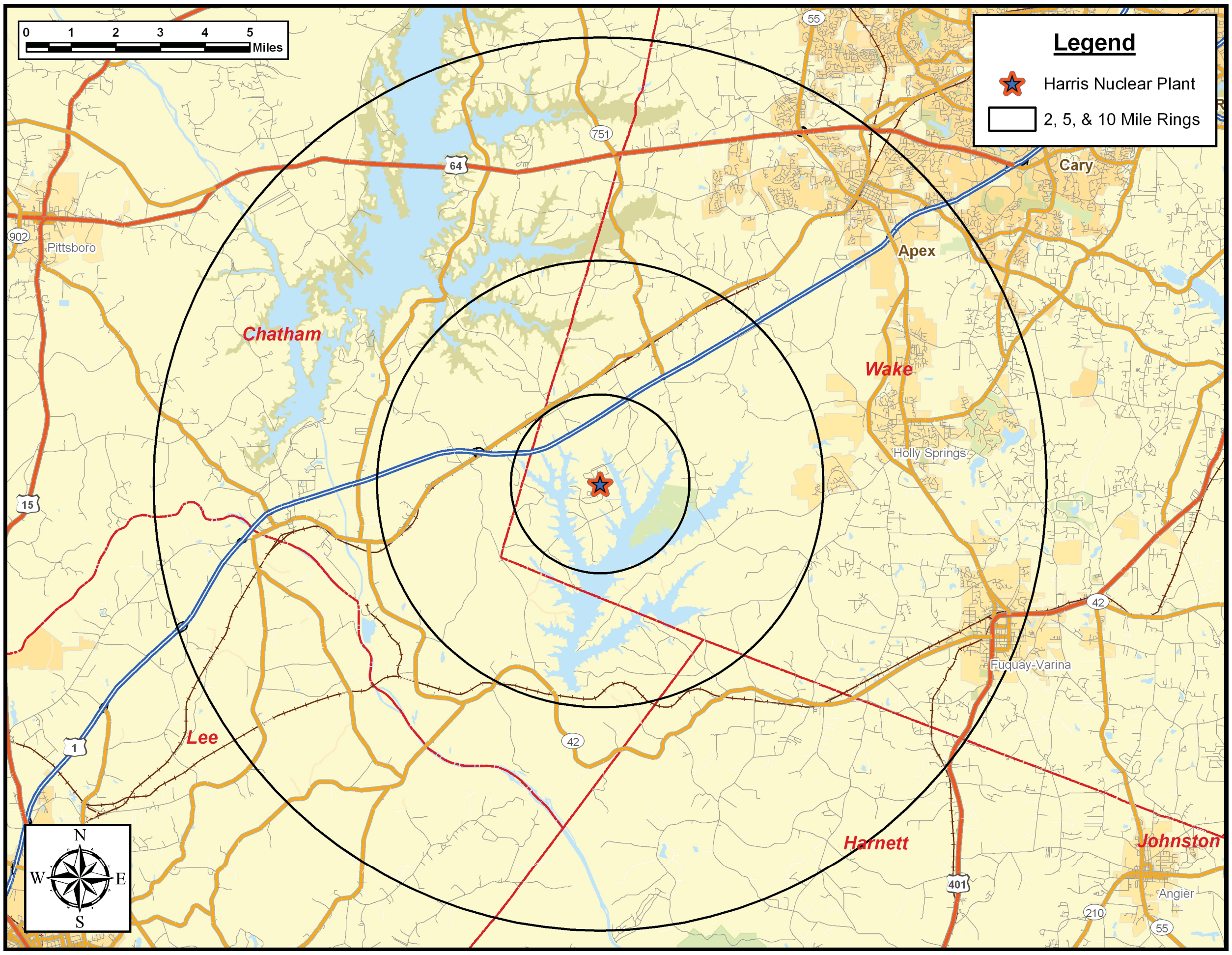
Harris Nuclear Plant

Development of Evacuation Time Estimates



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EXECUTIVE SUMMARY

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Harris Nuclear Plant (HNP) located in New Hill, North Carolina. ETE are part of the required planning basis and provide HNP and State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, all available prior documentation relevant to ETE was reviewed. Other guidance is provided by documents published by Federal Government agencies. Most important of these are:

- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG 0654/FEMA-REP-1, Rev. 1, November 1980.
- Analysis of Techniques for Estimating Evacuation Times for Emergency Planning Zones, NUREG/CR-1745, November 1980.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

Overview of Project Activities

This project began in December, 2006 and extended over a period of 6 months. The major activities performed are briefly described in chronological sequence:

- Attended "kick-off" meetings with Progress Energy personnel and emergency management personnel representing state and local governments.
- Reviewed prior ETE reports prepared for HNP and accessed U.S. Census Bureau data files for the year 2000. Studied Geographical Information Systems (GIS) maps of the area in the vicinity of HNP, then conducted a detailed field survey of the highway network.
- Synthesized this information to create an analysis network representing the highway system topology and capacities within the Emergency Planning Zone (EPZ), plus a Shadow Region extending 15 miles radially from the plant.
- Designed and sponsored a telephone survey of residents within the EPZ to gather focused data needed for this ETE study that were not contained within the census database. The survey instrument was reviewed and modified by State and county personnel prior to the survey.
- Received GIS files from the Wake County Office of Emergency Management providing data on employment, traffic control points, and the locations of special facilities. Data collection forms (provided to the counties at the kickoff meeting) were returned with data pertaining to employment, transients, and special facilities in each county.

- The traffic demand and trip-generation rates of evacuating vehicles were estimated from the gathered data. The trip generation rates reflected the estimated mobilization time (i.e., the time required by evacuees to prepare for the evacuation trip) computed using the results of the telephone survey of EPZ residents.
- Following Federal guidelines, the EPZ is subdivided into 14 sub-zones. These sub-zones are then grouped within circular areas or “keyhole” configurations (circles plus radial sectors) that define a total of 25 Evacuation Regions.
- The time-varying external circumstances are represented as Evacuation Scenarios, each described in terms of the following factors: (1) Season (Summer, Winter); (2) Day of Week (Midweek, Weekend); (3) Time of Day (Midday, Evening); and (4) Weather (Good, Rain, Ice). One special scenario involving construction of a new unit at the HNP site was considered.
- The Planning Basis for the calculation of ETE is:
  - A rapidly escalating accident at HNP that quickly assumes the status of General Emergency such that the Advisory to Evacuate is virtually coincident with the siren alert.
  - While an unlikely accident scenario, this planning basis will yield ETE, measured as the elapsed time from the Advisory to Evacuate until the last vehicle exits the impacted Region, that represent “upper bound” estimates. This conservative Planning Basis is applicable for all initiating events.
- If the emergency occurs while schools are in session, the ETE study assumes that the children will be evacuated by bus directly to specified host schools located outside the EPZ. Parents, relatives, and neighbors are advised to not pick up their children at school prior to the arrival of the buses dispatched for that purpose. The ETE for school children are calculated separately.
- Evacuees who do not have access to a private vehicle will either ride-share with relatives, friends or neighbors, or be evacuated by buses provided as specified in the county evacuation plans. Those in special facilities will likewise be evacuated with public transit, as needed: bus, van, or ambulance, as required. Separate ETE are calculated for the transit-dependent evacuees and for those evacuated from special facilities.

<u>Computation of ETE</u>

A total of 300 ETE were computed for the evacuation of the general public. Each ETE quantifies the aggregate evacuation time estimated for the population within one of the 25 Evacuation Regions to completely evacuate from that Region, under the circumstances defined for one of the 12 Evacuation Scenarios (25 x 12 = 300). Separate ETE are calculated for transit-dependent evacuees, including school children for applicable scenarios.

Except for Region R03, which is the evacuation of the entire EPZ, only a portion of the people within the EPZ would be advised to evacuate. That is, the Advisory to Evacuate applies only to those people occupying the specified impacted region. It is assumed that 100 percent of the people within the impacted region will evacuate in response to this Advisory. The people occupying the remainder of the EPZ outside the impacted region may be advised to take shelter.

The computation of ETE assumes that a portion of the population within the EPZ but outside the impacted Region, will elect to “voluntarily” evacuate. In addition, a portion of the population in the Shadow Region will also elect to evacuate. These voluntary evacuees could impede those who are evacuating from within the impacted region. The impedance that could be caused by voluntary evacuees is considered in the computation of ETE for the impacted region.

The computational procedure is outlined as follows:

- A link-node representation of the highway network is coded. Each link represents a unidirectional length of highway; each node usually represents an intersection or merge point. The capacity of each link is estimated based on the field survey observations and on established procedures.
- The evacuation trips are generated at locations called “zonal centroids” located within the EPZ. The trip generation rates vary over time reflecting the mobilization process, and from one location (centroid) to another depending on population density and on whether a centroid is within, or outside, the impacted area.
- The computer models compute the routing patterns for evacuating vehicles that are compliant with federal guidelines (outbound relative to the location of HNP), then simulate the traffic flow movements over space and time. This simulation process estimates the rate that traffic flow exits the impacted region.
- The ETE statistics provide the elapsed times for 50 percent, 90 percent, 95 percent and 100 percent, respectively, of the population within the impacted region, to evacuate from within the impacted region. These statistics are presented in tabular and graphical formats.

Traffic Management

This study includes the development of a comprehensive traffic management plan designed to expedite the evacuation of people from within an impacted region. This plan, which was reviewed with State and local law enforcement personnel, is also designed to control access into the EPZ after returning commuters have rejoined their families.

The plan is documented in the form of detailed schematics specifying: (1) the directions of evacuation travel to be facilitated, and other traffic movements to be discouraged; (2) the traffic control personnel and equipment needed (cones, barricades) and their deployment; (3) the locations of these "Traffic Control Points" (TCP); (4) the priority assigned to each traffic control point indicating its relative importance and how soon it should be manned relative to others; and (5) the number of traffic control personnel required.

Selected Results

A compilation of selected information is presented on the following pages in the form of Figures and Tables extracted from the body of the report; these are described below.

- Figure 3-1 displays a map of the HNP site showing the layout of the 14 sub-zones that comprise, in aggregate, the EPZ.
- Table 3-1 presents the estimates of permanent resident population in each sub-zone based on the 2000 Census data. Extrapolation to the year 2007 reflects population growth rates in each county derived from Census data.
- Table 6-1 defines each of the 25 Evacuation Regions in terms of their respective groups of sub-zones.
- Table 6-2 lists the 12 Evacuation Scenarios.
- Tables 7-1C and 7-1D are compilations of ETE. These data are the times needed to *clear the indicated regions* of 95 and 100 percent of the population occupying these regions, respectively. These computed ETE include consideration of mobilization time and of estimated voluntary evacuations from other regions within the EPZ and from the Shadow Region.
- Table 8-5A presents ETE for the schoolchildren in good weather.
- Table 8-7A presents ETE for the transit-dependent population in good weather.
- Table 8-8A presents ETE for ambulatory patients at medical facilities in good weather.

Conclusion

This report presents the methodological details supporting the results obtained and recommendations for consideration by local emergency responders.

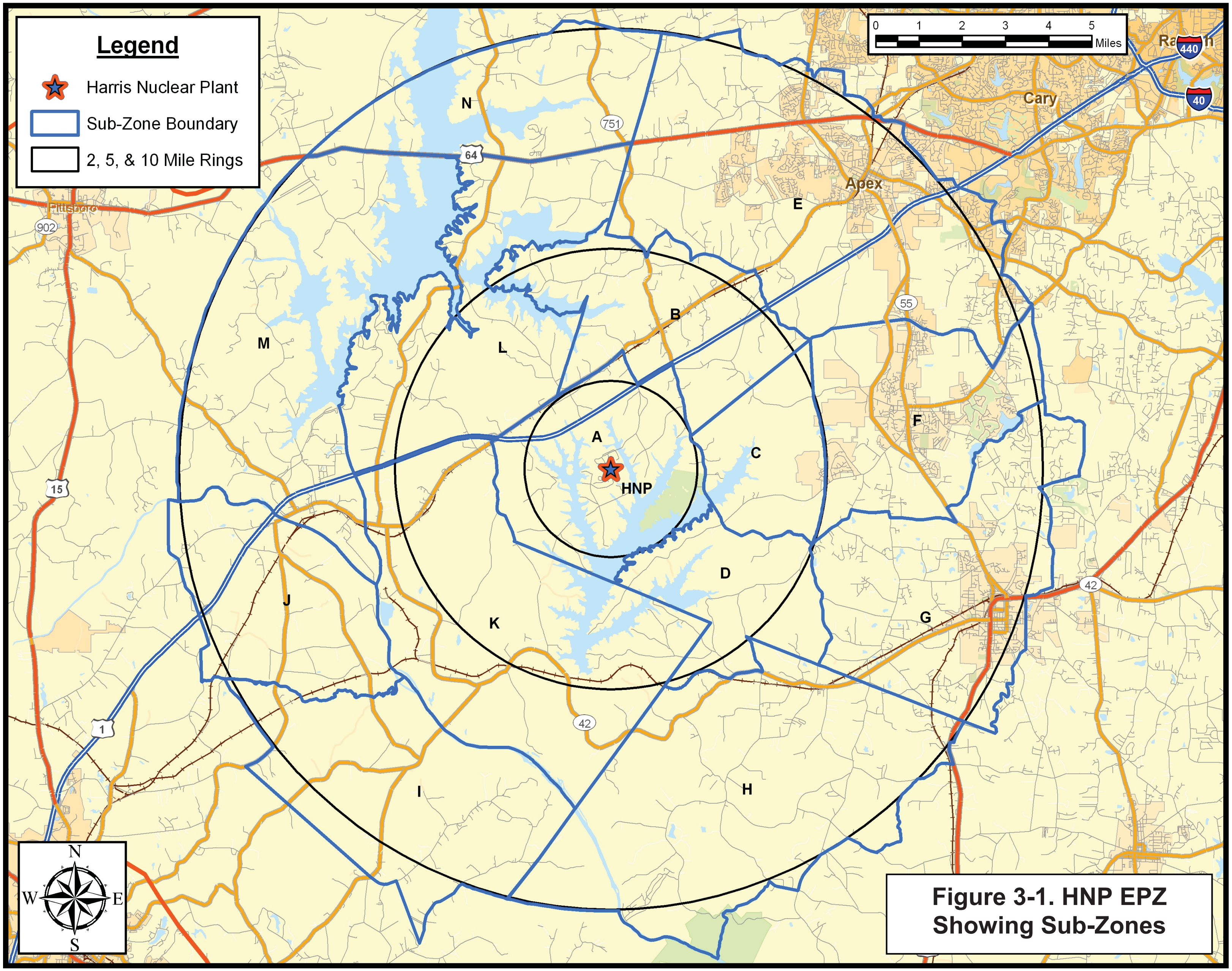

Figure 3-1. HNP EPZ Showing Sub-Zones

Table 3-1. EPZ Permanent Resident Population		
Sub-Zone	**2000 Population**	**2007 Population**
A	143	180
B	1,113	1,397
C	331	416
D	258	319
E	26,146	32,879
F	10,764	13,534
G	12,324	15,497
H	2,906	3,444
I	804	947
J	1,145	1,348
K	619	763
L	708	874
M	1,440	1,778
N	584	721
TOTAL	**59,285**	**74,097**
	Population Growth:	**25.0%**

Table 6-1. Description of Evacuation Regions															
Region	**Description**	**Sub-Zone**													
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R01	2 mile ring	■													
R02	5-mile ring	■	■	■	■							■	■		
R03	Full EPZ	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Evacuate 2-mile ring and 5 miles downwind															
Region	**Wind Direction Towards:**	**Sub-Zone**													
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R04	N,NW,NNW	■	■										■		
R05	NNE	■	■												
R06	NE,ENE	■	■	■											
R07	E	■	■	■	■										
R08	ESE	■		■	■										
R09	SE	■		■	■							■			
R10	SSE,S	■			■							■			
R11	SSW, SW	■										■			
R12	WSW,W,WNW	■										■	■		
Evacuate 5-mile ring and downwind to EPZ boundary															
Region	**Wind Direction Towards:**	**Sub-Zone**													
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R13	N,NNE	■	■	■	■	■						■	■		■
R14	NE	■	■	■	■	■	■					■	■		
R15	ENE, E	■	■	■	■	■	■	■				■	■		
R16	ESE	■	■	■	■		■	■	■			■	■		
R17	SE	■	■	■	■			■	■			■	■		
R18	SSE	■	■	■	■			■	■	■		■	■		
R19	S	■	■	■	■				■	■		■	■		
R20	SSW	■	■	■	■				■	■	■	■	■		
R21	SW	■	■	■	■					■	■	■	■		
R22	WSW	■	■	■	■					■	■	■	■	■	
R23	W,WNW	■	■	■	■						■	■	■	■	
R24	NW	■	■	■	■							■	■	■	■
R25	NNW	■	■	■	■	■						■	■	■	■

Table 6-2. Evacuation Scenario Definitions

Scenario	Season	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	Ice	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Midweek, Weekend	Evening	Good	None
12	Summer	Midweek	Midday	Good	New Plant Construction

Table 7-1C. Time to Clear the Indicated Area of 95 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
Region Wind Toward:	Midday		Midday		Evening	Region Wind Toward:	Midday			Midday		Evening	Region Wind Toward:	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather		Good Weather	Rain	Ice	Good Weather	Rain	Good Weather		New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	2:10	2:10	1:55	1:55	2:25	R01 2-mile ring	2:10	2:10	2:10	1:55	1:55	2:30	R01 2-mile ring	2:45
R02 5-mile ring	2:20	2:20	2:40	2:55	2:00	R02 5-mile ring	2:25	2:25	2:25	1:55	1:55	2:00	R02 5-mile ring	2:50
R03 Entire EPZ	2:55	3:00	2:30	2:40	2:30	R03 Entire EPZ	3:00	3:05	3:15	2:25	2:35	2:30	R03 Entire EPZ	3:25
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	2:15	2:15	2:45	2:55	1:55	R04 N, NW, NNW	2:20	2:20	2:20	1:50	1:55	1:55	R04 N, NW, NNW	2:50
R05 NNE	2:25	2:25	1:55	1:55	2:00	R05 NNE	2:25	2:25	2:25	1:55	1:55	2:00	R05 NNE	2:45
R06 NE, ENE	2:30	2:30	1:55	1:55	2:00	R06 NE, ENE	2:30	2:30	2:30	1:55	1:55	2:00	R06 NE, ENE	2:45
R07 E	2:30	2:30	1:55	1:55	2:10	R07 E	2:30	2:35	2:35	2:00	2:00	2:10	R07 E	2:45
R08 ESE	2:45	2:45	2:05	2:05	2:25	R08 ESE	2:45	2:50	2:50	2:15	2:15	2:25	R08 ESE	2:40
R09 SE	2:20	2:20	1:50	1:50	2:05	R09 SE	2:20	2:20	2:20	1:50	1:55	2:05	R09 SE	2:40
R10 SSE, S	2:10	2:15	1:50	1:50	2:00	R10 SSE, S	2:15	2:15	2:15	1:50	1:50	2:00	R10 SSE, S	2:40
R11 SSW, SW	2:05	2:05	1:50	1:50	1:55	R11 SSW, SW	2:05	2:05	2:05	1:50	1:50	1:55	R11 SSW, SW	2:40
R12 WSW, W, WNW	2:15	2:20	2:45	3:00	2:00	R12 WSW, W, WNW	2:25	2:25	2:25	1:50	1:50	2:05	R12 WSW, W, WNW	2:40
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	2:55	2:55	2:35	2:40	2:25	R13 N, NNE	2:55	2:55	3:00	2:25	2:25	2:30	R13 N, NNE	3:10
R14 NE	2:55	3:00	2:35	2:40	2:30	R14 NE	2:55	3:00	3:15	2:25	2:35	2:30	R14 NE	3:25
R15 ENE, E	2:55	3:00	2:35	2:40	2:30	R15 ENE, E	2:55	3:00	3:15	2:25	2:35	2:30	R15 ENE, E	3:25
R16 ESE	2:55	2:55	2:35	2:45	2:25	R16 ESE	2:55	3:00	3:10	2:25	2:30	2:25	R16 ESE	3:20
R17 SE	2:50	2:55	2:35	2:45	2:25	R17 SE	2:55	3:00	3:10	2:20	2:30	2:25	R17 SE	3:15
R18 SSE	2:50	2:55	2:35	2:45	2:25	R18 SSE	2:55	3:00	3:10	2:20	2:30	2:25	R18 SSE	3:15
R19 S	2:40	2:40	2:35	2:45	2:15	R19 S	2:45	2:45	2:45	2:05	2:05	2:15	R19 S	2:55
R20 SSW	2:40	2:45	2:35	2:45	2:15	R20 SSW	2:45	2:45	2:45	2:05	2:05	2:20	R20 SSW	2:55
R21 SW	2:30	2:35	2:35	2:45	2:10	R21 SW	2:35	2:35	2:35	2:00	2:00	2:10	R21 SW	2:55
R22 WSW	2:30	2:35	2:35	2:45	2:10	R22 WSW	2:40	2:40	2:40	2:00	2:00	2:10	R22 WSW	2:55
R23 W, WNW	2:30	2:30	2:35	2:45	2:05	R23 W, WNW	2:35	2:35	2:35	2:00	2:00	2:10	R23 W, WNW	2:55
R24 NW	2:25	2:25	2:35	2:45	2:05	R24 NW	2:30	2:30	2:35	1:55	1:55	2:05	R24 NW	2:50
R25 NNW	2:55	2:55	2:30	2:35	2:25	R25 NNW	2:55	2:55	3:00	2:20	2:25	2:25	R25 NNW	3:10

Table 7-1D. Time to Clear the Indicated Area of 100 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
	Midday		Midday		Evening		Midday			Midday		Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Ice	Good Weather	Rain	Good Weather	Region Wind Toward:	New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	4:00	4:00	3:00	3:00	3:00	R01 2-mile ring	4:00	4:00	4:00	3:00	3:00	3:00	R01 2-mile ring	4:00
R02 5-mile ring	4:05	4:05	3:10	3:20	3:05	R02 5-mile ring	4:05	4:05	4:05	3:10	3:10	3:05	R02 5-mile ring	4:10
R03 Entire EPZ	4:10	4:10	4:05	4:05	4:05	R03 Entire EPZ	4:10	4:10	4:10	4:05	4:05	4:00	R03 Entire EPZ	4:15
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	4:05	4:05	3:05	3:20	3:05	R04 N, NW, NNW	4:05	4:05	4:05	3:05	3:05	3:05	R04 N, NW, NNW	4:05
R05 NNE	4:00	4:05	3:00	3:00	3:00	R05 NNE	4:00	4:05	4:05	3:00	3:00	3:00	R05 NNE	4:00
R06 NE, ENE	4:00	4:05	3:00	3:00	3:00	R06 NE, ENE	4:00	4:05	4:05	3:00	3:00	3:00	R06 NE, ENE	4:00
R07 E	4:00	4:05	3:00	3:05	3:00	R07 E	4:00	4:05	4:05	3:00	3:05	3:00	R07 E	4:00
R08 ESE	4:00	4:00	3:00	3:05	3:00	R08 ESE	4:00	4:00	4:00	3:00	3:05	3:00	R08 ESE	4:00
R09 SE	4:00	4:00	3:00	3:05	3:00	R09 SE	4:00	4:05	4:05	3:00	3:05	3:00	R09 SE	4:00
R10 SSE, S	4:00	4:00	3:05	3:05	3:00	R10 SSE, S	4:00	4:05	4:05	3:05	3:05	3:00	R10 SSE, S	4:00
R11 SSW, SW	4:00	4:00	3:05	3:05	3:00	R11 SSW, SW	4:00	4:00	4:00	3:05	3:05	3:00	R11 SSW, SW	4:00
R12 WSW, W, WNW	4:00	4:05	3:10	3:20	3:05	R12 WSW, W, WNW	4:05	4:05	4:05	3:10	3:10	3:05	R12 WSW, W, WNW	4:05
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	4:05	4:05	4:00	4:00	4:00	R13 N, NNE	4:05	4:05	4:10	4:00	4:00	4:00	R13 N, NNE	4:10
R14 NE	4:05	4:05	4:00	4:00	4:00	R14 NE	4:05	4:05	4:10	4:00	4:00	4:00	R14 NE	4:10
R15 ENE, E	4:05	4:05	4:05	4:05	4:05	R15 ENE, E	4:05	4:05	4:10	4:00	4:00	4:00	R15 ENE, E	4:10
R16 ESE	4:10	4:10	4:05	4:05	4:05	R16 ESE	4:10	4:10	4:10	4:05	4:05	4:00	R16 ESE	4:10
R17 SE	4:10	4:10	4:05	4:05	4:00	R17 SE	4:10	4:10	4:10	4:00	4:00	4:00	R17 SE	4:10
R18 SSE	4:10	4:10	4:05	4:05	4:00	R18 SSE	4:10	4:10	4:10	4:00	4:00	4:00	R18 SSE	4:10
R19 S	4:10	4:10	3:50	3:50	3:50	R19 S	4:10	4:10	4:10	3:50	3:50	3:50	R19 S	4:10
R20 SSW	4:10	4:10	3:50	3:50	3:50	R20 SSW	4:10	4:10	4:10	3:50	3:50	3:50	R20 SSW	4:10
R21 SW	4:05	4:05	3:05	3:20	3:05	R21 SW	4:05	4:05	4:10	3:10	3:10	3:05	R21 SW	4:10
R22 WSW	4:05	4:10	3:10	3:25	3:05	R22 WSW	4:05	4:05	4:10	3:10	3:10	3:05	R22 WSW	4:10
R23 W, WNW	4:05	4:10	3:10	3:25	3:05	R23 W, WNW	4:05	4:05	4:10	3:10	3:10	3:05	R23 W, WNW	4:10
R24 NW	4:05	4:10	3:50	3:50	3:05	R24 NW	4:05	4:05	4:10	3:50	3:50	3:05	R24 NW	4:10
R25 NNW	4:05	4:10	4:00	4:00	4:00	R25 NNW	4:05	4:05	4:10	4:00	4:00	4:00	R25 NNW	4:10

Table 8-5A. School Evacuation Time Estimates - Good Weather									
School	**Driver Mobilization Time(min)**	**Loading Time (min)**	**Dist. to EPZ Boundary (mi.)**	**Average Speed* (mph)**	**Travel Time to EPZ Bdry (min)**	**ETE (hr:min)**	**Dist. EPZ Bndry to R.C. (mi.)**	**Travel Time EPZ Bdry to RC (min)**	**ETE to R.C. (hr:min)**
Wake County Schools									
Apex Elementary School	90	5	3.23	5.47	36	**2:15**	15.1	23	**2:35**
Apex High School	90	5	1.13	45.00	2	**1:40**	16.4	25	**2:05**
Apex Middle School	90	5	2.89	6.97	25	**2:00**	18.3	28	**2:30**
Baucom Elementary School	90	5	2.66	12.68	13	**1:50**	19.6	30	**2:20**
Community Partners Charter High School	90	5	6.12	8.55	43	**2:20**	13.7	21	**2:40**
Fuquay-Varina High School	90	5	1.44	9.80	9	**1:45**	5.9	9	**1:55**
Fuquay-Varina Middle School	90	5	1.30	35.81	3	**1:40**	28.6	43	**2:25**
Holly Grove Elementary School	90	5	7.24	11.68	38	**2:15**	25.1	38	**2:55**
Holly Ridge Elementary School	90	5	4.26	9.36	28	**2:05**	25.1	38	**2:45**
Holly Ridge Middle School	90	5	4.26	9.36	28	**2:05**	25.1	38	**2:45**
Holly Springs Elementary School	90	5	4.83	8.53	34	**2:10**	25.1	38	**2:50**
Holly Springs High School	90	5	7.24	11.68	38	**2:15**	25.1	38	**2:55**
Hope Montessori	90	5	0.43	40.23	1	**1:40**	16.4	25	**2:05**
Lincoln Heights Elementary School	90	5	2.02	4.99	25	**2:00**	28.6	43	**2:45**
Lufkin Rd Middle School	90	5	0.70	14.85	3	**1:40**	18.3	28	**2:10**
Olive Chapel Elementary School	90	5	4.55	19.25	15	**1:50**	19.6	30	**2:20**
Salem Elementary School	90	5	0.43	40.23	1	**1:40**	19.6	30	**2:10**
Salem Middle School	90	5	0.43	40.23	1	**1:40**	19.6	30	**2:10**
Southern Wake Montessori School	90	5	5.74	9.79	36	**2:15**	25.1	38	**2:50**
St. Mary Magdalene Catholic School	90	5	4.21	6.84	37	**2:15**	10.6	16	**2:30**
The New School Montessori Center	90	5	3.72	13.69	17	**1:55**	13.7	21	**2:15**
Chatham County Schools									
Moncure Elementary School	90	5	5.06	45.00	7	**1:45**	14.3	22	**2:05**
					Maximum for EPZ:	**2:20**		**Maximum:**	**2:55**

*The average speed for each bus route is output by DYNEV. North Carolina State Law governs bus speeds to 45 mph. If the speed output by DYNEV exceeds 45 mph, the speed is adjusted downward to 45 mph. The route travel time and the resultant ETE are computed using the adjusted average speed, where applicable.

Table 8-7A. Transit Dependent Evacuation Time Estimates - Good Weather														
		Single Wave						Second Wave						
Route Number	**Bus Number**	**Mobilization (min)**	**Route Length (mi.)**	**Average Speed* (mph)**	**Route Travel Time (min)**	**Pickup Time (min)**	**ETE**	**Travel Time to Rec. Ctr (min)**	**Unload (min)**	**Driver Rest (min)**	**Return time to EPZ (min)**	**Route Travel Time (min)**	**Pickup Time (min)**	**ETE**
1	1	90	7.23	45.00	10	10	1:50	**Second Wave is Not Needed**						
2	1	90	6.76	13.45	30	10	2:10	**Second Wave is Not Needed**						
	2	105	6.76	13.80	29	10	2:25							
3	1	90	7.59	45.00	10	10	1:50	**Second Wave is Not Needed**						
4	1	90	13.00	17.21	45	10	2:25	25	5	10	20	19	10	3:55
	2	105	13.00	16.68	47	10	2:45	25	5	10	20	19	10	4:15
5	1	90	12.02	18.43	39	10	2:20	30	5	10	25	18	10	4:00
6	1	90	5.38	35.88	9	10	1:50	25	5	10	20	10	10	3:10
Maximum ETE for Single Wave:							**2:45**	**Maximum ETE for Second Wave:**						**4:15**

*The average speed for each bus route is output by DYNEV. North Carolina State Law governs bus speeds to 45 mph. If the speed output by DYNEV exceeds 45 mph, the speed is adjusted downward to 45 mph. The route travel time and the resultant ETE are computed using the adjusted average speed, where applicable.

Table 8-8A. Evacuation Time Estimates for Ambulatory Patients at Medical Facilities - Good Weather							
Facility Name	**Number of Ambulatory Patients**	**Driver Mobilization Time(min)**	**Loading Time (min)**	**Route Length (mi.)**	**Average Speed (mph)**	**Travel Time (min)**	**ETE (hr:min)**
Wake County Medical Facilities							
Brown's Family Care Home	5	90	5	8.72	30.27	17	**1:55**
James Rest Home	32	90	32	8.72	30.25	17	**2:20**
Buck Jones Road Home	3	90	15	5.50	10.99	30	**2:20**
Mason Street Home	6						
Seagroves Family Home	6						
Rex Rehab & Nursing Care	38	90	38	2.33	8.28	17	**2:25**
Spring Arbor of Apex	59	90	59	3.11	17.90	10	**2:40**
Atwater Rest Home	30	90	30	2.96	42.58	4	**2:05**
Adams Care Home	3	90	11	12.44	17.17	43	**2:25**
Harrison Home	2						
VOCA Olive Home	6						
Autumn Green Adult Care Home	3	90	17	8.48	26.52	19	**2:10**
Avent Ferry House	6						
Country Lane Group Home	6						
Herbert Reid Home	2						
Hickory Street Group Home	5	90	7	7.95	14.34	33	**2:15**
Murchison Adult Family Living	2						
St. Mark's Manor	9	90	15	8.14	29.99	16	**2:05**
Trotter's Bluff	6						
Brighton Manor	10	90	10	2.35	8.70	16	**2:00**
Evans-Walston Home	3	90	9	5.05	12.93	23	**2:05**
VOCA Creekway	6						
Fuquay-Varina Home for the Elderly	59	90	59	2.33	40.77	3	**2:35**
Kinton Sunset Retirement Community	15	90	15	2.35	8.80	16	**2:05**
Wake Med Fuquay-Varina Outpatient and Skilled Nursing Facility	2	90	3	2.35	8.7	16	**1:50**
Mims Family Care Home	1						
Windsor Point	47	90	47	1.80	9.08	12	**2:30**
Chatham County Medical Facilities							
Sanford Health and Rehabilitation	12	90	12	1.48	41.46	2	**1:45**
						Maximum for EPZ:	**2:40**

1. INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to update the existing Evacuation Time Estimates (ETE) for the Harris Nuclear Plant (HNP), located in Wake County, North Carolina. Evacuation time estimates are part of the required planning basis and provide State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, all available prior documentation relevant to Evacuation Time Estimates was reviewed.

Other guidance is provided by documents published by Federal Government agencies. Most important of these are:

- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG 0654/FEMA-REP-1, Rev. 1, November 1980.

- Analysis of Techniques for Estimating Evacuation Times for Emergency Planning Zones, NUREG/CR-1745, November 1980.

- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

We wish to express our appreciation to all the directors and staff members of the Chatham County, Harnett County, Lee County and Wake County emergency management agencies and local and state law enforcement and planning agencies, who provided valued guidance and contributed information contained in this report.

1.1 Overview of the ETE Update Process

The following outline presents a brief description of the work effort in chronological sequence:

1. Information Gathering:
   - Defined the scope of work in discussion with representatives of Progress Energy.
   - Reviewed existing reports describing past evacuation studies.
   - Attended meetings with emergency planners from the four EPZ Counties to identify issues to be addressed.
   - Conducted a detailed field survey of the EPZ highway system and of area traffic conditions.

- Obtained demographic data from census and state agencies.
- Conducted a random sample telephone survey of EPZ residents.
- Conducted a data collection effort to identify and describe schools, special facilities, major employers, transportation providers, and other important sources of information.

2. Estimated distributions of Trip Generation times representing the time required by various population groups (permanent residents, employees, and transients) to prepare (mobilize) for the evacuation trip. These estimates are primarily based upon the random sample telephone survey.
3. Defined Evacuation Scenarios. These scenarios reflect the variation in demand, trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.
4. Defined Evacuation Areas or Regions. The EPZ is partitioned into sub-zones which serve as a basis for the ETE analysis presented herein. Evacuation "Regions" are comprised of contiguous sub-zones for which ETE are calculated. The configuration of these Regions reflects the fact that the wind can take any direction and that the radial extent of the impacted area depends on accident-related circumstances. Each Region, other than those that approximate circular areas, approximates a "key-hole" configuration within the EPZ as required by NUREG/CR-6863.
5. Estimated demand for transit services for persons at "Special Facilities" and for transit-dependent persons at home.
6. Defined a traffic management strategy. Traffic control is applied at specified Traffic Control Points (TCP) located within the Emergency Planning Zone (EPZ), and at Security Road Blocks (SRB) located outside the EPZ. Local and state police personnel have reviewed all traffic control plans.
7. Prepared the input streams for the I-DYNEV system.
   - Estimated the traffic demand, based on the available information derived from Census data, from prior studies, from data provided by local and state agencies and from the telephone survey.
   - Applied the procedures specified in the 2000 Highway Capacity Manual (HCM[1]) to the data acquired during the field survey, to estimate the capacity of all highway segments comprising the evacuation routes.

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[1] Highway Capacity Manual (HCM2000), Transportation Research Board, National Research Council, 2000.

- Developed the link-node representation of the evacuation network, which is used as the basis for the computer analysis that calculates the Evacuation Time Estimates (ETE).
- Calculated the evacuating traffic demands for each Region and for each Evacuation Scenario. Considered the effects on demand of “voluntary evacuation” and of “shadow evacuation”.
- Represented the traffic management strategy.
- Specified the candidate destinations of evacuation travel consistent with outbound movement relative to the location of the HNP.
- Prepared the input stream for the I-DYNEV System.

8. Executed the I-DYNEV models to provide the estimates of evacuation routing and Evacuation Time Estimates (ETE) for all residents, transients and employees (“general population”) with access to private vehicles. Generated a complete set of ETE for all specified Evacuation Regions and Scenarios.
9. Documented ETE in formats responsive to the cited NUREG reports.
10. Calculated the ETE for all transit activities including those for special facilities (schools, health-related facilities, etc.) and for the transit-dependent.

Steps 7 and 8 are iterated as described in Appendix D.

1.2 The Harris Nuclear Plant Site Location

The Harris Nuclear Plant is located approximately 20 miles southwest of Raleigh, North Carolina. The Emergency Planning Zone (EPZ) consists of parts of four counties: Chatham County, Harnett County, Lee County, and Wake County. Figure 1-1 displays the area surrounding the Harris Nuclear Plant. This map identifies the communities in the area and the major roads.

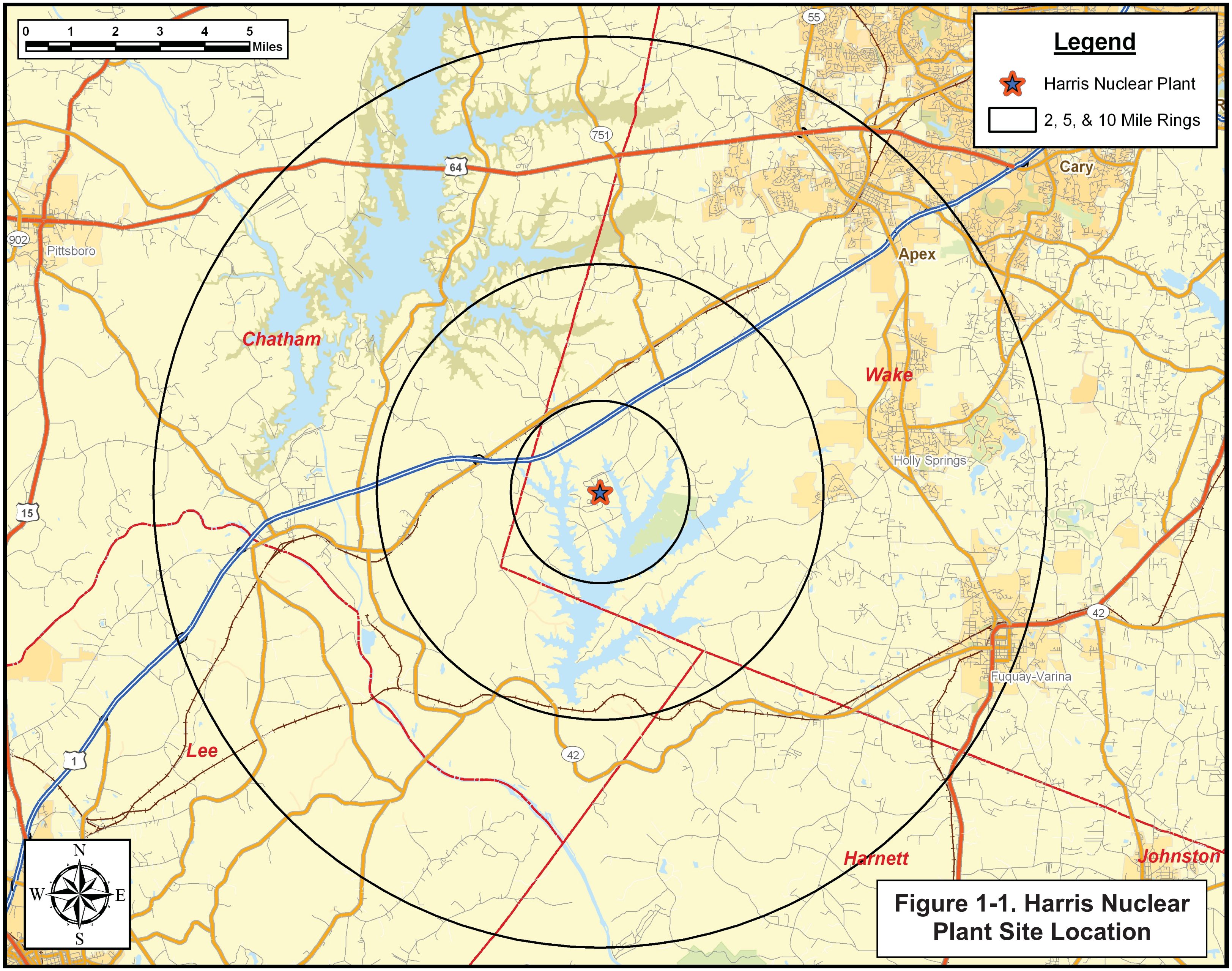

Figure 1-1. Harris Nuclear Plant Site Location

1.3 Preliminary Activities

Since this plan constitutes an update of an existing document, it was necessary to review the prior process and findings. These activities are described below.

Literature Review

KLD Associates was provided with copies of documents describing past studies and analyses leading to the development of emergency plans and of the ETE. We also obtained supporting documents from a variety of sources, which contained information needed to form the database used for conducting evacuation analyses.

Field Surveys of the Highway Network

KLD personnel drove the entire highway system within the EPZ and for some distance outside. A personal computer equipped with Geographical Information Systems (GIS) software was used during the road survey to acquire and record data. The characteristics of each section of highway were recorded. These characteristics include:

• Number of lanes	• Posted speed
• Pavement Width	• Actual free speed
• Shoulder type & width	• Abutting land use
• Intersection configuration	• Control devices
• Lane channelization	• Interchange geometries
• Geometrics: Curves, grades	• Street parking
• Unusual characteristics: Narrow bridges, sharp curves, poor pavement, flood warning signs, inadequate delineations, etc.	

Video and audio recording equipment were used to capture a permanent record of the highway infrastructure. No attempt was made to meticulously measure such attributes as lane width and shoulder width; estimates of these measures based on visual observation and recorded images were considered appropriate for the purpose of estimating the capacity of highway sections. For example, Exhibit 20-5 in the Highway Capacity Manual (HCM) indicates that a reduction in lane width from 12 feet (the “base” value) to 10 feet can reduce free flow speed (FFS) by 1.1 mph – not a material difference – for two lane highways. Exhibit 12-15 in the HCM shows no sensitivity for the estimates of Service Volumes at Level of Service (LOS) E (near capacity), with respect to FFS. The highway terrain (Level, Rolling, and Mountainous) is a far more

important factor than lane and shoulder width when estimating capacity.

The data from the audio and video recordings were used to create detailed GIS shapefiles and databases of the roadway characteristics and of the traffic control devices observed during the road survey; this information was referenced while preparing the input stream for the I-DYNEV System.

As documented on page 20-3 of the HCM2000, the capacity of a two-lane highway is 1700 passenger cars per hour for each direction of travel. For freeway sections, a value of 2250 vehicles per hour per lane is assigned. The road survey has identified several segments which are characterized by adverse geometrics which are reflected in reduced values for both capacity and speed. These estimates reflect the service volumes for LOS E presented in HCM Exhibit 12-15. These links may be identified by reviewing Appendix K. Link capacity is an input to I-DYNEV which calculates the ETE. The locations of these sections may be identified by reference to the large-scale map of Figure1-2 which is discussed below. Further discussion of roadway capacity is provided in Section 4 of this report.

Telephone Survey

A telephone survey was undertaken to gather information needed for the evacuation study. Appendix F presents the survey instrument, the procedures used and tabulations of data compiled from the survey returns.

These data were utilized to develop estimates of vehicle occupancy during an evacuation and to estimate elements of the mobilization process. This database was also referenced to estimate the number of transit-dependent residents.

Developing the Evacuation Time Estimates

The overall study procedure is outlined in Appendix D. Demographic data were obtained from several sources, as detailed later in this report. These data were analyzed and converted into vehicle demand data.

Highway capacity was estimated for each highway segment based on the field surveys and on the principles specified in the HCM2000. The link-node representation of the physical highway network was developed using Geographic Information System (GIS) mapping software and the observations obtained from the field survey. This network representation of “links” and “nodes” is shown in Figure 1-2.

Given the scale of Figure 1-2, it is not feasible to identify the links and nodes to enable the reader to relate to the information presented in Appendix K. Therefore, an annotated map is provided in electronic format which can be printed at a suitable scale, if desired.

Analytical Tools

The I-DYNEV System that was employed for this study is comprised of several integrated computer models. One of these is the PC-DYNEV (DYnamic Network EVacuation) macroscopic simulation model that was developed by KLD under contract with the Federal Emergency Management Agency (FEMA).

I-DYNEV consists of three submodels:

- A macroscopic traffic simulation model (for details, see Appendix C).
- An intersection capacity model (for details, see Highway Research Record No. 772, Transportation Research Board, 1980, papers by Lieberman and McShane & Lieberman).
- A dynamic, node-centric routing model that adjusts the "base" routing in the event of an imbalance in the levels of congestion on the outbound links.

Another model of the I-DYNEV System is the TRAD (TRaffic Assignment and Distribution) model. This model integrates an equilibrium assignment model with a trip distribution algorithm to compute origin-destination volumes and paths of travel designed to minimize travel time. For details, see Appendix B.

Still another software product developed by KLD, named UNITES (UNIfied Transportation Engineering System) was used to expedite data entry. Finally, software to display animations of the evacuating traffic environment, named EVAN (EVacuation ANimation), was used to assist the analysts during the iterative procedure described above, and to prepare some of the displays in this report.

The procedure for applying the IDYNEV System within the framework of developing an update to an ETE is outlined in Appendix D. Appendix A is a glossary of terms.

For the reader interested in more details of the model than are provided in Appendices B, C and D, and in Highway Research Record No. 772 (discussed in Section 4 of this report), the following references are suggested:

- NUREG/CR-4873 – Benchmark Study of the I-DYNEV Evacuation Time Estimate Computer Code
- NUREG/CR-4874 – The Sensitivity of Evacuation Time Estimates to Changes in Input Parameters for the I-DYNEV Computer Code

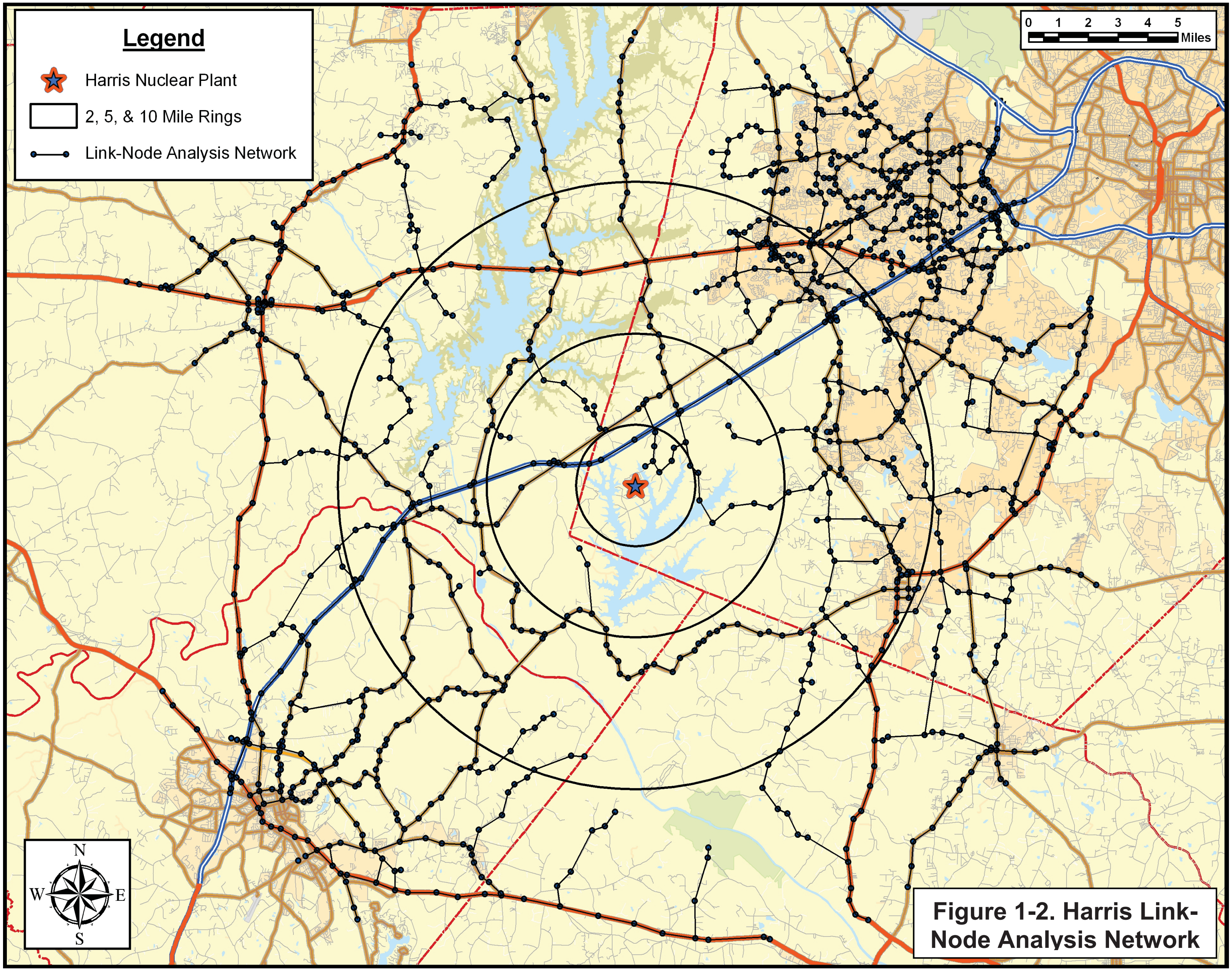

Figure 1-2. Harris Link-Node Analysis Network

The evacuation analysis procedures are based upon the need to:

- Route traffic along paths that will expedite their travel from their respective points of origin to points outside the EPZ
- Restrict movement toward HNP to the extent practicable, and disperse traffic demand so as to avoid focusing demand on a limited number of highways
- Move traffic in directions that are generally outbound, relative to the location of HNP.

A set of candidate destination nodes on the periphery of the EPZ is specified for each traffic origin (or centroid) within the EPZ. The TRAD model produces output that identifies the "best" traffic routing, subject to the design conditions outlined above. In addition to this information, rough estimates of travel time are provided, together with turn-movement data required by the PC-DYNEV simulation model.

The simulation model is then executed to provide a detailed description of traffic operations on the evacuation network. This description enables the analyst to identify bottlenecks and to consider the development of countermeasures designed to expedite the movement of vehicles. These are discussed in subsequent sections. The outputs of this model are the volume of traffic, expressed as vehicles/hour, that exit the evacuation region along the various highways (links) that cross the region boundaries. These outputs are exported into a spreadsheet which documents the ETE. Intermediate, detailed results are also produced, at specified time intervals, for each network link. Section 7 presents a further description of this process along with the ETE Tables.

As outlined in Appendix D, this procedure consists of an iterative design-analysis-redesign sequence of activities. When properly done, this procedure converges to yield an evacuation plan which best services the evacuating public.

1.4 Comparison with Prior ETE Study

Table 1-1 presents a comparison of the present ETE study with the 2002 study. The major factors contributing to the differences between the ETE values obtained in this study and those of the previous study can be summarized as follows:

- An increase in permanent resident population.
- Vehicle occupancy and Trip-generation rates are based on the results of a telephone survey of EPZ residents.
- Voluntary and shadow evacuations are considered.
- The highway representation is far more detailed.
- Traffic management plan included.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Resident Population Basis	ArcGIS Software using 2000 US Census blocks; area ratio method used. Population = 61,845	ArcGIS Software using 2000 US Census blocks; block centroid method used; population extrapolated to 2007. Population = 74,097
Resident Population Vehicle Occupancy	Average household size varies by County. 2.5 persons/vehicle.	3.05 persons/household, 1.33 evacuating vehicles/household yielding: 2.29 persons/vehicle
Employee Population	Employees grouped with transient population. Employee estimates based on information provided about major employers in EPZ. 2.5 employees/vehicle.	Employees treated as separate population group. Employee estimates based on information provided about major employers in EPZ, supplemented by observations of commercial property in EPZ from aerial imagery. 1.08 employees/vehicle based on telephone survey results.
Voluntary evacuation from within EPZ in areas outside region to be evacuated	Not considered	50 percent of population within the circular portion of the region; 35 percent, in annular ring between the circle and the EPZ boundary (See Figure 2-1).
Shadow Evacuation	Not considered.	30% of people outside of the EPZ within the shadow region (See Figure 7-2).
Network Size	349 links; Number of nodes not provided.	1,720 Links; 1,234 Nodes.

Table 1-1. ETE Study Comparisons (cont.)		
Roadway Geometric Data	Field surveys conducted in 2002.	Field surveys conducted in 2006. Major intersections were video archived. GIS shape-files of signal locations and roadway characteristics created during road survey. Road capacities based on HCM2000.
School Evacuation	Direct evacuation to designated Reception Center/Host School.	Direct evacuation to designated Reception Center/Host School.
Transit Dependent Population	Not considered.	Defined as households with 0 vehicles. Telephone survey results used to estimate transit dependent population.
Ridesharing	Not considered.	50 percent of transit dependent persons will ride out with a neighbor of friend.
Trip Generation for Evacuation	Trip Generation curves adapted from chemical stockpile evacuation studies. Same distribution used for all population groups; all population is mobilized within 50 minutes.	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters leave between 30 and 240 minutes. Households without commuters leave between 15 and 180 minutes. Employees and transients leave between 15 and 150 minutes. All times measured from the Advisory to Evacuate.

Table 1-1. ETE Study Comparisons (cont.)		
Traffic and Access Control	Not considered.	Traffic and Access Control used in all scenarios to facilitate the flow of traffic outbound relative to HNP.
Weather	Adverse. The capacity of each link in the network is reduced by 25% for adverse weather.	Normal, Rain, or Ice. The capacity and free flow speed of all links in the network are reduced by 10% in the event of rain and 20% for ice.
Modeling	Evacuation Simulation Model (ESIM) – part of Oak Ridge Evacuation Modeling System (OREMS)	I-DYNEV System: TRAD and PC-DYNEV.
Special Events	None considered.	One considered – new plant construction.
Evacuation Cases	35 Regions (single sector wind direction used) and 4 Scenarios producing 108 unique cases	25 Regions (central sector wind direction and each adjacent sector technique used) and 12 Scenarios producing 300 unique cases
Evacuation Time Estimates Reporting	ETE reported for 90 and 100th percentile population. Results presented by Region and Scenario	ETE reported for 50th, 90th, 95th, and 100th percentile population. Results presented by Region and Scenario.
Evacuation Time Estimates for the entire EPZ, 100th percentile.	Full EPZ – Summer Weekday: Good weather = 4:13 Full EPZ – Summer Weekend: Good weather = 5:46	Summer Weekday Midday Good weather = 4:10 Summer Weekend Midday Good weather = 4:05

2. STUDY ESTIMATES AND ASSUMPTIONS

This section presents the estimates and assumptions utilized in the development of the evacuation time estimates.

2.1 Data Estimates

1. Population estimates are based upon Census 2000 data, projected to year 2007. County-specific projections are based upon growth rates estimated by comparing the 2000 census data and 2005 census estimates. Estimates of employees who commute into the EPZ to work are based upon employment data obtained from county emergency management officials.
2. Population estimates at special facilities are based on available data from county emergency management offices.
3. Roadway capacity estimates are based on field surveys and the application of Highway Capacity Manual 2000[1].
4. Population mobilization times are based on a statistical analysis of data acquired from the telephone survey.
5. The relationship between resident population and evacuating vehicles is developed from the telephone survey. The average values of 3.05 persons per household and 1.33 evacuating vehicles per household are used.
6. The relationship between persons and vehicles for special facilities is as follows:
    a. Parks/Recreational: 1 vehicle per family
    b. Boat Ramps: 2 vehicles (vehicle plus trailer) per family
    c. Employees: 1.08 employees per vehicle (telephone survey results)
7. Evacuation Time Estimates (ETE) are presented for the evacuation of the 100th percentile of population for each Region and for each Scenario, and for the 2-mile, 5-mile and 10-mile distances. ETEs are presented in tabular format and graphically, showing the values of ETE associated with the 50th, 90th and 95th percentiles of population. An Evacuation Region is defined as a group of sub-zones that is issued the Advisory to Evacuate.

2.2 Study Methodological Assumptions

1. The Evacuation Time is defined as the elapsed time from the Advisory to Evacuate issued to persons within a specific Region of the EPZ, and the time that Region is clear of the indicated percentile of people.
2. The ETEs are computed and presented in a format compliant with the

[1] Highway Capacity Manual (HCM2000), Transportation Research Board, National Research Council, 2000.

guidance in the cited NUREG documentation. The ETE for each evacuation area ("Region" comprised of included sub-zones) is presented in both statistical and graphical formats.

3. Evacuation movements (paths of travel) are generally outbound relative to the power plant to the extent permitted by the highway network, as computed by the computer models. All available evacuation routes are used in the analysis.
4. Regions are defined by the underlying "keyhole" or circular configurations as specified in NUREG/CR-6863. These Regions, as defined, display irregular boundaries reflecting the geography of the sub-zones included within these underlying configurations.
5. Voluntary evacuation is considered as indicated in the accompanying Figure 2-1. Within the circle defined by the distance to be evacuated but outside the Evacuation Region, 50 percent of the people not advised to evacuate are assumed to evacuate within the same time-frame. In the annular area between the circle defined by the central "key-hole" of the Evacuation Region and the EPZ boundary, it is assumed that 35 percent of people will voluntarily evacuate. In the area between the EPZ boundary and a 15-mile annular area centered at the plant (the "shadow region"), it will be assumed that 30 percent of the people will evacuate voluntarily. Sensitivity studies explored the effect on ETE, of increasing the percentage of voluntary evacuees in this area (See Appendix I).
6. A total of 12 "Scenarios" representing different seasons, time of day, day of week and weather are considered. One special event scenario is studied: the construction period of a new nuclear plant. These Scenarios are tabulated below:

Scenario	Season	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	Ice	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Midweek, Weekend	Evening	Good	None
12	Summer	Midweek	Midday	Good	New Plant Construction

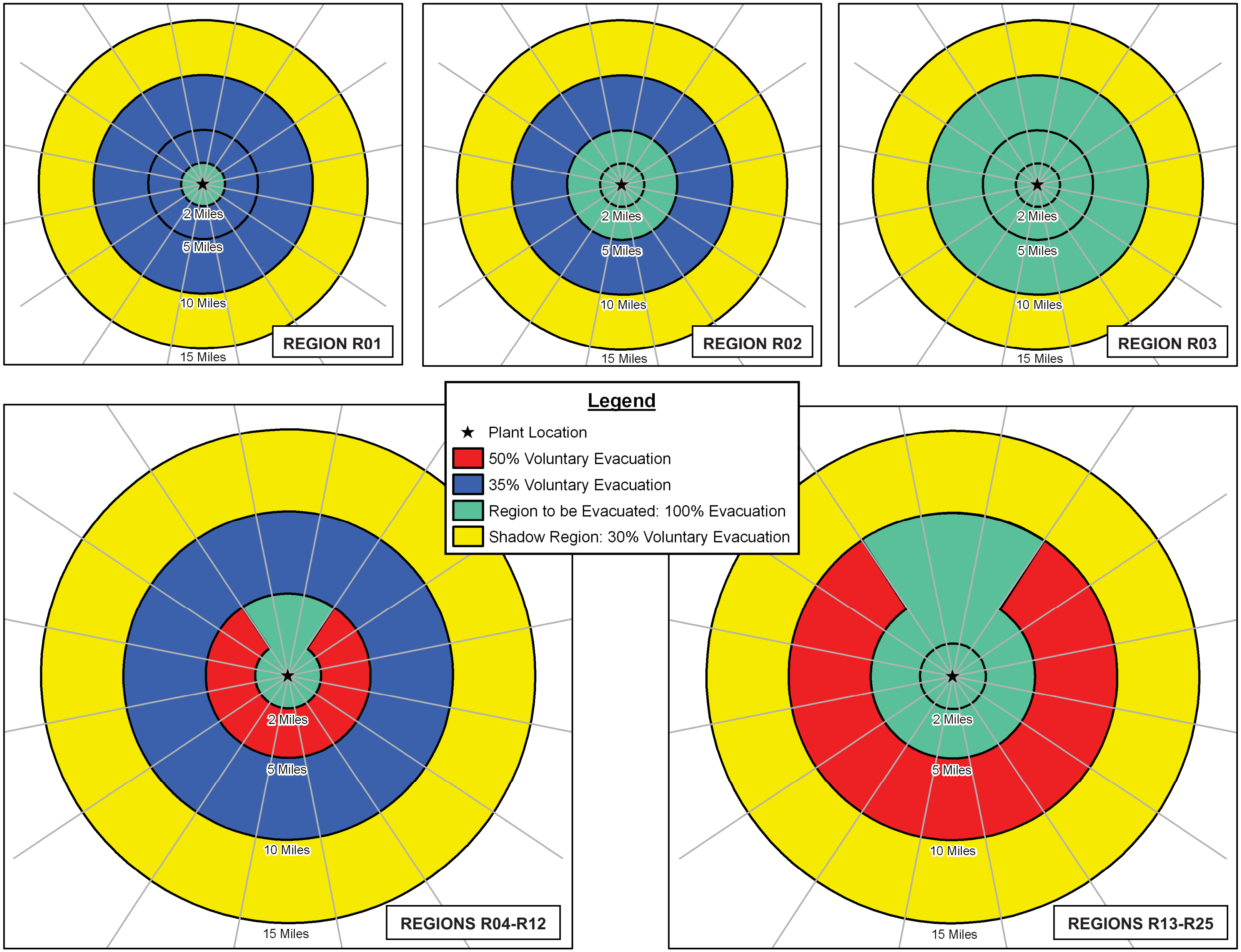

Figure 2-1. Voluntary Evacuation Methodology

7. The models of the IDYNEV System represent the state of the art, and have been recognized as such by the Atomic Safety and Licensing Board (ASLB) in past hearings. (Sources: Atomic Safety & Licensing Board Hearings on Seabrook and Shoreham; Urbanik[2]).
8. ETE for transit dependent persons and for those in special facilities are computed separately.

2.3 Study Assumptions

1. The Planning Basis Assumption for the calculation of ETE is a rapidly escalating accident that requires evacuation, and includes the following:
   a. Advisory to Evacuate is announced coincident with the siren notification.
   b. Mobilization of the general population will commence within 10 minutes after Advisory to Evacuate.
   c. ETE are measured relative to Advisory to Evacuate.
2. It is assumed that everyone within the group of sub-zones forming a Region that is issued an Advisory to Evacuate will, in fact, respond in general accord with the planned routes.
3. It is conservatively estimated that 68 percent of households in the EPZ have at least one commuter, and will await the return of the commuter before beginning their evacuation trip for mid-week, mid-day scenarios, based on the telephone survey results.
4. A portion of the population outside the evacuated Region will elect to evacuate even though not advised to do so ("voluntary evacuation"). See Figure 2-1.
5. The ETE will also include consideration of "through" (External-External) trips during the time that such traffic is permitted to enter the evacuated Region. "Normal" traffic flow is assumed to be present within the EPZ at the start of the emergency.
6. Security Road Blocks (SRB) will be staffed within approximately 90 minutes following the siren notifications, to divert traffic attempting to enter the EPZ. Earlier activation of SRB locations could delay returning commuters. It is assumed that no vehicles will enter the EPZ after this 90 minutes mobilization time period.
7. Traffic Control Points (TCP) within the EPZ will be staffed over time, beginning at the Advisory to Evacuate. Their number and location will depend on the Region to be evacuated and personnel resources available. It is assumed that drivers will act rationally, travel in the directions identified in the plan (as documented in the public information material), and obey all control devices and traffic guides.

[2] Urbanik, T., et. al. Benchmark Study of the I-DYNEV Evacuation Time Estimate Computer Code, NUREG/CR-4873, Nuclear Regulatory Commission, June, 1988

8. Traffic Control Points (TCP) outside the EPZ should be established to facilitate evacuation flow to the Reception Centers.
9. Buses will be used to transport those without access to private vehicles:
   a. If schools are in session, transport (buses) will evacuate students directly to the assigned relocation schools.
   b. School children, if school is in session, are given priority in assigning transit vehicles.
   c. Bus mobilization time is considered in ETE calculations.
   d. Analysis of the number of required "waves" of transit vehicles used for evacuation is presented.
10. It is reasonable to assume that some of the transit-dependent people will ride-share with family, neighbors, and friends, thus reducing the demand for buses. We assume that the percentage of people who rideshare is 50 percent. This assumption is based upon reported experience for other emergencies[3], which cites previous evacuation experience. The remaining transit-dependent portion of the general population will be evacuated to reception centers by bus.
11. Two types of adverse weather scenario are considered. Rain may occur for either winter or summer scenarios. In the case of rain, it is assumed that the rain begins prior to, or at about the same time as the evacuation advisory is issued. Ice occurs as a winter scenario, only. No weather-related reduction in the number of transients who may be present in the EPZ is assumed. Adverse weather scenarios affect roadway capacity, free flow highway speeds and the time required to mobilize the general population. The factors assumed for the ETE study are:

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time for General Population
Rain[4]	90%	90%	No Effect
Ice[4]	80%	80%	No Effect
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.			

12. School buses used to transport students are assumed to have the capacity to transport 70 children per bus for elementary schools, and 50 children per bus for middle and high schools. Transit buses used to transport the transit-dependent general population are assumed to transport an average of 30 people per bus.
13. Officials in boats will use sirens, colored smoke and flares to alert people on Jordan and Harris Lakes.

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[3] Institute for Environmental Studies, University of Toronto, THE MISSISSAUGA EVACUATION FINAL REPORT, June 1981. The report indicates that 6,600 people of a transit-dependent population of 8,600 people shared rides with other residents; a ride share rate of 76% (Page 5-10).
[4] Agarwal, M. et. Al. Impacts of Weather on Urban Freeway Traffic Flow Characteristics and Facility Capacity, Proceedings of the 2005 Mid-Continent Transportation Research Symposium, August, 2005.

3. DEMAND ESTIMATION

The estimates of demand, expressed in terms of people and vehicles, constitute a critical element in developing an evacuation plan. These estimates consist of three components:

1. An estimate of population within the Emergency Planning Zone (EPZ), stratified into groups (resident, employee, transient).
2. An estimate, for each population group, of mean occupancy per evacuating vehicle. This estimate is used to determine the number of evacuating vehicles.
3. An estimate of potential double-counting of vehicles.

Appendix E presents much of the source material for the population estimates. Our primary source of population data, the 2000 Census, however, is not adequate for directly estimating some transient groups.

Throughout the year, vacationers and tourists enter the EPZ. These non-residents may dwell within the EPZ for a short period (e.g. a few days or one or two weeks), or may enter and leave within one day. Estimates of the size of these population components must be obtained, so that the associated number of evacuating vehicles can be ascertained.

The potential for double-counting people and vehicles must be addressed. For example:

- A resident who works and shops within the EPZ could be counted as a resident, again as an employee and once again as a shopper.
- A visitor who stays at a hotel and spends time at a park, then goes shopping could be counted three times.

Furthermore, the number of vehicles at a location depends on time of day. For example, motel parking lots may be full at dawn and empty at noon. Similarly, parking lots at area parks, which are full at noon, may be almost empty at dawn. It is clearly wrong to estimate counts of vehicles by simply adding up the capacities of different types of parking facilities, without considering such factors.

Analysis of the population characteristics of the Harris Nuclear Plant (HNP) EPZ indicates the need to identify three distinct groups:

- Permanent residents - people who are year-round residents of the EPZ.
- Transients - people who reside outside of the EPZ, who enter the area for a specific purpose (e.g., boating, camping) and then leave the area.

- Commuter-Employees - people who reside outside the EPZ and commute to businesses within the EPZ on a daily basis.

Estimates of the population and number of evacuating vehicles for each of the population groups are presented for each sub-zone and by polar coordinate representation (population rose). The HNP EPZ has been subdivided into 14 Sub-Zones as shown in Figure 3-1.

Permanent Residents

The primary source for estimating permanent population is the latest U.S. Census data. The average household size (3.05 persons/household) and the number of evacuating vehicles per household (1.33 vehicles/household) were adapted from the telephone survey results.

Comparing census estimates available for the year 2005, with that for 2000, it is possible to estimate the rate of population change over time and to project the year 2000 resident population to a 2007 base year. The rate of population change was found for each County in the EPZ and applied to project population growth to 2007[1]. The data in Table 3-1 show that the EPZ population has increased by 25 percent over the last 7 years.

Permanent resident population and vehicle estimates for 2007 are presented in Table 3-2. Figures 3-2 and 3-3 present the permanent resident population and permanent resident vehicle estimates by sector and distance from the HNP. This "rose" was constructed using GIS software.

Construction

A "special event" scenario (Scenario 12) which represents a typical summer, mid-week, midday with construction workers on-site at the time of the emergency, was considered. The peak construction period – based on discussions with Progress Energy – would be in the year 2016, with workforce estimates of 3,500 workers. An average vehicle occupancy of 1.08 workers per vehicle (adapted from telephone survey results) was used to convert workers to vehicles – 3,241 total vehicles. The existing roadway system was used for the construction scenario; no roadway improvements were considered.

All vehicles were extrapolated to 2016 for this scenario, with the exception of external traffic. Permanent resident population and shadow population were extrapolated using the county-specific yearly population growth rates. The population estimates for year 2016 are 93,129 permanent residents in the EPZ and 214,897 permanent residents in

[1] Based on data provided on the U.S. Census Bureau QuickFacts website (http://quickfacts.census.gov), accessed on March 5, 2007, the yearly permanent resident population growth rates for the EPZ counties are: Chatham County +3.35%; Harnett County +2.65%; Lee County +2.51%; Wake County +3.67%.

the Shadow Region. Employees were extrapolated using county-specific yearly employment growth rates obtained from the U.S. Department of Labor - Bureau of Labor Statistics website[2]. As the permanent resident population increases, the number of school children and transient attractions in the EPZ will also likely increase. The ratio of school buses to permanent resident vehicles for Scenario 1 (62 ÷ 32,314 = 0.2% - see Table 6-4) was applied to the 2016 estimate of permanent resident vehicles in order to estimate the school buses evacuating for the construction scenario. The same methodology was used to estimate the transient population for the construction scenario (3,127 ÷ 32,314 = 9.7% - see Table 6-4). As indicated in Table 8-4, 2.0% of the EPZ permanent resident population is transit dependent, after ridesharing. Applying this percentage to the 2016 permanent resident population estimate yields 1,863 transit dependent people, evacuating in 62 buses (assuming 30 passengers per bus). As indicated in Table 8-1, 0.5% of the EPZ permanent resident population is transit dependent, after ridesharing. Applying this percentage to the 2016 permanent resident population estimate yields 466 transit dependent people, evacuating in 16 buses (assuming 30 passengers per bus).

External traffic by definition are those vehicles that pass through the EPZ. Thus, growth within the EPZ does not impact the external traffic. Generally speaking, the external traffic should grow as capacity on the major through routes within the EPZ increases. There are no major roadway improvements scheduled for the major roadways traveling through the EPZ; therefore, the current external traffic estimates are retained for the construction scenario. Table 6-4 summarizes the vehicles evacuating for the construction scenario.

A Traffic Impact Analysis (TIA) was conducted by Kimley-Horn and Associates, Inc. in July 2008 to assess the impact of construction traffic on the roadways surrounding the Harris Nuclear Plant. Appendix N compares the ETE for the construction scenario based on the assumptions presented above with the ETE based on the assumptions presented in the TIA report.

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[2] www.bls.gov The yearly employment growth rates for the EPZ counties are: Chatham County +0.8%; Harnett County +1.6%; Lee County +0.1%; Wake County +2.6%.

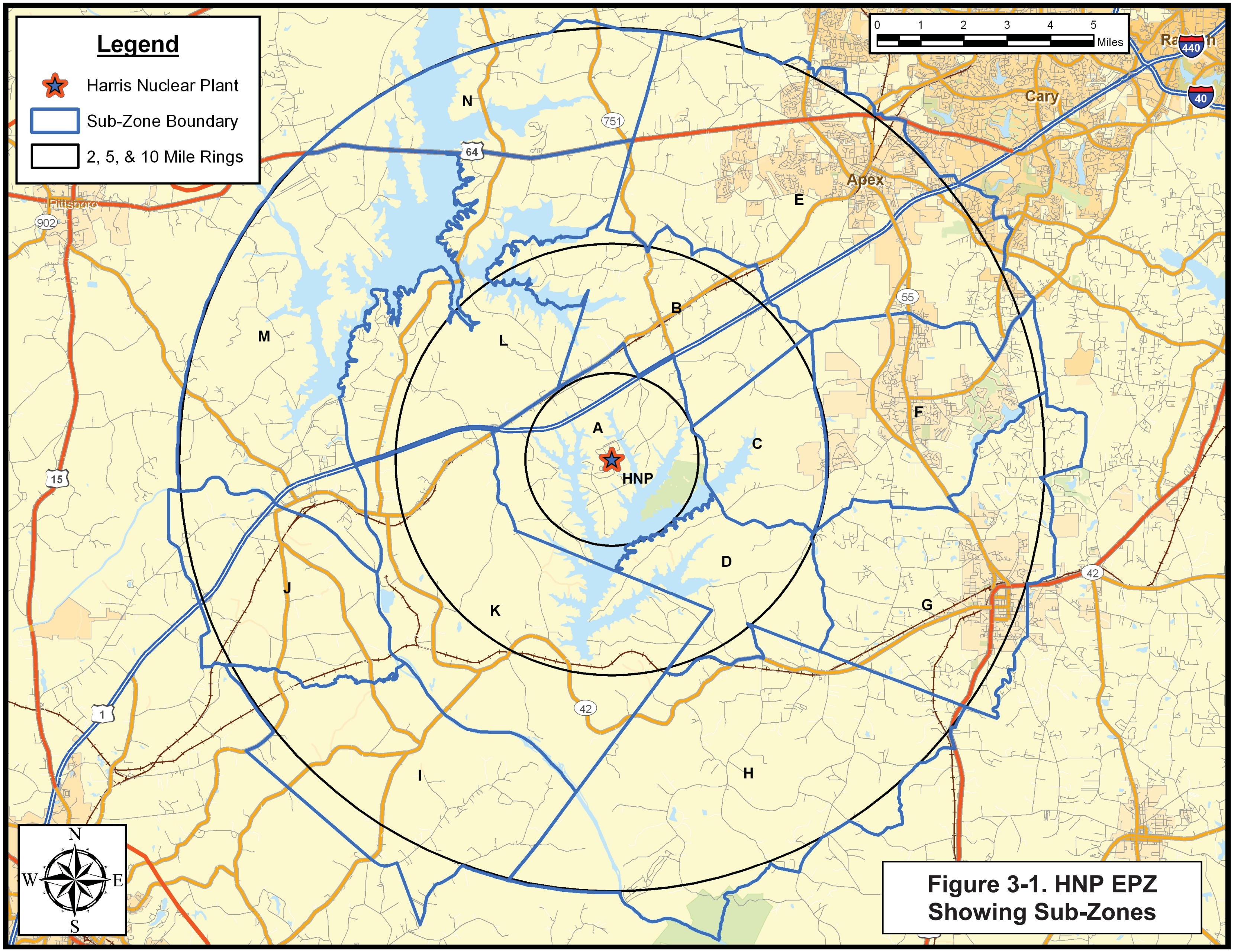
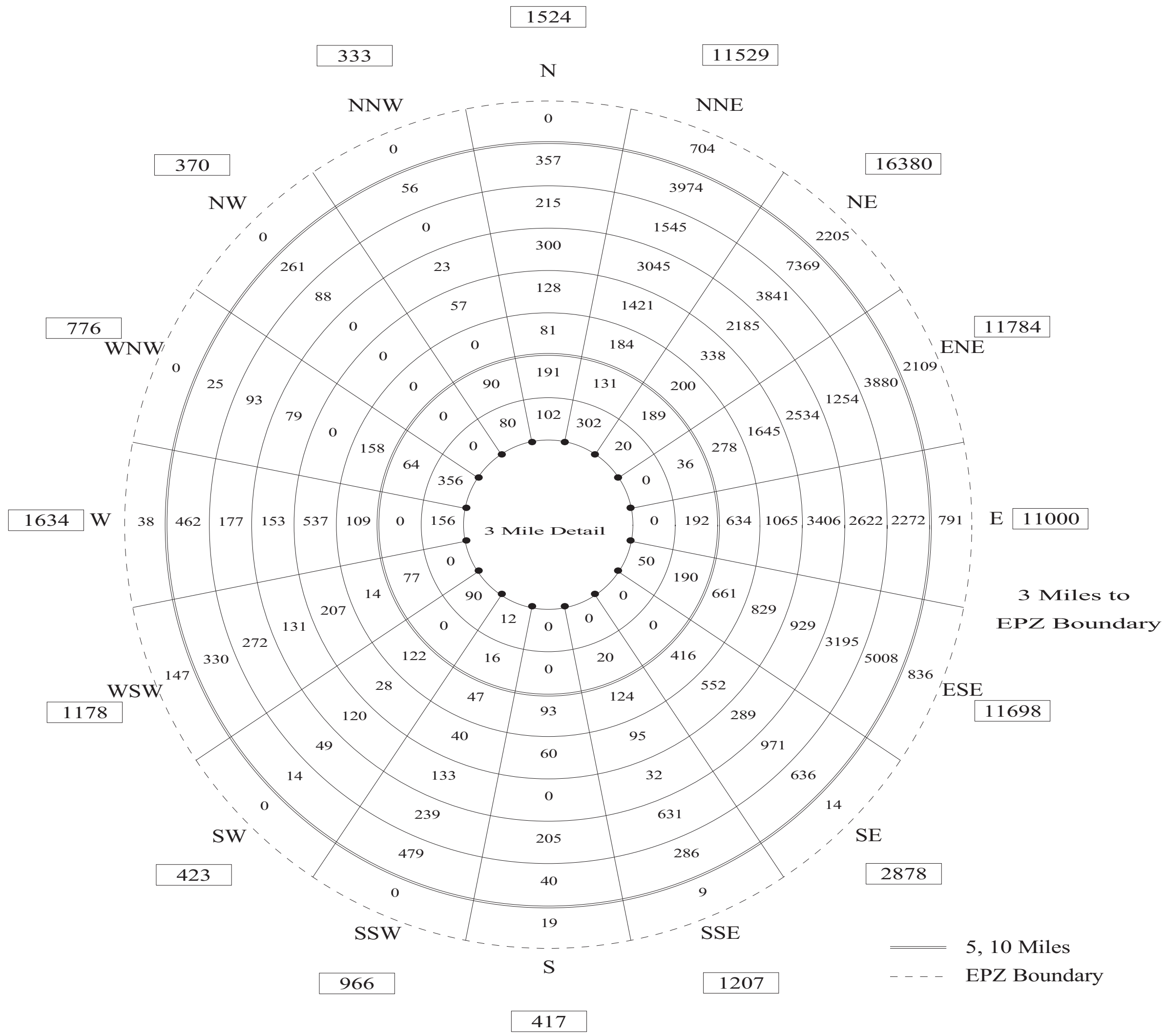


Figure 3-1. HNP EPZ Showing Sub-Zones

Table 3-1. EPZ Permanent Resident Population		
Sub-Zone	**2000 Population**	**2007 Population**
A	143	180
B	1,113	1,397
C	331	416
D	258	319
E	26,146	32,879
F	10,764	13,534
G	12,324	15,497
H	2,906	3,444
I	804	947
J	1,145	1,348
K	619	763
L	708	874
M	1,440	1,778
N	584	721
TOTAL	**59,285**	**74,097**
Population Growth:		**25.0%**

Table 3-2. Permanent Resident Population and Vehicles by Sub-Zone		
Sub-Zone	**2007 Population**	**2007 Vehicles**
A	180	77
B	1,397	610
C	416	182
D	319	140
E	32,879	14,338
F	13,534	5,901
G	15,497	6,762
H	3,444	1,501
I	947	413
J	1,348	587
K	763	333
L	874	380
M	1,778	776
N	721	314
TOTAL	**74,097**	**32,314**



Resident Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	87	0-2	87
2-3	446	0-3	533
3-4	1168	0-4	1701
4-5	1196	0-5	2897
5-6	3121	0-6	6018
6-7	7002	0-7	13020
7-8	13359	0-8	26379
8-9	15397	0-9	41776
9-10	25449	0-10	67225
10-EPZ	6872	0-EPZ	74097

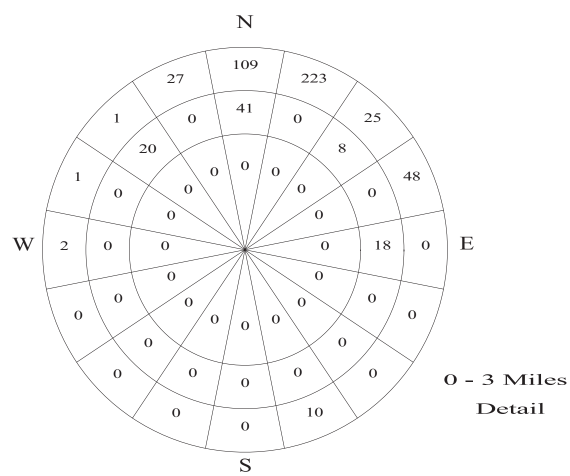
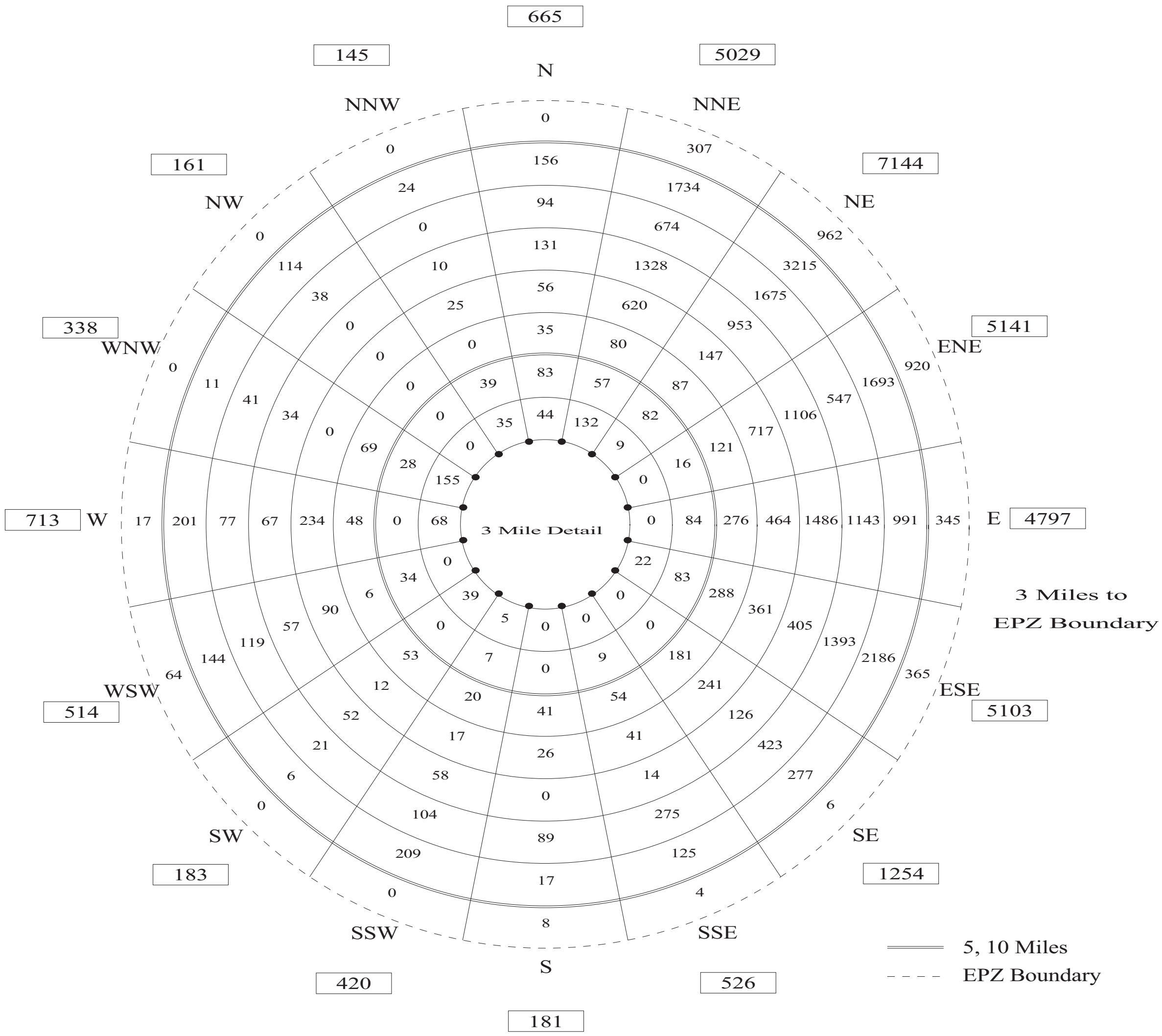


Figure 3-2. Permanent Residents by Sector



Resident Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	38	0-2	38
2-3	194	0-3	232
3-4	509	0-4	741
4-5	522	0-5	1263
5-6	1359	0-6	2622
6-7	3051	0-7	5673
7-8	5827	0-8	11500
8-9	6713	0-9	18213
9-10	11103	0-10	29316
10-EPZ	2998	0-EPZ	32314

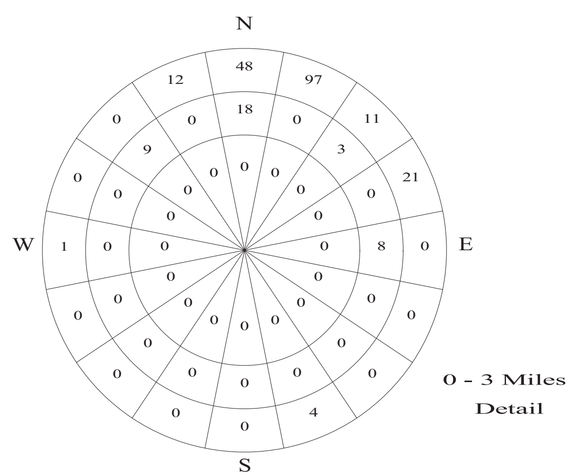


Figure 3-3. Permanent Resident Vehicles by Sector

Transient Population

Transient population groups are defined as those people who are not permanent residents and who enter the EPZ for a specific purpose (shopping, recreation). Transients may spend less than one day or stay overnight or longer at rented apartments, camping facilities, hotels and motels. The Harris EPZ has a number of areas that attract transients, including:

- Jordan Lake State Recreation Area
- Harris Lake

Estimates of the peak attendance at these transient facilities were provided by County emergency management offices. Internet searches were also used to obtain more detailed information about these facilities and supplement the data provided. The average household size of 3.05 persons per household was applied to the transient facilities to estimate the number of visiting persons; one evacuating vehicle per transient family was assumed. The following are estimates of the transient population at each of these facilities during peak times:

Jordan Lake State Recreation Area

Jordan Lake is a 46,768 acre lake located in the northwestern portion of the EPZ, occupying parts of sub-zones L, M, and N. The Jordan Lake State Recreation Area consists of 12 separate facilities (11 of which are in the EPZ) that offer camping, fishing, swimming, and boating:

1. New Hope Overlook: Offers 2 boat ramps to public, primitive camping at 24 campsites, fishing and trails. The campsites can only be accessed by hiking the trails. Overhead imagery indicates parking for 200 vehicles with trailers which is modeled as 400 passenger car equivalents (PCEs) in DYNEV.
2. Ebenezer Church: Offers a boat ramp with 24 hour access, fishing, picnic areas, a swimming area, and trails. Overhead imagery indicates parking for 275 vehicles at the swimming and picnic areas and parking for 150 vehicles with trailers (300 PCEs).
3. Poplar Point: Offers primitive camping, recreational vehicle (RV) camping, boat ramps for campers only, fishing, swimming, and trails. There are a total of 579 campsites with 6 people and 2 vehicles per campsite on a peak day. Overhead imagery shows parking for 80 additional vehicles at the swimming area.
4. Crosswinds Campground: Offers primitive camping, RV camping, boat ramps for campers only, fishing, swimming and trails. A total of 160 campsites with 6 people and 2 vehicles per campsite on a peak day.
5. Robeson Creek: Offers 24 hour boat ramp and fishing to the public. Overhead

imagery indicates parking for 70 vehicles with trailers (140 PCEs).

6. Seaforth: Offers 2 public boat ramps, fishing, picnic areas, a swimming area, and trails. Overhead imagery indicates parking for 175 vehicles with trailers (350 PCEs) and an additional 350 parking spaces for the picnic and swimming area.
7. Parker's Creek: Offers group camping, primitive camping, and RV camping, fishing, picnic areas, a swimming area, and boat ramps for campers only. There are a total of 250 campsites with 6 people and 2 vehicles per campsite on a peak day.
8. Vista Point: Offers group camping, RV camping, fishing, picnic areas, a swimming area for campers only, and trails. There are a total of 330 campsites with 6 people and 2 vehicles per campsite on a peak day. Overhead imagery indicates additional parking for 100 vehicles with trailers (200 PCEs) outside of the campsites.
9. White Oak: Offers 2 boat ramps to the public, fishing, picnic areas, and a swimming area. Overhead imagery indicates parking for 90 vehicles with trailers (180 PCEs) and an additional 40 parking spaces for the swimming and picnic areas.
10. Crosswinds Marina: Overhead imagery indicates approximately 275 slips available for boats and a parking lot capacity of approximately 100 vehicles with trailers (200 PCEs).
11. Poe's Ridge: Offers 2 public boat ramps with 24 hour access. Overhead imagery indicates parking for 82 vehicles with trailers (164 PCEs)

Appendix E includes a map of these recreation areas. It is assumed that 1 vehicle per family is used at these facilities. The average family size for the EPZ (3.05 persons/household) is multiplied by the number of vehicles at each facility to estimate the number of transients present. The peak transient population for Jordan Lake is estimated as 13,138 people evacuating in 5,317 vehicles.

Harris Lake

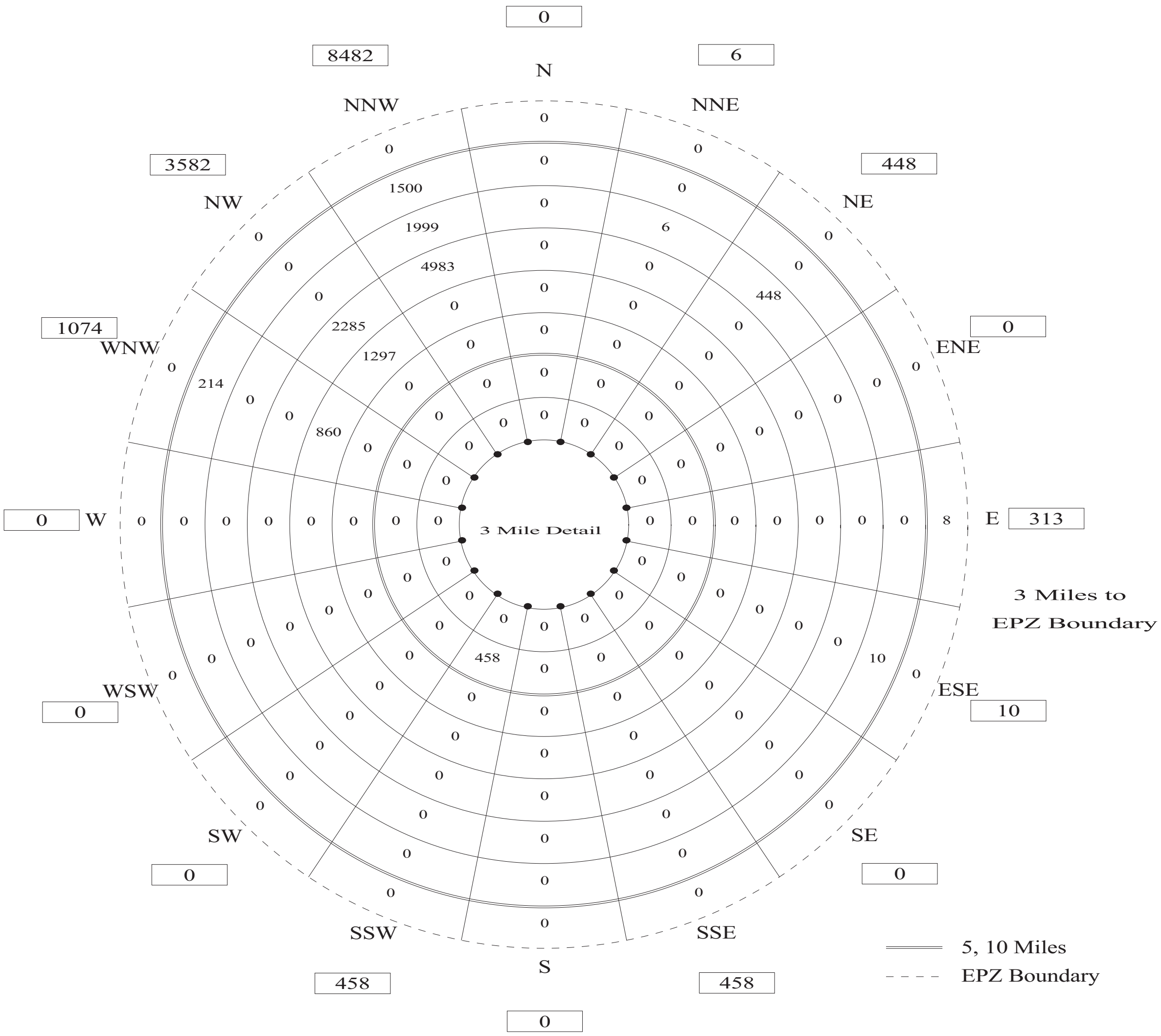
The Harris Nuclear Plant is located on Harris Lake which occupies parts of sub-zones A, C, D and K. Attractions at the site include the Harris Lake County Park, 2 boat ramps, and a fishing pier. The Harris Lake County Park spans 680 acres, including the Buckhorn Disc Golf Course (golf played by throwing Frisbees) and several mountain bike and hiking trails. There is parking for 150 vehicles with trailers (300 PCEs) at each of the boat ramps and parking for 100 vehicles at the County Park; the number of parking spaces for the boat ramps and for the County Park was estimated using overhead imagery. The peak attendance is estimated as 1,221 persons evacuating in 700 vehicles.

Hotels and Motels

There are 3 major hotels (50 or more rooms) and three bed and breakfast lodgings in the EPZ. Appendix E details the hotel data provided by county emergency management offices. The peak attendance at the hotels and motels is estimated as 472 people evacuating in 236 vehicles.

Table 3-3. Summary of Transients by Sub-Zone

Sub-Zone	Transients	Transient Vehicles
A	305	100
B	**No Transients**	
C		
D	458	300
E	454	227
F	**No Transients**	
G	18	9
H	**No Transients**	
I		
J		
K	458	300
L	5,625	2,213
M	4,351	1,864
N	3,162	1,240
TOTAL	**14,831**	**6,253**



Transient Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	305	0-2	305
2-3	458	0-3	763
3-4	0	0-4	763
4-5	458	0-5	1221
5-6	0	0-6	1221
6-7	2157	0-7	3378
7-8	7268	0-8	10646
8-9	2453	0-9	13099
9-10	1724	0-10	14823
10-EPZ	8	0-EPZ	14831

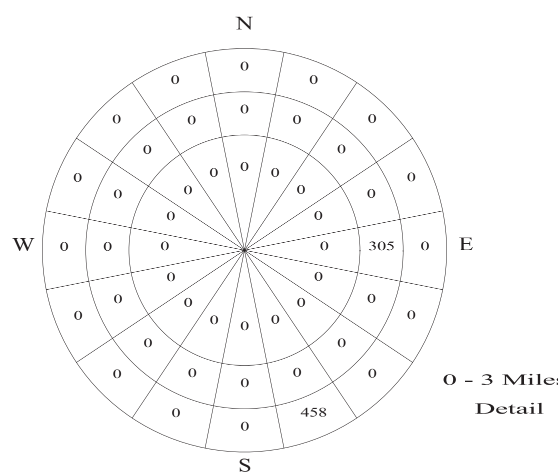
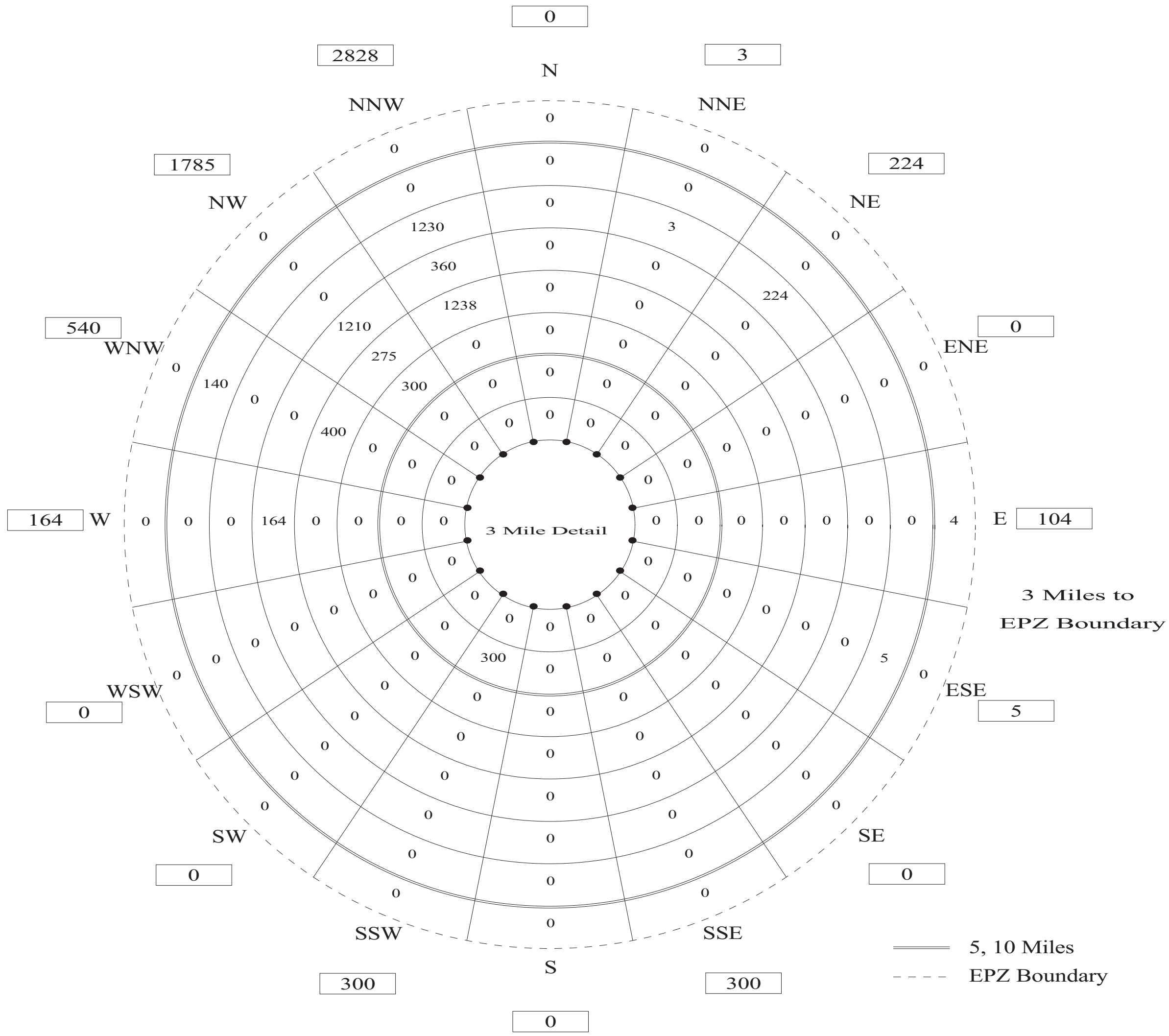


Figure 3-4. Transient Population by Sector



Transient Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	100	0-2	100
2-3	300	0-3	400
3-4	0	0-4	400
4-5	300	0-5	700
5-6	300	0-6	1000
6-7	1913	0-7	2913
7-8	1734	0-8	4647
8-9	1457	0-9	6104
9-10	145	0-10	6249
10-EPZ	4	0-EPZ	6253

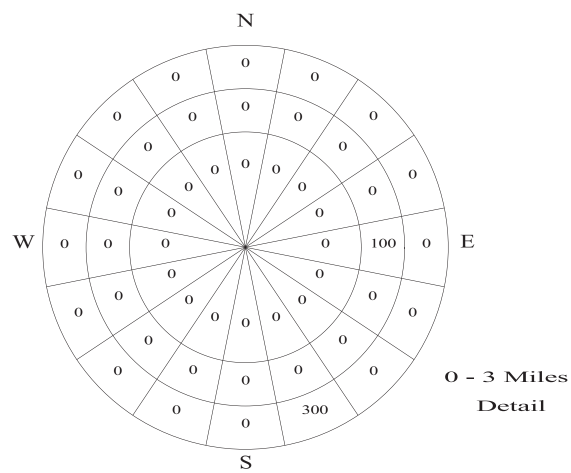


Figure 3-5. Transient Vehicles by Sector

Employees

Employees who work within the EPZ fall into two categories:

- Those who live and work in the EPZ
- Those who live outside of the EPZ and commute to jobs within the EPZ.

Those of the first category are already counted as part of the permanent resident population. To avoid double counting, we focus on those commuting employees who will evacuate along with the permanent resident population.

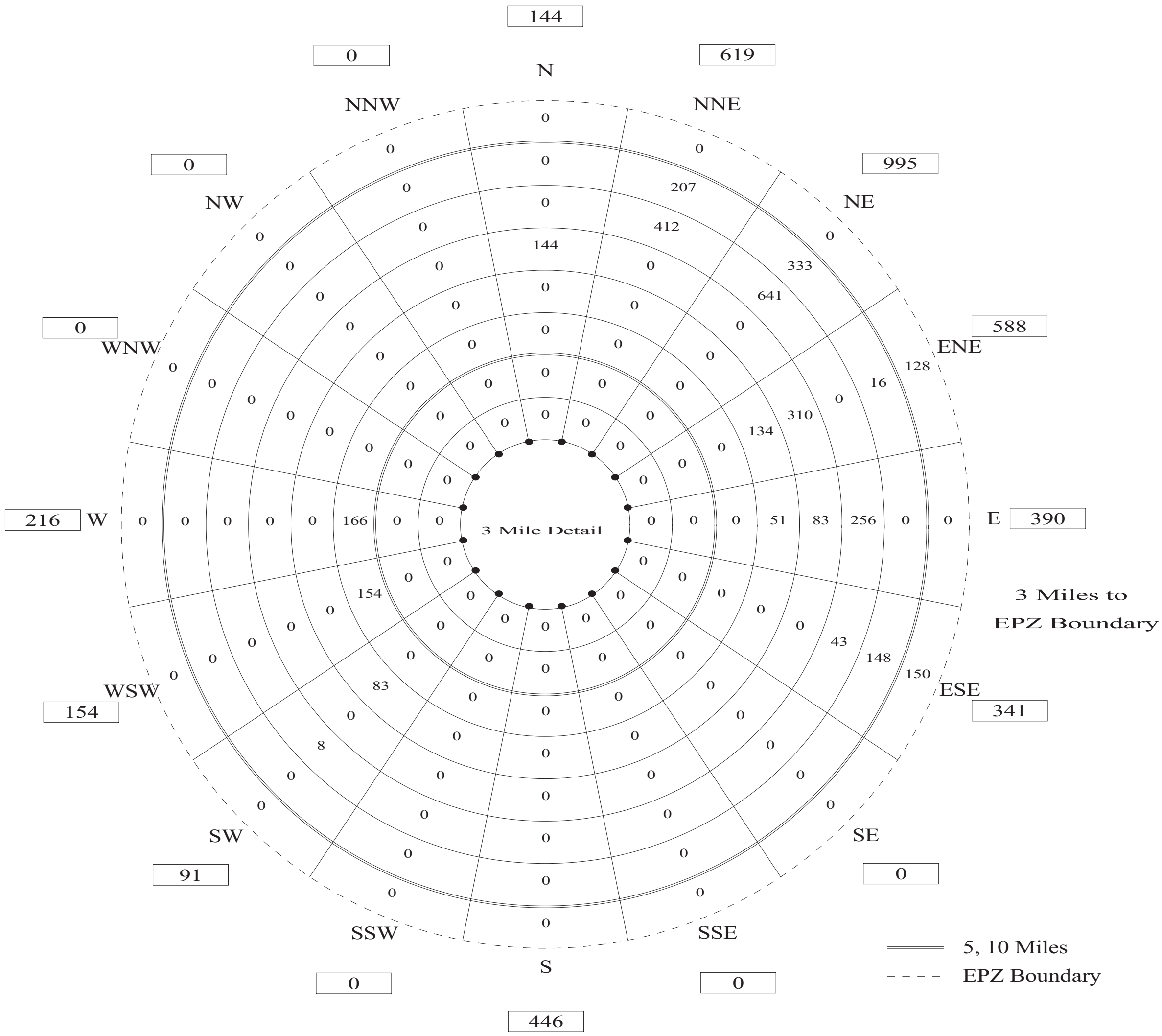
Data for major employers (more than 50 total employees) in the EPZ was provided by the county offices of emergency management. The locations of these facilities were mapped using GIS software. Additional commercial properties were located using overhead imagery and mapped in GIS; estimates of parking lot capacity were also made using the imagery. The GIS map was overlaid with the evacuation analysis network and employees were loaded onto appropriate links. The map of major employers and commercial properties in the EPZ can be seen in Appendix E.

Data provided by the county offices of emergency management indicate that, on average, 64% of the employees in the EPZ travel to work from outside the EPZ. This percentage was applied to the data provided by the counties to estimate the total number of people commuting into the EPZ to work.

An occupancy of 1.08 persons per employee-vehicle obtained from the telephone survey, was used to determine the number of evacuating employee vehicles.

Table 3-4 presents non-EPZ Resident employee and vehicle estimates by sub-zone. Figures 3-6 and 3-7 present these data by sector.

Table 3-4. Summary of Non-EPZ Employees by Sub-Zone		
Sub-Zone	**Total Non-EPZ Employees**	**Employee Vehicles**
A	467	432
B	**No employment**	
C		
D		
E	2,048	1,896
F	267	247
G	597	554
H	**No employment**	
I	8	7
J	**No employment**	
K	453	419
L	144	133
M	**No employment**	
N		
TOTAL	**3,984**	**3,688**



Employees			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	446	0-1	446
1-2	0	0-2	446
2-3	71	0-3	517
3-4	0	0-4	517
4-5	0	0-5	517
5-6	320	0-6	837
6-7	268	0-7	1105
7-8	537	0-8	1642
8-9	1360	0-9	3002
9-10	704	0-10	3706
10-EPZ	278	0-EPZ	3984

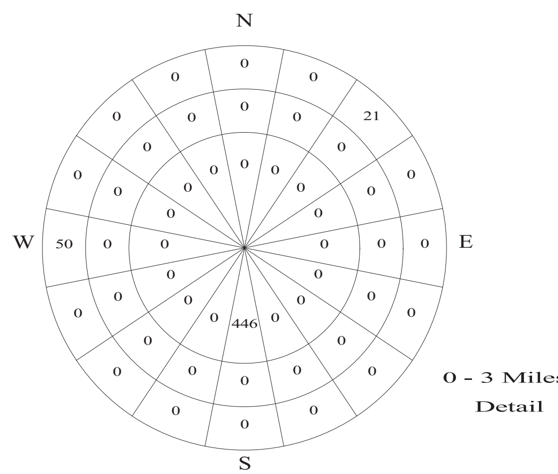
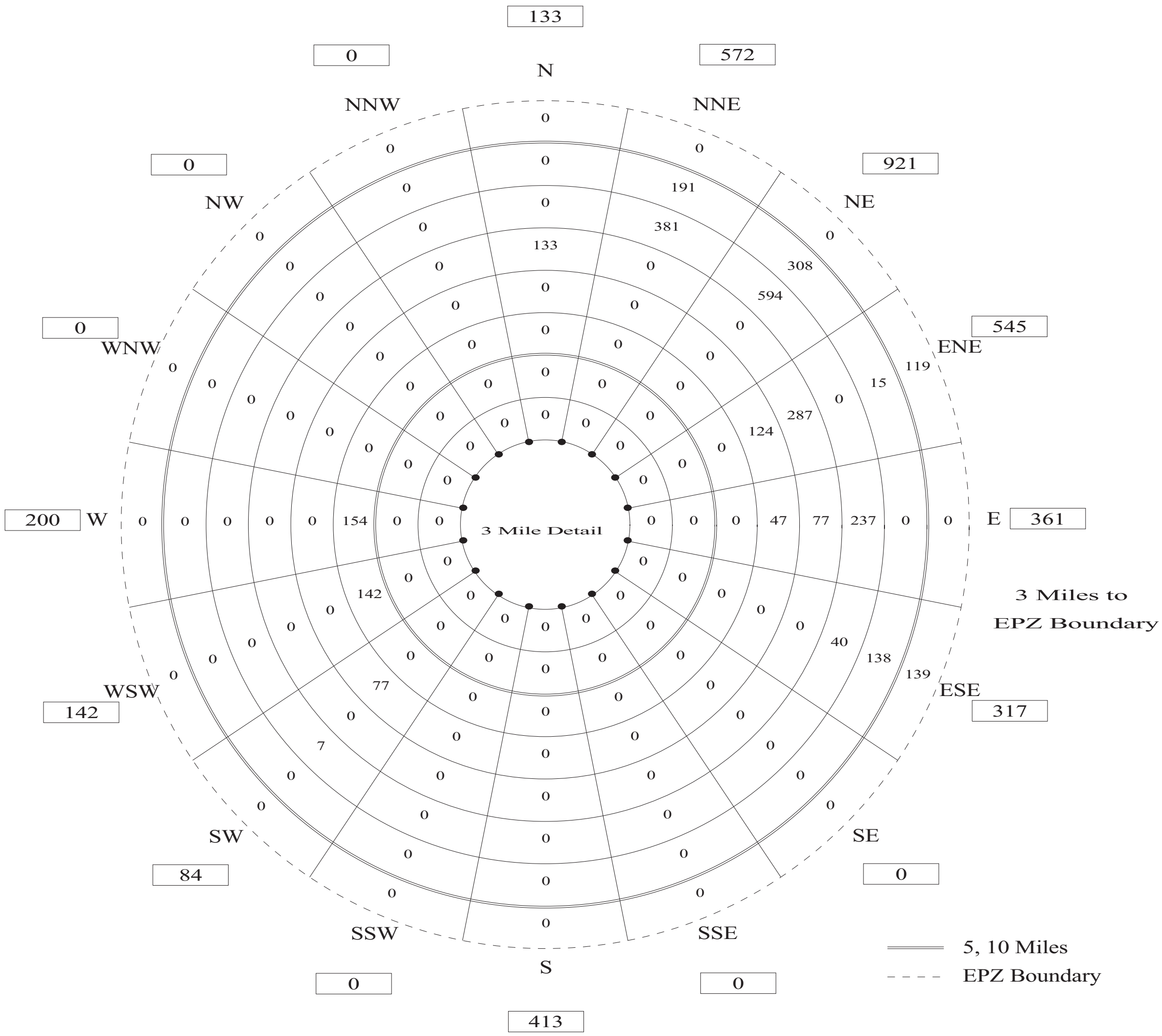


Figure 3-6. Employee Population by Sector



Employee Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	413	0-1	413
1-2	0	0-2	413
2-3	65	0-3	478
3-4	0	0-4	478
4-5	0	0-5	478
5-6	296	0-6	774
6-7	248	0-7	1022
7-8	497	0-8	1519
8-9	1259	0-9	2778
9-10	652	0-10	3430
10-EPZ	258	0-EPZ	3688

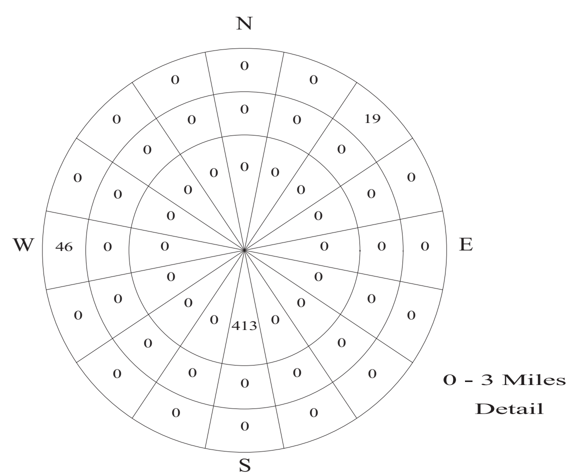


Figure 3-7. Employee Vehicles by Sector

Medical Facilities

Data request forms were completed for each of the medical facilities within the HNP EPZ. Chapter 8 details the evacuation of medical facilities and their patients. The number and type of evacuating vehicles that need to be provided depends on the patients' states of health. Buses can transport up to 30 people; wheelchair buses, up to 15 people; wheelchair vans, up to 4 people; ambulances, up to 2 people (patients).

External Traffic

Vehicles will be traveling through the EPZ (external-external trips) at the time of an accident. After the Advisory to Evacuate is announced, these through travelers will also evacuate. These through vehicles are assumed to travel on the major routes through the EPZ (e.g. US Hwy 1 and US Hwy 64). It is assumed that this traffic will continue to enter the EPZ during the 90 minutes following the Advisory to Evacuate. We estimate approximately 12,150 vehicles enter the EPZ as external-external trips during this period. External traffic is 40% less for evening scenarios.

4. ESTIMATION OF HIGHWAY CAPACITY

The ability of the road network to service vehicle demand is a major factor in determining how rapidly an evacuation can be completed. The capacity of a road is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane of roadway during a given time period under prevailing roadway, traffic and control conditions as stated in the 2000 Highway Capacity Manual (HCM).

In discussing capacity, different operating conditions have been assigned alphabetical designations, A through F, to reflect the range of traffic operational characteristics. These designations have been termed "Levels of Service" (LOS). For example, LOS A connotes free-flow and high-speed operating conditions; LOS F represents a forced flow condition. LOS E describes traffic operating at or near capacity.

Another concept, closely associated with capacity, is “Service Volume” (SV). Service volume is defined as “The maximum hourly rate at which vehicles, bicycles or persons reasonably can be expected to traverse a point or uniform section of a roadway during an hour under specific assumed conditions while maintaining a designated level of service.” This definition is similar to that for capacity. The major distinction is that values of SV vary from one LOS to another, while capacity is the service volume at the upper bound of LOS E, only.

This distinction is illustrated in Exhibit 12-15 of the HCM. As indicated there, the SV varies with Free Flow Speed (FFS), Terrain and LOS. However, the SV at LOS E (which approximates capacity) varies only with Terrain. This Exhibit was referenced when estimating capacity for two-lane rural highways within the EPZ and Shadow Region; such highways are predominant within the analysis network.

Other factors also influence capacity. These include, but are not limited to:

- Lane width
- Shoulder width
- Pavement Condition
- Percent Truck Traffic
- Weather conditions (rain, snow, fog, wind speed, ice)

These factors are considered during the road survey and in the capacity estimation process; some factors have greater influence on capacity than others. For example, lane and shoulder width have only a limited influence on free flow speed (FFS) according to Exhibit 20-5 of the HCM. Consequently, lane and shoulder widths at the narrowest points were observed during the road survey and these observations were recorded, but no detailed measurements of lane or shoulder width were taken. The estimated FFS were measured using the survey vehicle’s speedometer and observing local traffic.

As discussed in Section 2.3, it is necessary to adjust capacity estimates to represent the prevailing conditions during inclement weather. Based on limited empirical data, weather conditions such as heavy rain reduce the values of free speed and of highway capacity by approximately 10 percent. Over the last decade new studies have been made on the effects of rain on traffic capacity. These studies indicate a range of effects between 5 and 20 percent depending on wind speed and precipitation rates.

Given the suburban character of the EPZ, its population, and the availability of well-maintained highways, congestion arising from evacuation is likely to exist, especially in the northeastern portion of the EPZ near Raleigh. As such, estimates of roadway capacity must be determined with great care.

Rural highways generally consist of: (1) one or more uniform sections with limited access (driveways, parking areas) characterized by "uninterrupted" flow; and (2) approaches to at-grade intersections where flow can be "interrupted" by a control device or by turning or crossing traffic at the intersection. Due to these differences, separate estimates of capacity must be made for each section. Often, the approach to the intersection is widened by the addition of one or more lanes, to compensate for the lower capacity of the approach due to the factors there that can interrupt the flow of traffic. These additional lanes are recorded during the field survey and later entered as input to the I-DYNEV system.

Capacity Estimations on Approaches to Intersections

At-grade intersections are apt to become the first bottleneck locations under local heavy traffic volume conditions. This characteristic reflects the need to allocate access time to the respective competing traffic streams by exerting some form of control. During evacuation, control at critical intersections will often be provided by traffic control personnel assigned for that purpose, whose directions may supersede traffic control devices. The Traffic Management Plan identifies these locations (called Traffic Control Points, TCP) and the management procedures applied.

The per-lane capacity of an approach to a signalized intersection can be expressed (simplistically) in the following form:

$$Q_{cap,m} = \left(\frac{3600}{h_m}\right) \bullet \left[\frac{G-L}{C}\right]_m = \left(\frac{3600}{h_m}\right) \bullet P_m$$

where:

Qcap,m	=	Capacity of a single lane of traffic on an approach, which executes movement, *m*, upon entering the intersection; vehicles per hour (vph)
h_m	=	Mean queue discharge headway of vehicles on this lane that are executing movement, *m*; seconds per vehicle
G_m	=	The mean duration of GREEN time servicing vehicles that are executing movement, *m*, for each signal cycle; seconds
L	=	The mean "lost time" for each signal phase servicing movement, m;

seconds

C = The duration of each signal cycle; seconds

P_m = The proportion of GREEN time allocated for vehicles executing movement, *m*, from this lane. This value is specified as part of the control treatment.

m = The movement executed by vehicles after they enter the intersection: through, left-turn, right-turn, diagonal.

The turn-movement-specific mean discharge headway h_m, depends in a complex way upon many factors: roadway geometrics, turn percentages, the extent of conflicting traffic streams, the control treatment, and others. A primary factor is the value of "saturation queue discharge headway", h_{sat}, which applies to through vehicles that are not impeded by other conflicting traffic streams. This value, itself, depends upon many factors including motorist behavior. Formally, we can write,

$$h_m = f_m (h_{sat}, F_1, F_2, ...)$$

where:

h_{sat} = Saturation discharge headway for through vehicles; seconds per vehicle

F_1, F_2 = The various known factors influencing h_m

$f_m(\cdot)$ = Complex function relating h_m to the known (or estimated) values of $h_{sat}, F_1, F_2, \ldots$

The estimation of h_m for specified values of $h_{sat}, F_1, F_2, ...$ is undertaken within the PC-DYNEV simulation model and within the TRAD model by a mathematical model[1]. The resulting values for h_m always satisfy the condition:

$$h_m \geq h_{sat}$$

That is, the turn-movement-specific discharge headways are always greater than, or equal to the saturation discharge headway for through vehicles. These headways (or its inverse equivalent, “saturation flow rate”), may be determined by observation or using the procedures of the Highway Capacity Manual.

The above discussion is necessarily brief given the scope of this ETE report and the complexity of the subject of intersection capacity. In fact, the two longest chapters in the HCM (16 and 17), each well over 100 pages, address this topic. The factors, F_1, F_2, …, influencing saturation flow rate are indentified in equation (16-4) and Exhibit 16-7 of the

[1] Lieberman, E., "Determining Lateral Deployment of Traffic on an Approach to an Intersection", McShane, W. & Lieberman, E., "Service Rates of Mixed Traffic on the far Left Lane of an Approach". Both papers appear in Transportation Research Record 772, 1980.

HCM; Exhibit 10-12 identifies the required data and Exhibit 10-7 presents representative values of Service Volume.

Capacity Estimation Along Sections of Highway

The capacity of highway sections -- as distinct from approaches to intersections -- is a function of roadway geometrics, traffic composition (e.g. percent heavy trucks and buses in the traffic stream) and, of course, motorist behavior. There is a fundamental relationship which relates service volume to traffic density. Figure 4-1 describes this relationship.

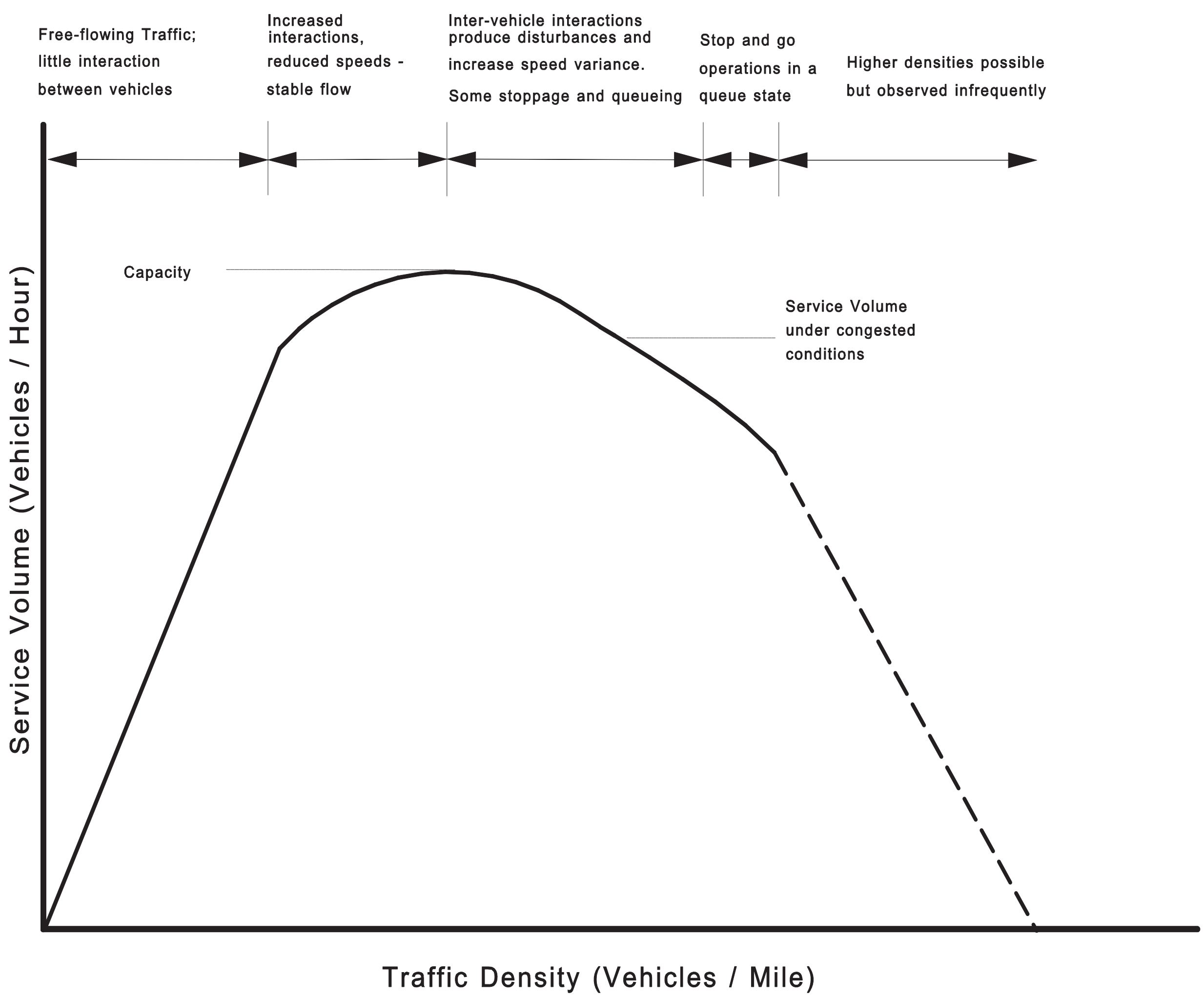


Figure 4-1. Fundamental Relationship Between Volume and Density

As indicated, there are two flow regimes: (1) Free Flow (left side of curve); and (2) Forced Flow (right side). In the Free Flow regime, the traffic demand is fully serviced; the service volume increases as demand volume and density increase, until the service volume attains its maximum value, which is the capacity of the highway section. As traffic demand and the resulting highway density increase beyond this "critical" value, the rate at which traffic can be serviced (i.e. the service volume) can actually decline below capacity. Therefore, in order to realistically represent traffic performance during congested conditions (i.e. when demand exceeds capacity), it is necessary to estimate the service volume, V_F, under congested conditions.

The value of V_F can be expressed as:

$$V_F = R \times \text{Capacity}$$

where R = Reduction factor which is less than unity.

We have employed a value of R=0.85. The advisability of such a capacity factor is based upon empirical studies that identified a fall-off in the service flow rate when congestion occurs at “bottlenecks” or “choke points” on a freeway system. Zhang and Levinson[2] describe a research program that collected data from a computer-based surveillance system (loop detectors) installed on the Interstate Highway System, at 27 active bottlenecks in the twin cities metro area in Minnesota over a 7-week period. When flow breakdown occurs, queues are formed which discharge at lower flow rates than the maximum capacity prior to observed breakdown. These queue discharge flow (QDF) rates vary from one location to the next and also vary by day of week and time of day based upon local circumstances. The cited reference presents a mean QDF of 2,016 passenger cars per hour per lane (pcphpl). This figure compares with the nominal capacity estimate of 2,250 pcphpl estimated for the ETE and indicated in Appendix K for freeway links. The ratio of these two numbers is 0.896 which translates into a capacity reduction factor of 0.90. The data collected in the cited reference indicates that the variation of QDF at a location is generally in the range of +/- 5% about the average QDF. That is, the lower tail of this distribution would be equivalent to a capacity reduction factor of 0.90 - 0.05 = 0.85 which is the figure adopted.

It is seen that a conservative view is taken in estimating the capacity at bottlenecks when congestion develops (this capacity, of course, is the QDF rate discussed above). One could argue that a more representative value for this capacity reduction factor could be 0.90 as discussed above. Given the emergency conditions, a conservative stance is justified. Therefore, a factor of 0.85 is applied only when flow breaks down, as determined by the simulation model.

[2] Lei Zhang and David Levinson, “Some Properties of Flows at Freeway Bottlenecks,” Transportation Research Record 1883, 2004.

Rural roads, like freeways, are classified as “uninterrupted flow” facilities. (This is in contrast with urban street systems which have closely spaced signalized intersections and are classified as “interrupted flow” facilities.) As such, traffic flow along rural roads is subject to the same effects as freeways in the event traffic demand exceeds the nominal capacity, resulting in queuing and lower QDF rates. As a practical matter, rural roads rarely break down at locations away from intersections. The breakdowns on rural roads which are experienced on this network occur at intersections where other model logic applies. Therefore, the application of a factor of 0.85 is appropriate on rural roads but rarely, if ever, activated.

The estimated value of capacity is based primarily upon the type of facility and on roadway geometrics. Sections of roadway with adverse geometrics are characterized by lower free-flow speeds and lane capacity. Table 12-15 in the Highway Capacity Manual was referenced to estimate saturation flow rates. The impact of narrow lanes and shoulders on free-flow speed and on capacity is not material, particularly when flow is predominantly in one direction.

The procedure used here was to estimate "section" capacity, V_E, based on observations made traveling over each section of the evacuation network, by the posted speed limits and travel behavior of other motorists and by reference to the 2000 Highway Capacity Manual. It was then determined for each highway section, represented as a network link, whether its capacity would be limited by the "section-specific" service volume, V_E , or by the intersection-specific capacity. For each link, the model selects the lower value of capacity.

<u>Application to the Harris Nuclear Plant EPZ</u>

As part of the development of the Harris Nuclear Plant (HNP) EPZ traffic network, an estimate of roadway capacity is required. The source material for the capacity estimates presented herein is contained in:

> 2000 Highway Capacity Manual (HCM)
> Transportation Research Board
> National Research Council
> Washington, D.C.

The highway system in the HNP EPZ consists primarily of three categories of roads and, of course, intersections:

- Two-lane roads: Local, State
- Multi-lane Highways (at-grade)
- Freeways (e.g., US Hwy 1)

Each of these classifications will be discussed.

Two-Lane Roads

Ref: HCM Chapters 12 and 20

Two lane roads comprise the majority of highways within the EPZ. The per-lane capacity of a two-lane highway is estimated at 1700 passenger cars per hour (pc/h). This estimate is essentially independent of the directional distribution of traffic volume except that, for extended distances, the two-way capacity will not exceed 3200 pc/h. The HCM procedures then estimate Level of Service (LOS) and Average Travel Speed. The evacuation simulation model accepts the specified value of capacity as input and computes average speed based on the time-varying demand: capacity relations.

Based on the field survey and on expected traffic operations associated with evacuation scenarios:

- Most sections of two-lane roads within the EPZ are classified as “Class I”, with "level terrain"; some are “rolling terrain”.
- “Class II” highways are mostly those within city limits.

Multi-Lane Highway

Ref: HCM Chapters 12 and 21

Exhibit 21-23 (in the HCM) presents a set of curves that indicates a per-lane capacity of approximately 2100 pc/h, for free-speeds of 55-60 mph. Based on observation, the multi-lane highways outside of urban areas within the EPZ, service traffic with free-speeds in this range. The actual time-varying speeds computed by the simulation model reflect the demand:capacity relationship and the impact of control at intersections.

Chapter 12 presents the basic concepts underlying the procedures in Chapters 20 and 21.

Freeways

Ref: HCM Chapters 13, 22-25

Chapter 22 of the HCM describes a procedure for integrating the results obtained in Chapters 23, 24 and 25, which compute capacity and LOS for freeway components. The discussion also references Chapter 31, which presents a discussion on simulation models. The simulation model, PC-DYNEV, automatically performs this integration process.

Chapter 23 of the HCM presents procedures for estimating capacity and LOS for “Basic Freeway Segments". Exhibit 23-3 of the HCM2000 presents capacity vs. free speed estimates.

Free Speed:	55	60	65	70+
Per-Lane Capacity (pc/h):	2250	2300	2350	2400

The inputs to the simulation model are highway geometrics, and free-speeds and capacity based on field observations. The simulation logic calculates actual time-varying speeds based on demand: capacity relationships.

Chapter 24 of the HCM presents procedures for estimating capacity, speed, density and LOS. The simulation model contains logic that relates speed to the demand volume: capacity ratio. The value of capacity that is obtained from Exhibit 24-8 (of the HCM2000) depends on the "Type" and geometrics of the weaving segment and on the "Volume Ratio" (ratio of weaving volume to total volume).

Chapter 25 of the HCM presents procedures for estimating capacities of ramps and of "merge" areas. The capacity of a merge area "is determined primarily by the capacity of the downstream freeway segment". Values of this merge area capacity are presented in Exhibit 25-7 of the HCM2000, and depend on the number of freeway lanes and on the freeway free speed. The KLD simulation model logic simulates the merging operations of the ramp and freeway traffic. If congestion results from an excess of demand relative to capacity, then the model allocates service appropriately to the two entering traffic streams and produces LOS F conditions. (The HCM does not address LOS F explicitly).

Chapter 13 presents basic concepts underlying the procedures in the later chapters.

<u>Intersections</u>

Ref: HCM Chapters 10, 16, 17

Procedures for estimating capacity and LOS for approaches to intersections are presented in Chapters 16 (signalized intersections) and 17 (unsignalized intersections). As previously mentioned, these are the two longest chapters in the HCM 2000, reflecting the complexity of these procedures. The simulation logic is likewise complex, but different; as stated on page 31-21 of the HCM2000:

> *“Assumptions and complex theories are used in the simulation model to represent the real-world dynamic traffic environment.”*

Simulation and Capacity Estimation

Chapter 31 of the HCM is entitled, "Simulation and other Models." The lead sentence on the subject of Traffic Simulation Models is:

> Traffic simulation models use numerical techniques on a digital computer to create a description of how traffic behaves over extended periods of time for a given transportation facility or system…by stepping through time and across space, tracking events as the system state unfolds. Traffic simulation models focus on the dynamic of traffic flow.

In general terms, this description applies to the PC-DYNEV model, which is further described in Appendix C. It is essential to recognize that simulation models do not replicate the methodology and procedures of the HCM – they *replace* these procedures by describing the complex interactions of traffic flow and computing Measures of Effectiveness (MOE) detailing the operational performance of traffic over time and by location.

All simulation models must be calibrated properly with field observations that quantify the performance parameters applicable to the analysis network. Two of the most important of these are: (1) Free flow speed (FFS); and (2) saturation headway, h_{sat}. The first of these is estimated by direct observation during the road survey; the second is estimated using the concepts of the HCM, as described earlier. These parameters are listed in Appendix K, for each network link.

5. ESTIMATION OF TRIP GENERATION TIME

Federal Government guidelines (see NUREG 0654, Appendix 4) specify that the planner estimate the distributions of elapsed times associated with mobilization activities undertaken by the public to prepare for the evacuation trip. The elapsed time associated with each activity is represented as a statistical distribution reflecting differences between members of the public. The quantification of these activity-based distributions relies largely on the results of the telephone survey (Appendix F). We define the sum of these distributions of elapsed times as the Trip Generation Time Distribution.

Background

In general, an accident at a nuclear power station is characterized by the following Emergency Action Classification Levels (see Appendix 1 of NUREG 0654 for details):

1. Unusual Event
2. Alert
3. Site Area Emergency
4. General Emergency

At each level, the Federal guidelines specify a set of Actions to be undertaken by the Licensee, and by State and Local offsite authorities. As a Planning Basis, we will adopt a conservative posture, in accord with Federal Regulations, that a rapidly escalating accident will be considered in calculating the Trip Generation Time. We will assume:

a. The Advisory to Evacuate will be announced coincident with the emergency notification.
b. Mobilization of the general population will commence up to 10 minutes after the alert notification.
c. Evacuation Time Estimates (ETE) are measured relative to the Advisory to Evacuate.

The adoption of this planning basis is not a representation that these events will occur at the Harris Nuclear Plant (HNP) within the indicated time frame. Rather, these assumptions are necessary in order to:

- Establish a temporal framework for estimating the Trip Generation distribution as recommended in Appendix 4 of NUREG 0654.

- Identify temporal points of reference that uniquely define "Clear Time" and ETE.

It is more likely that a longer time will elapse between the various classes of an emergency at HNP and that the Advisory to Evacuate is announced somewhat later than the siren alert.

For example, suppose one hour elapses from the declaration of a General Emergency (and the siren alert) to the Advisory to Evacuate. In this case, it is reasonable to expect some degree of spontaneous evacuation by the public during this one-hour period. As a result, the population within the Emergency Planning Zone (EPZ) will be lower when the Advisory to Evacuate is announced, than at the time of the General Emergency. Thus, the time needed to evacuate the EPZ, after the Advisory to Evacuate will be less than the estimates presented in this report.

The notification process consists of two events:

- Transmitting information (e.g. using sirens, tone alerts, EAS broadcasts, loud speakers).
- Receiving and correctly interpreting the information that is transmitted.

The peak population within the EPZ approximates 91,000 persons[1] who are deployed over an area of approximately 314 square miles and are engaged in a wide variety of activities. It must be anticipated that some time will elapse between the transmission and receipt of the information advising the public of an accident.

The amount of elapsed time will vary from one individual to the next depending where that person is, what that person is doing, and related factors. Furthermore, some persons who will be directly involved with the evacuation process may be outside the EPZ at the time that the emergency is declared. These people may be commuters, shoppers and other travelers who reside within the EPZ and who will return to join the other household members upon receiving notification of an emergency.

As indicated in NUREG 0654, the estimated elapsed times for the receipt of notification can be expressed as a distribution reflecting the different notification times for different people within, and outside, the EPZ. By using time distributions, it is also possible to distinguish between different population groups and different day-of-week and time-of-day scenarios, so that accurate ETE may be obtained.

For example, people at home or at work within the EPZ will be notified by siren, and/or tone alert and/or radio. Those well outside the EPZ will be notified by telephone, radio, TV and word-of-mouth, with potentially longer time lags. Furthermore, the spatial distribution of the EPZ population will differ with time of day - families will be united in the evenings, but dispersed during the day. In this respect, weekends will also differ from weekdays.

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[1] This estimate is for a summer, weekend, midday scenario (Scenario 3) and includes 100% of permanent residents, 47% of employees commuting into the EPZ to work, and 100% of transients.

Fundamental Considerations

The environment leading up to the time that people begin their evacuation trips consists of a sequence of events and activities. Each event (other than the first) occurs at an instant in time and is the outcome of an activity.

Activities are undertaken over a period of time. Activities may be in "series" (i.e. to undertake an activity implies the completion of all preceding activities) or may be in parallel (two or more activities may take place over the same period of time). Activities conducted in series are functionally dependent on the completion of prior activities; activities conducted in parallel are functionally independent of one another. The relevant events associated with the public's preparation for evacuation are:

Event Number	Event Description
1	Notification-accident condition
2	Awareness of accident situation
3	Depart place of work or elsewhere, to return home
4	Arrive (or be at) home
5	Begin evacuation trip to leave the area

Associated with each sequence of events are one or more activities, as outlined below:

Event Sequence	Activity	Distribution
1 → 2	Public receives notification information	1
2 → 3	Prepare to leave work	2
2,3 → 4	Travel home*	3
2,4 → 5	Prepare to leave for evacuation trip	4

*If already at home, this is a null (no-time-consumed) activity.

These relationships are shown graphically in Figure 5-1.

An employee who lives outside the EPZ will follow sequence (c) of Figure 5-1. A household within the EPZ that has one or more commuters at work, and will await their return before beginning the evacuation trip will follow the first sequence of Figure 5-1(a). A household within the EPZ that has no commuters at work will follow the second sequence of Figure 5-1(a), regardless of day of week or time of day. Note that event 5, "Leave to evacuate the area," is conditional either on event 2 or on event 4. For this study, we adopt the conservative posture that all activities will occur in sequence.

Households with no commuters on weekends or in the evening/night-time, will follow the applicable sequence in Figure 5-1(b). Transients will always follow one of the sequences of Figure 5-1(b). Some transients away from their residence could elect to evacuate immediately without returning to the residence, as indicated in the second sequence.

It is seen from Figure 5-1, that the Trip Generation time (i.e. the total elapsed time from Event 1 to Event 5) depends on the scenario and will vary from one household to the next. Furthermore, Event 5 depends, in a complicated way, on the time distributions of all activities preceding that event. That is, to estimate the time distribution of Event 5, we must obtain estimates of the time distributions of all preceding events.

Estimated Time Distributions of Activities Preceding Event 5

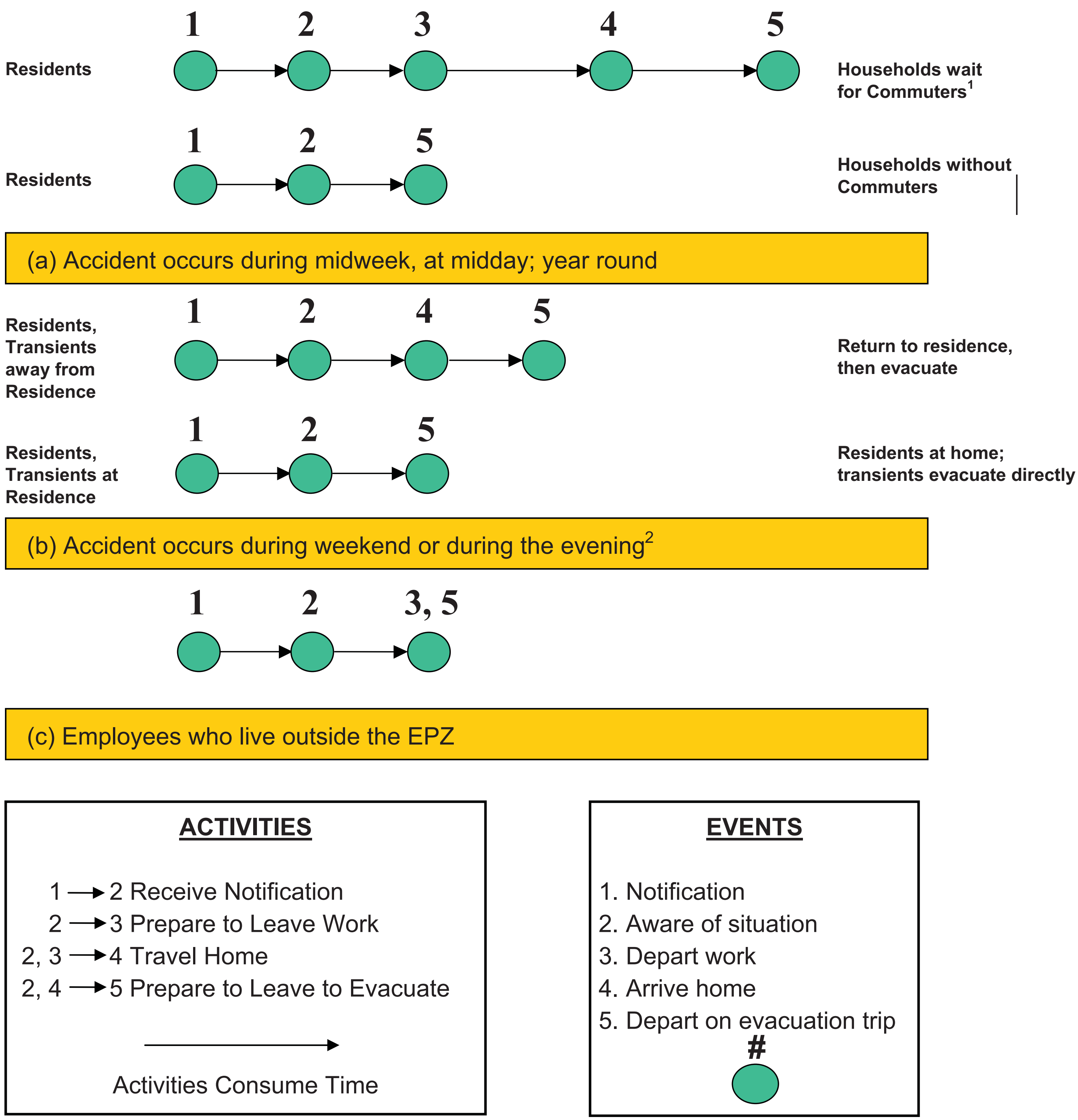
The time distribution of an event is obtained by "summing" the time distributions of all prior contributing activities. (This "summing" process is quite different than an algebraic sum since we are operating on distributions – not scalar numbers).

Time Distribution No. 1, Notification Process: Activity 1 → 2

It is assumed that 85 percent of those people within the EPZ will be aware of the accident within 30 minutes, with the remainder notified within the following 20 minutes. The notification distribution is given below:

Distribution No. 1, Notification Time: Activity 1 → 2

Elapsed Time (Minutes)	Percent of Population Notified
0	0
5	7
10	13
15	26
20	46
25	65
30	85
35	90
40	95
45	98
50	100



[1] Applies for evening and weekends also if commuters are at work.
[2] Applies throughout the year for transients.

Figure 5-1. Events and Activities Preceding the Evacuation Trip

Distribution No. 2, Prepare to Leave Work: Activity 2 $\rightarrow$ 3

It is reasonable to expect that the vast majority of business enterprises within the EPZ will elect to shut down following notification and most employees would leave work quickly. Commuters, who work outside the EPZ could, in all probability, also leave quickly since facilities outside the EPZ would remain open and other personnel would remain. Personnel or farmers responsible for equipment or livestock would require additional time to secure their facility. The distribution of Activity 2 → 3 reflects data obtained by the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work
0	0
5	29
10	43
15	56
20	63
25	67
30	83
35	86
40	88
45	92
50	93
55	93
60	98
65	98
70	98
75	99
80	99
85	99
90	99
95	99
100	99
105	99
110	99
115	99
120	100

NOTE: The survey data was normalized to distribute the "don't know" response. That is, the sample was reduced in size to include only those returns which included responses to this question. The underlying assumption is that the distribution of this activity for the “Don’t know” responders, if the event takes place, would be the same as those responders who provided estimates.

Distribution No. 3, Travel Home: Activity 3 → 4

These data are provided directly by the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0
5	8
10	19
15	33
20	50
25	59
30	76
35	82
40	85
45	94
50	96
55	96
60	98
65	98
70	99
75	99
80	99
85	99
90	99
95	99
100	100

NOTE: The survey data was normalized to distribute the "Don't know" response

Distribution No. 4, Prepare to Leave Home: Activity 2, 4 → 5

These data are provided directly by the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Pct. Ready to Evacuate
0	0
5	9
10	18
15	27
20	39
25	51
30	63
35	66
40	69
45	72
50	76
55	81
60	85
65	88
70	90
75	92
80	92
85	92
90	92
95	93
100	93
105	93
110	94
115	95
120	95
125	96
130	96
135	97
140	97
145	97
150	97
155	97
160	97
165	97
170	97
175	97
180	98
185	99
190	99
195	100

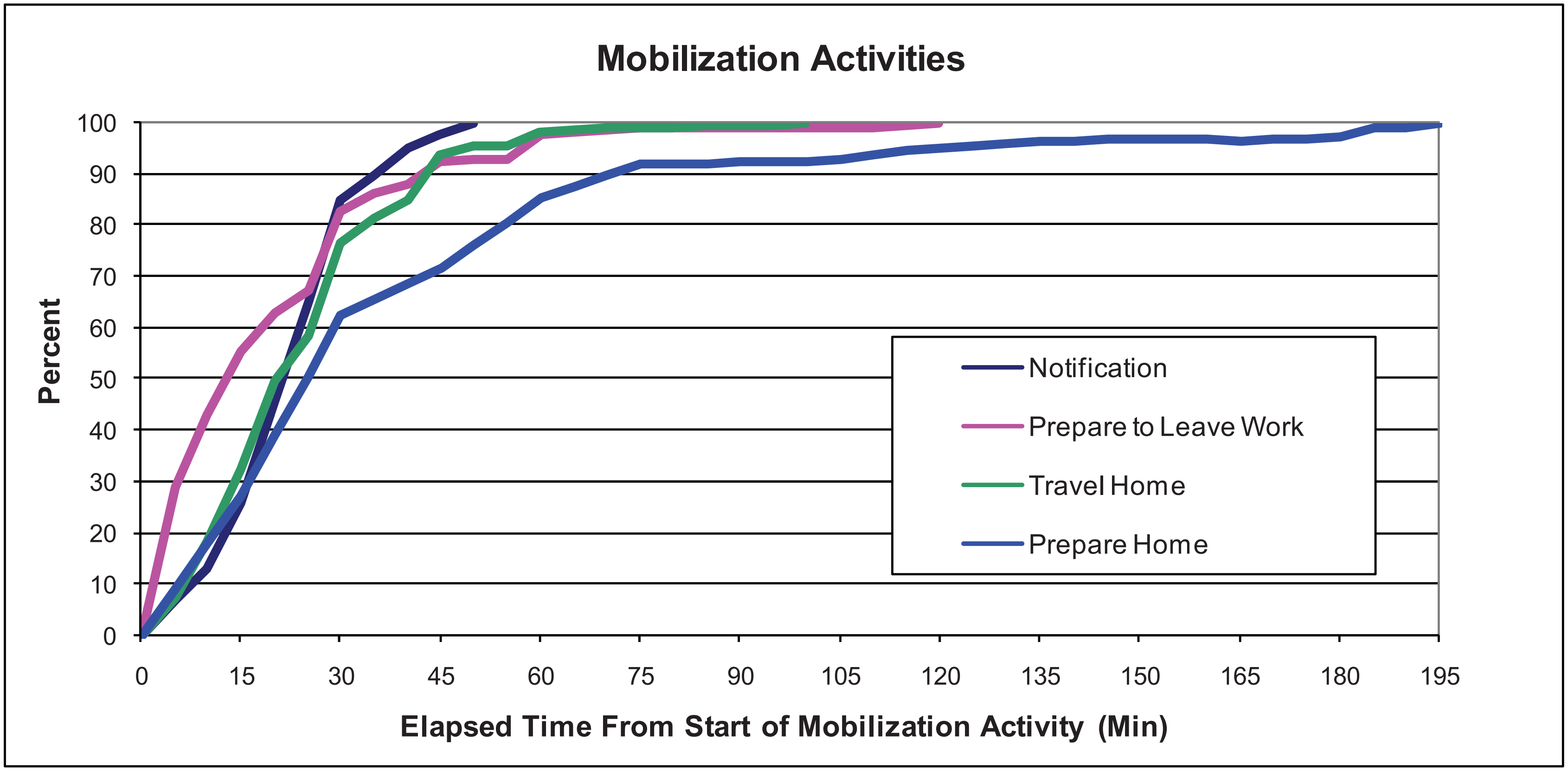


Figure 5-2. Evacuation Mobilization Activities

Calculation of Trip Generation Time Distribution

The time distributions for each of the mobilization activities presented herein must be combined to form the appropriate Trip Generation Distributions. We assume that the stated events take place in sequence such that all preceding events must be completed before the current event can occur. For example, if a household awaits the return of a commuter, the work-to-home trip (Activity 3 → 4) must precede Activity 4 → 5.

To calculate the time distribution of an event that is dependent on two sequential activities, it is necessary to "sum" the distributions associated with these prior activities. The distribution summing algorithm is applied repeatedly as shown to form the required distribution. As an outcome of this procedure, new time distributions are formed; we assign "letter" designations to these intermediate distributions to describe the procedure.

Apply "Summing" Algorithm To:	Distribution Obtained	Event Defined
Distributions 1 and 2	Distribution A	Event 3
Distributions A and 3	Distribution B	Event 4
Distributions B and 4	Distribution C	Event 5
Distributions 1 and 4	Distribution D	Event 5

Distributions A through D are described below:

Distribution	Description
A	Time distribution of commuters departing place of work (Event 3). Also applies to employees who work within the EPZ who live outside, and to Transients within the EPZ.
B	Time distribution of commuters arriving home.
C	Time distribution of residents with commuters leaving home to begin the evacuation trip.
D	Time distribution of residents in households without commuters to begin the evacuation trip.

As shown in Figure 5-2 and in Appendix F, the mobilization activity distributions have long tails. Combining multiple distributions with long tails results in a distribution with an even longer tail. Thus, the 100th percentile of the combined distribution is indistinct and difficult to quantify. Given these characteristics, a statistical analysis on the mobilization distributions was performed to quantify a “confidence band” about the distribution. This band serves as the basis for establishing the point in time where the long tail should be “truncated”.

The ETE for the vast majority of evacuees should not be distorted for those few stragglers (typically less than 2 percent of households) who take considerably longer to prepare to evacuate. As such, the combined distributions are “truncated” to avoid biasing the ETE. In “truncating” these distributions, the mobilization of the stragglers is advanced. Therefore, the stragglers are not eliminated from the ETE. Appendix F presents the raw distributions for the various mobilization activities. Appendix O describes the statistical analysis used to “truncate” the resultant distributions.

Figure 5-3 presents the combined trip generation distributions designated A, C, and D. These distributions are presented on the same time scale. Comparison of the distributions in Appendix F with those in Figures 5-2 and 5-3 indicates that the combined distributions are somewhat shorter (4 hours) than the individual distributions (up to 6 hours). This is a result of the aforementioned “truncation” procedure.

The PC-DYNEV simulation model is designed to accept varying rates of vehicle trip generation for each origin centroid, expressed in the form of histograms. These histograms, which represent Distributions A, C, and D, properly displaced with respect to one another, are tabulated in Table 5-1 (Distribution B, Arrive Home, omitted for clarity).

The final time period (10) is 900 minutes long. This time period is added to allow the analysis network to clear, in the event congestion persists beyond the trip generation period. Note that there are no trips generated during this final time period.

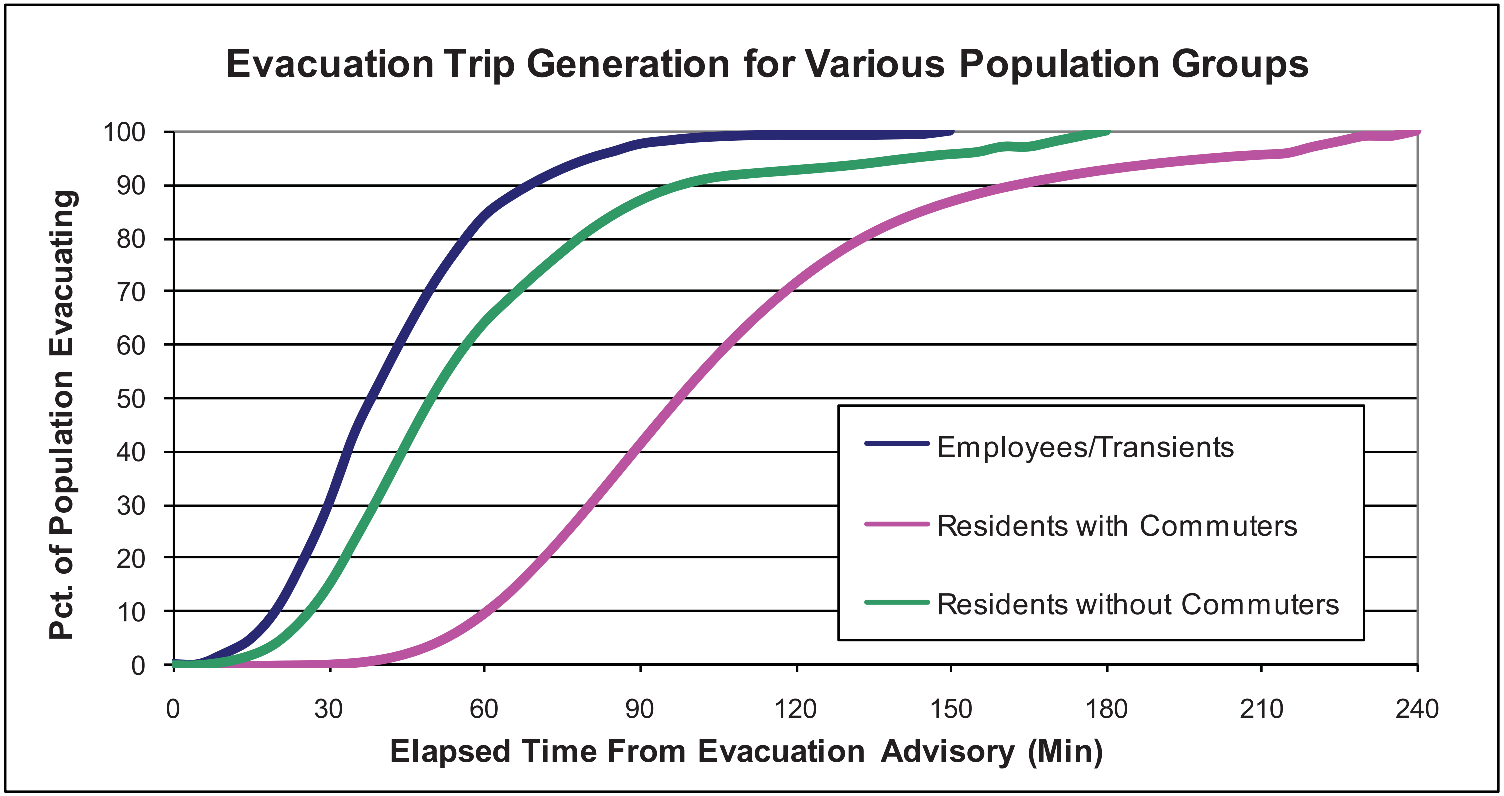


Figure 5-3. Comparison of Trip Generation Distributions

Table 5-1. Trip Generation Time Histograms for the EPZ Population					
Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period			
		Residents With Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Employees (Distribution A)	Transients (Distribution A)
1	15	0	2	5	5
2	15	0	13	23	23
3	15	2	26	33	33
4	15	8	23	22	22
5	30	32	23	14	14
6	30	30	6	2	2
7	30	15	3	1	1
8	30	6	4	0	0
9	60	7	0	0	0
10	900	0	0	0	0

6. DEMAND ESTIMATION FOR EVACUATION SCENARIOS

An evacuation "case" defines a combination of Evacuation Region and Evacuation Scenario. The definitions of "Region" and "Scenario" are as follows:

Region — A grouping of contiguous evacuation sub-zones, that forms either a "keyhole" sector-based area, or a circular area within the EPZ, that must be evacuated in response to a radiological emergency.

Scenario — A combination of circumstances, including time of day, day of week, season, and weather conditions. Scenarios define the number of people in each of the affected population groups and their respective mobilization time distributions.

A total of 25 Regions were defined which encompass all the groupings of sub-zones considered. These Regions are defined in Table 6-1. The sub-zone configurations are identified in Figure 6-1. Each keyhole sector-based area consists of a circular area centered at the Harris Nuclear Plant (HNP), and three adjoining sectors, each with a central angle of 22.5 degrees. These sectors extend to a distance of 5 miles from HNP (Regions R04 to R12), or to the EPZ boundary (Regions R13 to R25). The azimuth of the center sector defines the orientation of these Regions.

A total of 12 Scenarios were evaluated for all Regions. Thus, there are a total of 12 x 25=300 evacuation cases. Table 6-2 is a description of all Scenarios.

Each combination of region and scenario implies a specific population to be evacuated. Table 6-3 presents the percentage of each population group assumed to evacuate for each scenario. Table 6-4 presents the vehicle counts for each scenario.

Table 6-1. Description of Evacuation Regions															
		Sub-Zone													
Region	Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R01	2 mile ring	■													
R02	5-mile ring	■	■	■	■							■	■		
R03	Full EPZ	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Evacuate 2-mile ring and 5 miles downwind															
		Sub-Zone													
Region	Wind Direction Towards:	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R04	N,NW,NNW	■	■										■		
R05	NNE	■	■												
R06	NE,ENE	■	■	■											
R07	E	■	■	■	■										
R08	ESE	■		■	■										
R09	SE	■		■	■							■			
R10	SSE,S	■			■							■			
R11	SSW, SW	■										■			
R12	WSW,W,WNW	■										■	■		
Evacuate 5-mile ring and downwind to EPZ boundary															
		Sub-Zone													
Region	Wind Direction Towards:	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R13	N,NNE	■	■	■	■	■						■	■		■
R14	NE	■	■	■	■	■	■					■	■		
R15	ENE, E	■	■	■	■	■	■	■				■	■		
R16	ESE	■	■	■	■		■	■	■			■	■		
R17	SE	■	■	■	■			■	■			■	■		
R18	SSE	■	■	■	■			■	■	■		■	■		
R19	S	■	■	■	■				■	■		■	■		
R20	SSW	■	■	■	■				■	■	■	■	■		
R21	SW	■	■	■	■					■	■	■	■		
R22	WSW	■	■	■	■					■	■	■	■	■	
R23	W,WNW	■	■	■	■						■	■	■	■	
R24	NW	■	■	■	■							■	■	■	■
R25	NNW	■	■	■	■	■						■	■	■	■

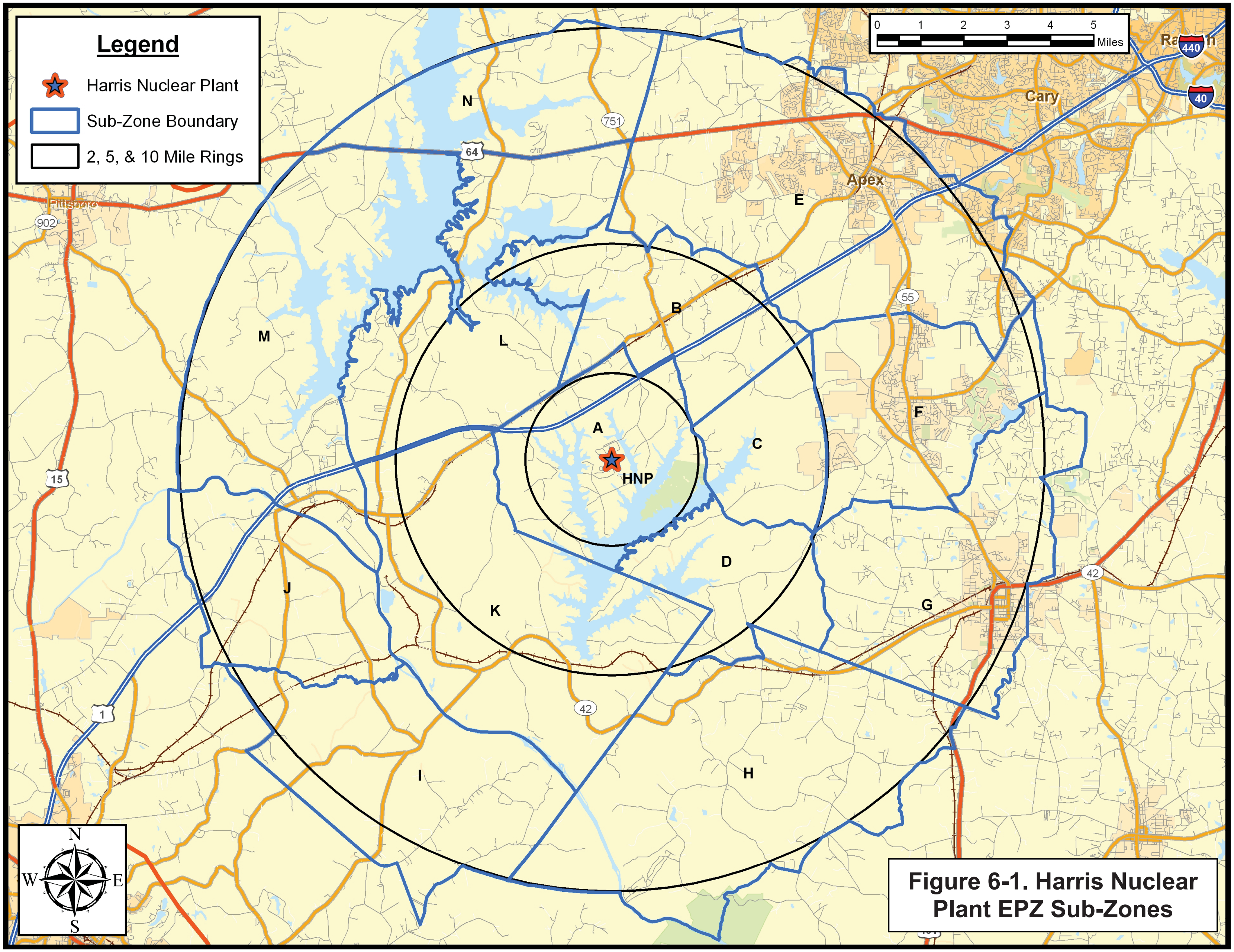


Figure 6-1. Harris Nuclear Plant EPZ Sub-Zones

Table 6-2. Evacuation Scenario Definitions					
Scenario	**Season**	**Day of Week**	**Time of Day**	**Weather**	**Special**
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	Ice	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Midweek, Weekend	Evening	Good	None
12	Summer	Midweek	Midday	Good	New Plant Construction

Note: Schools are assumed to be in session for the Winter season (midweek, midday).

Table 6-3. Percent of Population Groups Evacuating for Various Scenarios

Scenarios	Residents With Commuters in Household	Residents With No Commuters in Household	Employees	Transients	Shadow	Special Events	School Buses	Transit Buses	External Through Traffic
1	68%	32%	96%	50%	33%	0%	10%	100%	100%
2	68%	32%	96%	50%	33%	0%	10%	100%	100%
3	10%	90%	47%	100%	32%	0%	0%	100%	100%
4	10%	90%	47%	100%	32%	0%	0%	100%	100%
5	10%	90%	10%	25%	30%	0%	0%	100%	60%
6	68%	32%	100%	25%	33%	0%	100%	100%	100%
7	68%	32%	100%	25%	33%	0%	100%	100%	100%
8	68%	32%	100%	25%	33%	0%	100%	100%	100%
9	10%	90%	47%	40%	32%	0%	0%	100%	100%
10	10%	90%	47%	40%	32%	0%	0%	100%	100%
11	10%	90%	10%	15%	30%	0%	0%	100%	60%
12	68%	32%	96%	50%	33%	100%	10%	100%	100%

Resident Households With Commuters .... Households of EPZ residents who await the return of commuters prior to beginning the evacuation trip.

Resident Households With No Commuters .... Households of EPZ residents who do not have commuters.

Employees .... EPZ employees who live outside of the EPZ.

Transients .... People who are in the EPZ at the time of an accident for recreational or other (non-employment) purposes.

Shadow .... Residents and employees in the shadow region (outside of the EPZ) who will spontaneously decide to relocate during the evacuation. The basis for the values shown is a 30% relocation of shadow residents along with a proportional percentage of shadow employees. The percentage of shadow employees is computed using the scenario-specific ratio of EPZ employees to residents.

Special Events .... Additional vehicles in the Harris Nuclear Plant area during the construction phase of the new unit.

School and Transit Buses .... Vehicle-equivalents present on the road during evacuation servicing schools and transit-dependent people (1 bus is equivalent to 2 passenger vehicles), respectively.

External Through Traffic .... Traffic on local highways and major arterial roads at the start of the evacuation. This traffic is stopped by access control approximately 90 minutes after the evacuation begins.

Table 6-4. Vehicle Estimates By Scenario*										
Scenarios	**Residents with Commuters**	**Residents without Commuters**	**Employees**	**Transients**	**Shadow**	**Special Events**	**School Buses**	**Transit Buses**	**External Traffic**	**Total Scenario Vehicles**
1	22,048	10,266	3,540	3,127	24,862	-	62	24	12,150	76,079
2	22,048	10,266	3,540	3,127	24,862	-	62	24	12,150	76,079
3	2,205	30,109	1,733	6,253	23,609	-	-	24	12,150	76,083
4	2,205	30,109	1,733	6,253	23,609	-	-	24	12,150	76,083
5	2,205	30,109	369	1,563	22,663	-	-	24	7,290	64,223
6	22,048	10,266	3,688	1,563	24,965	-	618	24	12,150	75,322
7	22,048	10,266	3,688	1,563	24,965	-	618	24	12,150	75,322
8	22,048	10,266	3,688	1,563	24,965	-	618	24	12,150	75,322
9	2,205	30,109	1,733	2,501	23,609	-	-	24	12,150	72,331
10	2,205	30,109	1,733	2,501	23,609	-	-	24	12,150	72,331
11	2,205	30,109	369	938	22,663	-	-	24	7,290	63,598
12**	30,219	14,122	4,877	4,291	32,585	3,241	85	32	12,150	101,602

***The values presented are for an evacuation of the full EPZ (Region R03).**
****All vehicles (except external traffic) have been extrapolated to the Year 2016, which is when the construction workforce will be at its peak. See discussion of construction scenario on pages 3-2 and 3-3.**

7. GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the current results of the computer analyses using the I-DYNEV System described in Appendices B, C and D. These results cover 25 regions within the HNP EPZ and the 12 Evacuation Scenarios discussed in section 6.

The ETE for all Evacuation Cases are presented in Tables 7-1A through 7-1D. **These tables present the estimated times to clear the indicated population percentages from the Evacuation Regions for all Evacuation Scenarios.** The tabulated values of ETE apply to the general population (those not evacuated using transit vehicles) and are obtained from the PC-DYNEV simulation model outputs of vehicles exiting the specified evacuation areas. These data are generated at 10-minute intervals, and then interpolated to the nearest 5 minutes. The ETE for persons evacuated by transit vehicles (schools, special facilities, transit dependent) are presented in section 8.

7.1 Voluntary Evacuation and Shadow Evacuation

We define "voluntary evacuees" as people who are within the EPZ in sub-zones located outside the Evacuation Region, for which an Advisory to Evacuate *has not* been issued, yet who nevertheless elect to evacuate. We define "shadow evacuation" as the movement of people from areas *outside* the EPZ for whom no protective action recommendation has been issued. Both voluntary and shadow evacuation are assumed to take place over the same time frame as the evacuation from within the impacted Evacuation Region.

The ETE for the HNP addresses the issue of voluntary evacuees as discussed in Section 2.2 and displayed in Figure 7-1 (same as Figure 2-1). Figure 7-2 presents the area identified as the Shadow Evacuation Region. This region extends radially from the boundary of the EPZ to a distance of 15 miles from HNP. The estimated 2007 permanent-resident population within the Shadow Region is 171,271 people; this estimate was obtained using the same methodology described in section 3 for permanent resident population residing within the EPZ.

Traffic generated within this Shadow Evacuation Region, traveling away from the HNP location, has a potential for impeding evacuating vehicles from within the Evacuation Region. We assume that the traffic volumes emitted within the Shadow Evacuation Region correspond to 30 percent of the residents there plus a proportionate number of employees in that region (see the Shadow footnote to Table 6-3). **All ETE calculations include this shadow traffic movement.**

7.2 Patterns of Traffic Congestion During Evacuation

Figures 7-3 through 7-6 illustrate the patterns of traffic congestion that arise for the case when the entire EPZ (Region R03) is advised to evacuate during the summer, midweek, midday period under good weather conditions (Scenario 1).

Traffic congestion, as the term is used here, is defined as Level of Service (LOS) F. LOS F is defined as follows (2000 HCM):

> Level of Service F is used to define forced or breakdown flow. This condition exists wherever the amount of traffic approaching a point exceeds the amount that can traverse the point. Queues form behind such locations. Operations within the queue are characterized by stop-and-go waves, and they are extremely unstable. Vehicles may progress at reasonable speeds for several hundred feet or more, and then be required to stop in a cyclic fashion. Level of Service F is used to describe the operating conditions within the queue, as well as the point of the breakdown. It should be noted, however, that in many cases operating conditions of vehicles or pedestrians discharged from the queue may be quite good. Nevertheless, it is the point at which arrival flow exceeds discharge flow, which causes the queue to form, and Level of Service F is an appropriate designation for such points.

This definition is general and conceptual in nature, and applies primarily to uninterrupted flow. Levels of Service for interrupted flow facilities vary widely in terms of both the user's perception of service quality and the operational variables used to describe them.

All highway "links" which experience LOS F at the indicated times are delineated in these Figures by a red line; all others are lightly indicated. Congestion develops in areas with concentrations of population and at traffic bottlenecks. Congestion develops southbound on US Highway 401(south of Fuquay-Varina) and on the approaches to US Highway 1, especially along North Carolina Highway 55 by 1 Hour (Figure 7-3) after the evacuation advisory. Pronounced congestion also exists in Fuquay-Varina at this time.

Figure 7-4 presents the congestion pattern 2 hours after the Advisory to Evacuate. This represents the peak congestion period. The majority of the congestion is in the shadow region within Wake County; however, considerable congestion persists within Fuquay-Varina, southbound on US Highway 401, on the NC Highway 55 approaches to US Highway 1, and on Holly Springs Road northbound. By 3 hours after the Advisory to Evacuate (Figure 7-5), congestion within the EPZ has dissipated; however, some congestion persists in the shadow region.

By 3 hours and 15 minutes (Figure 7-6), all congestion in the study area has dissipated. The absence of congestion on network links (white colored links) implies that traffic demand there has decreased below the roadway capacity for a period of time sufficient

to dissipate any traffic queues. It does not necessarily imply that traffic has completely cleared from these roadway sections.

The average delays (in minutes per vehicle) experienced by evacuees at representative congestion points (CP) in the network (see Figures 7-3 through 7-6 for locations), at various times during the evacuation, are presented in Table 7-2. These delays are experienced by traffic on the indicated links during the 10 minute period preceding the specified times. For, example, vehicles that travel on link, (762,445) between 1:50 (hr:min) and 2:00 after the advisory to evacuate, experience an average delay of 7.0 minutes. Since this delay approaches the 10 minute sampling period, vehicles on this link at this time experience pronounced congestion as shown in Figure 7-4. One hour later, the average delay per vehicle for traffic traversing this link has declined to 0.0 minutes, indicating that congestion has dissipated. The delay measures in Table 7-2 further illustrate that the peak congestion within the EPZ exists 2 hours after the advisory to evacuate.

7.3 Evacuation Rates

Evacuation is a continuous process, as implied by Figures 7-3 through 7-6. Another format for displaying the dynamics of evacuation is depicted in Figure 7-7. This plot indicates the rate at which traffic flows out of the indicated areas for the case of an evacuation of the entire EPZ (Region R03) under the indicated conditions. Appendix J presents these plots for all Evacuation Scenarios for Region R03.

As indicated in Figure 7-7, there is typically a long "tail" to these distributions. Vehicles evacuate an area slowly at the beginning, as people respond to the Advisory to Evacuate at different rates. Then traffic demand builds rapidly (slopes of curves increase). When the roadway system becomes congested, traffic exits the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more routes clear, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, relatively few evacuation routes service the remaining demand. It is reasonable to expect that some evacuees may delay or lengthen their mobilization activities and evacuate at a later time as a result; these ETE estimates do not (and should not) be distorted to account for these relatively few stragglers.

This decline in aggregate flow rate, towards the end of the process, is characterized by these curves flattening and gradually becoming horizontal. Ideally, it would be desirable to fully saturate all evacuation routes equally so that all will service traffic near capacity levels and all will clear at the same time. For this ideal situation, all curves would retain the same slope until the end – thus minimizing evacuation time. In the real world, this ideal is generally unattainable, reflecting the variation in population density and in highway capacity over the EPZ.

7.4 Guidance on Using ETE Tables

Tables 7-1A through 7-1D present the ETE values for all 25 Evacuation Regions and all 12 Evacuation Scenarios. They are organized as follows:

Table	Contents
7-1A	ETE represents the elapsed time required for 50 percent of the population within a Region, to evacuate from that Region.
7-1B	ETE represents the elapsed time required for 90 percent of the population within a Region, to evacuate from that Region.
7-1C	ETE represents the elapsed time required for 95 percent of the population within a Region, to evacuate from that Region.
7-1D	ETE represents the elapsed time required for 100 percent of the population within a Region, to evacuate from that Region.

The user first determines the percentile of population for which the ETE is sought. The applicable value of ETE within the chosen Table may then be identified using the following procedure:

1. Identify the applicable **Scenario**:
    - The Season
        - Summer (schools not in session)
        - Winter (also Autumn and Spring)
    - The Day of Week
        - Midweek (work-day)
        - Weekend, Holiday
    - The Time of Day
        - Midday (work and commuting hours)
        - Evening
    - Weather Condition
        - Good Weather
        - Rain
        - Ice
    - Special Event (if any)
        - New Plant Construction

While these Scenarios are designed, in aggregate, to represent conditions throughout the year, some further clarification is warranted:

- The conditions of a summer evening (either midweek or weekend) and rain are not explicitly identified in Tables 7-1A through 7-1D. For these

conditions, Scenario (4) applies.

- The conditions of a winter evening (either midweek or weekend) and rain are not explicitly identified in Tables 7-1A through 7-1D. For these conditions, Scenario (10) applies.
- The seasons are defined as follows:
  - Summer implies that public schools are *not* in session.
  - Winter, Spring and Autumn imply that public schools *are* in session.
- Time of Day: Midday implies the time over which most commuters are at work.

2. With the Scenario (and column in the Table) identified, now identify the **Evacuation Region**:

- Determine the projected azimuth direction of the plume (coincident with the wind direction). This direction is expressed in terms of compass orientation: *towards* N, NNE, NE, …
- Determine the distance that the Evacuation Region will extend from the Harris Nuclear Plant. The applicable distances and their associated candidate Regions are given below:
  - 2 Miles (Region R01)
  - 5 Miles (Regions R02 and R04 through R12)
  - to EPZ Boundary (Regions R03 and R13 through R25)
- Enter Table 7-3 and identify the applicable group of candidate Regions based on the wind direction and on the distance that the selected Region extends from HNP. Select the Evacuation Region identifier in that row from the first column of the Table.

3. Determine the **ETE for the Scenario** identified in Step 1 and the Region identified in Step 2, as follows:

  - The columns of Table 7-1 are labeled with the Scenario numbers. Identify the proper column in the selected Table using the Scenario number determined in Step 1.
  - Identify the row in this table that provides ETE values for the Region identified in Step 2.
  - The unique data cell defined by the column and row so determined contains the desired value of ETE expressed in Hours:Minutes.

<u>Example</u>

It is desired to identify the ETE for the following conditions:

- Sunday, August 10th at 4:00 AM.
- It is raining.
- Wind direction is *to* the northeast (NE).
- Wind speed is such that the distance to be evacuated is judged to be 10 miles (to EPZ boundary).
- The desired ETE is that value needed to evacuate 95 percent of the population from within the impacted Region.

Table 7-1C is applicable because the 95th-percentile population is desired. Proceed as follows:

1. Identify the Scenario as summer, weekend, evening and raining. Entering Table 7-1C, it is seen that there is no match for these descriptors. However, the clarification given above assigns this combination of circumstances to Scenario 4.

2. Enter Table 7-3 and locate the group entitled “Evacuate 5-mile ring and downwind to EPZ boundary”. Under “Wind Direction Towards:”, identify the NE (northeast) azimuth and read REGION R14 in the first column of that row.

3. Enter Table 7-1C to locate the data cell containing the value of ETE for Scenario 4 and Region R14. This data cell is in column (4) and in the row for Region R14; it contains the ETE value of **2:40**.

7.5 Discussion of ETE Results

The 95th and 100th percentile ETE for an evacuation of the entire EPZ (Region R03) during construction increases by 30 and 5 minutes, respectively (compare the ETE for scenarios 1 and 12 in Table 7-1D). The extrapolation of population to Year 2016 for the construction scenario results in a significant increase in the number of evacuating vehicles (see Table 6-4), which results in increased congestion within the EPZ and longer ETE.

The significant transient population evacuating from the Jordan Lake area on summer weekends results in longer ETE (at the 95th percentile) for those regions which evacuate the 2-mile ring and downwind to 5-miles and include sub-zone L. For example, the 95th percentile ETE for Regions R04 and R12 is 50 minutes longer, on average, than the ETE for Regions R05 through R11, for an evacuation under Scenario 3 conditions.

Comparison of the ETE for the 95th and 100th percentiles indicates that between 1 and 2 additional hours are needed to evacuate the remaining 5% of the EPZ population. As indicated in Figure 7-6, congestion has dissipated within the EPZ by 3 hours after the advisory to evacuate – well before the trip generation time of 4 hours (Table 5-1). Therefore, the 100th percentile ETE is dictated by the mobilization activities of the evacuating populace, except for Scenario 12. The ETE should not be distorted for those relatively few stragglers who take significantly longer to begin their evacuation trips. **Therefore, it is recommended that the 95th percentile ETE (Table 7-1C) be referenced by decision makers when preparing recommended protective actions.**

Table 7-1A. Time to Clear the Indicated Area of 50 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
	Midday		Midday		Evening		Midday			Midday		Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Ice	Good Weather	Rain	Good Weather	Region Wind Toward:	New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	0:50	0:50	0:45	0:45	0:50	R01 2-mile ring	0:50	0:50	0:50	0:45	0:45	0:50	R01 2-mile ring	1:20
R02 5-mile ring	1:00	1:00	1:00	1:00	0:55	R02 5-mile ring	1:00	1:00	1:05	0:55	0:55	0:55	R02 5-mile ring	1:15
R03 Entire EPZ	1:25	1:30	1:10	1:15	1:10	R03 Entire EPZ	1:30	1:30	1:35	1:10	1:15	1:10	R03 Entire EPZ	1:35
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	1:00	1:05	1:05	1:05	0:55	R04 N, NW, NNW	1:00	1:00	1:05	0:55	0:55	0:55	R04 N, NW, NNW	1:15
R05 NNE	1:05	1:05	0:55	0:55	0:55	R05 NNE	1:05	1:05	1:05	0:55	0:55	0:55	R05 NNE	1:20
R06 NE, ENE	1:05	1:05	0:55	0:55	0:55	R06 NE, ENE	1:05	1:05	1:10	0:55	0:55	0:55	R06 NE, ENE	1:20
R07 E	1:05	1:05	0:55	0:55	0:55	R07 E	1:05	1:10	1:10	0:55	0:55	0:55	R07 E	1:20
R08 ESE	1:00	1:00	0:50	0:50	0:50	R08 ESE	1:00	1:00	1:00	0:50	0:50	0:50	R08 ESE	1:20
R09 SE	0:55	0:55	0:50	0:50	0:55	R09 SE	0:55	1:00	1:00	0:50	0:55	0:55	R09 SE	1:10
R10 SSE, S	0:55	0:55	0:50	0:50	0:55	R10 SSE, S	0:55	0:55	0:55	0:50	0:50	0:55	R10 SSE, S	1:10
R11 SSW, SW	0:55	0:55	0:50	0:50	0:55	R11 SSW, SW	0:55	0:55	0:55	0:50	0:50	0:55	R11 SSW, SW	1:10
R12 WSW, W, WNW	0:55	1:00	1:00	1:00	0:55	R12 WSW, W, WNW	0:55	0:55	0:55	0:50	0:55	0:55	R12 WSW, W, WNW	1:15
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	1:20	1:25	1:05	1:05	1:05	R13 N, NNE	1:20	1:25	1:25	1:05	1:05	1:05	R13 N, NNE	1:30
R14 NE	1:25	1:30	1:10	1:15	1:10	R14 NE	1:25	1:30	1:35	1:10	1:15	1:10	R14 NE	1:40
R15 ENE, E	1:25	1:30	1:10	1:15	1:10	R15 ENE, E	1:30	1:30	1:35	1:10	1:15	1:10	R15 ENE, E	1:40
R16 ESE	1:20	1:25	1:10	1:10	1:05	R16 ESE	1:20	1:25	1:30	1:05	1:10	1:10	R16 ESE	1:30
R17 SE	1:15	1:20	1:05	1:10	1:05	R17 SE	1:20	1:20	1:25	1:05	1:05	1:05	R17 SE	1:30
R18 SSE	1:15	1:20	1:05	1:10	1:05	R18 SSE	1:20	1:20	1:25	1:05	1:05	1:05	R18 SSE	1:30
R19 S	1:10	1:10	1:00	1:00	0:55	R19 S	1:10	1:10	1:10	0:55	0:55	0:55	R19 S	1:20
R20 SSW	1:10	1:10	1:00	1:00	0:55	R20 SSW	1:10	1:15	1:15	0:55	0:55	0:55	R20 SSW	1:20
R21 SW	1:05	1:05	1:00	1:00	0:55	R21 SW	1:05	1:10	1:10	0:55	0:55	0:55	R21 SW	1:15
R22 WSW	1:05	1:05	1:00	1:00	0:55	R22 WSW	1:05	1:10	1:10	0:55	0:55	0:55	R22 WSW	1:15
R23 W, WNW	1:05	1:05	1:00	1:00	0:55	R23 W, WNW	1:05	1:05	1:10	0:55	0:55	0:55	R23 W, WNW	1:15
R24 NW	1:00	1:00	0:55	1:00	0:55	R24 NW	1:05	1:05	1:05	0:55	0:55	0:55	R24 NW	1:15
R25 NNW	1:20	1:20	1:05	1:05	1:00	R25 NNW	1:20	1:25	1:25	1:05	1:05	1:05	R25 NNW	1:30

Table 7-1B. Time to Clear the Indicated Area of 90 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
	Midday		Midday		Evening		Midday			Midday		Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Ice	Good Weather	Rain	Good Weather	Region Wind Toward:	New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	1:40	1:40	1:25	1:25	1:50	R01 2-mile ring	1:40	1:40	1:40	1:30	1:30	1:55	R01 2-mile ring	2:30
R02 5-mile ring	1:55	1:55	2:20	2:25	1:45	R02 5-mile ring	1:55	2:00	2:00	1:40	1:40	1:45	R02 5-mile ring	2:30
R03 Entire EPZ	2:35	2:45	2:15	2:25	2:05	R03 Entire EPZ	2:35	2:45	3:00	2:10	2:20	2:05	R03 Entire EPZ	3:10
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	1:50	1:50	2:25	2:35	1:40	R04 N, NW, NNW	1:55	1:55	1:55	1:40	1:40	1:45	R04 N, NW, NNW	2:30
R05 NNE	1:55	1:55	1:40	1:45	1:45	R05 NNE	1:55	2:00	2:00	1:45	1:45	1:45	R05 NNE	2:30
R06 NE, ENE	2:00	2:00	1:45	1:45	1:45	R06 NE, ENE	2:00	2:00	2:00	1:45	1:45	1:45	R06 NE, ENE	2:30
R07 E	2:05	2:05	1:45	1:45	1:45	R07 E	2:05	2:05	2:05	1:45	1:45	1:45	R07 E	2:30
R08 ESE	2:10	2:10	1:35	1:35	1:55	R08 ESE	2:15	2:15	2:15	1:40	1:40	1:55	R08 ESE	2:30
R09 SE	1:50	1:55	1:40	1:40	1:45	R09 SE	1:55	1:55	1:55	1:40	1:40	1:45	R09 SE	2:20
R10 SSE, S	1:50	1:50	1:35	1:40	1:45	R10 SSE, S	1:50	1:50	1:55	1:40	1:40	1:45	R10 SSE, S	2:20
R11 SSW, SW	1:45	1:45	1:35	1:40	1:40	R11 SSW, SW	1:45	1:45	1:50	1:40	1:40	1:40	R11 SSW, SW	2:20
R12 WSW, W, WNW	1:50	1:50	2:30	2:40	1:40	R12 WSW, W, WNW	1:55	1:55	1:55	1:40	1:40	1:45	R12 WSW, W, WNW	2:20
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	2:25	2:30	2:05	2:15	2:00	R13 N, NNE	2:30	2:35	2:40	2:00	2:05	2:00	R13 N, NNE	2:55
R14 NE	2:35	2:45	2:15	2:25	2:05	R14 NE	2:35	2:45	2:55	2:10	2:20	2:05	R14 NE	3:10
R15 ENE, E	2:35	2:45	2:15	2:25	2:05	R15 ENE, E	2:35	2:45	2:55	2:10	2:20	2:05	R15 ENE, E	3:10
R16 ESE	2:30	2:40	2:15	2:25	2:05	R16 ESE	2:35	2:40	2:55	2:05	2:15	2:05	R16 ESE	3:00
R17 SE	2:25	2:35	2:15	2:25	2:00	R17 SE	2:30	2:35	2:50	2:05	2:10	2:05	R17 SE	2:55
R18 SSE	2:25	2:35	2:15	2:25	2:00	R18 SSE	2:30	2:35	2:50	2:05	2:10	2:05	R18 SSE	2:55
R19 S	2:10	2:10	2:10	2:15	1:45	R19 S	2:15	2:15	2:15	1:45	1:45	1:50	R19 S	2:30
R20 SSW	2:15	2:15	2:15	2:20	1:50	R20 SSW	2:20	2:20	2:20	1:45	1:45	1:50	R20 SSW	2:35
R21 SW	2:05	2:05	2:15	2:20	1:45	R21 SW	2:10	2:10	2:10	1:45	1:45	1:50	R21 SW	2:30
R22 WSW	2:05	2:05	2:15	2:20	1:45	R22 WSW	2:10	2:10	2:10	1:45	1:45	1:50	R22 WSW	2:30
R23 W, WNW	2:00	2:05	2:10	2:20	1:45	R23 W, WNW	2:05	2:10	2:10	1:40	1:45	1:45	R23 W, WNW	2:30
R24 NW	2:00	2:00	2:10	2:20	1:45	R24 NW	2:05	2:05	2:05	1:40	1:40	1:45	R24 NW	2:30
R25 NNW	2:25	2:30	2:05	2:15	2:00	R25 NNW	2:30	2:35	2:40	2:00	2:05	2:00	R25 NNW	2:55

Table 7-1C. Time to Clear the Indicated Area of 95 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
	Midday		Midday		Evening		Midday			Midday		Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Ice	Good Weather	Rain	Good Weather	Region Wind Toward:	New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	2:10	2:10	1:55	1:55	2:25	R01 2-mile ring	2:10	2:10	2:10	1:55	1:55	2:30	R01 2-mile ring	2:45
R02 5-mile ring	2:20	2:20	2:40	2:55	2:00	R02 5-mile ring	2:25	2:25	2:25	1:55	1:55	2:00	R02 5-mile ring	2:50
R03 Entire EPZ	2:55	3:00	2:30	2:40	2:30	R03 Entire EPZ	3:00	3:05	3:15	2:25	2:35	2:30	R03 Entire EPZ	3:25
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	2:15	2:15	2:45	2:55	1:55	R04 N, NW, NNW	2:20	2:20	2:20	1:50	1:55	1:55	R04 N, NW, NNW	2:50
R05 NNE	2:25	2:25	1:55	1:55	2:00	R05 NNE	2:25	2:25	2:25	1:55	1:55	2:00	R05 NNE	2:45
R06 NE, ENE	2:30	2:30	1:55	1:55	2:00	R06 NE, ENE	2:30	2:30	2:30	1:55	1:55	2:00	R06 NE, ENE	2:45
R07 E	2:30	2:30	1:55	1:55	2:10	R07 E	2:30	2:35	2:35	2:00	2:00	2:10	R07 E	2:45
R08 ESE	2:45	2:45	2:05	2:05	2:25	R08 ESE	2:45	2:50	2:50	2:15	2:15	2:25	R08 ESE	2:40
R09 SE	2:20	2:20	1:50	1:50	2:05	R09 SE	2:20	2:20	2:20	1:50	1:55	2:05	R09 SE	2:40
R10 SSE, S	2:10	2:15	1:50	1:50	2:00	R10 SSE, S	2:15	2:15	2:15	1:50	1:50	2:00	R10 SSE, S	2:40
R11 SSW, SW	2:05	2:05	1:50	1:50	1:55	R11 SSW, SW	2:05	2:05	2:05	1:50	1:50	1:55	R11 SSW, SW	2:40
R12 WSW, W, WNW	2:15	2:20	2:45	3:00	2:00	R12 WSW, W, WNW	2:25	2:25	2:25	1:50	1:50	2:05	R12 WSW, W, WNW	2:40
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	2:55	2:55	2:35	2:40	2:25	R13 N, NNE	2:55	2:55	3:00	2:25	2:25	2:30	R13 N, NNE	3:10
R14 NE	2:55	3:00	2:35	2:40	2:30	R14 NE	2:55	3:00	3:15	2:25	2:35	2:30	R14 NE	3:25
R15 ENE, E	2:55	3:00	2:35	2:40	2:30	R15 ENE, E	2:55	3:00	3:15	2:25	2:35	2:30	R15 ENE, E	3:25
R16 ESE	2:55	2:55	2:35	2:45	2:25	R16 ESE	2:55	3:00	3:10	2:25	2:30	2:25	R16 ESE	3:20
R17 SE	2:50	2:55	2:35	2:45	2:25	R17 SE	2:55	3:00	3:10	2:20	2:30	2:25	R17 SE	3:15
R18 SSE	2:50	2:55	2:35	2:45	2:25	R18 SSE	2:55	3:00	3:10	2:20	2:30	2:25	R18 SSE	3:15
R19 S	2:40	2:40	2:35	2:45	2:15	R19 S	2:45	2:45	2:45	2:05	2:05	2:15	R19 S	2:55
R20 SSW	2:40	2:45	2:35	2:45	2:15	R20 SSW	2:45	2:45	2:45	2:05	2:05	2:20	R20 SSW	2:55
R21 SW	2:30	2:35	2:35	2:45	2:10	R21 SW	2:35	2:35	2:35	2:00	2:00	2:10	R21 SW	2:55
R22 WSW	2:30	2:35	2:35	2:45	2:10	R22 WSW	2:40	2:40	2:40	2:00	2:00	2:10	R22 WSW	2:55
R23 W, WNW	2:30	2:30	2:35	2:45	2:05	R23 W, WNW	2:35	2:35	2:35	2:00	2:00	2:10	R23 W, WNW	2:55
R24 NW	2:25	2:25	2:35	2:45	2:05	R24 NW	2:30	2:30	2:35	1:55	1:55	2:05	R24 NW	2:50
R25 NNW	2:55	2:55	2:30	2:35	2:25	R25 NNW	2:55	2:55	3:00	2:20	2:25	2:25	R25 NNW	3:10

Table 7-1D. Time to Clear the Indicated Area of 100 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
	Midday		Midday		Evening		Midday			Midday		Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Ice	Good Weather	Rain	Good Weather	Region Wind Toward:	New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	4:00	4:00	3:00	3:00	3:00	R01 2-mile ring	4:00	4:00	4:00	3:00	3:00	3:00	R01 2-mile ring	4:00
R02 5-mile ring	4:05	4:05	3:10	3:20	3:05	R02 5-mile ring	4:05	4:05	4:05	3:10	3:10	3:05	R02 5-mile ring	4:10
R03 Entire EPZ	4:10	4:10	4:05	4:05	4:05	R03 Entire EPZ	4:10	4:10	4:10	4:05	4:05	4:00	R03 Entire EPZ	4:15
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	4:05	4:05	3:05	3:20	3:05	R04 N, NW, NNW	4:05	4:05	4:05	3:05	3:05	3:05	R04 N, NW, NNW	4:05
R05 NNE	4:00	4:05	3:00	3:00	3:00	R05 NNE	4:00	4:05	4:05	3:00	3:00	3:00	R05 NNE	4:00
R06 NE, ENE	4:00	4:05	3:00	3:00	3:00	R06 NE, ENE	4:00	4:05	4:05	3:00	3:00	3:00	R06 NE, ENE	4:00
R07 E	4:00	4:05	3:00	3:05	3:00	R07 E	4:00	4:05	4:05	3:00	3:05	3:00	R07 E	4:00
R08 ESE	4:00	4:00	3:00	3:05	3:00	R08 ESE	4:00	4:00	4:00	3:00	3:05	3:00	R08 ESE	4:00
R09 SE	4:00	4:00	3:00	3:05	3:00	R09 SE	4:00	4:05	4:05	3:00	3:05	3:00	R09 SE	4:00
R10 SSE, S	4:00	4:00	3:05	3:05	3:00	R10 SSE, S	4:00	4:05	4:05	3:05	3:05	3:00	R10 SSE, S	4:00
R11 SSW, SW	4:00	4:00	3:05	3:05	3:00	R11 SSW, SW	4:00	4:00	4:00	3:05	3:05	3:00	R11 SSW, SW	4:00
R12 WSW, W, WNW	4:00	4:05	3:10	3:20	3:05	R12 WSW, W, WNW	4:05	4:05	4:05	3:10	3:10	3:05	R12 WSW, W, WNW	4:05
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	4:05	4:05	4:00	4:00	4:00	R13 N, NNE	4:05	4:05	4:10	4:00	4:00	4:00	R13 N, NNE	4:10
R14 NE	4:05	4:05	4:00	4:00	4:00	R14 NE	4:05	4:05	4:10	4:00	4:00	4:00	R14 NE	4:10
R15 ENE, E	4:05	4:05	4:05	4:05	4:05	R15 ENE, E	4:05	4:05	4:10	4:00	4:00	4:00	R15 ENE, E	4:10
R16 ESE	4:10	4:10	4:05	4:05	4:05	R16 ESE	4:10	4:10	4:10	4:05	4:05	4:00	R16 ESE	4:10
R17 SE	4:10	4:10	4:05	4:05	4:00	R17 SE	4:10	4:10	4:10	4:00	4:00	4:00	R17 SE	4:10
R18 SSE	4:10	4:10	4:05	4:05	4:00	R18 SSE	4:10	4:10	4:10	4:00	4:00	4:00	R18 SSE	4:10
R19 S	4:10	4:10	3:50	3:50	3:50	R19 S	4:10	4:10	4:10	3:50	3:50	3:50	R19 S	4:10
R20 SSW	4:10	4:10	3:50	3:50	3:50	R20 SSW	4:10	4:10	4:10	3:50	3:50	3:50	R20 SSW	4:10
R21 SW	4:05	4:05	3:05	3:20	3:05	R21 SW	4:05	4:05	4:10	3:10	3:10	3:05	R21 SW	4:10
R22 WSW	4:05	4:10	3:10	3:25	3:05	R22 WSW	4:05	4:05	4:10	3:10	3:10	3:05	R22 WSW	4:10
R23 W, WNW	4:05	4:10	3:10	3:25	3:05	R23 W, WNW	4:05	4:05	4:10	3:10	3:10	3:05	R23 W, WNW	4:10
R24 NW	4:05	4:10	3:50	3:50	3:05	R24 NW	4:05	4:05	4:10	3:50	3:50	3:05	R24 NW	4:10
R25 NNW	4:05	4:10	4:00	4:00	4:00	R25 NNW	4:05	4:05	4:10	4:00	4:00	4:00	R25 NNW	4:10

Table 7-2. Average Delay for Selected Roadways in the HNP EPZ							
Congestion Point Number	Link		Description	Average Delay (min/veh) at Indicated Time after the Advisory to Evacuate (hr:min)			
	From Node	To Node		1:00	2:00	3:00	3:15
1	734	758	NC 55 SB – access to US Hwy 1 NB	0.0	5.2	0.0	0.0
2	762	445	NC 55 NB – access to US Hwy 1 NB	0.5	6.5	0.0	0.0
3	525	511	Holly Springs Rd NB intersection with Ten-Ten Rd	2.1	5.1	0.0	0.0
4	584	718	US Hwy 64 EB interchange with US Hwy 1 NB	0.0	6.1	0.0	0.0
5	598	45	US Hwy 1 NB north of interchange with US Hwy 64	0.0	1.1	0.0	0.0
6	1031	424	NC 55 SB intersection with NC 42/US Hwy 401	4.6	4.5	0.0	0.0
7	203	1030	NC 42/US Hwy 401 NB – intersection with NC 55	2.4	2.5	0.0	0.0
8	215	220	US Hwy 401 SB – south of Fuquay-Varina	0.1	3.3	2.1	0.0
9	752	130	Beaver Creek Rd NB – intersection with US Hwy 64	6.4	0.0	0.0	0.0
10	488	489	Mt. Gilead Church Rd NB – intersection with US Hwy 15/501	1.0	4.7	0.0	0.0

Table 7-3. Description of Evacuation Regions															
		Sub-Zone													
Region	**Description**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R01	2 mile ring	■													
R02	5-mile ring	■	■	■	■							■	■		
R03	Full EPZ	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Evacuate 2-mile ring and 5 miles downwind															
		Sub-Zone													
Region	**Wind Direction Towards:**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R04	N,NW,NNW	■	■										■		
R05	NNE	■	■												
R06	NE,ENE	■	■	■											
R07	E	■	■	■	■										
R08	ESE	■		■	■										
R09	SE	■		■	■							■			
R10	SSE,S	■			■							■			
R11	SSW, SW	■										■			
R12	WSW,W,WNW	■										■	■		
Evacuate 5-mile ring and downwind to EPZ boundary															
		Sub-Zone													
Region	**Wind Direction Towards:**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R13	N,NNE	■	■	■	■	■						■	■		■
R14	NE	■	■	■	■	■	■					■	■		
R15	ENE, E	■	■	■	■	■	■	■				■	■		
R16	ESE	■	■	■	■		■	■	■			■	■		
R17	SE	■	■	■	■			■	■			■	■		
R18	SSE	■	■	■	■			■	■	■		■	■		
R19	S	■	■	■	■				■	■		■	■		
R20	SSW	■	■	■	■				■	■	■	■	■		
R21	SW	■	■	■	■					■	■	■	■		
R22	WSW	■	■	■	■					■	■	■	■	■	
R23	W,WNW	■	■	■	■						■	■	■	■	
R24	NW	■	■	■	■							■	■	■	■
R25	NNW	■	■	■	■	■						■	■	■	■

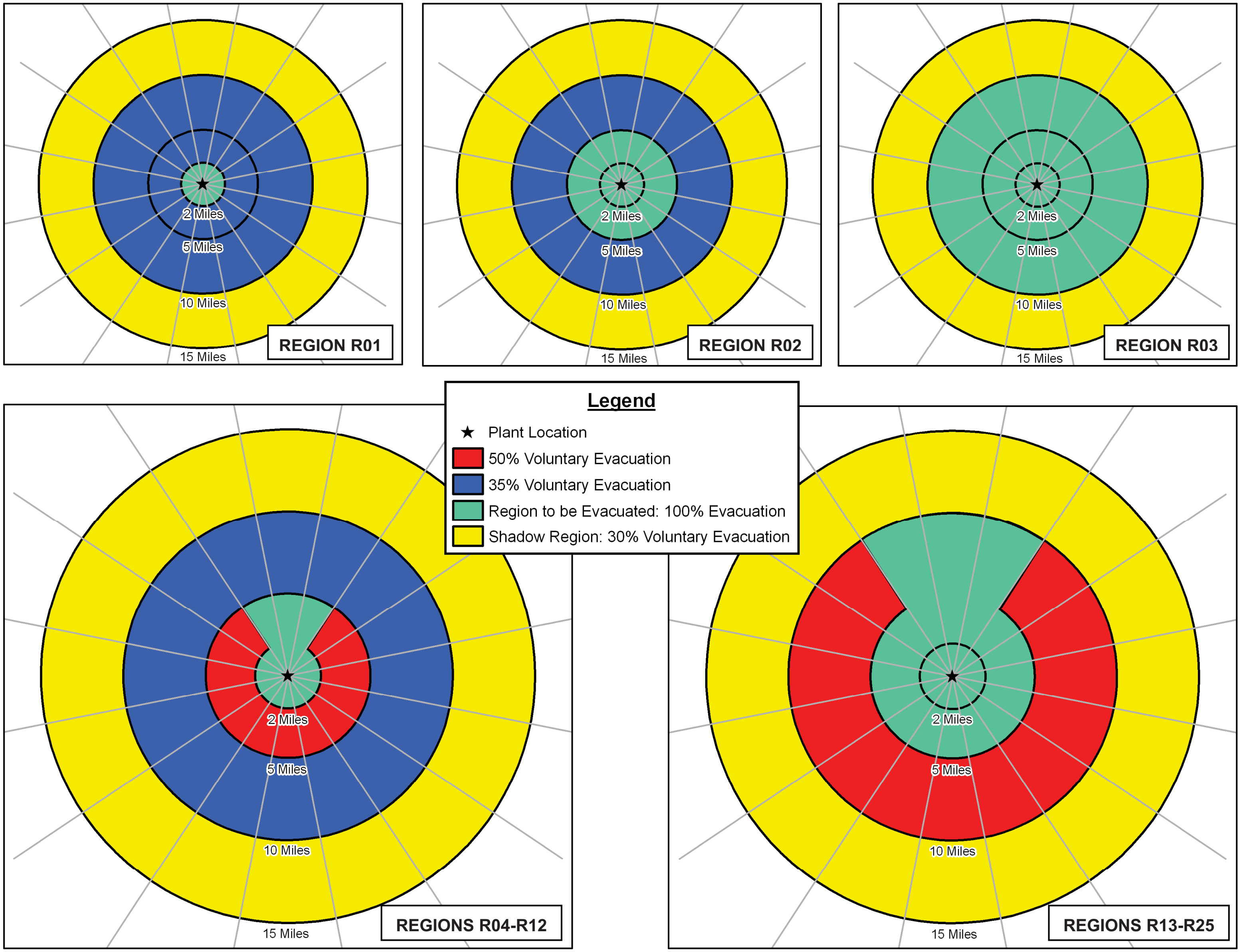


Figure 7-1. Assumed Evacuation Response

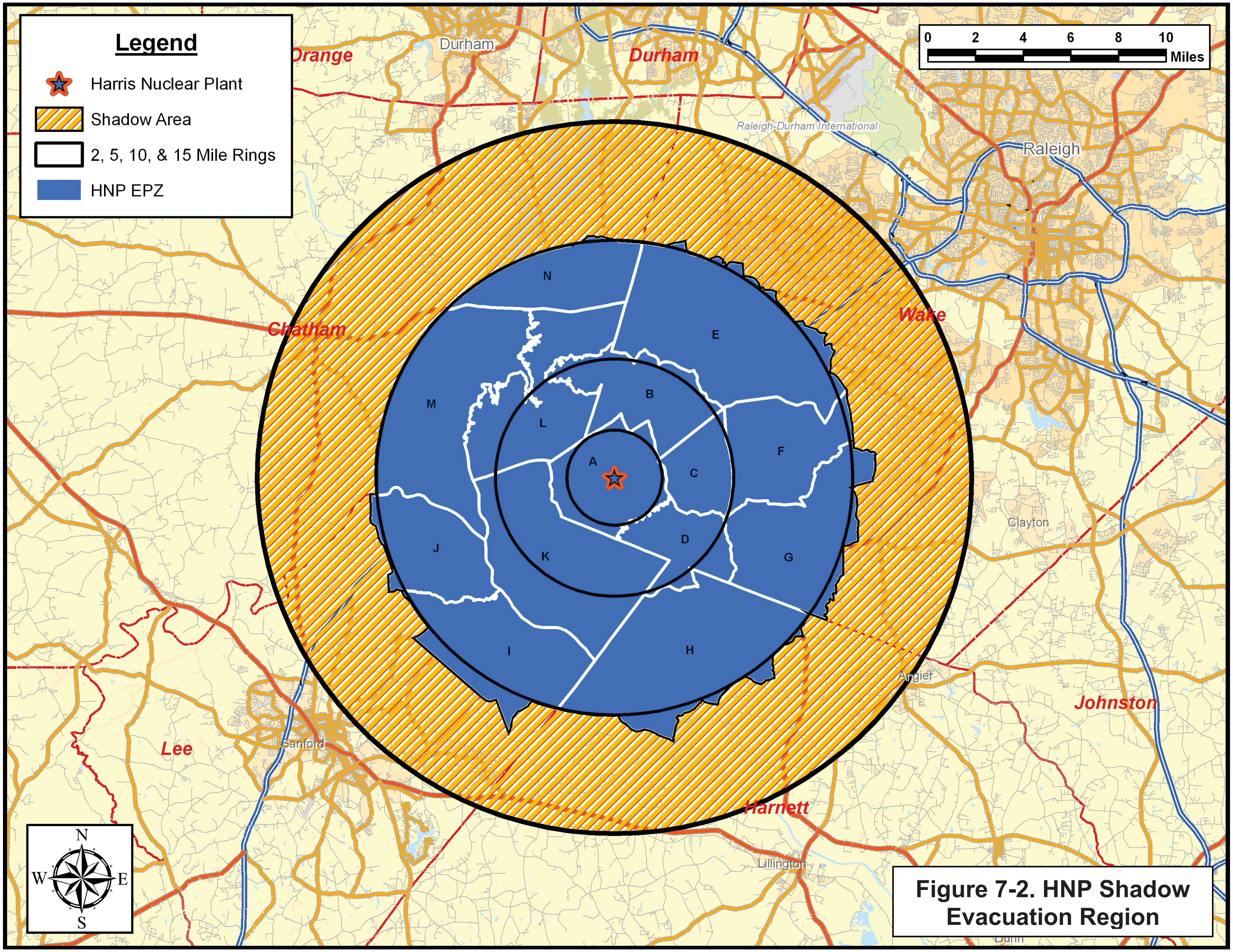


Figure 7-2. HNP Shadow Evacuation Region

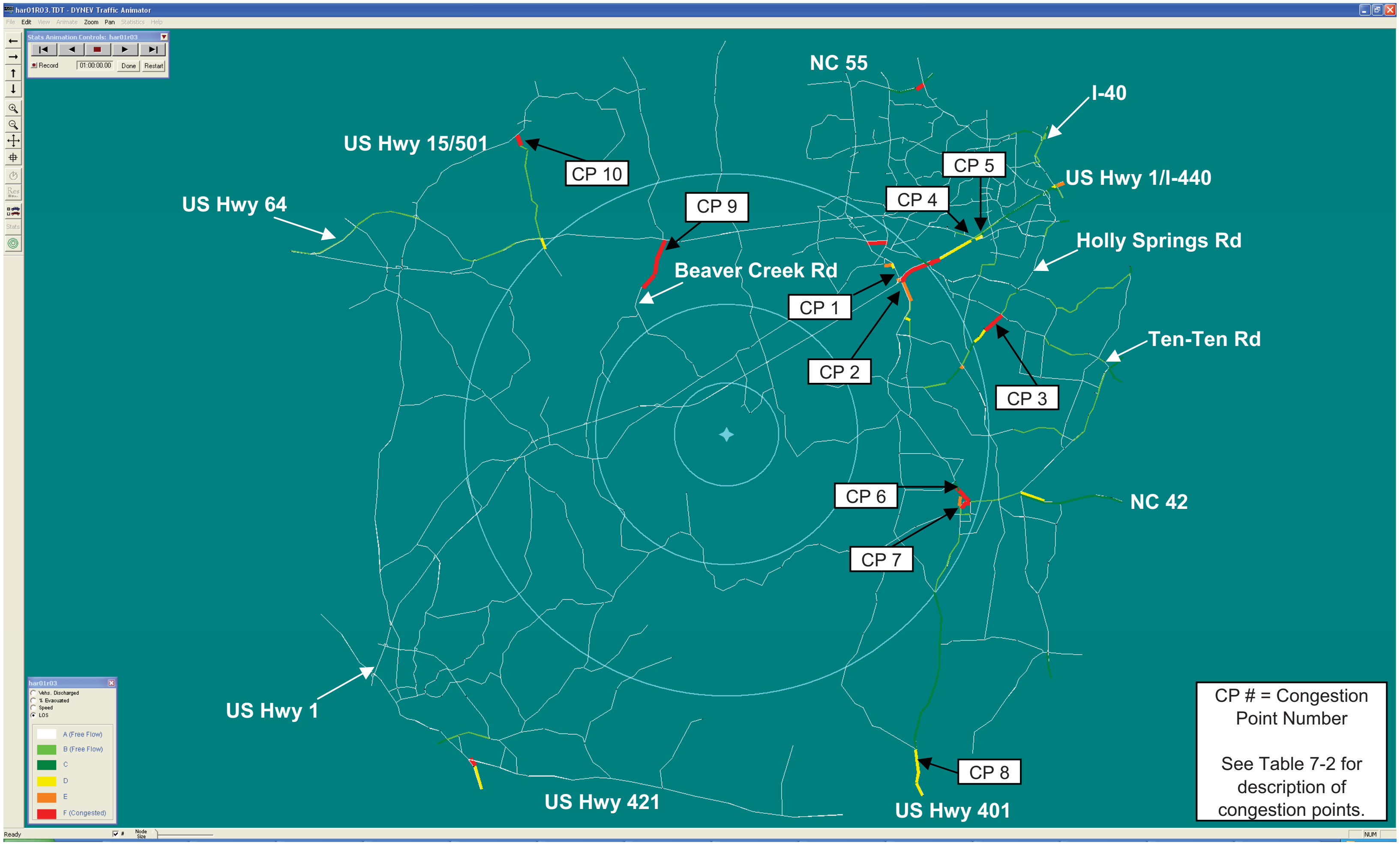


Figure 7-3. Congestion Patterns at 1 Hour after the Evacuation Advisory (Region 3, Scenario 1)

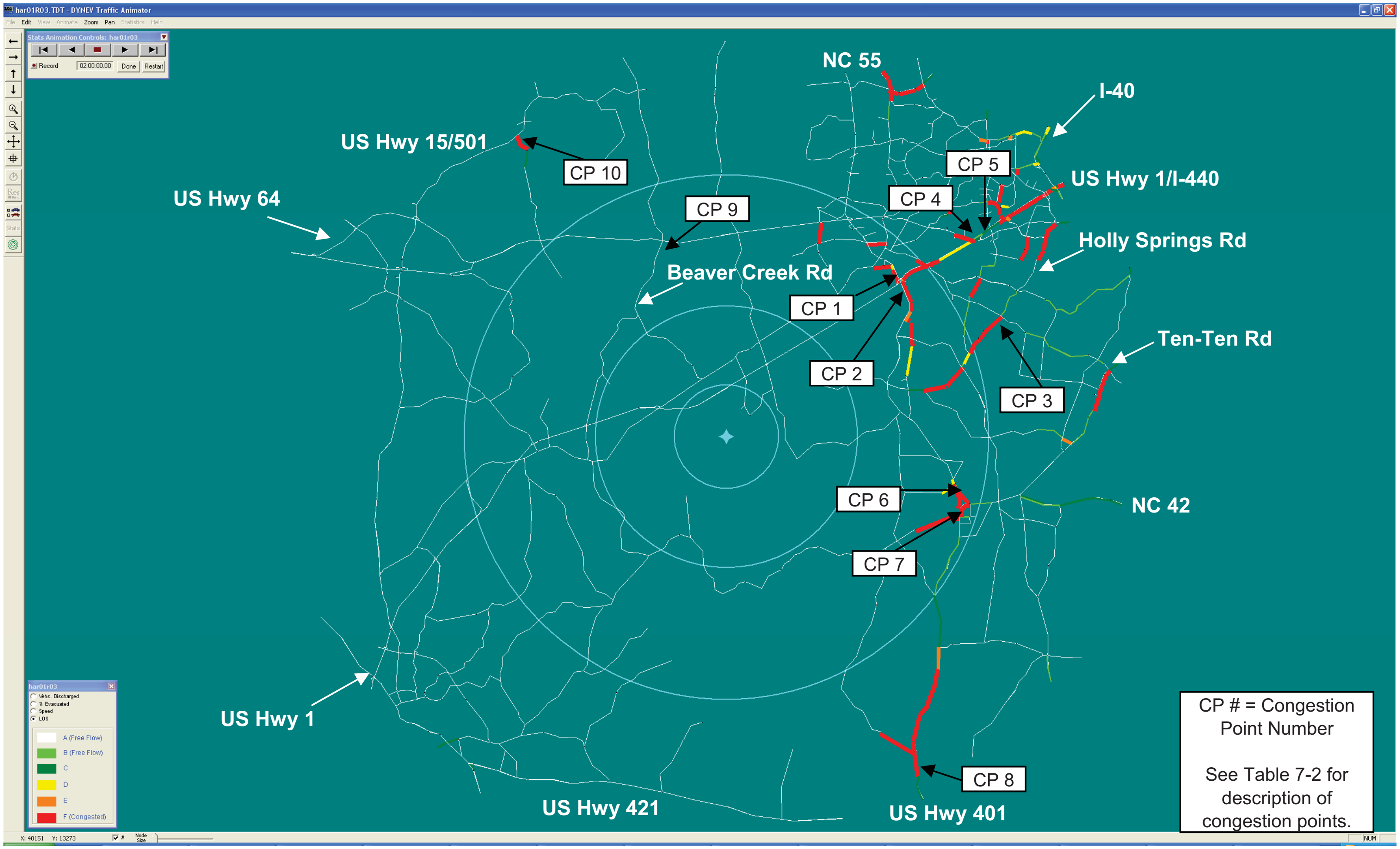


Figure 7-4 Congestion Patterns at 2 Hours after the Evacuation Advisory (Region 3, Scenario 1)

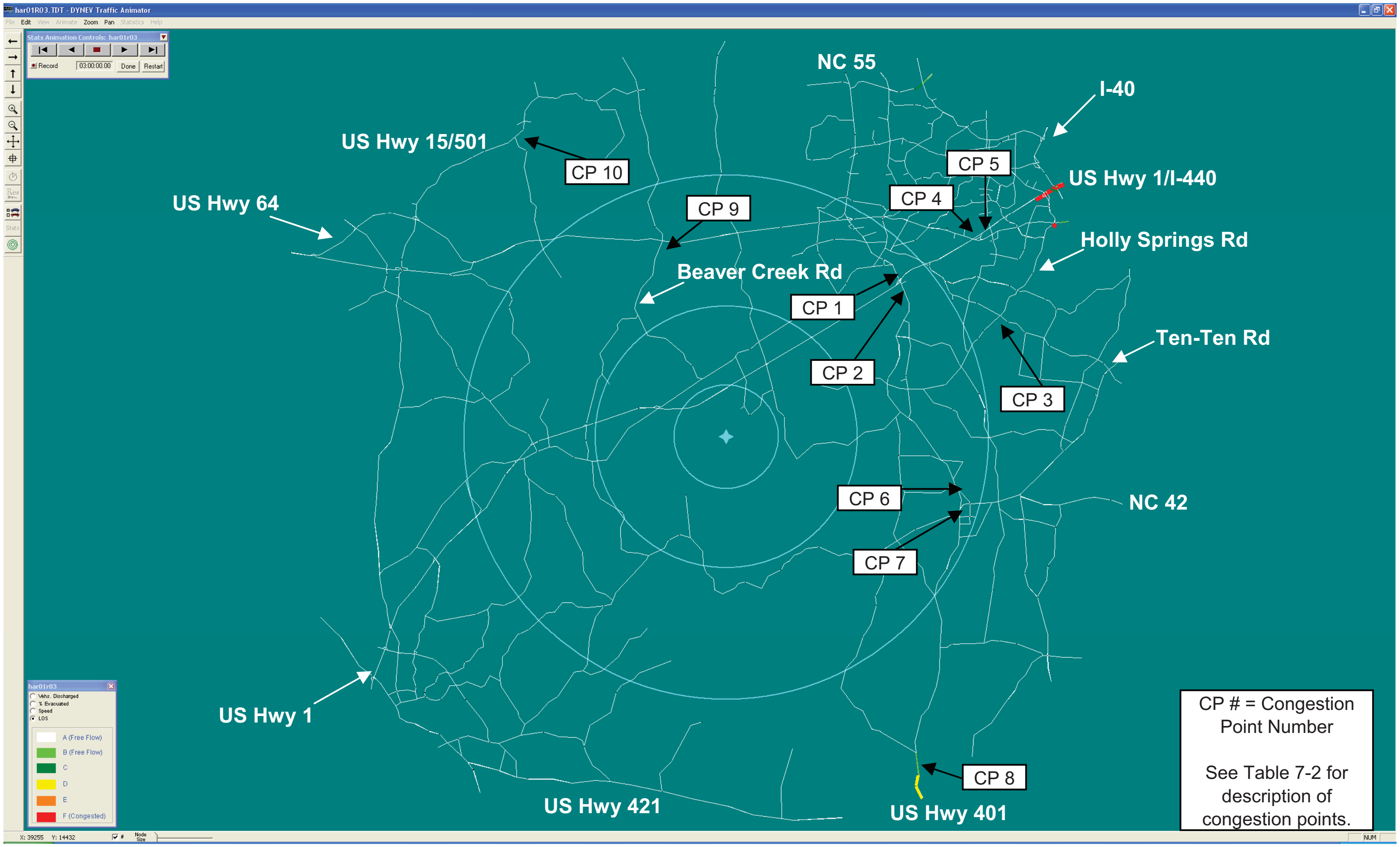


Figure 7-5 Congestion Patterns at 3 Hours after the Evacuation Advisory (Region 3, Scenario 1)

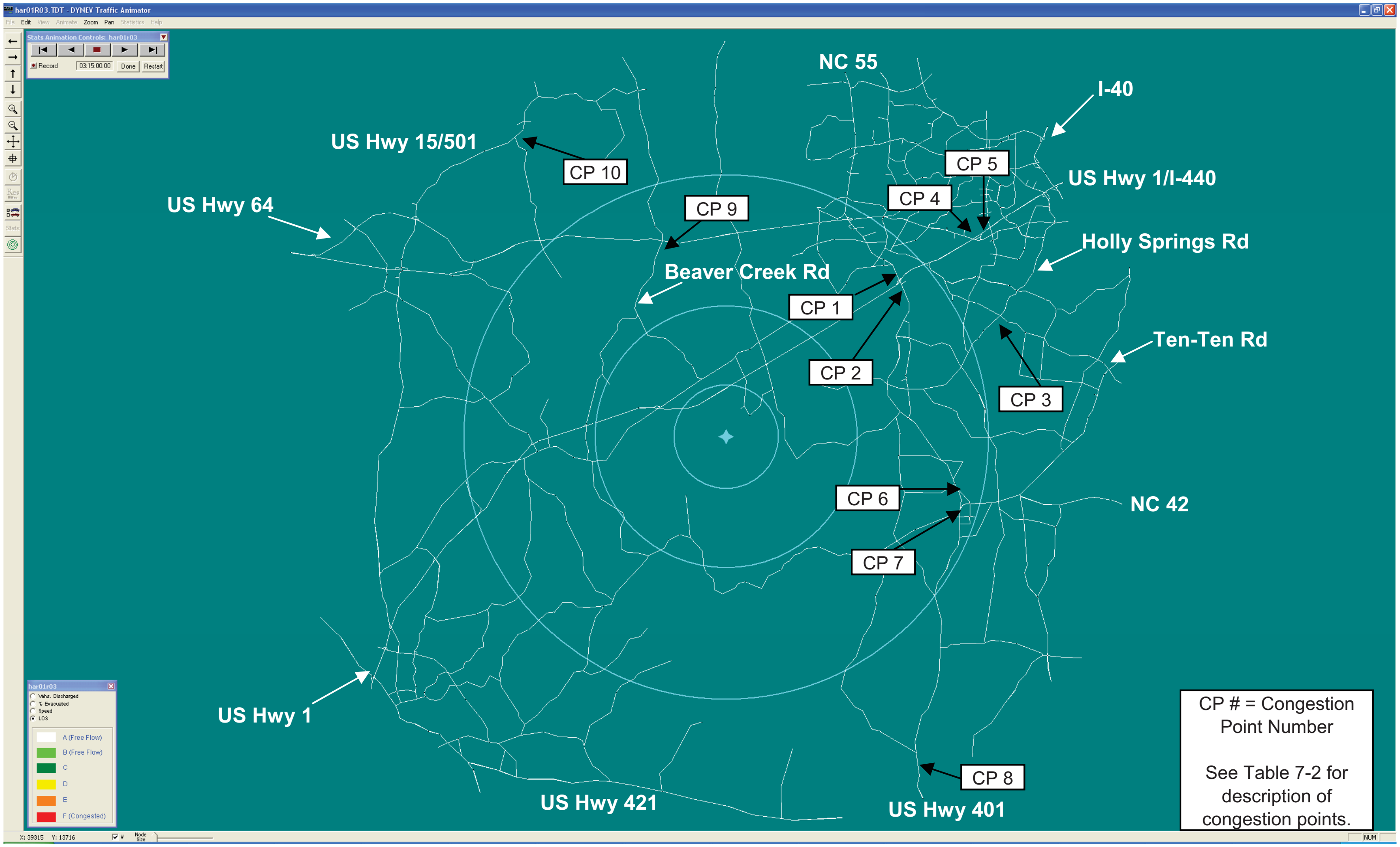


Figure 7-6 Congestion Patterns at 3 Hours:15 Minutes after the Evacuation Advisory (Region 3, Scenario 1)

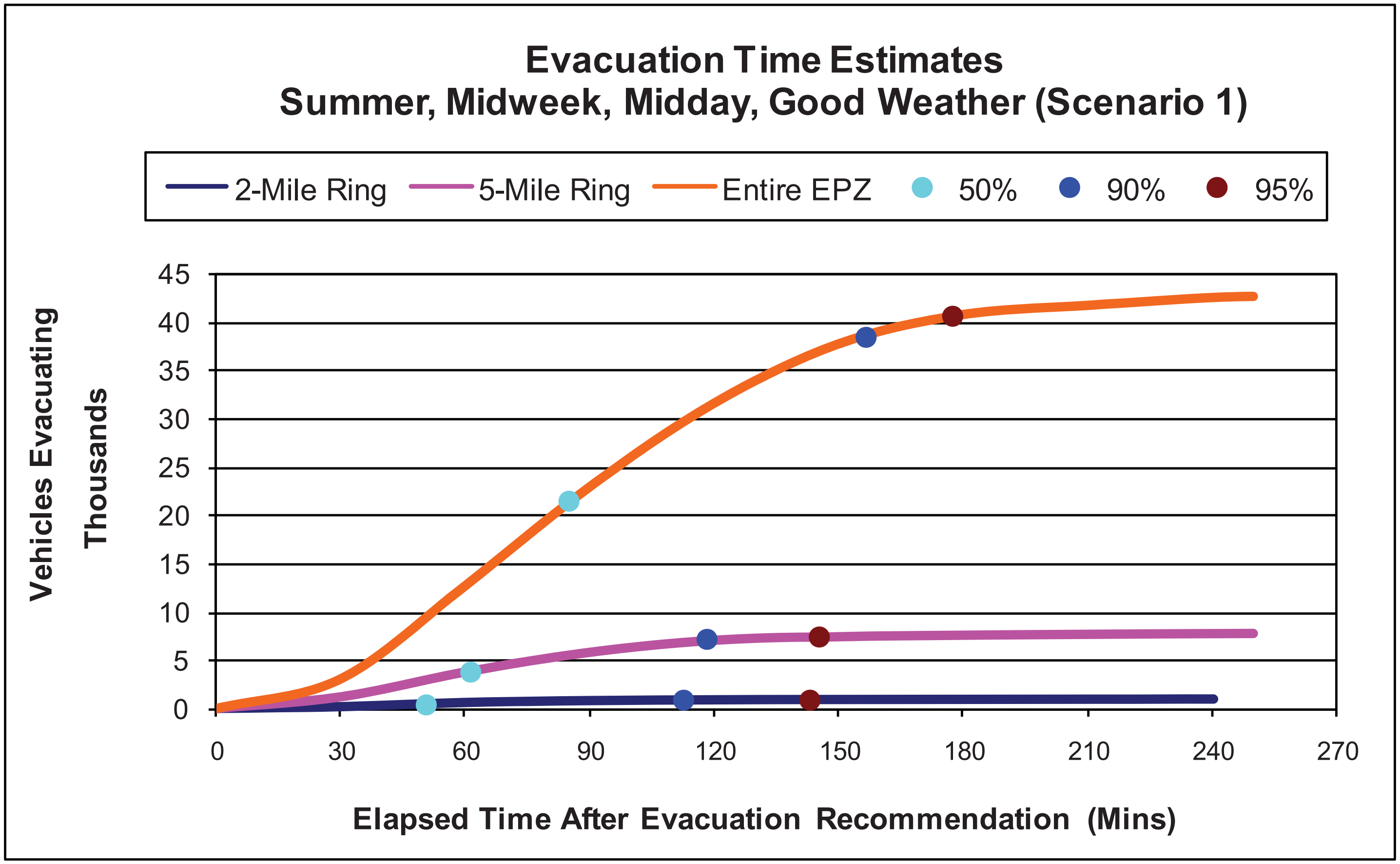


**Figure 7-7. Evacuation Time Estimates for HNP
Summer, Midweek, Midday, Good Weather
Evacuation of Region R03 (Entire EPZ)**

8. TRANSIT-DEPENDENT AND SPECIAL FACILITY EVACUATION TIME ESTIMATES

This section details the analyses applied and the results obtained in the form of evacuation time estimates for transit vehicles (buses). The demand for transit service reflects the needs of two population groups: (1) residents with no vehicles available; and (2) residents of special facilities such as schools, health-support facilities, institutions and child-care facilities.

These transit vehicles merge into and become a part of the general evacuation traffic environment that is comprised mostly of “passenger cars” (pc’s). The presence of each transit vehicle in the evacuating traffic stream is represented within the modeling paradigm described in Appendix D as equivalent to two pc’s. This equivalence factor represents the larger size and more sluggish operating characteristics of a transit vehicle relative to those of a pc.

Transit vehicles must be mobilized in preparation for their respective evacuation missions. Specifically:

- Bus drivers must be alerted
- They must travel to the bus depot
- They must be briefed there and assigned to a route or facility

These activities consume time. Based on experience at other suburban plants, it is estimated that bus mobilization time will average approximately 90 minutes extending from the Advisory to Evacuate to the time when buses arrive at their respective assignments.

During this mobilization period, other mobilization activities are taking place. One of these is the action taken by parents, neighbors, relatives and friends to pick up children from school prior to the arrival of buses, so that they may join their families. Virtually all studies of evacuations have concluded that this “bonding” process of uniting family members is universally prevalent during emergencies and should be anticipated in the planning process. Many emergency plans, however, call for parents to pick up children at host schools or reception centers to speed the evacuation of the school children in the event that buses need to return to the EPZ and evacuate other transit dependent persons. We provide estimates of buses under the assumption that no children will be picked up at school by their parents as an upper bound estimate of the transit vehicles needed. It is assumed that children at day-care centers are picked up by parents or guardians and that the time to perform this activity is captured in the trip generation times discussed in Section 5.

The procedure is:

- Estimate demand for transit service
- Estimate time to perform all transit functions
- Estimate route travel times to the EPZ boundary and to the school reception centers

8.1 Transit-Dependent People - Demand Estimate

The telephone survey (see Appendix F) results for persons in households that do not have a vehicle available were used to estimate the portion of the population requiring transit service.

Table 8-1 presents estimates of transit-dependent people. Note:

- Estimates of persons requiring transit vehicles include school children. For those evacuation scenarios where children are at school when an evacuation is advised, separate transportation is provided for the school children. The actual need for transit vehicles by residents is thereby less than the given estimates. However, we will not reduce our estimates of transit vehicles since it would add to the complexity of the implementation procedures.
- It is reasonable and appropriate to consider that many transit-dependent persons will evacuate by ride-sharing with neighbors, friends or family. For example, nearly 80 percent of those who evacuated from Mississauga, Ontario who did not use their own cars, shared a ride with neighbors or friends. Other documents report that approximately 70 percent of transit-dependent persons were evacuated via ride-sharing. **We will adopt a conservative estimate that 50 percent of transit-dependent persons will ride-share.**

The estimated number of bus trips needed to service transit-dependent persons is based on an estimate of average bus occupancy of 30 persons at the conclusion of the bus run. Transit vehicle seating capacities typically equal or exceed 60 children (equivalent to 40 adults). If transit vehicle evacuees are two-thirds adults and one-third children, then the number of “adult seats” taken by 30 persons is 20 + (2/3 x10) = 27. On this basis, the average load factor anticipated is (27/40) x 100 = 68 percent. Thus, if the actual demand for service exceeds the estimates of Table 8-1 by 50 percent, the demand for service can still be accommodated by the available bus seating capacity.

$$\left(20+\left(\frac{2}{3}\times 10\right)\right)\div 40\times 1.5=1.00$$

Table 8-1 indicates that transportation must be provided for 690 people. Therefore, a total of 12 bus runs are required to transport this population to reception centers.

To illustrate this estimation procedure, we calculate the number of persons, P, requiring public transit or ride-share, and the number of buses, B, required for the Harris EPZ:

$$P = 24{,}300 \times (0.02 \times 1.42)$$
$$P = 24{,}300 \times (0.0284) = 690$$
$$B = (0.5 \times P) \div 30 = 12$$

These calculations are explained as follows:

- All members (1.42 avg.) of households (HH) with no vehicles (2.0%) will evacuate by public transit or ride-share. The term 24,300 (number of households) x 0.020 x 1.42, accounts for these people.
- Households with 1 or more vehicles are assumed to have no need for transit vehicles.

8.2 School Population – Transit Demand

Table 8-2 presents the school population and transportation requirements for the direct evacuation of all schools within the EPZ. The column in Table 8-2 entitled "Bus Runs Required" specifies the number of buses required for each school under the following set of assumptions and estimates:

- No students will be picked up by their parents prior to the arrival of the buses.
- Bus capacity, expressed in students per bus, is set to 70 for primary schools and 50 for middle and high schools.
- Those staff members who do not accompany the students will evacuate in their private vehicles.
- No allowance is made for student absenteeism which is in the neighborhood of 3 percent, daily.

We recommend that the Counties introduce procedures whereby the schools are contacted prior to the dispatch of buses from the depot (approximately one hour after the Advisory to Evacuate), to ascertain the current estimate of students to be evacuated. In this way, the number of buses dispatched to the schools will reflect the actual number needed. Some parents will likely pick up their children at school, although they are asked to pick children up at the relocation schools. Those buses originally allocated to evacuate school children that are not needed due to children being picked up by their parents, can be gainfully assigned to service other facilities or those persons who do not have access to private vehicles or to ride-sharing.

Table 8-3 presents a list of the relocation schools for each school in the EPZ. Those students not picked up by their parents prior to the arrival of the buses, will be transported to these centers where they will be subsequently retrieved by their respective families.

It is assumed that children at daycare centers are picked up by their parents and that this activity is accounted for in the mobilization times for residents presented in Section 5. As discussed on Page F-1, the telephone survey asks questions about activities performed by the residents on a daily basis. Those parents with children in daycare

typically drop the child off in the morning and pick the child up later in the day. Question 9 (Page F-15) of the telephone survey asks how long it would take the worker to travel home from work. Figure F-10 shows that the travel home from work activity takes up to 2½ hours to complete. It is reasonable to assume that, if applicable, this activity includes the picking up of children at daycare centers.

8.3 Special Facility Demand

Table 8-4 presents the census of special facilities in the EPZ as of the June, 2007. Approximately 686 people have been identified as living in, or being treated in, these facilities. This census also indicates the number of wheelchair-bound people and the number of bed-ridden people. The transportation requirements for this group are also presented. The number of bus runs estimated assumes 30 ambulatory patients per trip. Wheelchair buses can transport 15 patients, while vans can transport 4 patients. Ambulances can transport 2 patients per trip.

8.4 Evacuation Time Estimates for Transit-Dependent People

When school evacuation needs are satisfied, subsequent assignments of buses to service the transit-dependent should be sensitive to their mobilization time. Clearly, the buses should be dispatched after people have completed their mobilization activities and are in a position to board the buses when they arrive at the pick-up points.

If there are not sufficient buses to support the evacuation of all school children and all transit-dependent persons in one wave, buses will be prioritized for school evacuation. These buses, once they have dropped off school children at the reception centers, will return to the EPZ to perform a “second-wave” evacuation of transit-dependent persons.

Evacuation Time Estimates for Transit Trips were developed using both good weather and adverse weather conditions. Figure 8-1 presents the chronology of events relevant to transit operations. The elapsed time for each activity will now be discussed with reference to Figure 8-1.

Activity: Mobilize Drivers (A→B→C)

Mobilization is the elapsed time from the Advisory to Evacuate to when the buses are dispatched from their respective depots. It is assumed that for a rapidly escalating radiological emergency with no observable indication before the fact, drivers would likely require 90 minutes to be contacted, to travel to the depot, be briefed, and to travel to the transit-dependent facilities. Mobilization time is slightly longer – 100 minutes – when raining.

Activity: Board Passengers (C→D)

Studies have shown that passengers can board a bus at headways of 2-4 seconds (Ref. HCM2000 Exhibit 27-9). Therefore, the total dwell time to service passengers boarding a bus to capacity at a single stop (e.g., at a school) is about 5 minutes. A loading time of 10 minutes will be used for rain scenarios.

For multiple stops along a pick-up route we must allow for the additional delay associated with stopping and starting at each pick-up point. The time, t, required for a bus to decelerate at a rate, "a", expressed in ft/sec/sec, from a speed, "v", expressed in ft/sec, to a stop, is t = v/a. Assuming the same acceleration rate and final speed following the stop yields a total time, T, to service boarding passengers:

$$T = t + B + t = B + 2t = B + \frac{2v}{a},$$

Where B = Dwell time to service passengers. The total distance, "s" in feet, travelled during the deceleration and acceleration activities is: $s = v^2/a$. If the bus had not stopped to service passengers, but had continued to travel at speed, v, then its travel time over the distance, s, would be: s/v, or $(v^2/a)/v = v/a$. Then the total delay (i.e. pickup time, P) to service passengers is:

$$P = T - \frac{v}{a} = B + \frac{v}{a}$$

Assigning reasonable estimates:

- B = 20 seconds: a generous value for about 2 passengers per stop
- v = 25 mph = 37 ft/sec
- a = 4 ft/sec/sec, a moderate average rate

Then, P ≈ 30 seconds per stop. Allowing 10 minutes pick-up time per bus run implies 20 stops per run. This additional delay to service passengers expands this estimate of boarding time to 10 minutes in good weather, and 15 minutes in rain.

<u>Activity: Travel to EPZ Boundary (D→E)</u>

<u>School Evacuation</u>

The UNITES software discussed in Section 1.3 was used to define bus routes along the most likely path from a school being evacuated to the EPZ boundary, traveling toward the appropriate relocation school. This is done in UNITES by interactively selecting the series of nodes from the school to the EPZ boundary. The bus route is given an identification number and is written to the I-DYNEV input stream. UNITES computes the route length and DYNEV outputs the average speed for each 10 minute interval for each bus route input. The travel times to the EPZ boundary are computed from the route length and the speeds output by the model (at the mobilization plus loading time). The bus routes input are documented in Table 8-9.

The cases considered for computing school ETE are an evacuation of the full EPZ (Region R03) under Scenario 6 (school in session, good weather) and Scenario 7 (school in session, rain) conditions.

Based on discussions with Chatham and Wake Counties, there are adequate buses to evacuate the school children in a single wave. Table 8-12 summarizes the transportation resources available, by county. Comparison of Table 8-2 with 8-12 indicates that there are ample buses to service the school demand.

Tables 8-5A (good weather) and 8-5B (rain) present the following evacuation time estimates (rounded up to the nearest 5 minutes) for schools in the EPZ: (1) The elapsed time from the Advisory to Evacuate until the bus exits the EPZ; and (2) The elapsed time until the bus reaches the School Reception Center. The evacuation time out of the EPZ can be computed as the sum of travel times associated with Activities A→B→C, C→D, and D→E (For example: 90 min. + 5 + 37 = 2:15 for Holly Springs High School, with good weather). The evacuation time to the School Reception Center is determined by adding the time associated with Activity E→F (discussed below), to this EPZ evacuation time.

<u>Evacuation of Transit-Dependent Population</u>

The buses dispatched from the depots to service the transit-dependent evacuees will be scheduled so that they arrive at their respective routes after their passengers have completed their mobilization. As indicated in Section 5, about 90 percent (see Distribution D in Table 5-1) of the evacuees will complete their mobilization when the first buses will begin their routes, 90 minutes after the Advisory to Evacuate.

Those buses servicing the transit-dependent evacuees will first travel along their pick-up routes, then proceed out of the EPZ. Table 8-6 details the proposed bus routes to service the transit dependent people in the Harris EPZ, while Figure 8-2 maps the proposed bus pick-up routes. The number of buses assigned to each route is proportional to the total population of the sub-zones (see Table 3-1 in the ETE report) serviced by that route, as indicated in Table 8-6. The population of those sub-zones which are serviced by multiple routes is divided amongst the routes based on the estimated percentages shown in the third column of Table 8-6. The number of buses for each route is calculated by dividing the population of the sub-zones serviced by that route and the total population of the sub-zones serviced by all routes and then multiplying by the 12 bus runs required (see Section 8.1). For example, it is estimated that Route 2 services 15%, 10% and 10% of the population in sub-zones E, F and G, respectively. Based on the sub-zone populations provided in Table 3-1 of the ETE report, 7,835 people reside in the sub-zones serviced by this route (.15 x 32,879 +.10 x 13,534 + .10 x 15,497 = 7,835). As the final row of Table 8-6 indicates, the total population of the sub-zones serviced by all routes is 67,786. Therefore, the number of buses needed for Route 2 is estimated as: 7,835 ÷ 67,786 x 12 = 2 (rounded up).

The transit-dependent bus routes were also input in UNITES, as was done for schools. The route length is computed by UNITES and the average speed along the route is output by DYNEV at 10 minute intervals. The route length and average speed (at the mobilization time) are used to compute the route travel time.

Tables 8-7A and 8-7B present the transit-dependent population evacuation time estimates for each route in good weather and rain, respectively, computed using the methodology discussed above.

Activity: Travel to School Reception Centers (E→F)

The distances from the EPZ boundary to the relocation schools are measured using Geographical Information Systems (GIS) software along the most likely route from the EPZ to the relocation school. For a one-wave evacuation, this travel time outside the EPZ does not contribute to the ETE. For a two-wave evacuation, the ETE for buses must be considered separately, since it could exceed the ETE for the general public. The travel time from the EPZ boundary to the Reception Center was computed assuming an average speed of 40 mph and 35 mph for good weather and rain, respectively.

Activity: Passengers Leave Bus (F→G)

Passengers can de-board within 5 minutes. The driver takes a 10-minute break.

Activity: Bus Returns to Route for Second Wave Evacuation (G→C)

The buses assigned to return to the EPZ to perform a "second wave" evacuation of transit-dependent evacuees will be those that evacuated the first wave since the bus drivers will be familiar with the pick-up routes. The travel time back to the EPZ is calculated using distances estimated from GIS and the free-flow inbound travel speeds. The bus then travels its route and picks up transit-dependent evacuees along the route. Those routes servicing high population density areas (Route 4, 5 and 6) perform two waves of evacuation, as indicated in Table 8-6.

Analysis of Bus Route Operations

Route 1

The bus on this route will pick up evacuees living in less populated areas in the southern part of the EPZ. The bus assigned to this route will begin its trip 90 minutes after the Advisory to Evacuate (ATE). The route travel time is 10 minutes, based on the route length and average speed output by DYNEV. Pickup time is 10 minutes. The bus exits the EPZ at 1:50.

Route 2

Buses on this route will pick up evacuees living in the eastern part of the EPZ. The first of 2 buses assigned to this route will begin its trip 90 minutes after the ATE; 1 bus will follow at a headway of 15 minutes. The route travel time ranges from 29 to 30 minutes (see Table 8-7A) with 10 additional minutes needed for pickups. The last bus trip will begin at 1:45 after the ATE and exit the EPZ at 2:25.

Route 3

The bus on this route will pick up evacuees living in less populated areas in the northern part of the EPZ and will follow a similar schedule to the bus of Route 1, with the bus exiting the EPZ at 1:50.

Route 4

Buses on this route will circulate through Apex, transport the evacuees to Reception Centers to the east of the EPZ, then return to Apex to repeat the process. The first of 2 buses will begin its trip 90 minutes after the ATE; an additional bus will follow 15 minutes later. The route travel time is computed using the average speed output by DYNEV and 10 minutes are added for pick-up time. Thus, the first bus will exit the EPZ at 2:25 after the ATE. Travel to the Reception Center is 25 minutes plus 5 minutes to unload passengers, 10-minute rest time for the driver and 20 minutes to return to Apex at 3:25. This bus will repeat the first trip and exit the EPZ at 3:55; the 2nd bus will exit the EPZ 20 minutes later at 4:15.

Route 5

The bus on this route will circulate through Holly Springs, transport the evacuees to Reception Centers to the northeast outside the EPZ, then return to Holly Springs to repeat the process. The bus will exit the EPZ at 2:20 after the ATE for the first trip, return to Holly Springs at 3:30 and then exit the EPZ at 4:00.

Route 6

The bus on this route will circulate through Fuquay-Varina, transport the evacuees south to the Reception Center outside the EPZ, then return to Fuquay-Varina to repeat the process. The schedule is the same as for Route 1. The bus will complete its second wave and exit the EPZ at 3:10.

The ETE for good weather and rain for all routes and buses are given in Tables 8-7A and 8-7B, respectively. Travel times to and from the reception center are 10% longer for rain.

Evacuation of Ambulatory Persons from Special Facilities

The bus operations for this group are similar to those for school evacuation except:

- Several buses will pick up evacuees at more than one facility.
- Buses are assigned on the basis of 25-30 patients per bus to allow for staff to accompany the patients.
- The passenger loading time will be longer at approximately one minute per patient to account for the time to move patients from inside the facility to the vehicles.

As is done for the schools, it is estimated that mobilization time averages 90 minutes. In the event there is a shortfall of transit vehicles for a "first-wave" evacuation, then buses used to evacuate schools will have to return to evacuate the special facilities. The maximum school ETE to the Reception Centers is 2:55 (see Table 8-5A), and about 15 minutes of additional inbound travel time to the special facility from the Reception Centers would be required. It follows, therefore, that about one hour and 40 minutes would have to be added to the calculated ETE for special facilities, in the event they are evacuated as a "second wave."

As is done for the schools, the bus routes from the medical facility being evacuated to the EPZ boundary was input in UNITES. The bus route length is computed by UNITES and the average speeds are output by DYNEV. The route lengths and average speeds are shown in Tables 8-8A and 8-8B; the route travel time is computed using these data. Those buses assigned to pick up multiple facilities have these facilities clustered within a mile or two of one another. The routes input to UNITES include travel from one facility to the next for those buses evacuating multiple facilities. These facilities are grouped together within Tables 8-8A and 8-8B as they have the same bus route. Table 8-9 documents the bus routes input in UNITES.

Table 8-4 indicates that 15 wheelchair bus runs and 14 wheelchair van runs are needed for the entire EPZ. Table 8-12 indicates that there are 50 wheelchair vans and 4 wheelchair buses available to the EPZ counties. The surplus wheelchair vans can be used in place of wheelchair buses. Regular school buses can also be used to transport wheelchair bound patients. Patients would occupy the front portion of the bus and their wheelchairs would be folded and stacked in the back of the bus. Loading times are estimated at 5 minutes per wheelchair bound person as staff will have to assist them on the bus. For example, the ETE for the wheelchair bound at Spring Arbor of Apex is:

ETE: 90 + 15 x 5 + 13 = 3:00 (rounded up to the nearest 5 minutes).

Tables 8-5B, 8-7B and 8-8B provide ETE for rain; these results indicate that rain adds 20 minutes, on average, to the ETE for good weather. Thus, the ETE for wheelchair bound patients at medical facilities in rain can be estimated by adding 20 minutes to the computed good weather ETE.

Emergency Medical Services (EMS) Vehicles

The previous discussion focused on transit operations for ambulatory persons residing at medical facilities within the Evacuation Region. It is also necessary to provide transit services to non-ambulatory persons at medical facilities who do not – or cannot – have access to private vehicles. Based on the data provided in Table 8-4, a total of 26 ambulance runs are needed to evacuate all of the bed ridden patients in the EPZ, assuming 2 people per ambulance. These ambulances will be provided by EMS providers within the EPZ counties. Table 8-12 indicates that 86 ambulances are available to the EPZ counties.

It is estimated that 30 minutes will be needed to mobilize ambulances and travel to the medical facilities. Loading times are conservatively estimated as 30 minutes. Most of the medical facilities in the EPZ are located in Wake County near the EPZ boundary (see Figure E-3). It is conservatively estimated that ambulances will have to travel 5 miles, on average, to leave the EPZ. The average speed output by the model at 1 hour for Region 3, Scenario 6 is 46.4 mph; thus, travel time out of the EPZ is 7 minutes.

The ETE for ambulances is: 30 + 30 + 7 = 1:10 (rounded up to the nearest 5 minutes)

Special Needs Population

Table 8-10 details the registered special needs population in each of the EPZ counties. As stated in Section 8.3, buses can transport 30 ambulatory persons per trip, wheelchair buses can transport 15 persons per trip, wheelchair vans can transport 4 persons per trip and an ambulance can transport 2 bed-ridden persons per trip. Table 8-11 the transportation resources needed to evacuate the homebound special needs population residing within the Harris EPZ based on the data provided in Table 8-10 and the aforementioned capacities.

Comparison of Tables 8-11 and 8-12 indicates that the counties have sufficient resources to evacuate the homebound special needs population. The EPZ counties have adopted the North Carolina state-wide mutual aid agreement which outlines consistent procedures and policies regarding the delivery of local mutual aid resources, including ambulances, wheelchair vans and buses. In the event one of the EPZ counties lacks sufficient transportation resources, those resources will be provided through this state-wide agreement. It is reasonable to expect that the requisite transportation resources would be available within a 90 minute mobilization time. Note that approximately 40% (99 of 163) special needs persons require transportation assistance – see Table 8-10. Other special needs persons living at home have their transport needs provided by other members of the household and would not require assistance from the county.

ETE for Special Needs Persons

Buses

Assuming no more than one special needs person per household implies that 76 households (HH) need to be serviced. While only 5 buses are needed from a capacity perspective, if 15 buses are deployed to service these special needs HH, then each would require about 5 stops. The following outlines the ETE calculations:

1. Assume 15 buses are deployed, each with 5 stops, to service a total of 76 HH.
2. The ETE is calculated as follows:
    a. Buses arrive at the first pickup location: 90 minutes
    b. Load HH members at first pickup: 5 minutes
    c. Travel to next pickup locations: 4 @ 6 minutes = 24 minutes
    d. Load HH members: 4 @ 5 minutes = 20 minutes
    e. Travel to EPZ boundary (assume 8 miles): 24 minutes.

    ETE: 90 + 5 + 24 + 20 + 24 = 2:45

    Rain ETE: 100 + 5 + 28 + 20 + 28 = 3:00

The estimated travel time between pickups is based on a distance of 2 miles @ 20 mph = 6 minutes. If planned properly, the pickup locations for each bus run should be clustered within the same general area. The estimated travel time to the EPZ boundary is based on a distance of 8 miles @ 20 mph = 24 minutes. It is assumed that mobilization time to first pickup is 10 minutes longer in rain = 100 minutes. It is further assumed that travel speeds are 10% lower in rain – travel time to the EPZ boundary at free speed from last pickup requires 28 minutes (8 miles @ 18 mph) in rain and that travel time between pickups is 7 minutes (2 miles @ 18 mph). All ETE are rounded to nearest 5 minutes.

Assuming all HH members (avg. HH size equals 3.05 persons) travel with the disabled person yields 5 x 3.05 = 16 persons per bus. From the perspective of bus capacity, fewer buses could be deployed. For example, 10 buses, each servicing 8 HH could accommodate 3.05 x 8 = 25 people, but the additional 3 stops would add 3 x (6 + 5) = 33 minutes to the ETE. The ETE would equal 3:15 with good weather and 3:35 for rain using 10 buses.

Ambulances

It is estimated that 4 ambulance runs will be needed to service the homebound bed-ridden population (Table 8-11) and that 26 ambulance runs will be needed to evacuate the institutionalized bed-ridden population within the EPZ (Table 8-4). Table 8-12 indicates that there is a surplus of ambulances; thus, the institutionalized and homebound bed-ridden populations can be evacuated in a single wave.

As stated on page 8-11 of the ETE report, mobilization time and loading time are assumed to be 30 minutes each. Each ambulance servicing the homebound bed-ridden population will make 2 stops with an estimated distance of 5 miles between stops and an estimated distance of 5 miles to the EPZ boundary after the final stop. It is conservatively assumed that ambulances will travel at 30 mph within the EPZ. Mobilization time is 5 minutes longer and travel speed is 10% less in rain – 27 mph. All ETE are rounded to nearest 5 minutes.

The ETE are computed as follows:

a. Ambulance arrives at first household: 30 minutes
b. Loading time at first household: 30 minutes
c. Ambulance travels to second household: 5 miles @ 30 mph = 10 minutes
d. Loading time at second household: 30 minutes
e. Travel time to EPZ boundary: 5 miles @ 30 mph = 10 minutes

ETE: 30 + 30 + 10 + 30 + 10 = 1:50

Rain ETE: 35 + 30 + 11 + 30 + 11 = 2:00

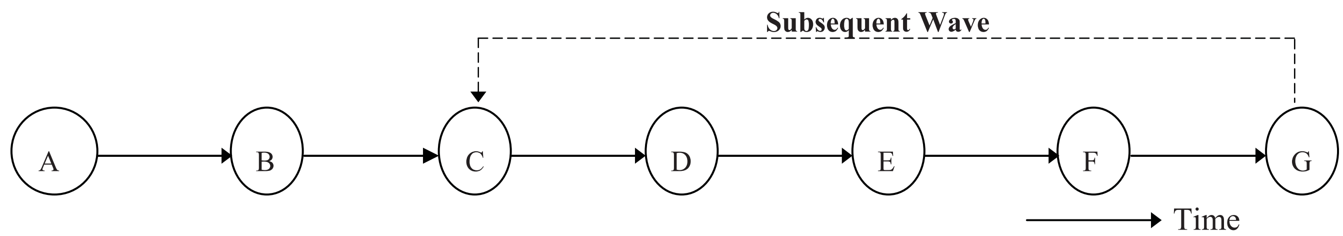
Wheel-Chair Vans

Table 8-10 indicates that there are 17 homebound wheelchair bound persons in the EPZ, while Table 8-11 indicates that 5 wheelchair vans are needed to evacuate this population. Assuming one special needs person per household, each wheelchair van will service about 4 households. It is conservatively assumed that the households are spaced 5 miles apart and that van speeds (20 mph) between households approximate those of buses evacuating the mobile homebound population. It is further assumed that vans travel 5 miles to the EPZ boundary after the last pickup. Mobilization time is 10 minutes longer and travel speed is 10% less in rain.

a. Assumed mobilization time for wheelchair van resources to arrive at first household: 90 minutes
b. Loading time at first household: 15 minutes
c. Travel to next household: 3 @ 15 minutes (5 miles @ 20 mph) = 45 minutes
d. Loading time: 3 @ 15 minutes = 45 minutes
e. Travel time to EPZ boundary: 5 miles @ 20 mph = 15 minutes

ETE: 90 + 15 + 45 + 45 + 15 = 3:30

Rain ETE: 100 + 15 + 51 + 45 + 17 = 3:50



Event

A	Advisory to Evacuate
B	Bus Dispatched from Depot
C	Bus Arrives at Facility/Pick-up Route
D	Bus Departs for Reception Center
E	Bus Exits Region
F	Bus Arrives at School Reception Center
G	Bus Available for “Second Wave” Evacuation Service

Activity

A→B	Driver Mobilization
B→C	Travel to Facility or to Pick-up Route
C→D	Passengers Board the Bus
D→E	Bus Travels Towards Region Boundary
E→F	Bus Travels Towards School Reception Center Outside the EPZ.
F→G	Passengers Leave Bus; Driver Takes a Break

Figure 8-1. Chronology of Transit Evacuation Operations

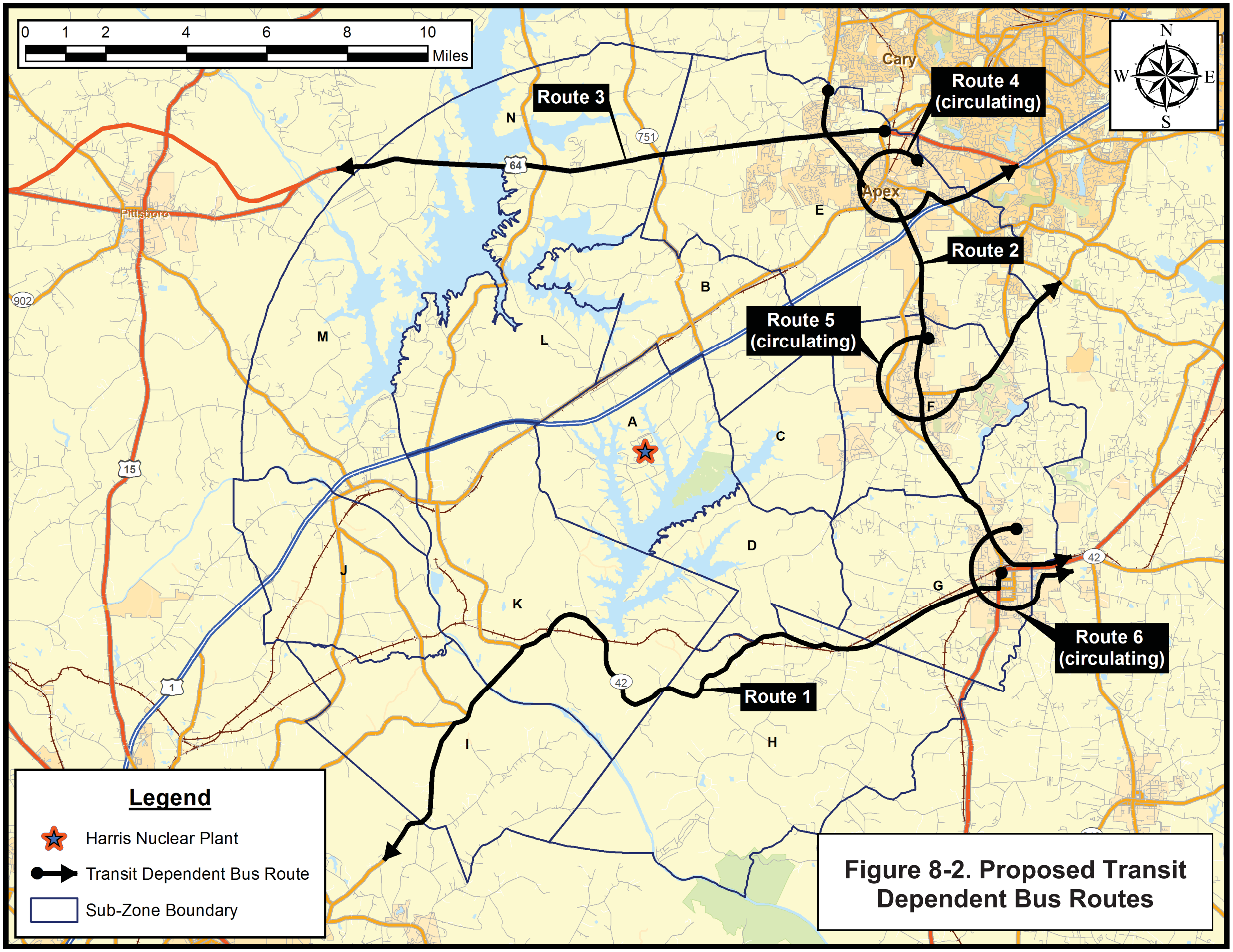


Figure 8-2. Proposed Transit Dependent Bus Routes

Table 8-1. Transit Dependent Population Estimates								
Facility Name	**2007 EPZ Population**	**Survey Average Household Size With 0 Vehicles**	**Estimated Number of Households**	**Survey Percent Households With 0 Vehicles**	**Total People Requiring Transport**	**Estimated Ridesharing Percentage**	**People Requiring Public Transit**	**Percent of Population Requiring Public Transit**
Harris Nuclear Plant	74,097	1.42	24,300	2.0%	690*	50%	345	0.5%

*See Section 8.1 for detailed calculation.

Table 8-2. School Population Demand Estimates							
Sub-Zone	**Distance (miles)**	**Direction**	**School Name**	**Municipality**	**Enroll-ment**	**Staff**	**Bus Runs Required**
Wake County Schools							
E	8.3	NE	Apex Elementary School	Apex	639	42	10
E	8.8	NE	Apex High School	Apex	2215	115	45
E	10.1	NE	Apex Middle School	Apex	1166	63	24
E	9.1	NE	Baucom Elementary School	Apex	904	52	13
E	10.3	NE	Hope Montessori	Apex	44	4	1
E	9.3	NE	Lufkin Rd Middle School	Apex	1066	65	22
E	7.8	NE	Olive Chapel Elementary School	Apex	925	62	14
E	10.3	NE	Salem Elementary School	Apex	757	45	11
E	10.3	NE	Salem Middle School	Apex	656	87	14
E	7.7	NE	St. Mary Magdalene Catholic School	Apex	510	45	8
F	7	E	Community Partners Charter High School	Holly Springs	115	12	3
F	6	E	Holly Grove Elementary School	Holly Springs	462	82	7
F	8	E	Holly Ridge Elementary School	Holly Springs	714	38	11
F	8	E	Holly Ridge Middle School	Holly Springs	1285	110	26
F	7.4	E	Holly Springs Elementary School	Holly Springs	818	85	12
F	6	E	Holly Springs High School	Holly Springs	805	82	17
F	7.2	E	Southern Wake Montessori School	Holly Springs	100	N/A	2
F	9.6	E	The New School Montessori Center	Holly Springs	117	13	2
G	9.2	E	Fuquay-Varina High School	Fuquay-Varina	1730	97	35
G	9.7	SE	Fuquay-Varina Middle School	Fuquay-Varina	989	51	20
G	8.8	SE	Lincoln Heights Elementary School	Fuquay-Varina	630	50	9
				Wake County Totals:	16,647	1,200	306
Chatham County Schools							
M	6.9	W	Moncure Elementary School	Moncure	203	42	3
				Chatham County Totals:	203	42	3
				EPZ Totals:	**16,850**	**1,242**	**309**

* N/A – Not Available

Table 8-3. Relocation Schools		
Facility	**Sub-zone**	**Relocation School**
High Schools		
Apex Senior High School	E	Sanderson High School
Community Partner's Charter High School	F	Southeast Raleigh High School
Fuquay-Varina Senior High School	G	Garner Senior High School
Holly Springs High School	E	Knightdale High School
Middle Schools		
Apex Middle School	E	Leesville High School
Fuquay-Varina Middle School	G	Millbrook High School
Holly Ridge Middle School	F	Knightdale High School
Lufkin Road Middle School	E	Leesville High School
St. Mary Magdalene Catholic School	E	Cardinal Gibbons High School
Salem Middle School	E	Leesville High School
Southern Wake Montessori School	E	Southeast Raleigh High School
Elementary Schools		
Apex Elementary School	E	Sanderson High School
Baucom Elementary School	E	Leesville High School
Holly Ridge Elementary School	F	Knightdale High School
Holly Springs Elementary School	F	Knightdale High School
Holly Grove Elementary School	E	Knightdale High School
Hope Montessori School	E	Sanderson High School
Lincoln Heights Elementary School	G	Millbrook High School
Moncure Elementary School	M	Northwood Senior High School
The New School, Inc. Montessori	G	Southeast Raleigh High School
Olive Chapel Elementary School	E	Leesville High School
Salem Elementary School	E	Leesville High School

Table 8-4. Special Facility Transit Demand

ERPA	Facility Name	Municipality	Cap-acity	Current Census	Ambu-latory	Wheel-chair Bound	Bed-ridden	Ambu-lance Runs	Wheel-chair Bus Runs	Wheel-chair Van Runs	Bus Runs
	WAKE COUNTY										
A	Brown's Family Care Home	New Hill	6	5	5	0	0	0	0	0	1
A	James Rest Home	New Hill	40	39	32	7	0	0	0	2	2
E	Buck Jones Road Home*	Apex	6	5	3	2	0	0	0	1	A
E	Mason Street Home	Apex	6	6	6	0	0	0	0	0	A
E	Rex Rehab & Nursing Care	Apex	107	100	38	50	12	6	3	2	2
E	Seagroves Family Home	Apex	6	6	6	0	0	0	0	0	A
E	Spring Arbor of Apex	Apex	76	74	59	15	0	0	1	0	2
E	Atwater Rest Home*	Apex	55	48	30	14	4	2	1	0	2
F	Adams Care Home*	Apex	5	4	3	1	0	0	0	1	B
F	Harrison Home	Apex	2	2	2	0	0	0	0	0	B
F	Autumn Green Adult Care Home*	Holly Springs	6	5	3	2	0	0	0	1	D
F	Avent Ferry House	Holly Springs	6	6	6	0	0	0	0	0	D
F	Country Lane Group Home	Holly Springs	6	6	6	0	0	0	0	0	D
F	Herbert Reid Home*	Holly Springs	3	3	2	1	0	0	0	1	D
F	Hickory Street Group Home	Holly Springs	6	6	5	1	0	0	0	1	E
F	Murchison Adult Family Living	Holly Springs	2	2	2	0	0	0	0	0	E
F	St. Mark's Manor	Holly Springs	9	9	9	0	0	0	0	0	F
F	Trotter's Bluff	Holly Springs	6	6	6	0	0	0	0	0	F
G	VOCA Olive Home	Apex	6	6	6	0	0	0	0	0	B
G	Brighton Manor	Fuquay-Varina	80	59	10	43	6	3	3	0	1
G	Evans-Walston Home	Fuquay-Varina	3	3	3	0	0	0	0	0	C
G	Fuquay-Varina Home for the Elderly	Fuquay-Varina	60	59	59	0	0	0	0	0	2
G	Kinton Sunset Retirement Community*	Fuquay-Varina	28	24	15	7	2	1	0	2	1
G	VOCA Creekway	Fuquay-Varina	6	6	6	0	0	0	0	0	C
G	Wake Med Fuquay-Varina Outpatient and Skilled Nursing Facility	Fuquay-Varina	36	31	2	22	7	4	1	2	G
G	Windsor Point	Fuquay-Varina	100	71	47	11	13	7	1	0	2
G	Mims Family Care Home	Holly Springs	6	1	1	0	0	0	0	0	G
	LEE COUNTY										
J	Sanford Health and Rehabilitation	Sanford	97	94	12	77	5	3	5	1	1
		Total:	**775**	**686**	**384**	**253**	**49**	**26**	**15**	**14**	**23**

*Detailed census data were not available for these facilities. Census data was based on average values for those facilities in Wake County which did provide detailed data.

Buses A, B, C, D, E, F and G will make multiple stops as indicated.

Table 8-5A. School Evacuation Time Estimates - Good Weather									
School	**Driver Mobilization Time(min)**	**Loading Time (min)**	**Dist. to EPZ Boundary (mi.)**	**Average Speed* (mph)**	**Travel Time to EPZ Bdry (min)**	**ETE (hr:min)**	**Dist. EPZ Bndry to R.C. (mi.)**	**Travel Time EPZ Bdry to RC (min)**	**ETE to R.C. (hr:min)**
Wake County Schools									
Apex Elementary School	90	5	3.23	5.47	36	**2:15**	15.1	23	**2:35**
Apex High School	90	5	1.13	45.00	2	**1:40**	16.4	25	**2:05**
Apex Middle School	90	5	2.89	6.97	25	**2:00**	18.3	28	**2:30**
Baucom Elementary School	90	5	2.66	12.68	13	**1:50**	19.6	30	**2:20**
Community Partners Charter High School	90	5	6.12	8.55	43	**2:20**	13.7	21	**2:40**
Fuquay-Varina High School	90	5	1.44	9.80	9	**1:45**	5.9	9	**1:55**
Fuquay-Varina Middle School	90	5	1.30	35.81	3	**1:40**	28.6	43	**2:25**
Holly Grove Elementary School	90	5	7.24	11.68	38	**2:15**	25.1	38	**2:55**
Holly Ridge Elementary School	90	5	4.26	9.36	28	**2:05**	25.1	38	**2:45**
Holly Ridge Middle School	90	5	4.26	9.36	28	**2:05**	25.1	38	**2:45**
Holly Springs Elementary School	90	5	4.83	8.53	34	**2:10**	25.1	38	**2:50**
Holly Springs High School	90	5	7.24	11.68	38	**2:15**	25.1	38	**2:55**
Hope Montessori	90	5	0.43	40.23	1	**1:40**	16.4	25	**2:05**
Lincoln Heights Elementary School	90	5	2.02	4.99	25	**2:00**	28.6	43	**2:45**
Lufkin Rd Middle School	90	5	0.70	14.85	3	**1:40**	18.3	28	**2:10**
Olive Chapel Elementary School	90	5	4.55	19.25	15	**1:50**	19.6	30	**2:20**
Salem Elementary School	90	5	0.43	40.23	1	**1:40**	19.6	30	**2:10**
Salem Middle School	90	5	0.43	40.23	1	**1:40**	19.6	30	**2:10**
Southern Wake Montessori School	90	5	5.74	9.79	36	**2:15**	25.1	38	**2:50**
St. Mary Magdalene Catholic School	90	5	4.21	6.84	37	**2:15**	10.6	16	**2:30**
The New School Montessori Center	90	5	3.72	13.69	17	**1:55**	13.7	21	**2:15**
Chatham County Schools									
Moncure Elementary School	90	5	5.06	45.00	7	**1:45**	14.3	22	**2:05**
					Maximum for EPZ:	**2:20**		**Maximum:**	**2:55**

*The average speed for each bus route is output by DYNEV. North Carolina State Law governs bus speeds to 45 mph. If the speed output by DYNEV exceeds 45 mph, the speed is adjusted downward to 45 mph. The route travel time and the resultant ETE are computed using the adjusted average speed, where applicable.

School	Driver Mobilization Time(min)	Loading Time (min)	Dist. to EPZ Boundary (mi.)	Average Speed* (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bndry to R.C. (mi.)	Travel Time EPZ Bdry to RC (min)	ETE to R.C. (hr:min)
Wake County Schools									
Apex Elementary School	100	10	3.23	4.36	45	**2:35**	15.1	26	**3:05**
Apex High School	100	10	1.13	40.91	2	**1:55**	16.4	29	**2:25**
Apex Middle School	100	10	2.89	5.26	33	**2:25**	18.3	32	**2:55**
Baucom Elementary School	100	10	2.66	12.23	14	**2:05**	19.6	34	**2:40**
Community Partners Charter High School	100	10	6.12	5.02	74	**3:05**	13.7	24	**3:30**
Fuquay-Varina High School	100	10	1.44	8.38	11	**2:05**	5.9	11	**2:15**
Fuquay-Varina Middle School	100	10	1.30	32.34	3	**1:55**	28.6	50	**2:45**
Holly Grove Elementary School	100	10	7.24	10.49	42	**2:35**	25.1	44	**3:20**
Holly Ridge Elementary School	100	10	4.26	8.63	30	**2:20**	25.1	44	**3:05**
Holly Ridge Middle School	100	10	4.26	8.63	30	**2:20**	25.1	44	**3:05**
Holly Springs Elementary School	100	10	4.83	7.66	38	**2:30**	25.1	44	**3:15**
Holly Springs High School	100	10	7.24	10.49	42	**2:35**	25.1	44	**3:20**
Hope Montessori	100	10	0.43	36.14	1	**1:55**	16.4	29	**2:20**
Lincoln Heights Elementary School	100	10	2.02	4.44	28	**2:20**	28.6	50	**3:10**
Lufkin Rd Middle School	100	10	0.70	13.08	4	**1:55**	18.3	32	**2:30**
Olive Chapel Elementary School	100	10	4.55	18.41	15	**2:05**	19.6	34	**2:40**
Salem Elementary School	100	10	0.43	36.14	1	**1:55**	19.6	34	**2:25**
Salem Middle School	100	10	0.43	36.14	1	**1:55**	19.6	34	**2:25**
Southern Wake Montessori School	100	10	5.74	8.79	40	**2:30**	25.1	44	**3:15**
St. Mary Magdalene Catholic School	100	10	4.21	5.49	47	**2:40**	10.6	19	**3:00**
The New School Montessori Center	100	10	3.72	12.70	18	**2:10**	13.7	24	**2:35**
Chatham County Schools									
Moncure Elementary School	100	10	5.06	40.00	8	**2:00**	14.3	25	**2:25**
					Maximum for EPZ:	**3:05**		**Maximum:**	**3:30**

Table 8-5B. School Evacuation Time Estimates - Rain

*The average speed for each bus route is output by DYNEV. North Carolina State Law governs bus speeds to 45 mph. If the speed output by DYNEV exceeds 45 mph, the speed is adjusted downward to 40 mph for rain. The route travel time and the resultant ETE are computed using the adjusted average speed, where applicable.

Table 8-6. Summary of Transit Dependent Bus Routes				
Route Number	**Route Description**	**Sub-Zones Serviced**	**2007 Population of Sub-Zones Serviced**	**Number of Buses**
1	NC Hwy 42 from Fuquay-Varina west out of the EPZ toward Sanford	G(10%)+H+I+K	6,704	1
2	NC Hwy 55 southbound from entrance into EPZ through Holly Springs and Fuquay-Varina	E(15%)+ F(10%)+G(10%)	7,835	2
3	US Hwy 64 westbound from intersection with State Hwy 1011 (Salem St) out of EPZ toward Pittsboro	E(20%) + N	7,297	1
4	Circulate through Apex, then east out of EPZ to Reception Centers.	E(65%)	21,371	4*
5	Circulate through Holly Springs, then northeast out of EPZ to Reception Centers.	F(90%)	12,181	2*
6	Circulate through Fuquay-Varina, then south out of EPZ to Reception Centers.	G(80%)	12,398	2*
		TOTAL:	**67,786**	**12**

*Each bus makes 2 round trips out of EPZ

Table 8-7A. Transit Dependent Evacuation Time Estimates - Good Weather														
		Single Wave						Second Wave						
Route Number	Bus Number	Mobilization (min)	Route Length (mi.)	Average Speed* (mph)	Route Travel Time (min)	Pickup Time (min)	ETE	Travel Time to Rec. Ctr (min)	Unload (min)	Driver Rest (min)	Retun time to EPZ (min)	Route Travel Time (min)	Pickup Time (min)	ETE
1	1	90	7.23	45.00	10	10	1:50	**Second Wave is Not Needed**						
2	1	90	6.76	13.45	30	10	2:10	**Second Wave is Not Needed**						
	2	105	6.76	13.80	29	10	2:25							
3	1	90	7.59	45.00	10	10	1:50	**Second Wave is Not Needed**						
4	1	90	13.00	17.21	45	10	2:25	25	5	10	20	19	10	3:55
	2	105	13.00	16.68	47	10	2:45	25	5	10	20	19	10	4:15
5	1	90	12.02	18.43	39	10	2:20	30	5	10	25	18	10	4:00
6	1	90	5.38	35.88	9	10	1:50	25	5	10	20	10	10	3:10
						Maximum ETE for Single Wave:	**2:45**						**Maximum ETE for Second Wave:**	**4:15**

*The average speed for each bus route is output by DYNEV. North Carolina State Law governs bus speeds to 45 mph. If the speed output by DYNEV exceeds 45 mph, the speed is adjusted downward to 45 mph. The route travel time and the resultant ETE are computed using the adjusted average speed, where applicable.

Table 8-7B. Transit Dependent Evacuation Time Estimates - Rain															
		Single Wave						Second Wave							
Route Number	**Bus Number**	**Mobilization (min)**	**Route Length (mi.)**	**Average Speed* (mph)**	**Route Travel Time (min)**	**Pickup Time (min)**	**ETE**	**Travel Time to Rec. Ctr (min)**	**Unload (min)**	**Driver Rest (min)**	**Retun time to EPZ (min)**	**Route Travel Time (min)**	**Pickup Time (min)**	**ETE**	
1	1	90	7.23	40.00	11	15	2:00	**Second Wave is Not Needed**							
2	1	90	6.76	10.69	38	15	2:25	**Second Wave is Not Needed**							
	2	105	6.76	9.48	43	15	2:45								
3	1	90	7.59	40.00	11	15	2:00	**Second Wave is Not Needed**							
4	1	90	13.00	13.30	59	15	2:45	28	5	10	22	19	15	4:25	
	2	105	13.00	13.45	58	15	3:00	28	5	10	22	19	15	4:40	
5	1	90	12.02	12.81	56	15	2:45	33	5	10	27	16	15	4:30	
6	1	90	5.38	32.49	10	15	1:55	28	5	10	22	10	15	3:25	
Maximum ETE for Single Wave:							**3:00**	**Maximum ETE for Second Wave:**						**4:40**	

*The average speed for each bus route is output by DYNEV. North Carolina State Law governs bus speeds to 45 mph. If the speed output by DYNEV exceeds 45 mph, the speed is adjusted downward to 40 mph for rain. The route travel time and the resultant ETE are computed using the adjusted average speed, where applicable.

Table 8-8A. Evacuation Time Estimates for Ambulatory Patients at Medical Facilities - Good Weather							
Facility Name	**Number of Ambulatory Patients**	**Driver Mobilization Time(min)**	**Loading Time (min)**	**Route Length (mi.)**	**Average Speed (mph)**	**Travel Time (min)**	**ETE (hr:min)**
Wake County Medical Facilities							
Brown's Family Care Home	5	90	5	8.72	30.27	17	**1:55**
James Rest Home	32	90	32	8.72	30.25	17	**2:20**
Buck Jones Road Home	3	90	15	5.50	10.99	30	**2:20**
Mason Street Home	6						
Seagroves Family Home	6						
Rex Rehab & Nursing Care	38	90	38	2.33	8.28	17	**2:25**
Spring Arbor of Apex	59	90	59	3.11	17.90	10	**2:40**
Atwater Rest Home	30	90	30	2.96	42.58	4	**2:05**
Adams Care Home	3	90	11	12.44	17.17	43	**2:25**
Harrison Home	2						
VOCA Olive Home	6						
Autumn Green Adult Care Home	3	90	17	8.48	26.52	19	**2:10**
Avent Ferry House	6						
Country Lane Group Home	6						
Herbert Reid Home	2						
Hickory Street Group Home	5	90	7	7.95	14.34	33	**2:15**
Murchison Adult Family Living	2						
St. Mark's Manor	9	90	15	8.14	29.99	16	**2:05**
Trotter's Bluff	6						
Brighton Manor	10	90	10	2.35	8.70	16	**2:00**
Evans-Walston Home	3	90	9	5.05	12.93	23	**2:05**
VOCA Creekway	6						
Fuquay-Varina Home for the Elderly	59	90	59	2.33	40.77	3	**2:35**
Kinton Sunset Retirement Community	15	90	15	2.35	8.80	16	**2:05**
Wake Med Fuquay-Varina Outpatient and Skilled Nursing Facility	2	90	3	2.35	8.7	16	**1:50**
Mims Family Care Home	1						
Windsor Point	47	90	47	1.80	9.08	12	**2:30**
Chatham County Medical Facilities							
Sanford Health and Rehabilitation	12	90	12	1.48	41.46	2	**1:45**
						Maximum for EPZ:	**2:40**

Table 8-8B. Evacuation Time Estimates for Ambulatory Patients at Medical Facilities - Rain							
Facility Name	**Number of Ambulatory Patients**	**Driver Mobilization Time(min)**	**Loading Time (min)**	**Route Length (mi.)**	**Average Speed (mph)**	**Travel Time (min)**	**ETE (hr:min)**
Wake County Medical Facilities							
Brown's Family Care Home	5	100	5	8.72	27.04	19	**2:05**
James Rest Home	32	100	32	8.72	27.03	19	**2:35**
Buck Jones Road Home	3	100	15	5.50	7.19	46	**2:45**
Mason Street Home	6						
Seagroves Family Home	6						
Rex Rehab & Nursing Care	38	100	38	2.33	6.87	20	**2:40**
Spring Arbor of Apex	59	100	59	3.11	32.50	6	**2:45**
Atwater Rest Home	30	100	30	2.96	38.62	5	**2:15**
Adams Care Home	3	100	11	12.44	14.43	52	**2:45**
Harrison Home	2						
VOCA Olive Home	6						
Autumn Green Adult Care Home	3	100	17	8.48	7.86	65	**3:05**
Avent Ferry House	6						
Country Lane Group Home	6						
Herbert Reid Home	2						
Hickory Street Group Home	5	100	7	7.95	12.83	37	**2:25**
Murchison Adult Family Living	2						
St. Mark's Manor	9	100	15	8.14	27.21	18	**2:15**
Trotter's Bluff	6						
Brighton Manor	10	100	10	2.35	7.58	19	**2:10**
Evans-Walston Home	3	100	9	5.05	10.31	29	**2:20**
VOCA Creekway	6						
Fuquay-Varina Home for the Elderly	59	100	59	2.33	36.67	4	**2:45**
Kinton Sunset Retirement Community	15	100	15	2.35	7.57	19	**2:15**
Wake Med Fuquay-Varina Outpatient and Skilled Nursing Facility	2	100	3	2.35	7.58	19	**2:05**
Mims Family Care Home	1						
Windsor Point	47	100	47	1.80	5.50	20	**2:50**
Chatham County Medical Facilities							
Sanford Health and Rehabilitation	12	100	12	1.48	37.28	2	**1:55**
						Maximum for EPZ:	**3:05**

Table 8-9: Bus Route Descriptions		
Bus Route Number	**Description**	**Nodes Traversed from Route Start to EPZ Boundary***
1	Apex Elementary School	292, 757, 320, 734, 758, 68, 690, 759, 691, 692, 601
2	Apex High School	1018, 120
3	Apex Middle School	319, 320, 734, 758, 68, 690, 759, 691, 692, 601
4	Baucom Elementary School	694, 297, 298, 670, 671, 123, 122, 587, 120
5	Hope Montessori Salem Elementary School Salem Middle School	62, 301, 674,
6	Lufkin Rd Middle School	447, 60, 692, 601
7	Olive Chapel Elementary School	296, 299, 434, 127, 126, 672, 123, 122, 587, 120
8	St. Mary Magdalene Catholic School	1010, 291, 292, 757, 320, 734, 758, 68, 690, 759, 691, 692, 601
9	Community Partners Charter High School	439, 441, 1036, 443, 444, 29, 28, 27, 762, 445, 68, 690, 759, 691, 692, 601
10	Holly Grove Elementary School Holly Springs High School	156, 140, 21, 35, 438, 439, 555, 715, 716, 52, 790, 520, 522, 524, 525, 511
11	Holly Ridge Elementary School Holly Ridge Middle School	555, 715, 716, 52, 790, 520, 522, 524, 525, 511
12	Holly Springs Elementary School	439, 555, 715, 716, 52, 790, 520, 522, 524, 525, 511
13	Southern Wake Montessori School	438, 439, 555, 715, 716, 52, 790, 520, 522, 524, 525, 511
14	The New School Montessori Center	50, 51, 52, 790, 520, 522, 524, 525, 511
15	Fuquay-Varina High School	1031, 424, 226, 202
16	Fuquay-Varina Middle School	957, 226, 202
17	Lincoln Heights Elementary School	894, 228, 959, 204, 203, 1030, 226, 202
18	Moncure Elementary School	258, 256, 805, 23, 22, 78, 630, 83, 84
40	Bus Route 1 - Southern EPZ	872, 873, 874, 875, 807, 866, 809, 808, 810, 811, 839, 840, 841, 842
41	Bus Route 2 - Eastern EPZ	31, 32, 33, 21, 35, 435, 615, 431, 1032, 1033, 425, 1031, 424, 226, 202
42	Bus Route 3 - Northern EPZ	128, 641, 129, 130, 466, 1024, 1025, 135, 620, 655
43	Bus Route 4 - Apex	315, 314, 306, 299, 303, 304, 694, 297, 703, 585, 1018, 120, 587, 122, 123, 672, 126, 326, 325, 660, 665, 669, 710, 694, 702, 294, 319, 320, 734, 758, 68, 690, 759, 691, 692, 601
44	Bus Route 5 - Holly Springs	439, 441, 1036, 443, 444, 25, 26, 24, 30, 31, 32, 33, 21, 35, 438, 439, 555, 715, 716, 52, 790, 520, 522, 524, 525, 511
45	Bus Route 6 - Fuquay-Varina	957, 958, 229, 228, 957, 226, 1030, 203, 204, 959, 228, 229, 1100, 1099, 202
60	Brown's Family Care Home James Rest Home	452, 75, 73, 72, 582, 71, 690, 759, 691, 692, 601
61	Special Facility Bus Run A	292, 757, 320, 319, 294, 703, 585, 1019, 704, 581, 60, 447, 449, 1086, 1087, 562, 563, 564
62	Rex Rehab & Nursing Care	734, 758, 68, 690, 759, 691, 692, 601
63	Spring Arbor of Apex	304, 694, 297, 298, 670, 671, 123, 122, 587, 120
64	Atwater Rest Home	292, 294, 703, 297, 298, 670, 671, 123, 122, 587, 120
65	Special Facility Bus Run B	319, 320, 734, 758, 68, 445, 762, 27, 28, 25, 26, 24, 30, 31, 32, 775, 439, 555, 715, 716, 52, 51, 50, 49, 48, 47, 56
66	Special Facility Bus Run D	33, 21, 35, 438, 439, 441, 1036, 443, 444, 55, 54, 53, 791, 52, 790, 520, 522, 524, 525
67	Special Facility Bus Run E	1125, 158, 156, 140, 21, 35, 438, 439, 555, 715, 716, 52, 790, 520, 522, 524, 525
68	Special Facility Bus Run F	140, 21, 33, 32, 31, 30, 24, 26, 25, 444, 55, 54, 53, 791, 52, 790, 520, 522, 524, 525
69	Brighton Manor Kinton Sunset Retirement Community Special Facility Bus Run G	1100, 229, 228, 959, 204, 203, 1030, 226, 202
70	Special Facility Bus Run C	36, 1032, 1033, 425, 1029, 1028, 204, 959, 228, 229, 1100, 1099, 202
71	Fuquay-Varina Home for the Elderly	206, 1100, 1099, 202
72	Windsor Point	1033, 425, 1031, 424, 226, 202
73	Sanford Health and Rehabilitation	514, 515, 85, 84

*Refer to large-scale version of Figure 1-2 (provided electronically – see Section 1.3) for node locations.

Table 8-10. Registered Special Needs Population within the Harris EPZ					
Within EPZ	Chatham	Harnett	Lee	Wake	Total
Registered Special Needs Population	28	13	6	116	163
Bed-ridden	0	1	1	4	6
Wheelchair bound	3	4	2	8	17
Ambulatory	12	5	3	56	76
Total Population Requiring Transportation	15	10	6	68	99

Table 8-11. Transportation Needs for Evacuation of Special Needs Population					
Within EPZ	Chatham	Harnett	Lee	Wake	Total
Ambulances	0	1	1	2	4
Wheelchair Vans	1	1	1	2	5
Buses	1	1	1	2	5*

*Although 5 buses are needed from a capacity standpoint, 15 buses will be used so as to reduce the number of stops needed for each bus. See the discussion of buses in the Special Needs Population section for more information.

Table 8-12. Transportation Resource Availability					
County-wide	Chatham	Harnett	Lee	Wake	Total
Ambulances	7	25	6	48	86
Wheelchair Vans	12	2	5	31	50
Wheelchair Buses	0	0	0	4	4
Buses	136	100	101	893	1,230

9. TRAFFIC MANAGEMENT STRATEGY

This section presents the current traffic control and management strategy that is designed to expedite the movement of evacuating traffic. The resources required to implement this strategy include:

- Personnel with the capabilities of performing the planned control functions of traffic guides (preferably, not necessarily, law enforcement officers).
- Traffic Control Devices to assist these personnel in the performance of their tasks. These devices should comply with the guidance of the Manual of Uniform Traffic Control Devices (MUTCD) published by the Federal Highway Administration (FHWA) of the U.S.D.O.T. All state and most county transportation agencies have access to the MUTCD (also available online). Applicable devices include, with reference to the MUTCD:
    - Traffic Barriers: Chapter 6F, section 6F.61, 62 and Figure 6F-4.
    - Traffic Cones: Chapter 3F and section 6F.56.
    - Signs: Chapter 2I
- A plan that defines all necessary details and is documented in a format that is readily understood by those assigned to perform traffic control.

The functions to be performed in the field are:

1. Facilitate evacuating traffic movements that serve to expedite travel out of the EPZ along routes that the analysis has found to be most effective.
2. Discourage traffic movements that permit evacuating vehicles to travel in a direction which takes them significantly closer to the power station, or which interferes with the efficient flow of other evacuees.

We employ the terms "facilitate" and "discourage" rather than "enforce" and "prohibit" to indicate the need for flexibility in performing the traffic control function. There are always legitimate reasons for a driver to prefer a direction other than that indicated. For example:

- A driver may be traveling home from work or from another location, to join other family members preliminary to evacuating.
- An evacuating driver may be taking a detour from the evacuation route in order to pick up a relative, or other evacuees.
- The driver may be an emergency worker en route to perform an important activity.

The implementation of a plan must also be flexible enough for the application of sound judgment by the traffic guide.

The traffic management strategy is the outcome of the following process:

1. A field survey of these critical locations.
   The schematics describing traffic control, which are presented in Appendix G, are based on data collected during field surveys, upon large-scale maps, and on overhead photos.
2. Computer analysis of the evacuation traffic flow environment.
   This analysis identifies the best routing and those locations that experience pronounced congestion.
3. Consultation with emergency management and enforcement personnel.
   Trained personnel who are experienced in controlling traffic and are aware of the likely evacuation traffic patterns have extensively reviewed these control tactics.
4. Prioritization of TCPs.
   Application of traffic control at some TCPs will have a more pronounced influence on expediting traffic movements than at other TCPs. For example, TCPs controlling traffic originating from areas in close proximity to the power plant could have a more beneficial effect on minimizing potential exposure to radioactivity than those TCPs located far from the power plant. Thus, during the mobilization of personnel to respond to the emergency situation, those TCPs which are assigned a higher priority should be manned earlier. These priorities have been developed in conjunction with county emergency management representatives and law enforcement personnel.

The control tactic at each TCP is presented in each schematic that appears in Appendix G.

Concern was expressed over manpower and equipment shortages at meetings with law enforcement personnel representing the police jurisdictions within the EPZ, especially those within Wake County, where the majority of the traffic congestion is expected based on the analysis presented in Section 7. A sensitivity study was performed to quantify the benefit of manning the traffic control points during the evacuation; the results of this study can be seen in Appendix I. Note that the manning of traffic control points can reduce the ETE by at most 20 minutes. Traffic control guides at key intersections throughout the EPZ serve as fixed point surveillance for accidents or other problems that may arise during the evacuation, which could reduce capacity and extend the ETE. Traffic control guides also provide needed route guidance to those evacuees who may not be familiar with the area and the roadway system (i.e. transients), and to those residents who are uncertain of the proper direction of travel.

Concern was also expressed over mobilization of equipment during an evacuation. Many of the police agencies do not have sufficient cones and barricades readily available to perform the recommended traffic control duties in the event of an emergency, and they

would have to rely on the Department of Transportation (DOT) to provide assistance. It is recommended that the counties and the DOT develop joint emergency response implementation procedures to ensure that sufficient resources are available in a timely manner in the event of an emergency.

The use of Intelligent Transportation Systems (ITS) technologies can reduce manpower and equipment needs, while still facilitating the evacuation process. Dynamic Message Signs (DMS) can be placed within the EPZ to provide information to travelers regarding traffic conditions, route selection, and reception center information. DMS can also be placed outside of the EPZ to warn motorists to avoid using routes that may conflict with the flow of evacuees away from the nuclear power station. Highway Advisory Radio (HAR) can be used to broadcast information to evacuees en route through their vehicle stereo systems. Automated Traveler Information Systems (ATIS) can also be used to provide evacuees with information. Internet websites can provide traffic and evacuation route information before the evacuee begins his trip, while on board navigation systems (GPS units), cell phones, and pagers can be used to provide information en route. These are only several examples of how ITS technologies can benefit the evacuation process.

Chapter 2I of the MUTCD presents guidance on Emergency Management signing. Specifically, the Evacuation Route sign, EM-1 on page 2I-3, with the word “Hurricane” removed, could be installed selectively within the EPZ, if considered advisable by local and state authorities. Similar comments apply to sign EM-3 which identifies TCP locations.

Security Road Blocks (SRB) are deployed near the periphery of the EPZ to divert “through” trips. The ETE calculations reflect the assumption that all “external-external” trips are interdicted after 90 minutes have elapsed after the advisory to evacuate.

All transit trips and other responders entering the EPZ to support the evacuation are assumed to be unhindered by personnel manning TCP and SRB.