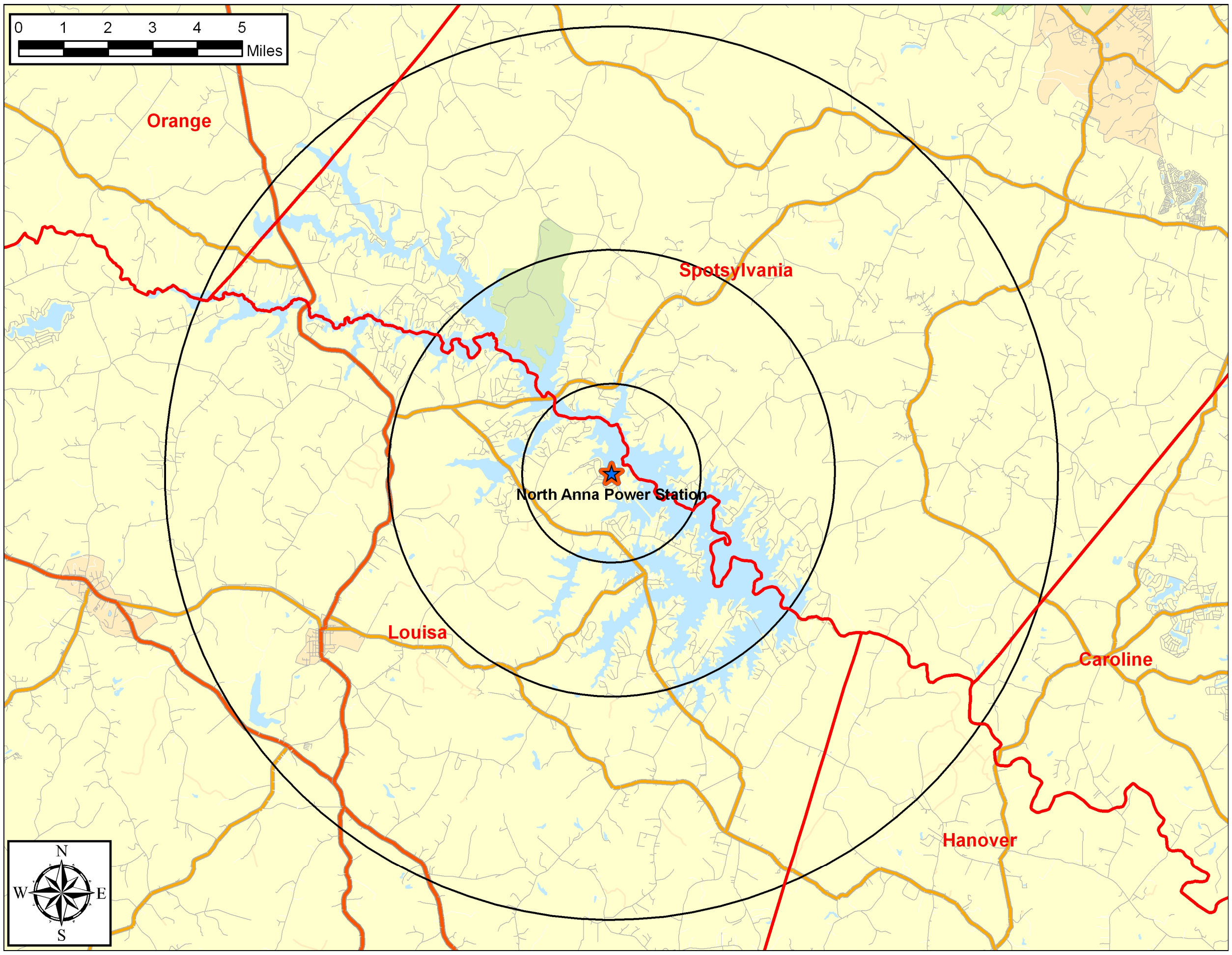
KLD ASSOCIATES, INC.

North Anna Power Station

Development of Evacuation Time Estimates



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Dominion Generation

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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 North Anna Power Station (NAPS) located in Louisa County, Virginia. ETE are part of the required planning basis and provide NAPS 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 published by Federal Government agencies and relevant to Evacuation Time Estimates was reviewed. 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 May, 2007 and extended over a period of 7 months. This report was revised in 2008 in response to RAI from the NRC. These revisions included a refinement of the calculations performed earlier. The major activities performed are briefly described in chronological sequence:

- Attended "kick-off" meetings with Dominion Generation personnel and emergency management personnel representing state and local governments.
- Reviewed prior ETE reports prepared for NAPS.
- Studied Geographical Information Systems (GIS) maps of the area in the vicinity of NAPS, then conducted a detailed field survey of the highway network.
- Obtained GIS shapefiles of address points within the EPZ from Virginia Department of Emergency Management (VDEM) and estimated 2008 population from this data.
- Synthesized this information to create an analysis network representing the highway system topology and capacities within the Emergency Planning Zone (EPZ), plus a "Shadow" area 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.

- 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 25 Protective Action Zones (PAZ). These PAZ are then grouped within circular areas or "keyhole" configurations (circles plus radial sectors) that define a total of 27 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, and Snow). Two special scenarios – construction of a new unit with and without refueling at the operating unit – were considered.
- The Planning Basis for the calculation of ETE is:
    - A rapidly escalating accident at NAPS 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 Evacuation Assembly Centers (EAC) 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.

- In response to RAI obtained from the NRC, refinements to the IDYNEV input data were introduced and a second set of ETE calculations were undertaken using updated transient population estimates. In addition, two snow scenarios were introduced.

Computation of ETE

A total of 378 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 27 Evacuation Regions to completely evacuate from that Region, under the circumstances defined for one of the 14 Evacuation Scenarios (27 x 14 = 378). 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 beyond the EPZ that extends to a distance of 15 miles from NAPS, 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 NAPS), 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.
- All ETE presented in this report reflect the work performed in 2008.

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 should be reviewed by 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 NAPS site showing the layout of the 25 PAZ that comprise, in aggregate, the Emergency Planning Zone (EPZ).
- Table 3-1 presents the estimates of permanent resident population and vehicles for 2008 in each PAZ based on the data provided by VDEM and on the results of the telephone survey.
- Table 6-1 defines each of the 27 Evacuation Regions in terms of their respective groups of PAZ.
- Table 6-2 lists the 14 Evacuation Scenarios.
- Tables 7-1C and 7-1D are compilations of Evacuation Time Estimates (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 8-3A presents ETE for the schoolchildren in good weather.
- Table 8-5A presents ETE for the transit-dependent population in good weather.

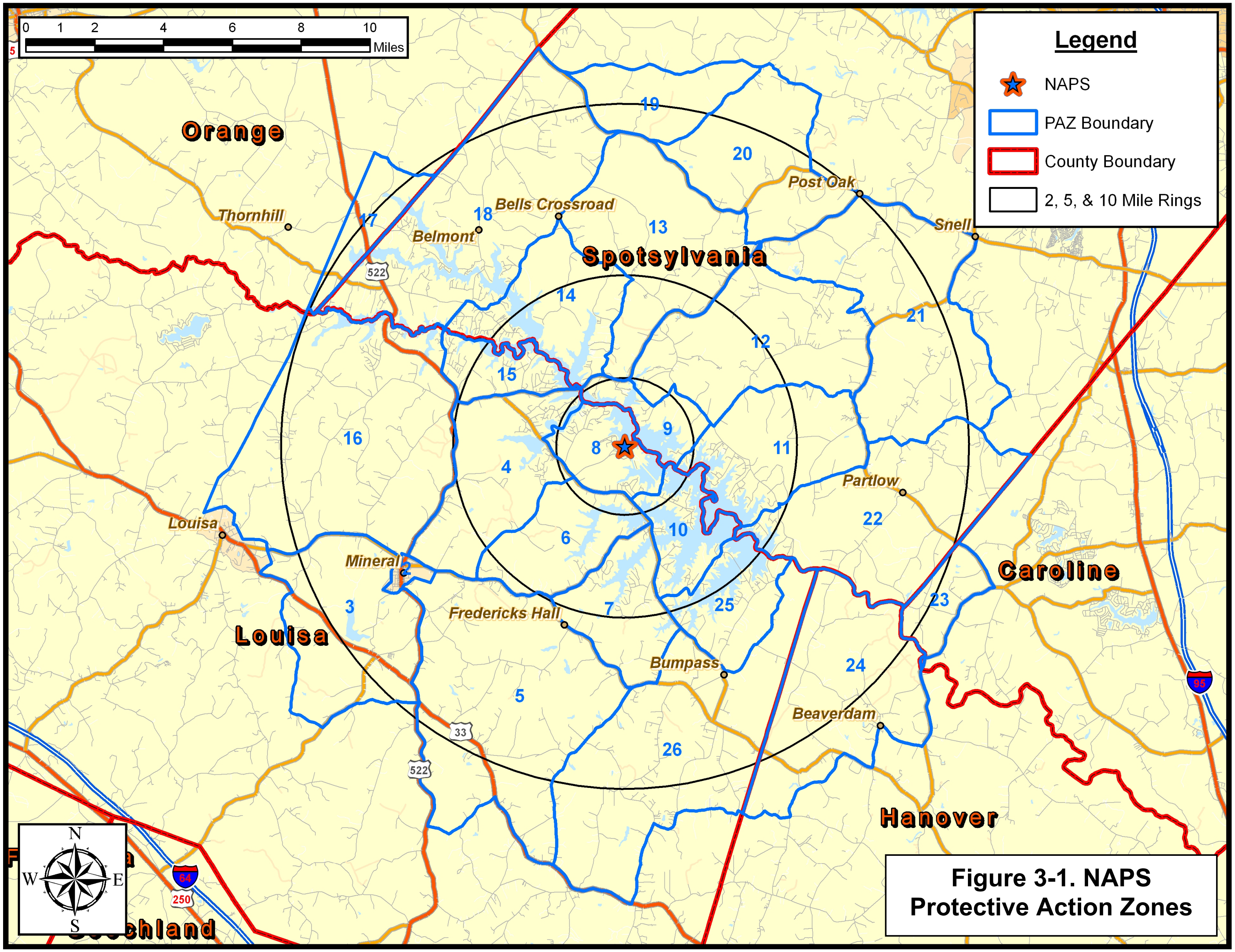

Figure 3-1. NAPS Protective Action Zones

Table 3-1. Permanent Resident Population and Vehicles by PAZ		
PAZ	**2008 POPULATION**	**2008 VEHICLES**
2	645	358
3	1,843	1,025
4	1,842	1,022
5	1,740	968
6	727	404
7	939	522
8	885	490
9	426	236
10	1,151	638
11	1,345	748
12	1,467	814
13	1,312	728
14	1,719	952
15	1,589	879
16	2,153	1,200
17	223	124
18	3,624	2,008
19	352	197
20	1,025	571
21	2,125	1,181
22	1,639	909
23	341	190
24	989	549
25	902	500
26	2,420	1,343
TOTAL:	**33,423**	**18,556**

Table 6-1. Decscription of Evacuation Regions																										
		Protective Action Zone (PAZ)																								
Region	**Description**	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R01	2 mile ring					X		X	X	X																
R02	5-mile ring			X		X	X	X	X	X	X	X	X	X	X										X	
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Evacuate 2 mile ring and 5 miles downwind																										
	Wind Direction	Protective Action Zone (PAZ)																								
Region	**Toward:**	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R04	N, NNE					X		X	X	X		X	X	X												
R05	NE					X		X	X	X	X	X	X													
R06	ENE, E					X		X	X	X	X	X														
R07	ESE, SE					X		X	X	X	X														X	
R08	SSE, S					X	X	X	X	X															X	
R09	SSW					X	X	X	X	X																
R10	SW			X		X	X	X	X	X																
R11	WSW			X		X		X	X	X																
R12	W			X		X		X	X	X					X											
R13	WNW, NW			X		X		X	X	X				X	X											
R14	NNW					X		X	X	X			X	X	X											
Evacuate 5 mile ring and downwind to EPZ boundary																										
	Wind Direction	Protective Action Zone (PAZ)																								
Region	**Toward:**	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R15	N			X		X	X	X	X	X	X	X	X	X	X			X	X	X					X	
R16	NNE			X		X	X	X	X	X	X	X	X	X	X			X	X	X	X				X	
R17	NE			X		X	X	X	X	X	X	X	X	X	X				X	X	X				X	
R18	ENE			X		X	X	X	X	X	X	X	X	X	X					X	X	X			X	
R19	E			X		X	X	X	X	X	X	X	X	X	X						X	X	X		X	
R20	ESE			X		X	X	X	X	X	X	X	X	X	X						X	X	X	X	X	X
R21	SE			X		X	X	X	X	X	X	X	X	X	X							X	X	X	X	X
R22	SSE, S			X	X	X	X	X	X	X	X	X	X	X	X									X	X	X
R23	SSW	X	X	X	X	X	X	X	X	X	X	X	X	X	X										X	X
R24	SW, WSW	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	
R25	W	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X							X	
R26	WNW, NW			X		X	X	X	X	X	X	X	X	X	X	X	X	X							X	
R27	NNW			X		X	X	X	X	X	X	X	X	X	X		X	X	X						X	

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	Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Weekend	Midday	Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Summer	Midweek	Midday	Good	New Plant Construction
14	Summer	Midweek	Midday	Good	New Plant Construction + Refueling

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer	Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)	(14)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday	Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	New Plant Construction	New Plant Construction + Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ																
R01 2-mile ring	3:20	3:20	2:40	2:40	2:50	R01 2-mile ring	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R01 2-mile ring	3:15	3:20
R02 5-mile ring	3:20	3:20	2:40	2:40	2:50	R02 5-mile ring	3:20	3:20	4:00	2:40	2:40	3:20	2:50	R02 5-mile ring	3:35	3:40
R03 Entire EPZ	3:30	3:30	3:20	3:30	3:00	R03 Entire EPZ	3:30	3:40	4:10	2:50	3:00	3:40	3:00	R03 Entire EPZ	3:50	3:55
2-Mile Ring and Downwind to 5 Miles																
R04 N,NNE	3:10	3:10	2:20	2:20	2:40	R04 N,NNE	3:20	3:20	3:50	2:30	2:30	3:10	2:40	R04 N,NNE	3:10	3:20
R05 NE	3:20	3:20	2:30	2:30	2:40	R05 NE	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R05 NE	3:20	3:20
R06 ENE,E	3:20	3:20	2:40	2:40	2:50	R06 ENE,E	3:30	3:30	4:00	2:40	2:40	3:20	2:50	R06 ENE,E	3:20	3:20
R07 ESE,SE	3:20	3:20	2:40	2:40	2:50	R07 ESE,SE	3:20	3:20	4:00	2:50	2:50	3:20	2:50	R07 ESE,SE	3:20	3:25
R08 SSE,S	3:10	3:10	2:40	2:40	2:50	R08 SSE,S	3:20	3:20	4:00	2:50	2:50	3:30	2:50	R08 SSE,S	3:25	3:35
R09 SSW	3:20	3:20	2:40	2:40	2:50	R09 SSW	3:20	3:20	3:50	2:40	2:50	3:20	2:50	R09 SSW	3:20	3:25
R10 SW	3:20	3:20	2:40	2:40	2:50	R10 SW	3:20	3:20	4:00	2:50	2:50	3:30	2:50	R10 SW	3:25	3:35
R11 WSW	3:20	3:20	2:40	2:40	2:50	R11 WSW	3:20	3:20	4:00	2:40	2:40	3:30	2:50	R11 WSW	3:20	3:30
R12 W	3:20	3:20	2:30	2:30	2:50	R12 W	3:20	3:20	4:00	2:40	2:40	3:20	2:40	R12 W	3:25	3:35
R13 WNW,NW	3:10	3:20	2:30	2:30	2:40	R13 WNW,NW	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R13 WNW,NW	3:30	3:35
R14 NNW	3:10	3:10	2:30	2:30	2:40	R14 NNW	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R14 NNW	3:20	3:25
5-Mile Ring and Downwind to EPZ Boundary																
R15 N	3:20	3:20	3:20	3:30	2:50	R15 N	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R15 N	3:35	3:45
R16 NNE	3:30	3:30	3:20	3:30	2:50	R16 NNE	3:30	3:30	4:00	2:50	3:00	3:30	3:00	R16 NNE	3:40	3:45
R17 NE	3:30	3:30	3:00	3:10	2:50	R17 NE	3:30	3:30	4:00	2:50	3:00	3:30	3:00	R17 NE	3:40	3:45
R18 ENE	3:30	3:30	3:00	3:10	2:50	R18 ENE	3:30	3:30	4:00	2:50	3:00	3:30	2:50	R18 ENE	3:40	3:45
R19 E	3:20	3:30	2:50	3:00	2:50	R19 E	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R19 E	3:40	3:45
R20 ESE	3:30	3:30	2:50	3:00	3:00	R20 ESE	3:30	3:30	4:00	2:50	2:50	3:30	3:00	R20 ESE	3:45	3:50
R21 SE	3:30	3:30	2:40	2:50	2:50	R21 SE	3:30	3:30	4:00	2:50	2:50	3:30	3:00	R21 SE	3:45	3:50
R22 SSE,S	3:20	3:30	2:40	2:50	2:50	R22 SSE,S	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R22 SSE,S	3:50	3:50
R23 SSW	3:20	3:20	2:40	2:50	2:50	R23 SSW	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R23 SSW	3:50	3:50
R24 SW,WSW	3:20	3:20	3:00	3:00	2:50	R24 SW,WSW	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R24 SW,WSW	3:45	3:50
R25 W	3:20	3:20	3:20	3:30	2:50	R25 W	3:30	3:30	4:00	2:50	3:00	3:30	2:50	R25 W	3:40	3:50
R26 WNW,NW	3:20	3:20	3:20	3:30	2:50	R26 WNW,NW	3:30	3:30	4:00	2:50	3:00	3:30	2:50	R26 WNW,NW	3:40	3:45
R27 NNW	3:20	3:20	3:20	3:20	2:50	R27 NNW	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R27 NNW	3:35	3:45

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer	Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)	(14)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday	Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	New Plant Construction	New Plant Construction + Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ																
R01 2-mile ring	5:00	5:00	4:00	4:00	4:00	R01 2-mile ring	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R01 2-mile ring	5:00	5:00
R02 5-mile ring	5:00	5:00	4:40	4:40	4:30	R02 5-mile ring	5:00	5:00	6:00	4:40	4:40	5:10	4:30	R02 5-mile ring	5:00	5:00
R03 Entire EPZ	5:10	5:10	4:50	4:50	4:50	R03 Entire EPZ	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R03 Entire EPZ	5:10	5:10
2-Mile Ring and Downwind to 5 Miles																
R04 N,NNE	5:00	5:00	4:00	4:00	4:00	R04 N,NNE	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R04 N,NNE	5:00	5:00
R05 NE	5:00	5:00	4:00	4:00	4:00	R05 NE	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R05 NE	5:00	5:00
R06 ENE,E	5:00	5:00	4:00	4:00	4:00	R06 ENE,E	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R06 ENE,E	5:00	5:00
R07 ESE,SE	5:00	5:10	4:00	4:10	4:00	R07 ESE,SE	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R07 ESE,SE	5:00	5:00
R08 SSE,S	5:00	5:00	4:00	4:10	4:00	R08 SSE,S	5:00	5:00	6:00	4:00	4:00	5:10	4:00	R08 SSE,S	5:00	5:00
R09 SSW	5:00	5:00	4:00	4:10	4:00	R09 SSW	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R09 SSW	5:00	5:00
R10 SW	5:00	5:00	4:00	4:10	4:00	R10 SW	5:00	5:00	6:00	4:00	4:10	5:00	4:00	R10 SW	5:00	5:00
R11 WSW	5:00	5:00	4:00	4:00	4:00	R11 WSW	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R11 WSW	5:00	5:00
R12 W	5:00	5:00	4:00	4:00	4:10	R12 W	5:00	5:00	6:00	4:00	4:00	5:00	4:10	R12 W	5:00	5:00
R13 WNW,NW	5:00	5:00	4:40	4:40	4:40	R13 WNW,NW	5:00	5:00	6:00	4:40	4:40	5:00	4:40	R13 WNW,NW	5:00	5:00
R14 NNW	5:00	5:00	4:40	4:40	4:40	R14 NNW	5:00	5:00	6:00	4:40	4:40	5:00	4:40	R14 NNW	5:00	5:00
5-Mile Ring and Downwind to EPZ Boundary																
R15 N	5:00	5:10	4:50	4:50	4:50	R15 N	5:00	5:10	6:10	4:50	4:50	5:10	4:50	R15 N	5:00	5:00
R16 NNE	5:10	5:10	4:50	4:50	4:50	R16 NNE	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R16 NNE	5:10	5:10
R17 NE	5:10	5:10	4:50	4:50	4:50	R17 NE	5:10	5:10	6:10	4:50	5:00	5:20	4:50	R17 NE	5:10	5:10
R18 ENE	5:10	5:10	4:40	4:50	4:50	R18 ENE	5:10	5:10	6:10	4:50	5:00	5:20	4:50	R18 ENE	5:10	5:10
R19 E	5:10	5:10	4:50	4:50	4:50	R19 E	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R19 E	5:10	5:10
R20 ESE	5:10	5:10	4:50	4:50	4:50	R20 ESE	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R20 ESE	5:10	5:10
R21 SE	5:10	5:10	4:50	4:50	4:50	R21 SE	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R21 SE	5:10	5:10
R22 SSE,S	5:10	5:10	4:50	4:50	4:50	R22 SSE,S	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R22 SSE,S	5:10	5:10
R23 SSW	5:10	5:10	4:50	4:50	4:50	R23 SSW	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R23 SSW	5:10	5:10
R24 SW,WSW	5:10	5:10	4:50	4:50	4:50	R24 SW,WSW	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R24 SW,WSW	5:10	5:10
R25 W	5:10	5:10	4:50	4:50	4:50	R25 W	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R25 W	5:10	5:10
R26 WNW,NW	5:00	5:10	4:40	4:40	4:50	R26 WNW,NW	5:00	5:10	6:10	4:40	4:40	5:10	4:50	R26 WNW,NW	5:10	5:10
R27 NNW	5:00	5:10	4:40	4:40	4:50	R27 NNW	5:00	5:00	6:10	4:50	4:50	5:10	4:40	R27 NNW	5:00	5:00

Table 8-4A. School Evacuation Time Estimates - Good Weather								
School	**Driver Mobilization Time(min)**	**Loading Time (min)**	**Dist. to EPZ Boundary (mi.)**	**Travel Time to EPZ Bndry (min)***	**ETE (hr:min)**	**Dist. EPZ Bndry to EAC (mi.)**	**Travel Time EPZ Bndry to EAC (min)****	**ETE to EAC (hr:min)**
Louisa County Schools								
Thomas Jefferson Elementary School	90	5	1.53	3	**1:40**	9.89	15	**1:55**
Jouett Elementary School	90	5	4.23	8	**1:45**	17.10	26	**2:10**
Louisa County High School	90	5	3.55	7	**1:45**	8.08	13	**1:55**
Louisa County Middle School	90	5	3.30	6	**1:45**	8.07	13	**1:55**
Mineral Christian Preschool (DAYCARE)	90	5	3.49	6	**1:45**	9.02	14	**1:55**
Spotsylvania County Schools								
Berkeley Elementary School	90	5	2.06	4	**1:40**	7.97	12	**1:55**
Livingston Elementary School	90	5	9.29	16	**1:55**	7.21	11	**2:05**
Post Oak Middle School	90	5	4.21	8	**1:45**	7.26	11	**1:55**
Spotsylvania High School	90	5	3.19	6	**1:45**	7.98	12	**1:55**
				Average for EPZ:	**1:45**		**Average:**	**2:00**

*Average speed within EPZ output by PC-DYNEV = 35.0 mph.
**Average speed outside EPZ (assumed) = 40.0 mph.

Table 8-6A. Transit Dependent Evacuation Time Estimates - Good Weather													
Route Number	Single Wave					Second Wave							
	Mobilization (min.)	Route Length (mi.)	Route Travel Time (min.)*	Pickup Time (min.)	ETE (hr:min)	Mobilization (min.)	Unload (min.)	Driver Rest (min.)	Return time to EPZ (min.)	Route Travel Time (min.)**	Pickup Time (min.)	ETE (hr:min)
1	120	22.1	46	30	3:20	120	5	10	20	38	30	3:45
2A	120	22.8	47	30	3:20	120	5	10	20	40	30	3:45
2B	120	27.9	58	30	3:30	120	5	10	20	49	30	3:55
2C	120	31.9	66	30	3:40	120	5	10	20	55	30	4:00
3A	120	21.8	45	30	3:15	120	5	10	20	38	30	3:45
3B	120	16.4	34	30	3:05	120	5	10	20	29	30	3:35
4	120	17.1	35	30	3:05	120	5	10	20	30	30	3:35
5	120	22.0	46	30	3:20	120	5	10	20	38	30	3:45
				Average for EPZ:	**3:20**						**Average for EPZ:**	**3:45**

*Average speed within EPZ output by PC-DYNEV at 2:00 = 29.0 mph.
** Average speed within EPZ output by PC-DYNEV at 2:35 = 34.5 mph.

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 North Anna Power Station (NAPS), located in Louisa County, Virginia. ETE 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 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.

We wish to express our appreciation to all the directors and staff members of the Louisa County, Spotsylvania County, Orange County, Caroline County and Hanover County emergency management agencies, the Virginia Department of Emergency Management (VDEM) 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 Dominion Generation.
   - Reviewed existing reports describing past evacuation studies.
   - Attended meetings with emergency planners from the five counties occupying a portion of the Emergency Planning Zone (EPZ), 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.
- Obtained Geographical Information Systems (GIS) shapefiles with detailed data for the EPZ from VDEM.
- 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 a traffic management strategy. Traffic control is applied at specified Traffic Control Points (TCP) located within the Emergency Planning Zone (EPZ), and at Access Control Points (ACP) located outside the EPZ. Local and state police personnel should review all traffic control plans.
5. Defined Evacuation Areas or Regions. The EPZ is partitioned into Protective Action Zones (PAZ) which form a basis for the ETE analysis presented herein. Evacuation Regions are comprised of contiguous PAZ 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.
6. Estimated demand for transit services for persons at “Special Facilities” and for transit-dependent persons at home.
7. Prepared the input streams for the IDYNEV system.

   - Estimated the traffic demand, based on the available information derived from GIS shapefiles of county address points, 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) to the data acquired during the field survey, to

estimate the capacity of all highway segments comprising the evacuation routes.

- Developed the link-node representation of the evacuation network, which is used as the basis for the computer analysis that calculates the ETE.
- Calculated the evacuating traffic demands for each Region and for each Evacuation Scenario. Considered the effects on demand of “voluntary evacuation” and of the “shadow effect”.
- Represented the traffic management strategy.
- Specified the candidate destinations of evacuation travel consistent with outbound movement relative to the location of the NAPS.
- Prepared the input stream for the IDYNEV System.
- Executed the IDYNEV models to provide the estimates of evacuation routing and ETE.

8. 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 4, 7 and 8 are iterated as described in Appendix D.

1.2 The North Anna Power Station Site Location

The North Anna Power Station is located approximately 40 miles northwest of Richmond, Virginia. The Emergency Planning Zone (EPZ) consists of parts of five counties: Louisa County, Spotsylvania County, Orange County, Caroline County and Hanover County. Figure 1-1 displays the area surrounding the North Anna Power Station site including all counties, the major roads and the site location relative to the City of Richmond. A map showing all communities is shown in Figure 3-1.

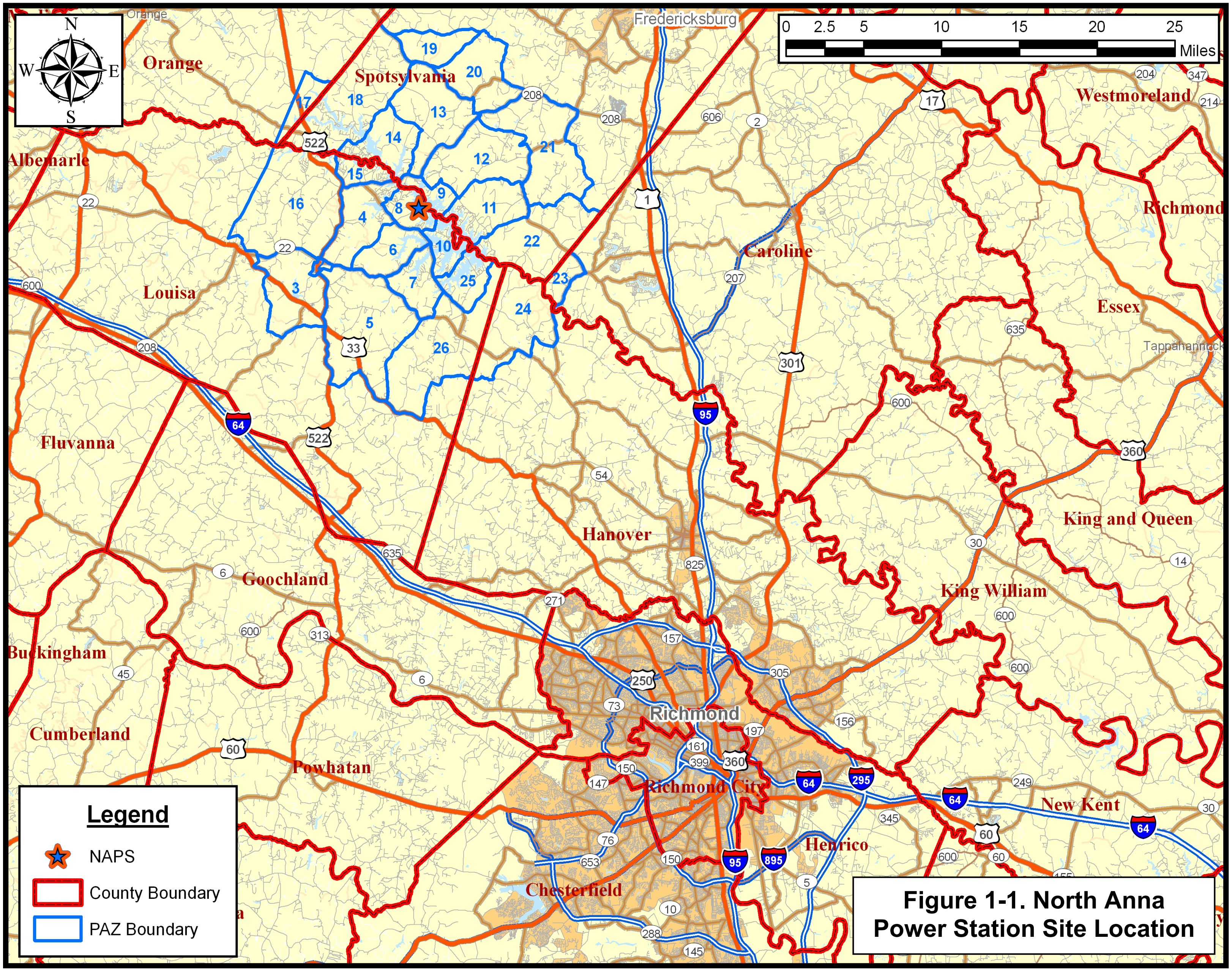

Figure 1-1. North Anna Power Station Site Location

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. 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.	

The data were then transcribed; this information was referenced while preparing the input stream for the IDYNEV System. Key highway locations were video archived. A tablet personal computer equipped with Global Positioning System (GPS) technology was used during the road survey to record observations within GIS shapefiles.

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 2000 Highway Capacity Manual (HCM[1]). The link-node representation of the physical highway network was developed using GIS mapping software and the observations obtained from the field survey. This network representation of "links" and "nodes" is shown in Figure 1-2. An electronic version of Figure 1-2, with all nodes numbered, is provided as a separate file.

Analytical Tools

The IDYNEV 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 IDYNEV 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.

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.

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

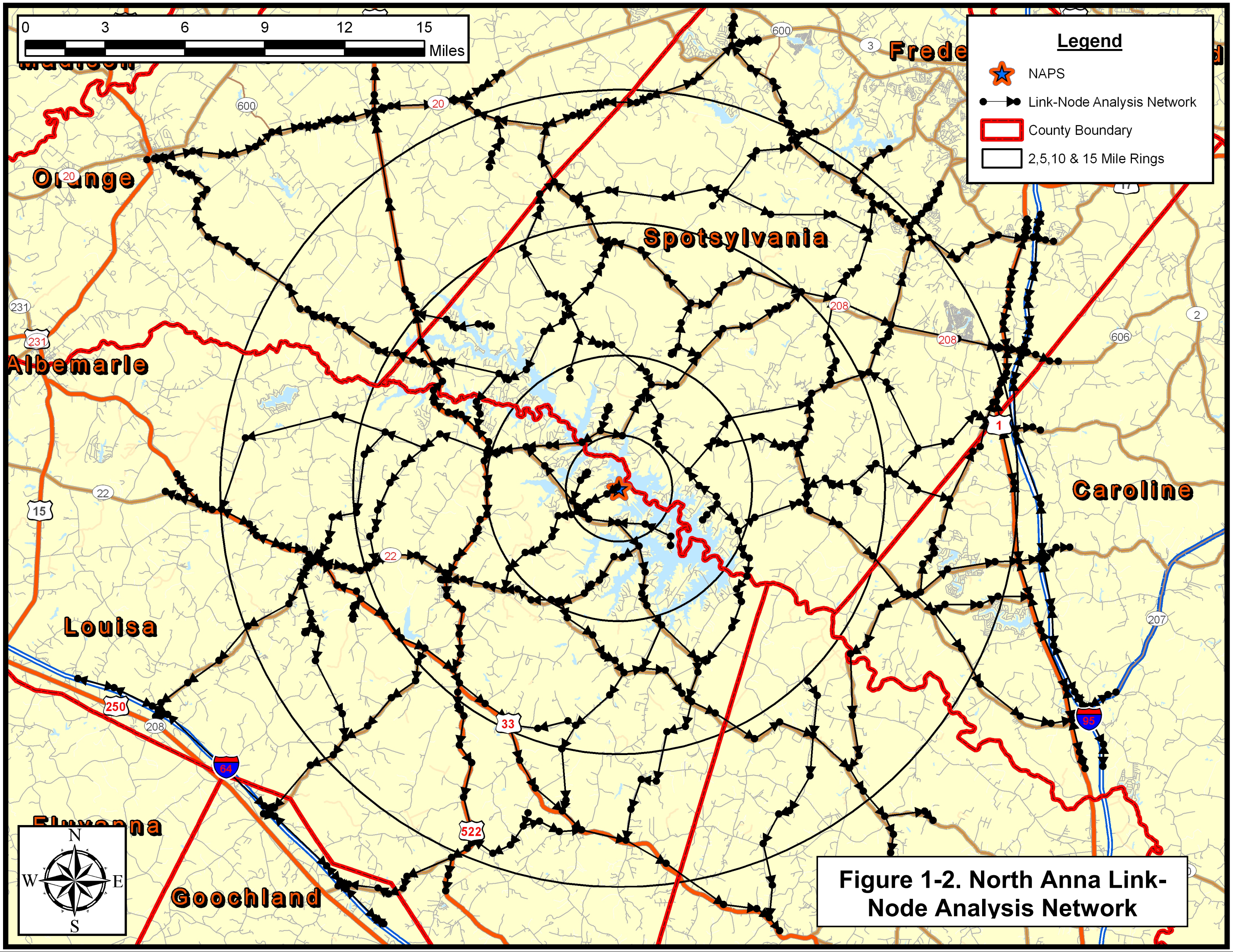


Figure 1-2. North Anna Link-Node Analysis Network

The evacuation analysis procedures are based upon the need to:

- Route traffic along paths of travel that will expedite their travel from their respective points of origin to points outside the EPZ
- Restrict movement toward NAPS 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 NAPS.

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 that are designed to expedite the movement of vehicles. The outputs of this model include the volumes of traffic, expressed as vehicles/hour, that exit the Evacuation Region along the various highway sections (links) that cross the Region boundaries. These outputs are exported into a spreadsheet, which contain the ETE. 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. If 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 2001 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.
- Many more evacuation cases considered, responsive to NUREG/CR-6863.
- 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. Population = 20,292	ArcGIS Software using county-specific address shapefiles. All addresses were assumed to be residential homes. Population = 33,423
Resident Population Vehicle Occupancy	Average household size varies by County. 2.5 persons/vehicle.	2.57 persons/household, 1.42 evacuating vehicles/household yielding: 1.81 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. 1.03 employees/vehicle based on phone survey results.
Voluntary evacuation from within EPZ in areas outside region to be evacuated	Not considered.	50 percent of population within the outer portion of the region; 35 percent, in annular ring between the outer portion and the EPZ boundary (See Figure 2-1).
Shadow Evacuation	Not considered.	30% of people outside of the EPZ, within the shadow area (See Figure 7-2).
Network Size	Network broken down into 106 segments.	635 Links; 487 Nodes (See Figure 1-2).

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Roadway Geometric Data	Field surveys conducted in 2001.	Field surveys conducted in 2007. Major intersections were video archived. GIS shape-files of signal locations and roadway characteristics created during road survey. Road capacities based on 2000 HCM.
School Evacuation	Direct evacuation to designated Evacuation Assembly Center/Host School.	Direct evacuation to designated Evacuation Assembly Center/Host School.
Transit Dependent Population	Identified the number of transit dependent persons; however, special treatment not identified.	Defined as households with 0 vehicles + households with 1 vehicle with commuters who do not return home + households with 2 vehicles with commuters who do not return home. Telephone survey results used to estimate transit dependent population. Detailed bus routes identified to service the transit dependent population.
Ridesharing	Assumed 100 percent of transit dependents will evacuate with a neighbor.	Assumed 50 percent of transit dependent persons will evacuate with a neighbor or friend.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
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	Trip generation curves based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 30 minutes and 5 hours; for snow scenarios this increases to between 30 minutes and 6 hours Residents without commuters returning leave between 15 minutes and 4 hours; for snow scenarios this increases to between 15 minutes and 5 hours. Employees and transients leave between 15 minutes and 3 hours. All times measured from the Advisory to Evacuate.
Traffic and Access Control	Not considered.	Traffic and Access Control used in all scenarios to facilitate the flow of traffic outbound relative to NAPS.
Weather	Adverse. The capacity of each link in the network is reduced by 40% for adverse weather.	Normal, Rain, and Snow. The capacity and free flow speed of all links in the network are reduced by 10% in the event of rain and 20% for snow.
Modeling	Evacuation Simulation Model (ESIM) – part of Oak Ridge Evacuation Modeling System (OREMS)	IDYNEV System: TRAD and PC-DYNEV.
Special Events	None considered.	Two considered – Construction of a new unit at NAPS with and without refueling of the operating units.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Evacuation Cases	7 Regions (2, 5, and 10 mile radius and 4 Quadrants) and 2 Scenarios producing 14 unique cases	27 Regions (central sector wind direction and each adjacent sector technique used) and 14 Scenarios producing 378 unique cases
Evacuation Time Estimates Reporting	ETE reported for 90th 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	Full EPZ–Good weather = 1:25 Full EPZ–Adverse weather = 1:30	Summer Midweek Midday Good weather = 5:10 Summer Weekend Midday Good weather = 4:50

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 GIS shapefiles of address points within each county in the EPZ. These shapefiles are updated regularly and were provided by the Virginia Department of Emergency Management. It is assumed that the address points are all residential homes with the exception of the address points for NAPS, the NAPS training center, and those addresses within Lake Anna State Park. The number of households was multiplied by the average household occupancy of 2.57 persons (obtained in the telephone survey) to estimate the 2008 population within the EPZ. GIS shapefiles of address points were not available for Caroline County; 2000 Census data were used and extrapolated to 2008 based on county growth rates.
2. Estimates of employees who commute into the EPZ to work are based upon data obtained from major employers by Dominion Generation.
3. Population estimates at special facilities are based on available data from county emergency management offices.
4. Roadway capacity estimates are based on field surveys and on the application of Highway Capacity Manual 2000[1].
5. Population mobilization times are based on a statistical analysis of data acquired from the telephone survey.
6. The relationship between resident population and evacuating vehicles is developed from the telephone survey. The average values of 2.57 persons per household and 1.42 evacuating vehicles per household are used.
7. The relationship between persons and vehicles for special facilities is as follows:
   a. Parks/Recreational: 2.5 persons per vehicle.
   b. Marinas: 195 vehicles per facility, 2 persons per vehicle.
   c. Employees: 1.03 employees per vehicle (telephone survey results)
8. Evacuation Time Estimates (ETE) are presented for the evacuation of the 100 percent of the population within each Region, for each Scenario, and for the 2-mile, 5-mile and 10-mile distances. ETE are presented in tabular format and graphically, showing the values of ETE associated with the

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

50th, 90th, 95th and 100th percentiles of population. An Evacuation Region is defined as a group of Protective Action Zones (PAZ) 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 ETE are computed and presented in a format compliant with the guidance in the cited NUREG documentation. The ETE for each evacuation area ("Region" comprised of included PAZs) is presented in both statistical and graphical formats.
3. Evacuation movements (paths of travel) are generally outbound relative to the power station 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 PAZs 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 outer circle defined by the "key-hole" sector of the Evacuation Region, and the EPZ boundary, it is assumed that 35 percent of people will voluntarily evacuate. In the annular area between the EPZ boundary and a 15-mile circular area centered at the plant (the "shadow region"), it is 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 shadow region (See Appendix I).
6. A total of 14 "Scenarios" representing different seasons, time of day, day of week and weather are considered. Two special event scenarios are studied: the construction period of a new nuclear plant with and without refueling at the operating 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	Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Weekend	Midday	Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Summer	Midweek	Midday	Good	New Plant Construction
14	Summer	Midweek	Midday	Good	New Plant Construction + Refueling

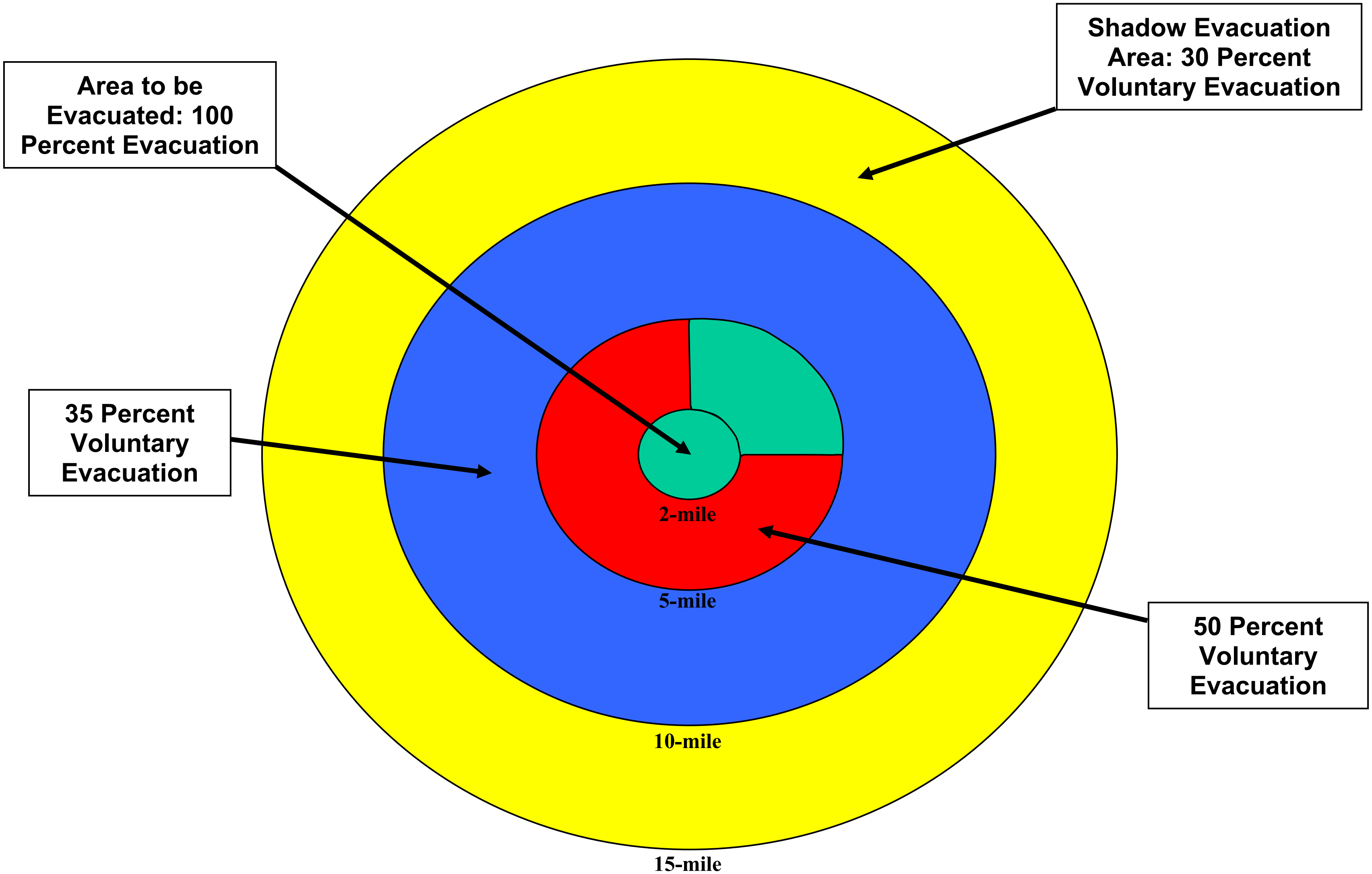


Figure 2-1. Voluntary Evacuation Methodology

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]). The models have continuously been refined and extended since those hearings and have been independently validated by a consultant retained by the NRC.

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 PAZs forming a Region that is issued an Advisory to Evacuate will, in fact, respond in general accord with the planned routes.
3. It is further estimated that 59 percent of the households in the EPZ have at least 1 commuter; and that 61 percent of these households will await the return of a commuter before beginning their evacuation trip, based on the telephone survey results.
4. A portion of the population outside the Evacuation Region will elect to evacuate even though not advised to do so ("voluntary evacuation"). See discussion above and 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 Evacuation Region. "Normal" traffic flow is assumed to be present within the EPZ at the start of the emergency.
6. Access Control Points (ACP) will be staffed approximately 90 minutes after the siren notifications, to divert traffic attempting to enter the EPZ. Earlier activation of ACP locations could delay returning commuters. It is assumed that no through vehicles will enter the EPZ after this 90 minute 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 general

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

directions identified in the plan (as documented in the public information material), and obey all control devices and traffic guides.

8. 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 Evacuation Assembly Centers (EAC).

   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.

9. 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 these 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 the EAC by bus.

10. Two types of adverse weather scenarios are considered. Rain may occur for either winter or summer scenarios. In the case of rain, it is assumed that the rain begins at about the same time the evacuation advisory is issued. Thus transient populations are not affected. That is, no weather-related reduction in the number of transients who may be present in the EPZ is assumed. Snow may occur in winter scenarios. Transient population reductions are not assumed for snow scenarios. Further, it is assumed that roads are passable and that the appropriate agencies are plowing the roads as they would normally.

    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:

[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).

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time
Rain[4]	90%	90%	No Effect
Snow[4]	80%	80%	Clear driveway before leaving home (Source: Telephone Survey at another site)
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.			

11. 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.

[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 North Anna Power Station (NAPS) 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 Protective Action Zone (PAZ) and by polar coordinate representation (population rose). The NAPS EPZ has been subdivided into 25 PAZs as shown in Figure 3-1.

Permanent Residents

The average household size (2.57 persons/household) and the number of evacuating vehicles per household (1.42 vehicles/household) were adapted from the telephone survey results.

Geographical Information Systems (GIS) shapefiles indicating the current address points within each county (except Caroline County) were provided by the Virginia Department of Emergency Management. These address points were used to estimate the 2008 EPZ population within each county, assuming 2.57 persons/household. Census data for the year 2000 was used for Caroline County and projected to 2008 using the county specific growth rate (3.3% per year) provided by the Census website[1].

Permanent resident population and vehicle estimates for 2008 are presented in Table 3-1. Figures 3-2 and 3-3 present the permanent resident population and permanent resident vehicle estimates by sector and distance from the NAPS. This "rose" was constructed using GIS software.

Construction

Based on discussions with Dominion, the peak construction period for a new unit at the North Anna Power Station will be January, 2011 through May, 2014 with workforce estimates of 3,000 workers. Construction will take place Monday thru Friday from 7:00 AM to 5:00 PM with no work on weekends. All workers are assumed to be traveling into the EPZ from neighboring cities (Richmond, Culpepper, Fredericksburg and Charlottesville). An average vehicle occupancy of 1.03 workers per vehicle (adapted from telephone survey results) was used to convert workers to vehicles – 2,913 total vehicles.

Two "Special Event" scenarios are considered: (1) construction of the new unit during a typical summer day, midweek, midday; (2) construction of the new unit during a typical summer day, midweek, midday with refueling at the operating unit. Refueling requires 500 workers (485 vehicles) during the day shift. The existing roadway system was used for both special event scenarios; no roadway improvements were considered. **Permanent resident population and shadow population were extrapolated to 2013 for these scenarios.** County-specific population growth rates, calculated from Census

[1] http://quickfacts.census.gov

population numbers for 2000 and 2006, were used to project population growth through 2013. The resulting numbers are shown in Table 6-4.

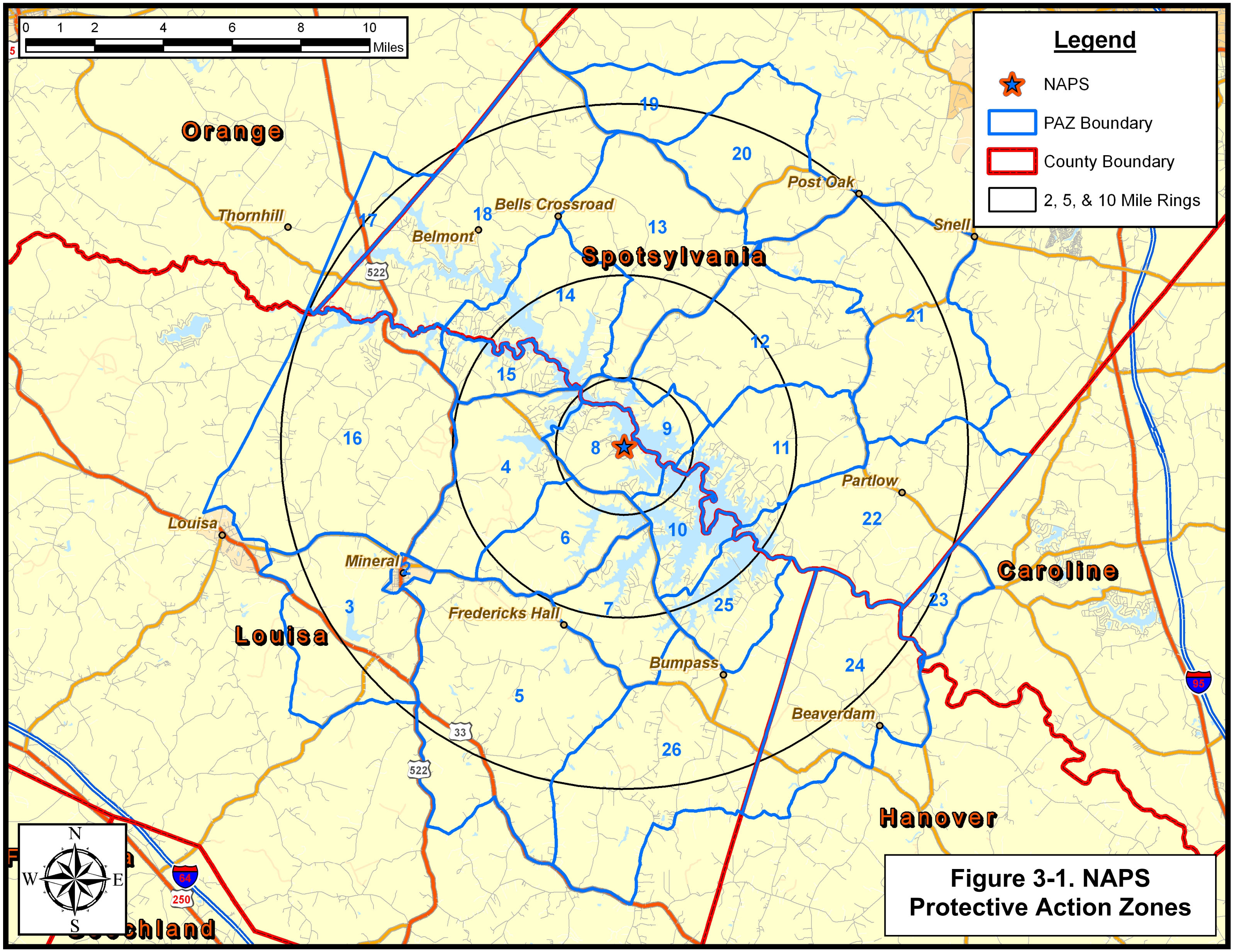
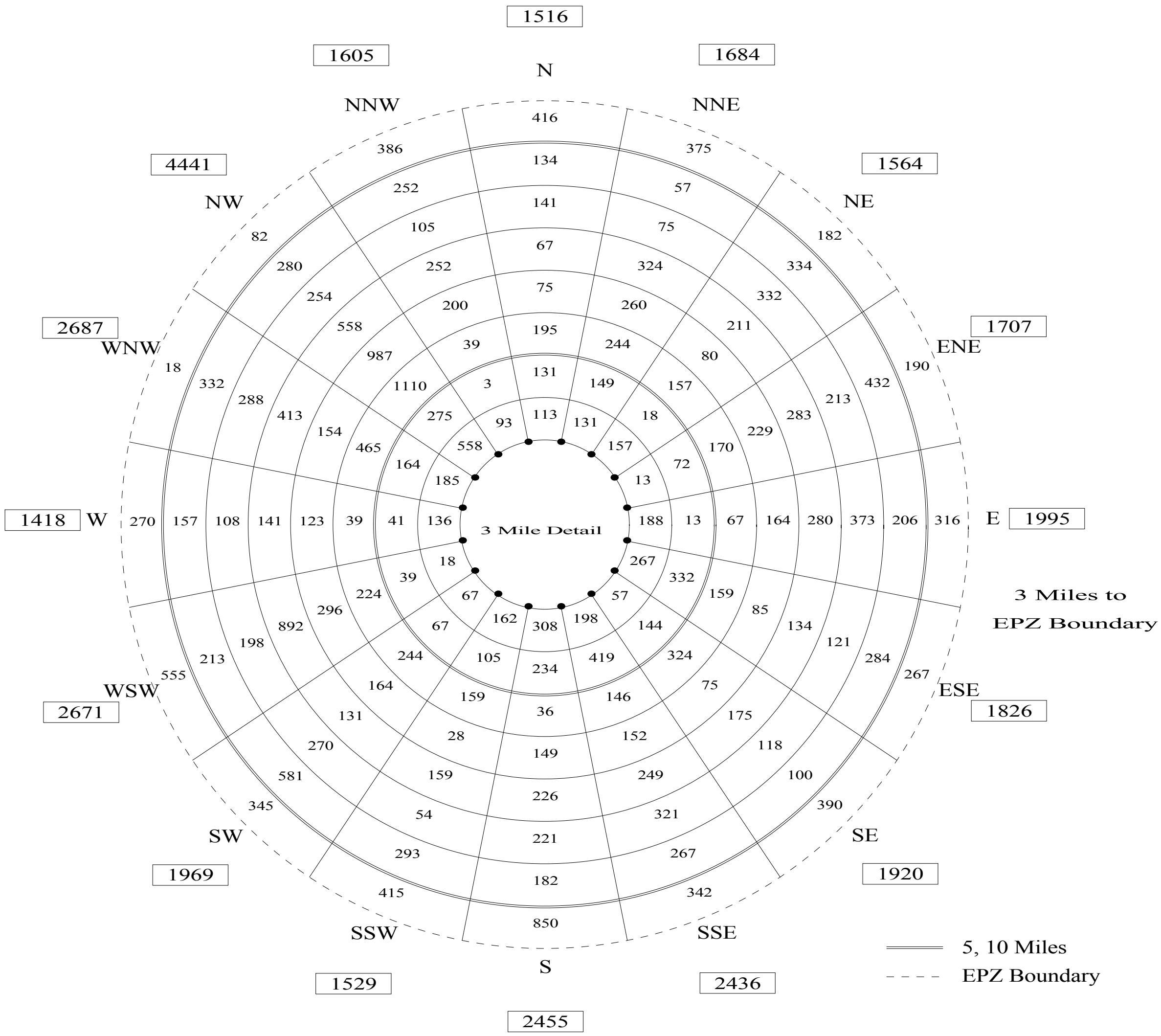
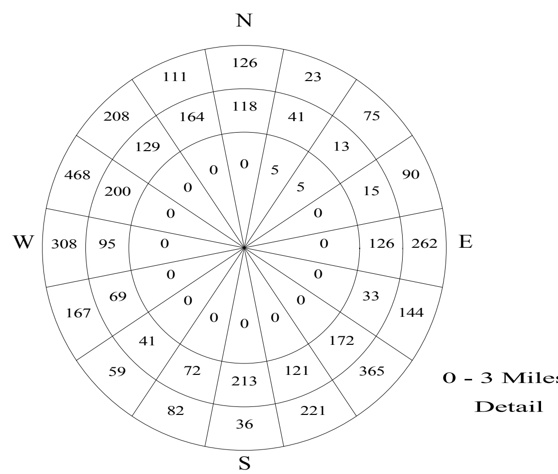


Figure 3-1. NAPS Protective Action Zones

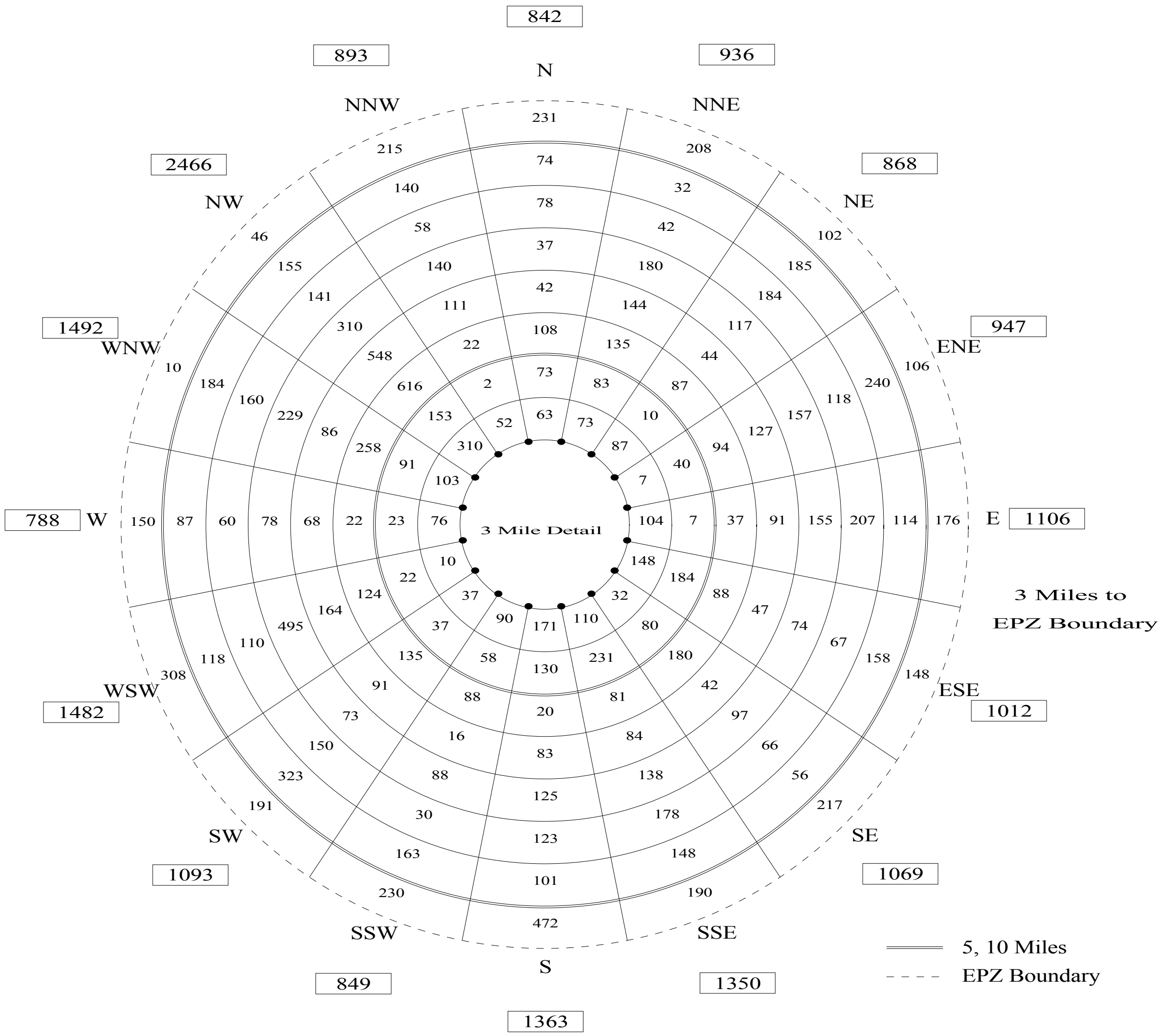
Table 3-1. Permanent Resident Population and Vehicles by PAZ		
PAZ	**2008 POPULATION**	**2008 VEHICLES**
2	645	358
3	1,843	1,025
4	1,842	1,022
5	1,740	968
6	727	404
7	939	522
8	885	490
9	426	236
10	1,151	638
11	1,345	748
12	1,467	814
13	1,312	728
14	1,719	952
15	1,589	879
16	2,153	1,200
17	223	124
18	3,624	2,008
19	352	197
20	1,025	571
21	2,125	1,181
22	1,639	909
23	341	190
24	989	549
25	902	500
26	2,420	1,343
TOTAL:	**33,423**	**18,556**





Resident Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	10	0-1	10
1-2	1622	0-2	1632
2-3	2745	0-3	4377
3-4	2651	0-4	7028
4-5	2206	0-5	9234
5-6	3778	0-6	13012
6-7	3221	0-7	16233
7-8	4495	0-8	20728
8-9	3192	0-9	23920
9-10	4104	0-10	28024
10-EPZ	5399	0-EPZ	33423

Figure 3-2. Permanent Residents by Sector



Resident Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	6	0-1	6
1-2	901	0-2	907
2-3	1526	0-3	2433
3-4	1473	0-4	3906
4-5	1224	0-5	5130
5-6	2095	0-6	7225
6-7	1788	0-7	9013
7-8	2493	0-8	11506
8-9	1772	0-9	13278
9-10	2278	0-10	15556
10-EPZ	3000	0-EPZ	18556

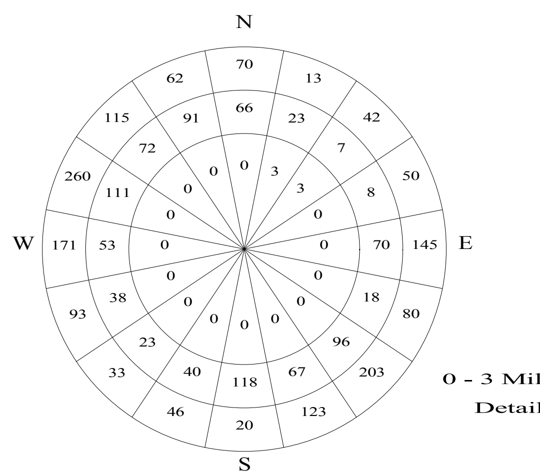


Figure 3-3. Permanent Resident Vehicles by Sector

Transient Population

Transient population groups are defined as those people who are not permanent residents and who enter the EPZ for a specific purpose (boating, recreation). Transients may spend less than one day or stay overnight or longer at rented apartments, camping facilities, hotels and motels. Lake Anna is the primary transient attraction within the EPZ with a large number of recreational areas, including:

1. Lake Anna State Park: Located in PAZ 14, the 2,493-acre park features a beach, 13 miles of hiking trails, 46 campsites, 10 family cabins and a boat ramp to access Lake Anna. The peak season for the park is from Memorial Day until Labor Day. According to the ESP FEIS there are as many as 4,370 people and 1,748 vehicles (2.5 persons/vehicle) in the park during the peak season on a peak day. The ETE presented in Section 7 and Appendix J reflect a population of 4,370 at the park. The number of transients in the park can vary considerably. A sensitivity study was performed to estimate the effect on the ETE of varying transient numbers within the park (see Appendix I).

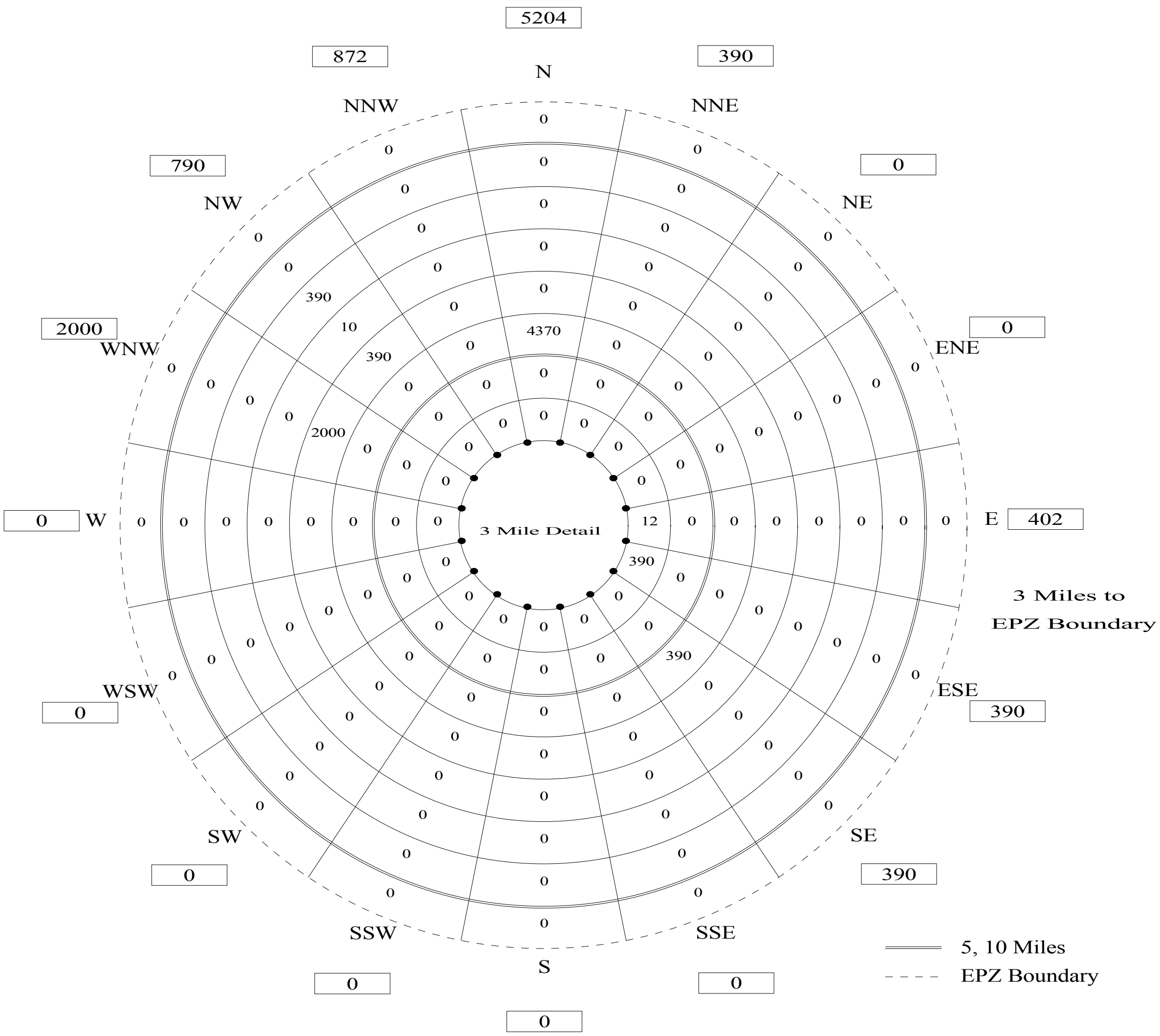
2. Christopher Run Campground: Located on the shores of Lake Anna in PAZ 16, the facility features 200 campsites, a beach, several boat ramps, fishing piers, picnic areas and group camping areas. The peak season is also from Memorial Day to Labor Day. On average, there are 2,000 transients and 800 vehicles (2.5 persons/vehicle) at the campground during the peak season.

3. Marinas and Boat Launch Sites: There are a number of marinas and boat launch sites (boat ramps) on the shores of Lake Anna. Appendix E contains the names of each site and a GIS map of the sites. According to the FEIS there are 5900 people on the lake boating or partaking in other activities. Christopher Run Campground accounts for 2,000 people; the remaining 3900 were distributed across the marinas and boat ramps. Ten sites were equally loaded resulting in 390 people per site or 195 vehicles per site assigning an average occupancy of 2 persons/vehicle.

4. Lodging Facilities: There are no major hotels surrounding Lake Anna; however, there are several smaller hotels and bed and breakfasts servicing those visitors to Lake Anna that stay overnight. Appendix E maps the lodging facilities and provides details for each facility. A total of 168 transients in 84 vehicles were loaded for EPZ lodging facilities.

The number of transients and transient vehicles are summarized by PAZ in Table 3-2. Figures 3-4 and 3-3 present this data by sector and distance from the NAPS.

Table 3-2. Summary of Transients by PAZ		
PAZ	**Transients**	**Transient Vehicles**
2	NO TRANSIENTS	
3		
4		
5		
6		
7		
8		
9	390	195
10	NO TRANSIENTS	
11	792	396
12	780	390
13	54	27
14	5,242	2,184
15	NO TRANSIENTS	
16	2,000	800
17	NO TRANSIENTS	
18	790	395
19	NO TRANSIENTS	
20		
21		
22		
23		
24		
25	390	195
26	NO TRANSIENTS	
TOTAL:	**10,438**	**4,582**



Transient Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	444	0-2	444
2-3	2042	0-3	2486
3-4	402	0-4	2888
4-5	0	0-5	2888
5-6	4760	0-6	7648
6-7	2390	0-7	10038
7-8	10	0-8	10048
8-9	390	0-9	10438
9-10	0	0-10	10438
10-EPZ	0	0-EPZ	10438

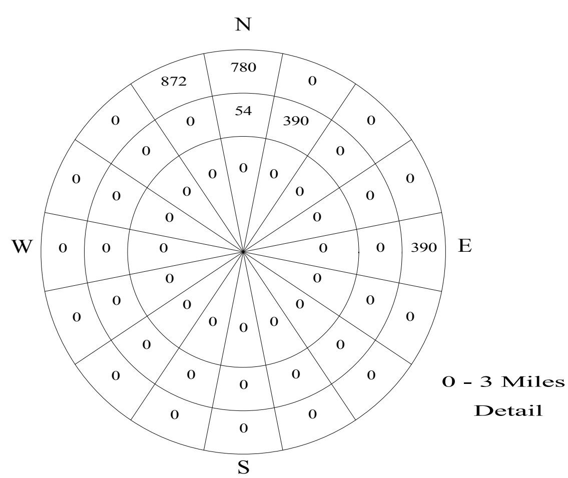
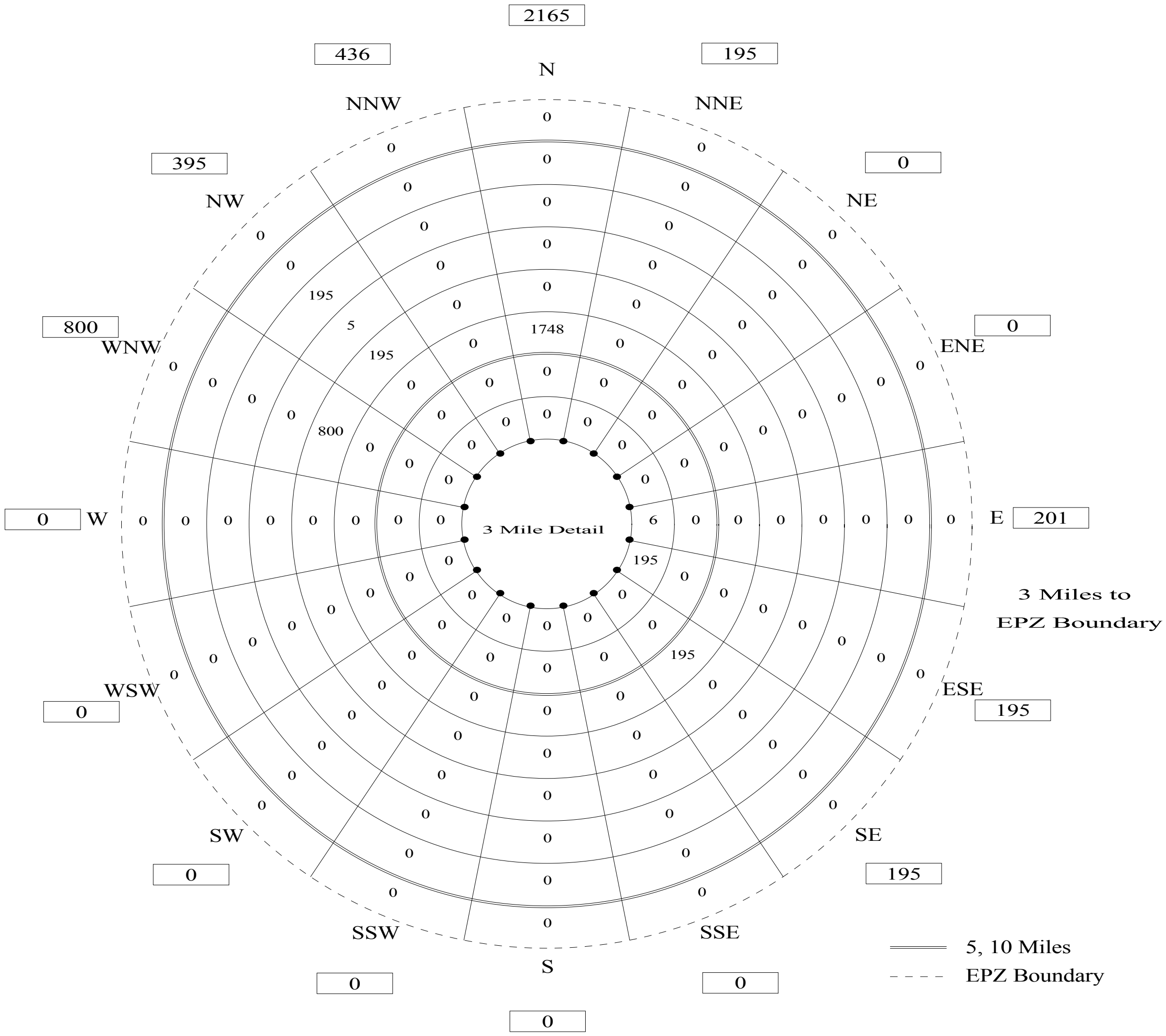
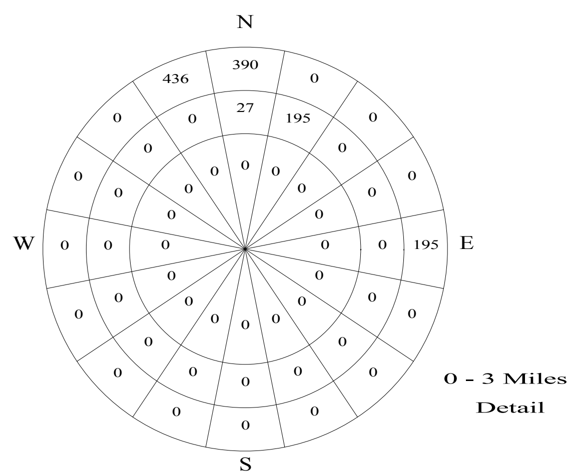


Figure 3-4. Transient Population by Sector





Transient Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	222	0-2	222
2-3	1021	0-3	1243
3-4	201	0-4	1444
4-5	0	0-5	1444
5-6	1943	0-6	3387
6-7	995	0-7	4382
7-8	5	0-8	4387
8-9	195	0-9	4582
9-10	0	0-10	4582
10-EPZ	0	0-EPZ	4582

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.

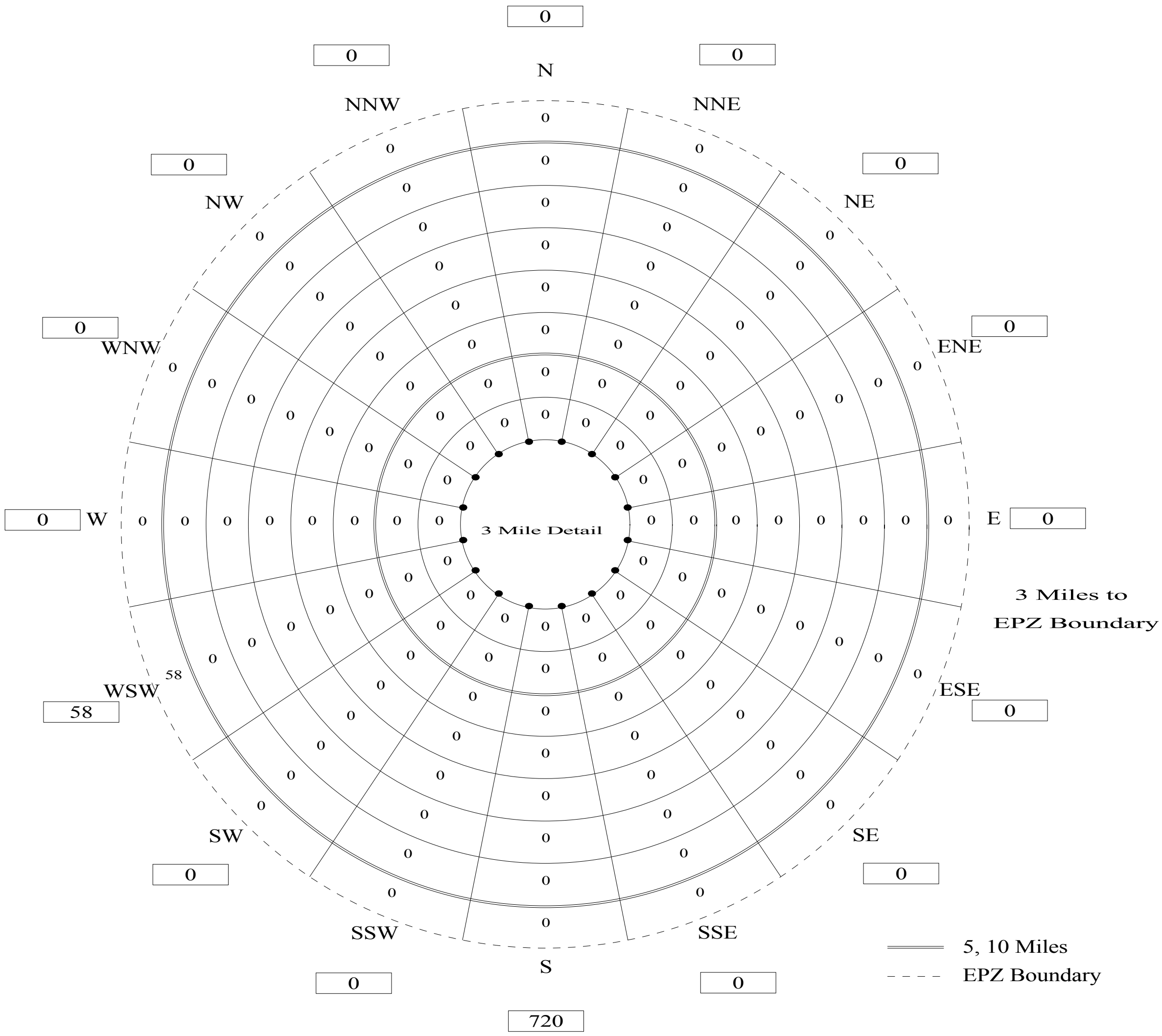
Those of the first category are already counted as part of the permanent resident population. To avoid double counting, we focus on those commuting employees who will evacuate along with the permanent resident population.

Data for major employers (more than 50 total employees) in the EPZ was provided by the county emergency management offices. The locations of these facilities were mapped using GIS software (Figure E-3). The GIS map was overlaid with the evacuation analysis network and employees were loaded onto appropriate links. A loading factor of 1.03 employees per vehicle (based on telephone survey results – limited carpooling within EPZ) was used to estimate the number of non-EPZ employee vehicles.

Three major employers were identified for the NAPS EPZ:

1. The North Anna Power Station (Located in PAZ 8)
   - Total employment of 900 people.
   - Maximum shift employment of 800 people.
   - 90% of employees are non-EPZ residents.
   - 720 non-EPZ employees, 699 vehicles.
2. Impac Klearfold (Located in PAZ 3)
   - Total employment of 156 people.
   - Maximum shift employment of 80 people.
   - 40% of employees are non-EPZ residents.
   - 32 non-EPZ employees, 31 vehicles.
3. Tri-Dim Filters (Located in PAZ 3)
   - Total employment of 210 people.
   - Maximum shift employment of 170 people.
   - 15% of employees are non-EPZ residents.
   - 26 non-EPZ employees, 25 vehicles.

There are a total of 778 non-EPZ employees evacuating in 755 vehicles. Figures 3-6 and 3-7 present non-EPZ employee data by sector.



Employees			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	720	0-1	720
1-2	0	0-2	720
2-3	0	0-3	720
3-4	0	0-4	720
4-5	0	0-5	720
5-6	0	0-6	720
6-7	0	0-7	720
7-8	0	0-8	720
8-9	0	0-9	720
9-10	0	0-10	720
10-EPZ	58	0-EPZ	778

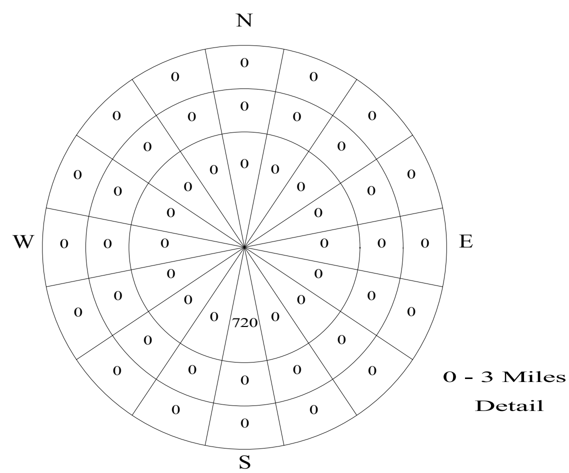
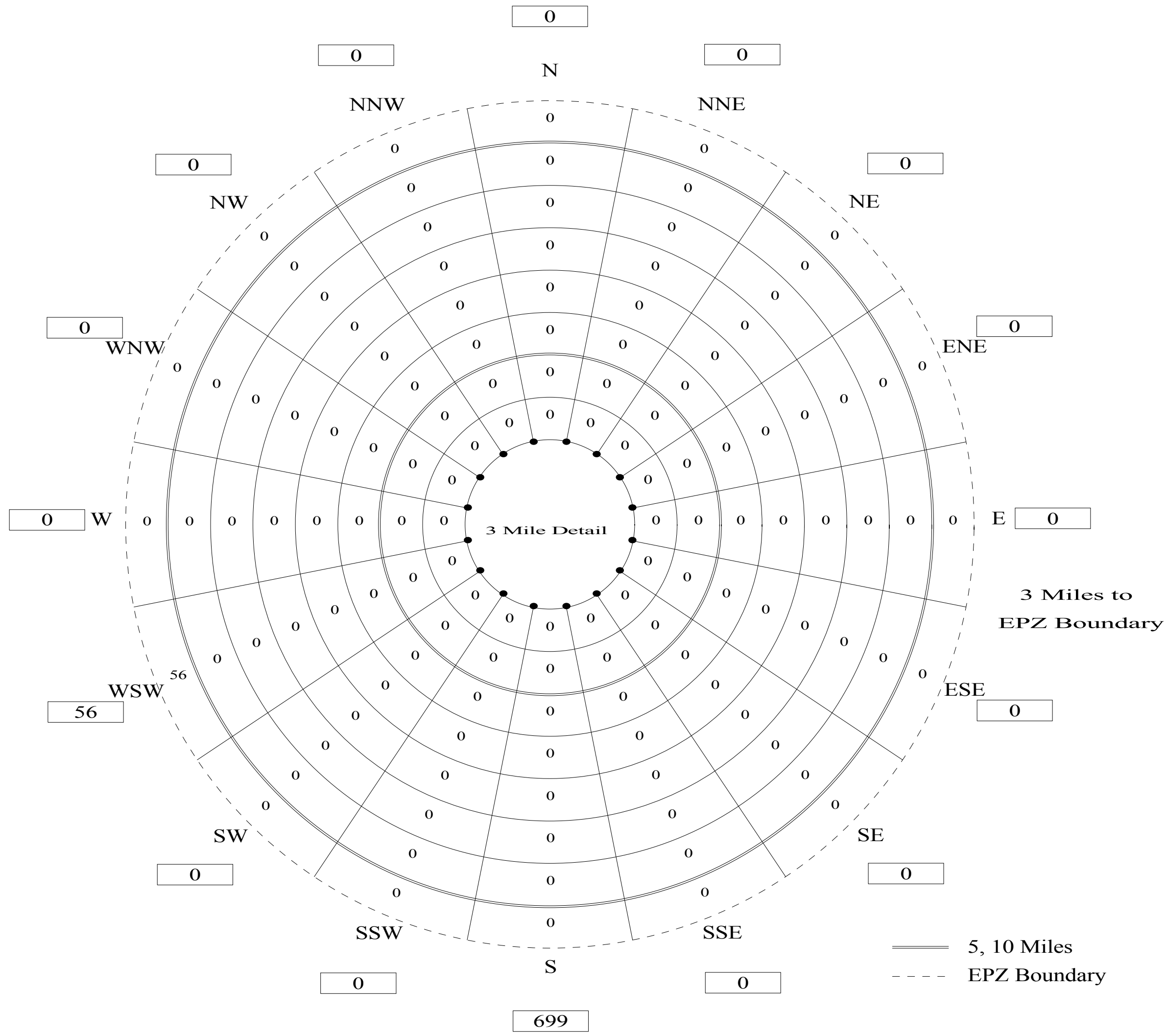


Figure 3-6. Employee Population by Sector



Employee Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	699	0-1	699
1-2	0	0-2	699
2-3	0	0-3	699
3-4	0	0-4	699
4-5	0	0-5	699
5-6	0	0-6	699
6-7	0	0-7	699
7-8	0	0-8	699
8-9	0	0-9	699
9-10	0	0-10	699
10-EPZ	56	0-EPZ	755

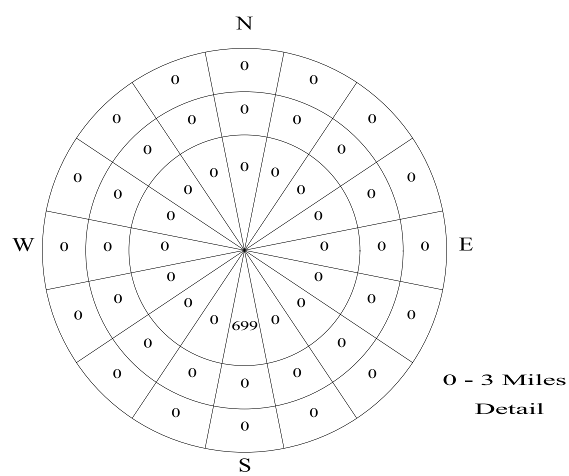


Figure 3-7. Employee Vehicles by Sector

Medical Facilities

There are no medical facilities within the NAPS EPZ.

Pass-Through Demand

Vehicles will be traveling through the EPZ (external-external trips) and the surrounding areas 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 Route 522) and on other routes on the periphery of the EPZ (e.g. US Route 1, Interstate-95 and Interstate 64) that evacuees will likely travel on during their evacuation trip. The pass through demand is loaded at a rate of 300 vehicles per lane per hour. It is assumed that this traffic will continue to enter the EPZ during the first 90 minutes following the Advisory to Evacuate. We estimate approximately 6,000 vehicles enter the EPZ as external-external trips during this period.

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. (From the 2000 Highway Capacity Manual)

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.

Because weather can affect the free-flow speed and capacity of a roadway, it is necessary to adjust the estimates of free-flow speed and capacity 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. Snow conditions have a greater adverse effect on free-flow speed and capacity.

Given the rural character of the EPZ and the availability of well-maintained highways, congestion arising from evacuation is not likely to be extensive over time. Nevertheless, estimates of highway capacity must be determined with care. Because of its importance, a brief discussion of the major factors that influence highway capacity is presented in this section.

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. However, no “credit” is taken in the form of higher capacities, to reflect the presence of traffic control personnel at TCPs, in estimating evacuation time.

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

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

where:

$Q_{cap,m}$	=	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_m	=	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

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.

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 by using the procedures of the Highway Capacity Manual.

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 (i.e. the number of vehicles serviced within a uniform highway section in a given time period) to traffic density. Figure 4-1 describes this relationship.

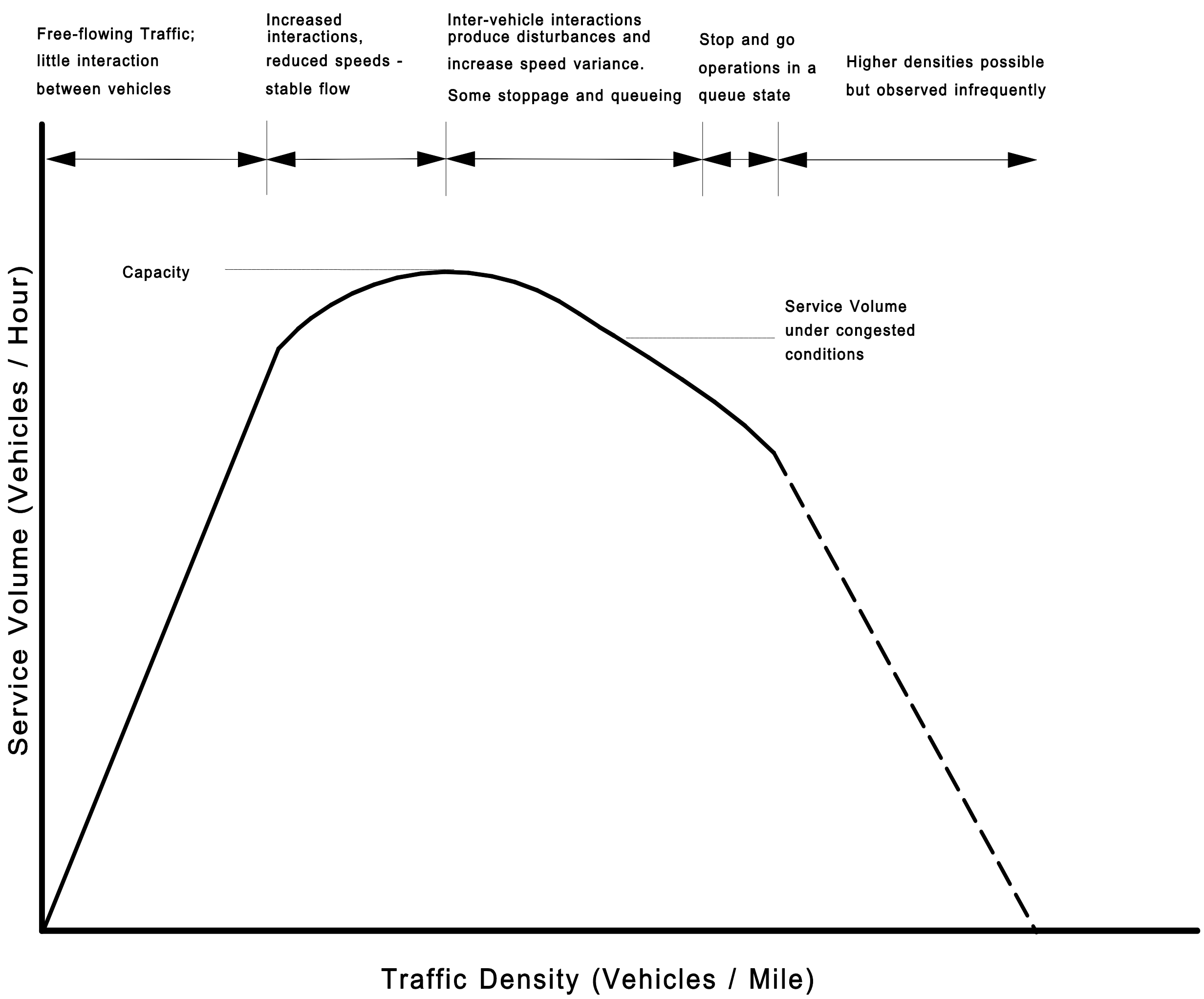


Figure 4-1. Fundamental Relationship Between Volume and Density

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; this 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 <u>decline</u> 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.

Based on empirical data collected on freeways, we have employed a value of R=0.85. It is important to mention that some investigators, on analyzing data collected on freeways, conclude that little reduction in capacity occurs even when traffic is operating at Level of Service, *F*. While there is conflicting evidence on this subject, we adopt a conservative approach and use a value of capacity, V_F, that is applied during LOS F conditions; V_F, is lower than the specified capacity.

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.

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. 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.

Application to the North Anna Power Station EPZ

As part of the development of the North Anna Power Station (NAPS) 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 NAPS EPZ consists primarily of two categories of roads and, of course, intersections:

- Two-lane roads: Local, State
- Multi-lane Highways (at-grade)

Each of these classifications will be discussed.

Two-Lane Roads

Ref: HCM Chapters 12, 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. This ideal capacity estimate may be moderated by the service volume estimates presented in Exhibit 12-15. 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, 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.

Intersections

Ref: HCM Chapters 16, 17

Procedures for estimating capacity and LOS for approaches to intersections are presented in Chapters 16 (signalized intersections) and 17 (un-signalized intersections). 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."

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). The composite of these distributions of elapsed times is 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, a conservative posture, in accord with Federal Regulations, is that a rapidly escalating accident will be considered in calculating the Trip Generation Time. 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 North Anna Power Station (NAPS) 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 NAPS and that the Advisory to Evacuate is announced somewhat later than the siren alert.

For example, suppose one hour elapses from 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 45,000 (permanent residents, employees and transients) persons who are deployed over an area of approximately 314 square miles and 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 ETEs 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.

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 of 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 (d) of Figure 5-1; a resident of the EPZ who is at work, and will return home before beginning the evacuation trip will follow sequence (a) of Figure 5-1. Note that event 5, "Leave to evacuate the area," is conditional either on event 2 or on event 4. That is, activity 2 → 5 by a resident at home can be undertaken in parallel with activities 2 → 3, 3 → 4 and 4 → 5 by a commuter returning to that home, as shown in Figure 5-1 (a). Specifically, one adult member of a household can prepare to leave home (i.e. secure the home, pack clothing, etc.), while others are traveling home from work. In this instance, the household members would be able to evacuate sooner than if such trip preparation were deferred until all household members had returned home. This study adopts the conservative posture that all activities will occur in 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, the estimate of the time distribution of Event 5depends upon the 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 on distributions is quite different than an algebraic sum).

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

It is reasonable to expect that 85 percent of those 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

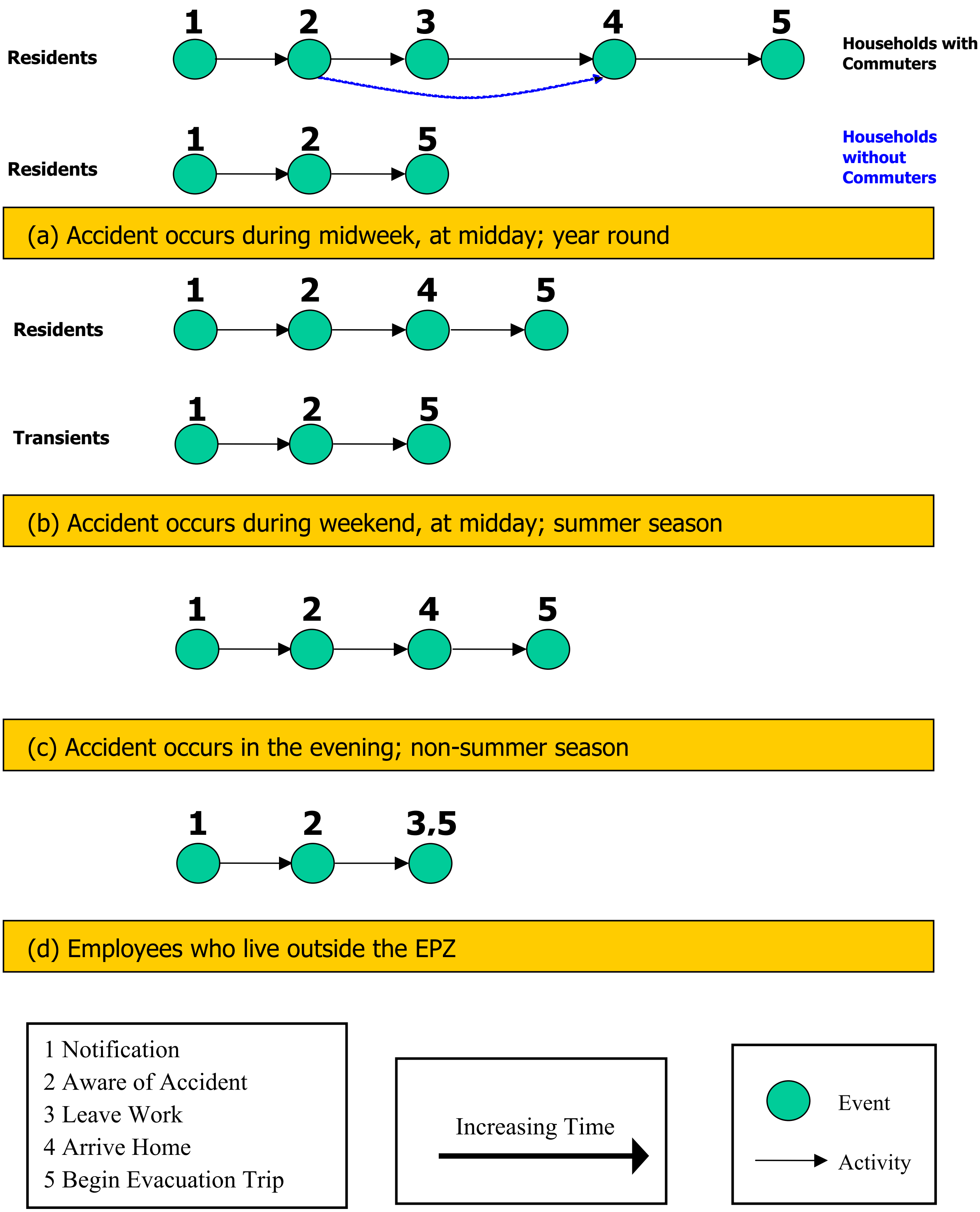


Figure 5-1. Events and Activities Preceding the Evacuation Trip

Distribution No. 2, Prepare to Leave Work: Activity 2 → 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	0
10	28
15	38
20	50
25	57
30	61
35	70
40	76
45	80
50	82
55	84
60	86
65	92
70	93
75	95
80	96
85	96
90	97
95	97
100	98
105	98
110	98
115	98
120	99
125	99
130	99
135	99
140	100

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

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	0
10	4
15	10
20	22
25	33
30	38
35	53
40	56
45	62
50	70
55	78
60	80
65	86
70	88
75	89
80	91
85	92
90	93
95	94
100	94
105	95
110	95
115	96
120	96
125	96
130	97
135	97
140	98
145	99
150	99
155	100

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

Distribution No. 4, Prepare to Leave Home: Activity 2, 4 $\rightarrow$ 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
15	21
30	45
45	63
60	75
75	86
90	91
105	92
120	93
135	95
150	96
165	96
180	97
195	98
210	98
225	98
240	99
255	99
270	99
285	99
300	99
315	99
330	99
345	99
360	100

Distribution No 5, Snow Clearance

Inclement weather scenarios involving snowfall must address the time lags associated with snow clearance. Discussions with local officials indicate that snow equipment is mobilized and deployed during a snowfall to maintain passable roads. The general consensus is that their efforts are generally successful for all but the most extreme blizzards when the rate of snow accumulation exceeds that of snow clearance over a period of many hours. A review of snow accumulation rate for the area reveals that a blizzard of this magnitude has not occurred over the past 5 years.

Consequently, it is reasonable to assume that the highway system will remain passable – albeit at a lower capacity – under the vast majority of snow conditions. Nevertheless, for the vehicles to gain access to the highway system, it may be necessary for driveways and employee parking lots to be cleared to the extent needed to permit vehicles to gain access to the roadways. These clearance activities take time; this time must be incorporated into the trip generation time distributions. These data are provided by a telephone survey conducted at a northern site. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Pct. Ready to Evacuate	Elapsed Time (Minutes)	Cumulative Pct. Ready to Evacuate
0	0	75	96
5	16	80	97
10	32	85	97
15	49	90	97
20	60	95	98
25	70	100	98
30	81	105	98
35	83	110	98
40	84	115	99
45	86	120	99
50	88	125	99
55	90	130	99
60	92	135	99
65	94	140	100
70	95		

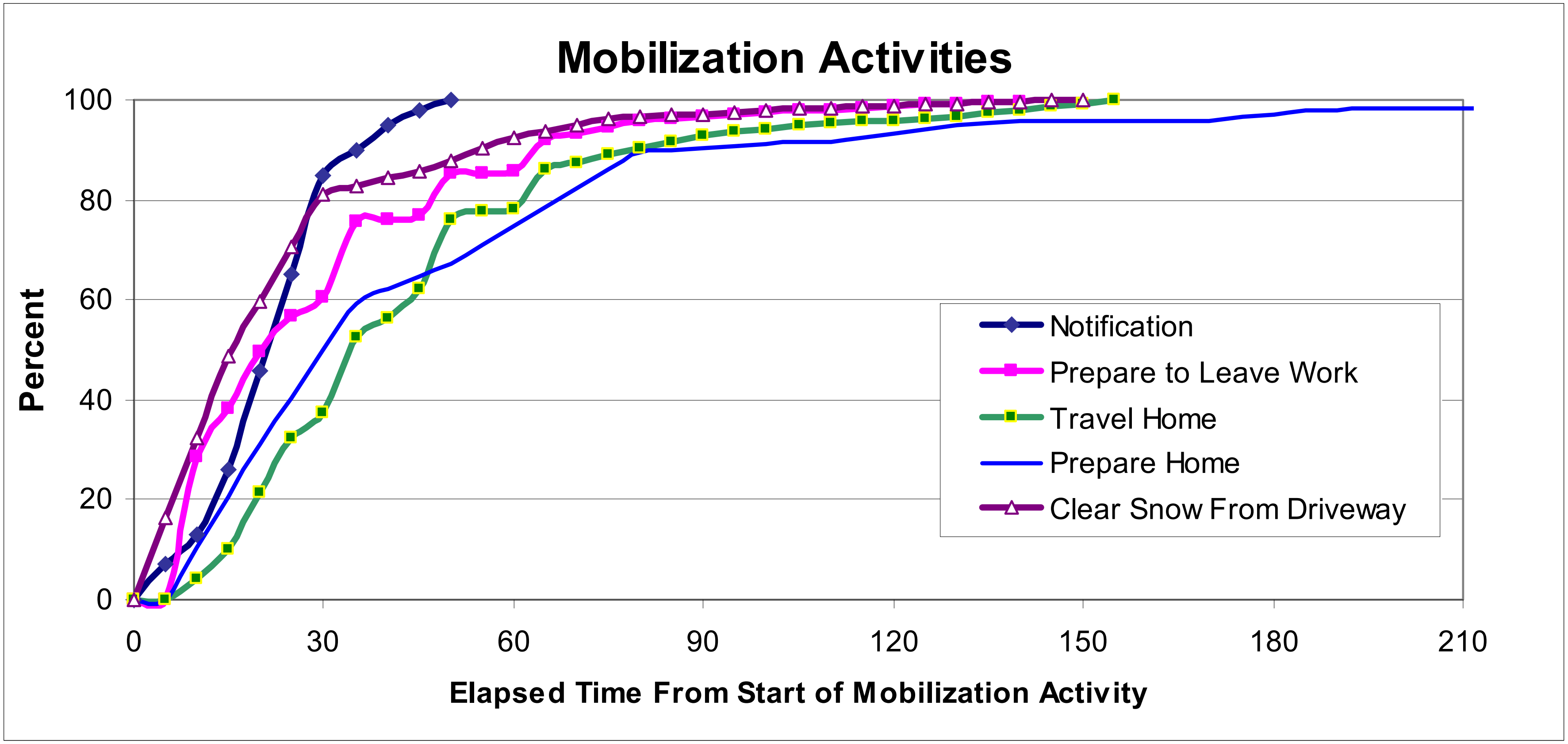


Figure 5-2. Evacuation Mobilization Activities

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. It is assumed 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 C and 5	Distribution E	Event 5
Distributions D and 5	Distribution F	Event 5

Distributions A through F 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 but live outside the EPZ, and to Transients within the EPZ.
B	Time distribution of commuters arriving home.
C	Time distribution of residents, who wait for commuters to return from work, leaving home to begin the evacuation trip.
D	Time distribution of residents, who do not wait for commuters to return from work, leaving home to begin the evacuation trip.
E	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip after snow clearance activities.
F	Time distribution of residents with no commuters returning home, leaving to begin the evacuation trip after snow clearance activities.

Figure 5-3 presents the combined trip generation distributions designated A, C, D, E and F. These distributions are presented on the same time scale.

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, E, and F, properly displaced with respect to one another, are tabulated in Table 5-1. Distribution B, representing commuters arriving home, is omitted for clarity and .the distribution for transients, which is equal to Distribution A, is shown.

The final time period (11) is 600 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.

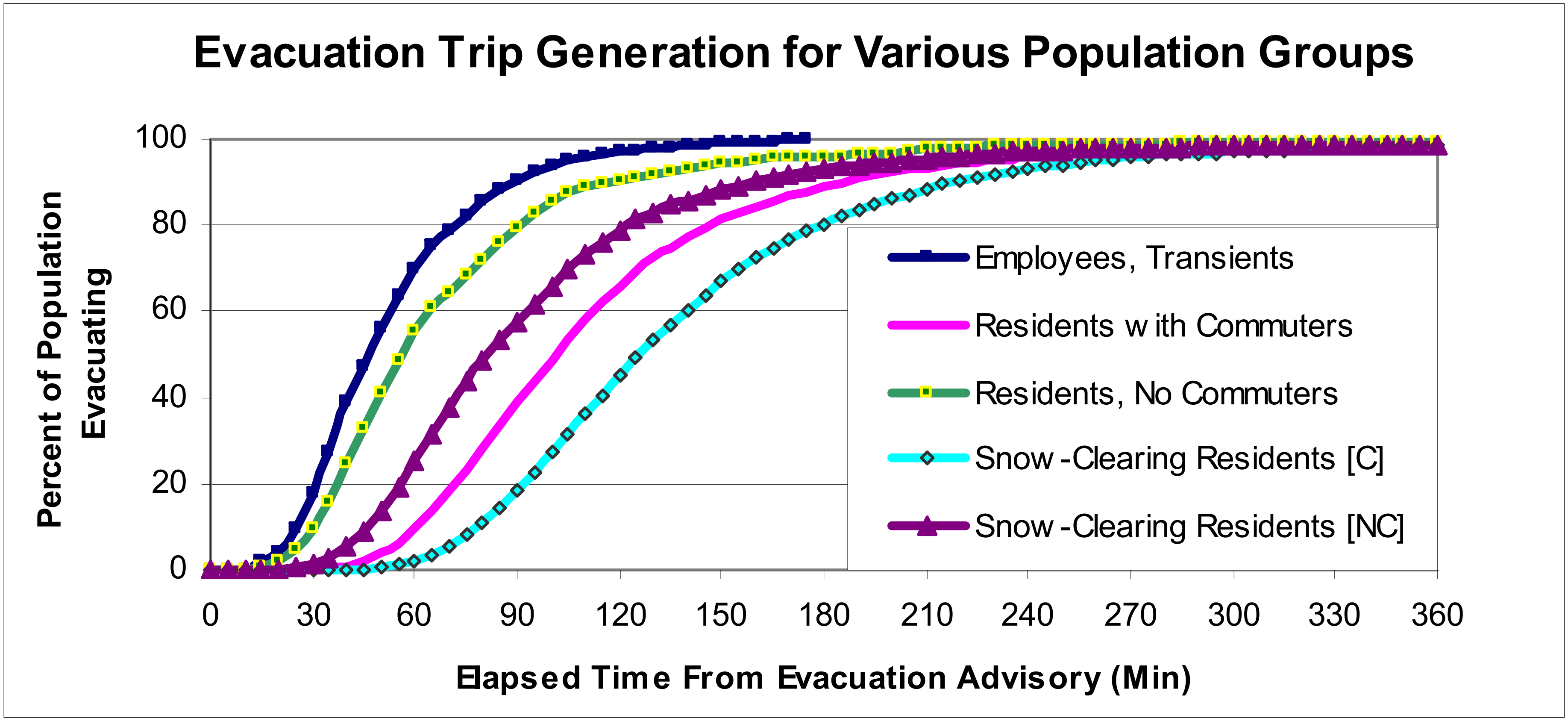


Figure 5-3. Comparison of Trip Generation Distributions

Table 5-1. Trip Generation Histograms for the EPZ Population							
Time Period	Duration (min)	Percent of Total Trips Generated Within Indicated Time Period					
		Employees (Distribution A)	Transients (Distribution A)	Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters Snow (Distribution E)	Residents Without Commuters Snow (Distribution F)
1	15	2	2	0	1	0	0
2	15	16	16	0	9	0	1
3	30	52	52	9	46	2	24
4	30	20	20	29	24	17	33
5	30	7	7	27	11	26	21
6	30	2	2	16	3	22	9
7	30	1	1	8	2	13	5
8	60	0	0	7	4	13	4
9	60	0	0	4	0	4	3
10	60	0	0	0	0	3	0
11	600	0	0	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 Protective Action Zones (PAZ), 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 27 Regions were defined which encompass all the groupings of PAZ considered. These Regions are defined in Table 6-1. The PAZ configurations are identified in Figure 6-1. Each keyhole sector-based area consists of a circular area centered at the North Anna Power Station (NAPS), and three adjoining sectors, each with a central angle of 22.5 degrees. These sectors extend to a distance of 5 miles from NAPS (Regions R4 to R14), or to the EPZ boundary (Regions R15 to R27). The azimuth of the center sector defines the orientation of these Regions.

A total of 14 Scenarios were evaluated for all Regions. Thus, there are a total of 14x27=378 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. Decscription of Evacuation Regions																										
Region	Description	Protective Action Zone (PAZ)																								
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R01	2 mile ring					X		X	X	X																
R02	5-mile ring			X		X	X	X	X	X	X	X	X	X	X										X	
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Evacuate 2 mile ring and 5 miles downwind																										
Region	Wind Direction Toward:	Protective Action Zone (PAZ)																								
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R04	N, NNE					X		X	X	X		X	X	X												
R05	NE					X		X	X	X	X	X	X													
R06	ENE, E					X		X	X	X	X	X														
R07	ESE, SE					X		X	X	X	X														X	
R08	SSE, S					X	X	X	X	X															X	
R09	SSW					X	X	X	X	X																
R10	SW			X		X	X	X	X	X																
R11	WSW			X		X		X	X	X																
R12	W			X		X		X	X	X					X											
R13	WNW, NW			X		X		X	X	X				X	X											
R14	NNW					X		X	X	X			X	X	X											
Evacuate 5 mile ring and downwind to EPZ boundary																										
Region	Wind Direction Toward:	Protective Action Zone (PAZ)																								
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R15	N			X		X	X	X	X	X	X	X	X	X	X			X	X	X					X	
R16	NNE			X		X	X	X	X	X	X	X	X	X	X			X	X	X	X				X	
R17	NE			X		X	X	X	X	X	X	X	X	X	X				X	X	X				X	
R18	ENE			X		X	X	X	X	X	X	X	X	X	X					X	X	X			X	
R19	E			X		X	X	X	X	X	X	X	X	X	X						X	X	X		X	
R20	ESE			X		X	X	X	X	X	X	X	X	X	X						X	X	X	X	X	X
R21	SE			X		X	X	X	X	X	X	X	X	X	X							X	X	X	X	X
R22	SSE, S			X	X	X	X	X	X	X	X	X	X	X	X									X	X	X
R23	SSW	X	X	X	X	X	X	X	X	X	X	X	X	X	X										X	X
R24	SW, WSW	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	
R25	W	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X							X	
R26	WNW, NW			X		X	X	X	X	X	X	X	X	X	X	X	X	X							X	
R27	NNW			X		X	X	X	X	X	X	X	X	X	X		X	X	X						X	

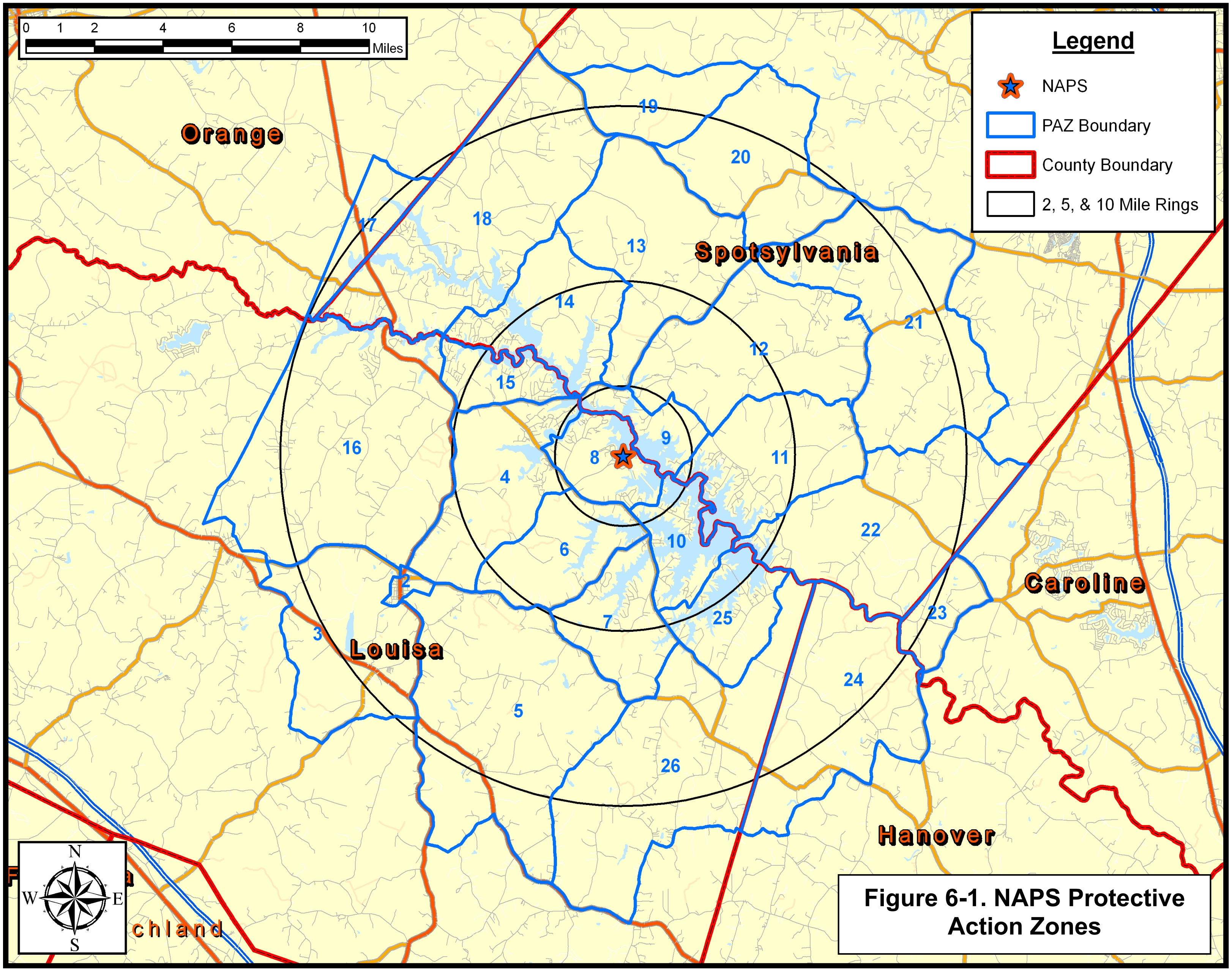


Figure 6-1. NAPS Protective Action Zones

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	Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Weekend	Midday	Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Summer	Midweek	Midday	Good	New Plant Construction
14	Summer	Midweek	Midday	Good	New Plant Construction + Refueling

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	59%	41%	96%	50%	31%	0%	10%	100%	100%
2	59%	41%	96%	50%	31%	0%	10%	100%	100%
3	10%	90%	47%	100%	31%	0%	0%	100%	100%
4	10%	90%	47%	100%	31%	0%	0%	100%	100%
5	10%	90%	10%	25%	30%	0%	0%	100%	60%
6	59%	41%	100%	25%	31%	0%	100%	100%	100%
7	59%	41%	100%	25%	31%	0%	100%	100%	100%
8	59%	41%	100%	25%	31%	0%	100%	100%	100%
9	10%	90%	47%	40%	31%	0%	0%	100%	100%
10	10%	90%	47%	40%	31%	0%	0%	100%	100%
11	10%	90%	47%	40%	31%	0%	0%	100%	100%
12	10%	90%	10%	15%	30%	0%	0%	100%	60%
13	59%	41%	96%	50%	31%	100%	10%	100%	100%
14	59%	41%	96%	50%	31%	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 or will not await the return of commuters prior to beginning the evacuation trip.

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 North Anna Power Station area during the construction phase of the new unit and during refueling of the operating 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 1-2 hours after the evacuation begins.

Table 6-4. Evacuating Vehicle Estimates By Scenario

Scenarios	Vehicles of Residents awaiting Commuters	Vehicles of Residents not awaiting Commuters	Employee Vehicles	Transient Vehicles	Shadow Vehicles	Special Event Vehicles	School Buses	Transit Buses	External Traffic	Total Scenari o Vehicles
1	11,022	7,534	725	2,291	5,536	-	25	32	6,000	33,165
2	11,022	7,534	725	2,291	5,536	-	25	32	6,000	33,165
3	1,102	17,454	355	4,582	5,430	-	-	32	6,000	34,955
4	1,102	17,454	355	4,582	5,430	-	-	32	6,000	34,955
5	1,102	17,454	76	1,146	5,350	-	-	32	3,600	28,760
6	11,022	7,534	755	1,146	5,544	-	252	32	6,000	32,285
7	11,022	7,534	755	1,146	5,544	-	252	32	6,000	32,285
8	11,022	7,534	755	1,146	5,544		252	32	6,000	32,285
9	1,102	17,454	355	1,833	5,430	-	-	32	6,000	32,206
10	1,102	17,454	355	1,833	5,430	-	-	32	6,000	32,206
11	1,102	17,454	355	1,833	5,430			32	6,000	32,206
12	1,102	17,454	76	687	5,350	-	-	32	3,600	28,301
13	13,555*	9,266*	725	2,291	6,722*	2,913	25	32	6,000	41,529*
14	13,555*	9,266*	725	2,291	6,722*	3,398	25	32	6,000	42,014*

***Permanent Resident population and Shadow population have been extrapolated to the Year 2013, which is when construction workforce will be at its peak.**

7. GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the current results of the computer analyses using the IDYNEV System described in Appendices B, C and D. These results cover 27 regions within the NAPS EPZ and the 14 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 are obtained from the PC-DYNEV simulation model outputs of vehicles exiting the specified evacuation areas. These data are generated at 10-minute intervals, then interpolated to the nearest 5 minutes.

7.1 Voluntary Evacuation and Shadow Evacuation

"Voluntary evacuees" are people who are within the EPZ, in protective action zones (PAZ) located outside the Evacuation Region. No Advisory to Evacuate *has* been issued for these PAZ, yet some people nevertheless elect to evacuate. "Shadow evacuation" is 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 NAPS includes 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 NAPS.

Traffic generated within this Shadow Evacuation Region, traveling away from the NAPS location, has the 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. **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, weekend, midday period under good weather conditions (Scenario 3).

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, 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 on the approaches to Mineral from US Highway (USHY) 522 southbound and East First Street, on the southbound approach from USHY 522 to USHY 33; on the approach to USHY 522 from USHY 208 westbound (transient traffic from Lake Anna); on the approaches to STHY 208 from STHY 652 westbound; on the approach from STHY 652 to STHY 601; and on other roadways close to the EPZ boundary by 1 Hour (Figure 7-3) after the evacuation advisory.

Figure 7-4 presents the pattern of peak congestion, two hours after the advisory to evacuate, while Figure 7-5 displays this pattern one hour later when congested conditions have eased. At 4 hours after the advisory to evacuate, no congestion appears within the EPZ.

The absence of congestion on network links (white colored links) implies that traffic demand there has decreased well 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.

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 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 elect to delay or lengthen their mobilization activities; they will 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 27 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
  - Snow
- Special Event (if any)
  - New Plant Construction
  - New Plant Construction plus Refueling of Operating Plant

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. For snow, Scenario (11) 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 North Anna Power Station. The applicable distances and their associated candidate Regions are given below:
     - 2 Miles (Region R01)
     - 5 Miles (Regions R02 and R04 through R14)
     - to EPZ Boundary (Regions R03 and R15 through R27)
   - Enter Table 7-2 and identify the applicable group of candidate Regions based on the wind direction and on the distance that the selected Region extends from NAPS. 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.

Example

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

- Sunday, August 10th at 4:00 AM.
- It is raining.
- Wind direction is *toward* 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 95-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 7-2 and locate the group entitled "Evacuate 5-Mile Ring and Downwind to EPZ Boundary". Under "Wind Direction Toward:", identify the NE (northeast) azimuth and read REGION R17 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 R17. This data cell is in column (4) and in the row for Region R17; it contains the ETE value of **3:10**.

Discussion of ETE Results

The delays experienced by evacuees on representative links in the network, at various times, are presented below:

Delay per Vehicle (minutes) Statistics on Representative Congested Highway Sections

			Elapsed Time after Advisory to Evacuate (hrs)		
I.D.	**Link**	**Location**	**1:00**	**2:00**	**3:00**
1	171, 7	U.S. Highway 208	5.1min	8.7min	3.9min
2	71, 74	State Highway 601	0.1	9.4	0.0
3	138, 446	State Highway 612	8.7	8.5	0.0
4	199, 321	State Highway 652	9.5	8.9	0.0
5	120, 416	State Highway 652	9.5	9.2	0.0
6	334, 280	State Highway 522	1.1	6.7	0.0

The links can be located in Figure 7-3. All delay estimates are average values experienced by vehicles on the link during a period of 10 minutes preceding the indicated elapsed times after the Advisory To Evacuate (ATE). This table presents traffic operations on those highway sections that become congested (i.e., experience LOS F conditions) during the course of evacuation:

- All links but one are operating at free-flow speed, 3 hours after the ATE
- The one link that still exhibits delay at that time (171, 7), displays a much lower level of delay than one hour earlier (3.9 vs. 8.7 minutes)).
- All but two links experience pronounced delay one hour after the ATE
- All links are congested two hours after the ATE with evacuees experiencing high delays during the 10-minute sampling period.

All ETE apply to the "general population" comprised of permanent residents, employees and transients. Since the evacuating vehicles of each group mix with one another during the trip-generation process to form the combined evacuating traffic stream, it is not feasible to separate ETE by population component, and such separation is not required by guidance.

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer	Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)	(14)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday	Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	New Plant Construction	New Plant Construction + Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ																
R01 2-mile ring	1:15	1:15	1:00	1:00	1:00	R01 2-mile ring	1:15	1:15	1:35	1:00	1:00	1:25	1:00	R01 2-mile ring	1:40	1:45
R02 5-mile ring	1:25	1:25	1:10	1:10	1:10	R02 5-mile ring	1:25	1:25	1:45	1:10	1:10	1:30	1:10	R02 5-mile ring	1:40	1:40
R03 Entire EPZ	1:40	1:45	1:35	1:35	1:25	R03 Entire EPZ	1:35	1:40	2:00	1:25	1:30	1:50	1:25	R03 Entire EPZ	1:55	1:55
2-Mile Ring and Downwind to 5 Miles																
R04 N,NNE	1:15	1:15	1:00	1:00	1:00	R04 N,NNE	1:20	1:20	1:40	1:00	1:00	1:20	1:00	R04 N,NNE	1:30	1:30
R05 NE	1:20	1:20	1:00	1:00	1:00	R05 NE	1:20	1:20	1:40	1:00	1:00	1:25	1:00	R05 NE	1:30	1:30
R06 ENE,E	1:20	1:20	1:00	1:00	1:00	R06 ENE,E	1:20	1:25	1:45	1:00	1:00	1:25	1:00	R06 ENE,E	1:35	1:35
R07 ESE,SE	1:25	1:25	1:05	1:05	1:10	R07 ESE,SE	1:20	1:25	1:40	1:05	1:10	1:30	1:10	R07 ESE,SE	1:45	1:45
R08 SSE,S	1:25	1:25	1:15	1:15	1:15	R08 SSE,S	1:25	1:25	1:45	1:10	1:15	1:30	1:15	R08 SSE,S	1:50	1:55
R09 SSW	1:20	1:20	1:10	1:10	1:10	R09 SSW	1:20	1:20	1:40	1:10	1:10	1:25	1:10	R09 SSW	1:45	1:50
R10 SW	1:20	1:25	1:15	1:15	1:10	R10 SW	1:25	1:25	1:45	1:15	1:15	1:30	1:10	R10 SW	1:50	1:55
R11 WSW	1:20	1:20	1:05	1:05	1:05	R11 WSW	1:20	1:20	1:45	1:05	1:05	1:25	1:05	R11 WSW	1:45	1:45
R12 W	1:20	1:25	1:05	1:10	1:05	R12 W	1:25	1:25	1:45	1:05	1:10	1:30	1:05	R12 W	1:45	1:45
R13 WNW,NW	1:20	1:20	1:05	1:05	1:05	R13 WNW,NW	1:20	1:25	1:40	1:05	1:05	1:25	1:05	R13 WNW,NW	1:35	1:40
R14 NNW	1:20	1:20	1:05	1:05	1:05	R14 NNW	1:20	1:20	1:40	1:05	1:05	1:25	1:05	R14 NNW	1:30	1:35
5-Mile Ring and Downwind to EPZ Boundary																
R15 N	1:35	1:35	1:30	1:35	1:20	R15 N	1:30	1:35	1:55	1:25	1:25	1:45	1:20	R15 N	1:55	1:55
R16 NNE	1:35	1:40	1:35	1:35	1:25	R16 NNE	1:35	1:35	1:55	1:25	1:30	1:45	1:20	R16 NNE	1:55	1:55
R17 NE	1:30	1:30	1:20	1:25	1:20	R17 NE	1:30	1:35	1:50	1:20	1:20	1:35	1:20	R17 NE	1:45	1:50
R18 ENE	1:30	1:35	1:20	1:25	1:20	R18 ENE	1:30	1:35	1:55	1:20	1:20	1:40	1:20	R18 ENE	1:45	1:50
R19 E	1:30	1:30	1:20	1:25	1:15	R19 E	1:30	1:35	1:55	1:15	1:20	1:35	1:15	R19 E	1:45	1:45
R20 ESE	1:30	1:35	1:20	1:25	1:20	R20 ESE	1:35	1:35	1:55	1:20	1:25	1:40	1:20	R20 ESE	1:45	1:45
R21 SE	1:30	1:30	1:15	1:15	1:15	R21 SE	1:30	1:30	1:55	1:15	1:15	1:35	1:15	R21 SE	1:40	1:45
R22 SSE,S	1:30	1:30	1:15	1:15	1:15	R22 SSE,S	1:30	1:30	1:55	1:15	1:15	1:35	1:15	R22 SSE,S	1:40	1:45
R23 SSW	1:30	1:30	1:15	1:15	1:15	R23 SSW	1:30	1:35	1:50	1:15	1:15	1:35	1:15	R23 SSW	1:40	1:45
R24 SW,WSW	1:30	1:30	1:15	1:20	1:15	R24 SW,WSW	1:30	1:35	1:50	1:15	1:15	1:35	1:15	R24 SW,WSW	1:45	1:45
R25 W	1:35	1:35	1:25	1:30	1:15	R25 W	1:30	1:35	1:55	1:20	1:25	1:40	1:15	R25 W	1:45	1:50
R26 WNW,NW	1:30	1:35	1:25	1:30	1:15	R26 WNW,NW	1:30	1:35	1:50	1:15	1:20	1:40	1:15	R26 WNW,NW	1:45	1:50
R27 NNW	1:30	1:35	1:25	1:30	1:15	R27 NNW	1:30	1:35	1:55	1:15	1:20	1:40	1:15	R27 NNW	1:50	1:50

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer	Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)	(14)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday	Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	New Plant Construction	New Plant Construction + Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ																
R01 2-mile ring	2:30	2:30	2:00	2:00	2:00	R01 2-mile ring	2:30	2:30	3:10	2:00	2:00	2:40	2:00	R01 2-mile ring	2:55	3:00
R02 5-mile ring	2:40	2:40	2:10	2:20	2:10	R02 5-mile ring	2:40	2:40	3:20	2:10	2:15	2:40	2:10	R02 5-mile ring	3:15	3:25
R03 Entire EPZ	2:55	3:00	3:00	3:10	2:30	R03 Entire EPZ	2:50	2:55	3:30	2:40	2:50	3:20	2:30	R03 Entire EPZ	3:30	3:35
2-Mile Ring and Downwind to 5 Miles																
R04 N,NNE	2:30	2:30	2:00	2:00	2:00	R04 N,NNE	2:40	2:40	3:10	2:00	2:00	2:30	2:00	R04 N,NNE	2:50	2:55
R05 NE	2:40	2:40	2:00	2:00	2:00	R05 NE	2:40	2:40	3:20	2:00	2:00	2:40	2:00	R05 NE	2:50	2:55
R06 ENE,E	2:40	2:40	2:00	2:00	2:00	R06 ENE,E	2:40	2:40	3:20	2:00	2:00	2:40	2:00	R06 ENE,E	2:50	2:55
R07 ESE,SE	2:40	2:40	2:10	2:10	2:10	R07 ESE,SE	2:40	2:40	3:20	2:10	2:10	2:40	2:05	R07 ESE,SE	3:05	3:10
R08 SSE,S	2:40	2:40	2:20	2:20	2:10	R08 SSE,S	2:40	2:40	3:20	2:15	2:15	2:40	2:10	R08 SSE,S	3:10	3:20
R09 SSW	2:40	2:40	2:05	2:05	2:05	R09 SSW	2:40	2:40	3:20	2:05	2:05	2:40	2:05	R09 SSW	3:00	3:10
R10 SW	2:40	2:40	2:05	2:05	2:05	R10 SW	2:40	2:40	3:20	2:05	2:05	2:40	2:05	R10 SW	3:10	3:20
R11 WSW	2:40	2:40	2:00	2:00	2:00	R11 WSW	2:40	2:40	3:20	2:00	2:00	2:40	2:00	R11 WSW	3:05	3:15
R12 W	2:40	2:40	2:10	2:10	2:00	R12 W	2:40	2:40	3:20	2:05	2:05	2:40	2:00	R12 W	3:10	3:20
R13 WNW,NW	2:30	2:30	2:10	2:10	2:05	R13 WNW,NW	2:40	2:40	3:10	2:10	2:10	2:30	2:00	R13 WNW,NW	3:05	3:15
R14 NNW	2:30	2:30	2:05	2:05	2:00	R14 NNW	2:40	2:40	3:10	2:00	2:00	2:30	2:00	R14 NNW	3:00	3:05
5-Mile Ring and Downwind to EPZ Boundary																
R15 N	2:50	2:50	3:00	3:05	2:20	R15 N	2:50	2:50	3:20	2:30	2:35	3:00	2:20	R15 N	3:25	3:25
R16 NNE	2:50	2:55	3:00	3:05	2:25	R16 NNE	2:50	2:50	3:30	2:30	2:40	3:05	2:25	R16 NNE	3:25	3:30
R17 NE	2:50	2:50	2:35	2:40	2:20	R17 NE	2:50	2:50	3:20	2:25	2:30	3:00	2:20	R17 NE	3:25	3:30
R18 ENE	2:50	2:50	2:35	2:40	2:20	R18 ENE	2:50	2:50	3:25	2:25	2:30	3:00	2:20	R18 ENE	3:25	3:30
R19 E	2:40	2:50	2:30	2:35	2:20	R19 E	2:50	2:50	3:20	2:20	2:30	2:55	2:20	R19 E	3:20	3:25
R20 ESE	2:50	2:50	2:35	2:40	2:25	R20 ESE	2:50	2:50	3:30	2:25	2:35	3:05	2:25	R20 ESE	3:25	3:30
R21 SE	2:50	2:50	2:25	2:30	2:20	R21 SE	2:50	2:50	3:30	2:20	2:30	3:00	2:20	R21 SE	3:25	3:30
R22 SSE,S	2:40	2:50	2:25	2:30	2:20	R22 SSE,S	2:50	2:50	3:25	2:20	2:30	3:00	2:20	R22 SSE,S	3:25	3:30
R23 SSW	2:40	2:50	2:25	2:30	2:20	R23 SSW	2:50	2:50	3:20	2:20	2:25	2:55	2:20	R23 SSW	3:25	3:30
R24 SW,WSW	2:40	2:50	2:30	2:40	2:20	R24 SW,WSW	2:50	2:50	3:30	2:20	2:30	3:00	2:20	R24 SW,WSW	3:25	3:30
R25 W	2:45	2:55	3:00	3:10	2:25	R25 W	2:45	2:50	3:25	2:30	2:40	3:10	2:20	R25 W	3:25	3:30
R26 WNW,NW	2:45	2:55	3:00	3:10	2:20	R26 WNW,NW	2:40	2:50	3:25	2:30	2:40	3:10	2:20	R26 WNW,NW	3:25	3:30
R27 NNW	2:45	2:50	2:50	3:00	2:20	R27 NNW	2:45	2:50	3:20	2:25	2:30	3:00	2:20	R27 NNW	3:20	3:25

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer	Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)	(14)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday	Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	New Plant Construction	New Plant Construction + Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ																
R01 2-mile ring	3:20	3:20	2:40	2:40	2:50	R01 2-mile ring	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R01 2-mile ring	3:15	3:20
R02 5-mile ring	3:20	3:20	2:40	2:40	2:50	R02 5-mile ring	3:20	3:20	4:00	2:40	2:40	3:20	2:50	R02 5-mile ring	3:35	3:40
R03 Entire EPZ	3:30	3:30	3:20	3:30	3:00	R03 Entire EPZ	3:30	3:40	4:10	2:50	3:00	3:40	3:00	R03 Entire EPZ	3:50	3:55
2-Mile Ring and Downwind to 5 Miles																
R04 N,NNE	3:10	3:10	2:20	2:20	2:40	R04 N,NNE	3:20	3:20	3:50	2:30	2:30	3:10	2:40	R04 N,NNE	3:10	3:20
R05 NE	3:20	3:20	2:30	2:30	2:40	R05 NE	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R05 NE	3:20	3:20
R06 ENE,E	3:20	3:20	2:40	2:40	2:50	R06 ENE,E	3:30	3:30	4:00	2:40	2:40	3:20	2:50	R06 ENE,E	3:20	3:20
R07 ESE,SE	3:20	3:20	2:40	2:40	2:50	R07 ESE,SE	3:20	3:20	4:00	2:50	2:50	3:20	2:50	R07 ESE,SE	3:20	3:25
R08 SSE,S	3:10	3:10	2:40	2:40	2:50	R08 SSE,S	3:20	3:20	4:00	2:50	2:50	3:30	2:50	R08 SSE,S	3:25	3:35
R09 SSW	3:20	3:20	2:40	2:40	2:50	R09 SSW	3:20	3:20	3:50	2:40	2:50	3:20	2:50	R09 SSW	3:20	3:25
R10 SW	3:20	3:20	2:40	2:40	2:50	R10 SW	3:20	3:20	4:00	2:50	2:50	3:30	2:50	R10 SW	3:25	3:35
R11 WSW	3:20	3:20	2:40	2:40	2:50	R11 WSW	3:20	3:20	4:00	2:40	2:40	3:30	2:50	R11 WSW	3:20	3:30
R12 W	3:20	3:20	2:30	2:30	2:50	R12 W	3:20	3:20	4:00	2:40	2:40	3:20	2:40	R12 W	3:25	3:35
R13 WNW,NW	3:10	3:20	2:30	2:30	2:40	R13 WNW,NW	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R13 WNW,NW	3:30	3:35
R14 NNW	3:10	3:10	2:30	2:30	2:40	R14 NNW	3:20	3:20	3:50	2:40	2:40	3:20	2:50	R14 NNW	3:20	3:25
5-Mile Ring and Downwind to EPZ Boundary																
R15 N	3:20	3:20	3:20	3:30	2:50	R15 N	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R15 N	3:35	3:45
R16 NNE	3:30	3:30	3:20	3:30	2:50	R16 NNE	3:30	3:30	4:00	2:50	3:00	3:30	3:00	R16 NNE	3:40	3:45
R17 NE	3:30	3:30	3:00	3:10	2:50	R17 NE	3:30	3:30	4:00	2:50	3:00	3:30	3:00	R17 NE	3:40	3:45
R18 ENE	3:30	3:30	3:00	3:10	2:50	R18 ENE	3:30	3:30	4:00	2:50	3:00	3:30	2:50	R18 ENE	3:40	3:45
R19 E	3:20	3:30	2:50	3:00	2:50	R19 E	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R19 E	3:40	3:45
R20 ESE	3:30	3:30	2:50	3:00	3:00	R20 ESE	3:30	3:30	4:00	2:50	2:50	3:30	3:00	R20 ESE	3:45	3:50
R21 SE	3:30	3:30	2:40	2:50	2:50	R21 SE	3:30	3:30	4:00	2:50	2:50	3:30	3:00	R21 SE	3:45	3:50
R22 SSE,S	3:20	3:30	2:40	2:50	2:50	R22 SSE,S	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R22 SSE,S	3:50	3:50
R23 SSW	3:20	3:20	2:40	2:50	2:50	R23 SSW	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R23 SSW	3:50	3:50
R24 SW,WSW	3:20	3:20	3:00	3:00	2:50	R24 SW,WSW	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R24 SW,WSW	3:45	3:50
R25 W	3:20	3:20	3:20	3:30	2:50	R25 W	3:30	3:30	4:00	2:50	3:00	3:30	2:50	R25 W	3:40	3:50
R26 WNW,NW	3:20	3:20	3:20	3:30	2:50	R26 WNW,NW	3:30	3:30	4:00	2:50	3:00	3:30	2:50	R26 WNW,NW	3:40	3:45
R27 NNW	3:20	3:20	3:20	3:20	2:50	R27 NNW	3:30	3:30	4:00	2:50	2:50	3:30	2:50	R27 NNW	3:35	3:45

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer	Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)	(14)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday	Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	New Plant Construction	New Plant Construction + Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ																
R01 2-mile ring	5:00	5:00	4:00	4:00	4:00	R01 2-mile ring	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R01 2-mile ring	5:00	5:00
R02 5-mile ring	5:00	5:00	4:40	4:40	4:30	R02 5-mile ring	5:00	5:00	6:00	4:40	4:40	5:10	4:30	R02 5-mile ring	5:00	5:00
R03 Entire EPZ	5:10	5:10	4:50	4:50	4:50	R03 Entire EPZ	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R03 Entire EPZ	5:10	5:10
2-Mile Ring and Downwind to 5 Miles																
R04 N,NNE	5:00	5:00	4:00	4:00	4:00	R04 N,NNE	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R04 N,NNE	5:00	5:00
R05 NE	5:00	5:00	4:00	4:00	4:00	R05 NE	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R05 NE	5:00	5:00
R06 ENE,E	5:00	5:00	4:00	4:00	4:00	R06 ENE,E	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R06 ENE,E	5:00	5:00
R07 ESE,SE	5:00	5:10	4:00	4:10	4:00	R07 ESE,SE	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R07 ESE,SE	5:00	5:00
R08 SSE,S	5:00	5:00	4:00	4:10	4:00	R08 SSE,S	5:00	5:00	6:00	4:00	4:00	5:10	4:00	R08 SSE,S	5:00	5:00
R09 SSW	5:00	5:00	4:00	4:10	4:00	R09 SSW	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R09 SSW	5:00	5:00
R10 SW	5:00	5:00	4:00	4:10	4:00	R10 SW	5:00	5:00	6:00	4:00	4:10	5:00	4:00	R10 SW	5:00	5:00
R11 WSW	5:00	5:00	4:00	4:00	4:00	R11 WSW	5:00	5:00	6:00	4:00	4:00	5:00	4:00	R11 WSW	5:00	5:00
R12 W	5:00	5:00	4:00	4:00	4:10	R12 W	5:00	5:00	6:00	4:00	4:00	5:00	4:10	R12 W	5:00	5:00
R13 WNW,NW	5:00	5:00	4:40	4:40	4:40	R13 WNW,NW	5:00	5:00	6:00	4:40	4:40	5:00	4:40	R13 WNW,NW	5:00	5:00
R14 NNW	5:00	5:00	4:40	4:40	4:40	R14 NNW	5:00	5:00	6:00	4:40	4:40	5:00	4:40	R14 NNW	5:00	5:00
5-Mile Ring and Downwind to EPZ Boundary																
R15 N	5:00	5:10	4:50	4:50	4:50	R15 N	5:00	5:10	6:10	4:50	4:50	5:10	4:50	R15 N	5:00	5:00
R16 NNE	5:10	5:10	4:50	4:50	4:50	R16 NNE	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R16 NNE	5:10	5:10
R17 NE	5:10	5:10	4:50	4:50	4:50	R17 NE	5:10	5:10	6:10	4:50	5:00	5:20	4:50	R17 NE	5:10	5:10
R18 ENE	5:10	5:10	4:40	4:50	4:50	R18 ENE	5:10	5:10	6:10	4:50	5:00	5:20	4:50	R18 ENE	5:10	5:10
R19 E	5:10	5:10	4:50	4:50	4:50	R19 E	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R19 E	5:10	5:10
R20 ESE	5:10	5:10	4:50	4:50	4:50	R20 ESE	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R20 ESE	5:10	5:10
R21 SE	5:10	5:10	4:50	4:50	4:50	R21 SE	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R21 SE	5:10	5:10
R22 SSE,S	5:10	5:10	4:50	4:50	4:50	R22 SSE,S	5:10	5:10	6:10	4:50	4:50	5:20	4:50	R22 SSE,S	5:10	5:10
R23 SSW	5:10	5:10	4:50	4:50	4:50	R23 SSW	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R23 SSW	5:10	5:10
R24 SW,WSW	5:10	5:10	4:50	4:50	4:50	R24 SW,WSW	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R24 SW,WSW	5:10	5:10
R25 W	5:10	5:10	4:50	4:50	4:50	R25 W	5:10	5:10	6:10	4:50	4:50	5:10	4:50	R25 W	5:10	5:10
R26 WNW,NW	5:00	5:10	4:40	4:40	4:50	R26 WNW,NW	5:00	5:10	6:10	4:40	4:40	5:10	4:50	R26 WNW,NW	5:10	5:10
R27 NNW	5:00	5:10	4:40	4:40	4:50	R27 NNW	5:00	5:00	6:10	4:50	4:50	5:10	4:40	R27 NNW	5:00	5:00

Table 7-2. Description of Evacuation Regions

Region	Description	Protective Action Zone (PAZ)																								
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R01	2 mile ring					X		X	X	X																
R02	5-mile ring			X		X	X	X	X	X	X	X	X	X	X										X	
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Evacuate 2 mile ring and 5 miles downwind																										
Region	Wind Direction Toward:	Protective Action Zone (PAZ)																								
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R04	N, NNE					X		X	X	X		X	X	X												
R05	NE					X		X	X	X	X	X	X													
R06	ENE, E					X		X	X	X	X	X														
R07	ESE, SE					X		X	X	X	X														X	
R08	SSE, S					X	X	X	X	X															X	
R09	SSW					X	X	X	X	X																
R10	SW			X		X	X	X	X	X																
R11	WSW			X		X		X	X	X																
R12	W			X		X		X	X	X					X											
R13	WNW, NW			X		X		X	X	X				X	X											
R14	NNW					X		X	X	X			X	X	X											
Evacuate 5 mile ring and downwind to EPZ boundary																										
Region	Wind Direction Toward:	Protective Action Zone (PAZ)																								
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
R15	N			X		X	X	X	X	X	X	X	X	X	X			X	X	X					X	
R16	NNE			X		X	X	X	X	X	X	X	X	X	X			X	X	X	X				X	
R17	NE			X		X	X	X	X	X	X	X	X	X	X				X	X	X				X	
R18	ENE			X		X	X	X	X	X	X	X	X	X	X					X	X	X			X	
R19	E			X		X	X	X	X	X	X	X	X	X	X						X	X	X		X	
R20	ESE			X		X	X	X	X	X	X	X	X	X	X						X	X	X	X	X	X
R21	SE			X		X	X	X	X	X	X	X	X	X	X							X	X	X	X	X
R22	SSE, S			X	X	X	X	X	X	X	X	X	X	X	X									X	X	X
R23	SSW	X	X	X	X	X	X	X	X	X	X	X	X	X	X										X	X
R24	SW, WSW	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	
R25	W	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X							X	
R26	WNW, NW			X		X	X	X	X	X	X	X	X	X	X	X	X	X							X	
R27	NNW			X		X	X	X	X	X	X	X	X	X	X		X	X	X						X	

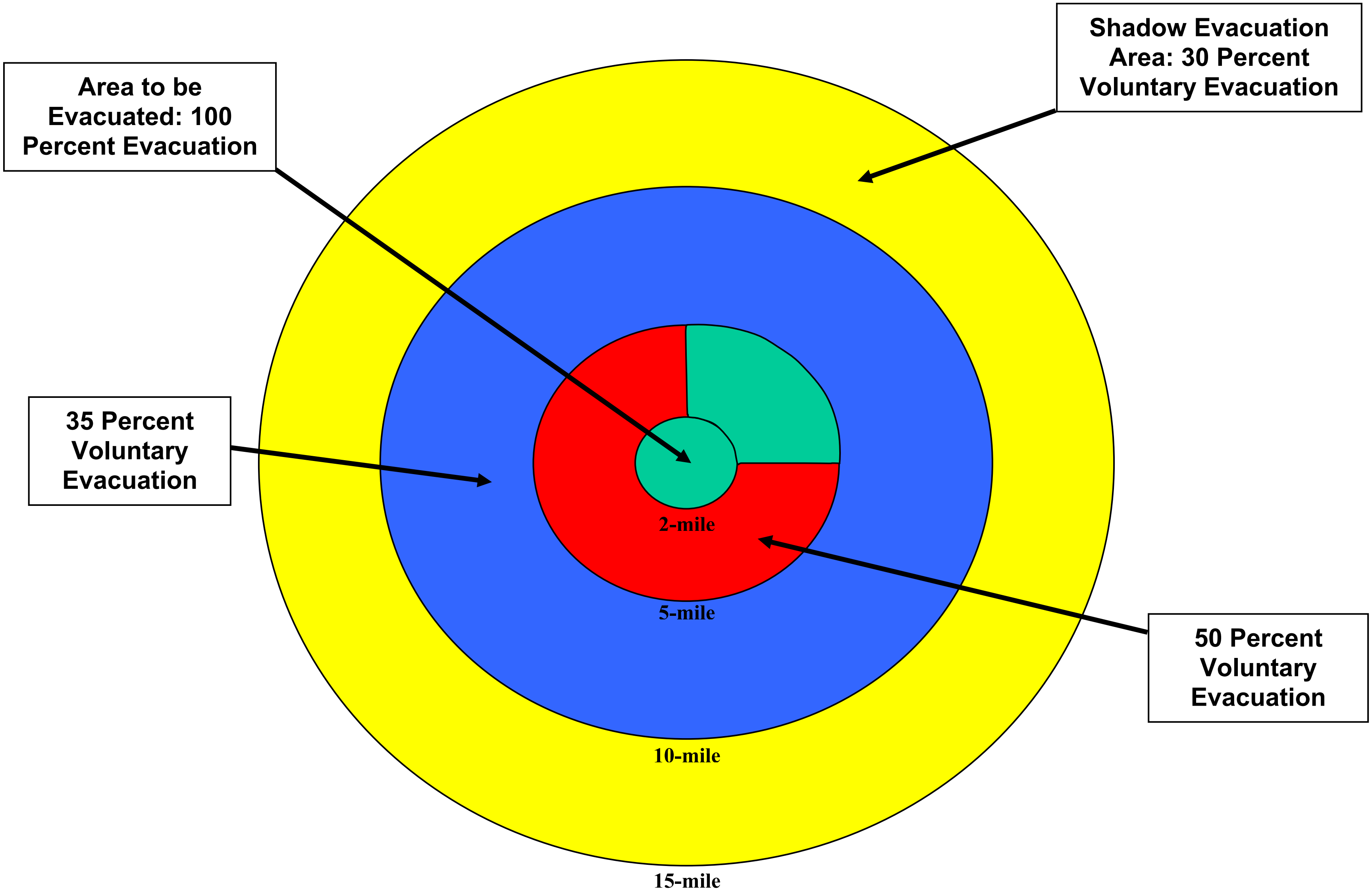


Figure 7-1. Assumed Evacuation Response

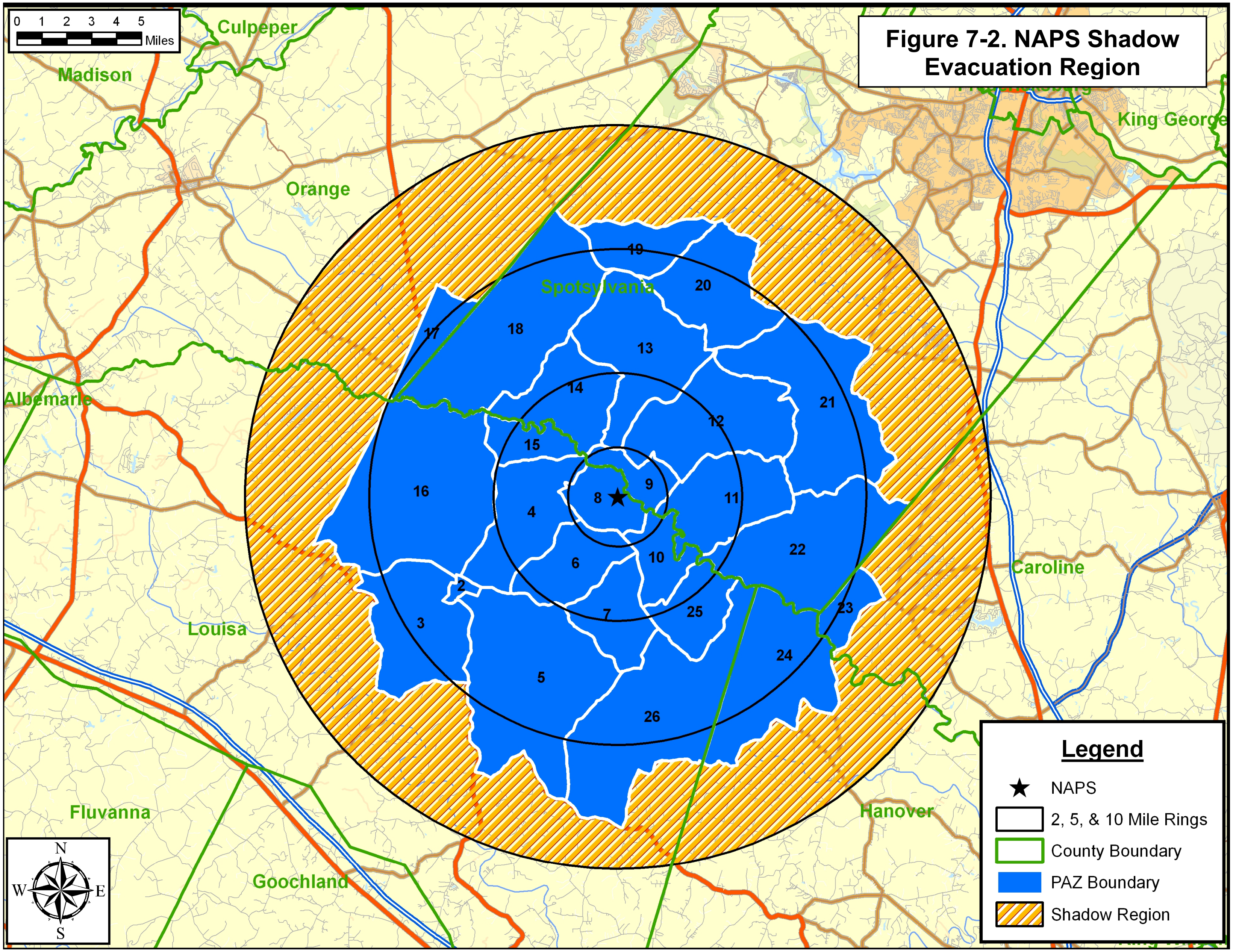


Figure 7-2. NAPS Shadow Evacuation Region
0 1 2 3 4 5
Miles
Culpeper
Madison
Orange
King George
Spotsylvania
Albemarle
Louisa
Caroline
Fluvanna
Goochland
Hanover
19
20
18
17
13
14
21
12
15
9
8
16
4
11
22
10
6
2
23
3
7
25
24
5
26
N
W
E
S
Legend
NAPS
2, 5, & 10 Mile Rings
County Boundary
PAZ Boundary
Shadow Region

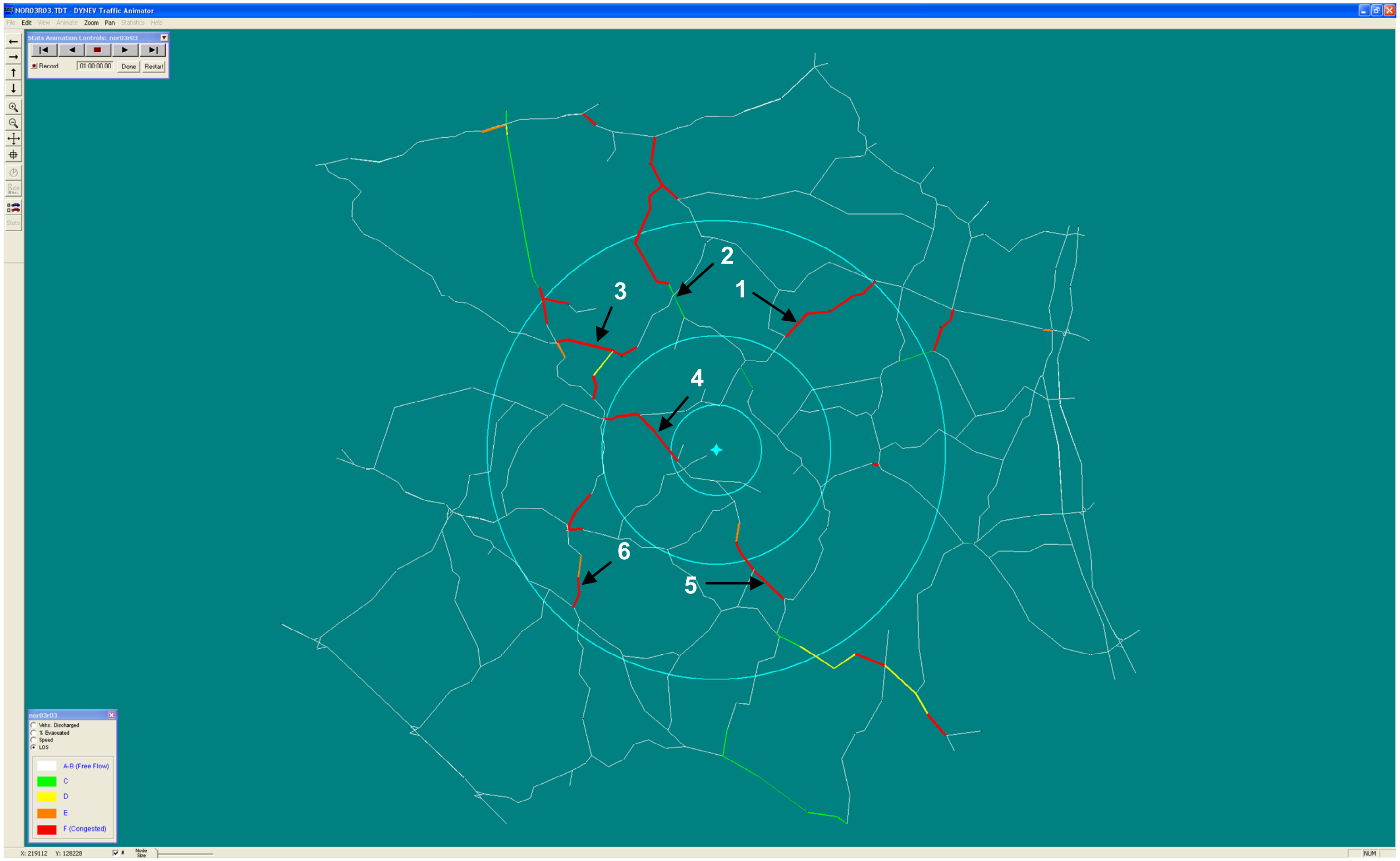


Figure 7-3. Congestion Patterns at 1 Hour after the Evacuation Advisory

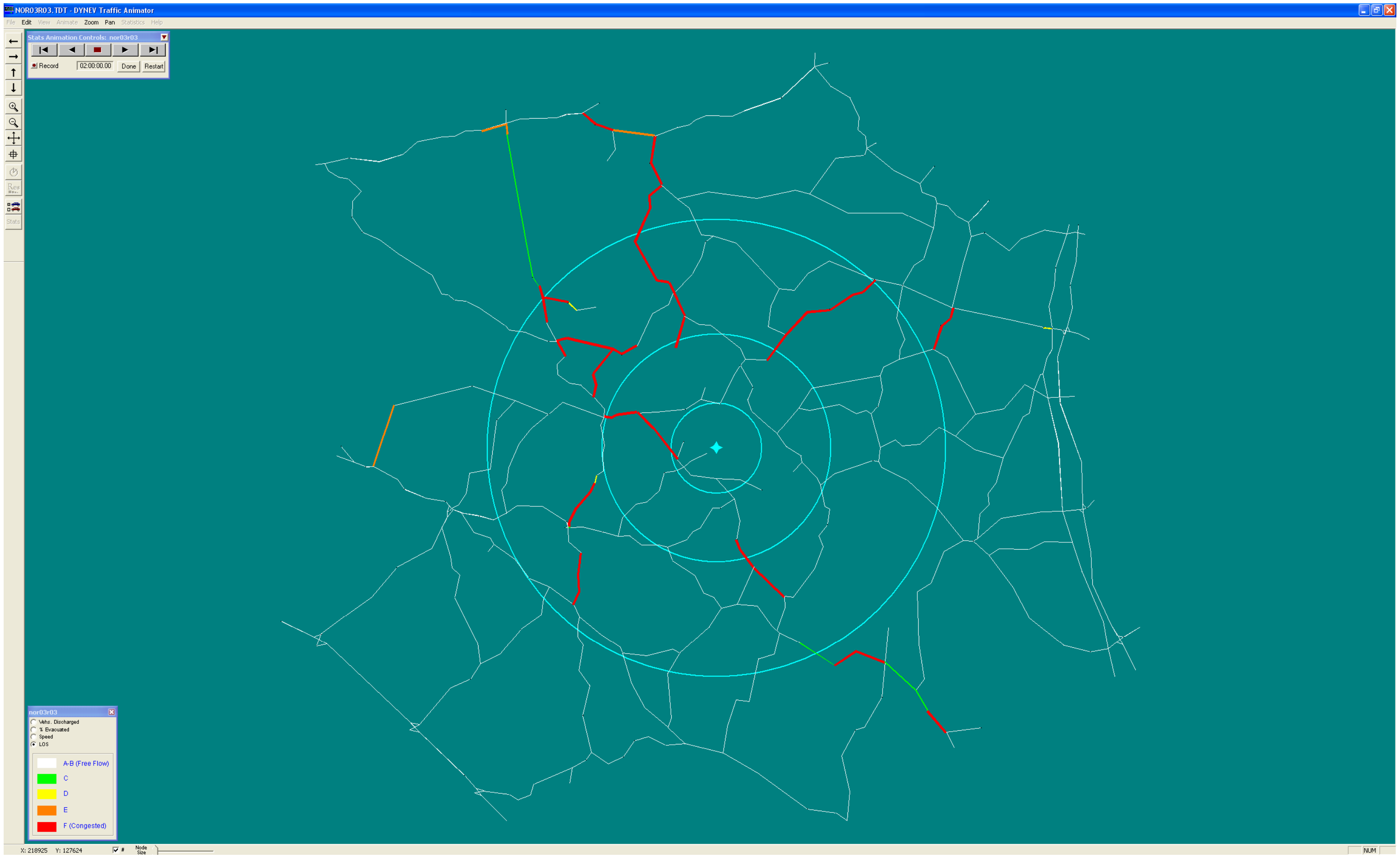


Figure 7-4 Congestion Patterns at 2 Hours after the Evacuation Advisory

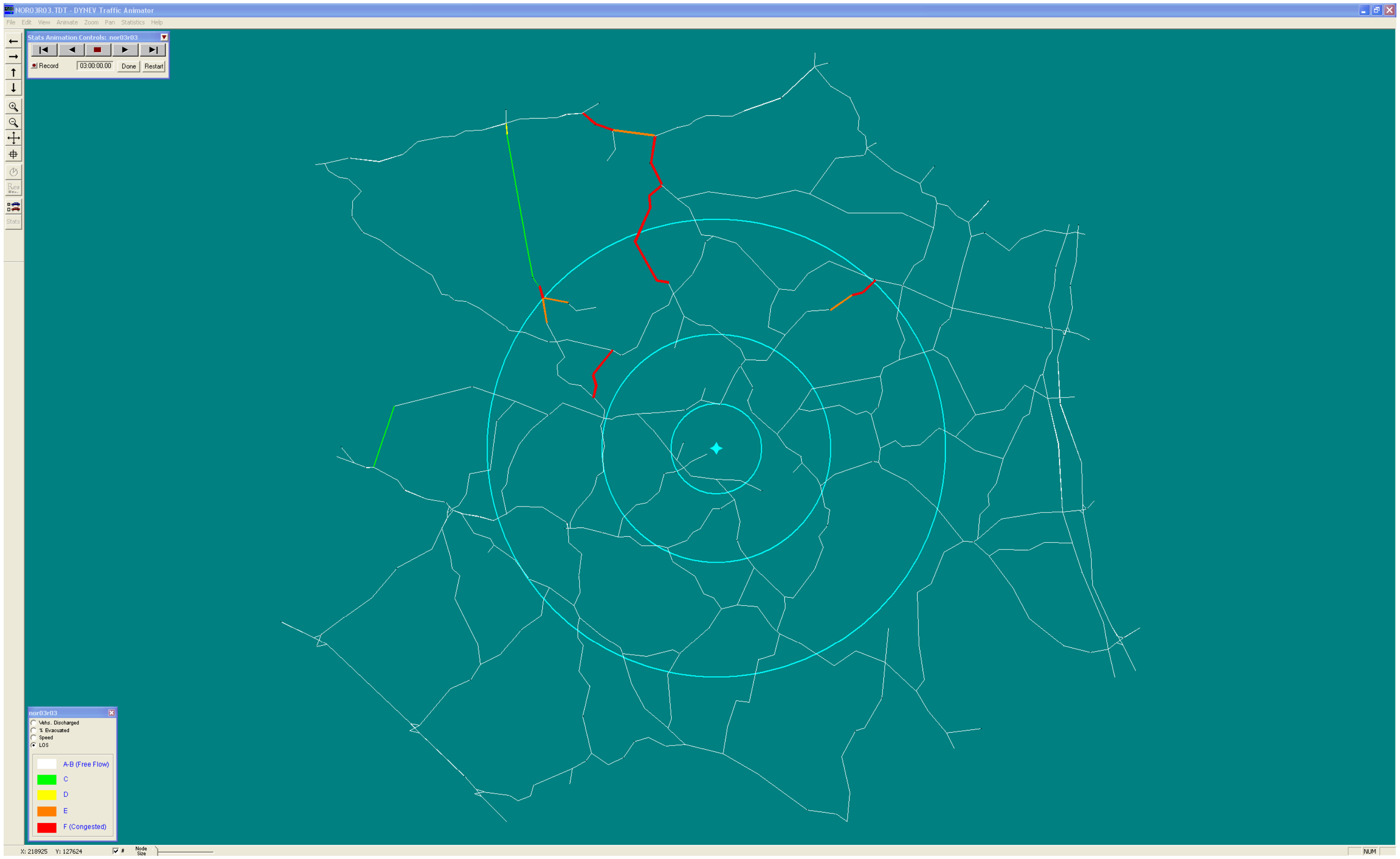


Figure 7-5 Congestion Patterns at 3 Hours after the Evacuation Advisory

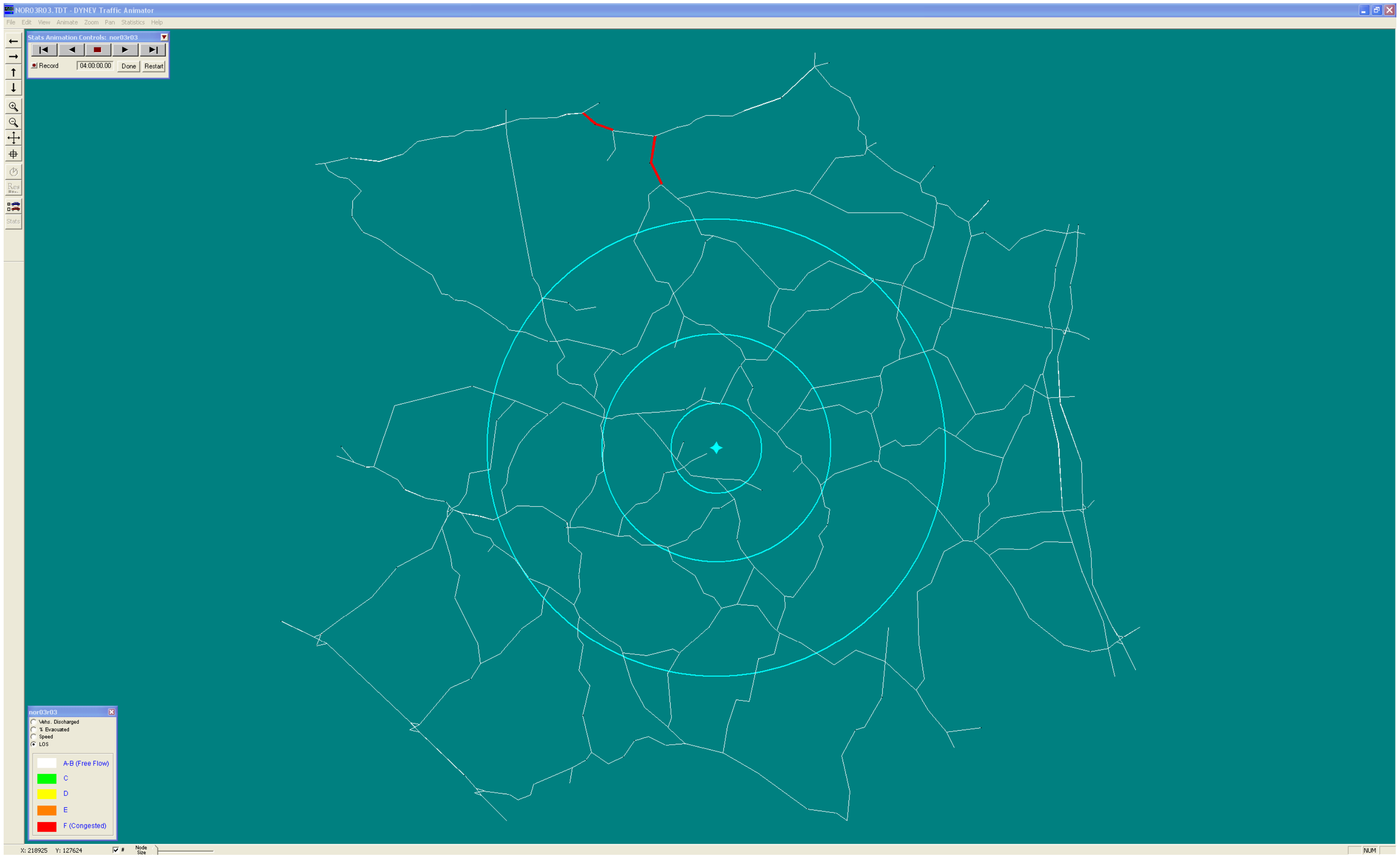


Figure 7-6 Congestion Patterns at 4 Hours after the Evacuation Advisory

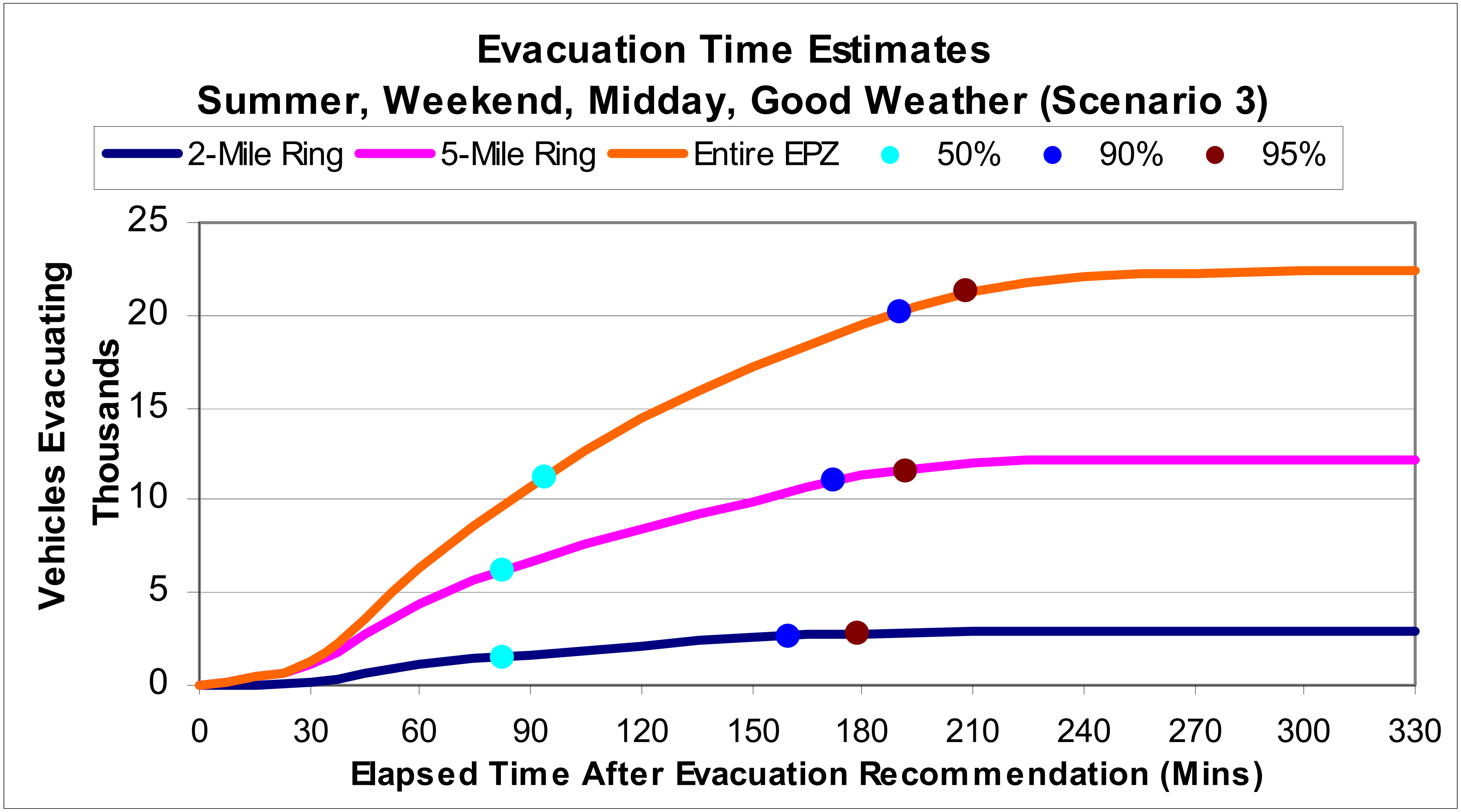


Figure 7-7. Evacuation Time Estimates for NAPS
Summer, Weekend, Midday, Good Weather
Evacuation of Region R03 (Entire EPZ)

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 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 longer 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 Evacuation Assembly Centers (EACs) to speed the evacuation of the school children in the event that buses need to return to the EPZ and evacuate transit dependents. The estimated number of buses is calculated under the assumption that no children will be picked up at school by their parents; this is an upper bound estimate of the transit vehicles needed.

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 EACs

8.1 Transit-Dependent People - Demand Estimate

The telephone survey (see Appendix F) results were used to estimate the portion of the population requiring transit service:

- Those persons in households that do not have a vehicle available.
- Those persons in households that do have vehicle(s) that would not be available at the time the evacuation is advised.

In the latter group, the vehicle(s) may be used by a commuter(s) who does not return (or is not expected to return) home to evacuate the household.

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, estimates of transit vehicles are not reduced accordingly, 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. **Here, a conservative estimate that 50 percent of transit-dependent persons will ride-share is adopted.**

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.

Table 8-1 indicates that transportation must be provided for 478 people. Therefore, a total of 16 bus runs are required to transport this population to the EACs.

To illustrate this estimation procedure, it is necessary to calculate the number of persons, P, requiring public transit or ride-share, and the number of buses, B, required for the North Anna EPZ:

$$P = 13{,}005 \times (0.022 \times 1.50 + 0.154 \times (1.85 - 1) \times 0.59 \times 0.39 + 0.410 \times (2.47 - 2) \times (0.59 \times 0.39)^2)$$
$$P = 13{,}005 * (0.07332) = 954$$
$$B = (0.5 \times P) \div 30 = 16$$

These calculations are explained as follows:

- Households (HH) with no vehicles constitute 2.2 percent of all households and contain an average of 1.5 persons who will evacuate by public transit or ride-share. The term 13,005 (number of households) x 0.022 x 1.5, accounts for these people.
- Households (HH) with 1 vehicle constitute 15.4 percent of all households and contain an average of 1.85 persons. The survey reveals that 59% of EPZ households have a commuter, 39% of whom would not return home in the event of an emergency. Thus the average number of persons at home is 1.85 -1 = 0.85. The number of persons who will evacuate by transit or ride-share is equal to 13,005 x 0.154 x 0.59 x 0.39 x (1.85 -1).
- Households (HH) with 2 vehicles constitute 41 percent of all households and contain an average of 2.47 persons. With both vehicles away, the average number of persons at home is 2.47 -2 = 0.47 persons. The total number of persons who will evacuate by transit or ride-share is equal to 13,005 x 0.41 x $(0.59 \times 0.39)^2$ x (2.47 -2). The squared term reflect the possibility that <u>neither</u> car will return home.
- Households with 3 or more vehicles are assumed to have no need for transit vehicles.
- The total number of persons requiring public transit is the sum of such people in HH with no vehicles, or with 1 or 2 vehicles that will remain away from home.

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.

It is recommended that the Counties introduce procedures to contact the schools 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, even though they are asked to pick children up at the EACs. 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 EACs 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.

8.3 Special Facility Demand

Data collection efforts by the counties within the EPZ indicate that there are no operating nursing homes, hospitals, or other medical facilities within the EPZ. There is one day care (Mineral Christian Pre-School) in the EPZ; it will be included in the school ETE analysis. Parents are responsible for picking up children at the day care; however, an ETE for the facility is included in the event transit assistance is needed.

8.4 Evacuation Time Estimates for Transit-Dependent People

County bus resources are assigned to evacuating school children as the first priority in the event of an emergency. In the event that the allocation of buses dispatched from the depots to the various facilities and to the bus routes is somewhat “inefficient”, or if there is a shortfall of available drivers, then there may be a need for some buses to return to the EPZ from the EACs after completing their first evacuation trip, to complete a “second wave” of providing transport service to evacuees. For this reason, the ETE is calculated for both a one wave transit evacuation and for two waves. Of course, if the Evacuation Region is other than R03 (the entire EPZ), then there will likely be ample transit resources relative to demand and this discussion of a second wave would likely not apply.

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 position to board the buses when they arrive at the pick-up points.

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 until the time 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 or 3 seconds (Ref. HCM2000 Ch. 27: Exhibit 27-9 and Ex. 1). 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. Multiple stops along a pick-up route must allow for the additional delay associated with the bus stopping and starting at each pick-up point. This additional delay to service passengers expands this estimate of boarding time to 30 minutes in good weather, and 35 minutes in rain.

Activity: Travel to EPZ Boundary (D→E)

The iterative procedure described in Appendix D (steps 13-16) was repeated in this revision and led to refined results that exhibited somewhat improved speeds than in the previous version. These improved speeds are reflected in Tables 8-4A, 8-4B, 8-6A, and 8-6B

School Evacuation

The distance from a school to the EPZ boundary is measured using Geographical Information Systems (GIS) software along the most likely route out of the EPZ. The travel times to the EPZ boundary are based on evacuation speeds computed by the model. The average speed for an evacuation of the full EPZ under Scenario 6 (winter, midweek, midday, good weather) conditions at 90 minutes (mobilization time) is 35.0 mph, while the average speed for an evacuation of the full EPZ under Scenario 7 conditions (winter, midweek, midday, Rain) is 29.6 mph. The counter-flow travel time from the EPZ boundary to the EAC was computed assuming an average speed of 40 mph and 35 mph for good weather and rain, respectively. Based on discussions with the EPZ Counties, there are adequate buses to evacuate the school children in a single wave.

Tables 8-4A (good weather) and 8-4B (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 EAC. 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 + 7 = 1:45 – rounded up to the nearest 5 minutes – for Louisa County High School, with good weather). The evacuation time to the Evacuation Assembly Center is determined by adding the time associated with Activity E→F (discussed below), to this EPZ evacuation time.

Evacuation of Transit-Dependent Population

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 prospective passengers have completed their mobilization. As indicated in Section 5 (Distribution D in Table 5-1), about 90 percent of the evacuees will complete their mobilization when the first buses will begin their routes, 120 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 8-5 details the proposed bus routes to service the transit dependent people in the North Anna EPZ, while Figure 8-2 maps the proposed bus pick-up routes. The travel distance along the respective pick-up routes within the EPZ is measured using GIS software. The average speed output by the PC-DYNEV model at the mobilization time is used to estimate the route travel time.

Tables 8-6A and 8-6B present the transit-dependent population evacuation time estimates for each route obtained using the above procedures. For example, the ETE for Route 5 is computed as 120 + 46 + 30 = 3:20 (rounded up to nearest 5 minutes) for good weather. Here, 46 minutes is the time to travel 22.0 miles at 29.0 mph (average speed output by PC-DYNEV at the mobilization time of 120 minutes). The average speed for rain scenarios is 23.5 mph at the mobilization time of 120 minutes. The ETE for a second wave (discussed below) is presented in the event there is a shortfall of available buses or bus drivers.

Activity: Travel to Evacuation Assembly Centers (E→F)

The distances from the EPZ boundary to the EAC are also measured using GIS software along the most likely route from the EPZ to the EAC. 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.

Activity: Passengers Leave Bus (F→G)

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

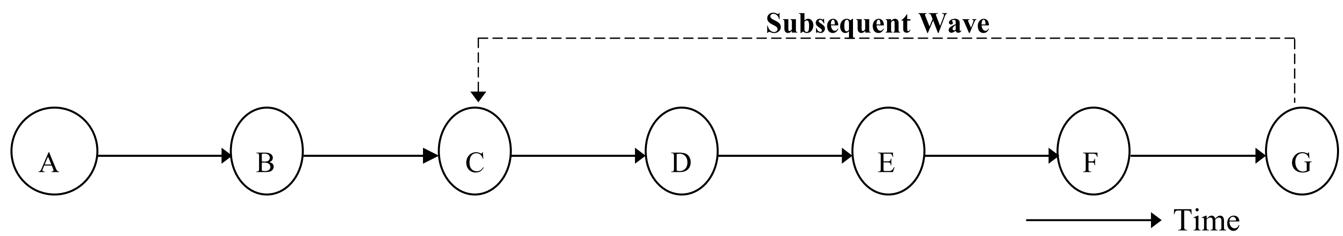
Activity: Bus Returns to Route for Second Wave Evacuation (G→C)

The buses assigned to return to the EPZ to perform a "second wave" evacuation of transit-dependent evacuees will be those buses that evacuated the schools. Thus, the mobilization time for the second wave is the average time that buses arrive at the evacuation assembly centers (See Tables 8-4A and 8-4B). The travel time back to the EPZ to the start of the route is estimated as 20 minutes for good weather and 25 minutes for rain. The bus then travels its route and picks up transit-dependent evacuees along the route. The average speed output by PC-DYNEV at the time the buses begin the second wave is used to compute the route travel time – 34.5 mph for good weather scenarios at the beginning of the second wave at 2:35 and 32.8 mph for rain scenarios at the beginning of the second wave at 3:00.

The travel times for Bus Route Number 5 are computed as follows for good weather:

- Bus arrives at EAC at 2:00 in good weather (average of "ETE to EAC (hr:min)" column in Table 8-4A).
- Bus discharges passengers (5 minutes) and driver takes a 10-minute rest: 15 minutes.
- Bus returns to EPZ to the start of its route: 20 minutes (assumed).
- Bus completes pick-ups along route and departs EPZ: 30 minutes + 38 minutes (22 miles @ 34.5 mph).
- Bus exits EPZ at time 2:00 + 0:15 + 0:20 + 1:08 = 3:45 (rounded up to nearest 5 minutes) after the Advisory to Evacuate.

The ETE estimates for the second wave are given in Tables 8-6A and 8-4B. The ETE for the transit-dependent population does not extend beyond the ETE for the general population.



Event

A	Advisory to Evacuate
B	Bus Dispatched from Depot
C	Bus Arrives at Facility/Pick-up Route
D	Bus Departs for Evacuation Assembly Center (EAC)
E	Bus Exits Region
F	Bus Arrives at School EAC
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 EAC Outside the EPZ.
F→G	Passengers Leave Bus; Driver Takes a Break

Figure 8-1. Chronology of Transit Evacuation Operations

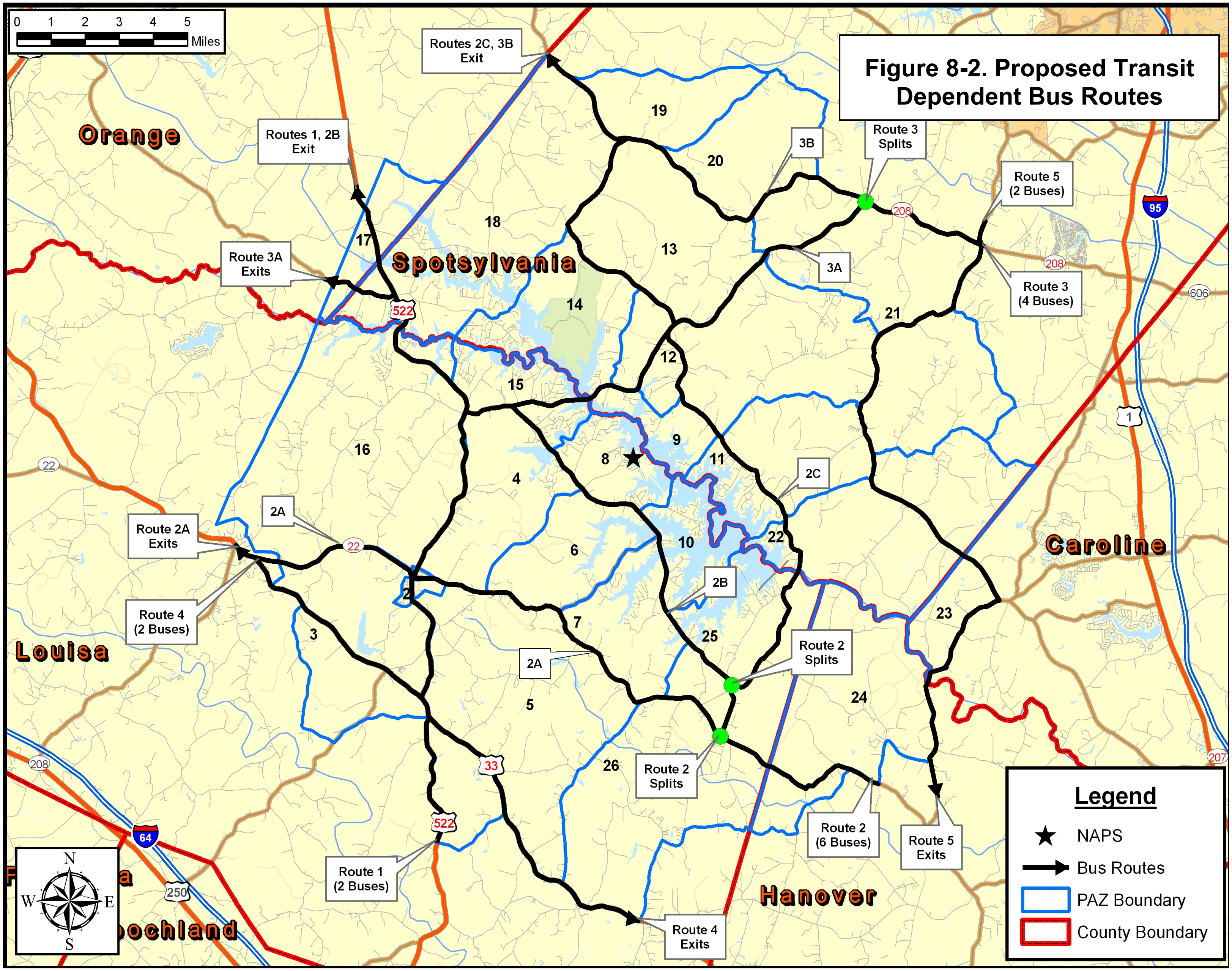


Figure 8-2. Proposed Transit Dependent Bus Routes
0 1 2 3 4 5 Miles
Orange
Spotsylvania
Louisa
Caroline
Hanover
Routes 2C, 3B Exit
Routes 1, 2B Exit
Route 3A Exits
Route 3 Splits
3B
3A
Route 5 (2 Buses)
Route 3 (4 Buses)
2C
2A
Route 2A Exits
Route 4 (2 Buses)
2B
2A
Route 2 Splits
Route 2 Splits
Route 2 (6 Buses)
Route 5 Exits
Route 1 (2 Buses)
Route 4 Exits
Legend
NAPS
Bus Routes
PAZ Boundary
County Boundary

Table 8-1. Transit Dependent Population Estimates														
Facility Name	2008 EPZ Population	Survey Average Household Size With Indicated No. of Vehicles			Estimated Number of Households	Survey Percent Households With			Survey Percent Households With Commuters	Survey Percent Households With Non-Returning Commuters	Total People Requiring Transport	Estimated Ridesharing Percentage	People Requiring Public Transit	Percent of Population Requiring Public Transit
		0	1	2		0 Veh-icle	1 Veh-icle	2 Veh-icle						
North Anna Power Station	33,423	1.50	1.85	2.47	13,005	2.2%	15.4%	41.0%	59%	39%	955*	50%	478	1.4%

*See Section 8.1 for detailed calculation.

Table 8-2. School Population Demand Estimates							
PAZ	Distance (miles)	Direction	School Name	Municipality	Enroll-ment	Staff	Bus Runs Required
Louisa County Schools							
2	7.2	WSW	Mineral Christian Pre-School (DAYCARE)	Mineral	60	9	1
3	7.8	WSW	Louisa County High School	Mineral	1493	170	30
3	7.9	WSW	Louisa County Middle School	Mineral	1080	119	22
3	10.6	WSW	Thomas Jefferson Elementary School	Louisa	796	124	12
5	11.8	SSW	Jouett Elementary School	Mineral	644	102	10
				Louisa County Totals:	4,073	524	75
Spotsylvania County Schools							
12	5.3	NNE	Livingston Elementary School	Spotsylvania	500	65	8
21	9.8	NE	Post Oak Middle School	Spotsylvania	786	125	16
21	10.1	NE	Spotsylvania High School	Spotsylvania	1150	165	23
21	10.3	ENE	Berkeley Elementary School	Spotsylvania	350	75	5
				Spotsylvania County Totals:	2,786	430	52
				EPZ Totals:	**6,859**	**954**	**127**

Table 8-3. School Evacuation Assembly Centers		
Facility	PAZ	EAC
High Schools		
Louisa County High School	3	Trevilians Elementary School
Spotsylvania High School	21	Massaponax High School
Middle Schools		
Louisa County Middle School	3	Trevilians Elementary School
Post Oak Middle School	21	Courtland High School
Elementary Schools		
Thomas Jefferson Elementary School	3	Trevilians Elementary School
Jouett Elementary School	5	Patrick Henry High School
Livingston Elementary School	12	Courtland High School
Berkeley Elementary School	21	Massaponax High School
Day Care Facilities		
Mineral Christian Pre-school	2	Trevilians Elementary School

Table 8-4A. School Evacuation Time Estimates - Good Weather								
School	**Driver Mobilization Time (min)**	**Loading Time (min)**	**Dist. to EPZ Boundary (mi.)**	**Travel Time to EPZ Bndry (min)***	**ETE (hr:min)**	**Dist. EPZ Bndry to EAC (mi.)**	**Travel Time EPZ Bndry to EAC (min)****	**ETE to EAC (hr:min)**
Louisa County Schools								
Thomas Jefferson Elementary School	90	5	1.53	3	**1:40**	9.89	15	**1:55**
Jouett Elementary School	90	5	4.23	8	**1:45**	17.10	26	**2:10**
Louisa County High School	90	5	3.55	7	**1:45**	8.08	13	**1:55**
Louisa County Middle School	90	5	3.30	6	**1:45**	8.07	13	**1:55**
Mineral Christian Preschool (DAYCARE)	90	5	3.49	6	**1:45**	9.02	14	**1:55**
Spotsylvania County Schools								
Berkeley Elementary School	90	5	2.06	4	**1:40**	7.97	12	**1:55**
Livingston Elementary School	90	5	9.29	16	**1:55**	7.21	11	**2:05**
Post Oak Middle School	90	5	4.21	8	**1:45**	7.26	11	**1:55**
Spotsylvania High School	90	5	3.19	6	**1:45**	7.98	12	**1:55**
				Average for EPZ:	**1:45**		**Average:**	**2:00**

*Average speed within EPZ output by PC-DYNEV = 35.0 mph.
**Average speed outside EPZ (assumed) = 40.0 mph.

Table 8-4B. School Evacuation Time Estimates - Rain								
School	**Driver Mobilization Time (min)**	**Loading Time (min)**	**Dist. to EPZ Boundary (mi.)**	**Travel Time to EPZ Bndry (min)***	**ETE (hr:min)**	**Dist. EPZ Bndry to EAC (mi.)**	**Travel Time EPZ Bndry to EAC (min)****	**ETE to EAC (hr:min)**
Louisa County Schools								
Thomas Jefferson Elementary School	100	10	1.53	4	**1:55**	9.89	17	**2:15**
Jouett Elementary School	100	10	4.23	9	**2:00**	17.1	30	**2:30**
Louisa County High School	100	10	3.55	8	**2:00**	8.08	14	**2:15**
Louisa County Middle School	100	10	3.30	7	**2:00**	8.07	14	**2:15**
Mineral Christian Preschool (DAYCARE)	100	10	3.49	8	**2:00**	9.02	16	**2:15**
Spotsylvania County Schools								
Berkeley Elementary School	100	10	2.06	5	**1:55**	7.97	14	**2:10**
Livingston Elementary School	100	10	9.29	19	**2:10**	7.21	13	**2:25**
Post Oak Middle School	100	10	4.21	9	**2:00**	7.26	13	**2:15**
Spotsylvania High School	100	10	3.19	7	**2:00**	7.98	14	**2:15**
				Average for EPZ:	**2:00**		**Average:**	**2:20**

*Average speed within EPZ output by PC-DYNEV = 29.6 mph.
**Average speed outside EPZ (assumed) = 35.0 mph.

Table 8-5. Summary of Transit Dependent Bus Routes		
Route Number	**Number of Buses**	**Route Description**
1	2	US Highway (USHY) 522 northbound out of the EPZ
2A	2	State Highway (STHY) 658 westbound from Hanover to STHY 618; westbound on STHY 618 to STHY 22/208; westbound on State Hwy 22/208 out of the EPZ
2B	2	STHY 658 westbound from Hanover to STHY 701; northbound on STHY 701 to STHY 652; westbound on STHY 652 to STHY 208; westbound on STHY 208 to USHY 522; northbound on USHY 522 out of the EPZ
2C	2	STHY 658 westbound from Hanover to STHY 701; northbound on STHY 701 to STHY 601; northbound on STHY 601 to STHY 208; eastbound on STHY 208 to STHY 601; northbound on STHY 601 to STHY 612; northbound on STHY 612 to STHY 606; northbound on STHY 606 out of the EPZ
3A	2	STHY 208 westbound from Spotsylvania to USHY 522; northbound on USHY 522 to STHY 612; westbound on State Hwy 612 out of the EPZ
3B	2	STHY 208 westbound from Spotsylvania to STHY 606; westbound on State Hwy 606 out of the EPZ
4	2	USHY 33 eastbound from Louisa out of the EPZ toward Hanover
5	2	STHY 738 southbound from Spotsylvania out of the EPZ toward Hanover

Table 8-6A. Transit Dependent Evacuation Time Estimates - Good Weather													
	Single Wave					Second Wave							
Route Number	Mobilization (min.)	Route Length (mi.)	Route Travel Time (min.)*	Pickup Time (min.)	ETE (hr:min)	Mobilization (min.)	Unload (min.)	Driver Rest (min.)	Return time to EPZ (min.)	Route Travel Time (min.)**	Pickup Time (min.)	ETE (hr:min)
1	120	22.1	46	30	3:20	120	5	10	20	38	30	3:45
2A	120	22.8	47	30	3:20	120	5	10	20	40	30	3:45
2B	120	27.9	58	30	3:30	120	5	10	20	49	30	3:55
2C	120	31.9	66	30	3:40	120	5	10	20	55	30	4:00
3A	120	21.8	45	30	3:15	120	5	10	20	38	30	3:45
3B	120	16.4	34	30	3:05	120	5	10	20	29	30	3:35
4	120	17.1	35	30	3:05	120	5	10	20	30	30	3:35
5	120	22.0	46	30	3:20	120	5	10	20	38	30	3:45
				Average for EPZ:	**3:20**						**Average for EPZ:**	**3:45**

*Average speed within EPZ output by PC-DYNEV at 2:00 = 29.0 mph.

** Average speed within EPZ output by PC-DYNEV at 2:35 = 34.5 mph.

Table 8-6B. Transit Dependent Evacuation Time Estimates - Rain													
	Single Wave					Second Wave							
Route Number	Mobilization (min.)	Route Length (mi.)	Route Travel Time (min.)*	Pickup Time (min.)	ETE (hr:min)	Mobilization (min.)	Unload (min.)	Driver Rest (min.)	Return time to EPZ (min.)	Route Travel Time (min.)**	Pickup Time (min.)	ETE (hr:min)
1	120	22.1	56	35	3:35	140	5	10	25	43	35	4:15
2A	120	22.8	58	35	3:35	140	5	10	25	45	35	4:20
2B	120	27.9	71	35	3:50	140	5	10	25	55	35	4:30
2C	120	31.9	81	35	4:00	140	5	10	25	62	35	4:35
3A	120	21.8	56	35	3:35	140	5	10	25	43	35	4:15
3B	120	16.4	42	35	3:20	140	5	10	25	32	35	4:05
4	120	17.1	44	35	3:20	140	5	10	25	33	35	4:10
5	120	22.0	56	35	3:35	140	5	10	25	43	35	4:15
				Average for EPZ:	**3:40**						**Average for EPZ:**	**4:20**

*Average speed within EPZ output by PC-DYNEV at 2:00 = 23.5 mph.

** Average speed within EPZ output by PC-DYNEV at 3:00 = 32.8 mph.

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.

The terms "facilitate" and "discourage" are employed 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 station 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.

The use of Intelligent Transportation Systems (ITS) technologies, where available, could reduce manpower and equipment needs, while still facilitating the evacuation process. Dynamic Message Signs (DMS) could be placed within the EPZ to provide information to travelers regarding traffic conditions, route selection, and evacuation assembly center information. DMS could 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 station. Highway Advisory Radio (HAR) could be used to broadcast information to evacuees en route through their vehicle stereo systems. Automated Traveler Information Systems (ATIS) could also be used to provide evacuees with information. Internet websites could provide traffic and evacuation route information before the evacuee begins his trip, while on board navigation systems (GPS units) can be used to provide information en route. These are only several examples of how ITS technologies could 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.