CRASH DATA RESEARCH CENTER
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CALSPAN ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION SYSTEM CRASH INVESTIGATION
SCI CASE NO.: CA09041

VEHICLE: 2007 KIA RIO

LOCATION: NORTH CAROLINA

CRASH DATE: MAY 2009

Contract No. DTNH22-07-C-00043

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points are coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. CA09041	*2. Government Accession No.*	*3. Recipient's Catalog No.*	
4. Title and Subtitle Calspan On-Site Side Impact Inflatable Occupant Protection System Crash Investigation Vehicle: 2007 Kia Rio Location: North Carolina		*5. Report Date*: October 2010 *6. Performing Organization Code*	
7. Author(s) Crash Data Research Center		*8. Performing Organization Report No.*	
9. Performing Organization Name and Address Calspan Corporation Crash Data Research Center P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* *11. Contract or Grant No.* DTNH22-07-C-00043	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date: May 2009 *14. Sponsoring Agency Code*	
15. Supplementary Note An investigation of the roadside departure/side impact crash of a 2007 Kia Rio.			

16. Abstract

This on-site investigation focused on the side impact inflatable occupant protection system of a 2007 Kia Rio sedan that was involved in a run-off-road/side impact crash. The vehicle was equipped with a Certified Advanced 208-Compliant frontal air bag system (CAC), front seat-mounted side impact air bags and Inflatable Curtain (IC) air bags. The manufacturer of the Kia has certified that the vehicle was compliant to the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The CAC system included dual-stage frontal air bags for the driver and right front passenger positions, front seat track positioning sensors, front safety belt retractor pretensioners, and a front right occupant presence sensor. Subsequent to passing a non-contact vehicle while negotiating a right curved portion of the roadway, the Kia departed the left side of the road and rotated clockwise. The left side of the Kia impacted a utility pole. The crash deployed the CAC frontal air bags and the driver seat-mounted side impact air bag and left IC. The 16-year-old female driver sustained moderate severity injuries and was transported by ground ambulance to a local hospital. The driver was then transferred and admitted to a trauma center for 5 days. The 17-year-old front right passenger sustained minor-severity injuries. She was transported to a local hospital and admitted overnight for observation. Both of the occupants were restrained by the manual safety belt systems. The Kia was towed from the scene of the crash.

17. Key Words Roadside departure Side Impact Rollover Inflatable Curtain		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 13	*22. Price*

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BACKGROUND

This on-site investigation focused on the side impact inflatable occupant protection system of a 2007 Kia Rio sedan **(Figure 1)** that was involved in a run-off-road/side impact crash. The vehicle was equipped with a Certified Advanced 208-Compliant frontal air bag system (CAC), front seat-mounted side impact air bags and Inflatable Curtain (IC) air bags. The manufacturer of the Kia has certified that the vehicle was compliant to the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The CAC system included dual-stage frontal air bags for the driver and right front passenger positions, front seat track positioning sensors, front safety belt retractor pretensioners, and a front right occupant presence sensor. Subsequent to passing a non-contact vehicle while negotiating a right curved portion of the roadway, the Kia departed the left side of the road and rotated clockwise. The left side of the Kia impacted a utility pole. The crash deployed the CAC frontal air bags and the driver seat-mounted side impact air bag and left IC. The 16-year-old female driver sustained moderate severity injuries and was transported by ground ambulance to a local hospital. The driver was then transferred and admitted to a trauma center for 5 days. The 17-year-old front right passenger sustained minor-severity injuries. She was transported to a local hospital and admitted overnight for observation. Both of the occupants were restrained by the manual safety belt systems. The Kia was towed from the scene of the crash.

Figure 1: Left oblique view of the 2007 Kia Rio.

The crash was identified through a visit to a regional salvage facility on Wednesday, June 17, 2009. Based on the side impact crash and the deployment of the left IC and left side impact air bag, this case was assigned for on-site investigation on June 18, 2009. The on-site investigation was initiated on June 19, 2009 and involved the inspection and documentation of the Kia, interviews with the driver of the vehicle, the owner of the vehicle (driver's mother) and the mother of the front right passenger, and documentation of the crash scene.

SUMMARY

Crash Site

Figure 2: Trajectory view at the crash site.

This crash occurred during daylight hours on a two-lane north/south rural roadway (**Figure 2**). The police reported weather conditions were clear and dry. At the area of the crash, there was a moderate radius right curve. The traffic lanes were 3 m (9.8 ft) in width and were surfaced with asphalt. A double-yellow centerline separated the traffic lanes. The shoulders were residential yards surfaced with grass. The west roadside contained a shallow ditch that was 40 cm (15.7 in) in depth which began at the road edge and extended 7 m (23 ft) west. The posted speed limit was 72 km/h (45 mph). In the pre-crash area, the roadway had a positive grade of 1.6 percent. The grade transitioned to a level in the area in where the Kia departed the left roadside and then to a negative 1.6 percent grade as the vehicle neared the point of impact. The struck utility pole measured 30 cm (11.8 in) in diameter and was located 5.4 m (17.7 ft) west of the west fog line. Per a local homeowner, the impacted pole was new and had been replaced approximately two weeks prior to the crash as part of a maintenance project. Crash Schematics are included as **Figures 11 and 12** of this report.

Vehicle Data

2007 Kia Rio

The 2007 Kia Rio LX was a four-door sedan that was identified by the Vehicle Identification Number (VIN) KNADE123776 (production number deleted). The vehicle was purchased new in the fall of 2008 by the mother of the driver in this crash. The driver used the vehicle primarily for transportation to and from school and recreational activities.

The front-wheel drive Kia was powered by a 1.6 liter, inline four-cylinder transverse-mounted engine linked to a four-speed automatic transmission. The braking system consisted of front disc and rear drum brakes with four-wheel antilock. The Kia was equipped with four Kumho Solus HP4 Plus tires mounted on steel wheels with plastic wheel covers. The tire size was P185/65R14. The vehicle manufacturer recommended tire size was P185/65R14 with a recommended cold tire pressure of 207 kPa (30 PSI) for the front and rear. The specific tire data at the time of the SCI inspection was as follows:

Position	Measured Tire Pressure	Measured Tread Depth	Tire/Wheel Damage
Left Front	Tire Flat	3 mm (4/32 in)	De-beaded
Left Rear	200 kPa (29 PSI)	3 mm (4/32 in)	None
Right Front	207 kPa (30 PSI)	4 mm (5/32 in)	None
Right Rear	214 kPa (31 PSI)	3 mm (4/32 in)	None

The interior of the Kia was configured with cloth-surfaced five-passenger seating. The front bucket seats were separated by a center console and equipped with adjustable head restraints. The front left head restraint was found adjusted 6 cm (2.4 in) above the full-down position with the front right head restraint adjusted to 8 cm (3.1 in) above the full-down position. The driver seat track was adjusted to a rear-track position 3 cm (1.2 in) forward of full rear. The post-crash driver seat back angle measured 36 degrees aft of vertical. The front right seat was in the full-rear track position, with a post-crash seat back angle of 50 degrees aft of vertical. The seat backs were reclined by the first responders during the removal of the occupants. The second row seat was a bench with split (60/40) forward folding seat backs. The two rear outboard seating positions had adjustable head restraints that were located in the full-down position.

The safety systems consisted of 3-point lap and shoulder belts for the five designated seating positions, front safety belt pretensioners, dual-stage frontal air bags, front seat-mounted side impact air bags, and side impact IC air bags that provide protection to the four outboard seating positions.

Crash Sequence

Pre-Crash

The 16-year-old driver had obtained her driver's license two months prior to the crash and stated in the interview that on the day of the crash she was in a hurry to get the 17-year-old front right passenger home on time. She was restrained and was operating the Kia northbound on a straight section of the two-lane roadway at a reported speed of 105 km/h (65 mph). The driver reported that a slower non-contact vehicle was traveling in front of the Kia. As the Kia entered the right curve, the driver initiated a passing maneuver and crossed the double-yellow centerline. Subsequent to passing the slower vehicle, the Kia departed the roadway to the left and entered the grass roadside **(Figure 3)**. The driver initiated a right steering input in an attempt to return to the roadway and she applied

Figure 3: Location at which the Kia departed the roadway.

the brakes. The rear tires of the vehicle broke traction and the Kia entered a clockwise yaw. The Kia rotated approximately 85 degrees clockwise as it traveled along the west roadside area. The Kia continued its trajectory and yaw to the point of impact with the utility pole (**Figure 4**). The yaw marks attributed to the left side tires measured 72 m (236.2 ft) in length.

Figure 4: Area of impact with the utility pole.

Crash

The left A-pillar area of the Kia impacted the utility pole. The impact did not fracture the pole. The barrier algorithm of the WINSMASH program was used to calculate a total delta-V of 49 km/h (30.5 mph). The lateral and longitudinal delta-V components were -9 km/h (-5.5 mph) and 48 km/h (29.8 mph), respectively. The Kia remained engaged with the pole and rotated approximately 15 degrees clockwise around the pole before coming to final rest facing east on the west roadside.

Post-Crash

Police, emergency medical personnel, and tow personnel responded to the crash site. The driver was entrapped in the Kia by the intruded floor pan. Displaced components around the driver's feet entrapped her feet and ankles. The driver and front right passenger were removed from the vehicle by the first responders and transported by ground ambulance to a local hospital. The pole was not fractured or displaced in this crash, and did not require replacement. The Kia was towed from the scene due to disabling damage.

2007 KIA RIO

Exterior Damage

The left side of the Kia sustained severe damage as a result of this crash. The impact to the tree occurred to the forward aspect of the front left door. The direct contact damage began 151 cm (59.4 in) forward of the left rear axle and extended forward 51 cm (20.1 in) to the left A-pillar area. Lateral crush was present to the left doors, B-pillar, A-pillar and left fender. The left front and rear door hinges were intact and remained attached to the A- and B-pillars, respectively. Both left side doors remained closed during the crash. The combined direct and induced damage (Field L) began 14 cm (5.5 in) forward of the left rear axle and extended forward 258 cm (101.6 in). The residual crush profile was measured at the lower door level and was as follows: C1 = 0 cm, C2 = 9 cm (3.5 in), C3 = 18 cm (7.1 in), C4 = 68 cm (26.8 in), C5 = 26 cm (10.2 in), C6 = 6 cm (2.4 in). The maximum crush was located 157 cm (61.8 in) forward of the left rear axle and measured 78 cm (30.7 in). The Collision Deformation Classification (CDC) assigned for this impact was 09LPAW5. **Figures 5 and 6** depict the left side damage sustained by the Kia.

Figure 5: Overall view of the left side damage to the Kia.

Figure 6: Lateral view of the pole impact damage.

Interior Damage

The Kia Rio sustained moderate-severity damage that was attributed to occupant contact and passenger compartment intrusion. The driver loaded the left door, resulting in a scuff to the left armrest 5 to 14 cm (2 to 5.5 in) forward of the rear of the armrest and a scuff on the Forward Lower Quadrant (FLQ) 0 to 14 cm (0 to 5.5 in) rear from the front edge of the door and 0 to 13 cm (0 to 5.1 in) above the lower edge of the door. The left doors, A- and B-pillars intruded laterally. The passenger compartment intrusions are listed in the following table:

Position	Component	Direction	Magnitude
Row 1 Left	Door Forward Lower Quadrant (FLQ)	Lateral	44 cm (17.3 in)
Row 1 Center	Door FLQ	Lateral	12 cm (4.7 in)
Row 1 Left	Side panel forward of A-pillar	Lateral	37 cm (14.6 in)
Row 1 Left	Lower A-pillar	Lateral	44 cm (17.3 in)
Row 1 Center	Lower A-pillar	Lateral	3 cm (1.2 in)
Row 1 Left	Sill	Lateral	44 cm (17.3 in)
Row 1 Center	Sill	Lateral	6 cm (2.4 in)
Row 1 Left	Roof side rail	Lateral	44 cm (17.3 in)
Row 1 Center	Roof side rail	Lateral	3 cm (1.2 in)
Row 1 Left	Door Forward Upper Quadrant (FUQ)	Lateral	44 cm (17.3 in)
Row 1 Center	Door FUQ	Lateral	2 cm (0.8 in)
Row 1 Left	Steering wheel rim	Lateral	22 cm (8.7 in)
Row 1 Center	Steering wheel rim	Lateral	44 cm (17.3 in)
Row 1 Right	Steering wheel rim	Lateral	19 cm (7.5 in)
Row 1 Left	B-pillar	Lateral	9 cm (3.5 in)
Row 1 Center	Left instrument panel	Lateral	44 cm (17.3 in)
Row 1 Right	Left instrument panel	Lateral	21 cm (8.3 in)
Row 1 Right	Center instrument panel	Lateral	24 cm (9.4 in)

Position	Component	Direction	Magnitude
Row 1 Center	Front left seat cushion	Lateral	8 cm (3.1 in)
Row 2 Left	Roof side rail	Lateral	8 cm (3.1 in)
Row 2 Left	Door FLQ	Lateral	6 cm (2.4 in)
Row 2 Left	Front seat back	Longitudinal	11 cm (4.3 in)
Row 2 Right	Front seat back	Longitudinal	20 cm (7.9 in)

Manual Restraint Systems

The Kia was equipped with manual 3-point lap and shoulder belt systems for the five designated seating positions. All belt systems utilized continuous loop webbing with sliding latch plates. The driver's belt retracted onto an Emergency Locking Retractor (ELR) with a retractor pretensioner. The upper D-ring was height adjustable and set to the full-down position. The actuated retractor pretensioner locked the safety belt in the used position. The total length of the spooled-out webbing was 155 cm (61 in). A frictional abrasion was located on the webbing and was attributed to the latch plate. The abrasion was located 56 to 66 cm (22 to 26 in) above the floor anchor. Based on the observations of the SCI inspection, the driver was restrained at the time of the crash.

The front right passenger's belt retracted onto a switchable ELR/Automatic Locking Retractor (ALR) and was equipped with a retractor pretensioner. The upper D-ring was height adjustable and was located in the full-down position. The actuated retractor pretensioner locked the safety belt in the used position. The spooled-out webbing measured 138 cm (54.3 in) in length. The front right passenger used the safety belt during the crash. Additional evidence of use consisted of a frictional abrasion on the webbing from the latch plate. This loading abrasion was located 58 cm (22.8 in) above the floor anchor.

The second row belt systems all utilized a switchable ELR/ALR. The second row was not occupied at the time of this crash.

Frontal Air Bag System

The Kia was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system. The driver's air bag was concealed within the center hub of the three-spoke steering wheel by three asymmetrical cover flaps. The top flap was 6 cm (2.4 in) in height and 15 cm (5.9 in) in width at the horizontal tear seam. The two lower flaps were symmetrical measuring 7 cm (2.8 in) in width at the tear seam and 10 cm (3.9 in) in height. The air bag **(Figure 7)** measured 60 cm (23.6 in) in diameter in its deflated state. The air bag was vented by two vent ports at the 11/1 o'clock positions on the rear aspect of the air bag. The air bag was tethered by two straps. There were no occupant contact points on the air bag, but a large amount of dirt and dust had accumulated on the air bag post-crash due to its exposure to the elements.

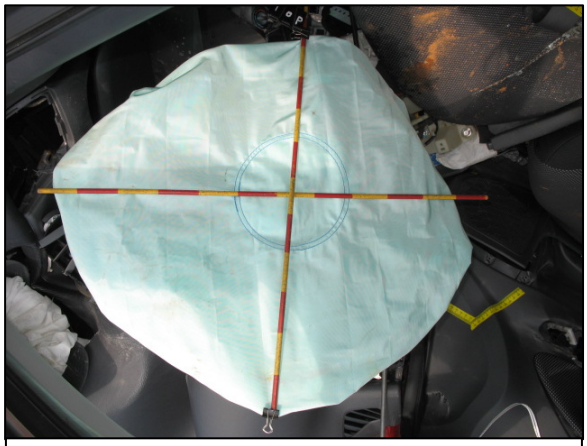

Figure 7: Deployed driver's frontal air bag.

The front right air bag was concealed within the top aspect of the right instrument panel. At the time of the crash, the front right seat was occupied. The occupant's weight was detected by the weight sensor in the front right seat. The CAC front right air bag deployed. The cover flap measured 23 cm (9.1 in) in width and 10 cm (3.9 in) in height. The air bag was vented by a single port at the twelve o'clock position. Due to the lateral intrusion of the steering assembly, the steering wheel rim was in-close proximity to the front right air bag. **Figure 8** depicts the front right air bag.

Figure 8: Deployed front right air bag.

Side Impact Air Bag System

The Kia was equipped with front seat-mounted side impact air bags and roof side rail-mounted IC air bags. The left IC and left side impact air bag deployed in this side impact crash. The right side impact air bags did not deploy.

The left IC measured 136 cm (53.5 in) in length. At the front left seating position, the air bag measured 44 cm (17.3 in) in height, and 40 cm (15.7 in) in height at the rear left seating position. The air bag was tethered to the A-pillar by a 44 cm (17.3 in) long strap. Vertically, the curtain air bag extended below the belt line at each outboard position. The IC provided head protection

from the roof side rail to the belt line and from the C-pillar to a location 42 cm (16.5 in) forward of the B-pillar. There was a gap between the front edge of the curtain air bag and the A-pillar. This gap could not be accurately measured due to the damage to the left front door and A-pillar. **Figure 9** depicts the left curtain air bag.

The left side impact air bag deployed from a panel in the outboard aspect of the front left seat back. The membrane measured 22 cm (8.7 in) in width and 36 cm (14.2 in) in height. It contained no vent ports or tethers. There was a scuff mark located on the inboard side of the air bag 5 to 14 cm (2 to 5.5 in) below the top of the bag and 10 to 19 cm (3.9 to 7.5 in) aft of the forward edge. **Figure 10** depicts the front left side air bag.

Figure 9: Left curtain air bag.

Figure 10: Left side impact air bag.

Driver Demographics/Data

Driver Age/Sex:	16-year-old/Female
Height:	163 cm (64 in)
Weight:	97 kg (214 lb)
Eyewear:	None
Seat Track Position:	Rear-track
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from Vehicle:	Removed by EMS due to entrapment and perceived serious injury
Mode of Transport From Scene:	Ground ambulance to local hospital
Type of Medical Treatment:	Treated in emergency department of a local hospital, transferred to regional trauma center and admitted for 5 days.

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Bilateral inferior and superior pubic rami fractures and diastasis of the pubic bone with mild associated avulsion injury (with left hip dislocation)	Moderate (852602.2,5)	Intruding left arm rest rear upper quadrant
Right acetabular fracture (right superior rami fracture extends into the anterior column of the acetabulum on the right side)	Moderate (852602.2,1)	Front right seat back
Right upper arm abrasion	Minor (790202.1,1)	Occupant to occupant contact
Right wrist abrasion	Minor (790202.1,1)	Frontal air bag
Left arm contusion (from shoulder to top of left hand)	Minor (790402.1,2)	Intruding left door panel rear upper quadrant
Right foot and ankle abrasion	Minor (890202.1,1)	Foot controls
Right knee abrasion	Minor (890202.1,1)	Center lower instrument panel
Right knee contusion	Minor (890402.1,1)	Center lower instrument panel
Left thigh, knee and lower leg abrasion	Minor (890202.1,2)	Intruding left door panel forward lower quadrant
Left knee contusion	Minor (890402.1,2)	Intruding left door panel forward lower quadrant
Left ankle laceration (1cm)	Minor (890602.1,2)	Side panel forward of the A-pillar intrusion
Left ankle and foot abrasion	Minor (890202.1,2)	Side panel forward of the A-pillar intrusion

Source: Medical Records and interview

Driver Kinematics

The 16-year-old female driver was seated in a rear-track position and was restrained by the manual 3-point lap and shoulder belt system. The Kia departed the roadway to the left, rotated clockwise and impacted a utility pole at the left A-pillar area.

As a result of the left side impact, the seat belt pretensioner actuated and the frontal air bags and the left seat back mounted and left IC air bags deployed. The deploying frontal air bag displaced the driver's right hand from the steering wheel and abraded the wrist. The restrained driver initiated a left trajectory within the front left seating position. Coincident to this kinematic pattern, the left door intruded. The driver's left hip loaded the door panel resulting in the left pelvic fracture. The soft tissue injuries of the left leg resulted from contact with the forward

lower quadrant of the intruded door panel. The intrusion of the side panel forward of the A-pillar entrapped the driver's feet and ankles and resulted in the laceration and abrasions to her left foot/ankle. The right knee contacted the center lower instrument panel resulting in an abrasion and contusion. The intruding door panel compressed the driver laterally against the front right seat back resulting in the right pelvic fracture.

The driver was impacted by the front right passenger as she responded to the left lateral crash forces. This occupant-to-occupant interaction resulted in a contusion to the driver's right upper arm.

The driver was assisted from the vehicle by EMS personnel and was transported by ground ambulance to a local hospital. She was subsequently transferred to a regional trauma center and admitted for five days.

Front Right Occupant Demographics/Data

Passenger Age/Sex:	17-year-old/Female
Height:	168 cm (66 in)
Weight:	54 kg (119 lb)
Eyewear:	None
Seat Track Position:	Rear-track
Manual Safety Belt Use:	Lap and shoulder belt
Usage Source:	Vehicle inspection
Egress from Vehicle:	Exited with some assistance
Mode of Transport From Scene:	Ground ambulance to local hospital
Type of Medical Treatment:	Admitted overnight for observation

Front Right Occupant Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Concussion (unknown L.O.C.)	Minor (160499.1,0)	Right front window frame
Right frontal scalp hematoma	Minor (190402.1,5)	Right front window frame
Center forehead laceration (3 cm)	Minor (290602.1,7)	Right front window frame
Left shoulder and upper arm contusion	Minor (790402.1,2)	Occupant to occupant contact
Right hip and thigh contusions	Minor (890402.1,1)	Door panel rear lower quadrant

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Right knee and lower leg contusions	Minor (890402.1,1)	Door panel forward lower quadrant
Left hip and upper thigh contusion	Minor (890402.1,2)	Occupant to occupant contact

Source: Medical record and Interview

Front Right Occupant Kinematics

The 17-year-old female front right passenger was seated in a rear-track position and was restrained by the manual 3-point lap and shoulder belt system. As the left side of the Kia impacted the pole, the passenger initiated a left trajectory in response to the lateral crash forces. The passenger loaded the lap portion of the belt system as her torso slid out of the shoulder belt webbing. Coincident to this pattern, the driver was being displaced laterally to the right. The passenger's left shoulder/arm and her left hip/thigh loaded the driver resulting in soft tissue injuries to these areas.

The passenger initiated a rebound trajectory to the right and loaded the right door panel, resulting in contusions to her right hip, thigh, and lower leg. The passenger's head likely contacted the right upper window frame resulting in the right frontal scalp contusion and the concussion. The forehead laceration possibly occurred as a result of this contact as well.

The passenger was assisted from the vehicle through the front right door and was transported to a local hospital. She was treated in the emergency department and admitted overnight for observation.

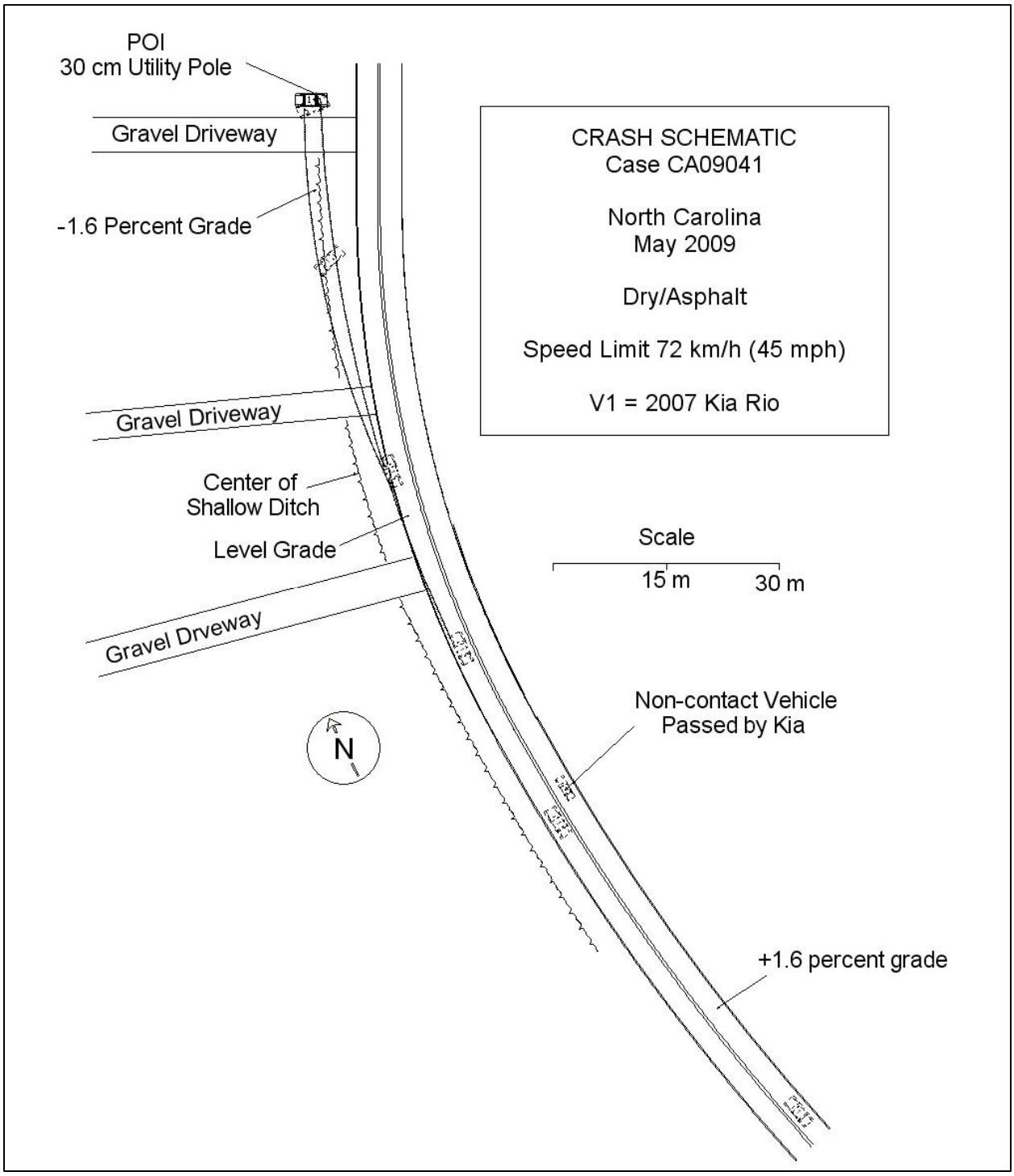

Figure 11: Crash Schematic

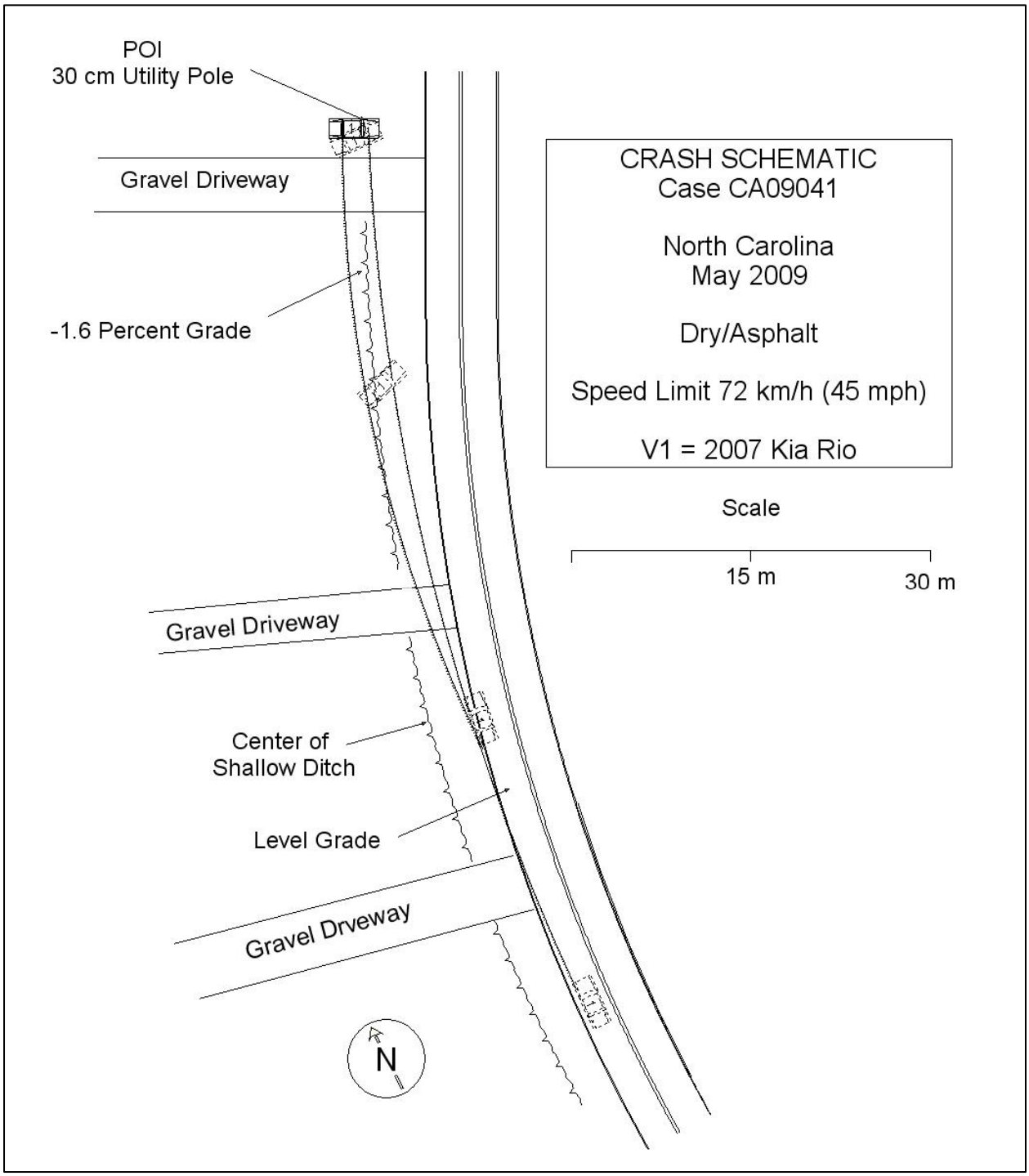

Figure 12: Crash Schematic at Road Departure