6.0 Transportation Analysis

6.1 Introduction

While hurricanes are relatively unusual for Rhode Island, tropical cyclones pushing north can impact the state bringing dangerous weather conditions to its residents and visitors. These storm systems can bring coastal storm surge and flooding, as well as tornadoes and associated wind damage. During these events, state and local emergency management officials may be required to call for evacuations for the Rhode Island coast. These protective action decisions could result in the local and regional road network having to process a significant number of vehicles in a relatively short period of time. This is especially true in the New England region where storms reaching the higher latitudes become entrained in the jet stream and can travel forward at speeds in excess of 50 miles per hour. Decisions to evacuate may need to be initiated when a storm threat is still off the coast of North Carolina.

Based on the results of this transportation model, Rhode Island enjoys very reasonable clearance times, that is to say most communities can successfully evacuate in the alert time created by a Hurricane Warning from the National Hurricane Center (NHC). Nonetheless congestion, particularly during the summer, can be quite heavy especially near tourist centers along the coast and near resort communities. Furthermore, Rhode Island is a densely populated state with a large metropolitan area in the center of the study region, daily rush hours will surely complicate an evacuation especially if it has to be initiated in the middle of a normal weekday or during the start of a normal business day.

In 2012, the Federal Emergency Management Agency (FEMA) and the United States Army Corps of Engineers (USACE), New England District, funded the New England Hurricane Evacuation Study (HES). That same year, Atkins was retained by the USACE through FEMA funding to complete the HES transportation analysis and then the Technical Data Report (TDR). The HES develops technical data concerning hurricane hazards; the vulnerability of the resident and tourist populations; public response to evacuation advisories; evacuation timing; and sheltering needs for various hurricane threat situations. A critical component in the HES is the transportation analysis to determine how many people and vehicles would be involved if a hurricane forced an evacuation of Rhode Island's coastal jurisdictions.

The principal purpose of the transportation analysis is to: 1) determine the time required to evacuate the vulnerable population (clearance times), and 2) evaluate general traffic control measures that could improve the flow of evacuating traffic. This chapter documents the basic inputs and findings of the study analysis. The list of the jurisdictions involved in the Rhode Island HES TDR is displayed in Table 6-1, and a map of the study area is located in Figure 6-1.

6.0 Transportation Analysis

Table 6-1: Rhode Island HES TDR Study Area

County	Community
Bristol County	Barrington
	Bristol
	Warren
Kent County	East Greenwich
	Warwick
Newport County	Jamestown
	Little Compton
	Middletown
	Newport
	Portsmouth
	Tiverton
Providence County	Cranston
	East Providence
	Pawtucket
	Providence
Washington County	Charlestown
	Narragansett
	New Shoreham
	North Kingstown
	South Kingstown
	Westerly

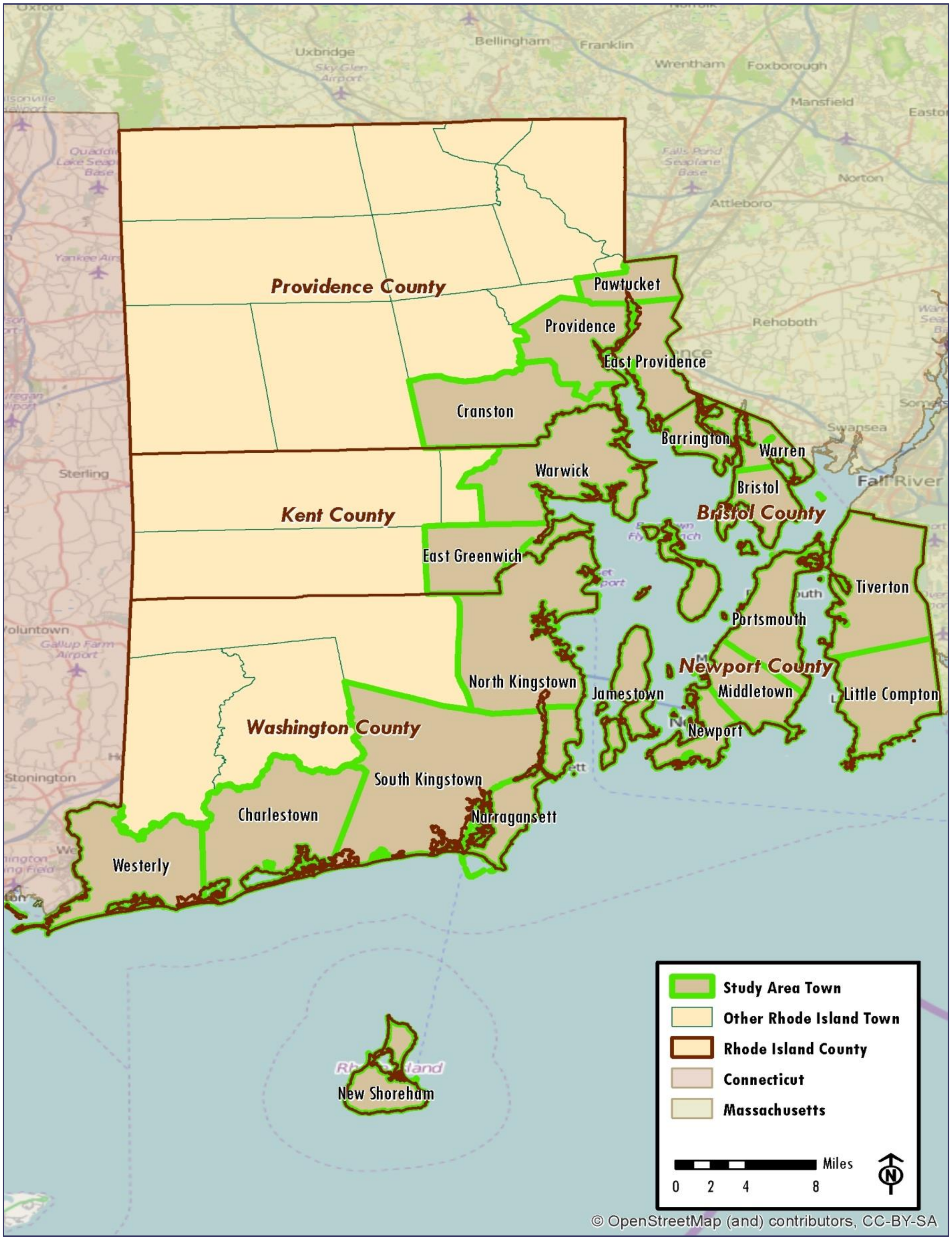

Figure 6-1: Rhode Island HES TDR Study Area

6.2 Analysis Objectives

During a hurricane evacuation, a large number of vehicles will have to travel through the local and regional road network. The number of evacuating vehicles will vary depending upon the intensity of the hurricane, publicity and warnings given about the storm, and certain behavioral response characteristics of the vulnerable population. During a typical evacuation, vehicles enter the road network at different times depending on the evacuees’ response relative to an evacuation order or storm advisory. Conversely, vehicles leave the roadway system depending on both the planned destinations of evacuees and the availability of acceptable destinations, such as public shelters, hotel/motel units, churches, and friend’s or relative’s homes in non-surge prone areas. Vehicles move across the road network from trip origin to destination at a speed dependent on the rate of traffic flowing on various roadway segments, and the number of vehicles per hour those segments can handle. Clearance times must be calculated and evacuation advisories issued so that evacuees can reach a relatively safe destination prior to the arrival of sustained tropical storm force winds.

The main objective of the transportation analysis performed for the Rhode Island HES TDR was to estimate evacuation clearance times; the time it takes to clear the roadway of all evacuating vehicles. To make these estimates, the evacuation road network had to be defined and general traffic control issues had to be examined. Clearance time is a value resulting from transportation engineering analysis performed under a specific set of assumptions. During an actual tropical cyclone event, it must be considered in conjunction with a pre-landfall hazards time to determine the optimal timeframe for issuing an evacuation order. The pre-landfall hazards time is the period before the forecast arrival of tropical storm force winds and/or the onset of roadway flooding prior to landfall of a hurricane.

The transportation analysis task initially identified traffic movements associated with a hurricane evacuation. Basic assumptions for the transportation analysis were related to storm scenarios, vulnerable population, behavioral and socioeconomic characteristics, as well as the roadway system and traffic control. A transportation model and the evacuation roadway system were developed for the Rhode Island study area to facilitate model application and development of clearance times. The major components involved in the transportation analysis were as follows:

1. Establish evacuation zones with the cooperation of Rhode Island’s state and local emergency management agencies;
2. Quantify the potential evacuation population for each storm scenario using socioeconomic and behavioral data;

3. Identify the existing evacuation roadway network, recognizing any recent or future infrastructure improvements, as well as state and local traffic control measures;
4. Using the evacuation road network develop:
   - Directional service volume per roadway segment;
   - Evacuation traffic congestion by roadway segment by storm scenario;
5. Identify local and regional bottlenecks/critical roadway segments;
6. Determine regional evacuation traffic that is expected to cross state and county lines and move inland;
7. Use evacuation zones to complete transportation modeling and clearance time calculations;
8. Develop hurricane evacuation clearance times.

6.3 Transportation Analysis and Input Assumptions

Since all hurricanes differ from one another, it is necessary to establish clear assumptions about storm characteristics and evacuees' expected responses before transportation modeling can begin. Not only does a storm vary in its track, intensity, and size, but also in the way the populations in vulnerable areas perceive it. Even the time of day that a storm makes landfall influences the time parameters of an evacuation. All these factors can have a major impact on evacuation response timing and hence the clearance times ultimately developed by this analysis.

Given that a real tropical cyclone’s characteristics may well differ from the simulated storms used to develop the clearance times provided in this analysis, a sensitivity analysis was performed during the transportation modeling. Since many of the factors that influence an evacuation can change dramatically prior to a storm making landfall, the sensitivity analysis determines which model variables will have the most impact on the transportation analysis results. Therefore, those characteristics (storm intensity, level of background traffic, tourist occupancy, traffic loading rate, etc.) having the greatest influence on clearance times were identified and then varied to establish the logical range within which the input values may fall. Key assumptions guiding the transportation analysis include the following:

- Traffic evacuation zones;
- Housing Unit and Population Data;
- Behavioral Assumptions of the Evacuating Population;
- Roadway Network and Traffic Control Assumptions.

6.4 Traffic Evacuation Zones

The foundational geographical unit of the analysis is a system of evacuation zones for every jurisdiction. The Traffic Evacuation Zones for the Rhode Island HES TDR were established by Rhode Island's state and county emergency management officials based on vulnerability data provided by the USACE, New England District. The above parties determined that the vulnerability areas would coincide with the storm tide limits delineated in the storm surge maps produced by USACE based on the results of the National Oceanic and Atmospheric Administration's (NOAA) Sea, Lake and Overland Surges from Hurricanes (SLOSH) model for the Providence/Boston 2 basin. The primary purpose of the vulnerability area is to specify which locales will be directed to evacuate by local emergency management in Category 1 through 4 storms. These vulnerability areas were then compiled into traffic evacuation zones and used as the basic unit for traffic clearance time modeling. Consequently, each traffic evacuation zone may be composed of a minimum of one vulnerability area (i.e., for wind/mobile home residents) to a maximum of four (i.e., for each of the Category 1 through 4 storm surge areas).

It is important to note that local officials are responsible for insuring that the vulnerability areas encompass all surge vulnerable residents and that evacuation advisories during a hurricane threat will adequately advise those living in evacuation zones to take action. Maps of the traffic evacuation zones for each individual jurisdiction are provided in Figures 6-2 through 6-22 as listed below, and are also available in the File Bank section as interactive maps:

- Figure 6-2: Hurricane Evacuation Zones – Bristol County / Barrington
- Figure 6-3: Hurricane Evacuation Zones – Bristol County / Bristol
- Figure 6-4: Hurricane Evacuation Zones – Bristol County / Warren
- Figure 6-5: Hurricane Evacuation Zones – Kent County / East Greenwich
- Figure 6-6: Hurricane Evacuation Zones – Kent County / Warwick
- Figure 6-7: Hurricane Evacuation Zones – Newport County / Jamestown
- Figure 6-8: Hurricane Evacuation Zones – Newport County / Little Compton
- Figure 6-9: Hurricane Evacuation Zones – Newport County / Middletown
- Figure 6-10: Hurricane Evacuation Zones – Newport County / Newport
- Figure 6-11: Hurricane Evacuation Zones – Newport County / Portsmouth
- Figure 6-12: Hurricane Evacuation Zones – Newport County / Tiverton
- Figure 6-13: Hurricane Evacuation Zones – Providence County / Cranston
- Figure 6-14: Hurricane Evacuation Zones – Providence County / East Providence
- Figure 6-15: Hurricane Evacuation Zones – Providence County / Pawtucket
- Figure 6-16: Hurricane Evacuation Zones – Providence County / Providence
- Figure 6-17: Hurricane Evacuation Zones – Washington County / Charlestown

- Figure 6-18: Hurricane Evacuation Zones – Washington County / Narragansett
- Figure 6-19: Hurricane Evacuation Zones – Washington County / New Shoreham
- Figure 6-20: Hurricane Evacuation Zones – Washington County / North Kingstown
- Figure 6-21: Hurricane Evacuation Zones – Washington County / South Kingstown
- Figure 6-22: Hurricane Evacuation Zones – Washington County / Westerly

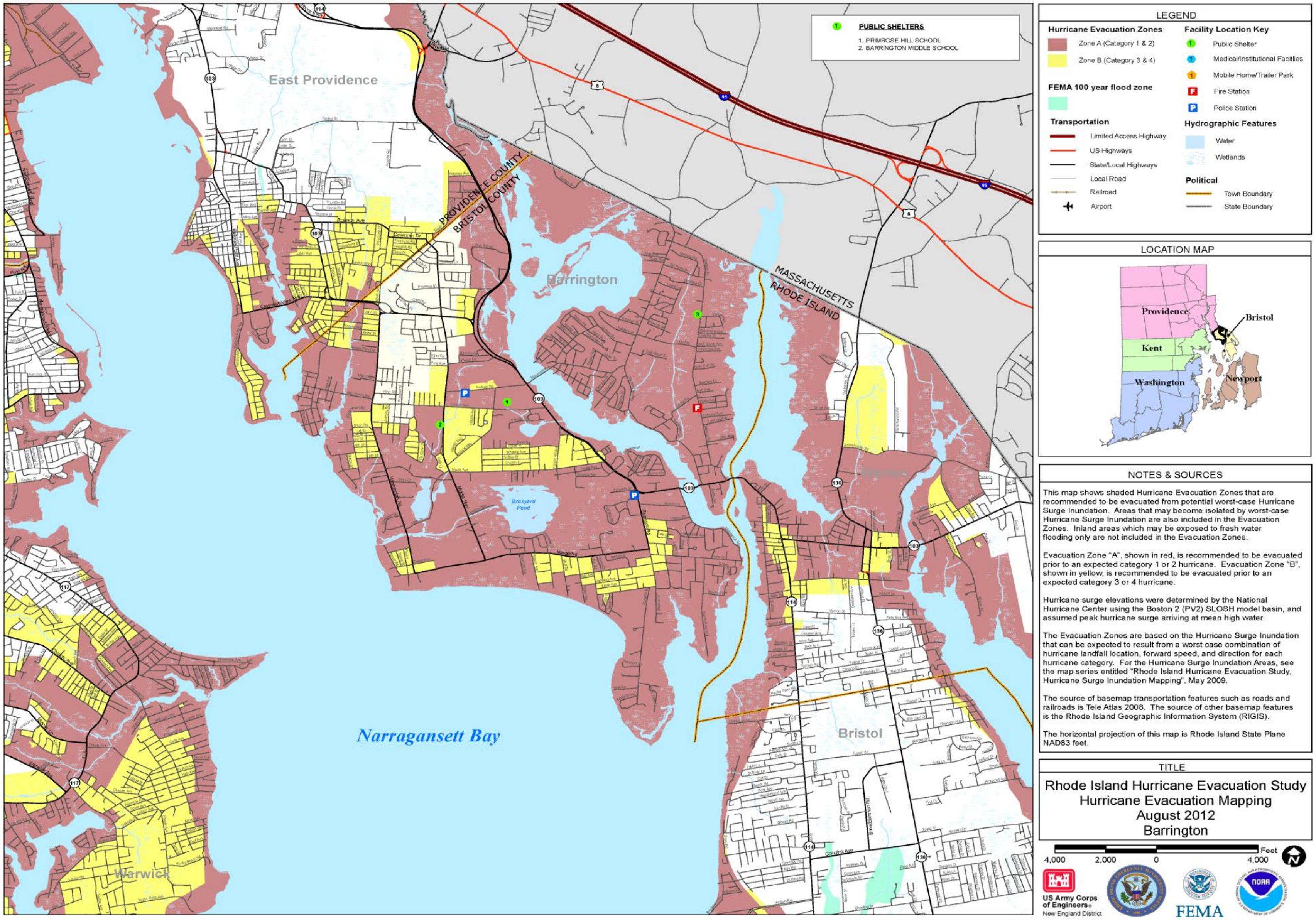

Figure 6-2: Hurricane Evacuation Zones – Bristol County / Barrington

6.0 Transportation Analysis

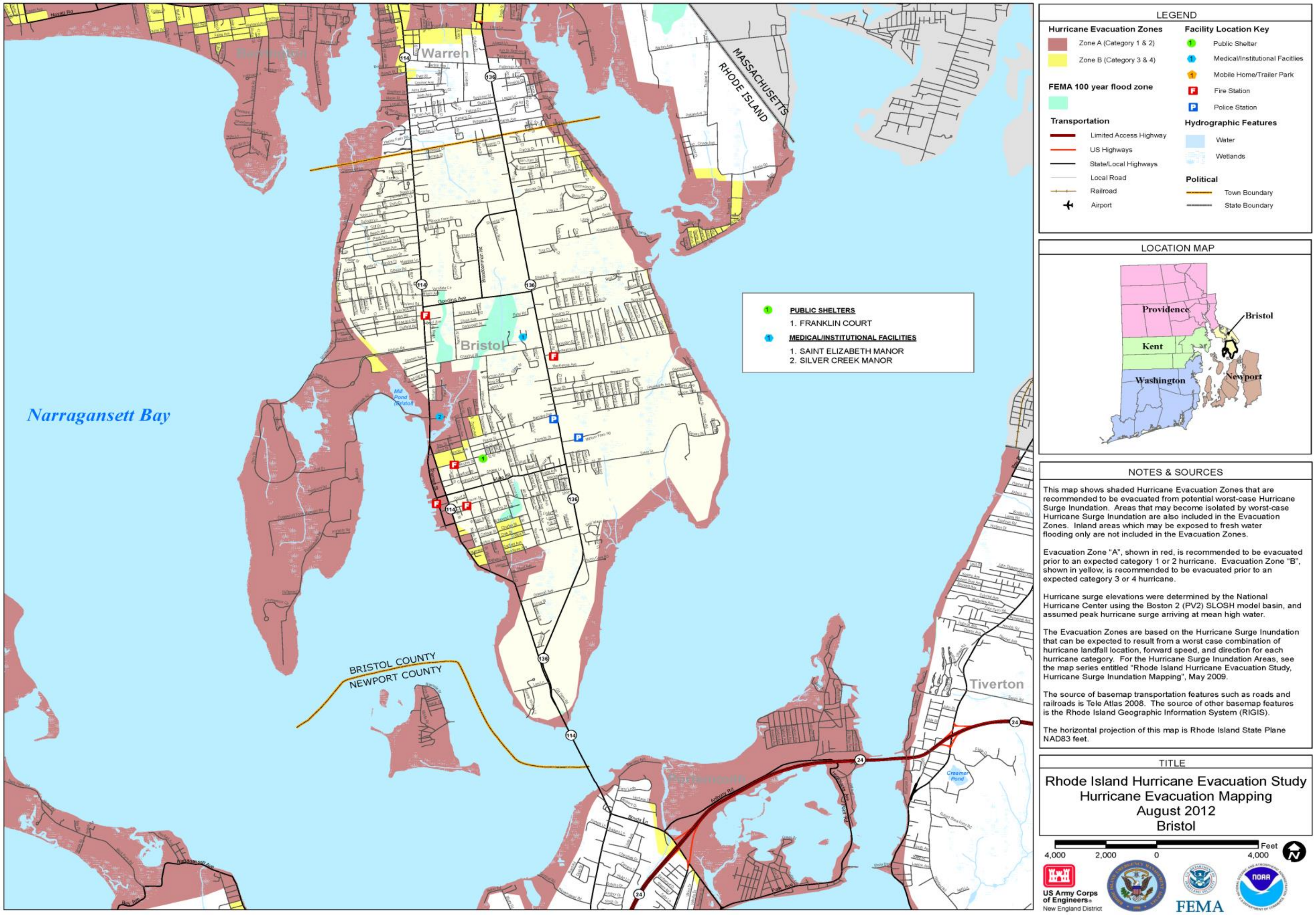

Figure 6-3: Hurricane Evacuation Zones – Bristol County / Bristol

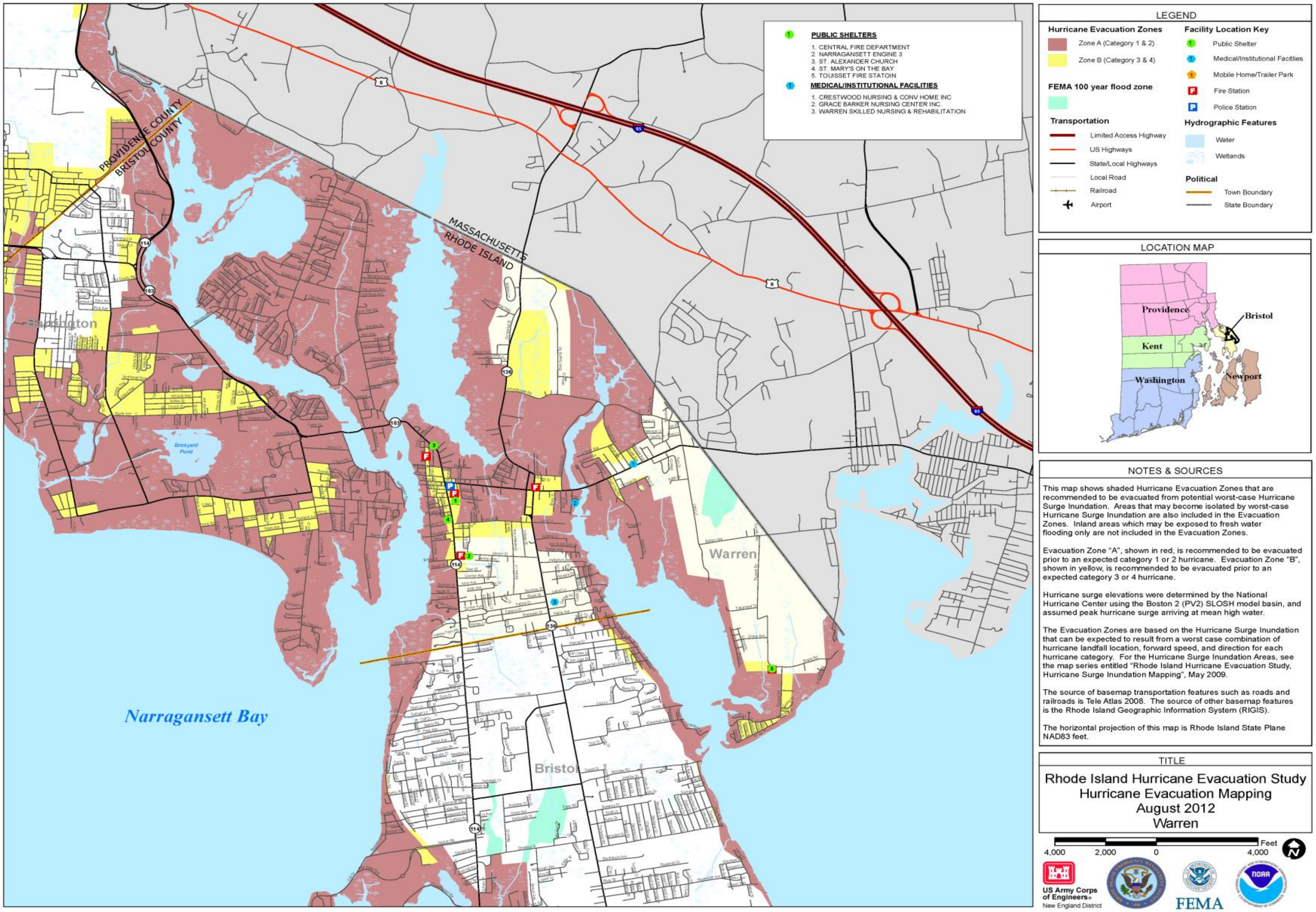

Figure 6-4: Hurricane Evacuation Zones – Bristol County / Warren

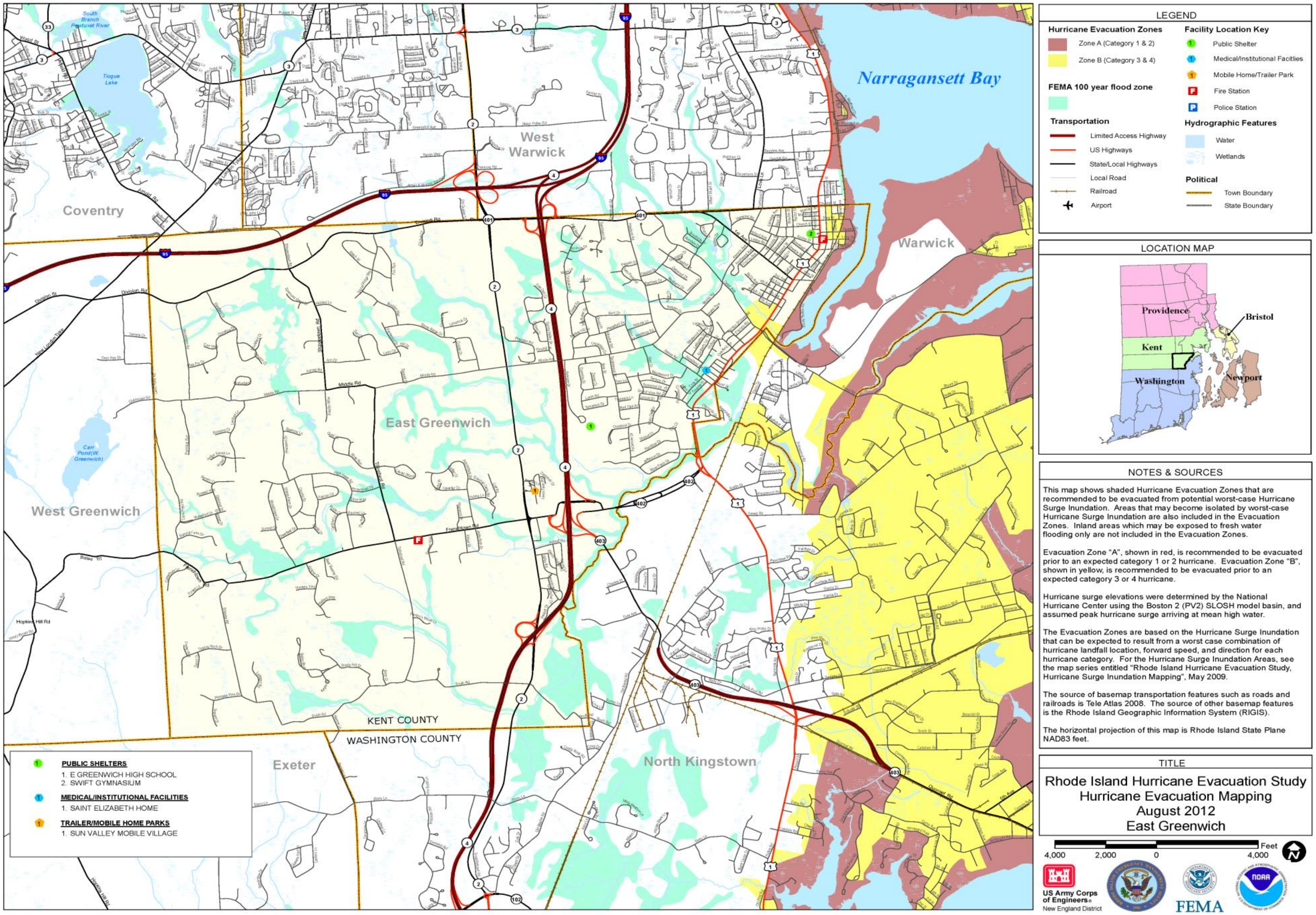

Figure 6-5: Hurricane Evacuation Zones – Kent County / East Greenwich

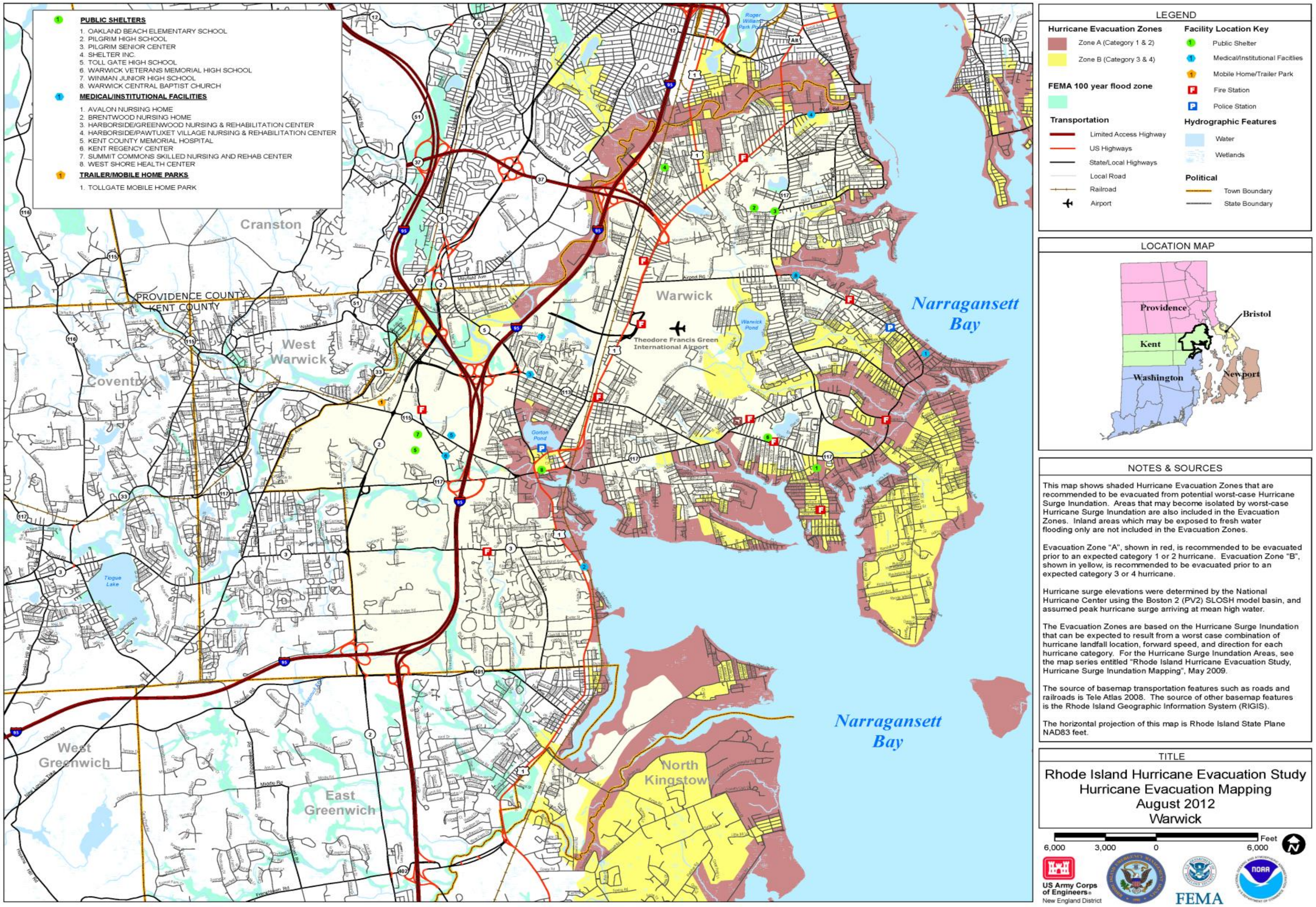

Figure 6-6: Hurricane Evacuation Zones – Kent County / Warwick

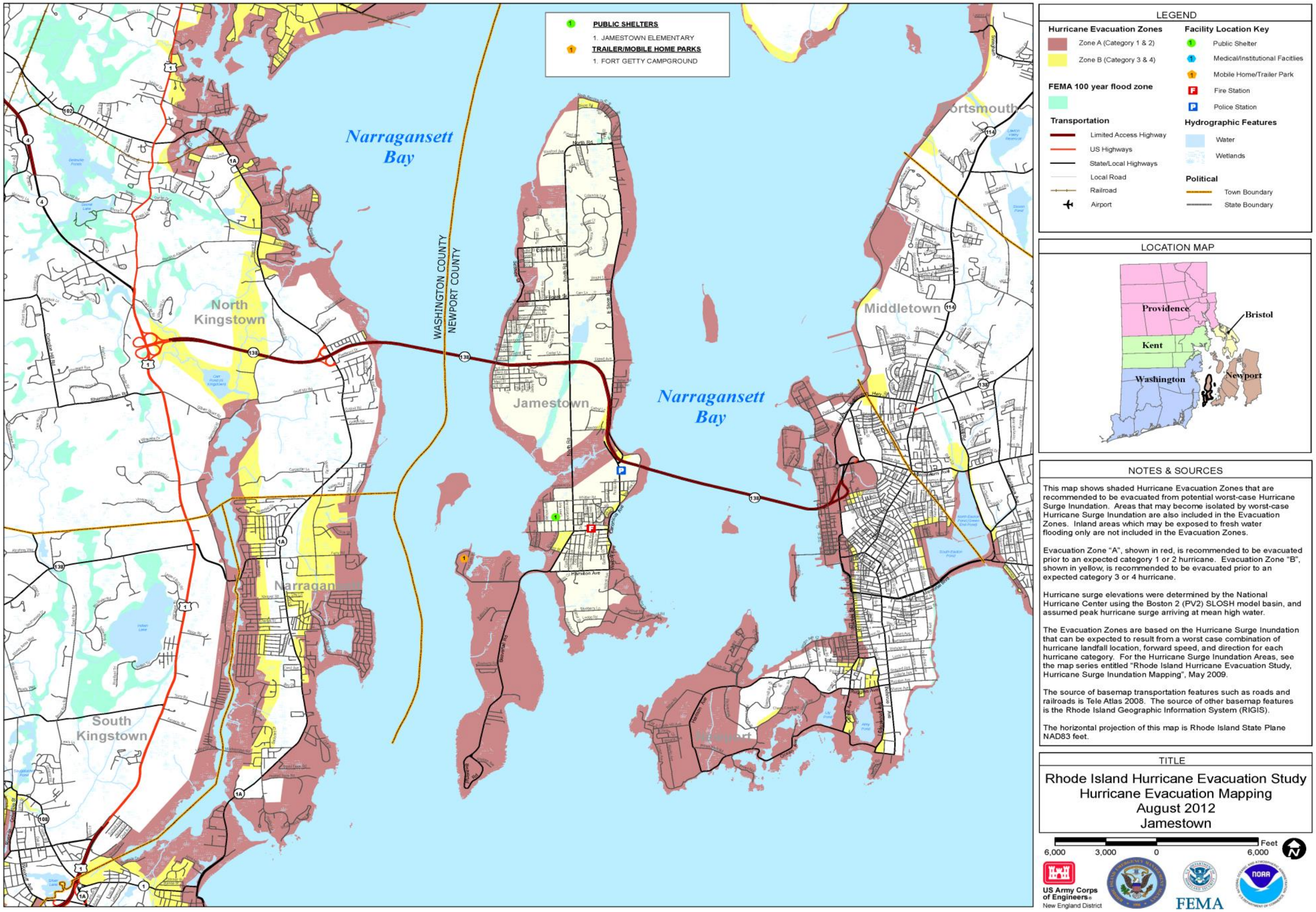

Figure 6-7: Hurricane Evacuation Zones – Newport County / Jamestown

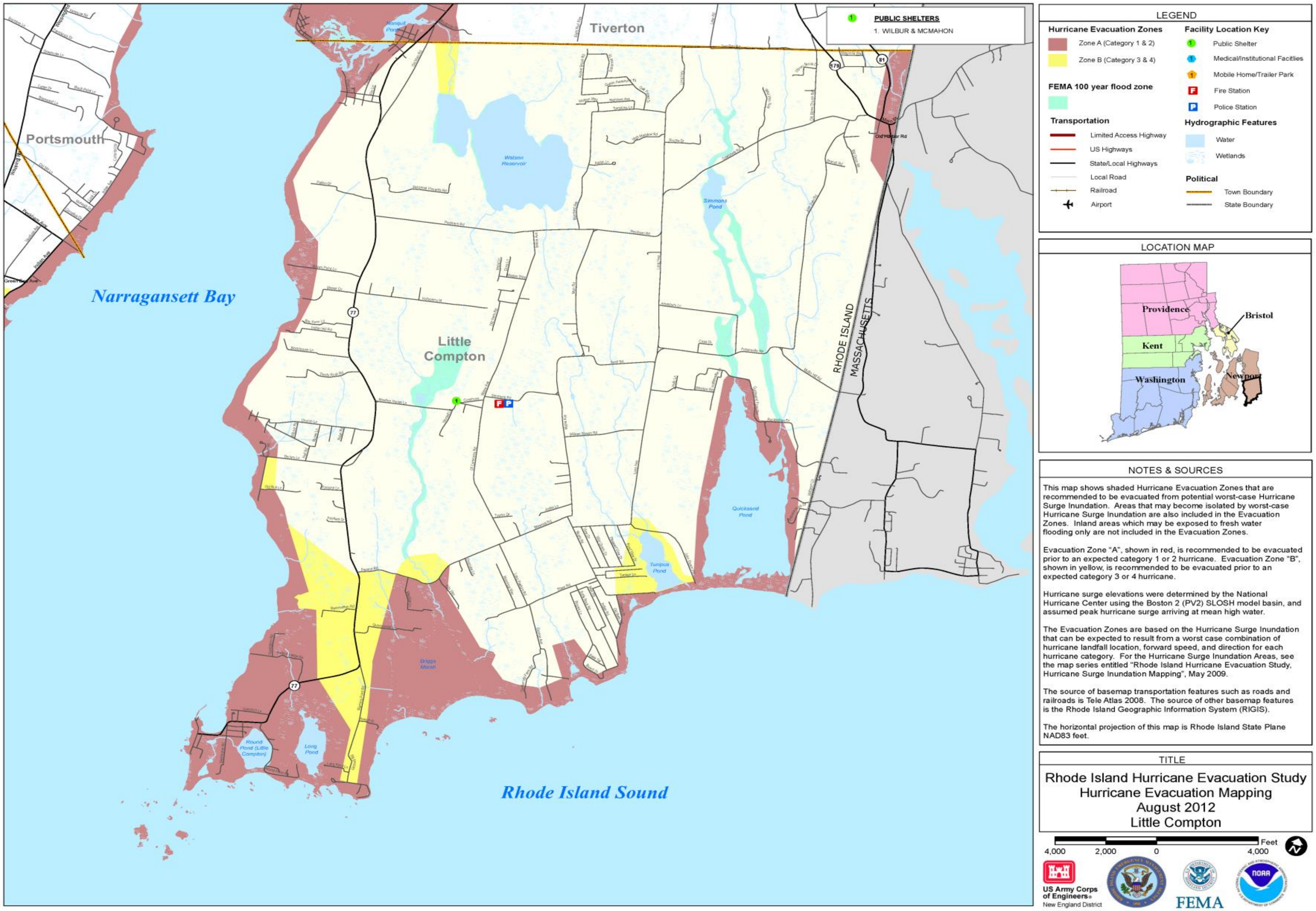

Figure 6-8: Hurricane Evacuation Zones – Newport County / Little Compton

6.0 Transportation Analysis

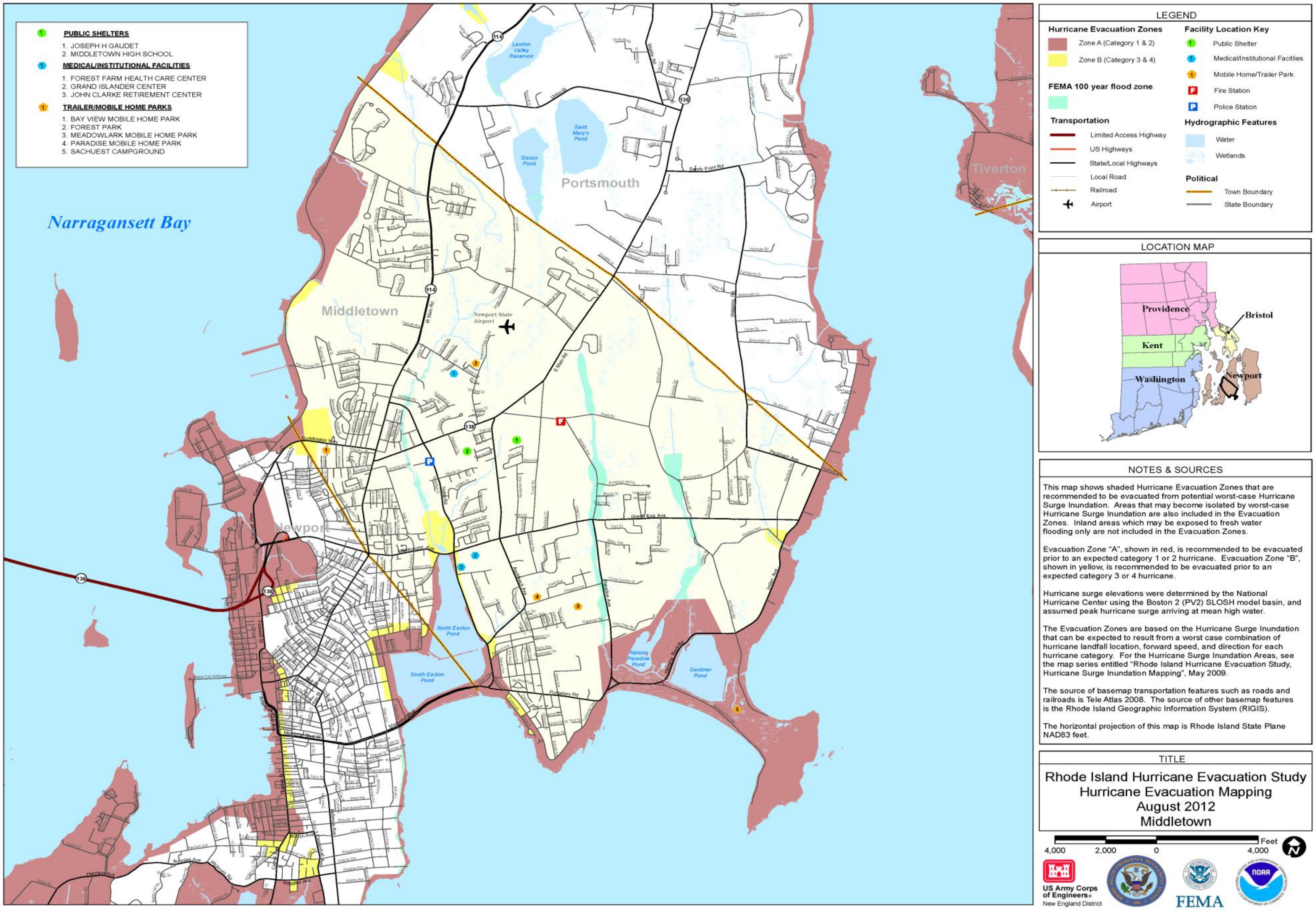

Figure 6-9: Hurricane Evacuation Zones – Newport County / Middletown

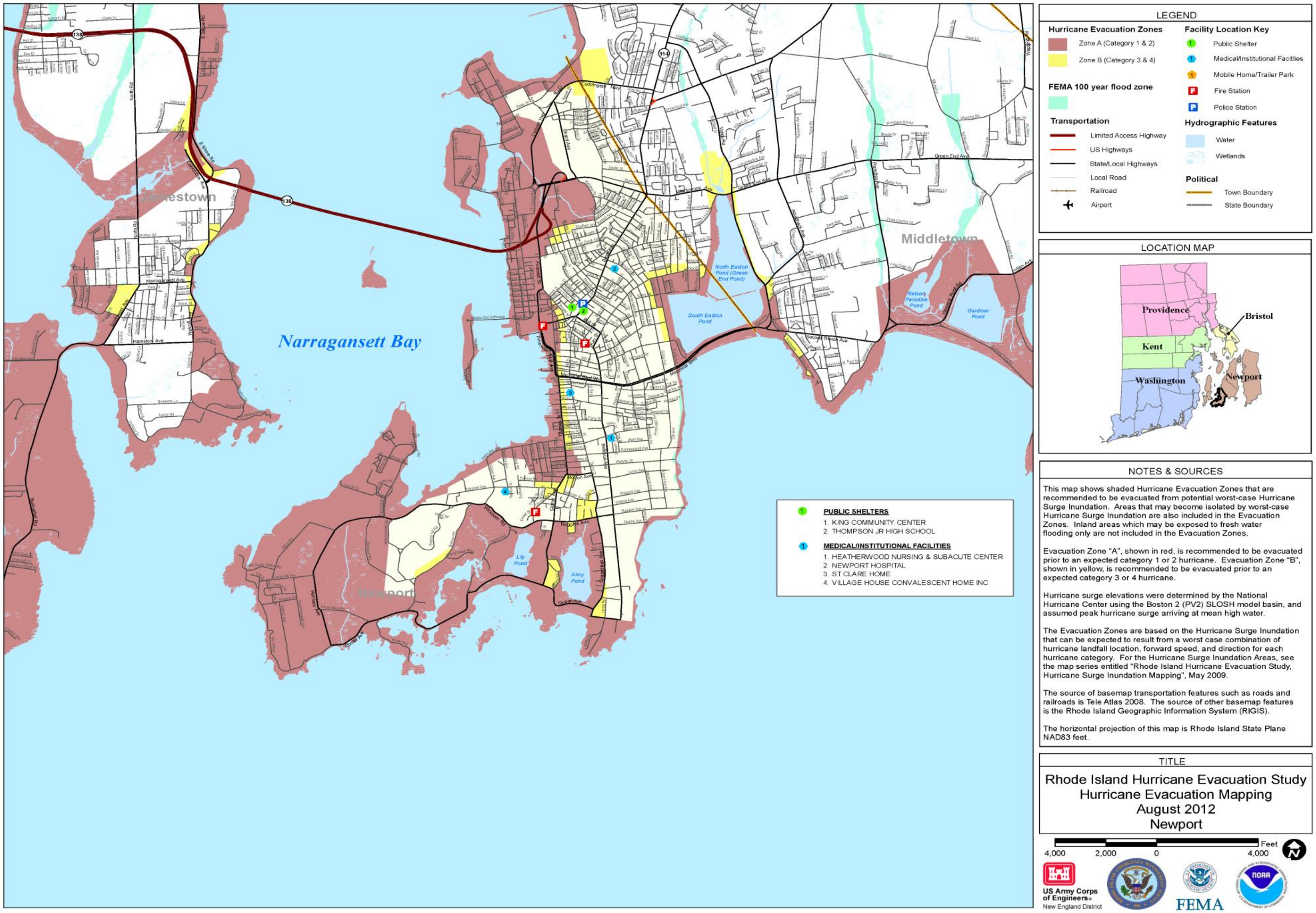

Figure 6-10: Hurricane Evacuation Zones – Newport County / Newport

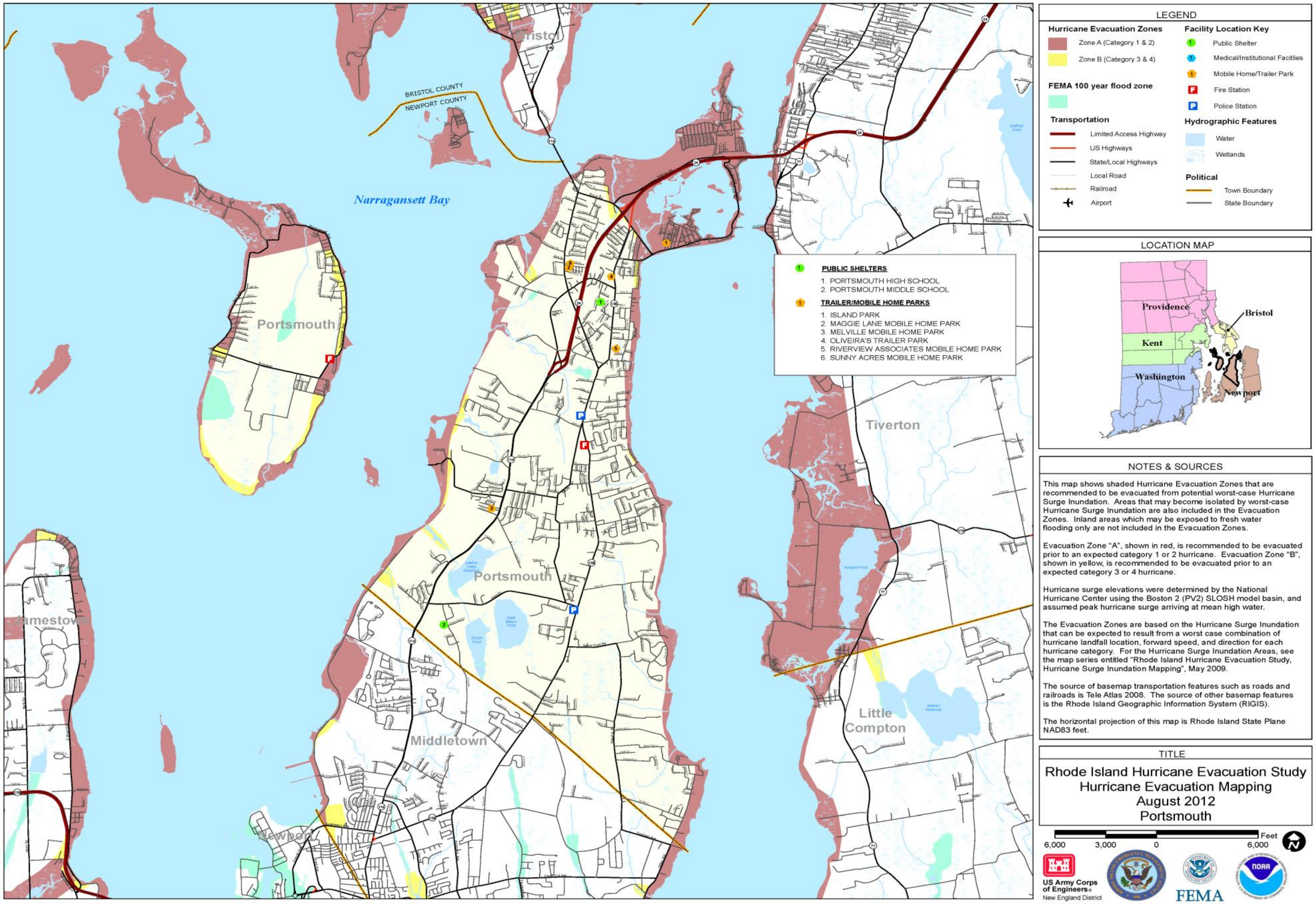

Figure 6-11: Hurricane Evacuation Zones – Newport County / Portsmouth

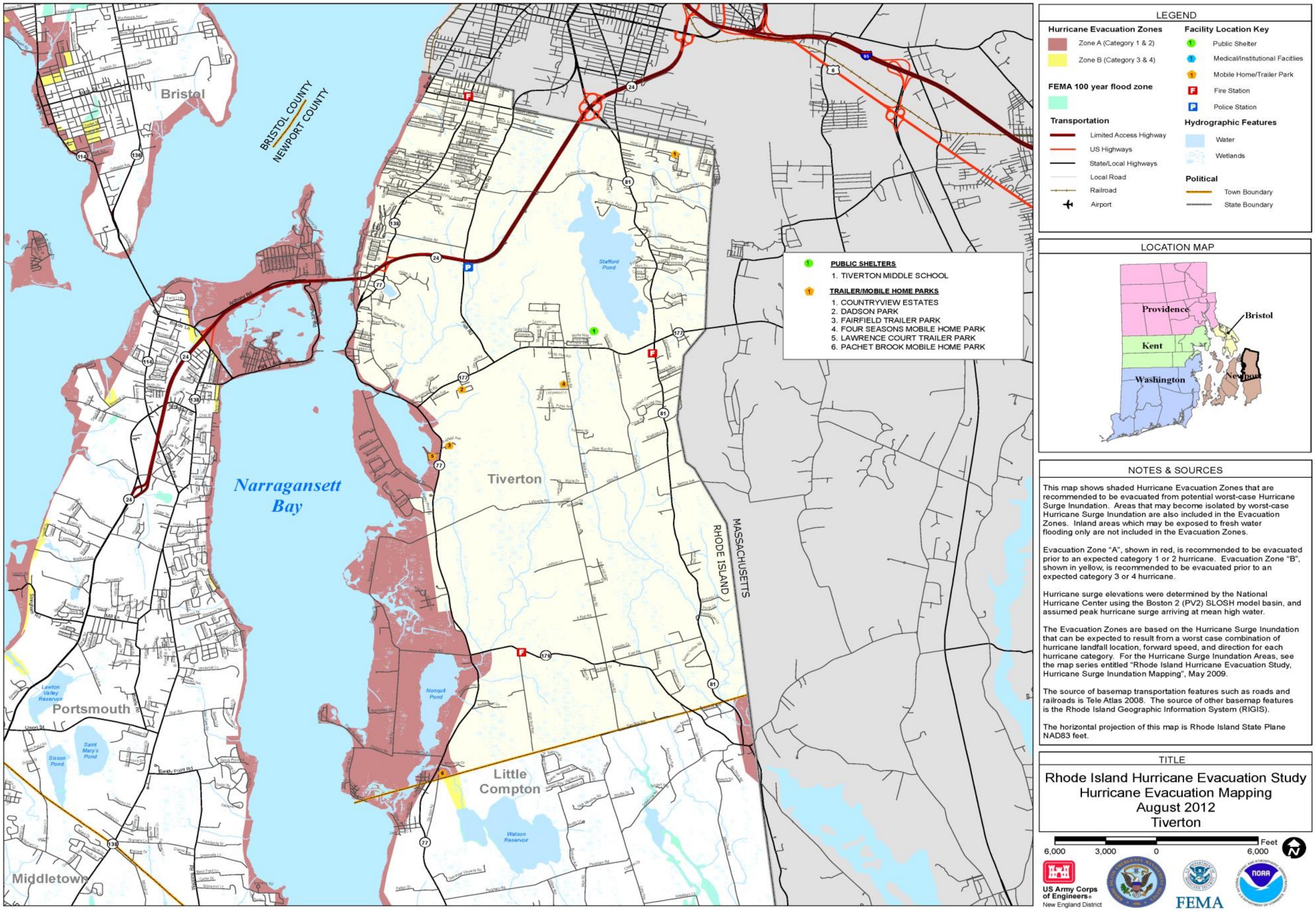

Figure 6-12: Hurricane Evacuation Zones – Newport County / Tiverton

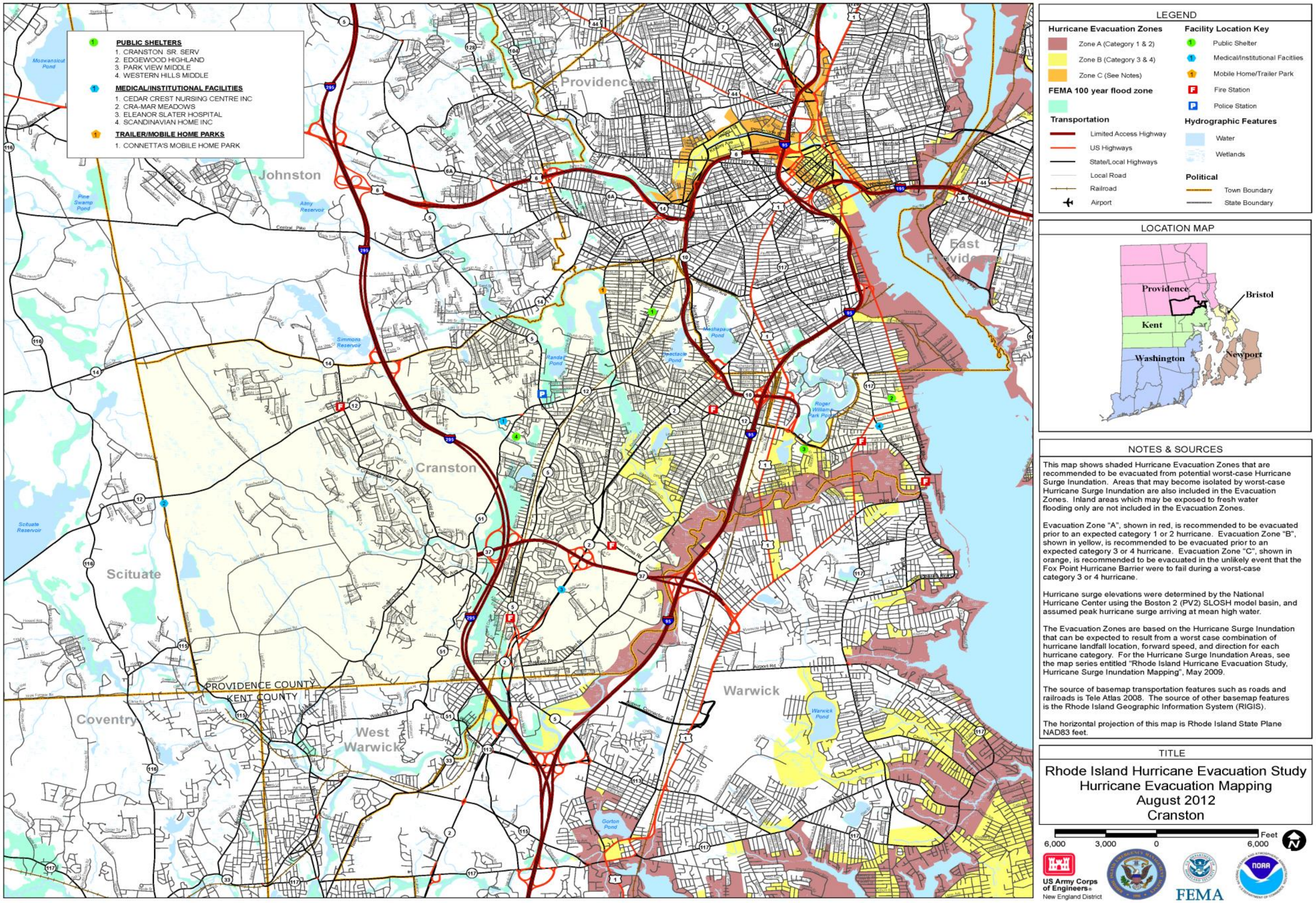

Figure 6-13: Hurricane Evacuation Zones – Providence County / Cranston

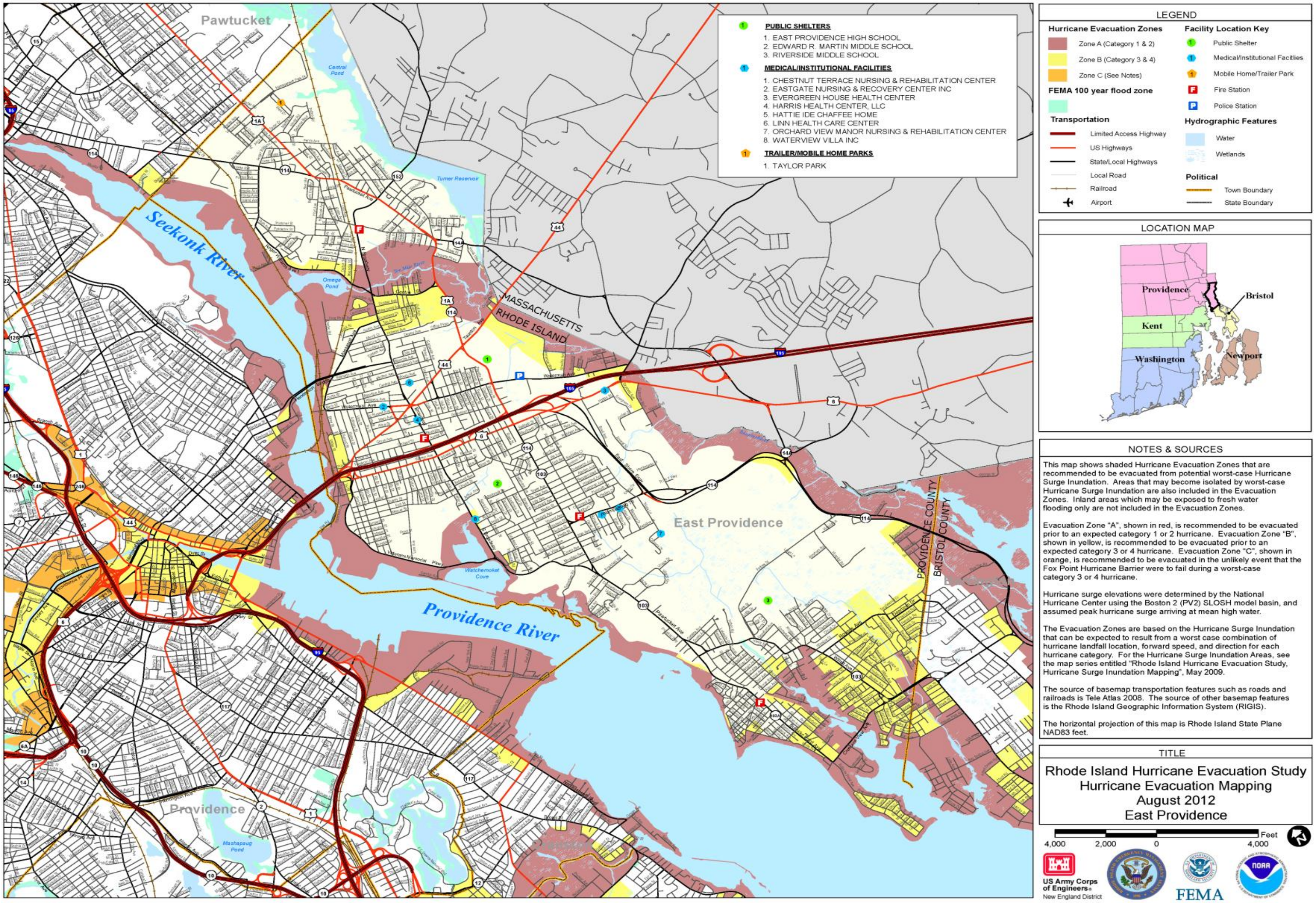

Figure 6-14: Hurricane Evacuation Zones – Providence County / East Providence

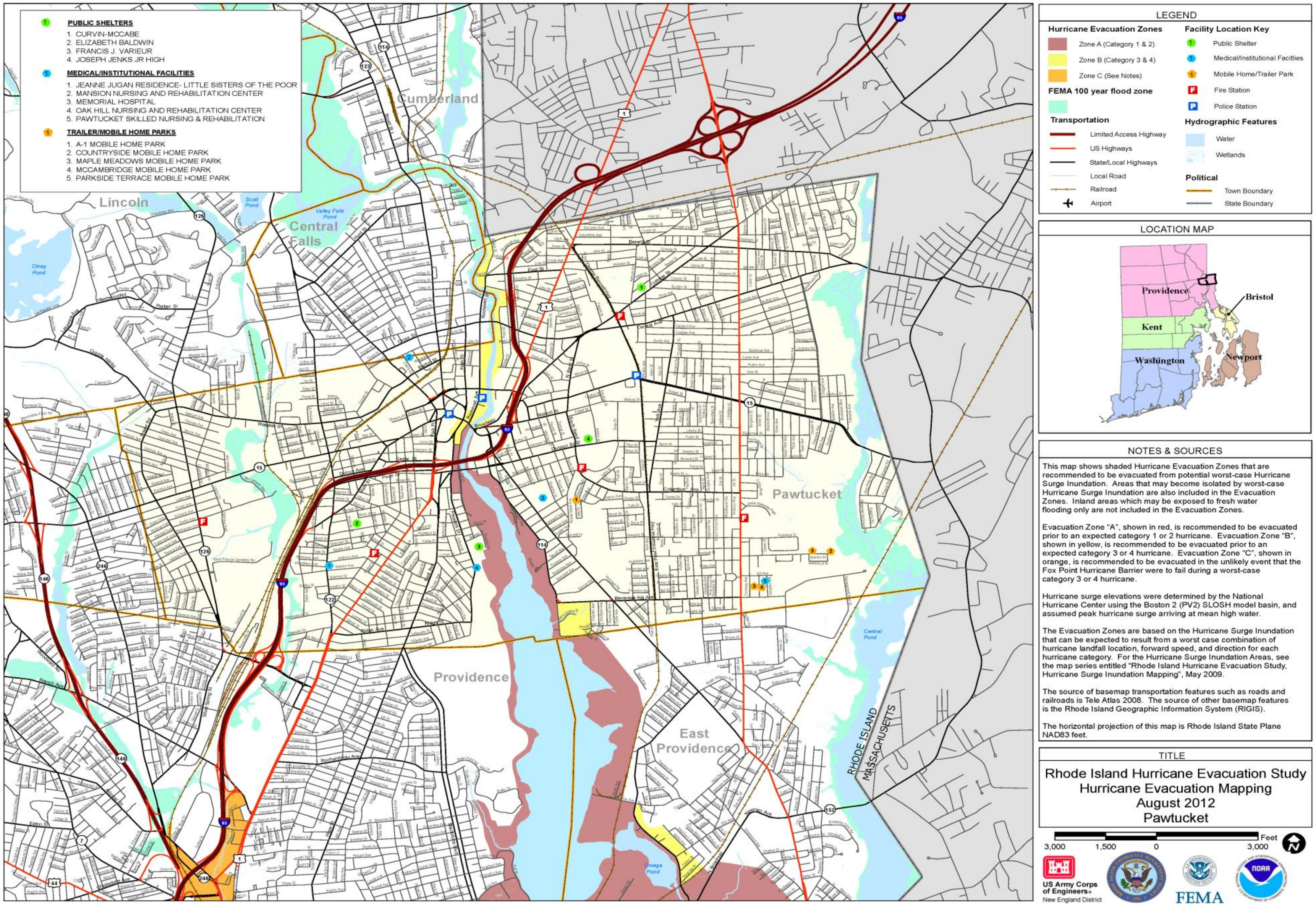

Figure 6-15: Hurricane Evacuation Zones – Providence County / Pawtucket

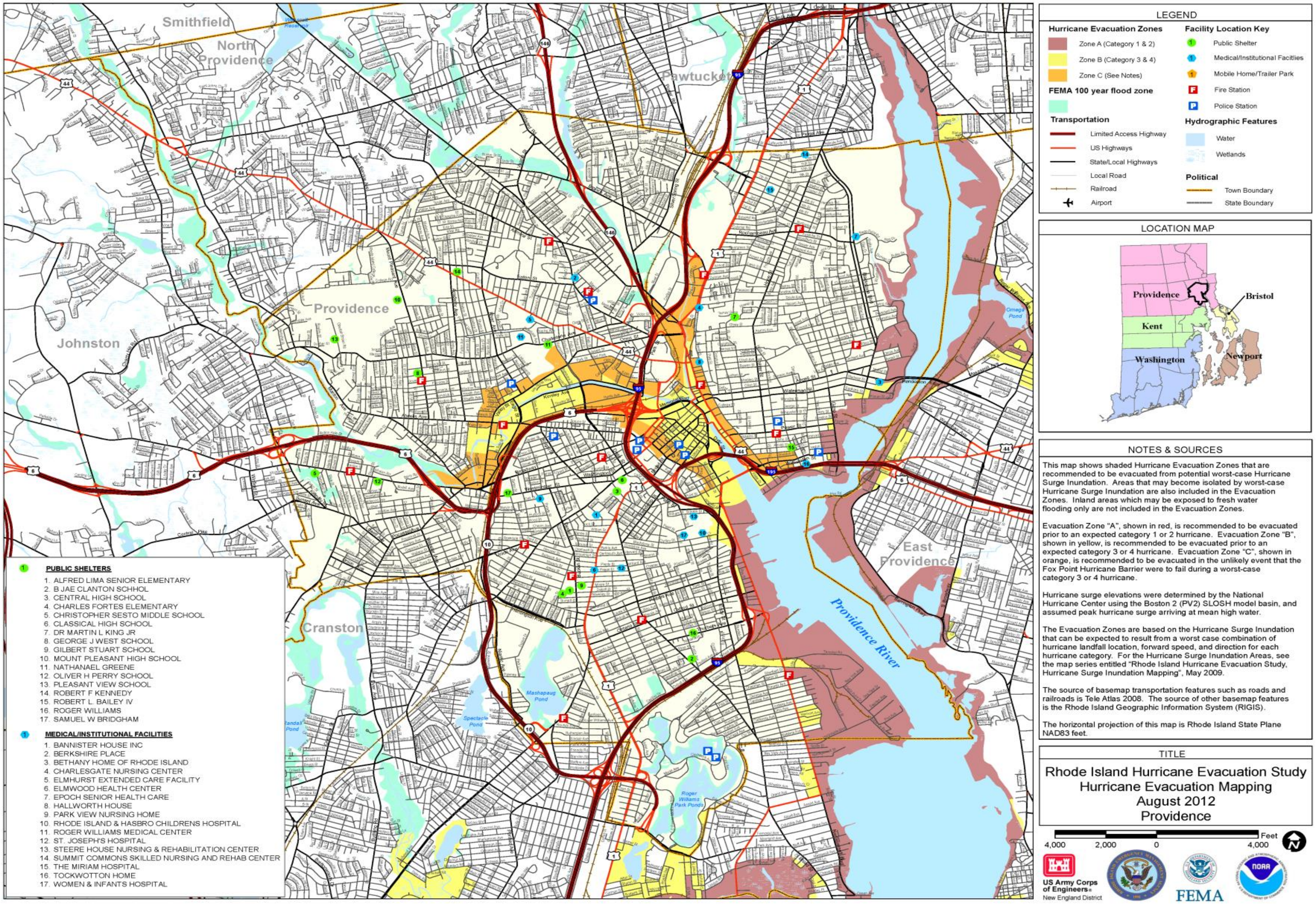

Figure 6-16: Hurricane Evacuation Zones – Providence County / Providence

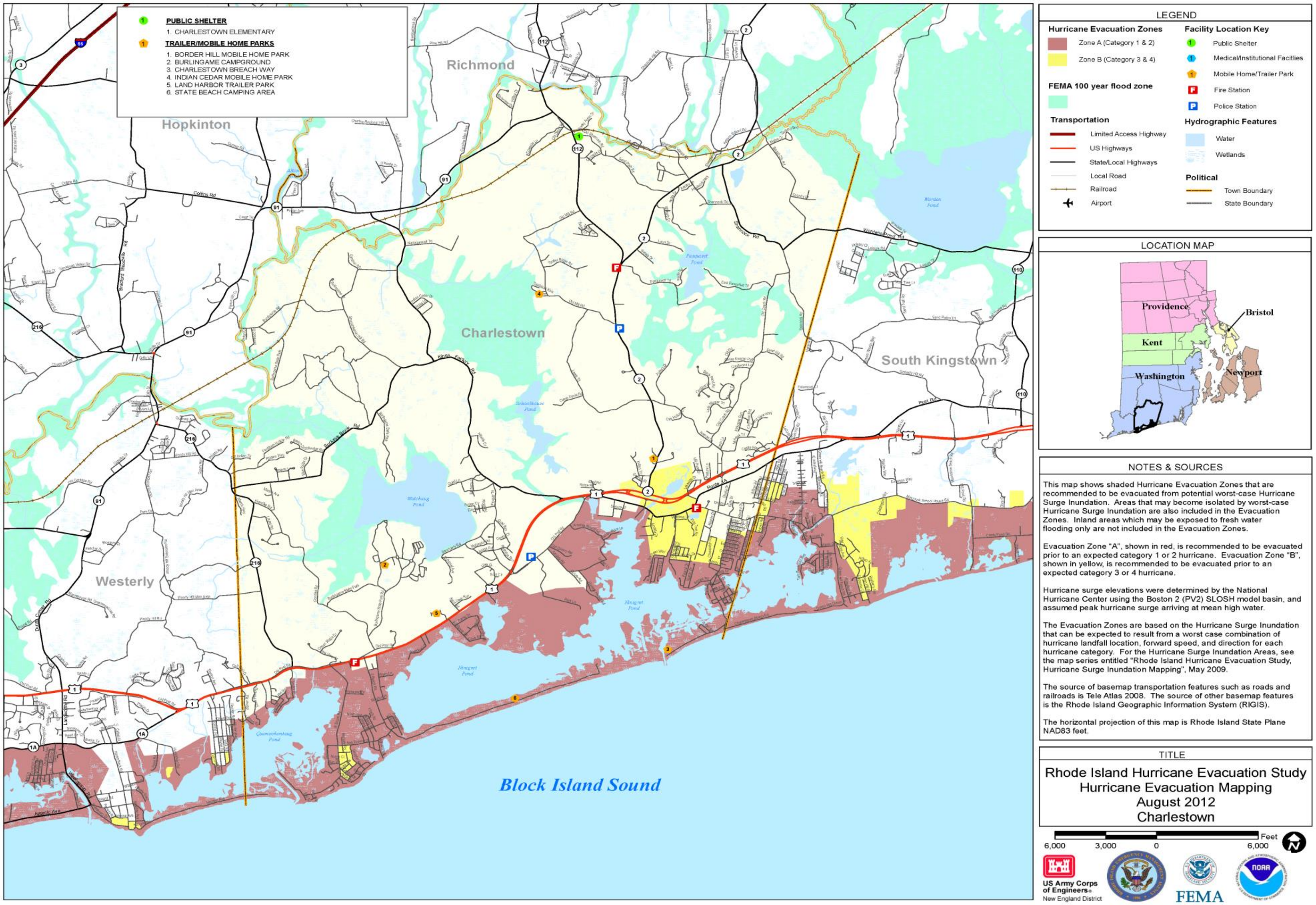

Figure 6-17: Hurricane Evacuation Zones – Washington County / Charlestown

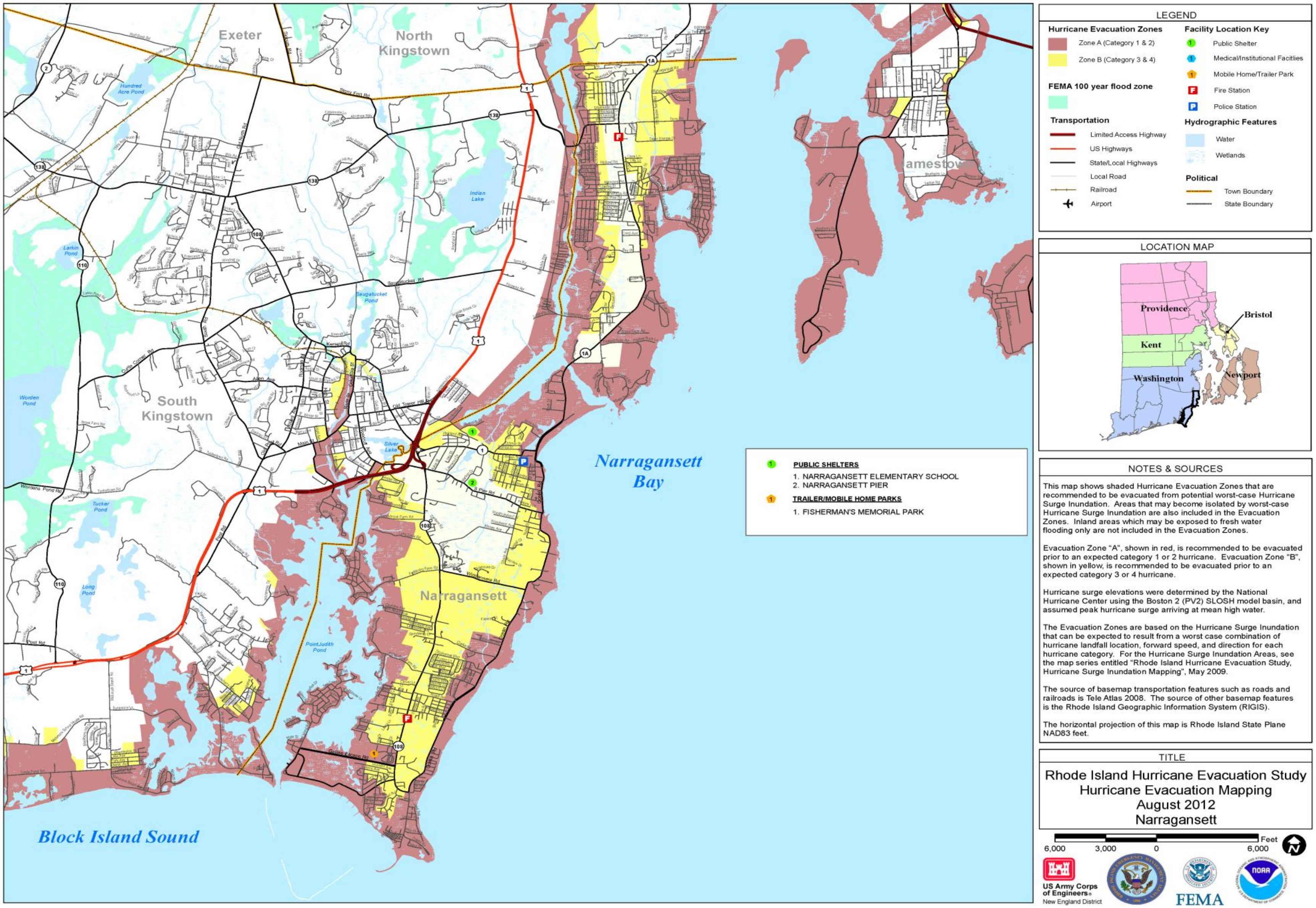

Figure 6-18: Hurricane Evacuation Zones – Washington County / Narragansett

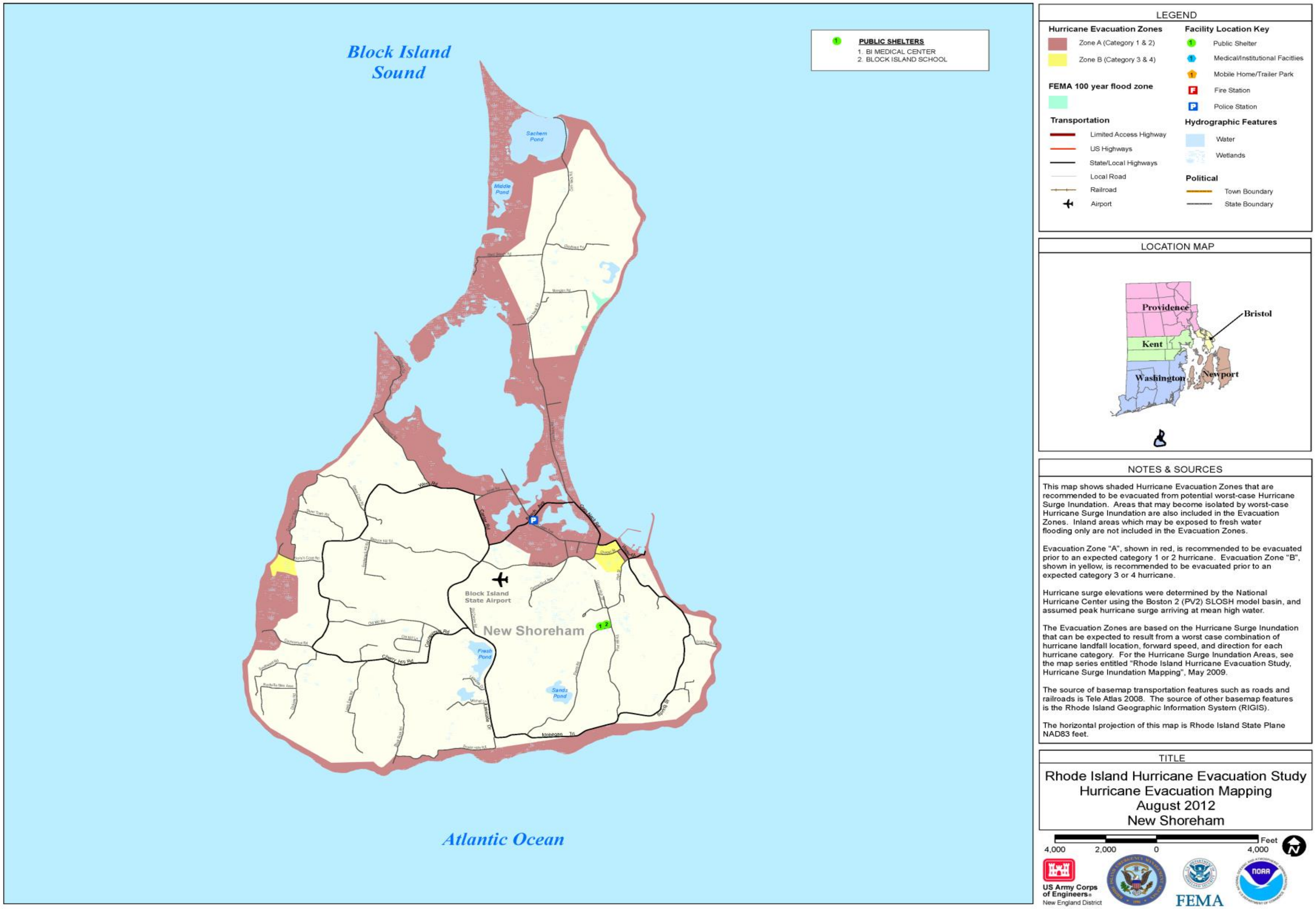

Figure 6-19: Hurricane Evacuation Zones – Washington County / New Shoreham

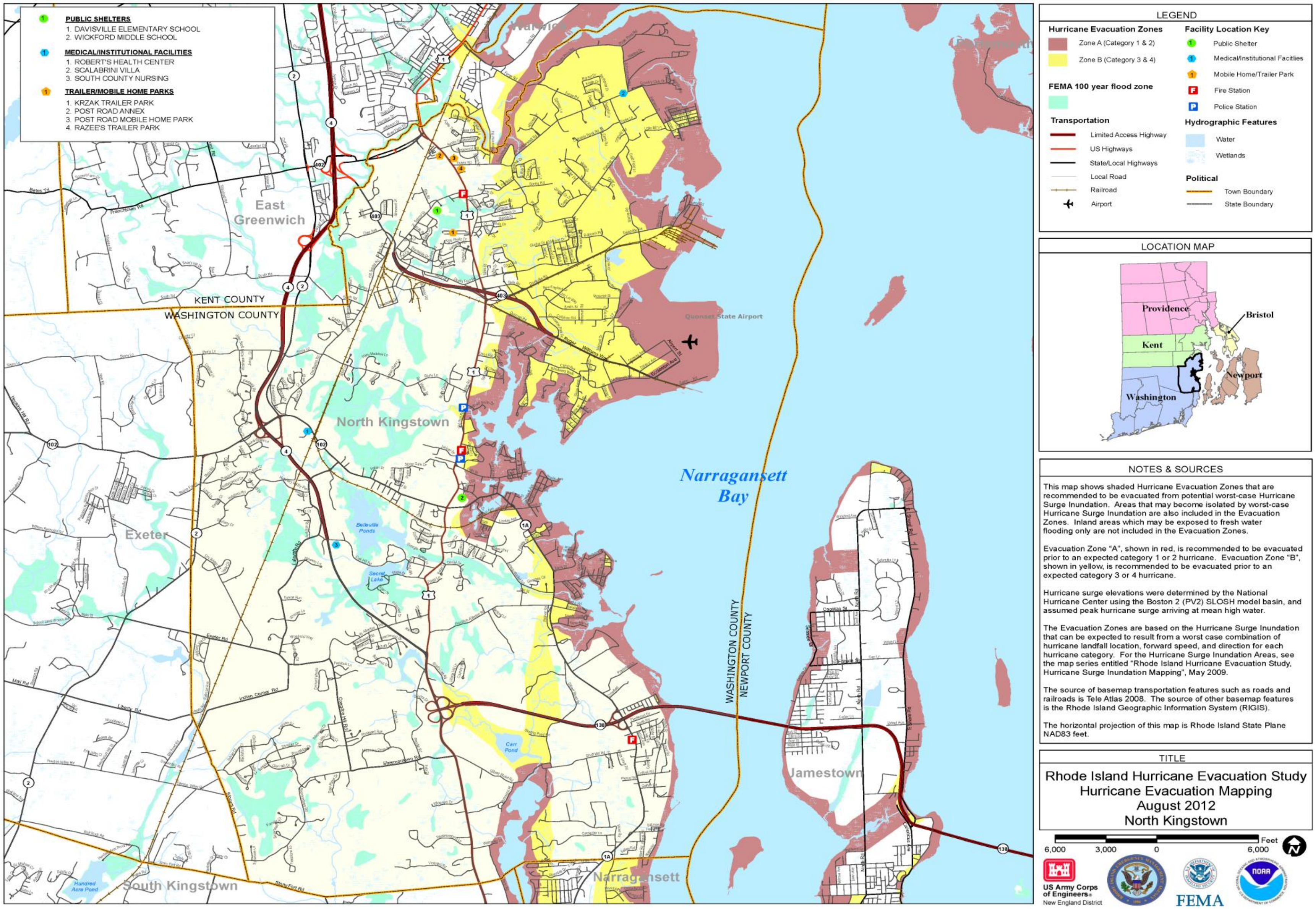

Figure 6-20: Hurricane Evacuation Zones – Washington County / North Kingstown

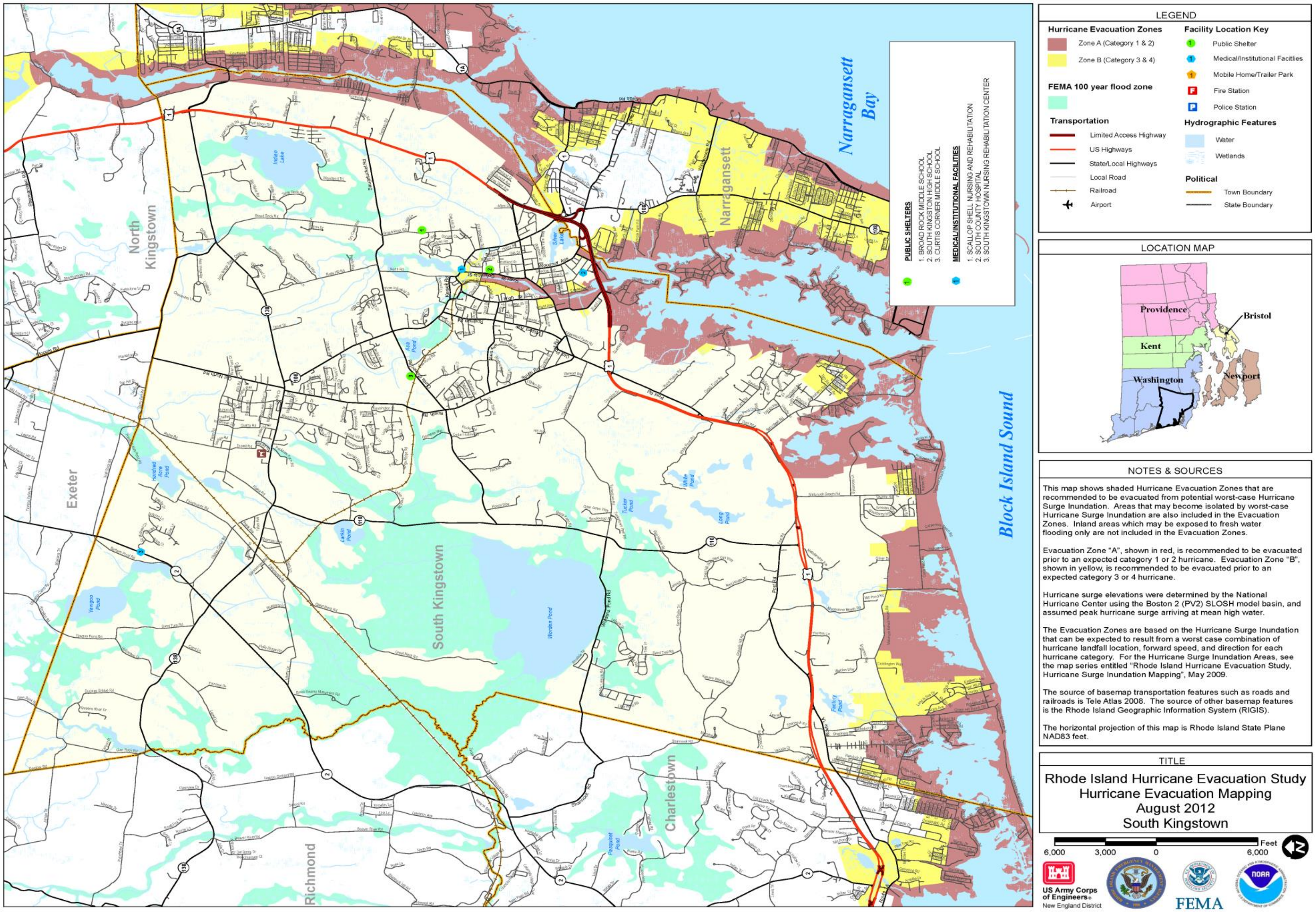

Figure 6-21: Hurricane Evacuation Zones – Washington County / South Kingstown

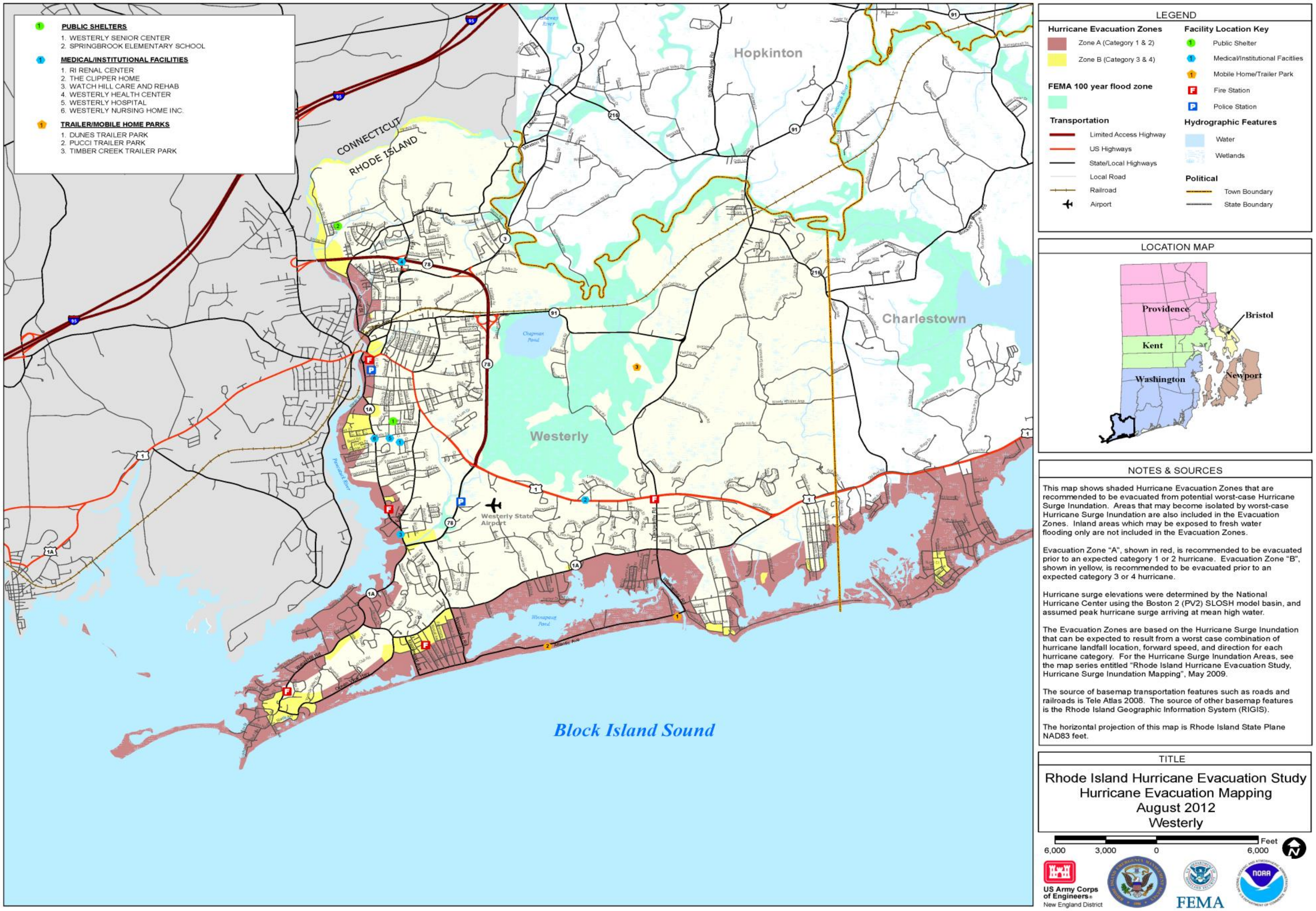

Figure 6-22: Hurricane Evacuation Zones – Washington County / Westerly

6.5 Housing Unit and Population Data

All housing unit and other socioeconomic data were developed for each traffic evacuation zone based on data prepared by the U.S. Census Bureau for the 2010 decennial census, as well as 5-year projections from the 2013 American Community Survey. Geographic Information Systems (GIS) were used to further reconfigure the census data to conform to the evacuation/traffic analysis zones that formed the basic unit for this study. In addition the U.S. Census also provided the data for the seasonal/vacation units in each traffic evacuation zones. The number of hotel and motel units on the other hand were obtained by a thorough investigation of various tourist information sites on the internet, as well as the information contained in the "Hurricane Evacuation Plan Phase 1" study done in April of 2007. Table 6-2 summarizes the key socioeconomic data used for the Rhode Island HES TDR locations, as well as jurisdiction-wide averages for people and vehicles per unit, people per unit and vehicle ownership numbers for every evacuation zone in the study area.

Table 6-3 shows the socioeconomic data for the Rhode Island HES TDR locations by vulnerability zone. This table represents the total aggregate number located in each vulnerability zone within a county and not the specific population and units that would be directed to evacuate from each sector. Tables 6-4 through Tables 6-8 provide further detail on a community basis for each county as follows:

- Table 6-4: Key Socioeconomic Data – Bristol County
- Table 6-5: Key Socioeconomic Data – Kent County
- Table 6-6: Key Socioeconomic Data – Newport County
- Table 6-7: Key Socioeconomic Data – Providence County
- Table 6-8: Key Socioeconomic Data – Washington County

The socioeconomic data used in the transportation model focuses on three types of housing units to determine the vulnerability data included in the evacuation statistics. The most important housing category is occupied residential; these are the full time inhabitants most likely to be impacted by evacuation decisions throughout the hurricane season, especially if located in storm surge flooding areas. The model also factors in occupied, mobile homes residences because of their vulnerability to hurricane winds, regardless of distance from the storm tide limits or proximity to the coast. The third housing type used in the model is seasonal/vacation and tourist units; people in these units, although their numbers may vary from day to day during the hurricane season, are more likely to evacuate and will usually travel further to do so.

6.0 Transportation Analysis

In the transportation model, each housing type described above will have specific socioeconomic and behavioral variables assigned to it to ensure that the inherent differences in the responses of their inhabitants during a hurricane event are factored into the vulnerability data. For instance the number of vehicles and people per unit will vary, in some cases dramatically, between occupied residential and seasonal/tourist units. Furthermore, this degree of specificity allows the model to factor in variations in occupancy levels, especially with respect to visitor units.

Table 6-2: Key Socioeconomic Data

County	Population[1]	Permanent Occupied Units[1]	Mobile Home Units[1]	Seasonal Vacation Units[1]	Tourist Motel / B&B Units[2]	Average People per Occupied Housing Unit[1]	Average Vehicle per Occupied Housing Unit[1]
Bristol County	49,432	18,979	0	530	85	2.53	1.82
Kent County	95,501	40,121	122	545	2,213	2.17	1.73
Newport County	82,541	34,764	797	4,145	4,023	2.17	1.76
Providence County	381,589	145,441	627	737	3,136	2.66	1.35
Washington County	105,237	41,188	612	9,776	3,826	2.28	1.87
Totals / Averages	**714,300**	**280,493**	**2,158**	**15,733**	**13,283**	**2.36**	**1.71**

1. Data represented in this table reflects data obtained and/or calculated from the 2009-2013 American Community Survey 5-Year Estimates.
2. Obtained from http://www.visitrhodeisland.com/where-to-stay/.

Table 6-3: Housing Unit and Population Data by Evacuation Zone

Evacuation Areas[1]	Population[2]	Permanent Occupied Units[2]	Mobile Home Units[2]	Seasonal Vacation Units[2]	Tourist Motel / B&B Units[3]	Average People per Occupied Housing Unit[2]	Average Vehicle per Occupied Housing Unit[2]
Bristol County	19,505	7,666	0	317	49	2.53	1.81
	6,108	2,466	0	36	8	2.40	1.78
	23,817	8,847	0	177	28	2.66	1.86
Kent County	12,169	5,254	12	177	15	2.01	1.64
	14,236	6,014	4	88	168	1.96	1.65
	69,096	28,853	106	280	2,030	2.52	1.90
Newport County	13,523	5,446	56	1,790	1,686	2.35	1.89
	1,952	929	0	261	209	1.81	1.54
	67,065	28,388	742	2,093	2,128	2.36	1.86
Providence County	8,633	3,229	9	25	136	3.14	1.40
	13,731	5,430	0	47	1,182	3.14	1.40
	4,800	2,419	0	40	441	1.98	1.01
	354,425	134,363	618	625	1,377	2.55	1.45
Washington County	15,966	7,220	182	5,647	1,155	2.13	1.87
	12,786	5,337	56	1,249	97	2.19	1.86
	76,484	28,632	374	2,881	2,574	2.52	1.87
Totals / Averages	**69,796**	**28,815**	**259**	**7,956**	**3,041**	**2.43**	**1.72**
	48,813	**20,176**	**60**	**1,681**	**1,664**	**2.30**	**1.65**
	4,800	**2,419**	**0**	**40**	**441**	**1.98**	**1.01**
	590,887	**229,083**	**1,840**	**6,056**	**8,137**	**2.52**	**1.79**
Overall Totals / Averages	**714,296**	**280,493**	**2,159**	**15,733**	**13,283**	**2.39**	**1.67**

1. Key: Zone A (Category 1 & 2) — Zone B (Category 3 & 4) — Zone C (Category 3 & 4/Fox Point Hurricane Barrier Failure, Providence County Only) — Inland Area (Non-Surge)
2. Data represented in this table reflects data obtained and/or calculated from the 2009-2013 American Community Survey 5-Year Estimates.
3. Obtained from http://www.visitrhodeisland.com/where-to-stay/.

Table 6-4: Key Socioeconomic Data – Bristol County

Evacuation Areas[1]	Population[2]	Permanent Occupied Units[2]	Mobile Home Units[2]	Seasonal Vacation Units[2]	Tourist Motel / B&B Units[3]	Average People per Occupied Housing Unit[2]	Average Vehicle per Occupied Housing Unit[2]
Barrington	11,013	4,081	0	95	0	2.70	1.98
	3,312	1,201	0	15	0	2.76	1.94
	1,974	707	0	8	0	2.79	1.89
Bristol	3,437	1,281	0	156	49	2.68	1.84
	1,088	486	0	4	0	2.24	1.77
	18,011	6,584	0	134	28	2.74	1.90
Warren	5,055	2,304	0	66	0	2.19	1.63
	1,709	779	0	17	8	2.19	1.63
	3,833	1,556	0	35	0	2.46	1.78
Totals / Averages	**19,505**	**7,666**	**0**	**317**	**49**	**2.52**	**1.82**
	6,109	**2,466**	**0**	**36**	**8**	**2.40**	**1.78**
	23,818	**8,847**	**0**	**177**	**28**	**2.66**	**1.86**
Overall Totals / Averages	**49,432**	**18,979**	**0**	**530**	**85**	**2.53**	**1.82**

1. Key: Zone A; Zone B; Inland Area (Non-Surge)
2. Data represented in this table reflects data obtained and/or calculated from the 2009-2013 American Community Survey 5-Year Estimates.
3. Obtained from http://www.visitrhodeisland.com/where-to-stay/.

Table 6-5: Key Socioeconomic Data – Kent County

Evacuation Areas[1]	Population[2]	Permanent Occupied Units[2]	Mobile Home Units[2]	Seasonal Vacation Units[2]	Tourist Motel / B&B Units[3]	Average People per Occupied Housing Unit[2]	Average Vehicle per Occupied Housing Unit[2]
East Greenwich	134	79	0	6	0	1.70	1.47
	490	325	4	1	0	1.51	1.47
	12,500	4,609	21	54	0	2.71	2.04
Warwick	12,035	5,175	12	171	15	2.33	1.81
	13,746	5,689	0	87	168	2.42	1.83
	56,596	24,244	85	226	2,030	2.33	1.75
Totals / Averages	**12,169**	**5,254**	**12**	**177**	**15**	**2.02**	**1.64**
	14,236	**6,014**	**4**	**88**	**168**	**1.97**	**1.65**
	69,096	**28,853**	**106**	**280**	**2,030**	**2.52**	**1.90**
Overall Totals / Averages	**95,501**	**40,121**	**122**	**545**	**2,213**	**2.17**	**1.73**

1. Key: Zone A (red) · Zone B (yellow) · Inland Area (Non-Surge) (white)
2. Data represented in this table reflects data obtained and/or calculated from the 2009-2013 American Community Survey 5-Year Estimates.
3. Obtained from http://www.visitrhodeisland.com/where-to-stay/.

Table 6-6: Key Socioeconomic Data – Newport County

Evacuation Areas[1]	Population[2]	Permanent Occupied Units[2]	Mobile Home Units[2]	Seasonal Vacation Units[2]	Tourist Motel / B&B Units[3]	Average People per Occupied Housing Unit[2]	Average Vehicle per Occupied Housing Unit[2]
Jamestown	1,185	524	0	225	142	2.26	2.11
	122	53	0	14	32	2.30	2.11
	4,116	1,790	0	232	9	2.30	2.11
Little Compton	359	166	0	263	14	2.16	2.12
	88	43	0	75	0	2.05	2.09
	3,043	1,291	51	414	6	2.36	2.12
Middletown	599	258	0	81	130	2.32	1.62
	178	81	0	18	9	2.20	1.69
	15,371	6,423	172	240	1,156	2.39	1.60
Newport	6,417	2,421	0	563	1,393	2.65	1.43
	1,337	652	0	78	168	2.05	1.43
	16,582	7,399	38	754	894	2.24	1.46
Portsmouth	3,533	1,444	11	514	1	2.45	1.86
	227	100	0	76	0	2.28	1.93
	13,579	5,424	222	290	63	2.50	1.93
Tiverton	1,430	634	45	144	6	2.26	2.20
	0	0	0	0	0	0.00	0.00
	14,375	6,061	258	164	0	2.37	1.93
Totals / Averages	**13,523**	**5,447**	**56**	**1,790**	**1,686**	**2.35**	**1.89**
	1,952	**929**	**0**	**261**	**209**	**1.81**	**1.54**
	67,066	**28,388**	**741**	**2,094**	**2,128**	**2.36**	**1.86**
Overall Totals / Averages	**82,541**	**34,764**	**797**	**4,145**	**4,023**	**2.17**	**1.76**

1. Key: Zone A Zone B Inland Area (Non-Surge)
2. Data represented in this table reflects data obtained and/or calculated from the 2009-2013 American Community Survey 5-Year Estimates.
3. Obtained from http://www.visitrhodeisland.com/where-to-stay/.

Table 6-7: Key Socioeconomic Data – Providence County

Evacuation Areas[1]	Population[2]	Permanent Occupied Units[2]	Mobile Home Units[2]	Seasonal Vacation Units[2]	Tourist Motel / B&B Units[3]	Average People per Occupied Housing Unit[2]	Average Vehicle per Occupied Housing Unit[2]
Cranston	2,056	722	9	6	0	2.85	1.54
	3,109	1,321	0	7	0	2.35	1.59
	75,305	29,001	63	169	79	2.60	1.65
East Providence	3,932	1,879	0	14	0	2.09	1.51
	6,790	2,877	0	12	0	2.36	1.60
	36,377	15,471	72	51	140	2.35	1.50
Pawtucket	260	79	0	0	0	3.29	1.27
	353	204	0	2	0	1.73	1.01
	70,550	28,745	323	74	138	2.45	1.41
Providence	2,384	549	0	5	136	4.34	1.31
	3,479	1,028	0	26	1,182	3.38	0.89
	4,800	2,419	0	40	441	1.98	1.01
	172,194	61,146	160	331	1,020	2.82	1.23
Totals / Averages	**8,632**	**3,229**	**9**	**25**	**136**	**3.14**	**1.41**
	13,731	**5,430**	**0**	**47**	**1,182**	**2.46**	**1.27**
	4,800	**2,419**	**0**	**40**	**441**	**1.98**	**1.01**
	354,426	**134,363**	**618**	**625**	**1,377**	**2.56**	**1.45**
Overall Totals / Averages	**381,589**	**145,441**	**627**	**737**	**3,136**	**2.66**	**1.35**

1. Key: Zone A (Category 1 & 2); Zone B (Category 3 & 4); Zone C (Category 3 & 4/Fox Point Hurricane Barrier Failure, Providence County Only); Inland Area (Non-Surge)
2. Data represented in this table reflects data obtained and/or calculated from the 2009-2013 American Community Survey 5-Year Estimates.
3. Obtained from http://www.visitrhodeisland.com/where-to-stay/.

Table 6-8: Key Socioeconomic Data – Washington County

Evacuation Areas[1]	Population[2]	Permanent Occupied Units[2]	Mobile Home Units[2]	Seasonal Vacation Units[2]	Tourist Motel / B&B Units[3]	Average People per Occupied Housing Unit[2]	Average Vehicle per Occupied Housing Unit[2]
Charlestown	872	455	0	987	23	1.92	1.96
	326	150	0	179	0	2.17	1.83
	6,623	2,640	92	481	854	2.51	1.98
Narragansett	6,777	2,952	92	1,543	354	2.30	2.03
	5,693	2,342	13	576	63	2.43	1.97
	3,339	1,385	0	186	6	2.41	1.96
New Shoreham	223	113	0	362	187	1.97	1.65
	52	27	0	41	24	1.93	1.71
	1,658	801	0	850	639	2.07	1.65
North Kingstown	3,411	1,556	0	178	60	2.19	1.79
	4,800	1,872	43	46	0	2.56	1.91
	18,143	6,956	179	148	86	2.61	1.91
South Kingstown	2,257	1,004	90	1,506	10	2.25	2.04
	925	432	0	221	10	2.14	2.05
	27,418	8,866	90	588	445	3.09	1.95
Westerly	2,426	1,141	0	1,071	521	2.13	1.75
	991	513	0	186	0	1.93	1.71
	19,303	7,983	13	627	544	2.42	1.77
Totals / Averages	**15,966**	**7,221**	**182**	**5,647**	**1,155**	**2.13**	**1.87**
	12,787	**5,336**	**56**	**1,249**	**97**	**2.19**	**1.86**
	76,484	**28,631**	**374**	**2,880**	**2,574**	**2.52**	**1.87**
Overall Totals / Averages	**105,237**	**41,188**	**612**	**9,776**	**3,826**	**2.28**	**1.87**

1. Key: Zone A (red) | Zone B (yellow) | Inland Area (Non-Surge) (white)
2. Data represented in this table reflects data obtained and/or calculated from the 2009-2013 American Community Survey 5-Year Estimates.
3. Obtained from http://www.visitrhodeisland.com/where-to-stay/.

6.6 Behavioral Assumptions of the Evacuating Population

An evacuation of the Rhode Island coast will involve decision making by thousands of individuals and households. In order to develop meaningful behavioral assumptions that account for these variations in decision making, the model incorporates data from the *Rhode Island Hurricane Evacuation Study Behavioral Analysis Survey Data Report* (September 13, 2013) conducted by Dr. Jay Baker of Hazards Management Group (HMG). Chapter 4 of the TDR contains the analysis of the behavioral report. Other behavioral trends from around the coastal United States were also considered in developing behavioral assumptions for the transportation analysis.

The contractor used this data source and nationwide experience to focus the transportation analysis on the following behavioral aspects:

- Participation rates - what percent of the population in different areas will evacuate their dwelling units for hurricane threats?
- Response rates (timing) - how quickly will evacuees respond to what local officials are telling them to do?
- Destination percentages - what percent of the population by evacuation zone, will evacuate to local destinations (public shelters, hotel/motels, churches, friends' and relatives' homes) or out of the area entirely?
- Vehicle usage - of the vehicles available to the households, what percent of those vehicles will be used in an evacuation?

6.6.1 Participation Rates

One of the biggest challenges in developing the evacuation model for this area is choosing the appropriate participation rates that should be used for each storm intensity scenario. Where possible, this report and the evacuation transportation model incorporate the participation rates provided in the September 2013 behavioral survey cited above. Nonetheless, in the interests of public safety, this transportation analysis assumes a 100 percent participation rate for all residential and tourist units in each storm surge evacuation zone for the corresponding intensity scenario. For example, in the transportation model, all permanent residents and visitors in the Scenario A evacuation zone are considered evacuees, regardless of what percentages were provided in the behavioral analysis. Clearly, it is understood that not all households will evacuate their residences, regardless of the intensity, during an actual tropical cyclone event; nonetheless this assumption results in clearance times that provide the <u>opportunity</u> for all evacuees to leave regardless of their propensity to do so. This ensures that local lead times used in decision making will not result in potential evacuees stranded in their

vehicles waiting to leave the vulnerable zones as hazardous conditions begin. Nonetheless, it should be noted that even in coastal regions of the United States that have a lot of hurricane experience, participation rates among surge vulnerable residents have been no more than approximately 90 percent. In some of the noteworthy hurricanes in urban areas, the surge zone participation rates have been as low as 70 percent.

Although it generally can be said people living close to the coastline are more likely to evacuate than those living further inland, proximity to water is not always a good indicator of how severe hurricane hazards will be, or predicting peoples' propensity to evacuate. Consequently, some residents outside surge vulnerable areas, fearing for their safety, may elect to evacuate, even in the absence of a directive from local officials to do so. Post event behavioral survey results show that in past evacuations, a percentage of households not under a specific order from local officials will decide to leave their residences anyway. These "shadow" participation rates typically run from 10 percent to 30 percent in areas with a lot of hurricane evacuation experience. In Hurricane Floyd (Southeast U.S. coast) and Hurricane Rita (Houston), inland participation rates were higher due to mixed messages that residents were receiving through various media releases and from local statements that abandoned the surge area risk concept.

For the Rhode Island HES TDR, based on the behavioral hypothetical responses provided in the 2013 study cited above, the range of participation rates from Category 2 to Category 4 scenarios for recommended evacuations was 62% to a high of 70% respectively. Clearly, based on a hypothetical scenario, especially in the inland areas, there is a tendency for households to over-evacuate. Nonetheless, these shadow evacuation figures were judged to be too extreme for use in the latest evacuation model, and figures more consistent with locally established norms were used. Therefore, based on planning guidance from Hazards Management Group, the firm that conducted the 2013 survey, regarding the shadow evacuation percentages, figures of 5 to 15 percent were used depending on intensity scenario and evacuation zone.

6.6.2 Response Rates

A critical behavioral assumption used in the transportation analysis is to establish how quickly after an evacuation order is issued the vulnerable population in a community will begin their evacuation trips, referred to as response time. Behavioral data from past hurricane evacuation research demonstrates wide variations in this evacuation response time ranging from a few hours to days, depending on the circumstances. To account for this disparity, clearance times were tested for three evacuation response rates represented by different behavioral response curves.

The resulting behavioral response curves describing mobilization by the vulnerable population define the rate at which evacuating vehicles will load onto the evacuation roadway network for each hourly interval relative to an evacuation order or advisory. These curves depict slow, medium and rapid responses by the public to an evacuation order. Typically, a small percentage of households will start evacuating before an order is issued. Upon receiving the evacuation order, some percentage of households will leave within an hour, others within two hours, some within three, etc. A curve can be drawn to show the cumulative percentage of households that have entered the evacuation network over a number of hours. A rapid loading of the network produces a steep curve; a medium loading scenario produces a flatter curve, etc. The response curves in Figure 6-22 reflect rapid, medium and long responses and are designed to include a range of mobilization times that may be experienced in a hurricane evacuation situation. For this analysis, the mobilization/ traffic loading time varied between 3 and 9 hours. From a traffic perspective, a more gradual loading of the network is preferred as the rapid loading of vehicles onto a transportation system results in heavier congestion and roadways reaching saturation levels very early on in an evacuation event.

The response curves depicted in the figure directly below relate to the following real-world examples regarding their use during an actual tropical cyclone response. A long response would be an appropriate clearance time assumption during nighttime hours, or during the middle of a normal weekday when most families are scattered to work, school and other routine activities away from home. A medium response curve would be appropriately applied during weekend days and any evening hours when most families have been rejoined at their residences and can be informed and mobilized in relatively short order. A rapid response relates to periods when most families are together and can be alerted and motivated to respond quickly, such as in the morning before most families have left from normal daytime activities and before schools and businesses are opened.

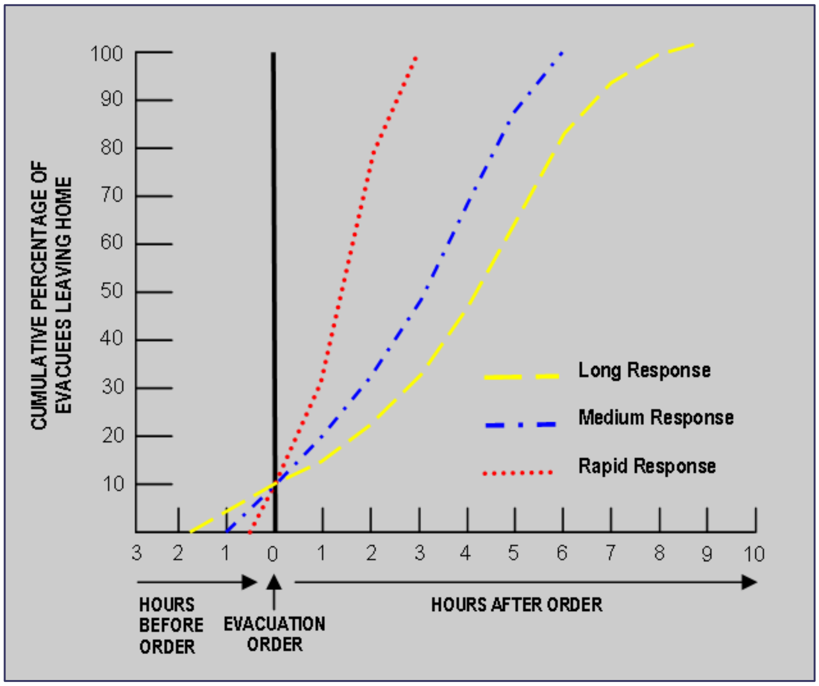

Figure 6-22 Behavioral Response Curve

6.6.3 Destination Percentages

Another essential input into the transportation analysis involves the destination percentages of evacuees. Generally, the traffic movements associated with hurricane evacuation have been identified by five general travel patterns as follows:

1. Internal Trips (In-Jurisdiction Origins to In-Jurisdiction Destinations)

   Vehicles primarily traveling from storm surge vulnerable areas and all mobile home units to destinations within the same community, such as public shelters, hotel and motel units, churches, and friends or relatives outside the storm surge vulnerable areas. An example of this pattern is a family leaving a home in Providence and evacuating to a shelter in Pawtucket.

2. External Trips (In-Jurisdiction Origins to Out-Of-Jurisdiction Destinations)

   Evacuation travel that originates in an individual community and ends in other jurisdictions within the study area or outside the region entirely. Generally, the more intense the storm scenario, the larger the percent assumed to be exiting the jurisdiction. These trips are the most common for tourists, such as a couple vacating a hotel room in Newport and evacuating to their home in Boston.

3. Entering Trips (Out-Of-Jurisdiction Origins to In-Jurisdiction Destinations)

Vehicles entering a jurisdiction after having evacuated from another community within or outside the study area. Evacuees from New London, Connecticut, traveling eastbound to seek destinations in Warwick, Rhode Island, are an example of these kinds of trips.

4. Pass Through Trips (Out-of-Jurisdiction Origins to Out-of-Jurisdiction Destinations)

   These trips pass through an individual jurisdiction while traveling from one jurisdiction outside the study area to another external location; for instance, a vehicle evacuating New Haven, Connecticut, and traveling through Rhode Island to reach Boston, Massachusetts.

5. Background Traffic

   Trips made by persons preparing for the arrival of hurricane conditions; these trips are primarily shopping trips to gather supplies. Background traffic can also include transit vehicles (vans/ buses) used to pick up evacuees without personal transportation.

Destinations are related to evacuees' proximity to the coast and socio-economic conditions. For instance, more affluent evacuees, who normally live closer to the coast, do not utilize public shelters as much as the remainder of the population, especially more inland populations. Persons of lower income generally utilize public shelters more because of the problems they may have with transportation and their inability to find affordable hotel/motel destinations. For the Rhode Island HES TDR study area destination options focused on: local public shelters, "other" local destinations, and out of the county destinations. Based on responses received during the behavioral analysis for the Rhode Island coastal areas, destination percentages were varied for each traffic evacuation zone in the study area depending on the category of risk (distance from the coastline and water bodies). Assumptions were also varied for permanent residents versus tourist/seasonal populations. With each increase in storm intensity, a larger percentage of evacuees were assumed to go out of region, which is consistent with what has been learned in actual evacuations. The percent of permanent residents and mobile home evacuees going out of region varied between 65 and 70 percent depending on storm category and unit type. The percent permanent residents and mobile home evacuees going to local public shelter ranged between 1 and 10 percent depending on type of unit and location. For modeling purposes, the remaining residents would then be seeking other safe locations, such as friends and relatives, within their own local jurisdictions. Although the model uses behavioral characteristics to calculate the first three types of destinations described above, pass-through and background traffic trips are determined by the routing tables and the service-volume-to-capacity formulas applied later on in the transportation modeling process.

6.6.4 Vehicle Usage

The final set of behavioral assumptions concerns vehicle usage rates during an evacuation. Vehicle usage rates pertain to the percentage of vehicles available at the home origin, assumed to be used in the evacuation. Some households will not evacuate using all of the vehicles at their disposal, choosing instead to consolidate their trips for fear of becoming separated along the route. Others will take all vehicles fearing damage to their automobiles. Vehicle usage percentages have been measured during actual evacuations and are consistently in the 60 to 80 percent range in all parts of the coastal United States. In this analysis, the percentage ranged from 70 to 75 percent for permanent residents and 100 percent for tourist/seasonal populations.

The key behavioral concepts and assumptions used for the study are summarized in Table 6-9.

Table 6-9: Behavioral Assumptions

Evacuation Areas[1]	Permanent Resident/Mobile Home Destination Percentages					
	Percent to In-County Locations			Percent to Out of County Locations		
	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
Bristol County	35%	30%		65%	70%	
	35%	30%		65%	70%	
	40%	35%		60%	65%	
Kent County	35%	30%		65%	70%	
	35%	30%		65%	70%	
	40%	35%		60%	65%	
Newport County	35%	30%		65%	70%	
	35%	30%		65%	70%	
	40%	35%		60%	65%	
Providence County	35%	30%		65%	70%	
	35%	30%		65%	70%	
	35%	30%	30%	65%	70%	70%
	40%	35%		60%	65%	
Washington County	35%	30%		65%	70%	
	35%	30%		65%	70%	
	40%	35%		60%	65%	
New Shoreham Only, All Zones:	100%	100%		0%	0%	

1. Key: Zone A (Category 1 & 2); Zone B (Category 3 & 4); Zone C (Category 3 & 4/Fox Point Hurricane Barrier Failure, Providence County Only); Inland Area (Non-Surge)

6.7 Transportation Modeling Methodology

6.7.1 Introduction

The general philosophy supporting all hurricane evacuation clearance time work around the country is that the analysis must be technically complex enough to produce reliable estimates of hurricane evacuation clearance times, yet clear enough for the emergency management community to be able to review key modeling assumptions and products. A brief overview of the steps in the modeling process and a description of the modeling framework are discussed in this section.

It is important to understand while applying the information in this section that the transportation analysis is predicated on the following important assumptions concerning traffic operations and other conditions:

- The evacuation of all vehicles will occur prior to the arrival of sustained tropical storm force winds (39 mph) and storm inundation of evacuation routes.
- Provisions will be made for the removal of vehicles in distress on the network through aggressive incident management and agreements worked out with tow truck operators.
- Traffic signals will be implemented to provide the most “green time” for movements away from the coast.
- Suspension and high altitude bridges will close when the wind speed exceeds that which is safe for the throughput of vehicles.

6.8 The Transportation Model

The model used for the Rhode Island HES TDR transportation analysis is a series of spreadsheets that consolidate all of the data collected during the study, as well as hazards information, the socioeconomic data, behavioral assumptions combined with the public shelter information, and the roadway network attributes. This transportation model is based on the same model used for HESs throughout the United States. The minor difference between the model developed for this region and other studies was required to account for the specific variations and circumstances related to the Rhode Island coastal communities. Nonetheless, the model process and methodology used in this study are essentially the same as those employed in other areas.

The primary results from the transportation analysis are clearance time calculations and an abbreviated version of the model. The model clearance times provide guidance to emergency managers and other local officials regarding the lead time needed to allow all evacuating vehicles the opportunity to reach their intended safe objective before the arrival of tropical storm force winds. This model has been updated over the past several years and enhanced for greater accuracy. Furthermore, an abbreviated version of the transportation model is provided as a customary component of the study results which allows greater transparency for the study users. With this abbreviated model, the assumptions, data sources and basic processes used to calculate the figures provided in this report are much more readily apparent and can be updated to account for annual developments and variations. The major inputs and outputs of the overall process are illustrated in Figure 6-23.

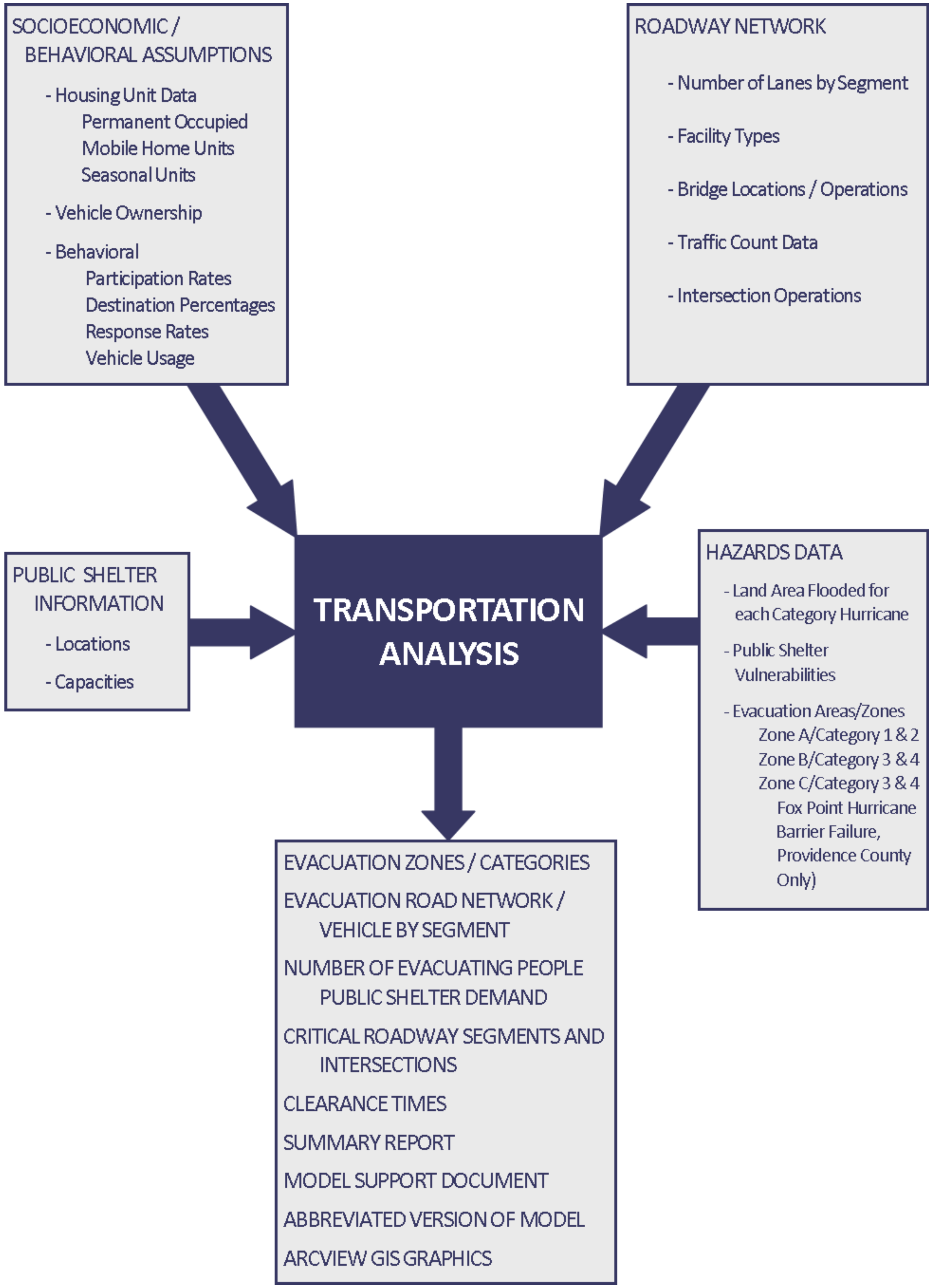

Figure 6-23: Clearance Time Model Process

6.0 Transportation Analysis

Basically, the basic key modeling steps used in this analysis for the Rhode Island jurisdictions are as follows:

- Development of Evacuation Zones and Data - Identifies who is vulnerable and who is evacuating; socioeconomic data is stratified by evacuation zones; data includes numbers of permanent residential dwelling units, mobile homes, and seasonal units compiled by zone.
- Trip Generation - Calculates how many people and vehicles will move for a particular hurricane category originating from each evacuation zone.
- Trip Distribution - Determines where evacuees will go (to destinations within the originating jurisdiction or out of area).
- Development of Evacuation Road Network – This step identifies which roads can be used for evacuation and includes the assignment of reasonable vehicle carrying capacities during an evacuation.
- Trip Assignment - Determines what route(s) evacuees will take to get from their point of origin to their destination based on shortest travel time. Additionally, terminating trips entering the jurisdiction of interest from other locations and pass-through vehicles are accounted for in this step of the modeling process.
- Calculation of Clearance Time – Determines how much time it will take for all evacuees to clear evacuation network bottlenecks including time for the "last vehicle" to reach assumed safety point. This modeling step also factors in the impacts of background traffic (those vehicles on the roadway that are not expressly evacuating, but instead traveling on local evacuation routes to prepare for the storm or to conduct other daily activities). The end product of this major step is the development of clearance times for each storm scenario for the Rhode Island jurisdictions.

At the conclusion of the study, the USACE, New England District, Rhode Island Emergency Management Agency (RIEMA), as well as each community in the study area received a simplified spreadsheet tool that allows officials to make changes to critical socioeconomic, behavioral, and roadway assumptions. This dynamic transportation model (DTM) was developed in order to facilitate the ability of the emergency management and other local officials to update clearance times in an efficient manner.

6.9 Transportation Modeling Process

The first step in developing the hurricane evacuation transportation model for the region was to assess the myriad roads in the region to determine which should be included primary evacuation routes. Fortunately, the Rhode Island Department of Transportation (RIDOT) and RIEMA staff, as well as local officials, had already designated official road corridors throughout

the region to be used for hurricane evacuation. The pre-designated evacuation network was made available to the study team in GIS files which mapped the evacuation routes, as well as the 2007 "Hurricane Evacuation Plan Phase 1", which detailed and depicted them also. In addition, roadways that would logically be used by the surrounding populace were considered for inclusion in the model and added where warranted. Once all the roadways were identified, the network was mapped using GIS and incorporated into the model. A "link-node" system was used to characterize the selected roadway sections and create a reasonable representation of the evacuation roadway system for the Rhode Island communities. Nodes are used to identify the intersection of two roadways or changes in roadway characteristics. Links are the roadway segments between nodes with each link identified by a letter designation. These are displayed in Figures 6-24 through 6-45 as follows:

- Figure 6-24: Evacuation Roadway Network – Bristol County / Barrington
- Figure 6-25: Evacuation Roadway Network – Bristol County / Bristol
- Figure 6-26: Evacuation Roadway Network – Bristol County / Warren
- Figure 6-27: Evacuation Roadway Network – Kent County / East Greenwich
- Figure 6-28: Evacuation Roadway Network – Kent County / Warwick
- Figure 6-29: Evacuation Roadway Network – Newport County / Jamestown
- Figure 6-30: Evacuation Roadway Network – Newport County / Little Compton
- Figure 6-31: Evacuation Roadway Network – Newport County / Jamestown
- Figure 6-32: Evacuation Roadway Network – Newport County / Middletown
- Figure 6-33: Evacuation Roadway Network – Newport County / Newport
- Figure 6-34: Evacuation Roadway Network – Newport County / Portsmouth
- Figure 6-35: Evacuation Roadway Network – Newport County / Tiverton
- Figure 6-36: Evacuation Roadway Network – Providence County / Cranston
- Figure 6-37: Evacuation Roadway Network – Providence County / East Providence
- Figure 6-38: Evacuation Roadway Network – Providence County / Pawtucket
- Figure 6-39: Evacuation Roadway Network – Providence County / Providence
- Figure 6-40: Evacuation Roadway Network – Washington County / Charlestown
- Figure 6-41: Evacuation Roadway Network – Washington County / Narragansett
- Figure 6-42: Evacuation Roadway Network – Washington County / New Shoreham
- Figure 6-43: Evacuation Roadway Network – Washington County / North Kingstown
- Figure 6-44: Evacuation Roadway Network – Washington County / South Kingstown
- Figure 6-45: Evacuation Roadway Network – Washington County / Westerly

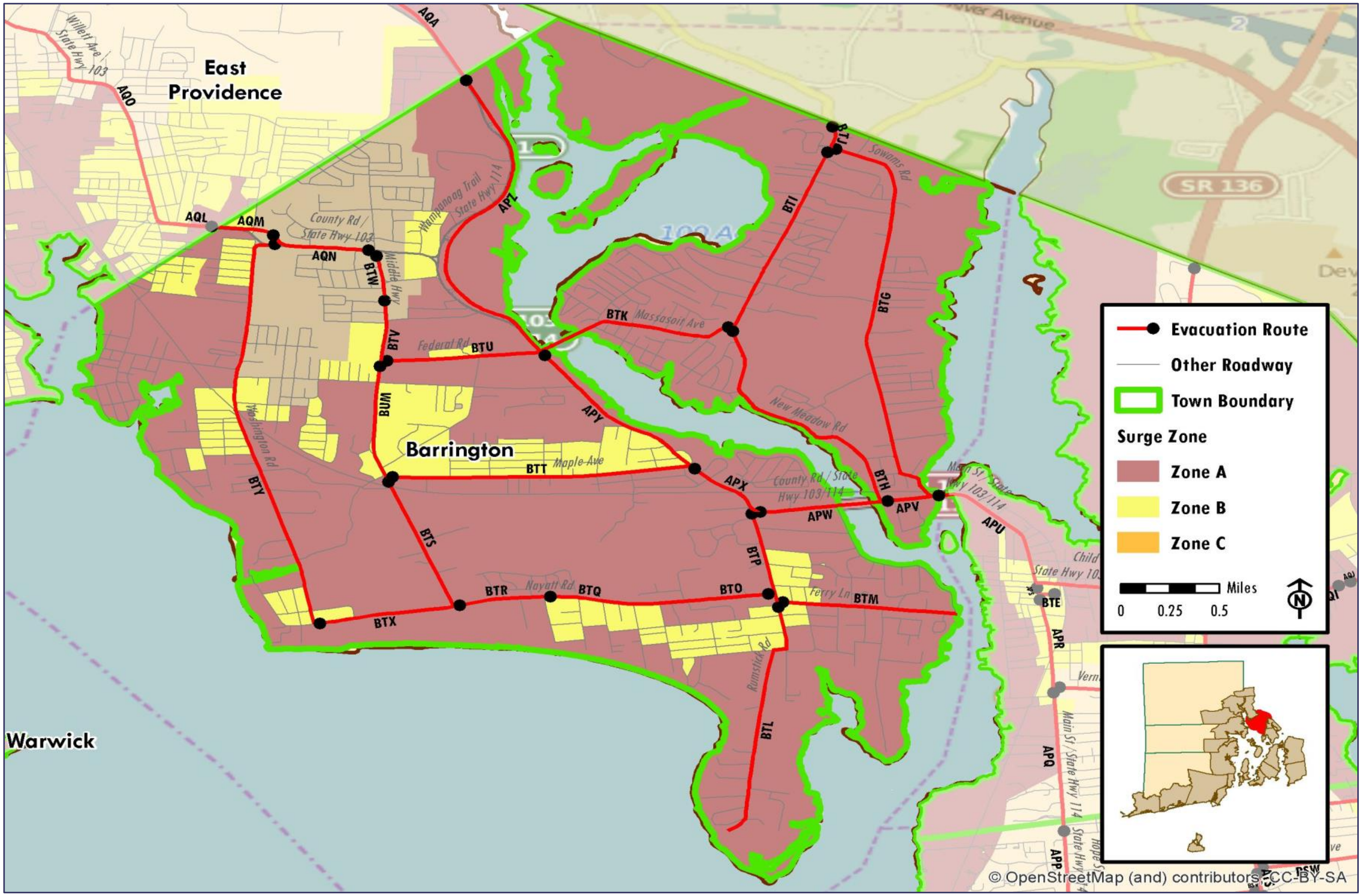

Figure 6-24: Evacuation Roadway Network – Bristol County / Barrington

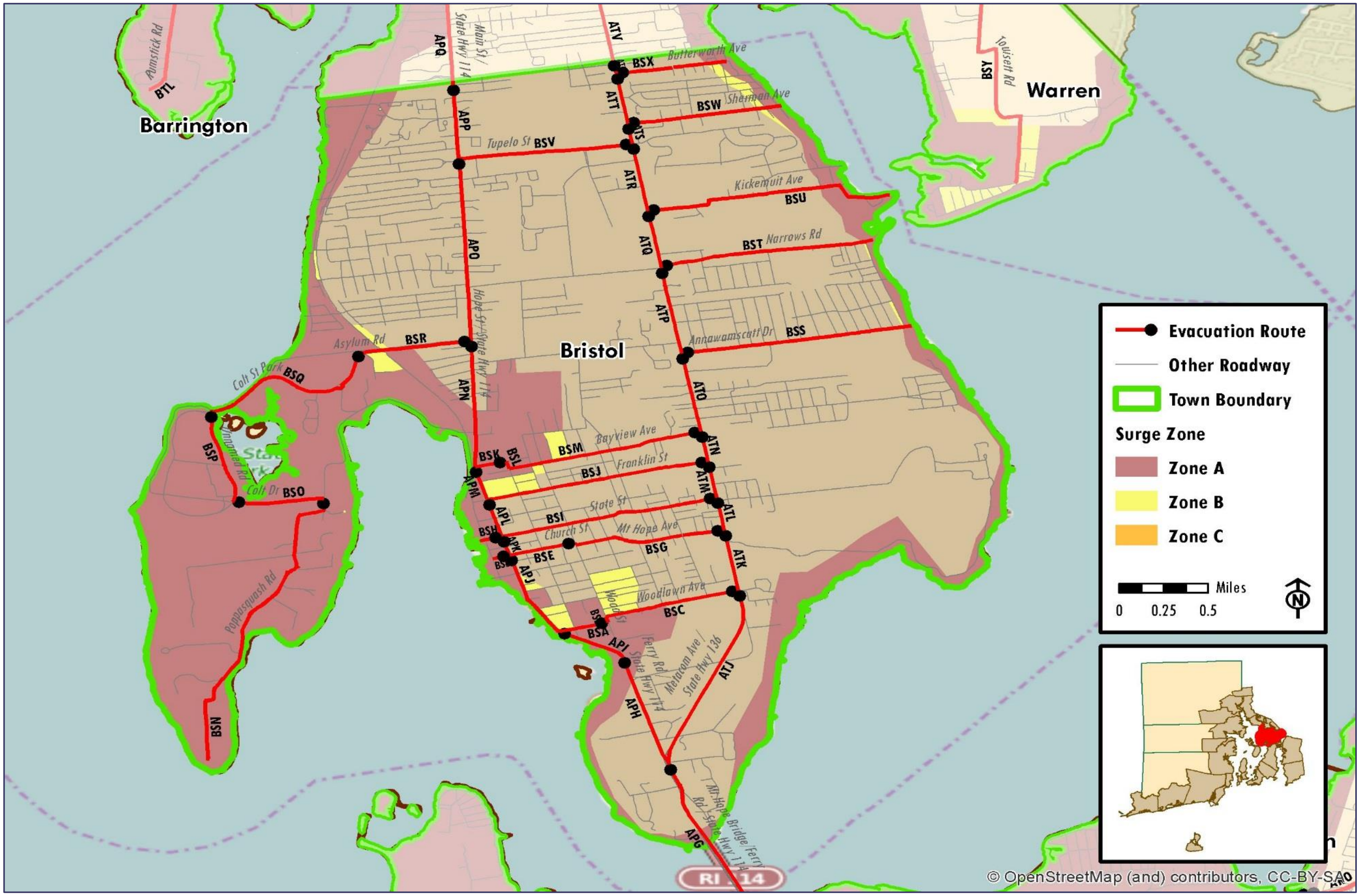

Figure 6-25: Evacuation Roadway Network – Bristol County / Bristol

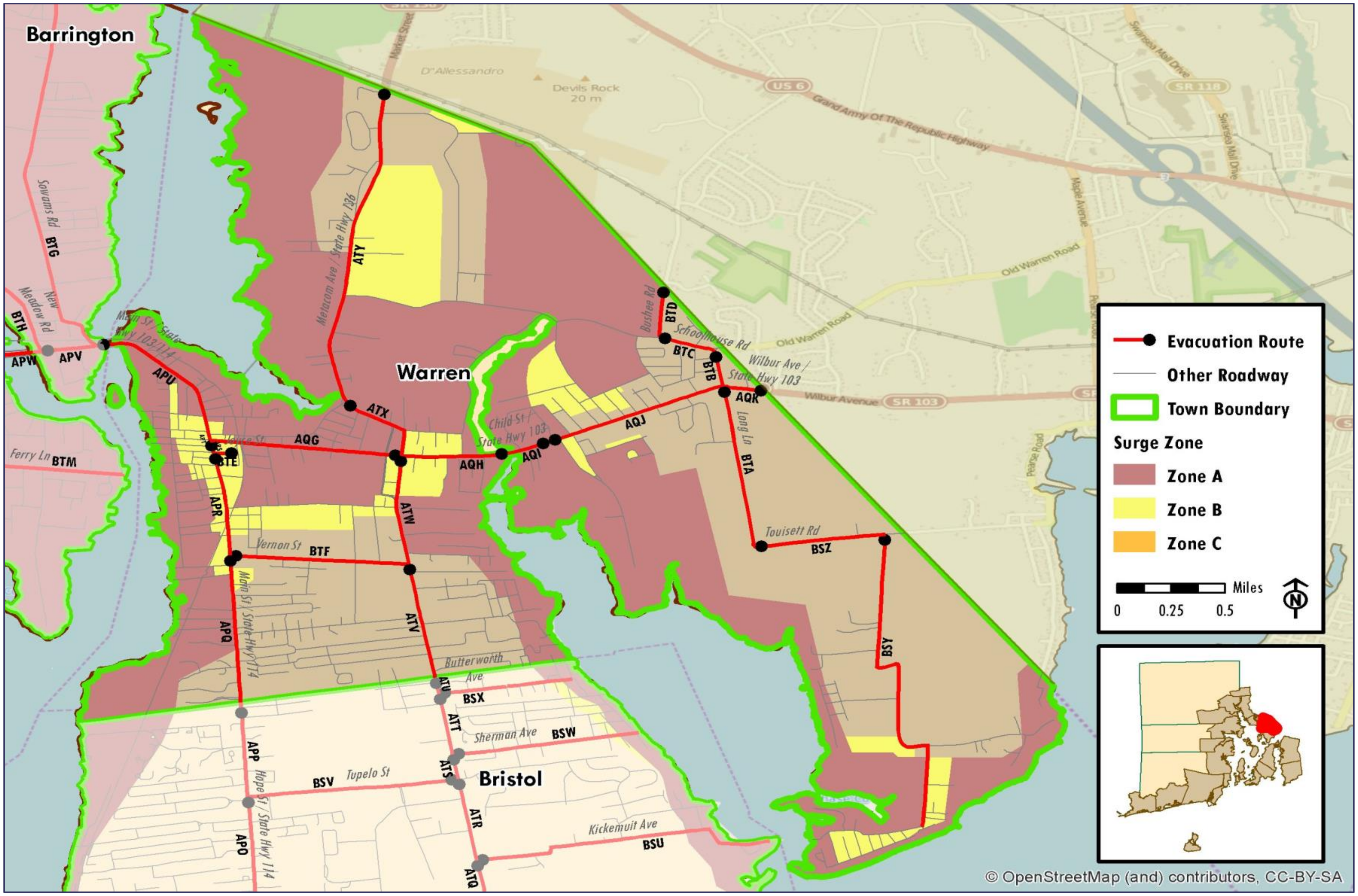

Figure 6-26: Evacuation Roadway Network – Bristol County / Warren

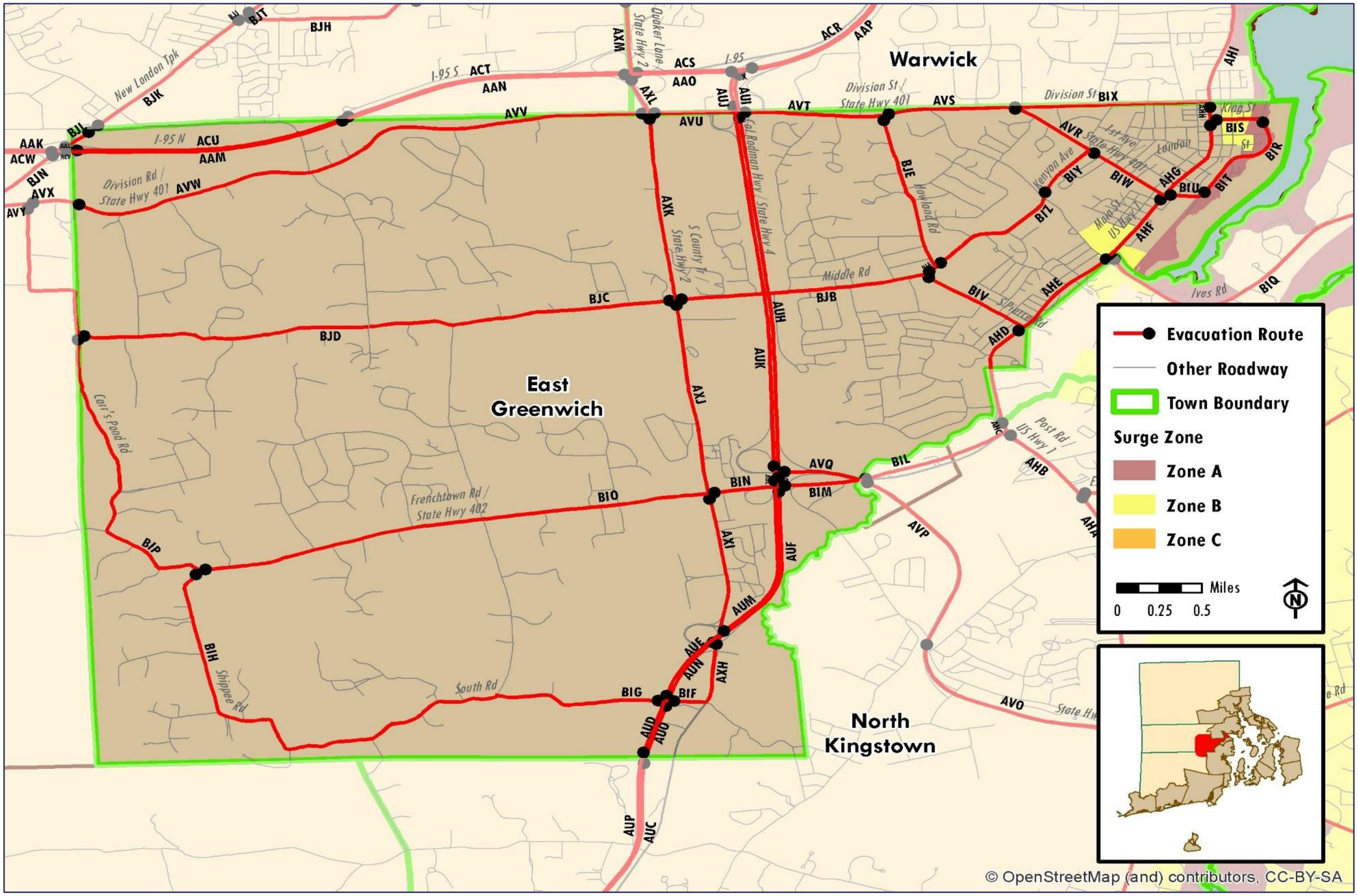

Figure 6-27: Evacuation Roadway Network – Kent County / East Greenwich

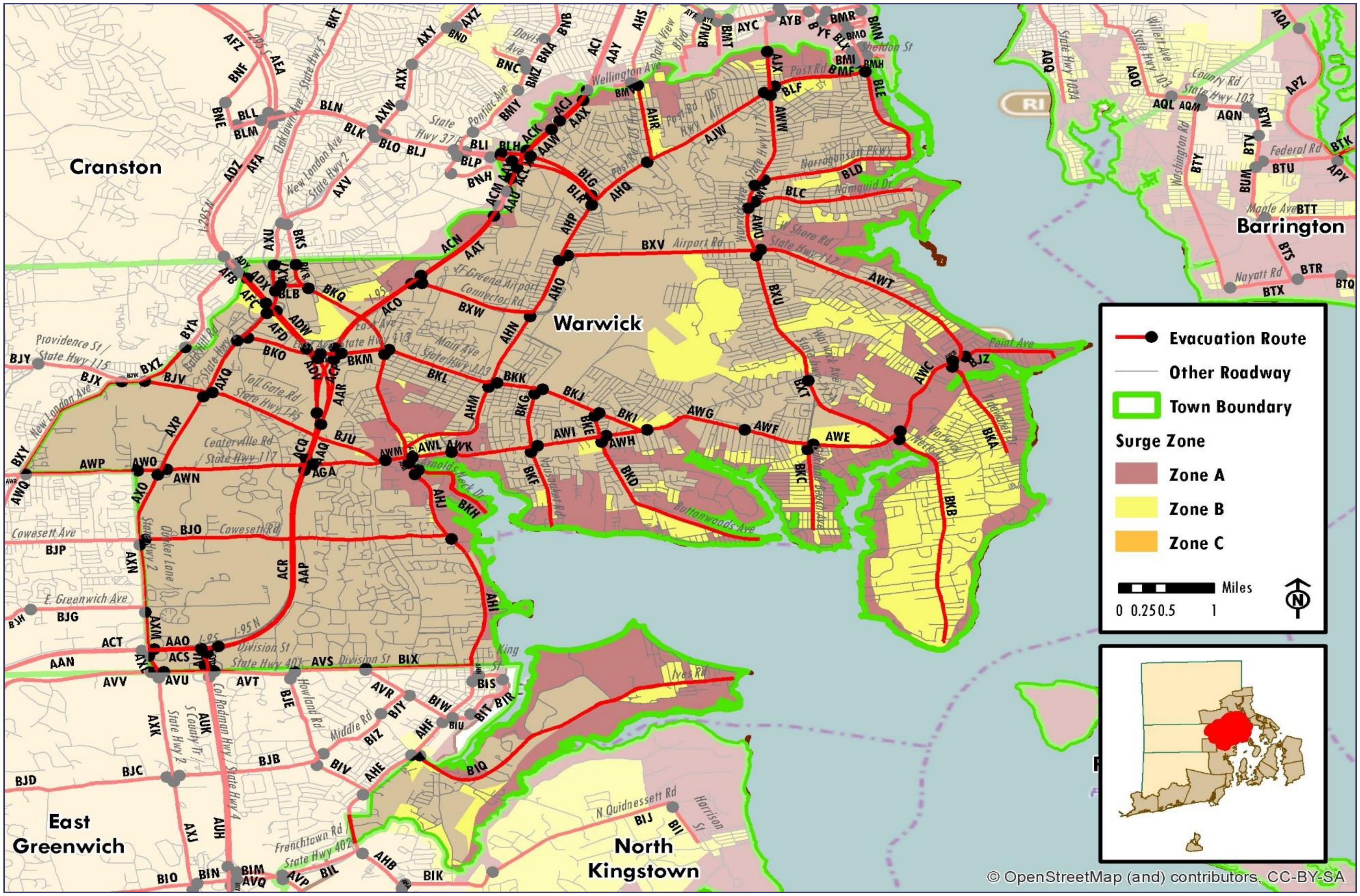

Figure 6-28: Evacuation Roadway Network – Kent County / Warwick

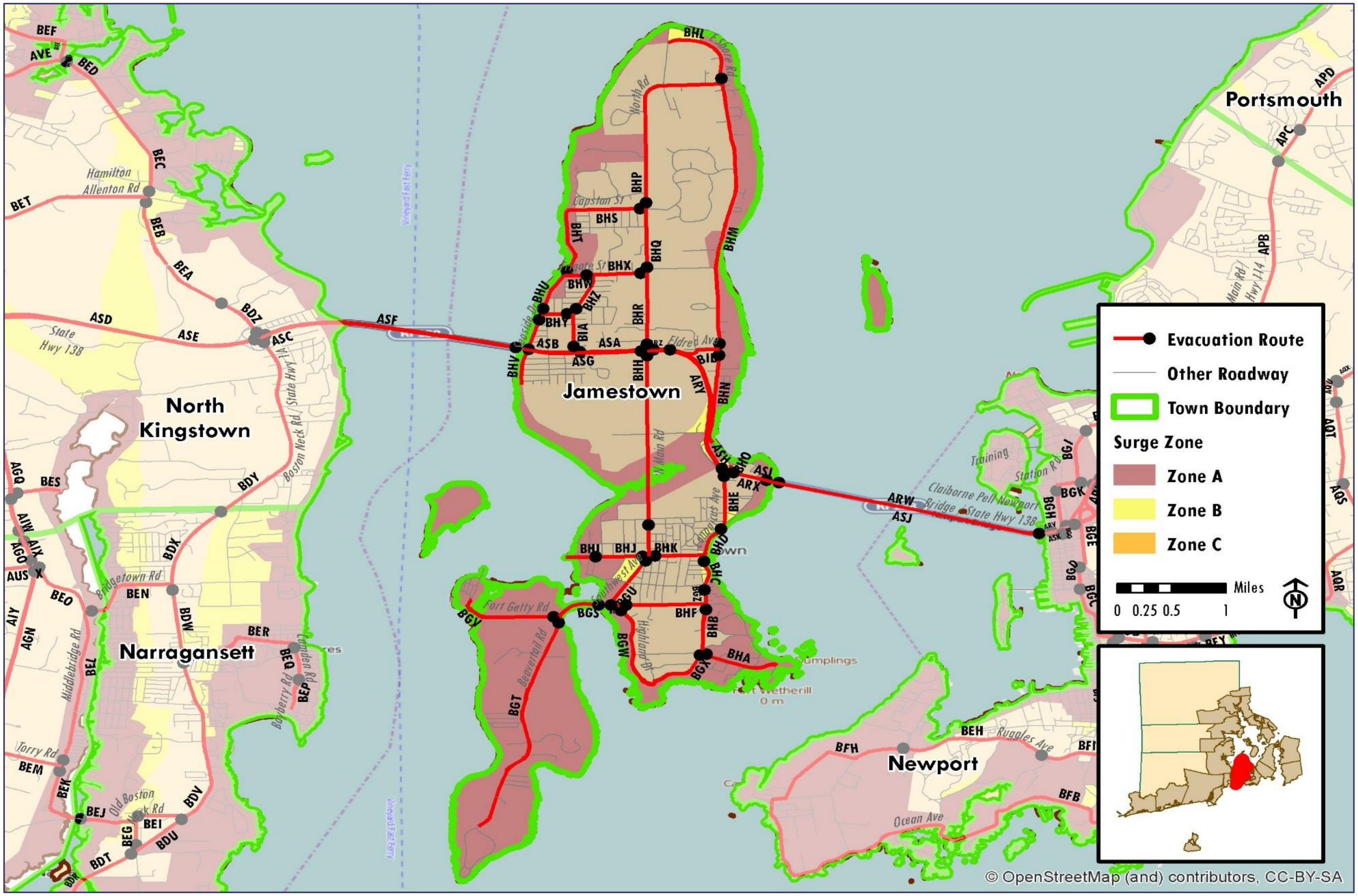

Figure 6-29: Evacuation Roadway Network – Newport County / Jamestown

6.0 Transportation Analysis

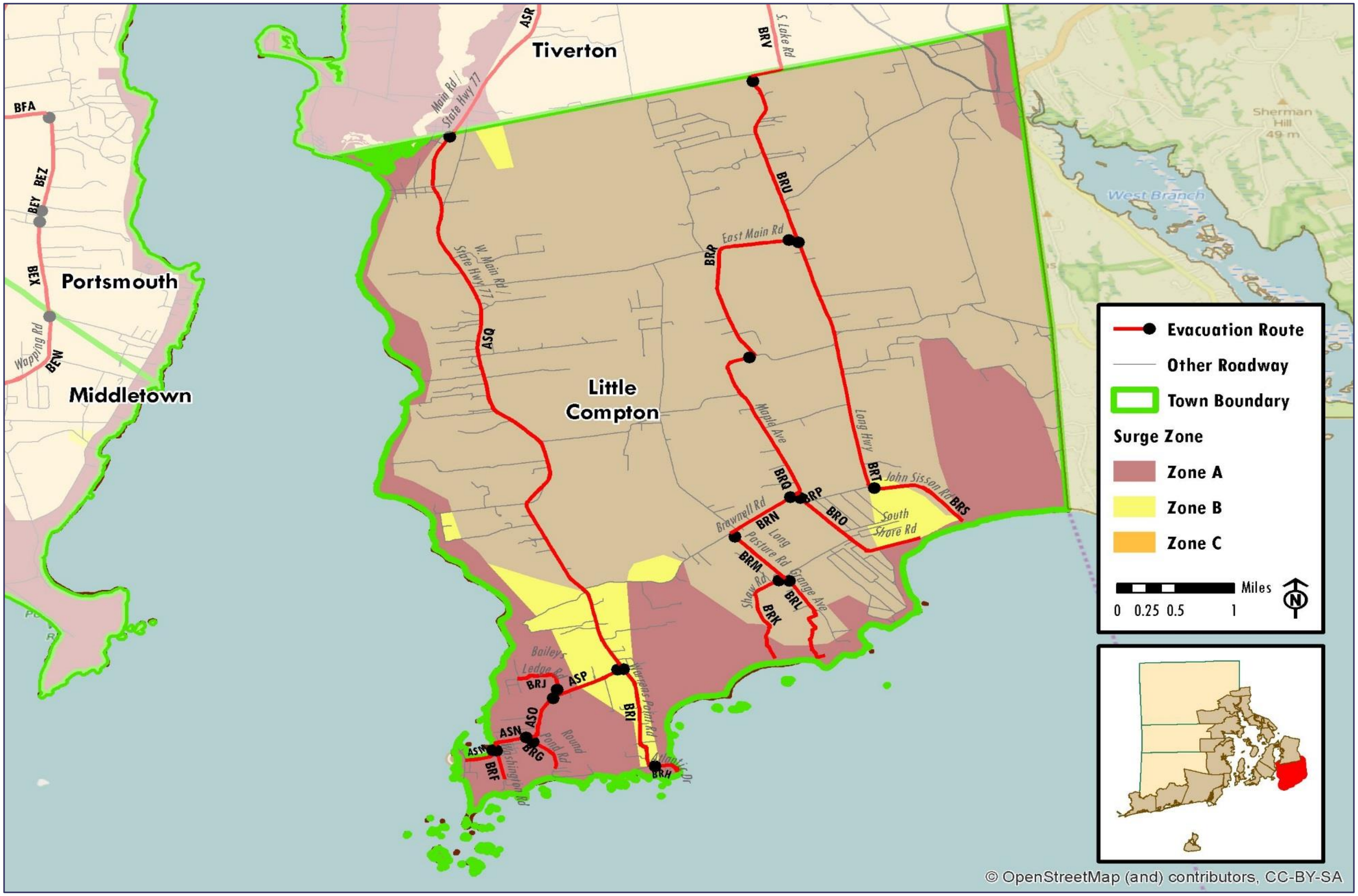

Figure 6-30: Evacuation Roadway Network – Newport County / Little Compton

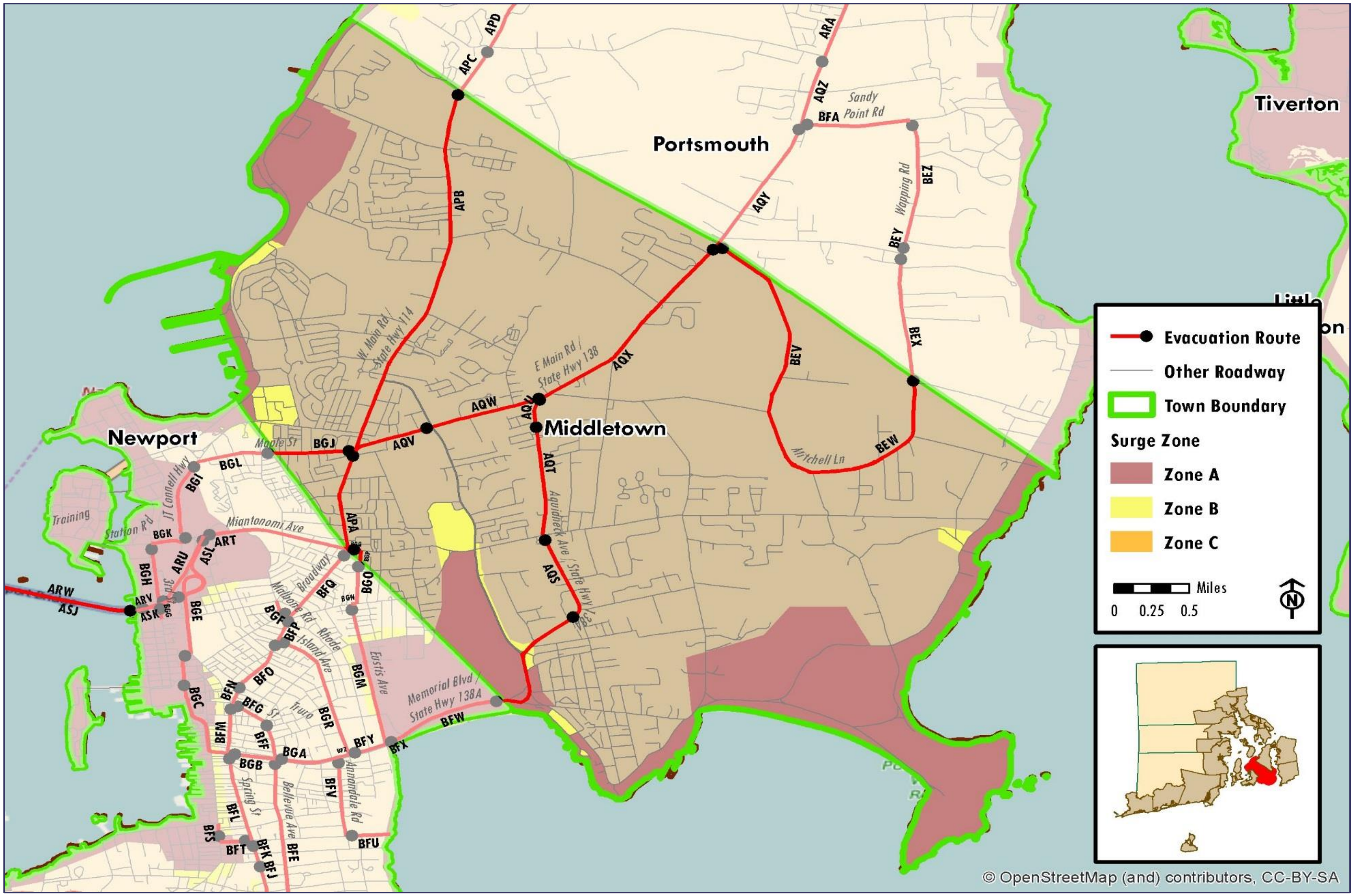

Figure 6-31: Evacuation Roadway Network – Newport County / Middletown

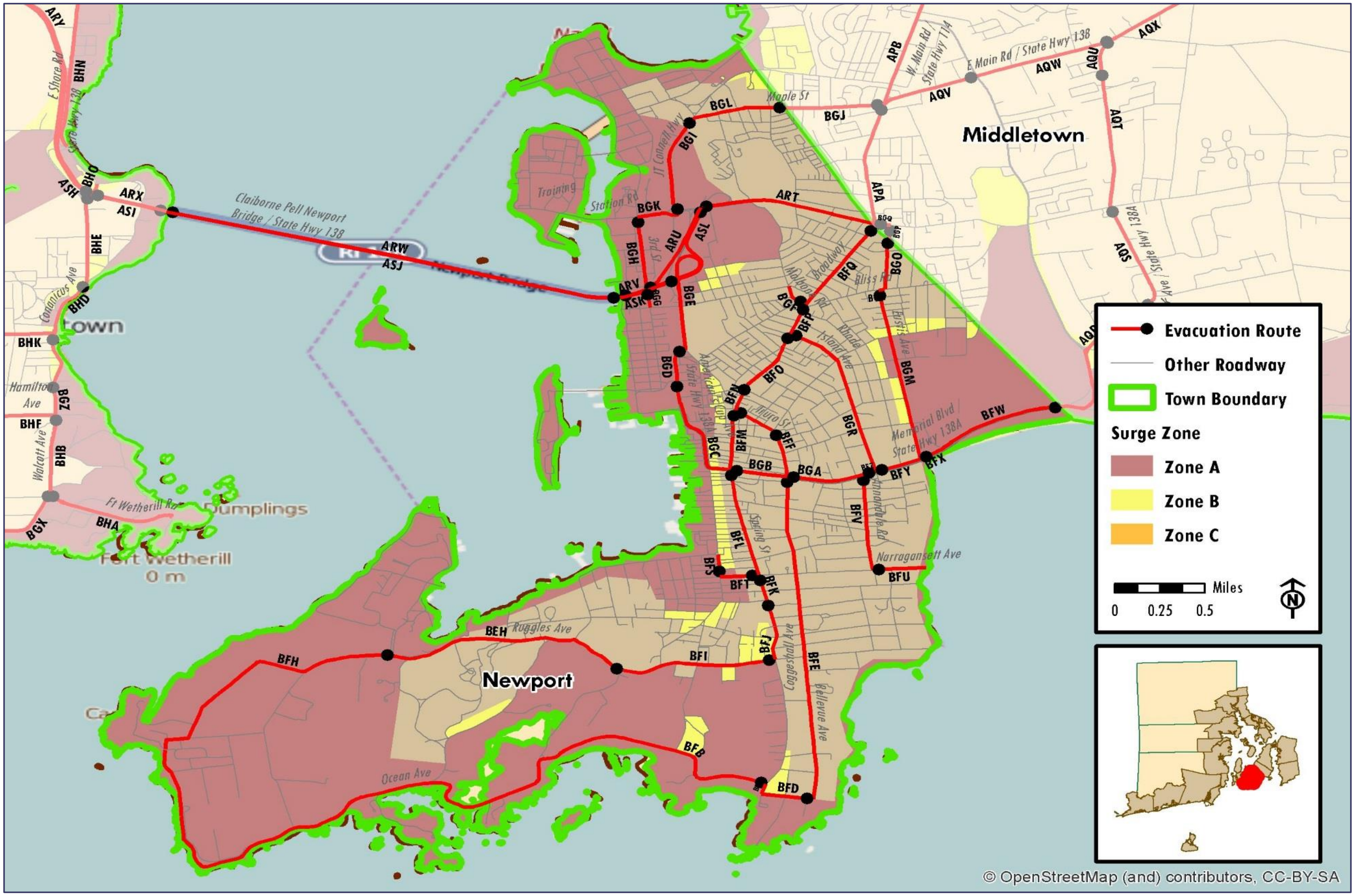

Figure 6-32: Evacuation Roadway Network – Newport County / Newport

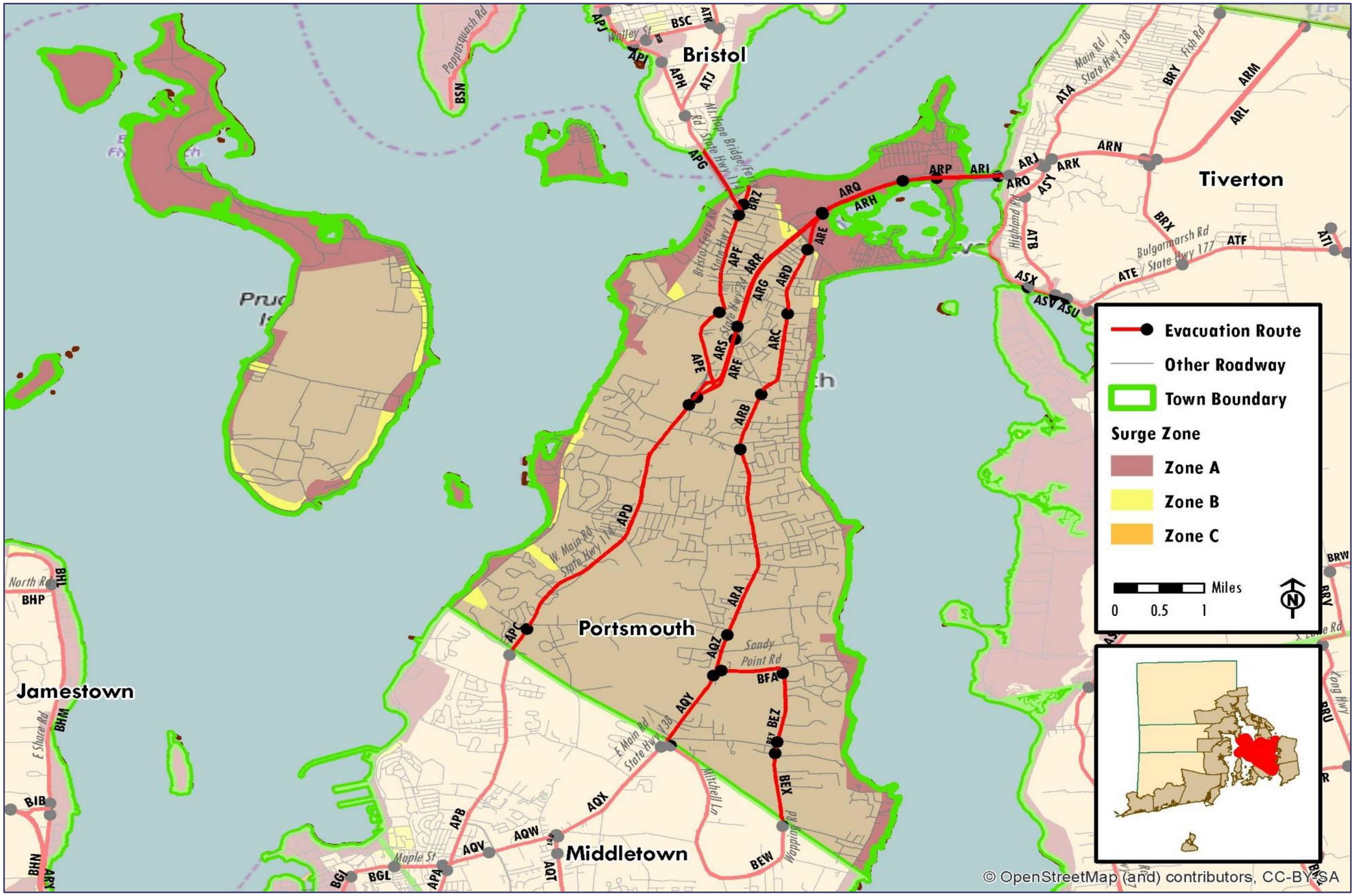

Figure 6-33: Evacuation Roadway Network – Newport County / Portsmouth

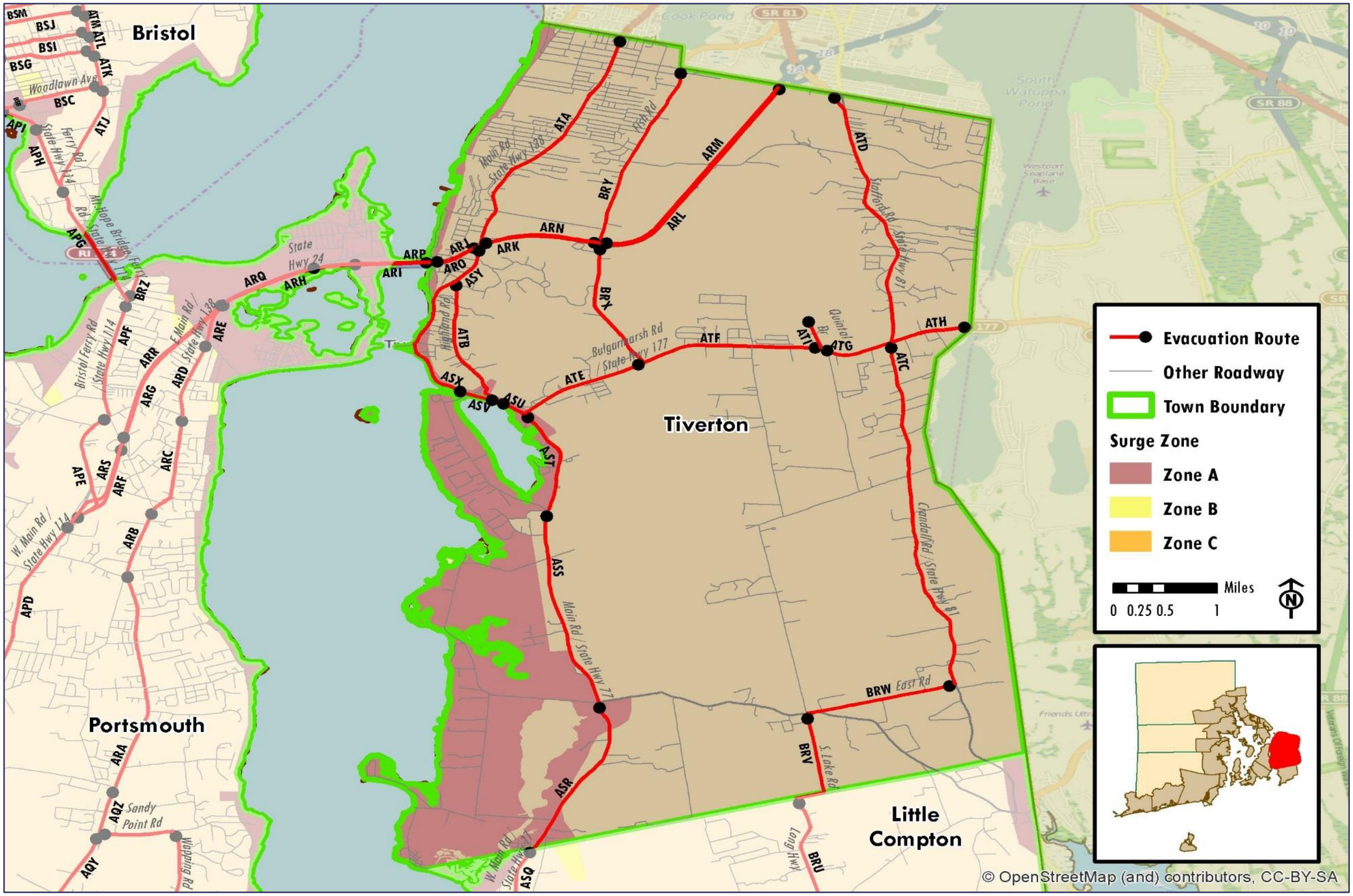

Figure 6-34: Evacuation Roadway Network – Newport County / Tiverton

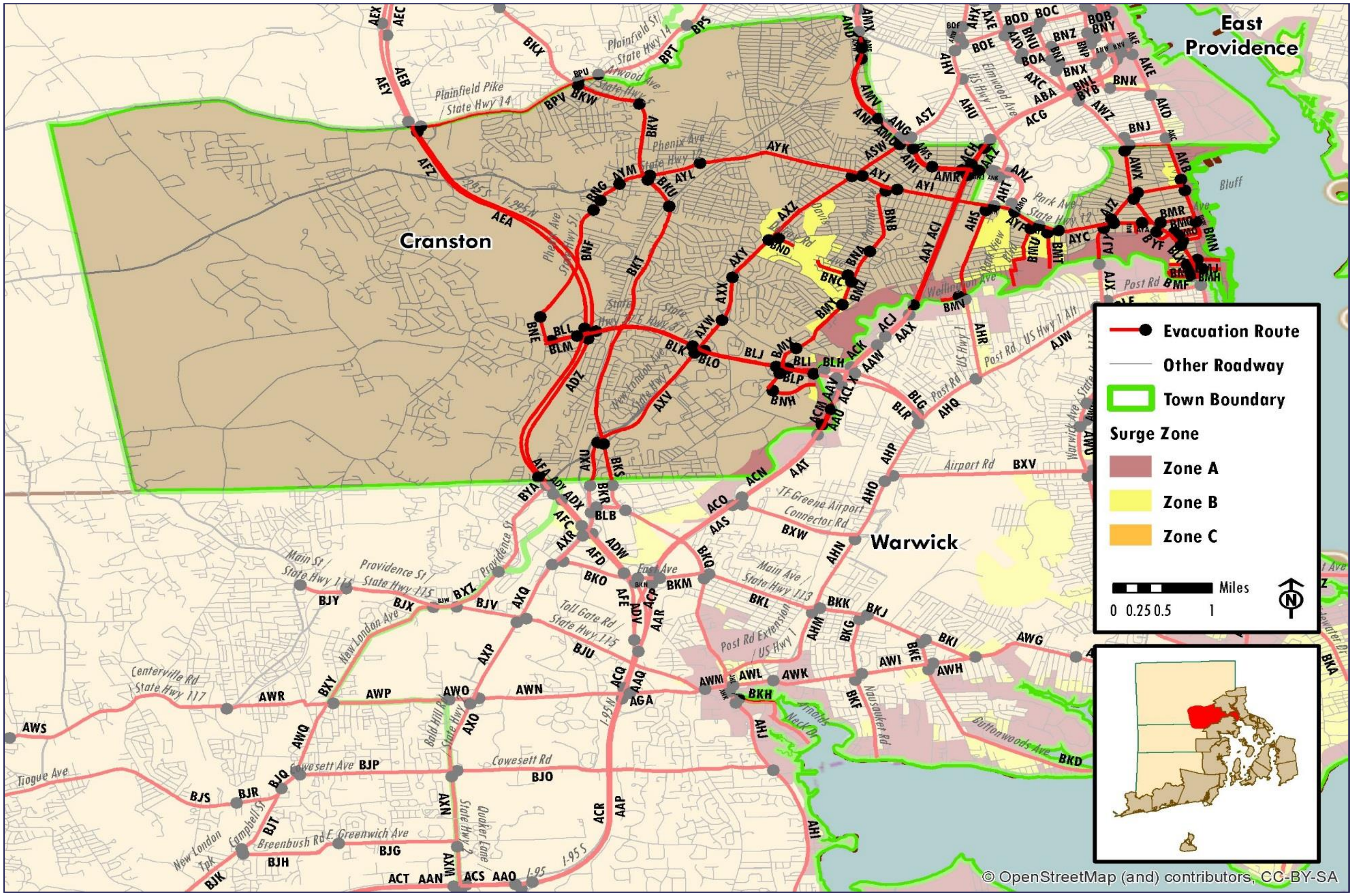

Figure 6-35: Evacuation Roadway Network – Providence County / Cranston

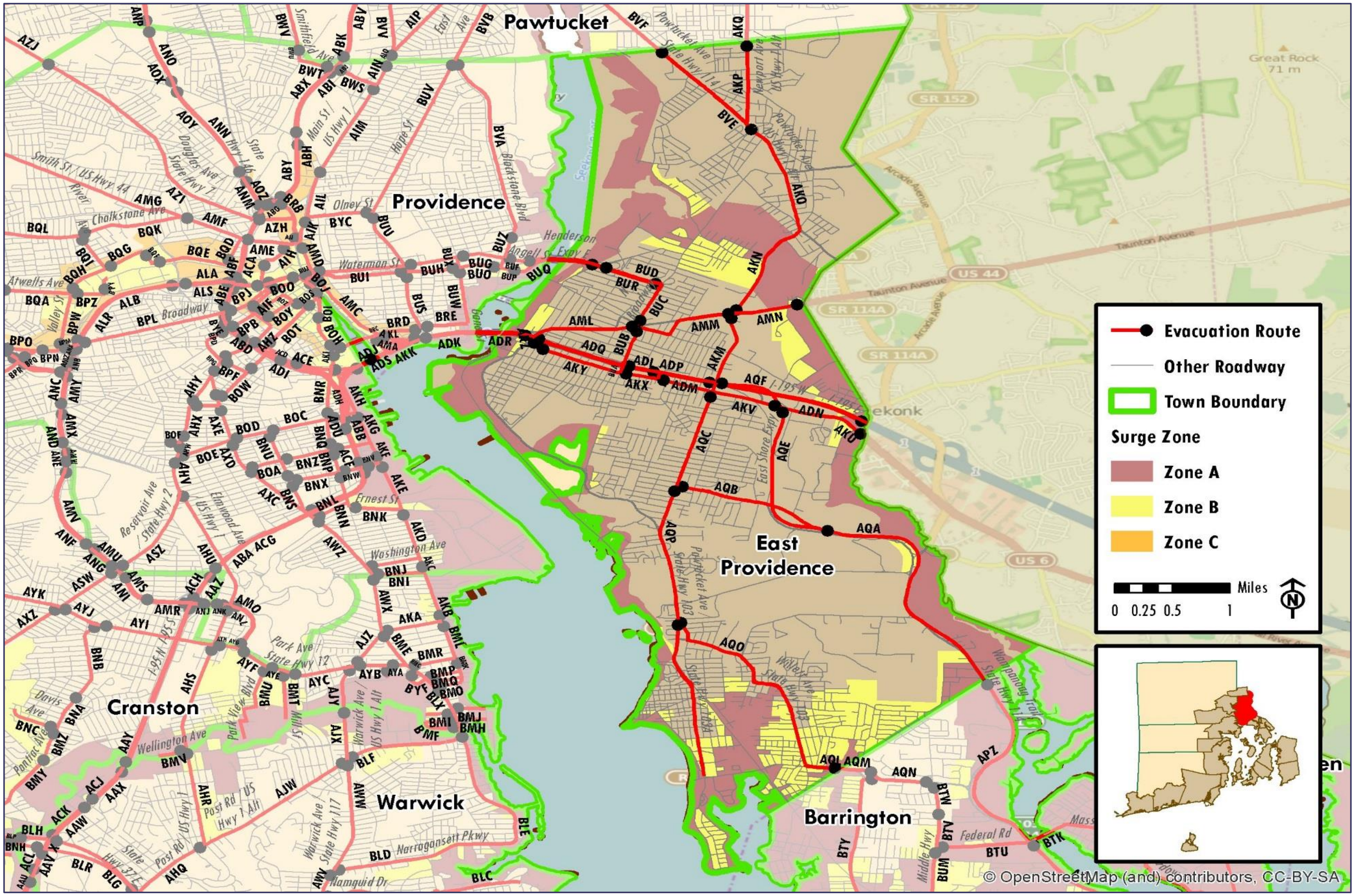

Figure 6-36: Evacuation Roadway Network – Providence County / East Providence

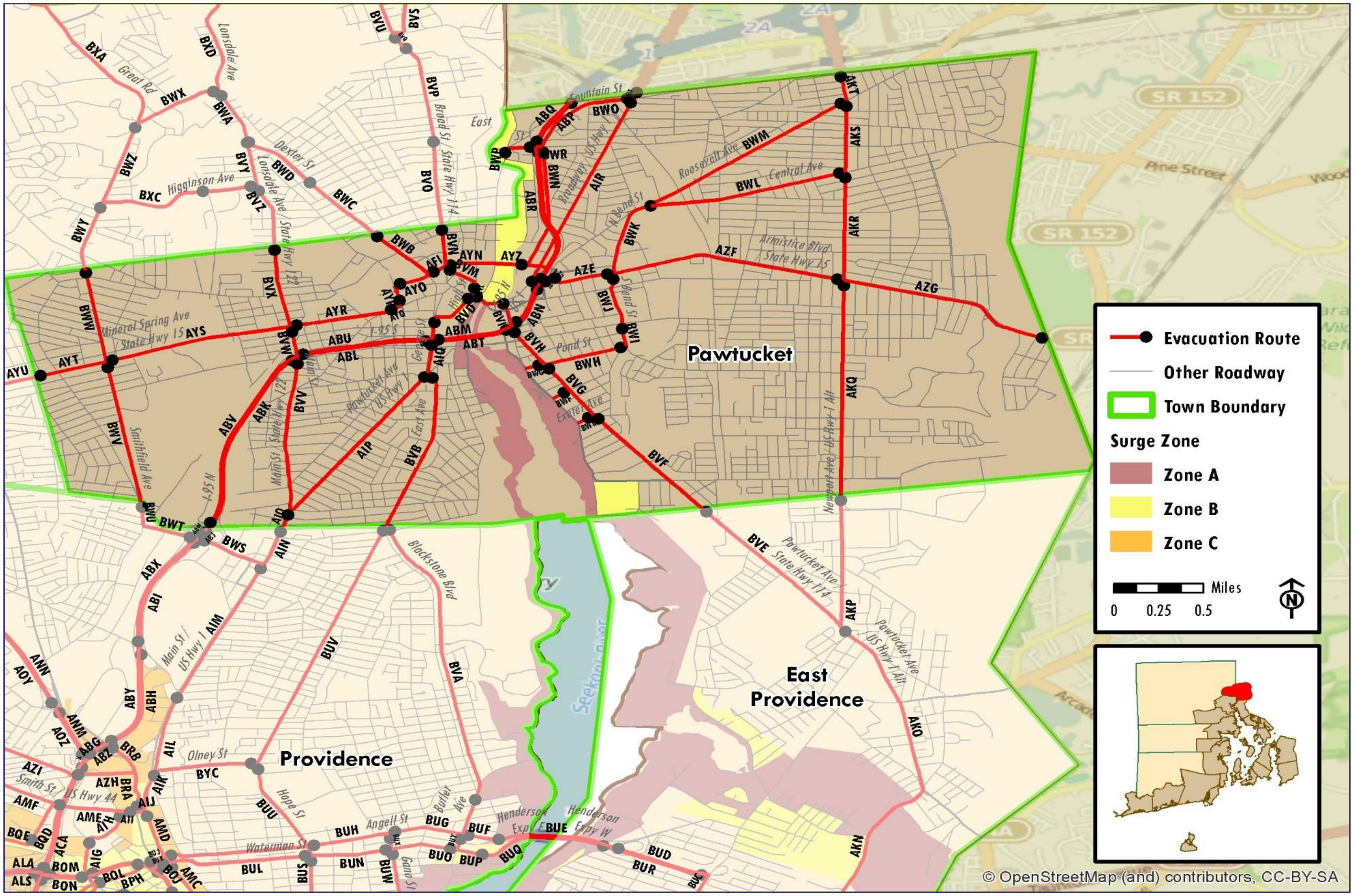

Figure 6-37: Evacuation Roadway Network – Providence County / Pawtucket

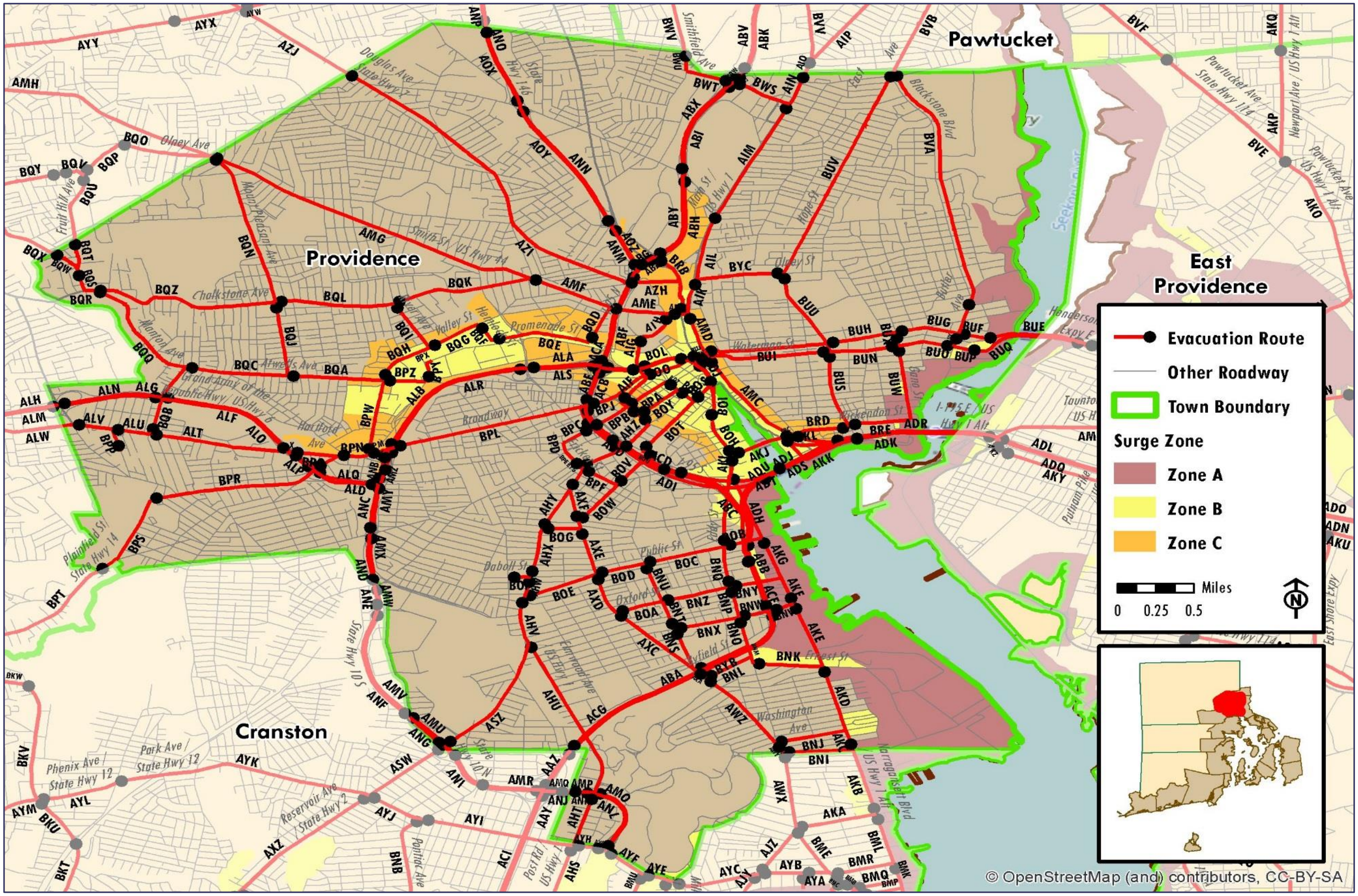

Figure 6-38: Evacuation Roadway Network – Providence County / Providence

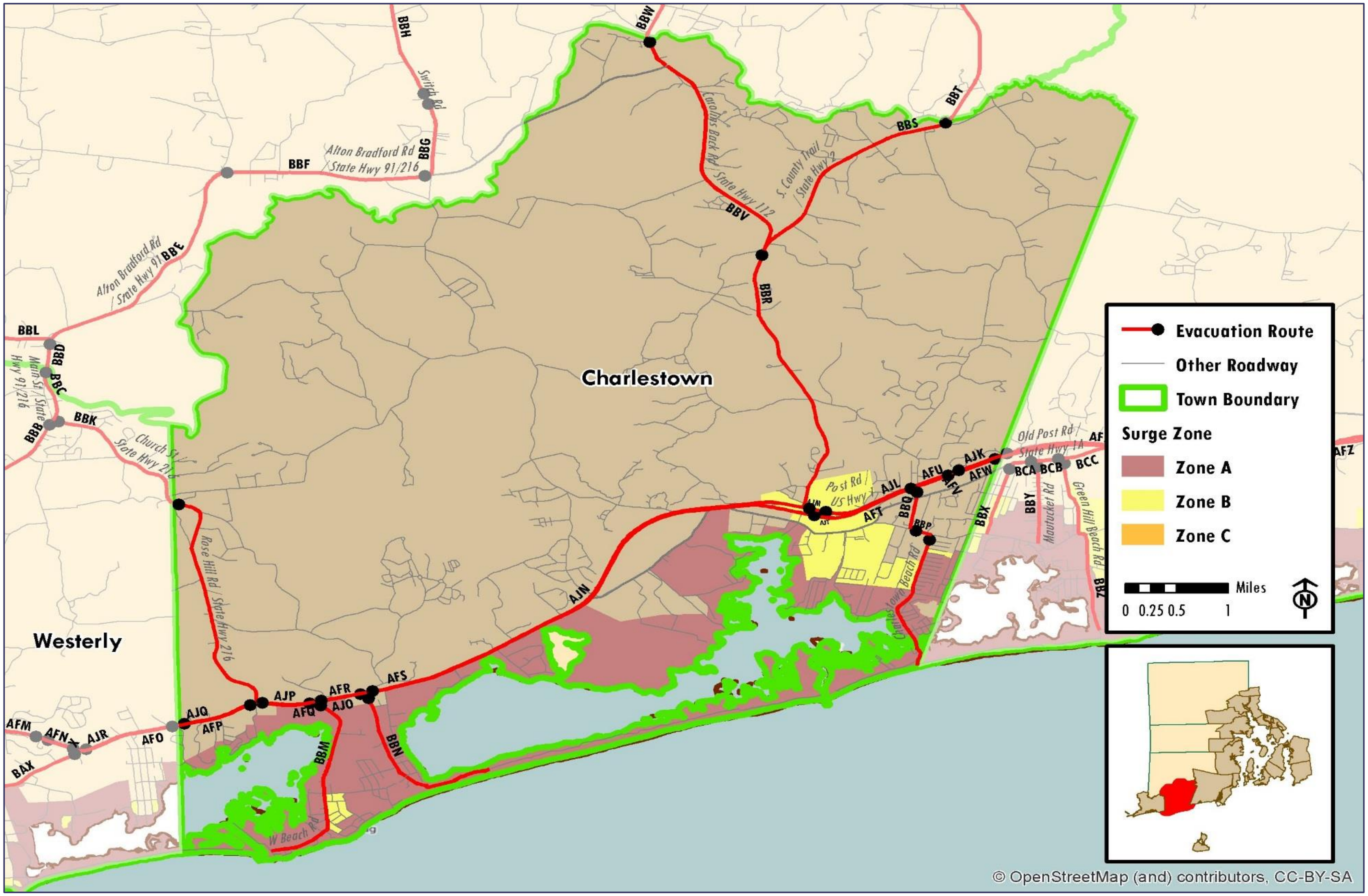

Figure 6-39: Evacuation Roadway Network – Washington County / Charlestown

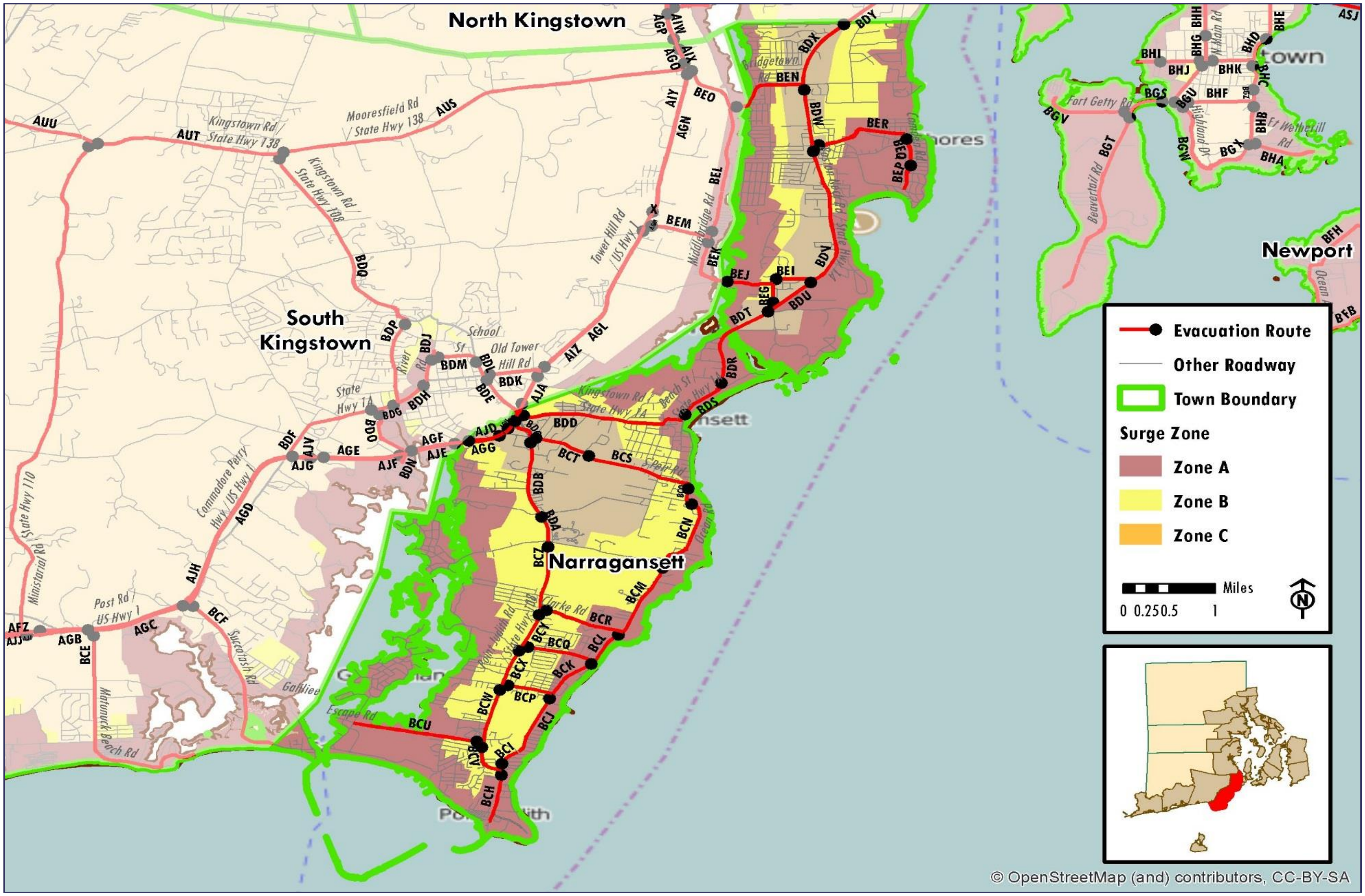

Figure 6-40: Evacuation Roadway Network – Washington County / Narragansett

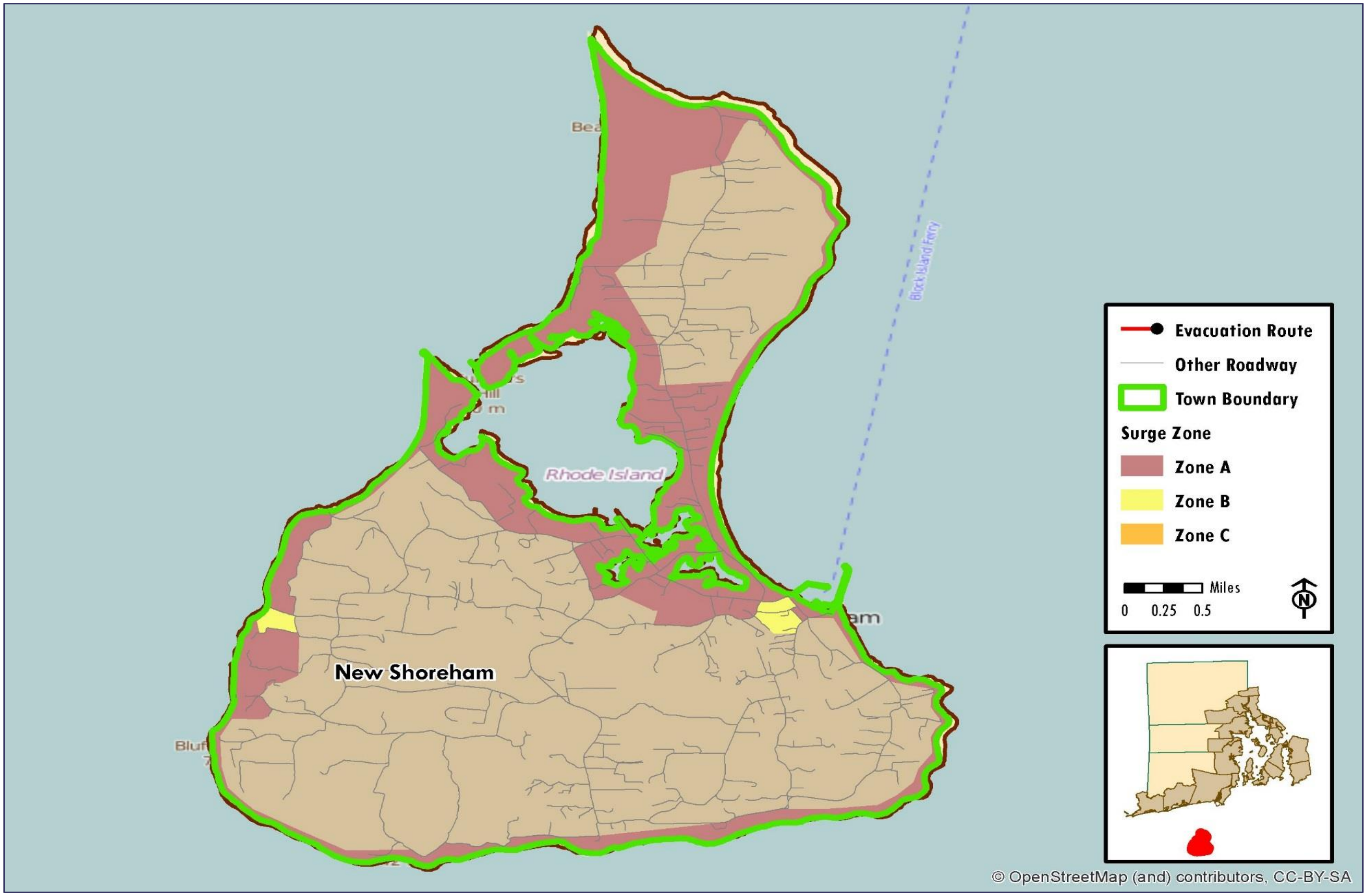

Figure 6-41: Evacuation Roadway Network – Washington County / New Shoreham

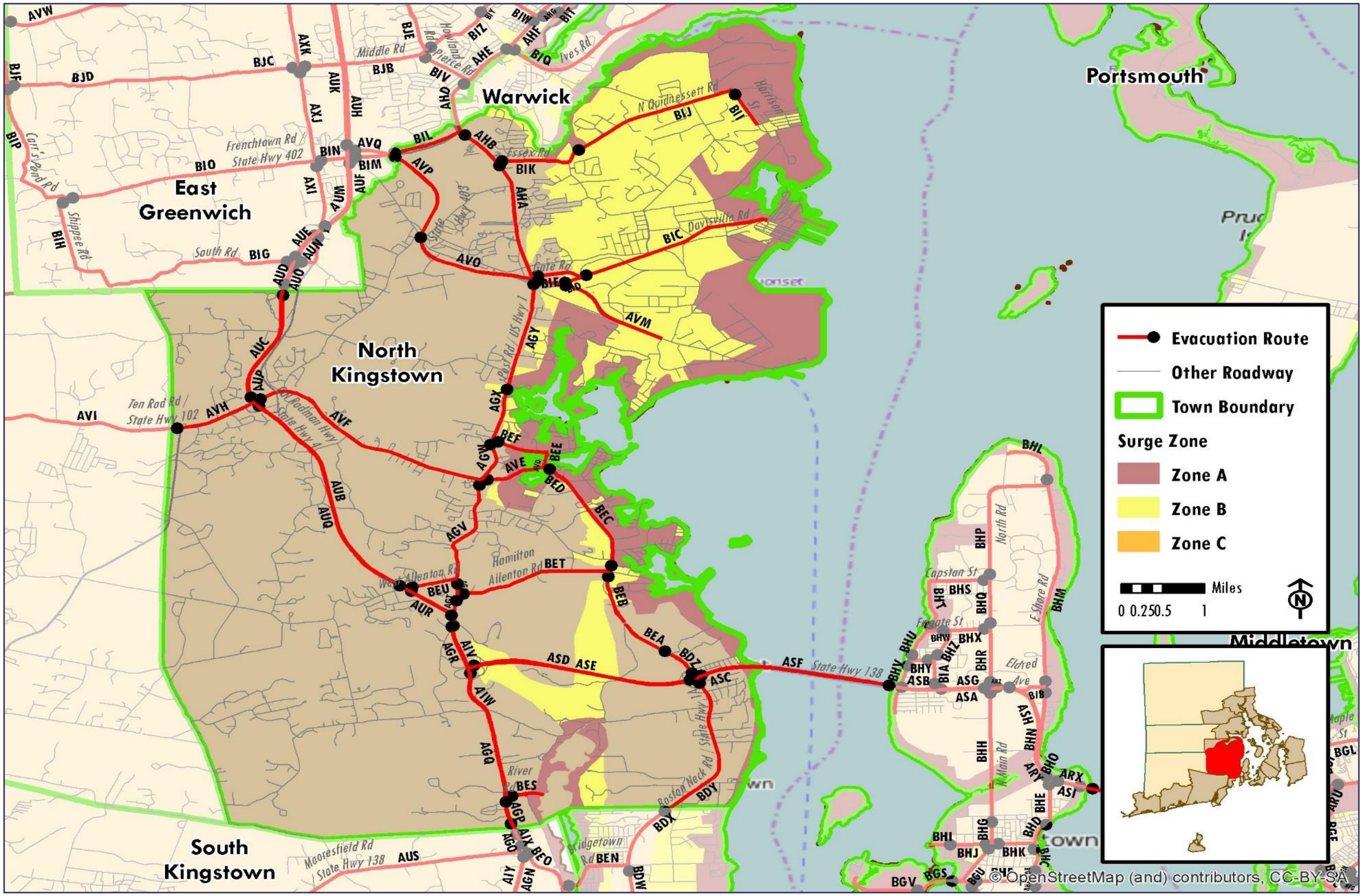

Figure 6-42: Evacuation Roadway Network – Washington County / North Kingstown

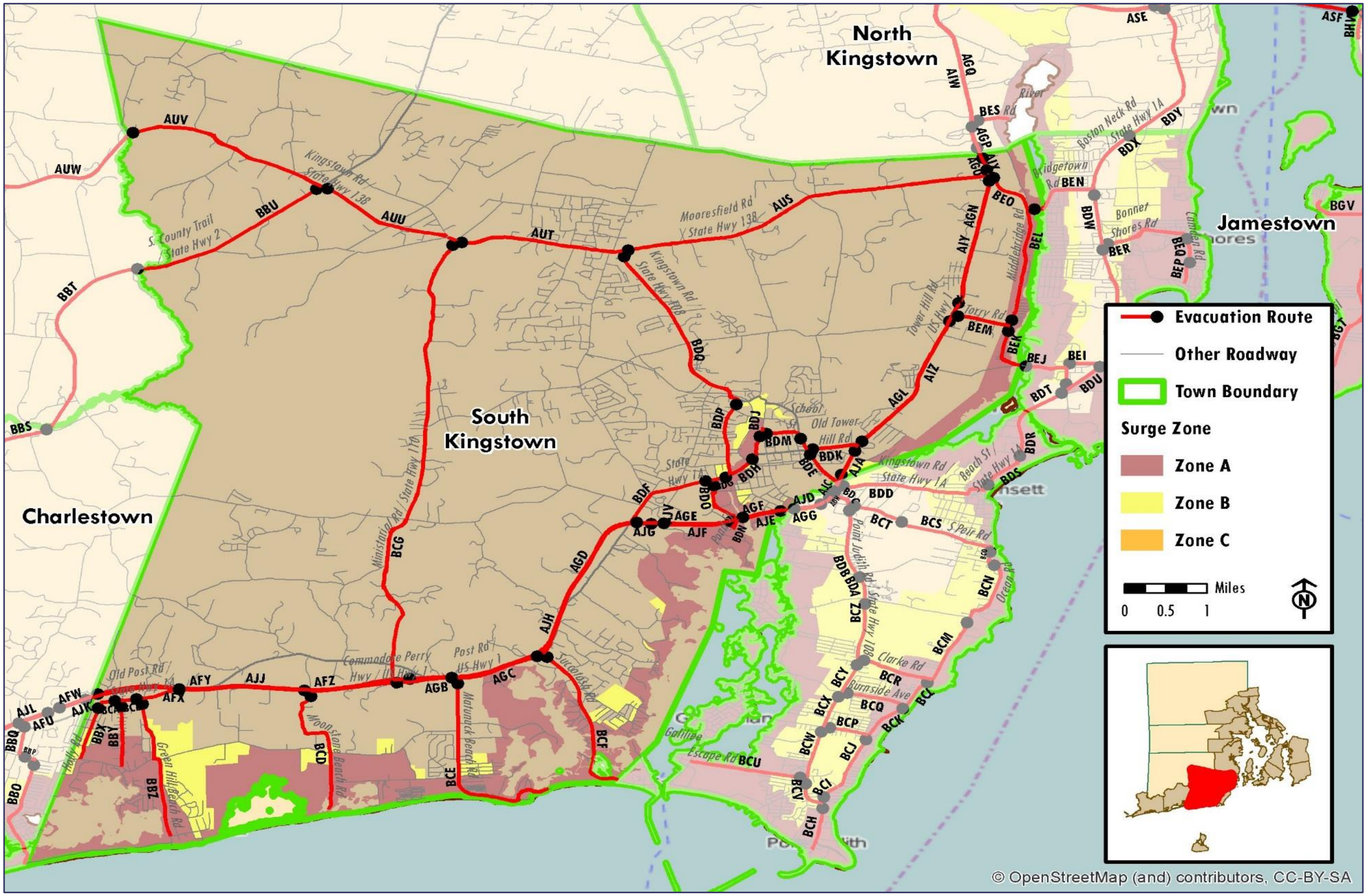

Figure 6-43: Evacuation Roadway Network – Washington County / South Kingstown

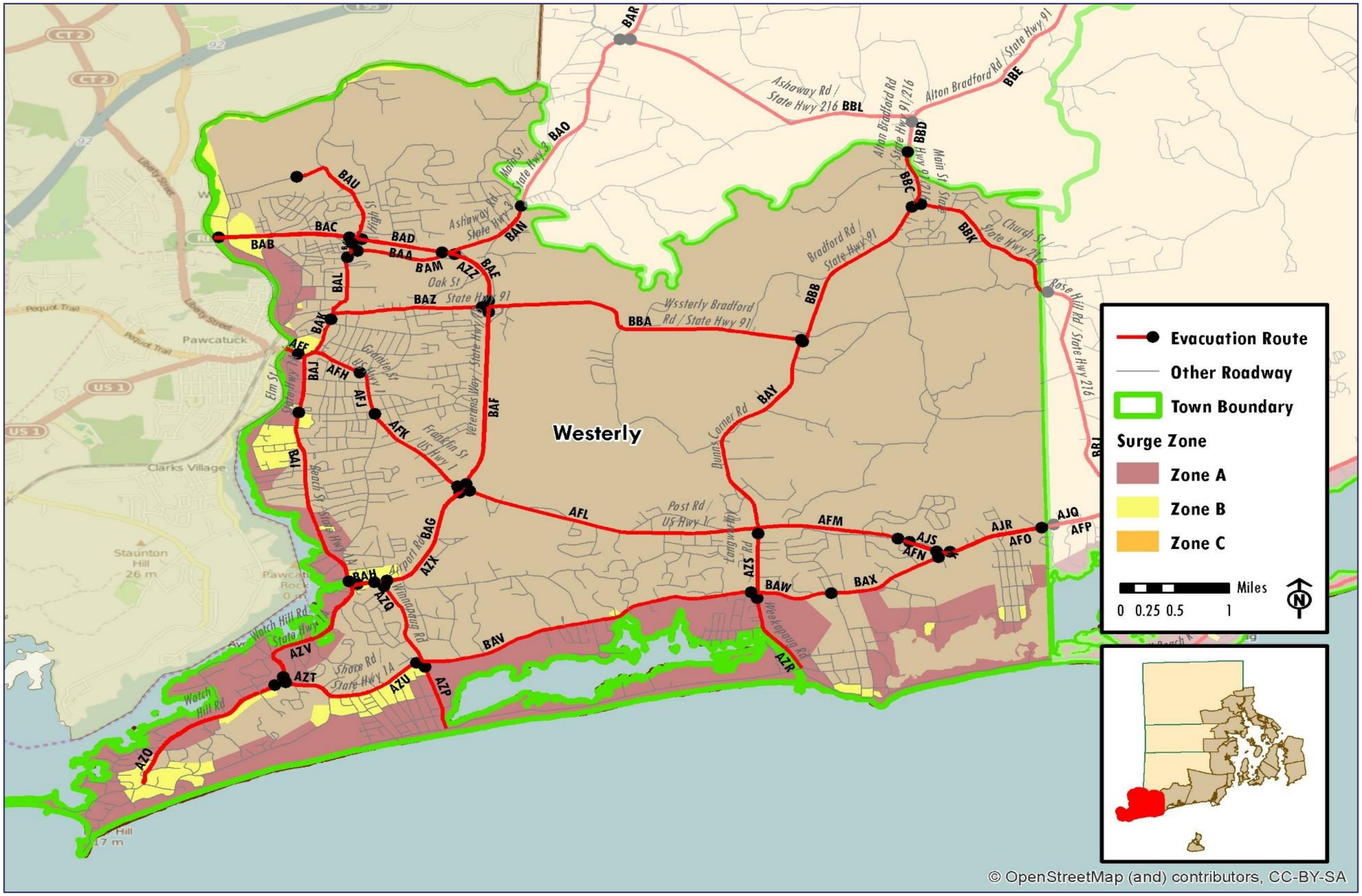

Figure 6-44: Evacuation Roadway Network – Washington County / Westerly

6.0 Transportation Analysis

With the roadway network broken down into its component parts, the next key step in the process was to quantify the performance of the roadway system (i.e., defining the capability of the roadway network to convey traffic) under hurricane evacuation conditions. Such characteristics as number of lanes, type of roadbed, surrounding land uses, number and spacing of traffic signals are important determinants in assessing a roadway's ability to convey traffic. Using aerial imagery and data, a specific value which represents an hourly directional peak service volume was assigned to each of the roadway segments identified above.

The assigned service volume for each roadway segment is an approximation of how many vehicles can flow through a roadway segment in one direction in one hour. With the roadway characteristic information described above, these capacity estimates can be derived from commonly used and widely recognized transportation planning guidance called Level of Service (LOS) tables from the Highway Capacity Manual. Using a LOS D figure, which is the category just below "free flow" conditions, each segment is associated with a number that represents its capacity to process vehicles under the less than optimal circumstances that normally will exist during a hurricane evacuation.

Another important variable in assessing roadway capacities is to investigate any traffic operations or other infrastructure related measures that may help or hinder the flow of vehicles during an evacuation. Contra flow, roadway barriers and diversions, toll operations as well as other traffic management schemes, especially if implemented to specifically control the flow of evacuating vehicles, can also have a significant impact on the service volume figures assigned to each roadway segment in the model.

Once the characteristics of the roadway system have been established, the travel demand (number of evacuating vehicles) is loaded by the model at the node assigned to each traffic evacuation zone. Those vehicles are then manually routed link by link through the entire evacuation roadway network from their originating node to their assumed safe destination points. Where the evacuation streams from traffic evacuation zones converge and/or overlap will determine those critical links requiring specialized attention over the course of an event. The application of this specialized transportation model allows the cumulative impacts of the multiple evacuation paths from competing vulnerability zones to be quantified and expressed as a period of time. Ultimately, the clearance time for a locale, jurisdiction, or region will be determined by the most congested roadway segment between the point of origin and the most distant destination node.

Those key roadway segments, once they are established as the most critical by virtue of their relative congestion, are subjected to additional, more detailed traffic analysis for clearance time development. The listing of the critical roadway network segments and their directional service volume is provided in Table 6-10. The selection of these network focal points is not meant to be a complete listing of every traffic control point or problem spot during an evacuation. It is meant to capture the controlling bottlenecks and provide enough coverage and complexity so that clearance times can be calculated adequately and officials can make informed decisions from an evacuation timing standpoint.

Table 6-10: Critical Roadway Segments

Bottleneck Location	Critical Roadway Segments	Directional Service Volume
Westerly	Beach St/RI 1A north of Winnapaug Rd intersection (BAI)	820
Westerly	Post Rd/US 1 east of Shore Rd/RI 1A intersection (AFO)	1,810
Charlestown	Post Rd/US 1 at Narrow Ln intersection (AFU)	2,980
South Kingston	Tower Hill Rd/US 1 at Old Tower Hill Rd intersection (AGK)	2,980
South Kingston	Tower Hill Rd/US 1 at Bridgetown Rd intersection (AGO)	1,810
Portsmouth	RI 24 westbound bridge across the Sakonnet River (ARP)	3,420
Portsmouth	RI 114/Mt Hope Bridge into Bristol (APG)	1,810
Newport	Admiral Kalbfus Rd/RI 138 intersection with Newport Bridge access (ART)	860
North Kingston	Tower Hill Rd/US 1 at Col Rodman Hwy/RI 4 intersection (AGR)	1,810
Warwick	Col Rodman Hwy/RI 4 at I-95 interchange (AUI)	3,420
Warwick	W. Shore Rd/RI 117 at RI 113 intersection (AWG)	1,860
Warwick	Post Rd/RI 117 at RI 115 intersection (AWM)	860
Warwick	I-95 Northbound at I-295 split (AAQ)	7,140
Cranston	I-95 Northbound at RI-10 interchange (AAV)	7,380
Cranston	Park Ave/RI 12 at Park View Blvd (AYF)	860
Providence	Thurbers Ave at I-95 (BNV)	760
Providence	Broadway at Hartford Ave (BPN)	760
Providence	Washington St @ Winter St	760
Providence	I-95 Northbound at I-195 interchange (ABB)	7,380
Providence	I-95 Northbound at US 6 interchange (ABE)	7,380
Providence	I-195 Northbound @ US 44 interchange (ADK)	7,380
Providence	US 6 Westbound @ RI 128 interchange (ALG)	5,410
Providence	I-95 Northbound at RI 146 interchange (ABF)	5,410
Bristol	Hope St/RI 114 @ Elmwood Dr (APP)	820
Warren	Main St/RI 103/114 bridge over the Warren River (APU)	820
Warren	Metacom Ave/RI 136 across Massachusetts state line (ATY)	820
Barrington	County Rd/RI103/114 @ Federal Rd (APY)	820
Barrington	Wampanoag Trail/RI 114 @ Argyle Ave (APZ)	2,980
Barrington	County Rd/RI 103 (AQM)	820
East Providence	Henderson Expy W (BUE)	3,230
East Providence	I-195 W / US 1 Alt (ADR)	7,380
Pawtucket	I-95 Northbound @ Broadway/RI15 interchange	5,410

6.10 Model Results

The transportation modeling completed for Rhode Island resulted in the items listed below. These are the most critical outputs for planning for shelter needs, anticipating bottlenecks and defining the timing requirements of an evacuation.

- Evacuating people and vehicle statistics by evacuation zone by storm category for each community;
- Shelter demand and capacity considerations by storm category for each community;
- Traffic volumes and critical roadway segments by storm category for each community;
- Estimated clearance times by storm category for each Rhode Island community.

6.10.1 Evacuating People and Vehicles

The transportation model distributes the evacuating vehicles and people generated by each evacuation scenario to three destinations. The destination types in the model are: to in-jurisdiction public shelters; to other refuges (internal hotels/motels, friends and family) within the originating jurisdiction; and those leaving the community altogether. The evacuation statistics include scenarios for each level of storm intensity (Zone A through Zone C) as well as high and low tourist occupancy levels. Low tourist occupancy was assumed to be 30 percent and high was set at 90 percent.

Tables 6-11 through 6-22 shows how many residents and tourists are estimated to leave the vulnerability areas by hurricane intensity scenario and low or high tourist occupancy level, as well as the number of evacuating vehicles. It must be noted however that these figures may be higher than the actual number of people and vehicles that may evacuate during a real storm event. The assumed 100 percent participation rate used for the residents and visitors in the Zone A vulnerability zone, regardless of storm intensity, cause the bias in these evacuation statistics to favor a higher, rather than a lower, estimate. For the residents and visitors in each of the other storm tide vulnerability areas (Zones B through C), the model also assumes a 100 percent participation rate for the corresponding scenario, again to assure that sufficient time is provided for everyone to safely leave the zone. Consequently, by design, these figures actually err on the side of public safety since it is usually better to have the planning expectations and the response measures exceed the actual impacts of an event, especially when lives are at stake.

6.0 Transportation Analysis

Table 6-11: Evacuating People and Vehicles – Low Occupancy – Bristol County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
Barrington	11,098	11,098	6,077	6,077	2,117	1,814	3,960	4,263
	509	1,835	267	967	92	289	175	679
	102	301	48	142	19	49	29	93
Bristol	3,622	3,622	1,830	1,830	619	530	1,212	1,300
	166	602	98	357	34	107	64	250
	974	2,804	463	1,348	175	460	288	889
Warren	5,115	5,115	2,836	2,836	986	845	1,851	1,991
	277	962	150	530	50	157	100	373
	207	597	102	298	39	102	64	197
Totals	**22,070**	**26,936**	**11,871**	**14,385**	**4,131**	**4,353**	**7,743**	**10,035**

1. Key: Zone A (Category 1 & 2) Zone B (Category 3 & 4) Inland Area (Non-Surge)

Table 6-12: Evacuating People and Vehicles – High Occupancy – Bristol County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
Barrington	11,269	11,269	6,137	6,137	2,117	1,815	4,020	4,322
	533	1,862	275	977	92	289	183	688
	109	311	51	146	19	49	32	97
Bristol	3,991	3,991	1,959	1,959	620	532	1,339	1,428
	173	609	100	359	34	107	66	253
	1,120	3,009	514	1,420	176	460	338	959
Warren	5,233	5,233	2,878	2,878	986	845	1,892	2,033
	317	1,007	164	546	50	157	114	389
	239	641	113	314	39	102	74	212
Totals	**22,984**	**27,932**	**12,191**	**14,736**	**4,133**	**4,356**	**8,058**	**10,381**

1. Key: Zone A (Category 1 & 2) Zone B (Category 3 & 4) Inland Area (Non-Surge)

Table 6-13: Evacuating People and Vehicles – Low Occupancy – Kent County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
East Greenwich	139	139	89	89	30	26	58	63
	79	277	57	202	20	60	37	141
	678	1,952	352	1,021	138	353	215	668
Warwick	12,230	12,230	7,106	7,106	2,467	2,115	4,639	4,991
	2,268	7,789	1,244	4,378	411	1,290	833	3,088
	3,944	10,059	1,895	5,039	620	1,595	1,276	3,445
Totals	**19,338**	**32,446**	**10,743**	**17,835**	**3,686**	**5,439**	**7,058**	**12,396**

1. Key: Zone A (Category 1 & 2) Zone B (Category 3 & 4) Inland Area (Non-Surge)

Table 6-14: Evacuating People and Vehicles – High Occupancy – Kent County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
East Greenwich	150	150	93	93	31	26	62	67
	80	278	58	203	20	60	38	142
	726	2,020	369	1,045	138	354	232	691
Warwick	12,566	12,566	7,224	7,224	2,468	2,116	4,755	5,108
	2,681	8,248	1,389	4,539	412	1,290	976	3,247
	5,975	12,902	2,606	6,034	627	1,605	1,979	4,430
Totals	**22,178**	**36,164**	**11,739**	**19,138**	**3,696**	**5,451**	**8,042**	**13,685**

1. Key: Zone A (Category 1 & 2) Zone B (Category 3 & 4) Inland Area (Non-Surge)

Table 6-15: Evacuating People and Vehicles – Low Occupancy – Newport County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
Jamestown	1,515	1,515	946	946	292	250	654	696
	18	67	13	46	4	14	8	32
	314	769	170	450	53	140	117	311
Little Compton	608	608	351	351	93	80	258	271
	74	116	31	61	4	11	28	49
	401	811	200	436	54	121	146	315
Middletown	789	789	381	381	111	95	270	286
	49	122	23	65	5	17	18	48
	1,603	3,494	676	1,532	185	431	491	1,100
Newport	8,178	8,178	3,205	3,205	912	783	2,293	2,422
	400	956	175	462	37	116	137	346
	1,614	3,590	657	1,526	162	411	495	1,116
Portsmouth	4,023	4,023	2,187	2,187	710	609	1,476	1,578
	95	193	43	103	8	24	35	79
	1,116	2,677	572	1,403	207	464	365	938
Tiverton	1,667	1,667	1,167	1,167	392	336	775	831
	0	0	0	0	0	0	0	0
	1,099	2,719	609	1,525	234	521	376	1,003
Totals	**23,563**	**32,294**	**11,406**	**15,846**	**3,463**	**4,423**	**7,942**	**11,421**

1. Key: Zone A (Category 1 & 2) Zone B (Category 3 & 4) Inland Area (Non-Surge)

Table 6-16: Evacuating People and Vehicles – High Occupancy – Newport County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
Jamestown	2,175	2,175	1,177	1,177	294	253	883	924
	18	67	13	46	4	14	8	32
	531	1,072	246	557	54	141	192	416
Little Compton	1,106	1,106	526	526	95	82	431	444
	195	251	74	108	4	12	70	96
	779	1,340	332	621	55	123	276	498
Middletown	1,169	1,169	514	514	112	96	402	417
	92	171	38	82	6	17	33	65
	2,859	5,253	1,116	2,147	189	438	927	1,710
Newport	11,699	11,699	4,438	4,438	925	795	3,513	3,642
	798	1,399	314	617	39	118	275	499
	3,096	5,666	1,176	2,253	167	418	1,009	1,835
Portsmouth	4,949	4,949	2,511	2,511	713	612	1,797	1,899
	218	330	86	151	8	24	78	126
	1,434	3,122	684	1,558	208	466	475	1,092
Tiverton	1,938	1,938	1,262	1,262	393	337	868	924
	0	0	0	0	0	0	0	0
	1,247	2,926	661	1,597	234	522	427	1,075
Totals	**34,303**	**44,633**	**15,168**	**20,165**	**3,500**	**4,468**	**11,664**	**15,694**

1. Key: Zone A (Category 1 & 2) Zone B (Category 3 & 4) Inland Area (Non-Surge)

Table 6-17: Evacuating People and Vehicles – Low Occupancy – Providence County

Evacuation Areas[1]	Evacuating People			Evacuating Vehicles			Evacuating Vehicles to In County Destinations			Evacuating Vehicles to Out of County Destinations		
	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
Cranston	2,087	2,087	2,087	843	843	843	294	252	252	549	591	591
	472	1,716	1,716	239	871	871	83	261	261	156	611	611
	3,959	11,575	11,575	1,753	5,142	5,142	686	1,781	1,781	1,067	3,361	3,361
East Providence	3,945	3,945	3,945	2,134	2,134	2,134	745	639	639	1,388	1,495	1,495
	1,028	3,745	3,745	523	1,908	1,908	182	571	571	341	1,337	1,337
	1,990	5,704	5,704	882	2,541	2,541	341	875	875	541	1,666	1,666
Pawtucket	260	260	260	75	75	75	26	23	23	49	53	53
	55	196	196	24	86	86	8	26	26	16	60	60
	4,019	11,311	11,311	1,611	4,540	4,540	631	1,573	1,573	980	2,967	2,967
Providence	2,511	2,511	2,511	583	583	583	189	162	162	394	421	421
	1,500	3,001	3,001	445	758	758	39	117	117	406	641	641
	783	2,070	3,073	289	778	1,160	65	194	304	224	584	856
	9,443	27,018	27,018	2,915	8,302	8,302	1,083	2,804	2,804	1,832	5,497	5,497
Totals	**32,052**	**75,139**	**76,142**	**12,316**	**28,561**	**28,943**	**4,372**	**9,278**	**9,388**	**7,943**	**19,284**	**19,556**

1. Key:
- Zone A (Category 1 & 2)
- Zone B (Category 3 & 4)
- Zone C (Category 3 & 4/Fox Point Hurricane Barrier Failure, Providence County Only)
- Inland Area (Non-Surge)

Table 6-18: Evacuating People and Vehicles – High Occupancy – Providence County

Evacuation Areas[1]	Evacuating People			Evacuating Vehicles			Evacuating Vehicles to In County Destinations			Evacuating Vehicles to Out of County Destinations		
	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
Cranston	2,098	2,098	2,098	847	847	847	295	252	252	553	595	595
	483	1,729	1,729	243	876	876	83	261	261	160	615	615
	4,182	11,888	11,888	1,831	5,251	5,251	687	1,782	1,782	1,144	3,469	3,469
East Providence	3,970	3,970	3,970	2,142	2,142	2,142	745	639	639	1,397	1,504	1,504
	1,048	3,767	3,767	530	1,915	1,915	182	571	571	348	1,344	1,344
	2,162	5,945	5,945	942	2,625	2,625	342	876	876	601	1,750	1,750
Pawtucket	260	260	260	75	75	75	26	23	23	49	53	53
	58	200	200	25	87	87	8	26	26	17	62	62
	4,210	11,578	11,578	1,678	4,634	4,634	632	1,574	1,574	1,046	3,060	3,060
Providence	2,765	2,765	2,765	672	672	672	190	163	163	482	509	509
	3,457	5,175	5,175	1,130	1,519	1,519	46	125	125	1,084	1,394	1,394
	1,389	2,849	3,939	502	1,051	1,463	67	197	307	434	854	1,156
	10,659	28,720	28,720	3,341	8,897	8,897	1,087	2,810	2,810	2,253	6,087	6,087
Totals	**36,741**	**80,944**	**82,034**	**13,958**	**30,591**	**31,003**	**4,390**	**9,299**	**9,409**	**9,568**	**21,296**	**21,598**

1. Key:
- Zone A (Category 1 & 2)
- Zone B (Category 3 & 4)
- Zone C (Category 3 & 4/Fox Point Hurricane Barrier Failure, Providence County Only)
- Inland Area (Non-Surge)

Table 6-19: Evacuating People and Vehicles – Low Occupancy – Washington County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
Charlestown	1,782	1,782	988	988	238	204	750	784
	194	340	82	169	11	34	70	135
	1,047	2,007	456	937	101	228	356	709
Narragansett	8,695	8,695	5,233	5,233	1,628	1,397	3,604	3,836
	1,393	3,737	714	2,124	188	579	525	1,545
	254	622	125	327	38	100	87	227
New Shoreham	717	717	304	304	131	131	173	173
	66	87	25	38	5	18	20	20
	1,423	1,589	515	608	46	139	469	469
North Kingstown	3,625	3,625	2,159	2,159	730	626	1,429	1,533
	834	2,791	459	1,554	156	462	303	1,092
	1,246	3,219	622	1,628	234	552	388	1,076
South Kingstown	3,824	3,824	2,148	2,148	589	506	1,558	1,642
	326	716	165	438	36	110	129	327
	1,975	4,972	829	2,136	268	670	561	1,466
Westerly	3,858	3,858	1,995	1,995	528	453	1,468	1,542
	300	713	152	421	35	109	117	312
	1,508	3,657	687	1,754	203	526	484	1,228
Totals	**33,067**	**46,951**	**17,658**	**24,961**	**5,165**	**6,844**	**12,491**	**18,116**

1. Key: Zone A (Category 1 & 2) — Zone B (Category 3 & 4) — Inland Area (Non-Surge)

6.0 Transportation Analysis

Table 6-20: Evacuating People and Vehicles – High Occupancy – Washington County

Evacuation Areas[1]	Evacuating People		Evacuating Vehicles		Evacuating Vehicles to In County Destinations		Evacuating Vehicles to Out of County Destinations	
	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B	Zone A	Zone B
Charlestown	3,600	3,600	1,624	1,624	244	210	1,380	1,414
	483	662	183	282	12	36	171	246
	2,248	3,689	877	1,526	105	234	772	1,292
Narragansett	12,110	12,110	6,428	6,428	1,640	1,408	4,788	5,020
	2,428	4,887	1,076	2,527	192	583	884	1,944
	427	864	186	412	39	101	147	311
New Shoreham	1,705	1,705	650	650	131	131	519	519
	183	204	66	79	5	18	61	61
	4,103	4,269	1,453	1,546	46	139	1,407	1,407
North Kingstown	4,054	4,054	2,309	2,309	731	627	1,577	1,681
	908	2,873	485	1,583	157	462	328	1,120
	1,457	3,514	696	1,731	235	553	461	1,178
South Kingstown	6,552	6,552	3,103	3,103	599	515	2,504	2,588
	699	1,132	296	583	37	112	259	471
	2,905	6,274	1,155	2,591	272	675	883	1,917
Westerly	6,724	6,724	2,998	2,998	538	463	2,460	2,535
	602	1,048	257	538	36	110	221	428
	2,562	5,132	1,056	2,271	207	531	849	1,739
Totals	**53,750**	**69,293**	**24,898**	**32,781**	**5,226**	**6,908**	**19,671**	**25,871**

1. Key: Zone A (Category 1 & 2) Zone B (Category 3 & 4) Inland Area (Non-Surge)

6.0 Transportation Analysis

Table 6-21: Evacuating People and Vehicles – Low Occupancy

Evacuation Areas[1]	Evacuating People			Evacuating Vehicles			Evacuating Vehicles to In County Destinations			Evacuating Vehicles to Out of County Destinations		
	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
Bristol	19,835	19,835		10,743	10,743		3,722	3,189		7,023	7,554	
	952	3,399		515	1,854		176	553		339	1,302	
	1,283	3,702		613	1,788		233	611		381	1,179	
Kent	12,369	12,369		7,195	7,195		2,497	2,141		4,697	5,054	
	2,347	8,066		1,301	4,580		431	1,350		870	3,229	
	4,622	12,011		2,247	6,060		758	1,948		1,491	4,113	
Newport	16,780	16,780		8,237	8,237		2,510	2,153		5,726	6,084	
	636	1,454		285	737		58	182		226	554	
	6,147	14,060		2,884	6,872		895	2,088		1,990	4,783	
Providence	8,803	8,803		3,635	3,635		1,254	1,076		2,380	2,560	
	3,055	8,658		1,231	3,623		312	975		919	2,649	
	783	2,070	3,073	289	778	1,160	65	194	304	224	584	856
	19,411	55,608		7,161	20,525		2,741	7,033		4,420	13,491	
Washington	22,501	22,501		12,827	12,827		3,844	3,317		8,982	9,510	
	3,113	8,384		1,597	4,744		431	1,312		1,164	3,431	
	7,453	16,066		3,234	7,390		890	2,215		2,345	5,175	
Totals	**71,485**	**71,485**		**39,002**	**39,002**		**12,573**	**10,800**		**26,428**	**28,202**	
	10,103	**29,961**		**4,929**	**15,538**		**1,408**	**4,372**		**3,518**	**11,165**	
	783	**2,070**	**3,073**	**289**	**778**	**1,160**	**65**	**194**	**304**	**224**	**584**	**856**
	38,916	**101,447**		**16,139**	**42,635**		**5,517**	**13,895**		**10,627**	**28,741**	

1. Key: Zone A (Category 1 & 2) | Zone B (Category 3 & 4) | Zone C (Category 3 & 4/Fox Point Hurricane Barrier Failure, Providence County Only) | Inland Area (Non-Surge)

Table 6-22: Evacuating People and Vehicles – High Occupancy

Evacuation Areas[1]	Evacuating People			Evacuating Vehicles			Evacuating Vehicles to In County Destinations			Evacuating Vehicles to Out of County Destinations		
	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
Bristol	20,493	20,493		10,974	10,974		3,723	3,192		7,251	7,783	
	1,023	3,478		539	1,882		176	553		363	1,330	
	1,468	3,961		678	1,880		234	611		444	1,268	
Kent	12,716	12,716		7,317	7,317		2,499	2,142		4,817	5,175	
	2,761	8,526		1,447	4,742		432	1,350		1,014	3,389	
	6,701	14,922		2,975	7,079		765	1,959		2,211	5,121	
Newport	23,036	23,036		10,428	10,428		2,532	2,175		7,894	8,250	
	1,321	2,218		525	1,004		61	185		464	818	
	9,946	19,379		4,215	8,733		907	2,108		3,306	6,626	
Providence	9,093	9,093		3,736	3,736		1,256	1,077		2,481	2,661	
	5,046	10,871		1,928	4,397		319	983		1,609	3,415	
	1,389	2,849	3,939	502	1,051	1,463	67	197	307	434	854	1,156
	21,213	58,131		7,792	21,407		2,748	7,042		5,044	14,366	
Washington	34,745	34,745		17,112	17,112		3,883	3,354		13,228	13,757	
	5,303	10,806		2,363	5,592		439	1,321		1,924	4,270	
	13,702	23,742		5,423	10,077		904	2,233		4,519	7,844	
Totals	**90,990**	**90,990**		**45,831**	**45,831**		**12,637**	**10,863**		**33,190**	**34,965**	
	15,454	**35,899**		**6,802**	**17,617**		**1,427**	**4,392**		**5,374**	**13,222**	
	1,389	**2,849**	**3,939**	**502**	**1,051**	**1,463**	**67**	**197**	**307**	**434**	**854**	**1,156**
	53,030	**120,135**		**21,083**	**49,176**		**5,558**	**13,953**		**15,524**	**35,225**	

1. Key:
- Zone A (Category 1 & 2)
- Zone C (Category 3 & 4/Fox Point Hurricane Barrier Failure, Providence County Only)
- Zone B (Category 3 & 4)
- Inland Area (Non-Surge)

6.10.2 Shelter Demand and Capacity Considerations

The potential public shelter lists provided in Chapter 5 in the TDR include the locations and capacities of those facilities. The opening and management of public shelters is an integral part of any evacuation operation, especially since mobile home residents typically have the highest propensity to use those facilities as their refuge location. For the Rhode Island study, shelter demand was determined using assumptions derived from data in the behavioral analysis. Tables in Chapter 5 compare for A, B and C response scenarios, the estimated public shelter demand with the available spaces in each jurisdiction to determine whether it has a surplus or deficit of spaces. The shelter locations and capacities provided in Chapter 5 were compiled by the USACE, New England District from data provided by the local emergency management offices, and the National Shelter System (NSS) database.

6.10.3 Traffic Volumes and Critical Roadway Segments

Once the evacuation statistics for each vulnerability area and evacuation zone have been developed and the departing vehicles distributed to the three major destinations mentioned above, the transportation model apportions the external trips to the routes that exit the jurisdiction. This allocation is particularly important because the vehicles leaving the community altogether will usually have to travel the furthest, over more segments than local trips, thereby increasing the likelihood that they will have to pass through one of the most congested segments identified in the model. These external trips will also spend more time traveling to their ultimate safe destination. In recognition of the relative difficulties associated with these out of jurisdiction vehicles, each evacuation sector is assigned a specific set of percentages that represent the proportion of those evacuating vehicles using each of the exiting routes. Table 6-23 displays the assigned average percentages used by the transportation model for each county in the Rhode Island study area. The specific per zone assignments can be found in the Rhode Island DTM. The DTM was developed in order to facilitate the ability of the emergency management and other local officials to update clearance times in an efficient manner.

Once the vehicle trips from each evacuation sector have been distributed according to the three destination categories, the model actually routes those vehicles from the start point of each evacuation sector to the three assumed safe objective points. The two types of internal trips and one external for every evacuation zone are assigned to the critical links, if warranted, and cumulated to provide a total number of evacuating vehicles for that key segment. Table 6-24 displays those figures for the most critical roadway segments by county and community. The volumes of traffic include both local and out of county movements for each response scenario and tourist occupancy scenario. The volumes shown also include vehicles that may be passing through coastal Rhode Island on their way out of the area.

The transportation model also factors in background traffic, namely those vehicles using the evacuation routes for purposes other than evacuating. These trips include travel associated with households procuring last minute supplies, individuals returning home to begin the evacuation process and other activities not at all related to the approaching storm. Depending on the time and day the evacuation order is issued, background congestion could prove to be a significant hindrance for those vehicles using the same road network to escape the impacts of a tropical cyclone threat.

The predicted traffic volume is based upon the specific behavioral assumptions employed in the transportation analysis. Assumptions regarding participation rates and tourist occupancy are the most critical. Since the Rhode Island area has very limited evacuation experience and since this analysis assumes full participation by the areas that should evacuate, actual volumes could be lower than the data presented in these tables. Many who should evacuate in lesser categories of hurricanes will underestimate the impact of a storm and will choose not to evacuate. However, clearance times calculated for this transportation analysis should allow for people to evacuate whether they choose to or not.

Table 6-23: Out Route Initial Assignment Assumptions

County	Community	Critical Roadway Segment	Initial % Assignment
Bristol County	Barrington	RI 103 northbound	20%
		RI 114 westbound	60%
		RI 103/114 southbound/eastbound	15%
		New Meadow Rd northbound	5%
	Bristol	RI 114 westbound	65%
		RI 136 westbound	35%
	Warren	RI 103/114 northbound/westbound	60%
		RI 136 westbound	25%
		Bushee Rd northbound	5%
		RI 103 southbound	10%
Kent County	East Greenwich	US 1 southbound	5%
		RI 4 westbound	10%
		Carr's Pond Rd northbound	5%
		RI 401 northbound	5%
		I-95 southbound	20%
		I-95 northbound	25%
		RI 2 eastbound	15%
		RI 4 eastbound	15%
	Warwick	US 1 southbound	5%
		RI 4 westbound	5%
		RI 2 westbound	1%
		I-95 southbound	12%
		Cowsett Rd westbound	1%
		RI 117 southbound	4%
		New London Ave southbound	1%
		RI 115 northbound	4%
		I-295 northbound	30%
		RI 2 eastbound	5%
		RI 5 northbound	5%
		I-95 northbound	19%
		RI 37 northbound	5%
		US 1 northbound	2%
		US 1 Alt northbound	1%

Table 6-23: Out Route Initial Assignment Assumptions

County	Community	Critical Roadway Segment	Initial % Assignment
Newport County	Jamestown	RI 138 westbound	100%
	Little Compton	RI 77 northbound	60%
		Long Hwy westbound	40%
	Middletown	RI 114 westbound	60%
		RI 114 eastbound	20%
		RI 138 eastbound	20%
	Newport	RI 114 eastbound	10%
		Maple St eastbound	5%
		RI 138 westbound	85%
	Portsmouth	RI 114 westbound	15%
		RI 138 westbound	15%
		RI 114 eastbound	50%
		RI 24 eastbound	20%
	Tiverton	RI 138 eastbound	5%
		Fish Rd northbound	5%
		RI 24 westbound	35%
		RI 24 eastbound	45%
		RI 81 northbound	0%
		RI 177 eastbound	10%
Providence County	Cranston	I-95 southbound	10%
		RI 37 southbound	2%
		RI 5 eastbound	1%
		RI 2 eastbound	2%
		I-295 northbound	35%
		RI 5 westbound	5%
		RI 10 northbound	20%
		I-95 northbound	14%
		US 1 northbound	5%
		RI 117 northbound	4%
		US 1 Alt northbound	2%
	East Providence	I-195 westbound	45%
		Henderson Expy westbound	35%
		RI 114 westbound	10%
		US 1 Alt northbound	5%

Table 6-23: Out Route Initial Assignment Assumptions

County	Community	Critical Roadway Segment	Initial % Assignment
Providence County (continued)	East Providence (continued)	US 44 eastbound	1%
		I-195 eastbound	3%
		US 6 eastbound	1%
	Pawtucket	East Ave southbound	1%
		US 1 southbound	5%
		I-95 southbound	30%
		RI 15 northbound	18%
		Dexter St northbound	1%
		RI 114 westbound	3%
		I-95 northbound	25%
		US 1 northbound	5%
		US 1 Alt northbound	5%
		RI 15 southbound	5%
		RI 114 eastbound	2%
	Providence	US 1 southbound	5%
		I-95 southbound	10%
		RI 2 eastbound	3%
		RI 14 northbound	5%
		US 6A northbound	5%
		US 6 westbound	20%
		Fruit Hill Ave northbound	2%
		US 44 westbound	5%
		RI 7 northbound	2%
		RI 146 northbound	15%
		Smithfield Ave northbound	1%
		I-95 northbound	15%
		US 1 northbound	5%
		Hope St northbound	1%
		Henderson Expy eastbound	3%
		I-195 eastbound	3%

Table 6-23: Out Route Initial Assignment Assumptions

County	Community	Critical Roadway Segment	Initial % Assignment
Washington County	Charlestown	US 1 southbound	20%
		RI 216 westbound	5%
		RI 112 westbound	10%
		RI 2 eastbound	5%
		US 1 northbound	60%
	Narragansett	US 1 southbound	15%
		US 1 northbound	50%
		Middlebridge Rd westbound	15%
		Bridgetown Rd westbound	15%
		US 1A northbound	5%
	North Kingstown	US 1 southbound	5%
		RI 102 northbound	5%
		RI 4 northbound	35%
		RI 403 westbound	45%
		US 1 northbound	10%
	South Kingstown	US 1 southbound	10%
		RI 138 westbound	20%
		US 1 northbound	70%
	Westerly	US 1 southbound	10%
		RI 78 westbound	10%
		RI 3 northbound	30%
		RI 91/216 northbound/westbound	5%
		US 1 northbound	45%

Table 6-24: Evacuating Vehicle Volume (Total Volume of Vehicles)

Bottleneck Location	Critical Roadway Segments	Evacuating Vehicles					
		Low Occupancy			High Occupancy		
		Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
Westerly	Beach St/RI 1A north of Winnapaug Rd intersection (BAI)	1,284	2,002		1,737	2,505	
	Post Rd/US 1 east of Shore Rd/RI 1A intersection (AFO)	1,161	1,713		1,823	2,447	
Charlestown	Post Rd/US 1 at Narrow Ln intersection (AFU)	1,830	2,660		3,232	4,251	
South Kingston	Tower Hill Rd/US 1 at Old Tower Hill Rd intersection (AGK)	4,048	5,810		6,309	8,318	
	Tower Hill Rd/US 1 at Bridgetown Rd intersection (AGO)	5,173	7,410		8,017	10,542	
Portsmouth	RI 24 westbound bridge across the Sakonnet River (ARP)	712	1,091		947	1,365	
	RI 114/Mt Hope Bridge into Bristol (APG)	1,957	2,895		2,747	3,822	
Newport	Admiral Kalbfus Rd/RI 138 intersection with Newport Bridge access (ART)	1,585	2,338		2,476	3,395	
North Kingston	Tower Hill Rd/US 1 at Col Rodman Hwy/RI 4 intersection (AGR)	6,380	9,197		9,909	13,147	
Warwick	Col Rodman Hwy/RI 4 at I-95 interchange (AUI)	6,374	9,715		9,849	13,354	
	W. Shore Rd/RI 117 at RI 113 intersection (AWG)	1,712	2,227		1,788	2,322	
	Post Rd/RI 117 at RI 115 intersection (AWM)	1,723	1,972		1,838	2,090	
	I-95 Northbound at I-295 split (AAQ)	6,187	9,432		9,428	12,836	
Cranston	I-95 Northbound at RI-10 interchange (AAV)	5,151	7,945		7,908	10,858	
	Park Ave/RI 12 at Park View Blvd (AYF)	1,196	2,736		1,244	2,801	

Table 6-24: Evacuating Vehicle Volume (Total Volume of Vehicles) (continued)

Bottleneck Location	Critical Roadway Segments	Evacuating Vehicles					
		Low Occupancy			High Occupancy		
		Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
Providence	Thurbers Ave at I-95 (BNV)	501	1,244		658	1,436	
	Broadway at Hartford Ave (BPN)	404	1,008	1,040	485	1,107	1,141
	Washington St @ Winter St	236	644	658	248	659	673
	I-95 Northbound at I-195 interchange (ABB)	3,374	5,280		5,177	7,191	
	I-95 Northbound at US 6 interchange (ABE)	2,282	3,939	3,976	3,484	5,243	5,284
	I-195 Northbound @ US 44 interchange (ADK)	1,558	2,505	2,512	2,386	3,389	3,397
	US 6 Westbound @ RI 128 interchange (ALG)	1,393	2,847	2,914	2,105	3,656	3,732
	I-95 Northbound at RI 146 interchange (ABF)	2,315	4,657	4,762	3,501	6,000	6,117
Bristol	Hope St/RI 114 @ Elmwood Dr (APP)	1,936	4,306		3,715	5,309	
Warren	Main St/RI 103/114 bridge over the Warren River (APU)	3,223	4,591		3,804	5,265	
	Metacom Ave/RI 136 across Massachusetts state line (ATY)	1,659	2,386		2,005	2,790	
Barrington	County Rd/RI103/114 @ Federal Rd (APY)	6,030	7,819		6,610	8,492	
	Wampanoag Trail/RI 114 @ Argyle Ave (APZ)	4,950	6,520		5,426	7,065	
	County Rd/RI 103 (AQM)	1,029	1,296		1,122	1,404	
East Providence	Henderson Expy W (BUE)	795	1,574		821	1,609	
	I-195 W / US 1 Alt (ADR)	5,130	7,436		5,559	7,933	
Pawtucket	I-95 Northbound @ Broadway/RI15 interchange	1,456	3,153	3,207	2,075	3,857	3,917

6.10.4 Compatibility with Other Hurricane Evacuation Related Studies

One other study exists in Rhode Island that directly addresses hurricane evacuation issues for the coastal and near-coastal inland areas. This study uses a different approach to analyze evacuation traffic and does not provide clearance times, but it goes into more depth relative to signal operations and other aspects of traffic control and congestion abatement. Nonetheless, this TDR and the data therein has been developed in full recognition of the other study, and to the extent possible, has attempted to be compatible with it.

The alternate Hurricane evacuation related study, entitled “Hurricane Evacuation Plan Phase 1”, was prepared in 2007 by Vanasse, Hangen Brustlin, Inc. (VHB) for the Rhode Island Department of Transportation. Despite the fact that this study was completed eight years after the VHB, their evacuating population and vehicle numbers were slightly higher than the figures in this report, but their assumptions regarding the number of shadow evacuees (i.e., those evacuees no under specific evacuation orders that elect to do so anyway) were considerably higher (27% versus 15%). Nonetheless, VHB did not have the benefit of a recently completed behavioral analysis, hence their estimates were slightly more numerically conservative than the figures provided in this study. Despite numerous other differences in methodology and assumptions, the results of the two studies supported the same conclusions. There was reasonably good agreement between the two studies on which roadway segments were critical in determining evacuation congestion and clearance times. Furthermore their figures supported this study’s determination that only a few evacuation roadway segments would need to operate at above saturation flow during a hurricane evacuation, and that those overload conditions would only exist for a relatively short period of time. , as well as the assertion that some of the evacuation roadways would only be above saturation flow for a relatively short time. The VHB conclusion at the executive summary states that the expected evacuating population and vehicles could be accommodated in the minimum 12 hour window, and the results of this analysis are in general agreement with that statement.

6.10.5 Estimated Evacuation Clearance Times

The most important product of the transportation analysis is the clearance times developed by storm scenario and by behavioral characteristics for each group of counties. Clearance time is one of two major considerations involved in issuing an evacuation or storm advisory. Clearance time must be weighed with the forecast arrival of sustained tropical storm winds to make a prudent evacuation decision. Figure 6-45 illustrates these two timing issues of evacuation and their relationship to each other.

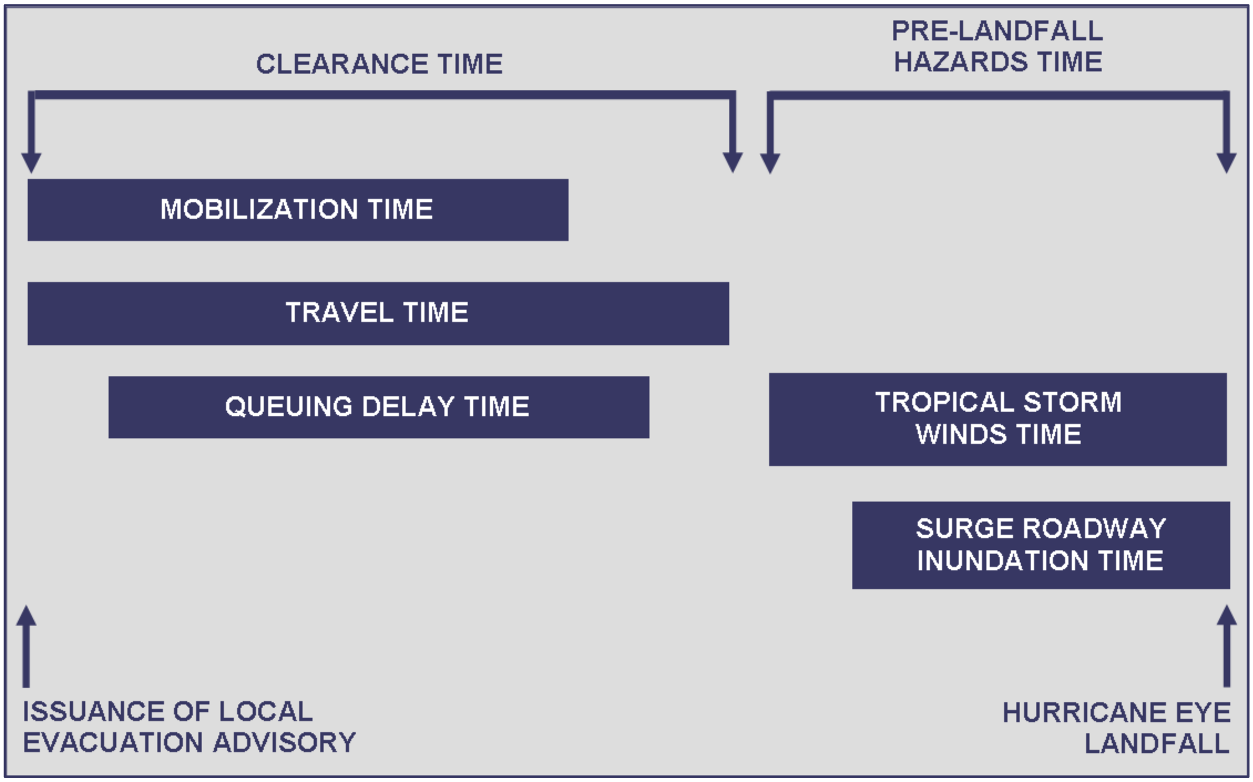

Figure 6-45: Components of Evacuation Timing

Clearance time is the time required to clear the roadway of all vehicles evacuating in response to a hurricane situation. Clearance time begins when the first evacuating vehicle enters the road network and ends when the last evacuating vehicle reaches an assumed point of safety. Clearance time includes the time required by evacuees to secure their homes and prepare to leave (referred to as mobilization time). Clearance time also encompasses the time spent by evacuees traveling along the road network (referred to as travel time), and the time spent by evacuees waiting along the road network due to traffic congestion (referred to as queuing delay time). Clearance time does not relate to the time any one vehicle spends traveling on the road network and does not include time needed for local officials to assemble and make a decision to evacuate.

Clearance times for Rhode Island were calculated by metering expected traffic through each regional and local route focal point location for every response and tourist occupancy scenario. A critical assumption for making these calculations is the hourly vehicular flow rate assumed at each focal point. Rhode Island traffic flow was modeled based on research from actual hurricane evacuations that shows traffic movement is near maximum capacity at the beginning of the evacuation. Then for each quarter of the evacuation thereafter, the service volume is reduced. In the last quarter of the evacuation, the flow rate “recovers” to near capacity. This approach does an excellent job of mirroring what actually happens in most evacuations where the public responds to evacuation advisories and loads the roadway gradually over an approximate eight hour time period (medium response rate). Another important element to recognize in the calculations is the presence of a certain amount of background traffic (non-evacuee) that may be on the road network at the start of the evacuation. These movements may include residents going to stores for supplies or even a work to home movement. Depending on the normal daily congestion in an area, this can add up to a significant increase in time in an area like Rhode Island.

Table 6-25 below details the clearance times for each individual community broken out by slow, medium and fast response times according to response scenarios A, B and C, as well as by low and high tourist occupancy. Although only Providence has a response scenario C in their evacuation plans, those adjoining communities whose clearance times are determined by the same critical links (see Table 6-26) will be impacted during their response scenario B evacuations. Therefore, once they become aware that Providence will evacuate their Scenario C zones, those other communities should substitute the Scenario C times in place of their Scenario B times. Table 6-26 referenced above details which of all the roadway segments labeled as critical links will determine the clearance time for each community in the study area. For many communities these “controlling” roadway segments are outside their jurisdictional control which indicates a need to coordinated operations at these locations to ensure as smooth an evacuation as possible.

The single largest factor influencing clearance times is response scenario (A, B, or C). Even in the most intense hurricanes, times are comfortably below the 24 hour time frame for a low tourist occupancy scenario. Even with the addition of evacuees from other regions and states, these clearance times do no escalate significantly and do not exceed the normal amount of response time allowed by a hurricane warning from the National Hurricane Center.

Table 6-25: Evacuation Clearance Times (in hours)

County	Community	SLOW Response						MEDIUM Response						RAPID Response					
		Scenario A		Scenario B		Scenario C		Scenario A		Scenario B		Scenario C		Scenario A		Scenario B		Scenario C	
		Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.
Bristol County	Barrington	14.6	15.4	17.1	18.1			13.0	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Bristol	14.6	15.4	17.1	18.1			13.0	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Warren	14.6	15.4	17.1	18.1			13.0	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
Kent County	East Greenwich	6.9	7.1	7.2	7.5			5.2	5.5	5.5	5.8			3.4	3.6	3.7	4.0		
	Warwick	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9		
Newport County	Jamestown	6.9	7.1	7.2	7.5			5.2	5.5	5.5	5.8			3.4	3.6	3.7	4.0		
	Little Compton	14.6	15.4	17.1	18.1			13.0	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Middletown	6.9	7.1	7.2	7.5			5.2	5.5	5.5	5.8			3.4	3.6	3.7	4.0		
	Newport	6.9	7.1	7.2	7.5			5.2	5.5	5.5	5.8			3.4	3.6	3.7	4.0		
	Portsmouth	14.6	15.4	17.1	18.1			13.0	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Tiverton	14.6	15.4	17.1	18.1			13.0	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
Providence County	Cranston	7.1	7.3	7.6	7.9	7.6	7.9	5.4	5.6	5.9	6.2	5.9	6.2	3.4	3.7	3.9	4.2	4.0	4.3
	East Providence	4.1	4.1	4.4	4.5			3.2	3.3	3.6	3.7			2.3	2.4	2.7	2.7		
	Pawtucket	3.9	4.1	4.3	4.5			3.0	3.1	3.4	3.5			2.0	2.1	2.3	2.5		
	Providence	7.1	7.3	7.6	7.9	7.6	7.9	5.4	5.6	5.9	6.2	5.9	6.2	3.4	3.7	3.9	4.2	4.0	4.3
Washington County	Charlestown	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9		
	Narragansett	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9		
	New Shoreham	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9		
	North Kingstown	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9		
	South Kingstown	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9		
	Westerly	6.2	6.8	6.8	7.3			4.9	5.4	5.4	6.0			3.4	3.9	3.9	4.5		

Table 6-26: Clearance Time Determining Critical Links

County	Physical Location	Name of Link	Impacted Towns
Bristol	Barrington	County Rd/RI103/114 @ Federal Rd (APY)	Barrington Bristol Warren
Newport	Barrington	County Rd/RI103/114 @ Federal Rd (APY)	Little Compton Portsmouth Tiverton
	Providence	I-95 Northbound at I-195 interchange (ABB)	Jamestown Middletown Newport
Providence	Providence	I-95 Northbound at RI 146 interchange (ABF)	Cranston Providence
	East Providence	I-195 W / US 1 Alt (ADR)	East Providence
	Pawtucket	I-95 Northbound @ Broadway/RI15 interchange (ABN)	Pawtucket
Kent	Providence	I-95 Northbound at I-195 interchange (ABB)	East Greenwich
	Warwick	Post Rd/RI 117 at RI 115 intersection (AWM)	Warwick
Washington	Providence	I-95 Northbound at I-195 interchange (ABB)	Charlestown Narragansett North Kingstown South Kingstown
	Warwick	I-95 Northbound at I-295 split (AAQ)	Westerly

The presentation of multiple clearance times can be confusing; the highest clearance time is the time to be used for decision making. Other times are shown so that local and state officials realize that once a roadway's congestion problem is "solved", the next most congested segment or corridor must be addressed. None of these clearance times factor in the effect of accidents, breakdowns or other exigent circumstances that may occur during an evacuation event. Although slow, medium and rapid scenarios have been included in the clearance time results, none of the figures take into account the adverse impacts of construction on the listed roadways, time of day considerations (middle of the workday or at night) or the additional travel demand created by short duration events (i.e., a well-attended special event in the area).

Additionally, the clearance times provided in both of the above tables are for an evacuation of the general population and not special needs evacuees. The evacuation of assisted or group living facilities and hospitals is driven more by operational constraints associated with the availability of adequate transportation and the time needed to prepare the evacuees, rather than any congestion or limitations to the roadway network. Therefore, no determination was made for the time required to evacuate nursing homes and other population groups with special needs.

Evacuations in this area will be problematic both for decision makers and the public given that in this part of the Atlantic coast, the forward speed of tropical cyclones is usually relatively fast and accelerating due to their proximity to the jet stream. Consequently, depending on the clearance time, the decision to evacuate may have to occur when the storm is still far from the forecast landfall point, well before the weather has begun to deteriorate and the need becomes evident to at-risk populations.

For evacuations to be successful, the public will have to start their movements in earnest, well before the threat is imminent, and at least a portion of the evacuees must be moving at the beginning of the clearance time period. Individual household evacuation commutes will be longer for those leaving in the middle of the evacuation for a major storm event. Evacuations must be started early enough so that movements are complete before the arrival of sustained tropical storm winds. Given the public's relative dearth of hurricane evacuation experience in the New England coastal area, it is likely that many evacuees may attempt to leave very late in the process. The flooding of roads may also force many residents to alter their evacuation plans. All of these factors can have a significant impact on the actual time it takes to clear the roadways in any of the jurisdictions within the region.

6.11 State to State Trips and Clearance Time Impacts

As an additional aid to hurricane and emergency preparedness planners, the transportation model calculated the number of vehicles moving between the states of Connecticut, Rhode Island and Massachusetts. Table 6-27 details the numbers of evacuating vehicles that will cross state lines during each response scenario. Only major highways are included in these tables since they are the corridors that have the most potential to impose enough traffic on their adjoining state roadways and thereby have an effect on clearance times. In addition, only those roadways impacted by evacuations in Providence will have numbers in the response scenario C columns.

Table 6-28 details the impacts on clearance times caused by the infusion of extra-state vehicles on the clearance times provided above in Tables 6-27. For Rhode Island, the exiting vehicles from Connecticut and Massachusetts add considerably less than one hour to the clearance times in any of the state. Finally, to expand upon all the clearance time tables above, Table 6-29 provides the revised clearance times for a multi-state evacuation.

Table 6-27: Interstate Trips by Scenario and Tourist Occupancy

Major In / Out Routes	From / To	Scenario A Low Tourism	Scenario A High Tourism	Scenario B Low Tourism	Scenario B High Tourism	Scenario C High Tourism	Scenario C High Tourism
US 1 NB	**From** Connecticut	3,308	3,799	4,718	5,255		
I-95 NB	**From** Connecticut	3,671	4,517	5,531	6,474		
US 6 EB	**From** Connecticut	2,214	2,650	3,478	3,977		
I-195 SB	**From** Massachusetts	1,430	1,736	2,203	2,684		
US 1 SB	**To** Connecticut	664	1,114	953	1,455		
I-95 SB	**To** Connecticut	665	763	1,305	1,432	1,309	1,436
I-95 NB	**To** Massachusetts	2,306	3,080	4,423	5,322	4,476	5,381
I-195 NB	**To** Massachusetts	154	198	349	403	357	412
RI 24 NB	**To** Massachusetts	1,084	1,420	1,681	2,081	1,084	1,420

Table 6-28: Change to Evacuation Clearance Times (in additional hours)

County	Town	SLOW Response						MEDIUM Response						RAPID Response					
		Scenario A		Scenario B		Scenario C		Scenario A		Scenario B		Scenario C		Scenario A		Scenario B		Scenario C	
		Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.
Bristol County	Barrington	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bristol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Warren	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kent County	East Greenwich	**0.3**	**0.3**	**0.4**	**0.4**	0	0	**0.3**	**0.3**	**0.4**	**0.5**	0	0	**0.3**	**0.4**	**0.4**	**0.5**	0	0
	Warwick	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Newport County	Jamestown	**0.3**	**0.3**	**0.4**	**0.4**	0	0	**0.3**	**0.3**	**0.4**	**0.5**	0	0	**0.3**	**0.4**	**0.4**	**0.5**	0	0
	Little Compton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Middletown	**0.3**	**0.3**	**0.4**	**0.4**	0	0	**0.3**	**0.3**	**0.4**	**0.5**	0	0	**0.3**	**0.4**	**0.4**	**0.5**	0	0
	Newport	**0.3**	**0.3**	**0.4**	**0.4**	0	0	**0.3**	**0.3**	**0.4**	**0.5**	0	0	**0.3**	**0.4**	**0.4**	**0.5**	0	0
	Portsmouth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tiverton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Providence County	Cranston	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.7**	**0.3**	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.4**	**0.4**	**0.5**	**0.6**	**0.5**	**0.6**
	East Providence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pawtucket	**0.2**	**0.2**	**0.3**	**0.2**	**0.3**	**0.3**	**0.2**	**0.2**	**0.3**	**0.3**	**0.4**	**0.4**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**
	Providence	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.7**	**0.3**	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.4**	**0.4**	**0.5**	**0.6**	**0.5**	**0.6**
Washington County	Charlestown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Narragansett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	North Kingstown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	South Kingstown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Westerly	**0.5**	**0.5**	**0.7**	**0.7**	0	0	**0.5**	**0.5**	**0.6**	**0.8**	0	0	**0.6**	**0.6**	**0.7**	**0.8**	0	0

Table 6-29: Multi-State Evacuation Clearance Times (in hours)

County	Town	SLOW Response						MEDIUM Response						RAPID Response					
		Scenario A		Scenario B		Scenario C		Scenario A		Scenario B		Scenario C		Scenario A		Scenario B		Scenario C	
		Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.	Low Tour Occ.	High Tour Occ.
Bristol County	Barrington	14.6	15.4	17.1	18.1			13	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Bristol	14.6	15.4	17.1	18.1			13	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Warren	14.6	15.4	17.1	18.1			13	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
Kent County	East Greenwich *	7.2	7.4	7.6	7.9			5.5	5.8	5.9	6.3			3.7	4	4.1	4.5		
	Warwick	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9		
Newport County	Jamestown *	7.2	7.4	7.6	7.9			5.5	5.8	5.9	6.3			3.7	4	4.1	4.5		
	Little Compton	14.6	15.4	17.1	18.1			13	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Middletown *	7.2	7.4	7.6	7.9			5.5	5.8	5.9	6.3			3.7	4	4.1	4.5		
	Newport *	7.2	7.4	7.6	7.9			5.5	5.8	5.9	6.3			3.7	4	4.1	4.5		
	Portsmouth	14.6	15.4	17.1	18.1			13	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
	Tiverton	14.6	15.4	17.1	18.1			13	13.8	15.5	16.4			11.6	12.5	14.2	15.2		
Providence County	Cranston *	7.5	7.7	8.1	8.4	8.2	8.6	5.7	6	6.3	6.7	6.4	6.8	3.8	4.1	4.4	4.8	4.5	4.9
	East Providence	4.1	4.1	4.4	4.5			3.2	3.3	3.6	3.7			2.3	2.4	2.7	2.7		
	Pawtucket *	4.1	4.3	4.6	4.7	4.6	4.8	3.2	3.3	3.6	3.8	3.7	3.9	2.2	2.3	2.6	2.8	2.7	2.9
	Providence *	7.5	7.7	8.1	8.4	8.2	8.6	5.7	6	6.3	6.7	6.4	6.8	3.8	4.1	4.4	4.8	4.5	4.9
Washington County	Charlestown	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9	8.9	9.1
	Narragansett	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9	8.9	9.1
	North Kingstown	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9	8.9	9.1
	South Kingstown	8.9	9.1	9.3	9.4			7.2	7.4	7.5	7.7			5.3	5.5	5.7	5.9	8.9	9.1
	Westerly *	6.9	7.4	7.6	8.2			5.5	6	6.2	6.9			4.1	4.6	4.8	5.5	6.9	7.4

* When evacuating with simultaneous evacuations in Connecticut and New York.

6.12 Traffic Control Measures

Most residents in Rhode Island, especially near Providence, are aware of the long traffic jams that occur during every day commutes. Officials from local jurisdictions must manage traffic flow along major routes. Emergency tow trucks should be in position to remove broken down vehicles blocking travel. Roadway maintenance and minor construction blockages must be cleared to allow for evacuee traffic. To lessen the amount of background traffic, officials at the highest levels must discourage home to work and school related movements on the day of an evacuation.

Rhode Island is fortunate to have an extensive transportation network that is further enhanced by a robust Intelligent Transportation System (ITS) framework. Real time traveler information systems such as the relatively dense network of web-based traffic cameras and other programs are not only useful for the users of the roadway network, but also the traffic managers and emergency management officials, especially during hurricane evacuation operations. As mentioned earlier, since these clearance times do not factor in the impacts of any incidents, it is of paramount importance that any temporary impediments to traffic flow are resolved quickly and efficiently, especially at those locations specified in Table 6-26. All measures should be undertaken to be able to continuously monitor the flow of traffic at these locations and insure that incident management teams are pre-positioned nearby to handle any exigent circumstances. These locations in Tables 6-25 and 6-26 should all have traffic cameras, or real-time traffic counters (preferably measuring vehicle counts and average speed), or other remote sensing capabilities, permanently emplaced with a means of getting the observations into the state and local Emergency Operations Centers (EOCs) and dispatch centers as they are collected.

Below are some general observations and recommendations concerning evacuations:

- Almost all of the critical links identified in Table 6-26 abut, or are inside storm tide inundation/evacuation zones. This increases the likelihood that vehicles could be stranded in hazardous areas if not allowed to clear that bottleneck before the arrival of tropical storm force winds. Law enforcement assets in addition to ITS measures must be emplaced at these locations during evacuations to ensure continuous monitoring and efficient emergency response of these locations.
- In the behavioral analysis included in this report, it says, "One way of looking at the numbers would be to say that there was under-response in [Scenario] Zone A in all three scenarios [Category 2, 3 and 4]; over-response in [Scenario] Zone B in the Category 2 scenario but under-response in the other two [Category 3 and 4]; and over-response in the non-surge area in all three scenarios." Given the high percentages of inland

residents who indicated that they would evacuate in the 2013 Behavioral Analysis commissioned by the USACE, it is imperative that public information before and during the disaster specifically address who should not evacuate, as well as who should. Indications are these inland residents who are electing to leave their homes may be the largest component of the evacuating population in many jurisdictions, regardless of storm intensity. During Hurricane Floyd in 1999, many of the southeastern states learned from experience, that it is as important for local officials to clearly specify who is not ordered to evacuate, rather than concentrating solely on those who should.

- Where the state and communities have sufficient personnel resources, officers should be stationed at critical intersections to facilitate traffic flow, especially those identified in Table 6-26 if not all of those in 6-23 and 6-24. Where intersections will continue to have signalized control, signal patterns should provide the most “green time” for the roadways identified and mapped as evacuation routes in this study.
- If possible, arrangements should be made with tow truck operators so that they are prepositioned along key travel corridors and critical roadway facilities such as bridges.
- High level bridges need to be monitored for the early arrival of sustained tropical storm winds. High profile vehicles such as recreational vehicles (RVs), trucks and buses could be adversely affected before the evacuation at ground level is completed or terminated.
- Coordinate with Providence and Worcester Railroad to coordinate train schedules for the spur that runs south to north through Pawtucket and East Providence from Phillipsdale to the Valley Falls. That spur crosses six evacuation roadway segments including: RI 114 / Pawtucket Ave (BVE); RI 15 / Armistice Blvd (AZF); Central Ave (BWL); Roosevelt Ave (BWM); US 1 / Broadway (AIR); and Fountain St/ Roosevelt Ave (BWO). Although none of these segments are considered critical according to the tables above, trains impacting these evacuation routes way have cascading effects that can propagate to other more vital roadway corridors or segments.
- State and local officials need to develop strategies to encourage the evacuating public, especially permanent residents, to use alternate routes where possible and to forsake the more obvious ones.
- Officials must identify and develop staffing/supply plans for the area’s public shelters and refuges of last resort.
- The area must further develop consistent communications protocols and compatible hardware to communicate across state and local jurisdictions. It will be imperative for inland counties to know what level of evacuation may be coming their way and when it will start. Emergency management, traffic control officers, and shelter providers need to be tied together in whatever communications network is established.

6.13 Report Summary

Fortunately, Rhode Island maintains a well-developed transportation system that provides a great deal of capacity during hurricane evacuations relative to evacuation demand. Most communities in the Rhode Island study region are on the immediate periphery of Providence. Consequently, the roadway network developed for daily commuting lends itself well to providing evacuation corridors for nearby coastal residents.

Despite the potential for a hurricane to require the evacuation of many residents from communities around Narragansett Bay, the network is generally able to accommodate the demand. The clearance times provided in this report, are within reasonable limits when compared with other areas around the country, especially when considering that even for a Zone C scenario can easily be completed within the alert time provided by the posting of a Hurricane Warning by the National Hurricane Center.

That being said, any exigent circumstances on the evacuation roadway network could dramatically increase the time needed to clear the transportation system of all vehicles using it to flee the storm. During the approach of a hurricane, any failure in the traffic management system to facilitate flow through any of the critical links identified in this report could increase the above clearance times significantly. Additionally, such uncontrollable factors as accidents, poor driving and roadway conditions and even the time of day an evacuation order is issued can serve to exacerbate the situation and inflate the timeframes provided in this report.

Differences between a hurricane’s actual approach and its forecast with respect to intensity, track, size, or storm characteristics can significantly compress the amount of time communities have to implement appropriate protective actions. This time compression can easily become a factor at these higher latitudes where the jet stream can pick up storms and propel them forward at very high speeds. Consequently, the proximity of some of the above identified critical links on the regional evacuation network to the coastline and surge vulnerable zones could easily result in vehicles queues extending back into the hazard areas, thereby trapping evacuees in harm’s way.

Hurricane evacuation planning issues should also include: identifying viable shelter facilities between the coast and the critical links provided in this study to intercept those evacuating vehicles before they reach those most congested roadway segments; preparing public information to better inform not only who should evacuate, but also who should not; and any measures to encourage evacuees to use less obvious and alternative routes away from the coast. In implementing the above measures, it is hoped that the information contained in this report will serve to increase the margin of safety for the residents and visitors of Rhode Island

and enhance the degree of comfort that local officials will need in implementing the necessary protective actions for any hurricane threat.