1. INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to update the existing Evacuation Time Estimates (ETE) for the Indian Point Energy Center (IPEC), located in Buchanan, New York. Evacuation time estimates provide State and local governments with site-specific information helpful for Protective Action decision-making.

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

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

- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG 0654/FEMA-REP-1, Rev. 1, November 1980.
- Analysis of Techniques for Estimating Evacuation Times for Emergency Planning Zones, NUREG/CR-1745, November 1980.
- State of the Art in Evacuation Time Estimate Studies for Nuclear Power Plants, NUREG/CR-4831, March 1992.

We wish to express our appreciation to all the directors and staff members of the Orange, Putnam, Rockland, and Westchester County Emergency Management Offices, the various county planning offices, New York State Emergency Management Office (SEMO), and local and state law enforcement agencies, who provided valued guidance and contributed information contained in this report.

1.1 Overview of the ETE Update Process

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

1. Information Gathering:
   - Attended initial meetings with representatives of Entergy Nuclear Northeast (ENN) to define the scope of work.
   - Reviewed existing reports describing past evacuation studies.
   - Attended meetings with each of the 4 counties that comprise the Indian Point Emergency Planning Zone (EPZ) to identify issues to be addressed and resources available.
   - Conducted a field survey of the EPZ highway system and of area traffic conditions.

- Attended meetings and briefings with state and county officials.
- Obtained demographic data from New York State Emergency Management Office.
- Conducted a random sample telephone survey of EPZ residents.
- Conducted a data collection effort by mail and telephone to identify and describe schools, special facilities, major employers, transportation providers, and other important sources of information.

2. Estimate distributions of Trip Generation times representing the time required by various population groups (permanent residents, employees, and transients) to prepare for the evacuation trip. These estimates are primarily based upon the random sample telephone survey performed as part of the data collection effort.
3. Define Evacuation Scenarios. These scenarios reflect the variation in demand, trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.
4. Define a traffic management strategy. Traffic control is applied at specified Traffic Control Posts (TCP) located within the Emergency Planning Zone (EPZ), and at Access Control Posts (ACP) located outside the EPZ. Local and state police personnel review all traffic control plans.
5. Define Evacuation Areas or Regions. The EPZ is partitioned into Emergency Response Planning Areas (ERPAs). These existing ERPA were accepted as the basis for the ETE analysis presented herein. "Regions" are groups of contiguous ERPAs for which ETE are calculated. The configurations of these Regions depend upon wind direction and the radial extent of the impacted area. Each Region, other than those that approximate circular areas, approximates a "key-hole section" within the EPZ as required by NUREG 0654.
6. Assign Reception Centers to each ERPA within the EPZ.
7. Estimate demand for transit services for persons at "Special Facilities" and for transit-dependent persons at home.
8. Prepare the input streams for the IDYNEV system.
   - Estimated the traffic demand, based on the available information derived from Census data, from prior studies, from data provided by county and state agencies and from the telephone survey.
   - Applied the procedures specified in the 2000 Highway Capacity Manual (HCM) to the data acquired during the field survey, to estimate the capacity of all highway segments comprising the evacuation routes.

- Developed the link-node representation of the evacuation network, which is used as the basis for the computer analysis that calculates the Evacuation Time Estimates (ETE). The IDYNEV System, developed by KLD for FEMA, was used to perform these calculations.
- Calculated the evacuating traffic demands for each Region and for each Evacuation Scenario.
- Represented the traffic management strategy.
- Specified the candidate destinations of evacuation travel consistent with outbound movement relative to the location of IPEC.
- Prepared the input stream for the IDYNEV System.
- Executed the IDYNEV models to provide the initial estimates of evacuation routing and Evacuation Time Estimates (ETE) for a single scenario.

9. Generate a complete set of ETE for all specified Regions and Evacuation Scenarios. In addition, two "special event" ETE were calculated.
10. Document ETE in formats responsive to NUREG 0654.
11. Calculate the ETE for all transit activities including those for special facilities (schools, health-related facilities, etc.) and for the transit-dependent.

Steps 4 through 9 are iterated as described in Appendix D.

1.2 The Indian Point Energy Center Site Location

The Indian Point Energy Center (IPEC) is located on the eastern shore of the Hudson River, in Westchester County, New York. The site is situated approximately 24 miles north of New York City at longitude 73^{o} 57' W and latitude 41^{o} 16'N.

The Emergency Planning Zone contains parts of four New York State counties: Orange, Putnam, Rockland, and Westchester. Figure 1-1 displays the area surrounding the Indian Point Energy Center. This map identifies the communities in the area and the major roads.

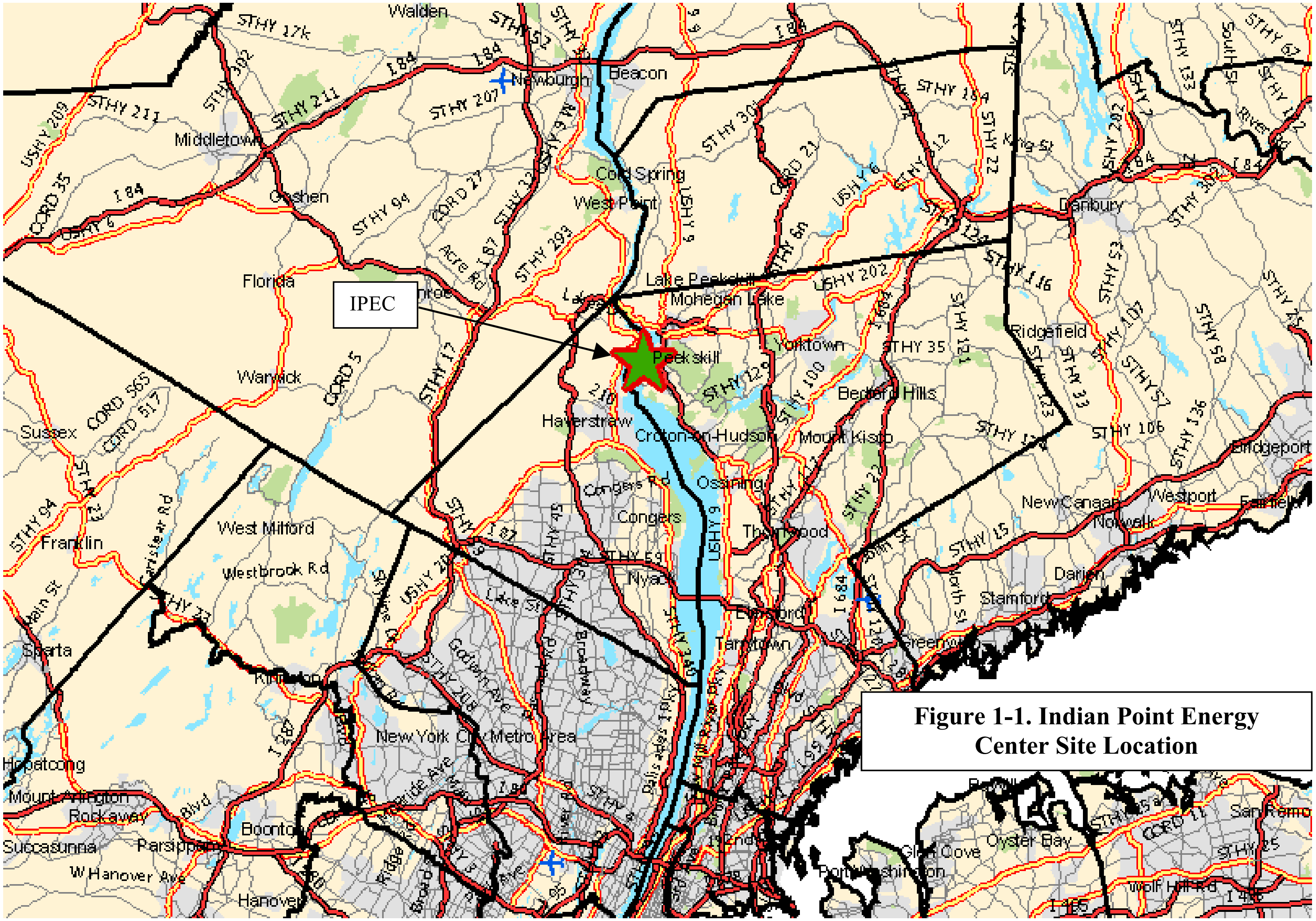

Figure 1-1. Indian Point Energy Center Site Location

1.3 Preliminary Activities

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

Literature Review

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

Field Surveys of the Highway Network

KLD personnel drove the entire highway system within the EPZ and for some distance outside to the bounding Interstate Highways: I-87 on the west; I-87/287 on the south; I-684 on the east; and I-84 on the north. The characteristics of each section of highway were recorded. These characteristics include:

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

The data were then transcribed; this information was referenced while preparing the input stream for the IDYNEV System. In addition, sketches were made at key highway locations.

Telephone Survey

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

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

Developing the Evacuation Time Estimates

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

Highway capacity was estimated for each highway segment based on the field surveys and on the principles specified in the 2000 Highway Capacity Manual (HCM[1]). The link-node representation of the physical highway network was developed using Geographic Information System (GIS) mapping software and the observations obtained from the field survey. This network representation of "links" and "nodes" is shown in Figure 1-2.

Analytical Tools

The IDYNEV System that was employed for this study is comprised of several integrated computer models. One of these is the PCDYNEV (DYnamic Network EVacuation) macroscopic simulation model that was developed by KLD under contract with the Federal Emergency Management Agency (FEMA) and subsequently migrated from a VAX mini-computer to the PC world.

PCDYNEV consists of three submodels:

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

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

Still another software product developed by KLD, named UNITES (UNIfied Transportation Engineering System) was used to expedite data entry.

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

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

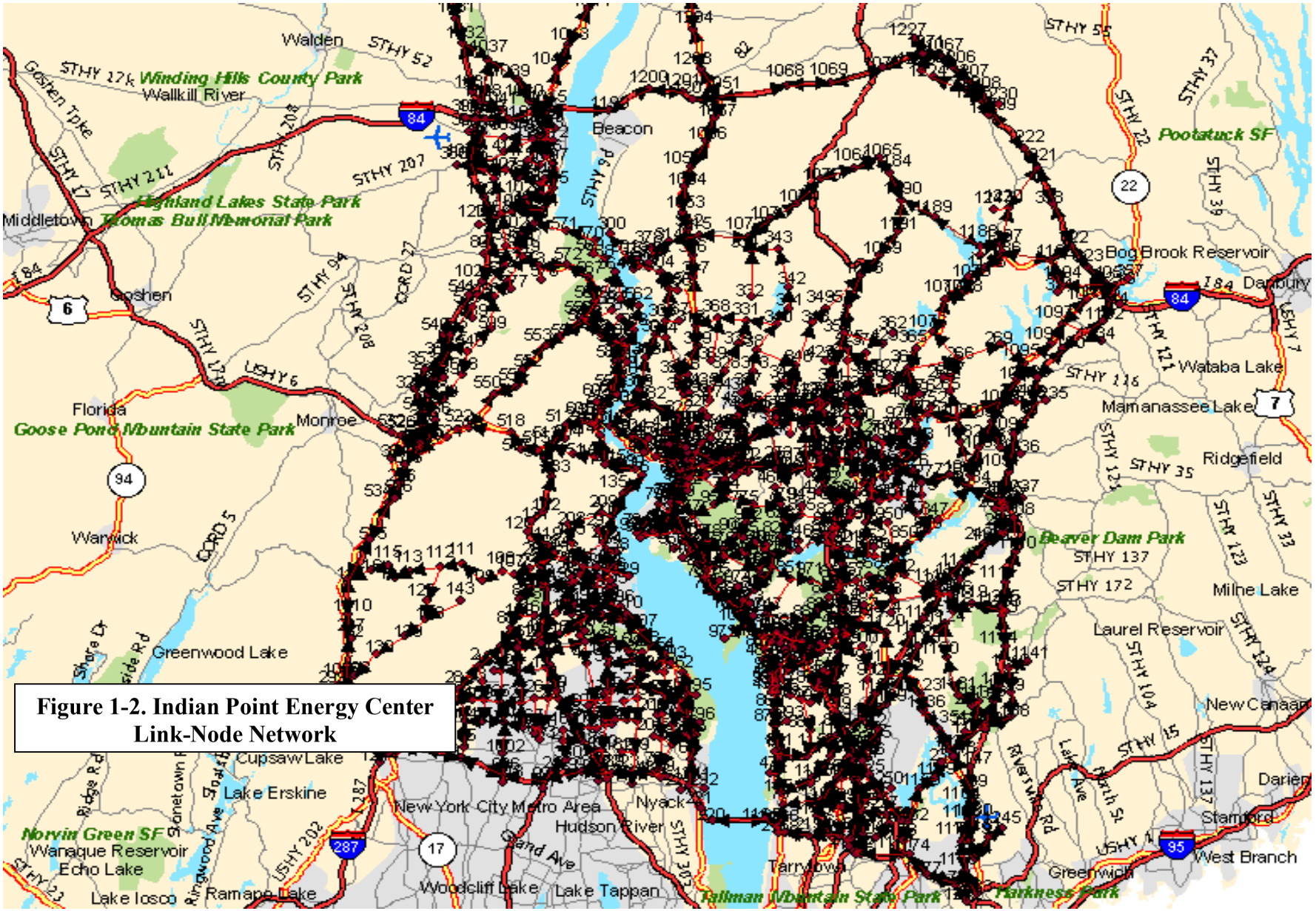

Figure 1-2. Indian Point Energy Center Link-Node Network

The evacuation analysis procedures are based upon the need to:

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

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

The simulation model is then executed to provide a detailed description of traffic operations on the evacuation network. This description enables the analyst to identify bottlenecks and to develop countermeasures that are designed to expedite the movement of vehicles.

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

1.4 Comparison with Prior ETE Study

Table 1-1 presents a comparison of the present ETE study with the study produced in 1994. The major factors contributing to the differences between the ETE values obtained in this study and those of the previous study can be summarized as follows:

- An increase of approximately 10 percent in resident population, based on Census data.
- An increase in the number of evacuating vehicles per household of approximately 25 percent based on the results of the telephone survey.
- An increase of approximately 300 percent in the estimated number of employees commuting to the EPZ based on NYS trip-to-work data and employment statistics.
- Explicit consideration of the impact of Shadow Region traffic movement on evacuation time.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Resident Population Basis	1990 Census	2000 Census, extrapolated to 2003. Approximately 10 percent higher.
Resident Population Vehicle Occupancy	Assumed 1.0 vehicle per household.	Based on residential telephone survey, County specific range from 1.24 to 1.27 vehicles per household.
Employee Population	Combined with transients. Based on telephone survey of employers with more than 50 employees. No distinction was made between employees who live and work in the EPZ and employees who enter the EPZ to work. Double counting of resident employees.	Treated as a separate population group. Employment journey to work data identified the proportion of employees who commute into the EPZ relative to the total number of employees. These proportions were applied on an ERPA by ERPA basis to total employment information for the year 2000 from NYS Dept. of Labor.
Employee Vehicle Occupancy	Assumed 1.1 vehicles per employee [sic]. Should have read 1.1 employees per vehicle.	County specific values ranging from 1.05 to 1.07 employees per vehicle. Data obtained from 2000 Census.
Transient Population	Based on telephone calls to individual facilities.	Based on telephone calls to individual facilities.
Voluntary evacuation from within EPZ in areas outside region to be evacuated	No treatment identified.	50 percent within circle. 35 percent in annular ring between the circle and EPZ boundary.
Shadow Evacuation	Not considered.	Population in areas between the EPZ boundary and the bounding interstate highways was considered. Nominally, 30 percent of this population will move away from the EPZ.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Roadway Geometric Data	Field surveys conducted in 1993. Road capacities based on 1985 HCM.	Field surveys conducted in 2002. Road capacities based on 2000 HCM.
Network Size	598 Links; 398 Nodes.	2,132 Links; 1031 Nodes.
Transit Dependent Population	Defined as non-auto owning population by ERPA.	Defined as households with 0 vehicles + households with 1 and 2 vehicles with commuters who do not return home. Household size varies by county and number of vehicles in household.
School Evacuation	Either early dismissal or direct evacuation.	Direct evacuation.
Ridesharing	50 percent except in Ossining and Peekskill where 0 percent ridesharing is assumed.	50 percent everywhere. Auto ownership in Ossining and Peekskill is consistent with rest of EPZ based on DMV data.
Special Events	USMA football weekend and graduation.	USMA football weekend. USMA midweek commencement ceremony.
Bus Availability	Based on inventory of resources.	Based on inventory of resources.
Trains	Not considered for ETE purposes.	Not considered for ETE purposes. However, recommendation to continue train service for about 1.5 hours after evacuation begins to help transport commuters.
Boats, Airports	Coast Guard alerts boaters who leave area in boats. Airports not considered for ETE purposes.	Coast Guard alerts boaters who leave area in boats. Airports not considered for ETE purposes.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Trip Generation for Evacuation	Residents assumed to take between 30 and 150 minutes. Transients and employees assumed to take between 30 and 60 minutes.	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 30 and 240 minutes. Residents without commuters returning leave between 15 and 150 minutes. Employees and transients leave between 15 and 90 minutes. All times measured from the Advisory to Evacuate for all above. Additional time to clear snow added to residential evacuation times for snow scenarios.
Traffic and Access Control	29 Traffic control points identified. Traffic management requirement stated. No maps, no intersection schematics, nor manning requirements nor priority assignment are presented.	Explicit treatment of over 150 traffic and access control locations. Each location is identified, mapped, and schematics prepared. Manning, equipment and priority assignments are defined for each location.
Weather	Clear or Adverse.	Clear or Rain or Snow.
Modeling	NETVAC	IDYNEV System: TRAD and PCDYNEV.
Evacuation Time Estimates Reporting	Reported for 90 and 100 percentile population. Results presented by County, Region and ERPA.	Reported for 50, 90, 95, and 100 percentile population. Results presented by Region.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Evacuation Time Estimates for the entire EPZ.	Winter midweek midday good weather = 5:30 Summer weekend midday good weather = 5:40	Winter midweek midday good weather = 9:25 Summer weekend midday good weather = 9:25