Final Report Summary:

RP-291 – Evaluation of Deer-Vehicle Collision Rates in West Virginia and a Review of Available Mitigation Techniques

Submitted by:

Rahall Transportation Institute at Marshall University

Western Transportation Institute at Montana State University

West Virginia University

August 25, 2014

DISCLAIMER

This research was jointly funded by State Farm Insurance, the West Virginia Division of Natural Resources, Federal Aid in Wildlife Restoration (W-48-R), and the West Virginia Department of Transportation. The opinions and conclusions expressed or implied herein are those of the Authors. They are not necessarily those of the funding agencies.

ACKNOWLEDGMENT

The authors would like to thank the individuals listed below, who served on the Technical Advisory Committee for the project. In particular, the input and expertise of Mike Pumphrey, Donald Williams, Dr. Chris Ryan, and Dr. James Crum were integral to the successful completion of this project.

Mike Pumphrey, PE	West Virginia Department of Transportation
Donald Williams, PE	West Virginia Department of Transportation
Kyle Stollings, PE	West Virginia Department of Transportation
Donna Hardy, PE	West Virginia Department of Transportation
Timothy Smith, PE	West Virginia Department of Transportation
Carl Ross	West Virginia Department of Transportation
Jeff Pifer, PE	West Virginia Department of Transportation
Ray Urse	West Virginia Department of Transportation
Kyle Weatherholt	West Virginia Department of Transportation
Christopher Ryan, PhD	West Virginia Division of Natural Resources
James Crum, PhD	West Virginia Division of Natural Resources
Ryan Brumfield, PE	Federal Highway Administration
Sgt. Chris Zerkle	West Virginia State Police
Aaron Baughman	West Virginia Insurance Commission

AUTHOR ACKNOWLEDGMENT

Andrew P. Nichols, PhD, PE, Associate Professor of Engineering at Marshall University (MU), was the Project Director and co-Principal Investigator. The other authors of this report are Marcel Huijser, PhD, Research Ecologist at Western Transportation Institute at Montana State University and co-Principal Investigator, Rob Ament, MSc, Road Ecology Program Manager at Western Transportation Institute at Montana State University and co-Principal Investigator, Avinash Unnikrishnan, PhD, Assistant Professor of Civil Engineering at West Virginia University and co-Principal Investigator, and Sinaya Dayan, MS, Geospatial Sciences Program Manager at the Nick J. Rahall Appalachian Transportation Institute (RTI) at Marshall University and co-Principal Investigator.

Others contributing to the research in this project included Tiantian Chen, Graduate Assistant at University of Minnesota, Tuan Nguyen, Geospatial Analyst at RTI, Chih-Sheng Chou, PhD, ITS Research Associate at RTI, Emiko Hori, Geospatial Analyst at RTI, Lan Nguyen, Geospatial Analyst at RTI, Carlos Ramirez, Geospatial Analyst at RTI, Robert Denzie, Bachelor of Science in Engineering major at MU, and Austin Cox, Bachelor of Science in Engineering major at MU.

PROJECT SUMMARY

Background

Wildlife-vehicle collisions (WVCs) affect human safety, property (through damage) and wildlife. The total number of large mammal–vehicle collisions has been estimated at 1-2 million in the United States annually. These collisions are estimated to cause 211 human fatalities, 29,000 human injuries, and over $1B in property damage annually. More recent estimates that include costs associated with human injuries and human fatalities estimate the yearly costs associated with WVCs between $6B-12B. A single deer-vehicle collision (DVC) can cost as much as $6,717, when taking into account vehicle repair, medical care, towing and law enforcement services, monetary value of deer, and carcass removal and disposal.

Over the last few years, West Virginia has been consistently identified as the state with the highest rate of DVCs within the United States. The likelihood of a licensed driver in West Virginia hitting a deer in 2012-13 was calculated by State Farm Insurance to be 1 in 41, whereas the probability is only 1 in 174 for the United States. This likelihood is interpreted as one out of every 41 licensed drivers in West Virginia are estimated to have hit a deer during that timeframe. Montana, Iowa, South Dakota, and Pennsylvania complete the top five states with the highest probability for DVCs. Four out of the five states neighboring West Virginia (Pennsylvania, Virginia, Kentucky, and Maryland) have also been identified by State Farm Insurance as states with a “high risk” for DVCs, while Ohio is classified as having a “medium risk”. However, based on total number of estimated DVC, West Virginia ranked 17th. Figure 1 indicates the total number of estimated DVC by State Farm by state. Pennsylvania ranks first.

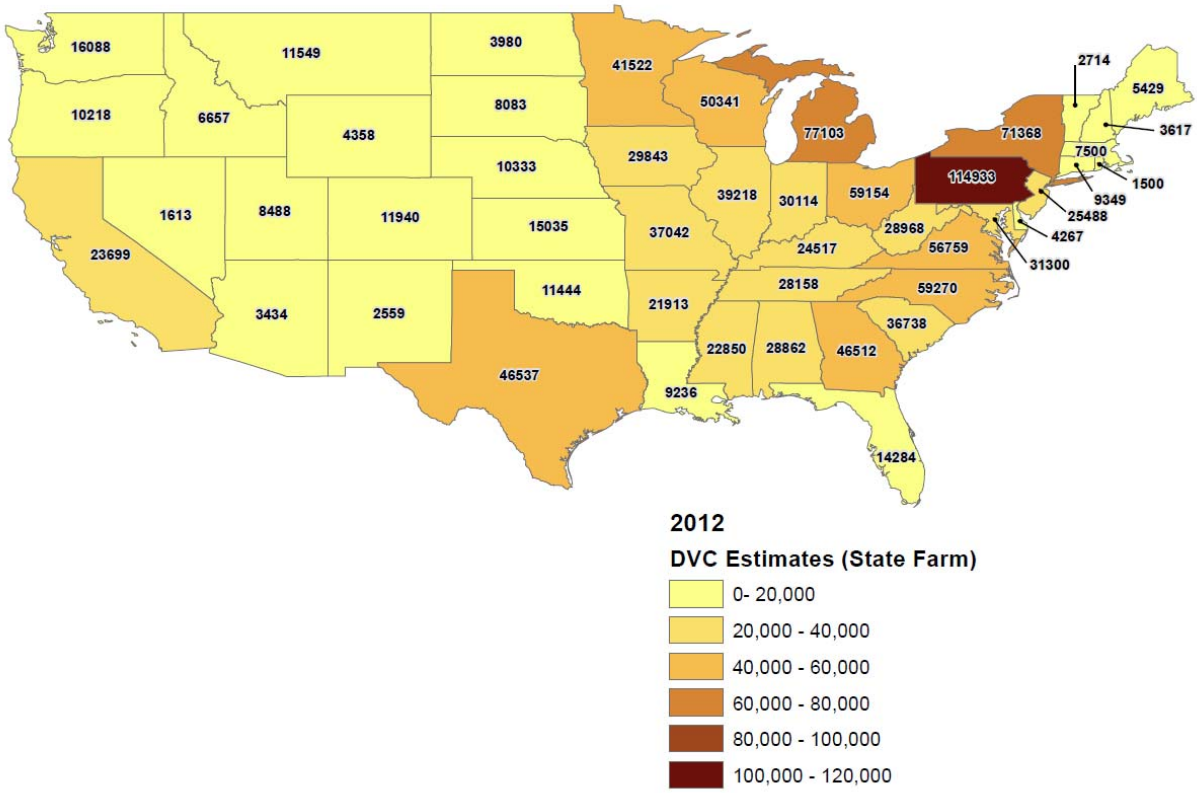

Figure 1 State Farm DVC Estimate by State (2012-13)

In January 2011, an agency review of the West Virginia Division of Natural Resources (WVDNR), as part of the Departmental Review of the Department of Commerce, was conducted by the Performance Evaluation and Research Division of the West Virginia Legislative Auditor's office. No major wrongdoing with the WVDNR was identified by the audit, however, the legislative auditor recommended that the WVDNR increase efforts to reduce the potential for DVCs in the state. As a partial response to the aforementioned auditor recommendation WVDNR initiated this evaluation and review of DVCs in cooperation with the West Virginia Department of Transportation (WVDOT). This project was jointly funded by State Farm Insurance, WVDNR, Federal Aid in Wildlife Restoration (W-48-R), and WVDOT. Other states have conducted similar studies to evaluate DVCs and investigate mitigation strategies for high frequency locations, including Alabama, Illinois, Iowa, Pennsylvania, Kansas, Washington, and Wisconsin.

Research Objectives

The overall goals of this project are to evaluate DVC rates in West Virginia to identify hotspots and review available mitigation techniques. The primary objectives that were defined at the outset of the project to achieve these goals are as follows:

1. Determine the site characteristics and other variables, inclusive of all roadway types (e.g. local routes, arterials, Interstates, etc.) that national and regional studies have shown to contribute to DVCs.
2. Identify and evaluate available DVC mitigation technologies and techniques.
3. Evaluate and summarize the current practices used in West Virginia for addressing DVC issues.
4. Identify DVC mitigation policies and practices, or parts thereof, from other state transportation and wildlife management agencies that would be applicable to West Virginia.
5. Summarize and rate the available mitigation technologies, countermeasures, policies, practices etc. that would apply to West Virginia and that should be considered for implementation and further study.
6. Evaluate national reports on DVC ranking methods and the statistics used for validity.
7. Evaluate and summarize the DVC data that has been collected in West Virginia and the collection methods used.
8. Conduct a Geographic Information System (GIS) analysis of DVCs in West Virginia to identify and rank hotspots, if the available data is adequate.
9. Model probable DVC locations across West Virginia to identify roadway, landscape, environmental, and traffic characteristics that contribute to DVC, if available data is adequate.
10. Identify possible funding sources at the local, state, and federal level for DVC mitigation implementation.

Findings and Recommendations

The findings and recommendations are summarized by objective.

Objective 1 . Determine the site characteristics and other variables, inclusive of all roadway types (e.g. local routes, arterials, Interstates, etc.) that national and regional studies have shown to contribute to DVCs.

Many DVC studies have been performed that evaluated the relationship of roadway, traffic, landscape, and environmental characteristics on the frequency of DVCs.

- Roadway. In general, over 89% of WVCs occur on two-lane roads whereas only 52% of all crashes (all types) occur on two-lane roads. DVCs are associated with relatively low road density. This is logical as higher road densities may not leave enough available habitat for deer to live in. While there is a shortage of data, concrete median barriers (e.g., Jersey barriers) may be a contributing factor to WVCs. While these barriers may reduce the likelihood that animals will try to cross the road (i.e. they may increase the barrier effect of roads and traffic), they may also cause the animals to spend more time on the road as they are trying to cross the barriers. While two-lane roads that have been upgraded with wider lanes, wider shoulders, and increased sight distance have improved overall safety, they tend to have an increase in WVCs. An increase in design speed of the highways was identified as the most likely explanation for the increase in WVCs. Interestingly, the vast majority (91.7%) of all WVCs occur on straight road sections with long sightlines than road sections with curves and shorter sight lines. This could be attributed to the relative frequency of these road types.
- Traffic. While it seems intuitive that higher traffic volumes result in higher numbers of DVCs, several authors have suggested the relationship between traffic volume and DVCs may be quite complex. As traffic volume increases, WVCs may increase initially, but when traffic volume reaches high levels, fewer animals attempt to cross the road, resulting in fewer DVCs. This means that at higher traffic volumes, DVCs may decrease, while the barrier effect of the road and traffic may increase (i.e., animals intentionally avoid due to fear). Though evidence is scarce, the probability of DVCs declines notably with speed limits below 45 mph.
- Landscape and Habitat. White-tailed deer occur in a wide variety of habitat types. Nonetheless, previous studies have associated DVC locations with certain landscape elements and with deer population density parameters. The location of DVCs is, in general, positively associated with edge habitat (transition cover-open habitat), proximity to forest, high landscape diversity, water, and to some degree also with development (houses), but only if sufficient green is mixed in with the houses and no physical barriers are present. Proximity of houses may also provide deer with shelter from human hunters and other predators. Larger areas of forest tend to be associated with fewer DVCs than mixed landscapes with abundant edge habitat. The effect of grasslands and croplands can be complex and partially depends on the proximity of cover (forest). Linear features (ridges, gullies) can lead deer to roads, but DVCs can also occur elsewhere in relatively high numbers.
- Deer Population. Not surprisingly, high deer density is generally associated with higher numbers of DVCs. However, driver behavior, road location, and other factors can still produce high DVCs in difference to relative deer density.

Objective 2. Identify and evaluate available DVC mitigation technologies and techniques.

DVC mitigation is classified in two general groups: 1) measures intended to modify human behavior and 2) measures intended to modify deer behavior.

- Modification of Human Behavior. The DVC mitigation measures intended to modify human behavior include posted speed limit reductions, standard signage (see Figure 2a), enhanced signage (see Figure 2b), temporal signage (see Figure 2c and d), animal detection systems (see Figure 3), vehicle-based warning systems, roadway lighting, and removal of vegetation from the road right-of-way.
- Modification of Deer Behavior. The DVC mitigation measures intended to modify deer behavior include mirrors and reflectors installed in the right-of-way, acoustic devices on cars, deer population reduction methods, and barriers along highways. There is no evidence that mirrors, reflectors, or acoustic devices are effective at modifying the deer behavior and are not considered viable mitigation methods. Deer population reduction methods have been shown to be effective, but the programs must be sustained in order to successfully reduce the herd sizes and impact DVCs. Wildlife fencing (see Figure 4) is considered to be the most effective mitigation for DVCs and should be used in conjunction with safe crossing opportunities (see Figure 5 for examples), animal escapes (see Figure 6), and proper fence end treatments .

(a) Standard

(b) Enhanced

(c) Seasonal Activation

(d) Seasonal Activation

Figure 2 Wildlife Warning Signs

(a) Triggered Enhanced Sign

(b) Triggered LED Sign

(c) Solar Powered Pole-Mounted Sensor

(d) Ground Mounted Sensor

Figure 3 Animal Detection System Components

(a) Mesh Fence with Metal and Wood Posts

(b) Electric Fence with Fiberglass Posts

Figure 4 Wildlife Fencing

(a) Wildlife Overpass in Montana

(b) Wildlife Underpass in Montana

Figure 5 Wildlife Safe Crossing Examples

(a) One-Way Gate with Curved Tines

(b) Jump Out Escape Ramp

(c) Jump-out (Upper View)

(d) Jump-out (Lower View)

Figure 6 Wildlife Escape Mechanisms Used with Fencing

Objective 3. Evaluate and summarize the current practices used in West Virginia for addressing DVCs issues.

Other than the standard deer crossing signs installed along roadways throughout the state and efforts by the WVDNR to control deer population, the only other documented DVC mitigation strategy used in West Virginia has been wildlife fencing installed on a portion of US 33.

- Location. When US 33 from I-79 to Elkins, WV was upgraded to a four-lane divided highway in 1991 (from Lorentz to Buckhannon) and 1994 (from Buckhannon to Elkins), wildlife fencing was installed along sections of the roadway in an effort to prevent deer from crossing the roadway (see Figure 7 and Figure 8). This recommendation was a result of a 3-year study initiated on I-79 by the WVDNR in 1974. The fencing begins approximately 8.2 miles east of the I-79 interchange and continues on both sides of the road for approximately 4.7 miles. Standard height right-of-way fencing is installed for the next 1.6 miles on both sides of the roadway, likely due to the presence of the interchange with US 119 in Buckhannon. The wildlife fencing was then installed for the next 14.4 miles on both sides of the roadway. The four-lane section of US 33 continues another 12.8 miles toward Elkins with standard right-of-way fencing.
- Effectiveness. Deer-vehicle crash data from police reports were analyzed for this entire segment of US 33 for the period covering 2008-2012. There were a total of 24 DVCs reported along the entire 41.7 mile segment. Of those, only 3 crashes occurred along the 19.1 miles of wildlife fencing and the other 21 occurred along the 22.6 miles that had no fencing or standard right-of-way fencing. The crash rates on segments without wildlife fencing was 4.8 DVCs per hundred million vehicle miles, which is six times higher than those segments with wildlife fencing, which had a crash rate of 0.8.

(a) Mesh Fencing with Wooden Posts

(b) Mesh Fencing with Metal Posts

Figure 7 Wildlife Fencing Used on US 33 in West Virginia

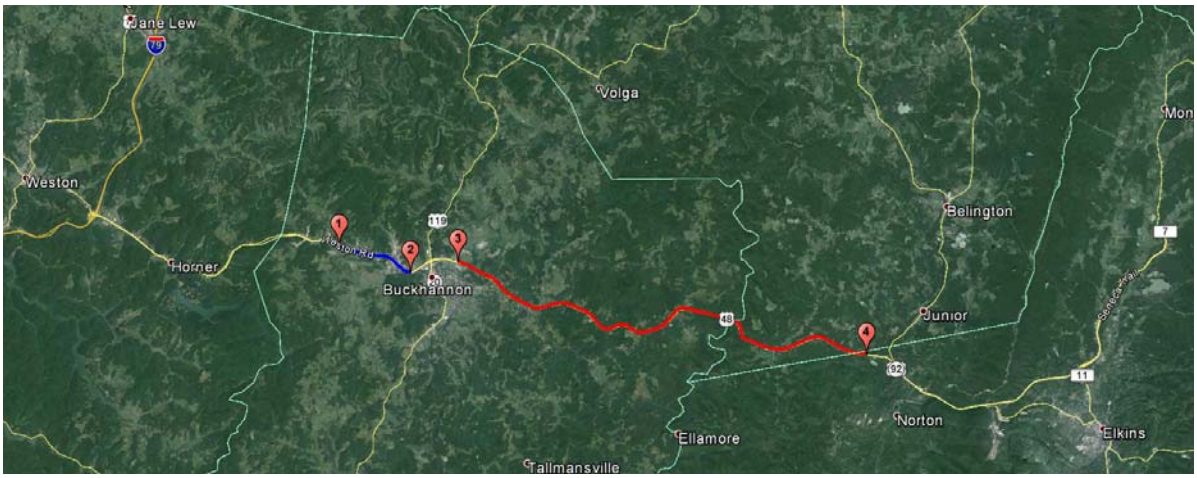

Figure 8 Fencing Location on US 33 in West Virginia

Objective 4. Identify DVC mitigation policies and practices, or parts thereof, from other state transportation and wildlife management agencies that would be applicable to West Virginia.

State transportation and wildlife management agencies in states bordering West Virginia were interviewed over the phone to obtain information regarding their policies, practices, and mitigation usage related to DVC. No new mitigation measures were identified through the interviews that were not already discussed in the literature review. It appears that the role of natural resource management agencies is to control deer population size through public hunting. The implementation of roadside mitigation measures depends on the transportation agencies. While general crash data analyses are standard to identify and prioritize road sections that may require mitigation, DVCs do not rise as a high priority because relatively few of these collisions result in human injuries and fatalities. DVCs would be better represented in the analyses if they also included vehicle repair costs, or more fundamentally, also included deer carcass removal data to account for under-reporting. This would then lead to more recognition of the DVC impact and the associated allocation of funding. However, it would involve a shift from primarily human injuries and fatalities to a more general monetary analysis. Some agencies are considering modifying their analysis process to allow for more emphasis on DVCs.

The funding of effective mitigation measures currently comes from federal sources, and implementation of these mitigation measures is typically restricted to (re)construction projects. Funding of roadside based mitigation measures is currently regarded as insufficient. In general there seems to be no high level coordination between transportation agencies and natural resource management agencies. Better coordination may lead to more population size reduction efforts through hunting in areas with high DVC

numbers. It may also lead to a shift to more effective mitigation measures as wildlife managers may be better informed about wildlife behavior and management tools than most engineers.

Objective 5. Summarize and rate the available mitigation technologies, countermeasures, policies, practices etc. that would apply to West Virginia and that should be considered for implementation and further study.

The recommendation for mitigation measures in West Virginia are based on what measures have been shown to be effective in previous documented research or show promise for effectiveness based on inconclusive data. The researchers consider wildlife fencing in combination with wildlife underpasses and overpasses the most robust mitigation measure. As long as relatively long road sections are mitigated (≥3 miles), DVCs can be expected to be reduced by at least 80%. Animal detection systems also have the potential to reduce DVCs substantially, but many projects involving these systems suffer from technical and management problems. In addition, the effectiveness of animal detection systems in reducing DVC is less predictable than the effectiveness of wildlife fencing in combination with wildlife underpasses and overpasses. Wildlife culling by sharpshooters or controlled urban archery hunts may also be successful in locations with high concentrations of deer and DVCs as long as the culling programs are sustained over a number of years. Other mitigation recommendations for West Virginia are summarized in Table 1 and Table 2. The annualized costs are based on estimates of the installation costs, maintenance costs, and removal costs at the end of the assumed life span. Each mitigation has a different assumed life span, but the analysis period for all mitigation was set to 75 years, which resulted in many mitigation types being replaced. For example, wildlife fencing only uses an assumed installation cost of $154,460/mile (fence installed on both sides of the road), maintenance of $805/mile, and removal cost of $16,010/mile. The life span of the fencing was assumed to be 25 years, which results in an annualized cost of $10,145/mile/year.

Table 1 Recommended Mitigation for WV Intended to Modify Driver Behavior (*2*)

Mitigation Measure	Estimated DVC Reduction	Robustness	Safe Wildlife Crossing Opportunity	Annualized Cost[a] ($/mi/yr)	Source(s)
Night time speed limit reduction (≤45-55 mph)	30%?	Uncertain. More data needed.	No	Unknown, but costs are very low for signs. Enforcement is likely most expensive component.	*(57)*
Wider striping, narrower lanes	?	Uncertain. More data needed.	No	Unknown, but incremental costs are likely relatively low when installed during routine re-striping.	*(58)*
Animal detection systems (most appropriate for roads with ≤10,000 vehicles per day)	33-97%	No. Many deployments fail because of technical or management problems. Nonetheless, systems that are installed successfully can detect large mammals reliably and can reduce deer-vehicle collisions.	Somewhat (drivers have been warned).	~$60,000	*(2, 71, 72, 73, 74, 75, 76, 77)*
Roadway lighting (be careful with negative side effects on wildlife)	65%?	No, more data are needed.	Somewhat (drivers can better see the animals)	Installation and operating costs for the lights are likely moderately expensive	*(90)*

[a] Includes installation cost, annual maintenance, and disposal cost converted to an annual cost over an assumed life cycle using a 3% discount rate.

Table 2 Recommended Mitigation for WV Intended to Modify Deer Behavior

Mitigation Measure	Estimated DVC Reduction	Robustness	Safe Wildlife Crossing Opportunity	Annualized Cost[a] ($/mi/yr)	Source(s)
Plant or seed native species in R/W that have low productivity and low nutritional quality	?	Uncertain. More data needed.	No	Costs are likely relatively low (seeding).	
Direct killing of deer by professionals or public hunts (if other measures are not an option and the population is small and isolated; only in very specific situation and needs to have outreach)	30-50%?	Uncertain. More data needed.	No	~$5,000 (if done by professionals)	*(2, 120)*
Wildlife fencing	79-97%	Yes, if implemented over relatively long distances (e.g. ≥3 mi)	No	~$10,145[b]	*(2, 123, 124, 125, 126, 127)*
Wildlife fencing in combination with jump-outs, gap in fence and traffic calming and standard or enhanced warning signs.	37-43%	Uncertain. More data needed.	Somewhat (drivers are warning at a specific location and vehicle speed may be lower at the crossing)	~$16,280	*(2, 69)*
Wildlife fencing in combination with jump-outs, underpasses, and/or overpasses	79-97%	Yes, if implemented over relatively long distances (e.g. ≥3 mi)	Yes	~$29,000-$39,000	*(2, 123, 124, 125, 126, 127)*
Wildlife fencing in combination with jump-outs, at grade crossing opportunity (gap in fence) with animal detection system.	33-97%	No. Many deployments fail because of technical or mgmt problems.	Somewhat (drivers have been warned).	~$45,300	*(2, 71, 72, 73, 74, 75, 76, 77)*

[a] Includes installation cost, annual maintenance, and disposal cost converted to an annual cost over an assumed life cycle using a 3% discount rate.

[b] Based on installation cost of $154,460/mile, maintenance cost of $805/mile, removal cost of $16,010/mile and a 25-year life span.

Objective 6. Evaluate national reports on DVC ranking methods and the statistics used for validity.

Based on national information provided by both State Farm Insurance and the Insurance Institute for Highway Safety, motorists in West Virginia are at a higher risk of being involved in DVCs than most states; despite the fact that West Virginia ranks from 11th to 17th in terms of total DVC estimates. These two annual reports base risk on the DVC per number of licensed drivers in the state. This study also evaluated roadway mileage, number of registered vehicles, and vehicle miles traveled as measures for normalization. Furthermore, these metrics were broken down into rural-only components to eliminate bias that occurs in states with large urbanized areas.

Table 3 lists each metric and West Virginia ranking. West Virginia still ranks first in all normalized comparisons that were drawn from the national data, except roadway mileage, before removing the urban portion of the normalizing data. When removing the large urban areas from all states, West Virginia's ranking drops, but is still in the top 5-11. Unfortunately, there is not a valid and reliable measure for performing state-by-state comparisons, although vehicle miles traveled is the most logical because it directly estimates driver exposure.

Recommendation: Any national DVC rankings and estimates should be used for informational and public education purposes only and not for decision-making purposes. The state-to-state ranking methods based on normalized rates (rather than total counts) do not adequately account for various factors that would actually cause state-to-state variations.

Table 3 Summary of West Virginia DVC Rankings by Normalization Measure

		2008-09	2010-11	2011-12	2012-13
Number of DVC Claims	Total	11th	17th	16th	17th
Per Registered Vehicle	Total	1st	1st	1st	1st
Per Square Mile Area	Total	11th	12th	11th	11th
	Rural	11th	12th	12th	12th
Per Licensed Driver	Total	1st	1st	1st	1st
	Rural	6th	7th	7th	6th
Per Roadway Mileage	Total	2nd	4th	6th	4th
	Rural	10th	11th	11th	11th
Per Vehicle Miles Traveled	Total	1st	1st	1st	1st
	Rural	3rd	6th	4th	3rd

Objective 7. Evaluate and summarize the DVC data that has been collected in West Virginia and the collection methods used.

WVC data are typically used to answer questions that relate to changes in numbers over time and spatial distribution (i.e., the location of hotspots for WVCs). It is important that the WVC data have been collected with consistent search and reporting effort over time for trend analyses and over the geographical area of interest for hotspot analyses. Police crash report data and carcass removal data collected by road maintenance crews are more likely to have the required search and reporting effort over a long time period (multiple years) and large geographical areas (e.g. a state).

At the outset of this project, it was anticipated that the carcass data reported by the WVDOT Daily Work Report – Form DOT-12 would be the main data used in the hotspot and modeling analysis because it was the data source with the highest quantity that included location information (approximately 13 times more carcass records than police DVC reports). However, after the data was reviewed, it is was clear that not all maintenance crews were recording the location information consistently, if at all. After evaluating all available data sources that contained specific crash location information, it was decided that the police crash report data would be utilized for the hotspot analysis and modeling. The location information recorded in the police crash reports contained problems that were corrected as much as possible based on the information provided. There were 6,833 DVC police reports from 2008-2012 and 90% of those had usable location information for the modeling and hotspot analysis. The location and frequency of the carcass data and police report data were analyzed to evaluate correlations, but none were found (most likely due to the deficiencies in the data).

Analysis of the West Virginia police crash report data from 2008-2012 revealed that the majority of the crashes were reported in October and November, crashes were evenly distributed across each weekday, and most crashes occurred at night. The majority of drivers involved in a DVC had a West Virginia driver's license. However, the percentage of out-of-state drivers involved in a DVC was 6% higher than the percentage of out-of-state drivers involved in all crash types in West Virginia (22% compared to 16%). Figure 9 illustrates the number of DVC by roadway type and severity. There were a total of 12 fatalities that resulted from a DVC (five on US routes, four on WV routes, and 3 on County routes), which is less than 1% of all fatal crashes (of all crash types) during that 5-year period.

Since safety-related DOT funding is based on monetary benefits, projects that reduce severe crashes tend to get the highest priority. The crash types with the highest percentage of overall fatalities in West Virginia are drivers hitting other vehicles for various reasons (31%), vehicle rollovers (16%), vehicles running off the road and hitting trees and embankments (13% and 7%), and vehicles hitting pedestrians (7%). Since most DVCs involve property damage only, it is unlikely that a DVC mitigation project would get prioritized over locations with other crash types with higher severities.

Recommendations: In order to facilitate future DVC analysis to identify hot spots and model roadway and habitat characteristics, it is recommended that the DVC data collection processes be improved. It is important for law enforcement agencies completing crash reports to collect GPS coordinates of the crash site to ensure the most accurate representation of the location. Since the quantity of carcasses picked up far exceeds the number of crashes reported, it would be ideal if the WVDOT maintenance crews could record the location of carcasses picked up in a consistent and detailed manner. While it might not be feasible for them to utilize GPS devices to record coordinates, the crews are familiar enough with the milepost numbering schemes along the routes in their jurisdiction to record those to a high degree of accuracy. It would also be beneficial to specifically add a check box on the police crash report form for the officer to indicate that a deer was involved. A free-form text box was previously added where the officer could indicate the type of animal after checking that an animal was a contributing factor. However, querying the free-form field for all variations of deer descriptions will always yield inaccuracies

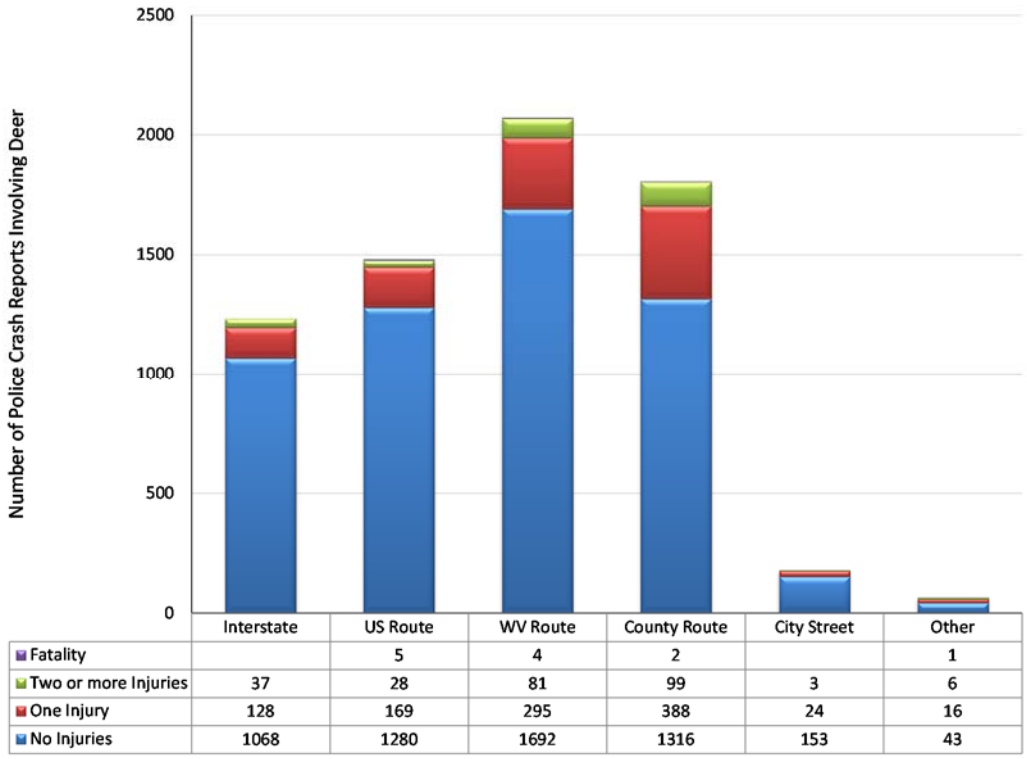

Figure 9 Deer-Vehicle Crash Reports Severity and Roadway Classification (2008-12)

Objective 8. Conduct a Geographic Information System (GIS) analysis of DVCs in West Virginia to identify and rank hotspots, if the available data is adequate.

The West Virginia roadway network was divided into 2-mile segments for hotspot analysis with the DVCs from police crash reports assigned. Hotspots were identified based on total DVC count along the 2-mile segment as well as crash rate along the 2-mile segment, which accounts for the traffic volume.

- Ranking based on count. After the frequencies were assigned to the segments, HIGH frequency segments are defined as segments that experienced 13 or more crashes over the 5 year period, MEDIUM frequency is defined as segments that experienced 3-12 crashes, and LOW frequency is defined as segments that experienced 1-2 crashes. Figure 10 illustrates these frequencies. There are a total of 3,128 Interstate, US Route, and WV Route segments statewide, which result in 0.6% of them being high, 16.9% medium, and 31.2% low. Therefore, 51.3% of the Interstate, US Route, and WV Route segments in the state did not have a documented DVC. The high DVC threshold of 13 per two-mile segment over five years (1.3 per mile per year) is slightly less than the "High" threshold applied in an Iowa study (1.75 per mile per year). Figure 11 illustrates the locations of the High, Medium, and Low frequency locations. Table 4 lists the locations and characteristics of the High frequency locations. The general locations of the High segments are

the eastern panhandle, the Summersville area in the central part of the state, the Parkersburg area in the western part of the state, and the Kanawha River Valley near Winfield in the western part of the state. The highest observed count was 22 on US-19 in Nicholas County. Figure 12, Figure 13, and Figure 14 provide zoomed views of three of the top ranked locations along with the specific locations of the police crash reports and carcass data records.

- Ranking based on crash rate. In addition to ranking segments by the total number of reported crashes, they were also ranked by the crash rate (crashes per hundred million vehicle miles traveled), which normalizes the data based on annual average daily traffic (AADT), number of years analyzed, and segment length. There are 3-10 segments that are visibly higher than the rest of the segments, with crash rates above 130 DVC per hundred million vehicle miles traveled. The majority of the top 35 sites are WV Routes, where the AADT values are much lower than the Interstates and US Routes. There are no Interstate segments in the top 35. Only two of the segments that were identified as hotspots in the previous section based on raw count are on this list: WV-62 in Mason County (ranked #2 by count and #3 by rate) and WV-9 in Jefferson County (ranked #11 by count and #20 by rate). The highest observed crash rate was 327 crashes per hundred million vehicle miles, which occurred on WV-20 in Summers County.

Recommendations: Due to some concerns with the validity of the AADT data for some roadway segments, the raw count hotspots were considered to be the more reliable list, although the ranked list by crash rate is certainly a useful tool. If a decision is made to implement mitigation, both the count and crash rate should be considered. The research team provided suggested mitigation for the highest segments based on raw count to serve as implementation examples. The process to select the segments for mitigation as well as the type of mitigation will involve a more extensive process that examines the severity of the crashes, the locations of the crashes along the segment, the site characteristics, and funding availability. Once a segment has been identified for mitigation, it is recommended that a before and after study be conducted to evaluate the mitigation effectiveness. The use of static segment lengths for the hotspot analysis is not necessarily the preferred method, but it was the only option based on the current WVDOT LRS. A recommendation for WVDOT is to complete the continuous LRS mapping in order to facilitate the application of more dynamic hotspot analysis techniques. It is also recommended that the AADT data be further evaluated to ensure that data is being collected and estimated for as many roadway segments as possible.

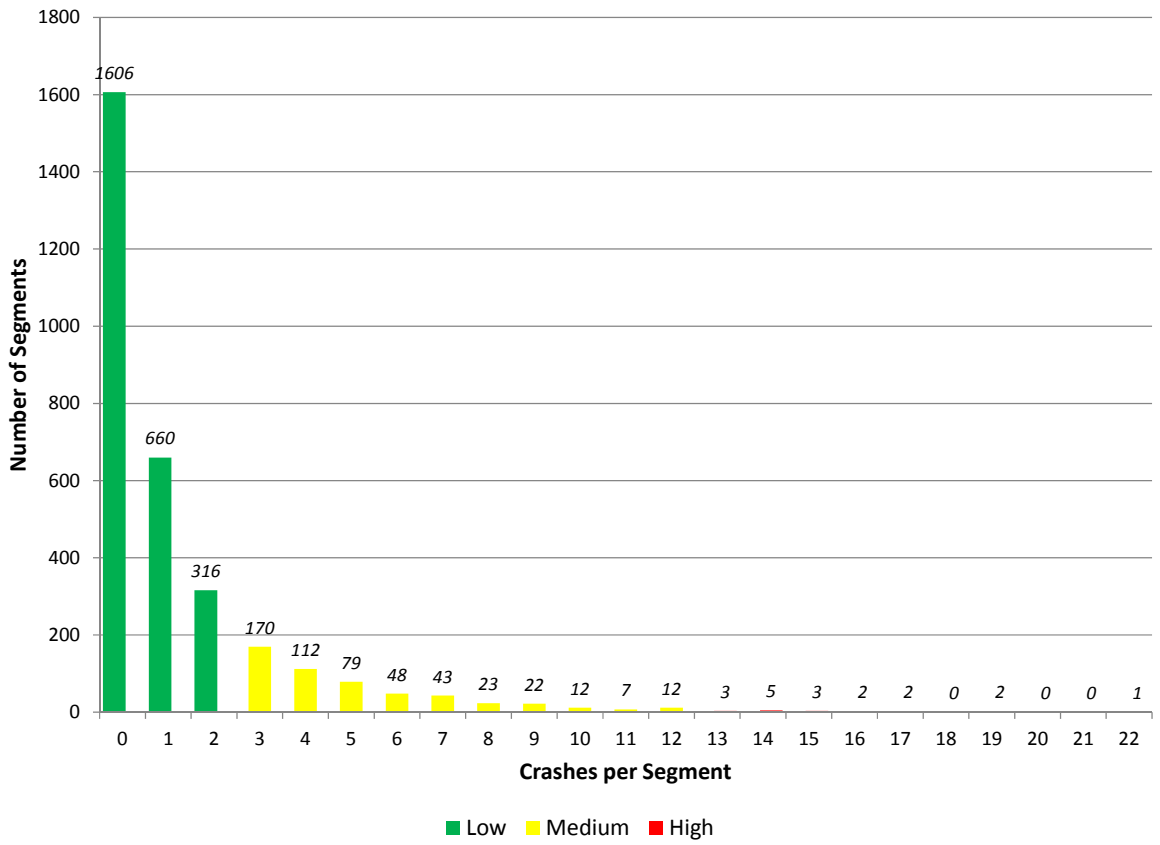

Figure 10 Frequency of DVCs per Segment (2008-2012)

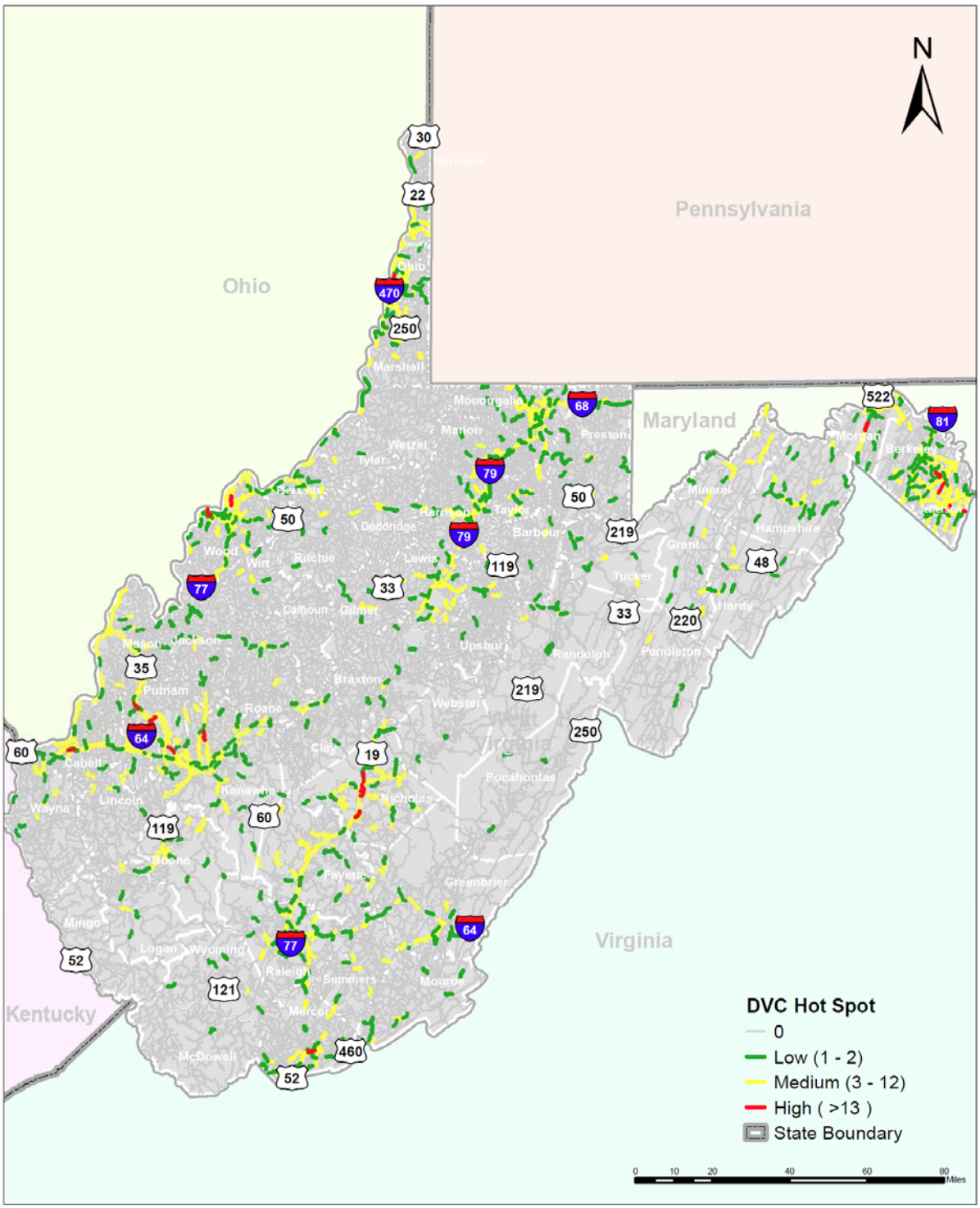

Figure 11 Location of Hotspot Segments based on Count for All Roads (2008-2012)

Table 4 Location Details of High Frequency Segments based on DVC Count

Rank	DVC Count	County	Route	Milepost Range	AADT	Crash Rate**
1	22	Nicholas	US 19	10.3-12.3	17,613	34.0
2*	19	Mason	WV 62	4.3-6.3	2,041	254.9
3	19	Kanawha	I 64	45.4-47.7	62,787	7.3
4	17	Wood	US 50	0.0-2.3	13,354	31.0
5	17	Jefferson	US 340	6.2-8.2	19,786	23.5
6*	16	Nicholas	WV 41	15.0-17.0	6,600	66.3
7	16	Cabell	US 60	10.3-12.3	22,781	19.2
8*	15	Morgan	US 522	8.2-10.2	9,355	44.0
9	15	Nicholas	US 19	14.3-16.4	13,745	29.7
10	15	Kanawha	I 77	109.7-111.7	21,438	19.1
11*	14	Jefferson	WV 9	0.0-1.66	4,972	92.9
12	14	Nicholas	US 19	4.3-6.3	12,803	29.8
13*	14	Putnam	WV 34	18.5-21.4	10,897	23.7
14	14	Mercer	US 460	12.7-14.8	16,564	23.0
15	14	Putnam	I 64	36.0-38.0	36,500	10.5
16*	13	Putnam	US 35	16.5-18.5	6,663	52.8
17*	13	Ohio	WV 2	4.6-6.6	14,433	24.7
18	13	Mercer	US 460	0.0-2.3	15,600	19.7

* Denotes 2-lane roadway

**Crash Rate = (Total # of Crashes * 10^8) ÷ (# of years * Segment AADT * Segment Length * 365)

Objective 9. Model probable DVC locations across West Virginia to identify roadway, landscape, environmental, and traffic characteristics that contribute to DVC, if available data is adequate.

Regression analysis was performed to examine the relationship of DVC presence and frequency with possible contributing factors. Since statewide DVC data was used, there wasn't a need to develop a model for prediction. Instead, the goal of the model was to identify roadway, landscape, environmental, and traffic characteristics that might be correlated to location with high DVCs. West Virginia data sets that could be converted to GIS layers were sought for this analysis and were primarily available from the U.S. Geological Society and the WVDOT Roadway Inventory Log (RIL). There were are a total of 1,150 segments on Interstate and US Routes with complete data (i.e., no missing values) and 698 segments have at least one observed crash (61%). There were 160 segments that were eliminated from the analysis because of a missing data field.

In this study, four types of models – negative binomial, zero-inflated negative binomial, two-step hurdle, and generalized additive negative binomial (GANB) – were developed to understand the factors affecting DVCs. Based on the Akaike information criterion (AIC) values, all four models performed very similarly, but the GANB yielded the best results, accounting for spatial relationships among the segments.

The variables in the GANB model and the signs of their coefficients were reasonable. As the AADT and landscape diversity increased, the expectation of a DVC increased. The presence of steep slopes on the side of the road reduced the expectation that a deer would be hit on a segment. Compared to rural areas, urban areas (defined as small towns and suburban areas around large cities) have higher expectation of crashes, while urbanized areas (defined as large city centers) have a lower expectation of crashes.

Recommendations: The modeling effort could be greatly enhanced if more complete and reliable roadway data were available in GIS format, particularly the data contained in the WVDOT RIL. Many of the roadway characteristics that were modeled in other studies and found to be significant could not be included in this study, such as sight distance (forward and to the side), geometric curvature, and shoulder width. The AADT estimates need to be reliably completed for all roadways within the state to facilitate a more reliable crash rate calculation.

Objective 10. Identify possible funding sources at the local, state, and federal level for DVC mitigation implementation.

There are a number of mitigation funding sources available at the federal and state levels. However, each funding source has different funding amounts and project requirements, so some effort is necessary to locate the appropriate funding for the appropriate project. Other states are creating partnerships among public transportation agencies, natural resource management agencies and wildlife-related private entities to help fund mitigation projects.

Recommendations: To accomplish a robust program of future DVC mitigation projects across West Virginia, it will be incumbent on WVDOT to seek a wider source of funding than that provided by traditional transportation programs. Experience in other states demonstrates that creating partnerships with allies that mutually benefit from DVC mitigation creates opportunities to tap individual, organizational, foundation and non-transportation agency sources of support. To attract the widest variety of funding from federal, state, local, and private interests it is recommended to: (a) convene a working group of allies to focus on DVC mitigation and seek priority projects that are attractive not only to WVDOT, but to others, (b) assure there are knowledgeable people that are familiar with what is needed for competitive grants to succeed with private foundations and corporations, and (c) contemplate assigning a WVDOT employee as a coordinator for a working group to facilitate meetings, communications, joint activities and fundraising.

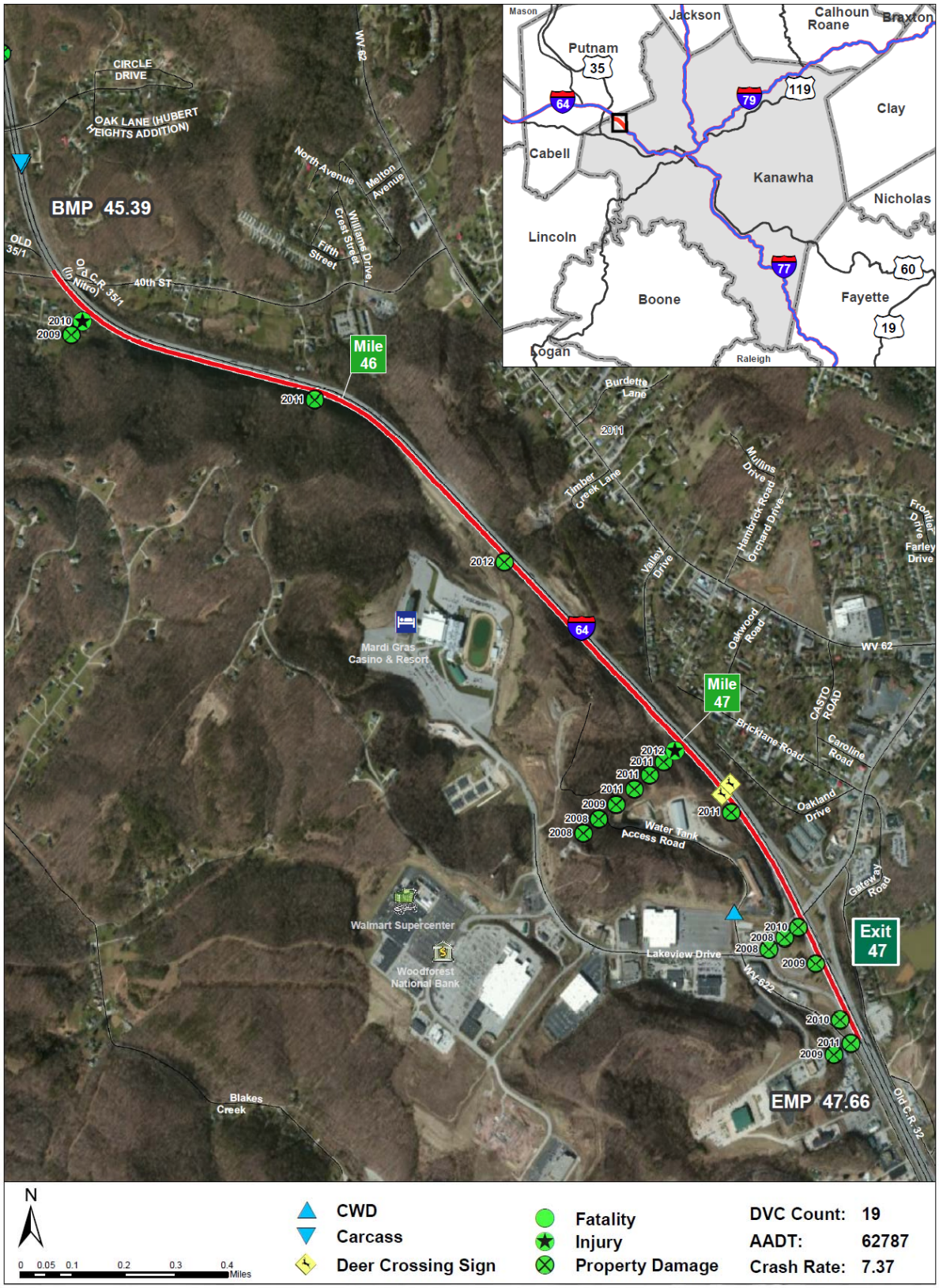

Figure 12 Enhanced Hotspot Map for I-64 from Nitro to Cross Lanes

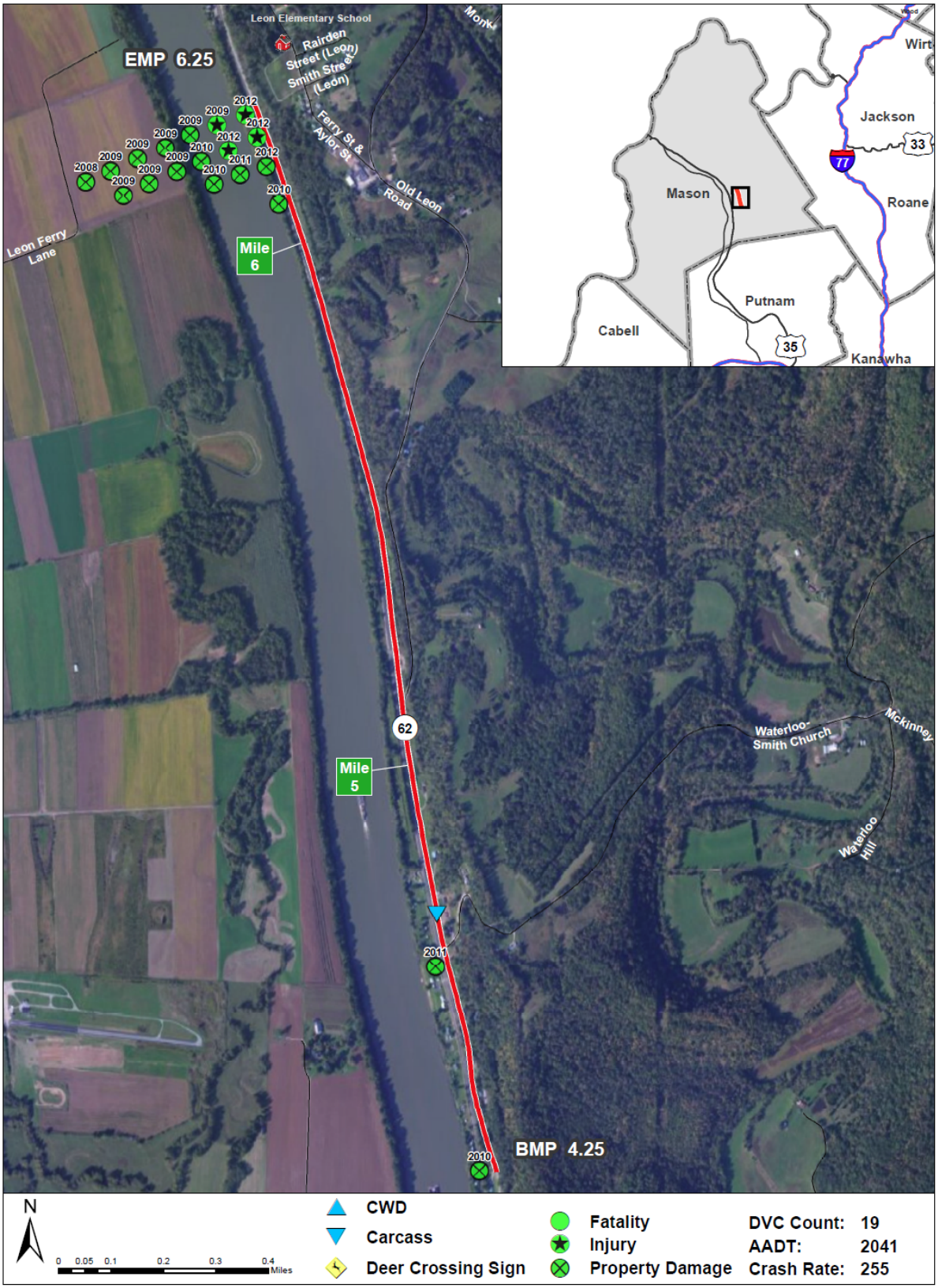

Figure 13 Enhanced Hotspot Map for WV-62 near Leon

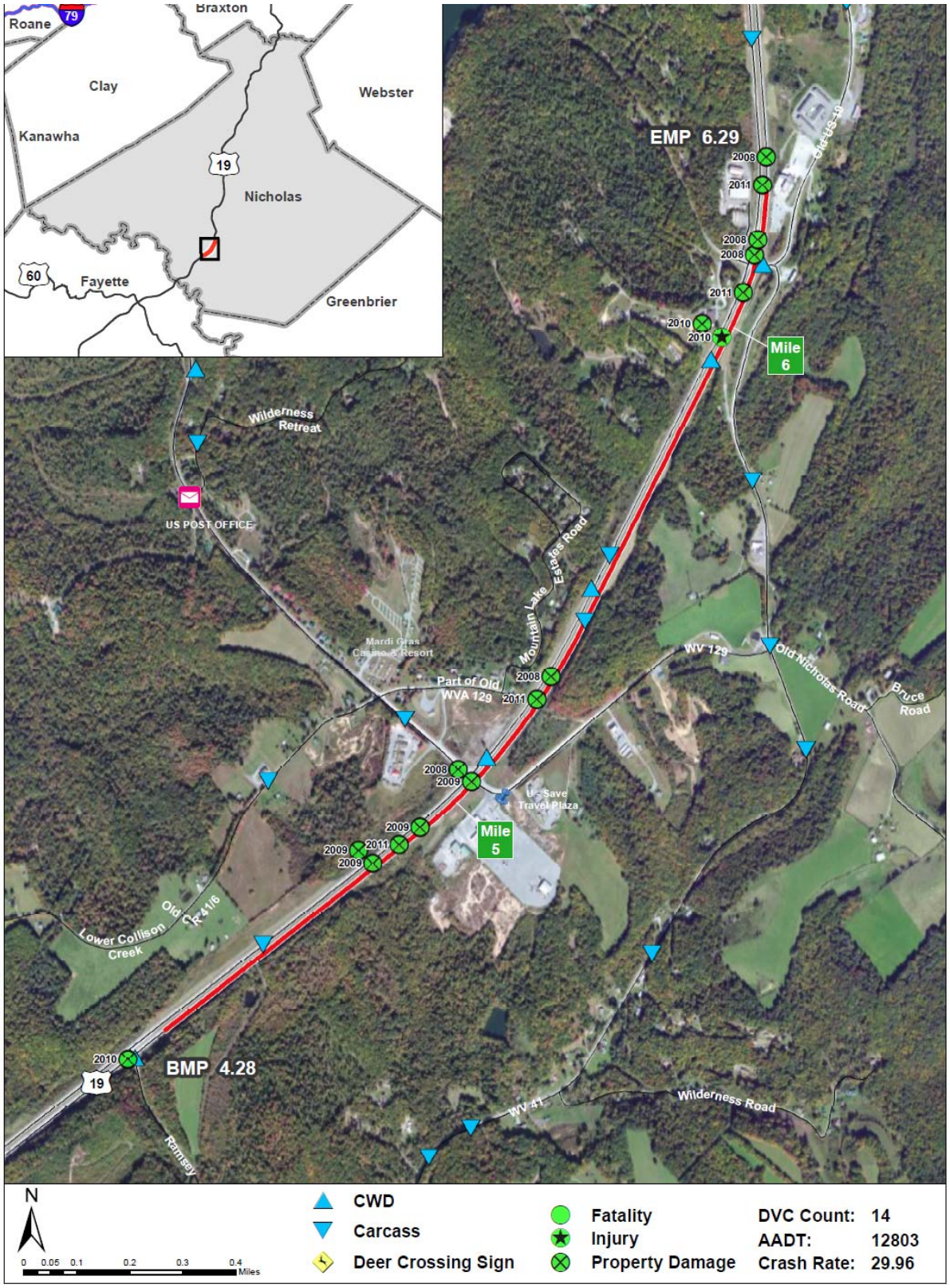

Figure 14 Enhanced Hotspot Map for US-19 near Summersville