Attachment

2012 Three Mile Island Nuclear Station EPZ ETE Analysis

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Evacuation Time Estimates for the Three Mile Island Plume Exposure Pathway Emergency Planning Zone

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Executive Summary

This report documents the approach and presents the results of the Evacuation Time Estimate (ETE) study performed by ARCADIS for Three Mile Island (TMI) in Londonderry Township, Dauphin County, Pennsylvania. The study reflects the current definition of the Emergency Planning Zone, which is the region within a nominal 10-mile distance of TMI. The most recent previous study of evacuation time estimates for TMI was performed in 2003. The present study was performed using population data from the 2010 census.

PTV Vision™ software was used to perform evacuation modeling for different scenarios. The PTV Vision traffic simulation software package includes VISUM (macroscopic traffic simulation) and VISSIM (microscopic traffic simulation). VISUM is a comprehensive, flexible software system for transportation planning, travel demand modeling, and network data management. VISSIM is capable of performing detailed microscopic simulation of traffic and can model any type of traffic signal control and geometric configuration.

The road network used in the evacuation simulations consisted of designated evacuation routes plus any additional roadways needed to accurately simulate conditions during an evacuation. Roadway capacities were determined using NAVTEQ™ digital data, updated by ARCADIS based on actual road and intersection data collected in the field in 2011. Evacuees were generally assumed to proceed out of the Emergency Planning Zone (EPZ) via recommended evacuation routes and to make their way to designated reception centers after leaving the EPZ.

The EPZ for TMI includes parts of five Pennsylvania counties: Cumberland, Dauphin, Lancaster, Lebanon and York. Based on the 2010 census, the estimated population residing in the EPZ is 226,034. Dauphin County has 47 percent of the EPZ resident population; 32 percent of the population resides in York County; 16 percent in Lancaster County; 4.5 percent in Cumberland County; and the remaining 0.5 percent in Lebanon County. The region is predominantly urban/industrial and suburban in character, including part of the city of Harrisburg, the city of Hershey (Derry Township), and several boroughs south of Harrisburg (Swatara, Steelton, Lower Paxton, Lower Swatara, Middletown). The population in the EPZ increased by 12 percent between 2000 and 2010; the most rapid population growth in the EPZ occurred in York County (21.6 percent) and Lancaster County (14.3 percent).

Three Mile Island is located in the Susquehanna River, which is about a mile wide as it crosses the EPZ, flowing from northwest to southeast. The river is a barrier to travel within the EPZ. The Pennsylvania Turnpike (I-76) crosses the river about 6 miles northwest of TMI, and I-83 crosses at the EPZ boundary, just beyond 10 miles northwest of TMI. U.S. 30 crosses the river about 13 miles southeast of TMI. The Zones within a nominal 2-mile

distance from TMI have 5,438 residents. The zones from 2-5 miles contain about 18 percent of the EPZ resident population, and the zones beyond 5 miles contain almost 80 percent.

The transient population, which includes large workplaces, recreational facilities and hotels/motels, was estimated at 61,058 persons for a winter weekday and 86,741 persons for a summer weekend. The special facilities population, including nursing homes and hospitals, was estimated at 11,364 persons (residents plus staff) for weekdays, and 6,773 for nights and weekends. The estimated population of schools and day care centers for a winter weekday is 48,874, including children and staff. These population estimates include intrinsic double counting, as some persons in the transient and special facility populations are also included in the permanent and seasonal resident counts. Thus, evacuation times using these population figures are considered conservative.

Vehicle demand for the resident population was developed based on estimated vehicle occupancy, using data obtained from a telephone survey of EPZ residents. The vehicle occupancy factor estimated from survey responses is 2.23 persons per vehicle, which represents 1.35 vehicles per household. For the 2003 study, vehicle occupancy was 1.65 persons per vehicle, assuming that all households with two or more vehicles would use two vehicles to evacuate.

Vehicle demand for the transient population was estimated using vehicle occupancy factors ranging from 1.0 person per vehicle for the workforce population up to 3.0 persons per vehicle for some recreational areas. Vehicle demand for the school population was based on bus occupancy of 48 persons. For nursing homes, vehicle occupancy is 20 persons per bus or van for residents, and two persons per ambulance for non-ambulatory patients. For nights and weekends, all facility staff would accompany patients; during weekdays, one vehicle per person was assigned for the additional staff. Total vehicle demand for all population categories ranges from 135,786 (winter night) to 163,273 (summer weekday).

Vehicle demand was also assigned to account for the potential "shadow evacuation" of the population residing immediately outside the EPZ, to a distance of 15 miles. The permanent resident population within this region is 409,742. It was assumed that 20 percent of the population in this region would evacuate. The occupancy factor for EPZ residents (2.23 persons per vehicle) was applied to estimate vehicle demand for this population. Shadow evacuees residing outside the EPZ add vehicle demand of 36,748 vehicles.

Evacuation times were estimated for evacuation of the entire EPZ for winter weekday (daytime and evening), winter weekend day, summer weekday (daytime and evening), and summer weekend cases under fair weather conditions. The weekday daytime cases were

also evaluated for adverse weather conditions (snow and rain, respectively, for winter and summer).

A set of "staged evacuation" scenarios was also evaluated. Under a staged evacuation scenario, only the population within the 2-mile zones closest to TMI would evacuate initially; evacuation of surrounding zones would be initiated after most traffic from the 2-mile zones has cleared. The purpose of evaluating these scenarios is to assess the potential reduction in evacuation times that might be achieved for the population at greatest risk.

Simulations were also performed to assess the potential impact of population growth on predicted evacuation times. This sensitivity analysis is used to define a threshold population figure that would trigger another ETE update study.

Evacuation times for the general population are summarized in Table E-1. For normal weather, ETEs are up to 9 hours 45 minutes for 90 percent of vehicles to evacuate the full 10-mile EPZ, and 10 hours 35 minutes for 100 percent to evacuate. The case with the longest ETEs for the full EPZ is Winter Weekday. With adverse weather, the predicted ETEs were up to 2 hours 40 minutes longer.

The ETEs to evacuate only the 2-mile zone are 2:40 to 4:10 (90 percent) and 3:05 to 4:40 (100 percent). The ETEs to evacuate all zones out to 5-miles are 3:50 to 5:25 (90 percent) and 4:05 to 5:50 (100 percent). The 90 percent ETEs from the current study are about 2 hours longer than corresponding times from the 2003 study, while 100 percent ETEs are roughly the same as times from the previous study.

The ETEs for the full EPZ reflect major traffic congestion in the zones more than 5 miles from TMI. Both the residential and transient populations are concentrated in these outer zones, particularly in Dauphin County.

Table E-1: Evacuation Time Estimate Summary for Three Mile Island EPZ

	Summer				Winter			
	Midweek Daytime		Weekend Daytime	Evening	Midweek Daytime		Weekend Daytime	Evening
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weather:	Normal	Adverse	Normal	Normal	Normal	Adverse	Normal	Normal
Evacuation Area	90 Percent Evacuation Time							
2-mile Zone	3:20	3:50	2:40	2:40	3:20	4:10	2:40	2:40
5-mile Zone	4:10	4:50	3:50	3:50	4:20	5:25	3:55	3:55
10-mile EPZ	9:55	11:35	8:30	8:15	10:25	13:00	8:30	8:05
	100 Percent Evacuation Time							
2-mile Zone	3:45	4:15	3:05	3:05	3:45	4:40	3:05	3:05
5-mile Zone	4:40	5:25	4:10	4:05	4:40	5:50	4:10	4:10
10-mile EPZ	10:50	12:30	9:15	9:00	11:25	14:20	9:15	8:50

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List of Acronyms and Abbreviations

ADT	Average daily traffic
BAO	ESRI Business Analyst Online
EAS	Emergency Alert System
EPZ	Exposure Pathway Emergency Planning Zone
ERPA	Emergency Response Protection Area
ETE	Evacuation time estimate
GIS	Geographic information system
GPS	Global Positioning System
LOS	Level-of-service
NRC	Nuclear Regulatory Commission
PAR	Protective Action Recommendation
PEMA	Pennsylvania Emergency Management Agency
TAR	Tone alert radios
TMI	Three Mile Island

1. Introduction

1.1 General

Evacuation time studies analyze the manner in which the population within the Plume Exposure Pathway Emergency Planning Zone (EPZ) surrounding a nuclear power plant site would evacuate during a radiological emergency. Evacuation time studies provide licensees and State and local governments with site-specific information helpful for protective action decision-making. The studies estimate the time necessary to evacuate the EPZ for a range of evacuation scenarios. Analysis of the evacuation simulation results also identifies locations where traffic management and control measures can facilitate the evacuation, and may identify unique evacuation constraints or conditions.

Estimates of the time required to evacuate from areas around nuclear power plant sites are required for all operating plants in the United States. Federal guidance has been prepared to outline the format and content of these evacuation time estimates (NUREG-0654, Rev. 1 (Nuclear Regulatory Commission (NRC), 1980), NUREG/CR-4831 (NRC, 1992) and NUREG/CR-7002 (NRC, 2011)).

Evacuation time estimate (ETE) studies were last updated for Three Mile Island (TMI) Plume Exposure Pathway EPZ in 2003 (Earth Tech, 2003). The guidance presented in NUREG/CR-7002 indicates that the evacuation time estimates should be updated as local conditions change, but at least once each decade, following release of the federal census. The current update study was prompted by the issuance of revised ETE guidance (CR-7002) and the availability of population data from the 2010 census. Census data indicate that the population residing within the EPZ increased by 24,140 between 2000 and 2010. The estimated 2010 population of the EPZ is 226,034, a 12 percent population increase since 2000. (Population data are discussed further below in section 1.4.)

The evacuation time estimates have been developed using current population, local roadway network characteristics and the PTV Vision™ traffic simulation software package to perform evacuation modeling for different scenarios. PTV Vision includes the VISSIM (microscopic traffic simulation) and VISUM (macroscopic traffic simulation) models. Evacuation times have been estimated for various areas, times and weather conditions, as outlined in CR-7002. These evacuation times represent the times required for completing the following actions:

- Public notification;

- Preparation and mobilization; and
- Actual movement out of the EPZ (i.e., on-road travel time, including delays associated with vehicle queuing).

1.2 Site Location and Emergency Planning Zone (EPZ)

This report describes the analyses undertaken, and the results obtained, in a study to update the existing Evacuation Time Estimates for TMI. The emergency response plan is designed to protect the health and safety of the public in the event that an evacuation is ordered as a protective action in response to an accident at TMI.

The TMI site is located off the eastern shore of the Susquehanna River in Londonderry Township, Dauphin County, Pennsylvania, about 10 miles southeast of Harrisburg. The location of the plant is shown in Figure 1-1. A listing of the municipalities included in the EPZ and their 2010 permanent resident population within the Three Mile Island EPZ is presented in Table 1-1.

The plume exposure pathway EPZ is the geographic area surrounding a nuclear power plant within which the NRC requires advance planning for evacuation or other short-term protective actions in the event of a radiological emergency. The EPZ for TMI consists of the area within an approximate 10-mile radius of TMI.

The Three Mile Island EPZ is subdivided into a total of 10 Sub-Areas, also known as Emergency Response Planning Areas (ERPAs). As a rule, such Sub-Areas are the basic units for which protective action recommendations are issued. It is understood that current Pennsylvania policy requires the evacuation of the entire EPZ if an evacuation is recommended. Nevertheless, it is necessary under NRC guidance to evaluate partial-EPZ evacuation scenarios. Sub-Area boundaries generally follow geographic (township and borough) boundaries, and reflect distance and direction from TMI. The distance ranges of concern are 0-2 miles, 2-5 miles, and beyond 5 miles. EPZ and Sub-Area boundaries are shown in Figure 1-1. The Sub-Areas are described in more detail in Section 3.

A listing of the permanent resident population for 2000 and 2010 by county and by Sub-Area within the Three Mile Island EPZ is included in Figure 1-1. Table 1-1 compares the EPZ population by township and borough from the 2010 and the 2000 census.

The EPZ for TMI includes parts of five Pennsylvania counties: Cumberland, Dauphin, Lancaster, Lebanon and York. Dauphin County has 47 percent of the EPZ resident population; 32 percent of the population resides in York County; 16 percent in Lancaster County; 4.5 percent in Cumberland County; and the remaining 0.5 percent in Lebanon County. The region is predominantly urban/industrial and suburban in character, including part of the city of Harrisburg, the city of Hershey (Derry Township), and several boroughs south of Harrisburg (Swatara, Steelton, Lower Paxton, Lower Swatara, Middletown). The population in the EPZ increased by 12 percent between 2000 and 2010; the most rapid population growth in the EPZ occurred in York County (21.6 percent) and Lancaster County (14.3 percent).

Three Mile Island is located in the Susquehanna River, which is about a mile wide as it crosses the EPZ, flowing from northwest to southeast. The river is a barrier to travel within the EPZ. The Pennsylvania Turnpike (I-76) crosses the river about 6 miles northwest of TMI, and I-83 crosses at the EPZ boundary, just beyond 10 miles northwest of TMI. U.S. 30 crosses the river about 13 miles southeast of TMI. The 2-mile Zones 2A and 2B have 5,438 residents. The zones from 2-5 miles contain about 18 percent of the EPZ permanent resident population, and the zones beyond 5 miles contain almost 80 percent.

NRC guidance requires consideration of potential "shadow evacuation" of the population residing immediately outside the EPZ, to a distance of 15 miles. The permanent resident population within this region is 409,742. This population is concentrated in two cities, Harrisburg, located north of the EPZ, and York, immediately south of the EPZ. A map showing the population by distance and direction sector within 15 miles of TMI is provided in Figure 1-2. (Due to roundoff errors that propagate when sector boundaries cut across census block boundaries, the population numbers disagree slightly between Figure 1-1 and Figure 1-2.)

1.3 Designated Reception Centers

The TMI emergency response evacuation plan directs residents of each community within the EPZ to evacuate to specified reception centers. If evacuation is initiated while schools are in session, students will be transported directly to designated Host Schools, and families are instructed to meet up with the students at those locations.

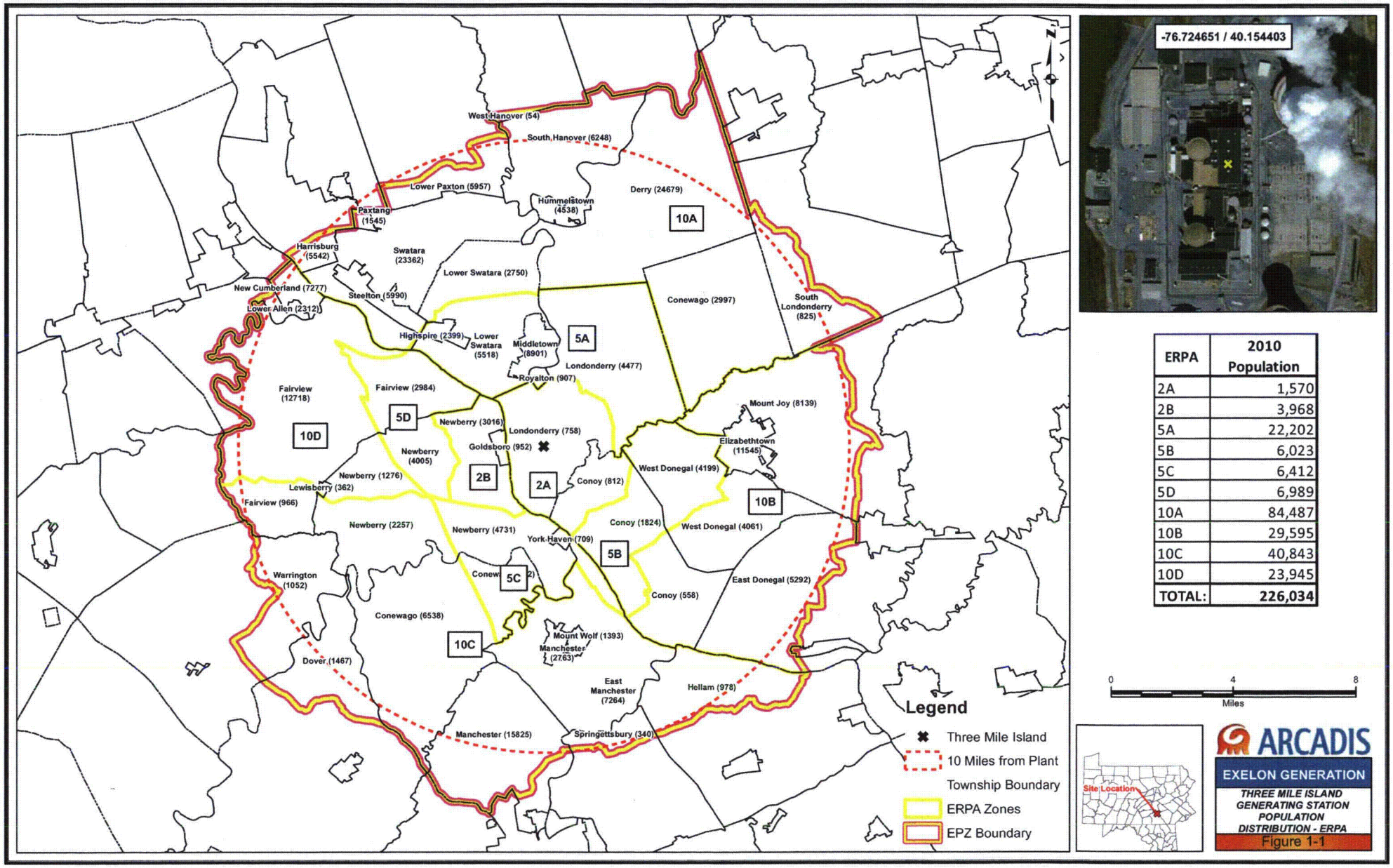
The designated reception centers for individual boroughs and townships are listed in Table 1-2. The roadway network used to develop evacuation time estimates includes the major roadways recommended to the public as evacuation routes from individual

communities to designated reception centers. The roadway network is described in detail in Section 4.

1.4 Overview of Changes from Previous ETE Study

The changes in residential population within the EPZ are summarized in Table 1-1. The revised NRC guidance and newly acquired data led to a number of other changes in the ETE methodology and assumptions. Table 1-3 provides a summary comparing the main features and assumptions of the current study to the 2003 ETE study. The telephone survey of EPZ residents provides a new basis for estimating vehicle occupancy and departure times, while new NRC guidance has specified different assumptions regarding background and "shadow" traffic. The ETE methodology and assumptions for the current study are discussed in greater detail in following sections of the report.

The revised vehicle occupancy for residents (2.23 persons per vehicle, based on survey), revised departure times for schools and special facilities (no "early warning") and the revised departure time curves for residents (based on survey responses and estimated time for warning diffusion) are expected to have the greatest influence on estimated evacuation times. The "shadow evacuation" adds vehicle demand of 36,748 vehicles in the area immediately outside the EPZ. Each of these issues is discussed in more detail in following sections of the report.



ERPA	2010 Population
2A	1,570
2B	3,968
5A	22,202
5B	6,023
5C	6,412
5D	6,989
10A	84,487
10B	29,595
10C	40,843
10D	23,945
TOTAL:	226,034

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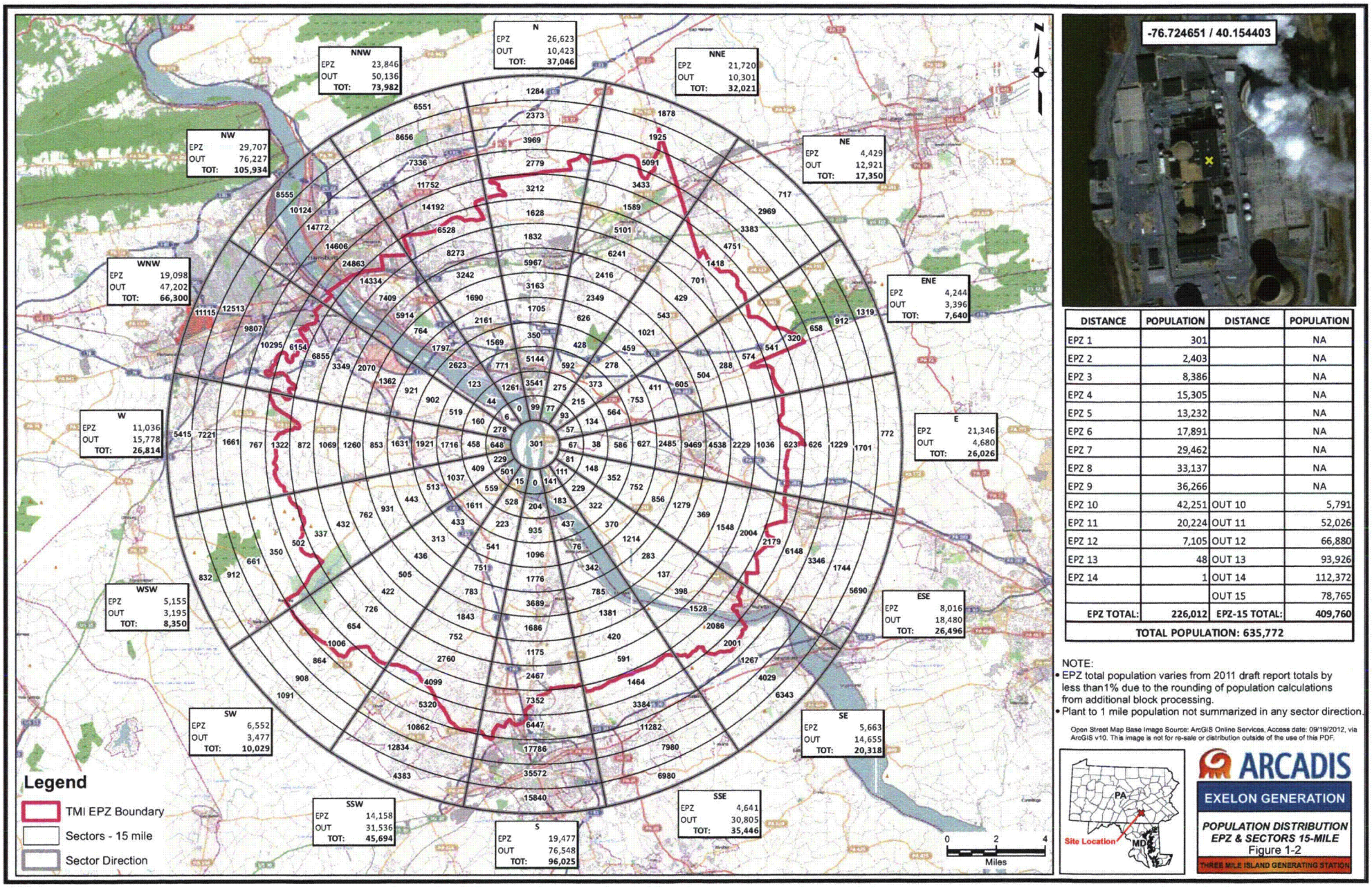
EXELON GENERATION

THREE MILE ISLAND GENERATING STATION POPULATION DISTRIBUTION - ERPA

Figure 1-1



DISTANCE	POPULATION	DISTANCE	POPULATION
EPZ 1	301		NA
EPZ 2	2,403		NA
EPZ 3	8,386		NA
EPZ 4	15,305		NA
EPZ 5	13,232		NA
EPZ 6	17,891		NA
EPZ 7	29,462		NA
EPZ 8	33,137		NA
EPZ 9	36,266		NA
EPZ 10	42,251	OUT 10	5,791
EPZ 11	20,224	OUT 11	52,026
EPZ 12	7,105	OUT 12	66,880
EPZ 13	48	OUT 13	93,926
EPZ 14	1	OUT 14	112,372
		OUT 15	78,765
EPZ TOTAL:	**226,012**	**EPZ-15 TOTAL:**	**409,760**
TOTAL POPULATION: 635,772			

NOTE:
- EPZ total population varies from 2011 draft report totals by less than1% due to the rounding of population calculations from additional block processing.
- Plant to 1 mile population not summarized in any sector direction.

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EXELON GENERATION

POPULATION DISTRIBUTION EPZ & SECTORS 15-MILE

Figure 1-2

THREE MILE ISLAND GENERATING STATION

Table 1-1: Permanent Resident Population in the Three Mile Island EPZ

County Subdivision	Census 2000[a]	Census 2010[b]	Percent Change
Cumberland County			
Lower Allen township (Part) 10D	7,349	7,277	
New Cumberland borough 10D	2,166	2,312	
County Subtotal	**9,515**	**9,589**	**0.8%**
Dauphin County			
Conewago township 10A	2,847	2,997	
Derry township 10A	21,273	24,679	
Harrisburg city (Part) 10A	5,426	5,542	
Highspire borough 5A	2,720	2,399	
Hummelstown borough 10A	4,360	4,538	
Londonderry township 2A, 5A	5,224	5,235	
Lower Paxton township (Part) 10A	4,919	5,957	
Lower Swatara township 5A, 10A	8,149	8,268	
Middletown borough 5A	9,242	8,901	
Paxtang borough 10A	1,570	1,545	
Royalton borough 5A	963	907	
South Hanover township 10A	4,793	6,248	
Steelton borough 10A	5,858	5,990	
Swatara township 10A	22,611	23,362	
West Hanover 10A	0	54	
County Subtotal	**99.955**	**106,622**	**6.7%**
Lancaster County			
Conoy township 2B, 5B, 10B	3,067	3,194	
East Donegal township (Part) 10B	3,895	8,139	
Elizabethtown borough 10B	11,887	11,545	
Mount Joy township (Part) 10B	6,471	5,292	
West Donegal township 5B, 10B	6,539	8,260	
County Subtotal	**31,859**	**36,430**	**14.3%**
Lebanon County			
South Londonderry township (Part)	906	825	
Lebanon County Subtotal	**906**	**825**	**9.2%**

Table 1-1: Permanent Resident Population in the Three Mile Island EPZ

County Subdivision	Census 2000[a]	Census 2010[b]	Percent Change
York County			
Conewago township 5C, 10C	5,278	7,510	
Dover township (Part) 10C	1,598	1,467	
East Manchester township 10C	5,078	7,264	
Fairview township 5D, 10D	14,321	16,668	
Goldsboro borough 2B	939	952	
Hellam township (Part) 10C	942	978	
Lewisberry borough 10D	385	362	
Manchester borough 10C	2,350	2,763	
Manchester township (Part) 10C	10,787	15,825	
Mount Wolf borough 10C	1,373	1,393	
Newberry township 2B, 5C, 5D, 10C, 10D	14,332	15,285	
Springettsbury township (Part) 10C	369	340	
Warrington township (Part) 10C	1,098	1,052	
York Haven borough 5C	809	709	
York County Subtotal	**59,659**	**72,568**	**21.6%**
EPZ Total	**201,894**	**226,034**	**12.0%**

Sources: a) 2000 census data from 2003 ETE study report

b) 2010 census data (block level); matches PEMA estimate.

Table 1-2: Designated Reception Centers for Evacuation

Reception Center	Evacuating Townships and Municipalities
Cumberland County	
Big Spring High School, Newville	Lower Allen, New Cumberland
Dauphin County	
Faust Junior High School	Harrisburg City, Highspire Borough, Steelton Borough
Shippensburg University, Shippensburg	Lower Paxton, Paxtang Borough, Swatara
Williams Valley High School, Williamstown	Conewago, Hummelstown Borough, Londonderry, South Hanover
Lebanon County Career & Tech Center	Derry Township
Blue Mountain High School, Schuylkill Haven	Lower Swatara, Middletown Borough, Royalton Borough
Lancaster County	
Park City Mall, Lancaster	Conoy, East Donegal, Elizabethtown Borough, Mount Joy, West Donegal
Lebanon County	
Lebanon County Career & Tech Center	South Londonderry Township
York County	
Red Lion High School, Red Lion	East Manchester, Hellam, Mount Wolf Borough, Springettsbury
Susquehannock High School, Shrewsbury	Conewago, East Manchester, Manchester Borough, Manchester, Newberry, York Haven Borough
Gettysburg Junior/Senior High School, Gettysburg	Conewago, Dover, Manchester, Warrington, Newberry, Fairview, Goldsboro Borough, Lewisberry Borough

Source: *Three Mile Island Nuclear Station Evacuation Plan Map*, prepared by Pennsylvania Emergency Management Agency, revised February 2006

Table 1-3: ETE Comparison

ETE Element	2003 ETE	Current study
Permanent Residents - Total population - Vehicle occupancy (persons per vehicle)	 - 201,894 - 1.62 persons per vehicle	 - 226,034 - 2.23 persons per vehicle
Transit dependent - Population estimate - Number of buses - Number of ambulances	Evacuation of transit dependent population was not addressed in 2003 study	 - 3,400 - 120 bus trips - No ambulances
Transient facilities - Estimated population - Vehicle demand - Adjust for double-count	(winter day/summer weekend) - 33,280 / 37,058 - 26,822 / 19,646 - Adjustment for workers	(all scenarios) - 61,058/86,741 - 45.962/47,096 - Adjust for selected facilities
Special facilities - Estimated population - Number bus, van - Ambulance, other	(winter weekday) - 3,892 - 150 bus/van - Not identified	(winter weekday) - 11,364 - 148 buses - 275 non-ambulatory patients
Schools and daycare - Student population - Number of buses	(winter weekday) school/daycare - 37,071 / 7,151 (includes staff) - 775 buses	(winter weekday) - 36,481 / 4,403 - 774 buses, 210 vans
Background traffic	None	Average traffic by time of day
Shadow evacuation (assumed basis)	None	20% of resident population outside designated zones
Special event(s)	None	None
Scenarios	- Winter weekday - Winter weeknight - Summer weekend - Both normal and adverse weather for all three cases	- Weekday (winter, summer) - Weeknight (winter, summer) - Weekend (winter, summer) - Adverse weather weekday only - Staged evacuation (weekday)
Adverse weather	Snow for winter, rain for summer	Snow for winter, rain for summer
Evacuation model name and version	NetVac2	PTV Vision VISUM, VISSIM
Departure times	- Residential based on literature - Transient based on literature - Specials based on notification at alert	- Warning based on literature - Residential based on survey - Transient based on survey - Specials notified with public
Evacuation times	Estimates provided for 90 and 100%	Estimates provided for 90 and 100%

2. Methodology and Assumptions

2.1 Sources of Data and General Assumptions

The following data sources were reviewed and assumptions made in order to develop the appropriate population and roadway databases used for the evacuation analysis:

- Population estimates for permanent residents were developed from 2010 U.S. Census Bureau data. Independent estimates developed from 2010 census data were provided by PEMA.

- Estimates for seasonal residents were developed from 2010 United States Census Bureau data on housing units. Census data identify the number of seasonal housing units (vacant housing units for "seasonal or occasional use") at different geographic levels (e.g., by township, census tract, block group, block). Census data indicate an insignificant number of seasonal housing units in the EPZ for TMI. (Less than 0.7 percent.)

- Population estimates for major employers were developed from the ESRI BAO list and the facility list from the 2003 study report. ARCADIS conducted internet searches and telephone surveys to estimate facility employment and staffing levels for different scenarios. Only facilities with potential staffing level of at least 50 persons per work shift were pursued.

- Information relating to hotels, motels and recreational facilities was obtained from tourism websites, 2011 AAA TourBook listings, and the 2003 study report, with telephone surveys to verify data and to assess seasonal occupancy. For parks, visitation information was obtained from state park agencies.

- Current population estimates for schools were obtained primarily from county emergency response agencies, plus enrollment information available on the internet. Some private schools and colleges were contacted by phone, using facility lists provided by county emergency management agencies.

- Lists of hospitals, rest homes and incarceration facilities were obtained from each county emergency management agency.

- The staffing levels at TMI reflect estimated peak personnel onsite during outage conditions. These data were provided by Exelon Generation.

- Initial estimates of roadway characteristics were obtained from the NAVTEQ database. Roadway geometric and operational data were compiled based on field surveys performed by ARCADIS in 2011.

- Average traffic volumes by time of day for weekday and weekend for designated evacuation routes were obtained from state and county transportation agencies. These data were used to assign background traffic volumes for the roadway network. It was assumed that access control would be established within 2 hours following the public notice to evacuate.

- Preparation and mobilization times for the permanent resident population were developed based on the results of a telephone survey, combined with published time estimates for warning diffusion. The survey provided estimates of the time to depart from home following notification, and commuting times for household members who would return from work before departing. Median and 90 percent departure times for residents are longer than the times assumed in the previous study.

- Departure times for transient facilities were estimated assuming relatively prompt evacuation of most workplaces and recreational facilities once notification is received. The distribution of departure times also reflects information gathered from the telephone survey of EPZ residents, as discussed in Section 3. Median and 90 percent departure times for transient facilities are longer than the times assumed in the previous study.

- The evacuation time estimates represent the time required to evacuate the EPZ and designated analysis areas and include the time required for initial notification.

- Evacuation time estimates are presented for 90 percent and 100 percent of evacuating vehicles. It is assumed that all persons within the EPZ area will evacuate. For the 100 percent evacuation time, evacuation of the EPZ will be considered complete after all evacuating vehicles are outside of the EPZ or the designated evacuation area.

- The general public will evacuate using designated evacuation routes and will proceed to the reception centers listed in Table 1-2 after leaving the EPZ. When schools are in session, children attending school will be transported directly to designated Host Schools.

- It is assumed that existing lane utilization will prevail during the course of the evacuation. Traffic control signals will be over-ridden or converted to flashing mode as necessary to give preference to flow on all major outbound roadways. It is also assumed that State and municipal personnel will restrict unauthorized access into the EPZ, consistent with existing traffic management plans.

- The evacuation analysis cases are described in Section 2.3 and represent a range of conditions, per guidance presented in CR-7002. These cases have been chosen to provide information for an appropriate range of conditions (i.e., low, typical and high population; fair and adverse weather) to guide the protective action decision-making process.

- Vehicle occupancy rates used for the various population categories are as follows:

  - Permanent residents – 2.23 persons per vehicle, based on telephone survey results

  - Major places of employment – 1 vehicle per employee.

  - Hotels/Motels – 1 vehicle (1 to 2 persons) per occupied room.

  - Recreational areas – 1 vehicle (3 persons) per campsite; 1.5 persons per vehicle at the Hershey Arena/Stadium and at Giant Center, shopping centers, visitor centers and museums; 3 persons per vehicle at amusement parks.

  - Schools – 45 students and 3 staff per bus; one vehicle per additional staff person.

  - Hospitals/ Nursing Homes/ Correctional Facilities – 2 persons per ambulance/medical van for non-ambulatory patients and 20 people per bus or van for ambulatory residents.

- Vehicle demand for most shopping centers and at the Hershey Arena/Stadium and at Giant Center was adjusted to reduce double-counting, assuming that 50 percent of attendees (and staff) reside in the EPZ, and 50 percent of those would return home before evacuating.

- The transport-dependent population will be evacuated by bus or ambulance through efforts coordinated by state and municipal emergency preparedness officials.

- Adverse weather refers to moderate to heavy rainstorms for summer conditions, and a moderate snowstorm for winter conditions.

2.2 Interaction with Agencies

Emergency management agencies responsible for planning and implementing the emergency response procedures during a radiological emergency were consulted during the development of this ETE study. The Pennsylvania Emergency Management Agency (PEMA) and emergency agencies for Cumberland, Dauphin, Lancaster, Lebanon and York Counties were contacted to obtain information regarding special and transient facilities in the EPZ, transportation resources available to evacuate special facilities, and the transport dependent general public. Those agencies were also consulted to identify any major events that take place within the EPZ that should be considered for a Special Event scenario. PEMA provided their own estimates of residential population for the EPZ based on 2010 census data, and a map of designated evacuation routes and reception centers. PEMA and the county agencies reviewed the draft report and the facility databases used in this study.

Representative background traffic volumes for the EPZ roadway network were obtained from state and county transportation agencies.

2.3 Summary of Methodology for Traffic Simulation

The evacuation time estimates developed for the Three Mile Island EPZ are based upon a time distribution of evacuation events as opposed to a summation of sequential events. This methodology assumes that the various time components in an evacuation (i.e., the time associated with preparation, mobilization, etc.) overlap and occur within certain time ranges. The time distribution approach is based upon assumptions consistent with the NRC guidance of CR-7002.

Trip generation times are used to develop vehicle loading curves for different population types within the permanent, transient, and special facility populations. A trip generation time consists of two main components: warning diffusion time and mobilization time. Warning diffusion time is the time it takes for people to receive an emergency notification. The type of warning systems employed in the EPZ, such as

emergency alert system (EAS), sirens, and tone alert radios (TARs) affects the distribution of warning times. Availability of more warning systems leads to faster warning diffusion to the public.

Mobilization time is the time between the receipt of notification and when individuals leave for evacuation. Mobilization time depends on the type of population and activity. Warning diffusion time and mobilization time distributions are used to develop composite loading distribution or trip generation curves for different population segments. Trip generation times for transit dependent facilities, special facilities and schools were developed separately from those for the general public.

2.4 Conditions Modeled

Pursuant to the guidance in CR-7002 and NUREG-0654, Rev. 1, evacuation time estimates have been prepared for a range of temporal, seasonal and weather conditions. Estimates have been prepared for weekday, weeknight and weekend scenarios during winter and summer. All scenarios are simulated with fair weather conditions; weekday scenarios are also simulated assuming adverse weather. Fair weather refers to conditions where roadways are clear and dry, and visibility is not impaired. Adverse weather during summer periods is defined as heavy rain, with impaired visibility; roadway capacities are reduced by 10 percent and speeds are reduced by 15 percent. Adverse weather during winter periods is defined as a snowstorm condition where roadway capacities and speeds are reduced by 15 percent.

The various population components which have been incorporated in the evacuation scenarios are summarized below:

2.4.1 Week Day

This situation represents a typical weekday period with the work force is at a full daytime level. During winter, schools are in session. Vehicle demand estimates for weekday scenarios reflect the following conditions:

- Most permanent residents within the EPZ will evacuate from their places of residence;

- Major work places are fully staffed at typical daytime levels;

- TMI employment is at an estimated peak daytime level, representative of operation during outage conditions;
- Schools and daycares are at current enrollment;
- Hospitals and nursing homes are at current enrollment or typical occupancy, with staffing at weekday levels;
- Hotel/motel facilities are occupied at peak (winter or summer) levels; and
- Recreational facilities are at winter or summer weekday levels.

2.4.2 Week Night

This situation reflects a typical night period when most permanent residents are home and the work force is at evening shift level. Assumptions on the population levels for this condition include the following:

- Permanent residents within the EPZ will evacuate from their places of residence;
- Major work places are at typical evening levels;
- TMI employment is at an estimated peak night-time level;
- Day schools and daycares are closed;
- Hospitals and nursing homes are at current enrollment or typical occupancy, and staffing is at typical night-time levels;
- Hotel and motel facilities are occupied at (winter or summer) weekday levels; and
- Recreational facilities are at typical (winter or summer) evening levels.

2.4.3 Weekend

The weekend scenario represents a daytime period when most residents are at home and major work places are at typical weekend levels. Assumptions on the population levels for this condition include the following:

- Residents within the EPZ will evacuate from their places of residence;
- Major work places are at typical weekend levels;
- Day schools and daycares are closed;
- Hospitals and nursing homes are occupied and staffed at weekend levels;
- Hotel and motel facilities are occupied at weekend (winter or summer) levels; and
- Recreational facilities are at (winter or summer) weekend levels.

2.4.4 Special Event Consideration

Based on discussions with PEMA and county agencies, the "events" that draw the largest traffic volume and pose the greatest challenge for evacuation of the EPZ for TMI center around Hershey Park and the associated complex of entertainment venues. The estimated population and traffic demand for summer weekday and weekend scenarios represents the estimated peak attendance at these venues. A separate Special Event scenario was therefore judged not to be necessary for this study.

2.4.5 Sensitivity to Population Growth and Roadway Impact

Additional scenarios were evaluated to assess the sensitivity of ETEs to population growth and roadway impact. These sensitivity cases used the Summer Weekday, Normal Weather case for the Full EPZ as the base case. The population growth analysis is used to determine how rapidly the ETE would increase as the resident population in the EPZ is increased.

For the roadway impact scenario, a major evacuation route is removed or reduced in capacity. Specifically, one of the five highest volume roadways is removed from service, or capacity is reduced by one lane (for a multi-lane, limited-access roadway such as an interstate highway). A more detailed description of the sensitivity analysis is provided in Section 6.5.

3. Population and Vehicle Demand Estimation

The development of vehicle demand estimates for the Three Mile Island EPZ consisted of two primary steps. The first step was the determination of the number and distribution of the population to be evacuated. The second step was the determination of the appropriate number of vehicles for each of the population categories. Federal guidance (CR-7002) indicates that three population categories should be considered: permanent residents, transients, and persons in schools and special facilities (such as medical facilities/ nursing homes, and day care facilities).

The methodology used to develop the total population and vehicle demand estimates within the Three Mile Island EPZ incorporates intrinsic double counting. For example, a portion of the identified employees and visitors to recreational areas are also permanent residents within the EPZ. In addition, school children are counted in the resident population, but are also counted in the special facility population. While population and vehicle demand estimates incorporate some adjustments for double-counting, the estimates are considered to be conservative (i.e., they over-estimate actual population and vehicle levels which may be in the area at any given time). Population and vehicle demand estimates for each of the population categories are summarized below.

3.1 Permanent Residents

Permanent residents are those persons identified by the census as having a permanent residence within the EPZ. The Census 2010 population data for census tracts, block groups and blocks were used to determine the permanent resident population within the EPZ and within each municipality and Sub-Area. The allocation of the resident population to entry nodes on the roadway network was based on detailed census block maps.

An estimated 226,034 persons reside permanently within the Three Mile Island EPZ. Table 3-1 presents the resident population and vehicle demand by Sub-Area. The ten EPZ Sub-Areas are defined based on distance and direction from TMI; zone boundaries generally follow geographic (township and borough) boundaries and major highways. The 2-mile ring Sub-Areas 2A and 2B cover the regions within 2 miles of TMI east and west, respectively, of the Susquehanna River. Sub-Area 2A includes part of Londonderry Township in Dauphin County, where TMI is located, and part of Conoy Township in Lancaster County. Sub-Area 2B includes Goldsboro Borough and part of Newberry Township in York County. The 5-mile zones proceed clockwise

around the EPZ: Sub-Area 5A, north and northeast, is in Dauphin County; Sub-Area 5B (southeast) is in Lancaster County; Sub-Areas 5C (southwest) and 5D (northwest) are in York County. The 10-mile zones follow the same general sequence. A small part of South Londonderry Township in Lebanon County is included in 10A, while the southwest corner of Cumberland County is in 10D. The specific townships and boroughs which comprise each of the Sub-Areas are identified in Table 1-1.

Sub-Area 10A has the largest population (84,487), and Sub-Area 5A (22,202) has the largest population in the 5-mile ring.

A telephone survey of EPZ residents was conducted to obtain information relating to how many vehicles residents would use to evacuate and how long it would take them to depart following notification. The survey questionnaire and a summary of survey results are provided in Appendix B.

3.1.1 Auto-Owning Permanent Population

Vehicle demand associated with the permanent resident population was estimated based on telephone survey responses. After adjusting survey responses to reflect the actual age distribution of the EPZ, the vehicle occupancy factor is 2.23 persons per vehicle, which corresponds to roughly 1.35 vehicles per household. Total vehicle demand for EPZ residents is 101,360. "Shadow evacuation" of 20 percent of the population residing outside the EPZ within 15 miles of TMI adds vehicle demand of another 36,748 vehicles.

For the 2003 ETE study, evacuation times were determined assuming vehicle demand of 1.65 persons per vehicle for permanent residents.

3.1.2 Transport-Dependent Permanent Population

Emergency response plans specify that the transport-dependent population will receive transportation assistance. County Emergency Response Plans include provisions for providing this assistance, including bus routes with designated pickup points. Based on telephone survey results, between one and two percent of households (with phones) have either no vehicle or no licensed driver. NRC guidance (CR-7002) indicates that between 1.5 and 5 percent of residents may require transportation.

Individuals requiring transit from reception centers to congregate care centers will be transported in a separate set of vehicles from those designated to transport the transit dependent and special facilities out of the EPZ.

3.2 Seasonal Residents

The seasonal population category includes those who reside in the area on a temporary basis, particularly during the summer period. Seasonal residences are typically not insulated and are suitable for occupancy for only a portion of the year. These residences may include vacation homes and migrant workforce housing. The 2010 U.S. Census of Population and Housing reports the number of vacant households classified as "for seasonal or occasional use".

The number of seasonal housing units in the Three Mile Island EPZ is less than 600, or less than 0.7 percent of occupied housing units. Based on this low percentage and the lack of any area with a high density of seasonal housing, seasonal population estimates were not developed for this study.

3.3 Transient Population

The transient population segment includes persons in the work force, hotels/motels, and recreational areas. Regional maps and mapping software were used to determine facility locations and assign entry nodes. Significant employers within the EPZ were identified using ESRI Business Analyst Online (BAO). BAO is a web-based analytical and mapping tool that facilitates location-specific queries about business and demographic data. Data available on BAO includes information on business location and number of employees. ESRI extracts business data from a comprehensive list of businesses (over 12 million U.S. businesses) licensed from Infogroup. ARCADIS used BAO to search for all employers with 50 or more employees located within an 11-mile radius of TMI. CR-7002 recommends consideration of "large employers" with 50 or more employees on a single shift.

The list from BAO was screened to eliminate businesses where workers do not remain on-site (e.g., transportation and trucking companies, construction, realtors, home health care). Employment at schools and special facilities (e.g., hospitals, nursing homes) is generally tracked as part of the special facilities database. Similarly, grocery or retail establishments are tracked along with the "shopping" population at large commercial establishments (e.g., shopping malls). The reduced list was then reviewed to exclude facilities located outside the EPZ, and to determine the ERPA for those

located in the EPZ. The new list of employers was compared to the list from the 2003 study.

Telephone calls were made to selected large employers to verify employment numbers and to estimate staffing levels during weekday, weeknight and weekend periods. The results from those calls confirmed that BAO listings provided accurate locations and current, reliable employment numbers for most establishments. Workforce numbers for TMI were provided by Exelon Generation and reflect the peak work force during outage conditions.

Data for hotels, motels and recreational areas were obtained from the TripAdvisor website, the 2011 AAA TourBook for Pennsylvania, and from state and county tourism websites. Seasonal occupancy was estimated based on capacity figures (e.g., number of campsites) and a telephone survey of selected facilities. State and local parks agencies also provided visitation numbers for parks and campgrounds.

For purposes of estimating the total number of vehicles associated with the transient population segment, an occupancy factor of 1.0 employee per vehicle was used for most work places. For the hotel/motel and recreational populations, it was assumed that there would be 1.0 vehicle (1.5 or 2 persons) per hotel/motel unit and 1.0 vehicle (3 persons) per campsite. For parks, visitation numbers were generally obtained as numbers of vehicles, and an occupancy factor of 3.0 persons per vehicle was assumed. For Hershey Park, assumed occupancy was 2.5 persons per vehicle. For museums and visitor centers, 1.5 persons per vehicle was assumed. Campgrounds were assumed to be fully occupied during summer weekends, and 80 percent on summer weekdays. Hotels and motels were assumed to be fully occupied for all scenarios.

For shopping centers and sports arenas, vehicle demand was reduced to avoid double counting. It was assumed that at least 50 percent of attendees and staff are EPZ residents, and half of those would return home before evacuating. Vehicle demand for these facilities was therefore reduced by 25 percent. Estimates for sports arenas assumed a hockey game at Giant Center in Hershey for winter weeknight and winter weekend (attendance 10,500), a sports event at Hershey Arena/Stadium (attendance 12,000) for summer weeknight, and a music concert (attendance 16,000) for summer weekend. Estimated peak attendance at Hershey Amusement Park is 30,000 for winter weekend and for all summer scenarios, based on information provided by Dauphin County. All Hershey Park attendees were considered to come from outside the EPZ. .

Visitation at Harrisburg International Airport was estimated based on reported statistics on passenger volume for 2012, assuming that passenger traffic for peak weekday is 20 percent higher than the monthly average, and that up to 40 percent of daily passengers may be present at the same time. The estimated daytime work force at the airport is 200 staff.

Population data and vehicle demand estimates for the transient population segment, including the work force, hotels and motels, and recreational areas are presented by facility in Appendix A. Table 3-2 presents a summary of the transient population by Sub-Area for each scenario. A breakdown of population by distance and direction sectors was not developed for transient and special facilities, since state and county agencies rely on population by Sub-Areas for emergency response planning.

3.4 Special Facilities Population

The special facility population segment includes persons in schools, hospitals, nursing homes and correctional facilities who will require transportation assistance during an evacuation. The special facilities population is summarized in Table 3-3.

3.4.1 Medical, Nursing Care and Correctional Facilities

One hospital and nine nursing homes are located in the EPZ, as identified in Appendix A, plus three detention facilities. Nine of these facilities are located in Dauphin County, and four are in Lancaster County. Vehicle occupancy for hospital and nursing home patients is two non-ambulatory patients and one staff per ambulance, 20 residents or patients plus 3 staff per vehicle (bus or van) for ambulatory patients, plus one vehicle per staff person who does not evacuate with patients.

3.4.2 Schools and Day Care

Sixty four (64) school facilities have been identified within the Three Mile Island EPZ, with a total population of 37,740 students and 6,008 staff. Most of the schools typically have students present only on weekdays during the school year. The Milton Hershey School, Elizabethtown College and Penn State Harrisburg are residential. Penn State Harrisburg also has regular evening classes. Vehicle occupancy for public schools is based on 48 persons (45 students, 3 staff) per bus, plus one vehicle per additional school staff. Student enrollment for most schools was provided by the counties; any gaps were filled using state-published enrollment information or calls to individual schools.

Fifty four (54) licensed institutional daycare facilities were identified in the EPZ, with an estimated winter daytime population of 4,403 children and 607 staff. Pennsylvania facilities were identified from lists of day care establishments provided by the counties, and facility lists available via internet (childcarecenter.us). The winter day population estimates represent the licensed capacity of each facility; the estimated summer day population was 20 percent lower. For smaller day care facilities (up to 20 children), it was assumed that evacuation would be accomplished by private vehicles (staff). Larger facilities would evacuate via bus or van. Smaller home-based daycare facilities (capacity 10 or less) were not tabulated; those facilities contribute little vehicle demand beyond that assigned to EPZ residents.

Table 3-3 summarizes the special facility population by Sub-Area, for winter and summer weekday, weeknight and weekend periods. A detailed listing of the population and associated vehicle demand for all identified special facilities within the Three Mile Island EPZ is presented in Appendix A.

3.5 Emergency Response Planning Area Population Totals

Population and vehicle demand totals for each Sub-Area are summarized in Table 3-4. The totals listed in the table represent the peak number of people to be evacuated for each analysis case discussed in Section 6 of this report.

The largest population and vehicle demand in the Three Mile Island EPZ are located in Sub-Area 10A in Dauphin County for all cases. The differences in vehicle demand between scenarios are significant, reflecting the important role of employers and recreational facilities in the EPZ. Vehicle demand is highest for summer weekday (163,273) and lowest for winter night (135,786). The differences are largest in Sub-Area 10A, which includes the Hershey Amusement Park and also has the largest shopping centers in the EPZ. The vehicle demand listed in Tables 3-2, 3-3 and 3-4 reflects the data used as input for the ETE traffic simulations.

Table 3-1: Resident Population and Vehicle Demand by EPZ Sub-Area

Sub-Area	Distance	Permanent Resident Population	Vehicle Demand
2A	2 miles	1,570	704
2B	2 miles	3,968	1,779
5A	5 miles	22,202	9,956
5B	5 miles	6,023	2,701
5C	5 miles	6,412	2,875
5D	5 miles	6,989	3,134
10A	10 miles	84,487	37,887
10B	10 miles	29,595	13,271
10C	10 miles	40,843	18,315
10D	10 miles	23,945	10,738
EPZ total		**226,034**	**101,360**

Table 3-2: Transient Population and Vehicle Demand within the Three Mile Island EPZ

Sub-Area	Population						Vehicles					
	Winter			Summer			Winter			Summer		
	Day	Night	Weekend	Day	Night	Weekend	Day	Night	Weekend	Day	Night	Weekend
2A	684	124	105	720	160	150	672	112	83	690	130	105
2B	150	36	57	186	72	102	138	24	35	156	42	57
5A	2,229	1,227	2,367	2,509	1,437	2,697	1,820	953	1,688	1,994	1,087	1,894
5B	701	189	249	851	339	519	686	174	204	761	249	339
5C	546	52	52	546	52	52	546	52	52	546	52	52
5D	470	135	148	470	135	148	470	135	110	470	135	110
10A	44,631	47,406	68,161	62,554	64,659	77,193	29,948	26,466	35,887	38,898	34,835	41,157
10B	1,292	387	1,040	1,815	910	1,270	1,159	254	472	1,333	428	548
10C	5,692	1,345	2,155	6,855	2,452	2,897	5,360	935	1,205	5,735	1,280	1,435
10D	4,665	1,608	1,713	4,665	1,608	1,713	4,665	1,608	1,399	4,665	1,608	1,399
EPZ total	**61,058**	**52,509**	**76,047**	**81,169**	**71,824**	**86,741**	**45,962**	**31,213**	**41,135**	**55,246**	**39,846**	**47,096**

Table 3-3: Population and Vehicle Demand for Schools and Special Facilities in the Three Mile Island EPZ

Sub-Area	Population						Vehicles					
	Winter			Summer			Winter			Summer		
	Day	Night	Weekend	Day	Night	Weekend	Day	Night	Weekend	Day	Night	Weekend
2A	0	0	0	0	0	0	0	0	0	0	0	0
2B	0	0	0	0	0	0	0	0	0	0	0	0
5A	5,508	982	558	1,095	558	558	1,726	430	69	299	69	69
5B	3,016	2,040	2,040	2,740	2,040	2,040	64	13	13	53	13	13
5C	595	0	0	211	0	0	62	0	0	21	0	0
5D	660	0	0	0	0	0	38	0	0	0	0	0
10A	28,766	7,612	7,612	9,952	3,912	3,912	6,354	1,392	1,392	5,184	1,252	1,252
10B	7,610	2,063	2,063	515	263	263	1,560	999	785	132	35	35
10C	8,569	0	0	608	0	0	533	0	0	55	0	0
10D	5,514	0	0	407	0	0	404	0	0	40	0	0
EPZ total	**60,238**	**12,697**	**12,273**	**15,528**	**6,773**	**6,773**	**11,624**	**3,213**	**2,638**	**6,667**	**1,748**	**1,748**

Table 3-4: Summary of Population and Vehicle Demand within the Three Mile Island EPZ

Sub-Area	Population						Vehicles					
	Winter			Summer			Winter			Summer		
	Day	Night	Weekend	Day	Night	Weekend	Day	Night	Weekend	Day	Night	Weekend
2A	2,254	1,694	1,675	2,290	1,730	1,720	1,376	816	787	1,394	834	809
2B	4,118	4,004	4,025	4,154	4,040	4,070	1,917	1,803	1,814	1,935	1,821	1,836
5A	29,939	24,411	25,127	25,806	24,197	25,457	13,510	11,375	11,749	12,257	11,148	11,955
5B	9,740	8,252	8,312	9,614	8,402	8,582	3,451	2,888	2,918	3,515	2,963	3,053
5C	7,553	6,464	6,464	7,169	6,464	6,464	3,483	2,927	2,927	3,442	2,927	2,927
5D	8,119	7,124	7,137	7,459	7,124	7,137	3,642	3,269	3,244	3,604	3,269	3,244
10A	157,884	139,505	160,260	156,993	153,058	165,592	74,689	66,245	75,166	81,969	73,974	80,296
10B	38,497	32,045	32,698	31,925	30,768	31,128	15,990	14,524	14,528	14,736	13,734	13,854
10C	55,104	42,188	42,998	48,306	43,295	43,740	24,208	19,250	19,520	24,105	19,595	19,750
10D	34,124	25,553	25,658	29,017	25,553	25,658	15,807	12,346	12,137	15,443	12,346	12,137
EPZ total	**347,330**	**291,240**	**314,354**	**322,731**	**304,631**	**319,548**	**158,946**	**135,786**	**145,133**	**163,273**	**142,954**	**150,204**

* Population totals reflect double-counting between categories (residents, workforce, schools, etc.)

4. Evacuation Roadway Network

4.1 Network Definition

In order to estimate evacuation times for the Three Mile Island EPZ, an evaluation of the roadway network likely to be used by departing vehicles was undertaken. ARCADIS relied on several sources of information to define the evacuation roadway network:

- Evacuation routes described in the existing State emergency response plan;
- Maps of highways and local roadways for the EPZ area;
- A field survey of the roadways in the Three Mile Island EPZ.

The primary evacuation routings used in the modeling are indicated in Figure 4.1.

4.2 Evacuation Route Descriptions

The evacuation routings were developed to simulate travel out of the EPZ using available roadways. For the Pennsylvania portion of the EPZ, the network relies primarily on the evacuation routings depicted in the Three Mile Island Nuclear Station Evacuation Plan Map (PEMA, 2006). Descriptions of the primary evacuation routes for different geographic areas within the EPZ are outlined in Table 4-1.

4.3 Characterizing the Evacuation Network

Roadway characteristics such as roadway class, number of lanes, lane and shoulder width, speed limit, lane configuration near intersections, and traffic control are key factors in determining how fast an evacuation can be completed. These roadway attributes control roadway capacity, which in turn governs operating traffic conditions measured in terms of level-of-service (LOS). LOS is measured from A to F for roadway segments and intersections. LOS A represents free-flow conditions, and LOS F represents force or breakdown flow conditions.

ARCADIS used NAVTEQ™ roadway data with detailed information, including local streets, to build the evacuation roadway network for the study. NAVTEQ data was imported into geographic information system (GIS) software (ESRI ArcGIS™) for conducting field surveys to verify evacuation roadway segment attributes. The

information provided in the public information brochure for the site was used to highlight evacuation routes in GIS. ARCADIS has developed an integrated GIS-Global Positioning System (GPS) tool that allows field personnel to record observations in an efficient and effective manner. The evacuation network, including traffic controls, was verified to a 15-mile radius from the plant, and along designated routes to the receptions centers. Once the NAVTEQ data was verified through the field survey, the evacuation roadway network was transferred to the traffic simulation software VISUM for modeling different evacuation scenarios.

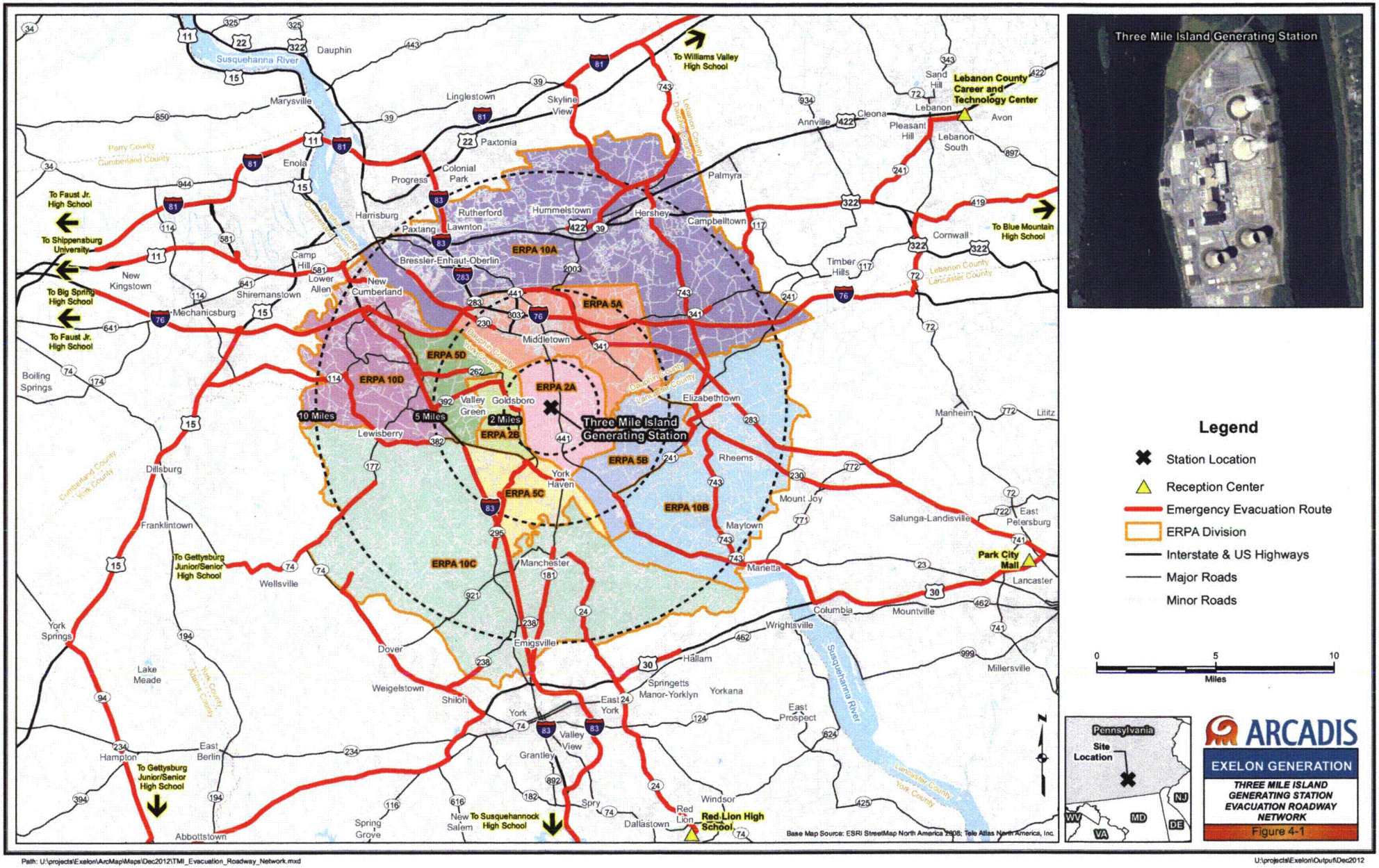
Having accurate traffic control information is important to accurately estimate evacuation times because intersections have potential to create bottleneck points. During an evacuation scenario, intersections might be manually controlled by officials, operated with existing traffic signal timing plans, or adjusted according to changing vehicular demand. In general, the emergency response plans for TMI call for signal override, i.e., signals set to flashing to give priority to outbound travel on designated evacuation routes. Traffic control information is coded as part of the evacuation network database.

Background and pass-through traffic in the EPZ could account for significant number of vehicles and could influence evacuation depending on the direction of travel. As recommended in CR-7002, average daily traffic (ADT) volumes, representative of typical background levels, were obtained from state and county transportation agencies. During the simulations, background traffic will be included during the initial 2-hours of the evacuation scenario, up to the time when access control is established to prevent vehicles from entering the EPZ.

A map of the evacuation network showing node numbers and links, as recommended by the latest guidance, is provided in Appendix C. Detailed attributes of each roadway segment, such as link number, number of lanes, speed limit, length, and roadway type are also tabulated in Appendix C.

Table 4-1: Three Mile Island EPZ Primary Evacuation Routes

Township or Municipality	Evacuation Routes
Cumberland County	
New Cumberland, Lower Allen	Rte 11 south
Dauphin County	
Hummelstown, Derry, South Hanover	Rte 39 north, Rte 743 north
Lower Swatara, Londonderry	Rte 283 southeast
Steelton, Highspire	Rte 283 to I-76 west
Royalton, Middletown	Local roads north to I-76 east
Swatara, Paxtang, Lower Paxton	I-83 north to I-81 south
Conewago Township	Rte 743 north or south to I-76 east
Lancaster County	
Mount Joy	Rte 283 southeast
Elizabethtown, West Donegal	Rte 743 south, Rte 230 southeast
Conoy, East Donegal	Rte 441 southeast
Lebanon County	
South Londonderry	Rte 322 east
York County	
York Haven, Newberry	Rte 295 south to I-83 south
Conewago, Manchester Township	I-83 south
Manchester Borough, East Manchester	Rte 181 south to I-83 south
Mount Wolf, East Manchester, Springettsbury, Hellam	Rte 24 south
Dover	Rte 74 south
Warrington	Rte 177 southwest
Newberry, Lewisberry, Fairview	Rte 382 northwest
Goldsboro, Newberry	Rte 392 west to I-83 north
Fairview	I-83 north to I-76 west



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5. Evacuation Time Estimate Methodology

5.1 Evacuation Analysis Cases

Time estimates have been prepared for a general evacuation scenario for each of these analysis cases:

- Winter Weekday, Fair Weather and Adverse Weather Conditions
- Winter Weeknight, Fair Weather Conditions
- Winter Weekend, Fair Weather Conditions
- Summer Weekday, Fair Weather and Adverse Weather Conditions
- Summer Weeknight, Fair Weather Conditions
- Summer Weekend, Fair Weather Conditions

Evacuation time estimates were developed for evacuation of the full EPZ, and for partial-EPZ evacuation cases based on distance and wind direction. These included evacuation of the following "keyhole" regions:

- 2-mile plus 5-mile, wind from South, SSW, SW: Sub-Areas 2A, 2B, 5A
- 2-mile plus 5-mile, wind from WSW, West: Sub-Areas 2A, 2B, 5A, 5B
- 2-mile plus 5-mile, wind from WNW, NW: Sub-Areas 2A, 2B, 5B
- 2-mile plus 5-mile, wind from NNW, N: Sub-Areas 2A, 2B, 5B, 5C
- 2-mile plus 5-mile, wind from NNE, NE, ENE: Sub-Areas 2A, 2B, 5C
- 2-mile plus 5-mile, wind from E: Sub-Areas 2A, 2B, 5C, 5D
- 2-mile plus 5-mile, wind from ESE: Sub-Areas 2A, 2B, 5D
- 2-mile plus 5-mile, wind from SE, SSE: Sub-Areas 2A, 2B, 5A, 5D
- 5-mile ring plus 10-mile, wind from SSE, S, SSW, SW: Sub-Areas 2 plus 5, 10A
- 5-mile ring plus 10-mile, wind from WSW: Sub-Areas 2 plus 5, 10A, 10B
- 5-mile ring plus 10-mile, wind from W, WNW: Sub-Areas 2 plus 5, 10B
- 5-mile ring plus 10-mile, wind from NW, NNW: Sub-Areas 2 plus 5, 10B, 10C

- 5-mile ring plus 10-mile, wind from N, NNE, NE, ENE: Sub-Areas 2 plus 5, 10C
- 5-mile ring plus 10-mile, wind from E : Sub-Areas 2 plus 5, 10C, 10D
- 5-mile ring plus 10-mile, wind from ESE: Sub-Areas 2 plus 5, 10D
- 5-mile ring plus 10-mile, wind from SE: Sub-Areas 2 plus 5, 10D, 10A

For all partial-EPZ evacuation cases, "shadow" vehicle demand (20 percent of residents) is assigned to all Sub-Areas which are not included in the evacuation region, in addition to the region outside of the EPZ.

For the evaluation of "staged evacuation" scenarios, the zones within 2 miles distance (Sub-Areas 2A and 2B), and all of the keyhole 2-mile plus downwind 5-mile zones were simulated.

5.2 Initial Notification

The EPZ surrounding TMI has an outdoor siren notification system consistent with the requirements of NUREG-0654, Rev. 1/FEMA-REP-1 Appendix 3. This system will be used by state and local officials to alert the population to turn on their radios and television sets. Pursuant to NUREG 0654, Rev. 1 guidance, notification messages will commence on the designated television and Emergency Alert System (EAS) radio stations concurrent with sounding of the sirens. Research has shown that a siren/EAS system will reach most of the population quickly, but it is expected to take 30 to 60 minutes for the last 10 to 20 percent of residents to receive an informational or instructional message, either because they do not hear the sirens or because they do not immediately understand what to do when the sirens sound. If evacuation is deemed necessary, the timing of the order to evacuate and notification measures will be controlled by the state and local emergency preparedness officials. Those officials may choose to alert and mobilize an emergency response work force to control and expedite evacuation prior to the evacuation order.

5.3 Transportation Dependent Population

The transportation dependent population includes individuals without access to transportation, as well as those requiring special transportation assistance. Transportation dependent persons will be notified of a protective action recommendation in the same manner as the general public. If evacuation is recommended, persons needing transportation assistance will be informed through the EAS to contact the appropriate officials for assistance. Evacuees who do not have

access to transportation and confined persons who require special transportation assistance will be provided transportation by the appropriate agency.

5.4 Evacuation Preparation Times and Departure Distributions

It is assumed that no vehicles will begin to evacuate during the 15-minute initial notification period. Accordingly, in the model simulations, vehicles will begin to evacuate at 15 minutes following the initial notification. After the initial 15-minute time period, vehicles are loaded at a linear rate over each 5-minute time interval, in accordance with the network loading distributions for each population type. For example, if 2 percent of 2500 vehicles (50 vehicles) are to be loaded at a specific location over a 5-minute period, PTV Vision will load 10 vehicles per minute at that location during the specified interval. Network loading distribution assumptions for the permanent population, transient population, and special facilities are based on the anticipated response of different population sectors to an evacuation order. Mobilization times for residents and workers reflect the data acquired by the telephone survey of EPZ residents, and are consistent with published data from actual historical events (ORNL, 1990). Loading distributions are explained below, and summarized in Figure 5-1.

5.4.1 Permanent and Seasonal Population

Permanent and seasonal residents with access to automobiles will take varying amounts of time to begin evacuating. Some persons will leave as quickly as possible; most will take some time to prepare, pack valuables and clothes and then depart; some will take added time to secure property before departing; and some may require transportation assistance. In addition, actual departure and preparation times may vary according to the perceived severity of a particular evacuation order.

Based upon these factors, it is estimated that permanent residents would begin to evacuate over a 3-hour period, taking into account warning diffusion, i.e., the time at which an instructional message is received, and the time for workers to return home before departing. Permanent resident households would begin to evacuate between 15 and 200 minutes after the decision to notify the population to evacuate is made. Roughly half of the resident population would begin to evacuate within 90 minutes following the evacuation decision, and 90 percent would depart between 90 and 130 minutes; the last 10 percent would depart between 130 and 200 minutes. The departure curve is shorter for nights and weekends, because many fewer residents would be returning from work. At night, all residents would depart within 125 minutes. These

time profiles reflect the distribution of journey-to-work travel times determined from the telephone survey of residents, and warning diffusion curves determined from observed behavior during evacuations for chemical releases.

5.4.2 Transient Population

It was assumed that the work force would also receive initial notification consistent with warning diffusion curves. It was also assumed that the majority of the work force would be released expeditiously (i.e., within 15 minutes subsequent to notification), with a smaller number remaining to secure businesses and/or shut down active operations. The departure time profile following notification is based on telephone survey responses. The first 45 percent of workers will depart between 15 and 40 minutes, and another 45 percent will depart within 70 minutes; the final 10 percent will depart between 70 and 125 minutes. For a few facilities, it may be necessary for a limited number of workers to remain on the job in order to safely shut down processes, secure the facility or maintain essential operations. The evacuation time estimates do not address those workers who remain behind, since there is no reliable basis for predicting whether or how soon they will evacuate. The assumption that all workers evacuate provides a conservative estimate of vehicle demand. Previous discussions with emergency preparedness officials indicated that the same time distribution is also reasonable for the other transient population categories within the EPZ, including shopping malls, hotels, motels and recreation areas.

5.4.3 Special Facilities

It was assumed that special facilities (i.e., schools, nursing homes) within the EPZ would all receive initial notification promptly, via direct phone calls from the county agencies. Based upon data obtained from previous studies, vehicle departure times were developed that reflect a distribution of notification, preparation and mobilization times.

Consistent with the current off-site emergency response plans, it was assumed that schools will be evacuated via bus to the designated host schools. For school facilities, it was assumed that up to 2.5 hours may be required to assemble buses and drivers, transport vehicles to schools and to load students onto buses. Vehicles stationed at the facilities at the time of the ordered evacuation could be loaded in as little as 15 minutes following notification. Accordingly, school buses were loaded onto the evacuation network from the period between 15 and 175 minutes following the decision to evacuate. The school time profile was also applied for daycare facilities.

Evacuation of nursing home facilities would also require additional time associated with preparation and transport of vehicles to the respective facilities. Based upon previous studies, it was assumed that these facilities would begin to evacuate between 15 minutes and 3 hours following notification. The first 25 percent will depart between 15 and 60 minutes after the decision to evacuate; another 50 percent between 60 and 105 minutes; and the last 25 percent between 105 and 190 minutes, reflecting the longer times required for the population needing greater assistance or supervision.

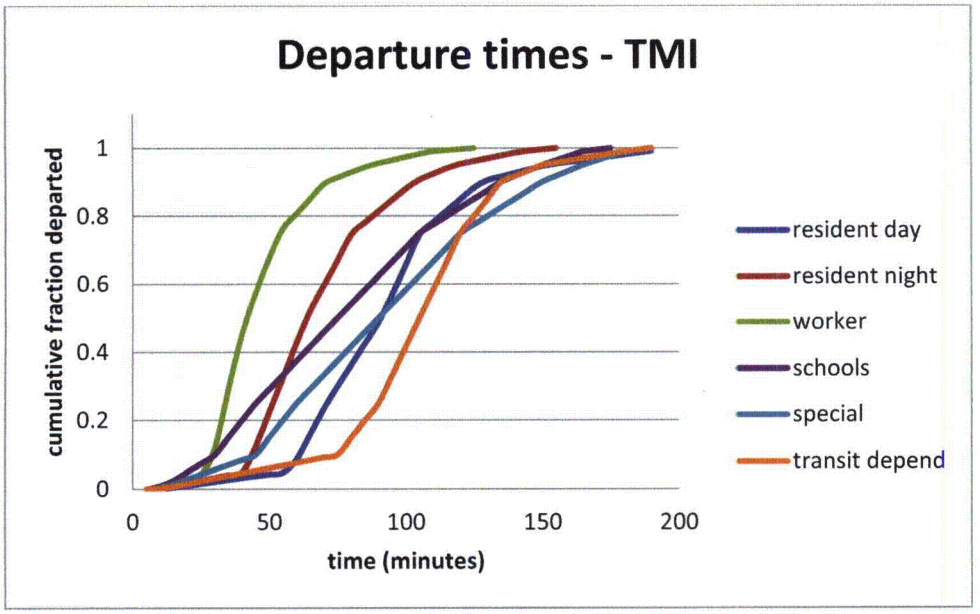

Figure 5-1. Departure Time Distributions for the EPZ for Three Mile Island

5.5 Evacuation Simulation

Traffic simulation provides the ability to analyze evacuation of an area in great detail. In most traffic simulation models, there are two main inputs: supply (roadway) network data and demand (population and vehicular) data. Traffic models use different types of algorithms to predict traffic flow and provide measures of effectiveness (MOEs) such as average travel times, total number of vehicles exiting the system, and queue lengths at various times and points.

5.5.1 General Structure

ARCADIS used PTV Vision to perform evacuation modeling for different scenarios. The PTV Vision traffic simulation software package includes VISSIM (microscopic traffic simulation) and VISUM (macroscopic traffic simulation). VISUM is a comprehensive, flexible software system for transportation planning, travel demand modeling, and network data management. VISSIM is capable of performing detailed microscopic simulation of traffic, public transport, and pedestrian simulations, and can model any type of traffic control and geometric configuration. Both VISUM and VISSIM are capable of performing multi-modal analysis including car, commercial vehicle, bus, train, motorcycles, bicycles, and pedestrians. The two programs work together seamlessly, saving valuable time and resources.

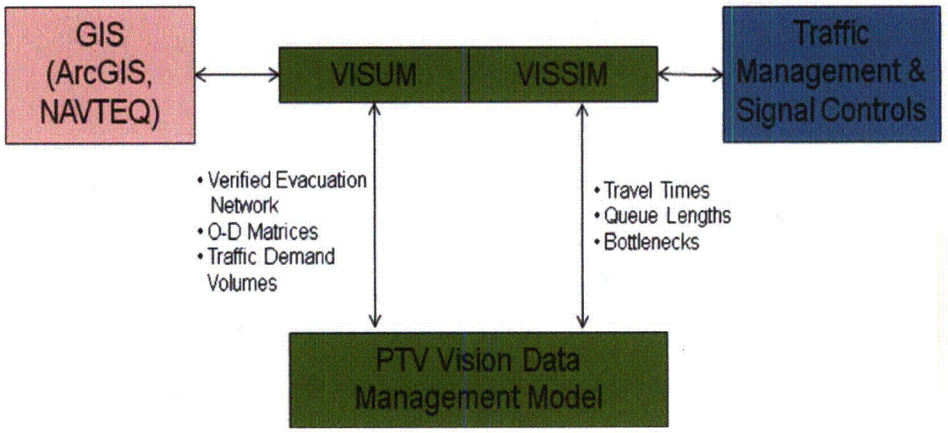

Figure 5-2. Evacuation Modeling and Simulation using PTV Vision Suite

VISUM was used to develop the evacuation network and population entry nodes (centroids). One of the key features of VISUM is its ability to interact seamlessly with GIS-data such as ESRI ArcGIS database. The field verified evacuation network data and demand data developed in ArcGIS were imported directly into VISUM. Origin-Destination trip tables were developed for the evacuation and imported into VISUM. VISUM software was then used to route the Origin-Destination information on the network using a dynamic equilibrium algorithm. This algorithm ensured that traffic levels on the network were realistic given the capacities available on individual links. Once an initial solution was found in VISUM, the information was exported into VISSIM for microsimulation. A microsimulation was deemed a necessary step in order to obtain detailed and realistic results on queuing and average travel times. VISSIM can model intersection with different type of traffic control such as yield signs, stop signs, and signals. VISSIM also provides a better understating of critical and congested part of the network.

5.5.2 Simulation Process

The ETE results include the time to evacuate 90 percent and 100 percent of the total permanent and transient population. Based on the current guidance, ETEs for special facilities, schools, and the transit dependent population are developed separately; only the time to evacuate 100 percent of these population groups was needed.

Consistent with current guidance, vehicle demand for each scenario was based on 100 percent of the population residing in areas designated for evacuation, plus 20 percent of the population residing in Sub-Areas outside the designated evacuation area, and 20 percent of the population residing outside of the EPZ, out to a distance of 15 miles. Vehicle demand outside of the designated evacuation area is intended to account for the impact of "shadow evacuees". A sensitivity analysis was performed to evaluate the impact of changes different input parameters and assumptions such as changes in lane closures, trip generation times, vehicular demand, evacuation routes, and background traffic.

The simulation process can be summarized as follows:

VISUM

1. Create every scenario based on
    a. Background traffic
    b. Time of day

c. Day of week

d. Weather condition

e. Season

f. Wind Direction

g. Shadow traffic

2. Run Dynamic Traffic Assign to and calculate Permanent and Transient, Shadow, Special Needs/Schools volumes
3. Assignment process will last until suitable convergence is reached. VISUM provides output on the goodness of convergence after assignment. The convergence fit is not as critical because this is an evacuation model of a no-notice event, therefore full user equilibrium cannot be expected.
4. Export to VISSIM.

VISSIM

1. Warm-up time built into background/pass-through traffic generation.
2. Check for any local calibration parameters.
3. Run the final multimodal Dynamic Traffic Assignment in VISSIM to consider queues and intersection delays
4. Sensitivity analysis and count evacuees at 2, 5, and 10 miles
5. Prepare ETE times

MOEs

1. 90 percent evacuation time (for all wind directions and scenarios, staged and normal evacuations)

    a. This applies to evacuation of the PUBLIC only

2. 100 percent evacuation time (for all wind directions and scenarios, stage and normal evacuations)
3. Color-coded roadway map at various times (2, 4, 6 hrs) which identifies where long queues exist, including LOS E and F conditions.

6. Analysis of Evacuation Times

6.1 Evacuation Time Estimate Summary

Predicted ETEs for the general population in the EPZ are summarized by scenario in Table 6-1 for the full EPZ and for zones within 2 miles and 5 miles. The pattern of evacuation times is consistent with the differences in vehicle demand and travel time for different scenarios. The 2-mile zone involves the shortest travel distance and the fewest vehicles; 90 percent ETEs for the 2-mile zone are 2:40 to 4:10, and 100 percent ETEs are 3:05 to 4:40.

For the 2-mile plus all 5-mile zones, the 90 percent ETEs are 3:50 to 5:25, and the 100 percent ETEs are 4:05 to 5:50. For the full EPZ, the 90 percent ETEs are 7:45 to 12:10, while the 100 percent ETEs are 8:30 to 13:15.

6.2 Comparison with Previous Study

The 90 percent ETEs for the current study are somewhat shorter than the corresponding times from the 2003 study. The 100 percent ETEs are roughly the same as 2003 estimates. Vehicle demand for the current study (158,946 for Winter Weekday) is 13 percent higher than the winter day vehicle demand from 2003 (140,581). The shorter 90 percent ETEs are predicted despite the addition of background traffic and despite longer departure times (based on the survey of residents).

6.3 All Conditions

ETEs for all of the keyhole zone scenarios (2-mile plus downwind 5-mile zones; all 5-mile plus downwind 10-mile zones) are summarized in Table 6-2. Very small differences are predicted for different wind directions, and small differences are predicted based on season, time of day, and weekday versus weekend. ETEs are much longer for the full EPZ or for selected 10-mile zones, compared to scenarios that only include zones to 5 miles. Adverse weather adds 2 hours or more to 10-mile ETEs. These results reflect the high population and vehicle demand in outer zones. The long times for evacuating the full EPZ indicate that major traffic congestion occurs in the outer zones.

6.4 Staged Evacuation Scenarios

A series of staged evacuation scenarios were evaluated based on NRC guidance (CR-7002). In a staged evacuation, the 2-mile zone evacuates first, while surrounding

zones shelter in place; after the population has evacuated the 2-mile zone, the outer zones would be instructed to evacuate. The "stage 1" time is determined by simulating evacuation of the 2-mile zone for the Winter Weekday, Normal Weather scenario, with only background and shadow traffic in other parts of the EPZ. Once the Stage 1 time (3:20) was determined, a revised set of departure curves was developed for the outer (Stage 2) zones. The Stage 2 departure curves for TMI are shown in Figure 6-1. The departure curves are much steeper at the beginning of Stage 2, because people are able to return home and prepare to depart during Stage 1. Similarly, the transportation resources needed to evacuate schools and special facilities will gather on-site in preparation for evacuation.

Results for staged evacuation scenarios are summarized in Table 6-3. The 90 percent and 100 percent ETEs for the staged scenarios are 5 to 10 minutes longer than the times for corresponding "unstaged" ETEs. The modeled results indicate that staged evacuation for TMI would result in little or no benefit, in terms of the time required to evacuate the 2-mile zone, and a very small penalty, in terms of increased ETEs for the zones which would initially be ordered to shelter.

6.5 Sensitivity to Population Growth and Roadway Impact

6.5.1 Population Growth

NRC guidance (CR-7002) for updating ETE studies more frequently than the 10-year federal census includes criteria based on population growth. Specifically, if the residential population growth in the EPZ since the last ETE update is sufficient to cause an increase in the ETE by 25 percent or by 30 minutes, whichever is less, then a full ETE update study must be performed.

A sensitivity analysis was performed by determining the 90 percent ETEs for increases of 5, 10, 15 and 20 percent of the EPZ residential population for the Winter Weekday, Normal Weather scenario. This scenario produced the longest ETE by season or time of day. The population was increased in the same manner in the surrounding region, out to 15 miles. Results are illustrated in Figure 6-2. With a 15 percent increase in residential population above the 2010 census values, the 90 percent ETE for the full EPZ increased to 10:08, an increase of 23 minutes. With a 20 percent increase in population, the 90 percent ETE increased to 10:17, an increase of 32 minutes. These results demonstrate that a population increase of more than 15 percent above the 2010 census values would be required to cause the ETE to increase by 30 minutes. (Linear extrapolation indicates that a population increase of 19 percent would produce an ETE increase of approximately 30 minutes.) Since the EPZ residential population

for TMI changed by about 12 percent between 2000 and 2010, it appears unlikely that an increase of 19 percent will occur before 2020.

The 100 percent ETEs increased more rapidly than the 90 percent ETEs, consistent with the general pattern of all ETE results. With a 15 percent increase in population, the 100 percent ETE for the full EPZ increased by 30 minutes, from 10:35 to 11:05. NRC guidance (CR-7002) indicates that emergency planning decisions should be based on the 90 percent ETEs. The recommended "update threshold" for the TMI EPZ, based on population growth, is therefore 15 percent.

6.5.2 Roadway Impact

NRC guidance (CR-7002) also requires analysis of a "roadway impact" scenario. For this scenario, a major evacuation route is removed or reduced in capacity. Specifically, one of the 5 highest volume roadways is removed from service, or capacity is reduced by one lane (for a multi-lane, limited-access roadway such as an interstate highway). This scenario is specified as Summer Weekday, Normal Weather for the Full EPZ. For Three Mile Island, the five highest-volume roadways for this scenario are listed below:

- US 322 EB – 22,462 vehicles
- US 322/I-83 NB – 22,207 vehicles
- I-83 SB (York) – 16,310 vehicles
- I-76 WB Green Lane – 9,379 vehicles
- SR 283 E – 9,291 vehicles

Predicted traffic volumes by link for the "base case" simulation with the full roadway network are shown in Figure 6-3.

One lane of one of the highest-volume roadways, US 322/I-83 NB just north of Union Deposit Rd, was removed for the roadway impact scenario. The impact location is shown in Figure 6-4. With this lane unavailable, the ETEs increased from 9:15 (90 percent) and 10:05 (100 percent) to 9:40 (90 percent) and 10:10 (100 percent). The traffic flow by link for the roadway impact scenario is shown in Figure 6-4. With one lane unavailable, traffic flow will not change on any other link since evacuees are not supposed to reroute to other roads.

6.6 Performance Metrics for Simulation Model

The performance of VISSIM is assessed using standard metrics, consistent with the guidance provided in CR-7002. Table 6-5 provides a summary of simulation parameters for Winter Day Normal Weather scenario for the full EPZ. Figure 6-5 illustrates the number of vehicles on the network over the course of the simulation, while Figure 6-6 compares the rate of vehicles loading onto the network to the frequency of departures. Both Figure 6-5 and Figure 6-6 illustrate the consequences of traffic congestion, as the rate of vehicles entering the road network is more rapid than the rate at which vehicles exit from the EPZ.

6.7 ETE for Transit Dependent Special Facilities and Schools

The ETE for transit dependent members of the general public is estimated based on the assumption of two sequential set of bus runs from most of the Dauphin County quadrant of the EPZ. The first run would begin 90 minutes after the evacuation notice, allowing time for evacuees to prepare and to travel to designated pickup points. The time sequence would then proceed in the following steps:

- 30 minutes for the bus to traverse up to ten pickup points (2 miles) and load passengers (2:00)
- 40 minutes to travel out to reception center (8 miles @ 12 mph), 10 minutes to unload, 10 minutes to return (3:00)
- Repeat pickup (30 min) and travel out of EPZ (20 min). TOTAL = 3:50

Estimated evacuation times for special facilities, schools and daycares located in the EPZ are summarized in Tables 6-5 and 6-6. These times are shorter than the 90 percent and 100 percent ETEs for the general population. Facility-specific estimates are based on a three-step time sequence: (1) mobilization, (2) loading, and (3) travel out of the EPZ. Mobilization and loading times are generally the largest components. At nursing homes and assisted living facilities, each vehicle will require about 10 minutes to load, with two vehicles loading simultaneously. While some school buses may mobilize more quickly depending on specific local circumstances, it will generally require on the order of 120 minutes to contact drivers, provide them with instructions and deploy them to assigned schools. For travel time, average speeds were estimated for the anticipated evacuation route, based on the traffic simulation for the Winter Day scenario. The simplified stepwise methodology used to determine these estimates provides a typical evacuation time, rather than an upper bound 100 percent value.

Table 6-1: Evacuation Time Estimate Summary for Three Mile Island General Population

		Summer				Winter			
		Midweek Daytime		Weekend Daytime	Evening	Midweek Daytime		Weekend Daytime	Evening
Affected ERPAs	Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Weather:	Normal	Adverse	Normal	Normal	Normal	Adverse	Normal	Normal
90 Percent Evacuation of Affected Areas									
2A,2B	2-mile Zone	3:20	3:50	2:40	2:40	3:20	4:10	2:40	2:40
2A,2B,5A,5B,5C,5D	5-mile Zone	4:10	4:50	3:50	3:50	4:20	5:25	3:55	3:55
ALL	10-mile EPZ	9:55	11:35	8:30	815	10:25	13:00	8:30	8:05
2A,2B	2-mile Zone	3:45	4:15	3:05	3:05	3:45	4:40	3:05	3:05
2A,2B,5A,5B,5C,5D	5-mile Zone	4:40	5:25	4:10	4:05	4:40	5:50	4:10	4:10
ALL	10-mile EPZ	10:50	12:30	9:15	9:00	11:25	14:20	9:15	8:50

Table 6-2: Evacuation Times for General Population for Keyhole Zones

(a) 2-mile zones plus 5-mile downwind zones

100 Percent Evacuation of Affected Areas									
		Summer				Winter			
		Midweek Daytime		Weekend Daytime	Evening	Midweek Daytime		Weekend Daytime	Evening
Affected ERPAs	Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Weather:	Normal	Adverse	Normal	Normal	Normal	Adverse	Normal	Normal
90 Percent Evacuation Times									
2A,2B,5B,5C	N,NW,NNW	4:05	4:45	3:25	3:25	4:05	5:05	3:25	3:25
2A,2B,5C	NNE	4:05	4:40	3:20	3:20	4:05	5:05	3:25	3:20
2A,2B,5C,5D	NE,ENE	4:05	4:40	3:50	3:50	4:20	5:25	3:55	3:55
2A,2B,5D	E	4:05	4:40	3:50	3:50	4:20	5:25	3:55	3:55
2A,2B,5A,5D	ESE,SE	4:05	4:40	3:50	3:50	4:20	5:25	3:55	3:55
2A,2B,5A	SSE,S,SSW,SW	4:10	4:50	3:50	3:50	4:20	5:25	3:55	3:55
2A,2B,5A,5B	WSW,W	4:10	4:50	3:50	3:50	4:20	5:25	3:55	3:55
2A,2B,5B	WNW	4:05	4:40	3:25	3:30	4:10	5:10	3:30	3:25
100 Percent Evacuation Times									
2A,2B,5B,5C	N,NW,NNW	4:40	5:25	3:50	3:55	4:40	5:50	3:55	3:50
2A,2B,5C	NNE	4:20	5:00	3:50	3:55	4:40	5:50	3:55	3:50
2A,2B,5C,5D	NE,ENE	4:20	5:00	4:10	4:05	4:35	5:45	4:10	4:10
2A,2B,5D	E	4:20	5:00	4:10	4:05	4:35	5:45	4:10	4:10
2A,2B,5A,5D	ESE,SE	4:40	5:25	4:10	4:05	4:35	5:45	4:10	4:10
2A,2B,5A	SSE,S,SSW,SW	4:40	5:25	4:10	4:05	4:40	5:50	4:10	4:10
2A,2B,5A,5B	WSW,W	4:40	5:25	4:10	4:05	4:40	5:50	4:10	4:10
2A,2B,5B	WNW	4:40	5:25	3:50	3:55	4:40	5:50	3:55	3:50

(b) 5-mile zones plus 10-mile downwind zones

100 Percent Evacuation of Affected Areas									
		Summer				Winter			
		Midweek Daytime		Weekend Daytime	Evening	Midweek Daytime		Weekend Daytime	Evening
Affected 10-mile ERPAs	Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Weather:	Normal	Adverse	Normal	Normal	Normal	Adverse	Normal	Normal
90 Percent Evacuation Times									
10C	N,NNE,NE	4:55	5:40	4:10	4:05	5:15	6:30	4:20	4:20
10C,10D	ENE,E	6:50	7:55	6:00	6:00	7:00	8:45	6:00	6:00
10A,10D	ESE,SE	9:55	11:35	8:30	815	10:25	13:00	8:30	8:05
10A	SSE,S,SSW	9:55	11:35	8:30	815	10:25	13:00	8:30	8:05
10A,10B	SW,WSW,W	9:55	11:35	8:30	815	10:25	13:00	8:30	8:05
10B	WNW	4:55	5:40	4:05	4:05	5:15	6:30	4:20	4:20
10B,10C	NW,NNW	4:55	5:40	4:10	4:05	5:15	6:30	4:20	4:20
100 Percent Evacuation Times									
10C	N,NNE,NE	5:30	6:15	4:35	4:30	5:45	7:15	4:45	4:50
10C,10D	ENE,E	8:35	9:50	7:15	7:20	8:50	11:00	7:10	7:20
10A,10D	ESE,SE	10:50	12:30	9:15	9:00	11:25	14:20	9:15	8:50
10A	SSE,S,SSW	10:50	12:30	9:15	9:00	11:25	14:20	9:15	8:50
10A,10B	SW,WSW,W	10:50	12:30	9:15	9:00	11:25	14:20	9:15	8:50
10B	WNW	5:30	6:15	4:35	4:30	5:45	7:15	4:45	4:50
10B,10C	NW,NNW	5:30	6:15	4:35	4:30	5:45	7:15	4:45	4:50

Table 6-3: Results for Staged Evacuation for 5-Mile Downwind Zones (Stage 1 ends at 3 hour 20 minutes)

		Summer				Winter			
		Midweek Daytime		Weekend Daytime	Evening	Midweek Daytime		Weekend Daytime	Evening
Affected ERPAs	Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Weather:	Normal	Adverse	Normal	Normal	Normal	Adverse	Normal	Normal
90 Percent Evacuation of Affected Areas									
2A,2B,5B,5C	N,NW,NNW	4:15	4:55	3:35	3:35	4:15	5:15	3:35	3:30
2A,2B,5C	NNE	4:15	4:50	3:25	3:25	4:15	5:15	3:35	3:25
2A,2B,5C,5D	NE,ENE	4:15	4:50	4:00	4:00	4:30	5:35	4:00	4:00
2A,2B,5D	E	4:15	4:50	4:00	4:00	4:30	5:35	4:05	4:05
2A,2B,5A,5D	ESE,SE	4:15	4:50	4:00	3:55	4:30	5:35	4:05	4:05
2A,2B,5A	SSE,S,SSW,SW	4:20	5:00	4:00	3:55	4:30	5:35	4:05	4:05
2A,2B,5A,5B	WSW,W	4:20	5:00	4:00	3:55	4:30	5:35	4:05	4:05
2A,2B,5B	WNW	4:15	4:50	3:35	3:35	4:15	5:20	3:35	3:35
100 Percent Evacuation of Affected Areas									
2A,2B,5B,5C	N,NW,NNW	4:50	5:35	4:00	4:00	4:50	6:00	4:00	4:00
2A,2B,5C	NNE	4:30	5:10	4:00	4:00	4:50	6:00	4:00	4:00
2A,2B,5C,5D	NE,ENE	4:30	5:10	4:15	4:15	4:45	5:55	4:15	4:15
2A,2B,5D	E	4:30	5:10	4:15	4:15	4:45	5:55	4:15	4:15
2A,2B,5A,5D	ESE,SE	4:50	5:35	4:15	4:15	4:45	5:55	4:15	4:15
2A,2B,5A	SSE,S,SSW,SW	4:50	5:35	4:15	4:15	4:50	6:00	4:15	4:15
2A,2B,5A,5B	WSW,W	4:50	5:35	4:15	4:15	4:50	6:00	4:15	4:15
2A,2B,5B	WNW	4:50	5:35	4:00	4:00	4:50	6:00	4:00	4:00

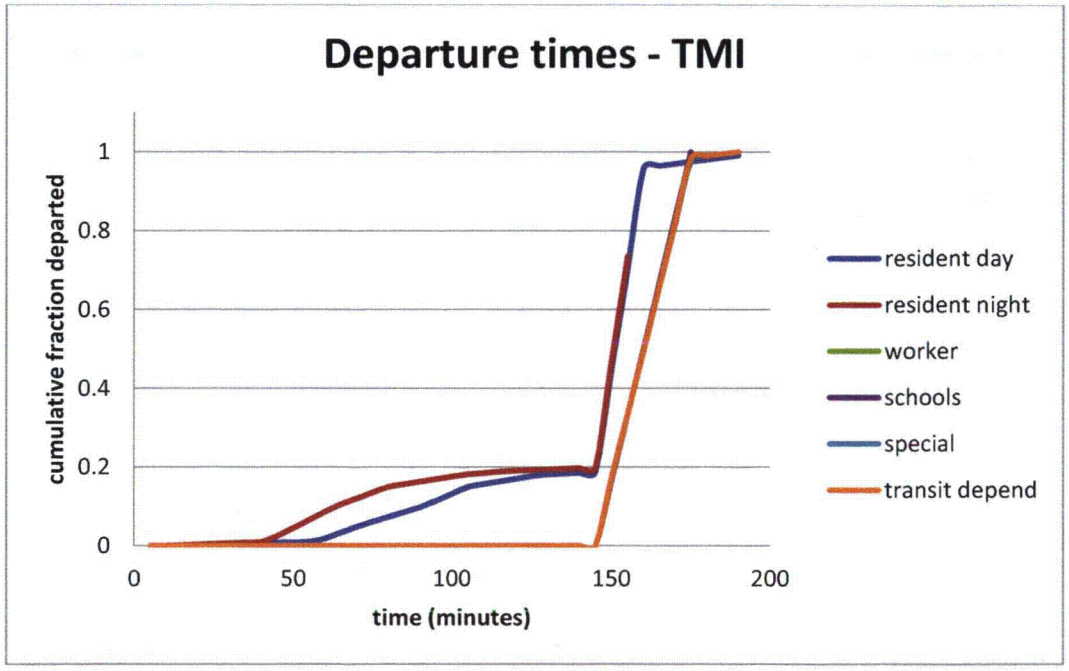

Figure 6-1. Departure Curves for Stage 2 Zones, Three Mile Island

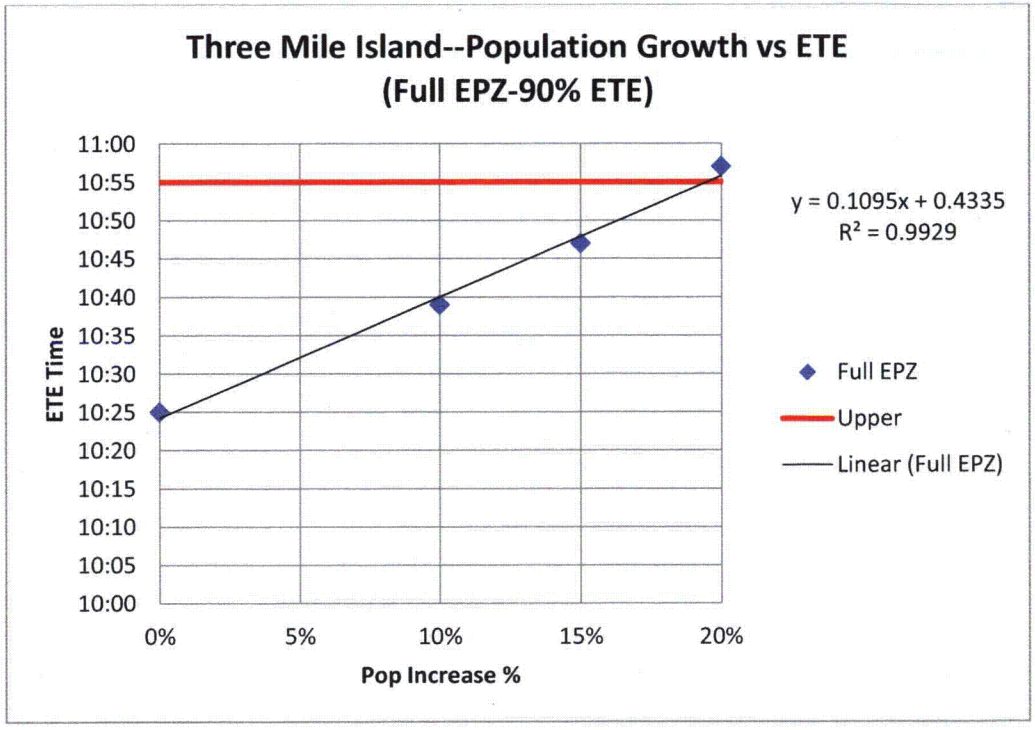

Figure 6-2. TMI Sensitivity of ETE to Growth of Residential Population (Winter Weekday, Normal Weather, Full EPZ)

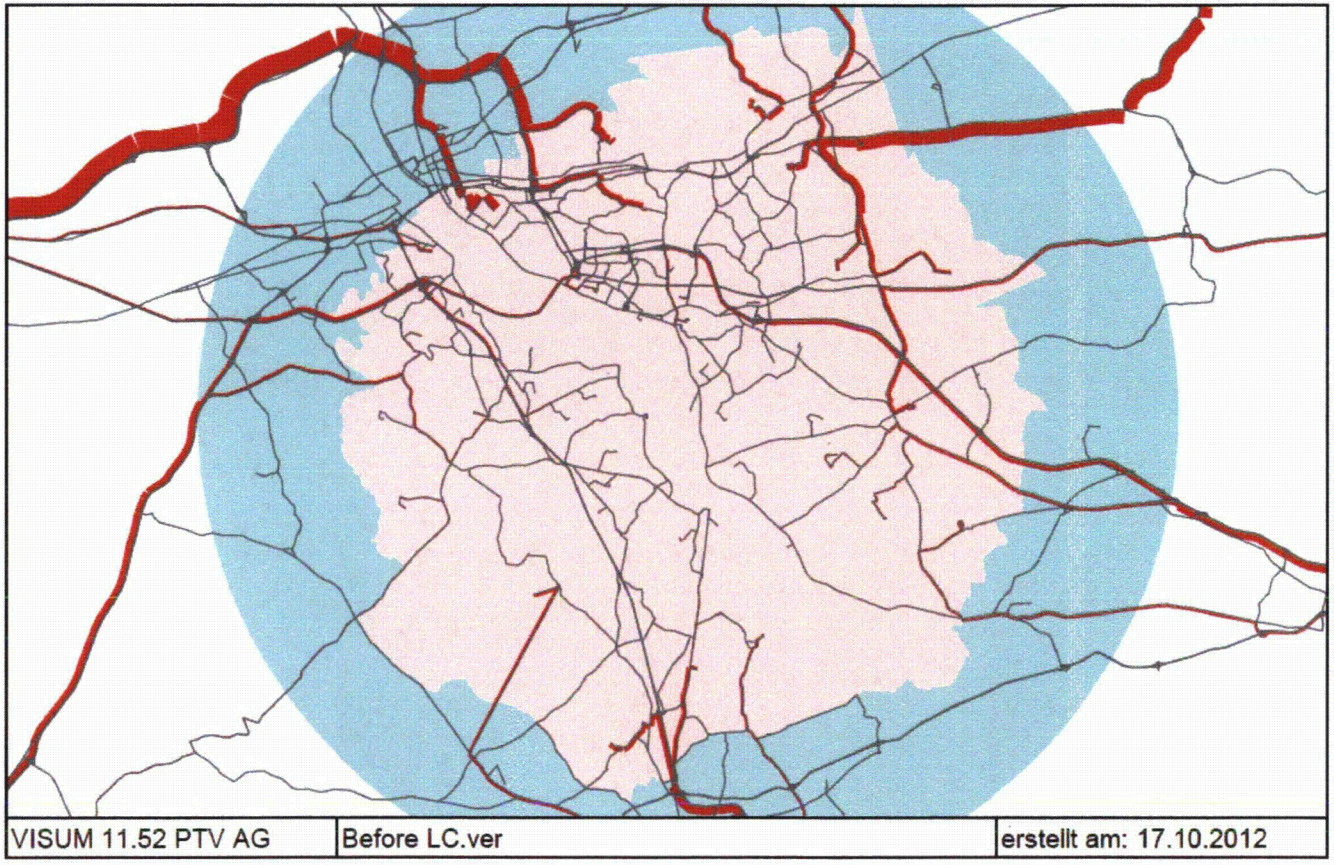

Figure 6-3. TMI Predicted Traffic Volume by Link with Full Network (Summer Weekday, Normal Weather, Full EPZ)

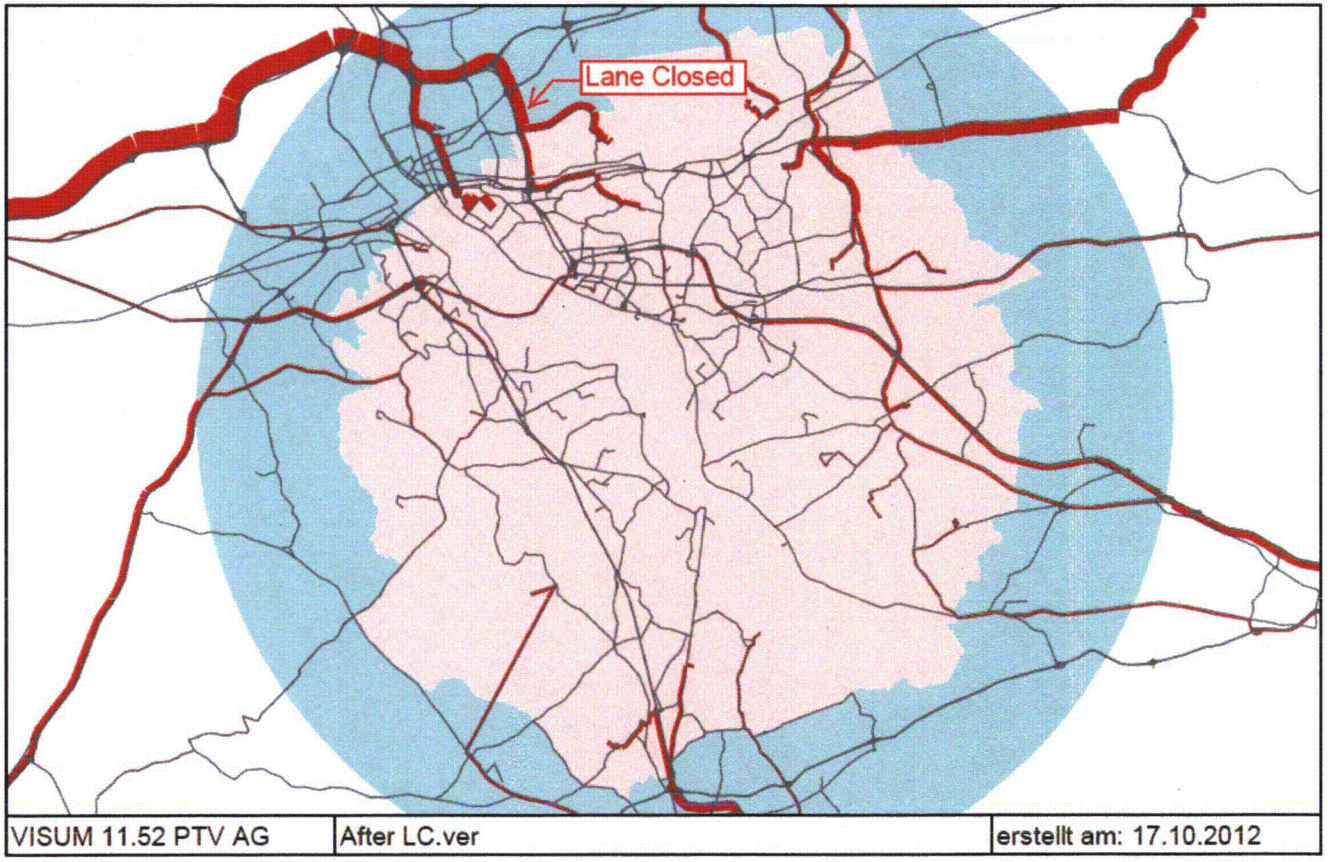

Figure 6-4. TMI Predicted Traffic Volume by Link with US 322/I-83 NB just north of Union Deposit Rd Link Removed (Summer Weekday, Normal Weather, Full EPZ)

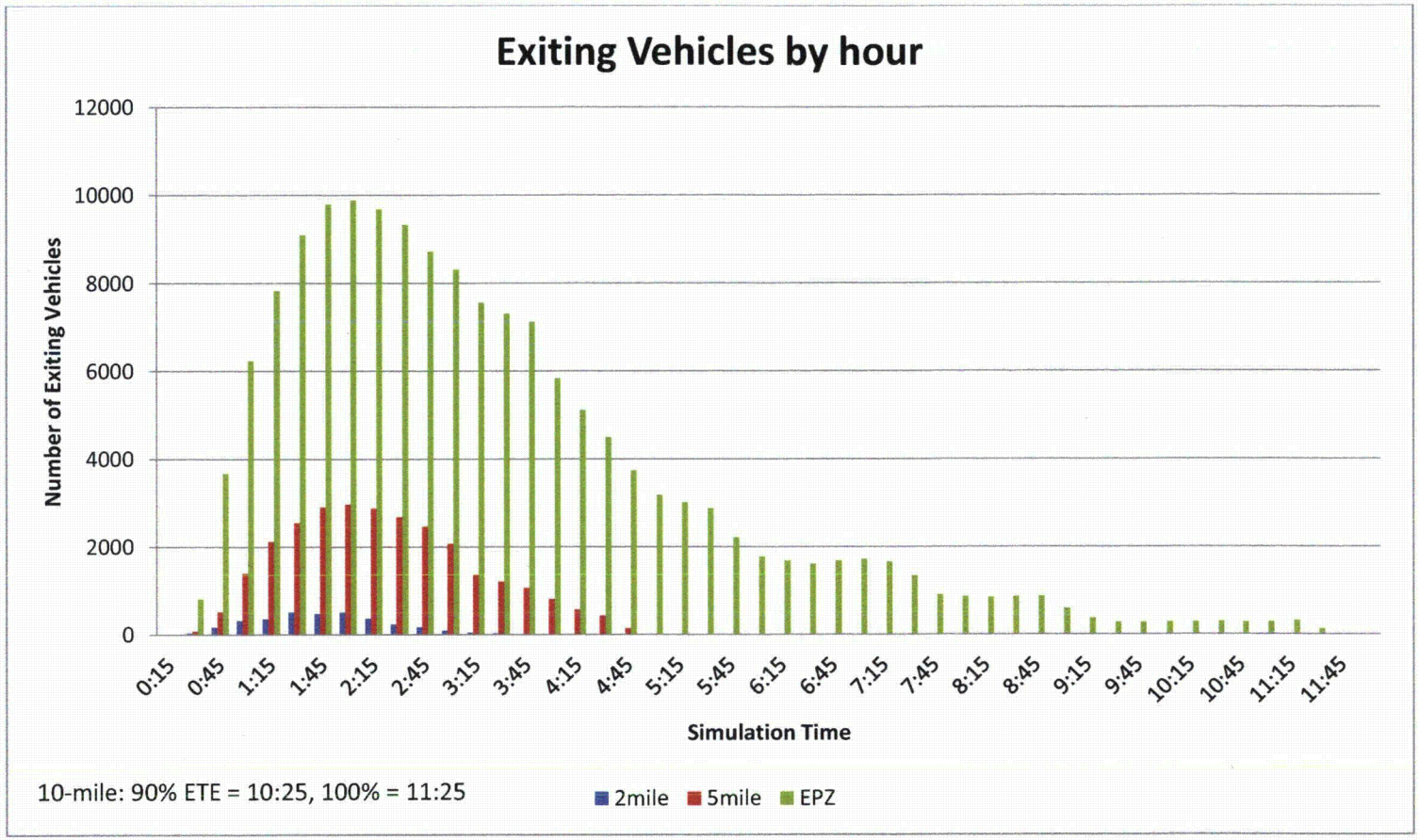

Figure 6-5. Time Distribution of Vehicles on the Network (Full 10-mile EPZ, Winter Weekday, Normal Weather)

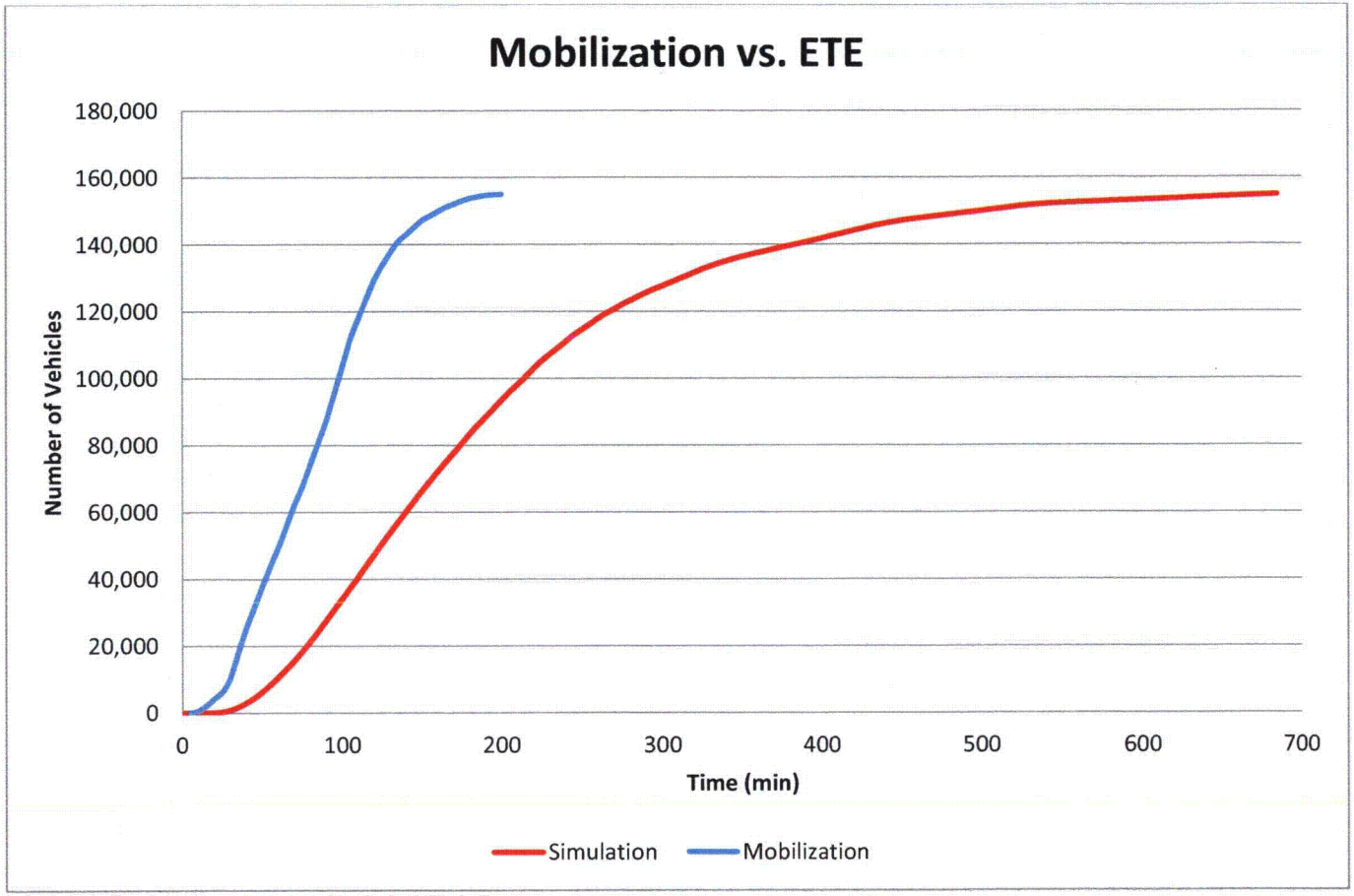

Figure 6-6. Comparison of Vehicle Mobilization and Departure Rates (total vehicles 154,970)

Table 6-4: Summary of Network Performance (Full 10-mile EPZ, Winter Weekday, Normal Weather)

Network Parameter	All Vehicles	BG/Shadow	Evacuation
Avg Delay (s)	9,652	1,599	13,104
Avg Stop Delay (s)	3,672	615	4,983
Avg # of Stops	2,172	239	3,001
Avg Speed (mph)	20.2	31.4	18.9
Avg Travel Time (min)	146	62	174

Table 6-5: ETE for Special Facilities, Three Mile Island EPZ (Full 10-mile EPZ, Winter Weekday, Normal Weather)

Facility	Population*	Vehicles*		Mobilization Time (min)	Loading Time (min)	Distance to EPZ Boundary (mi)	Outbound Travel Speed (mph)	Travel Time to EPZ Boundary (min)	ETE (min)
		#	Type						
Hershey Medical Center	4,968	127	Bus/Amb	120	120	4.5	17.6	15	255
Dauphin County Prison	1,340	40	Bus	120	60	2	25.4	5	185
Dauphin Cy Work Release	390	12	Bus	120	45	2	25.4	5	170
Shaffner Youth Center	108	2	Bus	120	30	2	25.4	5	155
Country Meadows	330	11	Bus/Amb	90	30	4	17.6	14	134
The Middletown Home	278	51	Bus/Amb	90	90	13	39.8	20	200
Frey Village	420	16	Bus/Amb	120	45	13	39.8	20	185
Spring Creek	423	19	Bus/Amb	120	45	5	58.1	5	170
Grayson View Manor	168	5	Bus/Amb	90	30	5	58.1	5	125
Manorcare Nursing Home	127	8	Bus/Amb	90	30	5	40.2	7	127
Longwood Manor	92	6	Bus/Amb	60	15	1.5	34.0	3	78
Masonic Home	2,600	154	Bus/Amb	120	120	6.5	40.2	10	250
Rheems Nursing Home	120	7	Bus/Amb	90	30	2.5	40.2	4	124

*Population numbers include residents and staff; vehicle numbers do not include staff vehicles

Table 6-6: ETE for Schools in Three Mile Island EPZ (Full 10-mile EPZ, Winter Weekday, Normal Weather)

Facility	Population*	Vehicles*		Mobilization Time (min)	Loading Time (min)	Distance to EPZ Boundary (mi)	Outbound Travel Speed (mph)	Travel Time to EPZ Boundary (min)	ETE (min)
		#	Type						
Hillside Elementary	494	10	Bus	120	45	7	40.1	10	175
New Cumberland Middle School	425	8	Bus	120	45	7	40.1	10	175
St. Theresa	451	9	Bus	120	45	7	40.1	10	175
Chamber Hills Elementary	235	4	Bus	90	30	3	21.7	8	128
Lawnton Elementary	345	6	Bus	90	30	3	21.7	8	128
Paxtang Elementary	292	6	Bus	90	30	3	21.7	8	128
Rutherford Elementary	407	8	Bus	120	45	3	21.7	8	173
Southside Elementary	643	13	Bus	120	45	1	21.7	3	168
St. Catherine Laboure	454	9	Bus	120	45	3	21.7	8	173
Swatara Junior High	610	12	Bus	120	45	5	21.7	14	179
Tri-Com Elementary	471	9	Bus	120	45	3	21.7	8	173
Hershey Elementary	1,195	23	Bus	120	45	4	44.4	5	170
Hershey High School	1,279	26	Bus	120	45	4	44.4	5	170
Hershey Middle School	961	19	Bus	120	45	4	44.4	5	170
Milton Hershey School	3,700	15/69	Bus/Van	30	30	4	44.4	5	65
St. Joan of Arc	370	8	Bus	120	45	4	44.4	5	170
State Police Academy	250	5	Bus	90	30	4	44.4	5	125
Foose Elementary	867	18	Bus	120	45	0.5	40.2	1	166
Conewago Elementary	288	6	Bus	90	30	7.5	42.2	11	131
L Dauphin High School	1,754	35	Bus	120	45	7.5	42.2	11	176
L Dauphin Middle School	1252	26	Bus	120	45	7.5	42.2	11	176

Table 6-6: ETE for Schools in Three Mile Island EPZ (Full 10-mile EPZ, Winter Weekday, Normal Weather)

Facility	Population*	Vehicles*		Mobilization Time (min)	Loading Time (min)	Distance to EPZ Boundary (mi)	Outbound Travel Speed (mph)	Travel Time to EPZ Boundary (min)	ETE (min)
		#	Type						
Londonderry Elementary	448	9	Bus	120	45	7.5	42.2	11	176
Nye Elementary	455	9	Bus	120	45	7.5	42.2	11	176
South Hanover Elementary	514	10	Bus	120	45	4	42.2	6	171
Reid Elementary	525	11	Bus	120	45	13	39.8	20	185
Feaser Middle School	677	13	Bus	120	45	13	39.8	20	185
Fink Elementary	238	4	Bus	90	30	13	39.8	20	140
Kunkel Elementary	464	9	Bus	120	45	13	39.8	20	185
Middletown Sr. High School	852	16	Bus	120	45	13	39.8	20	185
Seven Sorrows	248	5	Bus	90	30	13	39.8	20	140
PSU - Capital Campus	1,325	3	Bus	120	45	13	39.8	20	185
Steelton Highspire High School	652	12	Bus	120	45	3	25.4	7	172
Steelton Highspire Elementary	802	16	Bus	120	45	3	25.4	7	172
Bainbridge Elementary	318	6	Bus	90	30	5	40.2	7	127
East High Elementary	679	14	Bus	120	45	5	40.2	7	172
Bear Creek Elementary	660	14	Bus	120	45	5	40.2	7	172
Eliz'town Middle & High Schools	2,434	49	Bus	120	45	5	40.2	7	172
Mill Road Elementary	333	7	Bus	90	30	5	40.2	7	127
Mt. Calvary Christian	351	7	Bus	120	45	5	40.2	7	172
Rheems Elementary	520	10	Bus	120	45	5	40.2	7	172
St. Peters Parochial	74	2	Bus	60	15	5	40.2	7	82
Hayshire Elementary	635	13	Bus	120	45	2	35.3	3	168

Table 6-6: ETE for Schools in Three Mile Island EPZ (Full 10-mile EPZ, Winter Weekday, Normal Weather)

Facility	Population*	Vehicles*		Mobilization Time (min)	Loading Time (min)	Distance to EPZ Boundary (mi)	Outbound Travel Speed (mph)	Travel Time to EPZ Boundary (min)	ETE (min)
		#	Type						
Roundtown Elementary	637	13	Bus	120	45	2	35.3	3	168
Sinking Springs	774	16	Bus	120	45	2	35.3	3	168
Central York HS	1,824	37	Bus	120	45	2	35.3	3	168
Conewago Elementary	424	8	Bus	120	45	5	35.3	9	174
Mt. Wolf Early Learning Center	243	5	Bus	90	30	5	35.3	9	129
Northeastern Junior High	648	13	Bus	120	45	5	35.3	9	174
Northeastern Senior High	1,126	23	Bus	120	45	5	35.3	9	174
Orendorf Elementary	457	9	Bus	120	45	5	35.3	9	174
York Haven Elementary	331	6	Bus	90	30	5	35.3	9	129
Spring Forge Int	568	11	Bus	120	45	5	35.3	9	174
Shallow Brook Int	473	9	Bus	120	45	5	35.3	9	174
Crossroads Middle School	715	14	Bus	120	45	12	61.4	12	177
Fairview Elementary	243	5	Bus	90	30	12	61.4	12	132
Fishing Creek Elementary	585	12	Bus	120	45	12	61.4	12	177
Mt. Zion Elementary	239	5	Bus	90	30	12	61.4	12	132
Newberry Elementary	433	8	Bus	120	45	12	61.4	12	177
Red Land High School	1,370	27	Bus	120	45	12	61.4	12	177
Red Mill Elementary	660	13	Bus	120	45	12	61.4	12	177
The Circle School	50	1	Bus	60	15	12	61.4	12	87

*Population numbers include students and staff; vehicle numbers do not include staff vehicles

7. Traffic Control Recommendations

7.1 General

Evacuation simulation results have been reviewed to assess access control locations, traffic management locations and recommendations for the EPZ for TMI. Traffic control plans for each county were reviewed to confirm that traffic management will be implemented at key intersections on all designated evacuation routes. Predicted queuing at high-volume intersections inside the EPZ is summarized in Table 7-1. The results indicate that average queue length exceeds 400 feet at all ten intersections. The top four intersections have average queue length of more than 800 feet. All ten intersections are located more than 5 miles from TMI. Six intersections are located east of the Susquehanna River, including five in Dauphin County (three in Hershey). Four are located in the northwest quadrant, including two in York County and two in New Cumberland.

7.2 Evacuation Access Control Locations

Access control measures were not specifically addressed in the conduct of this study. Background traffic within the EPZ was not found to be a significant contributor to traffic congestion during the early stages of evacuation.

7.3 Traffic Management Locations and Tactics to Facilitate Evacuation

The traffic simulations show severe queuing inside the EPZ on several major evacuation routes. These include Route 39 and 322 in Hershey, and I-83 at the Pennsylvania Turnpike. The maps in Appendix D of predicted average speed by hour on roadway links clearly illustrate how the pattern of congestion evolves during a full-EPZ evacuation scenario. Travel speeds on key routes drop below 20 mph within the first four hours, and that congestion persists for the next 6 or 7 hours.

Traffic management measures to reduce or eliminate crossing traffic flows would offer the best prospect to reduce congestion and accelerate traffic flow. Alternative routes to evacuate west from northern York County, rather north via I-83, would reduce the predicted congestion at the Turnpike entrance. Modeling assumptions at some key intersections (e.g. I-83 at Turnpike) also bear close examination.

Table 7-1: Predicted Queuing at Major Intersections (Full 10-mile EPZ, Winter Weekday, Normal Weather)

Intersection Name	Type	EPZ (IN or OUT)	City or Town	Control Type	Average Queue (feet)	Volume
SR 283 EB Exit to State Highway 743 NB	Ramp	IN	Elizabethtown	Two-way stop	1,482	13,924
I-83 NB Exit ramp to I-76 WB	Ramp	IN	New Cumberland	Signalized	1,474	10,146
SR 230 E Harrisburg Pike / Toll House Road	T	IN	Middletown	Two-way stop	1,022	4,542
State Highway 743 / Old Hershey Rd	T	IN	Hershey	Signalized	804	14,644
SR 39 EB / SR 39 NB Hershey Rd	4 leg	IN	Hershey	Two-way stop	760	5,326
SR 114 / SR 382	T	IN	Fairview	Two-way stop	694	8,496
SR 177 / SR 382	4 leg	IN	Lewisberry	Signalized	623	4,340
SR 114 / SR 262	4 leg	IN	New Cumberland	Two-way stop	606	2,786
US 22 NB Merge to I-81 WB	Ramp	IN	Harrisburg	Two-way stop	524	5,556
US 322 / State Highway 743	4 leg	IN	Hershey	Two-way stop	472	12,956

8. References

Earth Tech, 2003: *Evacuation Time Estimates for Three Mile Island Plume Exposure Pathway Emergency Planning Zone,* prepared by Earth Tech, Inc. for Exelon Nuclear, May 2003.

NRC, 1980*: 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, U.S. Nuclear Regulatory Commission, Federal Emergency Management Agency, November 1980.

NRC, 1992: *State of the Art in Evacuation Time Estimate Studies for Nuclear Power Plants*, NUREG/CR-4831, T. E. Urbanik and J. D. Jamison, Pacific Northwest Laboratory, U.S. Nuclear Regulatory Commission, March 1992.

NRC, 2011*: Criteria for Development of Evacuation Time Estimate Studies*, NUREG/CR-7002, J. Jones and F. Walton, Sandia National Laboratories, and B. Wolshon, Louisiana State University, November 2011.

ORNL, 1990: *Evaluating Protective Actions for Chemical Agent Emergencies,* ORNL-6615, G.O. Rogers, et al., Oak Ridge National Laboratory, prepared for U.S. Department of the Army and Federal Emergency Management Agency, April 1990.

PEMA, 2006: *Three Mile Island Nuclear Station Evacuation Plan Map* prepared by Pennsylvania Emergency Planning Agency, revised February 2006