DRAFT-2

Delaware Emergency Evacuation for the Salem/Hope Creek Nuclear Power Generators

Charles W. W. Mitchell, III

University of Delaware

University Transportation Center &

Disaster Research Center

8 August 2008

Table of Contents

Abstract

This report and research is an assessment of the Delaware Emergency Evacuation Plans for a radiological emergency at the Salem/Hope Creek Nuclear Power Generators in Salem, NJ. In making this assessment information is drawn from engineering as well as social science literature and the primary past nuclear emergency in the United States, Three Mile Island. The engineering research takes a look at revisions to ideas about road capacities, affects of weather on an evacuation and new methods for viewing evacuation as a process rather than list of steps, including measures of effectiveness. The Social Science literature further develops the engineering principles and is included to better understand how evacuees will respond in an emergency. This includes how the warning message will be created, understood and understanding how evacuees will choose to take protective action. This knowledge is then used to assess the current plans for the State of Delaware and make recommendations for future improvements. The information is also applied to evacuation of Delaware City, Delaware in a rough estimate of the effects of evacuation. The end result of this research is recommendations to improve methods and practices for future evacuations.

I. Introduction

In the event of a significant emergency, populations of a state or region may have to be evacuated. Evacuations affect vast numbers of people every year due to events both large and small. The U.S. Nuclear Regulatory Commission found that an evacuation of 1,000 or more people is required every two to three weeks (Zimmerman, 2007: p5). It is critical that these evacuations, independent of the extent and intensity of the event, progress effectively to ensure everyone who needs to be evacuated has the opportunity and everyone who should not evacuate remains in place. “The major challenge presented in a large-scale evacuation is that routes exiting an evacuation area are often both limited in number and insufficient in capacity to handle the unusual surge in traffic demand that results from the concurrent evacuation activities” (Han, et al. 2007, p 1) There are significant and unusual demands on the transportation system; however it is not practical to design roads and other infrastructure to meet these demands because of the fact they are rare by their very nature. Therefore it is important to understand these demands and have plans in place to ensure an organized and effective evacuation.

The state of Delaware has taken many steps to assist in this process by drafting evacuation plans and identifying evacuation routes through the state. These plans look at several scenarios for evacuation from hurricanes and flooding to radiological emergencies. Although the state has taken steps to implement evacuation planning, residents of the affected area receive little education on what to do in an evacuation. With disasters happening nearly every week there is always new data to be understood. Because the world of evacuation planning is constantly evolving it is important to continually review evacuation plans and planning to ensure they are using the most up to date research and practices. There are ways in which the evacuation plan may be improved through better understanding of the effects of a mass evacuation.

With ever evolving research and methods evacuation plans should be reviewed on a continual basis. Drawing on Engineering and Social Science literature, the current evacuation plans for a nuclear emergency in Delaware are reviewed in this research with the intent of looking for possible improvements. The knowledge gained from this study is applied to a case study of Delaware City, Delaware, one of the several towns that may have to be evacuated in the event of a radiological emergency at the Salem/Hope Creek nuclear power generators. This case study is intended to highlight the strengths and limitations of the current plans in place and to be used as a tool to learn for future revisions of evacuation planning.

Section three of this report includes background information about the affected area of New Jersey and Delaware. Section four is a review of current literature of Engineering and Social Science literature relevant to the subject. Section five is a review of the current requirements and responsibilities by the Nuclear Regulatory Commission and Federal Emergency Management Agency, the two primary agencies for nuclear generator oversight. In section six details of pertinent research knowledge are made available to the reader. Section seven contains information from a previous nuclear emergency and evacuation, Three Mile Island. In section eight there is a description and analysis of the current plans for evacuation due to a radiological emergency in Delaware. Section nine recognizes special considerations that should be considered in evacuation planning. In section 10 the information from this research has been applied to an evacuation of Delaware City. Section 11 includes recommendations for improvements to current plans and in sections 12 and 13 there are recommendations for future research and conclusions about the current plans and research.

II. Objective

The objective of this research is to identify strengths and weaknesses for emergency evacuation planning for radiological emergencies affecting Delaware based upon reviews of:

a) Engineering Research on evacuation
b) Knowledge of evacuee behavior
c) Current regulations for nuclear and radiological emergency planning
d) Past experience with nuclear emergencies at Three Mile Island

This includes making suggestions for improving the existing plans to further the ongoing process of updating plans as new research is developed.

III. Background

The Salem/Hope Creek nuclear power plant is located on the eastern shore of the Delaware River about 6 miles south of Delaware City. In the event of an emergency at the Salem/Hope Creek nuclear power generators the affected area could involve populations of the state of Delaware and New Jersey. As a result, the two state emergency agencies and the owner of the plant PSEG Nuclear, LLC must work together in the event of an emergency. For planning purposes, there are preset zones defined by five, ten and fifty mile radius around the plant that may be affected during an emergency. The ten and file mile zones are shown in Figures 1 and 2. These planning zones are developed from requirements set by the Nuclear Regulatory Commission. More details on this can be found in Section five (5).

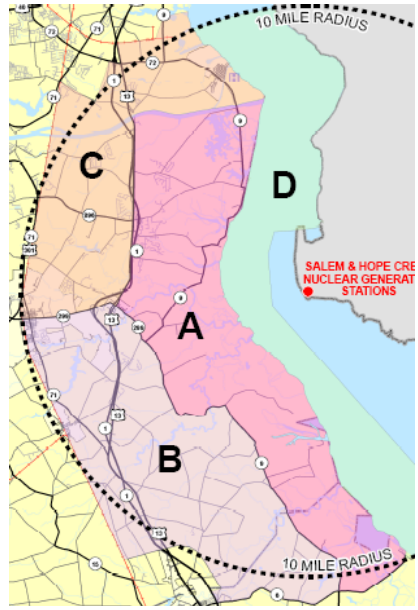


Figure 1: Ten Mile Zone
Jacobs Edwards and Kelcey, 2004

On any given day there are approximately 25,000 Delaware Residents and 13,000 New Jersey residents in the 10 mile zone (KLD Associates, INC. 2004). Additionally there are many more people who travel through this area for work or travel to tourist destinations on the two major highway, Delaware Routes 1 and 13. These highways are major travel routes to the beaches in southern Delaware and can have especially heavy traffic during the summer months.

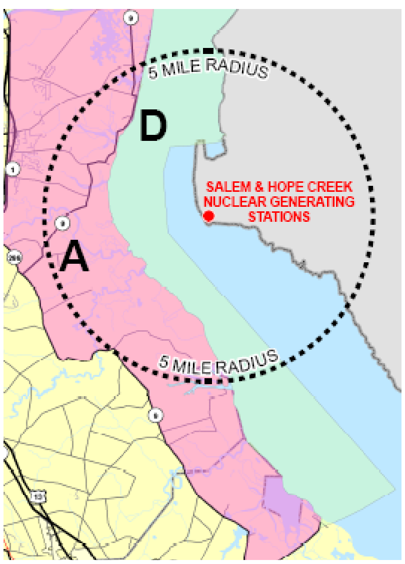


Figure 2: Five Mile Zone
Jacobs Edwards and Kelcey, 2004

The letters in Figure 1 and 2 correspond to the ERPAs (Emergency Response Planning Areas). ERPA A consists of Port Penn, Odessa, North Smyrna and South St. Georges. ERPA B consists of Middletown, East Townsend, and North Smyrna. ERPA C included Delaware City, North Middletown, St. Georges and Reybold. ERPA D is the Delaware Bay from North of Pea Patch Island to Woodland Beach.

Figure 3 shows several of the Nuclear Reactors in FEMA Region 3 that could affect Delaware if there was an emergency at any one of them. The red circles are the 50 mile ingestion pathway which is the primary area of concern for contaminated food and ingestion of settling radioactive material. The Salem/Hope Creek Nuclear Generators are shown in relation to the surrounding states and counties.

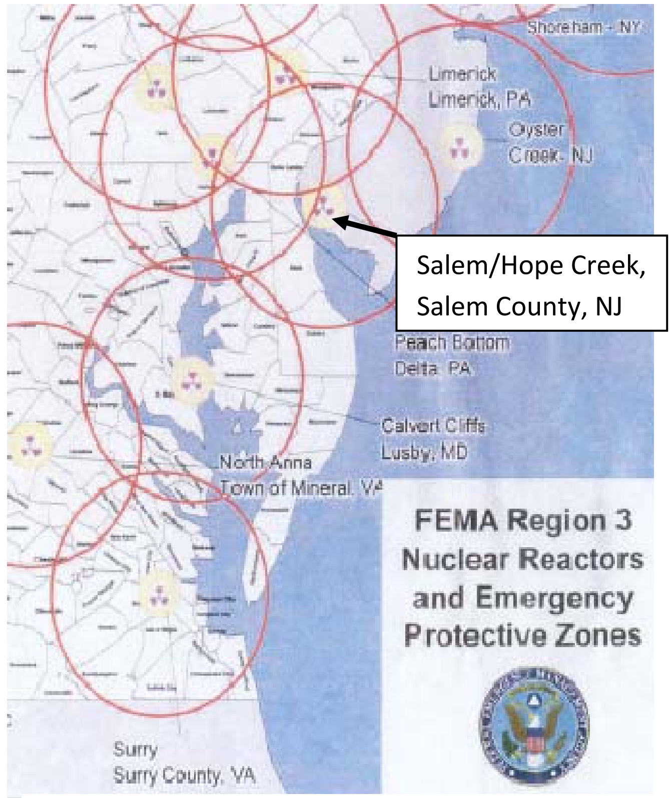


Figure 3: FEMA Region 3 State of Delaware, 2008

IV. <u>Literature Review</u>

There are several broad groups of literature relevant to evacuation planning and research. This review is divided by those categories with no intended hierarchy.

Research into Engineering Evacuation Modeling

In recent years there has been a significant interest in making evacuations more efficient. There has been a lot of engineering research into modeling traffic in no-notice evacuations. A no-notice evacuation is not always the case for a nuclear emergency; however it may be the worst case scenario. Evacuation due to a Nuclear Emergency seems to have a very different expectation than, for example, due to a hurricane where people often have several days of lead time and understand the effects of a hurricane. In contrast, nuclear emergencies are not well understood and often do give as much advance warning of an emergency.

Researchers are looking at the specifics of modeling evacuation situations. Chiu et al. (2007) have studied no-notice evacuation modeling. The authors cover some of the assumptions that can be made in this type of disaster and how these may be put into a model immediately after a disaster to aid with evacuation. Their analysis uses a nodal and network model to formulate a "network transformation and demand modeling technique that allows the optimal evacuation destination, traffic assignment and evacuation departure schedule" (Chiu, et al. 2007: p93). In addition to modeling observations of behavior, performance of infrastructure during evacuation is relevant. Moriarty et al. (2006) have studied traffic flow and capacity during evacuations which is be useful in the modeling of evacuations. Additionally, Wolshon (2007) was one of the first engineers to study field based data of traffic flow after the evacuations of Hurricane Katrina. Wolshon took sensor data from major highways and developed new ideas about highway capacities in mass evacuations. This information is detailed in his article and according to Wolshon, he is one of the first to "asses how well various roadway classifications in different geographic areas are able to carry traffic during emergencies under both normal and contra-flow operation" (Wolshon, 2007: p1). This information will be useful in updating estimates for evacuation times and road capacities.

One idea that is common in evacuation research is the idea of lane reversal, also known as contra flow lanes. Williams et al. (2007) studies the simulation of lane reversal for hurricane evacuations. Williams mentions several plans already in place that use contra flow and lists his scenarios used in modeling for various evacuations. He uses the specifics from the North Carolina I-40 lane reversal plan to facilitate evacuation. Wolshon (2007) builds on this information by offering information summarizing lane reversal practices and discusses the fact that there is little to no standardization among road reversal systems and plans. Wolshon's view on this comes by looking at current practices to gain insight to future planning.

Other researchers are very interested in the timing of evacuation. Urbanik, II (2000) has researched time estimates for evacuations for nuclear emergencies. This research focuses on when an evacuation order must be to given best reduce radiation exposure. Additionally, he is able to use this information for better traffic management and predict the effect of conditions such as weather on an evacuation (Urbanik 2000). Han et al. (2007) describes what makes an evacuation effective. The focus of this article is analyzing measures of effectiveness to be used in the optimization of the evacuation process. Their aim is to reduce exposure to an incident by minimizing evacuation time and risks.

In general engineers are looking at specific aspects of evacuation research, such as lane capacities, evacuation time, affects of weather, etc. There is not an extensive amount of multi-disciplinary research on evacuation procedures and modeling of evacuated populations. Additionally some researchers are beginning to look at the modeling picture and look at data from recent disasters to better predict the effectiveness of future evacuation plans (Wolshon, 2007).

Behavior of Individuals in Evacuations.

There is a body of scholarly work on the behaviors of people in evacuations. Drabek (1996, 1999) focuses on the behaviors of specific population secments affected by evacuations, specifically tourists and employees. In both cases Drabek found important, aspects of evacuation that are unique to the specific population groups, and identified preliminary findings that may explain how these two unique populations respond to an evacuation order. Drabek admits the research was limited to specific conditions but there were new areas of research exposed by his findings.

Stallings (1984) studied the evacuation behavior at Three Mile Island. In his research he uses field studies to see how the public surrounding the Three Mile Island Nuclear Generators responded to a potential emergency, although Stallings states an official evacuation order was not issued. In this research he brings to light many of the social issues that emerged from the disaster and presents a view on the information available to the public at the time of the incident. Stallings presents a review of future dilemmas in evacuations resulting from any disaster. He argues that many of his findings may be applicable to other types of disasters, especially disasters that may be relatively unknown and considered controversial by the affected population.

More recently Mileti & Peek (2000) have studied the reactions of individual's in a nuclear emergency. They argue that "people engage in protective action in response to warnings based upon the substance and course through which emergency warning information is disseminated" (Mileti & Peek, 2000: p181). They include in their research how to effectively alert the public such as with emergency sirens and note that in emergencies people do not panic. They also highlight the effects of concise messages and the influence of repeated false alarms. This article does a lot in the way of providing insight to emergency planners about the population they are planning for.

V. Regulations for Nuclear Emergency Planning

In the United States oversight of licensed nuclear power generators is shared by the Nuclear Regulatory Commission (NRC) and the Federal Emergency Management Agency (FEMA), as specified in a Memorandum of Understanding between the NRC and FEMA, from the President's decision on December 7, 1979 that FEMA will be responsible for planning with support from the NRC (U.S. NRC, 2006). The NRC still retains their role in public health and safety and "has overall authority for both onsite and offsite emergency preparedness (U.S. NRC, 2006: p1).

After the Three Mile Island accident in 1979 there was a strong push for new planning and communication procedures among all involved agencies from the federal to the local level. After September 11, 2001 the NRC is now also more heavily involved in planning for possible terrorist threats.

There are currently 104 commercially operated nuclear power generators at 65 sites in 31 states (U.S. NRC, 2006). Additionally it is interesting to note, “since commercial nuclear power plants began operating in the United States, there have been no physical injuries of fatalities from exposure to radiation from the plants among the members of the U.S. public” (U.S. NRC, 2006: p1).

“Before a plant is licensed to operate, the NRC must have ‘reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency’” (U.S. NRC, 2006: p2) The decision to license a power generator is determined through guidance from the NRC and compliance with regulations. Licensees must have periodic emergency exercises to demonstrate that licensees can carry out their emergency plans. The NRC assists with and reviews the procedures and training with the purpose of identifying improvements. Plant owners are required to practice their emergency plan once every two years with NRC, FEMA and local officials to ensure they “remain proficient in their emergency plans” (U.S. NRC, 2006: p2). FEMA initially is responsible for reviewing offsite planning and response, while the NRC takes the lead in reviewing onsite planning and response (U.S. NRC, 2006). FEMA’s findings from plan reviews and training exercises, as to the feasibility of offsite plans and recommendations are given to the NRC. The NRC reviews FEMA’s conclusions and their own assessments of the plant to ultimately determine if the plant will impact radiological health and be able to safely operate prior to issuing or continuing a particular license. In the event findings are not adequate the NRC “has the authority to take action, including shutting down any reactor deemed not to provide reasonable assurance of the protection of public health and safety” (U.S. NRC, 2006: p2).

At every power plant the NRC has predetermined two emergency planning zones (EPZs). These are allowed to vary from plant to plant due to local constraints however they are generally defined as a 10 mile and 50 mile radius around the plant. The 10 mile radius is the plume exposure pathway where the primary concern is inhalation of radiological material. The 50 mile radius primarily concerns the ingestion of food contaminated by radioactive materials.

In addition to the planning zones the NRC defines four types of emergencies from least to most serious: Notification of Unusual Event, Alert, Site Area Emergency and General Emergency. A General Emergency is declared when there had been or is potential for a radioactive release that will exceed a safe level. In the event of a General Emergency plant personnel evaluate the conditions of the emergency including weather, plant conditions, how large the release may be, etc. and make recommendations to officials as to the appropriate type of protective actions to take. “Under most conditions, evacuation may be preferred to remove the public from further exposure to radioactive material” (U.S. NRC, 2006: p4). Conditions may not always warrant complete evacuation of the 10 mile zone. In a General Emergency everyone within a 2 mile radius is evacuated and citizens downwind and to either side will be evacuated. People living outside the 5 mile zone and within the 10 mile zone may be told initially to shelter inside and listen to the media for further instructions (U.S. NRC, 2006).

An additional protective action is the use of potassium Iodide (KI) which may be used to prevent the thyroid from absorbing radioactive material. This reduces the possibility of thyroid cancer and other diseases that may result from exposure. This is approved for use by the Food and Drug Administration and 20 states, including Delaware, have a stockpile for all residents within a 10 mile zone of their power plants.(U.S. NRC , 2006). These will be brought the reception centers and made available to evacuees if an evacuation were to occur.

VI. Pertinent Research Knowledge

There are two broad categories of research knowledge that will be useful to planners and researchers in any type of evacuation. These are the research conducted by engineers on the physical aspects of evacuation as well as the research conducted by Social Science research on the human aspects of the evacuees and how they will respond.

Engineering Research

Engineering research in evacuations often refers to improving, modeling and optimizing evacuation planning and operations. In order to do this engineers need a method to determine what exactly is an effective evacuation. Han et al. have attempted to do this by defining an evacuation's effectiveness using "Measures of Effectiveness (MOEs). They argue that simply comparing evacuation times may not be an effective tool to analyze effectiveness because different networks with different efficiencies will have similar evacuation times. Additionally Han et al. notes that using time to evacuate 100% of the population is not adequate because it will not likely happen and is not a meaningful number. They suggest "the time for 95% of evacuees to have cleared the [Emergency Planning Zone] is a more practical and meaningful MOE for representing the entire evacuation process and evaluating an evacuation plan" (Han et al. 2007: p4). Han et al. recommend a Four-Tier MOE framework for measuring models of evacuation. Tier 1 is evacuation time, which is "the evacuation time, defined here as the duration T_n from the commencement of an evacuation order until a specified percentage of all evacuees has cleared the EPZ" (Han et al. 2007: p4). This time should be used at 95% because 100% evacuation will not likely occur due to people not wanting to leave or unable to leave due to social constraints.

The second tier is Individual Travel Time and Exposure time. This tier begins when the disaster first occurs. Han et al state that the percentage of evacuees leaving is represented by a loading curve. The evacuation time is represented by an additional curve and the space between them is the time required for individuals to evacuate. To analyze this and determine the effectiveness the goal is to reduce the distance between the two lines, thereby reducing the exposure to the danger. The third tier of Han et al.'s analysis is a time-bases risk and evacuation exposure. Traditionally evacuation time is the primary tool in measuring the effectiveness. However this tier adds the level of risk to the individual and/or system. If the risk of exposure changes over time the effectiveness may change even though it may have taken the same amount of time as another evacuation. The fourth tier is similar in to the third tier as it assesses risk. In the 4^{th} tier there is a time-space risk and evacuation exposure estimate. This looks at the risk level of evacuees not being evacuated. This will be largely related to time and the location of individuals over an affected area because the risk and quantity of exposure is not uniformly distributed over the evacuation area.

These "Measures of Effectiveness" can all be directly calculated and used as tools to compare evacuation scenarios and determine effectiveness. They are meant to be tools for modeling and Han et al. argue it "allows for more factors to be considered in different tiers" (Han et al. 2007: p7). These MOEs can be combined and used selectively or all at once for different types of emergencies and different evacuation situations.

One of the determinations as to whether or not an evacuation will be successful will be the road capacities at the time of evacuation. Unfortunately, until recently, there "has been a lack of field based study of traffic flow under actual evacuation conditions" (Wolshon, 2007: p0). Wolshon completed a study of road capacities by type and their ability to carry traffic in an evacuation. His data is hurricane specific from Hurricane Katrina, however it is likely applicable to many types of disasters because the physical road traits do not change from disaster to disaster. The empirical data collected shows that highways will not be able to reach their theoretical capacity during an evacuation. In reality the highways capacities will be very much reduced, especially where traffic merges from one type of roadway to another (roadways into controlled access highways etc.) Wolshon also states that there is a benefit to contra flow of traffic spreading the volume of traffic over a larger number of lanes. In the Hurricane Katrina evacuation data shows that for the 24 hour period of contra flow 31,000 vehicles were able to use the contra flow lanes for evacuation (Wolshon, 2007: p15). Although in a nuclear emergency Urbanik (2000) notes that contra flow lanes will not be acceptable because it prevents returning residents and emergency workers from entering the affected area.

Wolshon found the following practical maximum flow from the empirical data:

Conventionally Flowing (Non-Contra Flow) Freeways: 1,300 – 1,500 vphpl (vehicles per hour per lane)

Contra flowing Freeways: 1,000 – 1,200 vphpl

Four Lane Non Controlled Access arterial Highways: 800-1000 vphpl

Two lane rural arterial highways: 500 – 1000 vphpl

These values would be more effective numbers than traditional capacities for modeling and estimating timing of evacuation because they represent a practical capacity of the roadways rather than a theoretical maximum. Additionally these capacities represent roads in optimal weather and conditions. There is the possibility of compounding factors which may reduce road capacity.

Urbanik (2000) summarizes information from previous studies on capacity under adverse conditions. Weather such as rain, snow, ice and fog will reduce capacity. Rain reduces capacity by 10 – 20% and speed by 10%. Capacity will be more strongly affected because drivers will leave more room between vehicles. Urbanik finds that light snow is similar to rain but heavy snow will reduce capacity up to 30%. Its suggested that due to the various weather conditions a reduction of 20%-25% should be used in modeling and estimations.

Capacities are not usually affected by roadway construction because in an evacuation often construction can be moved out of the way and/or the disruptions are only temporary. Additionally breakdowns are not generally detrimental to the overall system because they are isolated events and do not affect large parts of the road network. This also can be further combated by having emergency repair and tow trucks pre-placed along the evacuation route. This will minimize disruption from any motor vehicle collisions or break downs that may occur (Urbanik 2000).

In addition to the capacity of the roadways it's important to talk about the demand that will be placed on the roadway and understand where that demand comes from. There are three groups of the population that will place a demand on the system. These are permanent residents, transients and special facility populations. The transients are visitors to the area who may not live in the evacuation zone but will be in it at the time such as workers or tourists in an area. The special facility populations are intuitions and schools inside of the evacuation zone (Urbanik 2000). Although during an evacuation we are evacuating people, the unit of analysis for evacuation planning is the number of vehicles that will be exiting a particular area. Some studies suggest about 1.3 vehicles per household will be used in an evacuation (Urbanik, 2000: p169). Once the number of vehicles is determined then evacuation time can be estimated through the use of mobilization time, loading time and travel time. Although the estimation of vehicles within the emergency planning zone is useful to planners it's also important to recognize there will be a shadow evacuation outside of the planning zone and background traffic which is not immediately part of the evacuation.

One of the important groups to recognize is the group of people who live outside the pre-planned areas that are traditionally studied, but whom will be using the same evacuation routes. "This group typically has not been considered in ETE studies" (Urbanik, 2000: p170). This group of people is problematic because they will be using the same roadways and adding to the demand or the roadways during evacuation. They will need to be considered in the evacuation demand estimates because they will likely evacuate as a result of the primary evacuation, although they have not been asked to do so. There is a second group of traffic that will need to be taken into consideration as well. This is the background traffic which will be the traffic on the major highways passing through an area at the time of evacuation. These vehicles will need to be considered in the evacuation estimates because, just like the voluntary evacuees, will be detrimental to the overall capacity of the roadways.

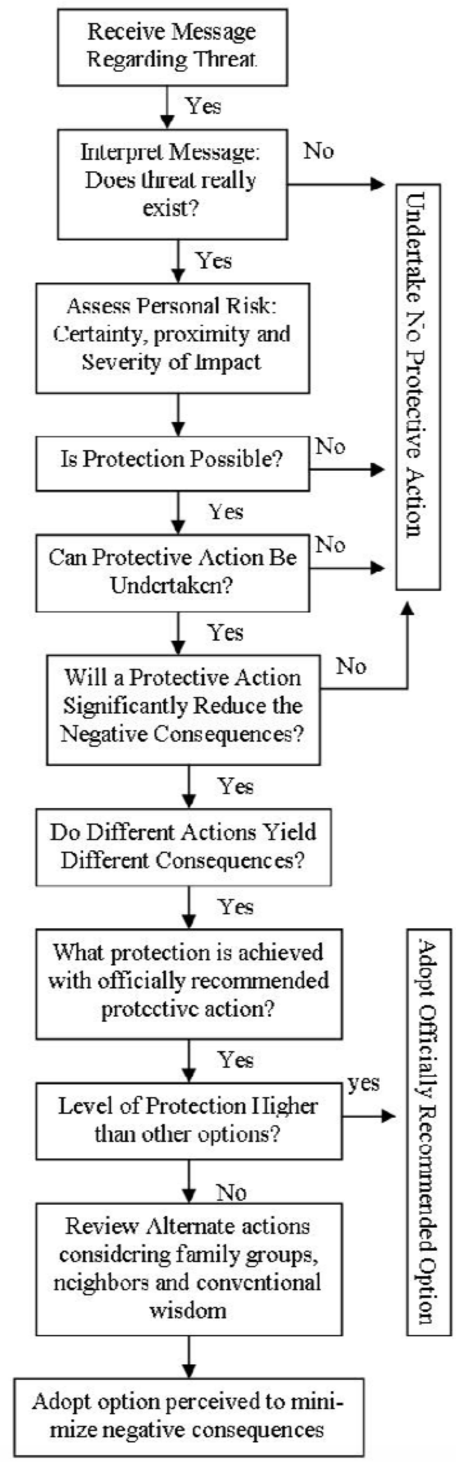


Figure 4
Modified from Perry and Geene, 1982

Social Science Research

In order to better plan evacuation routes it's important to understand the behaviors of the people using the routes. "It has been widely observed that people do not panic in an emergency" (Urbanik, 2000: p177). Typically the best driver in the family will be driving and that drivers will be orderly and act reasonably which will promote good traffic flow. There has been extensive research into the public response to warnings and emergencies and it appears that the same conclusions have been reached independent of the type of emergency (Mileti & Peek, 2000). There is a unique aspect to nuclear emergencies in that there is not a direct link from the nuclear power plant to the population at risk. There are usually several steps in between an emergency and notification to the public and these decisions are usually made by state and local officials with information from plant managers (Mileti & Peek, 2000).

Research shows that people go through a warning process from the time the warning issue until they choose what type of protective measures to take. Perry and Greene (1982) suggest the process from the issuing of the warning to taking action can be modeled by the chart in figure 4. This means that information must be plentiful and that the warning information must be disseminated effectively. "For example, sirens miht not be able to be heard if there is a strong wind and, especially, if people are indoors with noisy air conditioning or other equipment operating" (Mileti & Peek, 2000: p183). The information that there is a possible risk will need to be communicated in many ways to ensure that it is widely heard by the population at risk. Once the people have heard the warning they have to understand the warning. Simply because emergency management and officials say there is a danger does not mean people will perceive that they are in danger. Third people need to believe in the accuracy of the information they are being provided with. Once they believe the information is accurate they must personalize the risk. Once the individual has realized there is a personal threat they must decide what to do about the risk and carry out their decisions. In order to accomplish all these steps people will not wait for the information to be handed to them, they will seek information from media sources, friends and co-workers. For these reasons information must be abundant.

Mileti and Peek (2000) note that there are five parts to the content of the warning message: "hazard, location, guidance, time and source." It is important to have all this information so people can make better informed choices about the threat. Officials often worry about giving too much information but people are "information hungry" and "rarely, if ever, get too much emergency information in a warning" (Mileti & peek, 2000). People won't remember all the information they hear in a detailed emergency message so it should be repeated often so they may get all the details. A warning message isn't subject to the standard 30 second rule that advertisers use to sell a product (Mileti & Peek, 2000).

> "A warning message must provide the public with information about the impending hazard that has precipitated the emergency warning. Every warning should consist of two parts: a description of the event that s expected to occur and an explanation of how it is a threat to people's safety. For Example it is not adequate for a warning message to state simply that radioactive material might soon escape from the nuclear power plant. Such a warning would leave the hazard in a "black box." Instead, the warning must describe the character of the impending hazard. For example, one might say that rising pressure in the containment building might cause an explosion that would destroy the protective seals around the control cables into the reactor building. This would allow radioactive material to be released into the air like a cloud and dissipate as it travels downwind" (Mileti & Peek, 2000: p184).

A message like this including specific evacuation details and details about the nature of the emergency would be much better and allow the public to make an informed evacuation decisions. Officials are often concerned if the public is given too much information they will panic, however that is a myth propagated by the movies. The public does not panic, even in the event of a nuclear emergency (Mileti & Peek, 2000). People may have elevated stress as a result, but they will respond by becoming information hungry and withholding information from the public is detrimental to the warning and evacuation process (Mileti & Peek, 2000).

One reason officials may be afraid of issuing an evacuation or too much information is the fear of a false alarm. If dealt with properly a false alarm will not be detrimental to the public's view about evacuation.

When the reason for the mistaken alarm is properly explained to the public, the integrity of the future alerts will be maintained. One case where this is particularly true is with emergency sirens.

People are unable to remember particular siren patterns and if a siren is used is should be used simply as a tool to tell the public to go seek information about the emergency. If the sirens are falsely sounded without any explanation as to why there was a false alarm, the public will begin to ignore the sirens. Additionally if different patterns are used for different typed of emergencies it will cause confusion and ultimately the public will not respond to the method of warning (Mileti & Peek, 2000).

Often when a warning is issued the public will not automatically take protective action after the first warning and it can't be assumed they will follow instructions given by officials. People will first seek out more information in order to determine if the threat will affect them, as seen by figure four (4). They may wait for additional warnings to see if the threat is real or they may even call family and friends to see if they are taking any action. For this reason warning messages should be repeated often to establish the urgency of the warning. Additionally once the individual understands the threat and personalizes the message, if the warning message being repeated isn't clear they may try to follow someone else's instructions, such as a friend or neighbor or they may simply do "what makes sense" to them.

Research shows that a instructions and a warning will not simply cause everyone to evacuate. Everyone must go through a process of receiving the message and comprehending the risks before they will be willing to take action. Instructions must be very clear and detailed so the population at risk does not feel like information is being withheld from them. If the reason for the warnings are understood and people feel they are being all the information they will trust official sources. However before they take their own action they will still try to confirm the threat is real, which can be complicated for a radiological emergency. Emergency plans must account for this and take this information into consideration by providing frequent updates to the public through warning messages and media sources. How the public receives the risk will largely be determined by all these factors and their own personal experience with the emergency.

VII. <u>Three Mile Island Incident</u>

Nuclear evacuations are very infrequent, so there is little data and few historical accounts of actual incidents. The accident at Unit 2 of the Three Mile Island plant in March 1979 was the most recent and relevant nuclear emergency. “The accident at Unit 2 at the Three Mile Island nuclear power plant produced organizational and individual responses that were a mixture of those common to natural disasters and those that were unique” (Stallings, 1984: p1).

The events at Three Mile Island (TMI) began on March 28 with news of problems inside Unit 2, and by the next day the problems were improving. However on Friday March 30 some radioactive gas escaped to the air outside the containment building (Stallings, 1984). Official evacuation orders were never issued, although it is estimated that 144,000 people left in a voluntary evacuation (Stallings, 1984). Stallings (1984) found that approximately half of the residents within five miles of the reactor left and about one third of the residents within 10 to 15 miles from the reactor left. This may be due to several reasons. It was the weekend and many employees were let out early, so families simply decided it would be good to get away for the weekend to visit family and friends outside of the area. Additionally, there was an extreme amount of uncertainty about the threat of a true emergency causing people to leave out of fear of the unknown. Stallings (1984) found “The probability of evacuating was inversely proportional to the distance of that household from the unit” (Stallings, 1984: p13). Stallings also found that there was credibility issues with public officials and those who did not believe the officials were being truthful were more likely to evacuate.

This highlights one of the primary issues found from the TMI incident. Officials could not agree on whether or not to issue an official evacuation order. On Friday morning the Nuclear Regulatory Commission recommended an evacuation and Pennsylvania state officials stated there may be a possible evacuation (Stallings, 1984: p18). Several evacuation advisories were issued, including a recommendation to stay indoors and that pregnant women and children within 5 miles should leave. This was the closest statement to an actual order to evacuate that was ever issued by official sources. This is one of the major aspects that may be unique to Nuclear Emergencies. There are very few people who have any historical knowledge of this type of emergency and officials must rely on experts who often disagree within their own field about the magnitude of the emergency. There is a dilemma of what type of evacuation to issue or to even mandates an evacuation and on top of that there are the unknown political and physiological consequences of issuing an evacuation. Stallings (1984) argues that this dilemma is partly solved by making the evacuation a personal choice rather than an official mandate, which is effectively what emergency managers did at Three Mile Island. However this type of evacuation will be inhibited by social constraints such as people being prevented from leaving due to jobs or financial inability to evacuate. Evacuation can be expensive, with cost of fuel and if you don't have nearby family or friends who are unaffected, staying in a hotel can be too expensive for some residents.

Additionally the research from TMI shows families will not evacuate until everyone returns home and the family can evacuate as one unit. This was partly alleviated in Three Mile Island because many schools closed and many nonessential state employees were allowed to go home. State officials also encouraged private companies to follow suit. This is a huge dilemma faced by public officials in times of an emergency as rare as this. "The decision to order an evacuation when there [is] a chance that its costs will outweigh its benefits will be a difficult one to make. This should not mean that public officials should avoid taking steps to see that voluntary evacuation is a viable alternative" (Stallings, 1984: p23). Three Mile Island showed us that if there is a Nuclear/Radiological emergency at a nuclear facility an evacuation will occur whether or not the state issues an official order and there will be a population movement that will have to be managed.

VIII. <u>Current Nuclear Evacuation plans for Delaware</u>

Description

Many states and municipalities have developed “all-hazards” evacuation plans for their jurisdictions. Delaware has several plans in place to prepare for hazards from hurricane to nuclear emergencies and a host of other emergencies that can occur within and affect the state. The focus of this section of the review is on evacuation plans for a nuclear emergency in Delaware.

The state of Delaware has several plans in place that all address a nuclear emergency affecting Delaware’s residents. The primary plan in the event of a Nuclear Emergency at the Salem/Hope Creek Nuclear Power Generators is the State of Delaware Radiological Emergency Plan (REP). This plan was updated in January 2008 and is to “coordinate and implement a comprehensive state and county response to protect the public from the hazards of a radiological emergency” (State of Delaware, 2008: S2 P1). This plan provides very detailed responsibilities for all organizations that may respond in the event of an emergency at the Salem/Hope Nuclear Power Generators. The REP is organized into sections that define the role of each organization. The plan defines the role of every organization from the Department of Defense to state and local agencies and organizations like the Red Cross. There are a series of Standard Operating Procedures that should be carried out in an emergency evacuation for each aspect of the emergency.

The SOPs are organized by numbers from 100 to 1502 (Non Continuous). The 100 series of SOPs defines notification procedures for various organizations indulging DSP, DEMA, Salem/Hope Creek and the NRC. The 200 series is a SOP for mobilization. The 300 series are SOPs for analyzing the extent of the emergency with recommendations for action. The 500 series Covers Emergency Alert Message information including details for how to activate the Emergency Alert Siren Notification System and scripts of various messages to be read. There are also instructions for actions to be taken by local fire companies in the event the siren system fails. The 600 series is for protective actions and relocation of important information. SOP 700 defines the Traffic and Access Control. The 800 series of SOPs defined controls and monitoring for radiation exposure control. SOP 900 is a worker decontamination procedure. SOPs 1000, 1100 and 1200 define procedures to evacuate general and special populations. SOP 1300 and 1400 set up evacuation reception centers and shelters. The 1500 series of SOPs defines procedures for decontamination and transport of contaminated or injured individuals to receiving facilities.

In the REP there are predetermined 5 mile and 10 mile radii Emergency Planning Zones (EPZs) with specific access control points. A list of these control points can be found in SOP 700 of the radiological plan. At each of the access control points there is an access control sign with emergency information for evacuees. This sign is pictured in figure 5 and can be found at each of the control points at both the 5 and 10 mile radius.

Figure 5: Access Control Sign
State of Delaware Radiological Emergency Plan, 2008

Planners have also pre-determined two Emergency Evacuation Reception Centers, the Frank K. Stern Readiness Center in Wilmington and the Smyrna Readiness Center in Smyrna Delaware. SOP 1200 provides instructions for general population evacuation and does account for special needs populations, including residents without transportation. For those without transportation they have pre-planned bus routes, detailed in SOP 1200, to assist this portion of the population with evacuation. These busses will be provided by DelDot (Paratransit). SOP 1200 states there will be approximately 1000 people in need of transportation, as of 2004. There is an additional special needs population at the Delaware Correctional Center in Smyrna that the plan simply states will not be evacuated and provides no further details.

In addition to the State of Delaware Radiological Emergency Plan for an Emergency at Salem/Hope Creek there is a support plan, the Emergency Evacuation Operations Manual (Jacobs Edwards and Kelcey, 2007). This manual is provides guidance for traffic operations in the event of a nuclear emergency at Salem/Hope Creek. Planners have made this very detailed including where to put Variable Message Signs and how many barriers and cones will be needed at each traffic control point. There are 15 access control points for the five mile radius and 30 additional access control points for the 10 mile radius. This plan also addresses special needs and handicapped populations stating that they will "remain in their homes until emergency vehicles arrive to transport them to reception centers" and that DEMA updates a registry of individuals requiring special needs quarterly (Jacobs Edwards and Kelcey, 2007: S5 P1). This plan is designed primarily to be used by the Delaware Department of Transportation (DelDOT) and Delaware State Police (DSP).

There is a third plan that is designed simply to manage traffic incidents on a day to day basis such as major accidents and heavy congestion. Both of these plans provide detail for traffic management operations in the event of an emergency. These plans have details with expected behavior of traffic in emergencies and are a tool used by the management agencies to provide for effective evacuation. The Salem and Hope Creek plan is extremely detailed and provides diagrams for traffic control points limiting access to the affected area, while the Transportation Incident Plan is more general and has details for all traffic incidents.

The Delaware Emergency Management Agency (DEMA) and PSEG Nuclear, LLC, sponsored a study done by KLD Associates, Inc. which analyzed the evacuation time estimates within the exposure area. This report is titled Salem/Hope Creek Nuclear Generating Stations Evacuation Time Estimates within the Plume Exposure Pathway (KLD Associates, 2004). This study investigates the populations affected by an evacuation at the mentioned plant and provides insight into the expected time frame for complete evacuation of the five and ten mile exposure zone in New Jersey and Delaware. KLD included estimated highway capacities and Level of Service through use of field surveys, 2000 census data and generalized assumptions. KLD neglected the transient population and assume 100% of the population will evacuate if an evacuation ordered is issued. This is an update to a study of Evacuation time estimates for Delaware completed in 1994 by JB/A, Inc (JB/A, INC. 1994).

Strengths and Weaknesses

Although both plans often make references to each other and are meant to support each other there is one large discrepancy that unless the writers of the plans are the ones executing the plans could prove to be problematic. In the State of Delaware Radiological Emergency Plan it is stated that "During an evacuation, buses will be dispatched along pre-designated routes to pick up residents without personal transportation means" (State of Delaware, 2008 SOP 1200, p2). However the Traffic Operations Manual states "Residents living on an evacuation route will wait in their homes and watch for the arrival of the buses. Residents who do not live on an evacuation route will walk to the nearest bus route and wait for the busses to arrive" (Jacobs Edwards and Kelcey, 2007. S5 P1). There is evidence in the Traffic Operations manual this is for people without transportation, but it should be more clearly stated or stated in the same way in both plans. These plans were issued within about 3 months of each other

(January 2008 and October 2007, respectively). This issue needs to be addressed and may simply be a matter of wording in the plans; however it could cause significant confusion among practitioners of these plans. Additionally many of the special needs populations may not be able to walk to the busss to be evacuated or be aware of the bus route locations.

The State of Delaware has noted the special needs populations in their evacuation plans and has a plan to mobilize busses and emergency personnel to move these groups out of the evacuation zone. However the plan fails to recognize multiple trips will be necessary and does not address the issue of a timeframe for evacuation of these individuals. If the busses spend long periods of time idling in evacuation traffic they will be less effective in evacuating the special populations, such as residents without transportation means. Additionally the plans include the use of ambulances and other Emergency Medical Services (EMS) vehicles to move the special needs populations out of the emergency zones. However this does not seem to be a timely way to evacuate these individuals. The normal day to day ambulance calls for service will not end and people will still be calling 911 for non-evacuation related emergencies. It is unknown if there are enough additional EMS vehicles to meet the need for 911 emergencies as well as evacuating individuals from the affected area.

The Access Control Points in both plans are well defined and the plans even include specific directions for the agencies setting up the control points (State of Delaware, 2008 SOP 700-B5). One of the specific directions in SOP 700-B5 is "divert traffic away/prevent traffic from entering the evacuation area." This direction issued to State Police could be problematic for people wishing to enter the evacuation area to assist their families in evacuation. People will need to enter the area for very logical reasons and should not be prevented from doing so until a designated period of time after the evacuation has begun. For example in single vehicle families the family member with the vehicle may need to return home to assist with family evacuation. At a certain point this will have to be prevented as entrance is no longer safe. However it may prove to be problematic if people are not allowed to enter the area on an as needed basis for a designated amount of time at the beginning of the evacuation.

Time estimates of evacuation from the ERPAs were completed in 2004 by KLD Associates in a report for the Delaware Emergency Management Agency and PSEG Nuclear, LLC. the owner and operator of the Salem/Hope Creek nuclear power generators. In this plan there are very good details about the population characteristics of the emergency planning zones (EPZs). KLD Associates found many of the special details about the populations including major employers and special locations with transient populations, such as Fort Delaware and Fort DuPont, inside the 10 mile EPZ. Their estimates of population and the number of vehicles to be evacuated seem to be reasonable and useful to planners.

The estimates also make some suggestions about traffic management that are very prudent and should be incorporated into the current plans. KLD Associates state that police should be used to control traffic during an incident, but they are careful to mention they should facilitate traffic flow out and discourage movement towards the nuclear power generators. This terminology is used rather than words such as prohibit because traffic management will need to be flexible during an emergency. They note there are very good reasons why drivers may need to enter the evacuation area, such as to join their family picking up a relative or an emergency worker entering the area (KLD Associates, 2004 p.61). In their time estimates they do take this aspect into account by assuming people will arrive and depart over a span of time and do not assume everyone will depart at once.

The time estimates do address the need for transportation of special needs populations. The plan estimates that 33 Bus trips will be required for evacuation in Delaware and includes time estimates for the multiple waves of busses expected to occur. They have also collected population estimates of health care facilities and schools that may be affected by an evacuation. The evacuation time estimates for these specific populations are included as a separate piece of analysis in KLD Associate’s report.

However the plans make several aspects that could be improved upon. The time estimates have many possibilities of scenarios that are complicated and could be confusing to emergency planners. There are almost too many scenarios and possibilities that it becomes cumbersome. It's hard to find what exactly the evacuation time estimates will be for a given situation. Additionally there are a few assumptions that the time estimate uses that is concerning. KLD Associates do not take into account weather conditions into time changes for evacuation. "Rain does not influence ETE [Evacuation Time Estimates]. The longer ETE associated with the snow scenarios reflect an additional allocation of 30 minutes for people to clear their driveways sufficiently to gain access to the roadway system." (KLD Associates, 2004 p36) However research shows that highway capacities will be reduced in rain and further reduced by snow. The time estimates are very detailed and KLD Associates did very good research as to the people who would be affected in a nuclear emergency. This is a step in the right direction, but the time estimates need some revisions to take into account extenuating circumstances, such as inclement weather.

The time estimates also do not address the possibility of "Shadow Evacuations" The capacities suggested by the plan will not likely be obtained because people outside of the evacuation area will also evacuate when they perceive they may be at risk. These people will be using the same evacuation routes and be part of the same capacity, which will reduce the ability of the system to evacuate the population. A model for the Delaware evacuation should attempt to include this shadow evacuation in their estimates and include those residents in the evacuation plan.

Distribution of Information to the Public

In the event of a radiological emergency at the Salem/Hope Creek generators the Delaware Emergency Management Agency (DEMA) is primarily responsible for notification of the public. "Notification of the affected public will be by activation of the prompt notification siren system" (State of Delaware, 2008: s4 p15). The primary alerting system consists of 37 "Land Based" sirens which are linked as a single system and can be activated by the Delaware State Police at their headquarters in Dover, Delaware. (State of Delaware, 2008: SOP 501). Additionally Delaware Division of Parks and Recreation (DPR) and Delaware Fish and Wildlife Management (DFW) will notify visitors to their respective areas. The states that once people hear the sirens they will turn on their radios to listen for Emergency Messages on predetermined radio stations (See Appendix II). If this notification system fails instructions exist in the SOP 500 series for using the volunteer fire department for notification of the public using mobile route alerting. "Additional public notification can be made by the volunteer fire companies, if necessary" (State of Delaware, 2008: s4 p16).

Emergency warning messages will also be displayed on road signs. According to the Radiological Emergency Plan all evacuees will be directed to either of two shelters, for the North the DNG frank E. Stern Readiness Center near Wilmington with William Penn High School as a back up and in the South there is the Smyrna Readiness Center with Delaware State Fire School as a backup. The map that is to be given to evacuees can be found in Appendix I. Once evacuees have arrived at either reception center they will be monitored for twelve hours and decontaminated if necessary (State of Delaware, 2008: s4 p16).

Prior to a radiological emergency DEMA has two brochures/flyers designed to educate the public. These are available on DEMA's website but there is no information about availability or dispersion to the general public if they do not seek out the information on the website. A copy of these flyers can be found in Appendix II. The first flyer is a description of the Emergency Response Planning Areas (ERPAs) which are designated by a color and letter. It instructs citizens to locate their home and work or school and remember which zone they are in for evacuation purposes. The second flyer is on Potassium Iodide which is used to prevent the thyroid from absorbing radiation. It is a postcard that was sent out to residents of the ERPAs instructing them about the availability of KI and briefly about its purpose. A quick check of the most recent Wilmington Delaware phone book showed that there are descriptions of the ERPAs and radio stations to turn to in the event of a nuclear emergency. These are the only sets of information that appears to have been made available to the public about this type of emergency.

IX. Special Considerations

There are many considerations that will complicate evacuations and should be considered for future planning. For example, weather plays an important role in the direction and magnitude of an evacuation. As the plans are currently set up there are two radii at 5 and 10 miles preset for evacuation. In the event of an emergency, weather conditions, particularly wind direction and speed, may dictate a larger affected area than those zones.

Additionally, research shows that in a snow storm, road capacities are reduced by 30% and heavy wind and rain can reduce capacities by 10-20%. If these types of weather events were to occur during a radiological emergency they could have a significant impact on the effectiveness and time required to evacuate. Additional traffic on the roads due to holidays or beach goers in the summer may also have a significant impact on the effectiveness of an evacuation.

In addition special needs groups including those with disabilities, those without transportation and residents with medical problems that will have to have special evacuation requirements that will take longer than standard evacuation because those evacuation vehicles will be subject to the same traffic conditions as regular evacuees. There is also a special needs population that is non-English speaking which will require additional efforts to warn. At present time there is no mention of broadcast messages or warnings in other languages to help facilitate the warning process.

There is a possibility of a “shadow evacuation” where people outside the areas advised to evacuate will evacuate. Although this portion of the public has not been directly told to do so, upon hearing there is an emergency they too might evacuate. This could be detrimental to the system because it will add to the volume of vehicles evacuating. There are a limited number of evacuation routes in Delaware so it is likely that these evacuees will be using the same evacuation routes as the public directed to evacuate.

It is worthy to note that if there is an emergency at the Salem/Hope Creek nuclear generators an evacuation isn’t always going to occur. Officials and experts will determine if the best action, based upon the magnitude of the release, weather conditions and the threat the release poses to the public. Shelter in Place can be issued when a shelter-in-place exposure dose of radiation is expected to be less than 1 rem Total Effective Dose Equivalent (State of Delaware, 2008: s3 p4). Shelter in place will always be considered before evacuation. If evacuation is not required orders for shelter in place will be issued. Further information of Protective Action Guidelines, including instructions for sheltering in place, can be found in Section 3.4 of the Delaware Radiological Emergency Plan (State of Delaware, 2008).

X. <u>An Application: Delaware City Evacuation</u>

Using the information and knowledge from the existing plans, past studies and research and exploratory analysis of the evacuation time for Delaware City, Delaware in the event of a nuclear emergency at the Salem/Hope Creek site was conducted. This example is meant to highlight some of the issues that may arise in the event of an evacuation due to a radiological event at the Salem/Hope Creek nuclear power generators. It is a very basic example with many assumptions and more research should

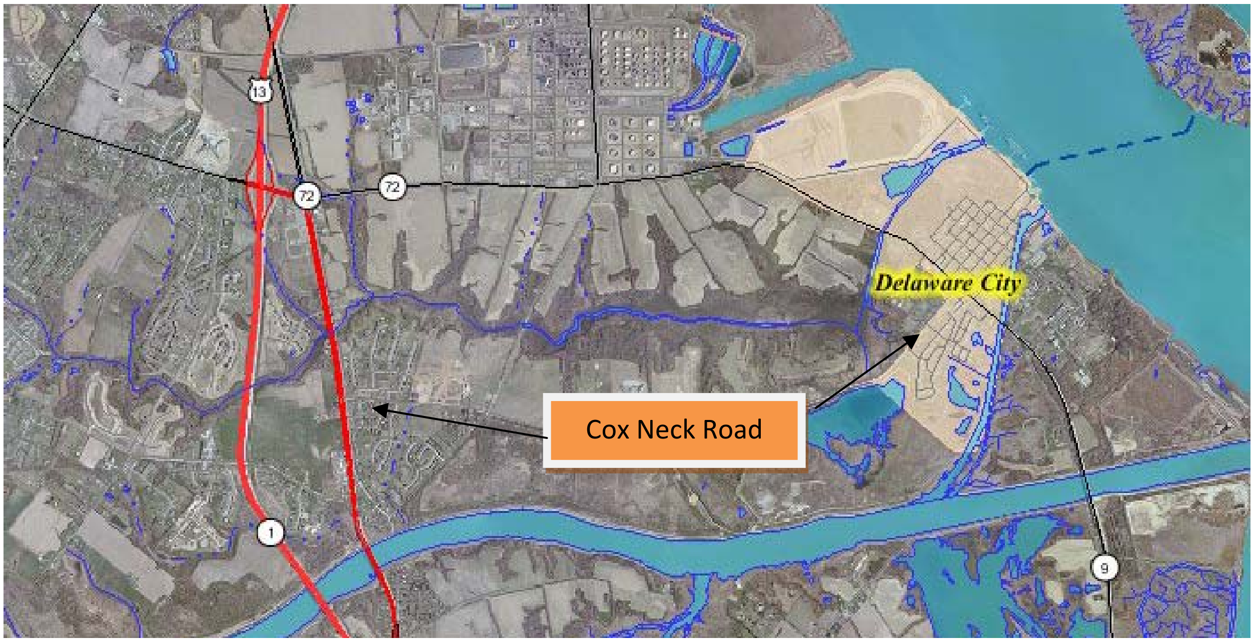


Figure 6
Data Acquired and compiled from Delaware Datamil: http://datamil.delaware.gov/

be done to get a more precise estimate. However this simple example works well as a practical example of the issues and the differences that arise in certain situations.

Delaware City is located on the corner created by the C & D canal and the Delaware Bay. It has a permanent population of approximately 1,500 and a transient population of approximately another 500, which represents approximately one twelfth of the total evacuation that may have to be evacuated. Delaware City lies near the outside edge of the 10 mile radius zone around the Salem/Hope Creek nuclear generator. There are two primary evacuation routes out of Delaware city: Route 9 / 72 West and Cox Neck Road. There are several special needs populations within Delaware City. This includes two tourist attractions, Fort Dupont and Fort Delaware (Pea Patch Island) and one long term health care facility, Governor Bacon Health Center.

Objective and Methodology

This assessment uses the knowledge gained from current evacuation plans and engineering and social science research to highlight issues that may arise during an evacuation. In order to do this assessment rough assumptions of vehicles and road capacities are used. The assessment is focused on evacuation from Delaware City and once the vehicles have joined the larger evacuation population they are no longer considered by this application. This is done in an effort to have a focused look at time estimates for vehicles leaving Delaware City.

Assumptions

In order to conduct the analysis, several assumptions are required. This section documents the assumptions used. Table 1 is an estimate of the number of vehicles that will require evacuation. Table 2 shows the details of the evacuation routes. This includes the average daily traffic, capacity during an evacuation and subsequently the additional vehicles that may be placed on the roadway, limited by capacity.

Table 1. Vehicles Requiring Evacuation

	Population	Vehicles
Delaware City Residents (2006)*	1512	756
Delaware City Marina**	150	62
Fort Dupont**	300	150
Fort Delaware**	200	75
Totals	2162	1043

*Population Estimate from City-Data.com
**KLD Associates (2004)

Table 2. Evacuation Route Details

	Existing Traffic*		Evacuation Capacity	Additional VPH	Delaware City Capacity to Evacuate
	VPHPL	North - VPH	North – VPH		VPH
Route 1+	900	1800	2800	1000	167
Route 13+	450	900	1800	900	150
Route 9+	0	0	500	500	500
Cox Neck Road+	0	0	500	500	500

+ Adapted from Wolshon, 2007 p15
* Adapted from USDOT – FHWA Highway Performance Monitoring System as of 24 July 2008

Time Estimates:

Using the 2004 report from KLD Associates (2004) and current population estimates the possible number of evacuees requiring evacuation is estimated. Additionally the KLD associates report was used to assume numbers of vehicles from special locations within Delaware City. The special locations included in this assessment include Fort Dupont and Fort Delaware (Pea Patch Island) which are both historical tourist attractions just outside Delaware City. For the population estimate it is assumed 1 vehicle will be used to evacuate on average 2 people, which is in line with other evacuation estimates. In the Emergency Operations Plan for Delaware City (Emergency Operations Plan Delaware City, 2008) there are two primary evacuation routes from the town center. These are Route 9/72 and Cox Neck Road, as seen in Figure 4. The evacuation plan is set up such that all traffic from Route 9/72 is routed onto Route 1 North and all traffic from Cox Neck Road is routed onto Route 13 Northbound. At the time an evacuation occurs there will be already existing traffic on Route 1 and 13. The Federal Highway Administration's Highway Performance Monitoring System was used to estimate potential traffic on any given day. The Average Daily Traffic (ADT) estimate was reduced to a daily rate of Vehicles per Hour per Lane by assuming 90% of the traffic occurs between 6am and 8pm and the knowledge that both roads are 4 lane highways. This leads to the result there will be 900 vehicles per hour per lane (vphpl) on Route 1 and 450 vphpl on Route 13. Assume all Delaware City traffic will go initially north (as the direction away from the power plant) there will be 1800 vehicles per hour (vph) and 900 vph, respectively, at the time of evacuation.

Research shows highway capacities during evacuations will be reduced Wolshon (2007). At the time of evacuation there will only be room for an additional 1000 vph on Route 1 and 900 vph on Route 13. The population in Delaware City and number of vehicles seen in Table 1 is approximately 1/6th of the overall population that will need to be evacuated using the northbound capacity of the highways. (This assumes that approximately half of the Delaware population will evacuate north and approximately half will evacuate south.) Assuming Delaware City gets "its fair share" of the evacuation capacity each capacity was divided by 6 to represent the possible number of vehicles per hour that will be able to be added to the highway system from Delaware City. This information is found in Table 2. Although the two primary roads leading out of Delaware City have a capacity of 500 vph during an evacuation the number of vehicles entering the highways at any time will be the governing factor in calculating time for evacuation. Using this information the following is found:

Route 9/72:
522 Vehicles / 167 Vehicles per Hour = 3.13 Hours

Cox Neck Road:
522 Vehicles / 150 Vehicles per Hour = 3.48 Hours

We can assume it will take up to 45 minutes for families to be ready to evacuate from the time the evacuation order is received. This is up to 15 minutes of time for the warning to be received and 30 minutes of preparation for evacuation (Urbanik, 2000). Some of these events may occur in parallel however this represents an estimate for the average evacuating family. The time for evacuation is the time when the last vehicle leaves therefore this results in an evacuation time of:

3.48 Hours + .75 Hours = 4.23 Hours (4 Hours, 14 Minutes)

There are several limitations to this estimate and it is meant to be a rough estimate for explanatory purposes only. This evacuation does assume 100% evacuation, however it does not take into account vehicles entering the area to evacuate the special needs populations because once they begin to exit they are part of the evacuee traffic. Therefore this is more likely to represent 90-95% evacuation of Delaware City. Knowing that 100% evacuation is not likely this can be assumed to be a reasonable of time required for evacuation. This does not represent the best case scenario of an approximate travel time of about 30 minutes from Delaware City to the North reception center and it is not a worst case scenario where traffic is not flowing at a rate that allows for evacuation. This is likely a middle time estimate.

Research shows that weather will have a significant impact on evacuation reducing capacities by 10-20%. Both of these evacuation routes are prone to flooding (Emergency Operations Plan Delaware City, 2008) which would lead to a reduction of road capacities in the event of an evacuation during a rain storm. Since these roads are prone to flooding if the capacities are reduced by 20% the following increase in evacuation time will occur:

Table 3: Evacuation Route Details Assuming Reduced Capacities due to Weather

	Existing Traffic*		Evacuation Capacity	Additional VPH	Delaware City Capacity of Evac.
	VPHPL	North - VPH	North – VPH		VPH
Route 1+	900	1800	2800	1000	134
Route 13+	450	900	1800	900	120
Route 9+	0	0	500	500	500
Cox Neck Road+	0	0	500	500	500

\+ Adapted from Wolshon, 2007 p15
* Adapted from USDOT – FHWA Highway Performance Monitoring System as of 24 July 2008

Route 9/72:
522 Vehicles / 134 Vehicles per Hour = 3.90 Hours

Cox Neck Road:
522 Vehicles / 120 Vehicles per Hour = 4.35 Hours

Total Evacuation Time: 4.35 +.75 = 5.1 Hours (5 Hours, 6 Minutes)

With the addition of rain as a factor the evacuation has increased to a scenario of 5 hours and 6 minutes. These assumptions assume that Delaware City will be able to receive its share of the evacuation capacity, however in an actual evacuation that will not likely be the case since there will be many people south of Delaware City evacuating simultaneously. Additionally research shows that there will be voluntary evacuees outside of the evacuation area that will be using the evacuation routes as well, which will add to the number of vehicles attempting to use the same possible capacity (Urbanik 2000).

This example shows that even in the best circumstances, with Delaware City receiving their “fair share” of the evacuation capacity evacuation will need to be ordered well in advance of the time for citizens to be out of the affected area. If conditions degrade due to weather or other circumstances the evacuation time can quickly be lengthened and slow the overall evacuation process. Additionally there is the complicating factor of evacuating the special needs group via buses because they will take as long to evacuate as vehicles inside of the area, they will not be able to make a simple loop and return to the area easily. This example is a simple model of the possibilities during an evacuation and enumerates what can happen when the conditions are not optimal which will likely be the case in any evacuation.

XI. Recommendations

In reviewing the research and current practices related to evacuation planning in Delaware several recommendations have become apparent. Evacuation plans need to be a process rather than a list of actions. In the existing plans there is a very detailed inclusion of where to put cones and personnel but it would be beneficial to turn this list of actions into a process that goes from formulating the warning message to implementing a process to facilitate evacuation and limit entrance into the emergency planning zones. Evacuation is a process that goes from formulating a warning to the population understand, comprehending and personalizing the warning and then taking protective action. Evacuation planning should plan, as best as possible, to facilitate this process.

Additionally there is a need for consistency in both primary Delaware plans. In many cases the plans are very consistent with the access control points, plans for reception centers and the locations of barriers. However there are several areas in which there could be improvements, for example the bus plan. Busses should be used to evacuate those without other means of transportation which is clearly stated in the Radiological Emergency Plan, however in the Traffic Management Plan it is not as clear. It may also me worthy to note that, as seen from other evacuations, bus drivers and other personnel who may be directly affected by the radiological emergency may be unable or refuse to show up for work. In spite of that the busses could be beneficial to evacuate special needs populations who do not have transportation but are able to ambulate on their own.

There is still the other portion of the population who will not be able to move themselves to the busses. The plan mentions the use of ambulances and wheelchair vans to evacuate this portion of the population. During any evacuation there will be a limited amount of resources, such as ambulances, because Emergency Medical Service vehicles will still need to respond to the same volume of 911 calls that remains unchanged even during an evacuation. There a limited number of ambulances to begin with, for example Delaware City only has two, and all these resources can't simply be redirected in an emergency. The ambulance aspect and the use of busses with the assistance of the National Guard should have the feasibility reviewed and perhaps have a contingency plan put in place, such as mutual aid from neighboring states.

Part of the review of the Delaware plans should be a look at the time estimates. KLD Associates did a very good job at extensively researching the population that would have to be evacuated in a radiological emergency. They have very good data on who, how many and where people will be located. However there are certain aspects they did not take into account. Research shows that weather can play an important factor in the amount of time required for evacuation. The current time estimates only allow 30 minutes additional for snow and no additional time for rain or heavy wind. They make the statement that weather will not have an effect on evacuation and the additional 30 minutes is for people to clear the snow from their driveways (KLD Associates, 2006: p36). In reality weather can reduce road capacities by as much as 30% for snow and 10-20% for rain during an evacuation. This aspect of the plan and evacuation should be reviewed. KLD associates have many scenarios accounting for different times of the year and magnitudes of emergencies however the report becomes almost too cumbersome with so many different possibilities. A streamlining of a few representative scenarios (Good Weather, Bad Weather, Summer Winter, etc.) would be useful to emergency management in creating a process for evacuation.

In the KLD Associates report (2004) they mention that traffic should be facilitated and entry into the emergency planning zones should be discouraged (KLD Associates, 2004: p61). This point is very good in stating that there is a need for flexibility in the evacuation plans. People will need to enter the evacuated areas, especially in the first stages of the evacuation, for very logical reasons. This will be important for the police to aid in this. This could remedied in part by viewing the evacuation as a process rather than a list if definitive steps. Additionally, in the plans part of the flexibility issue is being able to accommodate for additional evacuation traffic from shadow evacuations. The current plans do not take into account more people will be evacuating than requested to. DelDot and State Police will need to be able to accommodate this additional and unplanned traffic.

Briefly it may be worthwhile to mention the possibility of adding a Radiological Emergency signage plan. There are several evacuation routes with signs through the state of Delaware. However none of them are specific to a nuclear emergency. If an evacuation is ordered people may not always follow instructions given by emergency management so it is important to make the evacuation as clear as possible. If there was a different sign for a radiological emergency that people could be told to follow, perhaps a different shape and color, people might be more inclined to follow the signs. If they follow the current evacuation signs there could be significant confusion amongst the evacuees.

The addition of radiological emergency signage falls in the broad category of notification of a radiological to the public. At the present time the plan calls for the use of sounding of sirens to alert the public to tune into 93.7 FM and listen for further instructions. This sign can be seen in figure five (5). However many of the fire departments in Delaware have fire sirens that go off for certain types of fire emergencies and this could be confusing for citizens that do not know the different types of sirens. Additionally there needs to be more education about what a warning means and how people will be warned in an emergency. There are an unknown amount of the emergency siren notification signs through the affected portion of the area and there are several brochures put out by DEMA about radiological emergencies (Found in Appendix II), however research should be done as to if there is enough education to be useful to the public. Additionally some research (Mileti and Peek, 2000) states that sirens may not be a reliable method to notify the public especially if they are indoors or near noisy equipment they may not hear or understand the siren.

As a final note on warning information, there is also a growing Hispanic population in Delaware and multi-language warnings should be issued so people who have trouble with the English language will still able to receive the warning. The signs and brochures currently available on the State of Delaware’s website are only in English. There is no specific direction for broadcasting warning messages in English and Spanish during an evacuation. This may create confusion and a lack of warning to the Hispanic population that will need to be evacuated. This issue should be address to prevent leaving a portion of the population out of the warning information.

XII. Future Research

Continually there are emerging concepts and lessons to be learned in evacuation. Every time an evacuation occurs researches gain more information that can be applied to future evacuations. However no two evacuations will ever be alike. There are immediate areas which research would be useful for future evacuation planning. More research into road capacities and how evacuation routes are affected by the volume of traffic would be highly beneficial. There is currently very little empirical data on road capacities and capabilities in evacuations. Although it may be difficult, more empirical data from large scale evacuations would be useful to better understand evacuee behavior.

Additionally there are several other topics that have become apparent to this author that may be useful to the evacuation planning community:

- Advanced methods and for warning the public in a nuclear emergency
- Evacuation of Special Needs Populations
- Capacity of Delaware to handle a large scale evacuation (Included Numbers of busses, EMS Vehicles and other equipment available.)

XIII. Conclusion

Engineering and Social Science have often paralleled each other research and the bridges between the two fields existed but are often limited. By bringing the social aspects and engineering aspects together in one research project it is in effect the beginning of bridging the gap and merging the two "fields" of study into one larger multi-disciplinary group. It's an important aspect of disaster research because each group has significant expertise to put to use for planning and to understand the effects of disasters. This is especially prevalent in the engineering and planning aspects of disasters. Engineers are often taught to model a scenario for assumed conditions but in reality those conditions do not exist when what you are modeling is people's actions. These assumptions do not always follow people's behaviors based upon what is known from social science literature. This problem is often exposed in an evacuation. People will not follow the optimal engineering plan for very logical reasons.

This project is an attempt to bring together the two methods of comprehension of the subject for a greater understanding and usefulness to the disaster community.

The state of Delaware is moving in the right direction by the creation of a Radiological Emergency Plan, which has been updated as recently as 2008. With the current plans in place there is a need for continual revisions and updating. Officials have a good idea of how many cones and barriers will be needed and the magnitude of such an evacuation. In spite of this, evacuation is a process not a list of steps to be implemented. The process can be repetitive, overlap itself and even have multiple stages occurring simultaneously. Understanding that individuals have needs, they are going to be hard to warn and they may not listen to the warnings the first or second time will be useful in understanding how the evacuation is going to pan out. The best evacuation plans will be the ones that understand the population and assist in meeting their needs whether it is the need to return to the emergency area to pick up family or their needs for communication or transportation from the evacuation zone.

People are information hungry and giving them too much information is not possible. Officials need to be up front with the public and detailed about the emergency. As seen from the Three Mile Island Incident if officials leave the public out of the loop and can agree themselves about the best action the public will have trouble believing the messages that are being given out. This will be one of the largest challenges officials will face. As has been said evacuation is a process from the creation of the warning message to the actually process of people leaving. To best evacuate a population this process must be understood and steps implemented to facilitate an effective evacuation.

<u>References</u>

Chiu, Yi-Chang, Zheng, Hong, Villalobos, Jorge and Gautam, Bikash (2007) "Modeling no-notice mass evacuation using a dynamic traffic flow optimization model", IIE Transactions, 39:1, 83 — 94

City-Data.com. "Delaware City, Delaware (DE) – Detailed Profile." < http://www.city-data.com/city/Delaware-City-Delaware.html>

Drabek, Thomas E. (1996). <u>Disaster Evacuation Behavior Tourists and Other Transients</u>. Institute of Behavioral Science, University of Colorado.

Drabek, Thomas E. (1999). <u>Disaster-Induced Employee Evacuation</u>. Institute of Behavioral Science, University of Colorado.

Edwards and Kelcey (2004). "Transportation Incident & Management Plan". State of Delaware Department of Transportation. August 2004.

"Emergency Operations Plan Delaware City, New Castle County, De." 15 February 2008.

Han, Lee D., Fang Yuan and Thomas Urbaink (2007). "What Is an Effective Evacuation Operation?" *Journal of Urban Planning and Development.* ASE. March 2007.

Jacobs Edwards and Kelcey (2007). *Salem and Hope Creek Nuclear Generating Stations Emergency Evacuation Traffic Operations Manual [DEMA Plan].* October 2007.

JB/A, Inc. (1994). "Evacuation Time Estimates for Delaware Within The Plume Exposure Pathway Emergency Planning Zone For the Artificial Island Nuclear Generating Station." Delaware Emergency Management Agency and Public Service Electric & Gas Company. January 1994.

KLD Associates (2004). "Salem/Hope Creek Nuclear Generating Stations Evacuation Time Estimates Within the Plume Exposure Pathway." Delaware Emergency Management Agency and PSEG Nuclear, LLC. February, 2004.

Mileti, Dennis S. and Lori Peek (2000). "The social psychology of public response to warnings or a nuclear power plant accident". Journal of Hazardous Materials. 75 (2000) 181-194.

Moriarty, Kevin D., Daiheng Ni and John Collura (2006). "Modeling Traffic Flow under Emergency Evacuation Situations: Current Practice and Future Directions." TRB 2007 Annual Meeting CD-ROM.

NUREG-0728, Rev. 4 (2005). United States Nuclear Regulatory Commission. April 2005.

Stallings, Robert A. (1984). "Evacuation Behavior at Three Mile Island". International Journal of Mass Emergencies and Disasters. 1984.

Perry, Ronald W. and Greene, Marjorie, R. (1982). "The Role of Ethnicity in the Emergency Decision-Making Process." Sociological Inquiry 52 (4): 306-334.

State of Delaware (2008). *Radiological Emergency Plan.* Issued January 2008.

Urbanik II, Thomas (2000). "Evacuation time estimates for nuclear power plants." *Journal of Hazardous Materials.* Issue 75 (2000) 165-180.

U.S.NRC (2006). "Emergency Preparedness at Nuclear Power Plants." Office of Public Affairs. January 2006.

Williams, Billy M., Anthony P. Tagliaferri, Stephen S. Meinhold, Joseph E. Hummer and Nagui M. Rouphail (2007). "Simulation and Analysis of Freeway Lane Reversal for Costal Hurricane Evacuation". Journal of Urban Planning and Development. ASCE. March 2007.

Wolshon, Brian (2007). Empirical Characterization of Mass Evacuation Traffic Flow. *Transportation Research Board 2008 Annual Meeting CD-ROM.* 9 November 2007.

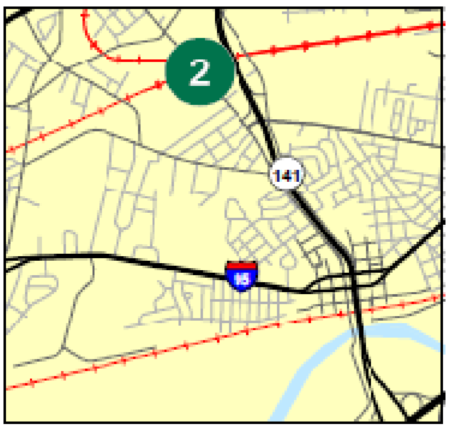
Wolshon, Brian and Laurence Lambert (2006). “Reversible Lane Systems: Synthesis of Practice”. Journal of Transportation Engineering. ASCE. December 2006.

Zimmerman, Carol, Robert Brodesky and Jordan Karp (2007). “Using Highways for No-Notice Evacuations: Routes to Effective Evacuation Planning Primer Series”. United States Department of Transportation Federal Highway Administration. November 2007. FHWA-HOP-08-003.

Emergency Evacuation Reception Centers

Directions to Reception Centers

Please tune to Radio Stations 1150 AM or 93.7 FM for emergency information



Frank K. Stern Readiness Center
Northern Reception Center
1420 Newport Gap Pike
Wilmington

Directions:
Follow routing on the Ten-Mile Emergency Planning Zone Map
Drive north and Route 1.
Take Route 1 to Christiana. Then take I-95 north.
Go 4.5 miles and take exit for Newport. Routes 141/41 north.
Go approximately 1.6 miles on 141/41 and take Boxwood Road exit.
Turn left at the first traffic light and go over the interstate extension.
Take the first right over overpass (about 100 feet). This is Newport Gap Pike (Route 62).
Go .3 miles. The Armory is on the left.

Smyrna Readiness Center
Southern Reception Center
103 Artisan Drive
Smyrna

Directions:
Follow routing on the Ten-Mile Emergency Planning Zone Map
Drive south on Route 1 to Smyrna
(Take Route 1 South to North Smyrna exit to Route 13).
In Smyrna, proceed on Route 13 approximately 1.8 miles turn right on DE-300/East Glenwood Avenue
Go approximately 1.7 miles.
Turn left on Artisan Drive approximately .1 miles.
Continue on Artisan Drive, Armory is on the right.

Appendix II

What are ERPAs?

- Emergency Response Planning Areas (ERPAs) are geographic zones located mostly in southern New Castle County Delaware, within the ten-mile Emergency Planning Zone (EPZ), from the Salem and Hope Creek Generating Stations.
- ERPAs are used to quickly describe which geographic area is affected by an emergency.

What's New?

- ERPAs have been combined using easily recognized boundaries such as major roadways, towns, waterways, etc.
- There are now four ERPAs instead of ten.
- New ERPAs are color coded (orange, blue, green, pink) and have corresponding letters (A, B, C, D).
- The four new zones have been successfully tested in radiological exercises conducted by DEMA.
- New ERPAs are used to simplify notification for sheltering and evacuation of residents, visitors, schools, businesses and other facilities within the ten-mile EPZ.

Additional Information

New Castle County
Office of Emergency
Preparedness
302-395-2700

Kent County
Emergency Management
302-735-3465

Delaware Emergency
Management Agency (DEMA)
302-659-DEMA (3362) or
877-SAY-DEMA
(877-729-3362)
Web Page:
dema.delaware.gov
(click on Nuclear Hazards
then Emergency Response Planning
Areas)

Federal Emergency Management
Agency (FEMA) Region III
215-931-5500
Web Page:
www.fema.gov/reg-iii

PSEG Nuclear LLC
800-232-0244
Web Page: www.pseg.com

DEMA
DELAWARE EMERGENCY MANAGEMENT AGENCY
Partners for Protection and Response

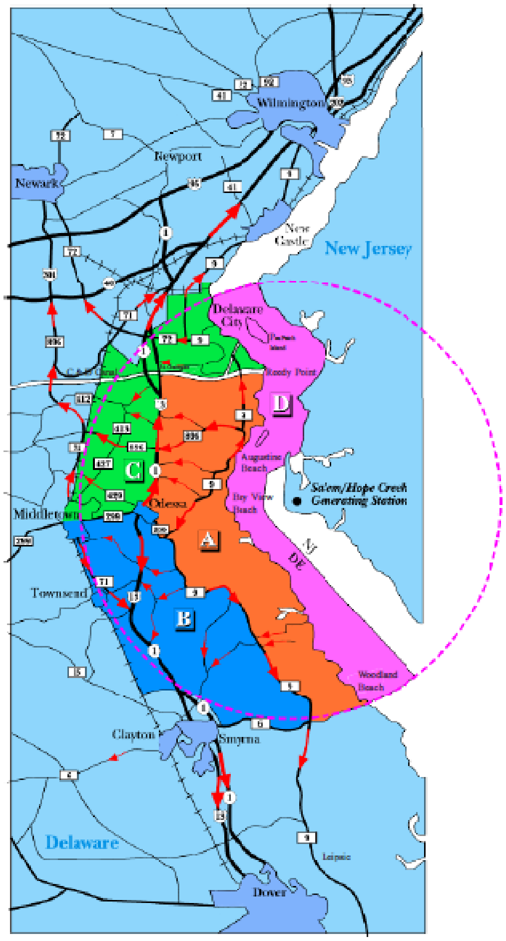
Delaware's NEW

Emergency
Response
Planning
Areas

Plan for protection in case of a radiological incident at the Salem and Hope Creek Nuclear Generating Stations.

Prepare Yourself

The four Emergency Response Planning Areas (ERPAs) that are shaded on the map (opposite) show the 10-mile Emergency Planning Zone (EPZ) of the Salem and Hope Creek Nuclear Generating Stations.



- Locate your residence, business or school on the map. If you are within the colored zones, note the corresponding ERPA color and letter.
- If warning sirens are sounded, tune your radio to an Emergency Alert System (EAS) station listed below:

WDEL-AM 1150	WWTX-AM 1290	WSTW-FM 93.7
WAMS-AM 1260	WILM-AM 1450	WDOV-AM 1410
WDSD-FM 92.9	WRJE-AM 1600	WJBR-FM 99.5
Marine Channel 16	WRDX-FM 94.7	

- Listen for emergency instructions that pertain to your ERPA zone.

ERPA Description

ERPA A
Port Penn, Odessa, East of Townsend, North Smyrna and South St. George's Areas
The area bounded to the west by Routes 13, 299 and 9; to the east by the Delaware River; to the north by the Chesapeake and Delaware Canal; to the south by Route 6.

ERPA B
Middletown, East of Townsend and North Smyrna Areas
The area bounded to the west by the Norfolk Southern Railroad; to the east by Route 9; to the north by Route 299; to the south by Route 6 and Smyrna Landing Road.

ERPA C
Delaware City, North Middletown, St. George's and Reybold Areas
The area bounded to the north of Route 299 by Kirkwood St. George's Road; to the east of the Norfolk Southern Railroad to Route 13; to the south of the Red Lion Creek and east of Route 9; to the south of the Norfolk Southern Railroad and east of Route 13 to the Chesapeake and Delaware Canal; to the south of Route 72 and east of McCoy Road to Route 13.

ERPA D
The Delaware River and Bay
The area just north of Pea Patch Island, near Delaware City, south to Woodland Beach.

POTASSIUM IODIDE (KI)

The Delaware Emergency Management Agency and the Delaware Division of Public Health will once again distribute Potassium Iodide (KI) for individuals who reside and/or work within the Emergency Response Planning Areas (ERPAs) listed below surrounding the Salem-Hope Creek Generating Stations.

Potassium Iodide provides limited protection only to the thyroid gland and only against radioactive iodine in the body. It does not protect the thyroid or any other parts of the body from other radionuclides that could be released during a nuclear incident; it does not protect against external exposure. Evacuation is the best protective action.

If you currently have expired KI supplies, please bring them with you on one of the dates listed, to receive your new tablets. If you have not already received KI, this is your opportunity to do so. You must work on reside within one of the following ERPAs.

ERPA A-Port Penn, Odessa, East of Townsend, North Smyrna and South St. George's Areas
The area bounded to the west by Routes 13, 299 and 9; to the east by the Delaware River; to the north by the Chesapeake and Delaware Canal; to the south by Route 6.

ERPA B- Middletown, East of Townsend and North Smyrna Areas
The area bounded to the west by the Norfolk Southern Railroad; to the east by Route 9; to the north by Route 299; to the south by Route 6 and Smyrna Landing Road.

ERPA C- Delaware City, North Middletown, St. George's and Reybold Areas
The area bounded to the north of Route 299 by Kirkwood St. George's Road; to the east of the Norfolk Southern Railroad to Route 13; to the south of the Red Lion Creek and east of Route 9; to the south of the Norfolk Southern Railroad and east of Route 13 to the Chesapeake and Delaware Canal; to the south of Route 72 and east of McCoy Road to Route 13.

ERPA D- The Delaware River and Bay -
The area just north of Pea Patch Island, near Delaware City, south to Woodland Beach.
Delaware's policy is to evacuate residents prior to exposure, which is the most effective protective action.

A stockpile of Potassium Iodide will be made available at the pre-designated reception centers in case of an emergency. Reception Centers are referenced in the Emergency Calendar on the DEMA website - **http://dema.delaware.gov/** (click on Nuclear Hazards then PSEG Calendar). Reception Centers are also shown on the map in the "Emergency Information" section of the PSEG Calendar. Bring along proof of residency Driver's License/other).

Location	Date	Time
Townsend Fire Company 107 Main Street, DE	**09/13/07**	**11:00 a.m. to 7:00 p.m.**
Appoquinimink State Service Center 120 Silver Lake Rd, Middletown, DE	**09/29/07**	**8:00 a.m. to 12:00 p.m.**
Townsend Fire Company 107 Main Street, DE	**10/03/07**	**11:00 a.m. to 7:00 p.m.**
Appoquinimink State Service Center 120 Silver Lake Rd, Middletown, DE	**10/27/07**	**8:00 a.m. to 12:00 p.m.**