1. INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the proposed William S. Lee Nuclear Station (WLS), located in Cherokee County, South Carolina. Evacuation time estimates provide State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, guidance is provided by documents published by Federal Government agencies. Most important of these are:

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

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

1.1 Overview of the ETE Process

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

1. Information Gathering:
    - Defined the scope of work in discussion with representatives of Enercon Services and Duke Energy.
    - Attended meetings with emergency planners from Cherokee County, Cleveland County, and York County to identify issues to be addressed and resources available.
    - Conducted a detailed field survey of the Emergency Planning Zone (EPZ) highway system and of area traffic conditions.
    - Obtained demographic data from census and state agencies.
    - Conducted a random sample telephone survey of EPZ residents.

- Conducted a data collection effort to identify and describe schools, special facilities, major employers, transportation providers, and other important sources of information.

2. Estimated distributions of Trip Generation times representing the time required by various population groups (permanent residents, employees, and transients) to prepare (mobilize) for the evacuation trip. These estimates are primarily based upon the random sample telephone survey.
3. Defined Evacuation Scenarios. These scenarios reflect the variation in demand, in trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.
4. Defined a traffic management strategy. Traffic control is applied at specified Traffic Control Points (TCP) located within the Emergency Planning Zone (EPZ). Local and state police personnel have reviewed all traffic control plans.
5. Defined ERPA and Evacuation Areas or Regions. The EPZ was partitioned into 14 Emergency Response Planning Areas (ERPAs) using political and geographic boundaries. "Regions" are groups of contiguous ERPA for which ETE are calculated. The configurations of these Regions reflect 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. Estimated demand for transit services for persons at "Special Facilities" and for transit-dependent persons at home.
7. Prepared the input streams for the IDYNEV system.
   - Estimated the traffic demand, based on the available information derived from Census data, and from data provided by local and state agencies, Enercon Services, and from the telephone survey.
   - Applied the procedures specified in the 2000 Highway Capacity Manual (HCM) to the data acquired during the field survey, to estimate the capacity of all highway segments comprising the evacuation routes.
   - Developed the link-node representation of the evacuation network, which is used as the basis for the computer analysis that calculates the ETE.
   - Calculated the evacuating traffic demands for each Region and for each Evacuation Scenario.

- Represented the traffic management strategy.
- Specified the candidate destinations of evacuation travel consistent with outbound movement relative to the location of the WLS.
- Prepared the input stream for the IDYNEV System.
- Executed the IDYNEV models to provide the estimates of evacuation routing and ETE.

8. Generated a complete set of ETE for all specified Regions and Evacuation Scenarios.
9. Documented ETE in formats responsive to NUREG 0654.
10. Calculated the ETE for all transit activities including those for special facilities (schools, health-related facilities, etc.) and for the transit-dependent.

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

1.2 The Lee Nuclear Station Site Location

The proposed Lee Nuclear Station is located just west of the Broad River, 7 miles southeast of Gaffney, South Carolina. The Emergency Planning Zone (EPZ) consists of parts of Cherokee County and York County in South Carolina, and part of Cleveland County in North Carolina. Figure 1-1 displays the area surrounding the Lee Nuclear Station. This map identifies the communities in the area and the major roads.

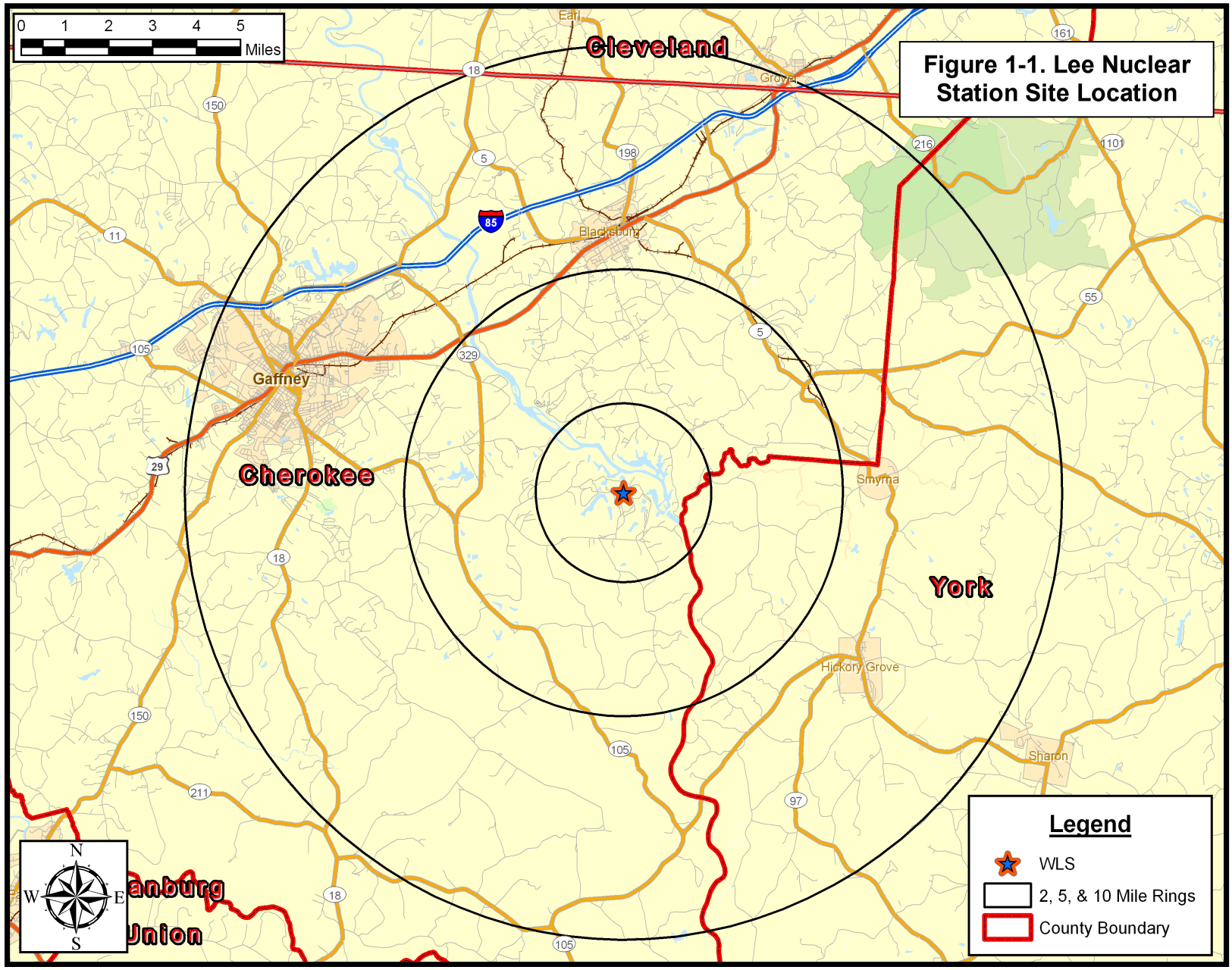
Figure 1-1. Lee Nuclear Station Site Location
0 1 2 3 4 5
Miles
Cleveland
Cherokee
York
Union
Gaffney
Blacksburg
Grover
Smyrna
Hickory Grove
Sharon
Legend
WLS
2, 5, & 10 Mile Rings
County Boundary
N
S
E
W

1.3 Preliminary Activities

These activities are described below.

Field Surveys of the Highway Network

KLD personnel drove the entire highway system within the EPZ and for some distance outside. The characteristics of each section of highway were recorded. These characteristics include:

• Number of lanes	• Posted speed
• Pavement Width	• Actual free speed
• Shoulder type & width	• Abutting land use
• Intersection configuration	• Control devices
• Lane channelization	• Interchange geometries
• Geometrics: Curves, grades	
• 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, key highway sections and intersections were video archived.

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 to estimate the number of evacuating vehicles 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 PC-DYNEV (DYnamic Network EVacuation) macroscopic simulation model that was developed by KLD under contract with the Federal Emergency Management Agency (FEMA).

PC-DYNEV consists of three submodels:

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

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

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

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

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

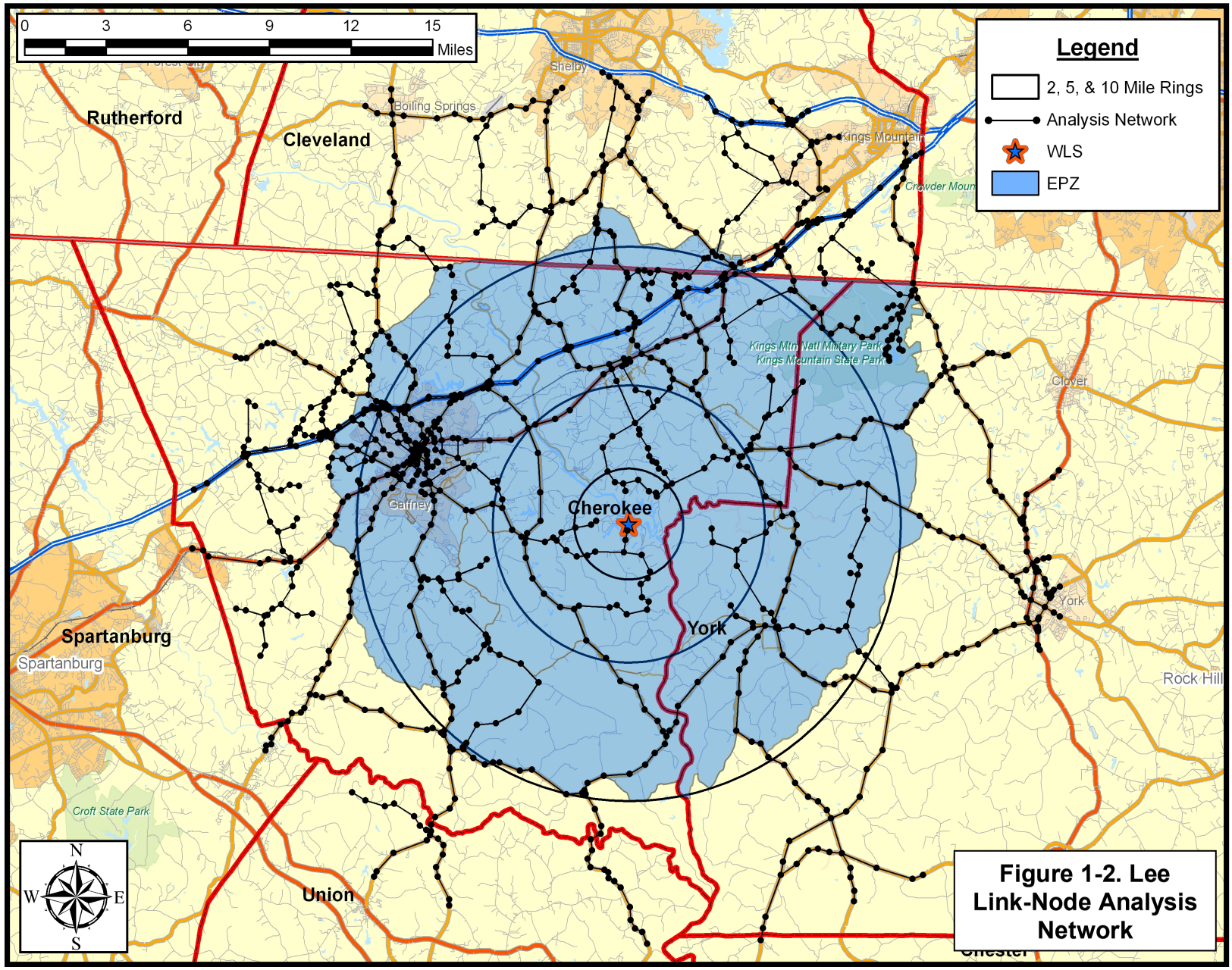

Figure 1-2. Lee Link-Node Analysis Network

The evacuation analysis procedures are based upon the need to:

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

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

The simulation model is then executed to provide a detailed description of traffic operations on the evacuation network. This description enables the analyst to identify bottlenecks and to 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 evacuation plan which best services the evacuating public.