



**Virginia Commonwealth University
Transportation Safety Training Center
Virginia Multi-disciplinary Crash Investigation Team**

Report Number 199 – March, 2007

ABSTRACT

The crash described in this report occurred when the driver of a tractor trailer entered a work zone where other vehicles had been stopped by a flagman. The tractor with double trailers came upon the stopped traffic and the driver failed to recognize the change in traffic conditions. He applied brakes, locking the drive axle and one trailer axle prior to impact. The front of the tractor struck the last vehicle in a line of five vehicles, pushing it into the vehicle ahead of it, setting off a chain reaction event. The fourth vehicle in the line was pushed into the third and this vehicle rotated counter-clockwise into the path of the tractor, which struck it broadside, mounted it and dragged it down the roadway. The rear of this vehicle struck the vehicle stopped ahead of it and caused it to rotate clockwise and slide off the right side of the road into the ditch. The momentum of the tractor trailer carried it into the lead vehicle, striking the top of the left rear corner in a downward motion. This driver attempted to accelerate out of the path of the tractor but failed to outrun the collision.

This crash report illustrates the need for vigilance while driving and increased attention in work zones. Issues related to the roadway and traffic volume and speeds, as well as black box technology are also discussed.

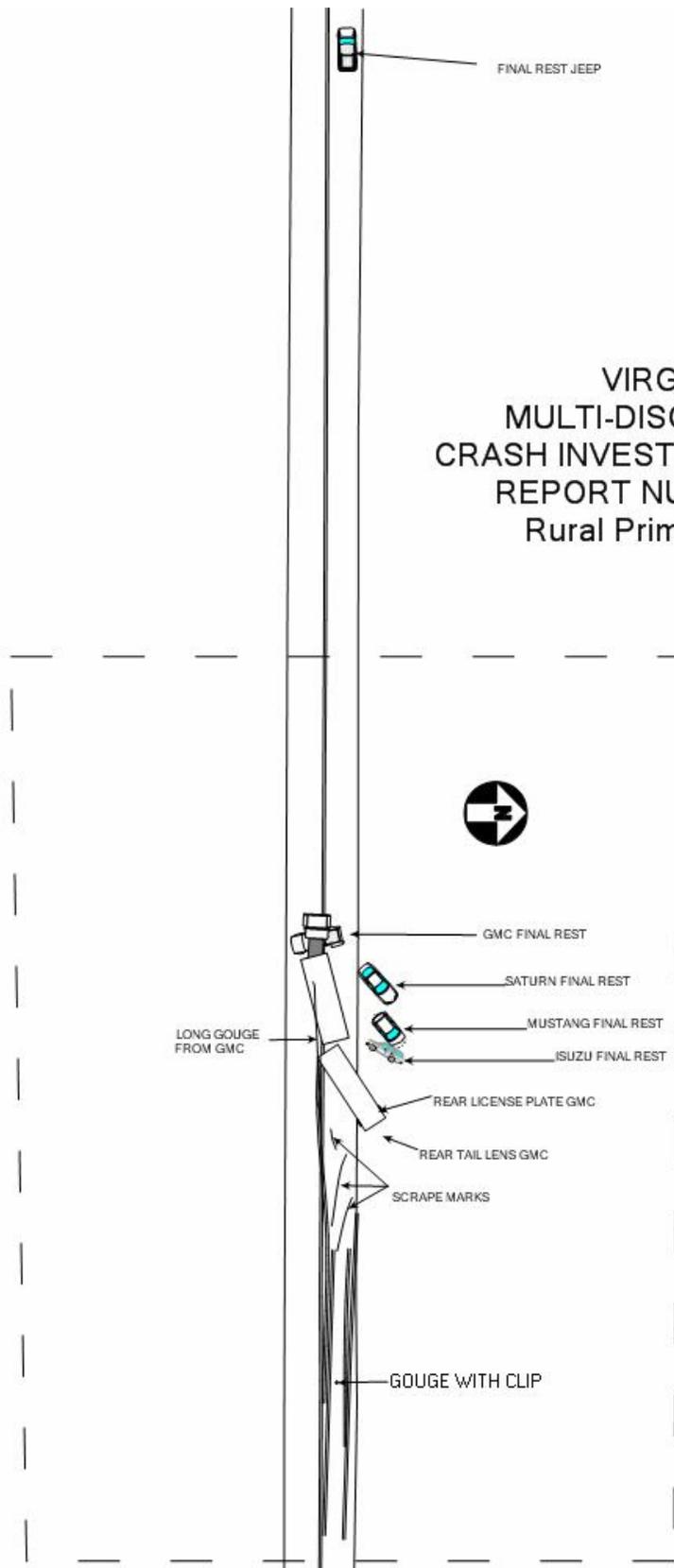
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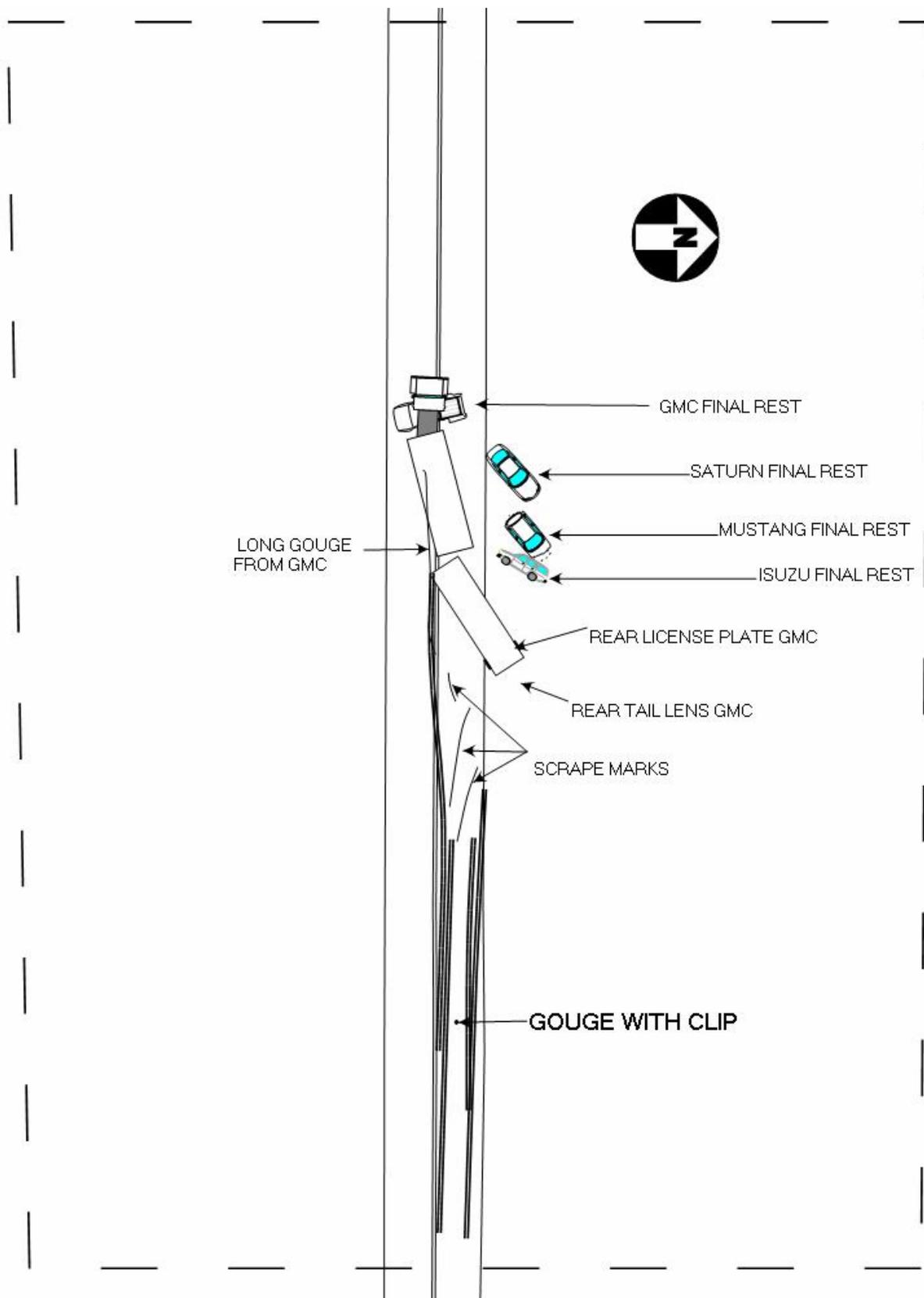
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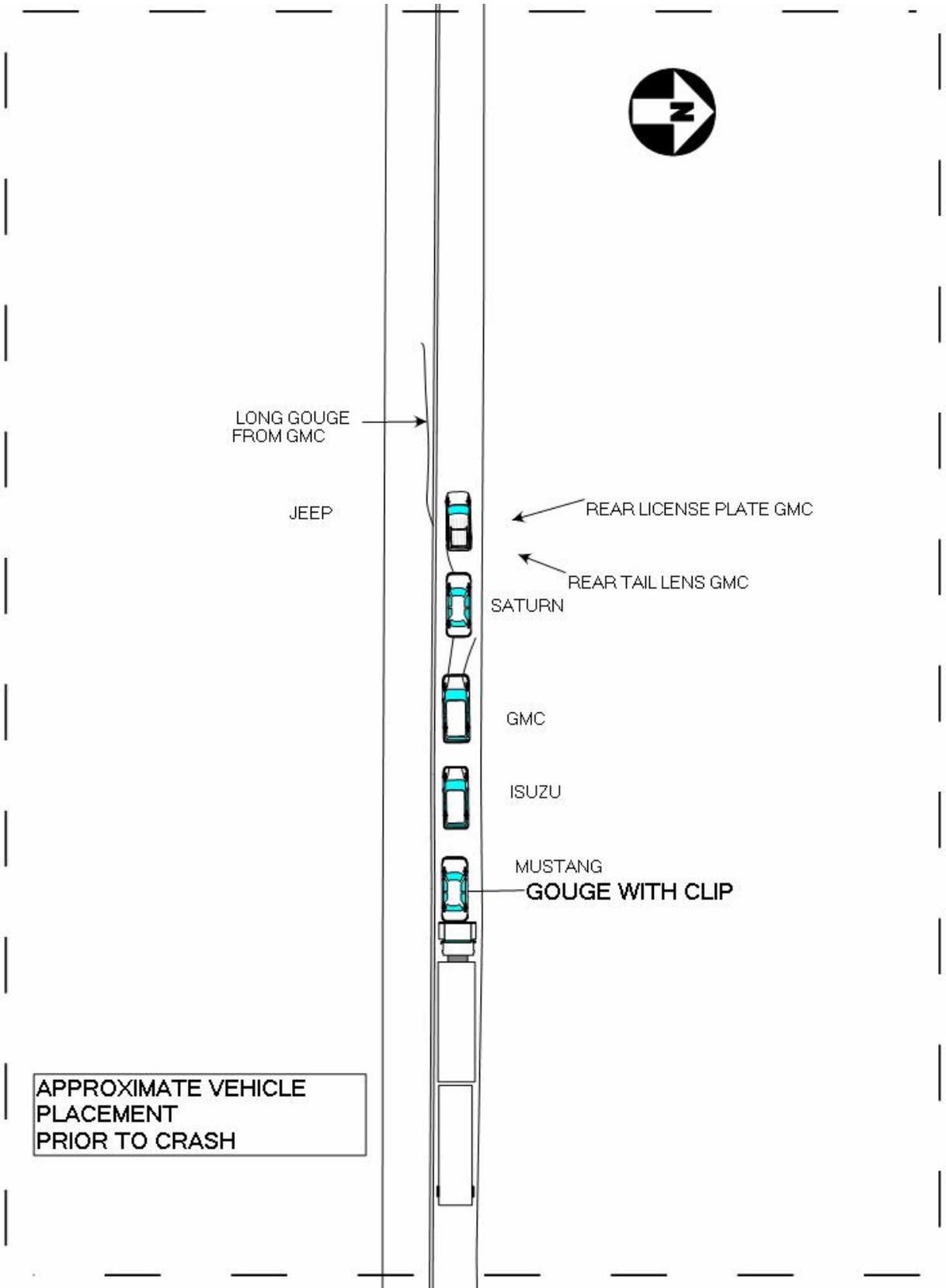
SYNOPSIS

<u>Day, Time, Season:</u>	Wednesday, 1:25 p.m., Summer
<u>Road/Weather:</u>	Rural two lane primary road; dry and clear
<u>Vehicles Involved:</u>	2006 Volvo Day Tractor, towing one semi-trailer and a second semi-trailer with a dolly converter 1994 Ford Mustang (fatality) 1999 Isuzu Amigo Sport Utility Vehicle (fatality and serious injury) 2005 GMC Yukon Denali Sport Utility Vehicle (serious injury) 1999 Saturn SCA-2 (minor injury) 1998 Jeep Cherokee Sport Utility Vehicle
<u>Summary:</u>	The driver of the tractor and double trailer failed to heed signs and a flagman in a work zone, running into and over the last of five vehicles in a line of stopped traffic. This set off a chain reaction of collisions among the six vehicles.
<u>Severity:</u>	Two fatalities, personal injuries and extensive property damage. Traffic blocked.
<u>Probable Cause:</u>	Inattentive driving.
<u>Significant Points:</u>	Safety considerations in work zones; inattentive driving, high traffic volume, speeds and tractor-trailers on rural two lane primary highways.

VIRGINIA
MULTI-DISCIPLINARY
CRASH INVESTIGATION TEAM
REPORT NUMBER 199
Rural Primary Road







CRASH DESCRIPTION

On a clear Wednesday afternoon in September at approximately 1:25 p.m., a 2006 Volvo Day Tractor pulling two 28 foot trailers was traveling west on a rural two lane primary roadway. The location of the crash was in a work zone on the westbound lane. The road is asphalt, on a slight downgrade, and each lane is approximately 11 feet wide. The shoulder is grass and gravel, varies from two to five feet wide and slopes to a ditch. The ditch is adjacent to an open farm field. The road is approximately 10 miles in length and is used as a shortcut between two major primary roads. With a speed limit of 55 miles per hour (mph), the road is generally straight with rolling hills and is controlled by pavement markings and signs which are in good condition. A passing zone for westbound traffic ends approximately 100 feet prior to tractor skid marks made the day of the crash. Further west, the two lanes are separated by double solid yellow center lines in the area where the crash occurred.

The 43 year old tractor driver, who was traveling alone, had turned onto this primary route and traveled less than a mile, then entered a work zone. Both trailers pulled by the tractor were empty of cargo: one was a semi-trailer attached to the tractor and the other a semi-trailer combined with a four wheel converter dolly to make a full trailer. The work zone was approximately 2.5 miles between the flaggers at either end. Each flagman held a pole-mounted double-sided sign with a stop sign on one side and a black on orange "SLOW" sign on the reverse. The flagmen would hold the traffic for a pilot vehicle to lead them through the work zone. The tractor trailer driver passed four different warning signs indicating, respectively, "ROAD WORK AHEAD" located approximately ½ mile from the beginning of the road, "ONE LANE ROAD" located approximately 1,851 feet prior to the flagman, "BE PREPARED TO STOP" located approximately 1,274 feet prior to the flagman and "FLAGMAN AHEAD" located approximately 745 feet prior to the flagman. This driver failed to heed the warning signs and did not slow his vehicle. Although he had over 1,700 feet of site distance, he also failed to note that a line of five vehicles was stationary in his lane until he was almost upon them.

The flagman, who had been waving his flag in an attempt to capture the tractor driver's attention, realized that the rig was not slowing. Seeing the impending crash, he dropped the stop sign and ran from the highway, narrowly escaping injury. The tractor driver applied his brakes at the last instant and skidded for a distance of approximately 50 feet before striking the last vehicle in the line, a 1994 Ford Mustang. The tractor rode up on the rear of the Mustang, collapsing the rear bumper and trunk forward into the passenger compartment. A metal clip from the Mustang

became embedded in the asphalt as the undercarriage deeply gouged the roadway, marking the area of initial impact. The Mustang was also propelled forward into a 1999 Isuzu Amigo, a small two door Sport Utility Vehicle (SUV), stopped a short distance in front of it. The Mustang under-rode the rear of the Amigo, with the rear license plate of the Amigo imprinted atop the right front corner of the Mustang's bumper cover. The Mustang was shoved off the right side of the roadway and came to rest on the shoulder facing northeast.



Photo 1: View facing west, showing tractor skid marks.

The Amigo was propelled forward into a 2005 GMC Yukon, a full size SUV, stopped a short distance in front of it. The front of the Amigo compressed and the hood buckled in an upward direction as it was forced into the rear of the Yukon. The tractor propelled the Amigo off the right edge of the road as it rotated clockwise out from between the two larger vehicles. The Amigo passed east of the Mustang and came to rest on its passenger side, on the shoulder beside the Mustang, facing southwest.



Photo 2: Final rest of the Mustang (foreground) and Amigo (wheels up beside Mustang) in relation to trailers.



Photo 3: Final rest of the Mustang and Amigo from a perspective facing southwest.

The Amigo's angular movement caused the Yukon to rotate counter-clockwise in the roadway and in the path of the still sliding tractor trailer combination. The front of the tractor struck the left side of the Yukon, mounted it and pushed it sideways down the roadway. The Yukon, wedged between the drive axle and the saddle (fuel) tanks, was still being pushed sideways when the right rear corner struck the left rear corner of a 1999 Saturn that had been stopped a short distance ahead of it. The Saturn was pushed forward, rotated clockwise off the roadway and came to rest in the ditch facing northeast.



***Photo 4: Final rest of the Saturn. Driver's side view shows damage to the rear end.
The first trailer is in the background.***

The driver of the 1998 Jeep Cherokee SUV, which had been at the head of the line near the flagman, attempted to accelerate away from the collision and failed. The right front corner of the tractor struck the left top rear of the Jeep, compressed it downward and propelled the vehicle forward. It came to rest still facing west in the westbound lane approximately 150 feet ahead of the finally stopped tractor and trailers.



Photo 5: Jeep at final rest, west of impact site.

The rig came to rest in the roadway with the rear wheels of the rear trailer off the right edge of the pavement and the body angled approximately 45° toward the center of the road. The first trailer was angled at approximately 20° toward the left side of the road edge and straddling the center lines. The tractor was straddling the center lines and angled back toward the right edge of the road at approximately 5°, with all couplings still attached and the Yukon firmly wedged between the saddle tanks and the drive axle. Fire broke out beneath the Yukon and scorched the left front corner of the first trailer before it was quickly extinguished by Virginia Department of Transportation (VDOT) workers.

Police, fire and rescue were summoned by VDOT workers and other witnesses and arrived shortly after the crash. Police closed the road to traffic. A heavy duty wrecker and a VDOT tractor were used to lift the tractor and pull the Yukon from beneath it in order to extricate the driver. The Yukon driver was pinned in his vehicle, but amazingly survived the crash.



Photo 6: Yukon at final rest under tractor. Note scorch marks on bottom edge of trailer from fire.

The Mustang driver, however, was killed during the collision. The driver of the Amigo was also killed but her husband, the front passenger, survived with serious injuries. The Saturn operator suffered minor injuries and the Jeep Cherokee driver was not physically harmed. The injured individuals were airlifted from the scene and flown to a hospital trauma center approximately 50 miles away.

VDOT safety engineers were summoned and photographed the final resting positions of the vehicles and the removal process of the Yukon. A State Police Divisional Crash Reconstruction Team was called, as well as a member of the Motor Carrier Unit, since a commercial motor carrier vehicle was involved. Because diesel fuel had spilled and threatened to run into a nearby stream, the Department of Environmental Quality (DEQ) was contacted. DEQ employees supervised the removal of hazardous material by a clean up crew hired by the company that owned the tractor. Once the vehicles and hazardous materials had been cleared from the scene, VDOT crews repaired the worst gouges in the road from the collision. The road was reopened approximately eight hours after the crash.



Photo 7: Damage to the front of the tractor.

REMARKS

All of the drivers involved were licensed in the Commonwealth at the time of the crash. The 43 year old driver of the tractor trailer had a fairly short driving history in Virginia, only four years. He did not have any convictions on his driving record prior to this event; however, he was convicted of reckless driving as a result of his involvement in this crash. He had no physical impairments and was not under the influence of alcohol or drugs while driving. This driver picked up the empty trailers at his employer's site and drove approximately 45 miles before the crash. He planned to drive for approximately 250 miles more to deliver them to another part of the state. He was familiar with the road and the area. Immediately after the crash, he called his employer, who sent a lawyer to the scene. The lawyer advised the driver not to talk to the investigating police officers. Consequently, his written statement was short. He wrote that he looked in the mirror "for a second" as he was traveling down the road. He saw four or five cars in front of him and "all of a sudden they hit the brakes." He indicated that he also braked and tried to steer to the left but did not have time to avoid the collision. He wore his lap/shoulder restraint and was able to ride down the jostling and deceleration without being injured.

The 56 year old driver of the Mustang had two speeding convictions of 15 to 19 mph in excess of 55 mph and had a negative three point balance. He did not have any physical defects and his blood alcohol content was .03%, well below the presumptive level of intoxication. He was wearing his lap/shoulder restraint when his vehicle was crushed by the tractor and he suffered fatal blunt force injuries.

The 59 year old driver of the Amigo had a clean driving record with a balance of plus five points. She was not impaired in any way prior to the crash and wore her lap/shoulder restraint. Her occupant area was compromised during the collision and she died as a result of blunt force trauma to her head. Her husband, similarly restrained in the front passenger seat, was seriously injured but survived.

The 45 year old Yukon driver held a commercial driver's license with a plus five point balance. He had convictions in 2005, all on the same date, two of which were for unspecified equipment charges, one for improper vehicle markings and one for failing to secure a load. At the time of the crash, he was not wearing his lap/shoulder restraints and was not impaired. He

was pinned in his vehicle during the collisions and suffered injuries requiring transport to a hospital.

The Saturn driver, a 40 year old female, had two convictions on her driving record. One in 2003 was for speeding 1 to 9 mph over the limit and the other was in 2005, for failing to obey a highway sign. She also wore her lap/shoulder belt and was not impaired. In her statement, she described being stopped in a line of traffic and seeing the flagman “jumping up and down and waving his free hand.” She confirmed that he displayed a stop sign. She started to look into her side mirror to determine why the flagman was so agitated when her vehicle was hit. After the crash, she was transported to a local hospital.

The 58 year old Cherokee driver had a clean driving record, with plus five points. She was not impaired prior to the crash. She wore her safety restraints and was not injured when the rear of her vehicle was struck.

Two of the stopped vehicles, the Yukon and the Saturn, were equipped with event data recorders that were read using the Crash Data Retrieval tool kit. The Yukon had one event recorded that was consistent with facts of this case. It showed the engine at idle around 512 RPM and the brake light circuit switch status “ON” for the period recorded (just shy of five seconds). The first four seconds showed the percent throttle at zero and the last reading was at 7%. The vehicle speed showed zero for the first four seconds and then was recorded at 4 mph, which is consistent with it being struck in the rear and pushed forward, where it impacted another vehicle and set off the recording sequence. These readings, combined with the physical evidence, clearly show that the Yukon was second in the traffic queue and had been stopped for more than 4 seconds. From his higher seating position in the cab, and with his unobstructed sight distance, the tractor driver should have been aware that at least two vehicles had already stopped ahead, whether or not the other three vehicles directly ahead of him were still in motion. The Saturn was equipped with the same type of device but no event was recorded for this crash. This is understandable considering the glancing blow coming into the right rear and the fact that this vehicle did not strike anything with its front. These devices are designed to “wake up” the system when sensing a sudden deceleration in forward movement and make a decision on whether to deploy the air bags (see *Special Report 16, Event Data Recorders Study* for more information).

The Volvo tractor is equipped with an Engine Control Module (ECM) which is readable with specialized equipment not in the Virginia Multi-disciplinary Crash Investigation Team

(VMCIT) inventory. These units are designed to record various functions of the vehicle when a “hard brake application” is detected. Different makes and models have different data available and for different lengths of time. Team members did learn that the ECM from this vehicle was downloaded. The only information released was that the vehicle was doing “normal everyday speed”.

Physical evidence found on the vehicles was used to determine their pre-impact placement. The red paint from the tractor’s oil pan was found transferred onto the rear of the Mustang. A partial license plate imprint from the front of the Mustang was found on the rear of the Amigo. Trace paint from the front of the Amigo was transferred to the rear of the Yukon. Wheel marks from the tractor were found on the left side of the Yukon and a small amount of trace paint was found from the Saturn on the right rear corner of the Yukon.

A variety of considerations related to the roadway were researched during this investigation. One issue was the crash history. In 1995, VDOT completed a corridor report on this roadway. The study covered a five year and two month period ending February 28, 1995 and included analyses of speed samples and crash reports. The reports revealed that 70 crashes had occurred on this roadway with a variety of crash types. To supplement this data, the VMCIT requested and analyzed all reportable crash reports received for this stretch of road for calendar years 2003, 2004 and 2005. According to these reports, a total of 65 crashes occurred on this roadway during the past three years: 27 rear end collisions, 30 single vehicle crashes, and 8 other collision crashes. Two of these crashes resulted in fatalities, 34 were injury crashes, and 29 were property damage only crashes. In addition, VDOT personnel performed a preliminary analysis of crash data for January 1, 2001 to September 1, 2006 and found that the crash rate is below the state-wide average rate for this type of primary road.

Speed samples analyzed in the 1995 VDOT study indicated that there was no justification for a speed limit reduction. The 85th percentile speeds for trucks and passenger vehicles were close to the current posted limits. Two of the two recommendations in the report were: (1) “widen roadway widths to 12 feet in each direction and widen shoulders throughout the entire corridor” and (2) “improvement of vertical sight distances” for several intersections (VDOT, 1995). Rural roads often fail to allow much room for errors on the part of drivers. The narrow shoulders along this roadway increase the risk of damage and injury for those who drift off the pavement. While the drainage ditch beside this road is an important feature to assure that the road remains clear of running or standing water during and after storms, it sometimes can

become a hazard as well. The first recommendation would give drivers more recovery area in run off the road types of crashes and for avoiding vehicles or objects in their travel lane. The second recommendation is designed to decrease rear end collisions and angle collisions that resulted from stopped or slowed vehicles preparing to turn. Some of the recommendations have been completed; however, the road and shoulder widening have only been made at a few spots due to a lack of funding.

A third consideration is the truck traffic on this road, especially in light of the number of hills and intersections with private driveways and secondary roads. The perception of individuals who live and work in the area was that truck traffic had increased and was a safety hazard to vehicles slowing or stopping to turn. A preliminary VDOT analysis of the past six calendar years of average daily traffic data revealed that the amount of traffic on the road has increased by about 11 percent, less than 2 percent per year. The percentage of trucks compared to other vehicles has remained fairly constant, at about 9 percent of the total vehicles. VDOT concluded that there were no safety reasons for restricting trucks from using this route.

On the day of the crash, work crews were filling potholes and repairing pavement edges that had been damaged by a severe storm that has passed through the area the week prior. The layout of the work zone exceeded the minimum requirement of VDOT's work zone safety guidelines (VDOT, 2004). VDOT meets and generally exceeds requirements of the Federal Highway Administration. Due to the geometrics of the roadway, a pilot vehicle was used to guide traffic through the work zone to further enhance safety. In addition, truck mounted attenuators were used to protect the workers. The flaggers directing traffic at each end of the zone were state certified and wore appropriate hard hats and safety vests.

A critical factor underlying this crash was inattentive driving. All the signs preceding the work zone were intended to prepare drivers to expect changes in traffic conditions and to anticipate a stop. The bright orange signs are highly conspicuous and the repeated warnings should have been sufficient to alert this driver. In his statement, he did not mention the signs. He wrote only that he was "going down the road", which indicates that he did not perceive anything unusual, and he indicated that he was aware of the vehicles in front of him. He reported that he had been looking into his rear view mirror when he saw that "all of a sudden they hit the brakes." Other evidence has shown that at least two of the vehicles had been stopped for more than four seconds, and the driver's view was not obstructed. His failure to respond appropriately in this situation could be characterized as inattention blindness. His attention was focused

elsewhere and he was “blind” to critical visual cues that would have alerted him to the dangers ahead.

While the visual cues should have been enough to alert an attentive driver, an inattentive or distracted driver may fail to notice such signals, and they cannot be perceived once they are beyond the range of the visual field. On the other hand, auditory or vibratory cues are not as limited in perceptibility and thus are better at alerting drivers of unusual or dangerous situations. Rumble strips placed just outside the lanes on highways, for example, help alert drowsy or distracted drivers when they have departed their normal path of travel. Tires passing over these strips vibrate, creating a loud noise and, especially in the case of smaller vehicles, shaking the occupants. Similarly, rumble strips are sometimes used on steeply curved exit ramps or approaches to dangerous intersections to alert drivers. A related approach has been tried in work zones in other states. The Texas Department Transportation (Fontaine, n.d.) and the New York State Department of Transportation (Morgan, 2003) have reported some success using temporary rumble strips in these high risk areas. Typically, two sets of six strips each are set at 500 and 100 feet from the start of a taper (or prior to the work zone). Installation takes about 40 minutes for a crew of three workers; disassembly can be completed in about 10 minutes. The studies were conducted on low volume roads and found that median speeds were slightly lower approaching the zones with these temporary rumble strips in place. In some vehicle groups, the percentage of vehicles traveling above the speed limit also decreased. Workers indicated that there were a few problems with the amount of time required to install the rumble strips and getting the strips to adhere was an issue in a few cases.

When designing and setting up work zones, highway engineers focus on capturing the attention of drivers and gaining their compliance in driving cautiously, slowing and/or stopping. Their purpose is to enhance safety in a hazardous area for workers and vehicle occupants. The temporary rumble strip studies measured speed reduction, which requires the driver to perceive the changes, make decisions and then implement changes in their driving behavior, as a way to address the effectiveness of these devices. However, a key component is the driver: drivers must attend to the driving task. Investigators are often puzzled by the number of obvious cues to changes or problems that are missed by drivers just prior to crashing. In this crash, the tractor driver passed four bright orange warning signs and failed to respond to them, the flagman who was jumping up and down, or the line of stopped traffic, despite having a clear view ahead for over a quarter of a mile. While roadway and vehicle designers will continue to seek ways to

enhance transportation safety, drivers must also do their part. They must recognize that driving is a serious task that requires their full attention and act responsibly. The consequences of inattention can quickly become deadly, as this tragic case illustrates.

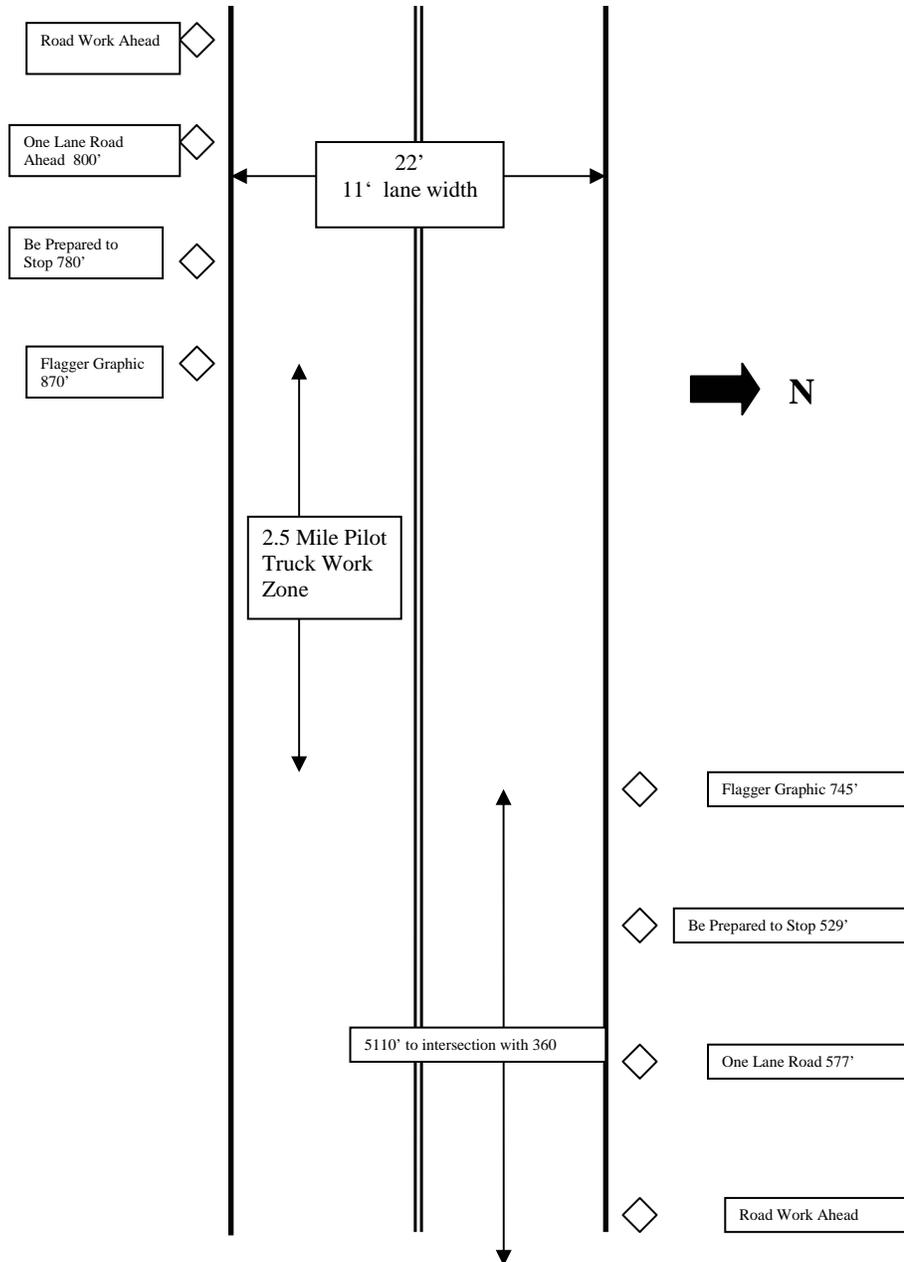


Figure 1: Work zone layout (Not to scale)

RECOMMENDATIONS

1. Since only preliminary analyses have been conducted in the 11 years since the last study, the Virginia Department of Transportation (VDOT) should conduct a full corridor study on this segment of roadway, which will help to determine:
 - a. if the accident rate is high,
 - b. if the 55 mph speed limit should be reduced, and
 - c. if the volume of commercial vehicle traffic is high for the roadway design.
2. VDOT should study the feasibility of using portable rumble strips and/or other types of audible devices in work zones to warn motorists to increase their attentiveness and reduce speed.
3. The Virginia Department of Motor Vehicles and educators involved with driver training and education should consider ways to highlight the importance of giving one's full attention to the driving task. These could emphasize the importance of avoiding distraction, such as cell phone use, radio and CD player adjustments and socializing with passengers, or they could focus on skills designed to improve attention and environmental scanning while driving.

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