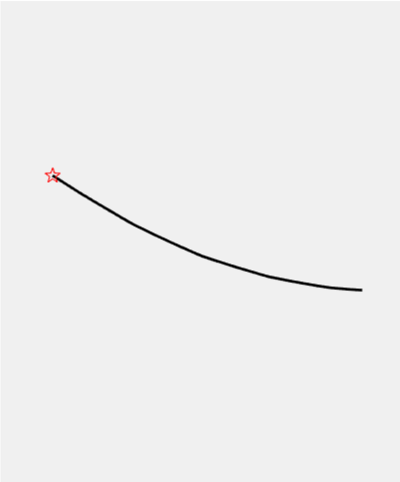
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	1083
Grade	-6.3
Superelevation	8.5
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #121 on State Route 2 in Rabun County

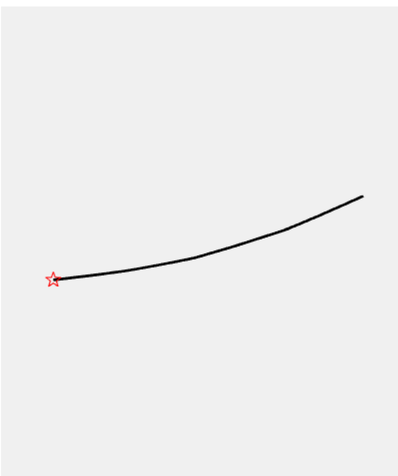
Scale: NA

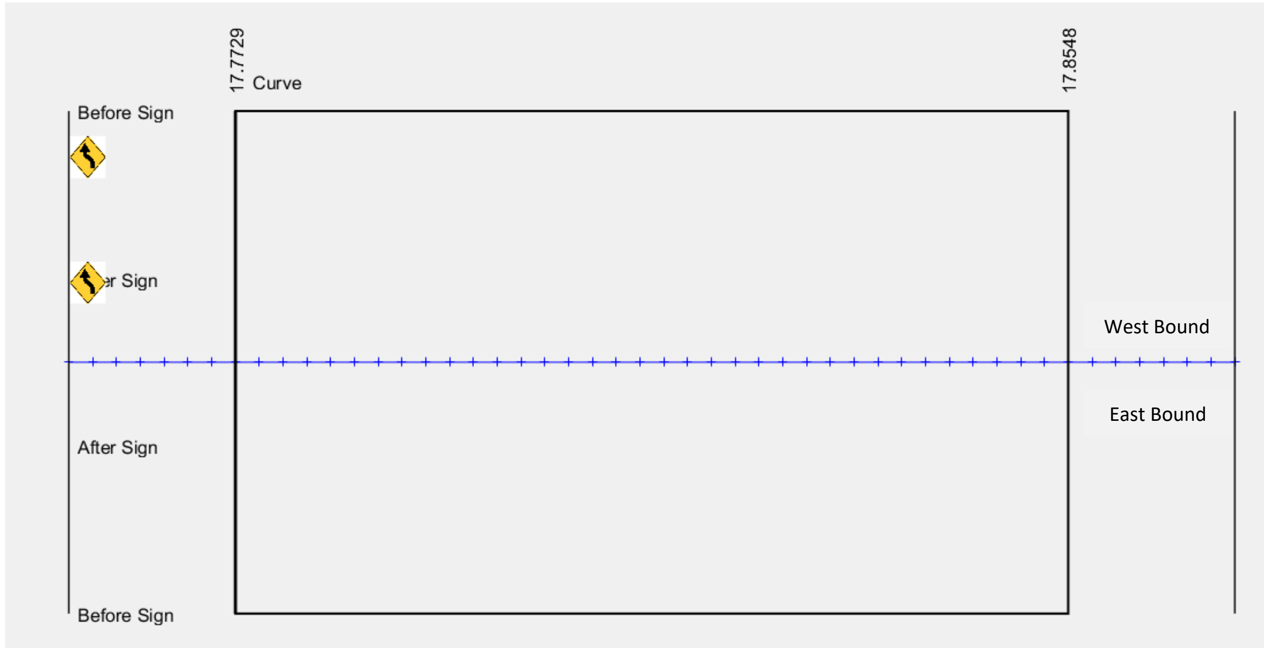
RCLINK:2411000200

Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1136
Grade	-4
Superelevation	6
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

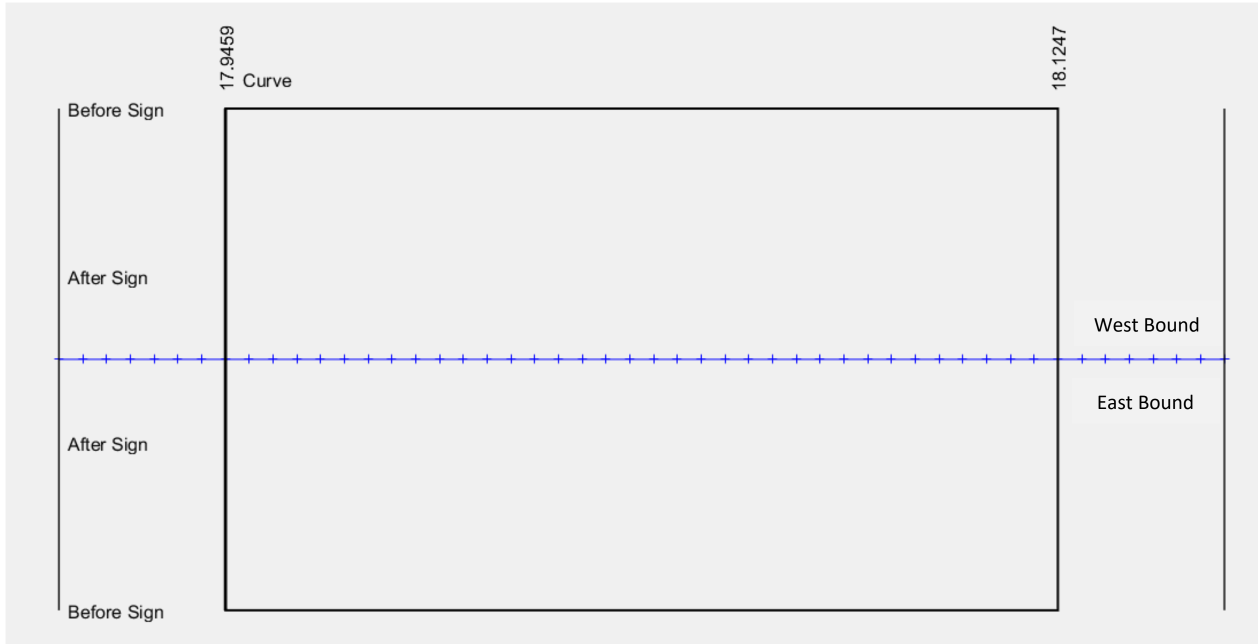
Curve #122 on State Route 2 in Rabun County

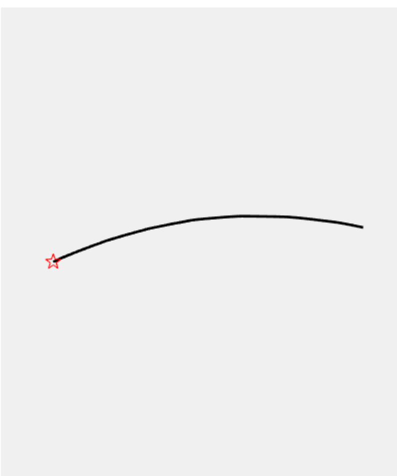
Scale: NA

RCLINK:2411000200

Road Characteristics

Radius	1397	
Grade	-7.3	
Superelevation	9	
Crashes	1	
BBI	4	
Posted Speed	45	
Advisory Speed	nan	
Road Type	Rural Collector	
AADT	2000	2016
Lane Width	12 ft.	
Shoulder Width	NA	





Horizontal Curve Schematic

Curve #123 on State Route 2 in Rabun County

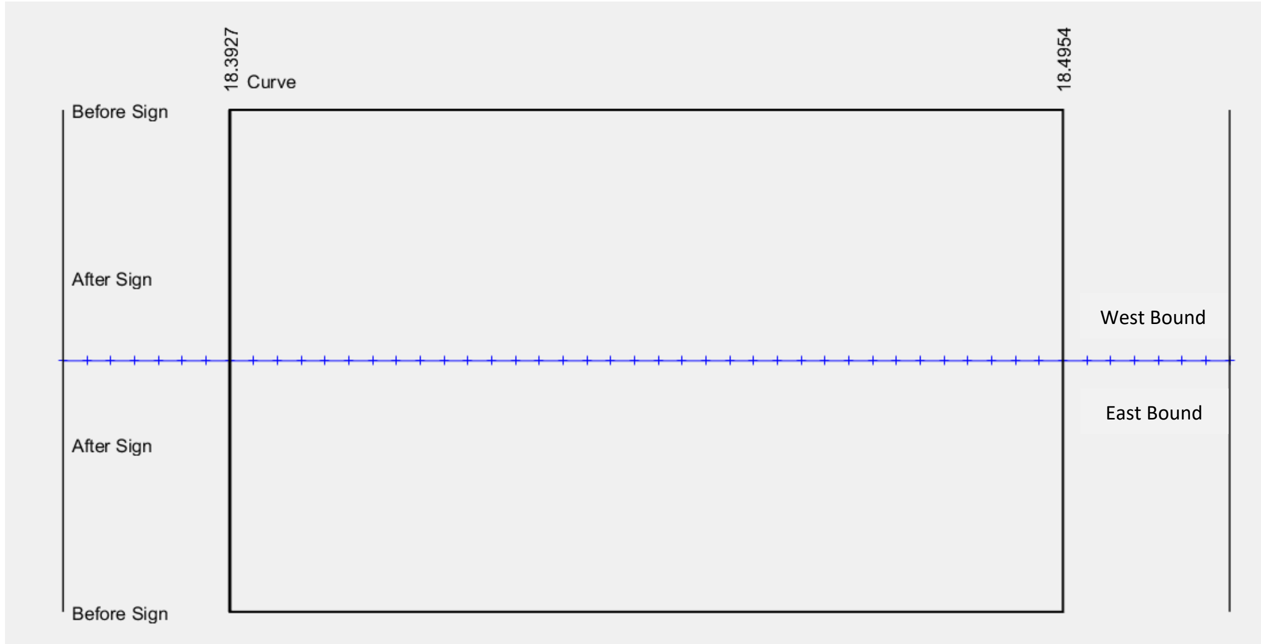
Scale: NA

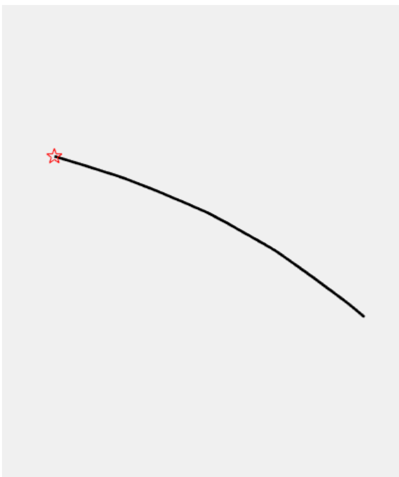
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1114
Grade	-2.8
Superelevation	7
Crashes	0
BBI	7
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #124 on State Route 2 in Rabun County

Scale: NA

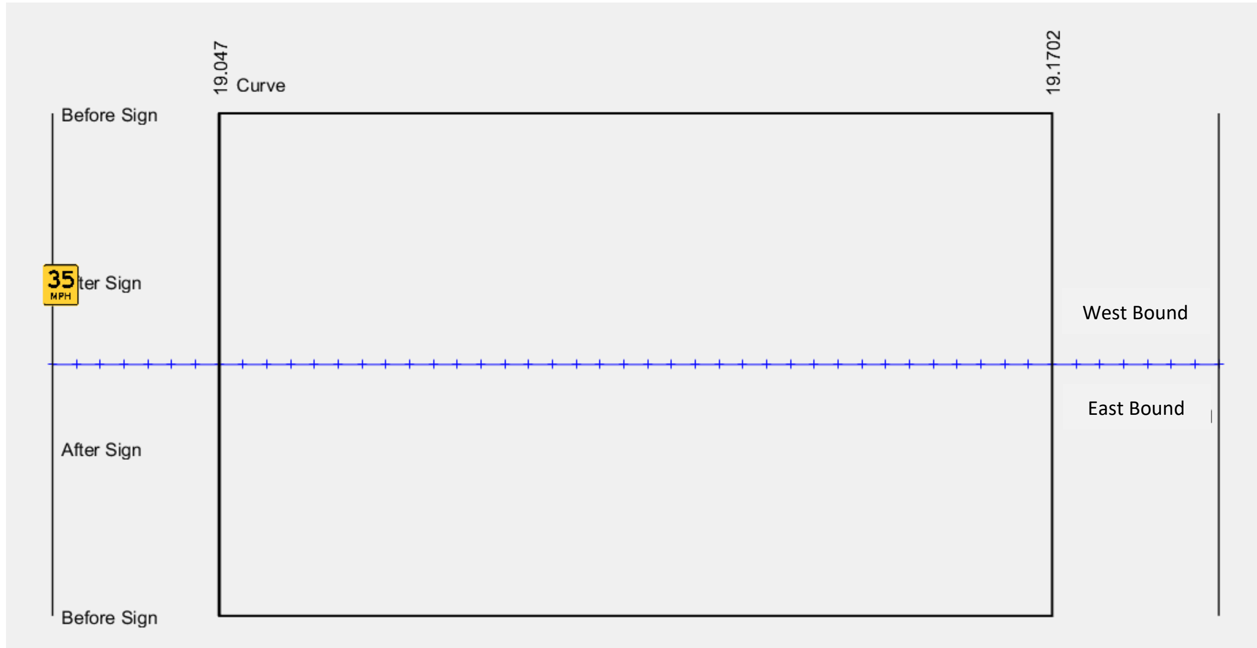
RCLINK:2411000200

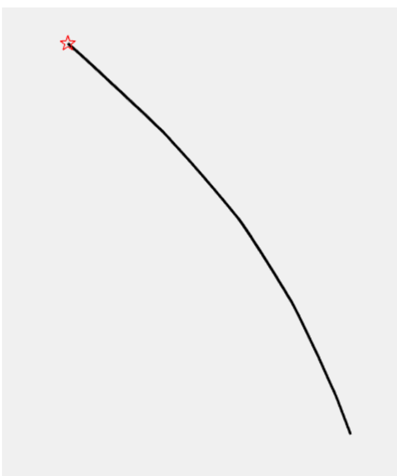
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	1083
Grade	2.2
Superelevation	7
Crashes	2
BBI	5
Posted Speed	45
Advisory Speed	45
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





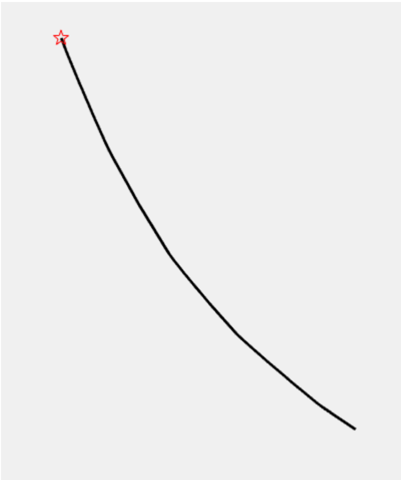
Horizontal Curve Schematic

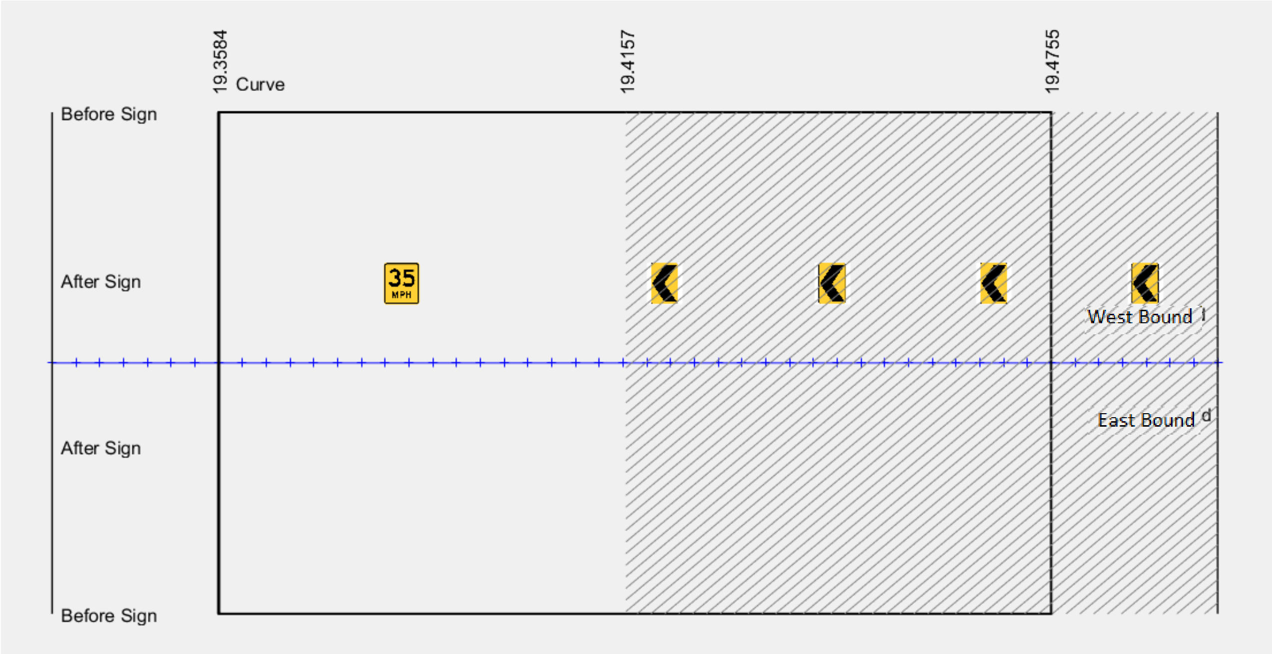
Curve #125 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	882
Grade	-6.2
Superelevation	9
Crashes	0
BBI	7
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

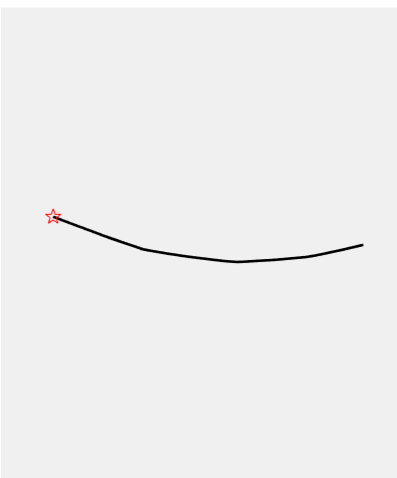
Curve #126 on State Route 2 in Rabun County

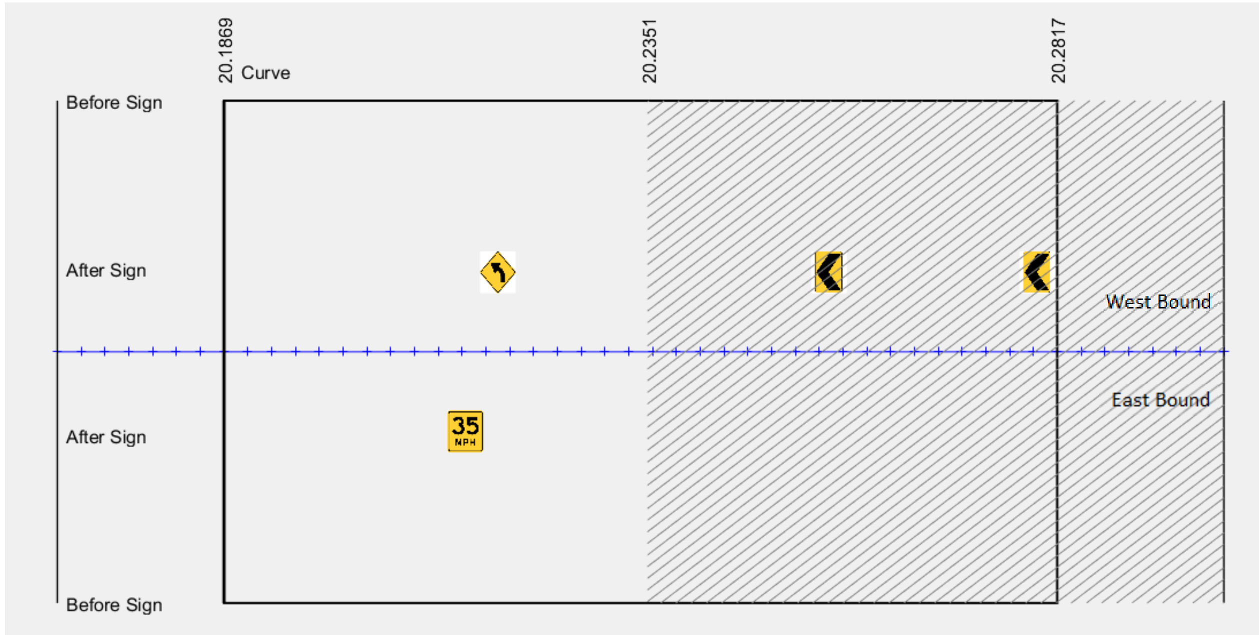
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	663
Grade	-2
Superelevation	7.5
Crashes	1
BBI	7
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #127 on State Route 2 in Rabun County

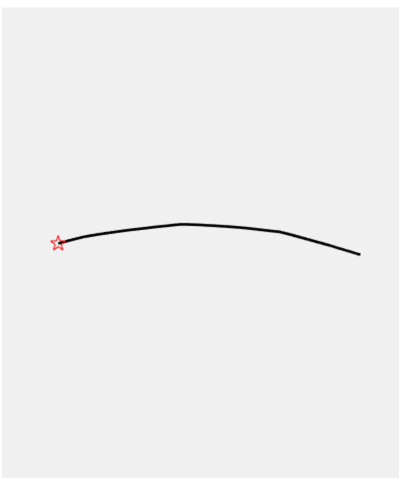
Scale: NA

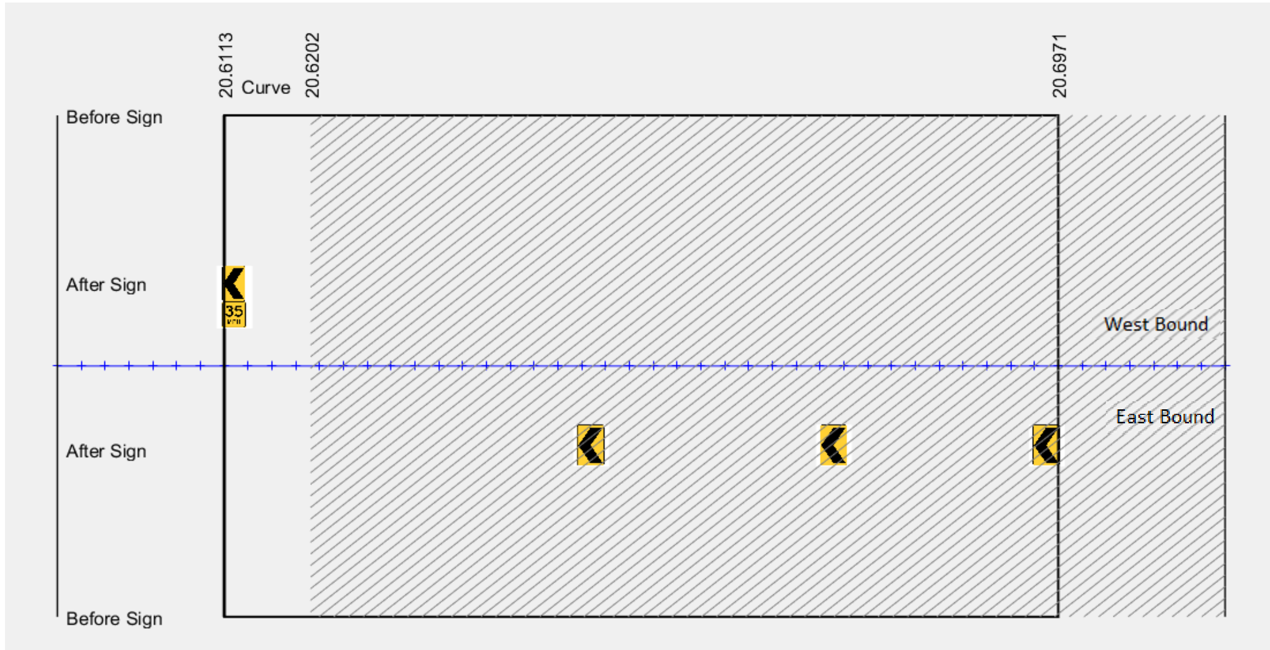
RCLINK:2411000200

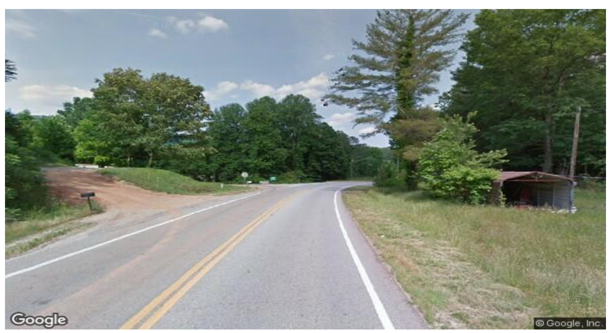
Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	730
Grade	-5.5
Superelevation	7.5
Crashes	3
BBI	8
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA







Horizontal Curve Schematic

GDOT Georgia Department of Transportation

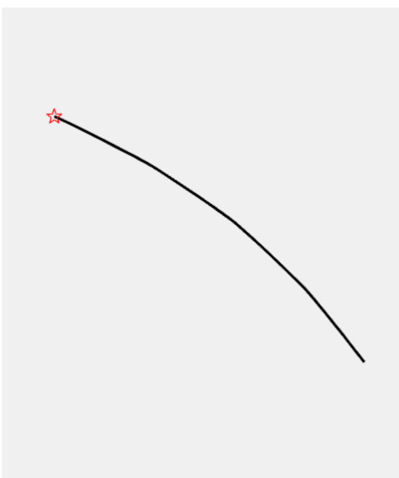
Curve #128 on State Route 2 in Rabun County

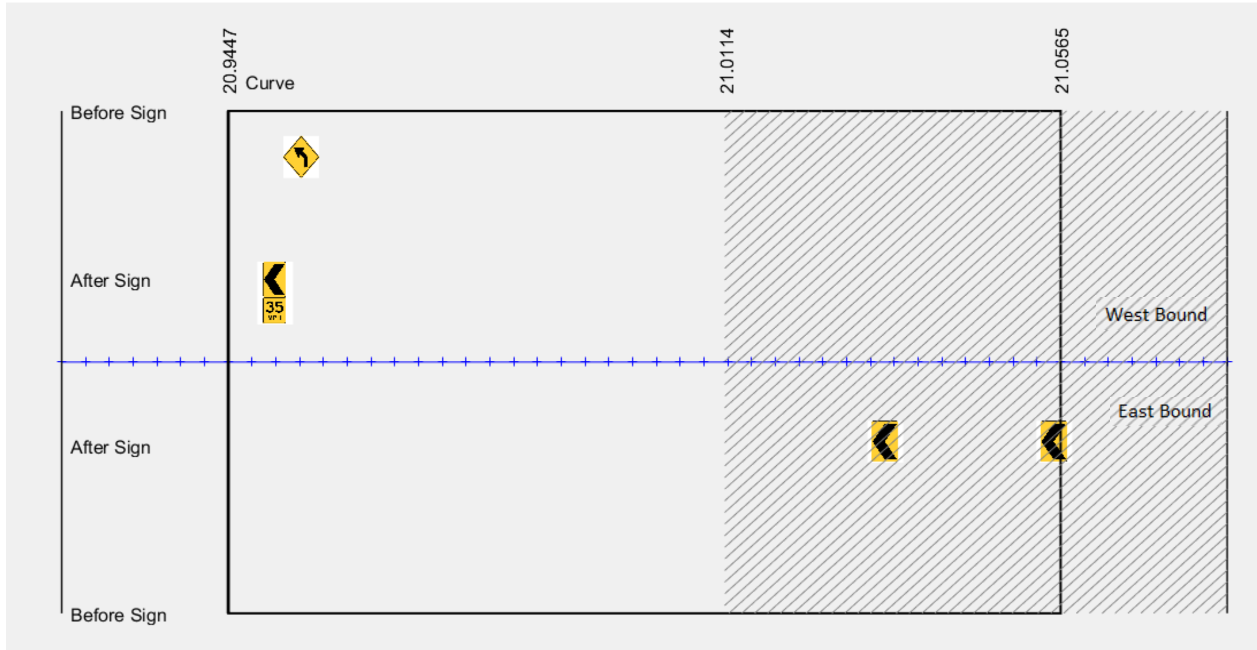
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	1004
Grade	5.7
Superelevation	5.5
Crashes	0
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





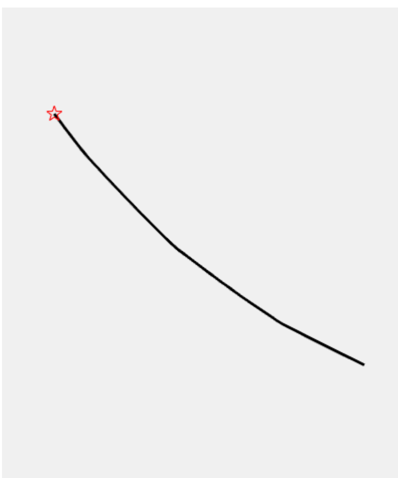
Horizontal Curve Schematic

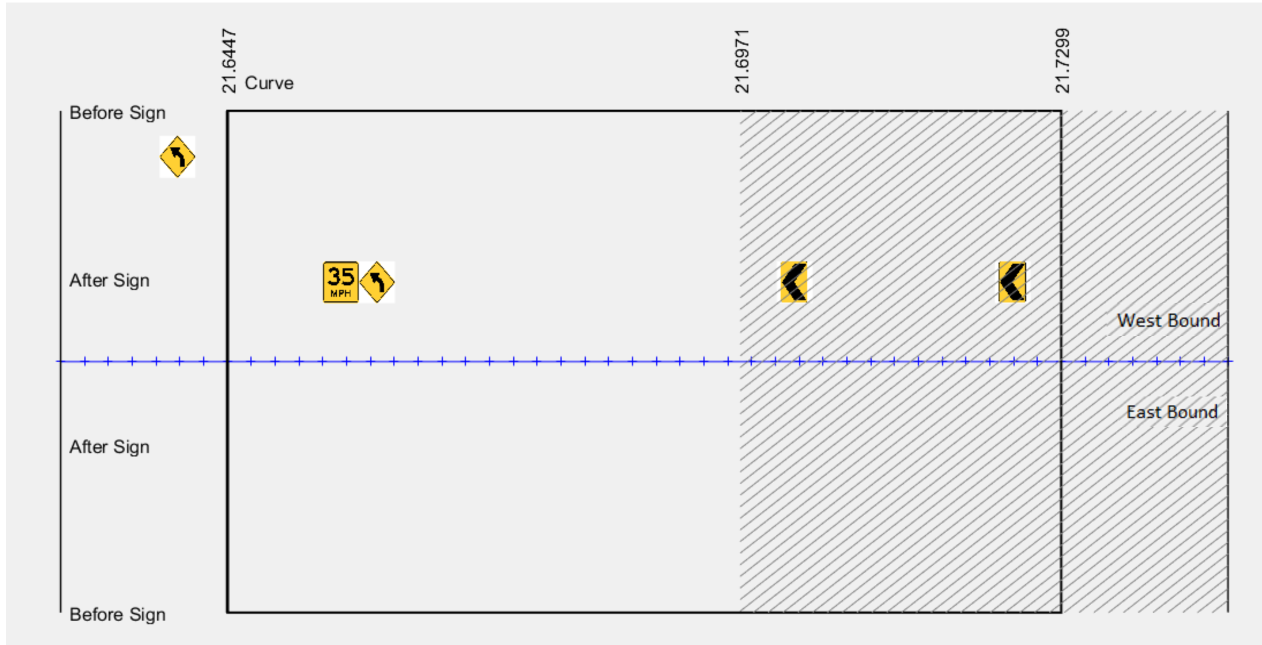
Curve #129 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	834
Grade	7.9
Superelevation	6
Crashes	1
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

Curve #130 on State Route 2 in Rabun County

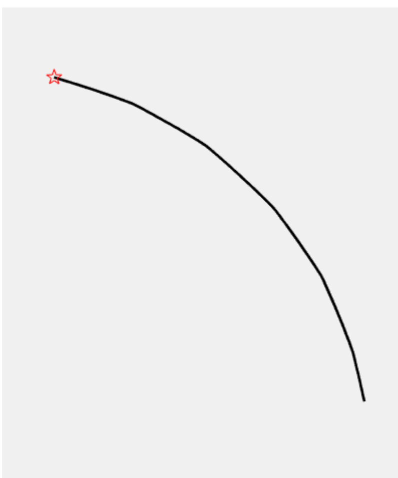
Scale: NA

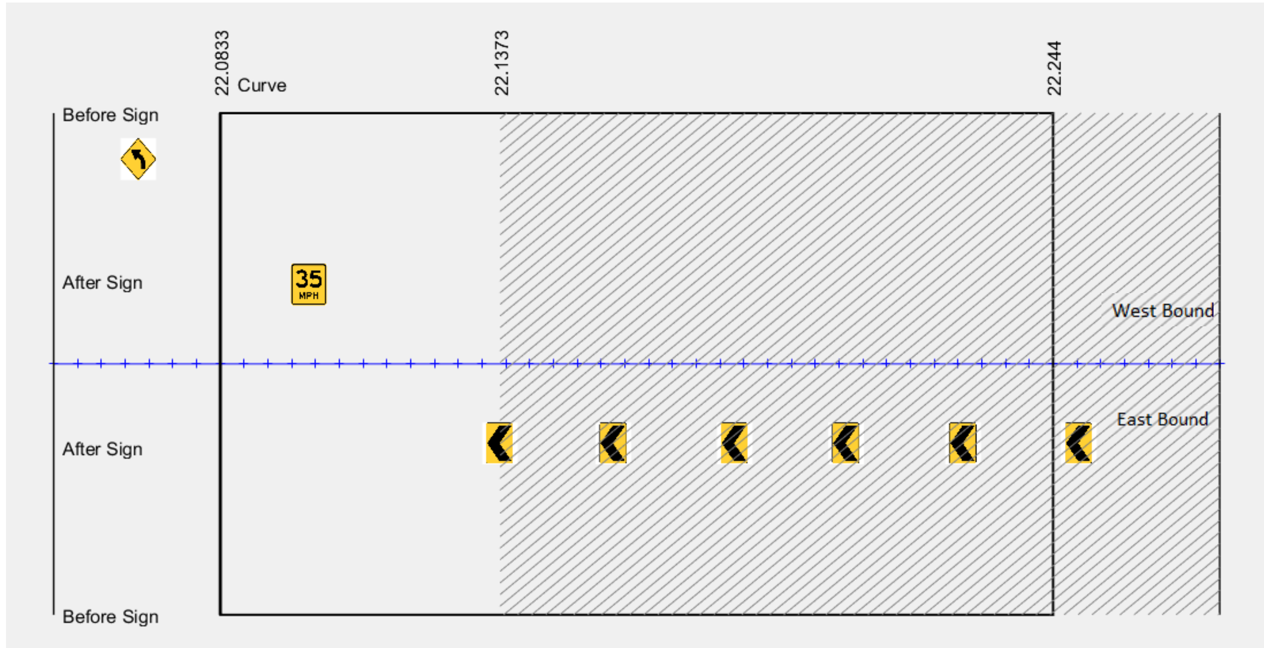
RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics

Radius	708
Grade	-2.9
Superelevation	10.5
Crashes	0
BBI	8
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #131 on State Route 2 in Rabun County

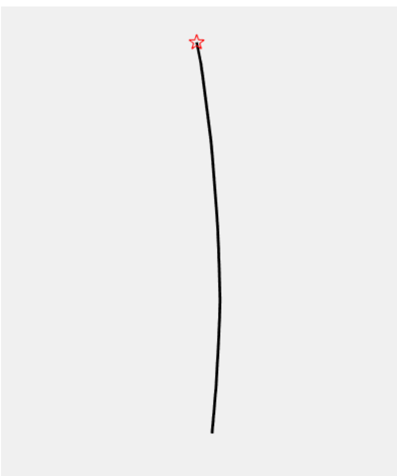
Scale: NA

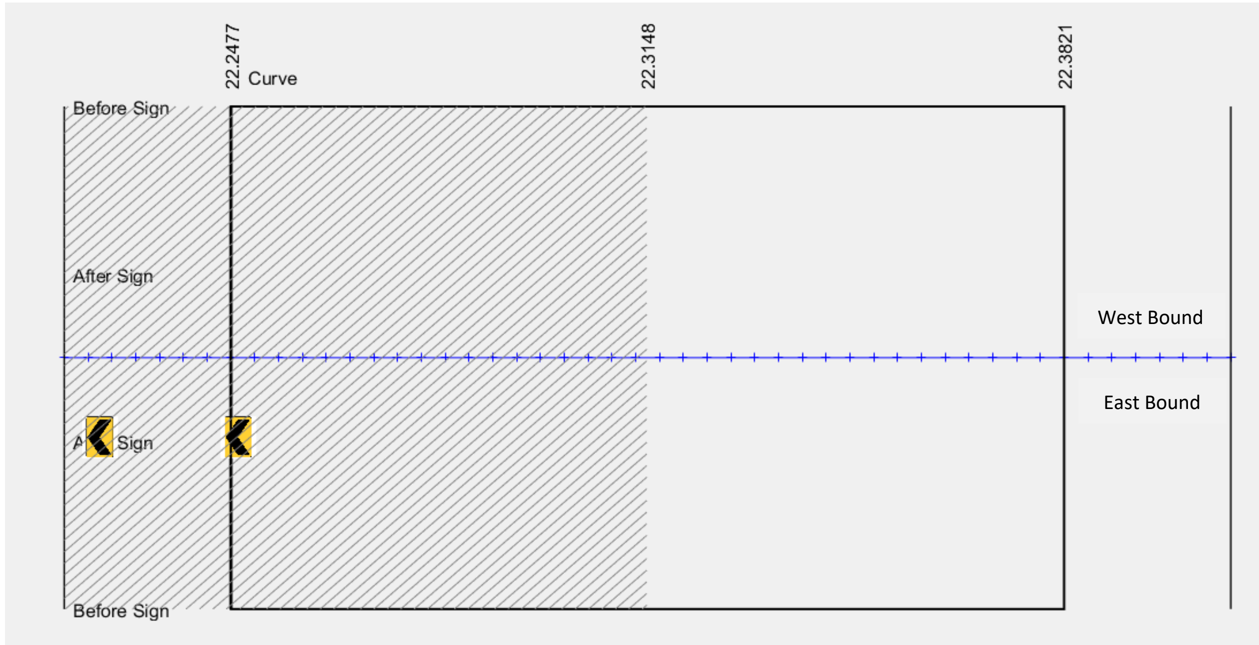
RCLINK:2411000200

Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	2519
Grade	-1.5
Superelevation	8
Crashes	0
BBI	3
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #132 on State Route 2 in Rabun County

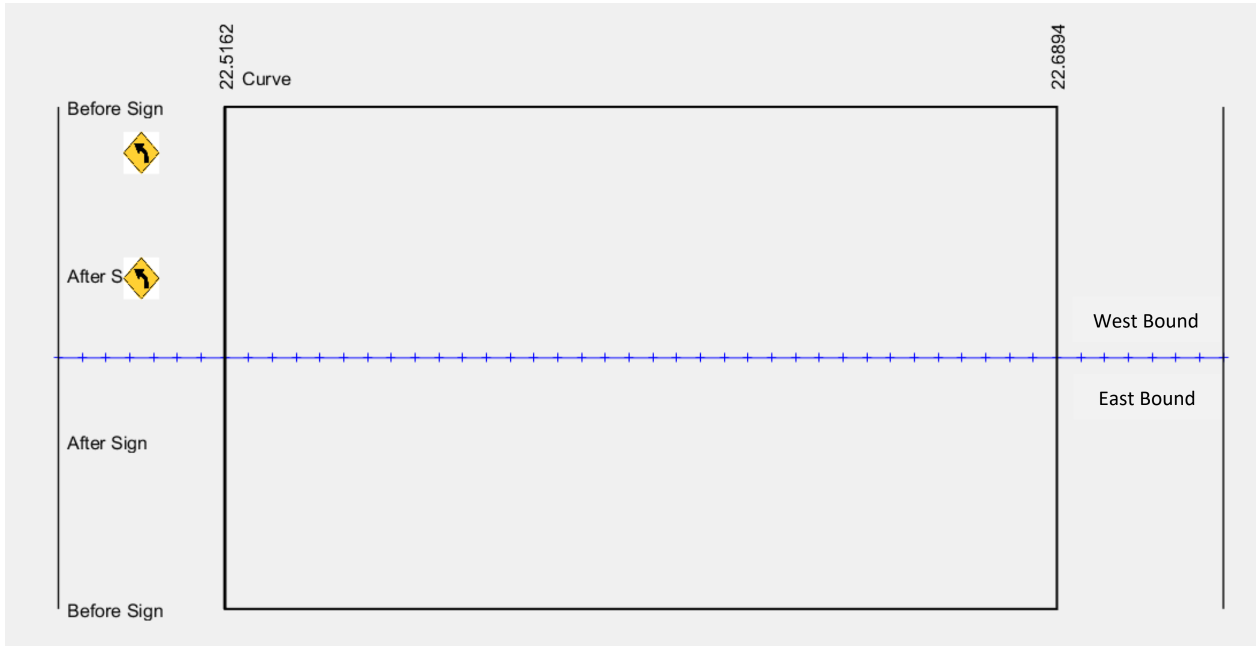
Scale: NA

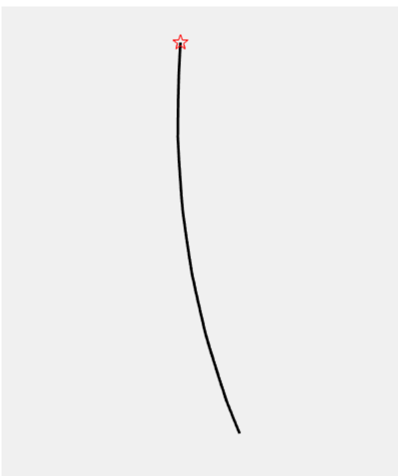
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1945
Grade	-3.4
Superelevation	6.5
Crashes	0
BBI	4
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #133 on State Route 2 in Rabun County

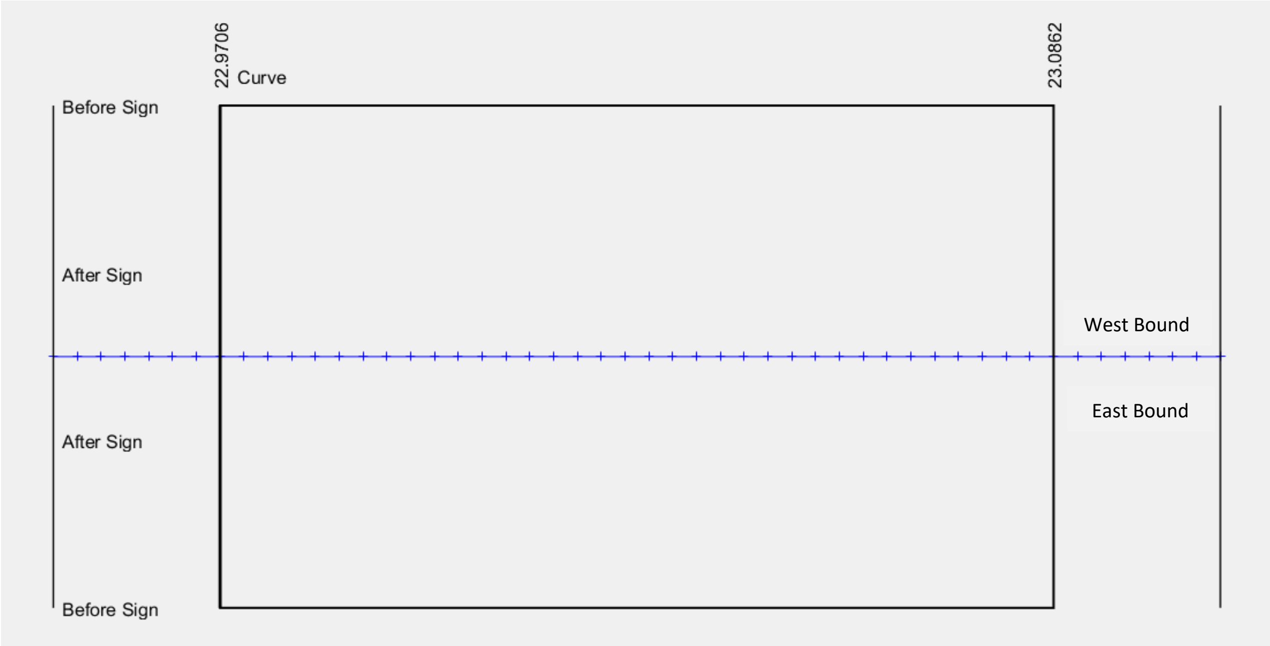
Scale: NA

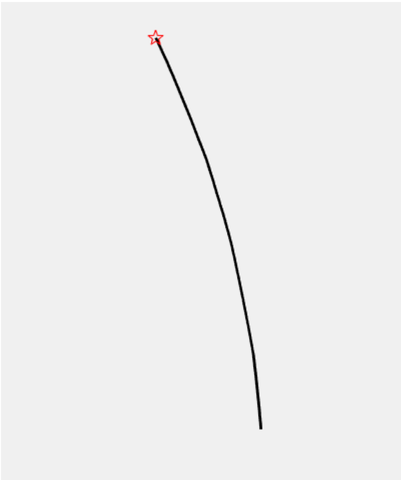
RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics	
Radius	1530
Grade	-3.8
Superelevation	6.5
Crashes	0
BBI	3
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





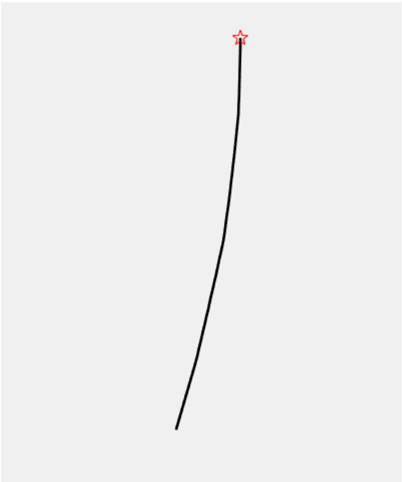
Horizontal Curve Schematic

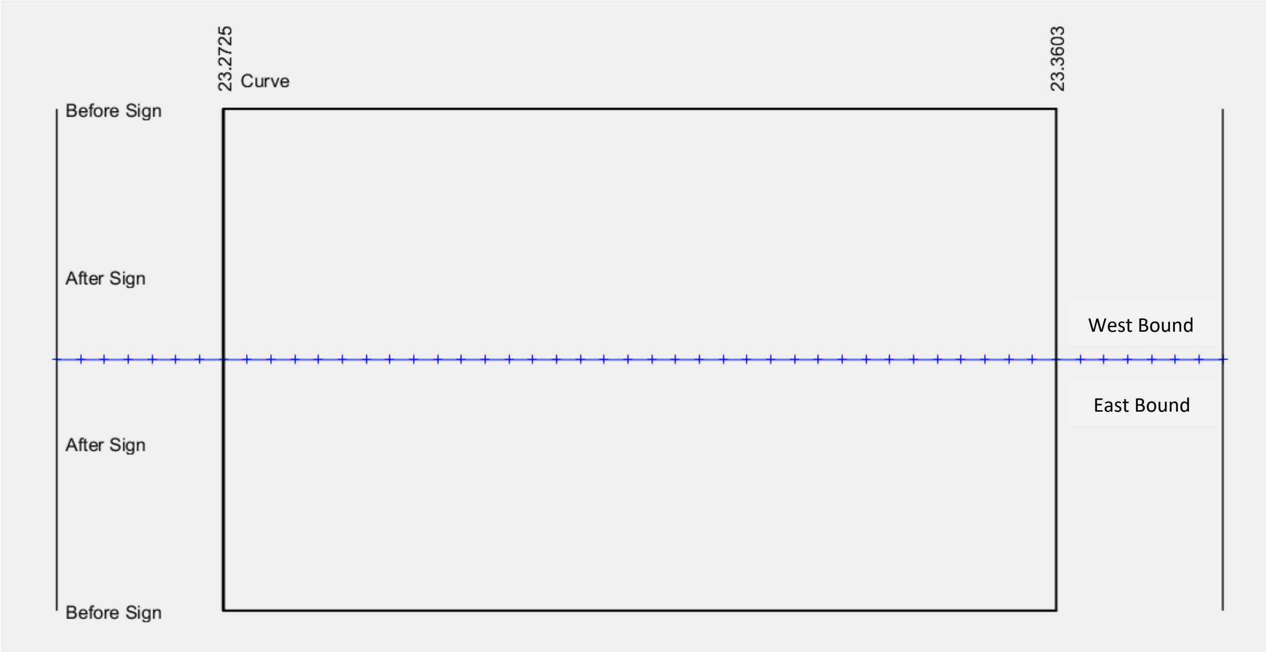
Curve #134 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	1454
Grade	-2.2
Superelevation	6.5
Crashes	0
BBI	3
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Georgia Department of Transportation

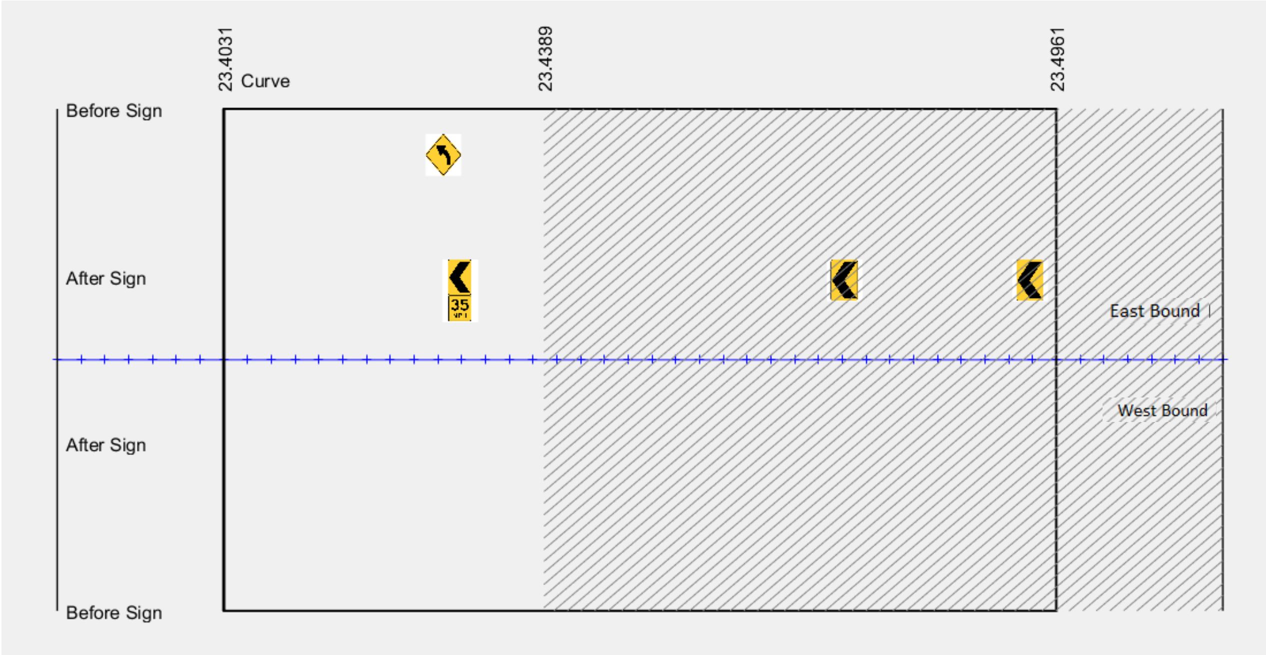
Curve #135 on State Route 2 in Rabun County

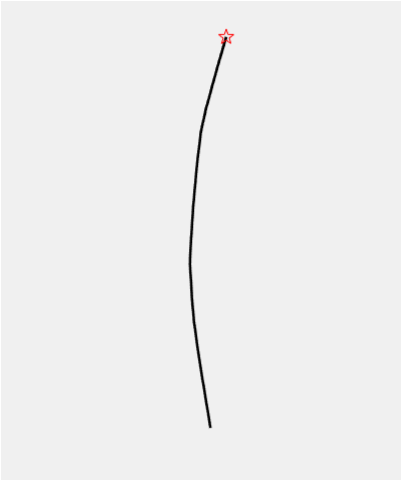
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	831
Grade	-3.5
Superelevation	5.5
Crashes	1
BBI	8
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

GDOT Georgia Department of Transportation

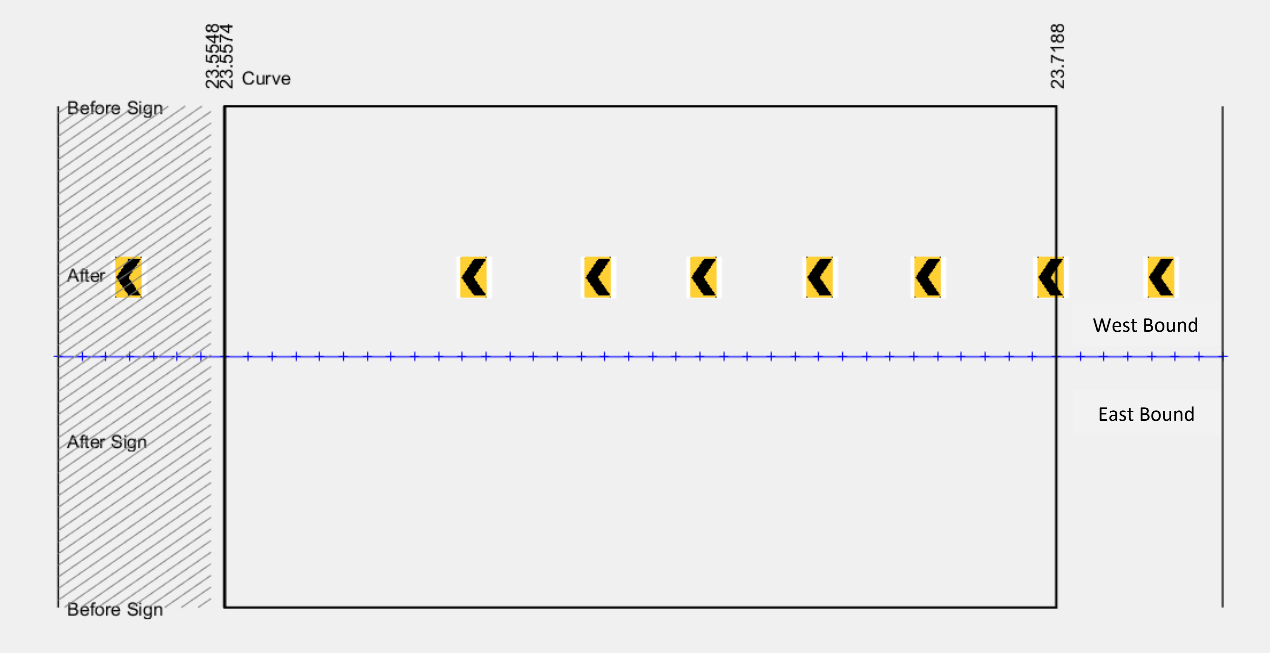
Curve #136 on State Route 2 in Rabun County

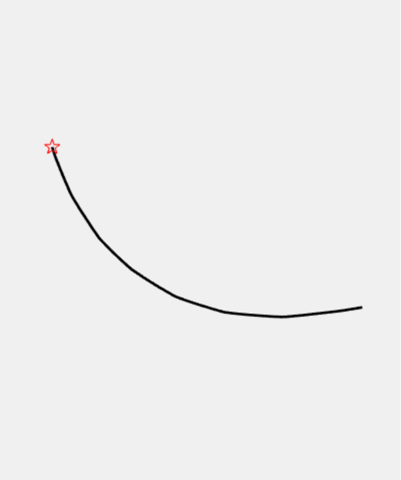
Scale: NA

RCLINK:2411000200

Georgia Institute of Technology

Road Characteristics	
Radius	508
Grade	-6.2
Superelevation	9
Crashes	2
BBI	11
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #137 on State Route 2 in Rabun County

Scale: NA

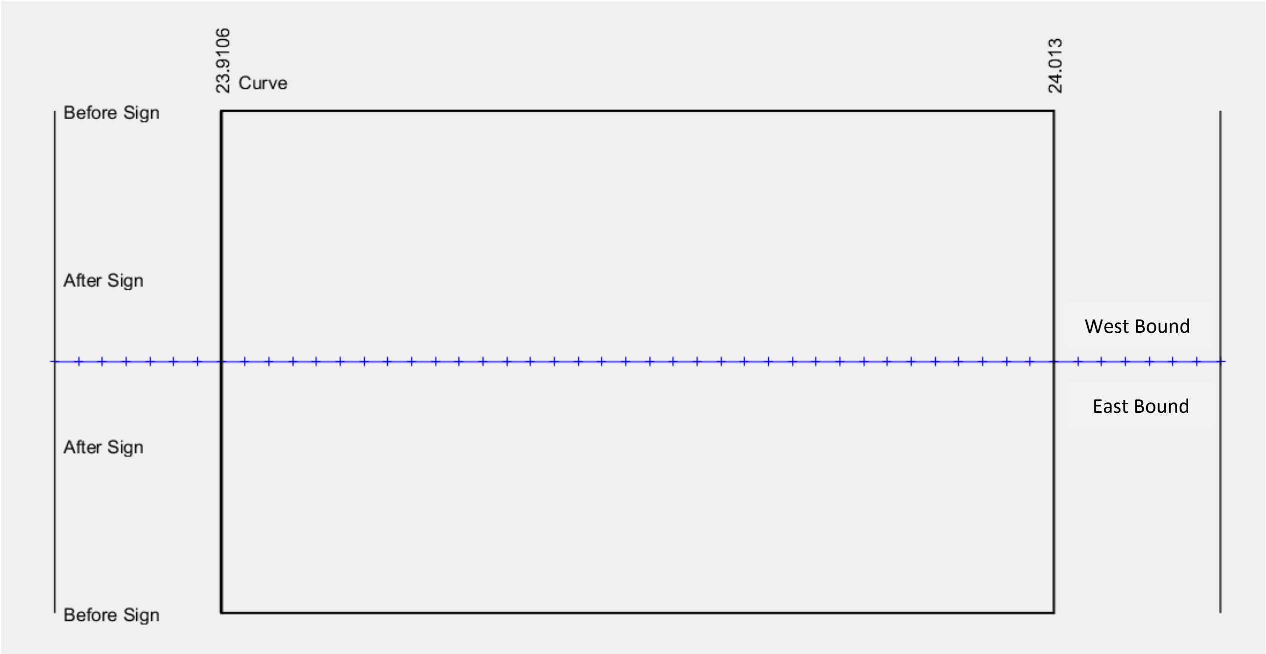
RCLINK:2411000200

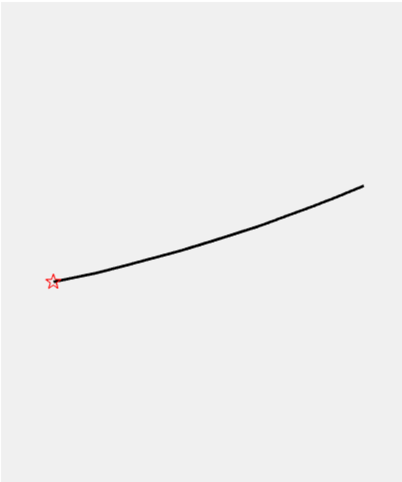
GDOT Georgia Department of Transportation

Georgia Institute of Technology

Road Characteristics

Radius	2725
Grade	-0.3
Superelevation	2.5
Crashes	1
BBI	6
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





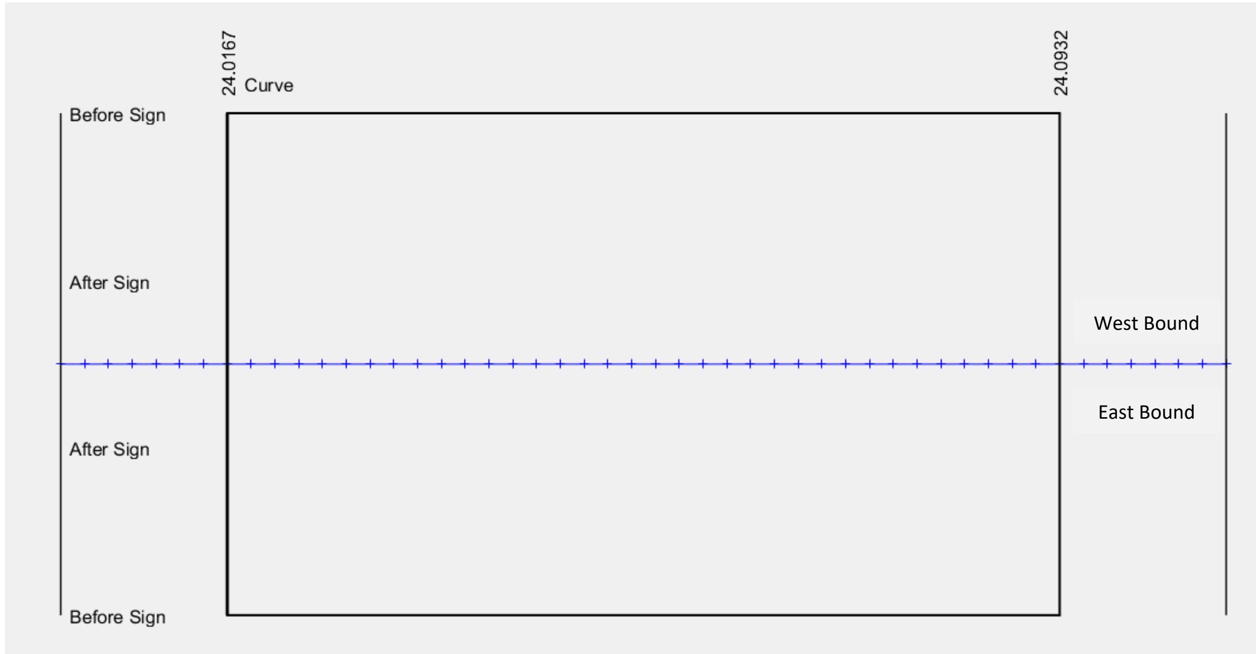
Horizontal Curve Schematic

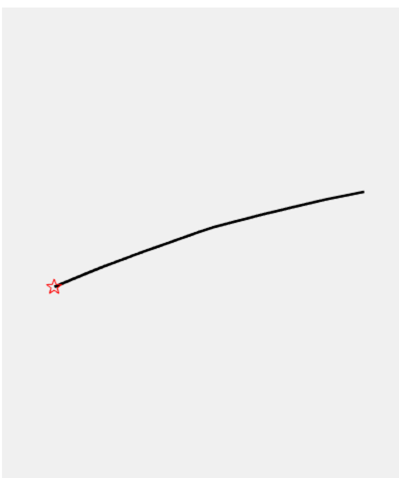
Curve #138 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	1699
Grade	-4.4
Superelevation	6
Crashes	0
BBI	2
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





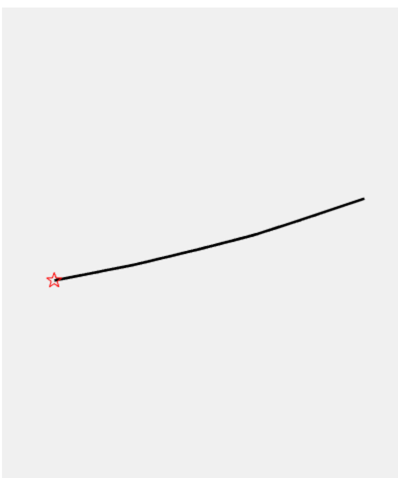
Horizontal Curve Schematic

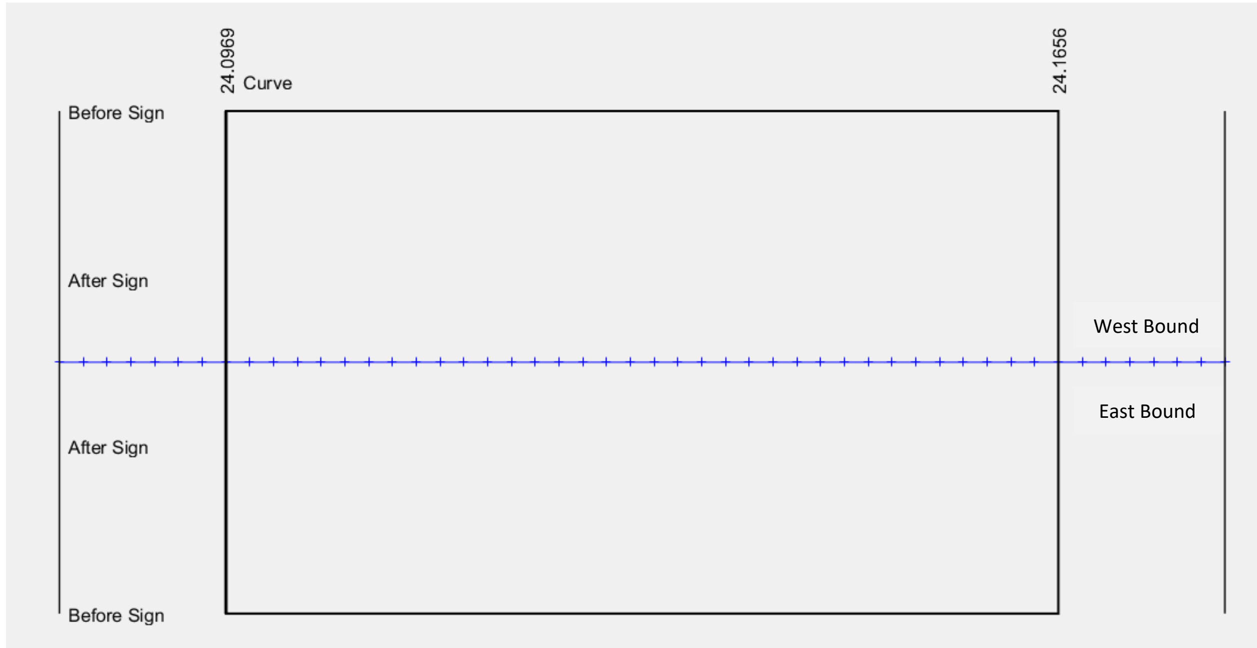
Curve #139 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

Road Characteristics	
Radius	2026
Grade	-7.2
Superelevation	2
Crashes	0
BBI	10
Posted Speed	45
Advisory Speed	nan
Road Type	Rural Collector
AADT	2000
	2016
Lane Width	12 ft.
Shoulder Width	NA





Horizontal Curve Schematic

Curve #140 on State Route 2 in Rabun County

Scale: NA

RCLINK:2411000200

GDOT Georgia Department of Transportation

Georgia Institute of Technology