Final Report

Contract BDV24-977-31

Investigation of Low Visibility Related Crashes in Florida

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UNITS CONVERSION

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg

T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	^oC
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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16. Abstract

Florida is among the top states in the United States with fatal crashes resulting from reduced visibility conditions due to fog or smoke, according to the National Highway Traffic Safety Administration (NHTSA). This project aims at identifying hotspot clusters for fog/smoke crashes in Florida, and investigating hot segments, hot intersections, and hot freeway/expressway ramps in the hotspot clusters. In Task 1, fog/smoke crash data of the period of 2013-2017 were collected from Signal Four Analytics. In Task 2, eight hot clusters were identified using the kernel density estimation (KDE) method, and found fog/smoke crashes are concentrated in Duval, Orange/Osceola, Pinellas/Hillsborough/Polk, Lee, Escambia, Alachua, Leon, and Miami-Dade Counties. In Task 3, the eight hot clusters identified in the previous task were examined more closely, and specific segments, intersections, and freeway/expressway ramps with frequent fog/smoke crashes were identified. Eighty-one segments, forty-nine intersections, and forty-five freeway/expressway ramps were discovered as fog/smoke crash hotspots.

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EXECUTIVE SUMMARY

Florida is among the top states in the United States with fatal crashes resulting from reduced visibility conditions due to fog or smoke, according to the National Highway Traffic Safety Administration (NHTSA). This project aims at identifying hotspot clusters for fog/smoke crashes in Florida, and investigating hot segments, hot intersections, and hot freeway/expressway ramps in the hotspot clusters. In Task 1, fog/smoke crash data of the period of 2013-2017 were collected from Signal Four Analytics. In Task 2, eight hot clusters were identified using kernel density estimation (KDE) method and found fog/smoke crashes are concentrated in Duval, Orange/Osceola, Pinellas/Hillsborough/Polk, Lee, Escambia, Alachua, Leon, and Miami-Dade Counties. In Task 3, the eight hot clusters identified in the previous task were examined more closely, and specific segments, intersections, and freeway/expressway ramps with frequent fog/smoke crashes were identified. Eighty-one segments, forty-nine intersections, and forty-five freeway/expressway ramps were discovered as fog/smoke crash hotspots. It is strongly recommended to pay attention to the identified hotspots and provide effective countermeasures, such as dynamic message sign warning messages and flashing beacons, to reduce the number of fog/smoke crashes. Effective crash prevention would also be expected from the adoption of connected vehicles to improve drivers' awareness and providing adequate advanced warning (Rahman et al., 2018; Wu et al., 2019). Especially, six segments and three intersections have been identified as hotspots for future safety countermeasures to prevent fog/smoke crashes.

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CHAPTER 1 Introduction. BACKGROUND

According to the National Highway Traffic Safety Administration (NHTSA), Florida is among the top states in the United States with fatal crashes resulting from reduced visibility conditions due to fog or smoke. In order to compare the numbers of fatal crashes related to fog or smoke of states in the country, data from NHTSA FARS (Fatality Analysis Reporting System) were collected. It was shown that Florida was the third after Texas and California in 2012-2016 with 134 crashes (Figure 1 & Table 1). Considering the fact that the population of Florida is only half of that of California, fog/smoke fatal crashes per capita of Florida is much higher than that of California, which indicates that visibility-related safety problems in Florida are quite serious.

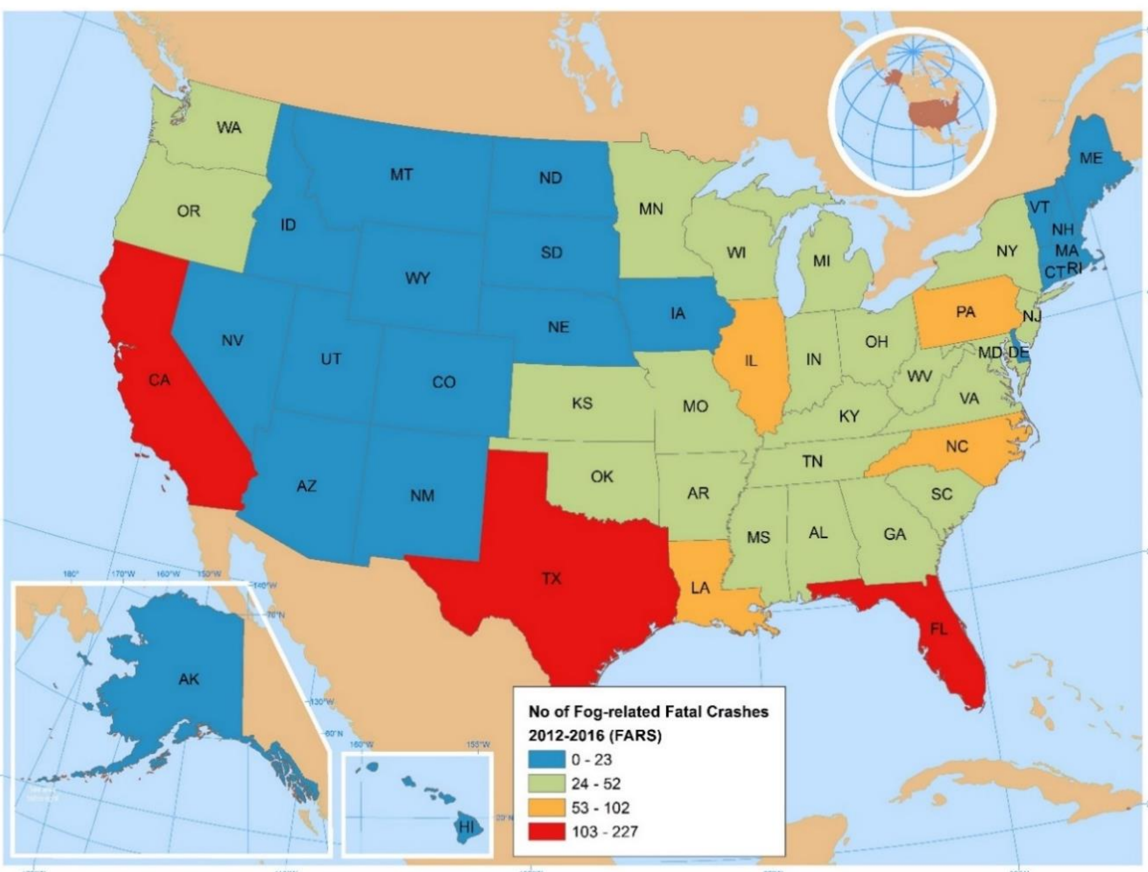


Figure 1: Spatial distribution of fog/smoke-related fatal crashes (2012-2016)

Table 1: Top five states with the most frequent fog/smoke-related fatal crashes

No.	State	Fog/Smoke Fatal Crashes
1	Texas	227
2	California	139
3	**Florida**	**134**
4	Pennsylvania	102
5	North Carolina	75

To alleviate safety problems caused by fog/smoke crashes, it would be essential understand the specific locations with visibility-related safety issues. In order to identify macro-level and micro-level hotspots, it is the first step to collect the most recent crash and network data. Therefore, the primary goals of the project is as follows:

- Task 1: Collect the most recent fog/smoke crash data from FDOT CARS (Crash Analysis Reporting Systems) and/or S4A (Signal Four Analytics) (Chapter 3)
- Task 1: Collect the relevant network and zone data to identify hotspots (Chapter 3)
- Task 2: Identify fog/smoke crash hotspots at macroscopic level using Kernel Density Estimation (KDE) and/or other methodologies (Chapter 4)
- Task 3: Identify fog/smoke crash hotspots at microscopic level (i.e., segment, intersection, and ramp) (Chapter 5)
- Task 4: Summarize the hotspot identification results (Chapter 6) and submit the draft final report
- Tasks 5: Submit the final report

CHAPTER 2. KICKOFF TELECONFERENCE

On October 24, 2018, the kickoff teleconference was held for presenting an overview of the project. The list of attendees from the Florida Department of Transportation (FDOT) and the University of Central Florida (UCF) is as follows:

- Fred Heery, P.E. (Project Manager, FDOT State TSM&O Program Engineer)
- David Sherman (FDOT Research Performance Coordinator)
- Javier Ponce, P.E. (FDOT State Traffic Studies Engineer)
- Mohamed Abdel-Aty, Ph.D., P.E. (Principal Investigator, UCF Professor & Chair of the Department of Civil, Environmental and Construction Engineering)
- Jaeyoung Lee, Ph.D. (Principal Investigator, UCF Assistant Professor)

Dr. Mohamed Abdel-Aty delivered a presentation that includes expected project benefits, introduction, project background, objectives, task outline, and project timeline. Only one question was asked from the FDOT: Is there any plan to use data from other sources such as weather data? Dr. Abdel-Aty answered: The project will mainly focus on collecting and analyzing crash data; but we might consider collecting additional data such as NOAA (National Oceanic and Atmospheric Administration). There was no further question. The FDOT attendees were very satisfied with Dr. Abdel-Aty's presentation and the kickoff teleconference was concluded.

CHAPTER 3. TASK 1: COLLECTION OF FOG/SMOKE CRASH AND NETWORK DATA

The first task involves collecting data for the project. The required data includes fog/smoke crash and network data. Fog/smoke data of the recent five years were collected (2013-2017) from the Signal Four Analytics (S4A). Network data consist of segments, intersections, and ramps. The network data were obtained from the FDOT's Transportation Data and Analytics Office.

3.1 Fog/Smoke Crash Data

This section pertains to the data collection and processing of fog/smoke crash data. The crash data of the recent five years (2013-2017) were acquired from the S4A. Overall, 9,871 crashes related to fog/smoke occurred during the three years. The collected data were processed for the GIS and preliminary analyses. Figure 2 presents the monthly distribution of the fog/smoke crashes. They are mostly concentrated from December to March. Especially, fog/smoke crashes occurred the most frequently in December (26%).

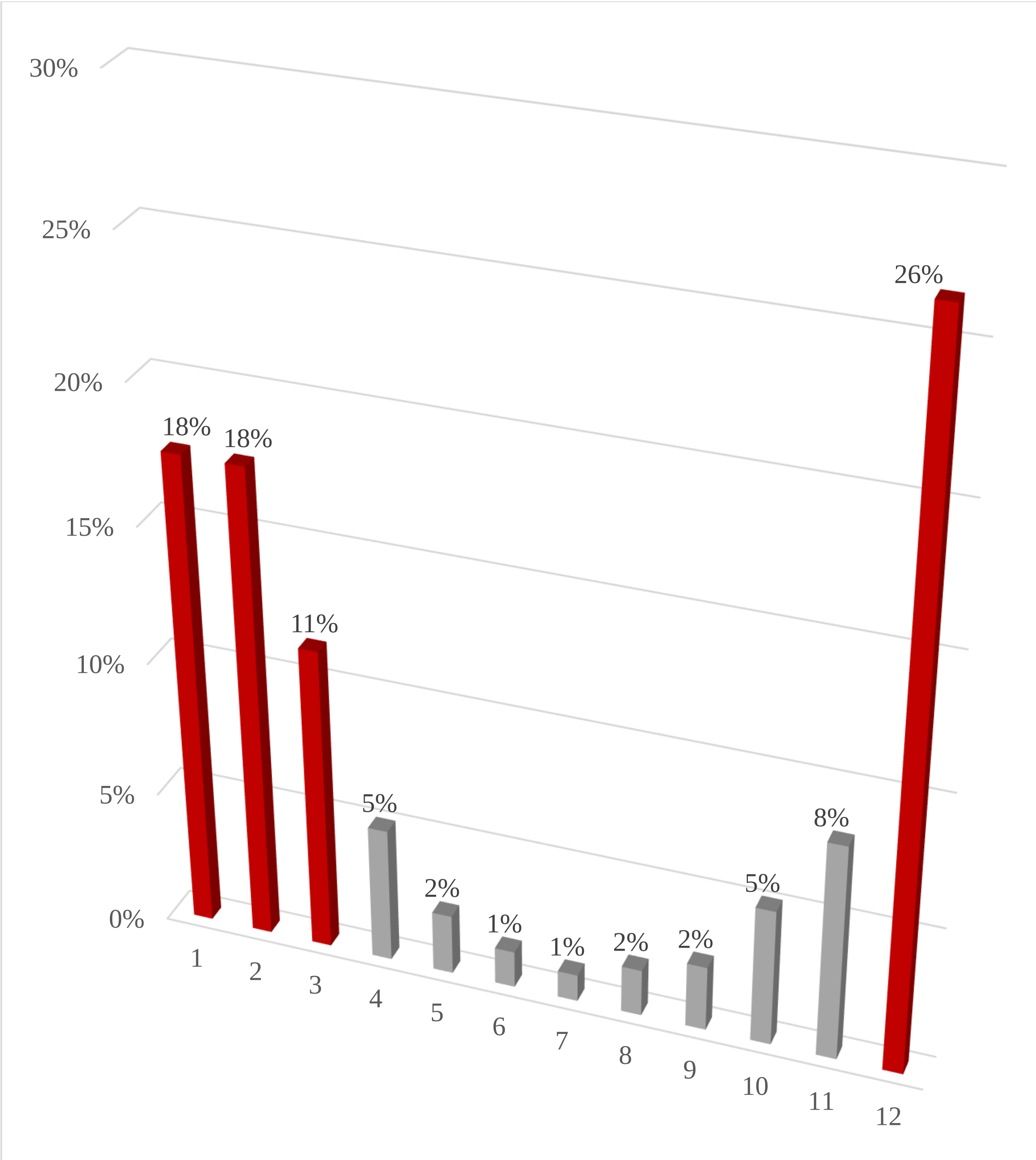


Figure 2: Monthly distribution of fog/smoke crashes

Figure 3 shows the hourly distribution of fog/smoke crashes. As seen in the chart, fog/smoke crashes often happened between 5 and 8 AM. Particularly between 6 and 7 AM, almost half of fog/smoke crashes occurred (46%).

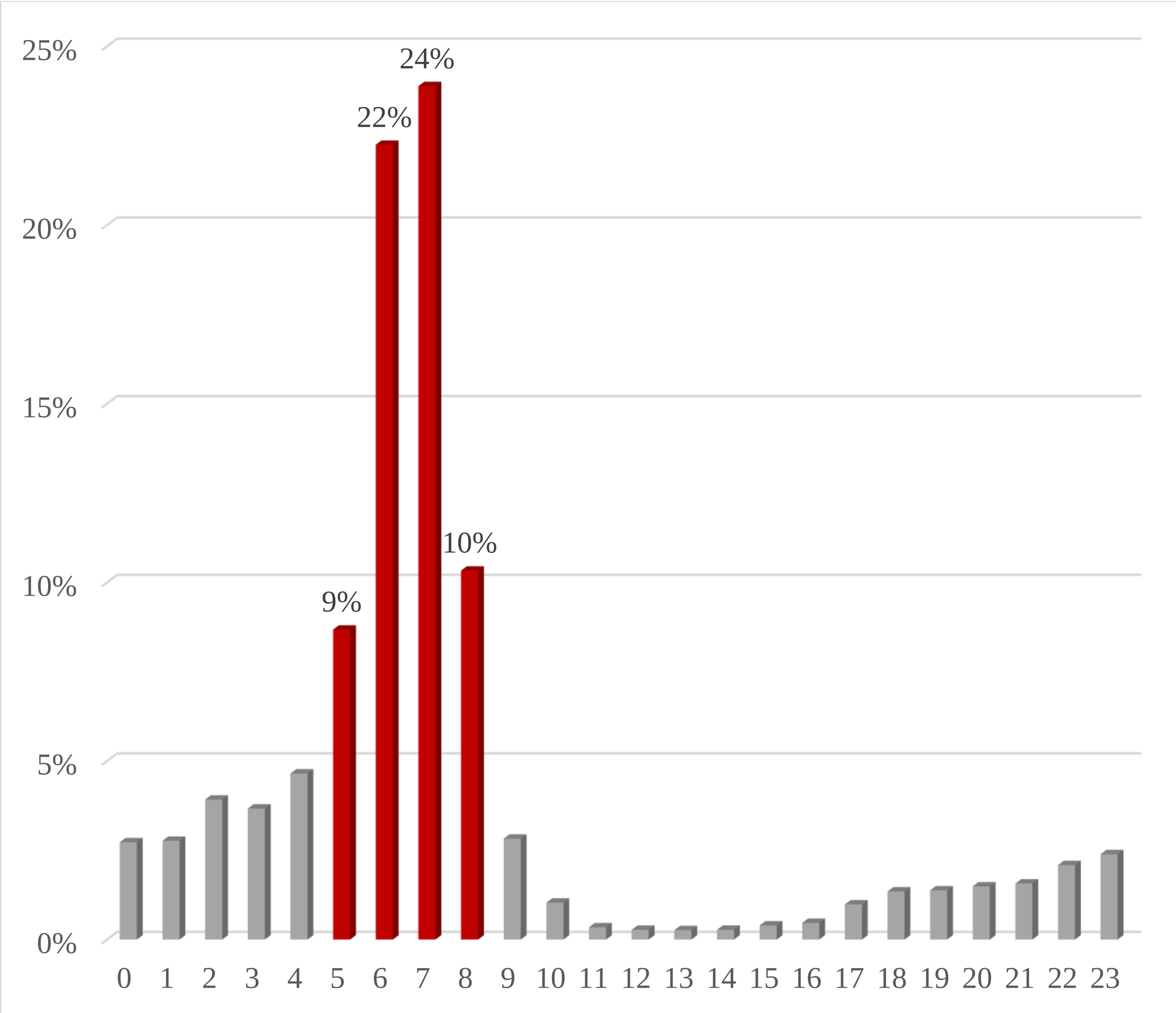


Figure 3: Hourly distribution of fog/smoke crashes

Table 2 summarizes the distribution of the fog/smoke crashes by road system. It was shown that the majority of fog/smoke crashes occurred on low-speed road systems (i.e., local, county, and state roads). On the other hand, the number of fog/smoke crashes occurring on high-speed road systems including U.S., interstate, and turnpike/toll roads are relatively small.

Table 2: Fog/smoke crashes by road system

Road System	Frequency	Percent
Local	2,419	24.5%
County	2,345	23.8%
State	2,248	22.8%
U.S.	1,211	12.3%
Interstate	920	9.3%
Parking Lot	419	4.3%
Turnpike/Toll	149	1.5%
Private Roadway	81	0.8%
Forest Road	5	0.1%
Other	74	0.8%
Total	**9,871**	**100%**

The distribution of fog/smoke crashes by facility type is shown in Table 3. The majority of fog/smoke crashes happened not at intersection (~67%). Non-intersection locations include segments and ramps. Approximately 31% of fog/smoke crashes occurred on intersections.

Table 3: Fog/smoke crashes by facility type

<table>
<tr><th colspan="2">Facility Type</th><th>Frequency</th><th>Percent</th></tr>
<tr><td colspan="2">Not at Intersection
(i.e., segment or ramp)</td><td>6,626</td><td>67.1%</td></tr>
<tr><td rowspan="6">Intersection</td><td>Four-Way</td><td>1,616</td><td>16.4%</td></tr>
<tr><td>T-Intersection</td><td>1,303</td><td>13.2%</td></tr>
<tr><td>Y-Intersection</td><td>67</td><td>0.7%</td></tr>
<tr><td>Roundabout</td><td>28</td><td>0.3%</td></tr>
<tr><td>Traffic Circle</td><td>6</td><td>0.1%</td></tr>
<tr><td>Five-Point, or More</td><td>2</td><td>0.02%</td></tr>
<tr><td colspan="2">Other</td><td>223</td><td>2.3%</td></tr>
<tr><td colspan="2">Total</td><td>6,463</td><td>100%</td></tr>
</table>

Table 4 summarizes the crash type of the fog/smoke crashes. Rear-end was the most common type in fog/smoke crashes (27.7%) and it was followed by off-road (18.8%) and single vehicle (8.3%), which are considered to be directly related to the low-visibility conditions.

Table 4: Fog/smoke crashes by type

Crash Type	Frequency	Percent
Rear-end	2,734	27.7%
Off-road	1,855	18.8%
Single Vehicle	822	8.3%
Same Direction Sideswipe	643	6.5%
Right Angle	540	5.5%
Animal	529	5.4%
Parked Vehicle	523	5.3%
Left Entering	483	4.9%
Rollover	292	3.0%
Left Rear	185	1.9%
Backed Into	176	1.8%
Pedestrian	139	1.4%
Unknown	135	1.4%
Head On	133	1.3%
Left Leaving	129	1.3%
Opposing Sideswipe	117	1.2%
Right/Through	85	0.9%
Bicycle	73	0.7%
Right/Left	14	0.1%
Other	264	2.7%
Total	**9,871**	**100%**

Figure 4 displays the spatial distribution of fog/smoke crashes by county. The counties with frequent fog/smoke crashes include Duval, Hillsborough, Orange, and Polk. On the other hand, northwestern and central south rural areas have less fog/smoke crashes.

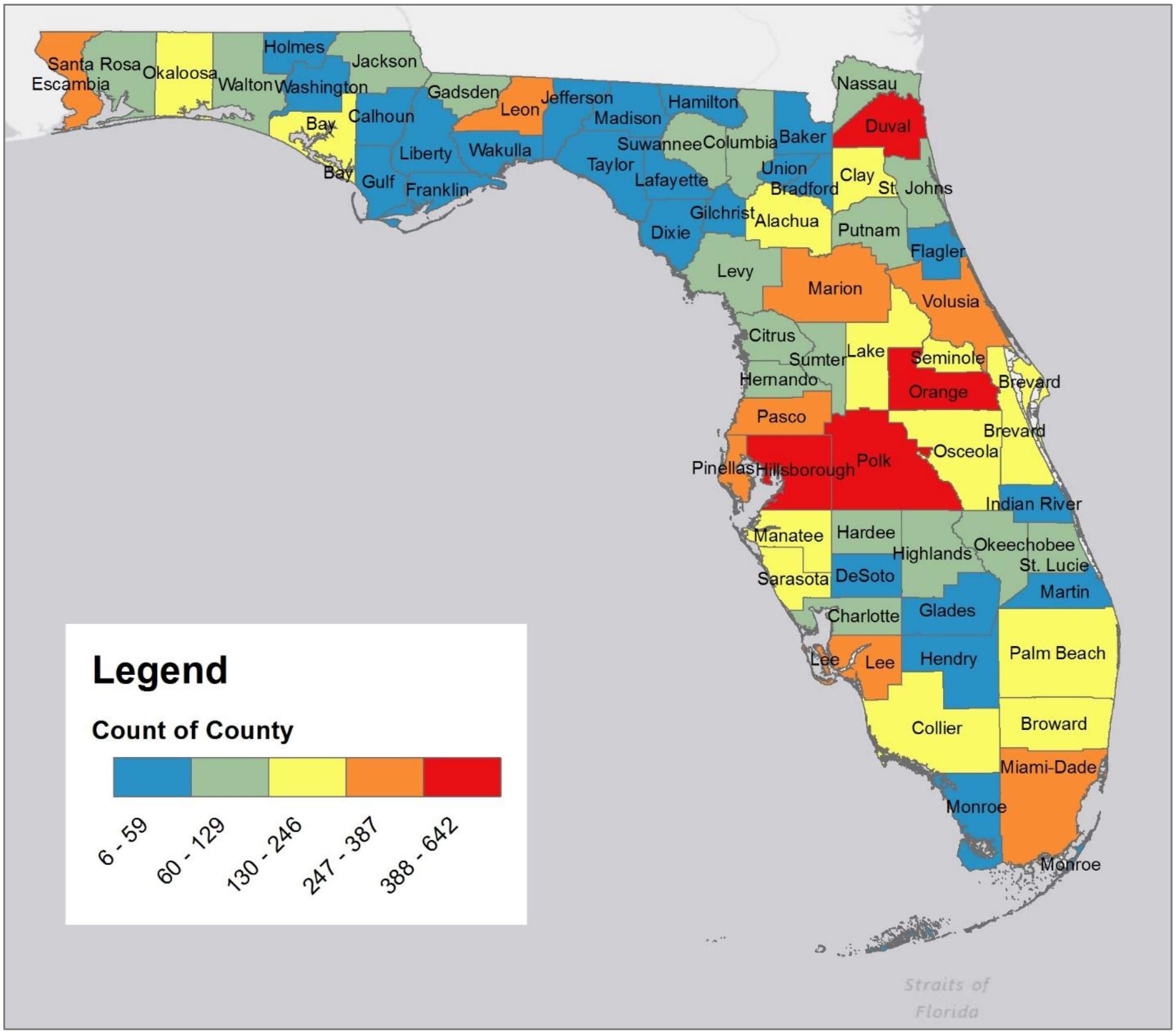


Figure 4: Geographic distribution of fog/smoke crashes by county

The specific location of fog/smoke crashes were identified from coordinates (i.e., latitudes and longitudes), as shown in Figure 5. The specific crash locations will be used for Task 2: Identification of Macro-level Hotspots and Task 3: Identification of Micro-level Hotspots. Overall, 786 fog/smoke crashes without coordinates or with incorrect location (e.g., middle of the sea) were removed. Thus, 9,103 fog/smoke crashes will be used for Tasks 2 and 3.

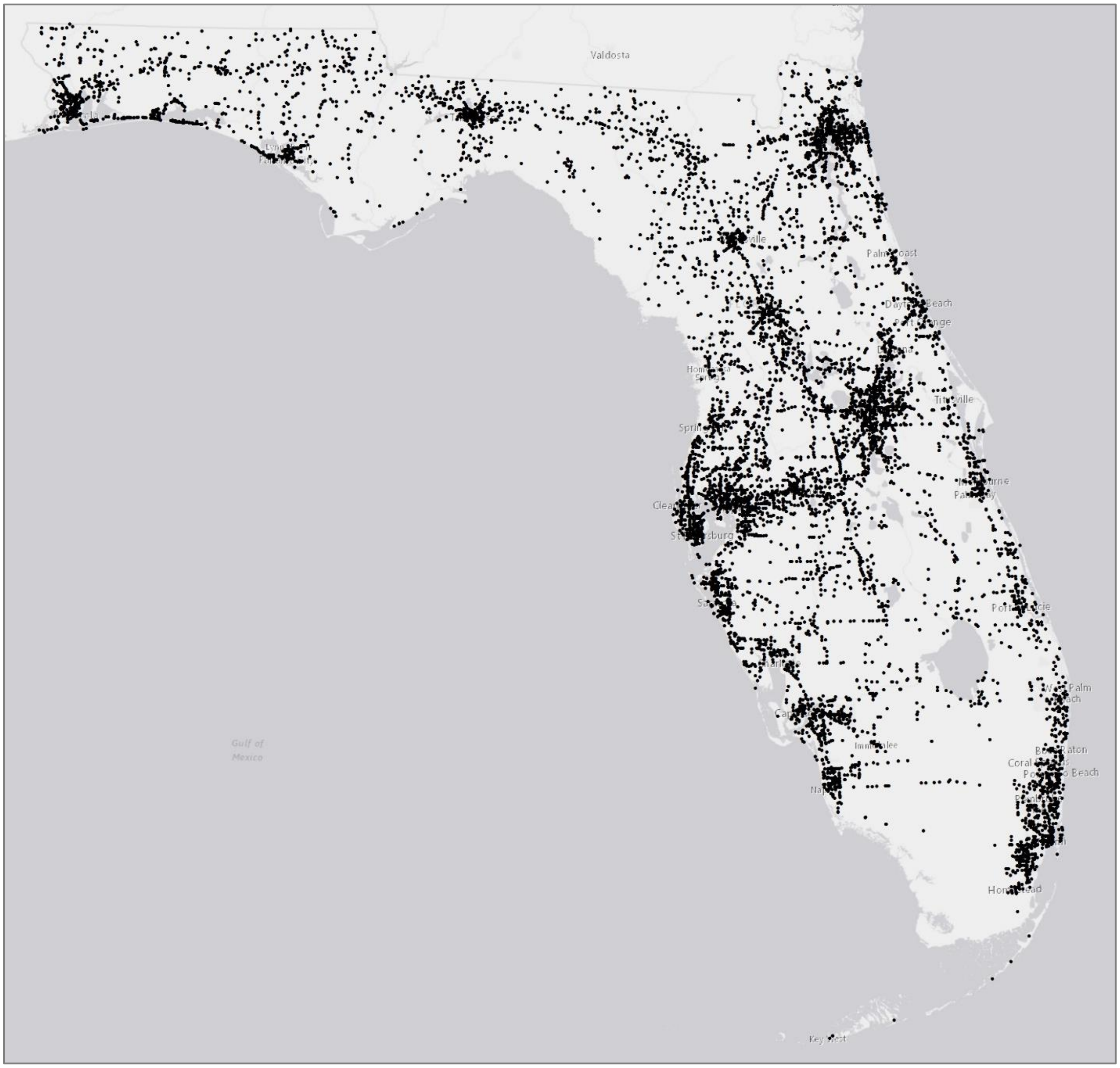


Figure 5: Fog/smoke crash locations

3.2 Network Data

Task 2: Identification of Macro-level Hotspots will adopt kernel density estimation (KDE), which will not require spatial units or network data because the method solely requires the point data (i.e., crash location). In contrast, Task 3: Identification of Micro-level Hotspots will require network data, which consist of segments, intersections, and ramps. In Task 3, hotspots will be identified based on the network data. From the FDOT's Transportation Data and Analytics Office, roadway segments and intersections were collected. The roadway segments were classified into typical segments and interstate highway/expressway ramp sections (Figures 6 and 7). The typical segments were divided into one-mile segments. The intersections are shown in Figure 8.

Figure 6: Roadway segments in Florida (one-mile basis)

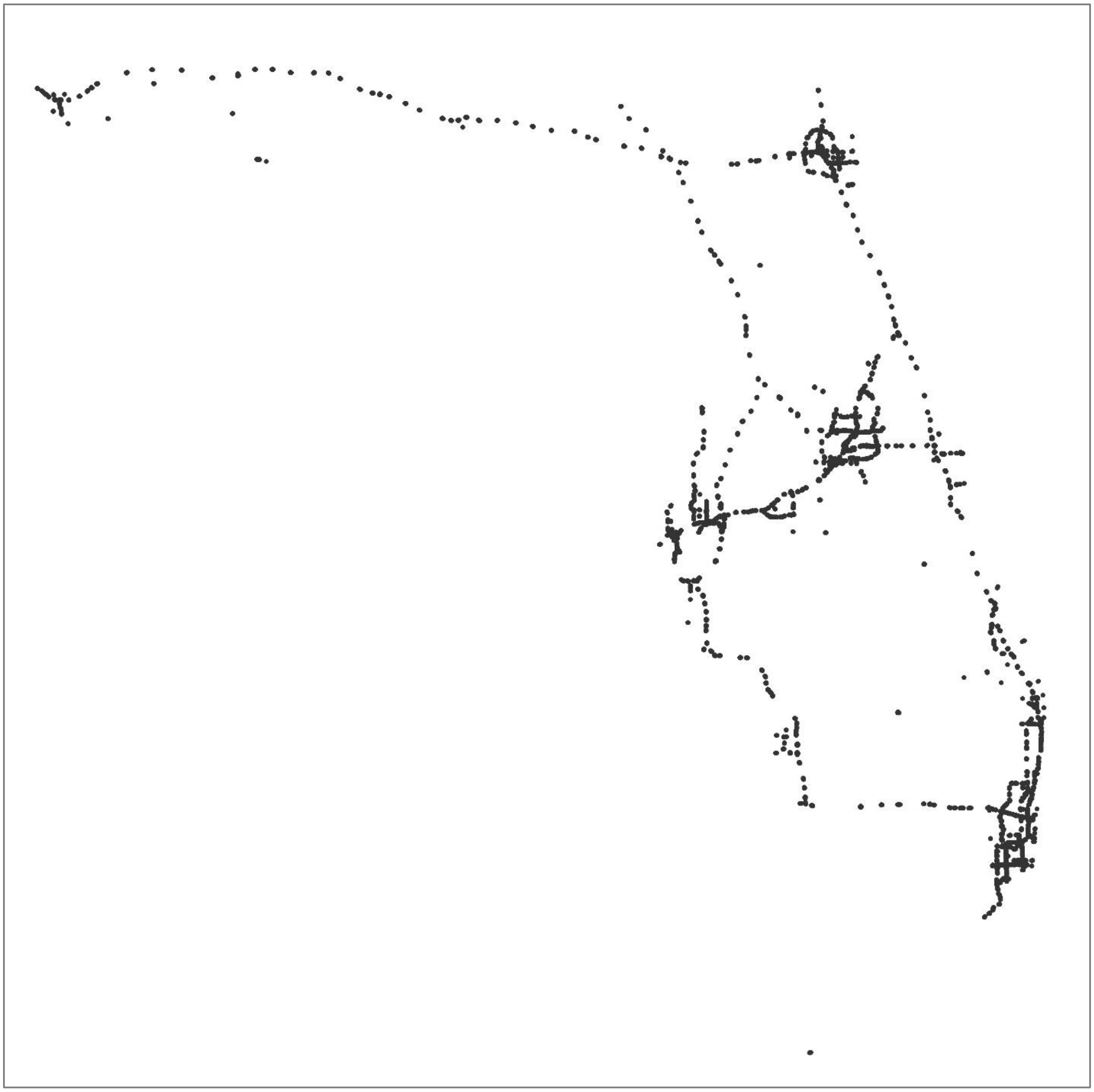


Figure 7: Interstate highways/expressway ramps in Florida

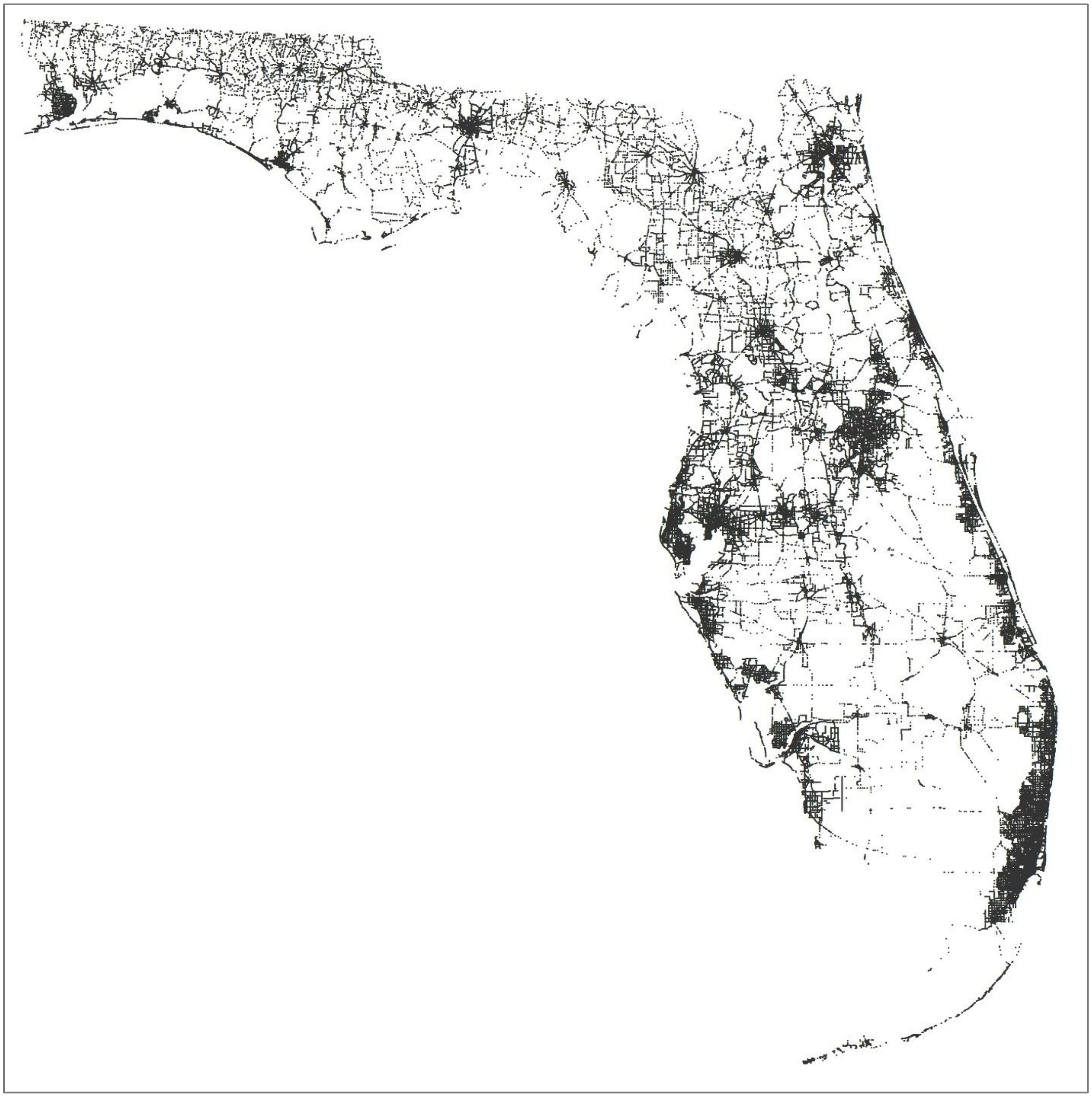


Figure 8: Intersections in Florida

CHAPTER 4. TASK 2: IDENTIFICATION OF MACRO-LEVEL HOTSPOTS

The second task is to identify macro-level hotspots for fog/smoke crashes in Florida. Fog/smoke data of the recent three years were used (2013-2017) that were collected from the Signal Four Analytics database in Task 1.

4.1 Methodology

In order to identify hotspots for fog and smoke crashes, the statewide map with frequent fog and smoke crash clusters was presented for better visualization and understanding of the spatial distribution of fog and smoke crashes using kernel density estimation (KDE). The KDE defines the spread of risk as an area around a defined cluster in which there is an increased probability of a crash to occur based on spatial dependency. In places a symmetrical surface over each point and then evaluates the distance from the point to a reference location based on a mathematical function and then sums the value for all the surfaces for that reference location. This procedure is repeated for successive points, which allows us to place a kernel over each observation, and summing these individual kernels gives us the density estimate for the distribution of crash points (Fotheringham et al. 2000).

$$f(x, y) = \frac{1}{nh^2} \sum_{i=1}^{n} K \left(\frac{d_i}{h} \right)$$

where f (x, y) is the density estimate at the location (x, y); n is the number of observations, h is the bandwidth or kernel size; K is the kernel function; and di is the distance between the location (x, y) and the location of the *i*th observation. The main objective of placing these kernels over the crash points is to create a smooth, continuous surface. Around each point at which the indicator is observed, a circular area (i.e., kernel) of defined bandwidth is created. This takes the value of the indicator at that particular point spread into it according to some appropriate function. Then it sums up all these values at all places, including those at which no incidences of the indicator variable were recorded, and gives a surface of density estimates. ESRI ArcMap (10.3.1) spatial analyst tool was used for the KDE analysis.

4.2 KDE analysis of fog/smoke crashes

Table 5 summarizes the locations of fog/smoke crash hotspot clusters from the KDE analysis and Figure 1 displays the statewide map with clustering output from the KDE. The KDE method presented seven distinctive fog/smoke crash hotspot clusters in Florida. The colors represent the density of fog/smoke crashes per square mile area. The uncovered seven clusters are associated with fog/smoke crash densities above 0.3 crashes per square mile. The most dangerous cluster has fog/smoke crash densities almost 1.0 crashes per square mile (Duval County).

Table 5: Summary of fog/smoke crash hotspot clusters in Florida (2013-2017)

Cluster No.	County	Area
1	Duval	The center of Duval County
2	Orange and Osceola	Extends from the center of Orange to the northern part of Osceola
3	Pinellas, Hillsborough and Polk	Ranges from the eastern part of Pinellas to the western part of Polk
4	Lee	The center of Lee County
5	Escambia	The southern part of Escambia
6	Alachua	The center of Alachua County
7	Leon	The center of Leon County

8	Miami-Dade	The eastern part of Miami-Dade

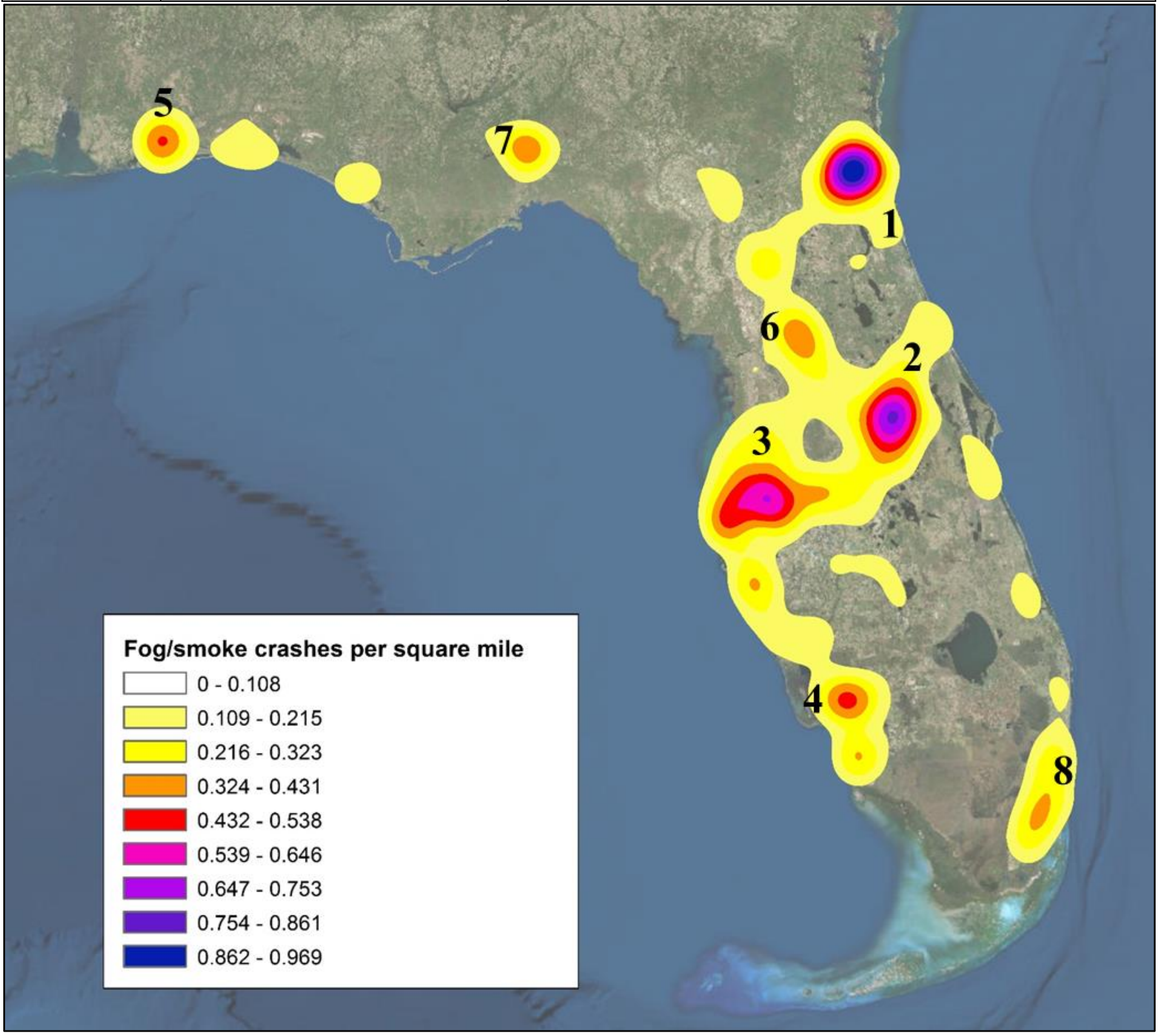
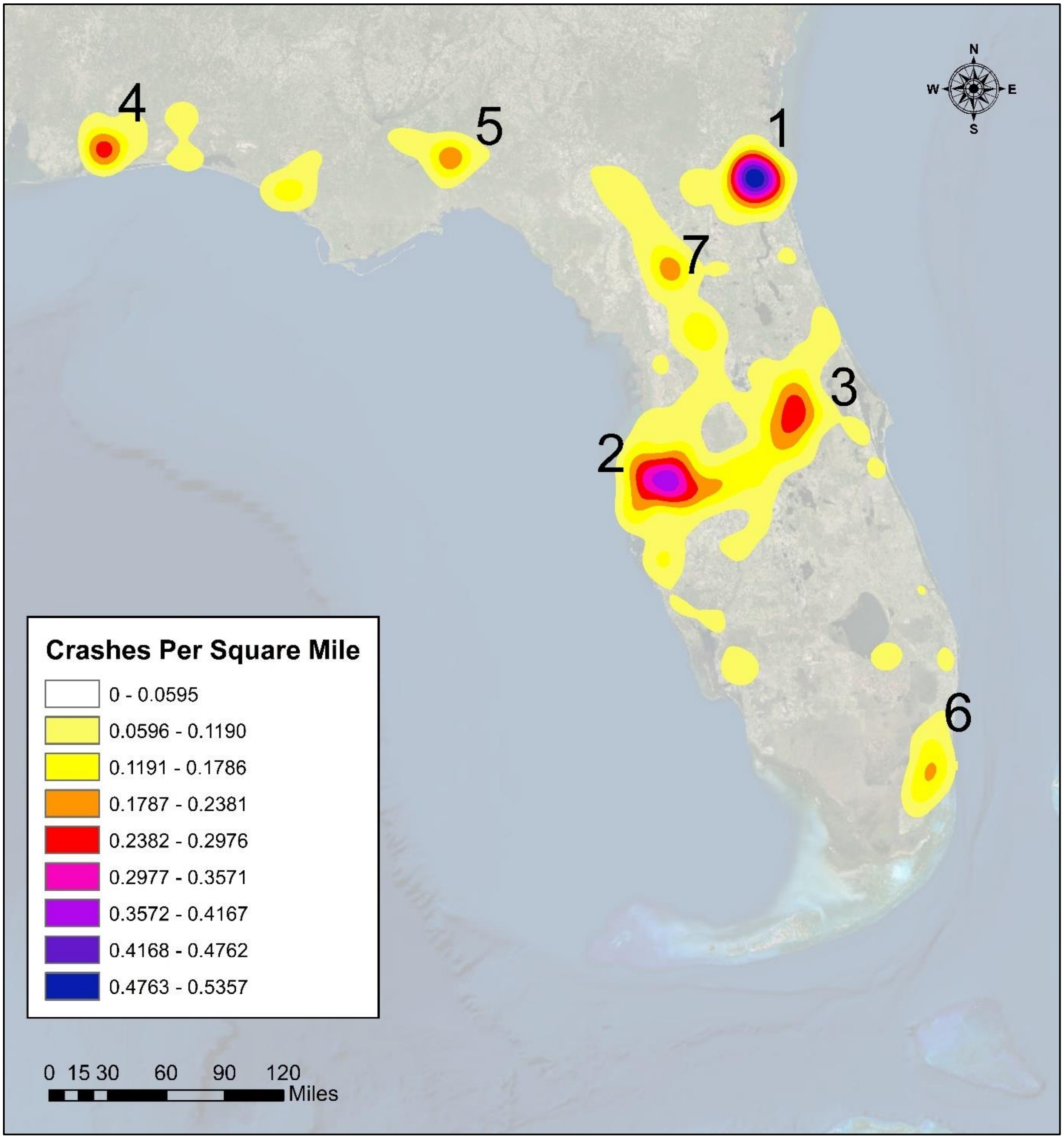


Figure 9: KDE Analysis of fog/smoke crash hotspots clusters (2013-2017)

The most dangerous clusters for fog/smoke crashes during the five years (2013-2017) are Duval, Orange/Osceola, and Pinellas/Hillsborough/Polk Counties. In addition, Lee, Escambia, Alachua, Leon, and Miami-Dade Counties were selected for fog/smoke crash hotspots. The identified hotspot clusters are quite consistent with the county-level fog/smoke crash frequency-based hotspots (Figure 4).

In the previous research project of the Florida Department of Transportation, titled: “Phase II: Real Time Monitoring and Prediction of Reduced Visibility Events on Florida’s Highways” (BDV 24 TWO 962-02), the same KDE method was applied for fog-related crashes occurring between 2008 and 2012. The previously revealed fog/smoke hotspot clusters include Duval, Hillsborough/Pinellas/Pasco, Polk/Osceola, Escambia, Leon, Miami-Dade/Broward and Alachua Counties (Figure 10).

The significant changes between the two periods are Lee County. In the period of 2008-2012, Lee County did have obvious problems with fog/smoke crashes; however, Lee County was identified as one of the clusters with hotspots for fog/smoke crashes in the period of 2013-2017.



Source: Final Report of Phase II: Real Time Monitoring and Prediction of Reduced Visibility Events on Florida's Highways (BDV 24 TWO 962-02)

Figure 10: KDE Analysis of fog/smoke crash hotspots clusters (2008-2012)

CHAPTER 5. TASK 3: IDENTIFICATION OF MICRO-LEVEL HOTSPOTS

In the previous second task, eight hot clusters for fog/smoke crashes were identified using the kernel density estimation (KDE) method (Figure 9). The third task was to zoom in the hot clusters and investigate fog/smoke crash hotspots from segments, intersections, and freeway/expressway ramps.

5.1 Segment-level screening for fog/smoke crashes

The research team magnified the eight hot clusters for fog/smoke crashes, and the number of fog/smoke crashes was counted based on the segments that were divided into one-mile sections. A segment with repeated fog/smoke crashes (i.e., two or more fog/smoke crashes) was defined as a hot segment in the segment-level screening. In total, 81 segments were revealed as hot segments for fog/smoke crashes from the eight hot clusters.

Cluster 1 Duval County

Cluster 1 covers the center of Duval County. Overall, 14 segments were discovered as hot segments for fog/smoke crashes (Figure 11 and Table 6). It is noted that two hot segments have three fog/smoke crashes and other hot segments have two crashes per mile.

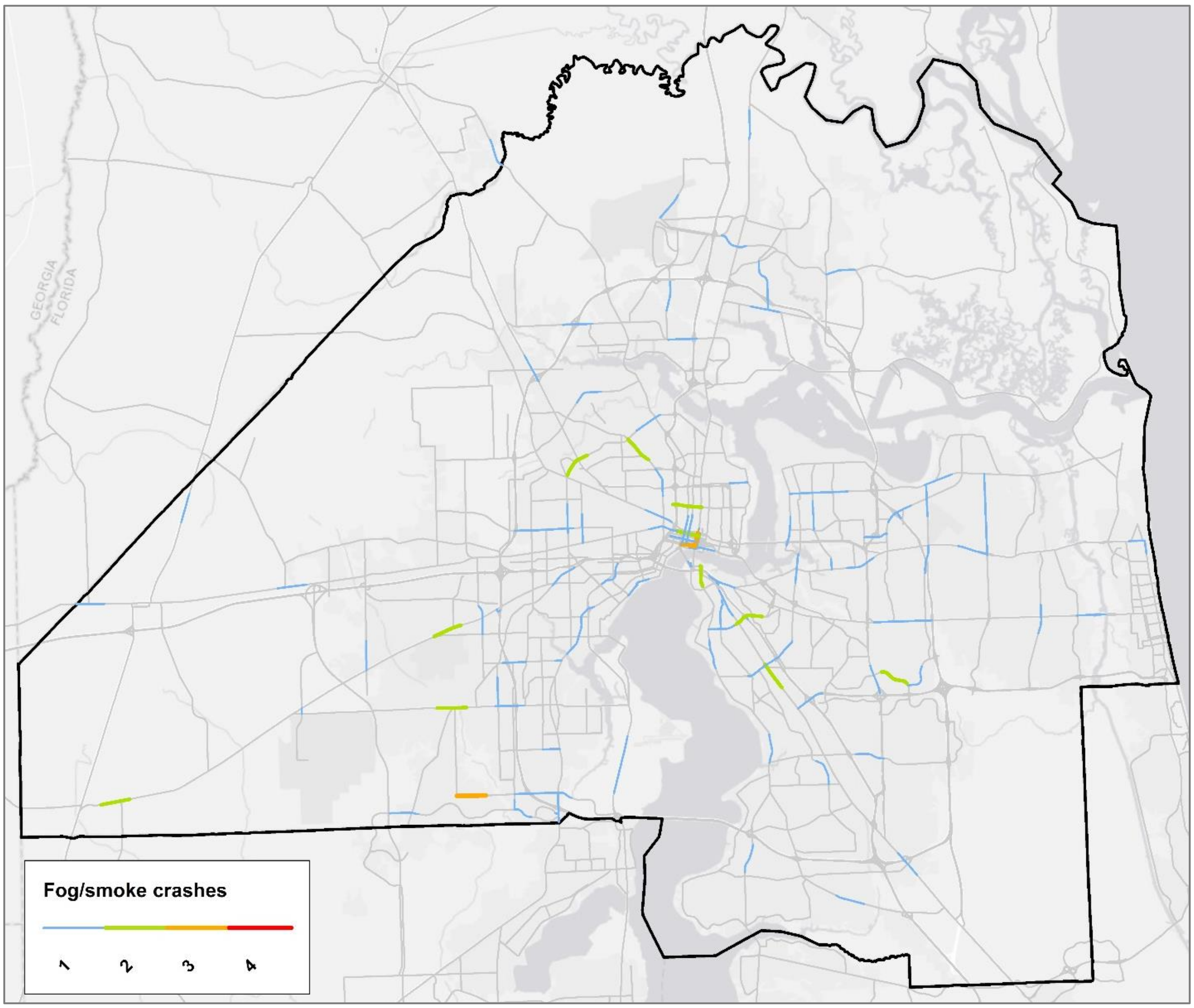


Figure 11: Hot segments for fog/smoke crashes in Cluster 1

Table 6: Hot segments for fog/smoke crashes in Cluster 1

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Duval	72050443	0.000	1.000	3
Duval	72800000	0.000	1.000	3
Duval	72000281	3.000	4.000	2
Duval	72070443	0.000	1.000	2
Duval	72070000	13.000	14.000	2
Duval	72005000	0.000	1.000	2
Duval	72010000	21.000	22.000	2
Duval	72291000	6.004	7.000	2
Duval	72220000	5.000	6.000	2
Duval	72015000	1.000	2.000	2
Duval	72120000	15.990	16.990	2
Duval	72120000	3.000	4.000	2
Duval	72560000	0.000	1.000	2

Cluster 2 Orange and Osceola Counties

Cluster 2 extends from the center of Orange County to the northwestern part of Osceola County. Overall, 24 hot segments were uncovered (Figure 12 and Table 7). All the hot segments in Cluster 2 have two fog/smoke crashes.

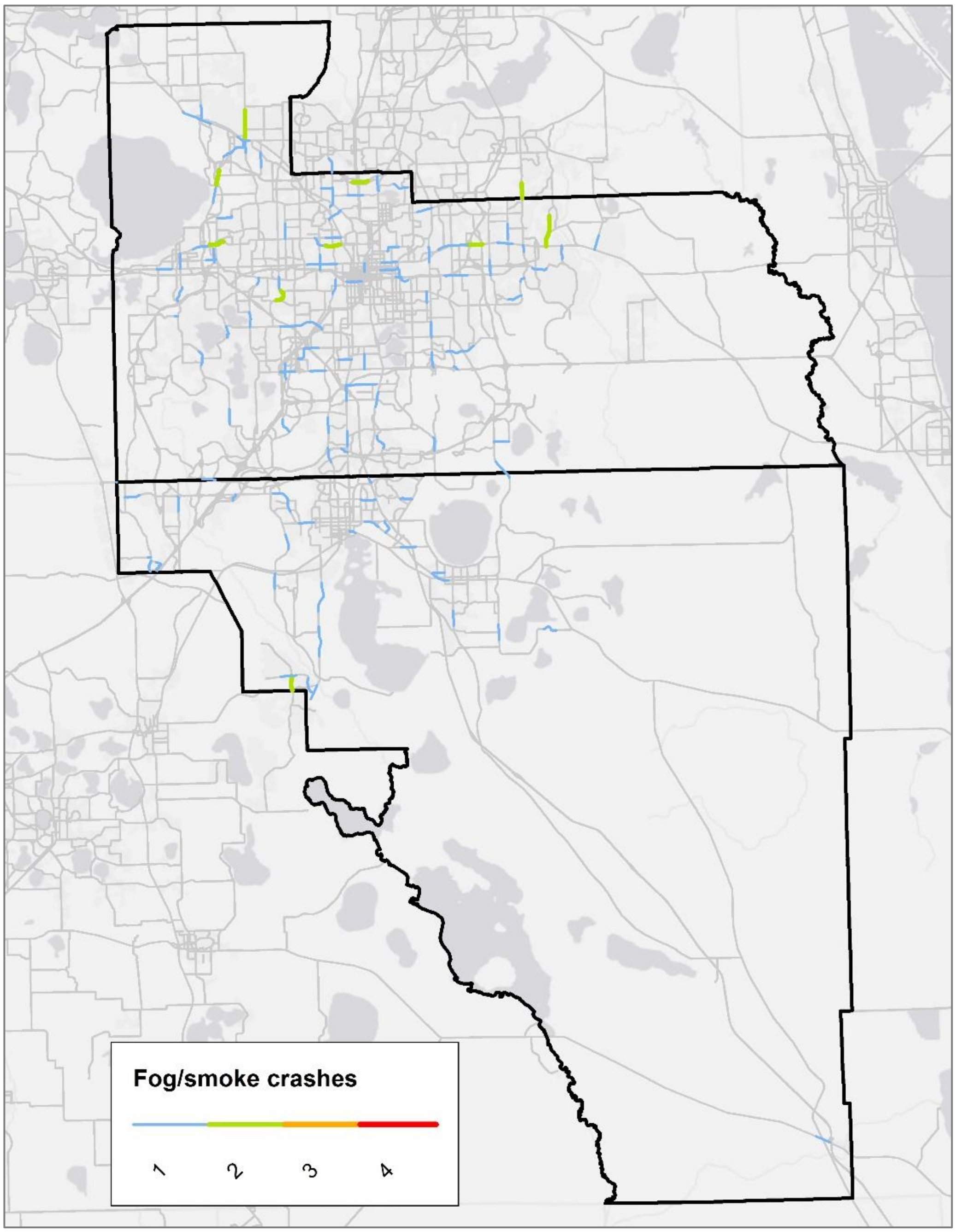


Figure 12: Hot segments for fog/smoke crashes in Cluster 2

Table 7: Hot segments for fog/smoke crashes in Cluster 2

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Orange	77170000	0.000	1.000	2
Orange	75000449	0.000	1.000	2
Orange	75520000	0.000	1.000	2
Orange	75000109	2.000	3.000	2
Orange	75070000	0.000	1.000	2
Orange	75070000	1.000	2.000	2
Orange	75160501	0.000	1.000	2
Orange	75011000	0.000	1.000	2
Orange	75251000	1.010	2.010	2
Orange	75060000	8.000	9.000	2
Orange	75250000	0.000	1.000	2
Osceola	92000104	0.000	1.000	2

Cluster 3 Pinellas, Hillsborough and Polk Counties

Cluster 3 stretches over Pinellas, Hillsborough, and Polk Counties. Twenty-six segments were discovered as hotspots in Cluster 3 as shown in Figure 13 and Table 8. It is noted that two of the hot segments in Polk County have been identified as hotspots for future safety countermeasures to prevent fog/smoke crashes.

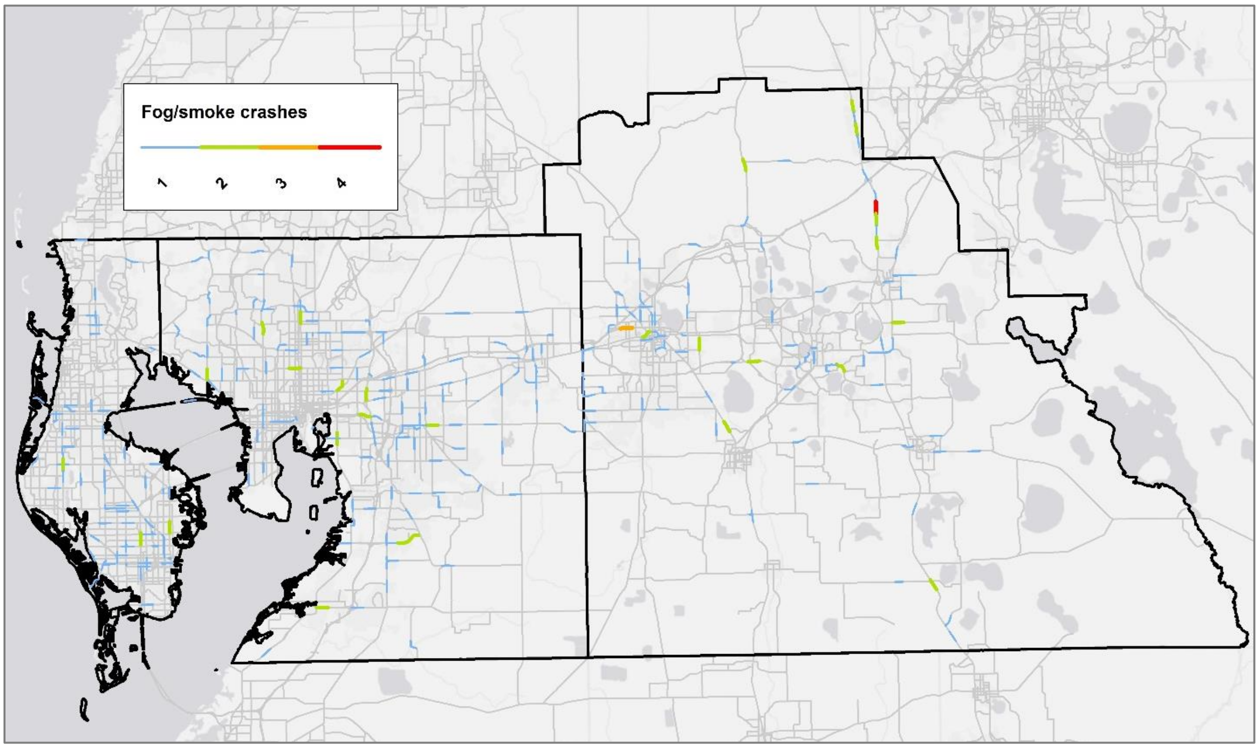


Figure 13: Hot segments for fog/smoke crashes in Cluster 3

Table 8: Hot segments for fog/smoke crashes in Cluster 3

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Polk	16180000	20.970	21.970	4
Polk	16100000	1.000	2.000	3
Pinellas	15150000	6.000	7.000	2
Pinellas	15090000	3.010	4.010	2
Pinellas	15010000	15.000	16.000	2
Hillsborough	10120000	0.000	1.000	2
Hillsborough	10000137	1.000	2.000	2
Hillsborough	10670000	0.000	1.000	2
Hillsborough	10330000	1.000	2.000	2
Hillsborough	10160000	4.000	5.000	2
Hillsborough	10060000	23.000	24.000	2
Hillsborough	10000379	2.000	3.000	2
Hillsborough	10000379	1.000	2.000	2
Hillsborough	10040000	8.000	9.000	2
Hillsborough	10010000	24.000	25.000	2
Hillsborough	10110000	9.990	10.990	2
Hillsborough	10110000	4.000	5.000	2
Polk	16503000	0.000	1.000	2
Polk	16070000	18.970	19.970	2
Polk	16118000	5.010	6.010	2
Polk	16300000	2.010	3.010	2
Polk	16310000	1.000	2.000	2
Polk	16000121	1.000	2.000	2
Polk	16170000	5.990	6.990	2
Polk	16180000	29.960	30.960	2
Polk	16180000	27.970	28.970	2
Polk	16180000	19.980	20.980	2
Polk	16180000	17.980	18.980	2
Polk	16060000	2.000	3.000	2

Cluster 4 Lee County

Cluster 4 is located in Lee County. Cluster 4 has eight hot segments as displayed in Figure 14 and Table 9. All of the hot segments in Cluster 4 have two fog/smoke crashes.

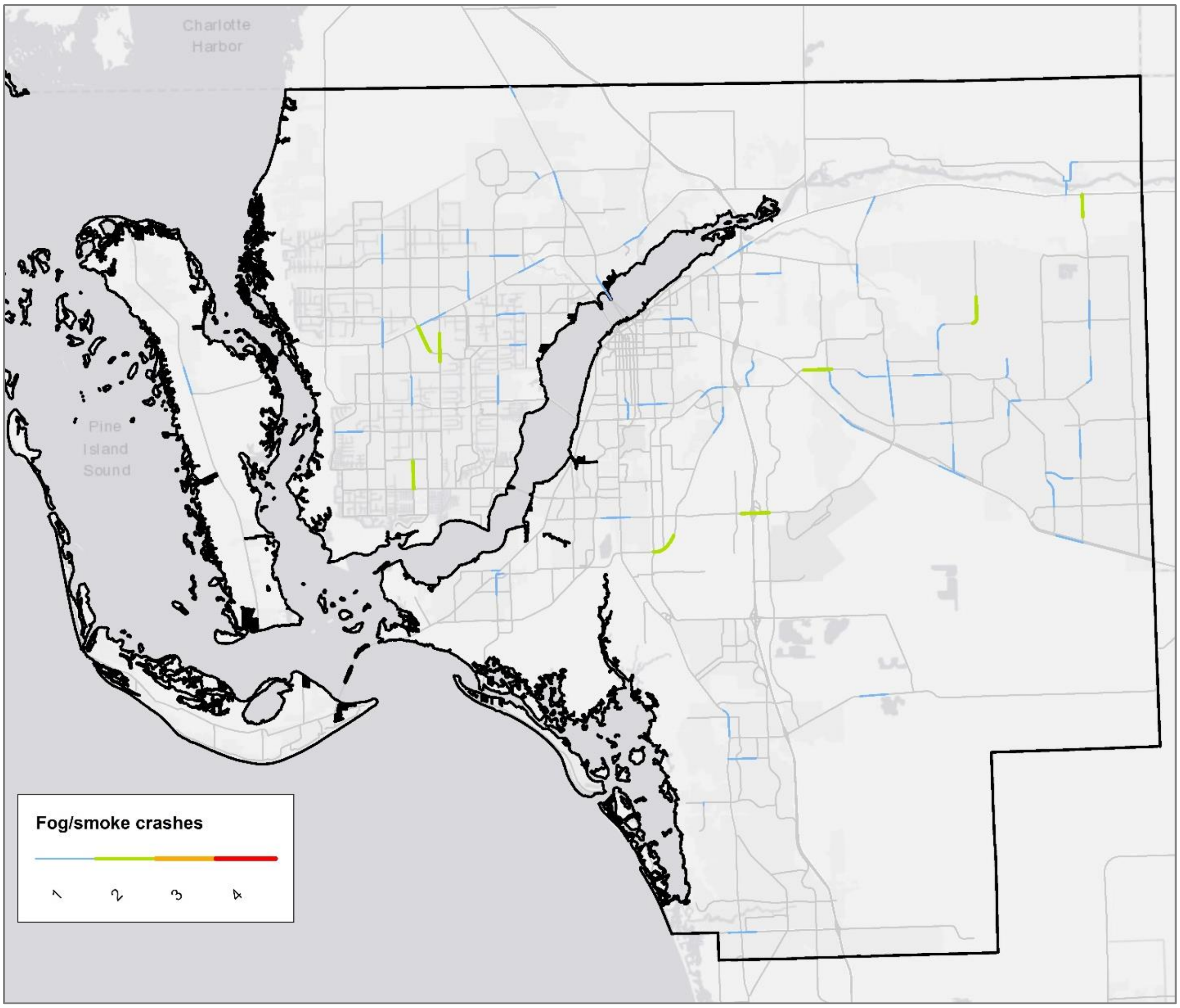


Figure 14: Hot segments for fog/smoke crashes in Cluster 4

Table 9: Hot segments for fog/smoke crashes in Cluster 4

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Lee	12100000	6.990	7.990	2
Lee	12570000	0.000	1.000	2
Lee	12005000	8.420	9.420	2
Lee	12005000	25.430	26.430	2
Lee	12000142	0.000	1.000	2
Lee	12000026	1.030	2.030	2
Lee	12000547	0.000	1.000	2
Lee	12000255	3.000	4.000	2

Cluster 5 Escambia County

Cluster 5 mainly covers Escambia County. In total, 12 segments were discovered as hotspots (Figure 15 and Table 10). It was shown that one of the segments has four fog/smoke crashes near Pensacola Bay.

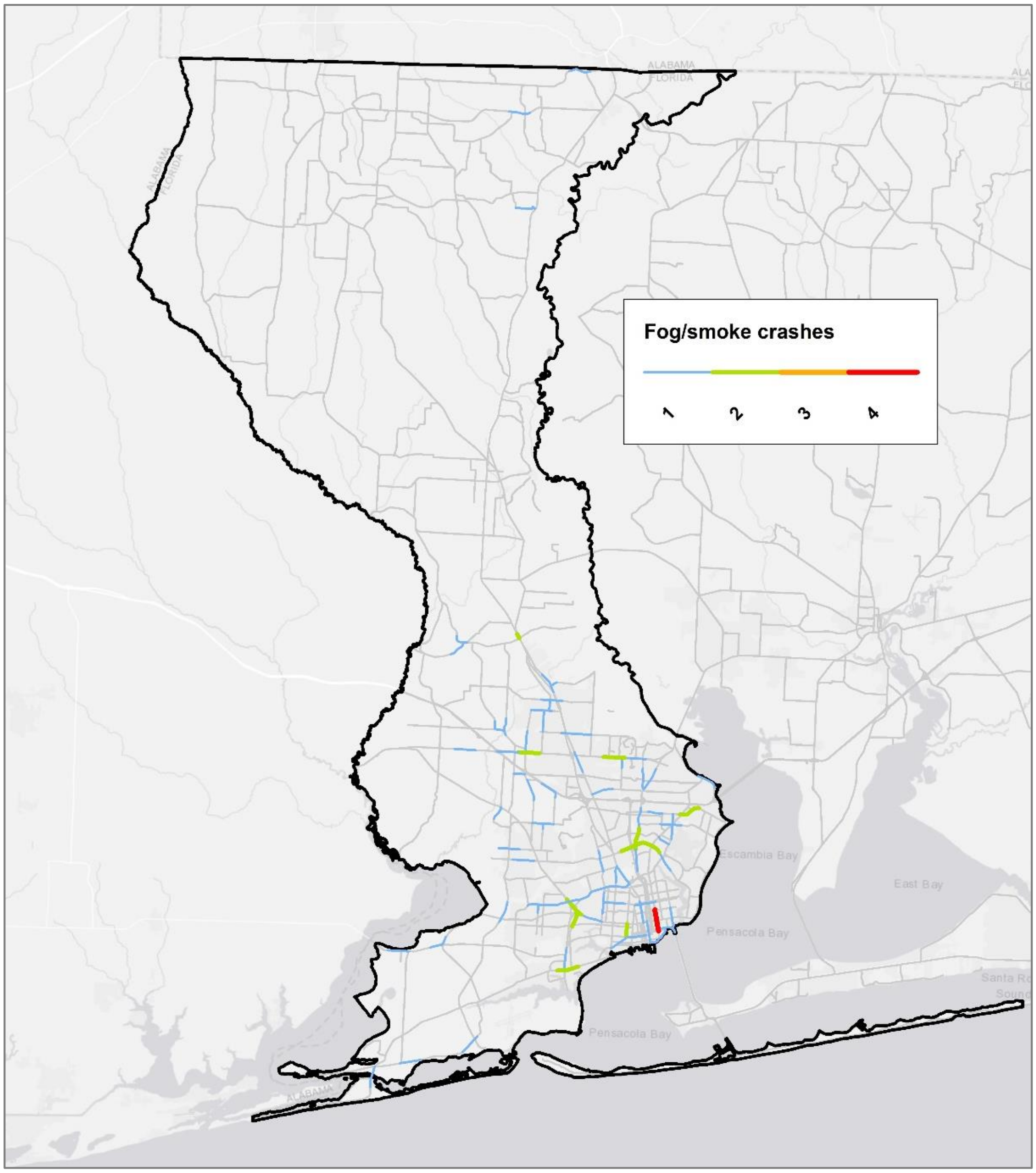


Figure 15: Hot segments for fog/smoke crashes in Cluster 5

Table 10: Hot segments for fog/smoke crashes in Cluster 5

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Escambia	48003000	0.000	1.000	4
Escambia	48000066	0.000	1.000	2
Escambia	48560000	1.990	2.990	2
Escambia	48070000	3.980	4.980	2
Escambia	48012000	4.980	5.980	2
Escambia	48012000	3.980	4.980	2
Escambia	48020000	10.960	11.960	2
Escambia	48013000	3.980	4.980	2
Escambia	48050000	16.930	17.930	2
Escambia	48040000	14.710	15.710	2
Escambia	48010000	11.940	12.940	2
Escambia	48010000	7.960	8.960	2

Cluster 6 Alachua County

Cluster 6 is placed at the center of Alachua County. Four hot segments were identified and all of the hot segments in Cluster 6 have two fog/smoke crashes (Figure 16 and Table 11).

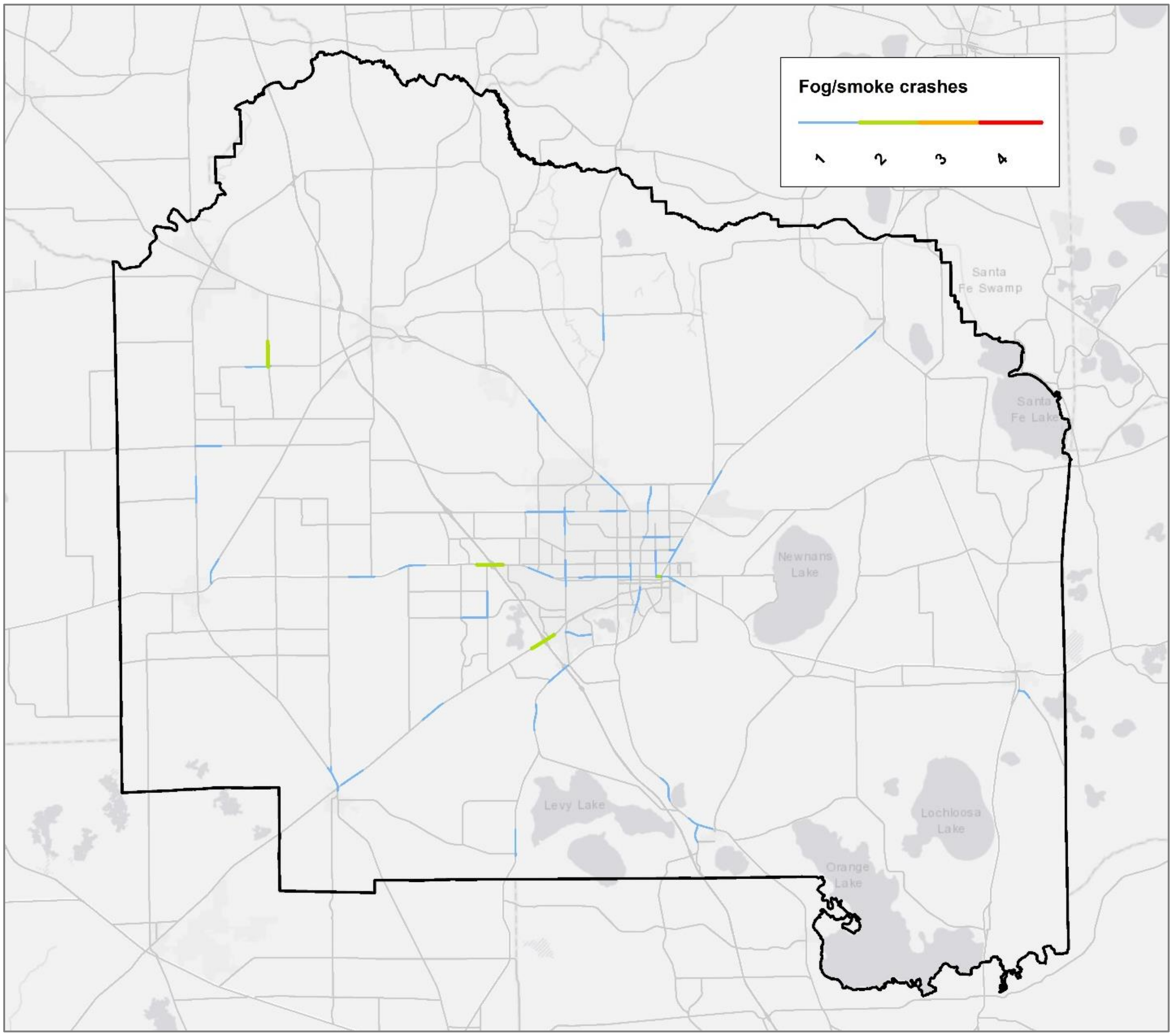


Figure 16: Hot segments for fog/smoke crashes in Cluster 6

Table 11: Hot segments for fog/smoke crashes in Cluster 6

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Alachua	26070000	14.000	15.000	2
Alachua	26070000	21.000	22.000	2
Alachua	26090000	12.000	13.000	2
Alachua	26000006	2.000	3.000	2

Cluster 7 Leon County

Cluster 5 is located in the center of Leon County. Overall, three segments were discovered as hotspots in Cluster 7 (Figure 17 and Table 12). One of the hot segments has three fog/smoke crashes while other hot segments have two fog/smoke crashes.

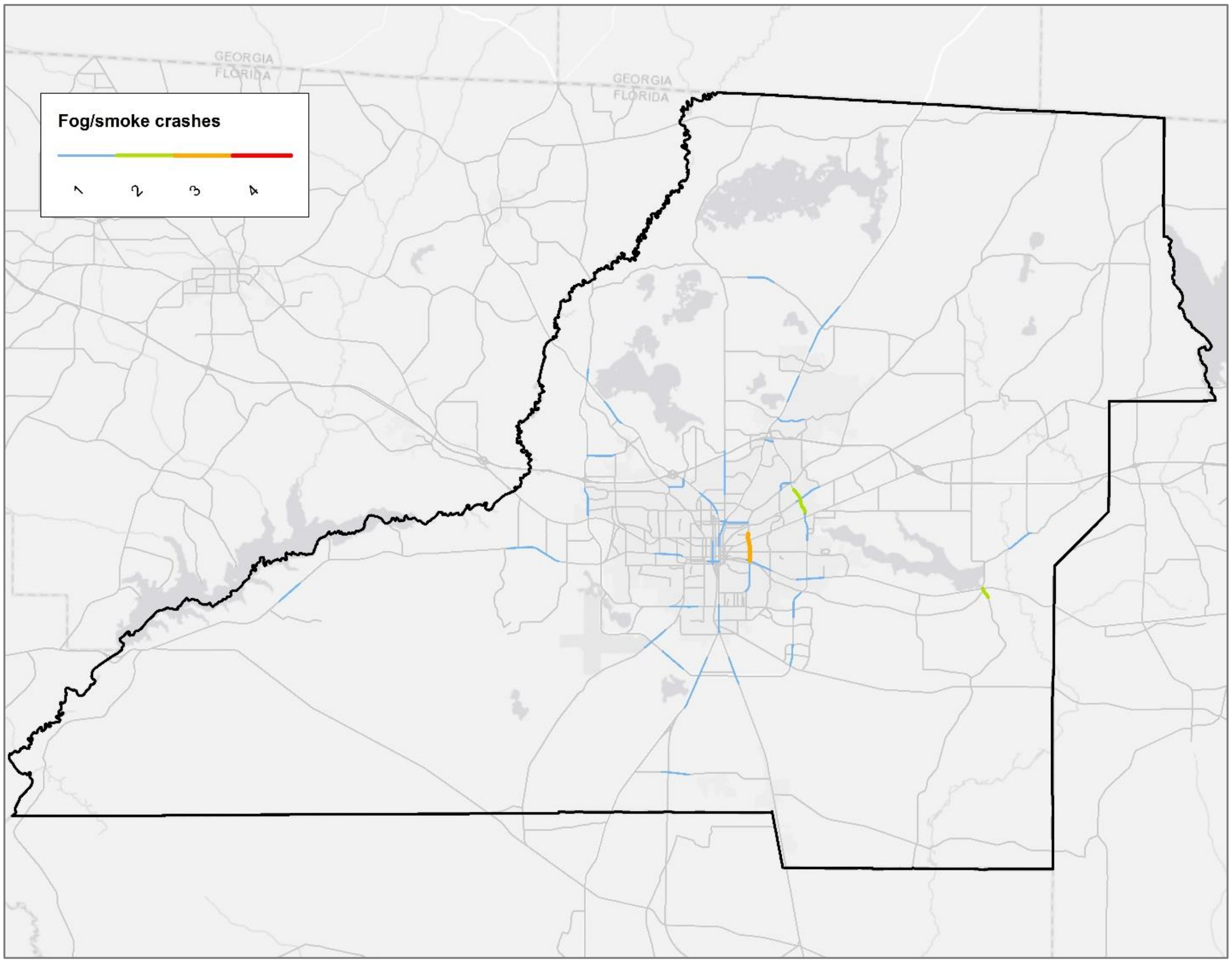


Figure 17: Hot segments for fog/smoke crashes in Cluster 7

Table 12: Hot segments for fog/smoke crashes in Cluster 7

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Leon	55005000	0.000	1.000	3
Leon	55003000	8.000	9.000	2
Leon	55630000	3.990	4.990	2

Cluster 8 Miami-Dade County

Cluster 8 covers the eastern part of Miami-Dade County. Although Cluster 8 has multiple segments with one fog/smoke crashes (Figure 18), there is no segment has more than one fog/smoke crashes. Thus, no hot segment for fog/smoke crashes was observed in Cluster 8.

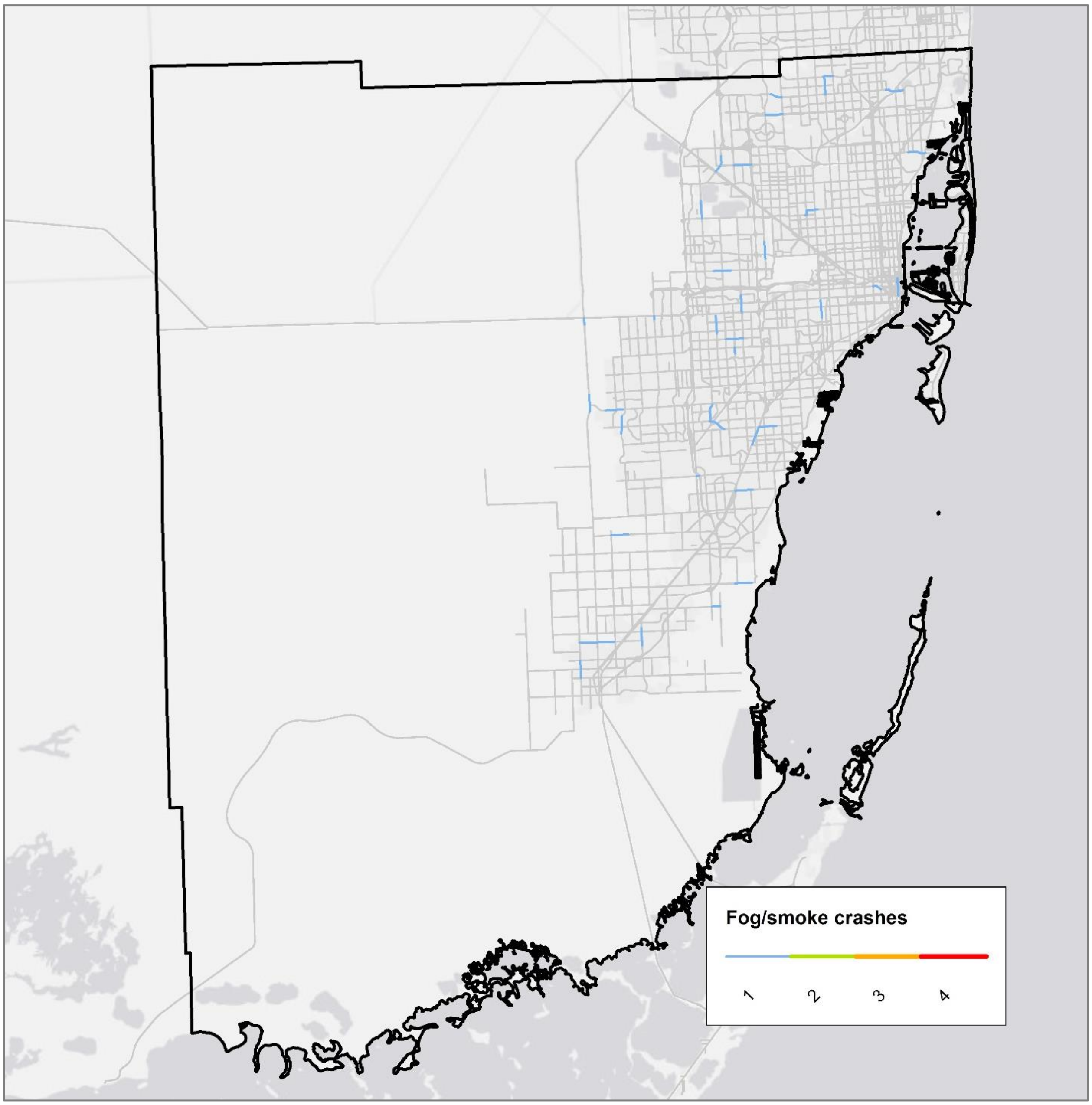


Figure 18: Segments with fog/smoke crashes in Cluster 8

5.2 Intersection-level screening for fog/smoke crashes

In this section, the number of fog/smoke crashes was counted for each intersection. Any intersection with two or more fog/smoke crashes was defined as a hot intersection in the intersection-level screening. In total, 49 intersections were identified as hot intersections for fog/smoke crashes from the eight hot clusters.

Cluster 1 Duval County

Cluster 1 has six hot intersections (Figure 19 and Table 13). One of the hot intersections in Cluster has three fog/smoke crashes.

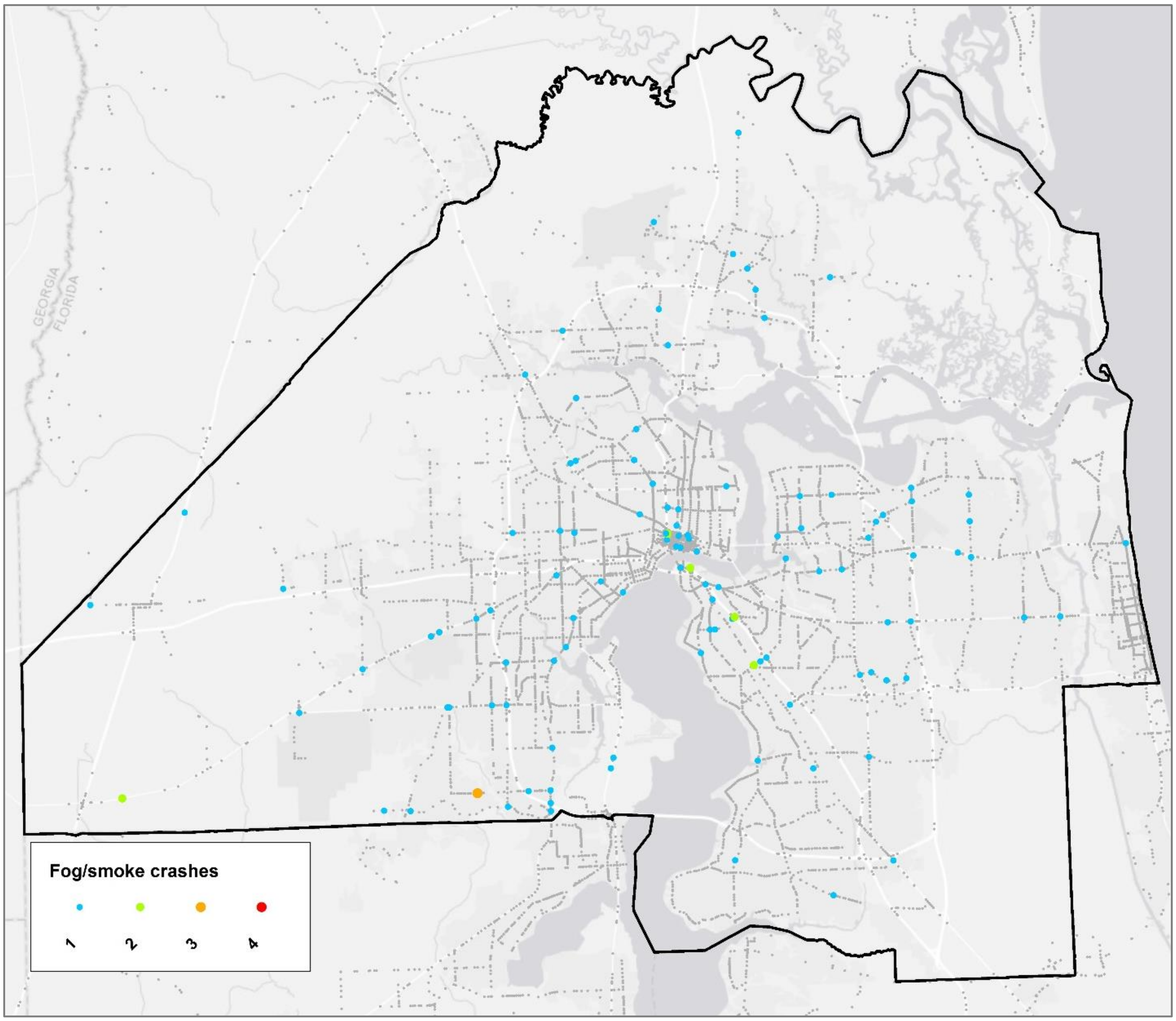


Figure 19: Hot intersections for fog/smoke crashes in Cluster 1

Table 13: Hot intersections for fog/smoke crashes in Cluster 1

County	Roadway ID	Milepost	Fog/smoke crashes
Duval	72800000	0.927	3
Duval	72120000	3.707	2
Duval	72160000	13.709	2
Duval	72010000	21.029	2
Duval	72014000	1.736	2
Duval	72015000	1.438	2

Cluster 2 Orange and Osceola Counties

Four hot intersections for fog/smoke crashes were identified in Cluster 2 (Figure 20 and Table 14). All of the hot intersections have two fog/smoke crashes.

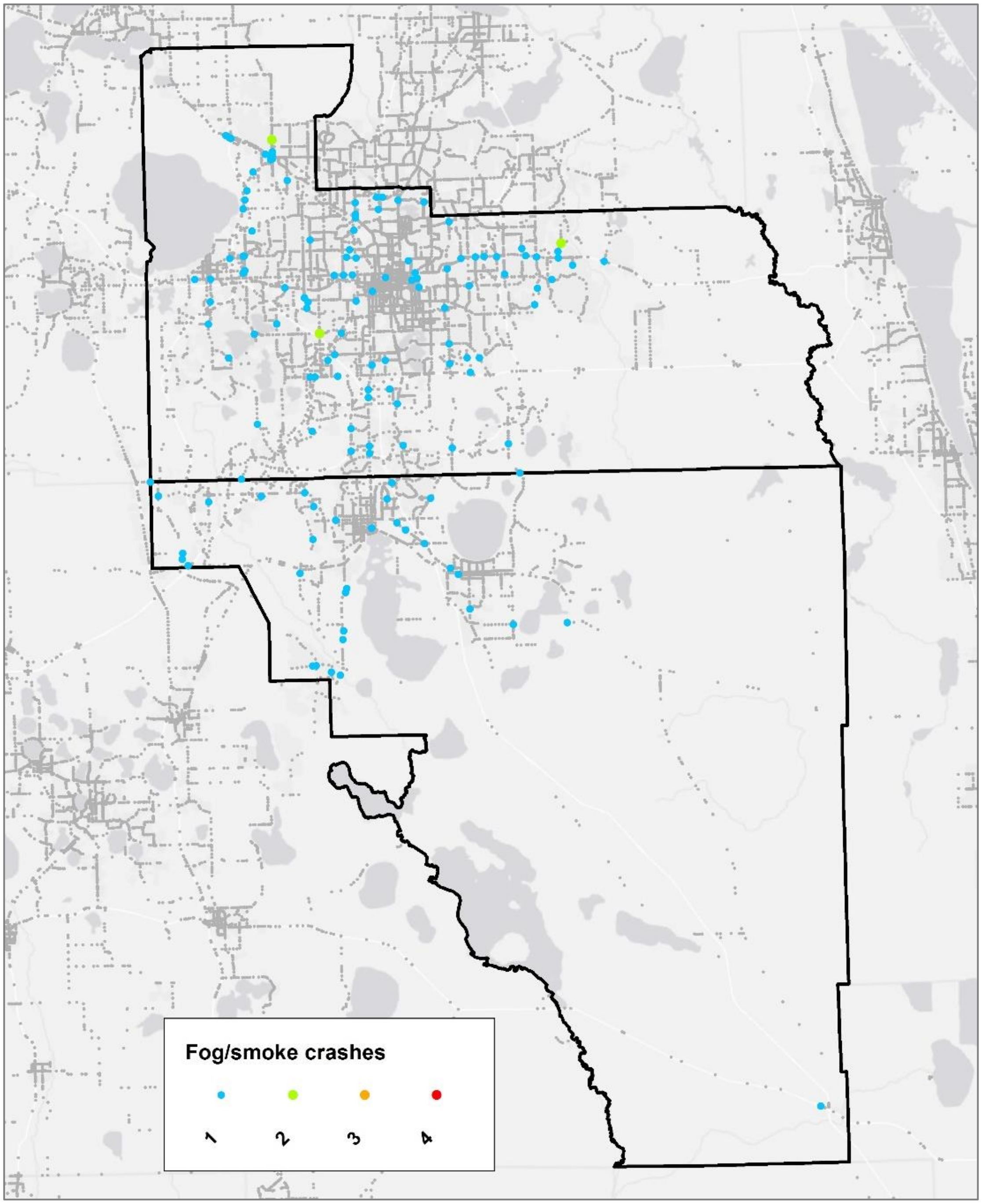


Figure 20: Hot intersections for fog/smoke crashes in Cluster 2

Table 14: Hot intersections for fog/smoke crashes in Cluster 2

County	Roadway ID	Milepost	Fog/smoke crashes
Orange	75070000	1.251	2
Orange	75000449	0.000	2
Orange	75000139	0.000	2
Orange	75000103	0.985	2

Cluster 3 Pinellas, Hillsborough and Polk Counties

Sixteen hot intersections for fog/smoke crashes were found in Cluster 3 (Figure 21 and Table 15). One of the hot intersections in Polk County has four fog/smoke crashes. One of the hot intersections in Polk County has been identified as a hotspot for future safety countermeasures to prevent fog/smoke crashes.

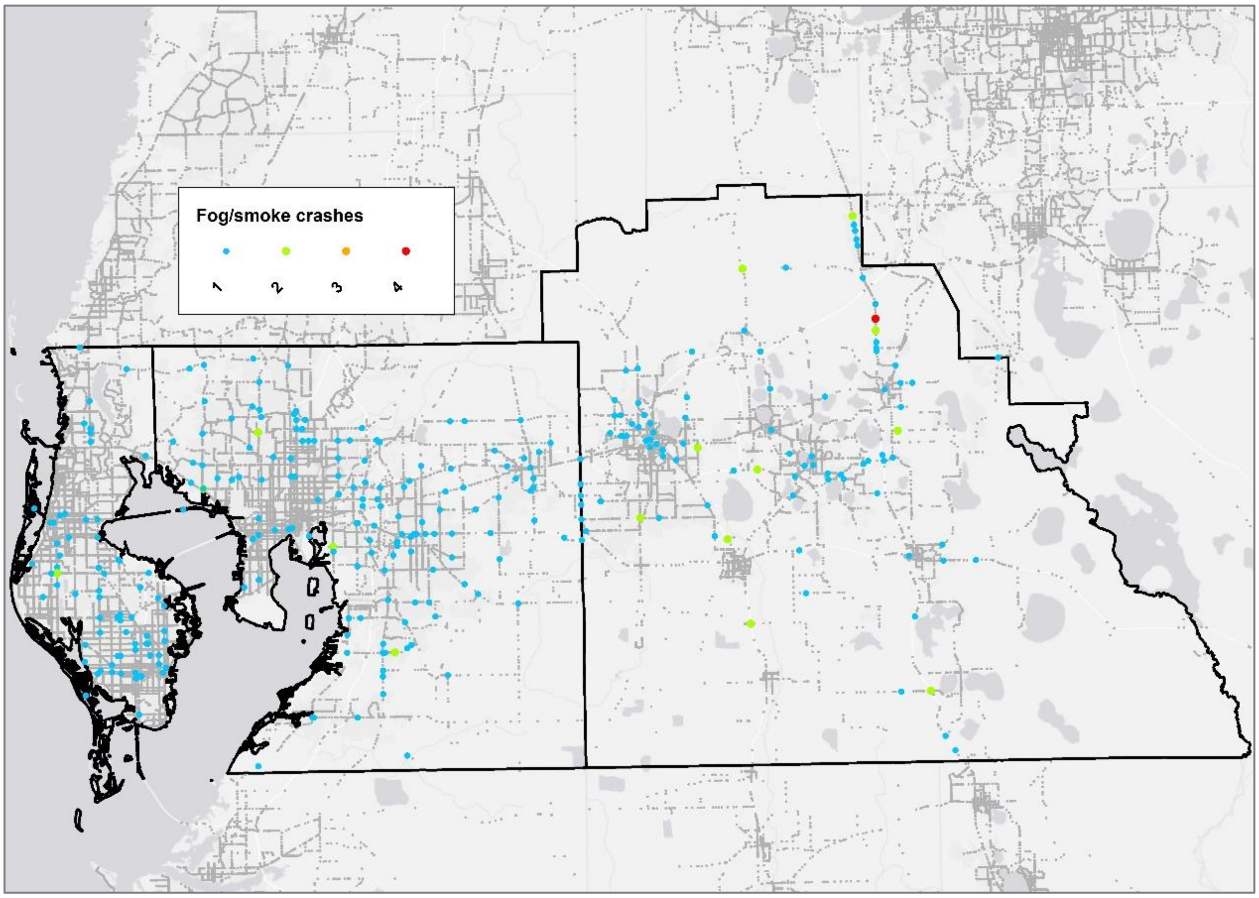


Figure 21: Hot intersections for fog/smoke crashes in Cluster 3

Table 15: Hot intersections for fog/smoke crashes in Cluster 3

County	Roadway ID	Milepost	Fog/smoke crashes
Polk	16180000	21.145	4
Pinellas	15010000	15.544	2
Hillsborough	10000379	1.049	2
Hillsborough	10250000	3.189	2
Hillsborough	10160000	4.818	2
Hillsborough	10150000	4.849	2
Polk	16000121	1.882	2
Polk	16000029	1.040	2
Polk	16030000	12.629	2
Polk	16180000	30.196	2
Polk	16730502	0.000	2
Polk	16119000	5.910	2
Polk	16503000	0.502	2
Polk	16060000	2.120	2
Polk	16170000	6.851	2
Polk	16180000	20.154	2

Cluster 4 Lee County

Six hot intersections were discovered in Cluster 4. Each hot intersection in Cluster 4 has two fog/smoke crashes (Figure 22 and Table 16).

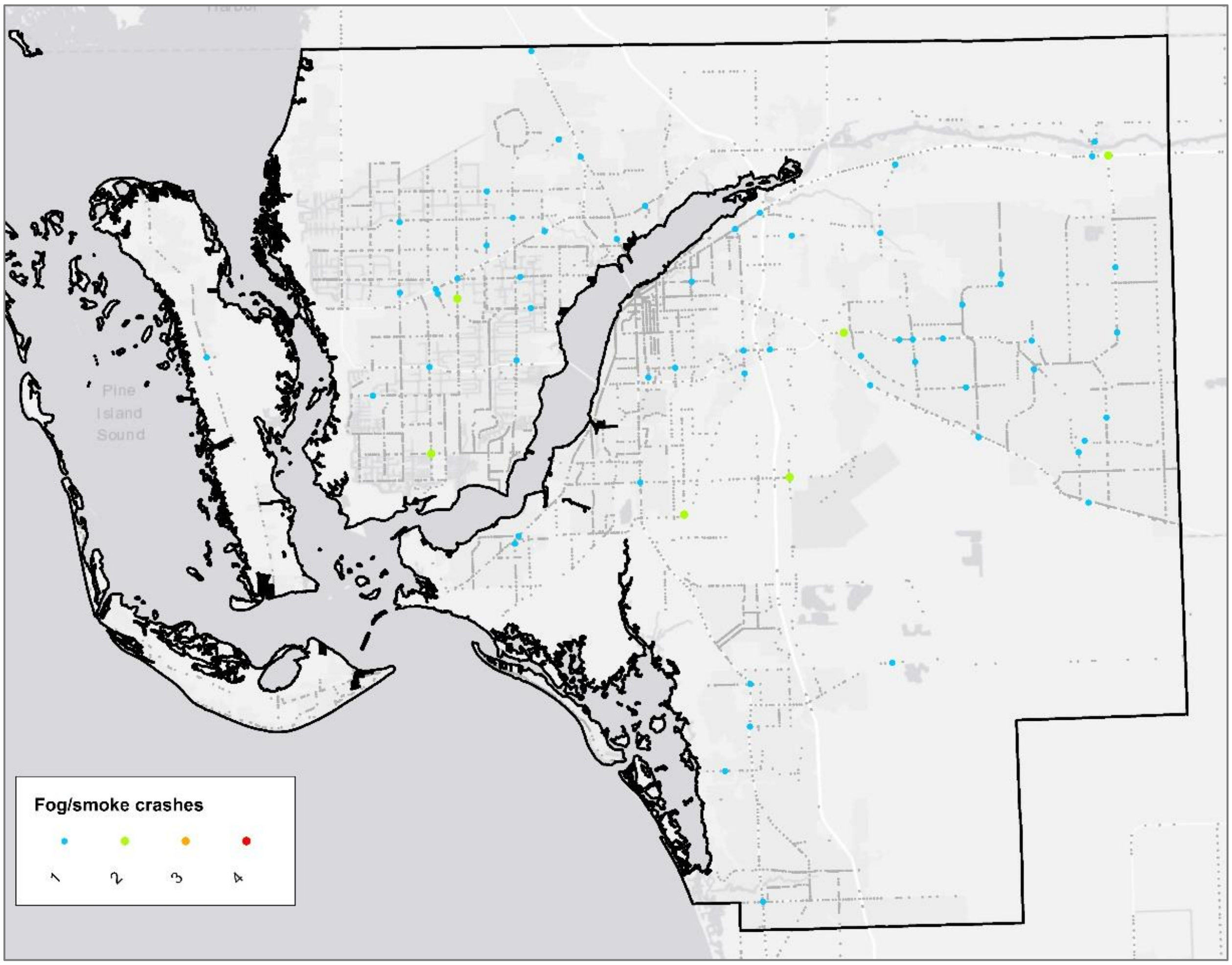


Figure 22: Hot intersections for fog/smoke crashes in Cluster 4

Table 16: Hot intersections for fog/smoke crashes in Cluster 4

County	Roadway ID	Milepost	Fog/smoke crashes
Lee	12020000	18.227	2
Lee	12000080	0.931	2
Lee	12000026	1.960	2
Lee	12005000	9.043	2
Lee	12000152	8.030	2
Lee	12570000	0.374	2

Cluster 5 Escambia County

Nine hot intersections were identified in Cluster 5 (Figure 23 and Table 17). One of the intersections close to Pensacola Bay has four fog/smoke crashes. This intersection is located on the hot segments that were discovered in the segment-level screening. It is advised to provide effective treatments to reduce fog/smoke crashes at this location.

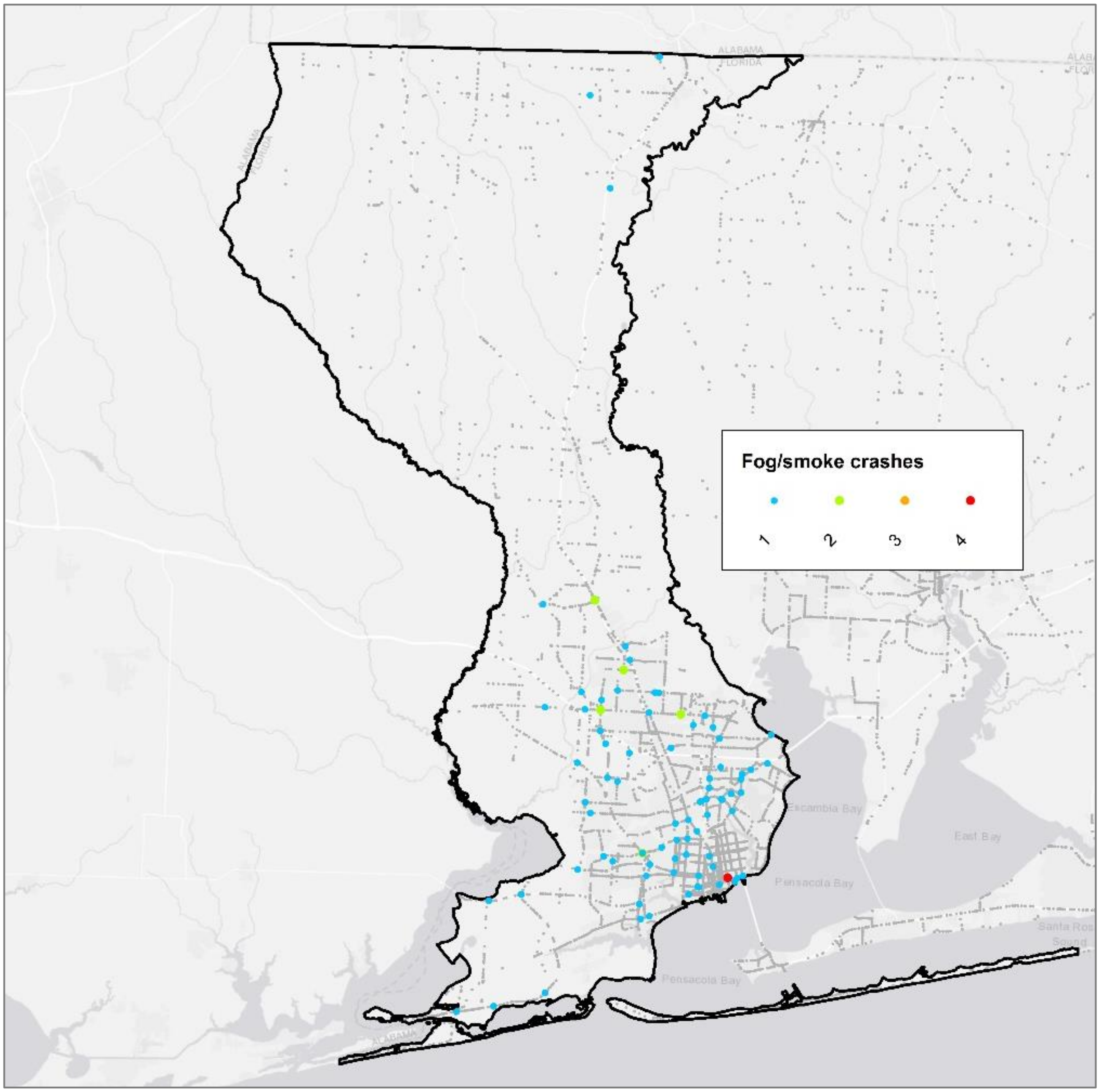


Figure 23: Hot intersections for fog/smoke crashes in Cluster 5

Table 17: Hot intersections for fog/smoke crashes in Cluster 5

County	Roadway ID	Milepost	Fog/smoke crashes
Escambia	48003000	0.175	4
Escambia	48190000	4.294	2
Escambia	48000133	0.000	2
Escambia	48004000	5.951	2
Escambia	48504000	2.250	2
Escambia	48010000	12.203	2
Escambia	48040000	14.713	2
Escambia	48720000	5.505	2
Escambia	48680000	0.000	2

Cluster 6 Alachua County

Cluster 6 has four hot intersections and all the hot intersections in Cluster 6 have two fog/smoke crashes (Figure 24 and Table 18).

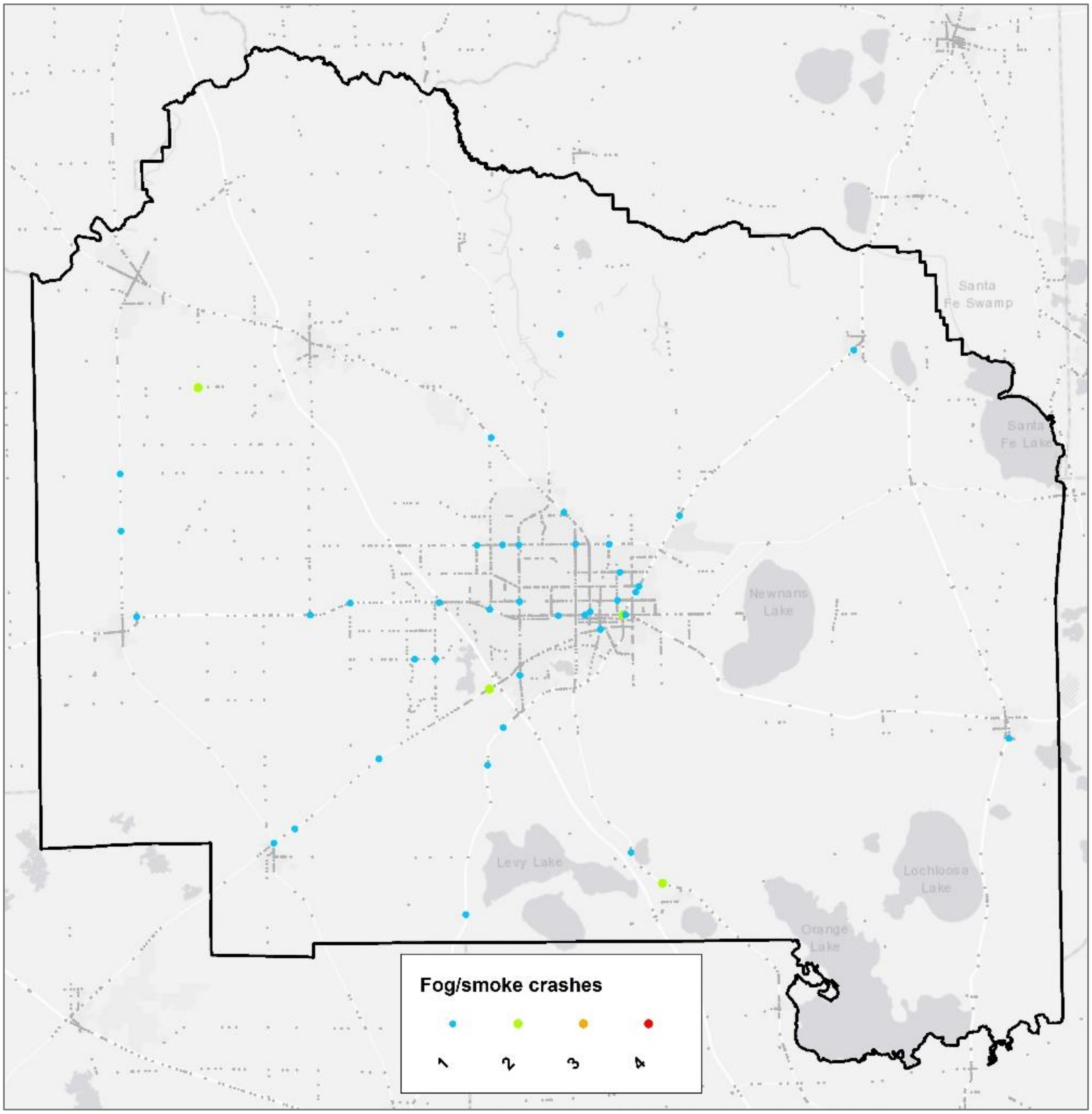


Figure 24: Hot intersections for fog/smoke crashes in Cluster 6

Table 18: Hot intersections for fog/smoke crashes in Cluster 6

County	Roadway ID	Milepost	Fog/smoke crashes
Alachua	26010000	3.574	2
Alachua	26070000	21.162	2
Alachua	26090000	12.263	2
Alachua	26000006	2.042	2

Cluster 7 Leon County

Cluster 7 has four hot intersections. Each hot intersection has two fog/smoke crashes (Figure 25 and Table 19).

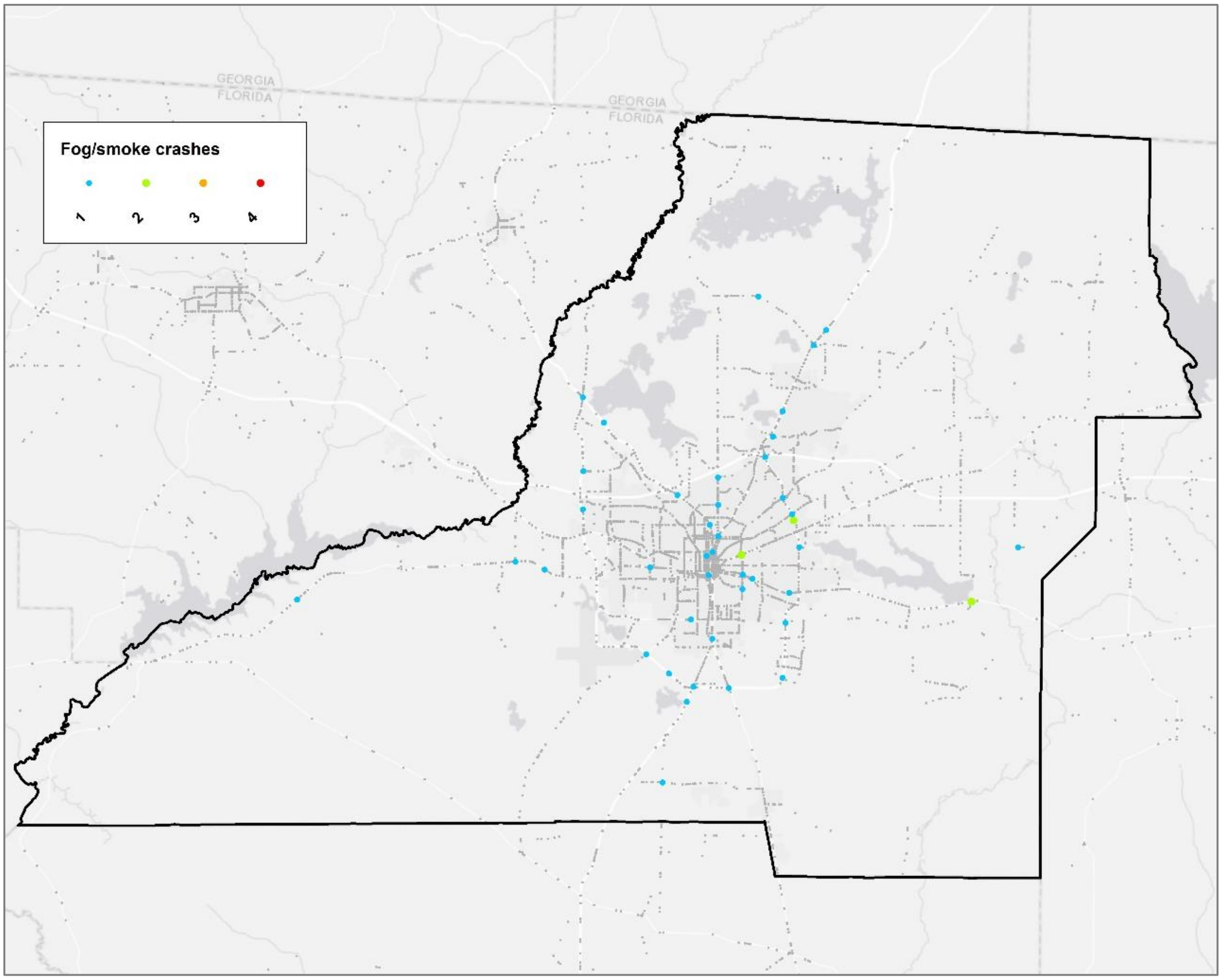


Figure 25: Hot intersections for fog/smoke crashes in Cluster 7

Table 19: Hot intersections for fog/smoke crashes in Cluster 7

County	Roadway ID	Milepost	Fog/smoke crashes
Leon	55005000	0.750	2
Leon	55003000	8.334	2
Leon	55630000	4.370	2
Leon	55660000	0.000	2

Cluster 8 Miami-Dade County

Cluster 8 has several intersections with only one fog/smoke crashes (Figure 26). However, it does not have an intersection with more than one fog/smoke crashes. Thus, there is no hot intersection in Cluster 8.

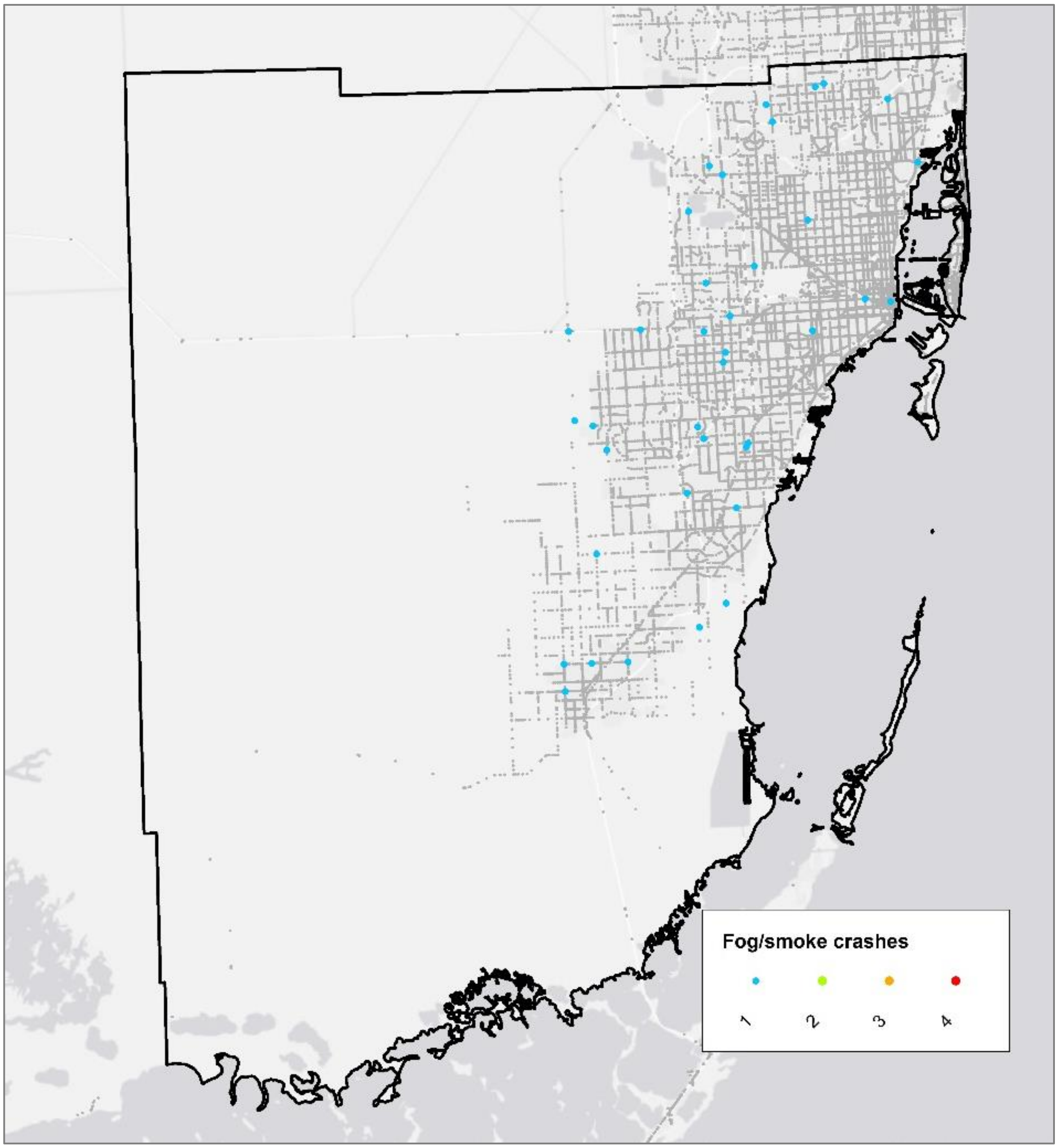


Figure 26: Intersections with fog/smoke crashes in Cluster 8

5.3 Freeway/expressway ramp screening for fog/smoke crashes

The number of fog/smoke crashes was counted for freeway/expressway ramps. Different from segment-level and intersection-level fog/smoke crashes, fog/smoke crashes on ramps are not frequent, and there was no ramp with more than one fog/smoke crash. Thus, any ramp with a fog/smoke crash was defined as a hot ramp in the ramp screening analysis. Overall, 45 ramps were discovered as hot ramps for fog/smoke crashes.

Cluster 1 Duval County

Cluster 1 has two freeway/expressway ramps with a fog/smoke crash (Figure 27 and Table 20).

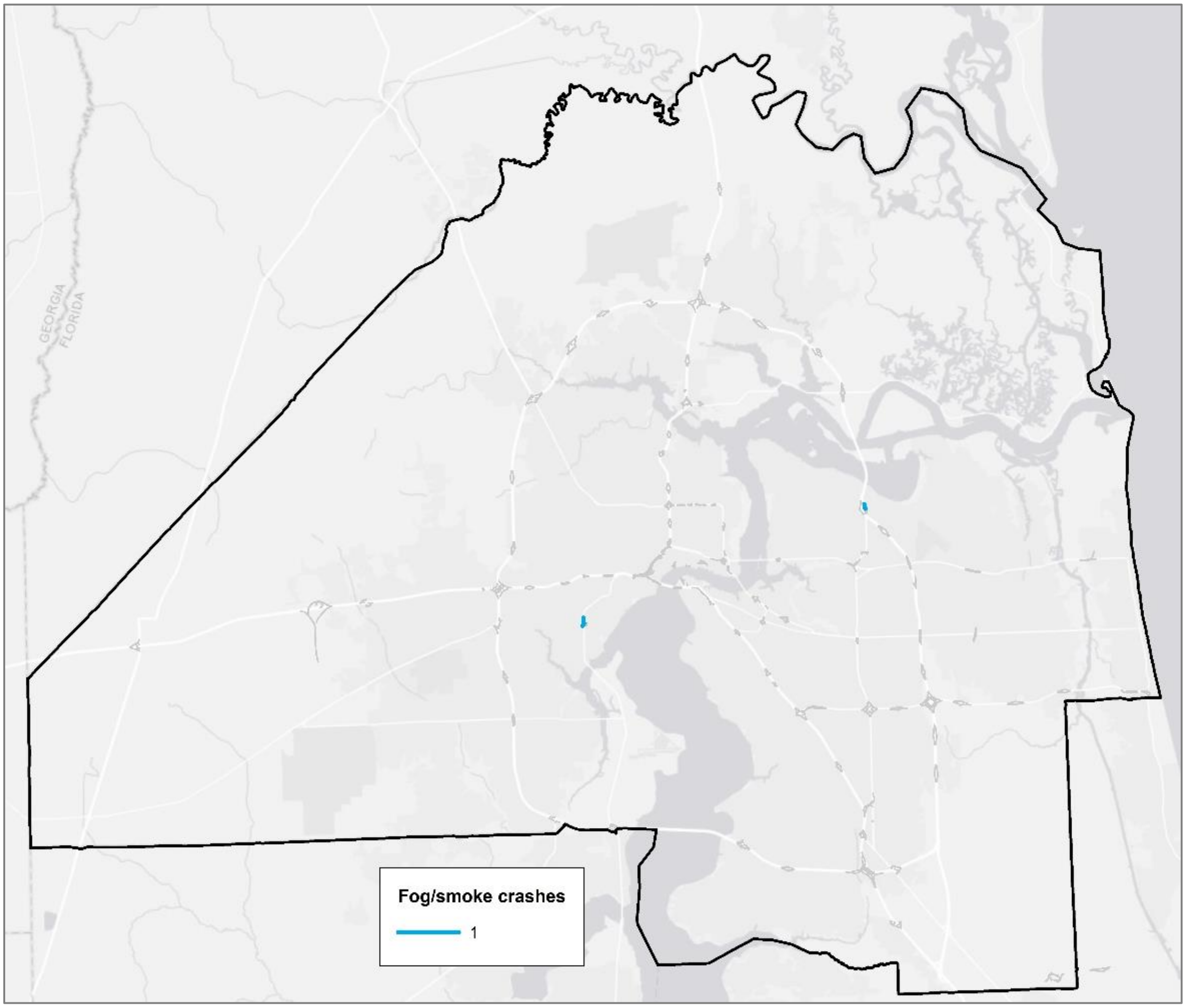


Figure 27: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 1

Table 20: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 1

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Duval	72031007	0	0.160	1
Duval	72170449	0	0.290	1

Cluster 2 Orange and Osceola Counties

Twelve hot ramps were discovered in Cluster 2 (Figure 28 and Table 21).

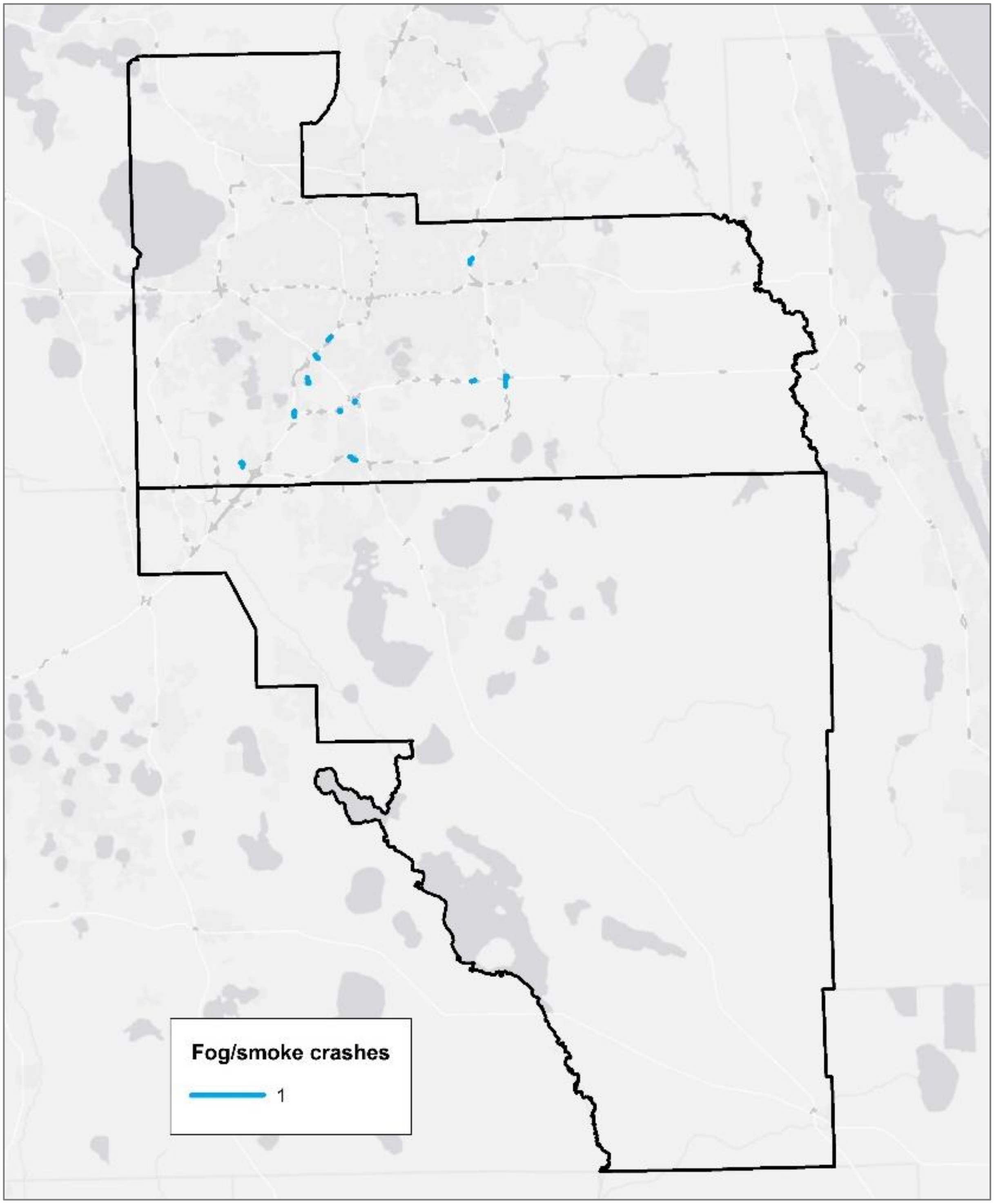


Figure 28: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 2

Table 21: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 2

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Orange	75301025	0	0.500	1
Orange	75301002	0	0.940	1
Orange	75470140	0	0.360	1
Orange	75470148	0	0.150	1
Orange	75280004	0	0.320	1
Orange	75002001	0	0.250	1
Orange	75002010	0	0.470	1
Orange	75000328	0	0.200	1
Orange	75000327	0	0.240	1
Orange	75471201	0	0.430	1
Orange	75471126	0	0.240	1
Orange	75300013	0	0.460	1

Cluster 3 Pinellas, Hillsborough and Polk Counties

Twenty hot ramps were uncovered in Cluster 3 (Figure 29 and Table 22).

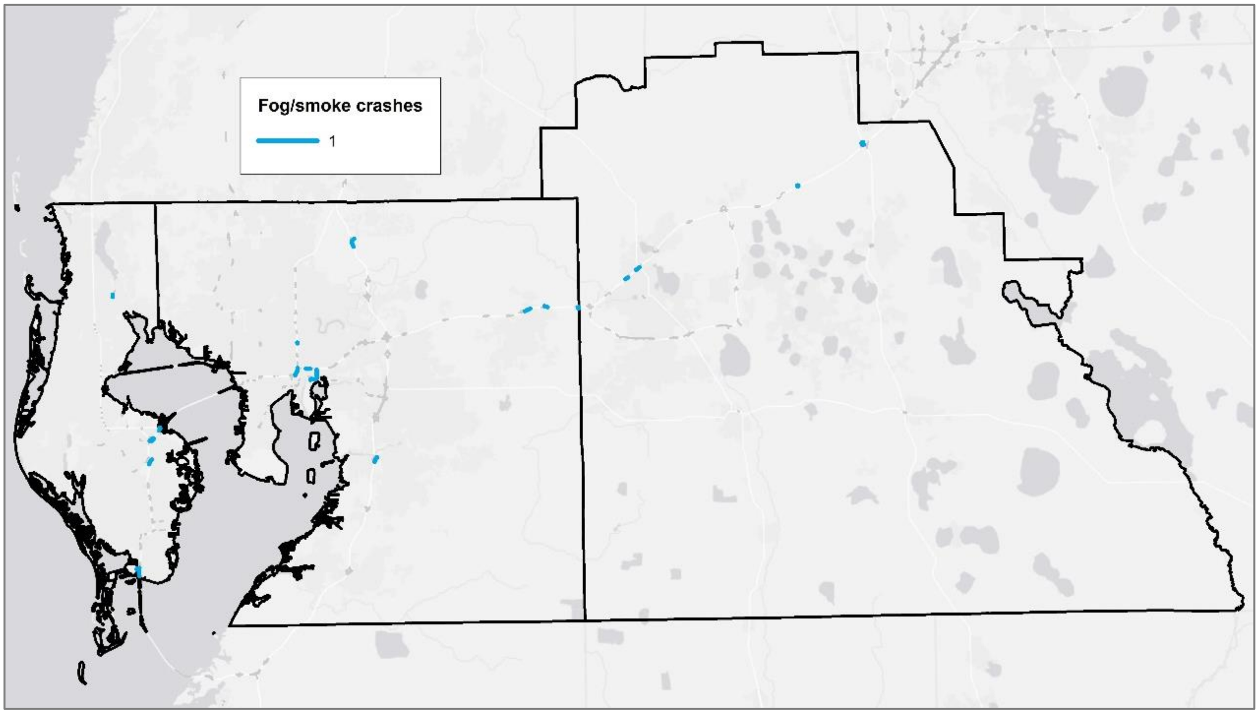


Figure 29: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 3

Table 22: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 3

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Pinellas	15190904	0	0.550	1
Pinellas	15240047	0	0.460	1
Pinellas	15000016	0	0.210	1
Pinellas	15035001	0	0.440	1
Pinellas	15190304	0	0.280	1
Pinellas	15190077	0	0.320	1
Pinellas	15035004	0	0.380	1
Hillsborough	10190449	0	0.370	1
Hillsborough	10320167	0	0.110	1
Hillsborough	10472502	0	1.340	1
Hillsborough	10190071	0	0.700	1
Hillsborough	10075366	0	0.820	1
Hillsborough	10075012	0	0.450	1
Hillsborough	10190141	0	0.510	1
Hillsborough	10190126	0	0.280	1
Hillsborough	10190137	0	0.210	1
Polk	16320035	0	0.180	1
Polk	16320060	0	0.280	1
Polk	16320071	0	0.380	1
Polk	16320101	0	0.420	1

Cluster 4 Lee County

Cluster 4 does not have any freeway/expressway ramps with a fog/smoke crash (Figure 30).

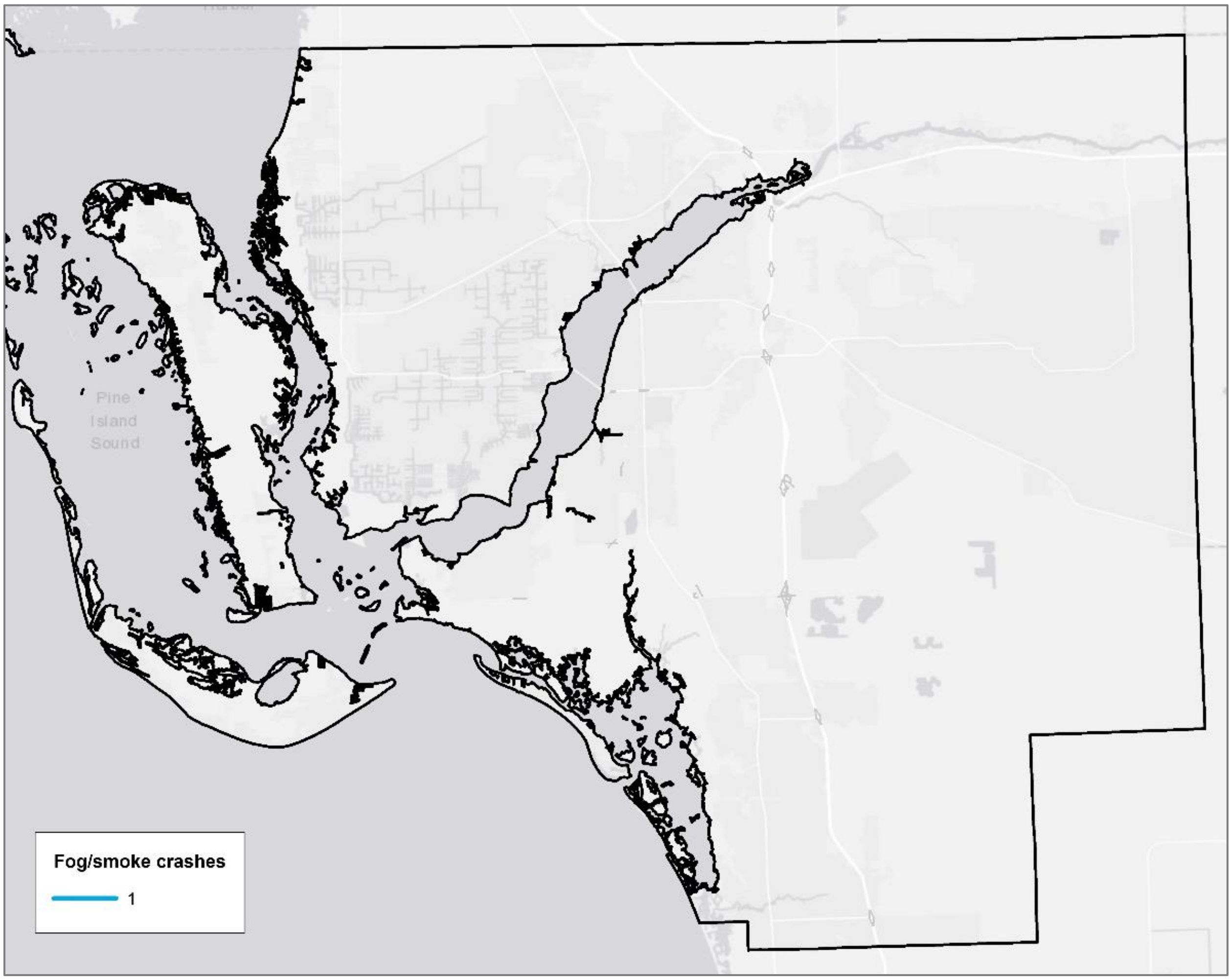


Figure 30: Freeway/expressway ramps in Cluster 4 (no hot ramps for fog/smoke crashes)

Cluster 5 Escambia County

Five hot freeway/expressway ramps were found in Cluster 5 (Figure 31 and Table 23).

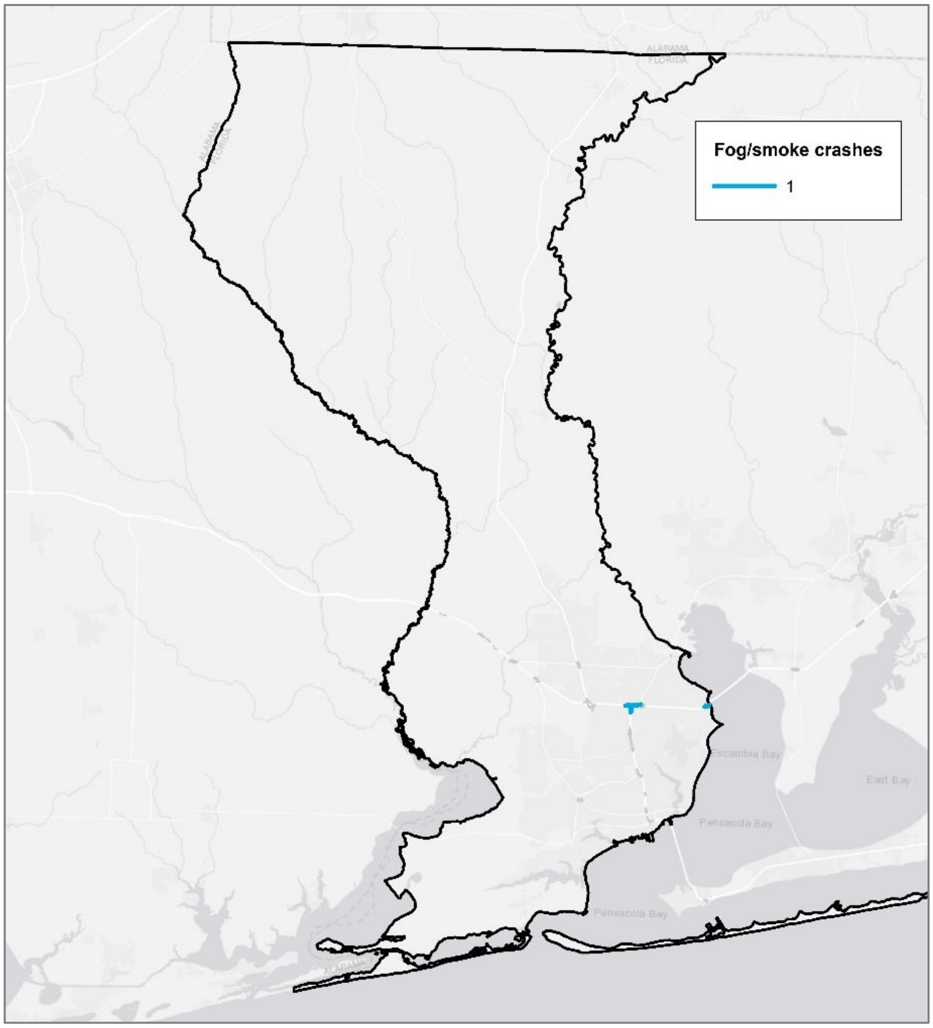


Figure 31: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 5

Table 23: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 5

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Pinellas	15190904	0	0.550	1
Pinellas	15240047	0	0.460	1
Pinellas	15000016	0	0.210	1
Pinellas	15035001	0	0.440	1

Cluster 6 Alachua County

Cluster 6 has one ramp with a fog/smoke crash as shown in Figure 32 and Table 24.

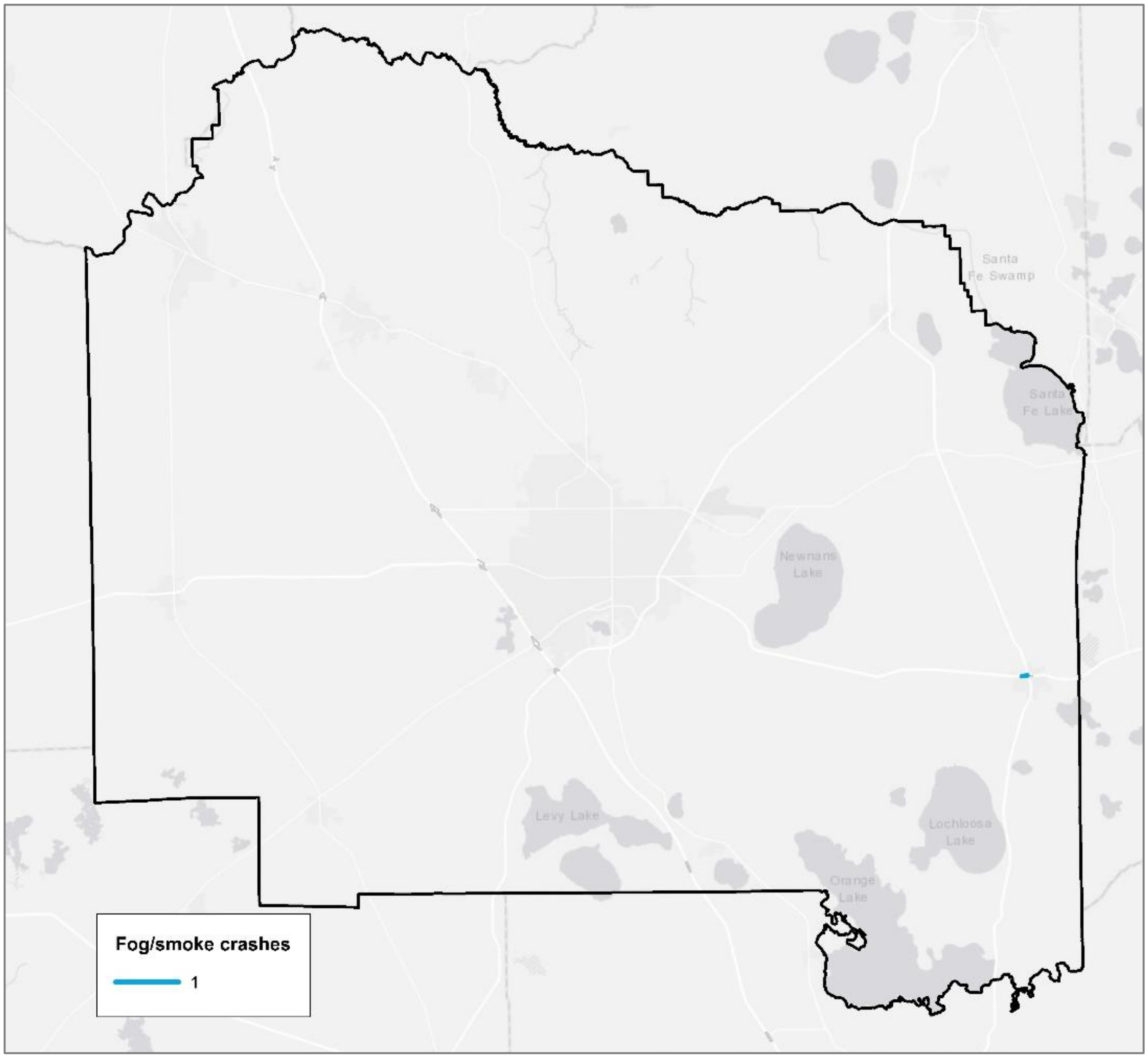


Figure 32: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 6

Table 24: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 6

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Pinellas	15190904	0	0.550	1

Cluster 7 Leon County

Cluster 7 does not have any freeway/expressway segments with a fog/smoke crash (Figure 33).

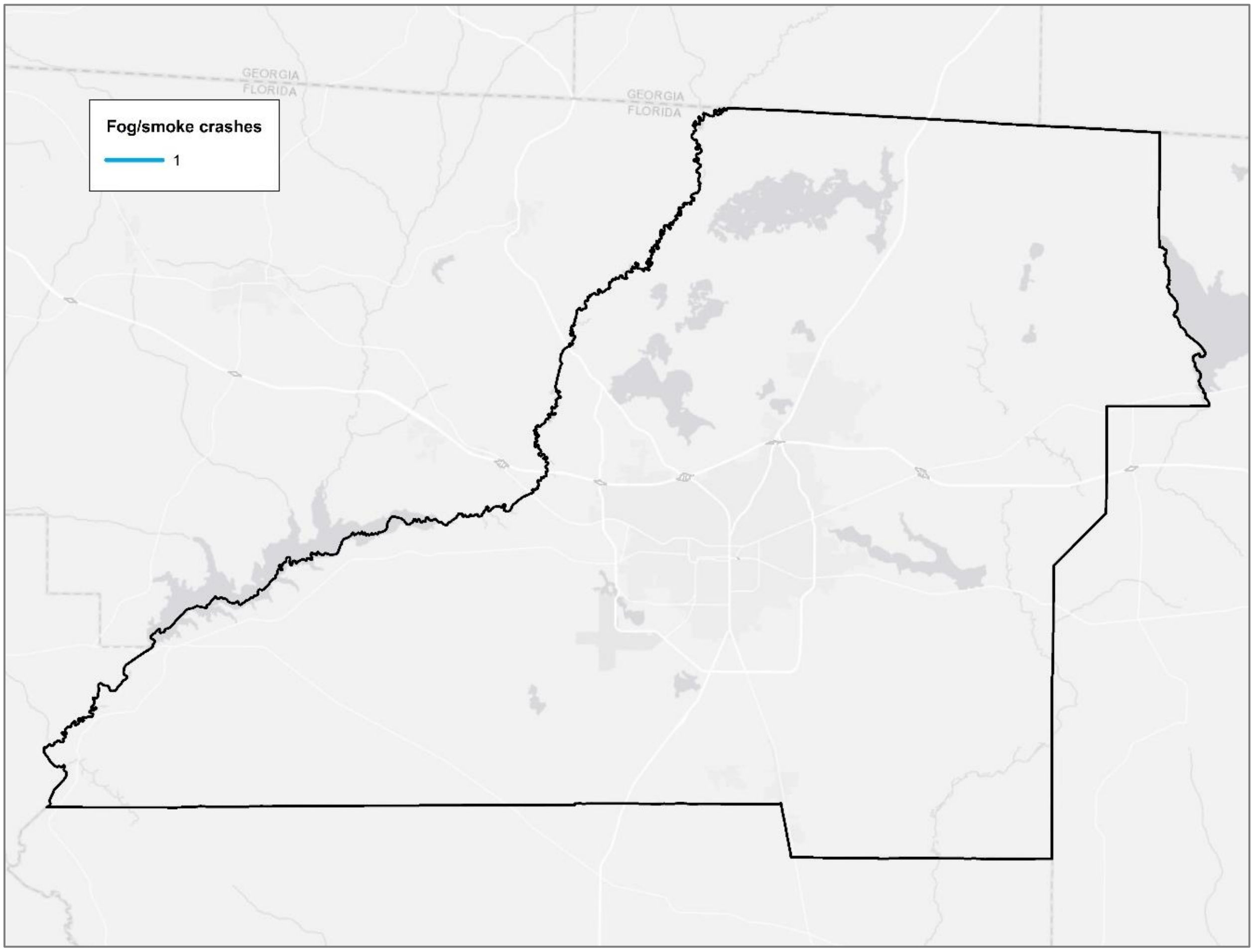


Figure 33: Freeway/expressway ramps in Cluster 7 (no hot ramps for fog/smoke crashes)

Cluster 8 Miami-Dade County

Five hot freeway/expressway ramps for fog/smoke crashes were identified in Cluster 8 (Figure 34 and Table 25).

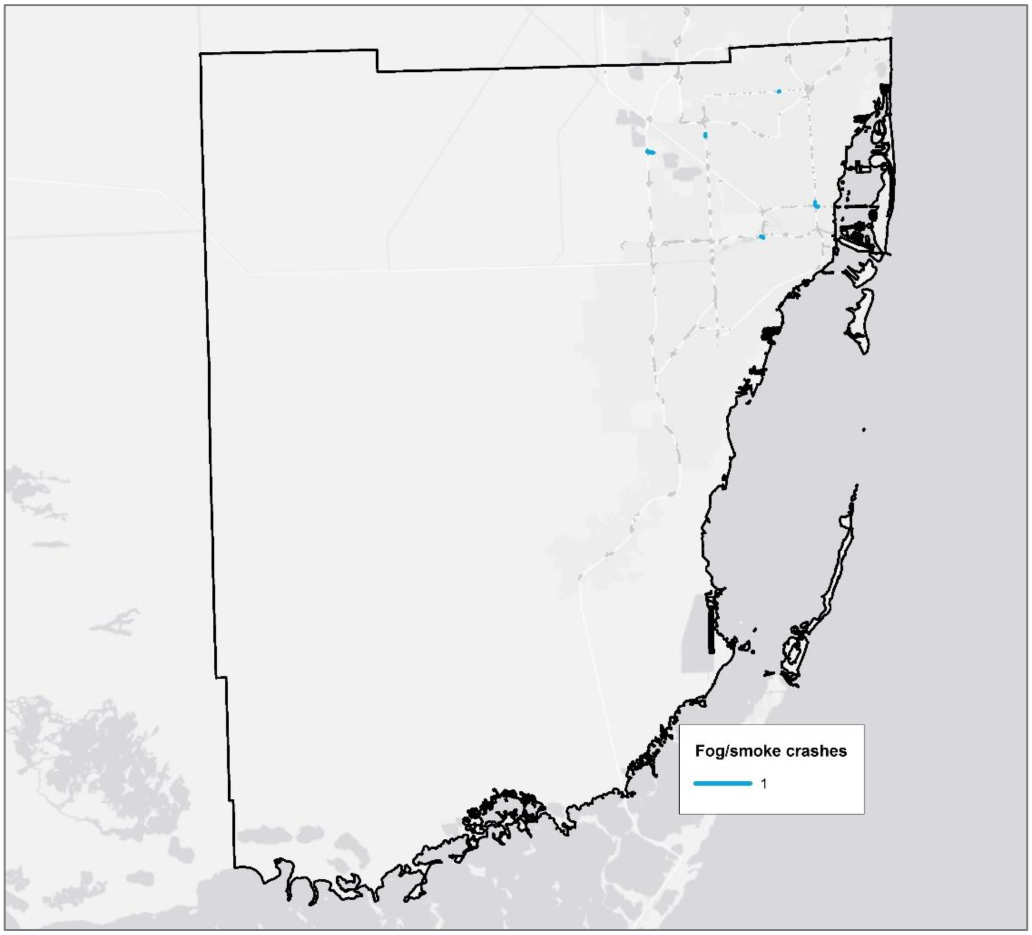


Figure 34: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 8

Table 25: Hot freeway/expressway ramps for fog/smoke crashes in Cluster 8

County	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Miami-Dade	87200091	0	0.210	1
Miami-Dade	87270180	0	0.440	1
Miami-Dade	87260319	0	0.150	1
Miami-Dade	87471508	0	0.480	1
Miami-Dade	87260159	0	0.060	1

CHAPTER 6. SUMMARY AND CONCLUSIONS

The main objective of this project was to identify hotspot clusters for fog/smoke crashes and to investigate hot segments, hot intersections, and hot freeway/expressway ramps in the hotspot clusters. In Chapter 2, fog/smoke crash data of the period of 2013-2017 were collected from Signal Four Analytics. In Chapter 3, eight hot clusters were identified using kernel density estimation (KDE) method and found fog/smoke crashes were concentrated in Duval, Orange/Osceola, Pinellas/Hillsborough/Polk, Lee, Escambia, Alachua, Leon, and Miami-Dade Counties. In Chapter 4, the eight hot clusters identified in the previous task were examined more closely, which revealed specific segments, intersections, and freeway/expressway ramps with frequent fog/smoke crashes were identified. Eighty-one segments, forty-nine intersections, and forty-five freeway/expressway ramps were discovered as fog/smoke crash hotspots. The most dangerous segments and intersections in Florida are summarized in Tables 26 and 27, respectively.

Table 26: The most dangerous segments in Florida

County	Street	Roadway ID	Begin Milepost	End Milepost	Fog/smoke crashes
Duval	N. Main St.	72050443	0.000	1.000	3
Duval	Collins Rd.	72800000	0.000	1.000	3
Polk	US-27	16180000	20.970	21.970	4
Escambia	N. 9th Ave.	48003000	0.000	1.000	4
Leon	N. Magnolia Dr.	55005000	0.000	1.000	3

Table 27: The most dangerous intersections in Florida

County	Street	Roadway ID	Milepost	Fog/smoke crashes
Duval	Collins Rd.	72800000	0.927	3
Polk	US-27	16180000	21.145	4
Escambia	N. 9th Ave.	48003000	0.175	4

It is worth to conduct a comparative analysis between the number of fog/smoke-related crashes in the recent years (2013-2017) and that in the past years (2008-2012).

Table 28: Changes in the number of fog/smoke-related crashes in 2008-2012 and 2013-2017

Cluster	County	2008-2012	2013-2017	Percent change
1	Duval	419	638	52.3%
2	Orange and Osceola	276	668	142.0%
3	Pinellas, Hillsborough and Polk	838	1338	59.7%
4	Lee	90	316	251.1%
5	Escambia	190	259	36.3%
6	Alachua	153	188	22.9%
7	Leon	165	260	57.6%
8	Miami-Dade	186	351	88.7%
Other Counties		2628	5085	93.5%
Total		4945	9103	84.1%

As shown in Table 28, the numbers of fog/smoke related crashes have much increased by 84.1% in Florida between 2008-2012 and 2013-2017. Especially, Lee County (Cluster 4) and the combination of Orange and Osceola Counties (Cluster 2) showed the highest increases (251.1% and 142.0%, respectively). Figure 35 compares the geographic distributions of fog/smoke-related crashes in the two time periods.

It is strongly recommended to pay attention to the identified hotspots and provide effective countermeasures, such as dynamic message sign warning messages and flashing beacons, to reduce the number of fog/smoke crashes to reduce the number of fog/smoke. Especially, six segments and three intersections have been identified as hotspots for future safety countermeasures to prevent fog/smoke crashes.

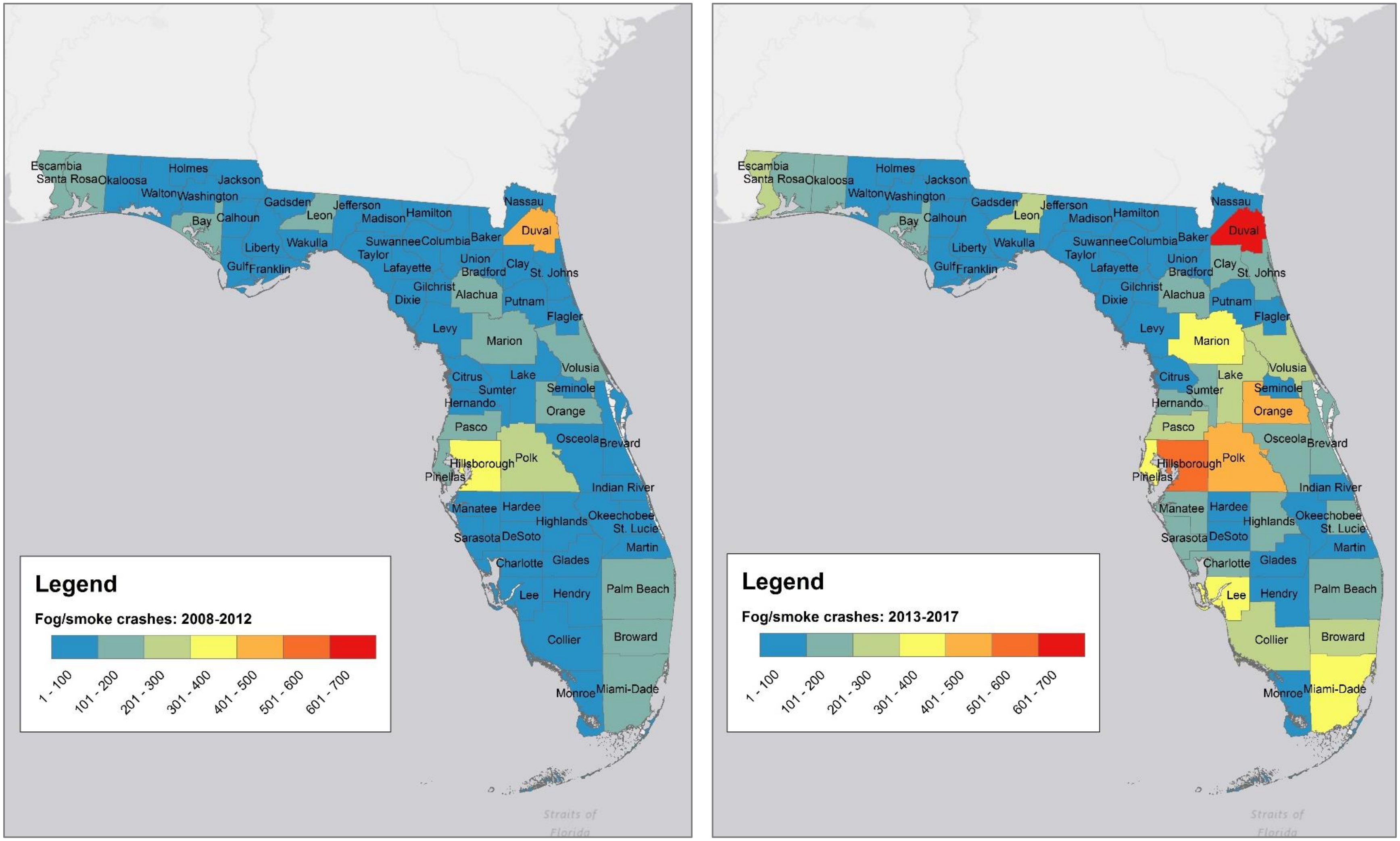


Figure 35: Geographic distributions of smoke/fog-related crashes in 2008-2012 and 2013-2017

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