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The objective of the overall project was to develop a center of excellence in disaster preparedness and emergency response, linking together three major institutions and gaining research, education, and clinical synergies from the collaborations between their subject matter experts. The University Center for Disaster Preparedness and Emergency Response (UCDPER) has been established as a joint initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital. UCDPER's missions include protection of the lives, health and well-being of the general public, vulnerable populations and the workforce – and protection of societal, economic and physical infrastructure – through research, education, community outreach and clinical advances in preparedness/response to all-hazards emergencies, disasters, and terrorism. The research projects conducted under the UCDPER umbrella have produced recommendations, guidelines, and models focused on maximizing effectiveness and efficiency of disaster preparedness and emergency response in all-hazards scenarios. Collaboration across the three partner institutions has become robust over the course of the project. Follow-up projects are being planned

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Abstract

The objective of the overall project was to develop a center of excellence in disaster preparedness and emergency response, linking together three major institutions and gaining research, education, and clinical synergies from the collaborations between their subject matter experts.

The University Center for Disaster Preparedness and Emergency Response (UCDPER) has been established as a joint initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital. UCDPER's missions include protection of the lives, health and well-being of the general public, vulnerable populations and the workforce – and protection of societal, economic and physical infrastructure – through research, education, community outreach and clinical advances in preparedness and response to all-hazards emergencies, disasters, and terrorism.

The research projects conducted under the UCDPER umbrella have produced recommendations, guidelines, and models focused on maximizing effectiveness and efficiency of disaster preparedness and emergency response in all-hazards scenarios.

Collaboration across the three partner institutions has become robust over the course of the project. Follow-up projects are being planned. The novel findings of this overall effort and its projects will be disseminated through publication and presentation.

Foreword

This project has been sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) – A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital - with support from Department of Defense Grant Number W9132T-10-1-0001.

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The Grant Principal Investigator was Clifton R. Lacy, M.D., (RUTGERS/UMDNJ-RWJMS/RWJUH).

Project Principal Investigators were Dr. Tayfur Altiok (RUTGERS), Dr. Rajiv Arya (RWJUH), Dr. Perumalsamy Balaguru (RUTGERS), Dr. George DiFerdinando (UMDNJ-SPH), Dr. Robert Eisenstein (RWJUH), Dr. Nina Fefferman (RUTGERS),
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INTRODUCTION

Background

The University Center for Disaster Preparedness and Emergency Response (UCDPER) is a joint initiative of Rutgers, The State University of New Jersey (RUTGERS), UMDNJ-Robert Wood Johnson Medical School (UMDNJ-RWJMS), and Robert Wood Johnson University Hospital (RWJUH). The overall effort was funded by the Construction Engineering Research Laboratory (CERL) of the Engineer Research and Development Center (ERDC) of the U.S. Army Corps of Engineers under Department of Defense Grant Number W9132T-10-1-0001.

Missions of University Center for Disaster Preparedness and Emergency Response are:

- to protect the lives, health, and well-being of the general public, vulnerable populations, and the workforce, and
- to protect the societal, economic, and physical infrastructure of New Jersey and the nation, through
- research, education, community outreach, and clinical advances in preparedness and response to all-hazards emergencies, disasters, and terrorism.

UCDPER is founded upon the strengths and successes of our three parent institutions in a unique partnership that includes world-class scientific strengths in disaster medicine, trauma, exposure science, toxicology, engineering, and mathematics/computer science.

UCDPER builds on highly successful interdisciplinary activities including Level 1 Trauma Center at RWJUH/UMDNJ-RWJMS; the EPA Center on Exposure and Risk Modeling at UMDNJ-RWJMS; the NIH CounterACT Center at UMDNJ-RWJMS; the Center for Advanced Infrastructure and Transportation (CAIT) at Rutgers; the National Transportation Security Center of Excellence (NTSCOE) at Rutgers; the International

Center for Terror Medicine (ICTM) at RWJUH; the DHS Center of Excellence for Command, Control, and Interoperability (CCICADA) at Rutgers, and the DHS University Center of Excellence in Dynamic Data Analysis (DyDAn) at Rutgers.

UCDPER links together subject matter experts from our three parent institutions creating a broad spectrum of multidisciplinary capabilities in all-hazards preparedness and response. This combination of efforts and strengths makes our Center a unique resource for New Jersey and the nation. Furthermore, our Center works closely with the Federal Departments of Defense, Health and Human Services, Energy, Environmental Protection, and Homeland Security, and with the New Jersey Office of Homeland Security and Preparedness, the New Jersey Department of Health and Senior Services, and the New Jersey Domestic Security Preparedness Task Force.

New Jersey is the home base for UCDPER. Strategically located between New York City and Philadelphia, New Jersey is the most densely populated state in the nation and is home to a major portion of the Northeast corridor of roadway and railway transit and transportation. New Jersey has a significant history of natural and man-made, accidental and intentional disasters and health emergencies. In addition, New Jersey has infrastructure vital to national security and economic stability including major industries and utilities, military bases, financial and commercial centers, population concentration points, and transportation/transit links.

The UCDPER's Executive Committee convenes on a monthly basis or more often if needed to discuss current events, issues, and projects and to provide guidance and recommendations. The Executive Committee is composed of the following members:

- Clifton R. Lacy, M.D. (RUTGERS/UMDNJ-RWJMS/RWJUH)
- Fred S. Roberts, Ph.D. (RUTGERS)
- Ali Maher, Ph.D. (RUTGERS)

- Michael R. Greenberg, Ph.D. (RUTGERS)
- Vicente H. Gracias, M.D. (UMDNJ-RWJMS)
- Paul J. Lioy, Ph.D. (UMDNJ-RWJMS)
- Jeffrey D. Laskin, Ph.D. (UMDNJ-RWJMS)
- Judith E. Burgis, M.S. (RWJUH)
- Michael Antoniades, M.P.A. (RWJUH)
- Robert Eisenstein, M.D. (RWJUH)

The findings derived from the Research and Development activities of the Center and from the Clinical and Health Care Preparedness and Response activities of the Center are establishing scientific advances that will improve both military and civilian disaster preparedness and emergency response.

Objective

The research conducted at Rutgers University and its partners (UMDNJ-RWJMS and RWJUH) is under the umbrella of the University Center for Disaster Preparedness and Emergency Response (UCDPER).

The various research efforts conducted under this grant are described in this document. The overall objective was to develop a center of excellence in disaster preparedness and emergency response.

Approach

Phase I of the current project consisted of thirteen research efforts which are presented along with their respective abstracts on Table 1: List of Research Projects. Ten of these projects have been successfully completed and three are still in progress.

Detailed Technical Reports for each research effort are presented in chapters 1 through 10.

Mode of Technology Transfer

Explicitly-stated aims and missions of UCDPER include Research and Development as well as the dissemination of research results to improve disaster preparedness and emergency response. The UCDPER Executive Committee, Project Leaders, and Investigators will produce journal quality scholarly articles and scientific presentations related to and highlighting Center development and research activities.

CONCLUDING CHAPTER

Summary

The University Center for Disaster Preparedness and Emergency Response (UCDPER) is a joint initiative of Rutgers, The State University, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital. UCDPER's missions are protection of the lives, health and well-being of the general public, vulnerable populations and the workforce – and protection of societal, economic and physical infrastructure – through research, education, community outreach and clinical advances in preparedness/response to all-hazards emergencies, disasters and terrorism.

The objective of this overall effort was to develop a center of excellence in disaster preparedness and emergency response.

The First Phase of the overall project has concluded with robust collaboration between subject matter experts of the three partner institutions, ten projects successfully completed, and three projects expected to be concluded by February 15, 2011.

The research projects conducted under the UCDPER umbrella have produced recommendations, guidelines, and models focused on maximizing effectiveness and efficiency of disaster preparedness and emergency response in all-hazards scenarios.

Fefferman's study showed that shelter location, resource allocation to shelters, and the ability to rapidly and accurately communicate appropriate evacuation routes to the public will drastically affect the success of public health preparedness/intervention strategies for heat-events. It further demonstrated the utility of coupling theoretical optimization strategies with simulation-based methods to determine likely outcomes for public health interventions.

Greenberg and Lahr designed and tested economic simulation models to assess the impact of regional economic impacts of hazards events on a major rail corridor and to estimate the costs and benefits of making the system more capable of withstanding events and recovering from them.

Cost containment and performance are major issues in Emergency Management (EM) and Disaster Recovery (DR) network operations. Garabaglu's results demonstrated that considerable cost savings and performance for EM/DR networks could be achieved when using more advanced technology and access methods. An optimal and cost-effective solution based on concepts of cloud communications and intelligent network architecture is recommended.

Laskin's study on biomarkers has provided significant new information on the mechanism of action of vesicants that it is likely to lead to new medicines that can be used to treat individuals exposed to these chemical agents.

Altiok addressed the issue of managing inventories of medical supplies and especially the critical ones in hospitals under surge (pandemic) scenarios. The purpose of the study was to provide guidelines to implement a formal procedure to help decision makers managing inventories in the health care industry. A Dynamic Programming optimization model was constructed to optimally manage the inventory of critical medical supplies in hospital settings.

The project on patient flow optimization and emergency hospital operations conducted by Jafari concluded that real time information on patient tracking and resource availability can significantly improve patient flow throughout hospitals.

Balaguru evaluated the levels of protection conferred by use of thin films to reduce blast-related fragmentation and shattering of glass panels on response vehicles' windshields. Two different protective films (VehicleGARD® and ShatterGARD®) were tested for their suitability in emergency response situations. Both films tested better than the control sample; however, VehicleGARD was more suitable for visibility after impacts.

The work on community catastrophic planning performed by Isukapalli and his team provides a framework that will allow improvement of emergency planning and response.

Three education and training sessions related to all-hazards health threats resulting in mass casualties were conducted and assessed under DiFerdinando's direction. These exercises were performed in conjunction with federal, state, county, and local partners.

Collaboration across the three partner institutions has become robust over the course of the project. Follow-up projects are being planned. The novel findings of this overall effort and its projects will be disseminated through publication and presentation. A regional scientific meeting of UCDPER, scheduled for December, 2011, will highlight the disaster preparedness and emergency response research findings.

Conclusions

Our efforts have created a highly productive collaboration between three major institutions in the State of New Jersey – Rutgers, the State University, UMDNJ-Robert Wood Johnson Medical School and Robert Wood Johnson University Hospital – resulting in the development of a multidisciplinary University Center for Disaster Preparedness and Emergency Response (UCDPER) and the successful completion of ten important research projects aimed at improving the capability and capacity to effectively and efficiently respond to a wide variety of disasters and major emergencies. Three projects are still underway and their results will be reported when completed. Conclusions of individual projects can be found in Chapters1 through 10.

Recommendations

A number of the projects carried out have yielded important results upon which additional research efforts should be based to further improve disaster preparedness and response.

Further collaborative efforts with institutions and investigators should be developed to address issues of regional and national importance.

Efforts should be developed to increase the spectrum of research to include all hazards: biological, chemical, radiological, nuclear, explosive and incendiary.

Widespread dissemination of the results to affiliated and unaffiliated subject matter experts will maximize the impact of the findings and the likelihood of further development and implementation.

Translation of the research findings into practice will yield products and interventions to benefit both civilian and military populations challenged by disasters and emergencies of natural, accidental, and intentional origin.

TABLE

Table 1: List of Research Projects	
09 01 F	Biomarkers of Exposure to Chemical Terrorism Agents (**Jeffrey D. Laskin, Ph.D.**) **Abstract**: This study focuses on developing biomarkers for sulfur mustard and related agents. The project determines whether vesicant chemical terrorism agents of related chemistry from different sources yield different signatures when reacted with a surrogate of an experimentally established target of the agents. This research provides an understanding of how the reactivity of various mustards will vary as a function of contamination with breakdown products. The project identifies the identity of targets for vesicants on sensitive proteins that can be used as biomarkers of exposure, compares different vesicants on the same target, and constructs a model on how vesicants bind to specific proteins. Unique alkylation profiles can be used to determine the identity, quality, and source of chemical terrorism agents.
09 02 F	Interpretation of Prospective Exposure Studies Completed in New York City for Community Catastrophic Planning (**Sastry S. Isukapalli, Ph.D.**) **Abstract**: This study focuses on utilizing exposure concentration results from the New York urban dispersion program (UDP) to establish the spatial and temporal patterns of impact from exposure to highly toxic substances on members of the general public in New York City. Exposures using typical human activity patterns are studied. UDP Data are interpreted in relation to information used currently by community planners and emergency responders within urban settings. The agent-specific analysis results are employed to augment or provide suggestions for adjustments to existing guidelines on evacuation, sheltering in place, transportation, and location of risk zone perimeters after hazardous events. The study also incorporates estimates of the magnitude and severity of casualties obtained for each toxic agent into a framework for characterizing stresses on health care resources and are used to improve the strategy for the spatial location of passive samplers in New York City and other locations that can be deployed after an event to determine the residual contamination from non-volatile agents.
09 03 F In Progress	Role Adherence Versus Role Abandonment in Disasters: Determinants of Response Personnel Availability and Willingness to Perform (**Clifton R. Lacy, M.D.**) **Abstract**: This study characterizes the likelihood of availability and willingness to perform their duties and the effect on role adherence versus role abandonment in response personnel of various disciplines during different disasters and health emergencies. The project also characterize the determinants of availability and willingness to perform and the impact of mitigating factors on improving availability and willingness to perform. The study characterizes and compare the differences in responses of personnel of various disciplines.

09 04 F	Emergency Shelter Location and Resource Allocation (**Nina H. Fefferman, Ph.D**.) **Abstract**: This study develops optimization and simulation models to examine the optimal location of emergency shelters and allocation of resources into the shelters and area hospitals to minimize access time and maximize quality of service in responding to needs of individuals. The proposal builds additions to the models to incorporate the potential for dynamic healthcare worker allocation. This project yields active research-ware which will be able to provide a robust set of shelter locations and evacuation routes for use in emergencies within specified study areas.
09 05 F	Supply Chain of Critical Medical Resources for Emergency Situations (**Tayfur Altiok, Ph.D**.) **Abstract:** This study evaluates supply chain activities of critical medical resources to be used by hospitals in emergency incidents. The study focuses on the understanding of demand patterns for critical medical resources and assessing optimal stockpiling and ordering policies. The project utilizes a simulation-based approach considering a number of random parameters impacting inventories of key drugs and equipment during emergencies. Based on demand patterns from historical data, new inventory management strategies are developed for effectively meeting hospitals' increased demand under emergency scenarios. A set of computational models are developed to assist hospital administrators in making informed decisions about supply chain.
09 06 F	Patient Flow Optimization under Regular and Emergency Hospital Operations (**Mohsen A. Jafari, Ph.D.**) **Abstract**: This study valuates techniques to optimize patient flow during regular and emergency hospital operations. The project takes a logistical view of patient flow. The study focuses on system-wide macro analysis of underlying processes that constitute the elements of patient flow in the emergency room and its surrounding operations. The study uses quantitative metrics to measure effectiveness and builds macro level simulations for patient flow under both normal and emergency situations.
09 07 F In Progress	Comparison of Turnaround Times of Point-of-Care Testing and Laboratory-Based Testing for Patients in the Emergency Department: Considerations for Use in Disaster Surge and Mass Casualty Situations (**Robert Eisenstein, M.D**.) **Abstract:** This study evaluates the use of Point-of-Care blood testing to avoid delays in patient management, improve patient turnaround time, and enhance throughput in the Emergency Department for routine care as well as during times of increased patient surge.
09 08 F	Use of Ultrasound in the Emergency Setting to Improve Triage of Trauma Patients (**Rajesh Geria, M.D.**) **Abstract**: This study evaluates the use of portable ultrasound in the prehospital setting. Ultrasound is used to rapidly determine presence or absence of pneumothorax, blood in the abdominal cavity, and appropriate endotracheal tube placement. This project determines how this information, obtained noninvasively in the prehospital setting, is used to improve patient care and to determine the most appropriate facility to which to send the trauma patient.

09 09 F In Progress	Use of Optical Scanning Devices to Improve the Speed of Emergency Patient Registration (**Rajiv Arya, M.D.**) **Abstract**: This study evaluates the use of optical scanning to improve speed and accuracy of data collection for emergency department patient registration during daily routine and during periods of increased patient surge. Speed and accuracy of registration are compared pre-and post implementation of this new technology. This capability is of additional value in patient tracking during mass casualty events.
09 10 P	Blast Resistant Glass Panels Using Thin Films for Protection of Emergency Vehicles (**Perumalsamy N. Balaguru, Ph.D.**) **Abstract:** This pilot study evaluates the levels of protection conferred by use of thin films to reduce blast-related fragmentation and shattering of glass panels. The project evaluates the level of protection provided by the film and the method to secure the film and the glass to the attached frame.
09 11 P	Assessing the Economic Benefits of Public Health Mitigation and Resilience Measures (**Michael Greenberg, Ph.D.**) **Abstract**: This study assesses the capacity to build low-cost regional economic models to evaluate the economic impacts of disasters and emergencies with and without both pre- and post-event interventions, with special focus on public health. The study examines and tests the feasibility of building and using a mathematical economic model that will enable ready assessments of the relative performance of a stressed economy. The study also addresses whether the costs of these models are offset by the potential value of their use in actual planning for catastrophic events, especially those related to public health.
09 12 P	Intelligent Demand Assigned Networks Cost and Performance (**Mohsen Garabaglu, Ph.D.**) **Abstract**: This study evaluates the use of intelligent demand assigned networks with shared space segment environments in reducing the cost of the satellite-based Disaster Recovery and Emergency Management networks used during catastrophic events. System architecture are developed for an intelligent demand assigned network with the capability of sharing network resources among multiple entities. Comparative business models associated with both typical satellite networks and intelligent demand assigned networks are developed. Intelligent demand assigned networks and typical satellite Disaster Recovery and Emergency Management networks are compared based on performance and cost savings.
09 13 F	Bridging the Gaps between Public Health, the Health Care System, and First Responders (**George DiFerdinando, M.D., MPH)** **Abstract**: This project involves conducting and assessing education and training sessions pertaining to all hazards health threats resulting in mass casualties. Training sessions target diverse multidisciplinary elements of disaster preparedness and emergency response in counties or multicounty regions of the state. Training and evaluation are performed in conjunction with federal, state, county, and local partners.

CHAPTER 1

Project 09 01F: Biomarkers of Exposure to Chemical Terrorism Agents

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Biomarkers of Exposure to Chemical Terrorism Agents

Project 09 01 F

Final Report

Investigators: Dr. Jeffrey D. Laskin,Ph.D., UMDNJ-RWJMS. Environmental and Occupational Health Sciences Institute, 170 Frelinghuysen Road, Piscataway, NJ 08854;

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Panos Georgopoulos at UMDNJ-RWJMS

Abstract

Chemical weapons remain a threat to the military as well as civilian populations. Mustard alkylating agents remain an agent of concern because of their toxicity, persistence in the environment, difficulty in treating exposures, and lack of medical countermeasures. Sulfur mustard is inexpensive and relatively easy to manufacture, it is also available from unaccounted for munitions or disposal sites. Work in the present studies analyzed alkylation profiles of mustard-class vesicants and yielded unique signatures when reacted with sensitive proteins so that the agents may be differentiated from one another based upon reactivity. Using techniques in analytical chemistry we also examined the possibility that breakdown products of vesicants can modify target proteins. Unique profiles of modified targets were determined.

Foreword

This project was performed by Dr. Jeffrey D. Laskin and Dr. Panos Georgopoulos and was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital-with support from Department of Defense Grant No. W9132T-10-1-0001.

We thank Yi-Hua Jan for expert technical assistance.

The views, opinions, positions, conclusions, or strategies in this work are those of the authors and do not necessarily reflect the views, opinions, positions, conclusions, strategies, or official policy or position of the Department of Defense or any agency of the U.S. government and no official endorsement should be inferred.

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INTRODUCTION

Background

There remains a major public health concern of exposure to toxic chemicals in a terrorist attack. Chemical threats include toxins, toxic industrial chemicals as well as chemical warfare agents. Higher priority chemical threats include vesicating agents such as sulfur mustard, neurotoxic agents such as organophosphorus nerve "gases," pulmonary agents such as chlorine gas and metabolic/cellular poisons such as cyanide. In an emergency situation, it is critical to know the nature of the chemical an individual has been exposed to and at what levels. This information is important for patient evaluation and for determining appropriate medical treatments and strategies for decontamination. Our plans are to focus on developing biomarkers for sulfur mustard and related agents. These compounds are potent alkylating agents. By determining the alkylation signatures of these vesicants on target proteins, we can gain knowledge as to how these toxins function and identify biomarkers of exposure. These biomarkers can be used by medical personnel to rapidly identify the nature of chemical exposure in an emergency situation.

Objective

The purpose of this proposal was to determine whether vesicant chemical terrorism agents of related chemistry from different sources yield different signatures when reacted with a surrogate of an experimentally established target of the agents. We hypothesize that the reaction of the model sulfur mustard vesicant 2-chloroethyl sulfide or a related analog mechlorethamine (HN2) with a likely naturally occurring substrate, thioredoxin reductase (Holmgren and Lu, 2010) or related antioxidants such as superoxide dismutase, will produce unique signatures when analyzed for adduct formation. In addition, we hypothesized that when mixed in varying proportions with naturally occurring sulfur mustard breakdown products, differentiable alkylation signatures will be produced, based upon the relative amounts of these contaminants present during the alkylation reaction. These products include thiodiglycol, which under certain conditions react with mustards to generate sulfonium salts, and related sulfoxide and sulfone derivatives which are oxidation products of the active principals. Little is known with regard to the reactivity of these products, alone or in combination with the vesicants, much less toward a likely protein substrate of the vesicant. Our research has provided a better understanding of how the reactivity of various mustards will vary as a function of contamination with breakdown products. They will also provide a set of biomarkers to establish exposure to vesicants.

Approach

Our approach was to analyze alkylation of target proteins by vesicants and to determine if alkylation signatures on target proteins are modified by contamination products found in vesicant preparations.

Methods

Proteins including thioredoxin reductase and superoxide dismutase were analyzed in cells by western blotting to determine if they were modified by nitrogen mustard. Using purified enzymes, proteins were analyzed using techniques in liquid chromatography mass spectroscopy to identify alkylation signatures.

CONCLUDING CHAPTER

Findings

Oxidative stress plays a critical role in the toxicity of the nitrogen mustard bis(2-chlorethyl) amine (HN2). The thioredoxin system, which consists of thioredoxin reductase (TrxR), thioredoxin, and NADPH, is a key cellular antioxidant that is important in redox regulation and protection against oxidative stress. HN2 contains two electrophilic chloroethyl side chains that can react with nucleophilic amino acids in proteins leading to changes in their structure and function. Previously, we reported that the monofunctionl vesicant 2-chloroethyl ethyl sulfide targets TrxR by alkylating selenocysteine in the C-terminal redox motif of the enzyme, a process leading to enzyme inhibition. In the present studies, we found that HN2 inhibits the thioredoxin system in A549 lung epithelial cells and in purified enzymes. Western blot analysis revealed marked decreases in the TrxR monomer and increases in TrxR dimer and oligmer formation indicating that HN2 cross-linked the enzyme. With the purified enzyme, NADPH reduced, but not oxidized TrxR, was inhibited and cross-linked by HN2. Using biotin-conjugated iodoacetamide (BIAM), which selectively reacts with selenol or thiol groups on proteins, HN2 was found to decrease BIAM-labeled TrxR, suggesting that HN2 inactivates TrxR by targeting critical selenol and/or thiol groups on TrxR. LC-MS/MS analysis confirmed that HN2 directly adducted to the cysteine- and selenocysteine-containing redox centers forming monoadducts, intra-molecule and inter-molecule cross-links, leading to enzyme inhibition. HN2 also cross-linked and inhibited dose-dependently on thioredoxin. LC-MS/MS analysis demonstrated that HN2 alkylated the cysteine residues in the redox center of thioredoxin, leading to enzyme inactivation and oligomerization. Disruption of the thioredoxin system is likely to contribute to HN2-induced oxidative stress and cytotoxicity.

We also found that HN2 targeted the antioxidant superoxide dismutase. Like thioredoxin reductase, HN2 was found to cross-link the protein in target cells. LC-MS/MS analysis identified the cross links at the interface of superoxide dismutase dimers on cysteine residues. Based on this work, two proteins, thioredoxin reductase and superoxide dismutase were identified as important biomarkers of exposure to vesicants. These studies should provide an initial framework for understanding the mechanism of action of vesicants, they will also provide important sites for assessing exposure to an important chemical threat agent.

Reports and Manuscripts

a. Studies on thioredoxin reductase as a biomarker of vesicant exposure

Jan, YH, Heck, DE, Laskin DL and Laskin JD, Selective cross-linking of thioredoxin reductase in lung epithelial cells by nitrogen mustard, a model sulfur mustard vesicant, manuscript in preparation

Oxidative stress plays a critical role in sulfur mustard-induced toxicity. The thioredoxin system, which consists of thioredoxin reductase (TrxR), thioredoxin, and NADPH, is a critical cellular antioxidant that is important in redox regulation and protection against oxidative stress. Nitrogen mustards, including mechlorethamine (HN2), contain two electrophilic chloroethyl side chains which can readily react with nucleophilic amino acids in proteins, a process that can lead to changes in protein structure and/or function. Previously, we reported that the monofunctionl vesicant 2-chloroethyl ethyl sulfide targets TrxR by selectively alkylating selenocysteine in the C-terminal redox motif of the enzyme, a process leading to enzyme inhibition. In the present studies, we evaluated the effect of HN2 on the thioredoxin system using A549 lung epithelial cells and purified TrxR. HN2 was found to cause a concentration-dependent (1-100 μM) inhibition of TrxR in both systems. Western blot analysis revealed decreases in the TrxR monomer and simultaneous increases in TrxR dimer formation. Using biotin-conjugated iodoacetamide (BIAM) to selectively react with low pKa selenol or thiol groups on proteins at pH 6.5, we found that HN2 differentially decreased BIAM-labeled TrxR in A549 cells and with purified enzyme, suggesting a decrease in the reduced form of TrxR. These results suggest that HN2 inactivates TrxR by targeting selenol and/or thiol containing redox centers and cross-linking TrxR peptides. Disruption of the Trx system is likely to contribute to vesicant-induced cytotoxicity.

b. Studies on cross-linking of superoxide dismutase as a biomarker of vesicant exposure

Y. Wang; D. E. Heck; D. L. Laskin; J. D. Laskin (2011) Mechanisms of vesicant-induced cytotoxicity in lung epithelial cells, report presented at the Society of Toxicology Annual Meeting, Washington, DC.

Inhalation of vesicants such as sulfur mustard can cause significant damage to the respiratory system including inflammation, upper and lower obstructive disease, and acute respiratory distress syndrome. A major factor contributing to vesicant-induced lung injury is cytotoxicity and oxidative stress. In the present studies, we used nitrogen mustard (NM, mechlorethamine), a bifunctional alkylating agent and model sulfur mustard vesicant, to characterize cytotoxicity and oxidative stress in A549 cells, a human type II lung epithelial cell line. NM was found to cause a concentration-dependent inhibition of A549 cell growth (IC50 = 1 μM). Pretreatment of the cells with 20 μM buthionine [S, R] sulfoximine (BSO) for 6 hr, which depletes glutathione (GSH), was found to enhance NM-induced growth inhibition (IC50 = 0.2 μM). Cell cycle analysis revealed that 27.1 ± 0.7 % of A549 cells were in the S phase, 18.0 ±1.0 in G2M and 53.4 ± 0.5% in GoG1. Twenty-four hr after treatment of the cells with NM (30 μM, 30 min), we observed a S-phase block, 64.6 ± 1.4% of the cells were in S phase, 25.2 ± 1.5% in G2M and 9.3 ± 0.4 in GoG1. Depletion of GSH in cells had no effect on NM-induced cell cycle arrest. NM (30-300 μM) also enhanced the generation of intracellular hydrogen peroxide, as determined by flow cytometry in conjunction with the hydroperoxy-sensitive probe 2',7'-dichlorofluorescein. Western blotting showed that while NM had no effect on expression of the antioxidant enzymes catalase or heme oxygenase-1; it cross-linked superoxide dismutase, forming a modified 32,000 molecular weight homodimeric protein. Taken together, these data indicate that NM induced cytotoxicity in lung epithelial cells is associated with oxidative stress and alterations in antioxidants, processes that can contribute to vesicant-induced tissue injury.

Grant Proposals

NIH grants on the mechanisms by which nitrogen mustard modified antioxidant proteins are in preparation.

Discussion

Sulfur mustard and related agents cause epithelial disruption and oxidative stress. Oxidoreductases are important enzymes mediating these processes. We have determined that thioredoxin reductase and superoxide dismutase are important targets for these compounds. Mustard alkylation sites were analyzed using techniques in limited protease digestion of the modified proteins, peptide purification by sodium dodecylsulfate polyacrylamide gel electrophoresis and sequence analysis by liquid chromatography (LC) tandem mass spectrometric (MS) analysis. For the ethylthioethyl-alkylated protein products, samples were first reduced with dithiothreitol, alkylated with iodoacetamide, and subjected to in-gel digestion with the proteinase Lys-C, prior to LC-MS/MS. Alkylation signatures of mustard derivatives were compared to determine their unique reactivity features. Based on this work, both thioredoxin reductase and superoxide dismutase have the potential to serve as biomarkers for exposure to vesicants.

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CHAPTER 2

Project 09 02 F: Interpretation of Prospective Exposure Studies Completed in New York City for Community Catastrophic Planning

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Interpretation of Prospective Exposure Studies Completed in New York City for Community Catastrophic Planning

Project 09 02 F

Final Report

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Abstract

This project utilizes the unique data set of actual human exposure and contaminant concentration measurements under realistic conditions tracer concentration and exposure data from the NY Urban Disperson Program (UDP) experiments, in order to improve upon our current understanding of the impact of emergency events on the general public and corresponding community planning efforts. The experimental data on outdoor, indoor, and personal exposure concentrations following releases of small amounts of inert tracers are scaled in order to characterize exposures that people would be experiencing in the event of releases of chemical, biological, or radiological agents. Novel methods have been developed for (a) scaling up tracer concentrations to specific CBR release scenarios, (b) specifying plausible population distributions in a Geographic Information Systems (GIS) setting, (c) estimating casualties and stress on health-care resources under different event and potential response scenarios.

Demonstration case studies highlight the major factors that must be accounted for in emergency response studies, and the overall uncertainty in casualty estimates due to uncertainties in release location and release timing. The computational modules and algorithms presented here can provide actionable and accurate information to personnel responding to emergency events in complex urban settings.

Foreword

This project was performed by Dr. Sastry S. Isukapalli and Dr. Paul Lioy and was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital-with support from Department of Defense Grant No. W9132T-10-1-0001.

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INTRODUCTION

This project utilizes the experimental data conducted during the NY Urban Disperson Program (UDP) experiments, which involved releases of small amounts of inert tracers and subsequent measurements of outdoor, indoor, and personal exposure concentrations. These data represent actual exposure concentration profiles and provide comprehensive dispersion/exposure measurements in real-life urban settings. Since these tracers were released from different locations and times to characterize multiple space and time profiles under the same conditions, and measured in different "receptor locations" representing exposures to personnel working near the release location, workers and general public passing through the area, and tourists that wander in multiple locations.

Background

Atmospheric dispersion of chemicals in urban settings is complicated by multiple factors such as irregular structures, street canyons, building ventilation characteristics, traffic, etc. In the recent past, the New York City Urban Dispersion Project (UDP- Lioy et al., 2007; Watson et al., 2006) was conducted as a collaborative effort involving multiple agencies such as the Department of Homeland Security, USEPA, NOAA, and DARPA, as well as the City of New York. The UDP experiments involved releases of very low levels of harmless perfluorocarbon tracers (PFT) that can be detected at very low levels and are used in leak detections, atmospheric tracking, and and building ventilation (Watson et al., 2006; NOAA, 2011). These were released in Midtown Manhattan at separate locations, during two seasons in 2005, and focused on measuring concentrations following both outdoor and indoor releases of the tracers. Within this project, prospective exposure tracer experiments were completed at the Madison Square Garden (MSG), at the Rockefeller Center (RC), and in the New York City subway system; these experiments involved realistic scripted activities of individuals for characterizing exposures that people would be experiencing in the event of releases of chemical, biological, or radiological agents. The concentration and exposure data obtained during the NY UDP lend themselves to easy scale up for other types of chemicals, and evaluation of computer simulation models. In some exposure scenarios, the concentrations stayed at higher levels due to "secondary PFT releases" from buildings that accumulated the contaminants during the period of release or that re-emitted the PFTs to the outdoor environment after the release stopped. Measurements of neighborhood scale PFT concentrations (up to distances of several blocks away from the release points) can provide information needed to establish a baseline for determining how different types of releases could affect exposures both to the general public and to emergency responders.

It must be noted that the NY UPD data represent a unique set of actual human exposure measurements under realistic conditions, and are not outputs from a computer model. Therefore, uncertainties associated with realistically representing emergency response situations (e.g. due to simplifications in model formulations) are reduced, and the results directly applicable to community emergency response planning process for NYC, and can be interpreted to help planners elsewhere.

Objective

The overall objective of the project is to improve the current understanding of the impact of emergency events on the general public and improve community planning efforts, by utilizing the realistic human exposure data available from the UDP study to increase awareness at multiple levels of emergency response on the health impacts of potential releases of highly toxic chemical, physical or biological agents in urban centers like New York City. This information can be interpreted in current planning approaches for community response and then be made available to planners in the federal government, the military, and the public improve or augment applicable community procedures for catastrophic events.

Specific Aims

This specific aims of this project were to:

1. Utilize the exposure concentration results from the NY Urban Dispersion Program to: establish the spatial and temporal patterns of impact from exposure to highly toxic substances on members of the general public in NYC, including typical activity patterns, and interpret them in relation to information used currently by the community planners and emergency responders within urban settings. The results and their visualization will provide realistic estimates of the contact that would have occurred if the tracers had been actual CBR agents. These transformed results provide information for assessing potential exposures and risks within a community from releases of selected highly toxic substances.
2. Employ agent-specific analyses of UDP data to augment and/or provide appropriate suggestions for adjustments to: existing guidelines on evacuation, shelter in place, transportation routes, and location of "cold zone" perimeters after hazardous events.
3. Incorporate estimates of the magnitude and severity of casualties obtained for each toxic agent into a framework for characterizing stresses on health care resources by: realistically estimating casualties (response personnel and general community) from a catastrophic release.
4. Interpret the agent-specific analyses for improving strategies for the spatial location of passive samplers in NYC and other locations that can be easily deployed after an event to determine the residual contamination from non-volatile agents.

Approach

This project follows an approach that will allow rapid analysis of casualties and stress on health care scenarios in a Geographic Information Systems (GIS) framework. Specifically it provides a procedure for performing GIS-based analysis for a diverse set of agent releases (chemical, biological, and radiological) and exposure scenarios provided as inputs to the system. It allows for estimating the overall impacts in terms of both casualties and in terms of stress on health care resources.

Selection of representative CBR agents:

The following agents were selected after consultations with project collaborators and agencies related to emergency response to study the following plausible emergency event scenarios: such as accidents involving transportation of hazardous material, and terrorist events involving a chemical warfare, biological, or radiological agents (CBR agents). Example CBR agents studied using this system include: (a) chlorine and phosgene representing industrial chemicals, (b) anthrax representing a biological warfare agent, (c) sarin representing a chemical warfare agent, and (d) cesium representing a radiological agent.

The interpretation of exposure data was performed by utilizing the Acute Exposure Guideline Levels (AGELs) as metrics relevant for exposures of general populations and emergency responders. In general, measures for response to community catastrophes as well as for disaster control can be projected more accurately on the basis of the AEGL framework (NRC, 2001). AEGL values represent toxicologically substantiated ceiling exposure levels for different relevant exposure periods (10 minutes, 30 minutes, 1 hour, 4 hours, 8 hours), with AEGL-1 denoting the threshold for notable discomfort; AEGL-2 denoting the threshold for serious, long-lasting effects or an impaired ability to escape; and AEGL-3 denoting the threshold for lethal effects. In case of agents such as anthrax, the corresponding analyses were made based on lethal doses (e.g. LD_{10} indicating that 10% of exposed population will be infected). These different metrics are useful in assisting the responders and planners in defining ways to address specific situations.

Interpreting the UDP data to plausible scenarios within the New York City:

The UDP data were translated to multiple CBR agents and applied to different scenarios within Midtown Manhattan. For example, the Madison Square Garden has a capacity of approximately 18,000 to 20,000 depending on the type of event. The Rockefeller Center, correspondingly, has about 200,000 to 350,000 visitors per day, translating to about 10,000 to 70,000 people in the area depending on the time of the day. A background population density of 27,500/km2 was also used to represent residential population in this region. Computer modules have been developed to represent and analyze, within a GIS system, these population distributions in relation to potential threat zones after the release of a CBR agent. Sensitivity analyses were performed considering differential impacts of emergency events based on different potential occupancy levels, distribution of people around the location based on different time periods in relation to an event. This approach will be applicable to many other urban areas that share similar geographic attributes as areas studied in the NY UDP experiment.

Characterizing the zones of population distributions:

In order to assess the impact of releases of CBR agents on the general populations, estimates of number of people (event attendees and general public in the area) are required in conjunction with information on the spread of contaminant plumes or threat zones. These zones are developed based on anticipated population distributions during an event at the MGS or during a specific time of day at the Rockefeller Center. In the case of the MSG, the zones include an inner most zone (Zone 1) representing the MSG arena (with a total seating capacity of 18,000 to

20,000). Zone 2 represents the immediate vicinity (reflecting people walking into or out of the arena), Zone 3 represents nearby public (e.g. reflecting attendees that are making way to the event). Zone 4 reflects an expansion of Zone 3 (accounting for attendees walking from bus or train stations to the arena). Zone 5 reflects the general "background population" in the city, and covers the entire study area for impact analysis (a background population density of 27,500/km2 is assumed).

An emergency planner can specify how the overall attendees are distributed within each zone and can also specify any changes to the background population distribution due to the performance event. It must be noted that the extent of the plume spread cannot be extrapolated to larger areas than the measured distances in the original UDP experiment because the accuracy of such extrapolations reduces with increasing distances away from translated measurement locations.

Assessing the spread of contaminants across different threat zones:

The UDP data have been translated to Chlorine, Sarin, Phosgene, Cesium, and Anthrax, and focus on a "medium" scale warfare agent release or a transportation incident (e.g. 1 ton/hr release of chlorine from a truck; 100 kg/hr release of Sarin from a small truck; 1 ton/hr release of phosgene from a small truck; and 100 g/hr release of anthrax spores from a small bag).

The nature of the UDP data allows us to couple information on source characteristics and exposure measurements along with the chemical and physical characteristics of the tracer and an agent of concern in such a way as to obtain estimates of ambient concentrations and exposures to different chemical, radiological and biological agents by applying "realistic release scenarios." However, the approach still approximates the properties of the agents using an assumption of an ideal gas. Specifically, for each agent of concern, the agent is assumed to disperse in a manner similar to an ideal gas. The concentration estimates for each hypothetical release scenario are then based on scaling the source terms used in each UDP experiment, along with the properties of the agent of concern, and the source strength in the scenario. These scaled concentrations are then used to develop plume profiles and "threat zones" based on Acute Exposure Guideline Levels. In order to estimate potential stresses on the health care resources, these plume snapshots are integrated with spatial distributions of populations.

Specifying potential exposure scenarios for assessing impacts and casualties:

The approach and modules developed in this project for assessing risks associated with different hypothetical emergency events are formulated in terms of parameters that are tangible for an emergency responder or planner. These parameters are intended to accurately characterize potential population distributions, and are described in the following:

Release Location: The release location can be specified to correspond to one of the multiple different locations of tracer releases in the UDP experiment. For example, in case of the MSG experiment, valid options are release points A, B, C, and D, corresponding to the north west, north east, south east, and south west corners, of the MSG.

Type of Agent Released: This project focused on the following chemical, biological, and radiological warfare agents for exposure and risk estimation: chlorine, sarin, phosgene, fuel oil, cesium, and anthrax. The scenarios focused on "medium" scale warfare agent releases and transportation incidents, as described earlier.

Occupancy Percentage in the Arena: The analysis focused on different levels and types of population distributions within and around the arena: inside the arena (Zone 1), immediate vicinity (Zone 2), nearby public (attendees and general public; Zone 3), additional event-related people (Zone 4), and the general background population in the city (Zone 5). Different hypothetical occupancy levels and population distributions were specified by using numbers for percentages of the event population within each zone. It must be noted that the event related population is partitioned into Zones 1 through 4, with 100% indicating full attendance.

Based on this approach, the following examples illustrate the types of scenarios that can be specified:

1. [Zone 1: 20%, Zone 2: 20%, Zone 3: 40%, Zone 4: 20%] indicates that the event is completely sold out (sum of percentages adding up to 100% of the arena capacity) and with the distribution of the population mostly in the area around the arena.

2. [Zone 1: 100%, Zone 2: 0%, Zone 3: 0%, Zone 4: 0%] indicates that the event is completely sold out and all attendees are inside the arena.

3. [Zone 1: 40%, Zone 2: 0%, Zone 3: 0%, Zone 4: 0%] indicates that the event is not fully sold out (only 40% sold) and all attendees are inside the arena.

4. [Zone 1: 0%, Zone 2: 0%, Zone 3: 0%, Zone 4: 0%] indicates that the incident is specified for a time when there is no ongoing event taking place.

Similar distributions can be specified to address additional scenarios.

Background Population Distribution (relative to residential population distribution): This specifies the increase or decrease in the population levels nearby (e.g. increased number of people due to commuting during weekdays, decrease in the number of people during weekends, etc.) The baseline density of the population is set to the average population density in the city (27,500/km2). Increases and decreases can be specified by relative percentages, with 100% corresponding to no change in population density.

Indoor Penetration of Contaminants: This corresponds to the relative levels of an agent indoors based on estimates of outdoor levels and utilizes a simplified approximation of the factors affecting the penetration of outdoor contaminants indoors. Specifically, a linear ratio of outdoor to indoor levels has been used to estimate potential impacts and risks. These ratios are directly applied to the estimates of corresponding outdoor risks to estimate indoor risks. For example, if the level outdoors is at AEGL-3, and the indoor ratio is 0.1, this approach estimates that 10% of the people indoors will be at risk level corresponding to AEGL-3. This assumption is not always applicable, but it has been used to account for the heterogeneity within the indoor environment and to account for the incomplete understanding of complex processes governing indoor and outdoor levels.

Estimated Risks: These are based on spatial multiplications of the maps of the population distribution fields with the spatial fields reflecting different risk levels, and the results are summarized in terms of as numbers of people that suffer (a) serious injury, (b) non-serious injury, and (c) mild inconvenience. The AEGL levels for individual chemicals have been used to characterize the threat levels.

Impact on Available Health Care Resources: Information on available hospitals and emergency care facilities near the vicinity of the arena has been used to estimate the potential impacts on the health care system. The major attributes considered in this analysis include (a) capacity of the facility (in terms of available number of beds), (b) distance to the facility, and (c) an analyst-specified "preference" of the health care facility. Examples of major hospitals near the MSG area include: (1) Beth Israel Medical Center, with a capacity of approximately 1400 beds, at a distance of 1.2 miles, (2) Bellevue Hospital Center, with a capacity of about 800 beds, at a distance of 1.1 miles, (3) NYU Lagone Medical Center (Tisch Hospital) with a capacity of 700 beds, at a distance of 1.2 miles.

One of the default options in the computational modules is the assignment of individual weights to each hospital based on the distance (an inverse distance metric using the nearest rounded mile). The approach also provides an option to input the preference of the operator, based on expert judgment and an understanding of the areas to be studied.

Scope

The approach of scaling the UDP measurements and the computational modules developed here are intended to be a resource for emergency planners and responders, with an understanding that it will supplement their wide range of experience and expertise with actionable information that is based on new experimental data on contaminant dispersion and exposures to populations in complex urban areas. The data interpreted in this study are based on tracer experiments that consider real settings of urban geography, and movement of people in the vicinity of a release, etc. Thus, the findings of this project are expected to aid the emergency planner and responder. The computational modules allow an analyst an understanding of and actionable information on the following:

1. Patterns threat zones in terms of severity of consequences following an emergency incident: serious injury resulting in illness or death, moderate injury, minor effects, and safe area. This will also provide information on areas emergency responders should not enter, where they should use full protective equipment, and where they can enter even in the absence of complete protective equipment. These will also help in identifying where temporary treatment facilities should be set up (i.e. outside the lowest threat zone, but with an adequate margin of safety).

2. Changes in the different threat zones changes based on the type of the agent involved in the incident (i.e., to understand how the zones of impact change based on the toxicity of the agent).
3. Casualties expected under different release conditions (timing and amount of releases), focusing on various degrees of injury for the local population, workers, visitors, and emergency responders.
4. Impact on the health care facilities in the vicinity, to understand the type of plans needed to address the level of expansion required for available facilities or adjunct units (e.g. mobile hospitals).
5. Uncertainty in estimates of threat zones and casualties. This allows for providing a degree of confidence in different estimates, and what type of "margin of safety" should be employed in preparedness, planning and response actions.

The results provide information useful in achieving the following community catastrophic emergency preparedness and response goals:

1. Identifying the types of threat detection systems that need to be in place for different threat scenarios. This is critical because for many event locations, currently there is a lack of realistic estimates of potential human exposure and risks to attendees and local population following a large-scale accident or a terrorist event.
2. Providing a resource for an in-service training system for emergency responders that complements existing training material.
3. Provide a rational scientific basis for incorporating plume modeling and analysis outcomes into an overall training system/functional field program.

4. The analysis of different scenarios and reports on case studies are expected to be useful for soliciting feedback from specific stakeholders by providing information that would be most valuable for the stakeholders.

Mode of Technology Transfer

Detailed descriptions of the algorithms, computer source code for the algorithms, GIS shape files consisting of plume snapshots, population distributions, etc., will be provided as part of the final report.

CONCLUDING CHAPTER

Summary

The computational modules and the approach described above have been used for assessing the risks to attendees and to the general population at the Madison Square Garden, and the general public and visitors at the Rockefeller Center. Different chemical and biological agents were simulated and the estimates of casualties and the number of people to be admitted to the hospitals were computed. Additionally, the uncertainty associated with the estimates of overall casualties arising from the uncertainty in the release location has also been characterized by comparing the estimates from different release location assumptions. This highlights the need for accurately characterizing the local meteorology as well as the uncertainties in the release characteristics (location and timing). Based on the analysis results, the Project Team has suggested recommendations on the type of field studies that can be developed to ensure that effective planning, preparedness, and response strategies can be developed using all the available information. Additionally, these analyses can be extended for improving the mathematical models for predicting potential acute human exposures to accidental or deliberate releases of harmful gases Hanna & Baja, 2009, and for establishing more effective guidelines for emergency response entrance and exit strategies and for estimating the location of potential victims.

Conclusions

The analyses and case studies provided here can be considered more as "demonstration case studies" of a framework that will allow improvement of emergency planning and response. This approach can be translated to other arenas or urban locations of interest and can be expanded to other type of industrial chemicals, chemical warfare agents, non-infectious biological agents, and radiological agents. The example agents selected for this study are representative of the suite of agents that can be volatilized or released as fine particles into the atmosphere. It does not cover the longer impact of reactive materials or materials which of very molecular weight that will deposit and contaminate the ground or other surfaces (e.g. vesicants).

The project demonstrates the critical importance of the following factors in relation to potential impacts: (a) timing of an emergency incident in relation to the progress of an event, (b) accurate characterization of the release location (e.g. different corners of an arena), (c) ventilation conditions in an arena, (d) dynamics of urban dispersion that cannot be adequately captured by currently used simple dispersion models such as ALOHA (Areal Locations of Hazardous Atmospheres; NOAA, 2004), and HPAC (Hazard Prediction and Assessment Capability; DTRA, 2003), and (e) the relative toxicities of individual chemicals (which has substantial impact on the threat zones).

Recommendations

The following observations and recommendation can be made based on the analyses:

There is substantial sensitivity of casualty estimates to the time of the incident in relation to the progress of an event at the arena, and location of release. This implies that multiple alternative response strategies should be in place to address emergency events during different stages of an event in an arena. Overall, a complete ``toolbox" of measurement devices, dispersion models, and visualizations based on data analysis of the type presented will be valuable to emergency responders. These tool boxes will help an emergency planner/responder make decisions by taking into account all available data, along with their experience and judgment, in order to arrive at optimal approaches for responding to an emergency.

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CHAPTER 3

Project 09 04 F: Emergency Shelter Location and Resource Allocation

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Emergency Shelter Location and Resource Allocation

Project 09 04 F

Final Report

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Abstract

Climate-related health emergencies are a considerable burden to public health infrastructure. The objective of this project is evaluating quantitative strategies for the allocation of evacuees, resources, and healthcare workers in response to a sustained heat wave in the Newark, NJ area. Using an interdisciplinary team of researchers in climatology, operations research and epidemiology, we explored dynamic response plans to address the urgent care needs of vulnerable populations during heat events, as well as quantifying the timing and nature of medical complications that stem from extreme temperatures.

The research has yielded promising empirical results, quantifying both the extent and nature of heat waves and temperature spikes in the Newark area, and the consequences of heat spikes on gastrointestinal illness in the elderly population of the United States. Additionally, theoretical modeling studies building off these empirical results have shown that dynamic routing strategies that direct patients, health-care workers and equipment to available healthcare facilities and other shelters can have a direct and measurable impact to reduce excess mortality. Lastly, simulation based studies have shown that simple and practical routing algorithms can be successful in making progress toward theoretical optimal reduction in adverse health outcomes from heat-related emergencies.

Foreword

This project was performed by Fefferman, Nina H., Baykal-Gürsoy, Melike., Boros, Endre., Eisenstein, Robert., Carpenter, Tami., Roberts, Fred., Robinson, David., Naumova, Elena N., and Chui, Kenneth and was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School and Robert Wood Johnson University Hospital- with support from Department of Defense Grant No. W9132T-10-1-0001.

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INTRODUCTION

Background

Extreme climatic events, including hurricanes, blizzards and heat waves, have substantial health related consequences, including severe morbidity and mortality. The 1995 heat wave in Chicago, for example, caused an estimated 696 excess deaths (Whitman et al. 1997). During these events, with the prospect of failing heating or cooling systems, electrical grid failures etc., the elderly or other vulnerable populations may be evacuated to central locations for care. These types of evacuations – and the underlying increase in healthcare needs – can create sudden surges in demand for the healthcare system, and increase the complexity of disaster management operations. These logistical consequences can be mitigated somewhat by careful planning of the placement of evacuation shelters, emergency personnel and equipment, and evacuee routing strategy.

Building on previous research conducted as a project of the Climate and Health Research Initiative, supported by a grant from the Rutgers University Academic Excellence Fund (CHRI AEF), we explore health-outcome sensitive strategies for evacuation and shelter placement in cases with both assumed already-existing resources/capacities at hospitals and shelters, and then expand our findings to consider a dynamic problem where healthcare workers and services may be deployed in targeted areas to alleviate local shortages in essential personnel.

Our models allow for the handling of random capacity needs and demands, developed in close collaboration with UMDNJ and RWJ University Hospital, as well as state-level emergency management agencies. They were created and analyzed by the existing group of interdisciplinary collaborators, including experts in climatology, spatial modeling, operations research, epidemiology and industrial engineering. Our results are intended to help provide decision makers in emergency response agencies with more robust planning strategies for climate-related health emergencies, as well as establish a strong foundation for further research proposals.

Objective

This study will develop optimization and simulation models to examine the optimal location of emergency shelters and allocation of resources into the shelters and area hospitals to minimize access time and maximize quality of service in responding to needs of individuals. The proposal will build additions to the models to incorporate the potential for dynamic healthcare worker allocation. The project will yield active research-ware which will be able to provide a robust set of shelter locations and evacuation routes for use in emergencies with specified study areas.

Approach

For information on the research methodology, please refer to the Research Methods chapter.

Scope

The reader should be aware that the results in this report are based heavily on parameter values for the Newark, New Jersey area. While the methods themselves are generalizable, other locations that do not share these parameters will not necessarily have the same findings. Additionally, as with all models (both optimization and simulation), some simplifying assumptions have been made, and they may not fully represent real situations. The results are therefore meant only to explore the relative quality of different types of routing and allocation decisions, and not to predict the actual numbers of adverse health outcomes expected or mitigated by intervention during heat events.

Mode of Technology Transfer

Based on our research, our recommendation is to base actions/planning for the mitigation of adverse health outcomes from extreme heat events on a combination of theoretical optimization studies which will determine best placement of temporary health-care facility locations and resource allocation to those locations, and simulation experiments which will help determine which instructions/announcements to the public will help achieve best results for understanding, compliance, and overall health outcomes.

RESEARCH METHODS

Introduction

The design of optimal evacuation strategies for a climate-related emergency can be approached using a wide variety of methods from different fields. We use four primary techniques, rooted in Epidemiology, Climatology, Operations Research, and Agent-Based Simulation. The first two form the bulk of the task of parameterizing the models, providing empirically grounded data from which to build scenarios. The former uses well-established techniques to find solutions to challenging logistical problems – in this case, dynamic evacuation and emergency management routing during a climate-related health emergency. The present research focuses on a particular scenario, an extreme heat wave in the Newark area.

Climatology

Dr. David A. Robinson, New Jersey State Climatologist and Chair of the Rutgers University Department of Geography directed the climatology portion of the research. The primary aim of the climatology portion of the project was to characterize the levels of excessive heat in Newark, NJ during recent years – 1997 to 2010, in order to provide realistic heat wave scenarios for the given environment.

Temperature measurements over a 14-year period were collected at a National Weather Service Automated Surface Observing Station (NWS ASOS) situated between the outermost runaway of Newark Liberty Airport and the New Jersey Turnpike (Figure 1). This location is situated between downtown Newark and Elizabeth, with the surrounding land being either urban/suburban environments, or Newark Bay. The station itself has an aspirated thermistor to record temperatures roughly 5 feet above a grassy surface. In addition to direct temperature measurements, Heat Index (Steadman 1979) was calculated from the observed temperatures and relative humidity. From this information, the number of days, number of hours, and time of day where observed temperatures rise above 90° or 100°, as well as the duration and characteristics of sustained heat waves was determined (see Results).

Epidemiology

Along with the determination of the extent and nature of extreme heat events in the Newark area, it is necessary to assess the public health impacts of these events. Drs. Elena Naumova and Ken Chui, at Tufts University, have been working on a time-series analysis of the relationship between gastrointestinal infections in the U.S. elderly population and extreme heat events, using 8.6 million hospitalization records from the Centers for Medicare and Medicaid Services (CMS) databases in 122 cities in the continental United States. This problem is methodologically challenging, as there is likely a time-lag between a peak in temperature and a peak in observed infectious disease cases, as most gastrointestinal infections have a short but tangible incubation period before symptoms appear and require the patient to seek medical care.

The analysis (based on established techniques; cf. Naumova et al. 2007, Naumova and MacNeill 2005, and Lofgren et al. 2007), used a Poisson regression model with time-distributed effects, which proved in simulation studies to ably predict case numbers in outbreaks, and had superior performance to similarly construction Gaussian statistical models (see Results). The regression equation is as follows:

$$\log[E(Y)] = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \beta_4 \sin(2\pi\omega t) + \beta_5 \cos(2\pi\omega t) + \beta_6(\mu_t) + \varepsilon \quad \text{(Eq. 1)}$$

Briefly, the log number of expected cases is predicted by an intercept ($ß_0$), three terms for linear and higher-order trends over time ($ß_{1-3}$), two terms for seasonal fluctuations in disease incidence ($ß_{4-5}$) and finally a term for extreme heat events in the time series ($ß_6$), as well as an error term. It is $ß_6$ that is of special interest, as it describes the excess mortality due to extreme heat events not otherwise explainable by long-term trends in disease incidence, or the seasonal disease patterns many gastrointestinal infections exhibit. The difference in peak timing between gastrointestinal disease and temperature, as well as the variability in these rates, was assessed. See Results for examples of this analysis.

Operations Research

Once workable estimates of disease burden and the extent of extreme heat events in the Newark area was determined, optimization models were used to determine optimal response strategies to heat-emergency related evacuations, and compared to a model using more "realistic" solutions one might typically see on the ground (see Agent-Based Simulations section below), to compare how far from a theoretically optimal solution the more practical, realistic scenarios deviate. These models relied on parameter estimates from the Epidemiology and Climatology investigations and also from available published literature (Huang et al. 2010, Doherty et al. 2009, El-Zein et al. 2004, El-Zein and Twetwel-Salem 2005, and Lin 2009)

Drs. Melike Baykal-Gürsoy and Endre Boros headed the operations research component of the project. Two models seeking purely optimal results were developed, one for the optimal positioning of response centers, staffing and opening them from a list of known possible locations, such as local high schools or hospitals – as well as the allocation of a finite amount of resources, such as trained nurses, bottles of water, oxygen, EKG monitors, O2 SAT meters, defibrillators, IVs bags and stands, and cots. The objective of this model was to limit the number of people not served by facilities, resources or both, and thus at risk of death or illness due to non-treatment. These models assumed that individuals began their travels from home (according to US Census distribution) and experienced adverse heat-related health outcomes based on rates extracted from the Epidemiological averages analyzed (described below), first in a case of low-level extreme heat (LLEH), and then for a case of high-level extreme heat (HLEH). Individuals in each of these scenarios were limited spatially (rather than temporally) in their travel capabilities, required to seek care within either a 1-mile or 2-mile radius. This model included explicit facility capacity and resource availability (depleted by providing care in each additional unit by individual need).

The second optimization model concerned the location of evacuation centers (as above), but focused on the logistical aspects of evacuation of at-risk individuals from their homes to those evacuation centers. The scope of that problem is two-fold – both how to assign particular individuals to a location, and route them efficiently during an emergency. The area under study for this model is a portion of the Newark area (Figure 2), using Schools, Libraries and Hospitals (again see Figure 2) as potential evacuation center sites as a proof of concept for a more complex model spanning a larger area. Based on hospitalization rates for the Newark area provided by Dr. Naumova, hospitalization rates for three conditions, dehydration, cardiovascular disease and respiratory disease were modeled as potentially fatal outcomes, and three scenarios were modeled: the use of hospitals only as evacuation centers, hospitals and other cooling centers (such as schools or libraries converted temporarily for that purpose), and hospitals, other cooling centers and mobile acute care centers, all assuming a 7-day long heat event.

Agent-Based Simulation of Practical Routing Algorithms

Theoretically optimal solutions are only useful if they can be achieved in practice. We therefore additionally built a series of simulation models, in which individuals would travel particular routes (from home to a non-home location and back) around the city. The number of individuals 'living' on each city block was determined according to US Census data (see Figure 11). Travel along routes was limited by realistic road capacity (based on OpenStreetMap data), allowing for traffic jams to slow travel depending on demand over time. In cases of extreme heat, individuals had an independent probability of developing each type of heat-related health concern (e.g. dehydration, respiratory difficulty, or cardiovascular complications, or some combination thereof). Each individual then had an independently assigned 'delay duration' between onset of heat-related reaction and recognition that health care was needed. Once recognition of care was achieved, individuals headed for a health-care provision facility.

Facilities were assumed to provide one of three different levels of care: Level 1 – Public Schools Converted to Cooling Centers (assumed to have a capacity to care for 60 individuals at a time, able to care for individuals experiencing dehydration), Level 2 – Public Libraries Converted to Intermediate-Care Medical Facilities (assumed to have a capacity of 30 individuals at a time, able to care for individuals experiencing dehydration or respiratory distress), and Level 3 – Hospitals (assumed to have an available capacity to dedicate to heat-related illness of 60 individuals at a time, able to care for individuals experiencing dehydration, respiratory distress, or cardiovascular distress).

Individuals chose which facility to target based on one of three initial experimental algorithms: Nearest, Nearest Appropriate, and Nearest Exact. In the 'Nearest' case, each individual travels to the facility nearest to their current position, regardless of their need or the capability of the facility. In the 'Nearest Appropriate' case, each individual is able to recognize their own needs, and travel to the nearest facility that is able to provide treatment according to, or in excess of, their needs (i.e. even someone experiencing only minor dehydration may travel to a Hospital). Lastly, in the 'Nearest Appropriate Exact' case, each individual correctly identifies their own healthcare needs and travels to the nearest center able to treat at most their specific condition (i.e. dehydrated individuals will travel only to schools, individuals in respiratory distress will travel only to libraries, and individuals in cardiovascular distress will travel only to hospitals). Each of these scenarios require varying levels of cooperation and accuracy in self-diagnosis, but were considered as an initial set of cases, even though many more scenarios (expanding levels of knowledge, communication, and cooperation from the public) are underway.

Upon arrival at a treatment center, individuals were admitted (regardless of appropriateness of agreement in need to available care) so long as the facility had not yet reached capacity. Once admitted, individuals remained in the care of the facility for the remainder of the simulation. Individuals who arrived at a facility after the facility had reached its capacity were turned away, unable to receive care from the facility.

These simulations all employed an 'Extreme-Scenario' in which individuals who were unable to receive care at their first-choice facility were not redirected to other shelters, but instead waited (futilely) by that shelter. Further, heat exposure was assumed to lead uniformly to death if left untreated, even if the external, climatological level of heat itself fell (i.e. individuals who began to experience any adverse reaction to heat exposure were required to receive care at a health-care facility within a certain amount of time, or else were assumed to become worse, eventually leading to death at a rate dependent on the type of adverse reaction experienced). This Extreme-Scenario therefore implied that individuals whose first-choice shelter was full upon their arrival were very likely to die. This was done not due to any belief in the realism of the scenario, but to explore a 'worst case' outcome for the routing algorithm.

The input data for these simulations is listed in Table 3. Simulations were iterated under Monte Carlo Simulation until the variance in the outcomes was seen to converge.

RESULTS

Climatology

The Newark area spends a not inconsiderable amount of time with temperatures above 90°. On average, there are 124 hours spent at or above 90° in a year, with a maximum in the 14-year period of 319 hours (2010) and a minimum of 30 (2004). 90° or higher are reached on average 26 days annually, with a maximum of 54 days (2010) and a minimum of 13 days (2004). Using the Heat Index, a more physiologically grounded measure of how hot a person would "feel" on those days, these figures rise considerably. 197 hours are spent above 90°, with a maximum of 406 (2010) and a minimum of 85 (2009), and the heat index reaches or exceeds 90° 30 days annually, with a maximum of 58 days (2010) and a minimum of 16 days (2009). These temperatures begin rising around noon, and typically peak in the early to late afternoon, with temperatures not reaching morning levels until late at night. These results are summarized in Figures 3 – 5.

Sustained temperatures over 100° are somewhat rarer. On average, 1.43 days per year reach above 100°, with a maximum of 4 (2010) and a minimum of 0 (several years). Measured by Heat Index, this number rises to 3.71 days per year, with a maximum of 8 (2002) and a minimum of 0 (2000) (Figure 6). On average 2.4 hours are spent annually above 100°, with a maximum of 12 (2010) and a minimum of 0 (several years). There is however, considerable variability at this temperature level, especially when using the Heat Index (Figure 7).

In addition to the question of how often temperatures reach 'high temperatures' is the nature of heat waves – sustained periods of at least three consecutive days of maximum temperatures at or above 90°. On average, these periods last for 5 days, with the longest lasting a full 14 days (July 16 to July 29, 2010). The average hourly duration, from the first hourly reading over 90° to the last was 93 hours, with the maximum being 317 hours (same interval as above). Only 26% of hours in these intervals are spent below 80°, with a minimum of only 4% of hours spent below 80° (August 11th to August 14th, 2005). On average, four of these events occur per year, with a maximum of 7 (1999, 2010) and a minimum of 0 (2004). Evidently, heat waves and sustained periods of high temperature are not infrequent occurrences in the Newark area, and, assuming there are appreciable health impacts from these events (see below), planning for heat related emergencies is warranted.

Epidemiology

Gastrointestinal related hospitalizations are a significant public health burden in the U.S. Elderly. During the study period (1991 to 2004), there were 8.6 million hospitalizations with ICD (International Classification of Disease) codes related to gastrointestinal illness (Table 1). Both gastrointestinal infections ("GI", ICD codes 001-009) and non-specific gastrointestinal symptoms ("GS", ICD codes 558.9 and 787) peak in the spring months. GI is driven primarily by ICD code 008 – Other organisms not elsewhere classified. The timing of these illnesses (Figure

8) is consistent with viral infections, suggesting inadequate testing for them in elderly populations – unsurprising, as these organisms are often difficult to culture.

Examining the magnitude of the time-distributed regression model's term for the effect of extreme heat events (β_6 in the methods section), there is a significant effect of extreme heat events on the incidence of gastrointestinal illness, with a time-lag corresponding with many infectious diseases – and there is some evidence of a threshold effect depending on the temperature cut-point selected for the definition of an extreme heat event (ranging from 90^{th} percentile of temperature to 96^{th} percentile). This effect is present but less pronounced for non-specific gastrointestinal illness. There is however variability in both the observed incubation times and threshold effects. Examples of the analysis of two cities in the analysis, Boston and Cleveland, are shown in Figure 9.

Operations Research

The resource optimization model was run on an initial allocation-of-resources-to-shelters scenarios. This allocation scenario, run under both heat scenarios, and with both travel radii capabilities, converged to a solution in at most 5200 seconds (a little under 1.5 hours), and terminated entirely in at most 13334 seconds (a little under 4 hours), making them practical for real-time decision making support, once the initial implementation has been achieved for a given location/scenario, and the scenario-appropriate input data has been determined. Further, they exhibited at worst a 0.1% rate in relative error. (For specific results, see Table 7, though these were run more to investigate utility of these methods for real-time decision support.)

The evacuation routing model was successfully able to reduce the number of casualties due to the simulated heat emergency, in some scenarios eliminating extra casualties due to the event entirely (Table 2). Overall, even with sustained temperatures in the vicinity of 100^{o}, the combined use of hospitals, civic structures converted to cooling centers and mobile acute care centers was able to reduce the excess casualties from a heat related emergency by an order of magnitude over hospital-only strategies, let alone strategies that do not involve evacuating at-risk populations to stable shelters where they can find supplies and care. An example of block-level evacuation routing patterns generated by the first model can be seen in Figure 10.

Agent-Based Simulation of Practical Routing Algorithms

These investigations into the impact of having to effectively communicate simple strategies for evacuee routing to the public (rather than trying to communicate actually optimal strategies, which may be incredibly intricate), under the Extreme-Scenario showed some very promising initial results. No differences were seen in the number of individuals experiencing adverse reactions to heat events among the three initially tested routing algorithms (Figure 12). The expected number of deaths was artificially high due to the Extreme-Scenario assumption (Figure 13), however still provided valuable insight by allowing identification of facilities and traffic jams most likely to be responsible for increased numbers of fatalities by overcrowding (Figures 17-19; Tables 4-6). The 'Nearest Appropriate' algorithm was seen to result in substantial overcrowding at higher level facilities by lower-risk individuals, leading to bottlenecks in service provision (Figure 14). This exemplifies the type of trade-offs that can be expected between individual- and public-level motivation in health-care-seeking behavior. The 'Nearest' algorithm showed a distinct advantage over the other two algorithms when compared under the metric of 'Percent of Facilities at or Exceeding Capacity', however this was likely due to the Extreme-Scenario assumption of no redirection (Figure 15). Similarly, the results for the number of locations affected by traffic jams likely reflected only the severity of the Extreme-

Scenario (Figure 16) and actual insight from this effort will be gained during later investigations under different scenarios.

CONCLUSIONS AND RECOMMENDATIONS

Summary

Our studies show that shelter location, resource allocation to shelters, and the ability to rapidly and accurately communicate appropriate evacuation routes to the public will drastically affect the success of public health preparedness/intervention strategies for heat-events. We further demonstrate the utility of coupling theoretical optimization strategies with simulation-based methods to determine likely outcomes for public health interventions.

Conclusions

We conclude that adopted evacuation routing and resource allocation strategies should not attempt to attain theoretically optimal outcomes, but should rather choose the closest practicable approximation.

Recommendations

We recommend that the locations pin-pointed by the evacuation routing model as traffic jams and surge-overwhelmed facilities receive particular planning and attention (perhaps being scheduled to receive supplementary resources or personnel) to alleviate congestion and minimize negative outcomes. We anticipate further recommendations as the work to expand the agent-based simulations continues (under additional, external funding).

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FIGURES

Figure 1: Location of Newark Liberty International Airport - indicated by Marker A - and surrounding areas (© 2011 Google)

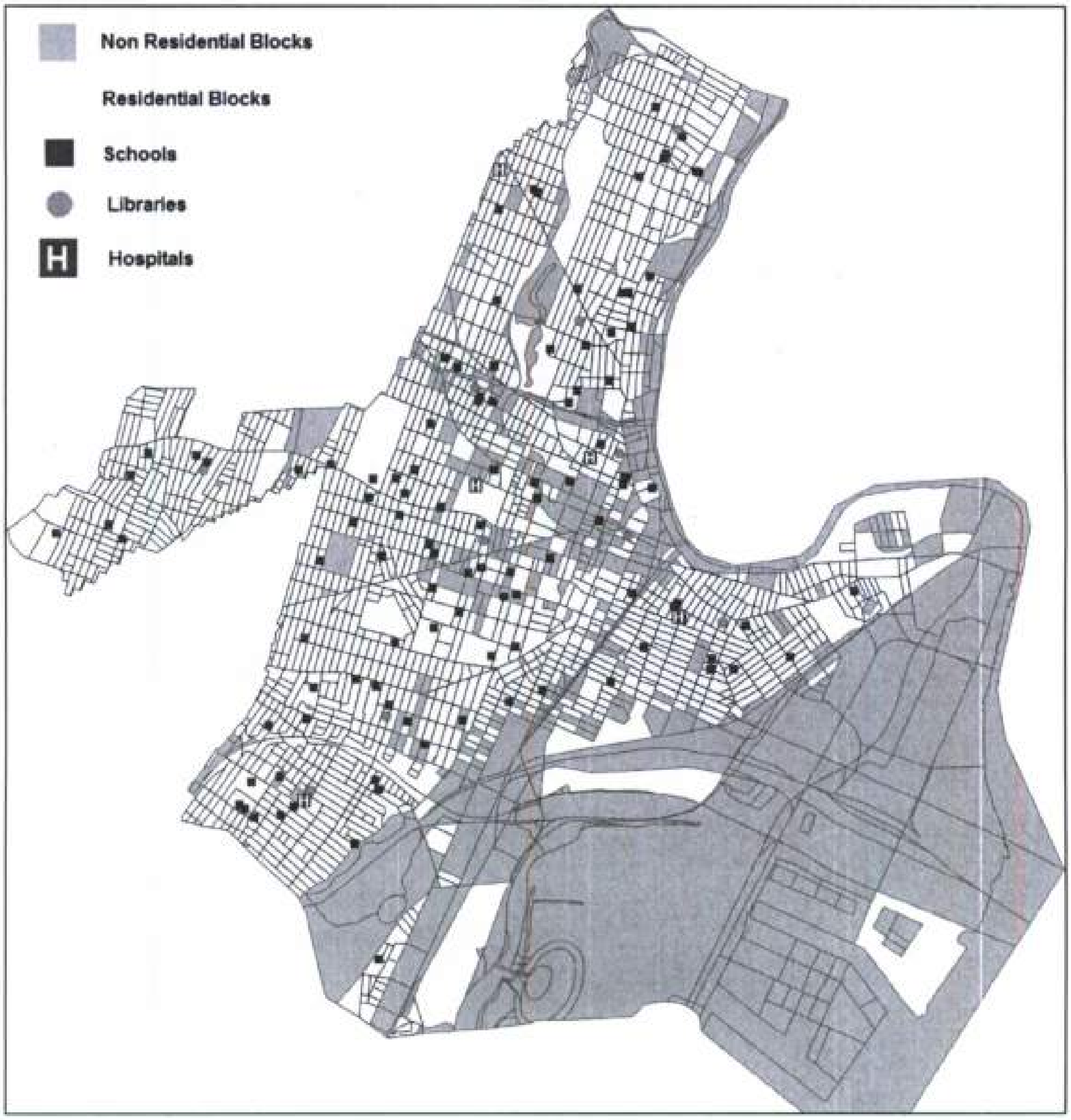

Figure 2: Area of study for evacuation routing optimization model of the Newark area, with potential evacuation sites and local zoning.

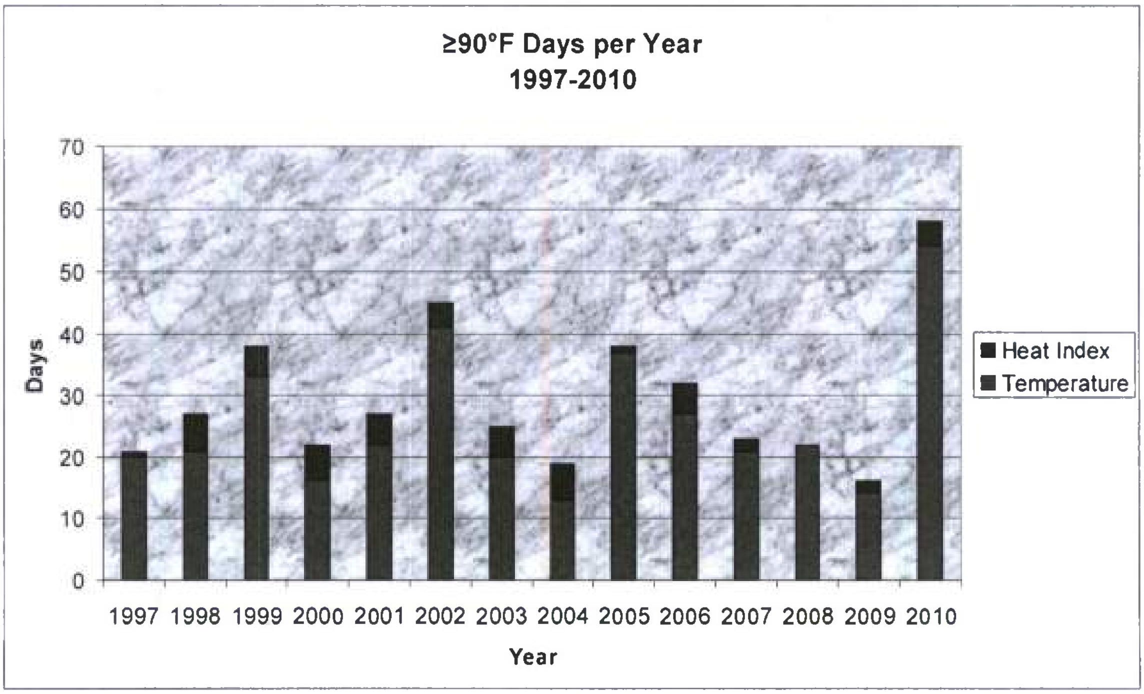

Figure 3: Days spent at or above 90° per year from 1997 to 2010. Figure includes both absolute measured temperatures as reported by the Newark Airport ASOS, as well as calculated heat index.

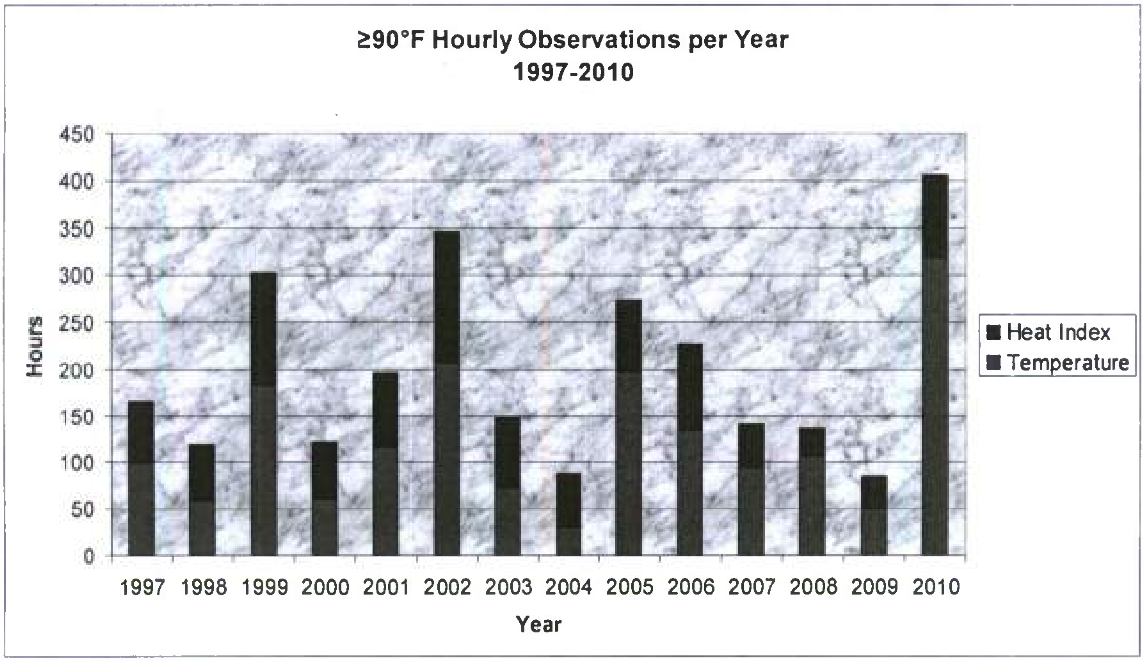

Figure 4: Hourly observations at or above 90° per year from 1997 to 2010. Figure includes both absolute measured temperatures as reported by the Newark Airport ASOS, as well as calculated heat index.

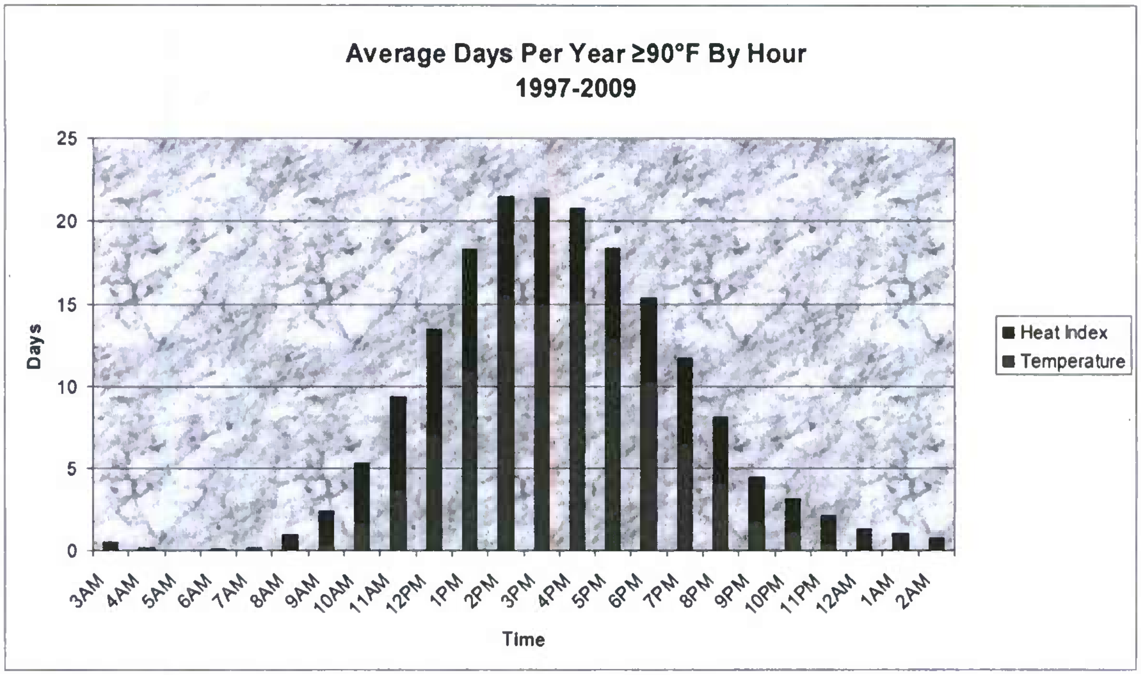

Figure 5: Average days per year spent at or above 90° per year by hour, from 1997 to 2009. Note 2010 measurements *are not* included in this figure. Figure includes both absolute measured temperatures as reported by the Newark Airport ASOS, as well as calculated heat index.

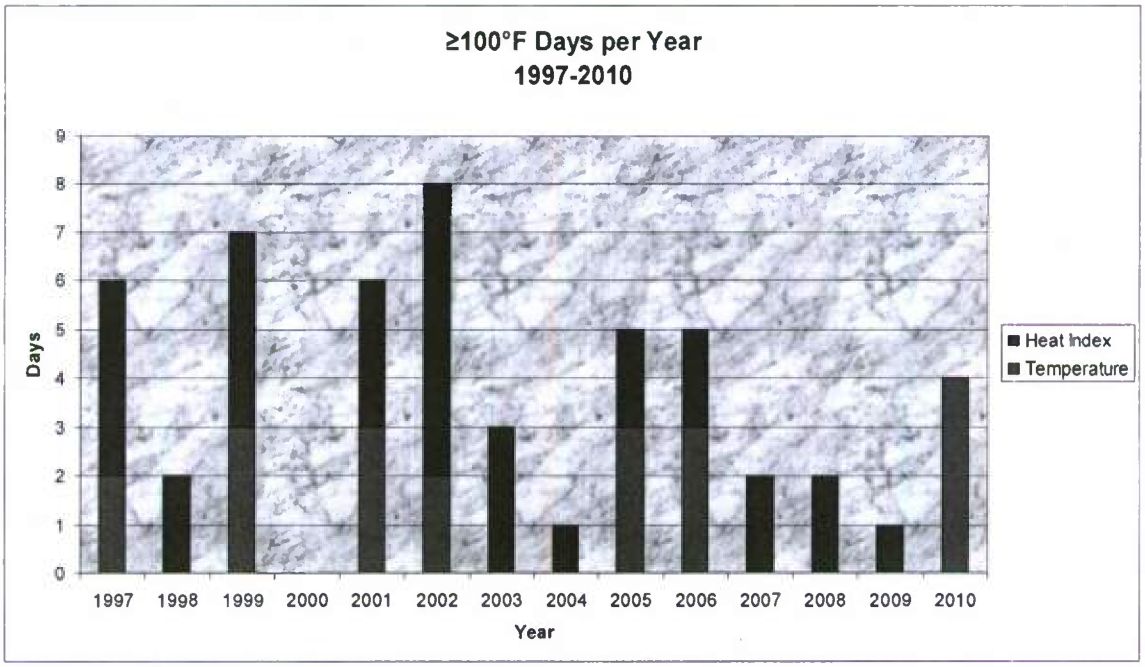

Figure 6: Days spent at or above 100° per year from 1997 to 2010. Figure includes both absolute measured temperatures as reported by the Newark Airport ASOS, as well as calculated heat index.

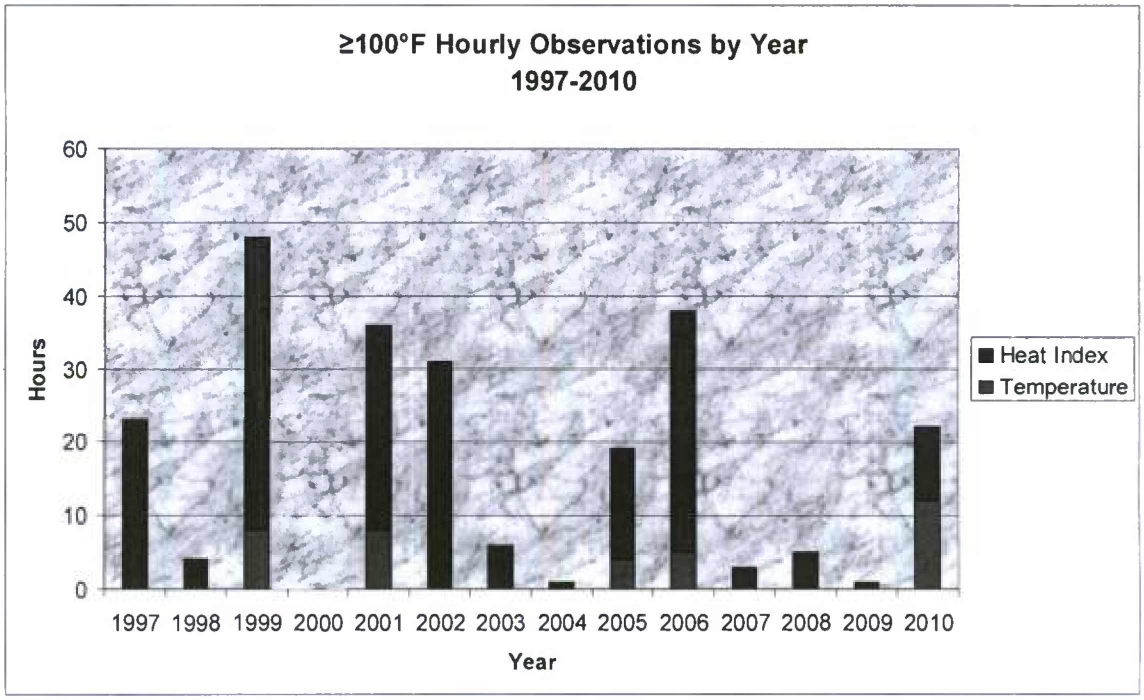

Figure 7: Hourly observations at or above 100° per year from 1997 to 2010. Figure includes both absolute measured temperatures as reported by the Newark Airport ASOS, as well as calculated heat index.

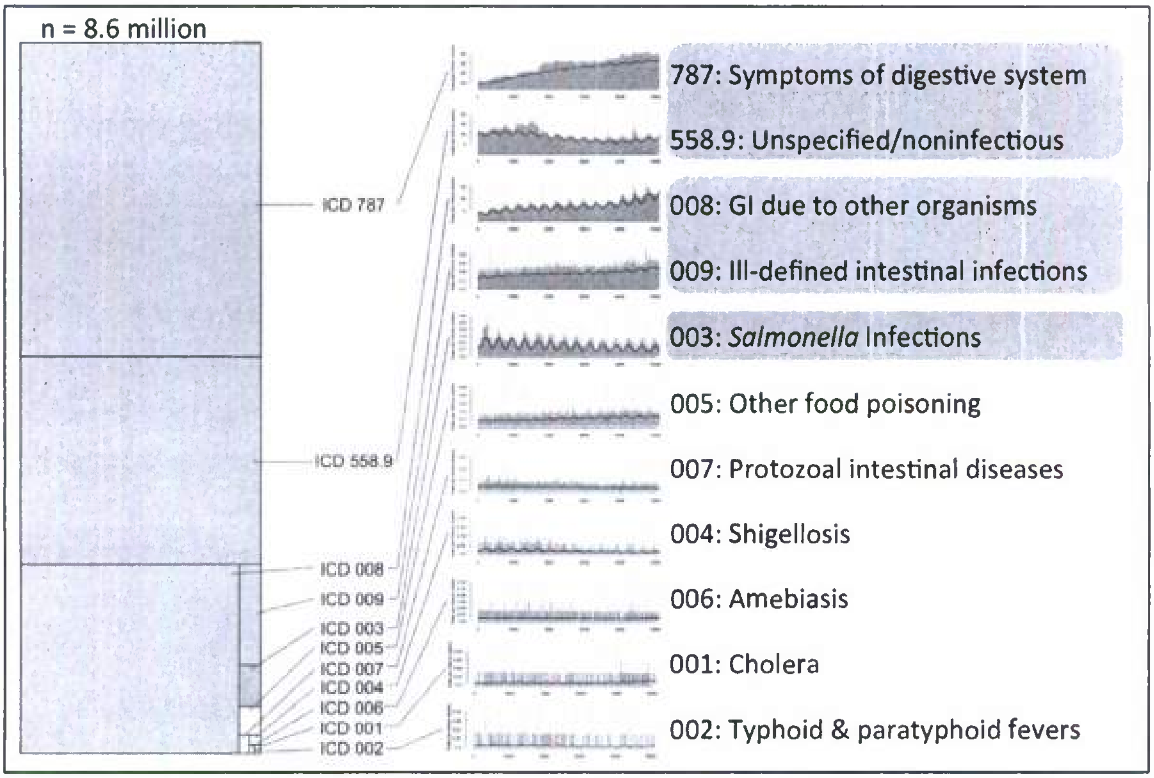

Figure 8: Distribution and timing of gastrointestinal hospitalization among U.S. elderly in 122 cities.

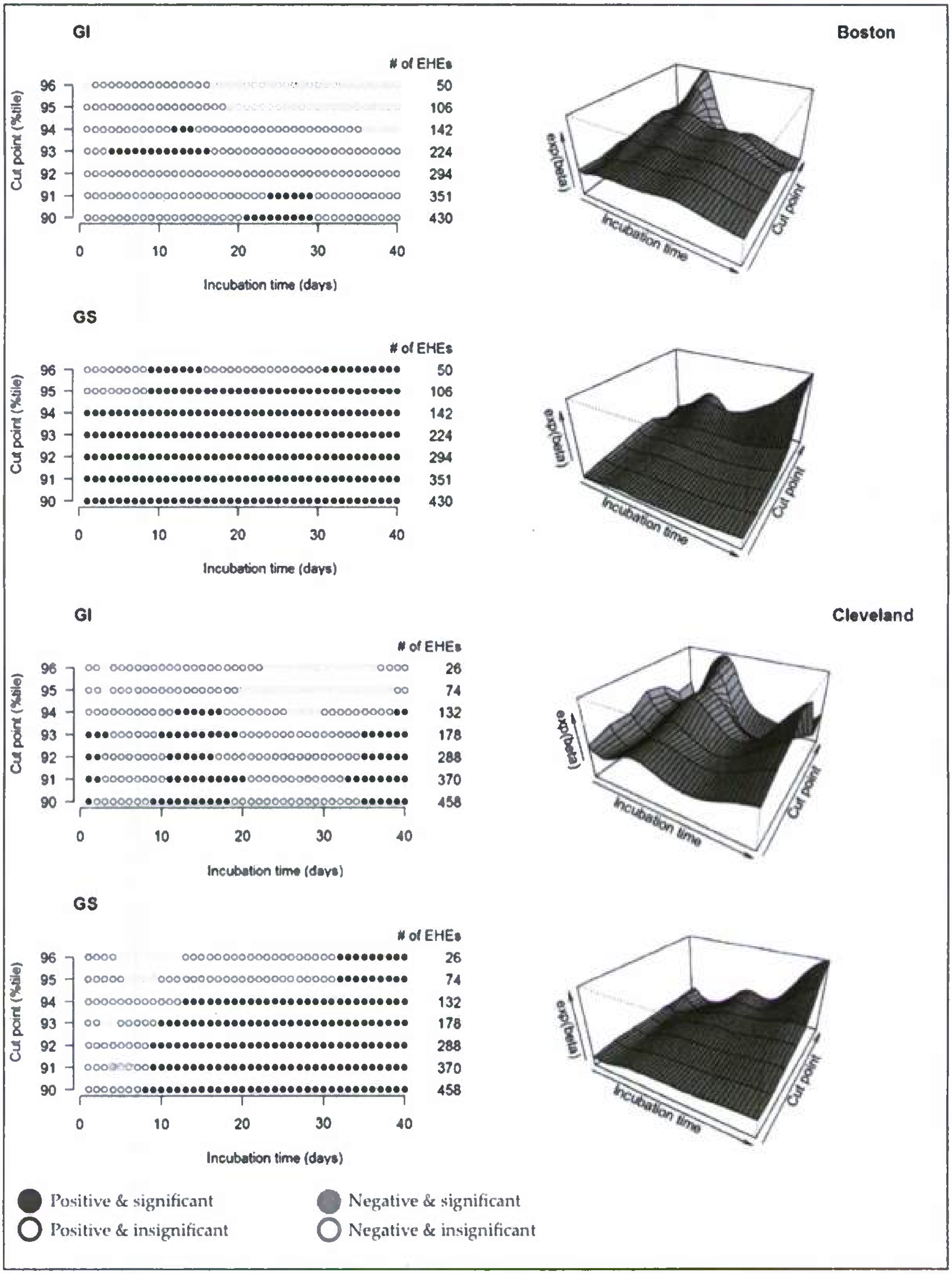

Figure 9: Magnitude of the estimated effect of extreme heat events on gastrointestinal infections (GI) and unspecified gastrointestinal disease (GS).

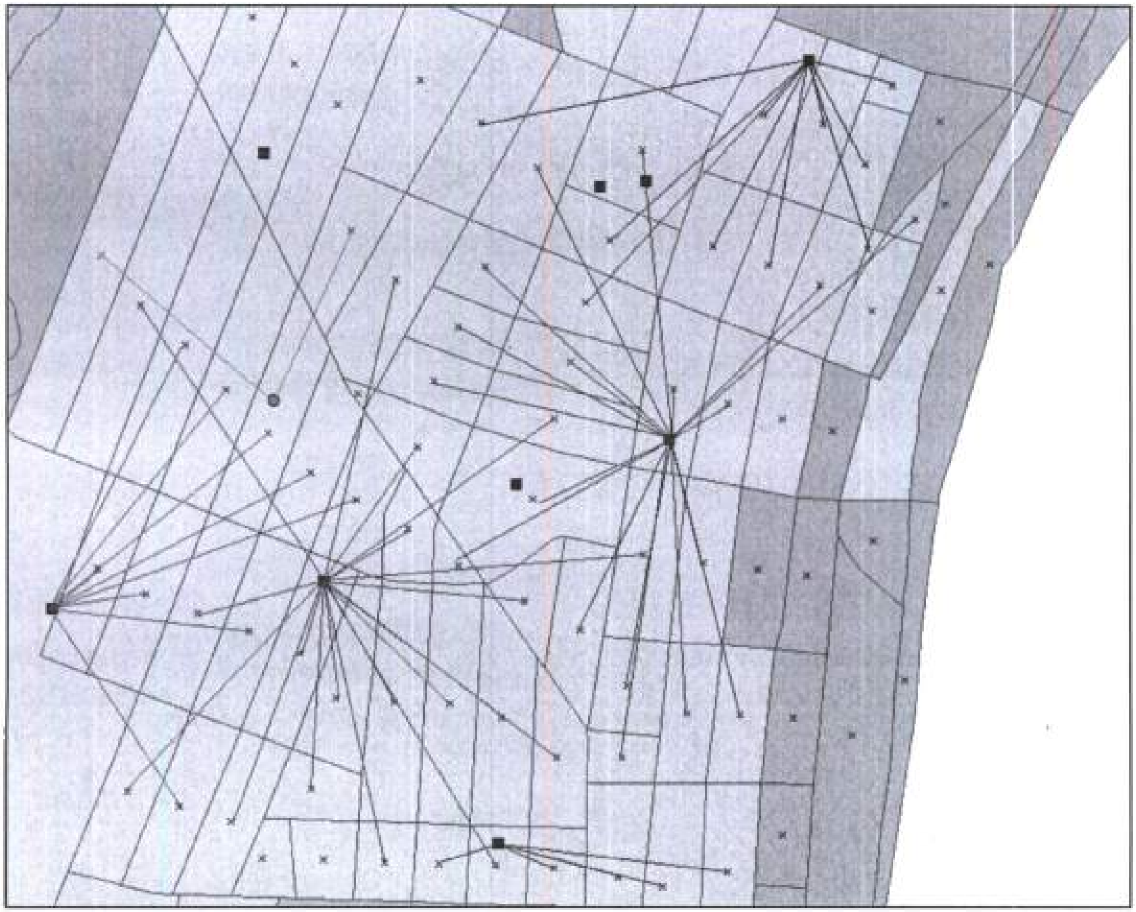

Figure 10: Example modeled evacuation routing scheme to cooling and treatment centers in the Newark area.

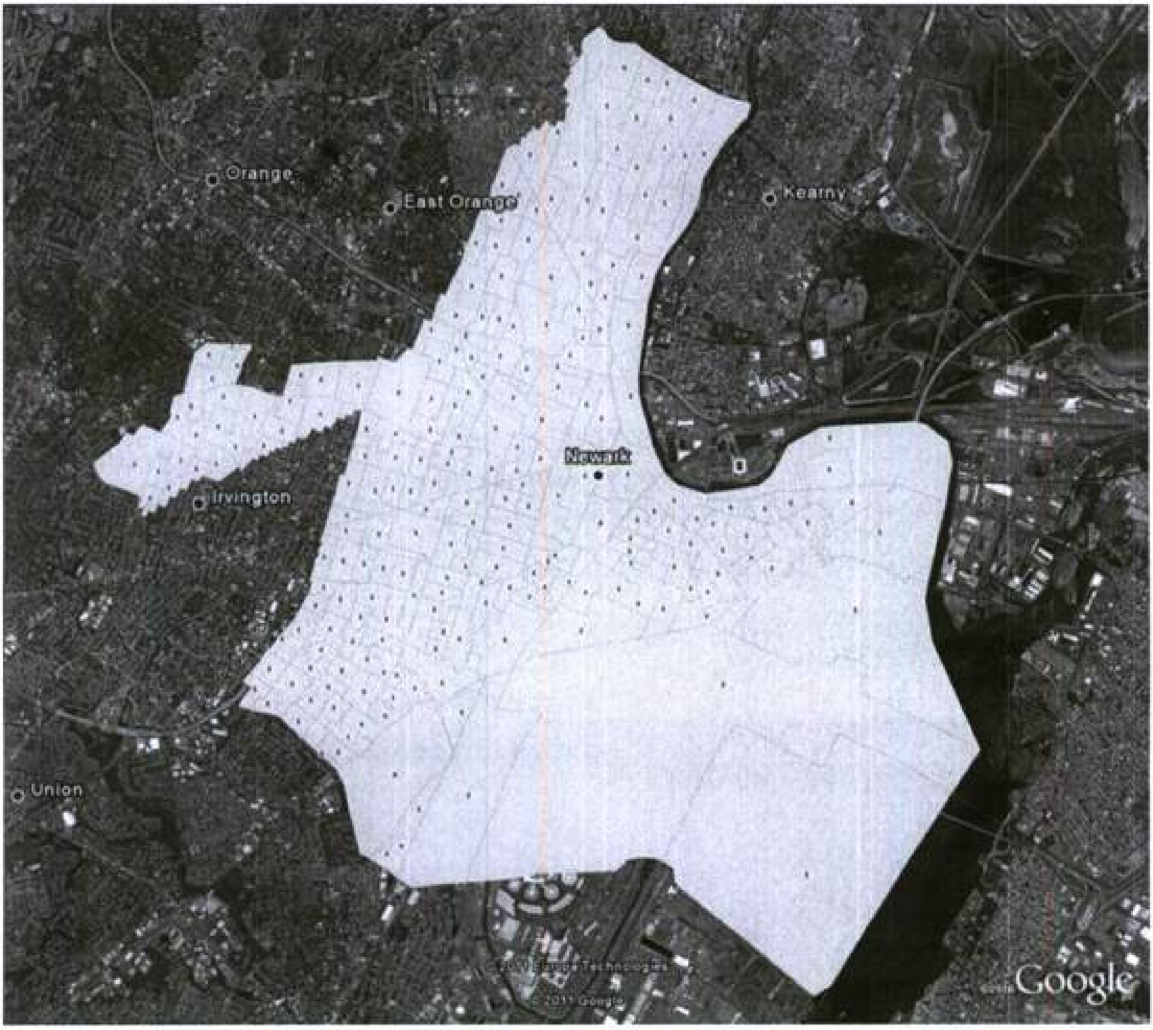

Figure 11: Map displaying census blocks (with centers noted in red) in Newark, NJ.

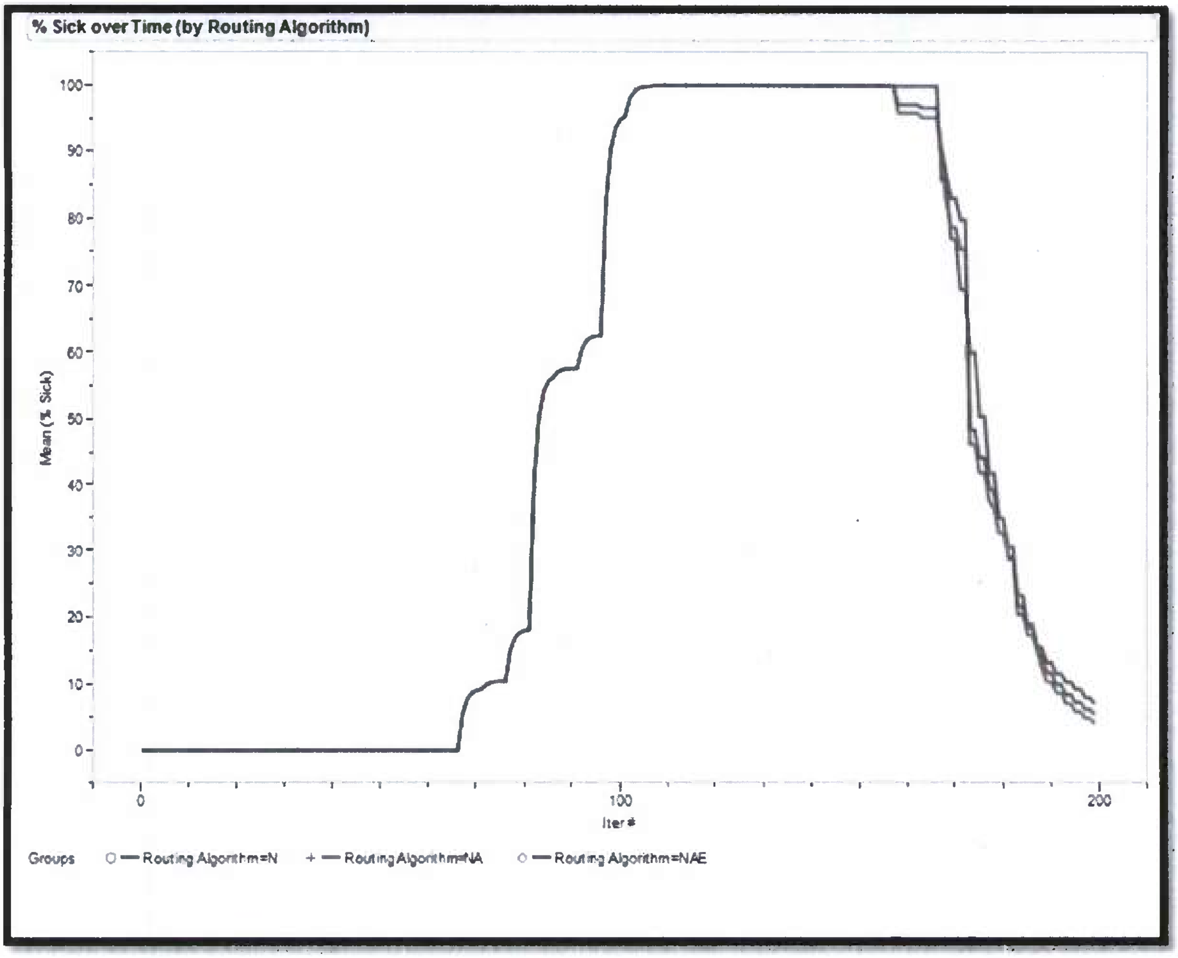

Figure 12: Extreme-Scenario percent of population suffering adverse reactions to heat exposure over time in Practical Routing Algorithms.

As expected, the rates of increasing adverse reactions over time are virtually the same, owing simply to the assumed linear increase in exposure and the fact that there is no recovery after the onset of adverse reactions to heat until the individual receives treatment at a treatment center. They show neither benefit nor cost in percent of population affected by heat due to choice of practical routing strategy.

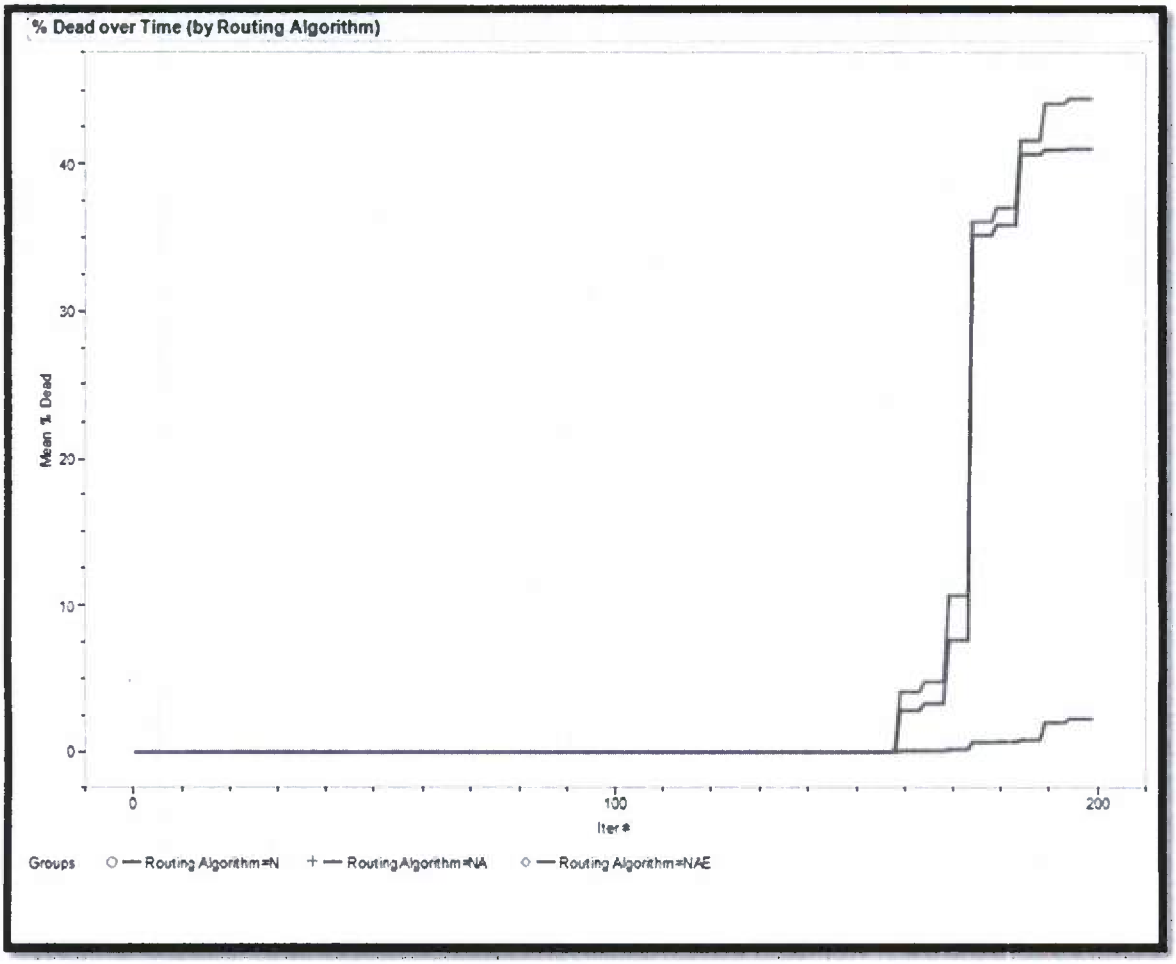

Figure 13: Extreme-Scenario Percent of Population "Dead" over Time in Practical Routing Algorithms.

The segmented behavior is expected, again due to the fact these simulations required treatment to recover from the effects of heat. If treatment was not obtained within a fixed amount of time, the individual was assumed to have died. This extreme scenario was explored to detect differences in efficiency in practical routing options.

The "Nearest" algorithm has a clear advantage over both other algorithms, since in this implementation all individuals were accepted at all treatment centers, regardless of health concern or type of facility resources available at the location. Therefore, individuals of all conditions were likely to be within a short distance of a school (the most dense option) whenever they developed a need for care. In comparison, when the algorithm directed individuals to only appropriate centers, according to their condition, those with more serious conditions were likely to require greater travel time to arrive at a center that had the appropriate equipment for their care.

We further expect that expanding the simulations to include "rejection" (i.e. re-direction to the nearest care-appropriate center) that the number of deaths seen when simulating the "Nearest" algorithm will rise significantly and should be slightly larger than both other algorithms, due to the additional travel time required to travel to the "incorrect" first-choice center.

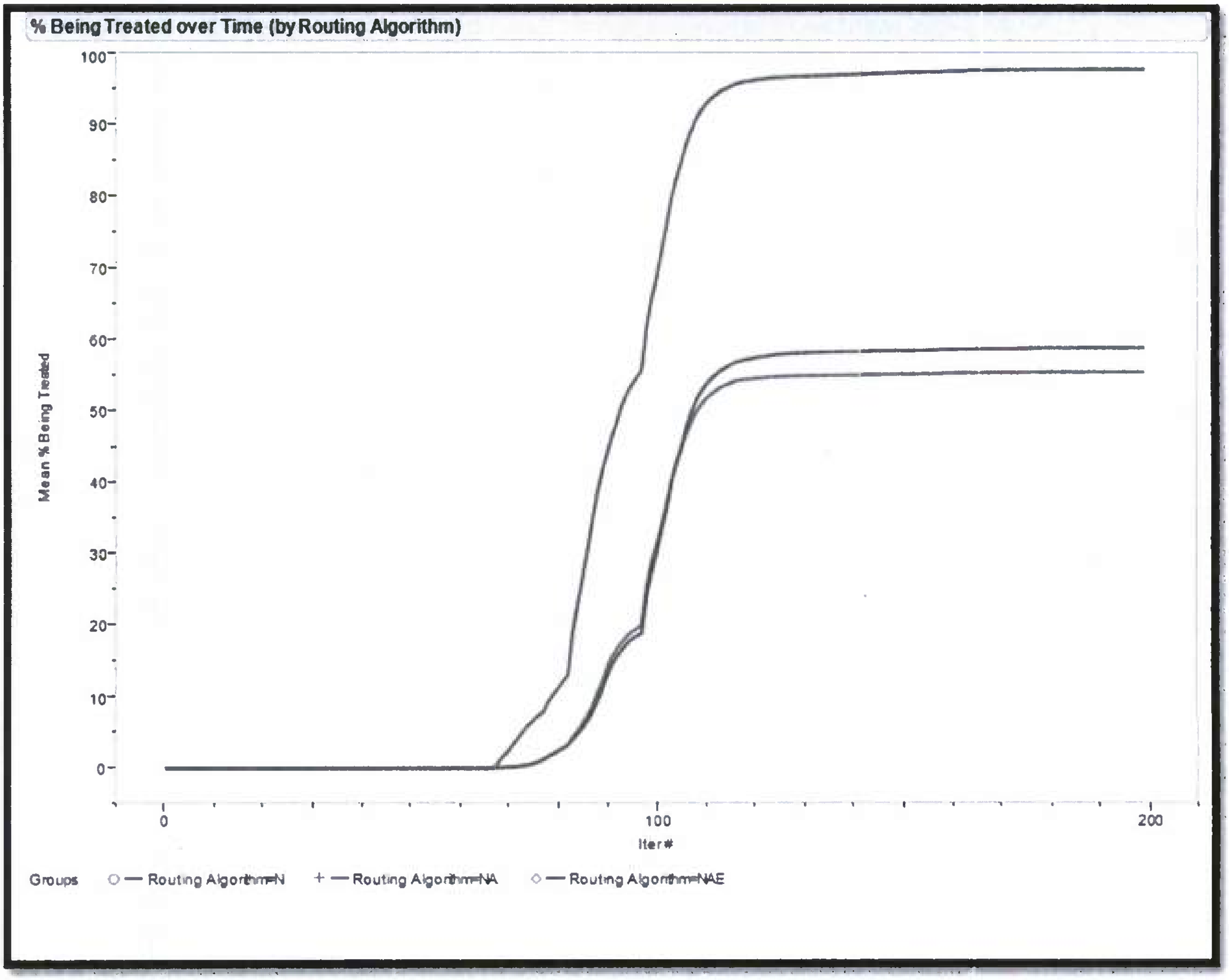

Figure 14: Extreme-Scenario Percent of Population Receiving Treatment over Time in Practical Routing Algorithms.

The "Nearest" algorithm again shows a clear advantage over the other algorithms with respect to the number of people who are in a treatment center over time. This again results from the significant probability of being in close proximity to a school at any point in the travel network. The fact that the "Nearest Appropriate" algorithm does slightly worse (and results in slightly more deaths) is likely due to overcrowding by low-risk individuals at the lower-capacity Level 2 and Level 3 centers which disallows higher-risk individuals from getting the necessary treatment at these centers.

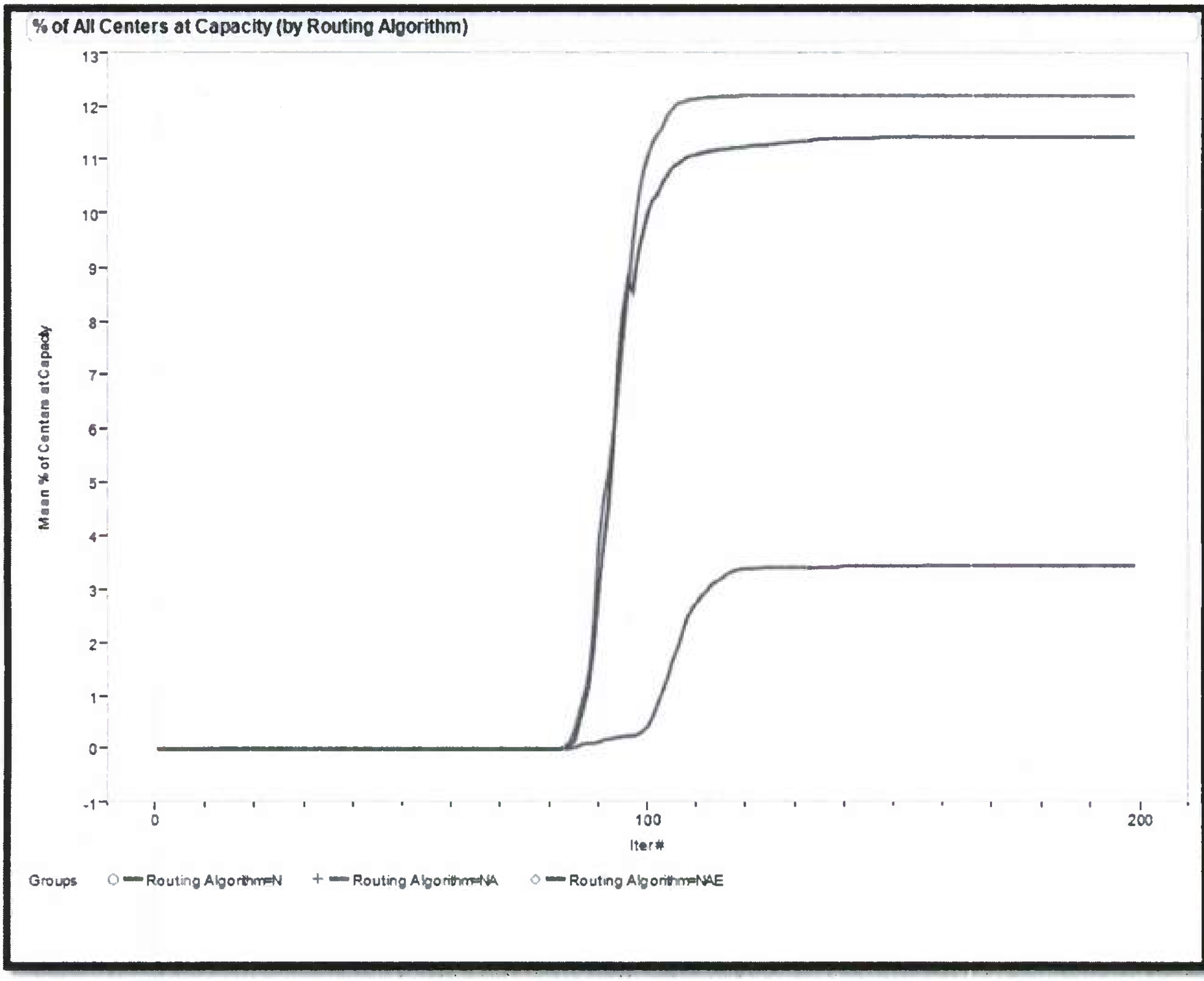

Figure 15: Extreme-Scenario Percent of All Centers at or Exceeding Capacity.

The "Nearest" algorithm again shows an advantage over the other algorithms, however, this is likely due to need-inappropriate care centers absorbing individuals who would otherwise overwhelm lower-capacity need-appropriate locations. We again anticipate these results changing once the model is expanded to include 'rejection', however, the insight provided by these extreme scenarios is a critical first step.

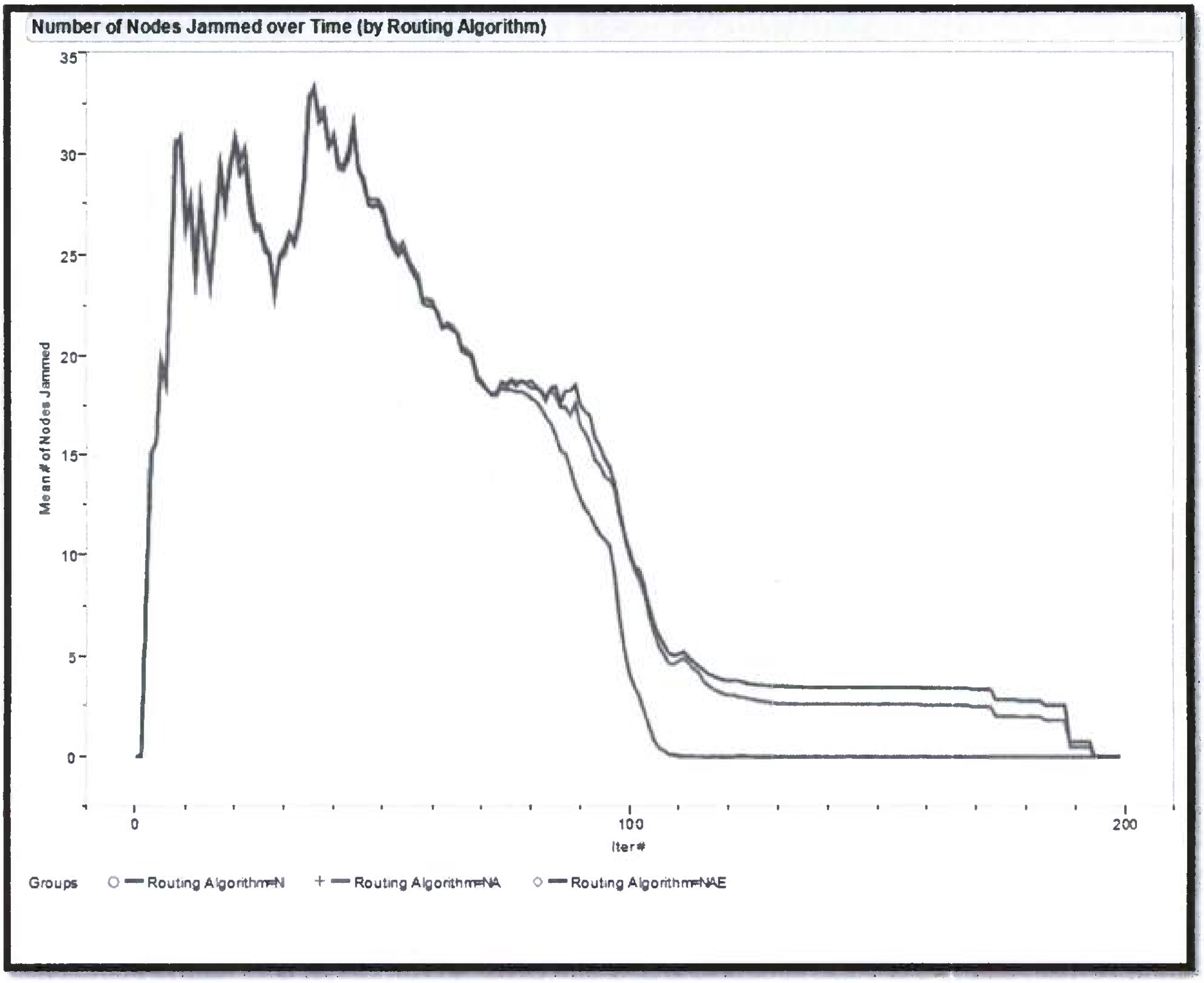

Figure 16: Extreme-Scenario Number of Locations Blocked by Traffic Jams over Time in the Practical Routing Algorithms.

The number of locations backed up by traffic were not seen to be significantly different across routing strategies until after untreated individuals began dying, alleviating congestion along the roadways. This is a result of both the extreme assumption of death in the model, and the lack of 'rejection' causing redirection to different facilities. We expect these results to change when both of these assumptions are altered, however, the insight provided by these extreme scenarios is a critical first step.

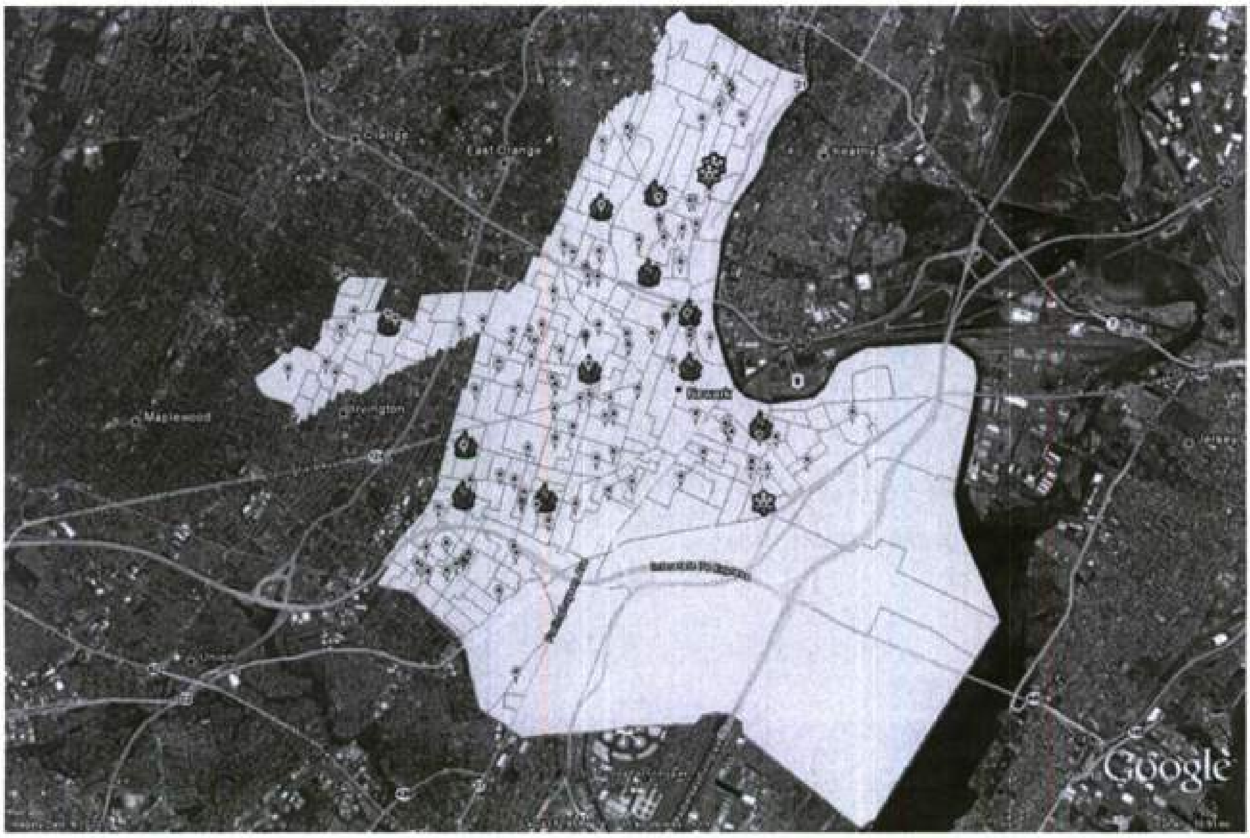

Figure 17: Extreme-Scenario Locations Where the Practical Routing Algorithms Predict Clusters of Deaths When Routing According to the "Nearest" Algorithm.

In the "Nearest" Algorithm, under the assumptions of the Extreme-Scenario, individuals were not redirected from their initial target center, even if that center was unable to treat their condition or was already at capacity. Therefore these individuals died while waiting for treatment. Centers where many of these deaths were predicted are indicated in Red (bonfires). Other individuals were prevented from reaching shelters in time to receive care by traffic jams clogging the roadways. These locations are indicated in Blue (snowflakes). (For further detail, see Table 3.)

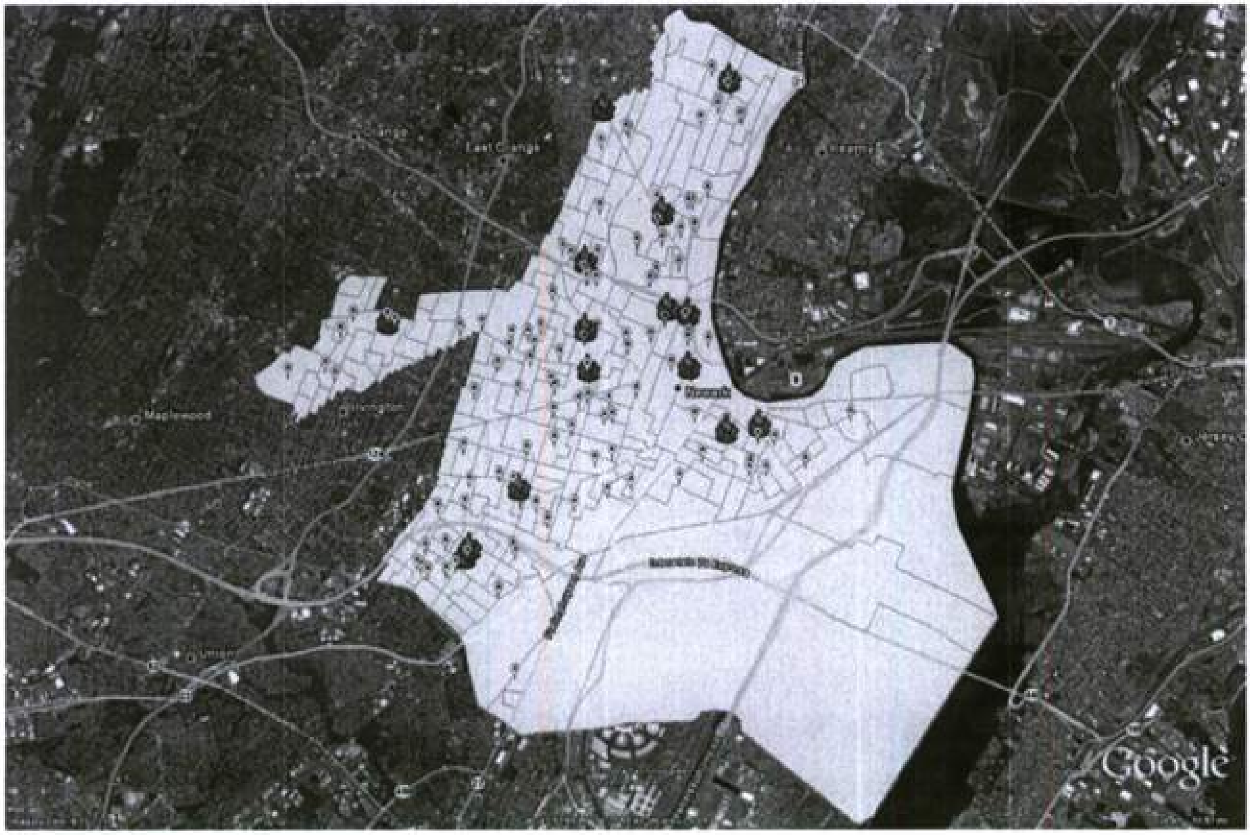

Figure 18: Extreme-Scenario Locations Where the Practical Routing Algorithms Predict Clusters of Deaths When Routing According to the "Nearest Appropriate" Algorithm.

In the "Nearest Appropriate" Algorithm, under the assumptions of the Extreme-Scenario, individuals were not redirected from their initial target center, even if that center was already at capacity. Therefore these individuals died while waiting for treatment. Centers where many of these deaths were predicted are indicated in Red (bonfires). In contrast to the "Nearest" algorithm, no particular locations were found to increase mortality risks due to traffic jams clogging the roadways. (For further detail, see Table 4.)

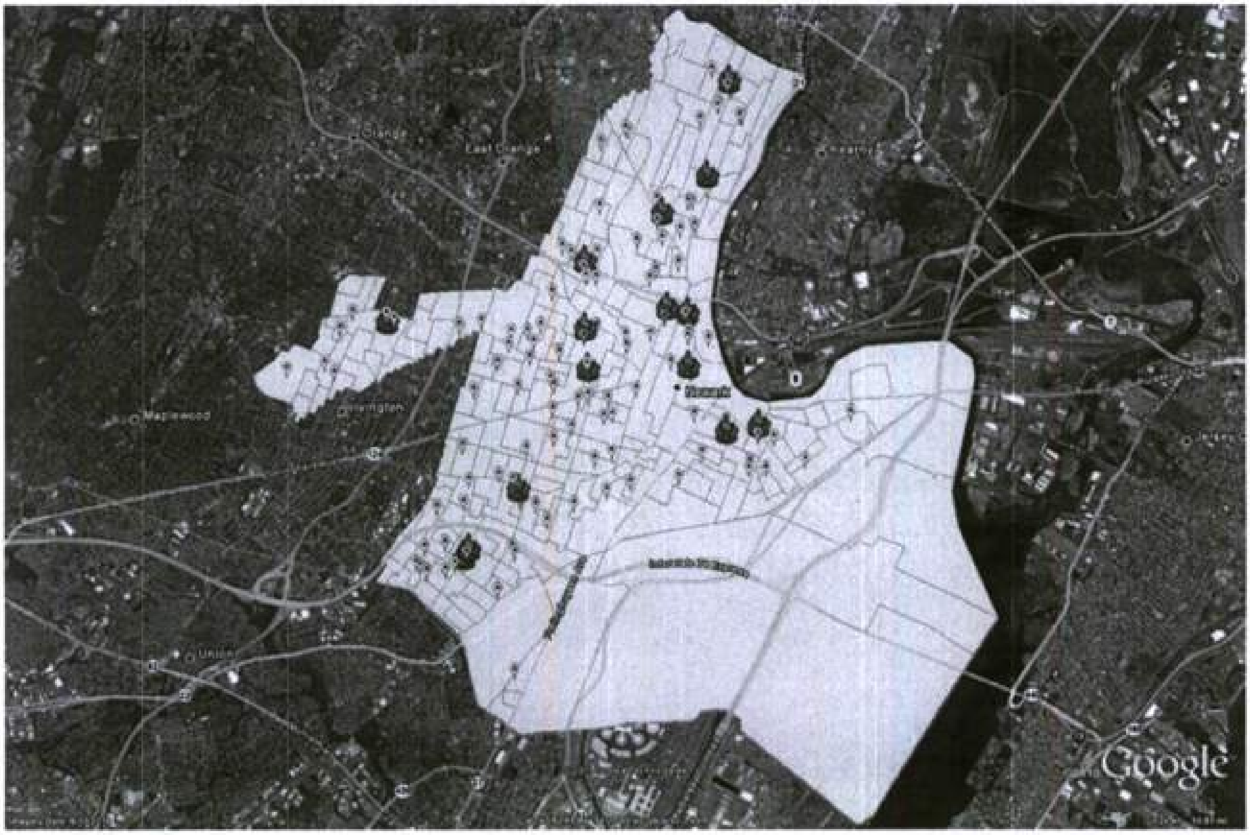

Figure 19: Extreme-Scenario Locations Where the Practical Routing Algorithms Predict Clusters of Deaths When Routing According to the "Nearest Appropriate Exact" Algorithm.

In the "Nearest Appropriate Exact" algorithm, under the assumptions of the Extreme-Scenario, individuals were not redirected from their initial target center, even if that center was already at capacity. Therefore these individuals died while waiting for treatment. Centers where many of these deaths were predicted are indicated in Red (bonfires). In contrast to the "Nearest" algorithm, no particular locations were found to increase mortality risks due to traffic jams clogging the roadways. (For further detail, see Table 5.)

TABLES

Table 1: Number of hospitalizations attributed to GI related illness in the U.S. elderly aged 65 or over between 1997 and 2004.

ICD-9 Code	Condition	# of Hospitalizations
001	Cholera	983
002	Typhoid and paratyphoid fevers	584
003	Salmonellosis	28,959
004	Shigellosis	3,395
005	Other food poisoning (bacterial)	20,464
006	Amebiasis	1,550
007	Other protozoal intestinal diseases	6,784
008	Intestinal infection due to other organisms	1,522,390
009	Ill-defined intestinal infections	76,993
787	Symptoms involving digestive system	5,394,934
558.9	Other & unspecified non-infectious gastroenteritis & colitis	1,795,399

Notes: ICD-9: International Classification of Diseases 9. Totals do not sum to 8,600,000 due to multiple ICD-9 codes per hospitalization in some records.

Table 2: Number of excess casualties during a simulated heat-related emergency in the Newark area, under increasing levels of evacuation shelter coverage.

	Temperature			
Scenario:	**86o**	**90o**	**95o**	**100o**
	Excess Casualties			
Hospitals only	335	494	796	1307
Hospitals and Cooling Centers	224	301	416	555
Hospitals, Cooling Centers, and Mobile Acute Care	0	0	0	55

Notes: 115 Cooling Centers and 8 Mobile Acute Care centers were used.

Table 3: Input Data for the Practical Routing Algorithms.

Input	Data Source
Map	Road network and geographic data from OpenStreetMaps, road capacities set according to categorizations given by same
Population	Used U.S. Census data to provide • number of people per census block center • geographic locations of census block centers
Available Public Facilities	Geographic locations given in GIS shape files provided by Center for Remote Sensing and Spatial Analysis at Rutgers University (CRSSA) Building capacities arbitrarily set according to facility "treatment level type" (see Agent-Based Simulation section above)
Adverse Heat-Related Health Outcome	Linear growth heat exposure arbitrarily parameterized around the desired running time of the model
Routing Algorithm	Choice of (Nearest, Nearest Appropriate, Nearest Appropriate Exact); simple self-explanatory routing methods which may be easily communicated via public media for self-determination of need/action by the public

Table 4: Extreme-Scenario Results from "Nearest" Algorithm in Practical Routing Algorithms.

Type	Center Waiting For	# Simulations Appeared In	% of Simulations Appeared In	Total Deaths over all Simulations	Average Deaths per Simulation	Max Deaths Per Simulation
School	Raphael Hernandez School	187	93.5	484	2.588235294	6
Library	75 Alexander St	142	71	976	6.873239437	18
School	Raphael Hernandez School	136	68	1941	14.27205882	44
School	Hawthorne Avenue School	131	65.5	202	1.541984733	4
School	Branch Brook School	95	47.5	1967	20.70526316	50
Library	140 Van Buren St	75	37.5	343	4.573333333	14
Library	5 Washington St	74	37	295	3.986486487	15
School	Madison Avenue School	65	32.5	733	11.27692308	59
School	Raphael Hernandez School	65	32.5	82	1.261538462	3
Library	50 Hayes St	51	25.5	760	14.90196078	43
School	Dr. William H. Horton School	49	24.5	595	12.14285714	38
Library	34 Commerce St	44	22	159	3.613636364	9
None	Traffic Jam	23	11.5	24	1.043478261	2
School	McKinley School	22	11	2335	106.1363636	166
School	Belmont Runyon School	20	10	21	1.05	2

Table 5: Extreme-Scenario Results from "Nearest Appropriate" Algorithm in Practical Routing Algorithms.

Type	Center Waiting For	# Simulations Appeared In	% of Simulations Appeared In	Total Deaths over all Simulations	Average Deaths per Simulation	Max Deaths Per Simulation
Hospital	U.M.D.N.J.	200	100	43762	218.81	268
Library	50 Hayes St	200	100	29505	147.525	205
Library	739 Bergen St	200	100	27528	137.64	187
Hospital	Newark Beth Israel Medical Center	200	100	21164	105.82	145
Library	75 Alexander St	200	100	18386	91.93	127
School	Burnet Street School	200	100	15502	77.51	178
Library	235 Clifton Avenue	200	100	15205	76.025	115
Hospital	St. James Hospital	200	100	14596	72.98	99
Library	99 Fifth St	200	100	10049	50.245	83
Library	355 Osborne Terr	200	100	9761	48.805	81
Library	140 Van Buren St	200	100	8136	40.68	66
Hospital	Columbus Hospital	200	100	7442	37.21	65
Library	5 Washington St	200	100	5141	25.705	50
Library	34 Commerce St	200	100	4845	24.225	43
Library	722 Summer Ave	200	100	3542	17.71	36

Table 6: Extreme-Scenario Results from "Nearest Appropriate Exact" Algorithm in Practical Routing Algorithms.

Type	Center Waiting For	# Simulations Appeared In	% of Simulations Appeared In	Total Deaths over all Simulations	Average Deaths per Simulation	Max Deaths Per Simulation
Library	50 Hayes St	200	100	39046	195.23	255
Hospital	U.M.D.N.J.	200	100	26188	130.94	163
Library	739 Bergen St	200	100	25736	128.68	164
Library	235 Clifton Ave	200	100	20555	102.775	137
Library	355 Osborne Terr	200	100	18540	92.7	118
Library	99 Fifth St	200	100	16765	83.825	136
Library	75 Alexander St	200	100	16116	80.58	107
Library	140 Van Buren St	200	100	12927	64.635	84
Hospital	Newark Beth Israel Medical Center	200	100	9745	48.725	75
Library	34 Commerce St	200	100	8665	43.325	62
Library	5 Washington St	200	100	7961	39.805	71
Library	722 Summer Ave	200	100	3700	18.5	36
Hospital	St. Michael's Medical Center	199	99.5	4867	24.45728643	61
School	Raphael Hernandez School	177	88.5	365	2.062146893	5
Hospital	St James Hospital	174	87	1871	10.75287356	32

Table 7: Results from Example Resource-Allocation-to-Shelters Scenarios from the OR optimization model.

	1 mile Travel Radius		2 mile Travel Radius	
	Total # Adversely Effected People	**Total # Deaths Expected (Worst Case)**	**Total # Adversely Effected People**	**Total # Deaths Expected (Worst Case)**
LLEH	659	30 (140)	659	30 (140)
HLEH	659	30 (140)	659	6 (66)

REFERENCE DOCUMENTATION:

Figure 1: Copyright owner is Google, Inc. Their permissions page may be found at http://www.google.com/permissions/geoguidelines.html

CHAPTER 4

Project 09 05 F: Supply Chain of Critical Medical Resources for Emergency Situations

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Supply Chain of Critical Medical Resources for Emergency Situations

Project 09 05 F

Final Report

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The views, opinions, positions, conclusions, or strategies in this work are those of the authors and do not necessarily reflect the views, opinions, positions, conclusions, strategies, or official policy or position of the Department of Defense or any agency of the U.S. government and no official endorsement should be inferred.

Abstract

The research carried out in this project addresses the issue of managing critical medical supply inventories in hospital under surge scenarios. It is based on an approach that optimizes inventory control parameters in hospital settings under scenarios such as the pandemic flu with surging demand for medical supplies. We combined epidemiologic modeling techniques with simulation and optimization modeling to provide the best strategy for inventory management under surging demand in pandemic-like scenarios.

The project aims to provide a guideline to implement a formal procedure to effectively control inventories of critical medical supplies and minimize inventory management costs while maintaining an acceptable customer service level in pandemic-like scenarios.

Project involves a high-fidelity Disease Progress Module (DPM) Influenza Pandemic like scenarios using already validated data from the historical epidemiological literature.

For the proposed simulation framework, a Virtual Hospital Module (VHM) was developed to capture resource consumption in healthcare settings during an Influenza Pandemic.

A Dynamic Programming optimization model was constructed to optimally manage the inventory of critical medical supplies (that is the decisions regarding when to order and how much to order) in hospital settings. A number of numerical scenarios were analyzed and results were obtained.

Foreword

This project was managed under the under the leadership of the University Center for Disaster Preparedness and Emergency Response that is a collaborative initiative among the UMDNJ - Robert Wood Johnson Medical School, Rutgers, the State University of New Jersey and the Robert Wood Johnson University Hospital. In particular, the project was carried out at Rutgers University's Center for Advanced Infrastructure and Transportation.

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INTRODUCTION

Background

In the decade before the 2009-10 influenza pandemic caused by the novel H1N1 virus (pH1N1), the spread of the much more lethal H5N1 "avian" influenza in Asia and parts of Africa raised concerns about the potentially devastating impact of a severe global influenza outbreak (Salomon and Webster 2009) and (Chan 2009). In response, most developed countries and many private corporations made considerable investments over the last decade in the purchase of antiviral medications (AVMs) to treat those infected with influenza during a pandemic. To date, most of the literature has addressed either pandemic mitigation or preservation of healthcare workforce capacity during the peak of an outbreak. However, to the best of our knowledge, there is no evidence-based research available in the medical literature that can guide healthcare facilities to establish sufficient medical supply in order to maintain adequate surge capacity for flu patients. In the inventory management and supply chain literature, most existing models make the assumption of independence and time-homogeneity of the demand for medical supply. However, during a pandemic, demand is uncertain and definitely non-stationary due to surge dynamics. It grows exponentially in the early part of the pandemic and will decline when there are less people that can be infected by the disease (herd immunity). The non-stationary demand pattern raises a unique problem for inventory management since it becomes difficult to decide on when to order and how much to order of each of the critical medical supplies. This is also a significant research issue in the inventory management literature. Non-stationarity of the demand gives rise to complexities that make the problem mathematically and practically intractable.

The research carried out in this project addresses the issue of inventory management that basically deals with how much of each unit to maintain on hand using and approach that optimizes inventory control system parameters in hospital settings under scenarios such as the pandemic flu with surging demand for medical supplies. This is a critical issue since too much of medical supply inventory can cost a lot while short inventories will not satisfy the demand. Finding the right amount of stock is always a challenge in inventory management due to uncertainties involved in demand.

The contribution of this research is in providing the proof of concept to hospital management that tools such as the one developed in this research will be instrumental in managing inventories once deployed in full scale.

Objective

The project aims to provide the proof of concept for developing an approach to handle inventory management under surge scenarios in hospitals. The objective is to help hospitals in making decisions regarding maintaining stocks of medical supplies. This is achieved by developing a formal procedure to help effectively control inventories of critical medical supplies and minimize inventory management costs while maintaining an acceptable customer service level in pandemic-like scenarios.

Approach

In essence, using a system of ordinary differential equations, a compartmental SEIR model (May and Anderson 1991) is developed describing the transmission dynamics of a pandemic in a large population. Then, the SEIR model is incorporated into a virtual hospital simulator using ARENA simulation tool to identify daily random demand over the course of the pandemic. Finally a dynamic programming algorithm is used to optimize the target inventory levels as well as reorder points for the duration of the pandemic period. Clearly, the values of these parameters vary over time due varying demand over the pandemic duration.

Scope

The project team received guidance from the Robert Wood Johnson University Hospital on what these critical medical supplies may be as well as what kind of an inventory management approach they may be using. Without lack of generality, the current approach employed in the project includes three types of medical supplies and it can be easily extended to any number supplies critical for the scenario at hand.

Mode of Technology Transfer

The methodology developed in the project is ready to be incorporated in a software tool for a large-scale implementation for operational purposes. The tool would have a proper user interface for parameter value entry for each of the supply items the hospital management wants to include. Thus, the technology transfer can be achieved through software development for decision making in inventory management in hospital setting.

APPROACH

In this research, epidemiological modeling techniques are combined with simulation and optimization methodologies to provide the best strategy for managing inventories of critical medical supplies in hospitals under surging demand scenarios in pandemic situations. On the epidemiological front, we have used a SEIR compartmental model to generate a hypothetical pandemic. This model produces a non-stationary patient flow into a virtual hospital where they get appropriate treatment. During the period of the pandemic, a single-item inventory model, assuming a non stationary demand process and a deterministic replenishment lead-time, is implemented at the virtual hospital and used determine the safety stock requirements for the item. This procedure is repeated for all three items considered on the study.

Below, each of the three components of the approach is described in detail.

Epidemiological Model

Mathematical models of the transmission of infectious agents are used to understand the behaviors of an emerging pandemic influenza and to evaluate the effectiveness of various intervention strategies. Using a system of ordinary differential equations (ODEs), we developed a compartmental model describing the transmission dynamics of a pandemic in a large population. A deterministic modeling framework was appropriate since our intention was to capture disease-spread dynamics in a population in which a pandemic has already been initiated; that is, we are not primarily concerned here with the effect of random perturbation of epidemic ignition or quenching.

Individuals in a population are divided into standard modeling compartments such as susceptible (S), exposed (E), infectious (I), recovered (R), and disease-induced dead (D). As shown in Figure 1, susceptible individuals may become infected, incubate the infection, progress to become fully contagious, and finally either recover and develop immunity from the disease or die.

The arrows that connect the boxed subgroups represent movement of individuals. Susceptible (S) will first become exposed (E). Exposed (E) will become infectious (I) after an incubation period. Infectious (I) can either recover (R) after a recovery period or die (D).

Following the schematic representation in Figure 1, the disease spread and control dynamics can be described by the following differential equations for a population of size N (May and Anderson 1991).

$$\begin{aligned} \dot{S} &= -\beta IS/N \\ \dot{E} &= \beta IS/N - \kappa E, \\ \dot{I} &= \kappa E - (\gamma + \delta)I, \\ \dot{R} &= \gamma I, \\ \dot{D} &= \delta I \end{aligned} \qquad (1)$$

Baseline values of the epidemiological model parameters used in the above model are summarized in Table 1. Values of these parameters are based on published epidemiological, clinical, and experimental data. The basic reproduction number R_0, defined as the average number of secondary cases generated from an average primary case in an entirely susceptible population, is used to quantify the transmissibility of an infectious disease (Keeling and Rohani 2008). We first calibrated the model for a range of R_0 values in order to reproduce typical patterns of a pandemic influenza assuming a baseline of no interventions. The type of SEIR model we have used, with simplified structures and assumptions, normally leads to an extremely high attack rate with even moderate R_0 values (McCaw and McVernon 2007). To simulate a realistic epidemic outbreak, we have assume that R_0 equals to 1.8, and 80% of the population in our baseline case are susceptible at the start of the pandemic (Mills, Robins et al. 2004). This assumption was motivated by the "herald wave" phenomenon observed in the 1918 pandemic where those who recovered from influenza infection in the spring were protected from the disease in the autumn pandemic because they acquired partial immunity from re-infection with similar strains of the virus (Ferguson, Mallett et al. 2003).

Estimates of the duration of the asymptomatic phase of both seasonal and H1N1 pandemic influenza range from 1 to 2 days; we have further defined the symptomatic and infectious phase to last 4 days (Longini, Halloran et al. 2004; Ferguson, Cummings et al. 2005; McCaw and McVernon 2007). (Khazeni, Bravata et al. 2009). The base case with no intervention (neither prophylaxis nor vaccination) produces a unimodal epidemic with a cumulative attack rate (CAR) of 35.9% lasting approximately 17 weeks from index cases to first day with <0.1% increase in CAR. This result is consistent with published pandemic preparedness assumptions from the U.S. Centers for Disease Control and Prevention (CDC 2008).

We implemented the SEIR model for demand generation for medical supplies in our virtual hospital simulator using the Arena simulation tool[1]. ARENA uses the fourth-order Runge-Kutta method to solve the model numerically. The model predicts the number of infected individuals throughout the pandemic and determines the potential impact and effectiveness of intervention strategies and time-course of the epidemic in a region of one million people.

Limitations:

[1] ARENA is a trademark of Rockwell Software.

We conducted a modeling study based on a number of assumptions regarding the disease characteristics. Although these parameters are based on reported data in the literature, preparing for influenza pandemic requires considering enormous uncertainty, such as the initiation of a pandemic, the speed of spread, its level of virulence, and the extent of its resistance. In the course of the pandemic, rapid decisions are required to be made in response to the pandemic as more information about the epidemiologic profile becomes available. We have ignored this process in our modeling effort due to its massive complexity.

Also, we did not consider the role of spatial and population heterogeneity in the spread of influenza pandemic. Our deterministic modeling approach assumes homogenous population mix where all individuals have the same contact and infection rates. A more realistic model should include age, social contact, and spatial structure of the population under consideration. In particular, the contact network structure is critical in determining the spread of the pandemic in the initial stage of the outbreak. Once an epidemic has begun, a deterministic model would probably provide a reasonable description of the disease dynamics.

Although these limitations may suggest the need for a more involved modeling effort, they are certainly outside of the context of this project. Our work highlights the importance of operational considerations in pandemic preparedness planning. We have emphasized the use of a modeling tool to assist policy makers in testing and providing insights on the effectiveness of their decisions regarding inventory management of medical supplies taking into account the uncertainties in a potential pandemic.

The Virtual Hospital Module

The virtual hospital module simulates the arrival and treatment of infected patients at their local healthcare facility during an influenza pandemic. The top level model comprises of two sub models: the first model calculates the ratio of patients that are susceptible, exposed, infected, and recovered or dead in a given population size at any given point in time. The number of patients in any of the above compartments is controlled by the disease progression parameters defined in the epidemiology model or the Disease Progression Module (DPM). The second model handles the daily consumption of medical supplies required for administering the treatment of the general population during the influenza pandemic. Obviously, this is dependent on the number of patients seeking treatment and their expected length of stay based on their condition at the time of admittance.

From the differential equations set (1), we have the number of people infected $I'(t)$ by the flu at any given time t given by

$$I'(t) = \kappa \cdot E(t). \tag{2}$$

And therefore the number of new people $P(t)$ that are added to the infectious compartment in a day is shown below

$$I'(t) - I'(t-1) = P(t). \tag{3}$$

Each person seeking treatment can be categorized as type severe or moderate and their number at any point in time t are $P_s(t)$ or moderate $P_m(t)$ and are given by

$$P_s(t) = P(t) \cdot r \cdot r_1$$

$$P_m(t) = P(t) \cdot r \cdot (1 - r_1) \tag{4}$$

where r is the percentage of the population that seeks treatment, i.e. patients, and r_1 is the percentage of patients that are categorized as type severe.

Finally, the probability of a patient in severe condition dying, that is P_d, is shown below

$$P_d = \frac{D(t)}{N} \cdot \alpha \cdot r \cdot (r_1 + c \cdot (1 - r_1)) \tag{5}$$

where

$D(t)$ = the number of patients deceased at any given point in time t

α = the attack rate

c = the percentage of moderate patients whose condition is expected to worsen and are therefore categorized as severe patients and moved to the ICU from the hospital floor.

The Simulation Model

Equations (2) - (5) are incorporated into the Arena model to create the pandemic dynamic and consequently the Arena model simulates the arrival and treatment of patients at the hospital. Each entity in the simulation model represents a patient. The number of people arriving at the hospital in any given day is determined by the epidemiological model. To model randomness in the arrivals, a normal distribution with parameters (0, *dv*) is introduced where *dv* is the daily variation. The variation factor is currently set at 20% of the number of people that are infected by the influenza pandemic in any given day. We will be assuming only 10% of the affected population seeking treatment at the hospital (Hupert 2010). This subset of the population is now classified as patients for modeling purposes. We will also assume that 15% of the patients are categorized as type severe and the rest as moderate (Hupert 2010). Patients whose condition is severe seek treatment in the ICU, moderate condition patients on the other hand are routed to the floor for treatment. Severe condition patients after completing their length of stay in the ICU are moved to the floor. All discharges from the hospital always take place from the floor. The treatment dynamics are pictorially represented in Figure 2 (AHRQ 2011).

Since the probability of a patient dying is already known, the model pre-designates patients that are going to be deceased as they arrive at the hospital. Only patients whose condition is severe die, furthermore their day of death coincides with their last day in the ICU. These assumptions have been made to reduce the complexity of the model. Patients whose condition is moderate are routed directly to the floor for treatment. We have assumed that the condition of 5% of the incoming moderate patients will deteriorate and they will have to be routed to the ICU for treatment. These patients will be reclassified as type severe and they may potentially die. Once their condition improves in the ICU, they will be moved back to the floor and then eventually discharged. The duration of their stay in the ICU and floor can vary by patient and is generated using a triangular distribution with parameters shown in Figure 3. A detailed patient process flow is shown in Figure 4.

Each entity representing a patient is routed appropriately to the ICU or the floor in the workflow of the model. Each entity is delayed in the model for its designated length of stay. The rules regarding the movement of patients from the ICU to the floor or vice versa described earlier are all enforced in the model. This obviously impacts the total number of patients in the ICU and the floor on a daily basis. The model keeps tracks of the total quantity of products consumed by all ICU and floor patients on a daily basis. In this study three products are considered. The quantity consumed per patient per day shown in Figure 5 and is dependent on the condition of the patient, i.e. severe or moderate.

<u>The Model's Output</u>

The length of each replication is determined by the arrival of new patients at the hospital. A simulation run terminates when new patients stop arriving and all existing patients are discharged. In this study we run the model for 100 replications, the total consumption per product per day is recorded into a Microsoft Excel spreadsheet. After completion of the final replication, the mean and standard deviation of product daily consumption figures are obtained and recorded in the same Excel file. For instance, Figure 6 shows the demand profile for one of the products. From the demand profile we can see that the period of greatest activity during the influenza pandemic is from days 16 to 76, or 60 days. The demand peaks somewhere around the mid to early 40th day mark. This 60-day period is when the greatest strain on the healthcare system is experienced.

Due to the inherent difficulty in forecasting the demand during an influenza pandemic, hospitals will either tend to overstock or fall short on medical supplies. Both these outcomes can have drastic consequences. Overstocking will lead to higher inventory management costs and potential wastage due to disposal of unused limited shelf life medical products, leading to increased operating costs for the hospital. On the other hand, maintaining an inadequate stockpile of critical products will impair its ability to treat patients, affect its customer service level and potentially damage its reputation in the long term. Below, in the third part of this study, we present an optimization model, incorporated into the virtual hospital model, to determine the best possible target inventory levels based on inventory costs of the products introduced earlier. Again, this is to provide a guideline to implement an inventory control policy that minimizes inventory management costs while maintaining an acceptable customer service level during such a surge period.

Optimizing Inventory Management in the Virtual Hospital

In this section, an optimization model and in particular a dynamic programming model is introduced to obtain the optimum target inventories of the three products mentioned earlier in the virtual hospital model. The optimization will be cost minimization based on inventory holding cost, shortage cost and the cost of changing the target inventory level. The model is to be incorporated into the simulation model to manage the inventories of the virtual hospital introduced earlier.

The inventory management concept used here is presented in Figure 7. We have employed a periodic review model where the inventory of each product is monitored daily and a replenishment order is placed every time the inventory is observed below its target level. The order is place at 13:00 in the afternoon and is assumed to arrive by the end of the day, presumably before the beginning of the next day. Below, we present the optimization model.

We will concentrate on a single product for analysis purposes. It is typical in the health care industry that the lead time for an order arrival is roughly a day. Thus, we assume that the lead time for an order, denoted by L, is at most a day, D_t is demand for the product on day t, Q_t is the amount ordered on day t, and x_t is the inventory on hand of the product at the beginning of day t.

Note that the beginning inventory level on day $t+1$ can be expressed as

$$x_{t+1} = (x_t - D_t)^+ + Q_t \tag{6}$$

where the order quantity is $Q_t = \bar{x} - x_t$, and $\bar{x}$ is the target inventory level for the medical supply in consideration.

On the other hand, by midday on day *t+1*, we also have

$$x_{t+1,1} = (x_{t,1} - (D_{t,1} + D_{t,2}))^{+} + Q_t \tag{7}$$

where $Q_t = \overline{x} - x_{t,2}$, and the midday on hand inventory is $x_{t,2} = (x_{t,1} - D_{t,1})^{+}$.

Assuming that the demand in the first half of the day will always be less than the day's starting inventory, i.e. $x_{t,1} > D_{t,1}$, we have

$$x_{t+1,1} = \begin{Bmatrix} \overline{x} - D_{t,2}, & x_{t,2} > D_{t,2} \\ \overline{x} - x_{t,2}, & \text{otherwise} \end{Bmatrix}.$$

(Arrow, Karlin et. al 1958) shows that if current stock size **x** is a random variable with density *f(x)*, distribution associated with the random variable measuring stock available at the next period,

Based on this construction, they have developed the following stationary distribution of the beginning inventory level

$$F(y) = \frac{\Phi(y)\left[1 - \Phi(\overline{x} - y)\right]}{1 - \left[1 - \Phi(y)\right]\left[1 - \Phi(\overline{x} - y)\right]} \tag{8}$$

where y the random variable representing the beginning inventory level and $\Phi(y)$ is the integral of daily demand density function.

The probability that demand exceeds supply on a given day is given by

$$\Pr\{\xi > y\} = \iint_{\xi > y} f(y)\varphi(\xi)d\xi dy = \int_0^{\bar{x}} \varphi(\xi)[F(\xi)]d\xi + \int_{\bar{x}}^{\infty} \varphi(\xi)d\xi . \tag{9}$$

Accordingly, the expected quantity of unsatisfied demand is given by

$$\begin{aligned} E(penalty) &= \iint_{\xi > y} (\xi - y) f(y)\varphi(\xi)d\xi dy \\ &= \int_0^{\bar{x}} \varphi(\xi)d\xi \int_0^{\bar{x}} (\xi - y) f(y)dy + \int_{\bar{x}}^{\infty} \varphi(\xi)d\xi \int_{\bar{x}}^{\infty} (\xi - y) f(y)dy \end{aligned} . \tag{10}$$

Also, the amount on hand at the end of a day is given by

$$E(handling) = \int_0^{\bar{x}} \int_0^{y} (y - \xi)\varphi(\xi) f(y)d\xi dy . \tag{11}$$

Now we have the expected on-hand inventory level and the expected shortage level, we are ready to evaluate the cost minimizing objective function for feasible levels of target inventory of the product. The following algorithm will be used to generate the optimal target inventory level of the medical supply we have under consideration.

The Algorithm for the Optimal Target Levels

Step 1: Compute $\bar{x}_t$ for every day t minimizing the expected total cost per day, that is

$$E[\text{Quantity short}] \cdot p + E[\text{On hand stock}] \cdot h .$$

Step 2: Use dynamic programming to determine when the target inventory level must be changed.

The dynamic programming formulation is done in such a way that the inventory level is the state, and the days are the stages in the model. So, the possible states (target inventory values) are $\bar{x}_1, \bar{x}_2, \cdots, \bar{x}_T$. Also, let us define $TC_t(\overline{I_t})$ to be the total cost up to day t, where the current inventory level is $\bar{I}_t = \bar{x}_1, \bar{x}_2, \cdots, \bar{x}_T$. Then, the following dynamic programming recursion can be established.

$$TC_t(\bar{I}_t) = \min_{\bar{x}_t} \left\{ P(\bar{x}_t) + TC_{t+1}(\bar{I}_{t+1}) \right\}$$

where

$$P(\bar{x}_t) = (I_t - D_t)^+ * h + (D_t - I_t)^+ * p + CC(\bar{x}_t)$$

and where

$$CC(\bar{x}_t) = \begin{cases} M, \bar{x}_t \neq \bar{I} \\ 0, otherwise \end{cases}$$

Thus, $\bar{I}_t = \bar{x}_1, \bar{x}_2, \cdots, \bar{x}_T$ gives us the optimal target inventory values for the medical supply under consideration for days 1 through T of the surge period. This algorithm can easily be programmed in an operational environment and implemented for each product on a daily basis. Below we provide a 3-product case scenario.

User Interface

We have built in the epidemiological model, the virtual hospital and the optimization model into the simulation. It has a user interface to provide starting information for the model. Screenshots from the user interface are shown in Figure 8 – 10. *Disease Model* dialog box receives values for the parameters for the epidemiological model. *Hospital Model* dialog box receives values for the parameters for virtual hospital. *Cost Model* dialog box receives values for the parameters for the optimization model. Below we present cases studies.

Case Studies

In this section, we present three case studies of the virtual hospital with 3 products and varying inventory costs. In all of these cases, we assume the following epidemiological parameter settings:

Incubation Period:	1.9 days
Infectious Period:	4.1 days
Parameter 3:	0.00063
N:	100,000

Case 1:

Unit inventory holing cost:	$8/day
Unit shortage cost:	$16/short
Cost of changing target level:	$1,000

The daily demand, and the optimized target inventory levels for products 1 to 3 and the total cost per day are shown in Figure 11 – 13. In this case, we have kept the values of th ecost parameters at relatively low levels. This encoures frequent changes in target levels to adapt the chaing environment due to surge.

Case 2:

Unit inventory holing cost:	$8/day
Unit shortage cost:	$16/short
Cost of changing target level:	$6,000/change

In this case, the cost of changing target inventory levels is increased by six fold. The daily demand, and the optimized target inventory levels for products 1 to 3 and the total cost per day are shown in Figure 14 – 16. Observe the impact of large target changing costs in the form of much lesser changes of target values. Compare the blue lines in Figures 14 – 16 to Figures 11 – 13. Unit shortage cost is relatively higher than the unit holding cost and therefore the optimization model tries to keep the target levels close to the demand and yet changes them much less infrequently as compared to Case 1.

Case 3:

In this case, we will look into the impact of high unit holding costs. The cost parameters are given below:

Unit inventory holing cost: $16/day
Unit shortage cost: $8/short
Cost of changing target level: $6,000/change

Observe the impact of large unti holding cost which discourage holding high inventories and push the target levels to low values as observed in Figure 17, shown only for product 1.

CONCLUSIONS AND RECOMMENDATIONS

The research in this project addressed the issue of managing inventories of medical supplies and especially the critical ones in hospitals under surge (pandemic) scenarios. Inventory management basically deals with how much of each unit to maintain on hand by deciding on when to order and how many to order for each item under consideration. This is a critical issue since too much of medical supply inventory can cost a lot while short inventories will not satisfy the demand. Finding the right amount of stock is always a challenge in inventory management due to uncertainties involved in demand. We have developed a sound and practical approach that combines epidemiologic modeling techniques with simulation and optimization modeling to provide the best strategy for managing inventories. It involves a high-fidelity Disease Progress Module Influenza Pandemic like scenarios using already validated data from the historical epidemiological literature. For the proposed simulation framework, a Virtual Hospital Module was developed to capture resource consumption in healthcare settings during an Influenza Pandemic. A Dynamic Programming optimization model was constructed to optimally manage the inventory of critical medical supplies (that is the decisions regarding when to order and how much to order) in hospital settings. A number of numerical scenarios were analyzed and results were obtained. The approach is quite practical and readily implementable in hospital settings.

Recommendations

As mentioned earlier, the project aims to provide guidelines to implement a formal procedure to help decision makers managing inventories in the health care industry. Due to that fact that shortcomings in medical supplies may end up in dire consequences, inventories are typically held at higher levels as compared to other industries. Clearly, this has consequences that appear as significant contributions to health care costs. A serious effort to reduce health care related costs is to implement effective inventory management policies so that supply stocks are kept at reasonable levels during times when there is no mass demand. During emergency scenarios such as pandemic situations the system should be effective enough to respond quickly to build right amount of inventories.

Our recommendation to health care system managers is to focus on effective supply management systems that are intelligent enough to respond high-consequence situations by rapid inventory build ups and yet maintain lower yet sufficient levels of inventories at other times. This will have reducing effects on health care costs in the U.S.

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FIGURES

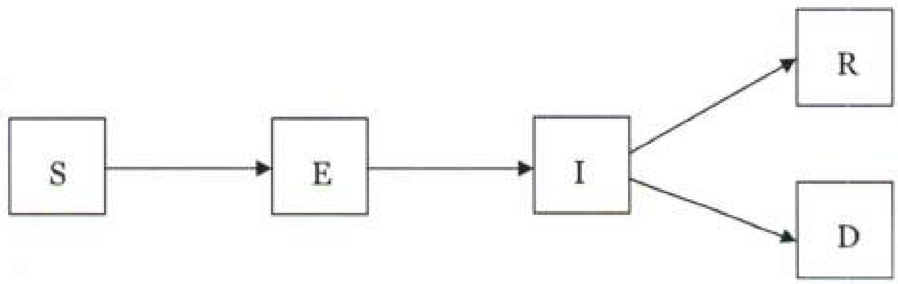

Figure 1. Schematic relationship between the five subgroups in the model

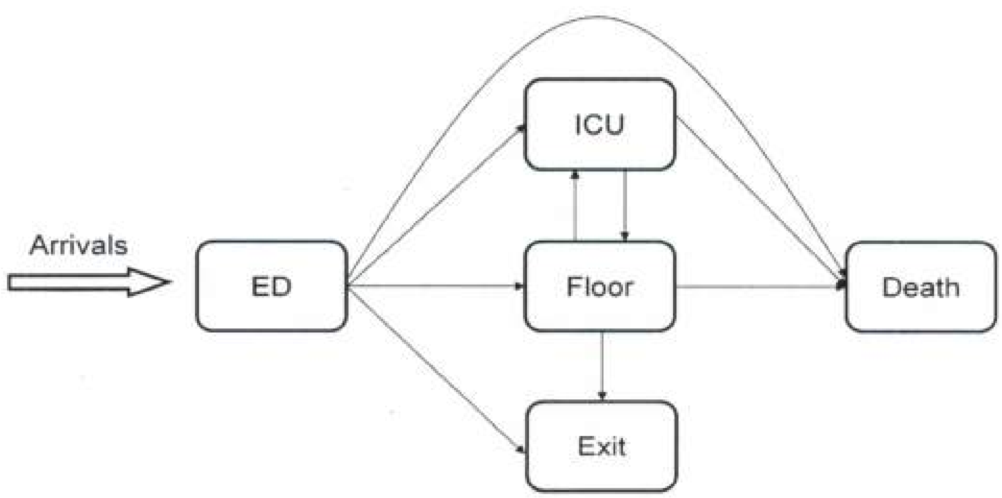

Figure 2. Treatment dynamics at the hospital

Days in the ICU	TRIA (4,7,10)
Days on the floor	TRIA(2,3,5)

Figure 3. Length of stay in the virtual hospital

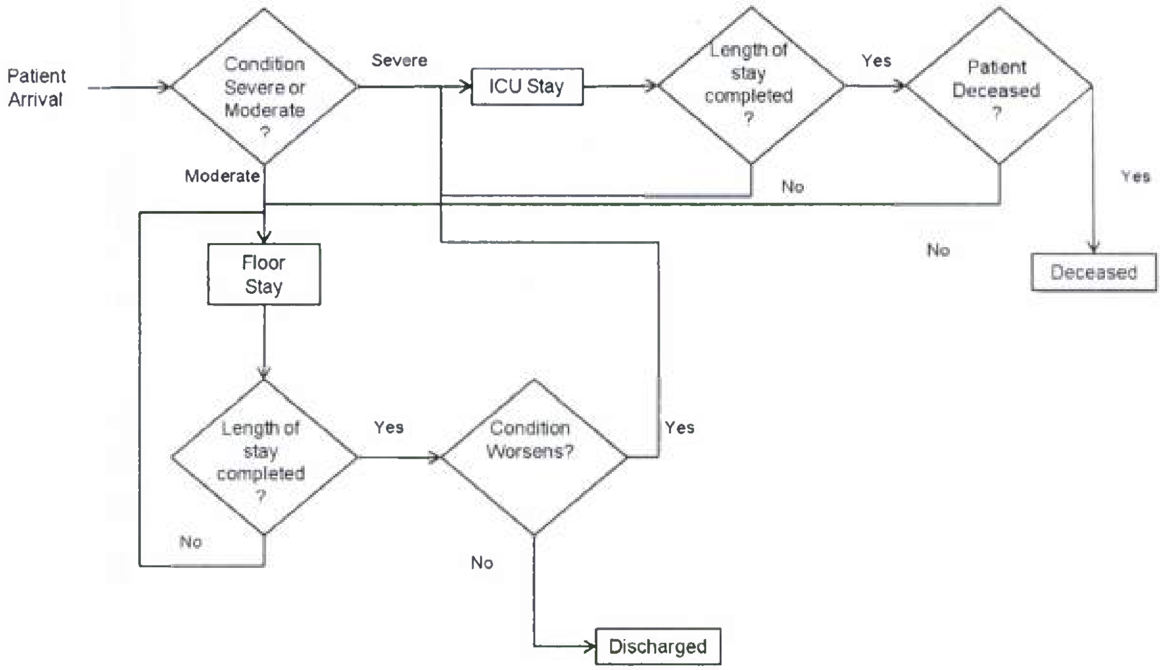

Figure 4. High level patient workflow

Patient Type	Tamiflu	IV Fluid	Mechanical Vent Tube
Severe	2 doses/day	2 liters/day	¼ segments/day
Moderate	2 doses/day	2 liters/day	n/a

Figure 5. Daily product consumption by patients (The products considered are typical medical and pharmaceutical supplies for flu patients.)

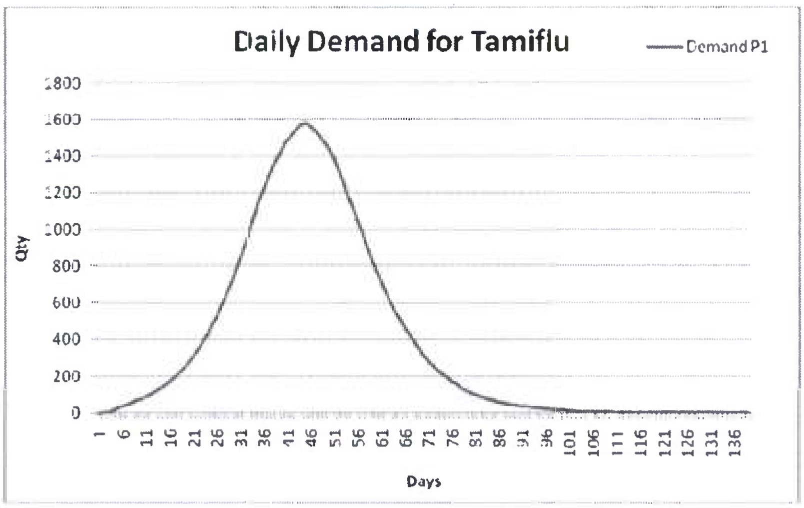

Figure 6. Daily demand for Tamiflu

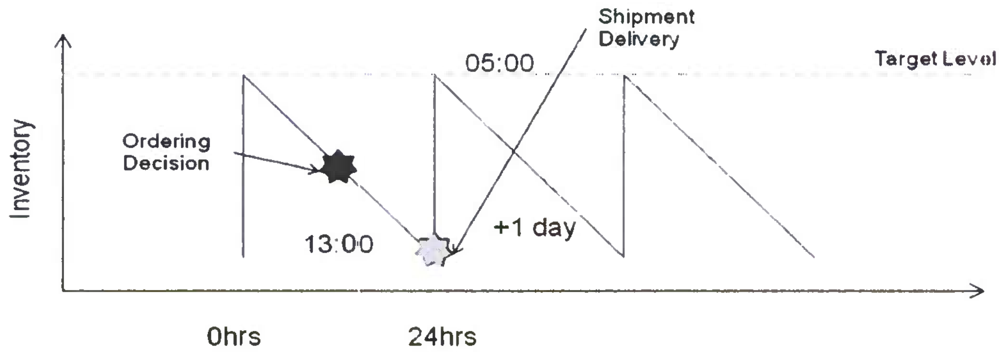

Figure 7. Inventory control model used in the hospital model

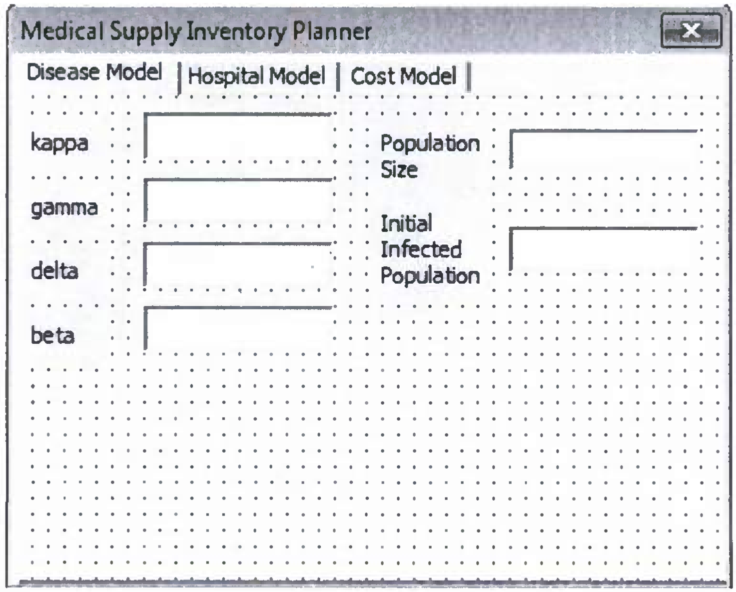

Figure 8. *Disease Model* dialog box of the user interface

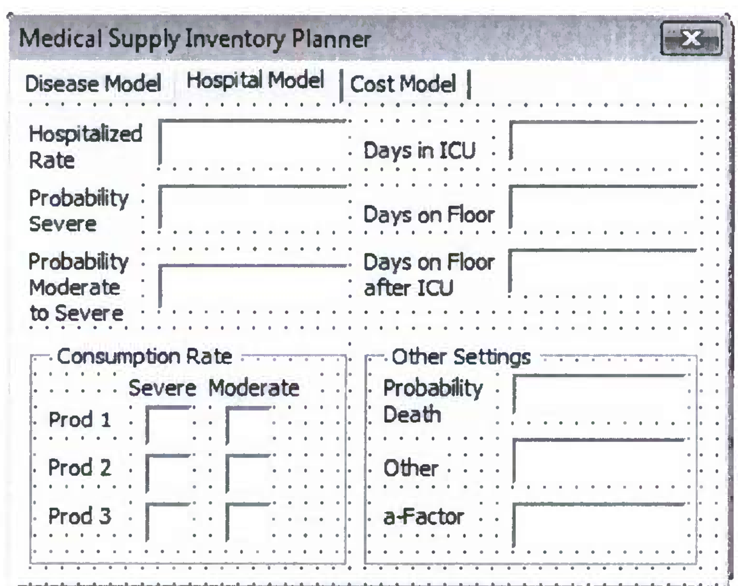

Figure 9. *Hospital Model* dialog box of the user interface

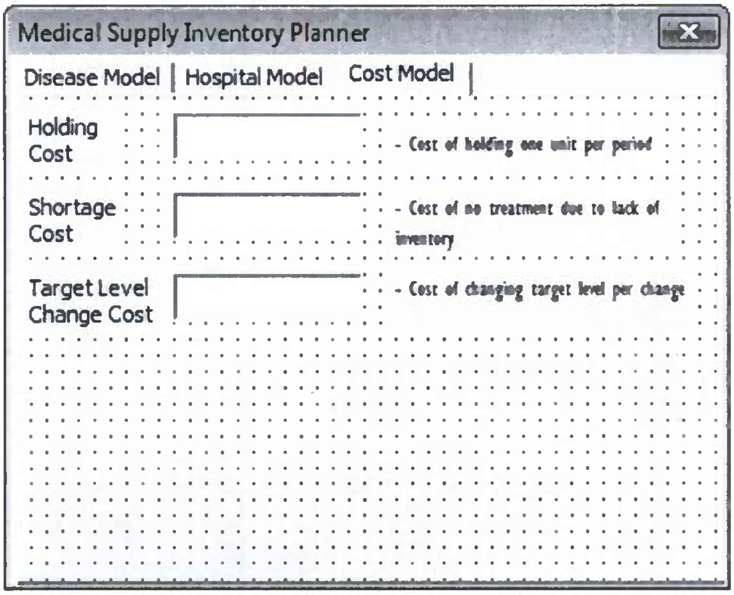

Figure 10. *Cost Model* dialog box of the user interface

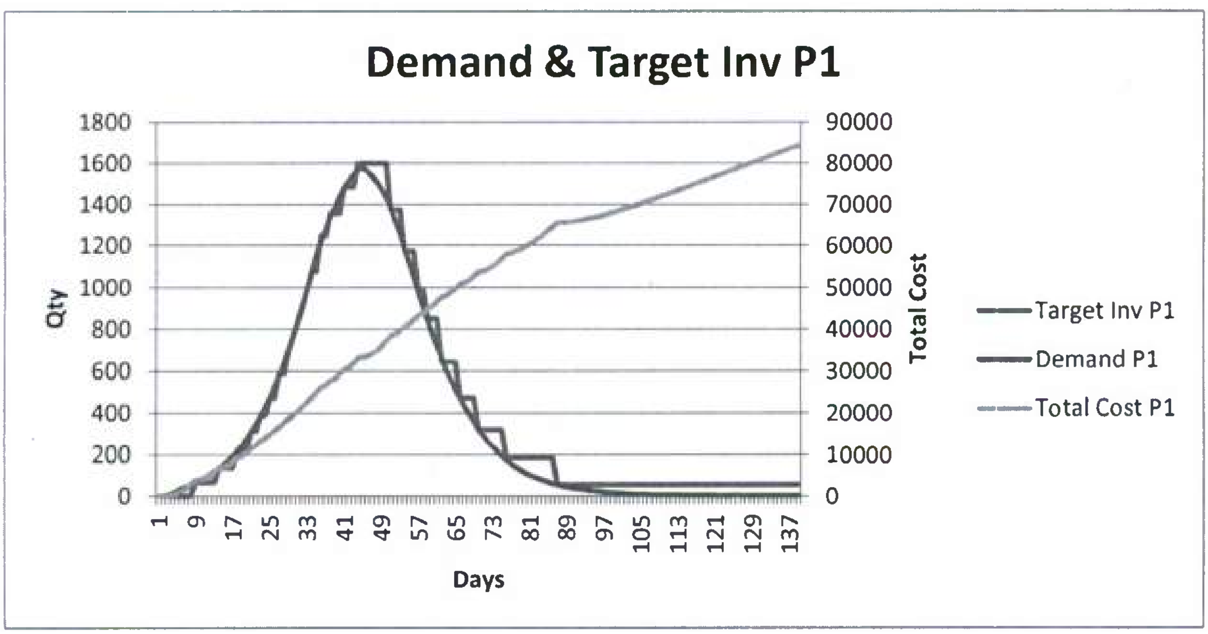

Figure 11. Daily demand, total cost per day and the optimized target inventory levels for products 1 in Case 1.

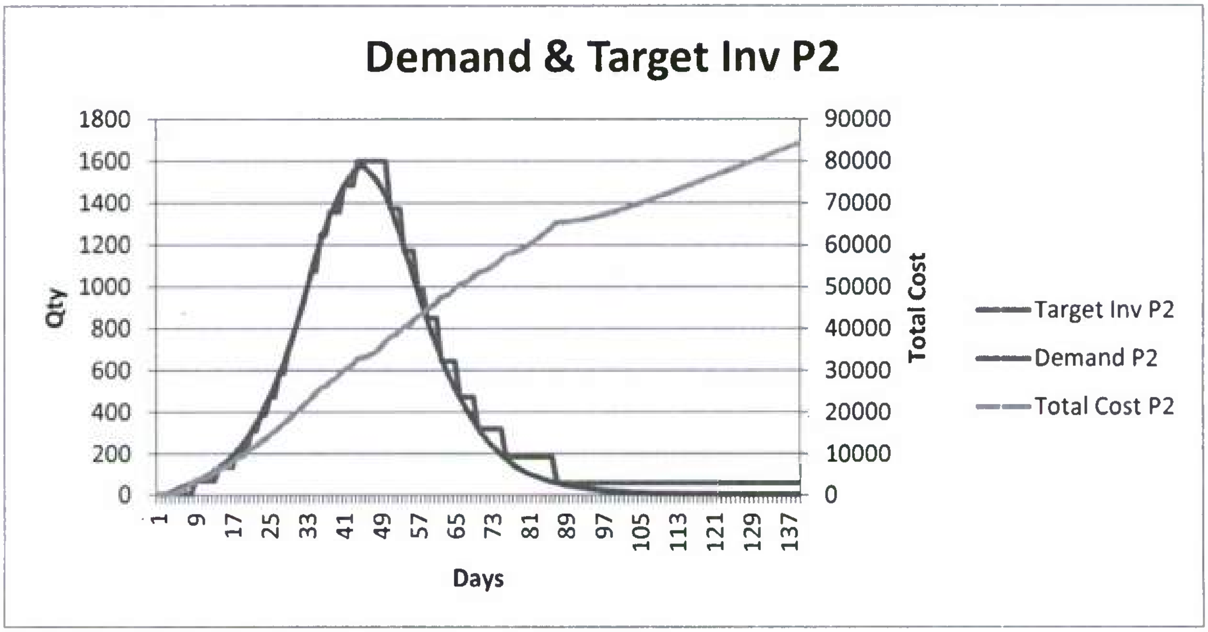

Figure 12. Daily demand, total cost per day and the optimized target inventory levels for products 2 in Case 1.

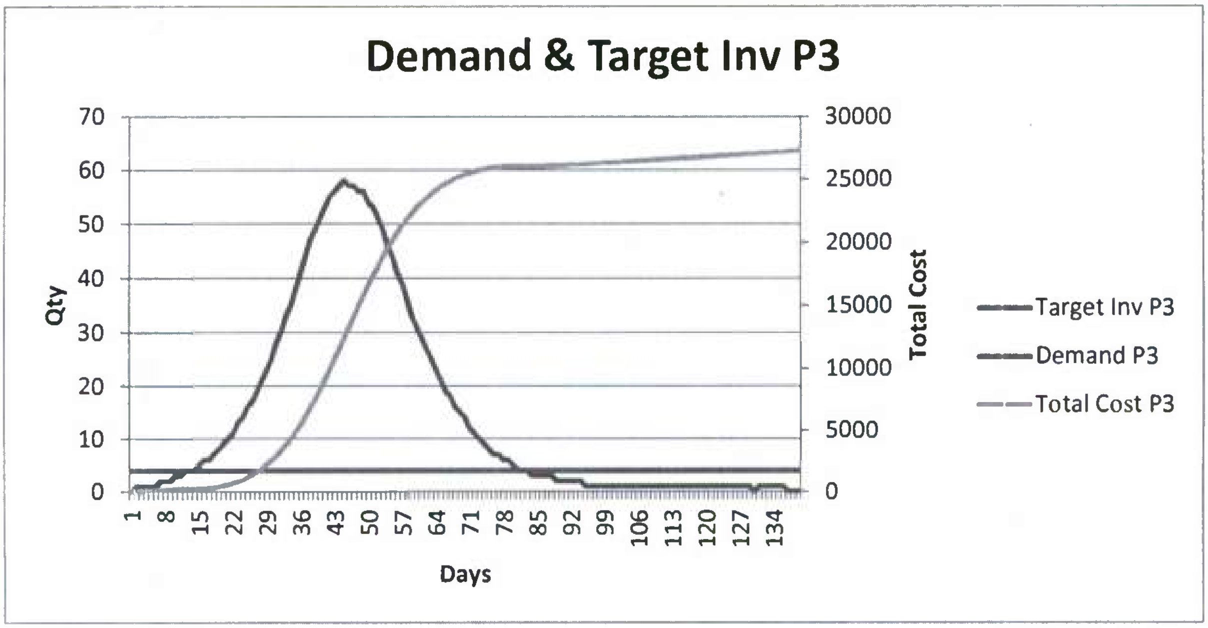

Figure 13. Daily demand, total cost per day and the optimized target inventory levels for products 3 in Case 1.

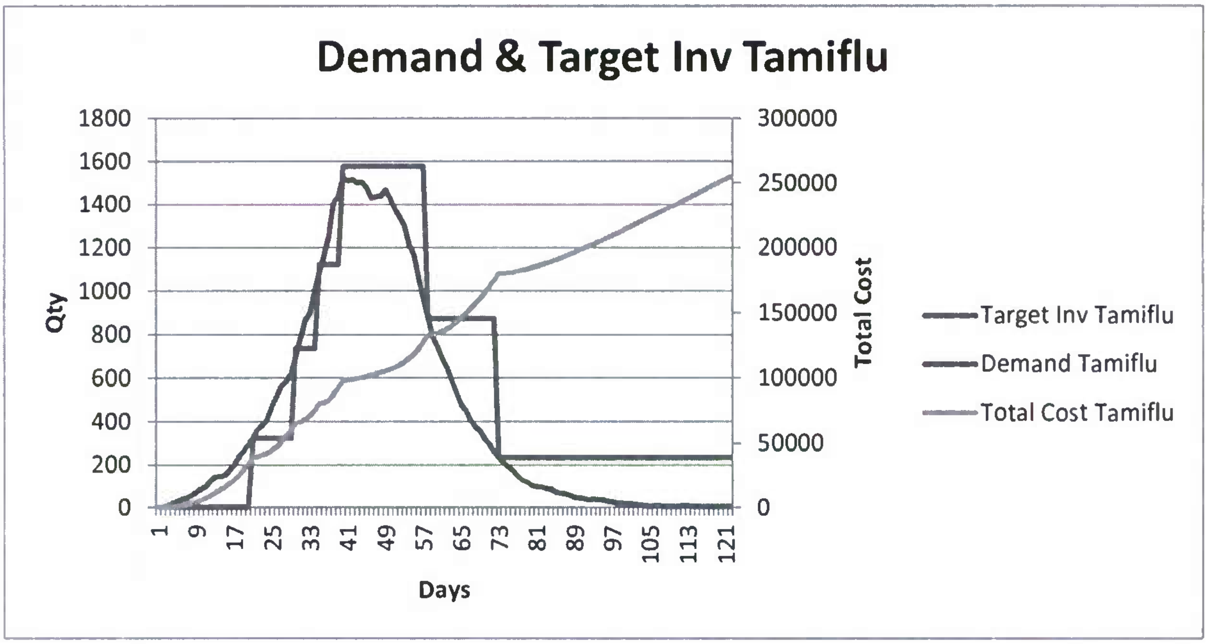

Figure 14. Daily demand, total cost per day and the optimized target inventory levels for products 1 in Case 2.

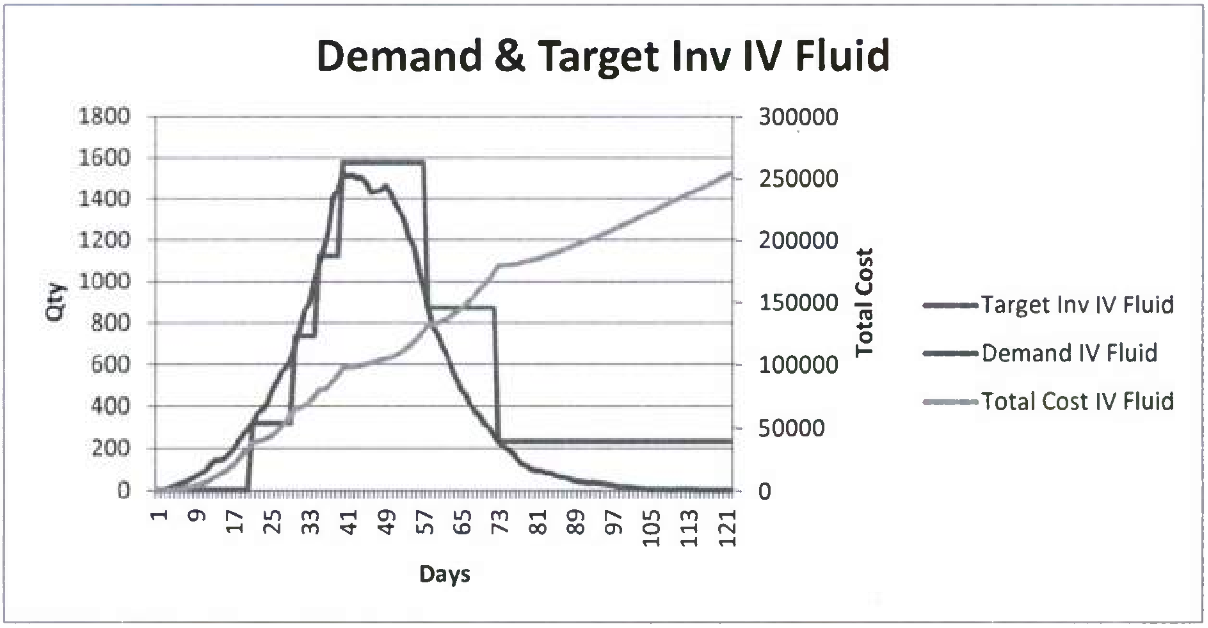

Figure 15. Daily demand, total cost per day and the optimized target inventory levels for products 2 in Case 2.

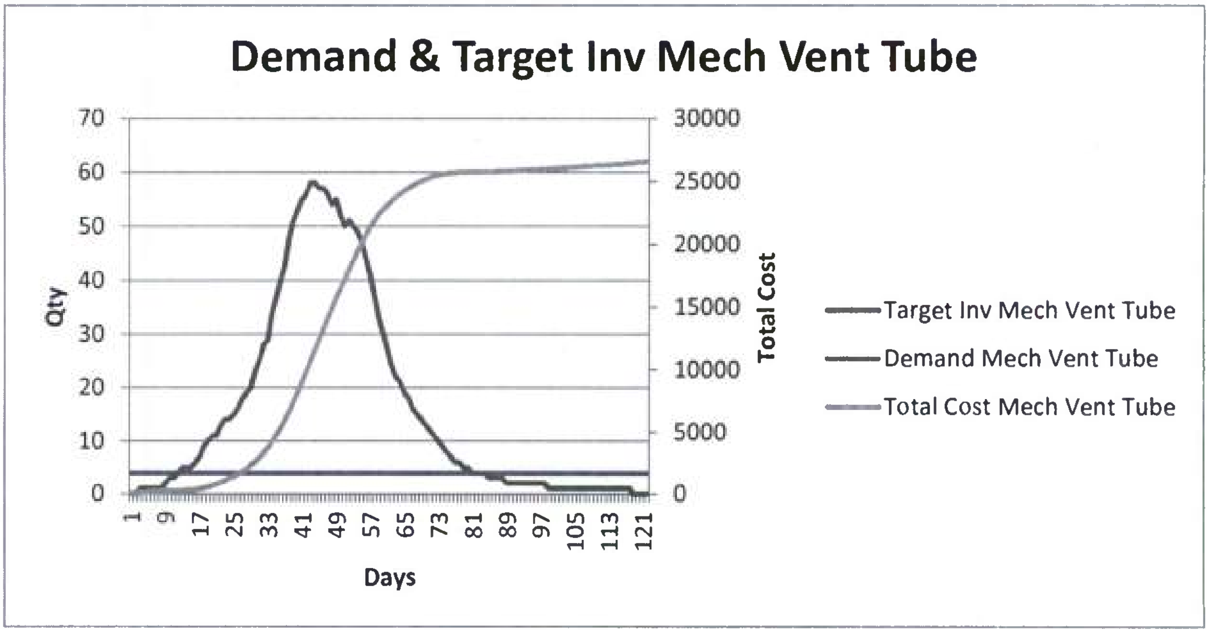

Figure 16. Daily demand, total cost per day and the optimized target inventory levels for products 3 in Case 2.

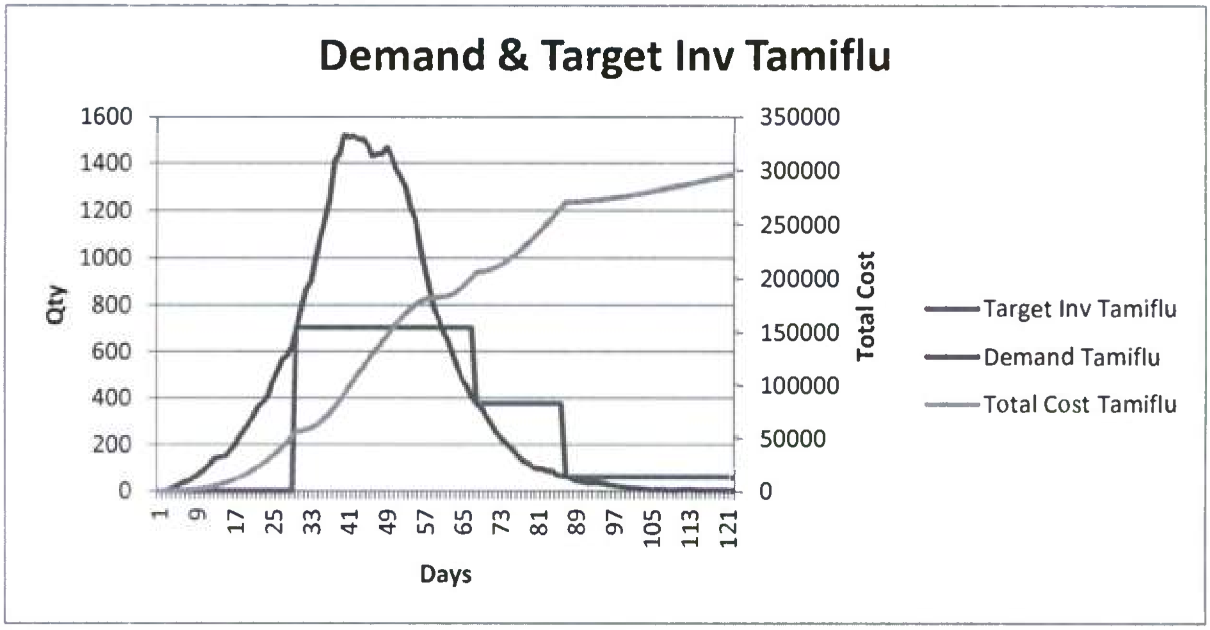

Figure 17. Daily demand, total cost per day and the optimized target inventory levels for products 1 in Case 3.

TABLES

Table 1. Epidemiological model parameters

Parameters	Description	Value
β	Transmission rate	0.39
$1/\kappa$	Latent period	4.1 days
$1/\gamma$	Recovery period	1.9 days
CFR	Case fatality ratio	0.02%
δ	Mortality rate	0.0005
$S(0)$	Population size	100,000
$I(0)/N$	Initially infected fraction of the population	0.002

CHAPTER 5

Project 09 06 F: Patient Flow Optimization under Regular and Emergency Hospital Operations

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Patient Flow Optimization under Regular and Emergency Hospital Operations

09 06 F

Final Report

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Abstract

The main objective of this project was to evaluate techniques to optimize patient flow during regular and emergency hospital operations. To achieve this objective, a two-step methodology was devised: (i) A statistical analysis technique was developed to identify significant sources of variability in patient flow, (ii) In order to support patient flow optimization and control, we hypothesized that real time patient and resource tracking will be required. To that end, a simulation of a typical emergency department at a hospital was built. Our overall conclusion is that real time information on patient tracking and resource availability can significantly improve patient flow throughout hospitals. The improvements are expected to be more significant under surge conditions when traditional tracking and offline techniques are no longer effective.

However, real time information by itself cannot mitigate the patient flow and safety issues unless causes of process variations are identified and corrected. RTLS can only be effective if used in conjunction with a solution platform that controls and optimizes patient flow. This concept has already proven to be doable and effective in other industries, such as manufacturing. To cut costs and improve patient safety, it is time to build these solutions for healthcare delivery systems.

Foreword

This project was performed by Dr. Mohsen A. Jafari and was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital- with support from Department of Defense Grant No. W9132T-10-1-0001.

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INTRODUCTION

Background

Patients' experiences during their hospital visits often involve redundant steps and procedures leading to unnecessary excessive time, lower quality of service, medical error, higher cost for patients and hospitals and patient dissatisfaction. The excessive costs are often covered by the hospitals or paid by individual patients since insurance companies and government run Medicare or Medicaid have standard payment plans according to pre-defined diagnosis and treatment procedures. Regardless of who pays for these excessive and unnecessary expenses, the adverse societal impacts and negative consequences are immense.

The common practice in many hospitals is to use patient flow data to calculate statistics on key performance indicators (KPIs) and for patient billing purposes. KPIs are used for reporting and sometimes as aggregate instruments for process improvements. Closed loop control and monitoring of patient flow patterns using situational awareness capabilities – e.g. RFID - and feedback loops has not been a common practice in hospitals. But some elements of this practice has already been proven to be very useful in the Internet online businesses which utilize their customer shopping habits and patterns to extend their market share and for the betterment of their services and offerings. While the situational awareness and feedback control models are more complex for hospitals due to extensive sources of variability and risks involved, the potential reduction in costs and increase in QoS and patient safety and satisfaction will be too rewarding to ignore. All these tools become handier especially when the regular normal operation of hospital is affected by an external incident varying from highway crashes to earth-quakes and terrorist attacks. It's in such situations that having a managed patient flow and situational awareness systems – e.g. RFID – can be of great help to the hospital to increase patient care and lower the number of fatalities.

Objective

This research intends to address the following specific issues:

1. To better understand sources of variability that impact patient flow within hospitals under normal and surge conditions;
2. To quantify the impact of real time information on streamlining patient flow, and quantify the value that Real Time Location Services (RTLS) technology can bring to hospitals.

Approach

Two methodologies used in this research: (i) a statistical data analysis model and (ii) a simulation based approach. These two methodologies are thoroughly explained in the technical chapter of this current report.

Scope

The scope of the research and methodologies introduced here include patient flow analysis throughout hospitals under normal and surge conditions. The underlying analysis requires highly granular patient flow data, typically available in Hospital Information System (HIS).

Mode of Technology Transfer

The results and outcomes of this research are only preliminary and cannot directly support commercialization. Further development will be required; especially additional analysis of real hospital data must be conducted.

TECHNICAL REPORT

Problem Definition

There are sources of variability that are intrinsic to all health care delivery systems. These can hardly be avoided, but having efficient management schemes in place can lead to advantageous outcomes both for patients and hospitals. These sources are: (i) variability due to patient individual characteristics – this is fully uncontrollable and can frequently cause major spikes in demand for resources; (ii) variability due to type and severity of disease or medical services that must be provided to patients; and (iii) variability in capabilities and the level of professional knowledge that medical staff possess and use under normal, surge and exceptional conditions. These sources of variability could severely impact patient safety, QoS, professional satisfaction, and hospital revenue. In this project, we attempt to introduce a data-driven statistical method to better understand these sources of variations. We will be using standard patient data which is available at typical HIS.

Additionally, patient safety, quality of care, and hospital revenue are greatly impacted by the way information and patients flows are synchronized and move across hospitals. Better synchronization of patient and information flows can significantly reduce the impact of the above sources of variability. In this project we will address the added value of using RTLS for this purpose. Many hospitals struggle with this issue in a way that they are not sure if access to real time information will streamline their existing processes and will eliminate problems relating to patient flow. As part of this research we attempt to model the use of Radio Frequency Identification (RFID) by a computer simulation and measure the performance measures for after and before environment.

Approach

Statistical Analysis of Patient Flow data

Our analysis is composed of the following steps:

- Clustering of patient flow data into homogeneous groups
- Development of fish bone diagrams to identify variables that contribute to variations within a cluster and between clusters
- Statistical feature selection leading to the identification of significant variables from the list of variables identified by the fish bone diagram.

With clusters and significant variables or factors identified, the hospital management should be able to optimize patient flow under normal and surge conditions. This is carried out by associating each new patient with an appropriate cluster, and by managing significant and controllable variables associated with that cluster. While the control and optimization steps are not investigated and modeled here, we believe that this methodology has major commercial potentials and can greatly and positively impact hospital performance under normal and surge conditions.

Next we present some details of our technical approach.

In a hospital information system, patients are assigned Diagnosis Related Group (DRG) codes which loosely speaking, show the type of the disease and identify the steps that these patients must follow while they receive care from the hospital. It is likely for a patient to change from one DRG to another depending on the outcome of tests and initial diagnosis. It is also possible for patient to belong to several DRGs. While each DRG groups patients according to their diagnosis and defines the basis for billing, there may be some significant differences in the care patterns of patients randomly sampled from the same DRG. In our analysis , sources of variations are categorized into three classes: : (Type I) unique characteristics of each patient (patient profile), including age, demographics, and other health conditions, (Type II) hospital resources, including medical staff and major equipments, (Type **III**) random noise. There are always un-assignable causes, which are usually grouped under random noise. Since random noise is statistically un-controllable, it is imperative to reduce its effect as much as possible. Any significant reduction on the un-controllable variations will increase "process capability" which will in turn lead to significant cost reductions.

The statistical method used in this research is a data driven method meaning that it will use the data extracted from the various data sources in a typical HIS. No private or confidential data is needed for our analysis. There will be a data node for each patient. Each node consist of patient identifier; patient profile information such as age, sex, ethnic group; and medical history. The above node is then associated to a series of medical procedures that are adopted to treat that certain patient. These series of events or activities is referred to as "sequence" throughout this report. We used an existing sequence clustering technique to group patient sequences within a DRG into clusters. The clustering model groups patients within a DRG into groups which are similar mostly in their treatment pattern and profile information. The variance within a cluster still exists but is less compared to the variance between clusters.

In order to identify the variables or factors that contribute significantly to the sources of variations in the patient flow or sequences, we use fishbone diagram also known as Ishikawa diagram or cause-and-effect diagram. It was first used in the 1940s, and is considered one of the seven basic tools of quality control. It is known as a fishbone diagram because of its shape, similar to the side view of a fish skeleton.

In this diagram (see Figure 1), causes are usually grouped into major categories to identify sources of variation. The categories typically include:

- People: Anyone involved with the process,
- Methods: How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, etc.,
- Machines: Any equipment, tools etc. required to accomplish the job,
- Materials
- Measurements: Data generated from the process that are used to evaluate its quality,
- Environment: The conditions, such as location, time, temperature, and culture in which the process operates.

Causes can be derived from brainstorming sessions. These groups can then be labeled as categories of the fishbone. They will typically be one of the traditional categories mentioned above but may be something unique to the application in a specific case. Figure 1(Appendix 1) shows an example of the fishbone diagram for cause and effect analysis of the patient flow variations in a general hospital.

The next step is to translate these potential causes into random variables. There are two types of variables:

- Quantitative or continuous variables,
- Categorical or discrete variables.

A quantitative variable is naturally measured as a number for which meaningful arithmetic operations make sense. Examples are height, age, temperature, etc.. Any variable that is not quantitative is categorical. Categorical variables take a value that is one of several possible categories. The easiest case is when there are only two classes or categories, such as "success" or "failure," "survived" or "died." These are often represented by a single binary digit or bit as 0 or 1, or else by −1 and 1. When there are more than two categories, several alternatives are available. Examples are gender, severity of illness, nurse level of expertise, etc..

Using the fishbone diagram and expert opinions, we are able to obtain a pool of potential variables which can be responsible for the patient flow variations. The next step is to apply a statistical method to find the most important variables which significantly affect these sequences. By targeting these variables, the hospital management can significantly improve patient flow. In order to define the most significant variables we use an existing classifier technique based on Random Forest {developed by Leo Breiman and Adele Cutler }. It is an ensemble classifier that consists of many decision trees and outputs the class that is the mode of the class's output by individual trees. Random forests are becoming increasingly popular in many scientific fields because they can cope with "small sample sizes and large predictor variables" problems, complex interactions and even highly correlated predictor variables. Random forest is unexcelled in accuracy among current algorithms, and runs efficiently on large data bases. Furthermore, while there is an expectation that all data elements are collected, it is recognized that in certain situations information may not be available (dates, times, codes, etc.). Random forest has an effective method for estimating missing data and maintains accuracy when a large proportion of the data are missing. It also has the capability to give estimates of what variables are important in the classification which specifically is in our interest in solving the feature selection problem. For our application the explanatory variables (factors) are classified in two main categories:

- Patient profile,
- Hospital resources.

Real time information and patient flow

Real time information of whereabouts of patients and availability of resources is essential to the deployment of optimal patient flow strategies. RFID (Radio Frequency Identification) technology has proven to be useful in other industries, such as manufacturing and distribution. RFID technology has also been adopted by some hospitals around the country, but the value added aspects of RFID in patient tracking is still under debate. It is not clear for many hospitals if the return of investment on the deployment of RTLS technology is significant. Many hospitals are not able to weigh the RFID technology costs versus the benefits that they expect from this technology on streamlining patient flow and increasing patient safety. While there are traditional means of tracking patients within the hospitals, RTLS (RFID as one example) can track patients from their point of entry and throughout their hospital experience. Furthermore, the quality of patient location and availability of resources remains intact when surge conditions occur. (Oranje et al, 2009)

The second major task in this project is to devise a methodology to quantify value of RTLS data with respect to the patient flow. We note that RTLS cannot by itself resolve inefficiencies in patient flow. However, we hypothesize that if RTLS were to be used in conjunction with an optimal patient flow solution platform, desirable outcomes should be achievable. A patient tracking system can facilitate the entry time stamps that are not currently captured. It can also provide real time information on when a patient is available for his/her next care activity. Such a system can also be integrated into an active compliance process by flagging patients whose waiting time is approaching stipulated maximums. Tracking of hospital resources can also help mitigate patient flow issues and reduce the expenditure on the procurement and maintenance of equipment. Generally speaking, asset invisibility at hospitals leads to the following problems:

- Hospitals over-procure 20-30% of their mobile assets
- Nursing staff spends 10-30% of their time searching for equipment
- Servicing an item takes 8 hours because 75% of the time is spent searching for it
- Assets are not serviced and maintained when required
- Hospitals are having a difficult time complying with the **Joint Commission on Accreditation of Healthcare Organizations** (**JCAHO**) and FDA regulations on equipment maintenance
- Critical staff cannot be located quickly
- Equipment is lost and stolen.

A computer simulation model can help hospital management to investigate the impact of asset visibility and patient tracking on the hospital's Key Performance Indicators (KPIs).

We developed a computer simulation model of emergency department (ED) in a hospital and used it to investigate the RTLS impact on patient flow optimization. While the model is specific to the ED it is modeling, the underlying concept and methodology is general and can be applied to different EDs, and can also be expanded to cover larger sections of hospitals.

Generally speaking, Simulation modeling allows exploration of the effect of alternative designs for improving operations by mimicking flows within a system. It allows experimentation to understand the impact of different scenarios or proposed changes to the system. There are many simulation language platforms and application that can be used to simulate manufacturing, transportation, and telecommunication systems. However, developing such models in the hospital environment is a challenge because of a traditional lack of adequate data. "One of the most critical parts of any simulation model development is validating the model—comparing the model's output with the data observed. In order to rely on such comparison one has to make sure that the incoming data for the model, as well as the data observed for comparison with the model output, are accurate." The use of Radio Frequency Identification (RFID) technology in hospitals has the potential to close this gap.

Emergency Department Simulation Model

We used Arena software to simulate the patent flow in the ED before and after implementing RTLS. We refer to these models as *basic* and *alternative* models, respectively. The basic model represents a general emergency department. There are two types of patients admitted to the ED: urgent and emergent patients. The main difference between these patient types is the severity of their conditions, i.e., the emergent patients have higher priority compared to the urgent patients. The resources in the emergency department (ED) are classified in three groups. The first group, human resources, consists of doctor(s), nurse(s), administrator staff and mover(s). The second group is equipment. We consider equipment as the assigned resources to the patient throughout his/her treatment. If an urgent patient arrives, that patient will get a wheelchair and a designated bed (used only by urgent patients). Likewise, when an emergent patient arrives, the patient will get a stretcher and a bed for emergent cases. There is a certain capacity limit for each class of resource. The last group of resources includes machines, such as X-Ray and EKG machines. They can only serve one patient at a time and they are occupied if the condition/treatment of the patient requires it.

As we mentioned before, there are two different types of patients arriving to the emergency department, and they are being taken to different types of treatment programs according to their conditions. The process flow chart of each patient type is shown in appendix 1. With the RTLS technology the simulation model changes in two aspects:

1- Asset management,
2- The flow of patients.

When the mobile assets have RFID tags, the staff knows the exact location of the equipment at any given time. In the alternative model we assume that wheelchairs and stretchers are RFID tagged. This is in contrast to the basic model where the mover needs to search for the required equipment. In the alternative model the mover directly goes to the location of the equipment and picks it up. This change in the model results in search time to be reduced to zero and a non-value added task to be removed from the process leading to a significant reduction in overall patients' waiting times.

With patients RFID tagged in the alternative model, patient movements are monitored throughout ED and its sections. By RFID tagging the caregivers, the model knows whether a caregiver is available at a given time or not. Having this real-time information, the patients are directed to the next available unit to receive their treatment instead of waiting in a queue of an unavailable service. This change in the alternative model facilitates the flow of patients in the emergency department and alleviates the bottlenecks, which were present in the basic model.

To compare the two models we consider the following performance measures or KPIs:

- Overall service time: time from the patient's admission to his/her discharge,
- Process time: service time excluding the paper work,
- Time from the patient's admission to his/her settlement on a bed
- Time of completion of required treatment procedures

In order to further validate the simulation results, we considered two hospital settings:

1- A hospital with low level of hospital resources,

2- A hospital with high level of hospital resources.

Furthermore, to evaluate the performance of the emergency department under different workloads we considered three settings, by changing the arrival rates of patients:

1- Low,

2- Medium,

3- High.

In total we investigate six scenarios with the above combinations. Table below illustrates the % change in the above KPIs for these scenarios. Clearly there are significant improvements in KPIs when RTLS is used at a typical emergency department.

CONCLUDING CHAPTER

Summary

The main objective of this project was to evaluate techniques to optimize patient flow during regular and emergency hospital operations with a microanalysis of underlying processes that constitute the elements of patient flow in the emergency room and its surrounding operations. To achieve this objective, we devised a two-step methodology: (i) A statistical analysis technique was developed to identify significant sources of variability in patient flow. We take the traditional view that excessive variation in any process is not desirable and must be eliminated. (ii) In order to support patient flow optimization and control, we hypothesized that real time patient and resource tracking will be required. To that end we built a simulation of a typical emergency department at a hospital. The simulation takes into account before and after RTLS scenarios and compares them with respect to some typical KPIs used at hospitals.

Conclusions

To conceptualize step (i) above, we experimented with a single DRG group of patients. The patients with a single DRG are expected to have similar diagnosis and go through statistically similar treatment processes. By exploring the sources of variations within this group and identifying significant factors or variables that contribute to these variations, we are able to establish decision space for hospital management. The hospital management must then attempt to choose and control some or all of the variables in this space in order to optimize the patient flow within the hospital. The optimization and control aspects of patient flow was not investigated in this project. Further research is required.

Simulation experiments from step (ii) above show that RTLS impact is statistically significant. Major improvements were observed in typical KPIs used by hospitals. While these results are specific to the ED model used in this project, the methodology is general. Further research is required to determine if these improvements can be generalized to typical ED and hospital settings.

Recommendations

Real time information on patient tracking and resource availability can significantly improve patient flow throughout hospitals. The improvements are expected to be more significant under surge conditions when traditional tracking and offline techniques are no longer effective. However, real time information by itself cannot mitigate the patient flow and safety issues unless causes of process variations are also identified and corrected. RTLS can only be effective is used in conjunction with a solution platform that control and optimizes patient flow in accordance to the dynamics of the hospital. This concept has already proven to be doable and effective in other industries, such as manufacturing. To cut costs and improve patient safety, it is time to build these solutions for healthcare delivery systems.

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Figures

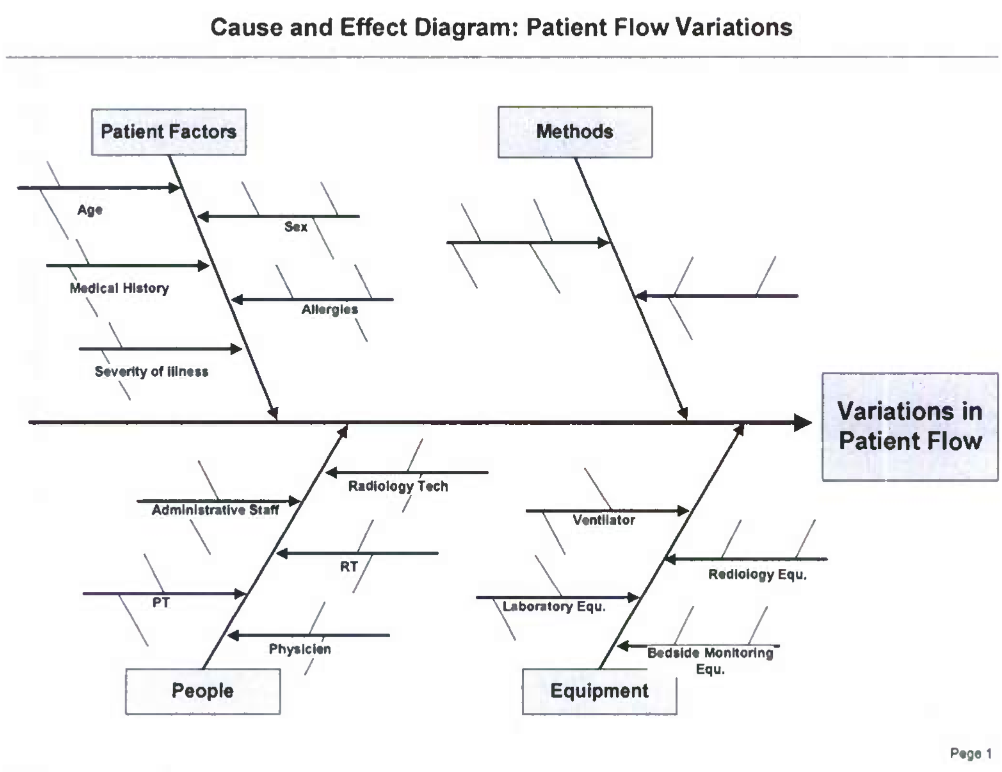

Figure 11 - Fishbone diagram of the patient flow variations

TABLES

Performance Measure	Low Level of Resources		
	Low Patients Arrival Rate	Medium Patients Arrival Rate	High Patients Arrival Rate
Emergent Patient			
Overall Service Time	9.973	59.659	76.798
Process Time	24.806	76.345	82.878
Time From ED Admission to his settlement on the Bed	51.342	88.120	91.742
Time of completion of required parallel procedures	64.227	92.466	86.602
Urgent Patient			
Overall Service Time	4.631	55.090	22.257
Process Time	10.381	67.119	23.494
Time From ED Admission to his settlement on the Bed	23.672	89.046	32.159
Time of Completion of Required Parallel Procedures	67.484	96.908	89.177

Table 1 - Simulation Result, Percent Decrease in KPIs with Low Level of Resourc

Performance Measure	High Level of Resources		
	Low Patients Arrival Rate	Medium Patients Arrival Rate	High Patients Arrival Rate
Emergent Patient			
Overall Service Time	8.742	6.630	44.671
Process Time	19.178	18.014	65.897
Time From ED Admission to his settlement on the Bed	47.212	48.802	82.710
Time of completion of required parallel procedures	24.147	48.729	90.625
Urgent Patient			
Overall Service Time	2.226	2.072	8.867
Process Time	5.679	10.180	0.990
Time From ED Admission to his settlement on the Bed	17.174	31.601	58.202
Time of Completion of Required Parallel Procedures	68.569	72.129	95.161

Table 2 - Result, Percent Decrease in KPIs with High Level of Resources

CHAPTER 6

Project 09 08 F: Use of Ultrasound in the Emergency Setting to Improve Triage of Trauma Patients

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Use of Ultrasound in the Emergency Setting to Improve Triage of Trauma Patients

Project 09 08 F

Final Report

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Abstract

This study evaluated the use of portable ultrasound by pre-hospital providers in the pre-hospital setting. Ultrasound imaging has been used to rapidly determine presence or absence of pneumothorax, blood in the abdominal cavity, and appropriate endotracheal tube placement non-invasively. Non-physician providers have used this technology in the advanced setting of the Emergency Department (ED). This project determined the feasibility of pre-hospital providers obtaining images in a more austere environment and if the images could be interpreted appropriately to improve patient care. Further study is needed with more robust equipment to determine if ultrasound can be used to augment rapid field triage of trauma patients.

Foreword

This project was performed by Rajesh Geria, MD and was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital- with support from Department of Defense Grant No. W9132T-10-1-0001.

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INTRODUCTION

Background

The Focused Assessment with Sonography for Trauma (FAST) is used to rapidly and non-invasively assess trauma patients for life-threatening injury in many hospitals across the globe. However, in the United States, the FAST exam is currently not within the scope of practice of pre-hospital paramedic personnel. The Emergency Medicine literature has an abundance of studies demonstrating that when used by adequately trained physicians it can serve as a risk stratification tool in trauma patients.

We feel this technology can be utilized in the pre-hospital arena, in particular at mass casualty incidents or the battlefield to help triage and enhance care of victims. Pilot studies conducted by Heegarard et al. have shown that after brief training sessions consisting of didactic and hands-on education, paramedics were able to accurately perform these studies on ambulances over a one-year period. An ultrasound expert at the hospital reviewed all ultrasounds performed. The data states that 86 FAST exams were performed of which 6 had positive findings, i.e. hemoperitoneum / hemopericardium. Although this research supports a growing movement to integrate FAST training into Emergency Medical Services (EMS) scope of practice, more studies need to be done. We feel paramedics should be first trained in a controlled setting and have a significant exposure to positive (abnormal) studies prior to being tested in the field setting. The P.I., Dr. Geria, and paramedics who volunteered their time for the training executed all work in this study.

Objective

We sought to determine if paramedics can accurately perform and interpret the FAST exam using portable ultrasound technology and a simulation model after brief training from an emergency physician expert sonographer.

Approach

Paramedics volunteered for a short didactic session followed by hands-on training using a Zonare (Mountain View, CA) ultrasound machine and Blue Phantom FAST (Redmond, WA) model (Appendix 1). Each paramedic filled out a pre-study survey relating previous ultrasound experience and knowledge. They then picked a study number that was written on survey sheet. The course instructor (PI) was blinded to paramedic number. Volunteers changed fluid states on the model every week to reflect one of the following scenarios: normal, + hemoperitoneum RUQ, + hemoperitoneum LUQ, + hemoperitoneum pelvis, + pericardial effusion or combination of any of the above. Paramedics had the opportunity to practice scanning on the model during designated times every month. Paramedics scanned the model in a closed room at the EMS barracks one at a time. They wrote their study number (not their name) and recorded their findings on a case report form that they placed in a locked drop box in the room. Data was reviewed by the PI. All paramedics filled out a post-study survey relating to their confidence in performing the FAST exam and how they envision they would use this in their practice; specifically a disaster situation or MCI.

Location

Research was conducted at Robert Wood Johnson University Hospital and Robert Wood Johnson Medical School in New Brunswick/Piscataway. Training was held in the EMS barracks.

Scope

The research was limited to paramedic volunteers who enrolled in the training session.

Mode of Technology Transfer

After completion of this project, the Army may choose to train their medics in the FAST exam and equip field units with portable machines as an additional method for assessing patients with hidden internal injury in a disaster situation.

CONCLUDING CHAPTER

Summary

23 paramedics participated in the didactic training sessions. The results of the pre-study survey revealed that none of them had ultrasound training prior to this course and all had at least 4 years of experience as a paramedic. In addition, 35% of the paramedics specifically mentioned they could envision the FAST exam dramatically changing their practice and improving risk stratification of patients involved in a MCI.

Three paramedics participated in scanning the FAST model and completed case report forms. Two paramedics participated in scanning the FAST model on multiple occasions. Paramedics reported they viewed the online review lecture prior to their scan 5/6 times.

Paramedics manipulated the machine parameters. During their practice scanning sessions, paramedics reported they needed to adjust the gain to improve image quality 4/6 times. When they made an adjustment, the gain was increased 4/4 times and during one session they both increased and decreased the gain. Both sessions where no attempts were made to adjust the gain were completed by a single paramedic. The location of positive internal fluid was changed on the model three times.

Paramedics were completely correct in their interpretation of their FAST exam session 3/6 times using intent to treat analysis. In the one session where the paramedic reported they did not view the online Review lecture prior to the scanning session, they correctly performed and interpreted their FAST exam. In all three examinations with errors, the paramedics had viewed the Review lecture. For intent to treat analysis, if paramedics identified an internal injury that was truly present they were considered correct since in real life the identification of an internal injury would likely impact triage, transport, and treatment decisions. If intent to treat analysis were not used and case report forms where the paramedic scored the exam as negative and positive for internal injury, paramedics would have been completely correct 1/6 times.

There were several limitations of this study. A significant delay occurred between the didactic training session and the actual testing phase due to multiple technical failures of the scanning model. The model had to be returned to the vendor twice indicating currently available models may not be robust enough for training in more austere environments such as pre-hospital provider barracks. Therefore, the paramedics were not able to frequently and quickly practice what they learned. We attempted to account for this by emailing the lecture reviewing ultrasound physics and how to perform a FAST exam but could not guarantee all of the paramedics viewed it prior to testing or that this stop-gap measure was adequate. Next, all of the paramedics who originally took the training class did not participate in the testing phase. This could have been because they forgot the skills or lost interest.

Conclusions

Teaching and assessing paramedics skills with portable ultrasound outside of the emergency department is technically difficult. While using ultrasound models afford paramedics to test their skills and identify positive findings at rates that would not be reproducible in real life with real patients, the available technology may be limited by its ability to withstand use in more austere environments. Further study is needed with more robust equipment to determine if ultrasound can be used by paramedics to augment rapid field triage of trauma patients.

Recommendations

In accordance with American College of Emergency Physicians Emergency Ultrasound guidelines, emergency physicians must complete at least 25 FAST exams after initial didactic training in order to be considered proficient. Although there is no hard rule about how many exams need to be abnormal, it is recommended that at least a small percent should. Although we have very limited data, preliminary results suggest that paramedics are unable to become proficient in this skill after only limited training. Although the FAST exam can in theory dramatically improve risk stratification of patients in a mass casualty incident, further study is needed to determine if paramedics can correctly identify internal injury with more robust training models that will allow more practice/evaluation time as well as teaching in more remote environments. Future skill acquisition may also be augmented by practice on human volunteers and image interpretation supplemented by using an online video library.

Appendix 1

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CHAPTER 7

Project 09 10 F: Strengthening Windshield Resistance

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Strengthening Windshield Resistance

Project 09 10 F

Final Report

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Abstract

The primary objective of this project is to evaluate methods for improving projectile resistance of response vehicles. These response vehicles are core part of emergency management because they are needed to transport injured people and medical professionals. Windshields of vehicles were chosen for experimental evaluation because of their importance for continued operation even after a possible attack. Review of the current literature of hardening mechanisms led to the conclusion that attaching high energy films is the most economical way to achieve projectile resistance. After careful evaluation of all the products available, two film types were chosen for evaluation: VehicleGARD® manufactured by ShatterGARD® and a film made by 3M and distributed from Shore Shield. The evaluation was conducted both at the laboratory and using actual vehicles. A setup was built to drop a steel ball from various heights. A total six enhanced windshields were tested in the laboratory and tests were also conducted on three vehicles. Both systems provide very good resistance in terms of preventing "flying glass". A careful evaluation of the fractured surfaces leads to the conclusion that VehicleGARD is better because it provides less spread of cracking. This aspect is important for drivability of vehicles after the attack.

Foreword

This project was performed under the direction of Dr. Perumalsamy Balaguru and was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital - with support from Department of Defense Grant No. W9132T-10-1-0001.

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INTRODUCTION

Since the 1970's automotive windshields have been made of laminated glass to protect passengers and drivers during normal driving. Laminated glass is strong enough to resist breaking from high velocity impact by small debris that may be flown into the air by other cars on the road and therefore ensuring the passengers' safety. It also helps to keep the people away from potentially fatal lacerations during vehicle accidents. This makes it perfect for its use in normal highway driving. It has also been used in architectural designs in hurricane prone areas to protect the people in the building from any large objects that would cause low velocity impacts such as tree branches or street signs.

Laminated glass is comprised of a layer of poly (vinyl butyral) (PVB) that is adhered to two plies of soda lime glass on either side. Although laminated glass has been used in both vehicles and architecture, the design of the windshield and the design of the building element are very different. A windshield is designed so that both glass plies break in the event a passenger is thrown into it in an accident. When both plies break, the windshield becomes softer and is more willing to deform around the person and saves his or her life. If the windshield were to stay hard and rigid then more harm may come to the passenger.

Apart from the accidents, the windshields can be damaged from many sources, such as explosions, sudden impacts, fire, etc. In general, to guard from all these sources a protective film can be applied on the windshields. In this study, two different protective film's performances were evaluated for the case of emergency response vehicles.

Background

Glass technologies have advanced greatly in recent decades. A material that is so brittle and yet so important to our daily lives. Glass has been used as a means of art through glass blowing and staining. It has been used in the advancement of science and technology. It allows us to investigate the objects at a nano-scale level and objects that are far away from the earth (microscopes, telescopes, etc). Glass has become an essential material in our daily lives. For example, today glass allows us to correct our vision with corrective lenses, watch the news on TV, and allows us to enjoy books at night simply by turning on the light. Glass also allows us to let the sun into our homes and see out of our cars.

The usage of the glass in vehicles calls for a major necessity for the advancement of glass technologies. Since glass is a very brittle material which can be easily broken, it requires special technology to increase its strength and ductility. The invention of laminated glass protects us from major injury or even death through lacerations since it breaks into many small pieces rather than a few large ones. Laminated glass will not break if it is hit by a small pebble accidentally tossed by a truck's tire or any other mishap.

Although laminated glass may be very useful for conventional windshields, military and police vehicles need to protect their passengers from more than just small flying debris. The windshields for these vehicles must withstand much higher impact loads and even blast loading. Some inexpensive and innovative materials have been created that can potentially increase the strength of laminated glass windshields. These materials come in the form of a transparent protective film that is applied to the windshield.

In general, these films can protect people inside the vehicles against many different types of hazards such as, UV rays, firearms, hurricane debris, bomb blasts, etc. Many research centers and commercial companies are constantly developing various kinds of protective films. There are a number of different films available in the market from various companies such as, 3M, ShatterGARD, Armorcoat, Apex, ACE Laminates, etc.

In this study, two different films from 3M and ShatterGARD were selected to evaluate the possibility in using on the windshields of an emergency response vehicles. The company 3M has been testing their films against a variety of close range explosive charges. Their protective film has demonstrated the ability to retain shattered glass, and to reduce significantly the potential of glass cut injuries. The other protective film manufactured by ShatterGARD has also tested their products against not only explosions, but a verity of other impact loads. Their film holds the glass pieces together, protecting occupants from injury. They claim to eliminate spalling, which occurs when a bullet hits the glass and becomes a white powder. In this paper, 3M Safety and Security Film and ShatterGARD's VehicleGARD film will be researched and compared to see which would be best suited to increase in the resistance of the emergency response vehicle's windshield.

Objective

The objective of this project is to test the increase in the resistance of the emergency response vehicles' windshields with the use of a protective film. This research will help to ensure the safety of our response teams during emergencies.

Approach

The impact resistance tests of the windshields were carried out in a lab setting and as well on real world vehicles based on a steel ball dropping experiment. The details of this work and results are discussed in the following sections.

EXPERIMENTAL WORK

Sample preparation

The protective film is generally applied on the windshield inside for vehicles. In this study, first, the windshield was scraped with a razor blade to ensure smoothness of the glass. It was then cleaned from dust and debris with simple soapy water. After cleaning and drying the surface, a film piece was then attached. This film piece was cut in such a way that it should be larger than the windshield size. Before attaching the film, the windshield was once again sprayed with soapy water. The adhesive side of the film was sprayed with same soapy water as in the case for the windshield. Finally, the film was then carefully placed on the inside of the windshield with the adhesive side of the film against the cleaned surface of the windshield. The complete sample preparation process is as shown in Fig.1 and Fig.2. The excess film hanging off the edges of the windshield was then cut off with a blade such that the film almost perfectly fit the windshield.

Upon application, air bubbles and excess soapy water may be trapped between the windshield and the protective film. These air bubbles form because the film does not want to conform to the curvature of the windshield. Air bubbles and soapy water can be removed by simply pushing them to the edges with a hard plastic scraper. The scraping was performed from the center of the windshield to the outside edge. Some of the bubbles around the edges needed to be removed. This can be done by simply scoring the film and overlapping the film on itself or by cutting small triangles out of the film. The windshields which are free from air bubbles were then set aside, standing, to cure for two weeks. The application of the film for the field samples was also done in the same manner. However, the curing time was shortened due to direct sunlight applied to the cars in field.

Testing Procedure

Lab testing took place in a controlled environment, with all research staff wearing the proper safety equipment: gloves, eye protection, closed toed footwear. The testing windshield was placed on the floor with the film-covered surface facing down. To replicate the conditions of the windshield installed in a car, foam insulation was used as light cushioning so that the windshield was not sitting solely on the four corners due to its curvature. For the testing, a 2.5 lbs (force) steel ball was dropped from different heights onto the windshield (starting from three feet and up to nine feet). For this purpose, a quad-pod system was designed, as shown in Fig 4 and 5. The steel ball was dropped on two different areas on the windshield, i.e. the center and off center locations.

The height at which the ball was dropped was increased one foot after every drop for center impact testing. On the other hand, the off center testing was performed only one time with the maximum height of center spot testing. Photos were taken of the windshield after every time the ball was dropped and a video was taken for each drop.

RESULTS AND DISCUSSIONS

Importance of adhesion between the windshield and protective film

The two selected films were attached to the windshields for the impact testing. The existence of air bubbles between the film and the windshield means that the film was not touching the windshield (Fig. 6).

Bubbles that formed between the windshield and the film were, at times, difficult to take out. Sometimes large scoring was needed and large triangular pieces of film were removed to get rid of the bubbles under the film. This, however, was also counterintuitive since scoring and removing material also meant that the film would not be reinforcing the windshield to its fullest capacity. An effort was therefore made to score and remove as little material as possible from the film (Fig. 3). It was observed that the thicker the film was, the harder it was to remove the bubbles out from under the film and hence more scoring was needed. The concavity and roundness of the surface seems to be one of the factors contributing to the creation of bubbles. The concavity of the windshield also made it very difficult to remove the bubbles and the excess soapy water out from under the film.

Performance of the films under impact loading

The windshields that were tested in the lab were of the same geometry, support conditions, and collision angel. The experiment was conducted in such a way that the impact was repeated in the same spot. During the tests, neither the 3M film nor the VehicleGARD failed and broke on the inside of the windshield whereas the control windshield did, as shown in Fig. 7. Here the control windshield means which does not have any protective film.

During the testing, the control windshield was very sensitive to the applied impacts. It was observed that, as the ball increased in height, the cracks got bigger and bigger resulting in failure of the windshield. A threshold height for the impact tests was chosen to be 9 feet, where the control windshield completely failed. During the experimental work, 3M films were initially tested. The first 3M film that was tested was not affected until the steel ball dropped from a height of 4 feet. However, the cracks increased in size, but the film did not fail even when the height increased to 9 feet (as shown in Fig. 8). It was observed that when the second 3M was used, the windshield was not affected until the ball was dropped from 6 feet, and did not fail at a height of 9 feet same as the first film. Next, when VehicleGARD films were used, initial cracking on windshield was observed at a height of 5 feet. However, both VehicleGARD films did not fail at a height of 9 feet either (Fig. 9).

The same experiments were also carried out at 14 feet to examine how the films affect the visibility of the driver after impact. It was observed that the VehicleGARD film had the best visibility after impact compared to all the others (Fig. 10).

Thus, it can be observed from the experiments that both protective films can enhance the strength of the windshield after impacts. However, visibility is better when VehicleGARD is used. The experimental results are summarized in Table 1 for lab samples.

The field experiments were carried out on actual cars. The impact testing on the cars was not done in a controlled setting as the lab, but variables were kept as low as possible. Fig. 11 shows the impact testing on a car windshield.

The enhanced windshields did not fail until the steel ball struck 5 times from a height of 10 feet, whereas the control failed immediately after the first strike. This behavior of the enhanced windshields is due to the structural integrity of the glass and the reduction of the crack propagation. Although the films did not prevent the windshields from cracking, they did prevent the object and glass shards from entering the vehicle. It was noticed that the exterior glass had a gash in the film after being struck, however, leaving the film intact in the interior of the car as shown in Fig. 12. This eventually help the driver and passengers from suffering any major injuries. It was observed that the energy required for the complete failure of these testing samples was approximately 210 ft-lbs, this is more than twice of a control sample. The field experiments are summarized in Table 2.

CONCLUSION

In this study, two different protective films were tested for their suitability in emergency response situations. The selected films were from 3M and ShatterGARD. Experiment work was carried out to evaluate the impact resistance and the visibility of the windshields when these films were applied. The employed steel ball dropping test serves as a promising technique for the impact resistance test on windshields. The testing samples were prepared carefully in the lab to represent the actual boundary conditions in the field. Further, the films were also tested on real car windshields to examine the protective films performance. It was observed that both the tested films performed better under the given impacts compared to the control sample. The windshield performance with VehicleGARD was more suitable for visibility after impacts. Since the visibility is being hampered by the scattered cracks, the vehicle became functionally obsolete when the 3M film was used. Therefore, VehicleGARD would be the best suitable film for emergency response vehicles. Further research work is needed to evaluate the significant difference in the material compositions of these two tested films, and the passengers' safety issues when the windshields are damaged.

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FIGURES

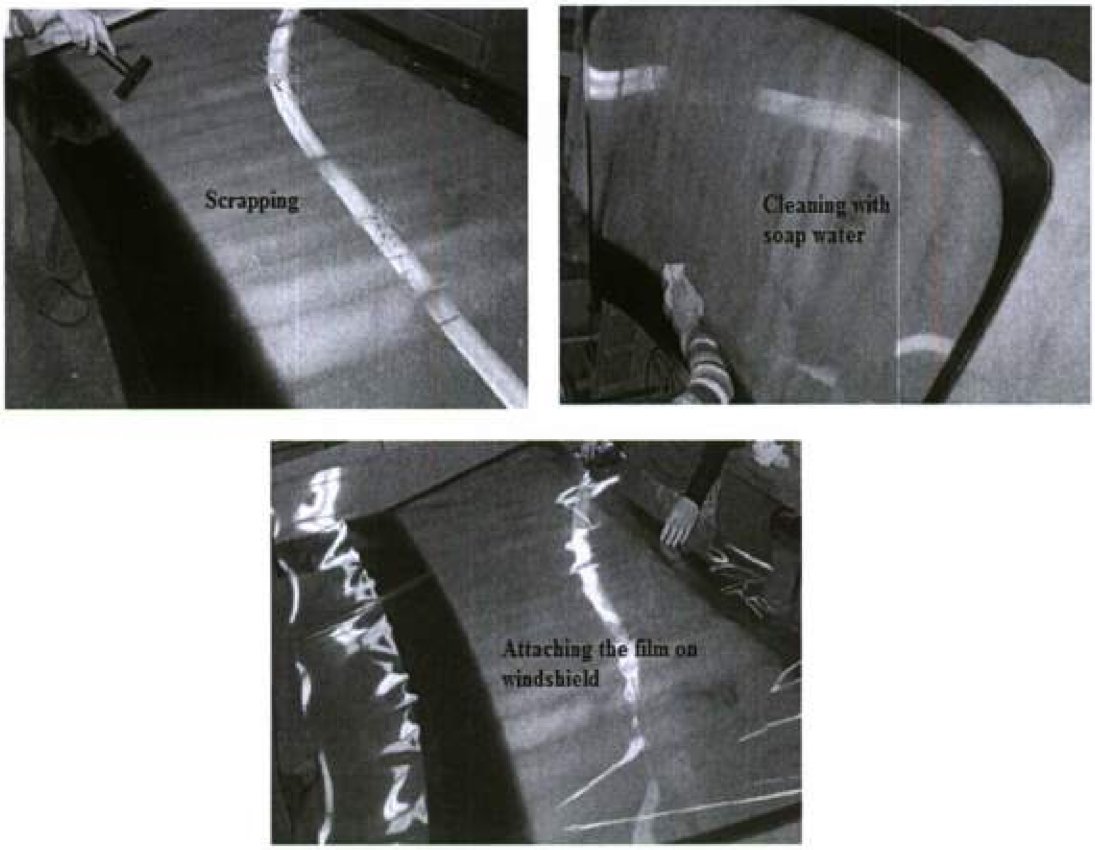

Figure.1 Preparation of the windshield sample for impact testing

Figure 2: Attaching the adhesive side of film to the inside of a windshield

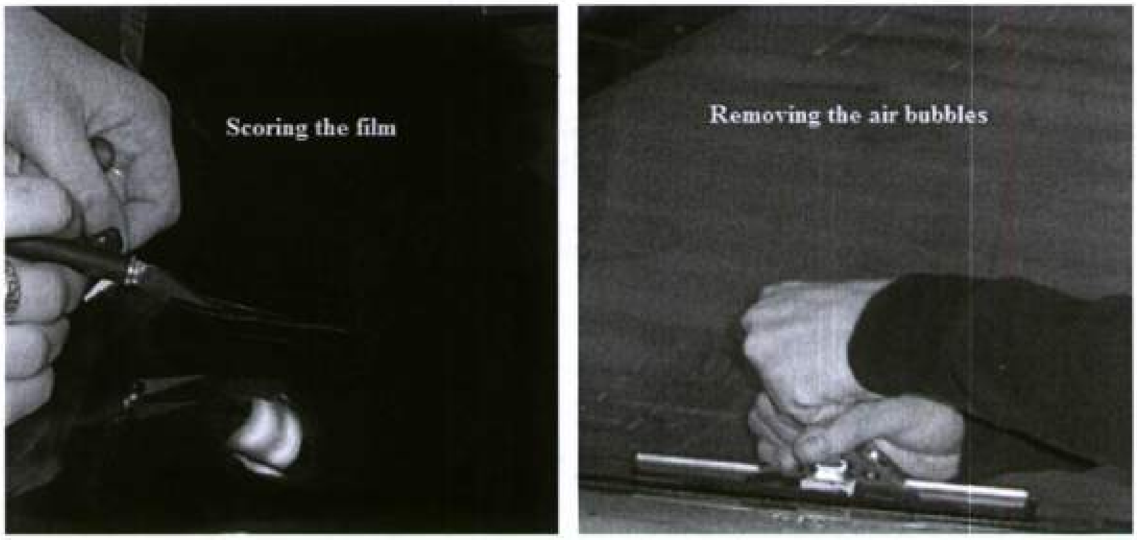

Figure 3: Procedure for air bubble removing

Figure 4: Impact testing setup in the lab

Figure 5: Impact testing setup in the field

Figure 6: The entrapped air bubbles between the film and windshield

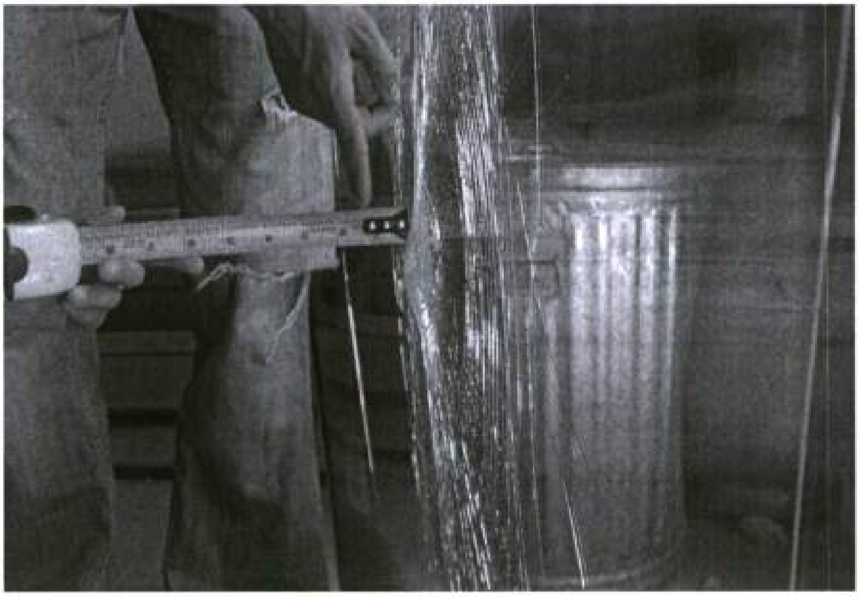

Figure 7: Failure of the control windshield

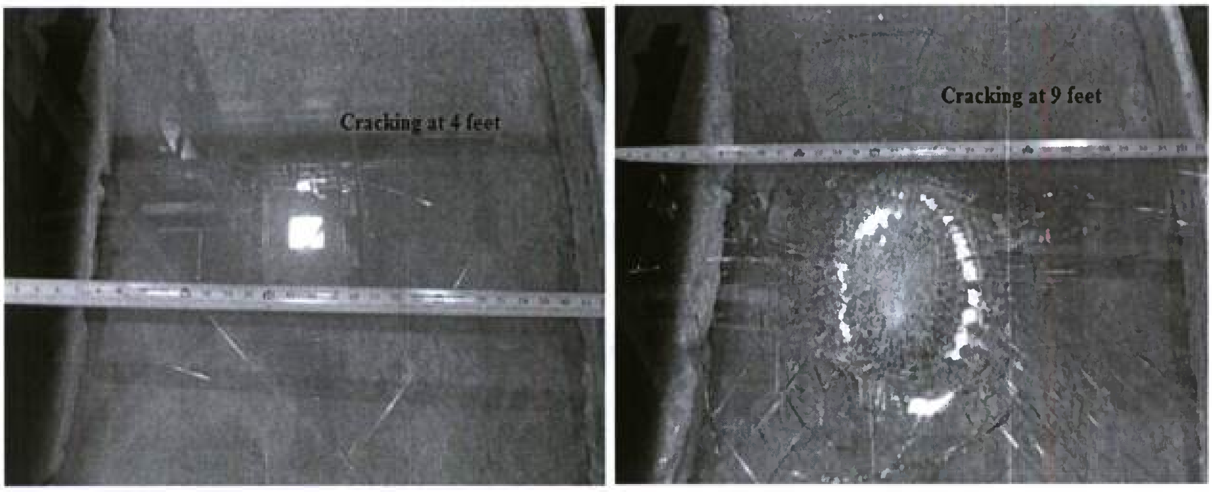

Figure 8: Cracking of windshield when 3M film used

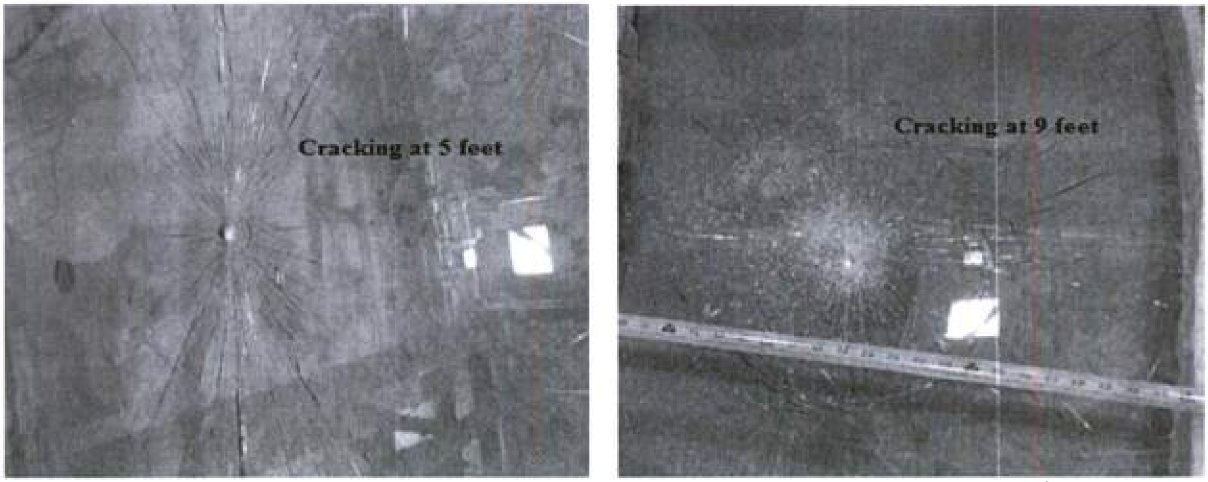

Figure 9: Cracking of windshield when VehicleGARD film used

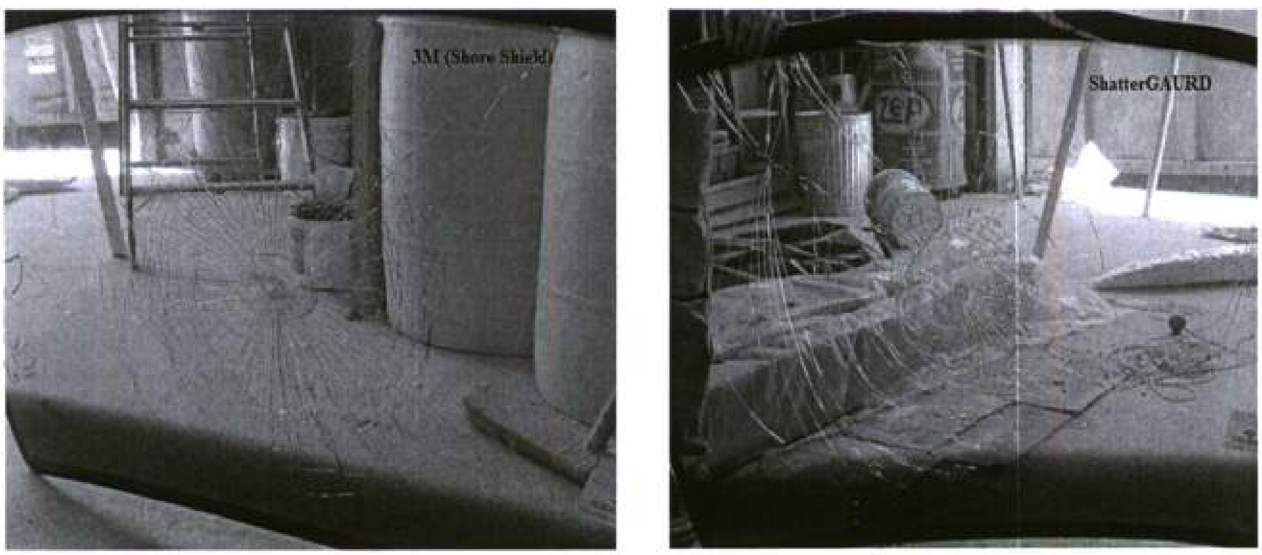

Figure 10: Comparison of the windshields visibility

Figure 11: Steel ball impacting at an angle

Figure 12: Integrity of the glass when field sample tested at 10 feet

TABLES

Table 1: Summary of lab results

Reinforcement Type	Height and Energy						
	3ft	4ft	5ft	6ft	7ft	8ft	9ft
	7.5 ft-lb	10 ft-lb	12.5 ft-lb	15 ft-lb	17.5 ft-lb	20 ft-lb	22.5 ft-lb
Control	No Affect	No Affect	Bottom right corner, crack 2 ft from center	Symmetric crack patter, Big spider crack in the center	large radial crack pattern	Dent forming	Dent increasing, Failure
3M 1	No Affect	Lateral crack down the center	Big spider crack in the center	small radial crack, increasing spider crack	increasing radial cracks, 1 lateral crack 1.5 ft from center	Increasing radial cracks	Increasing radial cracks
3M 1 Off Center							Localized radial cracks, Spider cracking
3M 2	No Affect	No Affect	No Affect	Bottom left corner crack 2ft from center	spider crack and shattering, few radial cracks	Increasing spider cracking, more defined radial cracks	Increasing spider cracking, more defined radial cracks
3M 2 Off Center							Localized radial cracks
VehicleGARD 1	No Affect	No Affect	Spider cracking	Increasing spider cracks, radial cracks forming	Increasing radial cracks, Increasing spider cracks	Increasing radial cracks, Increasing spider cracks	Breaking seems to be localized
VehicleGARD 1 Off Center 1							Deep radial cracks
VehicleGARD 1 Off Center 2							Deep radial cracks
VehicleGARD 2	No Affect	No Affect	Spider cracking	Increase spider crack, radial crack starts to form	More defined radial cracking, increase spider cracking	Large radial cracks, increase spider cracking	Cracking seems to stay localized
VehicleGARD 2 Off Center 1							Large radial and spider cracks
VehicleGARD 2 Off Center 2							Large radial and spider cracks

Table 2: Summary of field results

Test	Vehicle	Angle of Windshield	Height / Energy						
			4 ft / 10 ft-lbs	5 ft / 12.5 ft-lbs	6 ft / 15 ft-lbs	7 ft / 17.5 ft-lbs	8 ft / 20 ft-lbs	9 ft / 22.5 ft-lbs	10 ft / 25 ft-lbs
Control	Ford Crown Victoria LX	64.2°	N/A	No Affect	Dent w/ spider crack	Bigger Dent w/ spider crack	...	...	Smash / Failure
VehicleGARD	Nissan Sentra	66.4°	No Affect	Mark	Mark	Mark	Spider crack w/ dent	Bigger dent and crack	5 times until Failure
3M™	Ford Taurus 1995	61.9°	No Affect	Spider crack	...	...	...	...	5 times until Failure

CHAPTER 8

Project 09 11 P: Building a Decision Support Tool for Studying the Economic Impact of Loss of Passenger Rail Service: A Prototype of New Jersey's Urban Industrial Corridor

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Building a Decision Support Tool for Studying the Economic Impact of Loss of Passenger Rail Service: A Prototype of New Jersey's Urban Industrial Corridor

Project No. 09 11 P

Final Report

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Abstract

We describe options for building economic simulation models that will be used to assess the regional economic impacts of hazards events on a major rail corridor, and the costs and benefits of making the system more capable of withstanding events and rebounding from them.

Foreword

This research was supported through the University Center for disaster Preparedness and Emergency Response (UCDPER) – A collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital – with funds provided by Department of Defense Grant award W81EWF-9223-7361.

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INTRODUCTION

For many decades, while nations in Europe and Asia built high speed rail systems, the United States has built more highways. Only the Amtrak line between Boston and Washington, D.C. qualifies as a major passenger rail line, and it does not qualify as a high speed line by standards in Japan, China and parts of Europe. On April 16, 2009, President Barack Obama released a strategic plan that outlined a vision for high-speed rail in the United States (Federal Railroad Administration 2009). In his State of the Union speech date on January 27, 2010, the President mentioned this project.

> "We can put Americans to work today building the infrastructure of tomorrow. From the first railroads to the Interstate Highway System, our nation has always been built to compete. There's no reason Europe or China should have the fastest trains, or the new factories that manufacture clean energy products. Tomorrow, I'll visit Tampa, Florida, where workers will soon break ground on a new high-speed railroad funded by the Recovery Act. There are projects like that all across this country that will create jobs and help move our nation's goods, services, and information."

The report and presidential announcements identified ten high-speed rail corridors as potential recipients of federal funding. Those lines are: California, Pacific Northwest, South Central, Gulf Coast, Chicago Hub Network, Florida, Southeast, Keystone, Empire, and Northern New England. Since that announcement and subsequent visits by the President to Florida, a number of plans have appeared for an even more ambitious set of high speed rail systems. The US High Speed Rail Association (2011) described a 17,000 mile national high speed rail system built in four phases. The plan calls for linking the largest cities and the most developed corridors first. By 2030 it calls for lines that pass through large rural areas, for example from Salt Lake City through Boise to Seattle. Yet, the Orlando to Tampa, Florida, span—the one visited by

President Obama after a state of the union speech—was stopped by the Governor of Florida and others and now may also not be built. No one can say with certainty how much of the vision will be achieved.

The implementation of this vision has economic, environmental, social, and other benefits. The promise, however, comes with risks. Rail transit systems are vulnerable to the plethora of mechanical and human failures that have caused thousands of rail disasters and near disasters for centuries. In the 21st century, such a system would be vulnerable to a terrorist attack. In many ways rail networks could make more inviting target than do airways because of the very many entry and egress points, a lack of passenger screening, and little security around stopped vessels. Intelligence indicates that the threats to our nation's transit system may be increasing since 9/11 (Transportation Research Board 1997).

A hazardous event can disrupt service, cause injury, damage or loss of life at the site of the incident, and cause cascading effects throughout the transportation network, including delays and economic losses. As dependence on a national rail system increases, so also does the need to provide measures to protect the systems and to respond as effectively as possible to events. In short, carrying out a vision of building a world-class network of high-speed passenger rail corridors will require policy decisions to guide strategic investments to effectively manage security risks so that passengers can use these upgraded reliable systems in the safest possible circumstances with risks and vulnerabilities and consequences minimized.

New approaches to incident management and counterterrorism, including both human and technological processes, will become important components of transit systems. It will therefore be increasingly important to assess how these solutions impact whole systems (Kappia 2009). Although government and academic researchers have focused attention on prevention and response at some of the key nodes along the Northeast Corridor and have evaluated specific technologies (Transportation Research Board 2004), there has been limited research looking at the Corridor in large segments, let alone in its entirety, to determine ways to evaluate system resilience and response strategies so that cost-effective solutions can be discovered to reduce potential negative impacts.

If, in fact, we do create high -speed corridors, it is essential that we are able to protect the entire system and provide resilient paths around segments that are already regularly blocked or that may be likely to become blocked in the future. This is truly an instance where a weak link, in this case a vulnerable segment, can undermine the entire system: even one vulnerable entry point (for example, where commuter trains pull into the stations) can cause systemwide failure.

A logical place to test security-related options is the Northeast Corridor (NEC) that runs over 450 miles from Washington to Boston. The NEC is the most heavily travelled by ridership and service frequency. For example, more than 1,600 people per minute move through New York's Penn Station during rush hour (Bushue, 2006).

The purpose of this report is to describe a prototype economic model that would allow planners to assess economic damage caused by system failures and the benefits and costs of investments in the system to reduce impacts. Before describing the economic modeling options, it is important the models are viewed in context. We view rail security as a classical problem in risk analysis. In order to plan strategically, decision makers should have scientifically grounded answers to the four basic questions in risk analysis (Kaplan, Garrick 1981, Haimes 2009, Greenberg 2009).

1. What events can occur?
2. What is the likelihood of those events occurring?
3. What are the consequences of those events?

4. What investments should be made to prevent intolerable consequences and enable ecosystems to recover as quickly as possible?

Answering the first two questions in the context of rail security implies understanding vulnerability and threat, using pre-emptive intelligence and monitoring system state. Once risk analysts answer the first two of the four questions, then the challenge is to understand the consequences and to eliminate or reduce them.

The economic model we are building has the capacity to estimate the regional economic consequences of severe local hazard events and follow the ripples of the events through the economy. Furthermore, the primary model we selected as our prototype has the capacity to adjust for changes in the key economic sectors impacted by the hazard event. As described in more detail below this is a critical attribute. It also has the capacity to assess the economic consequences of risk management options that could eliminate or reduce the consequences.

Literature and Key Definitions

We briefly discuss consider key elements of the terrorism and economic–impact literatures.

Terrorism and Railroads

There is a large literature on rail system problems and reliability. The Office of Safety Analysis of the U.S. Federal Railroad Administration (FRA) maintains a web-list list of every reported accident since January 1975. The searchable file includes tens of thousands of accidents, and it is classified into broad categories of collisions, derailments, and other events: it is further subdivided into train accidents, high-rail grade crossing, and other incidents. The database includes about 500 different types of events, such as worn rail and defective and missing crossties. The most frequent are missing and broken crossties, switches, rails, fasteners, and other elements of the tracks and rail bed. The list also shows accidents related to workers failures, vandalism, employees falling asleep, and other human factors. The number of reported events is also accompanied by a list of direct reportable economic damage. Hence, an analyst can see the direct economic impacts of washouts of tracks and rail beds, buckled and misaligned tracks, and failure to comply with signals.

The searchable database can very quickly produce a list of incidents by state for a variety of incident outcomes. For example, it reports that there were 71 rail-related deaths in New Jersey in 2001 and that the number gradually declined to 40 in 2009. These data, in turn, can be divided into categories of who was killed (workers, trespassers, etc.). The FRA also publishes an annual report that provides raw data and rates and discusses federal government efforts to reduce the rates.

For those looking for less-imposing documents, Semmens (1994) and Kichenside (1997) have written books that describe the worst train disasters. For those with less patience, the BBC (2007) broadcasted a story about the world's 17 worst rail disasters from 1981 through 2007. The popular literature shows that almost all were in Asia and Africa and includes a range of causes from brake failures, collisions and derailments to gas explosions beneath two trains to cyclones toppling a train into a river. Some special studies have been done of terrorist-related events. Jenkins, Butterworth, and Clair (2010) examined the failed attempt to derail the French high - speed train in 1995, and they also examined 181 rail sabotage attempts. This interesting report provides insights into what terrorists might do.

Economic Impact

By economic impact we mean local, regional, national and international economic impacts that are direct, indirect and induced. There is no denying that a train station and area around it can be destroyed by bombs, tornadoes, and other natural and human-initiated events. Typically estimates of the direct costs of event damage are available within a week to two weeks of an incident and are widely featured in the media and discussed by elected officials. They include human and animal deaths and injuries, severe and moderate damage to structures and their contents, vehicles, infrastructure, utilities and their delivery systems, landscapes and agriculture, as well as cleanup and response costs in these local areas (Committee 1999, Mileti 1999, Heinz Center 2000). People in cutoff areas may not be able to go to work and school, and they may need to leave their homes. Physically handicapped may need assistance (Berube, Katz 2005). The literature has described the difficulties of accurately estimating local impacts (Committee 1999). Estimating local impacts is essential and difficult to estimate but only the start of the impact analysis.

County, state, and regional impacts cannot be ignored, especially in the case of an event that disrupts a rail-corridor event (Committee 1999, Rose Liao 2005, Greenberg et al. 2007, Rose 2004). A rail-related event doubtlessly leads to traffic congestion due to overburdened bridges, roads, and other impacts on parts of the transportation network. Some people may not be able to get to work, and some freight may not be delivered or be shifted to other modes. All of these will lead to reduced sales and as the impact spreads across the landscape. Indirect effects are due to lost sales as the impacts spread. These nonlocal impacts include declines in sales, wages, and profits due to loss of function in the areas impacted. Some affected households and businesses may be located many miles away from the event locale and, especially in the case of a rail corridor, can be quite extensive. These losses are attributable to reduced supplies and demand from the affected areas, and slowdowns in transporting products and people.

Induced effects come about when workers lose pay because of the direct and indirect effects. They buy less, especially of products that they do not immediately need. Government feels all these impacts because tax collections drop because of business losses and consequent reductions in worker earnings.

In the short run, the local area may benefit as insurance companies, not-for-profits, and government from outside of the state or region expend funds in the directly impacted area to restore it. Yet, in the worst case for the region, investors could lose confidence in the regions and withdraw their investments, leading to relocation of economic activity and jobs. Overall, estimating the spatial spread of impacts is an important objective of economic impact analysis.

Measuring the temporal spread of impacts is critical. The actual life cycle of a serious event is much longer than the period of active humanitarian, political and economic focus on it. For example, a derailment in which people are injured and killed may stop train traffic, and if the railroad administrators believe it is terrorist-related, then all traffic may stop. But repairs to infrastructure may be relatively inexpensive and quick to repair. In contrast, a bridge or tunnel collapse in an area with no alternative routes could seriously handicap and area economically and thereby yield effects that linger for an extended period. It is these economic vulnerabilities that could undermine a regional economy. It is in such susceptible regions that investors are most likely to hesitate about spending and perhaps choose not to. Decision makers could be misled into making unwise decisions about investments, if they are aware only of the short-term economic costs and benefits, when instead the bulk of the costs are incurred in the short term and the benefits accrue over a much longer period of time, or vice versa.

When engineered systems like rail lines, water pipelines, gas lines, power grids, dams, bridges and others fail, Greenberg et al. (2007) note that five managerial failures consistently raised:

1. to protect engineered systems,
2. to implement land-use planning and design tools to reduce hazards,
3. to provide resources that build resiliency into systems and mitigate against economically disastrous outcomes,
4. to adequately considered and planned for evacuation/relocation, and
5. to understand the implications of different levels and staging of restoration.

All five failures are relevant to rail corridors, but numbers 1 and 3 are of particular interest for this study because there draw attention to policy-significant tradeoff issues. For example, with respect to Hurricane Katrina, if the Corps of Engineers had spent more to bolster New Orleans's levees, would it have made much of a difference? What would they have needed to build the structures to cope with the hurricane? Yet, suppose one of those other locations suffered a serious event and the money it would have received to protect the location had gone to the New Orleans levees? Second guessing always follows events, however, but it would be helpful to at least have proactive analyses that could place costs in the context of potential consequences for decision makers that must make the tradeoffs. It would also be helpful to know what the cost would have been to have an evacuation plan that included functioning buses and other capabilities.

Data and Methods

Study Area

The study area for this pilot project is the State of New Jersey. In 2010, New Jersey has a population of 8.7 million spread over 7,417 square miles, and the highest population density of any U.S. state, more than 1,100 people per square mile. That population is spread out over 566 municipal governments with no one of them having more than 280,000 residents. The highest density of people and commercial activity is along the corridor between New York City in the northeast and Philadelphia in the west central part of the state. The central tread tying together this core of dense population is the Northeast Corridor Line.

In 1960, New Jersey was one of seven states with over 36 percent of non-agricultural jobs in manufacturing. In 1969, manufacturing accounted for 31 percent of non-agricultural jobs in the state. The vast majority of these jobs were concentrated along this same corridor. But the state lost 58 percent of its manufacturing jobs between 1969 and 2004. Manufacturing now accounts for less than 9 percent of jobs in the state. Only New York State registered a larger relative decrease (Braham, Anderson, 2001).

In New Jersey, more people now live and work in the suburbs and not along the corridor. Out of a total of 8.7 million in the year 2010, over 1.0 million New Jersey residents live in a municipality that abuts this main rail transit corridor and 3.4 million live within 10 miles of it. Another important demographic characteristic is it is important to note that over 25% of the state population primarily speaks a language other than English at home, a notably larger proportion than the US population as a whole. A total of 122,000 people who do not speak English at home live in a town that borders the corridor, and 290,000 live within 10 miles. This has implications in the event of a rail corridor or other mast transit hazard event because this population is disproportionately dependent on mass transit, which implies greater economic consequences for them.

While we will measure impacts for New Jersey as a whole in this prototype, we will focus the study on a segment of the Northeast Corridor rail line that is located along the main line from south to north beginning at the Elizabeth, New Jersey, station through to the southern terminus of Penn Station in New York. This highly traveled and highly trafficked segment is 15.4 miles long and runs through the most urbanized region in the United States, with two major bridges and an underground portion that tunnels under the Hudson River and into Manhattan. The line is used by Amtrak and New Jersey Transit for passenger service and by freight rail carriers. It operates by electric power with diesel available as a back-up. Further, the nodes (stations) along this system are intersection points for connecting transit lines operated by New Jersey Transit in New Jersey and by New York MTA trains at Penn Station, and its busy stations are filled with thousands of passengers daily who meet other surface transportation vehicles such as buses and taxis. The prototype economic model will examine the impacts in the counties that constitute this region (Hudson, Essex, and Union) and New Jersey as a whole.

Because this segment has examples of most of the infrastructure types that can be found on this or any other corridor, and its nodes are connection points for numerous linking systems, it provides a rich laboratory to build and test an economic model that will be useful outside the immediate study area. The modeling is readily expandable up and down the corridor to other stations, and is only constrained by availability of data to add depth to the system data base.

Methods of Analysis: Options

The prototype that we have been building for New Jersey will be integrated into a more comprehensive model that will include all of New Jersey and parts of New York State that border on New Jersey and are tied to it through the rail corridor. Because this is a prototype, the example we present later in this report is not based on any single event because we do not have a final set of hazard events. Indeed, the UCDPER team is, in fact, working a set of events that will be tested with the final economic model that is built. Before describing the primary model we picked, we summarize the major options.

Input-output (I-O) models are an obvious choice (Lahr, Stevens 2002, Leontief 1970, Miller, Blair 2009). They are built from data that describe the interactions of all sectors of the economy. For example, if one security option was to add more than a thousand concrete barriers, the I-O model would tell us what resources would be required by each business sector from every other sector, such as steel, concrete, wood, and many others. The authors have an I-O model with about 500 economic sectors. Our I-O model provides estimates of business transactions, jobs, earnings, gross state product, and federal, state and local taxes.

I-O models have advantages and disadvantages. One advantage is that the transactions in an I-O table are relatively easy to understand. A second advantage in the case of our model is substantial detail by business sector. The major limitations are that the data base used in the US I-O models is only updated every five years, and the model provides a single impact estimate rather than indicating the impacts by year of another convenient time period. Inoperability input-output models (IIM) overcome the fixed economy assumption by providing estimates of the change in the most impacted sectors and building it into their estimates (Santos, Haimes 2004, Haimes et al. 2005a,b)

Econometric time-series models are a second standard economic-estimating package (Conway 2001). Our econometric model for New Jersey has well over 200 equations that link changes in the national and state economies based on 25 to 30 years of data. National estimates of jobs, wages, and prices drive the state estimates. The major advantages of econometric time-series models are that they are grounded in economic trends and provide estimates on an annual or other time basis. Unfortunately, if the economy is rapidly changing the trends may lead to forecasts in the wrong direction. A second disadvantage is that compared to I-O models, econometric models lack the business sector detail. We plant on building an econometric model for the larger project in order to check the results of the primary model.

Regional economic modeling, Inc. (REMI) is an econometric time-series model that includes relationships among jobs, income, wages, prices and populations. It adds equations for interregional trade by industry, migration of labor and households for each region. Accordingly, REMI, it can be a strong tool to use for projects that impact multiple regions (REMI 1997, Treyz 1993, Greenberg et al. 1999), and are especially valuable when of econometric time-series model is not readily available. Since we have such a time-series model for the region of focus at the ready, a REMI model is not needed for this application.

Computable general equilibrium (CGE) models typically begin with an I-O model or slightly modified version of one. The analyst then assumes optimal economic decisions by producers and consumers in response to markets and prices subject to capital, resource, and labor constraints (Rose, Liao 2005, Rose, Lim 2002, Rose 2004). A disadvantage of the CGE is their tendency to reply upon non-regional data for estimating some price elasticities. After deliberation and assuring that key elasticities in the study could rely on regional data, we selected CGE as our model of choice for this exercise.

Applications of CGE Models and Application to Transportation

Because of their versatility, CGE models are a logical choice in many policy applications. Transportation applications make sense because an outage of a single transportation segment has system-wide effects. These effects can be observed on individual households and firms as well as on more aggregate levels—consumers and industries. In many cases deleterious transportation changes can disrupt production both at the firm and sector levels. Estimating the short-, medium, and long-term effects of outages of lifelines like a commuter rail system has important implications. Model estimates can be used to determine who, if anyone, should be compensated and by how much. It can also be used to identify the potential costs of recovering from a disaster. But more importantly CGE's may be used in advance of a potential threat to identify reasonable limits of efforts to mitigate a disaster or at least to improve an economy's resilience in the wake of a disaster.

An ever broadening CGE model literature shows models to assess the effect of disasters on economies. Lee and Kim (2005) point out how well suited spatio-temporal models are for analyzing network losses due to natural disasters. They apply a gravity-type model to a simple CGE production framework to identify the sectoral distribution of potential losses to an economy over time. Similarly, Nojima and Sugito (2000) use simulation and incremental assignment methods to evaluate post-disaster performance of transportation network systems, identifying vulnerable origin-destination pairs within transportation networks. Sohn et al. (2003) assume final demand declines and rises in transport costs to estimate the economic impact of Midwest U.S. floods on a transportation network. In particular they scrutinize intra-zonal flow of commodities, the modal share of traffic, and the average travel distance on the network to determine the transportation network resiliency of economic sectors and further identify critical segments (weakest links) on the transportation network.

Chang and Nojima (1997) identify two post-disaster measures of highway system performance: total length of highway open and total connected length of highway open. With these measures, they attempt to estimate both traffic volumes after the 1995 Kobe, Japan earthquake and economic impacts of the consequent reductions in transportation system throughput. In a subsequent paper, Chang and Nojima (1998) applied these measures to compare events. They used measures of the system's pre-disaster performance to estimate post-disaster consequences; thereby, they could compare performances of transportation networks across earthquake disasters and assessed economic activity in relation to transportation volumes. Later, Chang and Nojima (1999) assessed aggregate transportation system performance, including both highway and rail networks, to measure economic effects subsequent an earthquake disaster in Kobe, Japan. They used these performance measures to determine the ability of port facilities to re-establish services, and the short- and long-term impacts of the disaster on the local, national, and regional economies. They conducted comparative analyses of system performances in Kobe (Japan), Loma Prieta (California), and Northridge (California), and demonstrated that comparisons and assessments may be made in levels of damage, disruption, and restoration timeframes across systems. Chang (2000) quantifies the lasting economic impacts on Kobe's container shipping industry, and the long-term economic losses that resulted after the earthquake. She demonstrates that during the two-year restoration period subsequent the earthquake disaster, the Port of Kobe lost 20-30 percent of its total volume container cargo to regional competitors (such as Pusan, Korea; Hong Kong; and Singapore).

Rose et al. (1997) examined the impact of an earthquake disaster on electricity lifeline disruptions. They developed an approach to estimate economic losses by sector through the use of economic model simulations of production losses. Van der Veen et al. (2003) looked at the total structural economic effects of a flood disaster on households and government, quantifying production interruption, substitution effects, and both direct and multiplier effects. They identified three scenarios with varying effects on changes in final demand – ranging from none to lasting structural changes in the economy.

Interestingly, during the course of the literature search, no article was uncovered that considered a disaster that focused on a single, specific segment of a commuter rail network and its subsequent effect on the local economy. Still, the existing literature does provide some guidance. Sohn et al.'s (2003) focus on the relationship between final demand and transportation costs is quite instructive, for example. In the case of discontinued transit segment, it suggests closer examination of fuel consumption (the change in final demand) due to a change in commute mode. But what is the economic loss? Losses are quite evident in the various works of Chang and Nojima. In the case of a commuter changes, transportation costs are not just the change in the costs of transportation service itself, but also the opportunity costs of congestion time. This raises the question of how such costs are embedded in measureable household and business transactions so that they can be measured via conventional economic models. The answer derives from a decision made by the commuting worker and comes down to an answer to the following question. Does the worker decide to keep pre-disaster work hours and let the added commute time eat into time that would otherwise be committed to leisure, or does the worker instead opt to reduce his/her work hours at least somewhat and thereby reduce her/his workplace productivity?

Given these two building blocks—the economic impact of fuel price rises and the economic impact of temporary declines in labor productivity—we started to parameterize the model. We characterized the short-, medium-, and long-term effects of service disruptions to the rail network by first focusing on the immediate- and long-term effects of gasoline consumption due to price changes. We then empirically examined the relationship between the labor compensation-to-GDP ratio on GDP growth, assuming that the ratio would rise in the wake of the disaster to be modeled. With these two tools in hand, along with some concept of the size of the affected labor force and the duration that the rail segment was disabled, we could reasonably use the prototype to predict the economic impact of rail system disruption.

Effects of Transportation Infrastructure on Productivity

Estimating the short-, medium, and long-term effects of lifeline outages – such as a commuter rail system – has important implications in determining economic and social losses. Munnell (1992), by comparing output elasticities of public capital across several studies, found that as the level of aggregation narrows (from nation to state to metropolis), the [positive] productivity impact of public infrastructure becomes smaller—even as public infrastructure continues to demonstrate a significant and positive effect on productivity. Jara-Díaz (1986) described the relationship between individuals' benefits and transportation processes, showing that transportation surplus (i.e. lack of congestion) had positive economic effects. Fernald (1999) examined the relationship between road network capacity and productivity performance, looking at trends between 1953 and 1989, and addressing the endogenous and spurious relationships between transportation and productivity. He found that an increase in productivity nationwide resulted from the "technology shock" of government-provided roads. Further, Fernald observed that only after the completion of the highway system in 1973 did congestion become empirically important to productivity. Congestion has negative effects on productivity—with those industries with greater vehicle intensities experiencing larger productivity slowdowns due to congestion.

Boarnet (1998) explored the locational effects of changes in a road system, finding that public capital investment in one district (city, county, state, etc.) attracted additional resources which seek to benefit from the increased productive capacity, which leads to negative spillovers in adjacent or comparable districts. Increased output and productivity was observed in districts with increased capital investment, thereby drawing a connection between the productive capacity of a transportation system and output. Baird (2005) discussed the productivity of transportation infrastructure by looking at contrasting theories on spillover effects: positive spillover effects theory posits that a transportation network will be more productive if it is part of larger transportation network, and negative spillover effects theory posits that investments in public infrastructure in one jurisdiction result in losses of productivity in neighboring jurisdictions—notably both theories observe a clear link between productivity and transport systems. With the movement of goods and people as the primary factor in defining mobility, impediments to this movement (i.e. congestion) compromise productivity.

Van der Veen (2003) identified accounting frameworks (input-output analysis and computable general equilibrium models) to compute costs of incidents. She also lists change in consumer surplus (welfare economics) and recovery processes (macro-economics) as ways to measure the social and economic costs of incidents. Several researchers have devised theoretical frameworks for building multi-sector computational general equilibrium (CGE) models for transportation economics (Bröcker, Mercenier 2010, Conrad 1997) in order to measure the economic impacts of changes in capital and transportation flows.

Rose and Liao (2003) used CGE analysis to determine individual and producer responses to changes in market-prices that result from disaster; their approach assessed the economic impacts of a disruption in a life-line service, i.e. water supply, to a region. Their analysis compared results from both I-O and CGE models, including CGE indicators of consumer income, spending, and substitution considerations upon market behavior. Kim et al. (2002) used an input-output model to estimate flows of goods after a natural disaster, integrating an econometric model with interregional commodity flow and transportation network models; the integrated model simultaneously acknowledged highway and railway networks, allocating flows on the entire transportation network according to elasticities of substitution. Further, the model developed by Kim et al. used parameters to determine the performance, costs, and flows for links – or segments – of the transportation network, thereby allowing for the prioritization of critical segments.

Thissen (2003) suggested a spatial applied general equilibrium (SAGE) model to consider indirect economic effects of a terrorist attack on a transportation network. Accounting for changes in transportation costs, demand, and production, Thissen's model assesses the effects of changes of transport costs on the labor market, and the subsequent inter-regional distributive and national generative effects.

While the existing literature shows a growing use of integrated analytical models to capture the economic costs with respect to changes in transportation infrastructures, as noted above, it does not assess the effects upon an entire transportation network that result from a disruption to a specific link—namely the localized effects of increased road congestion subsequent disruption of rail service. As Fernald (1999) and Baird (2005) showed, congestion has negative effects on productivity. Using an integrated network model and CGE analysis, we will show that there are significant implications of time-delays due to congestion, and that increased levels of traffic on local road networks result from substitution of auto for rail transport. As Fernald indicates, as road networks become complete in their construction, congestion increases – as individuals have few or no alternative transportation modes or routes available other than the existing local road system. As road systems reach capacity and become saturated, output is reduced. Further, the model shows that the increases in the consumption of road transport results in increases in fuel costs and time-delays, which together have negative effects on productivity.

Gauging the Effect of Changes in Gasoline Consumption

We examined the temporal relationship between motor gas prices and motor gas consumption in both directions: prices increases affecting consumption and consumption affecting prices. The purpose of this was to determine how that diversion from rail transit would inevitably hit New Jersey's road system, either through increased bus service or by a return to the use of autos. Either way, the loss of rail service would increase the consumption of petroleum-based fuels, both gasoline and diesel fuel. Subsequently, the rise in fuel consumption should cause fuel prices to rise, at least in the very short run. In the long run, however, worldwide effects of OPEC-cartel oil prices would override any short-term effects that a localized change in consumption would have on local oil prices. From a theoretical perspective then, any short-run rise in price should feedback to cause fuel consumption to decline at least in the long run, as commuters adapt, opting either to find another job closer to home, carpool, or consumption and prices typically should converge to something close to their long-run equilibriums.

To estimate the elasticity of fuel consumption to its price, we used data for 1978 through 2009 from the Energy Information Administration (EIA) of the U.S. Department of Energy. Equation (1) shows the results of a simple bivariate time-series regression that was derived.

$$(1)\quad c = 3340062 \cdot p^{-0.0184} \cdot p_{t-1}^{-0.0149}$$

where

p = Average U.S. retail motor gasoline prices (all grades), dollar per gallon,

c = Total U.S. consumption of finished motor gasoline (thousands of barrels), and

t = time in years.

A Prais-Winsten and Cochrane-Orcutt generalized least squares regression approach was employed, which corrects for any serially correlated error. The effect of price on demand shows that a 1.0 percent rise in the price of gasoline results in a decline of gasoline consumption of

0.018 percent in the short run. Interestingly longer-term effects (a second year only) almost double the small short-term effect. But no more consumption affects attenuate beyond the second year after a change in fuel price. That is all further effects tested were undetectably different from the null and are not reported here. We also attempted to derive an equation about the relationship of demand on price. Logically, greater demand should drive up price, but we could not derive a stable equation, at least partly, we think, because of the aforementioned overarching role of OPEC on local prices.

In summary, as transport options become reduced and transit commuters resort to roads for travel, the expected demand for motor gasoline that would result would cause a temporary spike in gas prices. The spike in prices should cause gas consumption to moderate in the short-term, but return to usual gasoline demand expectations in the long run. Regardless, long-run changes in petroleum consumption due to congestion-derived price changes alone are expected to be small.

Congestion Effects: A Question of Commuter Productivity

As mentioned previously, required diversions from rail transit would undoubtedly increase usage of New Jersey's road infrastructure, causing congestion on freeways, motorways, arterials, and surface streets between the homes and workplaces of former rail commuters. We would expect that all commuters' travel times, not just those of rail commuters, would rise due to the increased demand on the roadway network. This is because traffic slows and accident frequencies rise as roads exceed their capacities. In the short-run, this increase in travel time would leave commuters three possible options: work from home, reduce their leisure time, or reduce work hours. In the longer run, however, they can change jobs.

While flex-place is a policy in which many firms participate when emergencies arise, the policy is generally temporary. An exception can be the set of workers who engage in project-based work activities that are not heavily team-oriented. For the most part, however, heightened congestion is likely to have a negative impact on productivity; either individuals are likely to become increasingly fatigued at their workplace due to declines in leisure activities or they wind up spending less time in the workplace, essentially counting time in transit as work hours. To measure the effects of such productivity decline, we analyzed the relationship between gross domestic product (GDP) and labor compensation in New Jersey's industries. We used data from the U.S. Bureau of Economic Analysis of the Department of Commerce and examined the effect of labor's share of GDP on the GDP yield in New Jersey across 69 industries from 1997 to 2008.[2]

To examine the relationship, we used a random-effects panel regression approach with New Jersey's industries as panel variables. As with our examination of fuel consumption, we examined both short- and intermediate-term effects, but this time GDP is the focus of the unexpected changes in transportation options and patterns (see Equation 2).

$$(2)\; Y_t^i = 0.987084\, \left(Y_{t-1}^i\right)^{1.0058} \left(w_t^i / Y_t^i\right)^{-0.8332}$$

where Y_t^i is the GDP (in $ millions) of industry *i* in year *t* and w_t^i is the total industry compensation for industry *i* in year *t*.

The implication of Equation (2) is that for each percentage rise in the compensation /GDP ratio, GDP falls almost equivalently—by 0.833 percent. Moreover, as no other lagged versions of the compensation/GDP ratio were able to enter the equation in a statistically significant fashion, the fall is permanent unless the compensation/GDP ratio itself rebounds. In the case of our simulations, the ratio rebounds only when the rail lines are back in operation and former rail commuters return to them.

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[2] The US BEA data set for GDP by state identifies 81 industries, of which 69 are used in this model due to federal data disclosure issues.

Disaster Scenarios

To investigate the possible economic impacts of a catastrophe occurring to rail transit on the economy of the State of New Jersey, we generated to basic scenarios. The first is the larger of the two and emanates from the tunnel into New York City from which full recovery takes about three years. The second is at Newark's Penn Station from which recovery takes about a year. Please note that these are hypothetical to illustrate the model.

Scenario 1: In this scenario, a disaster occurs from Newark Penn Station to New York's Penn Station. All traffic that uses that section of track, including the North River Tunnels, is discontinued for three years. Post-disaster, all traffic from the south must terminate in Elizabeth, New Jersey, and only that rolling stock that did not enter the North River Tunnels during the disaster can be used. Highway bridges, road tunnels, PATH trains, buses, and ferry systems into New York City operate without disruption. NJ Transit provides buses and shuttle service from Elizabeth to a nearby PATH station and to the Port Authority's bus terminal to help the usual 80,000 passengers daily to get into New York City.

Scenario 2: In this case, the disaster is much more localized. It is focused on Newark's Penn Station and some structures in the immediate neighborhood. Track and a temporary station are quickly built and are functional about a year later. Still, direct rail traffic into New York City from areas from areas south of Elizabeth is disabled. So all of the alternative transportation strategies needed for Scenario 1 must be employed, but for a single year only.

On the order of about 80,000-100,000 passengers use alternative means of getting to work and otherwise visiting New York City and the Meadowlands arenas—the latter are no longer accessible via Secaucus Station. In the wake of the disasters, workplaces generally accommodate their workers' commute issues, but at the expense of the firms' profit lines. The types of companies affected are those that pay their employees enough to enable the longer, more-expensive rail commutes. In Essex and Hudson counties—the core work areas in New Jersey that would be affected by the altered commuting patterns—jobs of this sort are concentrated in producer services, which are described best via the following seven industry titles: Security and commodity brokerage; Insurance carriers; Computer and data processing services; Advertising; Legal services; Engineering, architectural, and surveying services; and Accounting, auditing, and bookkeeping, and related services. Almost 60,000 people with an average pay of about $115,000 are presently employed in these Hudson-Essex industries, and they account for about 7.6 percent of the 790,000 jobs in the two counties. This set of industries in these two counties only produces on the order of $15.3 billion (3.1 percent) of the state's total $478.4 billion in GDP annually. Moreover, Essex and Hudson counties maintain roughly 21.9 percent of the state's total payroll for these industries but only about 17.1 percent of the state's payroll across all industries. So the region that we have targeted to be most affected by a scenario for a change in transportation patterns is particularly well endowed with producer services, the workers of which are likely to have their commutes altered most by the hazard scenarios.

We base our analysis of the productivity consequences of the longer commutes that result from the disaster on state-based GDP by focusing on the aforementioned producer-service industries. Applying constraints to this small set of industries simplifies simulations, a necessity since the modeling process is complex. Still, the industries represent very well the broader group of sectors likely to be affected by the sort of disasters that are the focus of the study.

Economic Impacts of Scenario 1

In this case, we did not perturb the demand for gasoline that would result through any heightened increase in the use of road-based transportation. The only long-run effect of fuel usage is that real prices of gasoline would rise very modestly. That is, our time-series analysis of the effect of fuel prices on fuel consumption suggests that the rapid rise in gasoline consumption would relax downward to long-run levels. This likely would occur as households in the long run engage in measures that improve the efficiency of gasoline use: moves closer to workplaces, changes to workplaces that are closer to home, use of alternative transportation (walking, bicycle, bus, carpooling), and the use of more fuel-efficient autos.

We did, however, disturb production levels of key producer services in Essex and Hudson counties. We did this by assuming workers reduced their time at work by 5.6 percent. The 5.6 percent is obtained by assuming workers on average subtract the 30 minutes of added daily commute from a typical 9 hour work day. Given that a 1 percent rise in compensation's share of value added decreases GDP on average by 0.833 percent, a 5.2 percent rise is expected to cause an annual GDP fall on the order of 4.33 percent in the case of severe Scenario 1. Again we limited these effects to the selected set of producer services in Hudson and Essex County. We assumed all area workers in the industries were equally affected.

The 4.33 percent fall in GDP in selected producer services in Essex and Hudson counties combined would hit the producer service sector rather hard. The 5.6 percent change in the compensation/GDP ratio alone implies a loss of nearly 10 percent of the industry's profits. According to Table 1, which presents losses for the peak year of loss only, the Producer service sector would lose about 10 percent of its jobs (5,708 to be precise) in the long run. That is these annual losses would be observed in perpetuity. Presumably the losses are incurred by specific producer service firms, which are already suffering from low profit margins and where workers have comparatively low rates of pay, e.g., engineering, architectural, and surveying services and securities and commodities brokers. About an equal number of jobs (another 5,800 jobs) would be lost in industries other than producer services. Perhaps more devastating to the state, given present circumstances, is that just over $90 million in state and local tax revenues would be lost as a result.

The case of federal tax revenues is radically different from that of state and local tax revenues in the instance of this scenario. They may be lost in the first year, but as the businesses that are losing business realize the durability of the congestion effects caused by the loss of the rail line, they will exit New Jersey causing the annual losses shown in Table 1 to continue in perpetuity as was mentioned earlier. The losses to New Jersey are necessarily a gain to some other geography if not some other set of firms as well. Inasmuch as the production shifts out of New Jersey but within the U.S., the federal tax revenues posited in Table 1 will, therefore, ***not*** be lost to the nation. Rather Table 1 suggests simply that they not be credited as having been generated by firms in New Jersey.

Economic Impacts of Scenario 2

As suggested in the formulation of this scenario, the basic direct effects are essentially the same. That is, the commutes for the same number and distribution of workers are disrupted through the disabling of the Northeast Corridor rail line from Elizabeth to Manhattan. The difference is strictly in the duration of the event. In this case, impacts that result from the event last a single year during which the line is repaired and after which it is operating. Note in this case and in the case of a long-run disruption, the reconstruction effects are not included. This is strictly because they are not easy to estimate without more precision in the scenarios. They would be included in a more-detailed study

In the case of the long-run scenario, Table 1 showed the peak annual long-run losses that would be achieved in perpetuity. In the case of an event that curtails commutes by rail on the key section of the Northeast Corridor Line for a single-year, Table 1 shows the totality of the impacts. That is the losses are incurred by the businesses for the year, but with the promise of the resumption of rail service operations and the clearing up of the congestion that resulted from its absence, affected business immediately rebound. That need not be the case. Some business might choose to relocate away from unreliable rail service, which would be costly. This illustration does not speak to those possibilities.

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APPENDIX: Data Limitations

Additional data that would allow us to add nuances to our economic forecasting models. Business revenue losses by detailed industrial categories due strictly to the lack of productive operation during the postulated failures will be estimated by assuming that national inter-industry relationships prevail in New Jersey. Losses due to the disruption of other systems as a result of the loss of rail service were not possible to pin down because pertinent critical data do not exist for the study area. However, we do capture some of these losses indirectly in the model transaction table. For example, business losses that will be incurred from disruptions in the delivery of food are captured by the links between transportation and the food industry. All of these are captured implicitly in part in the models because impacts of a loss of rail service impact many businesses. But an explicit capability to capture these transactions requires field investigations before they can be incorporated into models. Given the time and resources available, it was not feasible to conduct extensive field research, and even with time, some of the data may not be possible to collect because of security issues.

Table 1: Economic and Tax Impacts to New Jersey of Loss of Service to New York Penn Station (5.6% Rise in Compensation/GDP Ratio, all impacts are actually negative)

	Economic Component			
	Output (000 $)	Employment (jobs)	Income (000$)	Gross Domestic Product (000$)
I. TOTAL EFFECTS				
1. Agriculture	1,269.4	6	167.8	338.9
2. Agri. Serv., Forestry, & Fish	782.3	21	405.7	647.9
3. Mining	1,547.2	2	223.7	833.5
4. Construction	18,865.4	46	2,504.4	6,340.9
5. Manufacturing	45,739.9	185	10,215.9	11,498.5
6. Transport. & Public Utilities	86,083.9	294	22,664.4	35,505.9
7. Wholesale	33,883.4	226	13,778.8	14,553.1
8. Retail Trade	121,063.7	1,892	45,961.6	70,061.2
9. Finance, Ins., & Real Estate	788,748.2	2,800	340,364.9	423,778.9
10. Services	966,665.3	6,035	423,927.0	468,770.2
11. Government	13,331.9	98	6,048.6	7,349.8
Total Effects	2,077,980.8	11,605	866,262.7	1,039,678.8
II. DISTRIBUTION OF EFFECTS/MULTIPLIER				
1. Direct Effects	1,314,146.7	5,792	591,370.3	627,536.8
2. Indirect and Induced Effects	763,834.1	5,813	274,892.4	404,792.3
3. Total Effects	2,077,980.8	11,605	866,262.7	1,032,329.0
4. Multipliers (3/1)	1.581	2.004	1.465	1.645
III. COMPOSITION OF GROSS STATE PRODUCT				
1. Wages--Net of Taxes				798,178.73
2. Taxes				160,314.09
a. Local				26,258.15
b. State				22,980.47
c. Federal				111,075.46
General				18,845.39
Social Security				92,230.07
3. Profits, dividends, rents, and other				79,813.86
4. Total Gross State Product (1+2+3)				1,032,329.05
IV. TAX ACCOUNTS		**Business**	**Household**	**Total**
1. Income --Net of Taxes		798,178.73	817,217.96	------
2. Taxes		160,314.09	174,540.09	334,854.16
a. Local		26,258.15	22,365.96	48,624.11
b. State		22,980.47	19,587.74	42,568.19
c. Federal		111,075.46	132,586.39	243,661.85
General		18,845.39	132,586.39	151,431.78
Social Security		92,230.07	0	92,230.07
EFFECTS PER MILLION DOLLARS OF INITIAL EXPENDITURE				
Employment (Jobs)				8.5
Income				659,182.7
State Taxes				32,392.3
Local Taxes				37,000.5
Gross State Product				785,550.9

CHAPTER 9

Project 09 12 P: Intelligent Demand Assigned Networks Cost and Performance

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Intelligent Demand Assigned Networks Cost and Performance

Project 09 12 P

Final Report

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Abstract

This project studied state of the art satellite network architectures and technology. At any catastrophic event, communications networks play a key role in the effective management of the catastrophe and dissemination of vital information. Existing means of communications such as public switched telephone networks, cellular telephone networks and computer networks could be damaged, destroyed or over-loaded with heavy traffic caused by the emergency condition. Deploying wireless communications is typically among the first priorities in any emergency response, rescue and relief situation. However, terrestrial wireless networks (cellular and land mobile radios) are only useful when communications towers and other infrastructure systems are in place to connect wireless equipment to the local and global communications backbone. Satellite networks are the only wireless communications infrastructure that is not susceptible to damage from disasters. Satellite communications networks, due to its technology, inherently are immune from catastrophic events and can play a key role in providing an effective emergency management and disaster recovery network. Designing a cost effective and reliable EM/DR network architecture suitable for data, VoIP, video and content streaming applications, is crucial. It is concluded that an optimal and cost-effective solution is based on concepts of cloud communications and intelligent network architecture.

Foreword

This project was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital - with support from Department of Defense Grant No. W9132T-10-1-0001.

The views, opinions, positions, conclusions, or strategies in this work are those of the authors and do not necessarily reflect the views, opinions, positions, conclusions, strategies, or official policy or position of the Department of Defense or any agency of the U.S. government and no official endorsement should be inferred.

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1.0 INTRODUCTION

As noted, the inherent advantages associated with the satellite technology make these networks an ideal choice for DR and EM applications. International Telecommunications Union (ITU), the regulatory body of the world, recognizes the important role of satellite technology and its benefits in EM/DR situations with the following statement:

"Satellite transmissions using small aperture earth stations, i.e. fixed VSATs, Vehicle-Mounted Earth Stations (VMES) and transportable earth stations, are one of the most viable solutions to provide emergency telecommunication services for relief operations. These Fixed Service Satellites (FSS) systems are extremely effective in providing emergency telecommunication services for relief operations, as they are inherently suitable for data delivery and quick deployment. FSS can also be effectively utilized for early warning operations, including earthquakes and tsunamis" says Dr. Hamadoun Touré, ITU Secretary General.[1]

Although the satellite technology is greatly suitable for disaster recovery and emergency communications, the employed technology usually is not be up-to-date therefore resulting in inefficient utilization of expensive satellite resources (transponder power and bandwidth). Using state of the art technologies coupled with a suitable network architecture one can reduce network operation cost drastically while improving network overall performance. To achieve this objective, this study examines the next generation intelligent satellite EM/DR networks with emphasis on the cloud communications. In addition, certain network engineering and design issues that could result in a high degree of cost containments are studied within the framework of cloud communications. In general, following specific areas are studied in connection with EM/DR networks applications and cost containment.

1. Cloud communications satellite networks concept
2. Service-Oriented Architecture (cloud engineering)
3. Advanced demand assigned techniques
4. Advanced Quality of Service (QoS) protocols
5. Transmission coding techniques
6. Intelligent Radio Resource Management (RRM) systems

In addition, certain features and issues critical to EM/DR networks, including network heterogeneity, network security issues, wireless sensor application support, location awareness capability are discussed. Regarding the content structure, this document includes the following sections:

1. An introduction to DR/EM planning and satellite networks
2. Architectural design for intelligent demand assigned networks
3. Comparative cost/performance analysis of intelligent networks vs. typical legacy networks
4. Cost Containment business model

In order to better understand system tradeoffs and network architecture, certain design, engineering and disaster planning issues also are reviewed in following subsections.

1.1 PHASES OF DISASTER MANAGEMENT

When examining the communications requirements for a disaster management scenario, it is important to define the challenges and needs of each phase of the disaster. Depending on the phase in which the disaster relief efforts arc in, the communication requirements may change. This requires a flexible and scalable solution to support all essential communications applications. Typical applicable phases of a disaster management for communication needs may involve the followings [2]:

- Preparedness
- Response
- Recovery
- Reconstruction

Organizations and agencies shall develop emergency management plans and be prepared to respond to a disaster as quickly as possible. First Responders shall be equipped to optimal mobile solution that can be easily deployed and quickly establishes the first lines of communication. During the recovery and reconstruction period, communications network plays an important role in connecting the field staff to their central offices and/or EM centers.

PREPAREDNESS:

When a disaster strikes, immediate actions can be taken if relief agencies and aid organizations have prepared their EM/DR contingency plans, outlined their communications needs and coordinated any involved multi-agency activities. It is important to obtain all necessary permits, licenses and approvals from the government authorities that might be required for communications network operation. Preparedness can also include using wireless sensor networks for real-time warning purposes if applicable. For example, remote terminals of seismic stations, bottom pressure recorders and tide gauges sensors can detect earthquakes and tsunamis, and report the collected data to EM centers in a real-time basis using satellite network. All component of the network shall be routinely monitored and tested to insure a functional and operational network during the emergency. Emergency power systems, handheld communications equipment, network security systems and interagency interoperability also shall be periodically examined and tested.

RESPONSES:

Generally, the first response effort usually takes up to a couple of weeks after the disaster strikes and is characterized by small teams exploring the area to discover the state of the survivors and infrastructural damages. This phase involves mostly search and rescue work and fulfillment of emergency services and basic humanitarian needs. First responders face many obstacles during this phase and keeping two-way communication is critical between response teams and their command centers. Heavily damaged or destroyed terrestrial networks often throw entire regions into a complete communications blackout. Even if a part of the existing infrastructure is operational, available lines quickly become oversubscribed by heavy traffic volume, making communications through them intermittent or impossible. In either case, committed bi-directional communications is required to coordinate relief efforts across wide geographic areas where quick response times are the key to success. The communications systems used during this phase must ideally meet a range of requirements as:

- High mobility communications for both EM vehicles, ambulances and relief personnel
- Easy to transport
- Quick to deploy independent of geographical location
- Bypass traditional terrestrial networks
- Easily scalable to meet growing needs during the relief effort
- Offer user-friendly configuration and network management
- Highly reliable and easy to maintain with little technical expertise in the field
- Support high bandwidth for any mix of voice, data and video applications
- Require minimal power and can operate with alternative source of power
- Ensure data security with built-in encryption
- Support of wireless sensor communications
- Location awareness capability

- Support central network management

RECOVERY:

After the immediate danger and basic needs have been addressed, recovery efforts will focus on maintaining important infrastructures, semi-permanent accommodations, temporary offices, hospitals and medical centers to aid victims. The communication capabilities will need to scale up quickly and become more permanent while mobile groups will still need portable communications and power to provide service to other locations within the disaster area. The recovery applications may involve administrative work, voice calls, multicasting and video distributions, assessments of relief supplies, assessment of the damages and telemedicine data. Higher speed communications with enhanced application support are needed for this stage of the disaster including:

- Supporting higher speeds for more sophisticated applications such as VPN, multicasting, telemedicine, large file transfers, VoIP, internet browsing, emails
- Advanced IP Routing
- Security for sensitive information and transactions
- Quality of Service (QoS) management
- Advanced network management capabilities
- Easy reconfiguration and simple operation
- Multi-network interface and hetcrogeneity

RECONSTRUCTION:

As permanent development and reconstruction begin, the relief agencies and constructions entities requirements for communications become more formalized and complex. As reconstruction can take years to be completed, the communication network will need to grow to support more workers and more business critical applications like videoconferencing, VPN, file transfer, VoIP and Internet access. A hierarchy of offices will develop and a flexible infrastructure must be maintained to accommodate offices that are more permanent and field offices that still need portability. For this phase, the type of applications normally remain the same; only the size of the bandwidth and equipment required will have to scale up to support the increased communication needs.

BENEFITS OF SATELLITE SOLUTIONS:

Success in emergency relief and disaster recovery is measured by quick response times and the ability to establish real-time connectivity. Satellite communication networks are quickly deployable and provide the backbone for the rescue and support initiatives during time of crisis. Field tested emergency relief and disaster recovery satellite solutions provide immediate communications even in an inhospitable environment. Using global satellite networks, the first response, medical or any emergency team will have full communications capabilities with voice, data and video, whether the emergency team is in a densely populated urban area where the infrastructure is damaged, or a remote and isolated location where no infrastructure exists. Intelligent platforms discussed in this study can integrate various advanced technologies and support complex applications as noted above for various phases of a disaster scenario.

The modular nature and inherent scalability of the satellite systems delivers maximum flexibility to anticipate diverse operational and technical needs regardless of bandwidth requirements, application, and frequency band or network topology.

1.2 SYSTEMS OVERVIEW

Overall, a satellite network includes two major components; a) the communications satellite or space segment, and b) the earth stations or ground segments. A geostationary communications satellite (space segment) located at the altitude of 22,236 miles may operate at different frequency bands such as C-band, Ku-Band or Ka-Band to name a few. Each satellite may have some number of transponders with defined amount of power and bandwidth. Each transponder receives transmitted signals from the earth stations and re-transmits those back to the earth stations again. For some technical and engineering reasons, most DR and EM networks utilize fixed service Ku-band satellites (FSS) with 11.7 to 12.2 GHz downlink frequency band and 14.0 to 14.5 GHz uplink frequency band in North America region. Therefore, we consider a Ku-Band satellite for our tradeoff analysis in this project. A simple satellite link is illustrated in Figure-1.

A typical North America footprint of a Ku-band satellite is presented in Figure-2. Key subsystems of a typical earth station including the RF system and satellite modem are illustrated in Figure-3.

A satellite modem (modulator and demodulator) as shown in Figure-3, is utilized to establish the communications link between two earth stations using the satellite as a relay station in the space. The word "modem" stands for "modulator-demodulator". Satellite modems' main function is to transform an input bit stream to a radio signal and vice versa by employing certain modulation, demodulation, encoding and decoding techniques. Quadrature Phase Shift Keying (QPSK) and 8-Phase Shift Keying (8PSK), among others, are modulation schemes more often used to establish a satellite link between two earth station terminals.

Further, Forward Error Correction (FEC) coding schemes are used to reduce the link bit error rate. The FEC schemes may include 1/2, 2/3, 3/4, 5/6, and 7/8 coding rates just to mention a few. Beside the design and engineering factors of the satellite modem, a link performance is directly related to Eb/No value of the received signal at the input of the demodulator. Eb/No, the energy per bit to noise power spectral density ratio, is an important parameter in digital communications and data transmission. It is a normalized signal-to-noise ratio (SNR) measure, also known as the "SNR per bit". It is especially useful when comparing the bit error rate (BER) performance of different digital modulation schemes without taking bandwidth into account.

E_b/N_0 is closely related to the carrier-to-noise ratio (CNR or C/N), i.e. the signal-to-noise ratio (SNR) of the received signal, after the receiver filter but before detection:

$$C/N = E_b/N_0 \cdot \frac{f_b}{B}$$

Where:

f_b is the channel data rate (net bit rate), and

B is the channel bandwidth

The required Eb/No value at the input of a satellite modem is an important factor for a satellite link design and it is usually optimized in terms of modulation scheme, FEC coding, desired link availability and the satellite modem performance. Required Eb/No values for certain BER performance are provided in Figure-4.

However, a satellite modem is not the only device needed to establish a communication channel. Other equipment that are essential for creating a satellite link includes satellite antennas, low noise amplifiers, power amplifier and frequency converters collectively called RF System. In addition, the noise and inter-modulation characteristics of the RF system is an essential factor in overall satellite link performance.

1.3 SATELLITE LINK AVAILABILITY

In telecommunications, the term **availability** is defined as the period of the time that the systems or communications channel performs as per defined specifications. Mathematically, availability is expressed as percent of the time that system performs according to the committed specifications. For example, 99.5% availability for a satellite link means that link could be down and nonfunctional for 0.5% of the time i.e. 43.8 hours per year. Many factors could result in link unavailability including the link signal attenuation due to rainfall. Heavy rainfall could attenuate the radio signal causing interruption in the satellite link. Depending to required link availability, appropriate rain margins should be included in the link budget to prevent link outages due to rain attenuation. Certain intelligent satellite modems, as it will be discussed later, are designed to detect the rain fade and increase the transmitted signal level to compensate for the occurred signal attenuation. Since EM/DR networks shall be operational under severe conditions, necessary margins shall be included in system design criteria to guarantee minimum 99.5% network availability under severe climate operation conditions.

1.4 MOBILE AND TRANSPORTABLE TERMINALS

Mobile communications (vehicular and helicopter) shall be included in the network design to provide connectivity between ambulances and first responders vehicles and the EMC. This shall be done by utilizing automatic antenna pointing systems coupled with a GPS unit. Satellite link shall be designed to accommodate required data link capacity with appropriate link margin for voice, data and video streaming in a mobile environment. It is important to distinguish transportable units with the mobile units. In this project mobile units apply to the vehicular terminals with broad communications capability with EMC.

In addition to mobile units, unusually EM/DR networks shall include some transportable satellite terminals. These terminals shall be designed with appropriate antenna size and antenna alignment tools for quick deployment and ease of packing and transportation.

Some features of transportable terminals may include:

- Light weight carbon fiber construction
- Rapid deployment in less than 5 minutes
- Secure voice, data and video communications
- X, Ku and Ka Band RF system
- Modular design with field replaceable cartridge assemblies
- Auto-acquisition, Satellite ID and tracking
- Modem agnostic

- Quick-connect cartridge feed for RF line replacement unit

For greater portability and improved ease of use, tactical backpack satellite terminals with auto-pointing feature is now available with up to 1 Mb data transfer rate for secure voice, data and video communications. A self-contained and self-powering backpack with satellite, wireless, and radio-bridging capabilities provides immediate communications for a small team in extreme first-mile environments where there may be no roads, power, or any other means of communications. These terminals are designed for rapid assessments, command and control, and far-forward incident and disaster processes. These can also be used as a concealed communications platform for the transmission of unmanned ground sensor data. Its redundant systems and satellite-based Broadband Global Area Network (BGAN) ensure connectivity even in the most unpredictable settings. Some EM/DR applications for the backpack terminals may include:

1. Real-time local and remote collaboration
2. At-a-glance situational awareness
3. Smart alerts for incident data and looming secondary threats
4. Fusion of data from environmental, biometric, and security sensors
5. Quick access to subject-matter experts and other recovery resources
6. Instant language interpretation and translation
7. Location identification and awareness capability

And some backpack terminal features may include the followings:

- Secure, wireless local networking (Wi-Fi 802.11b/g)
- Integrated broadband wireless (EVDO/3G)
- Streaming and burst IP satellite connectivity (BGAN terminal/Inmarsat network)
- Solar power generation to run all components and for excess energy storage

- Methanol fuel cell (optional) for power generation when solar is unavailable
- Specialized Lithium Ion (Li) power storage unit with ultra-pulse capacitor for optimized charge and discharge
- Incident Commanders' Radio Interface™ interoperable radio bridge connects municipal public safety radios, state and federal radios, and telephones
- Options for VoIP telephony for use on the CommsPack network
- Satellite telephony
- Satellite connectivity and wireless capabilities for voice, video, and data
- Land mobile radios and interoperability solutions
- Independent power systems
- Streaming video, videoconferencing and surveillance
- Global location awareness support system

Typical Mobile, transportable and backpack terminals are illustrated in Figure 5, 6 and 7 respectively.

The most critical issue for an EM/DR network is the network availability and preparedness at the time of a disaster. This means that the network and all its components shall be functional all the time and entire network shall be monitored and tested routinely to insure specified network performance. Self-diagnostic and fault detection is readily available in many communications network including the satellite systems. Basically, the EM/DR network shall be turned on to function in an idle mode so the system can routinely monitor its health status.

1.5 POWER SYSTEMS AND LOGISTICS

In general, contingency planning and disaster preparation measure, including pre-positioning of emergency supplies and logistics, handheld communications equipment and power generators are crucial and can greatly reduce the impact of a disaster. Appropriate mobile and transportable power system shall be including in disaster planning and available in a 7X24 basis.

1.6 COMMUNITY SERVICES

In contingency planning and disaster preparation, special attention shall be given to community issues such as schools, nursing homes, hospitals, and medical institutions. Assisted care communications networks shall be provisioned for elderly and senior citizens along with evacuation plans and location aware systems.

1.7 NETWORK SECURITY

Security element is a fundamental requirement for a DR/EM network. This includes content reliability, access control and authentications. In addition, since the rescue workers may come from various organizations with different levels of responsibility and security clearance, access to appropriate information distributed in the network shall be carefully assigned. The network security issue becomes more complex for a mix of heterogeneous network involved in the rescue mission.

In general, the network security (authentication, authorization and access) can be achieved by using standard products including data encryption, digital certificate, digital signature and key management techniques. For a host of heterogynous networks, depending to networks architecture and protocols, overall network security could be achieved by employing various security platforms that are interfaced via appropriate security gateways. Security gateways shall be located at physically secure locations with limited access. Two-way encryption products that meet military and commercial standards are available for satellite communications. AES, TRANSEC and FIPS levels of securities are also available for more mission critical applications.

1.8 HETEROGENEITY AND NETWORK INTEGRATION

During a disaster condition, it is usually required that several networks of different entities to interface and exchange information. However, the network platforms and equipment belonging to different agencies within the disaster area mainly is different, in terms of both the protocols and equipment. Despite these differences, end-to-end communications shall be established between certain entities involves in the rescue operation and emergency management including the law enforcement agencies, local hospitals, ambulance centers, emergency vehicles, first-responders' network and communications infrastructure. Interoperability of any DR/EM network with supporting agencies and organization is the key for DR/EM effective operation. To achieve this interoperability the DR/EM networks of various agencies within a given region shall be integrated using appropriate switches and gateway equipment. Joint exercise and tests shall be routinely conducted to conform total network health status and interface functionality.

1.9 RESOURCE TRACKING AND LOCATION AWARENESS APPLICATIONS

For effective EM operation, it is critical to have the real-time tracking and positioning information of some deployed resources including certain first responder personnel, vehicles, ambulances, police and field equipment. Resource localization enables the EM managers to make highly informed decisions regarding use and assignment of the field resources. Satellite imagery and satellite navigation systems play a key role and greatly improve emergency response effectiveness and outcomes. A typical use of satellite imagery and asset tracking is illustrated in Figure-8. For example, in a health emergency care scenario, the position of the possible victims must be established to coordinate the rescue operation; or in managing a hurricane response, it is useful to identify the disaster scenarios and set up alternative transportation or communication solutions relating to an evacuation plan [3].

From technical point of view, localization of sensors, network nodes, and user terminals within an disaster area is one of the key issues of EM/DR communication systems. To meet the typical requirements of an emergency communications system, a localization protocol must be:

- Robust to node failures
- Insensitive to noise
- Low error in location estimation

- Flexible in any terrain

Currently, two types of localization techniques address these challenges: **beacon-based** and ***relative location-based***. Both techniques can use range and angle estimations for sensor node localization through received signal strength (RSS), time of arrival (TOA), time difference of arrival (TDOA), and angle of arrival (AOA) [4].

1.10 SENSOR DEVICE NETWORK

Wireless sensor devices are routinely used in disaster scenarios to detect and monitor certain critical issues including the vital signs of the rescue workers. The data generated by these devices shall be communicated to the emergency management center (EMC) via a secure local data network. Wimax or WiFi networks could be used to interconnect the sensor devices to the EMC and/or satellite DR/EM network. An illustration of sensor device network is presented in Figue-9.

1.11 TYPICAL DEMAND ASSIGNED NETWORKS

Satellite networking is reaching an inflection point, facilitated by net-centric architectural influences, for larger coverage area and ease of deployment. The role of IP protocol is central to efficient interoperability across diverse wired and radio transport technologies for both terrestrial and space components. Satellite networks are extensively used for commercial and governmental EM/DR applications and substantially extend the geographical range of distributed information systems. However, currently deployed networks have mainly been dominated by transponder point-to-point Single Channel per Carrier (SCPC) techniques or demand assigned architectures that are not up to date and do not feature extensive intelligent capabilities on network processing, resource management capabilities. This results in inefficient utilization of the network resources, namely satellite power and bandwidth, and consequently increases network operation cost.

Recent developments in communications technology, signal processing and computing techniques resulted in next generation intelligent satellite networks with much greater resource utilization efficiency, These network can detect and adapt to network operation environment and traffic conditions, and manage the network resources accordingly in a much effective and smart manner according to certain predefined protocols and criteria. Unfortunately, most of the existing networks utilize a legacy technology and a demand assigned criteria that assigns the resources in a first come first serve basis. Network bandwidth is assigned in a mechanistic fashion, with minimal intelligence and dynamism involved.

In many cases, the network architecture is based on SCPC technology that requires a permanent allocated bandwidth no matter the link is utilized or not. Even some platforms with TDMA access technology are not equipped with sufficient resource management techniques. Although TDMA and SCPC-DAMA technologies were great improvement over the traditional fixed SCPC technology, still these have great limitations in terms of network resource utilization efficiency.

To illustrate the inefficiency of the legacy networks, a typical SCPC-DAMA network is presented and explained as shown in Figure-10 and Figure-11. For simplicity, in this example, network contains four fixed rate channels; two 1.544 Kbps channels, one 768 Kbps channel and one 512 Kbps channel.

Depending on the network sites requirement and traffic load, these channels are assigned to connect any two given points based on a simple connection criteria that “who requested first”. The allocated channel will remain as assigned, i.e. “channel B” connecting the EM/DR center and remote site-3 until one of the sites terminates the connectivity. Then, this channel (Channel B) becomes available and can be assigned to another connectivity within the network.

As mentioned, one of the key issues in the EM/DR networks design is the network cost containment. Many organizations and agencies recognize the necessity for a EM/DR network but either they cannot do it due to budget restrictions or they deploy a partial ineffective network that practically would be a minimal help during a disaster condition. The legacy networks are expensive due to inefficient utilization of satellite capacity. Ku-Band satellite bandwidth, which is mostly used for EM/DR networks applications, averages at $5000 per MHz per month. In order to stay prepared, an organization shall pay this recurring cost every month plus the network operation and maintenance fees. This demands a much more cost effective and dynamic solution that in one hand supports challenging dynamic requirements of an EM/DR network and on the other hand reduces the network operation cost to an affordable level.

2.0 INTELLIGENT NETWORKS

In order to address the cost containment and inefficiency issues of the EM/DR networks, this project examines next generation intelligent platforms with advanced technologies and network architecture with emphasis on the following solutions:

- Cloud Communications satellite networks
- Service-Oriented Architecture (cloud engineering)
- Advanced dynamic access methods
- Advanced QoS utilization
- Efficient transmission techniques
- Adaptive network performance and Radio Resource Management systems

Recently, satellite network technology providers have recognize the need for more intelligent platforms and have developed certain features that coupled with an appropriate network design can improve network cost and performance considerably. However, there is still need for greater evolutions. Next generation satellite networks with drastically improved cost-performance characteristics could be developed based on the concepts described in following sections.

2.1.0 CLOUD COMMUNICATIONS

The National Institute of Standards and Technology (NIST) provides a concise and specific definition for cloud computing: "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." In telecommunications, a "cloud" is the unpredictable part of any network through which data passes between two end points of the network.

The Internet and ubiquitous broadband created a revolution in the way enterprises manage applications giving rise to the concept of *Cloud Computing.* A similar transformation is now changing the way enterprises can communicate giving birth to *Cloud Communications*.

The concepts of cloud communications conceives from the cloud computing that is based on resource sharing and ubiquitous communications environment that results in cost containment, productivity improvement and better network performance. Similar to cloud computing, cloud communications provides network services that do not require end-user knowledge of the physical location and configuration of the system (in this case "satellite") that delivers the services. Intelligent network management system (NMS) and Radio Resource Management (RRM) system would control the resource allocations and establishes requested connectivity. Parallels to this concept can be drawn with the electricity grid, where end-users do not know the origin of the power source.

Cloud communications is clearly gaining momentum in the information technology and telecommunications world as enterprises look for more efficient ways of distributing and disseminating information. This will dramatically change telecommunications and information technology landscape in upcoming years and more sophisticated satellites platforms will fuel even more demand for cloud-computing applications.

However, cloud technology demands what the Internet has been so effective at delivering: seamless routing across multiple networks without regard to geography or ownership. This has tended to leave satellites on the sidelines when it comes to accessing the cloud cost benefits and effectiveness. Nevertheless, the recent demands for communications around the world specially for areas without substantial terrestrial infrastructure and latest advances in wireless technology are opening opportunities for cloud satellite networks (I.e. O3B satellite networks and services). Further, this is facilitated by advancement and convergence of many enabling technologies and concepts by combining the operational benefits of virtualization, scalability along with advanced access techniques, routing schemes and system design benefits of service oriented architecture (SOA).

Utilizing combination of sophisticated routing techniques, access methods and intelligent network management systems, satellite cloud becomes an attractive solution for situations that terrestrial infrastructures does not exist or substantially damaged because of disaster. Dr, Hamadoun Touré, the Secretary General of International Telecommunications Union (ITU) recognizes the effectiveness of ubiquitous satellite network as:

"Owing to their ease of deployment, wide-area coverage, and independence from the local telecommunications infrastructure (which may be lost during a disaster), mobile satellite terminals and ancillary equipment are very effective means of providing emergency telecommunication services for relief operations. In order to strengthen disaster preparedness, Mobile Satellite Services (MSS) systems should be deployed ubiquitously, especially in disaster-prone regions". [1]

2.1.1 BASIC CONCEPT

The concept of cloud communications can be materialized by close cooperation among agencies, organizations, satellite service providers and regulatory bodies. Considering specifics of the EM/DR communications and functional requirement, an statewide, nationwide or even global cloud satellite network can be implemented as the wide area EM/DR network. For example, at the state level, all state agencies can use a single cloud network while maintaining their own autonomous communications and reducing the overall network cost. At the federal level, a national EM/DR cloud network can be materialized with much greater economical benefits. Community cloud may be established where several organizations have similar requirements and seek to share infrastructure so as to realize some of the benefits of cloud communications. For a community cloud with several tenants, the costs are spread over fewer users than a large public cloud. However, for EM/DR applications, due to random nature of disaster events, the economic benefit would be much greater. Community clouds usually offer a higher level of privacy, security and/or policy compliance due to limited number of tenants.

For the EM/DR cloud network, the economical advantages are directly related to the disaster event Correlation Coefficient among the community members. Lesser the correlation, greater the cloud economic gain. Based on the random nature of disaster, and the fact that disaster events are not strongly correlated for distant geographical locations, EM/DR network resources can be economically shared without any effect on network performance and availability. For example, it is less probable that two states that are geographically apart, (i.e. California and New York), to have the same disaster event than New York and New Jersey that are neighboring. Of course the geographical separation is only one factor in disaster event correlation. Other factors shall be studied and accounted when designing an EM/DR cloud network. At any rate, with appropriate network architecture, there would be considerable economic benefits for the EM/DR community members.

Required cloud network capacity can be estimated based on tenants' traffic loading predications and disaster event correlation factor among the tenants. Obviously, less disaster event correlation among tenants results in a smaller satellite capacity and greater bandwidth efficiency. A generic view of a satellite cloud network is shown in Figure-12.

2.2 CLOUD ENGINEERING

In addition to established satellite systems engineering practices, a cloud network design shall include certain design principles specific to cloud communications. Essentially, cloud communications, with a multidisciplinary organization, is a service oriented network. Cloud engineering could benefit greatly by employing a "Service-Oriented Architecture" (SOA) design approach. Service Oriented Architecture is a flexible set of design principles used during the phases of system development and integration in computing systems and platforms. A system based on a SOA will package functionality as a suite of interoperable services, processes and criteria that can be used within multiple, separate systems and entities from several business domains.

In other words, SOA defines how to integrate widely disparate applications and service components within a shared environment using multiple implementation platforms. In communications systems, for example, little development has taken place of solutions that use truly static bindings to talk to other equipment in the network. By formally embracing a SOA approach, such systems can position themselves to stress the importance of well-defined, highly interoperable interfaces [5]. Clearly, system agility, scalability, data security and network elasticity shall be a great concern of cloud engineering.

In a multitenant cloud environment, the overall network security and tenants' data isolation are critical components of cloud engineering. Basically, network security shall address data isolation, content encryption, authentication and access control. Secure partitioning schemes including Network Virtualization (NV), Partitioning Communication Systems (PCS), W-LANs, VLANs and fire-walls shall be an integral part of a multitenant cloud network design. Partitioning Communication System (PCS) is a high-assurance computer security architecture based on an information flow separation policy. PCS extends the four foundational security policies of MILS (Multiple Independent Levels of Security) to the entire network including:

- End-to-end Information Flow
- End-to-end Data Isolation
- End-to-end Periods Processing
- End-to-end Damage Limitation

The term Network Virtualization refers to the creation of logical isolated network partitions overlaid on top of a common physical infrastructure as illustrated in Figure-13.

Each partition is logically isolated from the others, and must behave and appear as a fully dedicated network to provide privacy, security, and an independent set of policies, service levels, and even routing decisions. The architecture of an end-to-end network virtualization solution can be separated in the following three logical functional areas:

- Access control
- Path isolation
- Services edge

While each area performs several functions at the mean time must interface with the other functional areas to provide the end-to-end solution as shown in Figure-14 [6].

The access control functional area identifies the users or devices logging into the network so they can be successfully assigned to the corresponding groups. An identity is an indicator of a client in a trusted domain and it is used as a pointer to a set of rights or permissions to allow for client differentiation. Identities not only can be used as security mechanism, but also can be used to provide permissions to specific service within a domain. Although network services are arbitrary, this represents a linkage to path isolation techniques to provide a holistic form of differentiation between various types of clients. Access control also promotes authentication: the process of establishing and confirming the identity of the client requesting services.

For wireless access, the concept of a port can be replaced by the association between client and access point (AP). When authorizing a wireless device, the association is customized to reflect the policy for the user or device. This customization can take the form of the selection of a different wireless LAN (WLAN), VLAN, or mobility group, depending on the wireless technology employed. When an endpoint is authorized on the network, it can be associated to a specific group that typically corresponds to a separate partition or domain. Thus, the authorization method ultimately determines the mapping of the endpoint to an end-to-end virtual network. The current state of the technology provides broad support for VLAN assignment as an authorization alternative. In essence, VLANs may be mapped into separate policy domains, which define the correct entrance criteria into the path isolation architecture alternatives.

In general, cloud operational issues including network security can be viewed within network homogeneity concept that shall be addressed by systems standardization, interoperability, communications protocols and interfaces, and use of SOA design approached. Basically, network standardization takes the EM/DR telecommunications to next level of engineering resolving many major interoperability issues. Emergency telecommunications standardization has been one of the key activities of ITU. The new ITU standards were developed in accordance with resolutions adopted at the ITU Plenipotentiary Conference in 2006, the ITU Radio-communication Assembly and the World Radio-communication Conference in 2007[7]. Recommendation ITU-R S1001-2 provides information on the range of radio-frequencies that can be used by fixed-satellite service (FSS) systems for emergency and disaster relief operations. Recommendation ITU-R M1854, provides information on the range of radio-frequencies for Mobile-Satellite Service (MSS) in order to enable a variety of functions such as voice and data communication, field reporting, data collection, position information, and image transmission. The adopted standard enhances the quality of satellite communications during emergencies and will greatly improve the network interoperability issues. It is important to note that wireless sensor communications, mobile and transportable systems, community health networks, assisted care network etc. all shall be fully integrated as part of cloud EM/DR network.

Satellite capacity resources associated with cloud network may reside on multiple satellites operating at the same frequency range, for example Ku-band. Satellite multi-feed antennas can be utilized to transmit and receive to/from multiple satellites. This further enhances network flexibility in term of satellite resource availability and network efficiency. Regarding the network topology, cloud shall be a fully agile network supporting both mesh and star connectives.

2.3 CHANNEL ACCESS METHODS

In telecommunications and computer networks, a channel access method or multiple access method defined as a technique that allows several communications terminals to use the same transmission medium to connect to remote terminals by sharing the same network capacity. Examples of shared physical media are wireless networks, bus networks, ring networks, hub networks and half-duplex point-to-point links. A channel-access scheme is based on a multiplexing method, that allows several data streams or signals to share the same communications channel same or physical medium. A channel-access scheme is also based on a multiple access protocol and control mechanism, also known as media access control (MAC). This protocol deals with issues such as addressing, assigning multiplex channels to different users, and avoiding collisions. The MAC-layer is a sub-layer in Layer 2 (Data Link Layer) of the OSI model and a component of the Link Layer of the TCP/IP model. Four fundamental channel access schemes can be listed as:

- Frequency Division Multiple Access (FDMA)
- Time division multiple access (TDMA)
- Code division multiple access (CDMA)
- Space division multiple access (SDMA)

2.3.1 FREQUENCY DIVISION MULTIPLE ACCESS (FDMA)

FDMA is a frequency domain access method that is based on the frequency-division multiplex (FDM) scheme, which provides different frequency bands to different data channels. Basically, FDMA can be viewed as a channelization protocol assigning users an individual allocation of one or several frequency bands. A related technique is wave-length division multiple access (WDMA), based on wavelength division multiplex (WDM), where different users get different colors in fiber-optical communication. It is important to distinguish between FDMA and frequency-division duplexing (FDD). While FDMA allows multiple users simultaneous access to a certain frequency spectrum, FDD refers to how the radio channel is shared between the uplink and downlink (for instance, the traffic going back and forth between a mobile-phone and a base-station). Furthermore, frequency-division multiplexing (FDM) should not be confused with FDMA. The former is a physical layer technique that combines and transmits low-bandwidth channels through a high-bandwidth channel. FDMA, on the other hand, is an access method in the data link layer. An example of FDMA systems were the first-generation cell-phone systems. FDMA access technique is extensively used in satellite communications.

2.3.2 TIME DIVISION MULTIPLE ACCESS (TDMA)

TDMA is a time domain channel access method for shared medium of the telecommunications networks. It allows several users to share the same frequency channel by assigning a transmission time slot to each user. The users transmit in rapid succession, one after the other, each using his own time slot. TDMA is extensively used in satellite systems, combat-net radio systems, and PON networks for upstream traffic from premises to the operator. In dynamic time division multiple access, a scheduling algorithm dynamically reserves a variable number of time slots in each frame to variable bit-rate data streams, based on the traffic demand of each data stream.

Packet based multiple-access schemes are also time domain multiplexing access methods but more with a dynamic (random) time slot assignment rather than an static cyclically repetitive frame structure. The packet based multiplexing, due to its random character, may be characterized as statistical multiplexing resulting in highly dynamic bandwidth allocation.

Followings are major characteristics of the TDMA access method:

- Shares single carrier frequency with multiple users
- Non-continuous transmission makes handoff simpler
- Slots can be assigned on demand in dynamic TDMA

2.3.3 CODE DIVISION MULTIPLE ACCESS (CDMA)

CDMA is an advanced wireless access technique based on spread spectrum technology that allows numerous communications channels (carriers) to transmit information simultaneously and at the same frequency occupying a single transmission capacity. Spread Spectrum technique is a method that transmits a signal by spreading its bandwidth over a broad range of frequencies. The bandwidth for the transmitted signal is much greater than the bandwidth of the original content to be transmitted. CDMA requires a unique identifying code for each channel (transmitter) that is embedded in the communications signal. Choosing the code that used to modulate the signal is crucial for performance of CDMA systems. The best performance will occur when there is good separation between the signals from various users. The separation of the signals is made by correlating the received signal with the locally generated code of the specific user. If the signal matches the desired user's code with a high correlation, the system can extract that signal. In general, CDMA includes to two basic categories: synchronous (orthogonal codes) and asynchronous (pseudorandom codes).

This access method, due to its advantages, extensively used in military communications applications, satellite communications and it is the foundation for 3G wireless networks worldwide. Regarding bandwidth utilization efficiency, CDMA has great advantages over FDMA and TDMA.

2.3.4 SPACE DIVISION MULTIPLE ACCESS (SDMA)

SDMA is a channel access method based on creating parallel spatial pipes through spatial multiplexing and diversity. Using smart phased array antenna systems and dynamic directive antenna technology both at transmitters and receivers, SDMA segments space into the transmission sectors creating a much effective communications channel and superior performance in radio communications.

2.3.5 CLOUD NETWORK ACCESS METHOD

The above mentioned access techniques highlight the main category of access methods. However, there are varieties of access techniques that fall under above-mentioned main categories. Considering the dynamic and unpredictable nature of the EM/DR network and in order to achieve an optimal level of resource utilization efficiency, a fusion of various access techniques shall be utilized. For cloud communications, the concept of access method shall be contemplated in conjunction with the intelligent network concepts and characteristics. A highly intelligent network management system (NMS) and radio resource management (RRM) system dynamically assigns an appropriate access method that fits the real time condition of the network. NMS and RRM system, based on the real time data collected from network parameters and traffic pattern, shall use an adaptive access method that best optimized to that condition. In certain scenarios, depending to traffic pattern and QoS requirements, the network bandwidth may automatically partitioned to some subset bandwidth and a certain access technique is applied to each subset. An illustration of various channel access methods is shown in Fugure-15 [8]

2.4 QUALITY of SERVICE (QoS)

Quality of Service (QoS) refers to a broad range of networking technologies, techniques and protocols that are collectively utilized to provide guarantees and predicable service level per predefined performance specifications. In other words, the QoS is the ability to provide different priority to different applications, users, data flows, or to guarantee a certain level of performance to a particular data flow. This involves management and control of network resources such as bandwidth reservation, throughput and data flow management, power and bandwidth availability settings against the network service quality and connectivity requirements. This resource management is done based on certain predefined protocols and policies for various types of network services, applications and groups. For example, traffic shaping, also known as "packet shaping," is the practice routinely used in regulating network data transfer to assure a certain level of performance and QoS. This practice involves delaying the flow of packets that have been designated as less important or less desired than those of prioritized traffic streams. Regulating the flow of packets into a network is known as "bandwidth throttling." Regulation of the flow of packets out of a network is known as "rate limiting."

An alternative to complex QoS control mechanisms is to provide high quality communication over a best-effort network by over-provisioning the capacity so that it has sufficient resources for the expected peak traffic load. This is basically how most legacy networks are operating now by sizing network resources to peak requirement which is specially cost prohibited for EM/DR applications. Further, in legacy network, certain network components may not be designed to support prioritized traffic or guaranteed performance levels, making it much more challenging to implement a QoS solutions across various segments of the network. QoS is especially important for the new generation of IP based applications such as VoIP, video streaming, IPTV, file transfer and content distribution services while there is not an abundant network resource.

The elements of network performance within the scope of QoS often include availability (uptime), bandwidth, throughput, latency and bit error rate. A network monitoring system must typically be deployed as part of QoS, to insure that network is performing at the desired level and per defined priorities and policies. QoS technology can be applied in a group level (GQoS) and Network level (NQoS) in cloud communications model. GQoS can provide service levels based on any specific group that can be defined in the network i.e. type of business process, site locations, user group, IP applications and data formats. This allows for a greater number of service level possibilities, resource management and traffic prioritization ideal for EM/DR applications. In a cloud network model, GQoS provides a significant increase in bandwidth management capabilities resulting in more flexibility with traffic configuration, prioritization and consequently more cost savings over conventional QoS. Further, in the satellite networks GQoS can be defined on the outbound and inbound traffic adding to greater resource management capabilities. An example of a GQoS structure is presented in Figure-16.

2.5 TRANSMISSION EFICIENCY

In telecommunications systems engineering, the transmission performance quality is directly related to the link bandwidth quantity introducing a conflicting problem. In one hand, the network capacity cost shall be maintained in a realistic level and on the other hand, the transmission performance shall meet a minimum acceptable specification. Digital Video Broadcasting Satellite- Second Generation (DVB-S2) standard addresses the challenge of cost-effectively transmitting of high-quality video contents and data services via satellite.

In addition, in cloud communications, substantial transmission gain can be achieved by multiplexing the data streams of smaller carriers to a single larger carrier by time division multiplexing—single carrier network vs. multicarrier network. This is particularly important in satellite communications that requires transponder input and outputs back-offs for multicarrier operation environment to avoid intermodulation problems. The single carrier approach may not be practical for a single agency or organization due to lesser traffic load and fractional transponder capacity requirement, but can be easily materialized for a multitenant cloud network. Satellite capacity efficiency achieved with single carrier transmission can exceed 3 dB (100%) even without accounting the potential modulation and coding gains.

In general, the transmission technique of cloud network also shall be viewed within the framework of intelligent networks allowing full agility in transmission parameter controlled by RRM system. At the present stage of technology, DVB-S2 transmission technique is the closest one that can satisfy cloud communications dynamic modulation, coding and transmission attributes. The DVB standards committee formally approved the DVB-S2 standard in 2005. Although digital video broadcasting was the main driver for DVB-S2 development, the committee took the opportunity to incorporate an "interactive data" element in the standard that is developed specifically for VSAT applications. This transmission technique, implemented in satellite outbound and inbound channels results the most efficient (Bits/Hz) physical layer data delivery solution available today. The main achievements and performance benefits of DVB-S2 standard results from development and implementation of three core techniques which form the heart of DVB-S2 standard:

1- An highly efficient forward error correction (FEC) coding
2- Optimized modulation schemes
3- Adaptive coding and modulation (ACM) technology

As noted, one of the great advancements within DVB-S2 is a new highly powerful FEC coding that is a key factor in achieving excellent performance in the presence of high levels of noise and interferences. It is currently anticipated that the efficiency of this EFC is so near the optimum that it is unlikely that there will be a need for further enhancements. DVB-S2 FEC scheme is based on concatenation of BCH (Bose-Chaudhuri-Hocquengham) code along with LDPC (Low Density Parity Check) inner coding which has been shown to provide a 30 percent increase over the DVB-S standard and a 15 percent improvement over Turbo FEC coding.

A second major enhancement in the DVB-S2 standard is the provision of higher order modulation schemes. Four modulation schemes include QPSK and 8PSK which are intended for non-linear applications where satellite transponder driven close to saturation point, and newly introduced 16APSK and 32APSK modulations, which requiring a higher level of C/N and are mainly targeted for professional applications such as news gathering and interactive services with larger satellite antennas. Contrary to previous standards, DVB-S2 recognizes the reality of non-linear characteristic of the satellite channels and defines new constellations that are optimized for non-linear environment as shown in Figure-17. DVB-S2 defined FEC rates and modulation schemes are shown in Table-1.

However, the most significant achievement of DVB-S2 is the provision of Adaptive Coding and Modulation (ACM) implemented within the standard. Using the return-channel of the network, real-time feedback on received data and transmission performance parameters can be forwarded from the remote terminals to NMS. With DVB-S2/ACM, the carrier to each remote terminal can be operated at the most efficient coding and modulation combination possible for that terminal at any given time. ACM enables each remote terminal to operate at its most efficient coding and modulation scheme, at any moment in time, depending on location within the satellite contour, antenna size, and atmospheric conditions.

The management of ACM functions is performed by an ACM router and router manager. The combinations of these two devices receive the quality of reception data from the remote receivers and instruct the modulator which modulation and FEC to use whilst managing the data rate flow into the modulator. With this, there would be no need any more to design a network for the worst-case terminal basis. ACM automatically monitors the condition of the data link to each remote terminal and adjusts the modulation and coding scheme for the outbound carrier continually in real time basis. This capability further can increase network resource utilization efficiency, improve network performance and availability.

2.5.1 DVB-S2 PERFORMANCE

As noted, DVB-S2 performance is extremely close to the theoretical performance of Shannon limit. Taking advantage of powerful FEC coding, ACM technique and optimized modulation schemes it delivers significantly higher throughput in a given satellite transponder bandwidth than the earlier standards. DVB-S2 throughput for a typical 36 MHz transponder in terms of some selected modulation and coding schemes ranges from 43 Mbps to 77 Mbps as presented in Table-2. It is important to note that a typical full transponder throughput for SCPC transmission would be around 42 Mbps. In general, DVB-S2 transmission gain ranges from 30% for broadcast operations and up to 100% for interactive data applications. Satellite capacity for interactive and point-to-point applications may be improved by 100%-200% using combination of ACM functionality with the use of a return channels to achieve a closed-loop adaptive coding and modulation functionality [9]. DVB-S2 performance in terms on required C/N versus spectrum efficiency in the *Additive white Gaussian Noise (AWGN)* channel is presented in Table-3.

2.6 RADIO RESOURCE MANAGEMENT SYSTEM

Radio Resource Management (RRM) system shall be an integral part cloud network effectively controlling network resource allocation based on real-time network performance and operation parameters collected from the network. From the functional point of view, RRM system interacts with network management system (NMS), protocol processor (PP) and other intelligent components of the network (for example ACM system) to effectively manage network resources. This may involve strategies and algorithms for controlling network parameters such as transmit power, channel allocation, C/N, channel bandwidth, channel QoS, data rates, handover criteria, modulation scheme, error correction coding scheme, etc.

The end objective of RRM system is to utilize the limited radio spectrum resources as efficiently as possible without sacrificing any significant performance. In general, within the frame work of intelligent networks, the smart component of the cloud network including RRM system, NMS, PP, ACM, etc. shall be based on the SOA and a systemic design approach using a distributed computing architecture.

RRM is especially important in systems limited by co-channel interference such as cellular systems and satellite networks that homogeneously covering large areas, and wireless networks consisting of many adjacent access points that may reuse the same channel frequencies. RRM technology is widely used in cellular network and can be easily adapted to satellite cloud communications environment. In fact, DVB-S2 standard employs this concept by use of adaptive coding and modulation (ACM) system described above.

2.7 STATE OF INDUSTRY

Although recently there were great technological advancements in the areas of intelligent satellite networks and platforms, still the industry somehow lagging behind the market dynamics particularly in the area of cloud networking. In order to make satellite networks more attractive and cost-effective, further developments are needed to reduce overall networks cost. Many of the network service providers and VSAT platform technology companies are trying to catch up with the market demands.

On November 2010, ND SatCom, a German based satellite technology company, introduced its cloud computing (cloud communications) solution, XWARP, in partnership with Citrix, a US based information technology Solution Company [10]. XWARP is based on integration of various technologies from both companies including Citrix Virtualization, a zero-latency engine, an intelligent management system for secure satellite network connection and SkyWAN satellite modem.

Many satellite industry companies and customers have voiced support for the future of satellite in the cloud computing world. Duncan McCarthy, a research scientist with the U.S. National Geospatial Intelligence Agency (NGA), told Satellite Today that he expects satellite players to invest more in having a cloud computing capability. "*I would suspect satellite companies would be investing in their own cloud computing capabilities at ground stations so data can be brought down and processed into information so more sophisticated products might quickly be delivered to customers.*" CTO of GeoEye corporation (a US based earth-imaging satellite company) Brian O'Toole said cloud computing could enable the satellite industry to build and offer new services to new sets of customers through subscription-based business models and cited Netflix as an example of the solution's commercial benefits. "*Customers may want to subscribe to imagery content for an area of interest and have that streamed directly into their business environment. If you take a look at what NetFlix is doing with on-demand services, you will see that they are starting to shift to focus on providing movies on demand through your cable box and over the Internet. I think the next 10 years will be exciting as we see new information products emerge with the added benefit of flexible access and delivery through cloud enabled solutions.*"[10]

ND SatCom claims that "*XWARP® provides greater efficiency, lower operating costs and increased productivity with any company with a distributed network topology and VoIP, Video, VPN, streaming media and internet access applications. ND SatCom's XWARP® shares bandwidth and significantly reduces satellite capacity by dynamic bandwidth allocation. Further, an advanced QoS allows efficient bandwidth allocation and priority management while mapping the network resources in terms of remote terminal locations. Mesh capabilities of XWARP® allow video, voice and data to be directly transferred to other remote stations without* *using a headquarters (hub) connection. As a result of this single hop, infrastructure, bandwidth usage and costs are reduced.*"

Another intelligent satellite network front-runner is *iDirect*, a US based VSAT platform technology company. This company earned credits for many innovative developments and solutions including their shared network architecture environment that easily can be adapted to a cloud communications model, Group Quality of Service (GQoS) protocols, and Deterministic Time Division Multiple Access (D-TDMA), Multi Frequency Time Division Multiple Access (MF-TDMA) techniques.

iDirect GQoS provides a comprehensive set of powerful and state-of-the-art features that allow a significant increase in bandwidth management capabilities of the network. This is especially important when prioritizing traffic in a shared network environment or cloud communications - resulting in greater flexibility for traffic configuration, prioritization consequently more bandwidth savings and improved service quality. When combining GQoS with DVB-S2/ACM it allows network operators to increase DVB-S2 efficiency gains by combining multiple small networks into a single, larger carrier. It also allows the network operator to maintain distinct QoS settings by remotes, bandwidth groups and applications. By tightly integrating ACM and GQoS, service providers can create more flexible service offerings and improve user satisfaction in geographies commonly impacted by adverse weather conditions. For example, they can establish Extended Information Rate (EIR) options that maintain a fixed Committed Information Rate (CIR) during periods of rain fade, giving the end-user the choice of more service level guarantees at different price points

Utilizing D-TDMA and MF-TDMA access methods, iDirect technology can dynamically manage the inbound and outbound satellite capacity in a mesh or star topology environment resulting in additional cost saving. The system constantly analyzes capacity demand at the network level and allocates bandwidth as frequently as eight times per second resulting in a payload efficiency of about 98%. This architecture is ideal for enterprise networks that have burst y TCP/IP traffic and also support real-time traffic such as VoIP, video conferencing and mission critical applications. MF-TDMA provides fast frequency hopping on a burst-by-burst basis and provides the highest efficiency in capacity usage and allocation. iDirect was one of the pioneers of Turbo Product Coding (TPC), a forward error correction (FEC) scheme for the inbound / return channel that improves link performance and reduces latency. TPC FEC is based on an iterative decoding technique, which recycles partially decoded messages back through the process. For the remote, this translates into a reduced need for retransmission, and allows more efficient use of satellite bandwidth. As a follow-on iDirect will introduce a new coding scheme to which it has exclusive rights. This will offer an improvement of up to 2dB in the Eb/No performance over TPC and add alternative block sizes, reinforcing iDirect's position as industry leader for inbound /return channel efficiency.

iDirect also supports Paired Carrier Multiple Access (PCMA) technique that is a satellite signal cancelling method that increases satellite capacity usage efficiency by about 50 percent. This is accomplished by combining the uplink and downlink transmissions into the same bandwidth, allowing two different signals to overlap in frequency and spectrum.

On July 2010, Harbinger Capital Partners announced that it will pay Nokia Siemens Network more than US$7 billion to build a 4G satellite network called LightSquared. According to the company, this network will reach 92 percent of the U.S. population with expected commercial launch in the second half of 2011. LightSquared, a combined terrestrial and satellite broadband network will be based on Long Term Evolution (LTE) technology, the most advanced 4G wireless standard today. LightSquared is the first to integrate LTE technology in satellite networks.

LTE standard includes a new radio platform technology that will allow operators to achieve even higher peak throughputs than any of the existing standards and technologies. Initial deployment of LTE is targeted for 2011 with an overall objective to provide an extremely high performance radio-access technology that offers full vehicular speed mobility and that can readily coexist with HSPA and earlier networks standards. LTE assumes a full Internet protocol (IP) network architecture and is designed to support voice in the packet domain. Employing state of the art radio techniques and advanced access methods, it achieves performance levels beyond what will be practical with CDMA approaches, particularly in larger channel bandwidths.

The latest news came on November 2010 that O3B Satellite Networks has raised$1.2 billion to launch its first 8 Satellites designed for high speed efficient and fiber quality broadband satellite services. [11] O3B's investors include SES (a Luxembourg based satellite company), Google, HSBC, Liberty Global and some other world renowned investment banking companies. The project will be carried out by Thales Alenia space, Ariane Space and Viasat, they key companies in satellite technology area. O3B network is based on low orbiting satellites technology with 8 spacecrafts constellation orbiting from 8,000 kilometers from the earth, four times closer to earth than regular geostationary satellites. This technology with steerable beams, dynamic bandwidth allocation, low propagation latency, fast configurable payloads provides opportunity for deployments of next generation intelligent satellite networks independent of traffic applications.

In the foreseeable future new platform and techniques will be used in satellite technology which will extend and improve the possibilities of satellite communications beyond present boundaries. The future telecommunication satellites will be evolved from transponded transmission in to Information processing spacecrafts offering a comprehensive host of high quality services with much greater network efficiency and contained operation cost.

3.0 BUSINESS MODELS COMPARISON

In order to examine cost advantages of an intelligent cloud satellite network compared with a legacy satellite networks we consider two scenarios with identical requirements and performance specifications as described below. Satellite capacity is further emphasized in this analysis based on the fact that it constitutes the main part of the network cost.

3.1 LEGACY NETWORK MODEL

Assume there are four independent networks with sufficient geographical separation and with no strong disaster event correlation coefficient. Each network which comprise of 15 satellite terminals with 1.2 meter antenna size shall support fifteen 1500X1000 Kbps outbound and inbound channels simultaneously at the time of a disaster (maximum network capacity). The hub earth station located at the EMC includes a 4.5 meter antenna utilizes SCPC DAMA technology to provide mesh/star connectivity among terminals. All four network are using typical QPSK modulation with 3/4 FEC Turbo coding for outbound links and QPSK with 7/8 Turbo coding for return links.

The modulation and coding parameters are selected based on network performance and cost tradeoffs. The network availability requirement is typical 99.5% and all networks use the same North America Ku-Band satellite. For the purpose of calculation and modeling it is assumed that these are all state-wide EM/DR networks with network hubs are located at New York, Chicago, Los Angeles and Dallas and basically are designed for statewide emergency applications. Therefore, satellite terminals of each network will be deployed within the given state. A simple illustration of the legacy model networks is presented in Figure-18. To determine satellite capacity requirements, link analysis were performed for all four networks. Summary of legacy network specifications and attributes are presented in Table-4.

3.2 CLOUD NETWORK MODEL

To construct the cloud network model, four independent networks of the legacy model with the same requirements, specifications and disaster event correlation is assumed to be the four tenants of the cloud network. Therefore, the cloud network model will comprised of four securely partitioned networks each supporting 15 terminals with 1500X1000 Kbps outbound and inbound channel capacity and 99.5% network availability as shown in Figure-19.

Cloud network model with mesh/star topology is based on intelligent network architecture that dynamically adapts to network environment, traffic pattern and constantly self-optimizes by changing network parameters. Therefore, main network parameters such as modulation scheme, coding, QoS and access method are dynamically transforming based on overall network condition.

To determine required cloud network capacity (shared among all four tenants) it is assumed that there will be no simultaneous disaster event for cloud members and disaster may occur only for one tenant at any given time. In addition, it is allowed that each tenant can use its network routinely at 20% capacity at any given time during non-disaster periods. Naturally, this assumption increases the resource utilization efficiency, nevertheless, even with a strong disaster event correlation, the recommended intelligent cloud network results in greatly improved network resource utilization. Based on above assumptions, cloud network traffic capacity is determined as presented in Table-5.

Comparing "total network capacity" for both models in Table-4 and Table 5, it can be seen that cloud network gain, even without accounting for other intelligent network features, reduces the total network capacity from 150 Mbps to 60 Mbps by a factor of 2.5. Obviously this directly translates to the cost containment on satellite capacity.

Further efficiency and performance improvements can be achieved by using DVB-S2 transmission technique, network adaptability, dynamic access methods and QOS. All four tenants' outbound traffic is multiplexed in one 36 Mbps DVB-S2 data stream. The multiplexed outbound data stream is received by all terminals and the traffic of each terminal, if any, is extracted from the data stream. To determine network outbound satellite capacity, link parameters calculations and link budget analysis were performed for DVB-S2. Although the modulation and coding schemes of cloud network are constantly changing in terms of network condition, for the calculation purposes, 8PSK modulation with 3/4 FEC coding is used.

The return channels utilize a combination of various access methods including dynamic TDMA transmission mode. However, for calculation purposes, 8PSK modulation along with 4/5 EFC coding scheme is used. The total inbound traffic of 24 Mbps is supported by 12 carriers each with 2 Mbps channel capacity. Each 2 Mbps carrier can be shared among all cloud terminals by the mean of frequency hopping. Summary of cloud network link analysis is provided in Table-6. As shown in Table-6, an intelligent cloud network can support identical traffic load utilizing one 36 MHz transponder.

4.0 COST ANALYSIS

As noted, the main cost component for the satellite networks is associated with the satellite capacity. As presented above, for a given traffic load, the legacy network utilizes 108 MHz of satellite capacity while an intelligent cloud network uses only 36 MHz to support the same traffic load. Assuming that other network operation cost factors are similar for both networks, satellite capacity remains as the main cost factor. Ku-band satellite capacity (bandwidth) pricing varies around $4000 per MHz and around $145000 per a 36 MHz transponder. This translates to $432,000 per month for the legacy network versus $144,000 per month for the cloud network. In addition the cost containment, cloud network provides a better network performance in terms of network availability and bit error rate.

5.0 CONCLUSION

As discussed in this document, satellite networks are the primary choice for EM/DR communications. Nevertheless, the satellite resources (power and bandwidth) are expensive and from economical point of view, making it difficult for deploy an EM/DR satellite network. To address this issue and to achieve significant cost containment, advanced techniques and technologies are discussed in this document. As shown in Table-7, a monthly recurring cost can be reduced with the factor of about 1/3 by utilizing multitenant intelligent cloud network.

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9] Yan Mostovoy, Maximizing Satellite Transmission Efficiency with DVB-S2, Harmonic Corporation

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11] G. M. Lamb, The Christian Science Monitor, September 2008

FIGURES

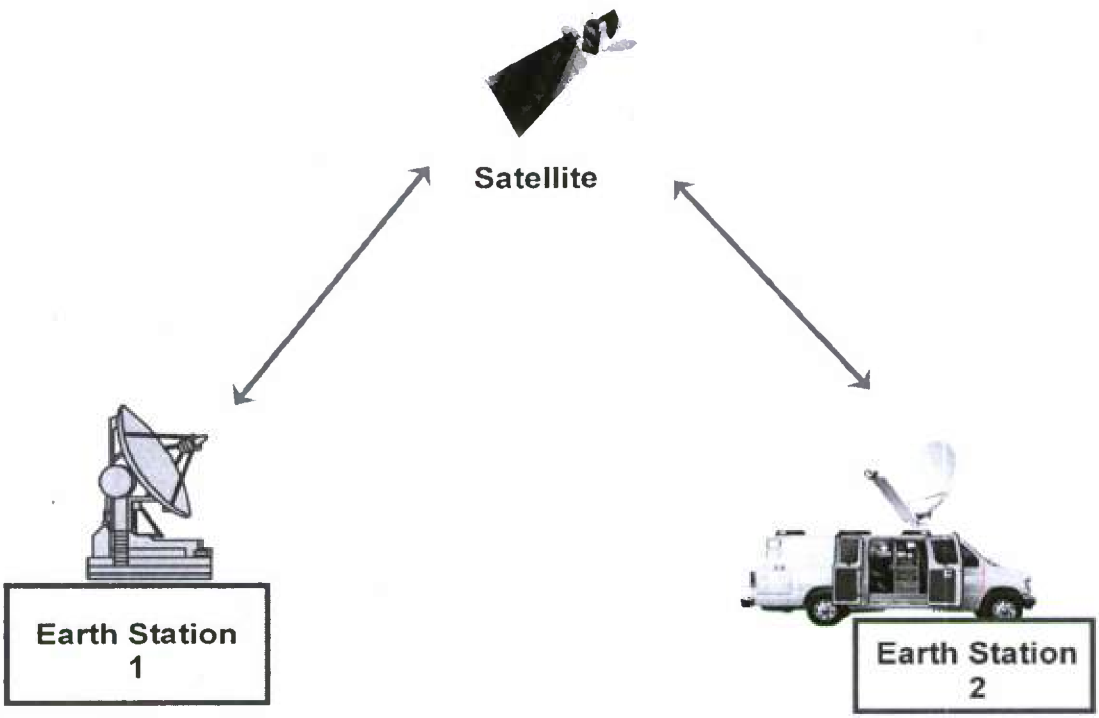


Figure-1, A simple satellite link

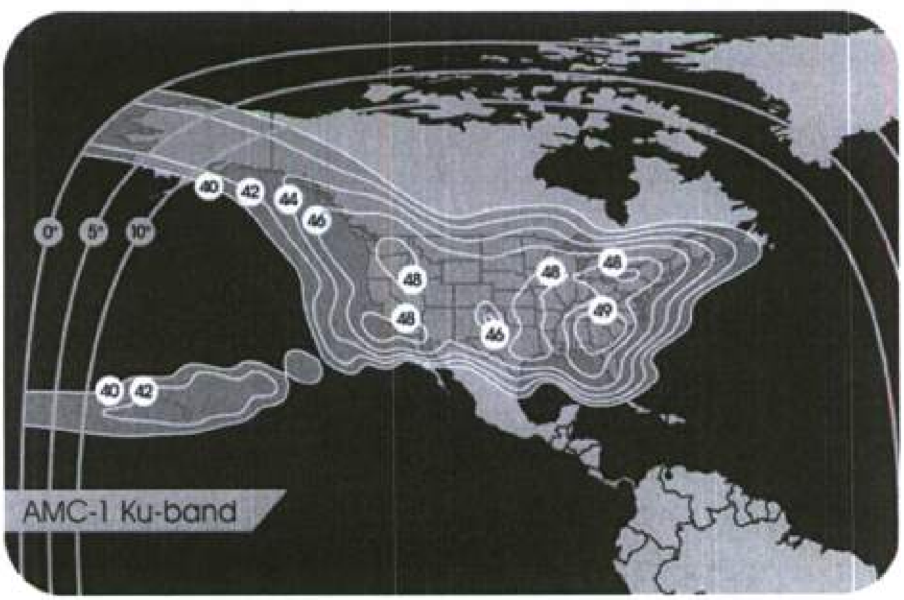


Figure-2, Typical North America Ku-band satellite footprint

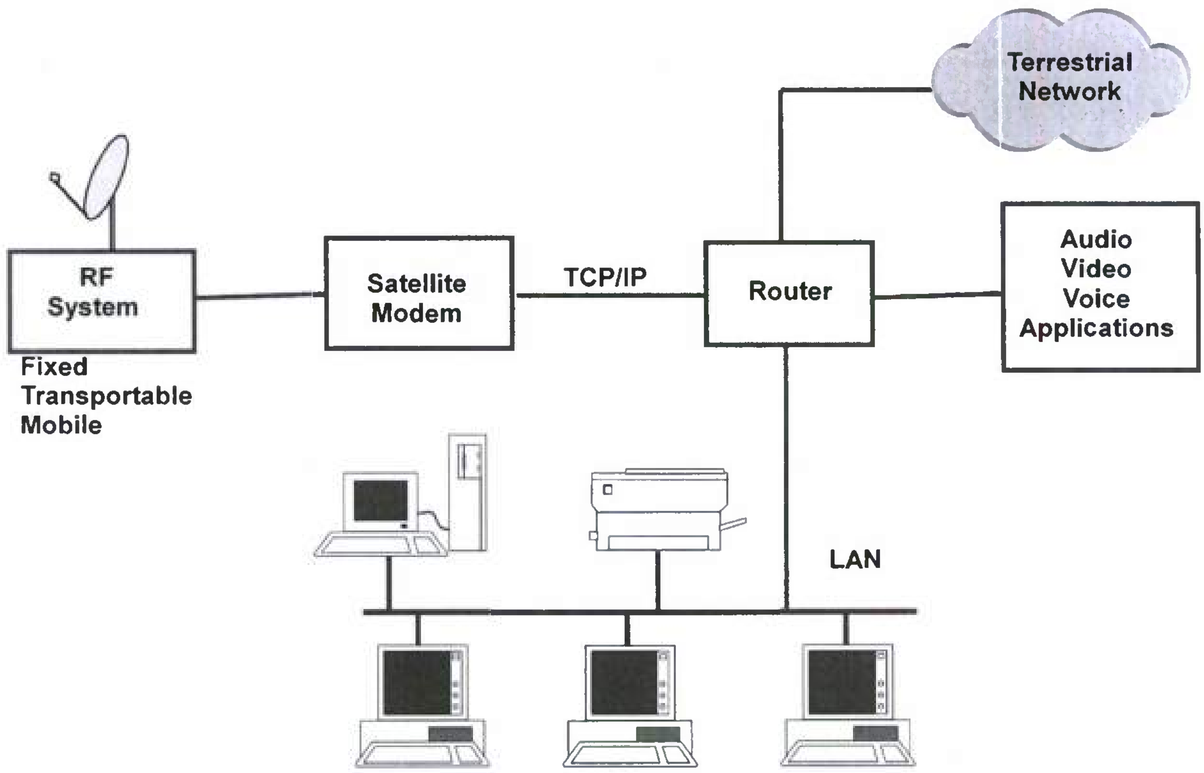


Figure-3, Typical earth station

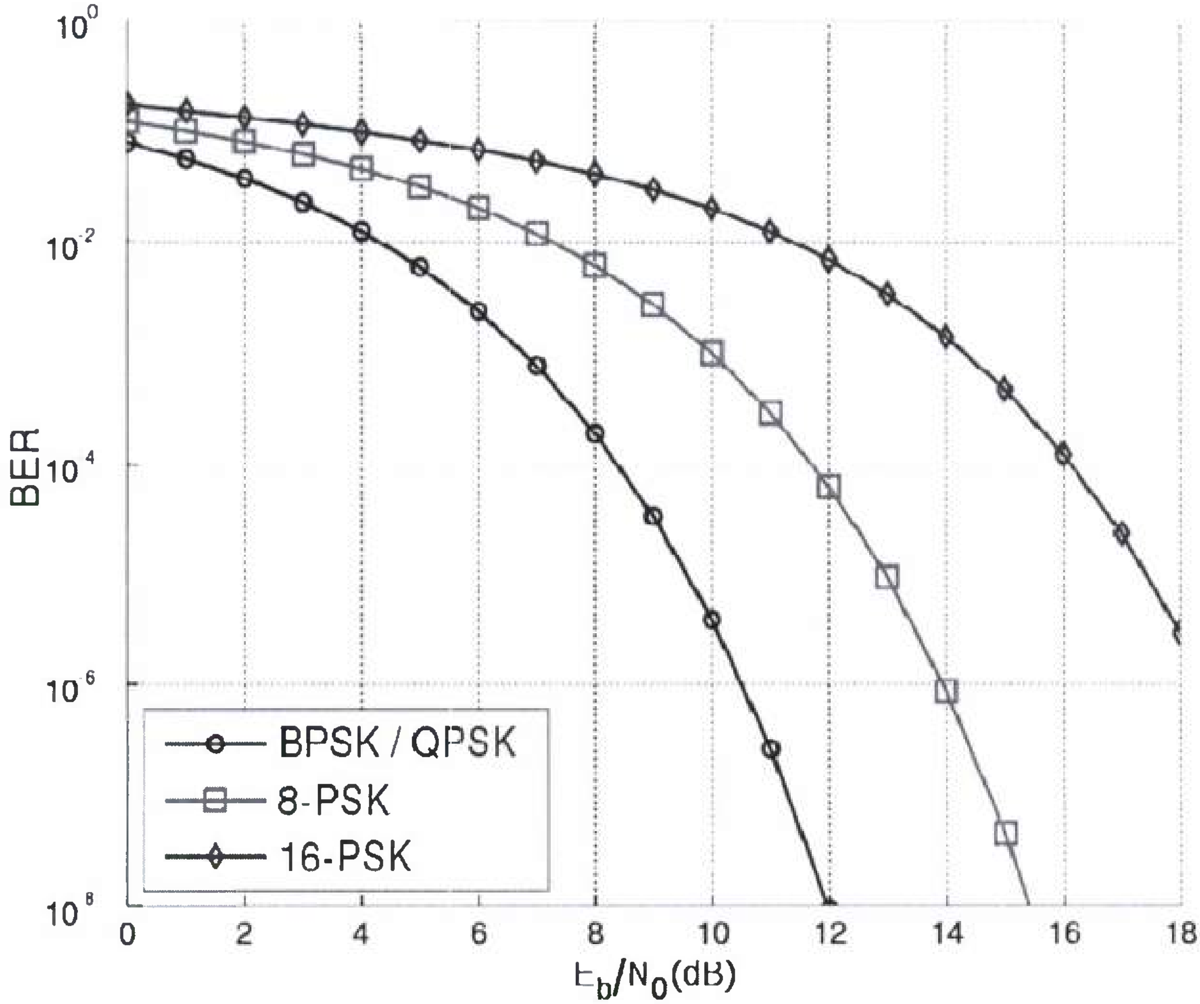


Figure-4, Eb/No Values for various BER performances

CAMMS™ (Command Anywhere Media Management System)

Figure-5, Typical mobile unit

Figure-6, Typical transportable /Flyaway unit with carrying case

US Marines set up a CommsPack™ to provide interoperable radio communications (Microsoft case study)

US Marines set up a CommsPack™ to provide interoperable radio communications (Microsoft case study)

Figure-7, A typical backpack satellite terminal

With satellite map views, visualize "off-road" locations such as parking lots, construction sites, and identify details like the front or back of buildings for precise asset location.

Figure-8, A typical use of satellite imagery and asset tracking data

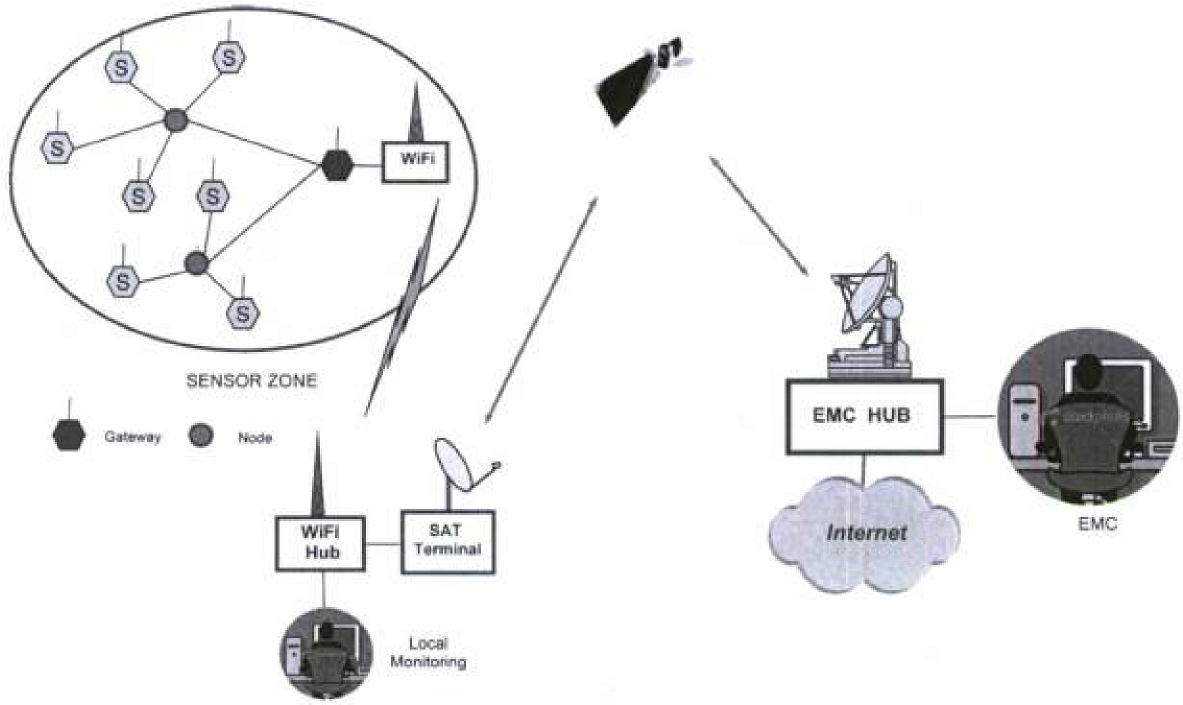


Figure-9, DR/EM Wireless sensor device network illustration

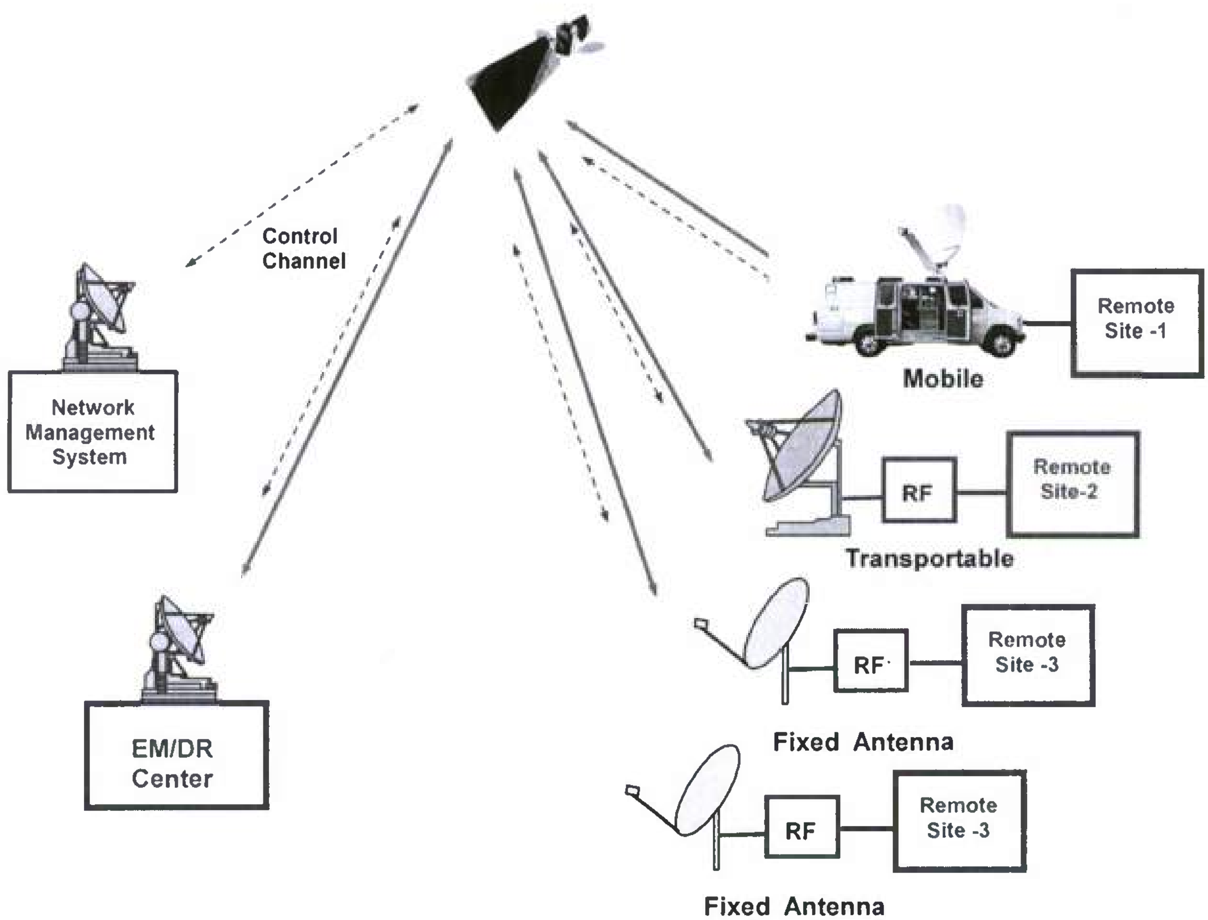


Figure-10, Typical legacy demand assigned network

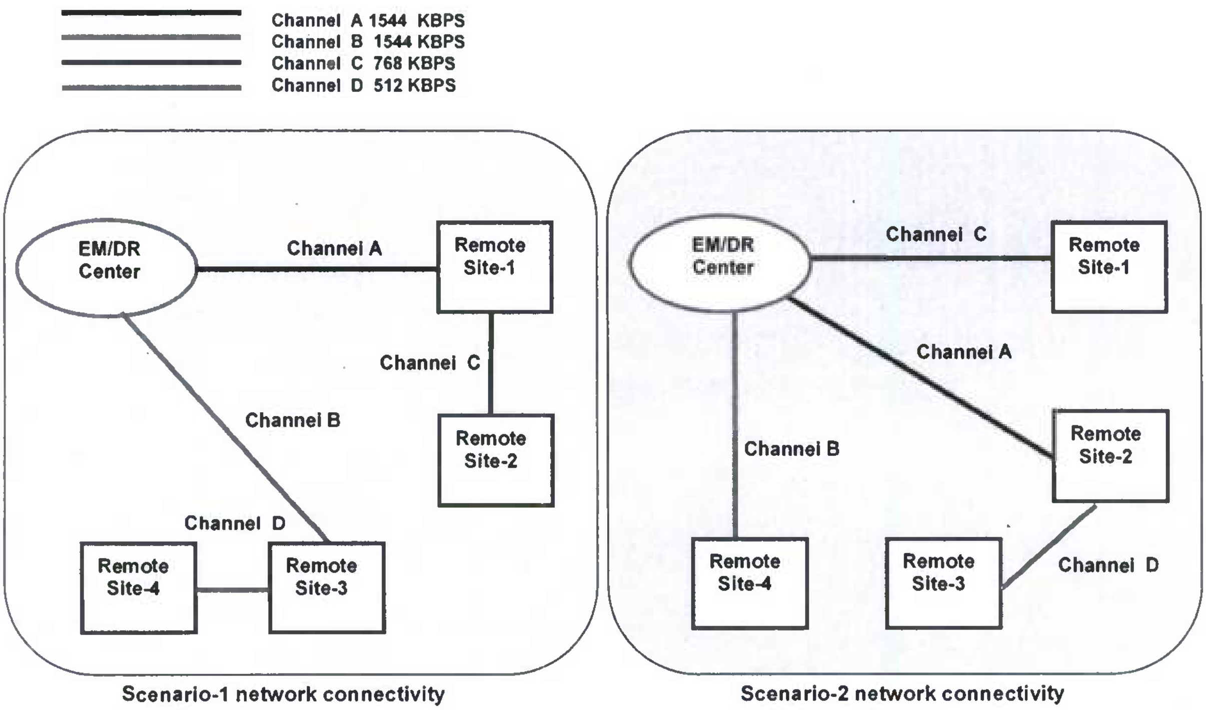


Figure-11, Legacy demand assigned network connectivity scheme

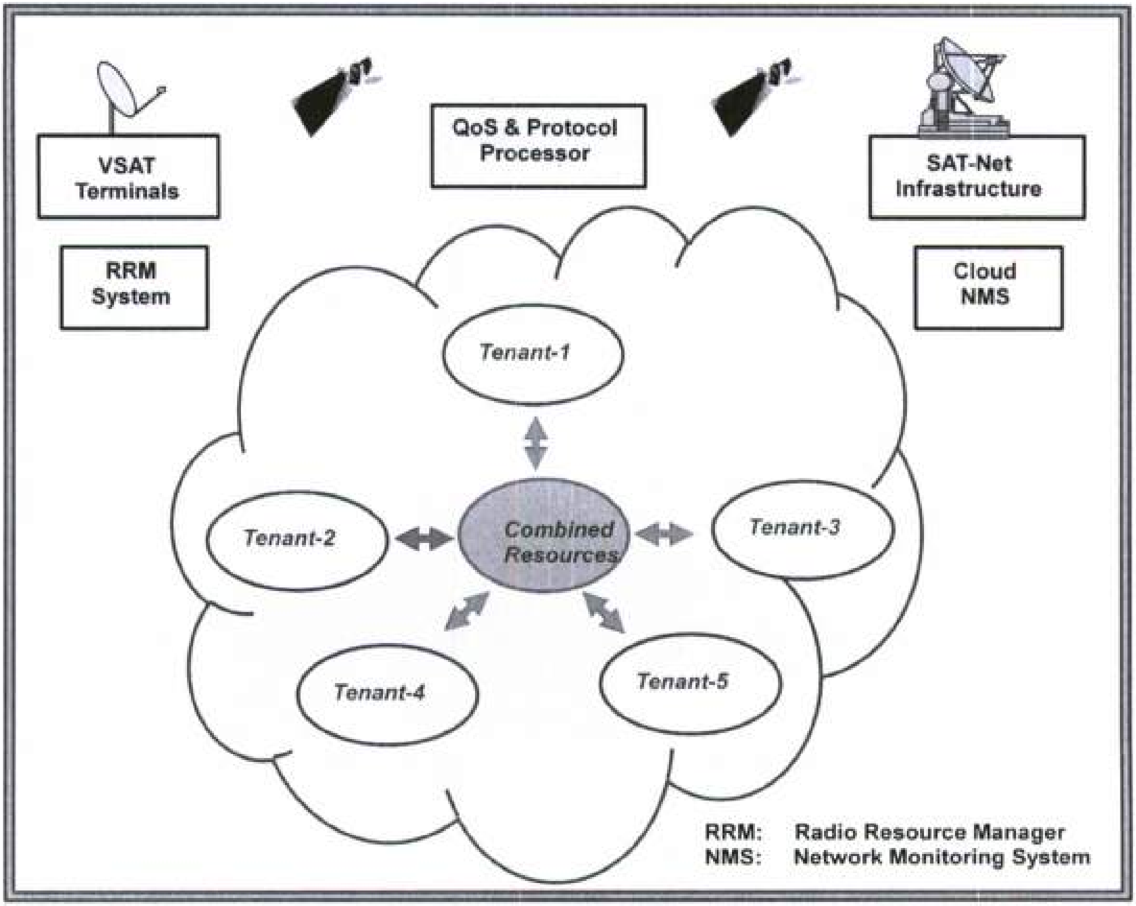


Figure-12, Cloud communications concept

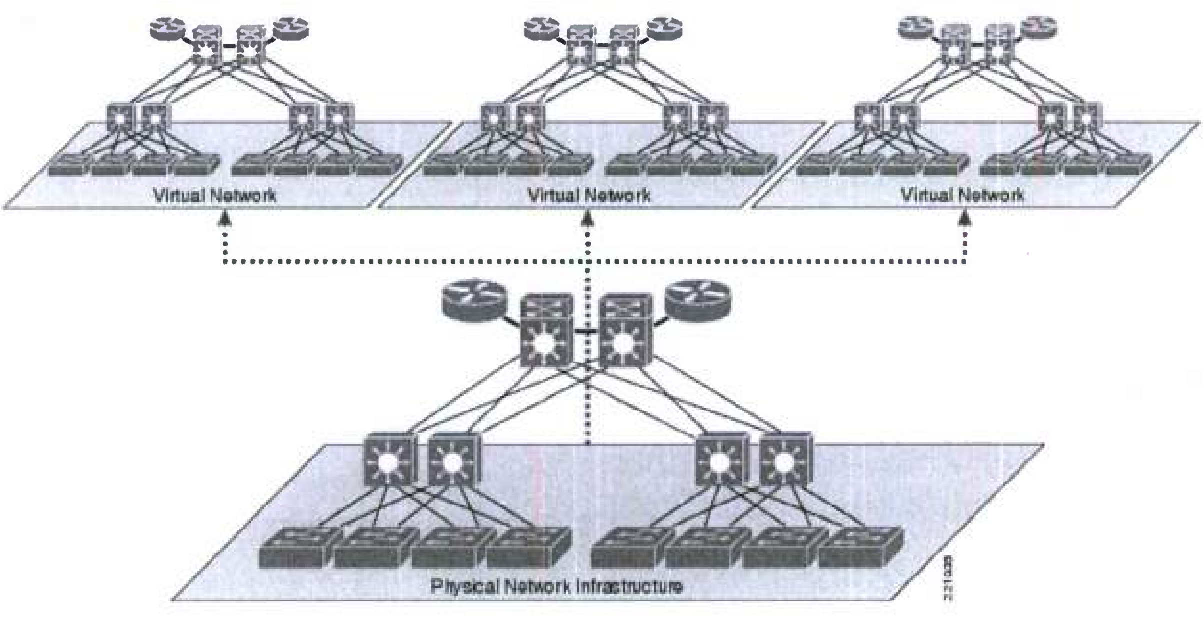
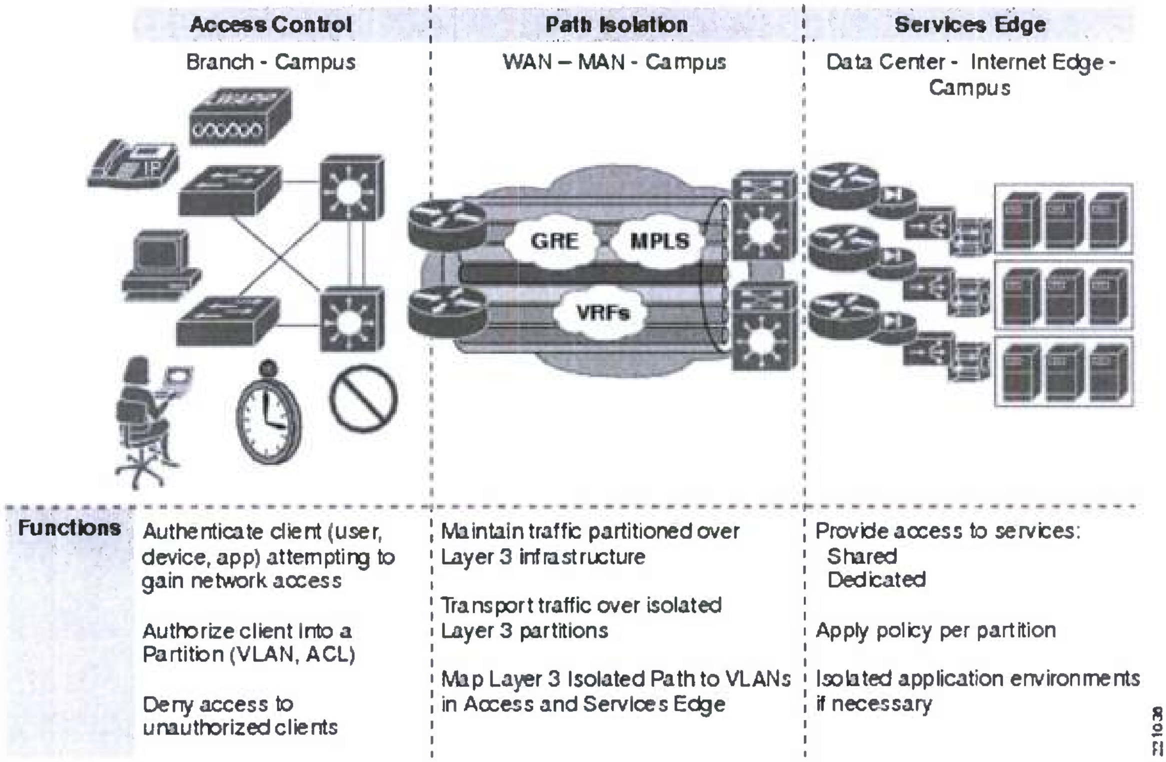


Figure-13, Network virtualization illustration (Cisco Networks)



1.1 Network Virtualization--Access Control - Cisco

Figure-14, Network virtualization functional areas (Cisco Networks)

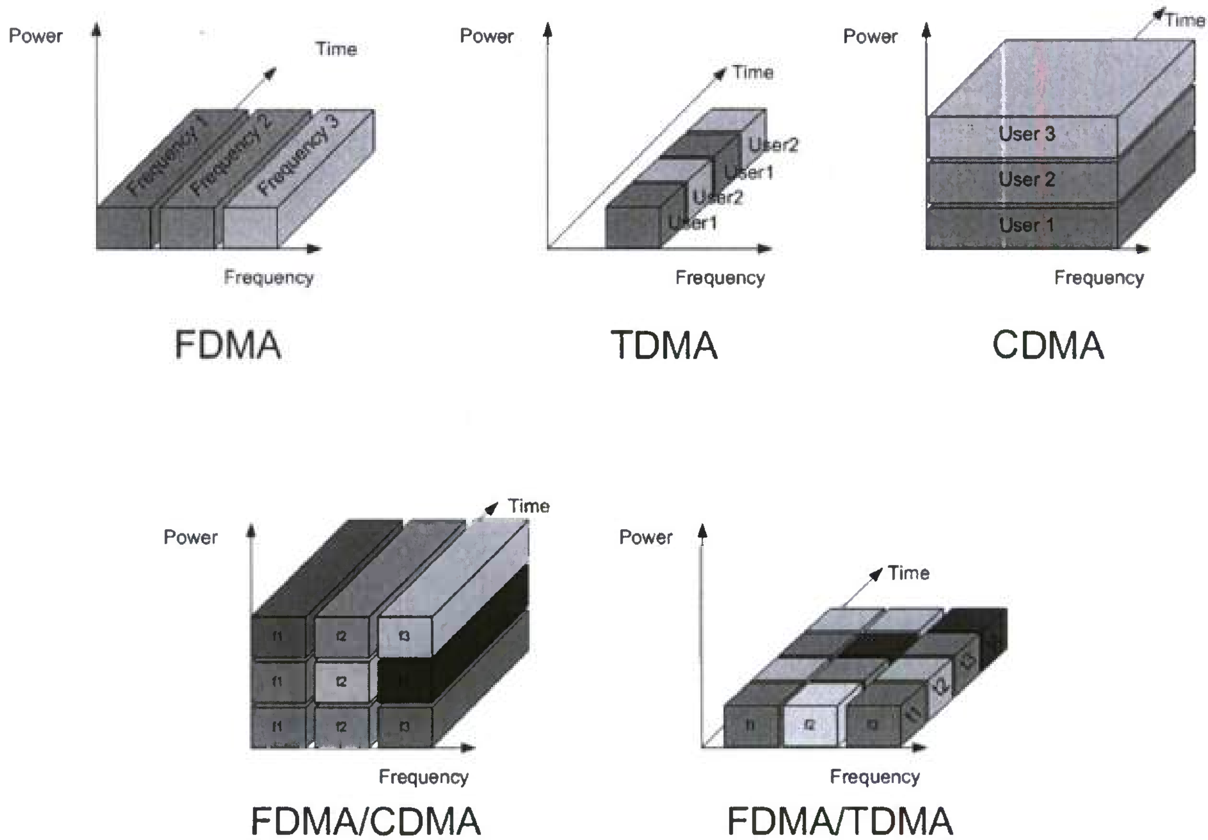


Figure-15, Access Methods Illustration

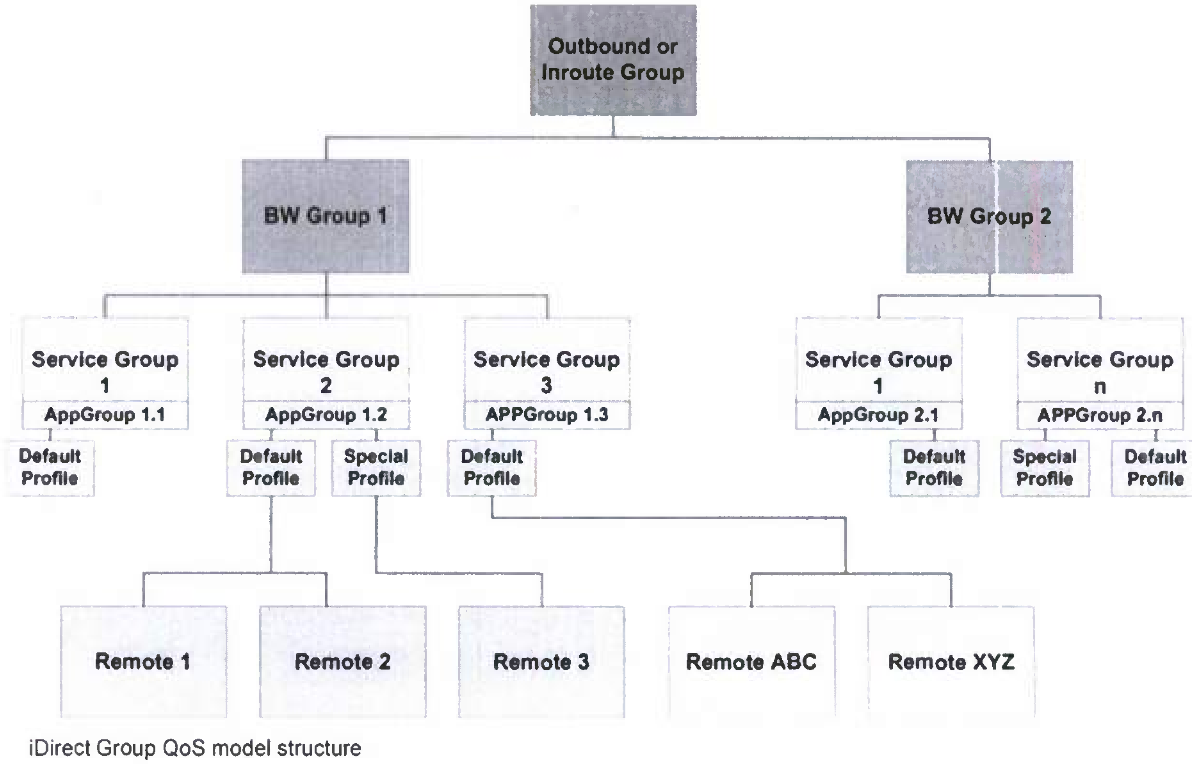


Figure-16, GQoS model structure illustration

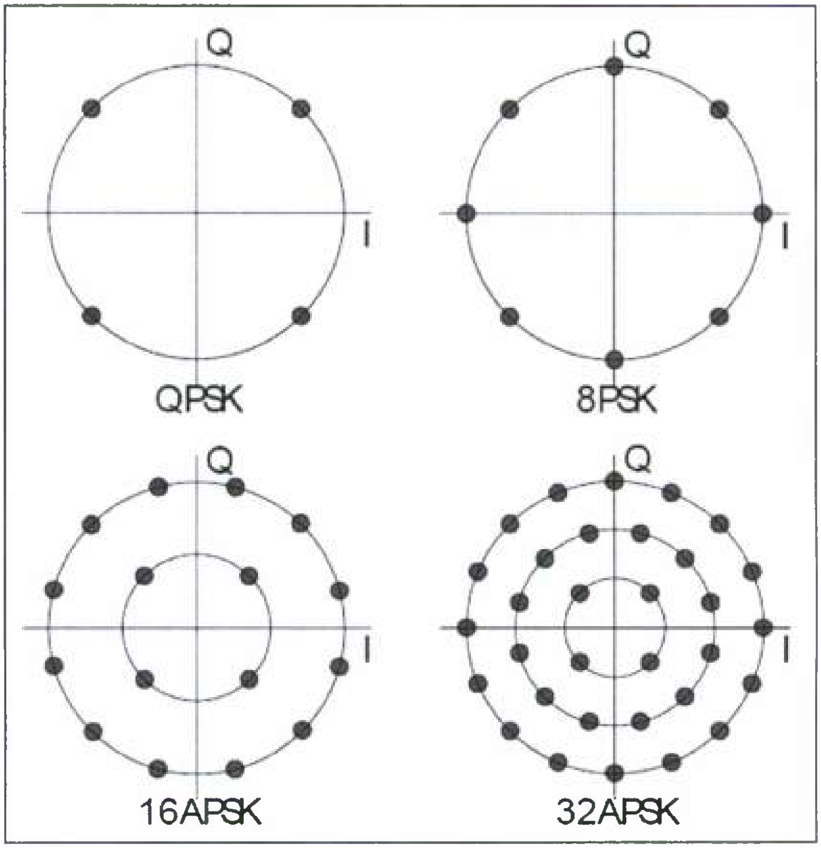


Figure-17, DVB-S2 Modulation Constellations

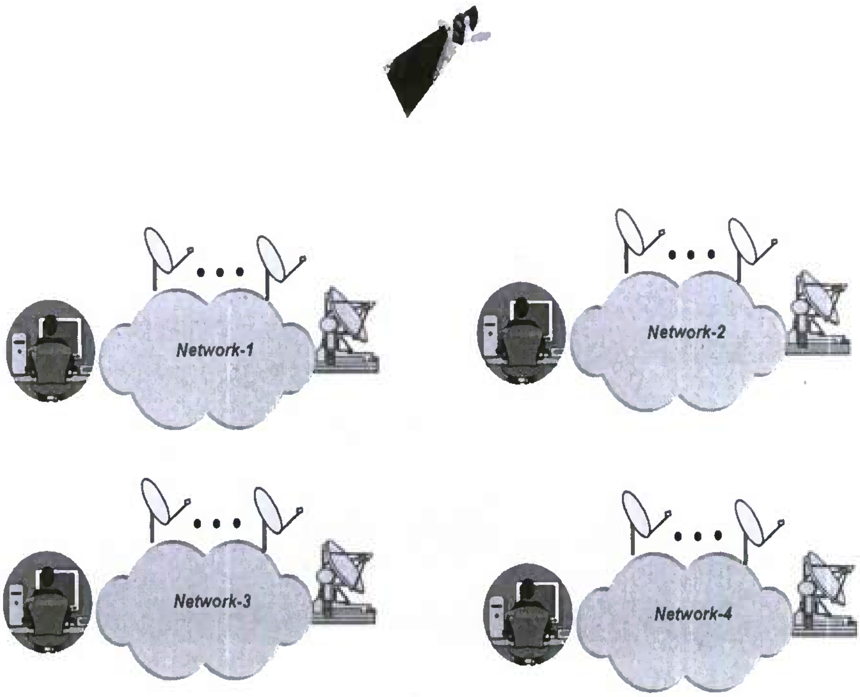


Figure-18, Legacy network model illustration

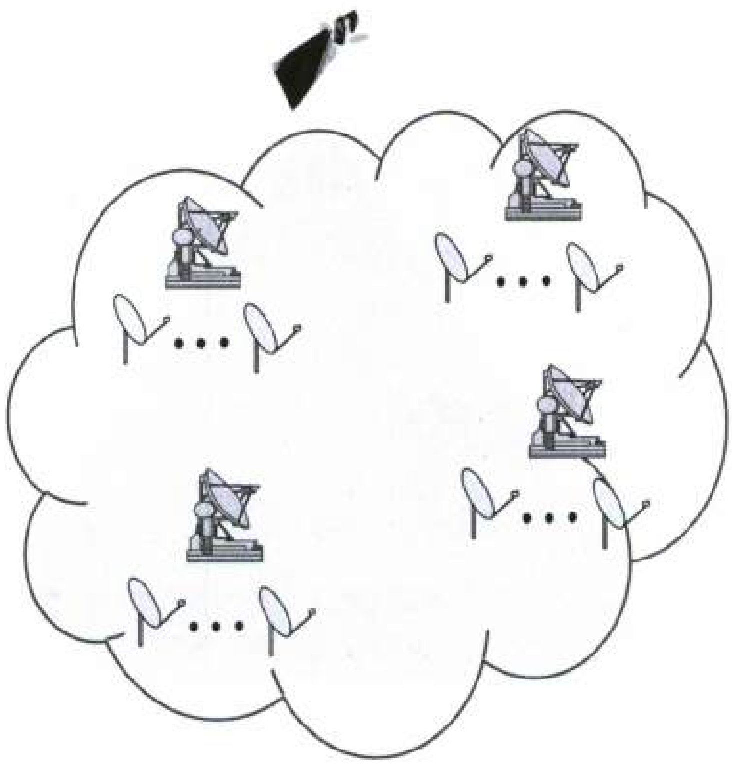


Figure-19, Cloud network model illustration

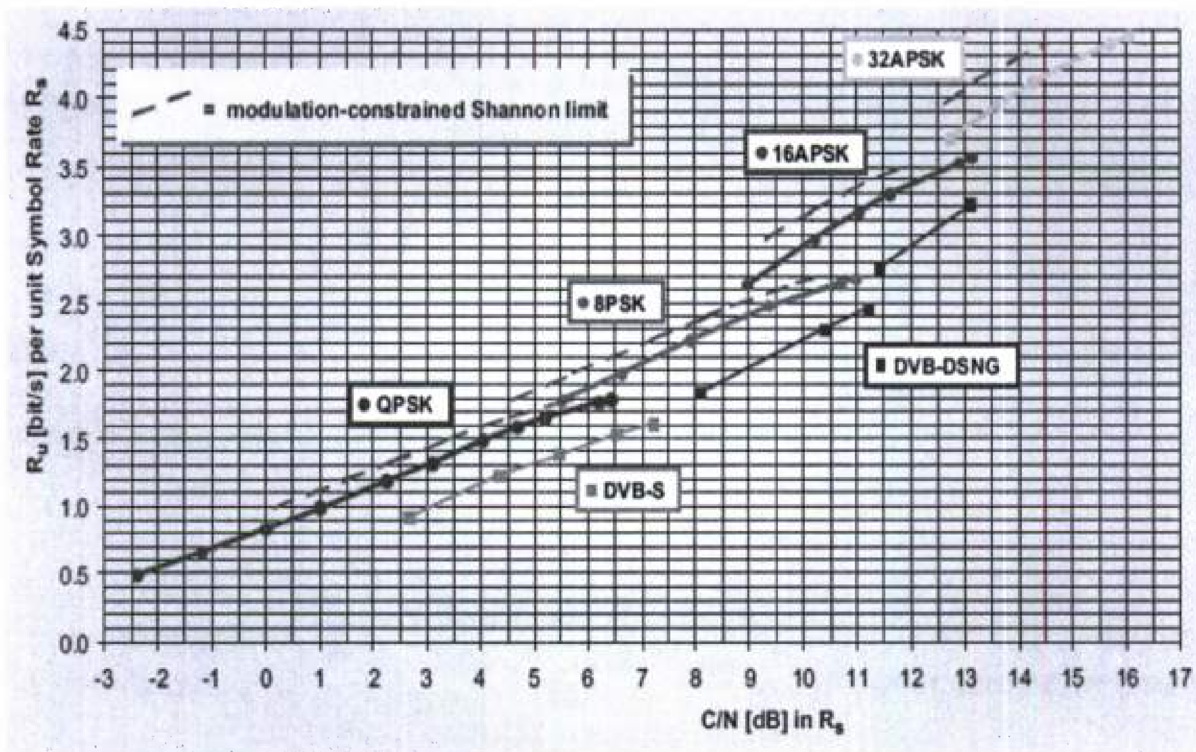
TABLES

FEC	QPSK	8PSK	16APSK	32APSK
1/4	✓	✗	✗	✗
1/3	✓	✗	✗	✗
2/5	✓	✗	✗	✗
1/2	✓	✗	✗	✗
3/5	✓	✓	✗	✗
2/3	✓	✓	✓	✗
3/4	✓	✓	✓	✓
4/5	✓	✗	✓	✓
5/6	✓	✓	✓	✓
8/9	✓	✓	✓	✓
9/10	✓	✓	✓	✓

Table-1, DVB-S2 FEC Rates

Modulation	Coding	Es/No dB *	Info Rate (Kbps)	Bit/Sym No Pilots
QPSK	3/4	4.30	43000	1.487472
QPSK	5/6	5.50	48000	1.654662
QPSK	8/9	6.60	51000	1.766451
8PSK	3/4	8.40	64000	2.228122
8PSK	5/6	9.70	72000	2.47856
8PSK	8/9	11.10	77000	2.646012

Table-2, DVB-S2 Throughput for 36 MHz Transponder



A. Morello and V. Mignone, EBU TECHNICAL REVIEW – October 2004

Table-3, DVB-S2 Spectrum efficiency versus required C/N on AWGN channel

Network Specifications		Notes
Number of networks	4	No disaster event correlation
Network Technology	SCPC DAMA	
Network topology	Star-mesh	
Satellite	SES-1 @ 101 Deg, West	
Links per network	15	Simultaneously, 15 terminals
Hub antenna size	4.5 meter	One hub Per network
Remote terminal antenna size	1.2 meter	
Network availability	99.5%	
Link Bit Error Rate (BER)	10E-7	
Outbound data rate/channel	1500 Kbps	
Outbound capacity per network	22.5 Mbps	
Inbound data rate/channel	1000 Kbps	
Inbound capacity per network	15 Mbps	
Total traffic per network	37.5 Mbps	Design capacity per network
Total network capacity	**150 Mbps**	**For all 4 networks**
Total outbound traffic	90 Mbps	All 4 networks
Total Inbound traffic	60 Mbps	
Outbound link modulation	QPSK	
Inbound link modulation	8PSK	
Outbound EFC coding Turbo	7/8 @ Eb/No = 4.60 dB	
Inbound FEC coding Turbo	7/8 @ Eb/No = 7.20 dB	
Bandwidth spacing factor	1.35	
Outbound channel bandwidth	1200 KHz	Rounded per industry practices
Inbound channel bandwidth	600KHz	Rounded per industry practices
Total required BW per network	27 MHz	15 links @ (1500X1000) Kbps
Total required BW	**108 MHz**	**For all 4 networks**

Table-4, Legacy networks specifications summary

Cloud network traffic specifications		**Notes**
Number of tenants (n)	4	With no disaster event correlation
Total outbound channels	60	15 per tenant
Outbound channel data rate	1500 Kbps	
Outbound traffic per tenant	22.5 Mbps	
Total outbound traffic, 4 tenants	90 Mbps	Before cloud network gain
Cloud network gain	75%	= (n-1)/n, n= number of tenants
Total outbound traffic, disastered tenant	22.50	Only one tenant at any given time
Outbound traffic, per non-disastered tenant	4.50 Mbps	@ 20% network capacity
Outbound traffic for all non-disastered tenant	13.50	Max 3 tenants
Cloud network disaster time outbound	**36.00**	**Maximum outbound traffic 4**
Total inbound channels	60	15 per network
Inbound channels data rate	1000 Kbps	
Inbound traffic per tenant	15 Mbps	
Total inbound traffic, 4 tenants	60 Mbps	Before cloud network gain
Cloud network gain	75%	= (n-1)/n, n= number of tenants
Total inbound traffic. disastered tenant	15 Mbps	Only one tenant at any given time
Inbound traffic, per non-disastered tenant	3.00 Mbps	@ 20% disaster time sharing factor
Inbound traffic fir all non-disastered tenants	9.00 Mbps	Max 3 tenants
Cloud network disaster time inbound	**24.00**	**Maximum inbound traffic 4**
Total Cloud network capacity	**60.00**	**For 4 tenants**

Table-5, Cloud network capacity estimate

Network Specifications		Notes
Number of networks	1 cloud network	
Network Technology	Intelligent cloud network	
Number of tenants	4	With secure partitioning
Network topology	Star-mesh	
Satellite	SES-1 @ 101 Deg, West	
Full duplex links per tenant	15	Simultaneously, 15 terminals
Hub antenna size	4.5 meter	One hub Per tenant
Remote terminal antenna size	1.2 meter	
Network availability	99.5%	
Minimum link Bit Error Rate (BER)	10E-7	
Transponder operation mode	Multicarrier	Inbound and outbound links
Transponder input backoff	7 dB	
Transponder output backoff	4 dB	
Outbound data rate/channel	1500 Kbps	
Outbound maximum traffic	36 Mbps	
Outbound transmission technology	DVB-S2	
Outbound link modulation	8PSK	dynamically adapting to network condition
Outbound link coding	¾	dynamically adapting to network condition
Required outbound Eb/No	5.02 dB	
Required outbound satellite capacity	**22.097 MHz**	
Inbound data rate/channel	1000 Kbps	
Inbound maximum traffic	24 Mbps	
Inbound transmission technology	Dynamic TDMA	
Number of inbound links	12	12 links @ 2 Mbps per link
Inbound link capacity	2 Mbps	
Inbound link modulation	8PSK	
Inbound link coding	4/5	
Required inbound Eb/No	7.9 dB	
Satellite capacity per link	1135 KHz	
Required inbound satellite capacity	**13.62 MHz**	
Total cloud network capacity	**35.75 MHz**	**Both for inbound and outbound**

Table-6, Link Analysis Summary

Network Attributes	**Legacy**	**Cloud**
Number of network	4	1
Number of hubs	4	4
Number of terminals per network	15	60
Total Satellite capacity (MHz)	108	36
Satellite capacity pricing per MHz ($)	4000	4000
Estimated Capital Cost Summary		
===		
Platforms	$400,000	$600,000
Satellite terminals	$90,000	$120,000
Civil work	$100,000	$100,000
Systems implementation	$80,000	$120,000
Remote terminals installation	$30,000	$30,000
	----------------	----------------
TOTAL:	**$700,000**	**$970,000**
Estimated Monthly Recurring Cost Summary		
===		
Transponder capacity	$432,000	$144,000
Hardware maintenance	$10,000	$12,000
Software maintenance	$5,000	$7,500
Overall operation (without staffing)	$4,000	$6,000
	----------------	----------------
TOTAL:	**$451,000**	**$169,500**

Table-7, Networks cost summary

CHAPTER 10

Project 09 13 F: Bridging the Gaps Between Public Health, the Health Care System, and First Responders

DEVELOPMENT OF THE UNIVERSITY CENTER FOR DISASTER PREPAREDNESS AND EMERGENCY RESPONSE (UCDPER)

Bridging the Gaps Between Public Health, the Health Care System, and First Responders

Project 09 13 F

Final Report

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Abstract

This project involved developing, conducting, and assessing education and training sessions pertaining to all-hazards health threats resulting in public health emergencies with the potential for mass casualties. Training sessions were in the table top exercise (TTX) model, targeting diverse multidisciplinary elements of emergency and disaster response in counties. Training and evaluation were performed in conjunction with federal, state, county, and local partners.

Three TTX were held, in different locations, on different topics, with varying participants: a hydrogen fluoride spill TTX in business, health care, and emergency response units in Gloucester County, NJ; a point of distribution (POD) Receipt, Stage, and Storage (RSS) warehouse operation TTX with county agencies health and first responders, and educational organizations, in Camden County NJ; and a mutual aid (MA)TTX with the Urban Area Security Initiative (UASI) group in the four county Capital District of New York State.

Foreword

This project was performed by George T. DiFerdinando, MD and was sponsored by the University Center for Disaster Preparedness and Emergency Response (UCDPER) - A Collaborative Initiative of Rutgers, The State University of New Jersey, UMDNJ-Robert Wood Johnson Medical School, and Robert Wood Johnson University Hospital - with support from Department of Defense Grant No. W9132T-10-1-0001.

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INTRODUCTION

Background

Prior to 9/11, civilian emergency response was often seen as the domain of emergency response professionals - those school in hazard and vulnerability analysis, emergency response and continuity of operations plans, and incident command system-based response to all hazards. However, the scope of both 9/11 and subsequent intentional (anthrax exposures, 2001) and 'natural' emergencies (Hurricane Katrina) continue to highlight a broader group of civilian, business, and, in some cases, military responders.

Thus, the scope of this project was to identify specific response needs within specific emergency scenarios and, with active participation of the broader responder group, create and then use exercise materials in the table top format, to improve readiness.

For the US Army, the impact of the problem is difficult to quantify, but real. Given the potential for Army involvement in catastrophic emergencies on US soil, as demonstrated by Hurricane Katrina, there exists some likelihood, however small, that the Army will need to work side-by-side during civilian response. However, it is likely that any event that brings US Army involvement on US soil will also be one that would have overwhelmed civilian and business response, making side-by-side response less of a reasonable scenario.

More valuable, perhaps, is the insight that review of such exercises might bring to how non-military parts of any society might work together in responding. Such insights might prove valuable both on US soil and during deployment abroad.

This project was led by the professional and support staff of the New Jersey Center for Public Health Preparedness at the University of Medicine and Dentistry of New Jersey (UMDNJ). Both the prior and current Center Directors -Glenn Paulson, Ph.D., and George DiFerdinando, MD, MPH, respectively - have direct experience responding to civilian emergencies during their tenures with New Jersey state government. Dr Paulson served as Assistant Commissioner at the NJ Department of Environmental Protection during the response to the Three Mile Island emergency in 1979; Dr. DiFerdinando was Acting Commissioner of the NJ Department of Health and Senior Services and thus led the public health response to 9/11 and the anthrax exposures in NJ, in 2001. Other key staff at the NJCPHP have had formal training in both health education and in developing, holding, and analyzing table top exercises (TTX).

Targeted users of this report and its associated work materials would be others charged with training civilian and business respondents through the use of TTX, either keyed to the content of the TTX developed or using these efforts as examples in which to model other content-based TTX .

Objective

The object of this activity was to identify areas of training need in the civilian, governmental, and business communities pertaining to all-hazards health threats that can result in public health emergencies with the potential for mass casualties; and developing, conducting, and assessing education and training sessions provided to diverse multidisciplinary elements of the emergency and disaster response personnel in counties. With the TTX developed from this activity, the knowledge, skills and attitudes of those trained would be enhanced, with the concrete potential of improving response under real emergency conditions, both with the hazard involved as well as in other hazard responses.

Approach

The pedagogical model of this project was twofold. Table top exercises are classified as discussion based exercises according to HSEEP. Discussion based exercises are less structured than a full scale exercise or drill and its primary benefit is to bring parties together to discuss and test a plan. All three exercises that were completed were tabletop exercises. TTX can be used as stepping stones towards a full scale or "live action" exercise in the future. Structurally, the table top exercise model was chosen for its documented ability to bring out both the strengths and weakness of those involved, during the exercise itself. The second, and in our opinion major, benefit of the TTX model is what occurs between and among participants during the preparation of the exercise, and the evaluation and after-action phases. 'Before and after' the TTX, participants work to clarify goals of the TTX, in light of known needs of competency/capability development within their respective organizations. The choice of the subject of the TTX, itself, requires knowledge of valid hazards and/or capability needs within the community; discussion and debate around the topic of the TTX typically initiates the process of team building among those representatives of the community to be exercised, long before the day of the formal TTX.

Similarly, the evaluation and after action process, ideally, allows the team members - now better known to each other - to review what happened, what it means, and what improved individual competencies, agency capabilities, and/or community resources will be needed to potentially improve the response exercised in the TTX, if it were to happen in real time.

For this group of exercises, we began with the insight and perceived need, explicit in the project title, that there are gaps between health care providers, first responders, and the public health community. Public health preparedness and emergency response is not the same as emergency management, in general. Based on the recently developed competencies for mid-level public health workers, there are many expectations of public health response that are distinct from traditional emergency management.

Participant identification in the project was done by first considering which groups we (NJCPHP) was targeting - public health, health care, first responders, etc. - and then direct outreach, by phone or in-person. Prior contacts of NJCPHP leadership and staff were called. The Gloucester Hydrogen Fluoride (HF) exercise (Addenda 01-08) developed from Dr. Paulson's knowledge of NJ chemical production facilities, and his outreach to members of that region on their perceived need to bring individuals together to enhance preparedness for a HF event. The

RSS (Addenda 09-11) and Mutual Aid (Addenda 12-15) exercises grew out of direct contacts with members of the NJ and NY public health community by Dr. DiFerdinando. Dr. DiFerdinando and a staff member, Ms. Rebecca Baron, attended the NJ Department of Health and Senior Services Training and Exercise Workshop, in December 2010. All NJ local health agencies were required to attend, as this meeting scheduled required training and exercises over the next two year cycle. Included in the meeting were staff from numerous NJ state departments - Health and Senior Services, Law and Public Safety, Environmental Protection, Military and Veterans Affairs, Community Affairs, and Transportation - along with the offices of Homeland Security and of Emergency Management. It is at this meeting that plans for the Camden TTX came together, along with the knowledge that both NJ and NYS UASI agencies were considering shared services trainings.

Once participants and topics were identified, Ms. Baron, working with Drs. Paulson and DiFerdinando, began the exercise development process. Ms. Baron has had extensive Homeland Security Exercise and Evaluation Program (HSEEP) training, and is HSEEP certified. HSEEP is a national standard for all exercises, and many agencies are either required or voluntarily choose to work within the HSEEP exercise rubric of capabilities. That the exercises developed were HSEEP compatible was a draw in and of itself for participation in the exercises developed.

The development process ranged in detail from a highly structured process for the HFEX/Gloucester exercise to a less structured process for the RSS/Camden and MA/Capital District UASI exercises. In the latter two, after the participants identified their needs, the great majority of development work was performed by NJCPHP staff, including performance of the TTXs. The HFEX/Gloucester exercised differed in the scientific subject matter mastery level needed, as exhibited in the detailed scenario (Addenda 03-04), to the number and 'rank' of participants, and the sheer logistics of a large group working at a business site.

The performance of the TTXs also varied by level of complexity. The HFEX/Gloucester exercise was more detailed, and was managed by a professional trainer with HF background, while the RSS and MA exercises were facilitated by Dr. DiFerdinando. The TTX exercises used both a SITMAN (situation manual) and Power Point slides to deliver the scenario to the participants. Attached in the addenda are the SITMANs (Addenda 01, 02, 09, 12, 13) and Power Point presentations (Addenda 03, 04, 10, 14) for the exercises.

All exercises included a formal evaluation process, including a 'hot wash' - immediate feedback between participants at the exercise location - and a written evaluation form to be completed and handed in for collation. The HSEEP process includes post exercise After Action Report (AAR) development, with sharing of that report with participants. All three AAR and evaluations have been completed, with the HFX evaluation (Addenda 05) and AAR (Addenda 06) attached.

Scope

The value of TTXs are often very dependent on an analysis of the specific strengths and needs of those involved in the training. Thus, it's likely that the appended TTX would be most valuable as *guides* to what would be used with other organizations, in other venues, rather than being used *'as is'.*

Mode of Technology Transfer

These materials could be used by Army users in creating TTXs for their own use, on location, based on their own analysis of local vulnerabilities. They also serve to provide Army users with a clearer view of the state of t local and regional civilian and business capabilities.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Three tabletop exercises, on three different, pertinent public health preparedness topics, were developed with participant identification, involvement in the process, and participation in the exercise and evaluation/After Action Report phase. The TTX included key public health, health care, and community responders, and ranged from an exposure focus (HFEX/Gloucester) to a materials management focus (RSS/Camden) to a personnel management focus (MA/Albany UASI District).

Based on feedback and AARs developed with the involved individuals and agencies, it is clear that the use of the TTX model can effectively bring together the often 'silo-ed' organizations that must combine to in emergency response. What is required is a topic that is of recognizable importance to the members of the community; involvement of those members in development of the exercise; overall, agencies feel that these exercises allow them to improve individual employee's competencies around specific hazards and/or activities; organizational capability to respond to those hazards and/or needs; and information to apply to current plans for continuous quality improvement. In following with the HSEEP model, the potential exists, at the community level, to build on these discussions based exercises into full-scale functional exercises.

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POC information for copyright clearances. None declared. All material in the public domain.

Addenda

Hydrogen Fluoride Exercise (HFEX)/Gloucester Materials

01 HFEX Facilitator's Situation Manual Final

02 HFEX Players' Manual Final

03 HFEX Scenario - Left Screen Presentation - Final

04 HFEX Scenario - Right Screen Presentation - Final

05 HFEX Evaluation Abstract - Final

06 HFEX After Action Report - Final

07 HFEX Steering Committee Members

08 HFEX Participant List

Receipt, Stage, and Storage (RSS)/Camden Materials

09 RSS Facilitator's Situation Manual

10 RSS Scenario Presentation

11 RSS Participant Feedback Form

Mutual Aid (MA)/Albany UASI Materials

12 MA Facilitator's Situation Manual

13 MA Players' Situation Manual

14 MA Scenario Presentation

15 MA Participant Feedback Form

Situation Manual

HFEX-Hydrogen Fluoride Exercise

Exercise Date: 05/25/2010

FACILITATOR

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Preface

The HFEX is sponsored by the New Jersey Center for Public Health Preparedness (NJCPHP). This Situation Manual (SitMan) was produced with input, advice, and assistance from the HFEX Steering Committee, which followed guidance set forth by the U.S. Department of Homeland Security (DHS) Homeland Security Exercise and Evaluation Program (HSEEP).

The HFEX Situation Manual (SitMan) provides exercise participants with all the necessary tools for their roles in the exercise. It is tangible evidence of Gloucester County's commitment to ensure public safety through collaborative partnerships that will prepare it to respond to any emergency.

The HFEX is an unclassified exercise. Control of exercise information is based on public sensitivity regarding the nature of the exercise rather than actual exercise content. Some exercise material is intended for the exclusive use of exercise planners, facilitators, and evaluators, but players may view other materials that are necessary to their performance. All exercise participants may view the SitMan.

All exercise participants should use appropriate guidelines to ensure proper control of information within their areas of expertise and protect this material in accordance with current jurisdictional directives. Public release of exercise materials to third parties is at the discretion of the DHS and the HFEX Steering Committee.

HANDLING INSTRUCTIONS

The title of this document is the HFEX- Hydrogen Fluoride Exercise Situation Manual (SitMan).

For more information about the exercise, please consult the following point of contact:

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INTRODUCTION

Background

An incident involving release of hydrogen fluoride (HF) presents unique challenges to the community because of its specific chemical and physical properties and the potential to cause serious harm to human health. Gloucester County in southern New Jersey (NJ) is the location of industrial facilities that store and use significant quantities of HF which is transported to the facilities via rail or tractor-trailer. This presents a potential hazard to the Gloucester County community and it is imperative that all partners in emergency response are aware of the specialized medical treatment required for HF exposures. HF is unique in that the onset of symptoms is often delayed. Symptoms include severe burns, inhalation hazards, and systemic toxicity. As important as the medical treatment is the leadership on the county and local level and the ability to effectively respond to the incident. Recent incidents in our region and across the country reinforce the need for this initiative. March 2009 in Wind Gap, Pennsylvania, a tractor-trailer carrying 33,000 pounds of hydrofluoric acid flipped over on a highway while trying to avoid a deer. The subsequent leak was contained by state and local HAZMAT teams. Approximately 5,000 residents were evacuated and the highway was closed. In January 2005, outside of Pittsburgh, Pennsylvania, a train car filled with anhydrous hydrogen fluoride derailed into the Allegheny River and released its contents.

Purpose

The purpose of this tabletop exercise (TTX) is to provide participants with an opportunity to evaluate their current emergency response plans and capabilities for a response to an HF incident in Gloucester County. The exercise will focus on key local and county capabilities in both external and internal communication, coordination, and critical decision-making.

Scope

The scenario for the exercise will be a transportation incident involving a tractor-trailer carrying HF. No specific Gloucester County industrial facility will be named or implicated in the exercise. The exercise will focus on specific issues associated with a release of HF and will be specifically aimed at hospital, public health, and first responder coordination of the incident. The emphasis will be on coordination, problem identification, and problem resolution. Decontamination issues will be covered, but the primary focus will be on response to and management of the incident.

Target Capabilities

The National Planning Scenarios and establishment of the National Preparedness Priorities have steered the focus of homeland security toward a capabilities-based planning approach. Capabilities-based planning focuses on planning under uncertainty because the next danger or disaster can never be forecast with complete accuracy. Therefore, capabilities-based planning takes an all-hazards approach to planning and preparation that builds capabilities that can be applied to a wide variety of incidents. States and urban areas use capabilities-based planning to identify a baseline assessment of their homeland security efforts by comparing their current capabilities against the Target Capabilities List (TCL) and the critical tasks of the Universal Task

List (UTL). This approach identifies gaps in current capabilities and focuses efforts on identifying and developing priority capabilities and tasks for the jurisdiction. These priority capabilities are articulated in the jurisdiction's homeland security strategy and Multiyear Training and Exercise Plan, of which this exercise is a component.

The capabilities listed here have been selected by the HFEX Steering Committee from the priority capabilities identified in Gloucester County's Multiyear Training and Exercise Plan. These capabilities provide the foundation for development of the exercise design objectives and scenario. The purpose of this exercise is to measure and validate performance of these capabilities and their associated critical tasks. The selected target capabilities are:

- Emergency Operations Center (EOC) Management
- Responder Safety and Health
- HazMat Response and Decontamination
- Citizen Evacuation and/or Shelter-in-Place
- Emergency Triage and Pre-Hospital Treatment
- Medical Surge
- Mass Care (Sheltering, Feeding, and Related Services)

Exercise Design Objectives

Exercise design objectives focus on improving understanding of a response concept, identifying opportunities or problems, and achieving a change in attitude. This exercise will focus on the following design objectives selected by the HFEX Steering Committee:

1. Assess and identify how to activate and maintain emergency communications essential to support response to an HF incident in Gloucester County.

2. Demonstrate the ability to alert, mobilize, and activate personnel for emergency response and maintain operations until the situation is brought under control.

3. Demonstrate the ability to mobilize and track equipment, people, and other resources in support of emergency operations.

4. Identify and implement appropriate actions to protect emergency workers and the public.

5. Demonstrate inter-agency (Gloucester County Health Department, hospitals, and first responders) communication and cooperation in response to an HF incident in Gloucester County.

Participants

- **Players.** Players respond to the situation presented, based on expert knowledge of response procedures, current plans and procedures, and insights derived from training.
- **Facilitators.** Facilitators provide situation updates and moderate discussions. They also provide additional information or resolve questions as required. Key Exercise Planning

Team members also may assist with facilitation as subject matter experts (SMEs) during the TTX.

- **Evaluators.** Evaluators observe and record the discussions during the exercise, participate in the data analysis, and assist in drafting the after-action report. (AAR)
- **Subject Matter Experts (SME):** SME are similar in role to an observer but may be asked by participants specific questions about their agencies, policies, or area of expertise.
- **Observers.** Observers are not participants in the moderated discussion, they only observe.

Exercise Structure

This tabletop exercise (TTX) will be a facilitated exercise with a multimedia presentation. Players will participate at different times in the event response. At different points in the response, there will be a multimedia update that summarizes key events occurring within that time period. After the updates, participants will engage in a facilitated group discussion of appropriate response issues and subsequent actions based on the scenario.

Exercise Guidelines

- This TTX will be held in an open, low-stress, no-fault environment. Varying viewpoints, even disagreements, are expected.
- Respond on the basis of your knowledge of current plans and capabilities (i.e., you may use only existing assets) and insights derived from your training.
- Decisions are not precedent setting and may not reflect your organization's final position on a given issue. This exercise is an opportunity to discuss and present multiple options and possible solutions.
- Issue identification is not as valuable as suggestions and recommended actions that could improve response and preparedness efforts. Problem-solving efforts should be the focus.

Assumptions and Artificialities

In any exercise, assumptions and artificialities may be necessary to complete play in the time allotted. During this exercise, the following apply:

- The scenario is plausible, and events occur as they are presented.
- There is no hidden agenda, and there are no trick questions.
- All players receive information at the same time.

SCENARIO PART 1

May 25, 2010: 11:00 am 0 Hour

A tank truck exits Interstate 295 northbound at exit 18 in East Greenwich, NJ next to the truck stop approaching Facility X. It is a sunny day and the temperature is 60 degrees with a 5 mph wind blowing from the northwest. The driver of the tank truck swerves and overturns on the exit ramp. A bystander calls 9-1-1 to report the overturned truck. Motorists are attempting to drive through the accident area while gawking at the accident causing a back up of traffic. The truck stop at the exit is busy with truckers and other patrons.

Injects:

- *The 9-1-1 dispatcher dispatches police, fire, and emergency medical services (EMS) to the scene.*

- *A white dense vapor with a pungent odor is coming from the tank truck.*

May 25, 2010: 11:10 am +10 minutes

The tank truck has a UN 1052 label and placards indicating corrosive and poison. The truck driver is unconscious. People from the truck stop and nearby businesses have been gathering near the accident to see what is happening. Cars are lined up at the exit ramp attempting in vain to get by.

Injects:

- *Bystanders at the truck stop have eye irritation, difficulty breathing and nausea.*
- *A few of the spectators have collapsed.*

Key Issues

- Traffic congestions limiting movement of emergency vehicles.
- Unknown condition of truck driver,
- Substance leaking from tanker not identified.
- Large numbers of people in the nearby surrounding area.
- Reports of minor physical irritations of people exposed in the area of the accident.

Discussion Questions

Based on the information provided, participate in the discussion concerning the issues raised. Identify any additional requirements, critical issues, decisions, or questions that should be addressed at this time.

The following questions are provided as suggested general subjects that you may wish to address as the discussion progresses. These questions are not meant to constitute a definitive list of concerns to be addressed, nor is there a requirement to address every question.

Law Enforcement

- At this stage of the response, what is the role of local law enforcement?
- What actions would you take at this point? What are your priority action items at this point in the response?
- What, if any, additional local resources would you request at this time?
- What are your perimeter and security concerns? How will these concerns be addressed? What steps will be taken, and what resources will be required?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?

Fire

- At this stage of the response, what is the role of the fire departments present?
- What actions would your agency take at this point? What are your priority action items at this point in the response?
- What, if any, additional local resources would you request at this time?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?

Emergency Medical Services

- At this stage of the response, what is the role of EMS?
- What actions would you take at this point? What are your priority action items at this point in the response?
- What are your communication procedures at this point in the response?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?
- What, if any, additional local resources would you request at this time?

Hospitals

- At this stage of the response, what is the role of the hospitals?
- What actions would you take at this point? What are your priority action items at this point in the response?
- What are your communication procedures at this point in the response?
- Is HF identified in the hospital hazard vulnerability analysis? If so, where is it on the list?

Emergency Management

- Who is the Incident Commander? Which jurisdiction? Where is the command post? Where is the staging area?
- At this point in the response, what notifications would have been made, and by whom? How would State agencies be notified of the situation?
- What mutual aid agreements (MAAs) or memorandums of understanding (MOUs) do you currently have in place that could be used for this response? Would mutual aid be requested at this point? If so, from whom?
- What are your primary safety concerns for citizens and first responders? What steps should be taken to address these safety concerns? What resources may be required?

Scenario Part 2

May 25, 2010: 11:30 am +30 minutes

The tanker truck is continuing to expel a white vapor with a strong, irritating odor and it is moving with the prevailing winds.

Injects:

- *The 9-1-1 call center has received a call from inside the truck stop (450 feet downwind) that there are approximately 30 people outside on the ground and unresponsive. Of the people inside, about twenty have difficulty breathing, are experiencing burns on their skin, eyes, and in their noses and mouths. Other people inside are also vomiting and collapsing.*
- *At East Coast Transportation Logistics, 900 feet downwind, the people gathered outside have difficulty breathing and are also experiencing eye and skin irritation.*
- *Five residents from Maple Avenue, further downwind, have called 9-1-1 reporting mild eye irritations and a strong chemical odor.*

May 25, 2010: 11:45 am +45 minutes

The Gloucester County Hazardous Materials (HazMat) Response Team arrives on the scene.

Inject:

- *HazMat team is on the scene, and the plume models are available.*

Key Issues:
- Increasing numbers of people expressing common symptoms.
- Downwind range effect seems to be increasing.
- Anyone exposed at the outset is now non-ambulatory and unresponsive.
- Hazardous substance still leaking from tankers valve line.
- 9-1-1 calls are being made from people further down wind of the accident.

Discussion Questions

Based on the information provided, participate in the discussion concerning the issues raised. Identify any additional requirements, critical issues, decisions, or questions that should be addressed at this time.

The following questions are provided as suggested general subjects that you may wish to address as the discussion progresses. These questions are not meant to constitute a definitive list of concerns to be addressed, nor is there a requirement to address every question in this section.

Law Enforcement

- What are your perimeter and security concerns at this point in the incident?
- What role does your agency have in facilitating an orderly evacuation of the area?
- What actions could be taken to improve the current situation and ensure that all responders have access to the site and that EMS has an unobstructed path to area hospitals?
- What are your priority action items for consideration at this point in the incident?
- What challenges are you facing?

Fire

- What are your priority action items for consideration at this point in the incident?
- As additional resources arrive for this incident, where could you stage these assets?
- What is the status of your communications?
- What challenges are you facing?

Emergency Medical Services

- What are your priority action items for consideration at this point in the incident?
- What are your staging, triage and medical treatment concerns at this point?
- What are your transportation concerns at this point? Where are you transporting patients to?
- What are your communication procedures with the health care facilities?
- What challenges are you facing?
- What are the decontamination concerns with the transport of patients?

Hospitals

- What are your priority action items for consideration at this point in the incident?
- Hospital emergency operations plans?
- What are your staffing concerns at this point?

- What are your decontamination and treatment concerns at this point? Do you have the necessary medications on site for HF treatment? If not, where is it available?
- What challenges are you facing?

Emergency Management

- Would the Emergency Operations Center (EOC) be activated at this point? If so, what is the activation process, and how long would it take?
- Would individual local agency EOCs or command centers be activated? If so, what is the activation process, and how long would it take? How would these various entities communicate?
- How is the Emergency Operations Center (EOC) staffed at this point in the incident?
- How would you prepare to staff for a possible extended activation? Are your current staffing protocols sufficient to support extended activation? If not, how might this situation be remedied?
- What are the priority action items for consideration at this point in the incident?
- What other agencies have been notified at this point in the response? What roles will these agencies fulfill?
- What challenges are you facing?
- Do you anticipate any State or Federal resources arriving or being assigned to this incident? If so, what issues regarding receipt, acceptance, tracking, management, and integration of State and Federal resources need to be considered?
- Who has the authority to order an evacuation? How large an area would you evacuate? What plans are in place to facilitate an evacuation?
- Is Facility X contacted? What information can they provide regarding the chemical and medical concerns?

HazMat

- What is the status of HazMat? When does the assessment team arrive?
- What are the priority action items for consideration at this point in the incident?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?
- What are your site management and control concerns?
- How will you coordinate information management and resource coordination?
- What challenges are you facing?

Mass Care

- What areas are being affected by the plume? What are the primary safety concerns for these areas?
- What are the decisions surrounding evacuation? What are the first considerations? Who will make the decision to evacuate or shelter in place?
- Who is responsible and will provide mass care services and resources to the shelter population?
- Have designated shelter sites been pre-established? How would the shelters be staffed?
- What challenges are you facing?

Health Department

- Is anyone checking the special needs registry?
- What is your role in citizen evacuation/shelter in place?
- What are your concerns regarding evacuation?
- What are your communication concerns at this point in the response?

SCENARIO PART 3

May 25, 2010: 12:00 pm +60 minutes

HF is still leaking from the tanker and plume modeling has shown a down wind effect of up to 1.2 miles from the release site. At this time, both the indoor and outdoor concentrations at the truck stop are above the Acute Exposure Guideline Level (AEGL)-3. Above the AEGL-3 any concentration is life threatening.

Injects:

- *Everyone at the truck stop is unresponsive.*
- *The outdoor concentration at the East Coast Transportation Logistics has also reached the AEGL-3 and people outside are unresponsive.*
- *The indoor concentration is below AEGL-2, indicating that exposed people will have long-lasting adverse health effects and/or an impaired ability to escape.*
- *More residents from Maple Ave, 1700 feet downwind, are calling 9-1-1 with more serious complaints of eye and skin irritation, mild nausea, and strong odors. Similar calls are coming in from residents on Whiskey Mill and Landing Roads, further downwind.*
- *EMS has transported a total of 20 patients to local hospitals.*
- *The local hospitals have reported that anywhere from 10 to 20 people have arrived on their own to the emergency departments. They are not yet sure of their condition and could be among the worried well.*
- *9-1-1 is getting calls from neighborhood homes about whether to shelter in place or to evacuate.*

Key Issues:

- HazMat is on scene however the leak still continues.
- Acute Exposure Guideline Levels are increasing which will increase exposure and debilitation of those exposed.
- Range of exposure downwind is now at 1.2 miles from the accident site.
- 9-1-1 calls still being made downwind of the incident.
- Numbers of patients transported to hospitals is increasing and currently at 20.
- Hospitals are concerned about the worried well arriving at the emergency departments.

Questions

Based on the information provided, participate in the discussion concerning the issues raised. Identify any additional requirements, critical issues, decisions, or questions that should be addressed at this time.

The following questions are provided as suggested general subjects that you may wish to address as the discussion progresses. These questions are not meant to constitute a definitive list of concerns to be addressed, nor is there a requirement to address every question in this section.

Law Enforcement

- What are your short- and long-term personnel needs for site security and the ongoing incident investigation? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required for these operations in the short and long terms?
- What are your long-term perimeter and security plans? How long do you expect to have to maintain a presence at the scene?
- What are your priority action items at this point?
- What challenges are you facing?

Fire

- What are your short- and long-term personnel needs for the ongoing operations? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required for these operations in the short and long terms?
- What are your priority action items at this point?
- What challenges are you facing?

HazMat

- What are your short- and long-term personnel needs for the ongoing search and rescue operations? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required to support these operations in the short and long terms?
- What are your priority action items at this point?

- What challenges are you facing?

Emergency Management

- What are your long-term staffing and support plans for your Emergency Operations Center (EOC) or agency? Do you currently have enough personnel to meet these needs? If not, how might they be obtained?
- What are your priority action items at this point?

Emergency Medical Services

- What are your short- and long-term personnel needs for ongoing medical treatment on site? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required to support these operations in the short and long terms?
- How long do you expect to have to maintain a presence at the scene?
- What are your priority action items at this point?
- What challenges are you facing?

Hospitals

- What are your priority action items at this point?
- What are your short- and long-term personnel needs for ongoing decontamination and medical treatment? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What are your bed surge procedures?
- What consideration has been given to the handling of the worried well?
- What challenges are you facing?
- What is the surge procedure for the hospitals?

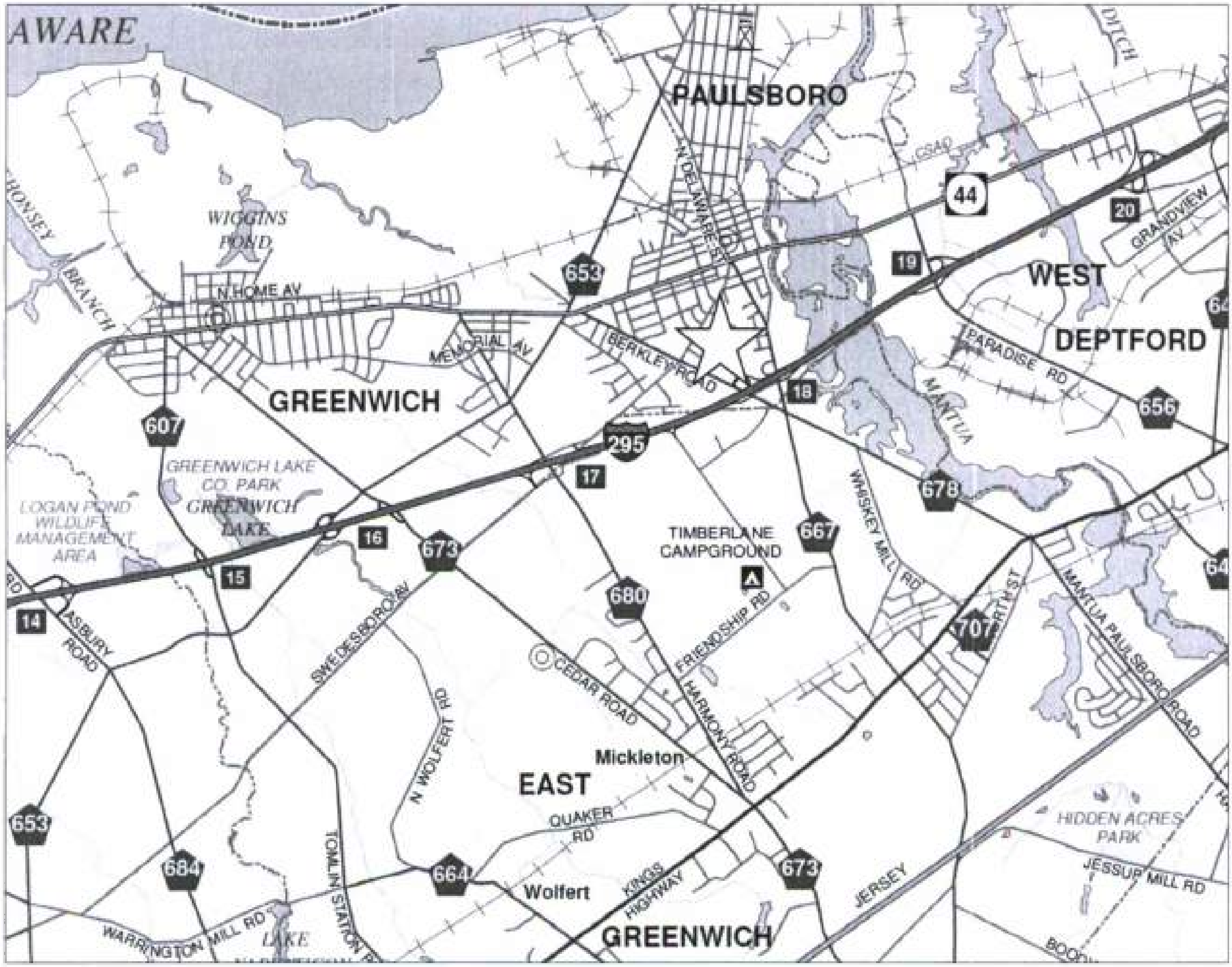
Health Department

- Special needs?
- What are your concerns regarding safety and sanitation within the shelters?
- What are the short and long term environmental concerns? What consideration should be given to nearby waterways?
- Special needs registry?

Mass Care

- What are your short- and long-term personnel needs for ongoing shelter operations? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- How long will this be open?
- How many more people can be expected?

APPENDIX A: AREA MAP



APPENDIX B: ACUTE EXPOSURE GUIDELINE LEVELS (AEGLS)

AEGLs represent threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from 10 minutes to 8 hours. AEGL-2 and AEGL-3, and AEGL-1 values as appropriate, will be developed for each of five exposure periods (10 and 30 minutes, 1 hour, 4 hours, and 8 hours) and will be distinguished by varying degrees of severity of toxic effects. It is believed that the recommended exposure levels are applicable to the general population including infants and children, and other individuals who may be susceptible. The three AEGLs have been defined as follows:

AEGL-1 is the airborne concentration, expressed as parts per million or milligrams per cubic meter (ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Airborne concentrations below the AEGL-1 represent exposure levels that can produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, nonsensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL.

APPENDIX C: HYDROGEN FLUORIDE FACT SHEET

Right to Know Hazardous Substance Fact Sheet

Emergency Responders Quick Reference

Common Name: **HYDROGEN FLUORIDE**

Synonyms: Fluoric Acid; HFA
CAS No: 7664-39-3
Molecular Formula: HF
RTK Substance No: 3759
Description: Colorless, fuming liquid or gas

HAZARD DATA

Hazard Rating	Firefighting	Reactivity
4 - Health **0 - Fire** **1 - Reactivity** **DOT#:** UN 1052 **ERG Guide #:** 125 **Hazard Class:** 8 (Corrosiva)	**Hydrogen Fluoride** is a noncombustible liquid or gas. Extinguish fire using en agent suitable for type of surrounding fire. POISONOUS GASES ARE PRODUCED IN FIRE, including *Fluorine*. Use water spray to keep fire exposed containers cool.	**Hydrogen Fluoride** reacts violently with STRONG BASES (such as SODIUM HYDROXIDE and POTASSIUM HYDROXIDE) and many other compounds. **Hydrogen Fluoride** reacts with WATER and STEAM to produce *toxic* and *corrosive gases*. **Hydrogen Fluoride** reacts with METALS (such as IRON and STEEL) to produce flammable and explosive *Hydrogen gas*. **Hydrogen Fluoride** is not compatible with OXIDIZING AGENTS (such as PERCHLORATES, PEROXIDE, PERMANGANATES, CHLORATES, NITRATES, CHLORINE, BROMINE and FLUORINE); STRONG ACIDS (such es HYDROCHLORIC, SULFURIC and NITRIC); AMINES; METAL SALTS; and SILICON COMPOUNDS.

SPILL/LEAKS

Isolation Distance:

Spill: 100 meters (330 feet)
Fire: 1,600 meters (1 mile)

If e ges laek, evacuate area end stop flow of ges. If source of leak is a cylindar and tha laak cannot ba stoppad in place, ramove tha leaking cylindar to a safa placa in tha opan air, and repair leak or allow cylinder to ampty.

If a liquid spill, allow to vaporiza end dispersa, or covar with sodium carbonata or an aqual mixtura of soda ash and slaked lima.

Water spray can be used to absorb **Hydrogen Fluoride** vapors escaping from leeking containers of *anhydrous* **Hydrogen Fluoride**. Usa water in flooding quantitias.

PHYSICAL PROPERTIES

Odor Threshold:	0.04 ppm
Flash Point:	Nonflammable
Vapor Density:	0.7 (air = 1)
Vapor Pressure:	760 mm Hg at 68°F (20°C)
Specific Gravity:	0.99 (water = 1)
Water Solubility:	Miscible
Boiling Point:	67°F (19.4°C)
Freezing Point:	-117.4°F (-83°C)
Ionization Potential:	15.98 eV
Molecular Weight:	20.1

EXPOSURE LIMITS

ACGIH: 0.5 ppm, 8-hr TWA; 2 ppm, Ceiling
IDLH: 30 ppm

The Protective Action Criterie values ere:

PAC-1 = 1 ppm PAC-3 = 44 ppm
PAC-2 = 24 ppm

PROTECTIVE EQUIPMENT

Gloves:	Barrier® (>8-hr breakthrough)
Coveralls:	Tychem® Responder® and TK; end Trellchem HPS (>8-hr breakthrough)
Respirator:	SCBA

HEALTH EFFECTS

Eyes:	Severe irritation, burns and possible eye damage
Skin:	Irritation end severe burns
Inhelation:	Nose, throat end lung irritation with coughing, end severe shortness of breath (pulmonary edema) Headache, dizziness, weakness, end convulsions

FIRST AID AND DECONTAMINATION

Remove the person from exposure.

Flush eyes with large amounts of water for at least 30 minutes. Remove contact lenses if worn. Seek medical ettention immediately.

Immediately flush with large amounts of water. Apply 2.5% *Celcium Gluconete* gel to the affected skin. Seek medical assistance immediately.

Begin artificial respiration if breathing hes stopped and CPR if necessary.

Transfer promptly to a medical feclity.

Medical observation is recommended es symptoms may be delayed.

HOT WASH GUIDE

The facilitators of the HFEX will run the "hot wash" after the TTX. The hot wash will be an unstructured discussion for the players only. Evaluators will submit their comments to lead evaluator and observers will be able to comment on the participant feedback form. Below are the talking points for the hot wash.

- Overall thoughts/comments
- Strengths
- Areas that need improvement

Situation Manual

HFEX- Hydrogen Fluoride Exercise

Exercise Date : 05/25/2010

Steering Committee

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New Jersey Department of Health and Senior Services
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New Jersey Department of Environmental Protection
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Gloucester County Department of Health and Senior Services

PREFACE

The HFEX is sponsored by the New Jersey Center for Public Health Preparedness (NJCPHP). This Situation Manual (SitMan) was produced with input, advice, and assistance from the HFEX Steering Committee, which followed guidance set forth by the U.S. Department of Homeland Security (DHS) Homeland Security Exercise and Evaluation Program (HSEEP).

The HFEX SitMan provides exercise participants with all the necessary tools for their roles in the exercise. It is tangible evidence of Gloucester County's commitment to ensure public safety through collaborative partnerships that will prepare it to respond to any emergency.

The HFEX is an unclassified exercise. Control of exercise information is based on public sensitivity regarding the nature of the exercise rather than actual exercise content. Some exercise material is intended for the exclusive use of exercise planners, facilitators, and evaluators, but players may view other materials that are necessary to their performance. All exercise participants may view the SitMan.

All exercise participants should use appropriate guidelines to ensure proper control of information within their areas of expertise and protect this material in accordance with current jurisdictional directives. Public release of exercise materials to third parties is at the discretion of the HFEX Steering Committee.

Handling Instructions

The title of this document is the HFEX- Hydrogen Fluoride Exercise Situation Manual (SitMan).

For more information about the exercise, please consult the following point of contact:

Exercise Director:

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INTRODUCTION

Background

An incident involving release of hydrogen fluoride (HF) presents unique challenges to the community because of its specific chemical and physical properties and the potential to cause serious harm to human health. Gloucester County in southern New Jersey (NJ) is the location of industrial facilities that store and use significant quantities of HF which is transported to the facilities via rail or tractor-trailer. This presents a potential hazard to the Gloucester County community and it is imperative that all partners in emergency response are aware of the specialized medical treatment required for HF exposures. HF is unique in that the onset of symptoms is often delayed. Symptoms include severe burns, inhalation hazards, and systemic toxicity. As important as the medical treatment is the leadership on the county and local level and the ability to effectively respond to the incident. Recent incidents in our region and across the country reinforce the need for this initiative. March 2009 in Wind Gap, Pennsylvania, a tractor-trailer carrying 33,000 pounds of hydrofluoric acid flipped over on a highway while trying to avoid a deer. The subsequent leak was contained by state and local Hazardous Materials (HazMat) teams. Approximately 5,000 residents were evacuated and the highway was closed. In January 2005, outside of Pittsburgh, Pennsylvania, a train car filled with anhydrous hydrogen fluoride derailed into the Allegheny River and released its contents.

Purpose

The purpose of this tabletop exercise (TTX) is to provide participants with an opportunity to evaluate their current emergency response plans and capabilities for a response to an HF incident in Gloucester County. The exercise will focus on key local and county capabilities in both external and internal communication, coordination, and critical decision-making.

Scope

The scenario for the exercise will be a transportation incident involving a tractor-trailer carrying HF. No specific Gloucester County industrial facility will be named or implicated in the exercise. The exercise will focus on specific issues associated with a release of HF and will be specifically aimed at hospital, public health, and first responder coordination of the incident. The emphasis will be on coordination, problem identification, and problem resolution. Decontamination issues will be covered, but the primary focus will be on response to and management of the incident.

Target Capabilities

The National Planning Scenarios and establishment of the National Preparedness Priorities have steered the focus of homeland security toward a capabilities-based planning approach. Capabilities-based planning focuses on planning under uncertainty because the next danger or disaster can never be forecast with complete accuracy. Therefore, capabilities-based planning takes an all-hazards approach to planning and preparation that builds capabilities that can be applied to a wide variety of incidents. States and urban areas use capabilities-based planning to identify a baseline assessment of their homeland security efforts by comparing their current capabilities against the Target Capabilities List (TCL) and the critical tasks of the Universal Task

List (UTL). This approach identifies gaps in current capabilities and focuses efforts on identifying and developing priority capabilities and tasks for the jurisdiction. These priority capabilities are articulated in the jurisdiction's homeland security strategy and Multiyear Training and Exercise Plan, of which this exercise is a component.

The capabilities listed here have been selected by the HFEX Steering Committee from the priority capabilities identified in Gloucester County's Multiyear Training and Exercise Plan. These capabilities provide the foundation for development of the exercise design objectives and scenario. The purpose of this exercise is to measure and validate performance of these capabilities and their associated critical tasks. The selected target capabilities are:

- Emergency Operations Center (EOC) Management
- Responder Safety and Health
- HazMat Response and Decontamination
- Citizen Evacuation and/or Shelter-in-Place
- Emergency Triage and Pre-Hospital Treatment
- Medical Surge
- Mass Care (Sheltering, Feeding, and Related Services)

Exercise Design Objectives

Exercise design objectives focus on improving understanding of a response concept, identifying opportunities or problems, and achieving a change in attitude. This exercise will focus on the following design objectives selected by the HFEX Steering Committee:

1. Assess and identify how to activate and maintain emergency communications essential to support response to an HF incident in Gloucester County.

2. Demonstrate the ability to alert, mobilize, and activate personnel for emergency response and maintain operations until the situation is brought under control.

3. Demonstrate the ability to mobilize and track equipment, people, and other resources in support of emergency operations.

4. Identify and implement appropriate actions to protect emergency workers and the public.

5. Demonstrate inter-agency (Gloucester County Health Department, hospitals, and first responders) communication and cooperation in response to an HF incident in Gloucester County.

Participants

- **Players.** Players respond to the situation presented, based on expert knowledge of response procedures, current plans and procedures, and insights derived from training.
- **Facilitators.** Facilitators provide situation updates and moderate discussions. They also provide additional information or resolve questions as required. Key Exercise Planning

Team members also may assist with facilitation as subject matter experts (SMEs) during the TTX.

- **Evaluators.** Evaluators observe and record the discussions during the exercise, participate in the data analysis, and assist in drafting the after-action report. (AAR)
- **Subject Matter Experts (SME):** SME are similar in role to an observer but may be asked by participants specific questions about their agencies, policies, or area of expertise.
- **Observers.** Observers are not participants in the moderated discussion, they only observe.

Exercise Structure

This tabletop exercise will be a facilitated exercise with a multimedia presentation. At different points in the response, there will be a multimedia update that summarizes key events occurring within that time period. After the updates, players will engage in a facilitated group discussion of appropriate response issues and subsequent actions based on the scenario.

Exercise Guidelines

- This TTX will be held in an open, low-stress, no-fault environment. Varying viewpoints, even disagreements, are expected.
- Respond on the basis of your knowledge of current plans and capabilities (i.e., you may use only existing assets) and insights derived from your training.
- Decisions are not precedent setting and may not reflect your organization's final position on a given issue. This exercise is an opportunity to discuss and present multiple options and possible solutions.
- Issue identification is not as valuable as suggestions and recommended actions that could improve response and preparedness efforts. Problem-solving efforts should be the focus.

Assumptions and Artificialities

In any exercise, assumptions and artificialities may be necessary to complete play in the time allotted. During this exercise, the following apply:

- The scenario is plausible, and events occur as they are presented.
- There is no hidden agenda, and there are no trick questions.
- All players receive information at the same time.

SCENARIO PART 1

May 25, 2010: 11:00am 0 Hour

A tank truck exits Interstate 295 northbound at exit 18 in East Greenwich, NJ next to the truck stop approaching Facility X. It is a sunny day and the temperature is 60 degrees with a 5 mph wind blowing from the northwest. The driver of the tank truck swerves and overturns on the exit ramp. A bystander calls 9-1-1 to report the overturned truck. Motorists are attempting to drive through the accident area while gawking at the accident causing a back up of traffic. The truck stop at the exit is busy with truckers and other patrons.

May 25, 2010: 11:10am (+10 minutes)

The tank truck has a UN 1052 label and placards indicating corrosive and poison. The truck driver is unconscious. People from the truck stop and nearby businesses have been gathering near the accident to see what is happening. Cars are lined up at the exit ramp attempting in vain to get by.

Key Issues

- Traffic congestions limiting movement of emergency vehicles.
- Unknown condition of truck driver.
- Substance leaking from tanker not identified.
- Large numbers of people in the nearby surrounding area.
- Reports of minor physical irritations of people exposed in the area of the accident.

Discussion Questions

Based on the information provided, participate in the discussion concerning the issues raised. Identify any additional requirements, critical issues, decisions, or questions that should be addressed at this time.

The following questions are provided as suggested general subjects that you may wish to address as the discussion progresses. These questions are not meant to constitute a definitive list of concerns to be addressed, nor is there a requirement to address every question.

Law Enforcement

- At this stage of the response, what is the role of local law enforcement?
- What actions would you take at this point? What are your priority action items at this point in the response?
- What, if any, additional local resources would you request at this time?
- What are your perimeter and security concerns? How will these concerns be addressed? What steps will be taken, and what resources will be required?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?

Fire

- At this stage of the response, what is the role of the fire departments present?
- What actions would your agency take at this point? What are your priority action items at this point in the response?
- What, if any, additional local resources would you request at this time?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?

Emergency Medical Services

- At this stage of the response, what is the role of EMS?
- What actions would you take at this point? What are your priority action items at this point in the response?
- What are your communication procedures at this point in the response?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?
- What, if any, additional local resources would you request at this time?

Hospitals

- At this stage of the response, what is the role of the hospitals?
- What actions would you take at this point? What are your priority action items at this point in the response?
- What are your communication procedures at this point in the response?
- Is HF identified in the hospital hazard vulnerability analysis? If so, where is it on the list?

Emergency Management

- Who is the Incident Commander? Which jurisdiction? Where is the command post? Where is the staging area?
- At this point in the response, what notifications would have been made, and by whom? How would State agencies be notified of the situation?
- What mutual aid agreements (MAAs) or memorandums of understanding (MOUs) do you currently have in place that could be used for this response? Would mutual aid be requested at this point? If so, from whom?
- What are your primary safety concerns for citizens and first responders? What steps should be taken to address these safety concerns? What resources may be required?

Scenario Part 2

May 25, 2010: 11:30am (+30 minutes)

The tank truck is continuing to expel a white vapor with a strong, irritating odor and it is moving with the prevailing winds.

May 25, 2010: 11:45am (+45 minutes)

The Gloucester County Hazardous Materials (HazMat) Response Team arrives on the scene.

Key Issues:

- Increasing numbers of people expressing common symptoms.
- Downwind range effect seems to be increasing.
- Anyone exposed at the outset is now non-ambulatory and unresponsive.
- Hazardous substance still leaking from tankers valve line.
- 9-1-1 calls are being made from people further down wind of the accident.

Discussion Questions

Based on the information provided, participate in the discussion concerning the issues raised. Identify any additional requirements, critical issues, decisions, or questions that should be addressed at this time.

The following questions are provided as suggested general subjects that you may wish to address as the discussion progresses. These questions are not meant to constitute a definitive list of concerns to be addressed, nor is there a requirement to address every question in this section.

Law Enforcement

- What are your perimeter and security concerns at this point in the incident?
- What role does your agency have in facilitating an orderly evacuation of the area?
- What actions could be taken to improve the current situation and ensure that all responders have access to the site and that EMS has an unobstructed path to area hospitals?
- What are your priority action items for consideration at this point in the incident?
- What challenges are you facing?

Fire

- What are your priority action items for consideration at this point in the incident?
- As additional resources arrive for this incident, where could you stage these assets?
- What is the status of your communications?
- What challenges are you facing?

Emergency Medical Services

- What are your priority action items for consideration at this point in the incident?
- What are your staging, triage and medical treatment concerns at this point?
- What are your transportation concerns at this point? Where are you transporting patients to?
- What are your communication procedures with the health care facilities?
- What challenges are you facing?
- What are the decontamination concerns with the transport of patients?

Hospitals

- What are your priority action items for consideration at this point in the incident?
- Hospital emergency operations plans?
- What are your staffing concerns at this point?

- What are your decontamination and treatment concerns at this point? Do you have the necessary medications on site for HF treatment? If not, where is it available?
- What challenges are you facing?

Emergency Management

- Would the Emergency Operations Center (EOC) be activated at this point? If so, what is the activation process, and how long would it take?
- Would individual local agency EOCs or command centers be activated? If so, what is the activation process, and how long would it take? How would these various entities communicate?
- How is the Emergency Operations Center (EOC) staffed at this point in the incident?
- How would you prepare to staff for a possible extended activation? Are your current staffing protocols sufficient to support extended activation? If not, how might this situation be remedied?
- What are the priority action items for consideration at this point in the incident?
- What other agencies have been notified at this point in the response? What roles will these agencies fulfill?
- What challenges are you facing?
- Do you anticipate any State or Federal resources arriving or being assigned to this incident? If so, what issues regarding receipt, acceptance, tracking, management, and integration of State and Federal resources need to be considered?
- Who has the authority to order an evacuation? How large an area would you evacuate? What plans are in place to facilitate an evacuation?
- Is Facility X contacted? What information can they provide regarding the chemical and medical concerns?

HazMat

- What is the status of HazMat? When does the assessment team arrive?
- What are the priority action items for consideration at this point in the incident?
- What are your primary safety concerns for your personnel? What steps should be taken to address these safety concerns? What resources may be required?
- What are your site management and control concerns?
- How will you coordinate information management and resource coordination?
- What challenges are you facing?

Mass Care

- What areas are being affected by the plume? What are the primary safety concerns for these areas?
- What are the decisions surrounding evacuation? What are the first considerations? Who will make the decision to evacuate or shelter in place?
- Who is responsible and will provide mass care services and resources to the shelter population?
- Have designated shelter sites been pre-established? How would the shelters be staffed?
- What challenges are you facing?

Health Department

- Is anyone checking the special needs registry?
- What is your role in citizen evacuation/shelter in place?
- What are your concerns regarding evacuation?
- What are your communication concerns at this point in the response?

SCENARIO PART 3

May 25, 2010: 12:00pm (+60 minutes)

HF is still leaking from the tanker and plume modeling has shown a down wind effect of up to 1.2 miles from the release site. At this time, both the indoor and outdoor concentrations at the truck stop are above the Acute Exposure Guideline Level (AEGL)-3. Above the AEGL-3 any concentration is life threatening.

Key Issues:

- HazMat is on scene however the leak still continues.
- Acute Exposure Guideline Levels are increasing which will increase exposure and debilitation of those exposed.
- Range of exposure downwind is now at 1.2 miles from the accident site.
- 9-1-1 calls still being made downwind of the incident.
- Numbers of patients transported to hospitals is increasing and currently at 20.
- Hospitals are concerned about the worried well arriving at the emergency departments.

Questions

Based on the information provided, participate in the discussion concerning the issues raised. Identify any additional requirements, critical issues, decisions, or questions that should be addressed at this time.

The following questions are provided as suggested general subjects that you may wish to address as the discussion progresses. These questions are not meant to constitute a definitive list of concerns to be addressed, nor is there a requirement to address every question in this section.

Law Enforcement

- What are your short- and long-term personnel needs for site security and the ongoing incident investigation? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required for these operations in the short and long terms?
- What are your long-term perimeter and security plans? How long do you expect to have to maintain a presence at the scene?
- What are your priority action items at this point?
- What challenges are you facing?

Fire

- What are your short- and long-term personnel needs for the ongoing operations? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required for these operations in the short and long terms?
- What are your priority action items at this point?
- What challenges are you facing?

HazMat

- What are your short- and long-term personnel needs for the ongoing search and rescue operations? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required to support these operations in the short and long terms?
- What are your priority action items at this point?

- What challenges are you facing?

Emergency Management

- What are your long-term staffing and support plans for your Emergency Operations Center (EOC) or agency? Do you currently have enough personnel to meet these needs? If not, how might they be obtained?
- What are your priority action items at this point?

Emergency Medical Services

- What are your short- and long-term personnel needs for ongoing medical treatment on site? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What material support will be required to support these operations in the short and long terms?
- How long do you expect to have to maintain a presence at the scene?
- What are your priority action items at this point?
- What challenges are you facing?

Hospitals

- What are your priority action items at this point?
- What are your short- and long-term personnel needs for ongoing decontamination and medical treatment? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- What are your bed surge procedures?
- What consideration has been given to the handling of the worried well?
- What challenges are you facing?
- What is the surge procedure for the hospitals?

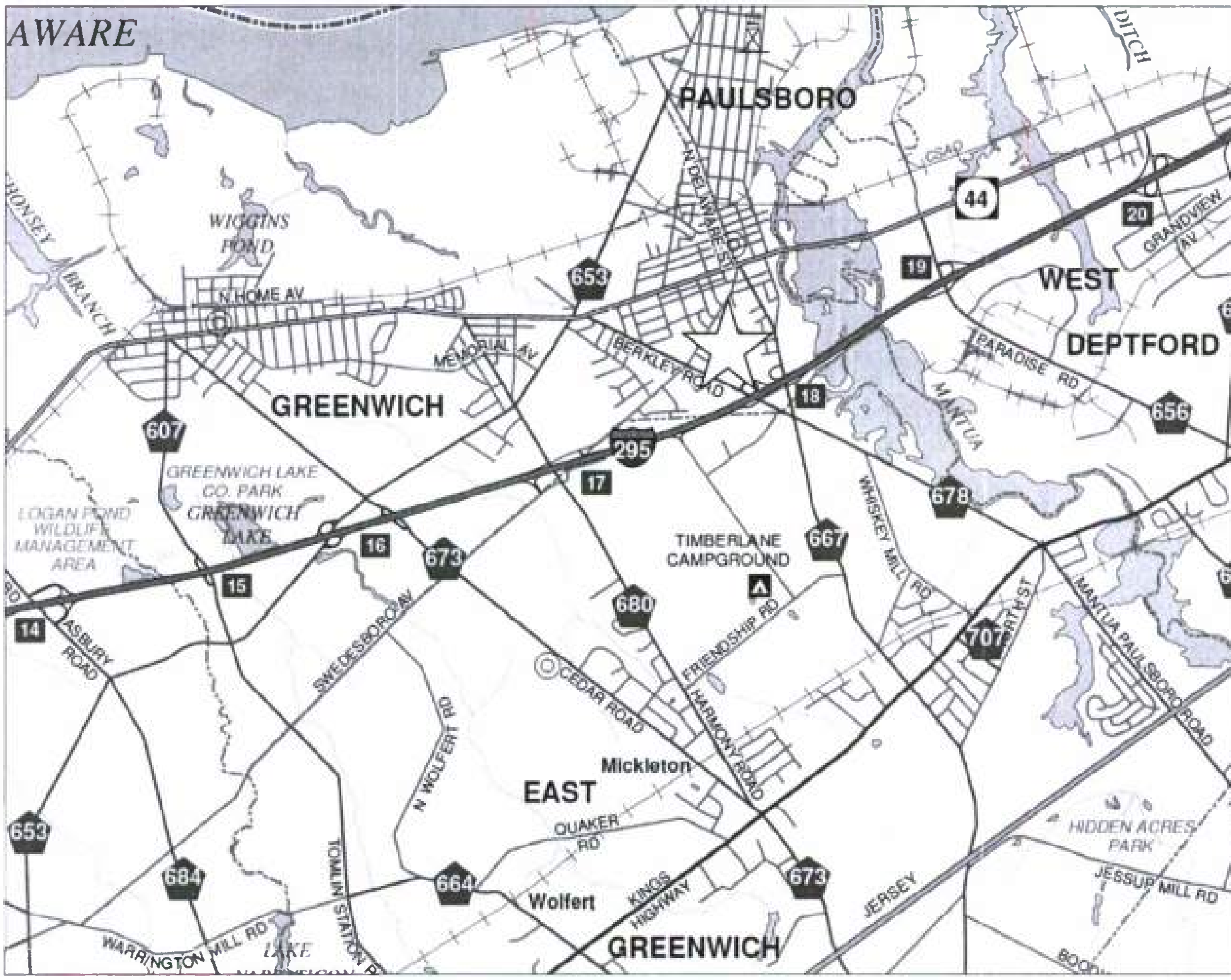
Health Department

- Special needs?
- What are your concerns regarding safety and sanitation within the shelters?
- What are the short and long term environmental concerns? What consideration should be given to nearby waterways?
- Special needs registry?

Mass Care

- What are your short- and long-term personnel needs for ongoing shelter operations? Do you currently have enough personnel to meet these needs? If not, how could the required additional personnel be obtained?
- How long will this be open?
- How many more people can be expected?

APPENDIX A: AREA MAP



APPENDIX B: ACUTE EXPOSURE GUIDELINE LEVELS (AEGLS)

AEGLs represent threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from 10 minutes to 8 hours. AEGL-2 and AEGL-3, and AEGL-1 values as appropriate, will be developed for each of five exposure periods (10 and 30 minutes, 1 hour, 4 hours, and 8 hours) and will be distinguished by varying degrees of severity of toxic effects. It is believed that the recommended exposure levels are applicable to the general population including infants and children, and other individuals who may be susceptible. The three AEGLs have been defined as follows:

AEGL-1 is the airborne concentration, expressed as parts per million or milligrams per cubic meter (ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Airborne concentrations below the AEGL-1 represent exposure levels that can produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, nonsensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL.

APPENDIX C: HYDROGEN FLUORIDE FACT SHEET

Right to Know Hazardous Substance Fact Sheet

Emergency Responders Quick Reference

Common Name: **HYDROGEN FLUORIDE**

Synonyms: Fluoric Acid; HFA
CAS No: 7664-39-3
Molecular Formula: HF
RTK Substance No: 3759
Description: Colorless, fuming liquid or gas

HAZARD DATA

Hazard Rating	Firefighting	Reactivity
4 - Health **0 - Fire** **1 - Reactivity** **DOT#:** UN 1052 **ERG Guide #:** 125 **Hazard Class:** 8 (Corrosive)	**Hydrogen Fluoride** is a noncombustible liquid or gas. Extinguish fire using an agent suitable for type of surrounding fire. POISONOUS GASES ARE PRODUCED IN FIRE, including *Fluorine*. Use water spray to keep fire exposed containers cool.	**Hydrogen Fluoride** reacts violently with STRONG BASES (such as SODIUM HYDROXIDE and POTASSIUM HYDROXIDE) and many other compounds. **Hydrogen Fluoride** reacts with WATER and STEAM to produce *toxic* and *corrosive gases*. **Hydrogen Fluoride** reacts with METALS (such as IRON and STEEL) to produce flammable and explosive *Hydrogen gas*. **Hydrogen Fluoride** is not compatible with OXIDIZING AGENTS (such as PERCHLORATES, PEROXIDE, PERMANGANATES, CHLORATES, NITRATES, CHLORINE, BROMINE and FLUORINE); STRONG ACIDS (such as HYDROCHLORIC, SULFURIC and NITRIC); AMINES; METAL SALTS; and SILICON COMPOUNDS.

SPILL/LEAKS

Isolation Distance:

Spill: 100 meters (330 feet)
Fire: 1,600 meters (1 mile)

If a gas leak, evacuate area and stop flow of gas. If source of leak is a cylinder and the leak cannot be stopped in place, remove the leaking cylinder to a safe place in the open air, and repair leak or allow cylinder to empty.

If a liquid spill, allow to vaporize and disperse, or cover with sodium carbonate or an equal mixture of soda ash and slaked lime.

Water spray can be used to absorb **Hydrogen Fluoride** vapors escaping from leaking containers of *anhydrous* **Hydrogen Fluoride**. Use water in flooding quantities.

PHYSICAL PROPERTIES

Odor Threshold:	0.04 ppm
Flash Point:	Nonflammable
Vapor Density:	0.7 (air = 1)
Vapor Pressure:	760 mm Hg at 68°F (20°C)
Specific Gravity:	0.99 (water = 1)
Water Solubility:	Miscible
Boiling Point:	67°F (19.4°C)
Freezing Point:	-117.4°F (-83°C)
Ionization Potential:	15.98 eV
Molecular Weight:	20.1

EXPOSURE LIMITS

ACGIH: 0.5 ppm, 8-hr TWA; 2 ppm, Ceiling
IDLH: 30 ppm

The Protective Action Criteria values are:
PAC-1 = 1 ppm PAC-3 = 44 ppm
PAC-2 = 24 ppm

PROTECTIVE EQUIPMENT

Gloves: Barrier® (>8-hr breakthrough)

Coveralls: Tychem® Responder® and TK; and Trellchem HPS (>8-hr breakthrough)

Respirator: SCBA

HEALTH EFFECTS

Eyes: Severe irritation, burns and possible eye damage

Skin: Irritation and severe burns

Inhalation: Nose, throat and lung irritation with coughing, and severe shortness of breath (pulmonary edema)
Headache, dizziness, weakness, and convulsions

FIRST AID AND DECONTAMINATION

Remove the person from exposure.

Flush eyes with large amounts of water for at least 30 minutes. Remove contact lenses if worn. Seek medical attention immediately.

Immediately flush with large amounts of water. Apply 2.5% *Calcium Gluconate* gel to the affected skin. Seek medical assistance immediately.

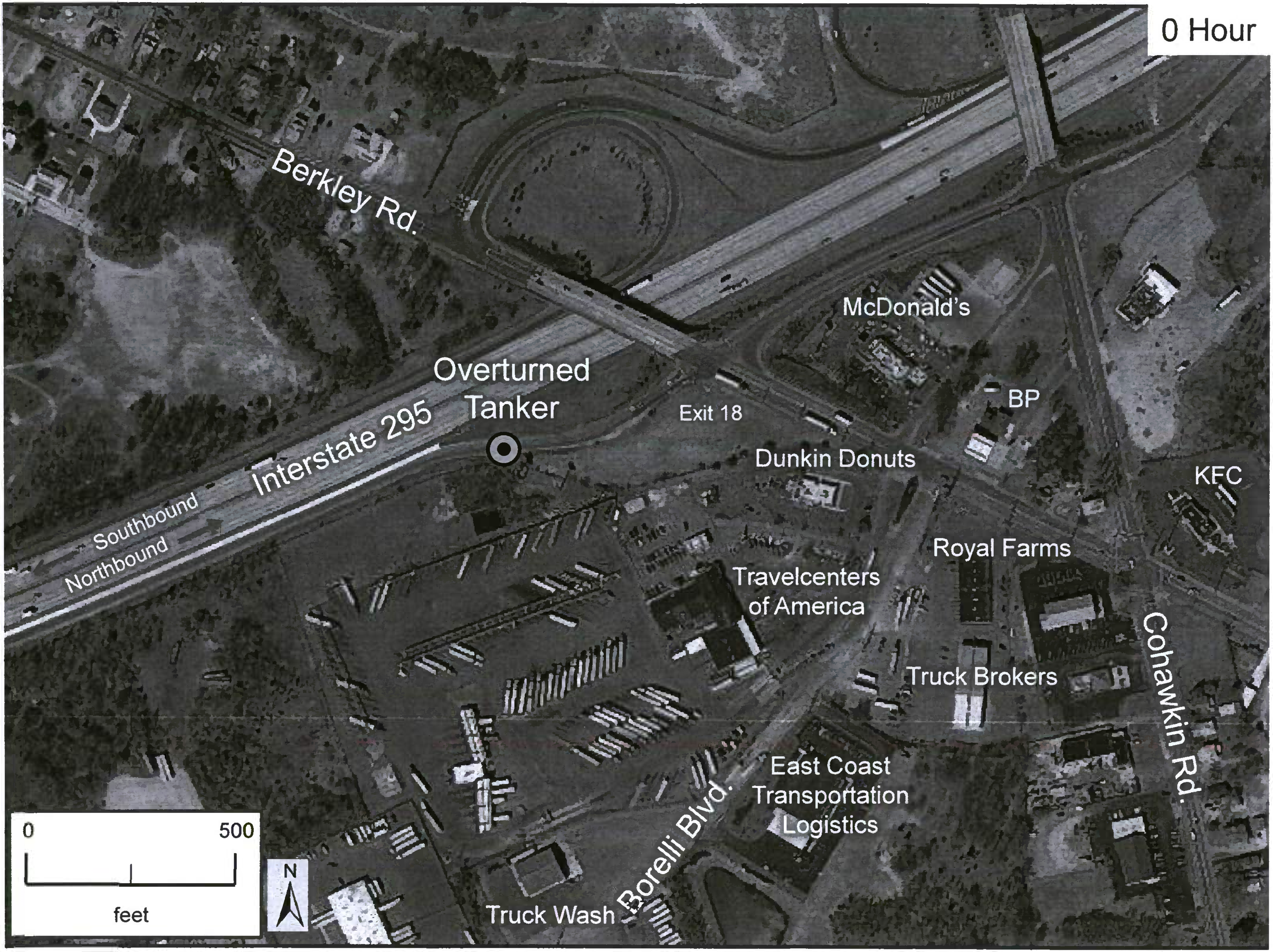
Begin artificial respiration if breathing has stopped and CPR if necessary.

Transfer promptly to a medical facility.

Medical observation is recommended as symptoms may be delayed.

HFEX - Hydrogen Fluoride Exercise
May 25, 2010

Homeland Security Exercise and Evaluation Program (HSEEP)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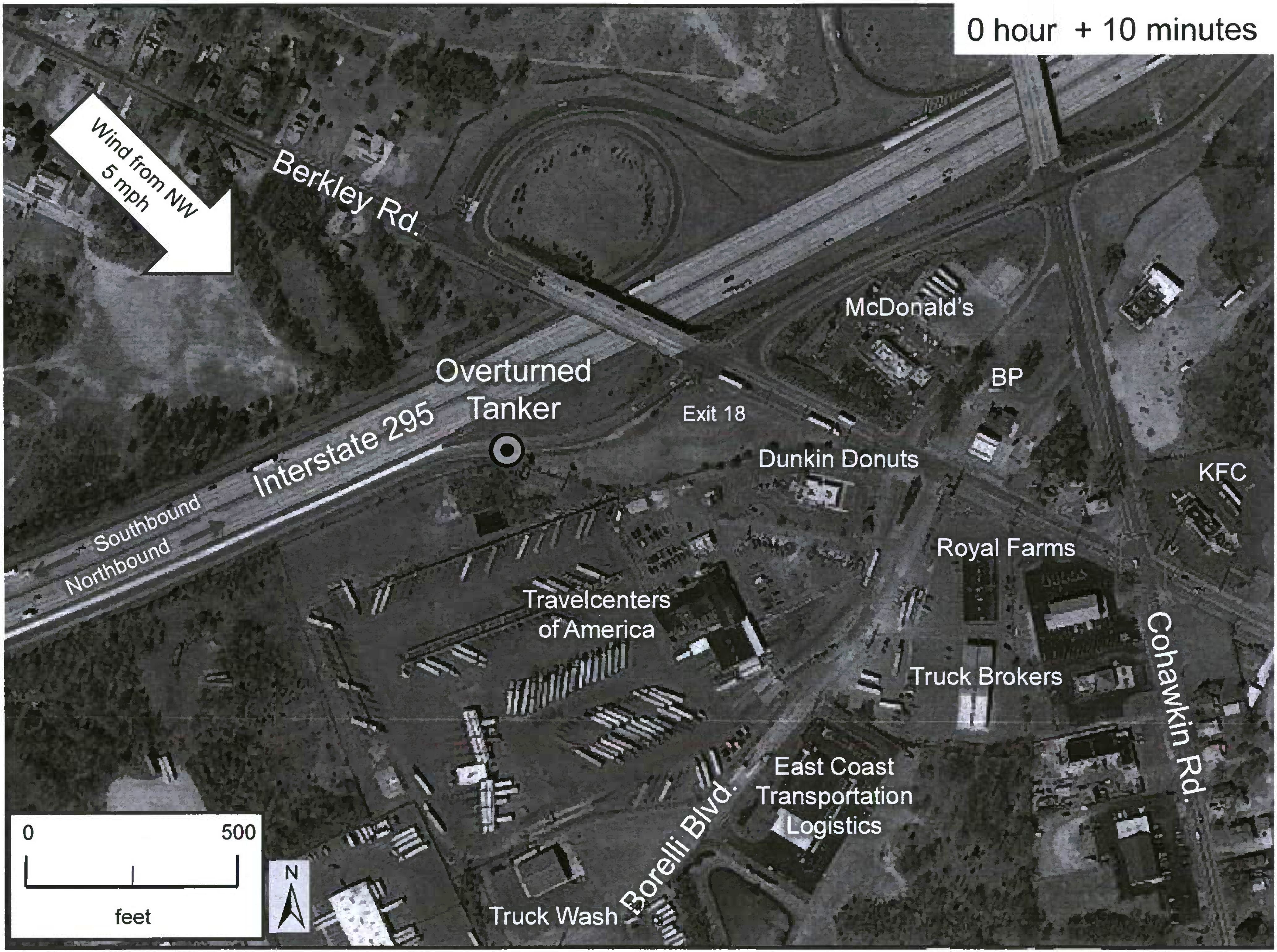
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KFC
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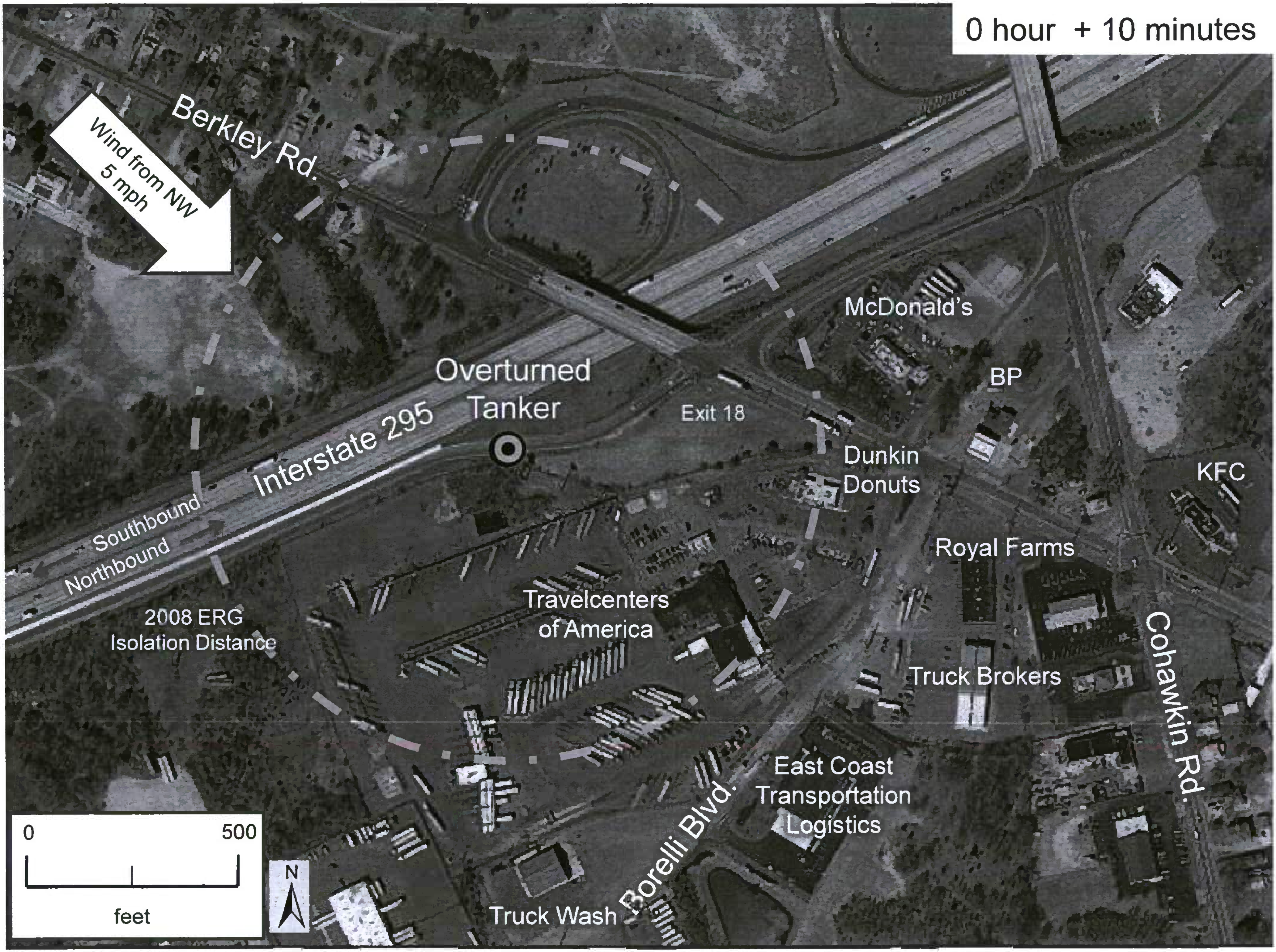
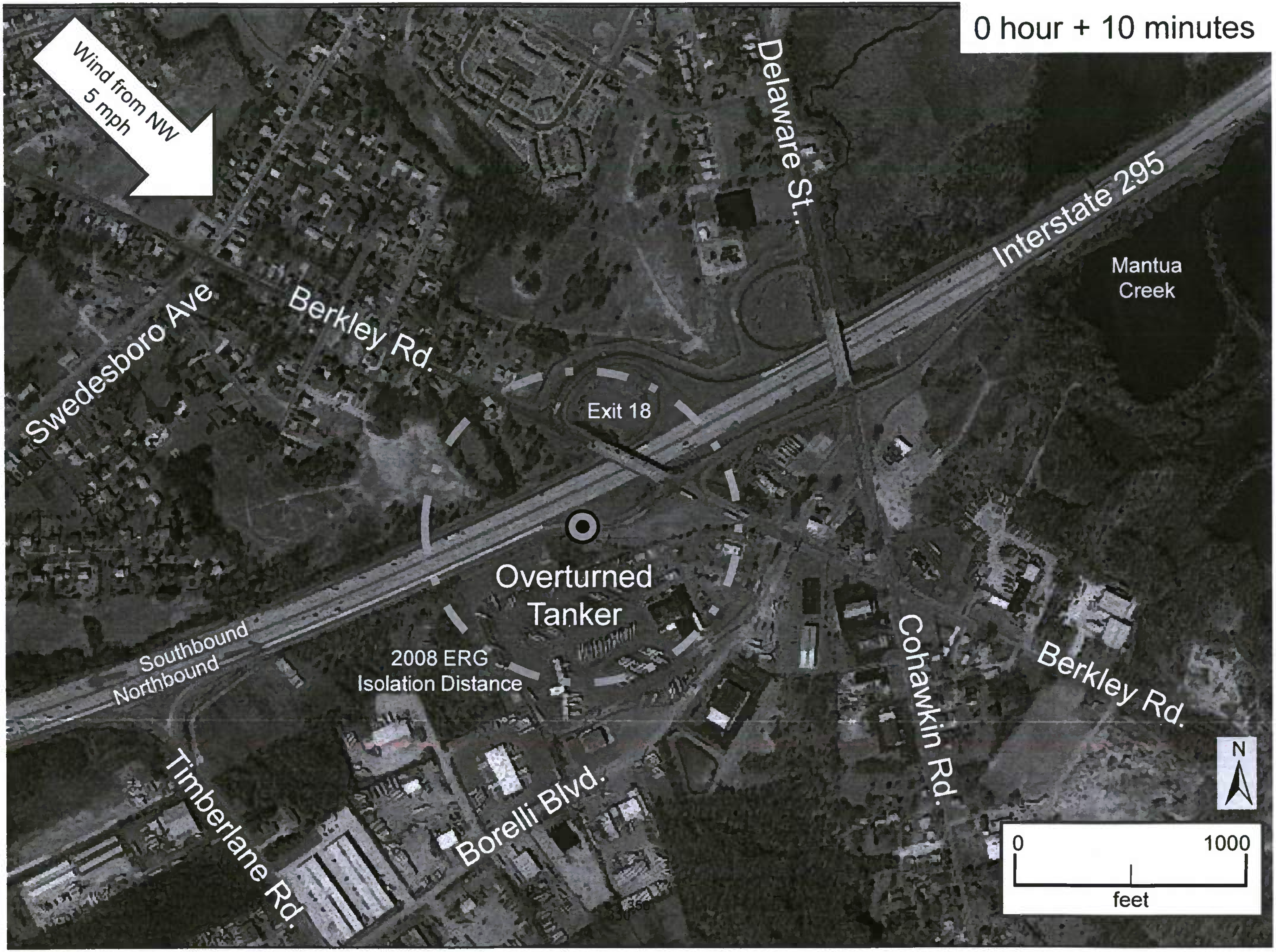
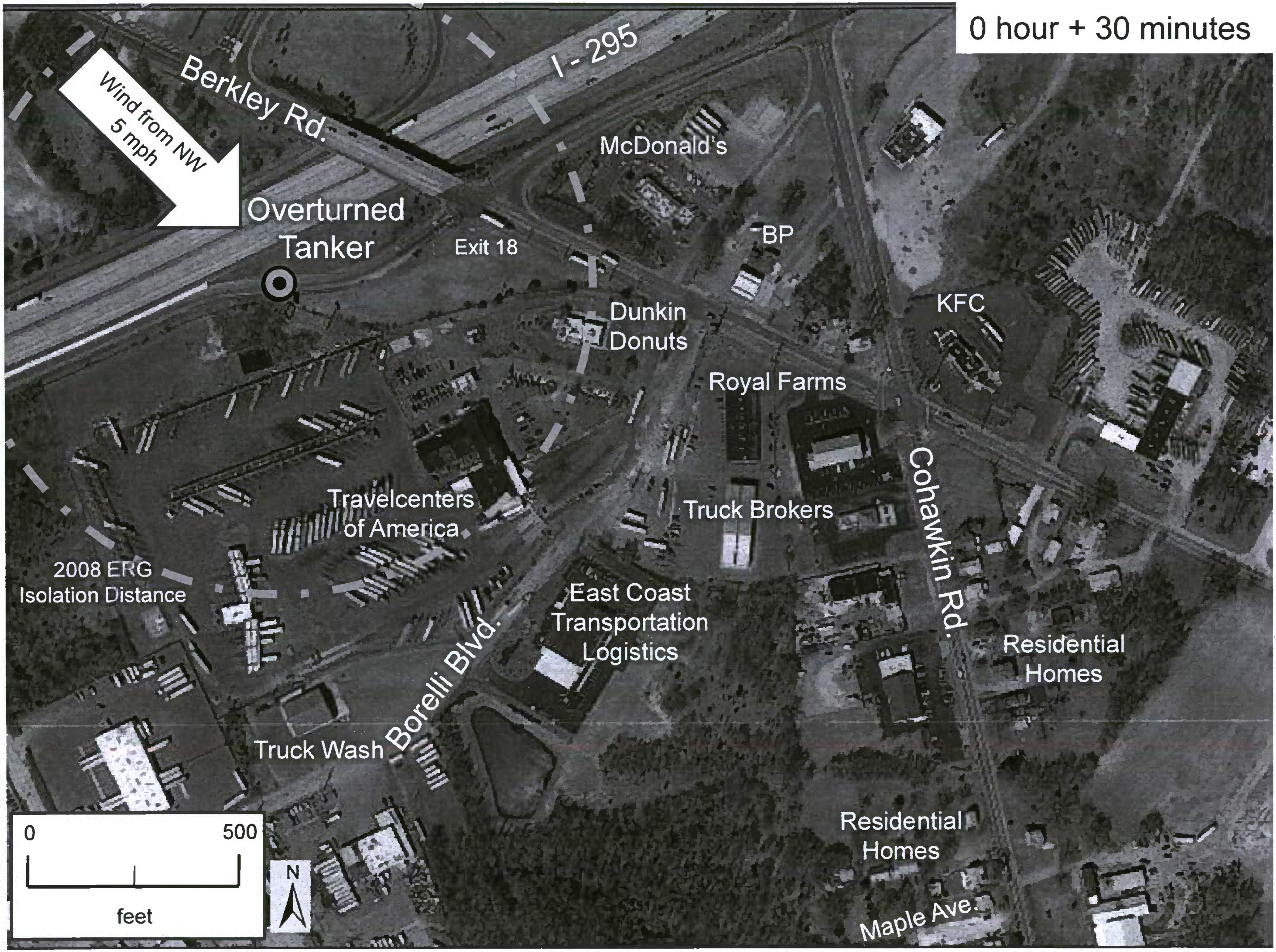
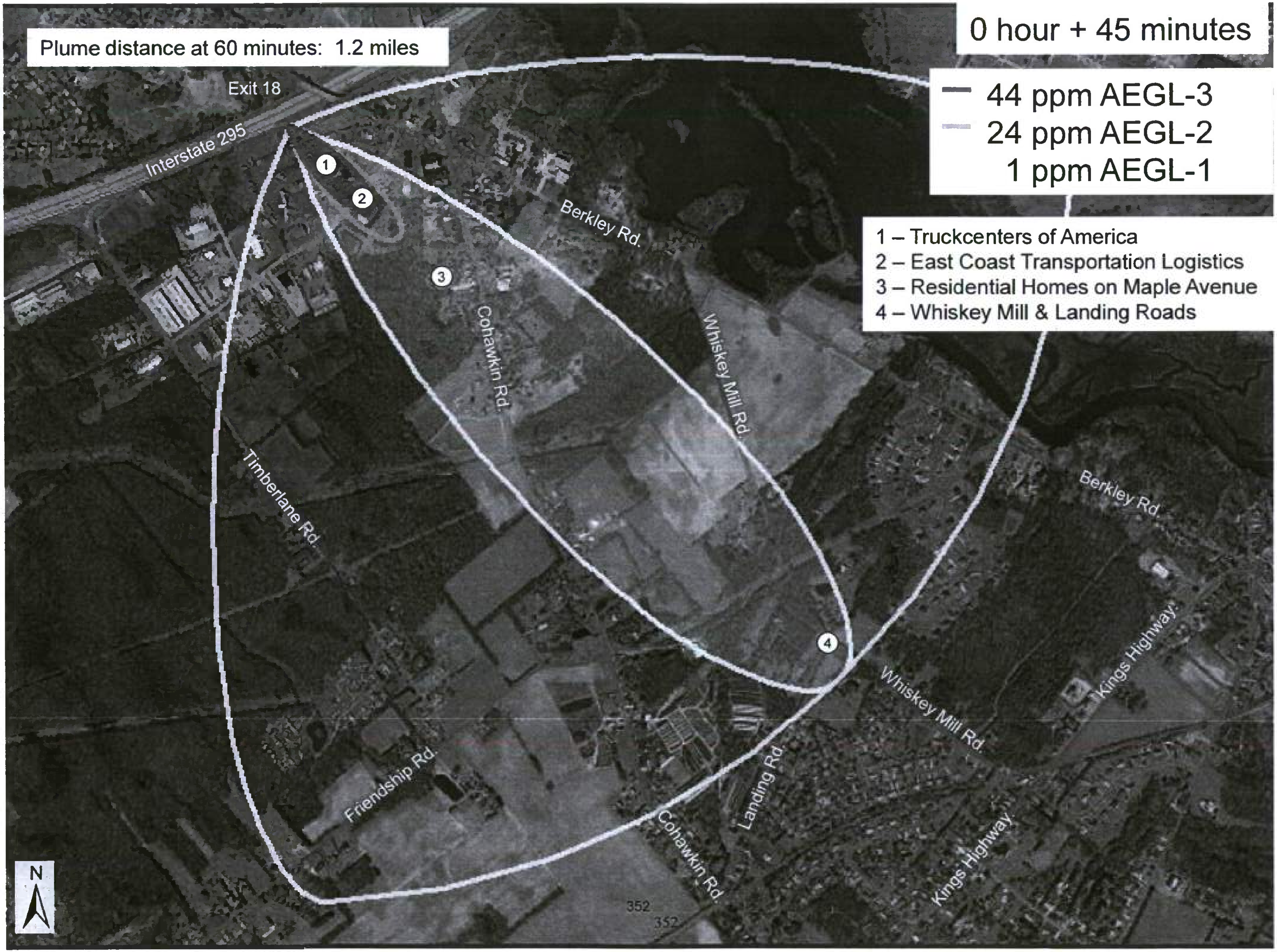
Travelcenters
of America
Truck Brokers
East Coast
Transportation
Logistics
Cohawkin Rd.
Borelli Blvd.
Truck Wash
0
500
feet
N

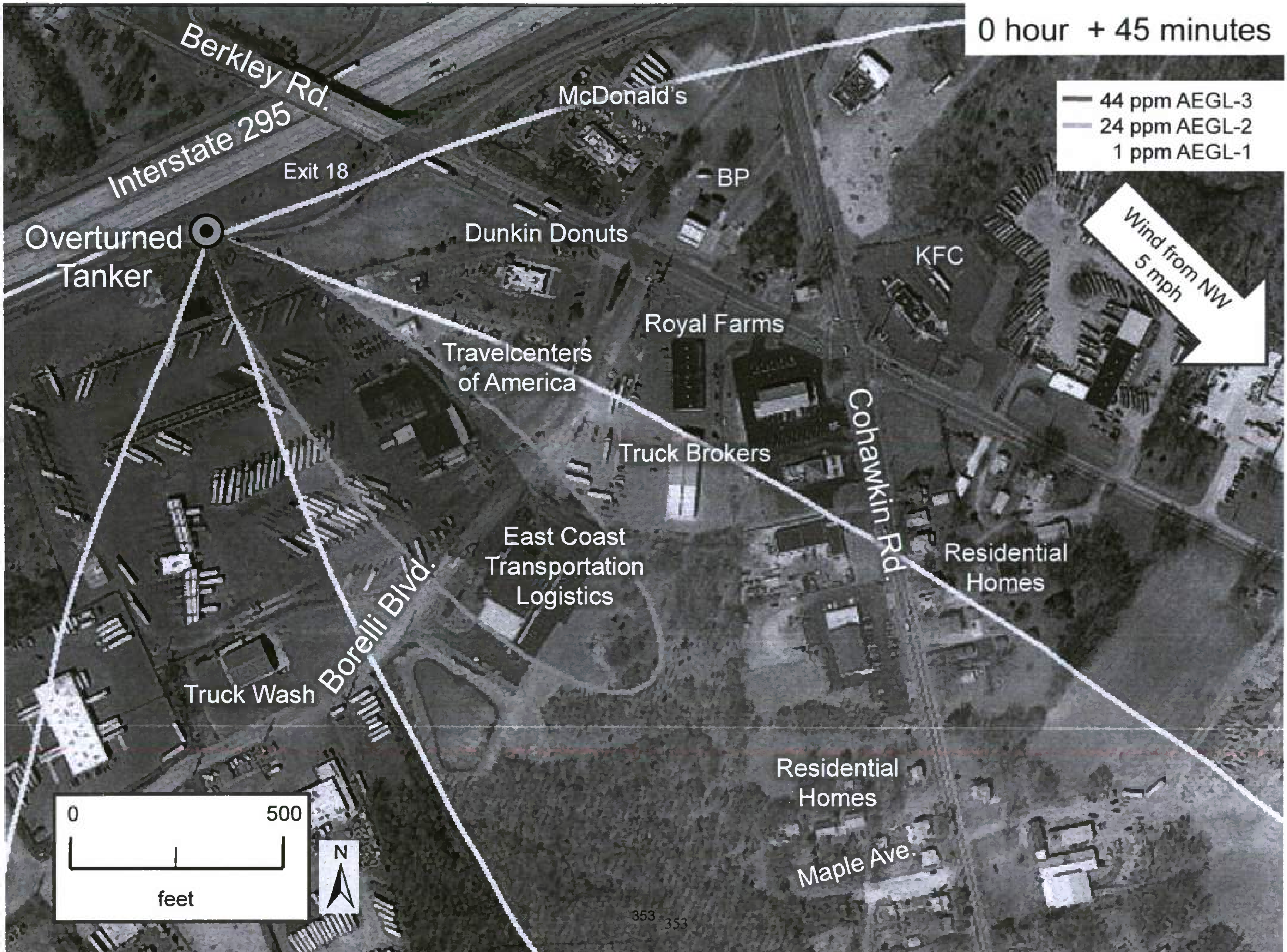


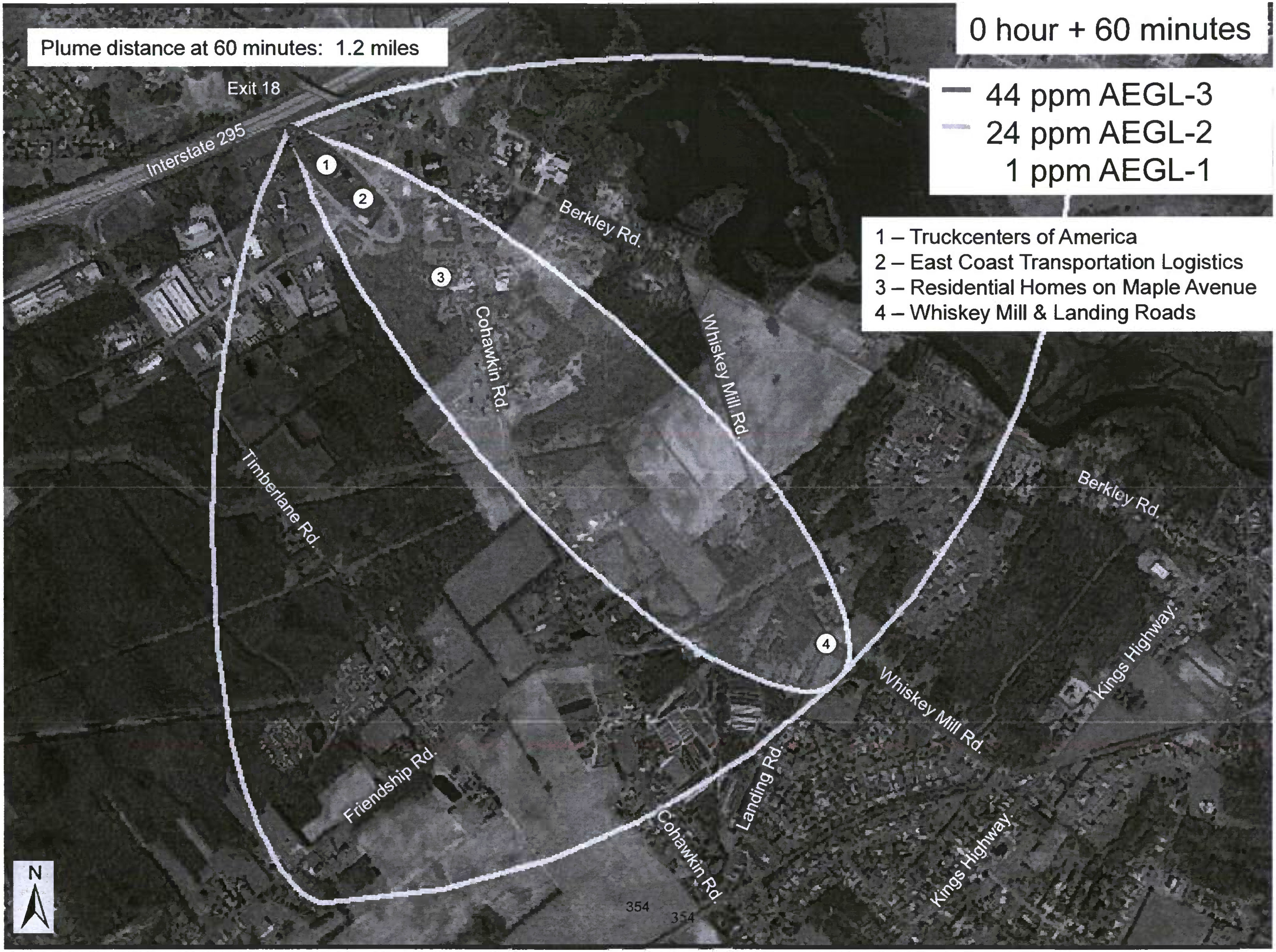
0 hour + 10 minutes
Berkley Rd.
Wind from NW
5 mph
Overturned
Tanker
Interstate 295
Exit 18
Southbound
Northbound
2008 ERG
Isolation Distance
McDonald's
BP
Dunkin
Donuts
KFC
Royal Farms
Travelcenters
of America
Truck Brokers
Cohawkin Rd.
East Coast
Transportation
Logistics
Borelli Blvd.
Truck Wash
0
500
feet
N


0 hour + 10 minutes
Wind from NW
5 mph
Delaware St..
Interstate 295
Mantua
Creek
Swedesboro Ave
Berkley Rd.
Exit 18
Overturned
Tanker
Southbound
Northbound
2008 ERG
Isolation Distance
Cohawkin Rd.
Berkley Rd.
Timberlane Rd.
Borelli Blvd.
N
0
1000
feet


0 hour + 30 minutes
Wind from NW
5 mph
Berkley Rd.
I - 295
Overturned
Tanker
Exit 18
McDonald's
BP
KFC
Dunkin
Donuts
Royal Farms
Travelcenters
of America
Truck Brokers
Cohawkin Rd.
2008 ERG
Isolation Distance
East Coast
Transportation
Logistics
Residential
Homes
Borelli Blvd.
Truck Wash
Residential
Homes
Maple Ave.
0
500
feet
N


Plume distance at 60 minutes: 1.2 miles
0 hour + 45 minutes
44 ppm AEGL-3
24 ppm AEGL-2
1 ppm AEGL-1
1 – Truckcenters of America
2 – East Coast Transportation Logistics
3 – Residential Homes on Maple Avenue
4 – Whiskey Mill & Landing Roads
Exit 18
Interstate 295
Berkley Rd.
Cohawkin Rd.
Whiskey Mill Rd.
Timberlane Rd.
Friendship Rd.
Landing Rd.
Kings Highway
352
N


0 hour + 45 minutes
44 ppm AEGL-3
24 ppm AEGL-2
1 ppm AEGL-1
Wind from NW
5 mph
Berkley Rd.
Interstate 295
Exit 18
Overturned
Tanker
McDonald's
BP
Dunkin Donuts
KFC
Royal Farms
Travelcenters
of America
Truck Brokers
Cohawkin Rd.
East Coast
Transportation
Logistics
Residential
Homes
Borelli Blvd.
Truck Wash
Residential
Homes
Maple Ave.
0
500
feet
N



Plume distance at 60 minutes: 1.2 miles
0 hour + 60 minutes
44 ppm AEGL-3
24 ppm AEGL-2
1 ppm AEGL-1
1 – Truckcenters of America
2 – East Coast Transportation Logistics
3 – Residential Homes on Maple Avenue
4 – Whiskey Mill & Landing Roads
Exit 18
Interstate 295
Berkley Rd.
Cohawkin Rd.
Whiskey Mill Rd.
Timberlane Rd.
Friendship Rd.
Landing Rd.
Kings Highway.
N
354
354

HFEX Hot Wash

- Overall thoughts/comments
- Strengths
- Areas that need improvement
- Limit to three comments
- Brief, concise, and to the point

HFEX Steering Committee

The New Jersey NJCPHP Center for Public Health Preparedness at UMDNJ

New Jersey Department of Health and Senior Services

Close to Everything, Gloucester County, Far From It All.

NJHA New Jersey Hospital Association

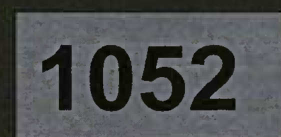
State Police NJ

Office of Homeland Security & Preparedness, The Great Seal of the State of New Jersey

U.S. Department of Homeland Security

0 Hour + 10 minutes

Overturned Tanker has these placards on it



TravelCenters of America (450 feet downwind)

- People outside are beginning to:
  - Have difficulty breathing
  - Experiencing burns on skin, eyes, and mucous membranes
  - Some are vomiting and collapsing

0 Hour + 30 minutes

TravelCenters of America (450 feet downwind)

- People outside are on the ground and unresponsive
- People inside are beginning to:
  - Have difficulty breathing
  - Experience burns on skin, eyes, and mucous membranes
  - Some are vomiting and collapsing

East Coast Transportation Logistics (900 feet downwind)

- People outside are beginning to:
  - Have difficulty breathing
  - Experience eye and skin irritation

Maple Ave (1/3 mile downwind)

- Residents call 911 reporting itchy eyes

0 Hour + 45 minutes

TravelCenters of America (450 feet downwind)

- People outside are on the ground and unresponsive
- People inside are beginning to:
  - Have difficulty breathing
  - Experience burns on skin, eyes, and mucous membranes
  - Some are vomiting and collapsing

East Coast Transportation Logistics (900 feet downwind)

- People outside are beginning to:
  - Have difficulty breathing
  - Experience eye and skin irritation

Maple Ave (1/3 mile downwind)

- Residents call 911 reporting itchy eyes

0 Hour + 60 minutes

TravelCenters of America (450 feet downwind)

- Everyone is unresponsive

East Coast Transportation Logistics (900 feet downwind)

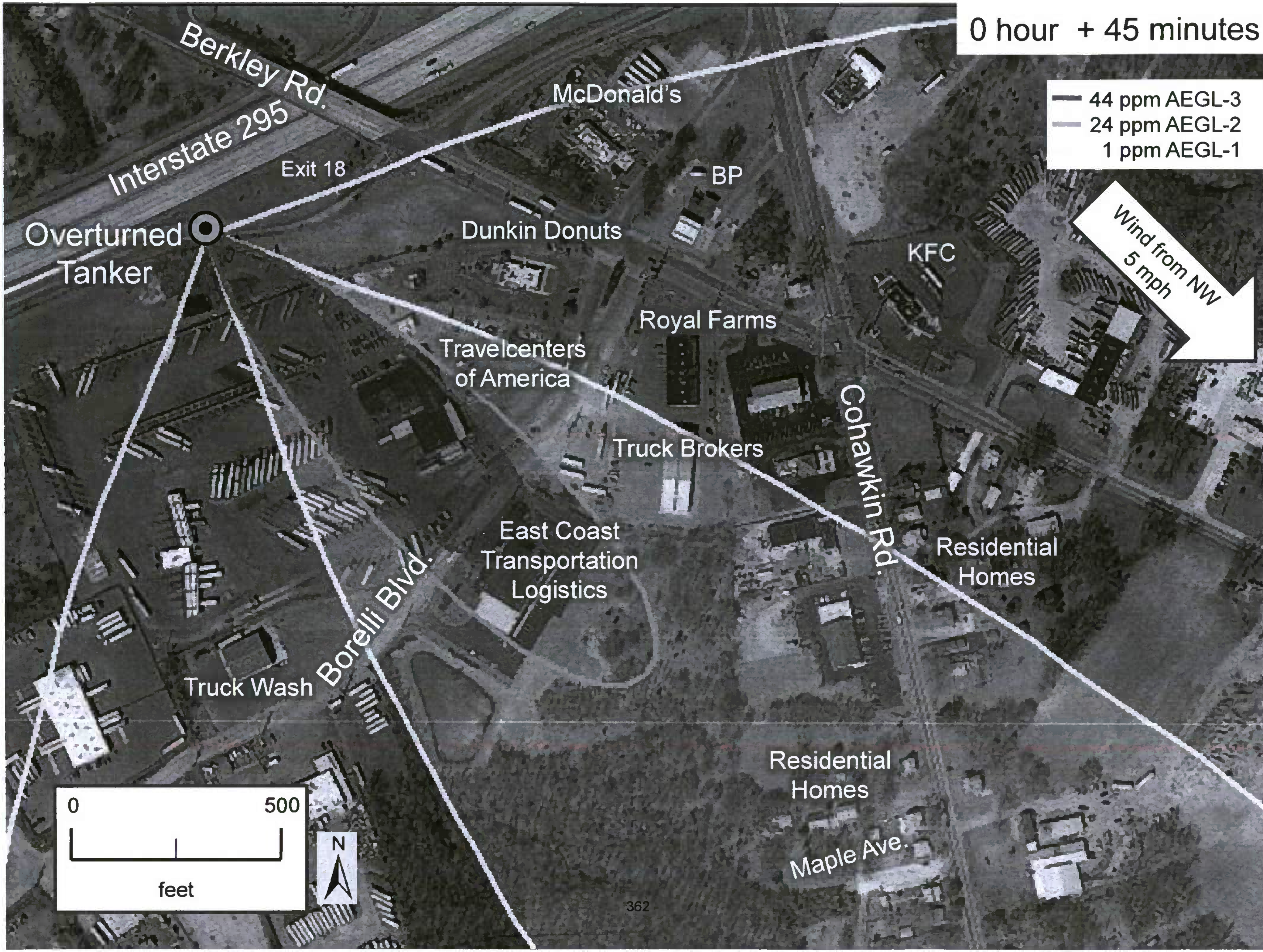
- People outside are unresponsive
- People inside are reporting eye and skin irritation

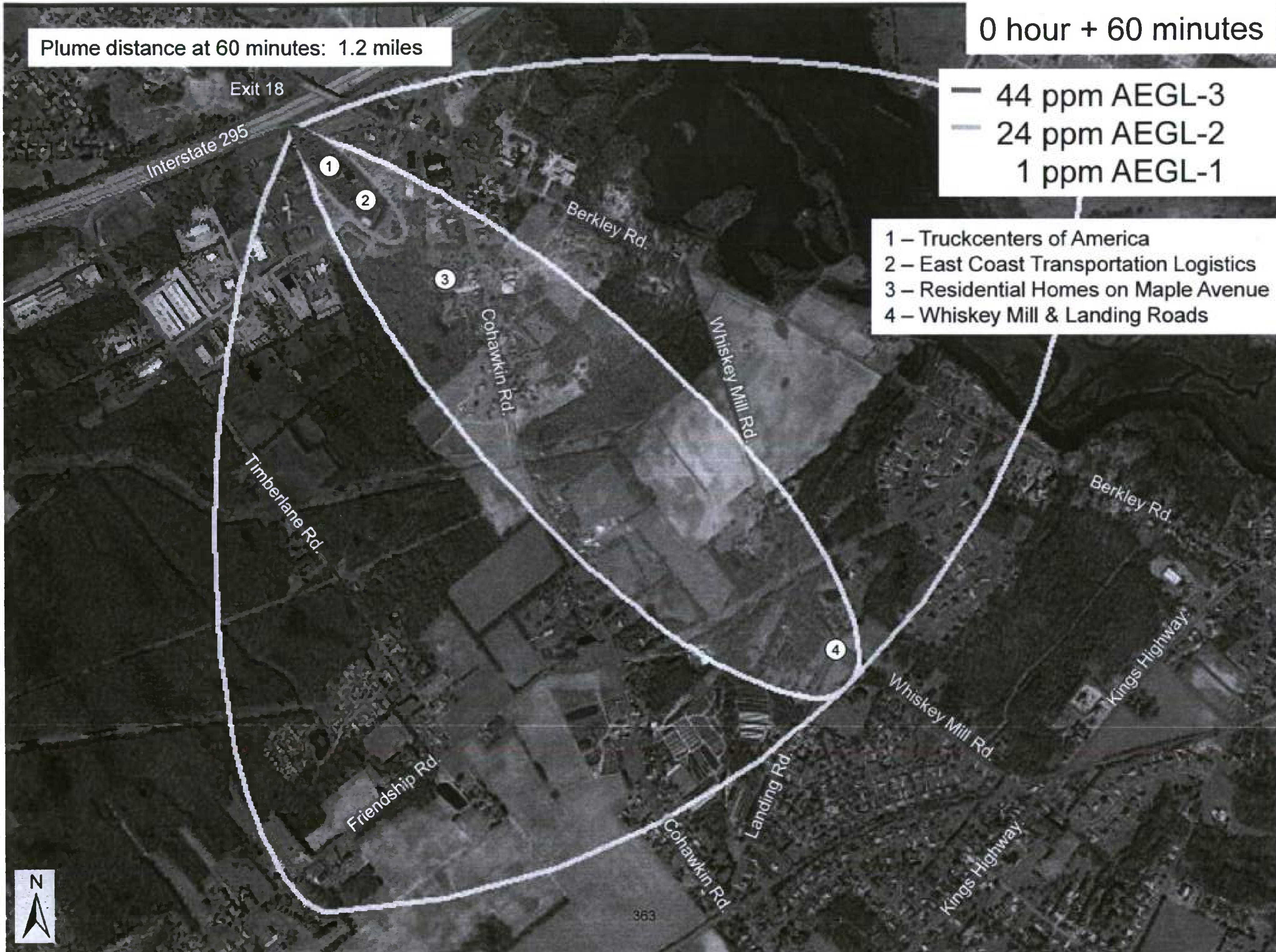
Maple Ave (1/3 mile downwind)

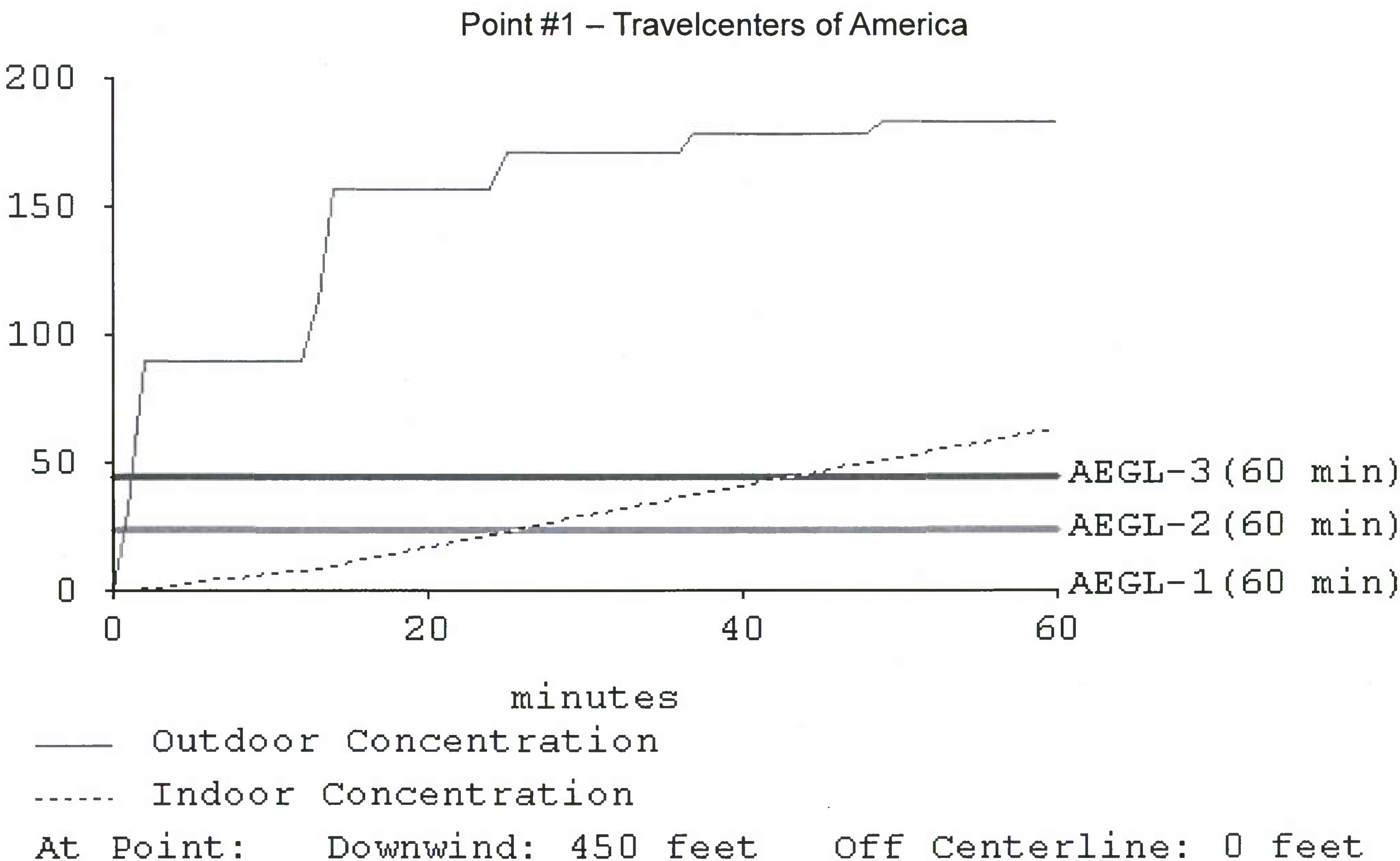
- Residents call 911 reporting eye and skin irritation

Whiskey Mill and Landing Roads (1.1 miles downwind)

- Residents call 911 reporting itchy eyes

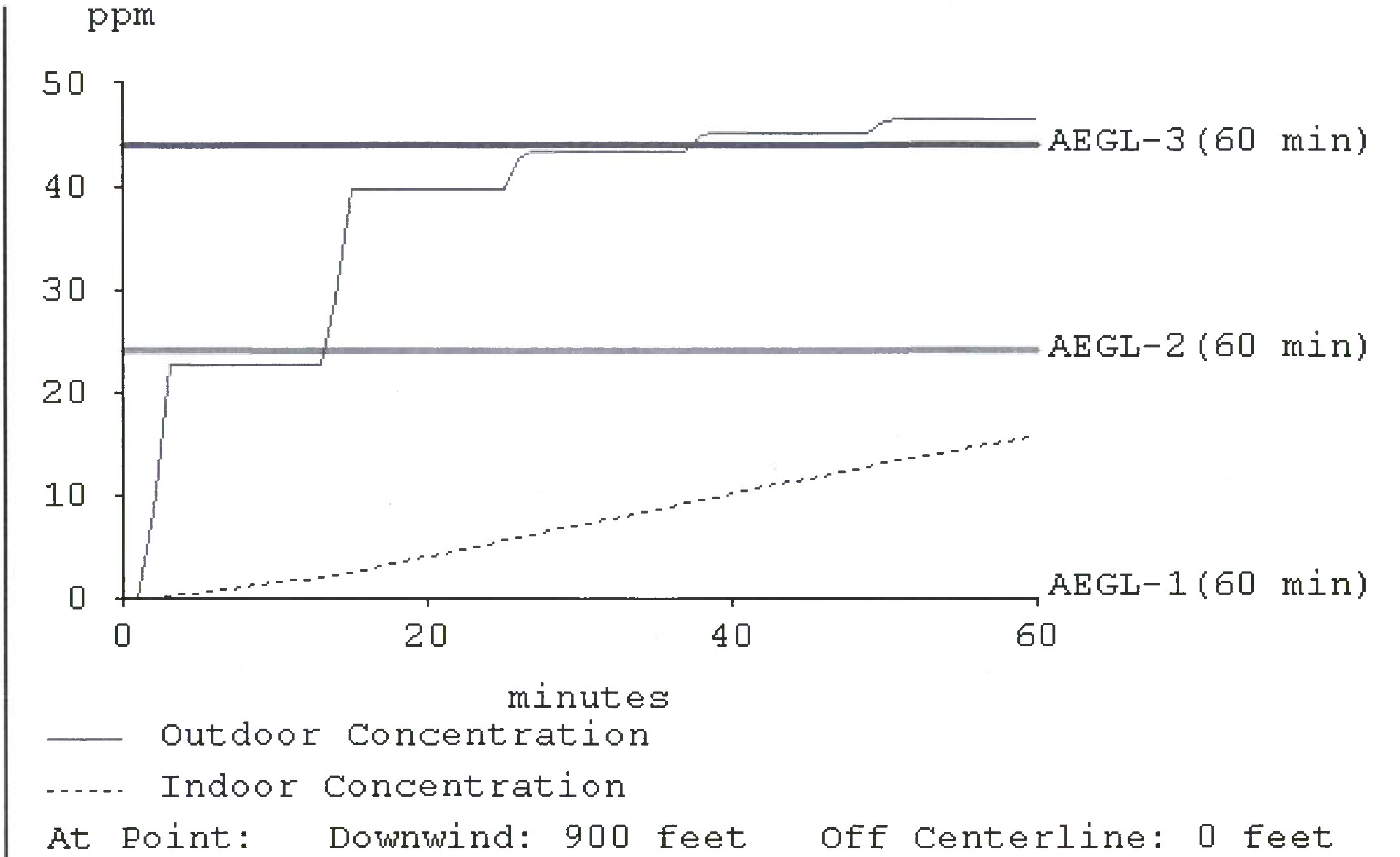

0 hour + 45 minutes
44 ppm AEGL-3
24 ppm AEGL-2
1 ppm AEGL-1
Wind from NW
5 mph
Berkley Rd.
Interstate 295
Exit 18
Overturned
Tanker
McDonald's
BP
Dunkin Donuts
KFC
Royal Farms
Travelcenters
of America
Truck Brokers
Cohawkin Rd.
East Coast
Transportation
Logistics
Residential
Homes
Borelli Blvd.
Truck Wash
Residential
Homes
Maple Ave.
0
500
feet
N


0 hour + 60 minutes
Plume distance at 60 minutes: 1.2 miles
44 ppm AEGL-3
24 ppm AEGL-2
1 ppm AEGL-1
1 – Truckcenters of America
2 – East Coast Transportation Logistics
3 – Residential Homes on Maple Avenue
4 – Whiskey Mill & Landing Roads
Exit 18
Interstate 295
Berkley Rd.
Cohawkin Rd.
Whiskey Mill Rd.
Timberlane Rd.
Friendship Rd.
Landing Rd.
Kings Highway
N
363

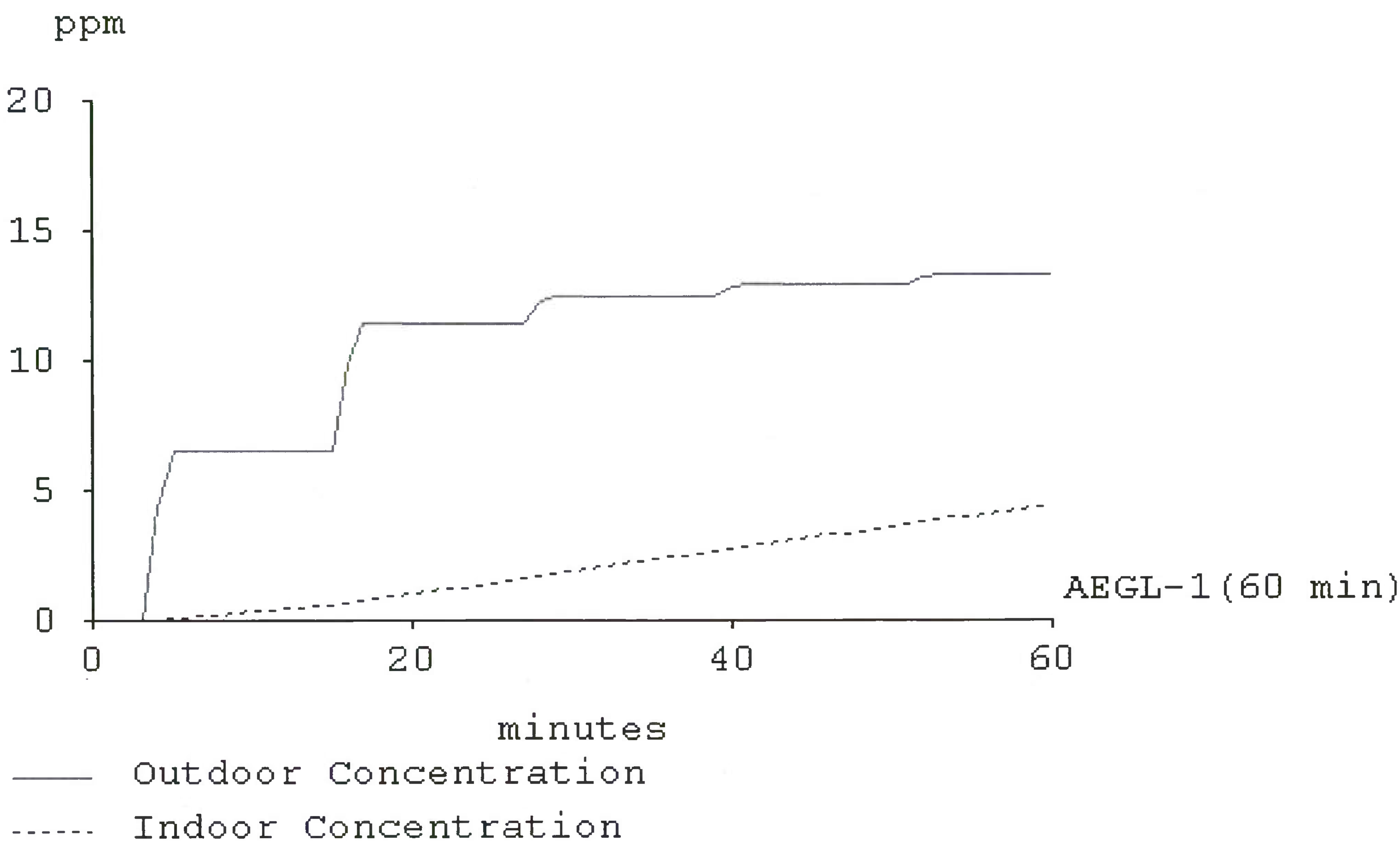

Point #1 – Travelcenters of America
200
150
100
50
0
0
20
40
60
minutes
AEGL-3(60 min)
AEGL-2(60 min)
AEGL-1(60 min)
Outdoor Concentration
Indoor Concentration
At Point: Downwind: 450 feet Off Centerline: 0 feet

[redacted]

Point #2 – East Coast Transportation Logistics

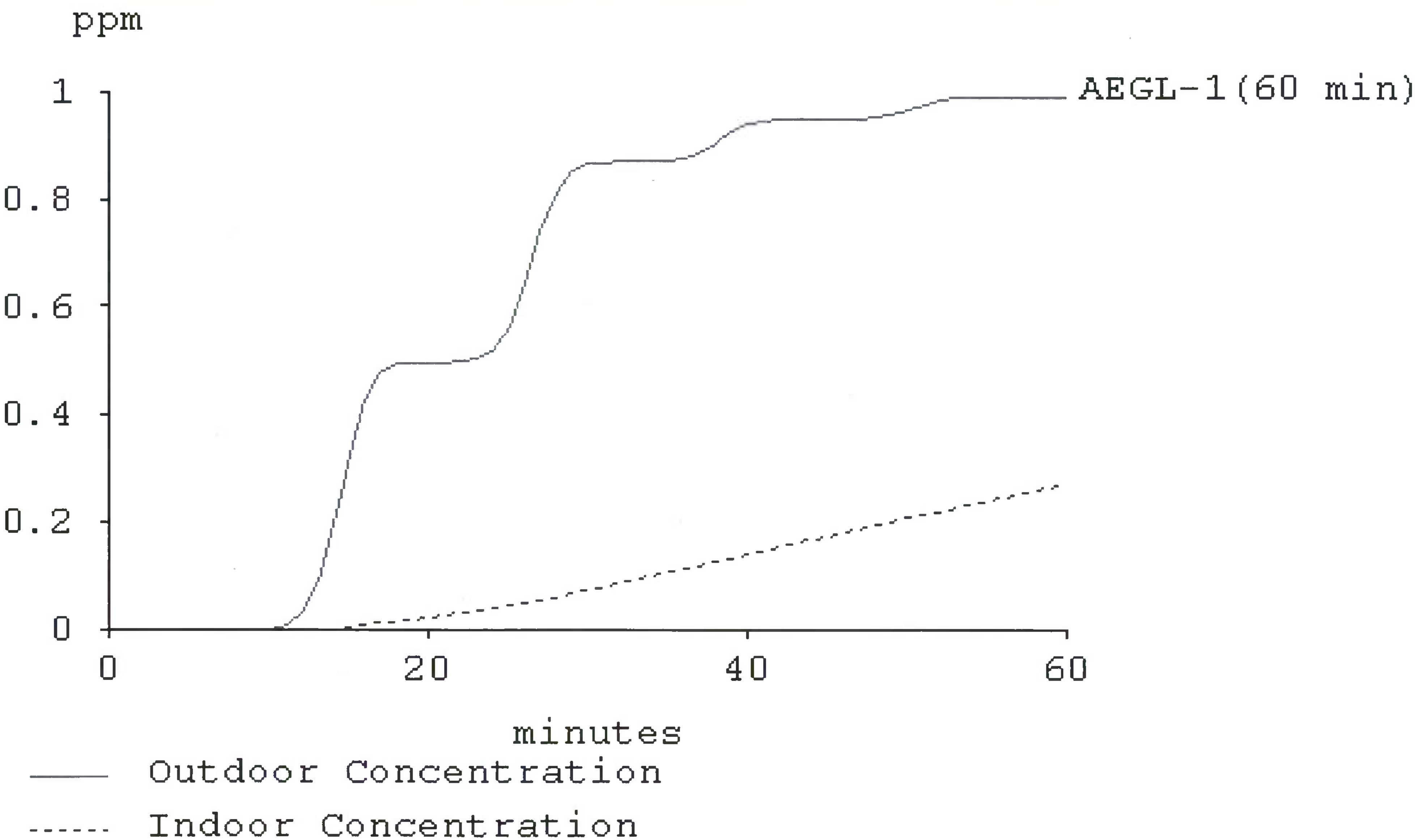


Point #3 – Homes of Maple Avenue

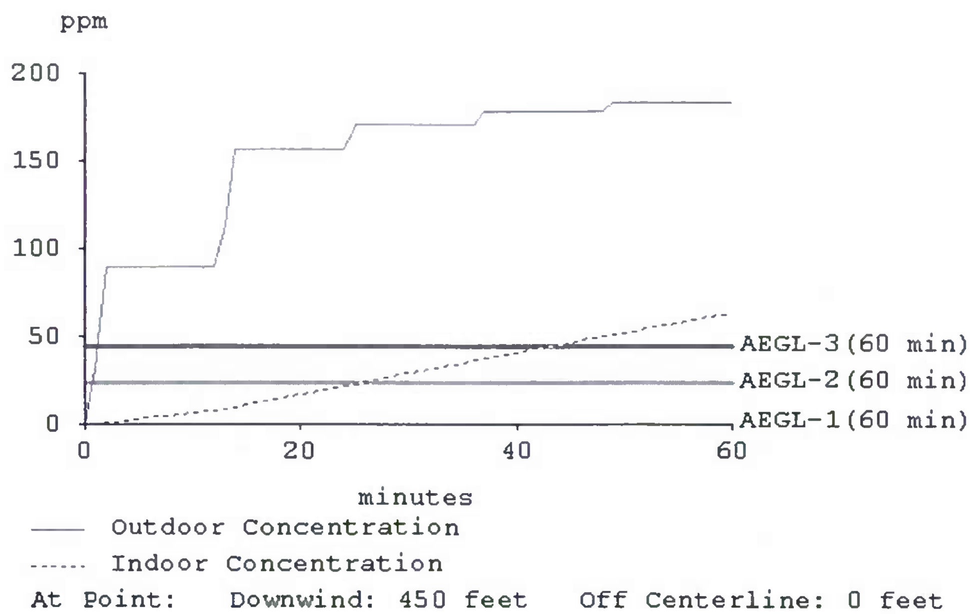


At Point: Downwind: 1700 feet Off Centerline: 0 feet

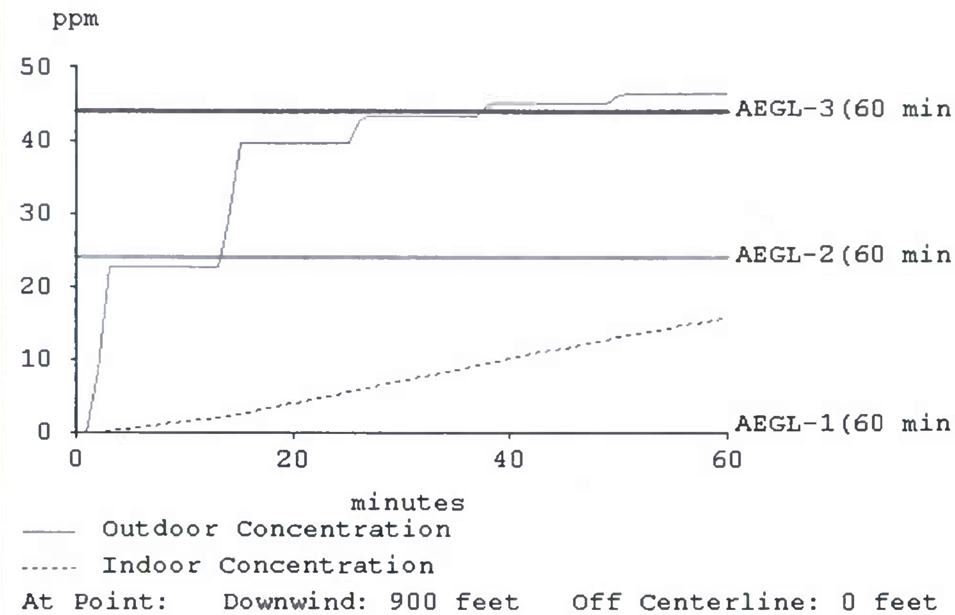
Point #4 - Whiskey Mill and Landing Roads



At Point: Downwind: 1.2 miles Off Centerline: 0 miles

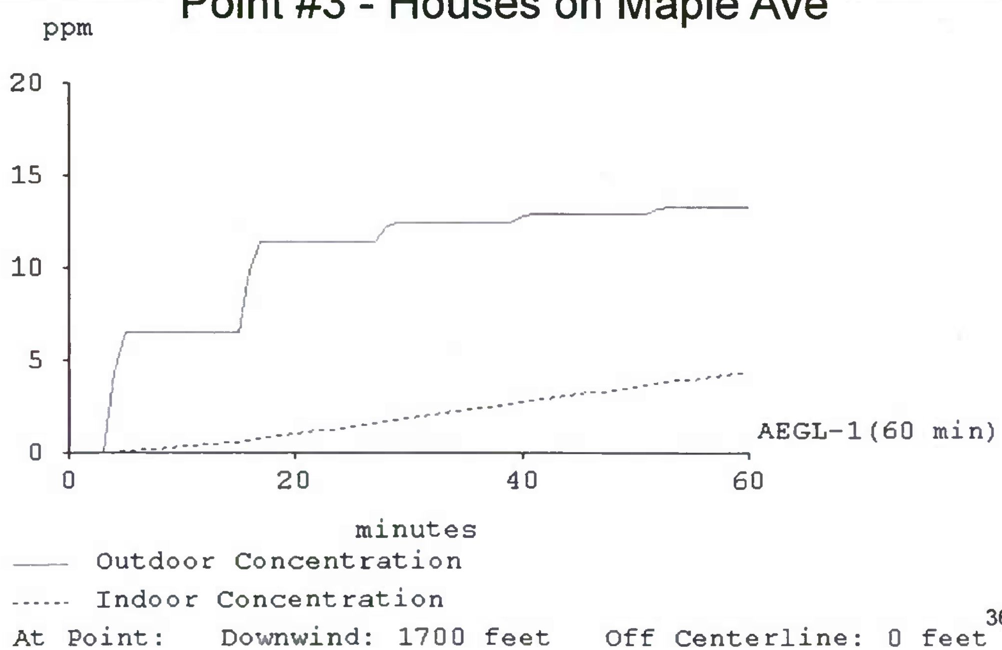


Point #1 – Travelcenters of America

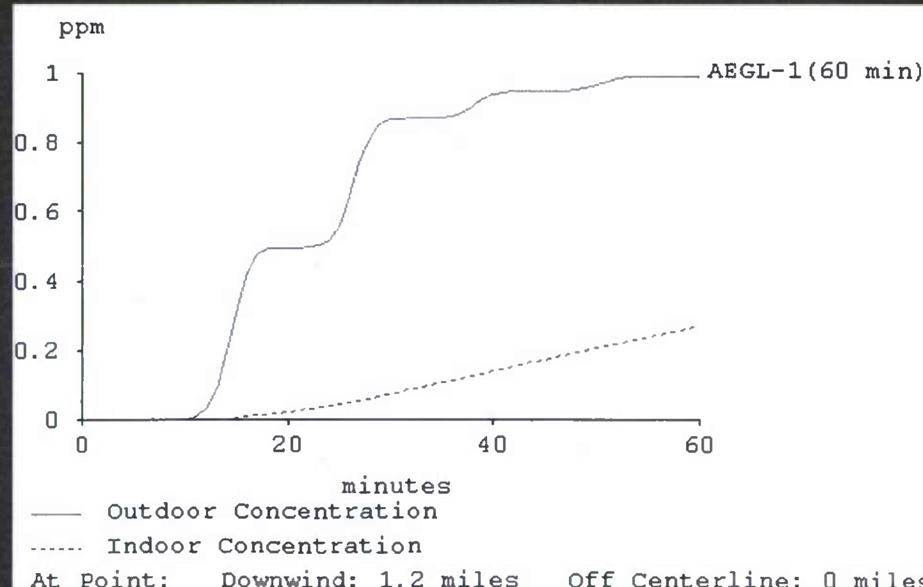


Point #2 – East Coast Transportation

Point #3 - Houses on Maple Ave



Point #4 - Whiskey Mill & Landing Roads



HFEX Hot Wash

- Overall thoughts/comments
- Strengths
- Areas that need improvement
- Limit to three comments
- Brief, concise, and to the point

05 HFEX Evaluation Abstract - Final

HFEX- HYDROGEN FLUORIDE EXERCISE PARTICIPANT FEEDBACK FORM SUMMARY

"HFEX- Hydrogen Fluoride Exercise" was held on May 24, 2010. The exercise was held at the Exxon-Mobil Technology Center in Paulsboro, NJ. There were a total of 101 participants and 40 (39.6%) completed participant feedback forms. Of the participants who completed the forms; 3 (8%) were evaluators, 18 (45%) were observers, 17 (43%) were players, and 2 (5%) were subject matter experts. The participants who completed the feedback forms were from a wide range of agencies that were at the exercise. Although it was optional, 27 of the participants wrote in their names and agencies.

The participant feedback form was altered from the Homeland Security Exercise and Evaluation Program (HSEEP) participant feedback form. The form had three sections; Part I: Recommendations and Corrective Actions, Part II: Assessment of Training Session and Exercise Design and Conduct, and Part III: Participant Feedback. The questions in Part II were written using a Likert scale of 1 to 5, with 5 being the highest value.

The first question in Part I asked the top strengths of the exercise. Communications, interagency cooperation, use of ICS and unified command were the top three strengths that were listed. Participants also noted the brainstorming of ideas, the participants were varied and representative, a comfortable exercise environment, the players had strong knowledge of their roles and responsibility, and a realistic scenario.

The second question in Part I asked the top three areas that need improvement.
The offensive actions of the HazMat team in controlling the spill, chain of command, and communications between agencies could be improved. Other comments including better communication with the hospitals, treatment of causalities, more discussion on how to protect first responders, and how to handle special needs populations.

The third question in Part I asked, " Identify the action steps that should be taken to address the issues you identified above. For each action step, indicate if it is a high, medium, or low priority." The corrective actions identified were:

High Priority	Medium Priority	Low Priority
County and local entities need to be able to communicate directly.	Expect that bystanders will be involved, call 9-1-1, and become victims themselves, and work the best solutions based on that more realistic model.	Fatality management.
Mitigation of the vapor/leak	Evaluate ability to save lives first before logistical and jurisdictional issues.	
Accuracy of the notifications.	Understanding scale of incident	

Good understanding of task forces plus resource needs	Recovery attempts	
Realize that initial units maybe affected and become part of the problem	Working of multiple PIO's together	
	Identify benefits and concerns upon evacuations of schools and senior housing areas and other special needs populations.	

The fourth question in Part I asked, "List the policies, plans, and procedures that should be reviewed, revised, or developed. For each, indicate if it is a high, medium, or low priority." The items for review identified were:

High Priority	Medium Priority	Low Priority
Evaluate behavioral science research and establish what people are likely to do and incorporate it into conops	Overturned tanker (HazMat suspected) protocol.	ARC needs from local municipalities, LE, EMS
Re-evaluate communication policies across counties and agencies	Department of Health's' role in similar situation, better identified	
Re-evaluate priorities on the incident and make sure the order of operations and urgency of patient care is realistic	Establishing a common meeting place for agency representatives.	
All SOPs should be reviewed.	Plume modeling for several other scenarios	
Preplan for extreme hazard chemicals found in jurisdiction, train all PD and FD to id chemical as first step.	Fatality management- ME, LE, and responder partnership	
Contacting immediate area (truck stop) and informing them to evacuate due to hazardous material spill, save lives.	Realistic plan to coordinate required evacuations with offensive actions that can be taken.	
Offensive action to minimize incident		
Special needs and shelter operations		

Part II of the form was Assessment of Training Session and Exercise Design and Conduct. Participants rated their overall assessment of the exercise on a scale from 1 to 5, with 1 indicating strong disagreement with the statement, 5 indicating strong agreement, and 7 indicating don't know or not applicable. All of the means for the assessment factors were greater than 4, with the highest being a 4.68. The assessment factor with the greatest average and most number of 5's was on the trainers. The weakest of the factors was on the Situation Manual and its use during the exercise.

Assessment Factor		Strongly Disagree →				Strongly Agree	Total	Mean
		1	2	3	4	5		
The morning training session prepared the participants for the tabletop exercise and discussion.	N	0	1	4	14	21	40	4.38
	%	0.0	0.03	0.10	0.35	0.53	1.00	
The trainers were knowledgeable on the topic and their presentations were understandable.	N	0	1	1	8	30	40	4.68
	%	0.0	0.03	0.03	0.20	0.75	1.00	
The exercise was well structured and organized.	N	0	0	3	16	21	40	4.45
	%	0.0	0.0	0.08	0.40	0.53	1.00	
The exercise scenario was plausible and realistic.	N	0	1	4	18	17	40	4.28
	%	0.0	0.03	0.10	0.45	0.43	1.00	
The multimedia presentation helped the participants understand and become engaged in the scenario.	N	0	2	3	18	17	40	4.28
	%	0.0	0.05	0.08	0.45	0.43	1.00	
The facilitators were knowledgeable about the material, kept the exercise on target, and were sensitive to group dynamics.	N	0	0	2	19	19	40	4.43
	%	0.0	0.0	0.05	0.48	0.48	1.00	
The Situation Manual used during the exercise was a valuable tool throughout the exercise.	N	0	0	11	14	13	40	4.05
	%	0.0	0.0	0.29	0.37	0.34	1.00	
Participation in the exercise was appropriate for someone in my position.	N	0	0	2	15	23	40	4.53
	%	0.0	0.0	0.05	0.38	0.58	1.00	
The participants included the right people in terms of level and mix of disciplines.	N	0	0	0	14	26	40	4.65
	%	0.0	0.0	0.0	0.35	0.65	1.00	

In part III – Participant Feedback of the exercise evaluation the participants were asked what changes they would make to the overall exercise and to provide recommendations for how to improve future exercises.

Overall the exercise was well received. Some of the positive comments on the exercise were that it was well planned, well organized, and well done; the facilitators did a good job moving along the scenario; the facility was good; and that it was a great opportunity for multiple agencies to collaborate.

Several participants made recommendations for how to change and enhance future exercises. Some people stated that the scenario and timeline could have more realistically reflected the numbers of victims and response timelines. One person felt that the numbers of victims were underestimated due to the fact that the exercise operated on what the people should do in such a situation and not what they will do. Another person felt that it is important to push the tabletop participants to be realistic in their time frames for response and completion of tasks.

Another area where participants recommended changes the focus of the exercise. Some participants recommended focusing more on mitigation and medical care/treatment and less on the HazMat response. Other suggestions were to discuss more in depth hot zone rescue, level A entry and shelter options. One participant suggested that if the tabletop content had been diminished there would have been more time to cover other areas. Another suggestion was to make the exercise in two phases, one like HFEX at 0-60 min and a second one at 12 or 24 hours to evaluate fatigue, shift change, etc. Finally, a participant stated that the facilitators need to control the focus of the exercise as some players by nature were more engaged and dominated the exercise with their specific concerns and responsibilities.

The exercise was accompanied by a PowerPoint presentation, but some participants recommended further exercise aides, such as: A map in the SitMan similar in scale to the map used in the PowerPoint presentation, access to the MSDS, Radio transmissions to support injects, a scribe taking notes for everybody to more easily follow the scenario and activities and responsibilities. One participant recommended that a brief instruction on how tabletop exercises proceed prior to start would get the exercise moving along better. Another participant suggested having a representative from CHEMTREC available to discuss how they would respond to a hydrogen fluoride spill.

Finally, there were suggestions for following up this tabletop exercise with a functional drill.

HFEX – Hydrogen Fluoride Exercise

May 25, 2010

After Action Report/Improvement Plan

July 25, 2011

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ADMINISTRATIVE HANDLING INSTRUCTIONS

1. The title of this document is "HFEX- Hydrogen Fluoride Exercise After Action Report/Improvement Plan."

2. Point of Contact:

   Exercise Director

   George DiFerdinando, Jr., MD, MPH
   Director
   New Jersey Center for Public Health Preparedness
   683 Hoes Lane West, First Floor
   Piscataway, New Jersey 08854
   (732) 235-9039
   diferdge@umdnj.edu

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EXECUTIVE SUMMARY

The Gloucester County chemical release tabletop exercise, HFEX – Hydrogen Fluoride Exercise, was developed to test Gloucester County's abilities to meet the meet the following Target Capabilities: Emergency Operations Center (EOC) Management, Responder Safety and Health, HazMat Response and Decontamination, Citizen Evacuation and/or Shelter-in-Place, Emergency Triage and Pre-Hospital Treatment, Medical Surge, and Mass Care (Sheltering, Feeding, and Related Services) capabilities. The exercise planning team was composed of numerous and diverse agencies, including Gloucester County Department of Health and Senior Services, Gloucester County Office of Emergency Management, Gloucester County Prosecutors Office, New Jersey Center for Public Health Preparedness, New Jersey Department of Environmental Protection, New Jersey Department of Health and Senior Services, New Jersey Hospital Association, New Jersey Office of Homeland Security and Preparedness, New Jersey State Police, and United States Department of Homeland Security.

The exercise planning team discussed the exercise goals and objectives, target capabilities to address; which agencies and people to involve as players, facilitators, evaluators, observers, and subject matter experts; type of scenario to use; and logistics for the exercise planning and implementation. Some of the issues encountered during the planning process included the scenario timeline, the number of players, and the scope of the exercise. There was discussion during the planning of the exercise to make sure that the scenario did not become so large that it was unmanageable and unrealistic. Another issue was whether or not the HF release was entirely accidental and that there were no criminal/terrorist implications. During the planning, the hospitals were concerned about their level of involvement and that it would be minimal. The hospitals provided discussion questions for each scenario

Based on the exercise planning team's deliberations, the following objectives were developed for HFEX:

- Objective 1: Assess and identify how to activate and maintain emergency communications essential to support response to an HF incident in Gloucester County.
- Objective 2: Demonstrate the ability to alert, mobilize, and activate personnel for emergency response and maintain operations until the situation is brought under control.
- Objective 3: Demonstrate the ability to mobilize and track equipment, people, and other resources in support of emergency operations.
- Objective 4: Identify and implement appropriate actions to protect emergency workers and the public.
- Objective 5: Demonstrate inter-agency (Gloucester County Health Department, hospitals, and first responders) communication and cooperation in response to an HF incident in Gloucester County.

The purpose of this report is to analyze exercise results, identify strengths to be maintained and built upon, identify potential areas for further improvement, and support development of corrective actions.

Major Strengths

The major strengths identified during this exercise are as follows:

- The organizations and agencies cooperate well, are familiar with each other's roles and responsibilities, and know agency representatives on a first name basis. There were no conflicts regarding command structures and responsibilities between players.
- The first responders on the scene accurately identified the safety perimeter of the incident site, arrived upwind, and remained outside the hot zone when assessing the situation. Staging area was established in the safe zone and later moved when wind direction was factored in.

Primary Areas for Improvement

Throughout the exercise, several opportunities for improvement in Gloucester County's ability to respond to the incident were identified. The primary areas for improvement, including recommendations, are as follows:

- No mitigation, no offensive or defensive actions were allowed until the Gloucester County HazMat team arrived on scene and assessed the situation. While the responders recognized the mutual aid agreement with Valero to provide HazMat assistance, the plan called for the Gloucester County HazMat team to arrive and assess prior to contacting Valero for assistance. The plan had no alternate procedure if the county HazMat team was delayed. The recommendation is to establish alternate procedures for requesting assistance from mutual aid agreement partners as part of a plan in case the primary authority is delayed.
- There was no Gloucester County contingency plan for a hydrogen fluoride release. The recommendation is to identify all chemicals in Gloucester County that are extremely hazardous to the public or environment and could potentially be released in large amounts during an emergency. Develop chemical specific contingency plans and standard operating procedures for different types of scenarios, including worst case scenarios. Consider including a pre-plan for a small, medium and large chemical release to be used initially until plume modeling can be accomplished. This will expedite the entire response effort, saving valuable time and potentially minimizing exposures.
- There was little consideration given to care and coordination of care for special needs populations. The only sheltering option was general shelters run by Red Cross and these shelters cannot manage medically fragile people. The only option then is to send the special needs population to the hospitals. The recommendation is to identify

the special needs populations within Gloucester County, so that appropriate plans are in place to handle this population and the necessary resources. A standard operating procedure should be drafted for special needs population care and coordination.

- The communications between first responders and healthcare/hospitals needs to be improved.

Overall this was a successful exercise and very well received by participants in different roles (i.e. players, evaluators, and observers). The suggestions for areas in which future exercises conducted by Gloucester County should focus are: issues related to special needs, such as identification of special needs populations, transportation, and shelter locations; exercises testing hospital surge capabilities, including space, staff, medications and other resources; regional incident command exercises to define roles and responsibilities, especially as turnover of positions occur; exercises focusing on EMS capabilities of mass care, including managing patients for triage, treatment and transportation; and exercises focusing on non-management personnel decision making in absence of management.

SECTION 1: EXERCISE OVERVIEW

Exercise Details

Exercise Name

HFEX – Hydrogen Fluoride Exercise

Type of Exercise

Tabletop exercise

Exercise Start Date

May 25, 2010

Exercise End Date

May 25, 2010

Duration

3 hours

Location

ExxonMobil Conference Center, 600 Billingsport Road, Paulsboro, New Jersey

Sponsor

New Jersey Center for Public Health Preparedness at UMDNJ-School of Public Health

Program

U.S. Department of Defense grant awarded to the New Jersey Center for Public Health Preparedness at UMDNJ – School of Public Health.

Mission

Response

Capabilities

- Emergency Operations Center (EOC) Management
- Responder Safety and Health
- HazMat Response and Decontamination
- Citizen Evacuation and/or Shelter-in-Place
- Emergency Triage and Pre-Hospital Treatment
- Medical Surge
- Mass Care (Sheltering, Feeding, and Related Services)

Scenario Type

Chemical release (hydrogen fluoride)

Exercise Planning Team Leadership

Diane Anderson, Planning
New Jersey Hospital Association

Rebecca Baron, Logistics, Planning, and Operations
New Jersey Center for Public Health Preparedness

Robert Brownlee, Planning and Evaluation Team Captain
New Jersey Department of Health and Senior Services

Jack DeAngelo, Planning
Gloucester County Office of Emergency Management

George DiFerdinando, Administrative/Finance
New Jersey Center for Public Health Preparedness

William Donovan, Planning and Operations
Gloucester County Prosecutors Office

Mitchell Erickson, Planning
United States Department of Homeland Security

Bryan Everingham, Planning, Logistics and Exercise Facilitator
New Jersey State Police

Kevin Hayden, Planning
New Jersey Department of Health and Senior Services

Glenn Paulson, Planning Team Leader
New Jersey Center for Public Health Preparedness

Christine Poulsen, Logistics, Planning, and Operations
New Jersey Center for Public Health Preparedness

Dennis Quinn, Planning
New Jersey Office of Homeland Security and Preparedness

Thomas Rafferty, Planning and Logistics
New Jersey State Police

Dennis Sample, Planning and Logistics
New Jersey Office of Homeland Security and Preparedness

Robert Van Fossen, Planning, Logistics and Exercise Facilitator

New Jersey Department of Environmental Protection

Scott Woodside, Planning
Gloucester County Department of Health and Senior Services

Participating Organizations

Atlantic Health
Burlington County Health Department
Camden County
Cooper University Hospital
Crozer-Chester Medical Center
DuPont
East Greenwich Township Fire / Rescue
ExxonMobil Tech Center
Gibbstown Fire Company
Gloucester County Emergency Medical Service
Gloucester County Department of Health and Senior Services
Gloucester County Hazardous Materials Response Team
Gloucester County Office of Emergency Management
Gloucester County Prosecutors Office
Gloucester County Chapter of the American Red Cross
Health Care Association of New Jersey
Honeywell
Kennedy Hospital
New Jersey Center for Public Health Preparedness
New Jersey Department of Environmental Protection
New Jersey Department of Health and Senior Services
New Jersey Department of Transportation
New Jersey Hospital Association
New Jersey Office of Homeland Security and Preparedness
New Jersey State Police
New Jersey Turnpike Authority Emergency Services Department
Paulsboro Emergency Management
Rowan University
Solvay Solexis, Inc.
Underwood Memorial Hospital
United States Coast Guard
United States Department of Homeland Security
Valero
West Deptford Police Department

Number of Participants

- Players: 26
- Evaluators: 8

- Facilitators: 2
- Observers: 67 (including planning team)

SECTION 2: EXERCISE DESIGN SUMMARY

Exercise Purpose and Design

The purpose of the HFEX – Hydrogen Fluoride Exercise was to provide participants with an opportunity to evaluate their current emergency response plans and capabilities for a response to a hydrogen fluoride release in Gloucester County. The exercise focused on key local and county capabilities in both external and internal communication, coordination, and critical decision-making, and was aimed at hospital, public health, and first responder coordination of the incident.

The HFEX exercise was developed and implemented by a planning team consisting of people from a wide array of agencies and organizations within New Jersey, primarily within Gloucester County. The planning process started in October, 2009 and meetings with the planning team were held at minimum monthly. The exercise was designed using the Homeland Security Exercise and Evaluation Program, and was organized as a facilitated tabletop exercise accompanied by a multimedia presentation. At different points in the exercise there were injects and updates which summarized key scenario events occurring within that time period. After the updates, participants engaged in a facilitated group discussion of appropriate response issues and subsequent actions based on the scenario. The exercise was funded by a grant from the U.S. Department of Defense awarded to the New Jersey Center for Public Health Preparedness at UMDNJ – School of Public Health.

Exercise Objectives, Capabilities, and Activities

Capabilities-based planning allows for exercise planning teams to develop exercise objectives and observe exercise outcomes through a framework of specific action items that were derived from the Target Capabilities List (TCL). The capabilities listed below form the foundation for the organization of all objectives and observations in this exercise. Additionally, each capability is linked to several corresponding activities and tasks to provide additional detail.

Based upon the identified exercise objectives below, the exercise planning team has decided to demonstrate the following capabilities during this exercise:

- **Objective 1:** Assess and identify how to activate and maintain emergency communications essential to support response to an HF incident in Gloucester County.
  - **Emergency Operations Center (EOC) Management:** Activity 1: Activate EOC/MACC/IOF; Activity 2: Direct EOC/MACC/IOF Tactical Operations; Activity 3: Gather and Provide Information; Activity 4: Identify and Address Issues; Activity 5: Prioritize and Provide Resources; Activity 6: Provide EOC/MACC/IOF Connectivity; Activity 7: Support and Coordinate Response; and Activity 8: Demobilize EOC/MACC/IOF Management.

- **Objective 2:** Demonstrate the ability to alert, mobilize, and activate personnel for emergency response and maintain operations until the situation is brought under control.
  - **Emergency Operations Center (EOC) Management:** Activity 1: Activate EOC/MACC/IOF; Activity 2: Direct EOC/MACC/IOF Tactical Operations; Activity 3: Gather and Provide Information; Activity 4: Identify and Address Issues; Activity 5: Prioritize and Provide Resources; Activity 6: Provide EOC/MACC/IOF Connectivity; Activity 7: Support and Coordinate Response; and Activity 8: Demobilize EOC/MACC/IOF Management.
  - **HazMat Response and Decontamination:** Activity 1: Site Management and Control; Activity 2: Identify the Problem; Activity 3: Hazard Assessment and Risk Evaluation; Activity 4: Information Management and resource Coordination; Activity 5: Implement Response Objectives; and Activity 6: Decontamination and Clean-Up/Recovery Operations.
  - **Emergency Triage and Pre-Hospital Treatment:** Activity 1: Direct Triage and Pre-Hospital Treatment Tactical Operations; Activity 2: Activate Triage and Pre-Hospital Treatment; and Activity 5: Transport.

- **Objective 3:** Demonstrate the ability to mobilize and track equipment, people, and other resources in support of emergency operations.
  - **Emergency Operations Center (EOC) Management:** Activity 1: Activate EOC/MACC/IOF; Activity 2: Direct EOC/MACC/IOF Tactical Operations; Activity 3: Gather and Provide Information; Activity 4: Identify and Address Issues; Activity 5: Prioritize and Provide Resources; Activity 6: Provide EOC/MACC/IOF Connectivity; Activity 7: Support and Coordinate Response; and Activity 8: Demobilize EOC/MACC/IOF Management.
  - **HazMat Response and Decontamination:** Activity 1: Site Management and Control; Activity 2: Identify the Problem; Activity 3: Hazard Assessment and Risk Evaluation; Activity 4: Information Management and resource Coordination; Activity 5: Implement Response Objectives; and Activity 6: Decontamination and Clean-Up/Recovery Operations.
  - **Emergency Triage and Pre-Hospital Treatment:** Activity 1: Direct Triage and Pre-Hospital Treatment Tactical Operations; Activity 2: Activate Triage and Pre-Hospital Treatment; and Activity 5: Transport.
  - **Citizen Evacuation and/or Shelter-in-Place:** Activity 1: Direct Evacuation and/or In-Place Protection Tactical Operation; and Activity 2: Activate Evacuation and/or In-Place Protection.
  - **Medical Surge:** Activity 1: Pre-event Mitigation and Preparedness; Activity 2: Incident Management; Activity 3: Increase Bed Surge Capacity; Activity 4: Medical Surge Staffing Procedures; Activity 5: Decontamination; Activity 6: Receive, Evaluate, and Treat Surge Casualties; Activity 7: Provide Surge Capacity for Behavioral Health Issues; and Activity 8: Demobilize.
  - **Mass Care (Sheltering, Feeding, and Related Services):** Activity 1: Direct

Mass Care Tactical Operations; Activity 2: Activate Mass Care; and Activity 3: Shelter Special Needs.

- **Objective 4:** Identify and implement appropriate actions to protect emergency workers and the public.
    - **Responder Safety and Health:** Activity 1: Activate Responder Safety and Health; Activity 2: Identify Safety/PPE Needs and Distribute PPE; and Activity 3: Site/Incident Specific Safety and Health Training.
    - **HazMat Response and Decontamination:** Activity 1: Site Management and Control; Activity 2: Identify the Problem; Activity 3: Hazard Assessment and Risk Evaluation; Activity 4: Information Management and resource Coordination; Activity 5: Implement Response Objectives; and Activity 6: Decontamination and Clean-Up/Recovery Operations.
    - **Citizen Evacuation and/or Shelter-in-Place:** Activity 1: Direct Evacuation and/or In-Place Protection Tactical Operation; and Activity 2: Activate Evacuation and/or In-Place Protection.
    - **Emergency Triage and Pre-Hospital Treatment:** Activity 1: Direct Triage and Pre-Hospital Treatment Tactical Operations; Activity 2: Activate Triage and Pre-Hospital Treatment; and Activity 5: Transport.
    - **Mass Care (Sheltering, Feeding, and Related Services):** Activity 1: Direct Mass Care Tactical Operations; Activity 2: Activate Mass Care; and Activity 3: Shelter Special Needs.

- **Objective 5:** Demonstrate inter-agency (Gloucester County Health Department, hospitals, and first responders) communication and cooperation in response to an HF incident in Gloucester County.
    - **Emergency Operations Center (EOC) Management:** Activity 1: Activate EOC/MACC/IOF; Activity 2: Direct EOC/MACC/IOF Tactical Operations; Activity 3: Gather and Provide Information; Activity 4: Identify and Address Issues; Activity 5: Prioritize and Provide Resources; Activity 6: Provide EOC/MACC/IOF Connectivity; Activity 7: Support and Coordinate Response; and Activity 8: Demobilize EOC/MACC/IOF Management.

Scenario Summary

The scenario for the exercise was a transportation incident involving a tank truck carrying hydrogen fluoride. No specific Gloucester County industrial facility was named or implicated in the exercise. The scenario was split into three parts. In part 1, a tank truck with a UN 1052 label and placards indicating corrosive and poison exits Interstate 295 northbound at exit 18 in East Greenwich, NJ. The truck swerves and overturns on the exit ramp next to a truck stop busy with truckers and other patrons. The contents of the tank truck are starting to leak. In part 2, the contents leaking are staring to move with the prevailing winds and people down wind are experiencing symptoms. In part 3, indoor and outdoor concentrations of HF at the site of the incident reached dangerous levels and calls are coming in from areas farther down wind reporting symptoms of HF exposure.

SECTION 3: ANALYSIS OF CAPABILITIES

This section of the report reviews the performance of the exercised capabilities, activities, and tasks. In this section, observations are organized by capability and associated activities. The capabilities linked to the exercise objectives of HFEX – Hydrogen Fluoride Exercise are listed below, followed by corresponding activities. Each activity is followed by related observations, which include references, analysis, and recommendations.

Capability 2: Responder Safety and Health

Capability Summary: Responder Safety and Health is the capability that ensures adequate trained and equipped personnel and resources are available at the time of an incident to protect the safety and health of on-scene first responders, hospital/medical facility personnel (first receivers), skilled support personnel, and, if necessary, their families through the creation and maintenance of an effective safety and health program. This program needs to comply with the Occupational Safety and Health Administration (OSHA) and any other applicable Federal and State regulations and health and safety standards.

Responder safety and health was not fully addressed in this exercise. No safety officer was named and as a result no safety and health plan was developed, on-going health and safety assessments were not occurring and site resource needs and training was not conducted. First responders correctly identified a place up-wind from the incident at which to place the incident command post, however, the chemical was not identified and mitigation was continuously delayed until the county HazMat team arrived on scene with proper PPE, which was 1-1.5 hours into the event.

Observation 1: Strength: First responders recognized the dangers of approaching the spill.

References: None

Analysis: Early arriving responders (police, EMS and fire) appropriately arrived from an upwind route, remained out of the hot zone when assessing the situation and during the identification of the contents of the overturned tanker. The two care accident victims still in the immediate area of the spill created an incentive to enter and rescue, but the responders recognized they were not appropriately protected.

Recommendations: None

Observation 2: Strength: First responders were aware of a mutual aid agreement with Valero.

References: None

Analysis: Responders recognized that Valero had experience and resources and a mutual aid agreement to provide assistance if called for local incidents in keeping with the plan.

Recommendations: None

Observation 3: Area of Improvement: The Valero mutual aid agreement required the County HazMat team to be on scene and assess situation prior to providing their assistance.

References: None

Analysis: Valero was not contacted because the County HazMat team did not arrive until an hour and a half into the incident. There was no alternate procedure discussed.

Recommendations: Establish alternate procedures for requesting assistance from mutual aid agreement partners as part of the plan, in case the primary authority is delayed.

Observation 4: Area of Improvement: The incident command post location was first set up down-wind, later moved upwind.

References: None

Analysis: Greenwich Police Department, the first on the scene and original incident command, selected the Travel Center south west of the incident as the incident command post location. They seemed aware of the wind location, but intent on other qualities of the location, such as easy reach. They were quick to change location up-wind but were still too close to the incident (<700 feet). The police department mentioned the emergency response guide for hydrogen fluoride, but did not show the requisite use of the guidance.

Recommendations: Identify the primary location of the incident command post and staging area to be up-wind from the incident at the distance defined in the emergency response guide for HF and include this distance in the contingency plan. Stress this issue in training of first responders and incident commanders.

Observation 5: Area of Improvement: The incident commander did not designate a safety officer.

References: None

Analysis: The incident commander is acting safety officer until one is designated. At the beginning, nobody with appropriate credentials was on site. However, with a HazMat incident the IC should recognize the immediate need for a safety officer who can focus on safety planning early in the incident. While there seemed to be some question of when the fire departments would arrive on scene, a fire chief should be on scene relatively quickly and capable of acting as a temporary safety officer.

Recommendations: Modify the emergency response plan and appropriate procedures to implement immediate evacuation/shelter-in-place warnings in keeping with the emergency response guide.

Observation 6: Area of Improvement: No mitigation, offensive or defensive actions were allowed until the HazMat team arrived on scene and assessed the situation.

References: None

Analysis: Waiting for HazMat even to begin the site assessment was too much of a delay in mitigation, especially considering the Valero HazMat team was five minutes away. Even if Valero cannot provide HazMat team for offensive mitigation operations, they may be able to supply expertise off-site, equipment, and perhaps perform plume modeling.

Recommendations: Identify local expertise in the emergency plan who can be contacted. Establish a procedure in which a primary authority that can activate mutual aid agreements can be in contact with people on site and thus assess the scene or establish alternate procedures for activating mutual aid agreements, not depending on arrival of HazMat team.

Observation 7: Area of Improvement: Create pre-plans for extremely hazardous materials.

References: None

Analysis: There was no Gloucester County contingency plan for a hydrogen fluoride release. Pre-planning for a hazardous materials release incident will allow responders to more quickly and safely deploy, plan and mitigate the incident. The Right to Know Standard mandates the collection of hazardous materials information at the local police and fire departments, as well as the local emergency planning committee at the county level. RTK information can be used to identify chemicals present in the community for which pre-plans should be developed.

Recommendations: The recommendation is to identify all chemicals in Gloucester County that are extremely hazardous to the public or environment and could potentially be released in large amounts during an emergency. Develop chemical specific contingency plans and standard operating procedures for different types of scenarios, including worst case scenarios.

Capability 3: HazMat Response and Decontamination

Capability Summary: Hazardous Materials Response and Decontamination is the capability to assess and manage the consequences of a hazardous materials release, either accidental or as part of a terrorist attack. It includes testing and identifying all likely hazardous substances onsite; ensuring that responders have protective clothing and equipment; conducting rescue operations to remove affected victims from the hazardous environment; conducting geographical survey searches of suspected sources or contamination spreads and establishing isolation perimeters; mitigating the effects of hazardous materials, decontaminating on-site victims, responders, and equipment; coordinating off-site decontamination with relevant agencies, and notifying environmental, health, and law enforcement agencies having jurisdiction for the incident to begin implementation of their standard evidence collection and investigation procedures.

HazMat response and decontamination was fully addressed in this exercise. Issues involving site management and control, hazard assessment and mitigation were discussed. The HazMat team was integrated into the unified command, they established hot and support zones and completed a full site assessment upon arrival. The HazMat priorities were verbalized, however, no incident action plan was developed and the HazMat team did not utilize or reference written plans during the exercise.

Observation 1: Strength: Early HazMat intervention and establishment of unified command.

References: 1. The 911 tele-communicators have HazMat training and can prompt for response. 2. The HazMat resources were incorporated into the incident command system fully and immediately upon arrival on scene.

Analysis: Based upon the 911 tele-communicators and the quick size up by the Fire Department, the HazMat assessment team was dispatched quickly.

Recommendations: None

Observation 2: Area of improvement: Develop pre-plans for incidents of this nature.

References: None

Analysis: SOPs/SOGs should not only be developed for the routine events and responses, but should also be considered for some worst case scenarios.

Recommendations: Develop SOP/SOG for a response to HF incidents – this will expedite the entire response effort, saving valuable time and possibly minimizing exposures. Consider preplanning a small, medium and large vapor release to be used initially until modeling can be accomplished.

Observation 3: Area of improvement: First aid training for hydrogen fluoride exposure.

References: None

Analysis: Hydrogen fluoride toxicology was discussed and while there was a consensus that a 5-minute wash is appropriate there seemed to be a lack of immediate follow-up treatment.

Recommendations: Examine how the follow-up treatment would be administered, in a timely manner, especially when dealing with mass exposures. Identify any impediments to this treatment and formulate solutions.

Capability 4: Citizen Evacuation and/or Shelter-in-Place

Capability Summary: Citizen evacuation and shelter-in-place is the capability to prepare for, ensure communication of, and immediately execute the safe and effective sheltering-in-place of an at-risk population (and companion animals), and/or the organized and managed evacuation of the at-risk population (and companion animals) to areas of safe refuge in response to a potentially or actually dangerous environment. In addition, this capability involves the safe reentry of the population where feasible.

We did not complete this capability because we ran out of time during the exercise.

Capability 5: Emergency Triage and Pre-Hospital Treatment

Capability Summary: Triage and Pre-Hospital Treatment is the capability to appropriately dispatch emergency medical services (EMS) resources; to provide feasible, suitable, and medically acceptable pre-hospital triage and treatment of patients; to provide transport as well as medical care en-route to an appropriate receiving facility; and to track patients to a treatment facility.

Emergency Triage and Pre-Hospital Treatment was not fully addressed in this exercise. Issues involving activation and direction of triage and pre-hospital treatment were discussed, but the actual triage, treatment and transport of patients was not emphasized because the exercise scenario did not allow for it. This exercise involved more the public safety and pre-hospital response and not the treatment of patients.

Observation 1: Strength: Interagency Communications worked well.

References: Procedural

Analysis: Noted EMS and fire could communicate directly via radio and indirectly with law enforcement through shared dispatch. Noted inclusion of basic life support and advanced life support supervisors to aid communications with personnel, unified command and the hospitals.

Recommendations: Assure that non-management personnel are aware of these communication procedures, in case management is not immediately available.

Observation 2: Strength: EMS and HazMat used proper safety precautions.

References: Procedural

Analysis: EMS was very firm in position of setting up and awaiting access to patients after decontamination.

Recommendations: Assure that non-management personnel are equally aware of safety procedures in this type of incident.

Observation 3: Strength: EMS demonstrated cooperation.

References: Procedural

Analysis: The EMS chief clearly demonstrated assessing the need for backfill of other EMS units (county wide system) either using off duty staff or out of county strike team.

Recommendations: Assure that supervisors would take similar actions that as the chief.

Observation 4: Area of Improvement: Exercise did not appropriately test EMS capabilities with mass care.

References: None

Analysis: Exercise did not fully expand and thus EMS was not challenged with managing patients for triage, treatment and transportation.

Recommendations: Consider this a component for a future exercise.

Observation 5: Area of Improvement: Exercise did not appropriately test hospital surge capabilities and management of impact on facility.

References: It was noted during the exercise that the incident management team would be alerted/activated, but without the patients it was never truly assessed.

Analysis: Exercise did not fully expand and thus the hospitals were not challenged for surge capacity and impact on facility.

Recommendations: Consider this a component for a future exercise.

Capability 6: Medical Surge

Capability Summary: Medical Surge is the capability to rapidly expand the capacity of the existing healthcare system (long-term care facilities, community health agencies, acute care facilities, alternate care facilities and public health departments) in order to provide triage and subsequent medical care. This includes providing definitive care to individuals at the appropriate clinical level of care, within sufficient time to achieve recovery and minimize medical complications. The capability applies to an event resulting in a number or type of patients that overwhelm the day-to-day acute-care medical capacity. Medical Surge is defined as the rapid expansion of the capacity of the existing healthcare system in response to an event that results in increased need of personnel (clinical and non-clinical), support functions (laboratories and radiological), physical space (beds, alternate care facilities) and logistical support (clinical and non-clinical equipment and supplies).

Medical surge was not fully addressed in this exercise. Issues involving hospital decontamination capabilities and triage were discussed, but the transport of patients from the field to the hospital was not emphasized. This exercise involved more the public safety and pre-hospital response and not the medical treatment of patients.

Observation 1: Strength: Incident command was appropriately activated.

References: NIMS/ICS

Analysis: Appropriate activation of incident command with upgrade to unified command. Lead agencies were quickly identified. Organizations were familiar with partners and stakeholders, even knowing each other in a first name basis.

Recommendations: Continue strengthening partnerships through discussions, projects and exercises.

Observation 2: Strength: Staging area was appropriately located.

References: Decon/HazMat

Analysis: Staging area was established based on hazards and later moved when wind direction was factored in.

Recommendations: Continue strengthening partnerships through discussions, projects and exercises.

Observation 3: Strength: Partnerships across organizations and agencies.

References: NIMS/ICS

Analysis: Organizations and agencies have worked together in the past and are familiar with roles and responsibilities. There were no conflicts regarding who is in charge and what each agency is supposed to do.

Recommendations: Continue to exercise and define roles and responsibilities, especially when turnover of positions occur.

Observation 4: Area of improvement: Special population needs were not fully considered.

References: Cashes of equipment to set up 25-50 beds for special needs sheltering have been purchased through regional grant funds, but a standard operating procedure has not been developed to address operations and logistics (location, staffing, liability coverage, evacuation criteria, etc.).

Analysis: There was a little consideration for the special needs population. With the plan to evacuate neighborhoods due to the chemical exposure, the only sheltering option is the general shelters run by Red Cross. Since these shelters cannot manage medically fragile people, there are no other options other than sending the special needs populations to the hospitals.

Recommendations: The special needs population needs to be identified so that appropriate resources are available. Default plan is to send this population to the hospitals. A standard operating procedure needs to be drafted, including major stakeholders. The upcoming regional exercise involving special needs populations will help illustrate the importance of this issue and vet problem through leadership.

Observation 5: Area of improvement: Medical surge was not fully tested in this exercise.

References: Hospital disaster plan, county emergency management plans.

Analysis: Medical surge at the hospitals was not tested to stress current plans and resources. Mass documentation and triage were not specifically addressed during the exercise.

Recommendations: An exercise to test hospital surge capabilities, including space, staff, medications, and other resources.

Observation 6: Area of improvement: Not all organizations were familiar with communications.

References: County communications plans.

Analysis: Some organizations were not familiar with the communication channels used by partners. Not all communication modalities interface together. A major issue was communication between EMS and hospitals, which appears to be separate from other modalities used by first responders.

Recommendations: Identify one point of contact for each agency, responsible for receiving information and sharing information to other partners. Create redundancy and test for interoperability.

Capability 7: Mass Care (Sheltering, Feeding and Related Services)

Capability Summary: Mass Care is the capability to provide immediate shelter, feeding centers, basic first aid, bulk distribution of needed items, and related services to persons affected by a large-scale incident, including special needs populations. Special needs populations include individuals with physical or mental disabilities who require medical attention or personal care beyond basic first aid. Other special-needs populations include non-English speaking populations that may need to have information presented in other languages. The mass care capability also provides for pet care/handling through local government and appropriate animal-related organizations. Mass care is usually performed by nongovernmental organizations (NGOs), such as the American Red Cross, or by local government-sponsored volunteer efforts, such as Citizen Corps. Special-needs populations are generally the responsibility of local government, with medical needs addressed by the medical community and/or its alternate care facilities. State and Federal entities also play a role in public and environmental health by ensuring safe conditions, safe food, potable water, sanitation, clean air, etc.

Mass care was not fully addressed in this exercise. While the mass care plan was activated and the services coordinated for the general populations, the mass care for special needs populations was not fully addressed.

Observation 1: Strength: Developed mass care plan and identified shelter sites.

References: None

Analysis: Plan was noted and shelter sites identified. , but needs revision given time and day of event, with respect to identified shelter.

Recommendations: Consideration should be given to coordination with a shelter provider, transportation needs, care of elderly and special needs populations.

Observation 2: Area of improvement: unclear coordination with school officials for sites of shelter.

References: None

Analysis: There was confusion concerning coordination with the school officials for shelter locations and consideration of on-going school activities.

Recommendations: Consider additional locations for sheltering and create contact ahead of time with persons in charge of these facilities.

Observation 3: Area of improvement: Transportation for mass care coordination was not fully planned out.

References: None

Analysis: Transport requirements for special needs and the elderly population was not fully addressed. Also, transportation of shelter supplies to sites was not discussed.

Recommendations: Identify special needs population within the county and develop special transportation services.

SECTION 4: CONCLUSION

The Gloucester County chemical release tabletop exercise, HFEX – Hydrogen Fluoride Exercise, was held on May 25, 2010. HFEX was developed to test Gloucester County's abilities to meet seven Target Capabilities. Participants exercised with the scenario of an accidental HF release from an overturned tanker in Gloucester County.

The major strengths of the exercise, based on hot wash and evaluation comments, included the organizations' and agencies' ability to cooperate; the participants' knowledge of command structures and of other agencies; and the setting up of the staging area and the identification of the hot zone.

Areas of improvement were also identified. Those areas were a delay in mitigation or offensive/defensive actions at the scene; no county contingency plan for a hydrogen fluoride release; no consideration for special needs populations; and a lack of communication between the hospitals and the first responders.

Recommendations from this exercise are the establishment of alternate procedures for requesting mutual aid for HazMat events; the development of a county contingency plan for a chemical release of different sizes; the creation of a standard operating procedure for special needs populations; and the improvement of communication methods between first responders and hospitals.

This report should be used by Gloucester County for corrective actions.

APPENDIX A: PARTICIPANT FEEDBACK SUMMARY

HFEX- HYDROGEN FLUORIDE EXERCISE PARTICIPANT FEEDBACK FORM SUMMARY

"HFEX- Hydrogen Fluoride Exercise" was held on May 24, 2010. The exercise was held at the Exxon-Mobil Technology Center in Paulsboro, NJ. There were a total of 101 participants and 40 (39.6%) completed participant feedback forms. Of the participants who completed the forms; 3 (8%) were evaluators, 18 (45%) were observers, 17 (43%) were players, and 2 (5%) were subject matter experts. The participants who completed the feedback forms were from a wide range of agencies that were at the exercise. Although it was optional, 27 of the participants wrote in their names and agencies.

The participant feedback form was altered from the Homeland Security Exercise and Evaluation Program (HSEEP) participant feedback form. The form had three sections; Part I: Recommendations and Corrective Actions, Part II: Assessment of Training Session and Exercise Design and Conduct, and Part III: Participant Feedback. The questions in Part II were written using a Likert scale of 1 to 5, with 5 being the highest value.

The first question in Part I asked the top strengths of the exercise. Communications, interagency cooperation, use of ICS and unified command were the top three strengths that were listed. Participants also noted the brainstorming of ideas, the participants were varied and representative, a comfortable exercise environment, the players had strong knowledge of their roles and responsibility, and a realistic scenario.

The second question in Part I asked the top three areas that need improvement.
The offensive actions of the HazMat team in controlling the spill, chain of command, and communications between agencies could be improved. Other comments including better communication with the hospitals, treatment of causalities, more discussion on how to protect first responders, and how to handle special needs populations.

The third question in Part I asked, " Identify the action steps that should be taken to address the issues you identified above. For each action step, indicate if it is a high, medium, or low priority." The corrective actions identified were:

High Priority	*Medium Priority*	*Low Priority*
County and local entities need to be able to communicate directly.	Expect that bystanders will be involved, call 9-1-1, and become victims themselves, and work the best solutions based on that more realistic model.	Fatality management.
Mitigation of the vapor/leak	Evaluate ability to save lives first before logistical and jurisdictional issues.	
Accuracy of the	Understanding scale of	

notifications.	incident	
Good understanding of task forces plus resource needs	Recovery attempts	
Realize that initial units maybe affected and become part of the problem	Working of multiple PIO's together	
	Identify benefits and concerns upon evacuations of schools and senior housing areas and other special needs populations.	

The fourth question in Part I asked, "List the policies, plans, and procedures that should be reviewed, revised, or developed. For each, indicate if it is a high, medium, or low priority." The items for review identified were:

High Priority	*Medium Priority*	*Low Priority*
Evaluate behavioral science research and establish what people are likely to do and incorporate it into conops (continuing operations)	Overturned tanker (HazMat suspected) protocol.	ARC needs from local municipalities, LE, EMS
Re-evaluate communication policies across counties and agencies	Department of Health's' role in similar situation, better identified	
Re-evaluate priorities on the incident and make sure the order of operations and urgency of patient care is realistic	Establishing a common meeting place for agency representatives.	
All SOPs should be reviewed.	Plume modeling for several other scenarios	
Preplan for extreme hazard chemicals found in jurisdiction, train all PD and FD to id chemical as first step.	Fatality management- ME, LE, and responder partnership	
Contacting immediate area (truck stop) and informing them to evacuate due to hazardous material spill, save lives.	Realistic plan to coordinate required evacuations with offensive actions that can be taken.	
Offensive action to minimize incident		

Special needs and shelter operations		

Part II of the form was Assessment of Training Session and Exercise Design and Conduct. Participants rated their overall assessment of the exercise on a scale from 1 to 5, with 1 indicating strong disagreement with the statement, 5 indicating strong agreement, and 7 indicating don't know or not applicable. All of the means for the assessment factors were greater than 4, with the highest being a 4.68. The assessment factor with the greatest average and most number of 5's was on the trainers. The weakest of the factors was on the Situation Manual and its use during the exercise.

Assessment Factor		**Strongly Disagree →**				**Strongly Agree**	**Total**	**Mean**
		1	**2**	**3**	**4**	**5**		
The morning training session prepared the participants for the tabletop exercise and discussion.	**N** **%**	0 0.0	1 0.03	4 0.10	14 0.35	**21** **0.53**	40 1.00	4.38
The trainers were knowledgeable on the topic and their presentations were understandable.	**N** **%**	0 0.0	1 0.03	1 0.03	8 0.20	**30** **0.75**	40 1.00	4.68
The exercise was well structured and organized.	**N** **%**	0 0.0	0 0.0	3 0.08	16 0.40	**21** **0.53**	40 1.00	4.45
The exercise scenario was plausible and realistic.	**N** **%**	0 0.0	1 0.03	4 0.10	**18** **0.45**	17 0.43	40 1.00	4.28
The multimedia presentation helped the participants understand and become engaged in the scenario.	**N** **%**	0 0.0	2 0.05	3 0.08	**18** **0.45**	17 0.43	40 1.00	4.28
The facilitators were knowledgeable about the material, kept the exercise on target, and were sensitive to group dynamics.	**N** **%**	0 0.0	0 0.0	2 0.05	**19** **0.48**	**19** **0.48**	40 1.00	4.43
The Situation Manual used during the exercise was a valuable tool throughout the exercise.	**N** **%**	0 0.0	0 0.0	11 0.29	**14** **0.37**	13 0.34	40 1.00	4.05
Participation in the exercise was appropriate for someone in my position.	**N** **%**	0 0.0	0 0.0	2 0.05	15 0.38	**23** **0.58**	40 1.00	4.53
The participants included the right people in terms of level and mix of disciplines.	**N** **%**	0 0.0	0 0.0	0 0.0	14 0.35	**26** **0.65**	40 1.00	4.65

In part III – Participant Feedback of the exercise evaluation the participants were asked what changes they would make to the overall exercise and to provide recommendations for how to improve future exercises.

Overall the exercise was well received. Some of the positive comments on the exercise were that it was well planned, well organized, and well done; the facilitators did a good job moving along the scenario; the facility was good; and that it was a great opportunity for multiple agencies to collaborate.

Several participants made recommendations for how to change and enhance future exercises. Some people stated that the scenario and timeline could have more realistically reflected the numbers of victims and response timelines. One person felt that the numbers of victims were underestimated due to the fact that the exercise operated on what the people should do in such a situation and not what they will do. Another person felt that it is important to push the tabletop participants to be realistic in their time frames for response and completion of tasks.

Another area where participants recommended changes the focus of the exercise. Some participants recommended focusing more on mitigation and medical care/treatment and less on the HazMat response. Other suggestions were to discuss more in depth hot zone rescue, level A entry and shelter options. One participant suggested that if the tabletop content had been diminished there would have been more time to cover other areas. Another suggestion was to make the exercise in two phases, one like HFEX at 0-60 min and a second one at 12 or 24 hours to evaluate fatigue, shift change, etc. Finally, a participant stated that the facilitators need to control the focus of the exercise as some players by nature were more engaged and dominated the exercise with their specific concerns and responsibilities.

The exercise was accompanied by a PowerPoint presentation, but some participants recommended further exercise aides, such as: A map in the SitMan similar in scale to the map used in the PowerPoint presentation, access to the MSDS, Radio transmissions to support injects, a scribe taking notes for everybody to more easily follow the scenario and activities and responsibilities. One participant recommended that a brief instruction on how tabletop exercises proceed prior to start would get the exercise moving along better. Another participant suggested having a representative from CHEMTREC available to discuss how they would respond to a hydrogen fluoride spill.

Finally, there were suggestions for following up this tabletop exercise with a functional drill.

07 HFEX Steering Committee Members

Hydrogen Fluoride Emergency Response Exercises
Steering Committer Members

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PLAYERS - HFEX	
Response	**Organization**
Attending	East Greenwich Twp Fire
Not attendin	Gibbstown Fire
Attending	Gibbstown Police Department
Attending	Paulsboro Fire
	West Deptford Fire
Attending	Paulsboro OEM/Fire
Attending	Paulsboro OEM/Fire
Not attendin	East Greenwich Twp OEM
Attending	Greenwich Township OEM
Not attendin	Gloucester County OEM
Attending	Gloucester County OEM
Attending	East Greenwich Twp Police
Not attendin	Greenwich Township Police Department
Attending	Greenwich Township Police Department
Attending	Greenwich Township Police Department
Attending	Greenwich Township Police Department
Attending	Greenwich Township Police Department
Attending	Paulsboro Police
Attending	West Deptford Police
Attending	West Deptford Police
Attending	NJSP, Incident Management Unit
Attending	NJ DOT
Attending	NJSP
Attending	NJ Turnpike Authority Emergency Services Dept
Attending	NJ Turnpike Authority Emergency Services Dept
Attending	Gloucester County EMS
No reply	Gloucester County EMS
Attending	Underwood Memorial Hospital
Attending	Underwood Memorial Hospital
Attending	Kennedy Health System
Attending	Kennedy University Hospital
Attending	Cooper University Hospital
Attending	Gloucester County HD
Attending	Gloucester County HD - Environmental
Not attendin	Gloucester County HD
Attending	Gloucester County HAZMAT
Attending	Gloucester County HAZMAT
Attending	Gloucester County HAZMAT
Attending	American Red Cross, Gloucester County Chapter
Not attendin	Gloucester County ERT
31 TOTAL	

Receipt, Stage, and Storage (RSS) Warehouse Operations: A Tabletop Exercise

Camden County
April 14, 2011

The New Jersey
NJCPHP
Center for Public Health Preparedness at UMDNJ

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Part I- Introduction

Purpose:

The purpose of the Camden County Receipt, Stage, and Storage (RSS) Warehouse Operations: A Tabletop Exercise is to coordinate RSS operations in Camden County. The exercise will test the capabilities of current plans, policies, and procedures related to RSS.

Scope:

The scope of this exercise will focus on the various emergency responders' roles in response to a bioterror attack and the stages of RSS operations. More important than the minute details are the processes and decision-making. The emphasis should be on coordination, integration, problem identification, and problem resolution.

Exercise Objectives:

1. To identify shortfalls in resources, limits in capabilities, and gaps in planning and coordination for RSS.
2. To exercise the local decision-making process and identify areas needing refinements.
3. Review and list the various roles, functions, and procedures involved in RSS activation
4. Identify issues relevant to RSS activation and preparing for mass dispensing, e.g., policies, resources, communication, coordination, and data management.

Participants:

- Players
- Facilitator
- Evaluator
- Observers

Exercise Agenda:

9:30 – 10:00	Welcome and Overview
10:00 – 11:40	Exercise
11:40 – 12:00	Hot Wash
12:00	Adjourn

Exercise Guidelines:

This TTX will be held in an open, low-stress, no-fault environment. Varying viewpoints, even disagreements, are expected. Respond on the basis of your knowledge of current plans and capabilities (i.e., you may use only existing assets) and insights derived from your training.

Decisions are not precedent setting and may not reflect your organization's final position on a given issue. This exercise is an opportunity to discuss and present multiple options and possible solutions. Issue identification is not as valuable as suggestions and recommended actions that could improve response and preparedness efforts. Problem-solving efforts should be the focus.

Assumptions and Artificialities:

In any exercise, assumptions and artificialities may be necessary to complete play in the time allotted. During this exercise, the following apply:

- The scenario is plausible, and events occur as they are presented.
- There is no hidden agenda, and there are no trick questions.
- All players receive information at the same time.

Part II- Scenario

Day 1: Tuesday, November 18, 2010
It's a football game between Gateway Regional High School and Highland High School at Highland, located in Blackwood, NJ.

This is the Homecoming game and is heavily attended by students, alumni, family, and members of the community.

A suspicious-looking man, wearing a cap and sunglasses, is observed using a hand-held aerosol-dispersion device, spraying some material around the bleachers and the snack bar area at the stadium.

Observers file a report with a school security guard, noting the suspicious behavior. The suspect, having fled the scene, cannot be apprehended for questioning.

The school security guard initiates investigation and notifies law enforcement officials.

The HAZMAT team and law enforcement officials arrive on the scene and secure the area.

Handheld assays yield preliminary results within two hours, suggesting that an anthrax exposure has occurred

Samples of the agent are collected for more sensitive and specific confirmatory testing at the state lab. Results will take 1-2 days.

Players and fans alike leave the game eager to share news of the commotion with friends and family.

Law enforcement officials call the duty officer at the Camden County Department of Health and Human Services (CCDHHS) and notify him of the potential, yet unconfirmed, anthrax attack at the football game.

Day 1 Questions

- What steps should the health department take while waiting for confirmatory lab results?
- Would you activate the incident command system within the health department?
- Would you activate the Emergency Operations Center?
- Is there a need to communicate any information to response partners or the public?

Day 2: Wednesday, November 19, 2010

The state lab confirms anthrax as agent in question.

Day 2 Questions 1

- What information should be considered to determine whether SNS assets are necessary?
- With whom should the Health Officer consult regarding public health response actions?
- Who else within the CCDHHS should be notified of this incident and potential response actions?
- Which agencies and jurisdictions outside of the CCDHHS should be notified of this incident?

Day 2: Wednesday, November 19, 2010

At 9am, the CCDHHS holds a conference call with the Camden County OEM, the Camden County Prosecutors Office, the two high schools, along with the NJDHSS, to discuss the situation.

During the conference call, the decision is made by the CCDHHS to request supplies from the Strategic National Stockpile.

A mass dispensing clinic must be activated to deliver antibiotics to potentially exposed individuals.

Day 2 Questions 2

- Who makes the request for SNS assets? To whom is the request made?
- Where will the warehouse be? And how will you gain access?
- Who is considered essential warehouse personnel?
- How are essential warehouse personnel alerted?
- What will they need to do before receipt of SNS materials?
- What security measures are put into place, and when will they need to be implemented?
- How will information regarding this operation be communicated to the public and those potentially exposed individuals?

Day 2: Wednesday, November 19, 2010

State DHSS coordinates a teleconference with the Governor's Office, CDC, and the local health department.

The Governor formally requests SNS deployment.

Following the conference call, the CDC director orders the deployment of SNS assets to the state.

Day 3: Thursday November 20, 2010
CCDHHS receives SNS assets at their warehouse.

The CCDHHS will begin Point of Delivery (POD) operations at a local venue.

Day 3 Questions 1 Receipt and Activation

- How are staff alerted for Primary RSS Operations?
- What, if any, just-in-time training is required?
- Who is the Incident Commander?
- Who will be receiving SNS assets?

Day 3 Questions 2 Activation and Use/Distribution

- How will the assets be unloaded, separated, and distributed to POD sites? How will the PODS receive the materials?
- How will the PODS manage inventory?
- How will the PODS maintain security during distribution?

Day 5: Saturday, November 22, 2010
The need being met, the decision is made by the CCDHHS to discontinue POD operations and demobilize and then close RSS operations.

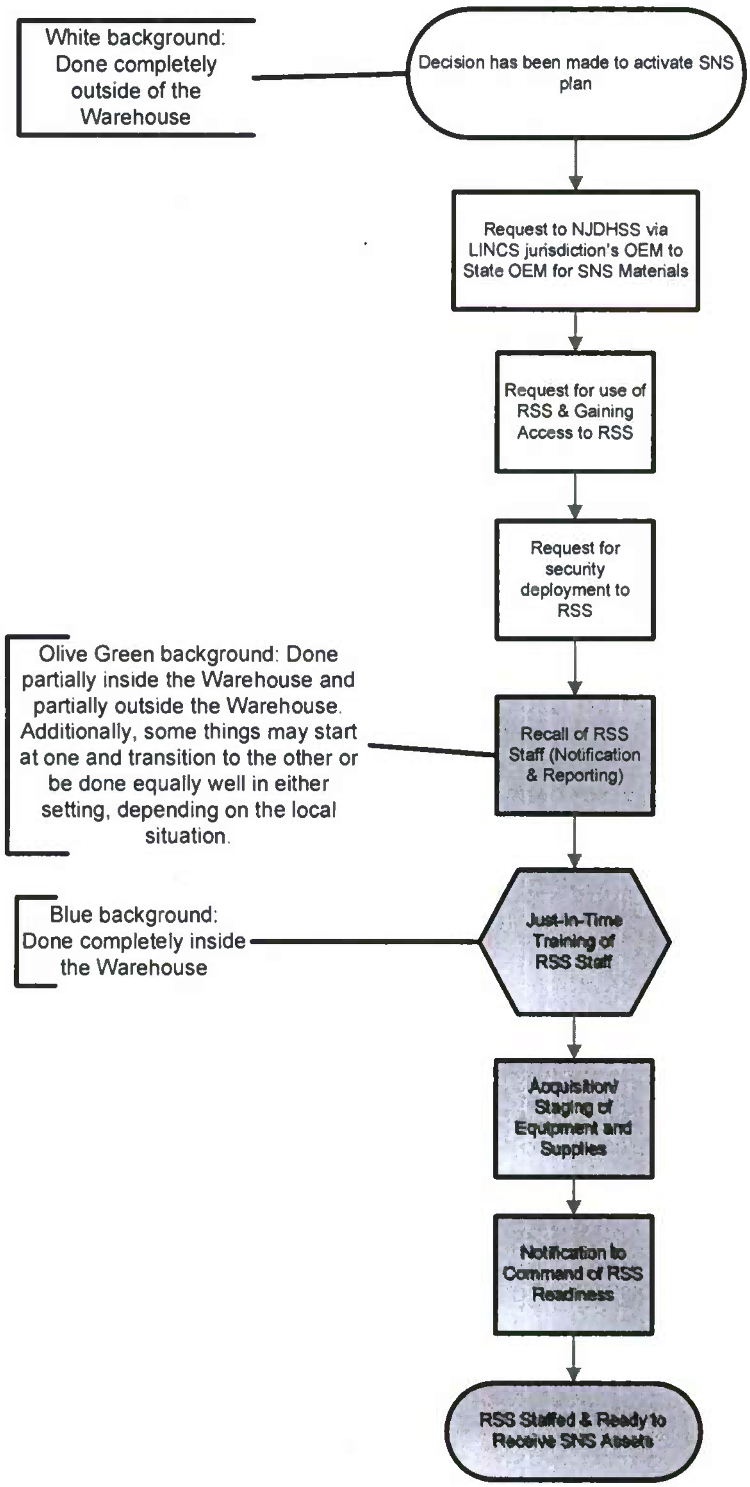
SNS supplies are no longer being received.

Day 5 Questions – Shut Down

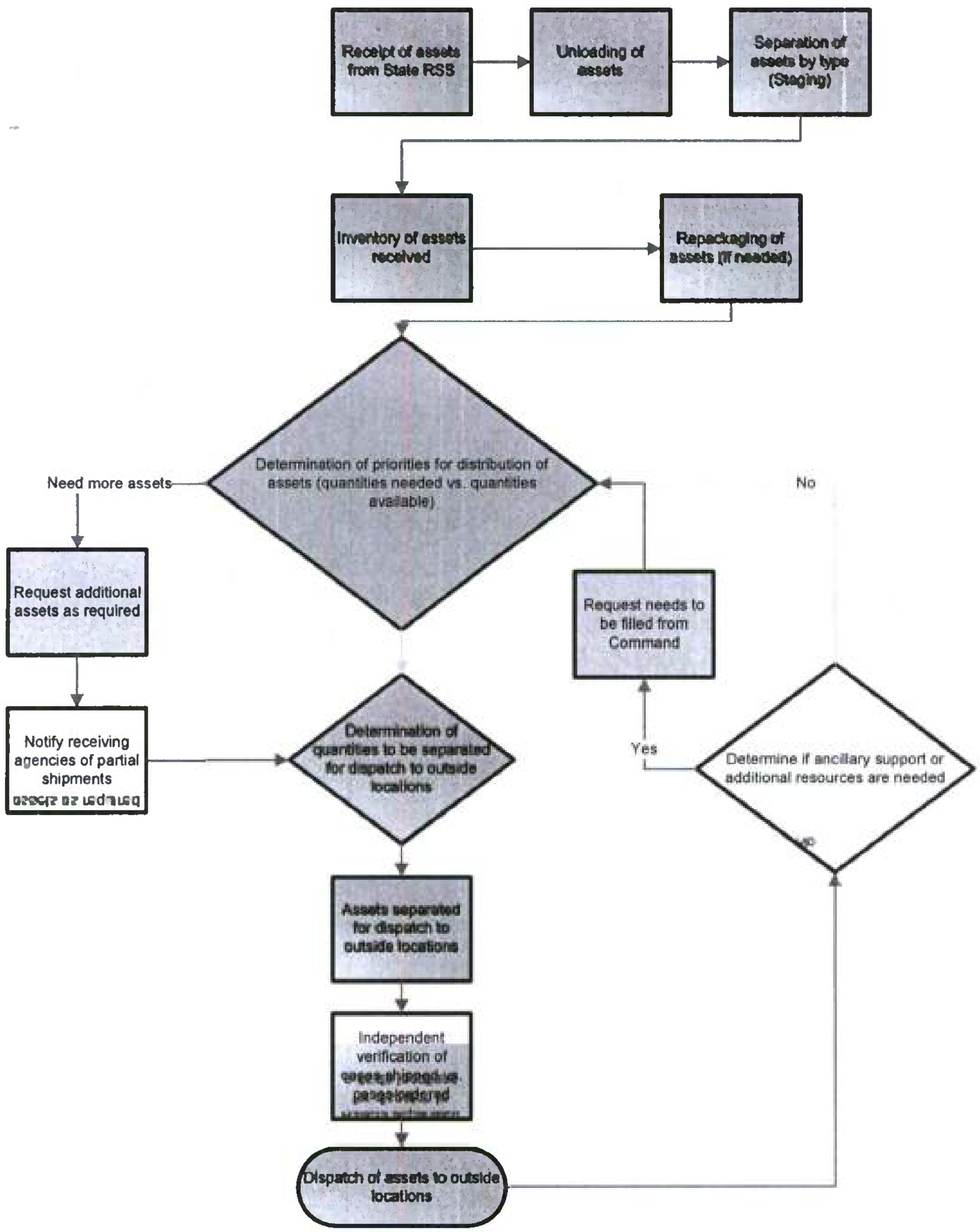
- Who needs to be notified?
- What personnel issues need to be considered?
- What inventory needs to be done?
- What needs to be done to the facility?
- Who is responsible for the Hot Wash?

Part III- Appendix

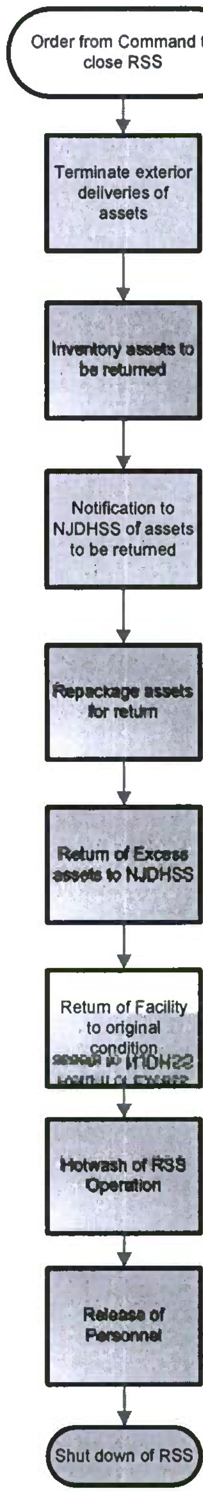
Prior to Receipt (Pre-RSS Operations)



Primary Operations for RSS



Post RSS Operations



Anthrax

What is anthrax?
Anthrax is a serious disease caused by *Bacillus anthracis*, a bacterium (germ) that forms spores. A spore is a cell that is dormant (asleep) but may come to life with the right conditions. There are three types of anthrax:

- Cutaneous (skin)
- Gastrointestinal (digestive)
- Inhalation (lungs)

What are the symptoms?
Cutaneous-The first symptom is a small sore that develops into a blister. The blister then develops into a skin ulcer with a black area in the center. The sore, blister and ulcer do not hurt.

Gastrointestinal-The first symptoms are nausea, loss of appetite, bloody diarrhea, and fever, followed by bad stomach pain.

Inhalation-The first symptoms of inhalation anthrax are like cold or flu symptoms and can include a sore throat, mild fever and muscle aches. Later symptoms include cough, chest discomfort, shortness of breath, tiredness and muscle aches.

How soon do infected people get sick?
Symptoms can appear within 7 days of coming in contact with the spores for all three types of anthrax. For inhalation anthrax, symptoms can appear within a week or can take up to 60 days to appear.

Is anthrax contagious?
Anthrax is not known to spread from one person to another. People can become infected with anthrax by handling products from infected animals or by breathing in anthrax spores from infected animal products like raw, untreated wool. People also can become infected with gastrointestinal anthrax by eating undercooked meat from infected animals.

How is anthrax treated?
Antibiotics treat all three types of anthrax. Early identification and treatment are important. Success depends on the type of anthrax and how soon treatment begins.

Can anthrax be prevented?
There is a vaccine to prevent anthrax, but it is not currently available for the general public. In the event of an anthrax attack, healthcare providers will administer vaccine and antibiotics to people who may have been exposed to *B. anthracis*, but are not sick.

What should I do if I think I have anthrax?
If you are showing symptoms of anthrax infection, call your healthcare provider right away.

Can anthrax be used as a biological weapon?
Anthrax has already been used as a weapon. This happened in the United States in 2001 in New Jersey and elsewhere. Anthrax was deliberately spread through the postal system by sending letters with powder containing anthrax. This caused 22 cases of anthrax infection. Five cases occurred in New Jersey, with no deaths.

How dangerous is anthrax?
The Centers for Disease Control and Prevention (CDC) classifies agents with the potential to be used for bioterrorism into three categories: A, B and C. Anthrax is a Category A agent.

Category A agents:
- pose the greatest possible threat to the public's health
- may spread across a large area
- require advance planning to protect the public's health

In most cases, early treatment with antibiotics can cure cutaneous anthrax. Even if untreated, 80 percent of people who become infected with cutaneous anthrax do not die. Gastrointestinal anthrax is more serious. Between 25 and 50 percent of cases result in death. Inhalation anthrax is much more severe. In 2001, about half of the cases of inhalation anthrax in the United States died.

What is New Jersey doing to prepare for a possible anthrax attack?
New Jersey is working with the CDC to prepare for an anthrax attack. Activities include:
- Developing plans and procedures to respond to an anthrax attack
- Training and equipping emergency response teams, gathering samples and performing tests to help state and local governments control infection
- Educating healthcare providers, the media, and the general public about what to do in the event of an attack
- Working closely with local health departments, veterinarians and laboratorians to watch for suspected cases of anthrax
- Working with hospitals, laboratories, emergency response teams, and healthcare providers to make sure they have the supplies they need in case of an attack

Where can I get more information?
- Your healthcare provider
- Your local department of health
- The New Jersey Department of Health and Senior Services
  - --Website – www.nj.gov/health
  - --DHSS Communicable Disease Service at (609) 826-5964
- CDC
  - --www.bt.cdc.gov/agent/anthrax
  - --1-800-CDC-INFO (4636) for assistance in English and Spanish
  - --TTY 1-888-232-6348
  - --E-mail: cdcinfo@cdc.gov

Revised 2/2011

Receipt, Stage, and Storage (RSS) Warehouse Operations: A Tabletop Exercise

Camden County
April 14, 2011

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Introductions

- Facilitators
- Players
- Observers

Housekeeping

- Keep all cell phones, blackberries, pagers, etc., on vibrate.
- Take breaks as you need them.
- Restrooms are located. . .

Purpose

- The purpose of the Camden County Receipt, Stage, and Storage (RSS) Warehouse Operations: A Tabletop Exercise is to coordinate RSS operations in Camden County. The exercise will test the capabilities of current plans, policies, and procedures related to RSS.

Scope

- The scope of this exercise will focus on the various emergency responders' roles in response to a bioterror attack and the stages of RSS operations. More important than the minute details are the processes and decision-making. The emphasis should be on coordination, integration, problem identification, and problem resolution.

Learning Objectives

1. To identify shortfalls in resources, limits in capabilities, and gaps in planning and coordination for RSS.
2. To exercise the local decision-making process and identify areas needing refinements.
3. Review and list the various roles, functions, and procedures involved in RSS activation.
4. Identify issues relevant to RSS activation and preparing for mass dispensing, e.g., policies, resources, communication, coordination, and data management

Exercise Agenda

9:30- Welcome and Overview
10:00- Exercise
11:40- Hot Wash
12:00- Adjourn

What is a tabletop exercise?

- Informal group discussion stimulated by a scripted disaster scenario
- Cross-agency exercise designed to promote free and open exchange of ideas
- Emphasis on training and learning, not testing—helps prepare participants for a full-scale or functional exercise
- Evaluation of current systems, response plans

Instructions to Remember

- Assume scenario is real
- Be AS SPECIFIC AS POSSIBLE
  - Names, titles, streets, places, etc.
- Make your best decision based on available information
- Play your department or agency role throughout

Instructions to Remember

- Consider policy issues as well as procedure
- Focus on identifying system gaps and strengths rather than deficits in individual knowledge
- Take notes for the debriefing discussion(e.g., gaps and strengths in resource planning, communication, information management)

Questions Before We Start?

Day 1: Tuesday, 11-18-2010

It's a football game between Gateway Regional High School and Highland High School at Highland, located in Blackwood, NJ.

This is the Homecoming game and is heavily attended by students, alumni, family, and members of the community.

Day 1: Tuesday, 11-18-2010

- A suspicious-looking man, wearing a cap and sunglasses, is observed using a hand-held aerosol-dispersion device, spraying some material around the bleachers and the snack bar area at the stadium.

- Observers file a report with a school security guard, noting the suspicious behavior. The suspect, having fled the scene, cannot be apprehended for questioning.

Day 1: Tuesday, 11-18-2010

- The school security guard initiates investigation and notifies law enforcement officials.
- The HAZMAT team and law enforcement officials arrive on the scene and secure the area.
- Handheld assays yield preliminary results within two hours, suggesting that an anthrax exposure has occurred

Day 1: Tuesday, 11-18-2010

- Samples of the agent are collected for more sensitive and specific confirmatory testing at the state lab.
- Results will take 1-2 days.
- Players and fans alike leave the game eager to share news of the commotion with friends and family.

Day 1: Tuesday, 11-18-2010

- Law enforcement officials call the duty officer at the Camden County Department of Health and Human Services (CCDHHS) and notify him of the potential, yet unconfirmed, anthrax attack at the football game.

Day 1 Questions

- What steps should the health department take while waiting for confirmatory lab results?
- Would you activate the incident command system within the health department?
- Would you activate the Emergency Operations Center?
- Is there a need to communicate any information to response partners or the public?

Day 2: Wednesday, 11-19-10

The state lab confirms anthrax as agent in question.

Day 2 Questions 1

- What information should be considered to determine whether SNS assets are necessary?
- With whom should the Health Officer consult regarding public health response actions?
- Who else within the CCDHHS should be notified of this incident and potential response actions?
- Which agencies and jurisdictions outside of the CCDHHS should be notified of this incident?

Day 2:Wednesday 11-19-2010

- At 9am, the CCDHHS holds a conference call with the Camden County OEM, the Camden County Prosecutors Office, the two high schools, along with the NJDHSS, to discuss the situation
- During the conference call, the decision is made by the CCDHHS to request supplies from the Strategic National Stockpile
- A mass dispensing clinic must be activated to deliver antibiotics to potentially exposed individuals.

Day 2 Questions 2

- Who makes **the request** for SNS assets?
- To whom is the request made?
- Where will the warehouse be? And how will you gain access?
- Who is considered essential warehouse personnel?
- How are essential warehouse personnel alerted?

Day 2 Questions 3

- What will they need to do before receipt of SNS materials?
- What security measures are put into place, and when will they need to be implemented?
- How will information regarding this operation be communicated to the public and those potentially exposed individuals?

Day 2:Wednesday 11-19-2010

- State DHSS coordinates a teleconference with the Governor's Office, CDC, and the local health department.
- The Governor formally requests SNS deployment.
- Following the conference call, the CDC director orders the deployment of SNS assets to the state.

Day 3:Thursday 11-20-2010

- CCDHHS receives SNS assets at their warehouse.
- The CCDHHS will begin Point of Delivery (POD) operations at a local venue.

Day 3 Questions 1 Receipt and Activation

- How are staff alerted for Primary RSS Operations?
- What, if any, just-in-time training is required?
- Who is the Incident Commander?
- Who will be receiving SNS assets?

Day 3 Questions 2 Activation and Use/Distribution

- How will the assets be unloaded, separated, and distributed to POD sites?
- How will the PODS receive the materials?
- How will the PODS manage inventory?
- How will the PODS maintain security during distribution?

Day 5: Saturday, 11-22-2010

- The need being met, the decision is made by the CCDHHS to discontinue POD operations and demobilize and then close RSS operations.
- SNS supplies are no longer being received.

Day 5 Questions – Shut Down

- Who needs to be notified?
- What personnel issues need to be considered?
- What inventory needs to be done?
- What needs to be done to the facility?
- Who is responsible for the Hot Wash?

(Our Own) Hot Wash

Your Ideas Here!

Participant Feedback Form

Name:
(optional) ______________________________ **Title:**
(optional) ____________________
Agency:
(optional) ____

Part I: Recommendations and Corrective Actions

1. List the top three demonstrated strengths after today's exercise.

2. List the top three areas that need improvement after today's exercise.

3. Identify the action steps that should be taken to address the issues you identified in questions 1. and 2.

4. List the policies, plans, and procedures that should be reviewed, revised, or developed for your agency.

Part II: Participant Feedback

What changes would you make to this exercise overall? Please provide any recommendations on how this exercise or future exercises could be improved or enhanced.

12 MA Facilitator's Situation Manual

Capital District Urban Areas Security Initiative (UASI) Mutual Aid Tabletop Exercise

March 24, 2011

Developed by
The Urban Areas Security Initiative (UASI) Public Health Sub-committee and the NY•NJ Preparedness and Emergency Response Learning Center (PERLC)

Part I- Introduction

Exercise Name
Capital District UASI Mutual Aid Tabletop Exercise

Exercise Purpose and Design
The purpose of the Capital District UASI TTX exercise is to inform and test mutual aid protocols between the policy makers, planners and coordinators of four Capital District counties (Albany, Rensselaer, Schenectady, Schoharie) in the event of a public health emergency. The intent of the exercise is to develop processes and protocols to initiate, maintain, track and recover critical personnel resources during a public health emergency at the agency level. A combination of discussion oriented pre-event planning workshops and a tabletop exercise was developed and delivered for the goals of this exercise.

This exercise is funded by the Homeland Security (HS) Urban Areas Security Initiative (UASI) grant intended to address and assist multi-discipline preparedness and emergency operations for high-threat urban areas. The exercise planning was a collaborative initiative between the Albany, Rensselaer, Schenectady, and Schoharie County public health departments. The NY-NJ PERLC was requested as a coordinating and advising agency to help with exercise development, facilitation, and evaluation.

Exercise Objectives, Capabilities and Activities
Capabilities-based planning allows for exercise planning teams to develop exercise objectives and observe exercise outcomes through a framework of specific action items that were derived from the Target Capabilities List (TCL). The capabilities listed below form the foundation for the organization of all objectives and observations in this exercise. Additionally, each capability is linked to several corresponding activities and tasks to provide additional detail. The capability selected for this exercise is Critical Resource Logistics and Distribution under the Response Mission.

The following are the Capital District UASI Mutual Aid Tabletop Exercise objectives and the capabilities to be demonstrated during this exercise:

Objective 1:
Identify and define each county's mutual aid agreements as utilized for the request, release and recall of skilled personnel during public health emergencies.

- **Capability**: Critical Resource Logistics and Distribution:
  - Activity 1: Direct Critical Resource Logistics(CRL) and Distribution
  - Activity 2: Activate Critical Resource Logistics and Distribution
  - Activity 3: Respond to Needs Assessment and Inventory
  - Activity 4: Acquire Resources
  - Activity 5: Transport, Track and Manage Resources
  - Activity 6: Maintain and Recover Resources
  - Activity 7: Demobilize Critical Resource Logistics and Distribution

Objective 2:
Determine how mutual aid and continuity of operations planning and operations interact when allocating skilled personnel during a public health emergency.

- **Capability**: Critical Resource Logistics and Distribution:
  - Activity 5: Transport, Track and Manage Resources
  - Activity 6: Maintain and Recover Resources

Objective 3:
Identify and define considerations informing the planning and allocation of skilled personnel during a regional public health emergency response effort in the Capital District counties. Factors included in this planning include:

a. Duration of the emergency.
b. Forms needed for resource sharing.
c. General guidance sheet for determining request, release and recall of skilled personnel.

- **Capability**: Critical Resource Logistics and Distribution:
  - i. Activity 1: Direct Critical Resource Logistics(CRL) and Distribution
  - ii. Activity 3: Respond to Needs Assessment and Inventory
  - iii. Activity 5: Transport, Track and Manage Resources

Objective 4:
Practice protocols for requesting, releasing, tracking and recovering skilled personnel during a public health emergency driven scenario during the tabletop exercise.

- **Capability**: Critical Resource Logistics and Distribution:
  - Activity 1: Direct Critical Resource Logistics(CRL) and Distribution
  - Activity 2: Activate Critical Resource Logistics and Distribution
  - Activity 3: Respond to Needs Assessment and Inventory
  - Activity 4: Acquire Resources
  - Activity 5: Transport, Track and Manage Resources
  - Activity 6: Maintain and Recover Resources
  - Activity 7: Demobilize Critical Resource Logistics and Distribution

Participants

- Players: Emergency Manager, BT Coordinator/DOH representatives from each of the participating counties
- Facilitators
- Evaluators
- Observers

Exercise Agenda

10:00 – 10:10	Welcome
10:10 – 10:15	Introduction to TTX
10:15 – 11:00	Scenario 1
11:00 – 11:15	Break
11:15 – 12:00	Scenario II
12:00 – 12:45	Lunch
12:45- 1:15	Scenario III
1:15 – 2:00	Hot Wash and Evaluation
2:00	Adjourn

Exercise Guidelines

This TTX will be held in an open, low-stress, no-fault environment. Varying viewpoints, even disagreements, are expected. Respond on the basis of your knowledge of current plans and capabilities (i.e., you may use only existing assets) and insights derived from your training. Decisions are not precedent setting and may not reflect your organization's final position on a given issue. This exercise is an opportunity to discuss and present multiple options and possible solutions. Issue identification is not as valuable as suggestions and recommended actions that could improve response and preparedness efforts. Problem-solving efforts should be the focus.

Assumptions and Artificialities

In any exercise, assumptions and artificialities may be necessary to complete play in the time allotted. During this exercise, the following apply:

- The scenario is plausible, and events occur as they are presented.
- There is no hidden agenda, and there are no trick questions.
- All players receive information at the same time.

Notes for Facilitators and Evaluators

Lead Facilitator Role-

The lead facilitator will guide the participants through the exercise. He will explain the purpose and objectives of the exercise, define expectations of the participants, and provide instructions and keep the exercise moving in accordance with the time allotted. The lead facilitator will present the scenario and the questions using the PowerPoint presentation. He will also act as a county facilitator. He will lead the group report out and discussion, soliciting responses from the group at each "Questions" slide.

County Facilitator Role-

For all three sections of the scenario, there will be a facilitator seated with each county. There will be fifteen minutes of discussion during that time within each county to react and respond to the scenario. During that time, the facilitator will solicit response from their county using the provided questions after each scenario as a guide. The lead facilitator will then lead a twenty-minute discussion with all of the counties. Discussion between the counties is permitted, and encouraged when it is appropriate to further the scenario.

Evaluators' Role-

An evaluator will be seated with each county. Each evaluator will be given an Exercise Evaluation Guide (EEG) and will use the EEG as a guide for note taking. Evaluators will:

- Identify strengths, weaknesses, and unanticipated responses to the scenario.
- Identify communication problems and needed additional resources
- Identify consistency with the exercise objectives, activities in the target capability, and related accomplishments.

Part 2- Scenario

Day 1- Monday

It is the beginning of spring in the Capital Region of New York state and the snow is finally beginning to melt and the flu season is drawing to a close. However, there has been a mixture of Influenza A and gastrointestinal illnesses being reported.

Within an eight hour period, twelve (12) patients, including a family of four (4) have been seen at the Cobleskill Regional Hospital emergency department; on a typical Monday, 1 or 2 might be seen in an entire 24 hour period. Symptoms included diarrhea, fever, nausea, headache, and cramping. The four family members have been admitted to the local hospital, with two of the four transferred to pediatrics. The hospital has notified the Schoharie County Health Department.

Questions

- Is further investigation warranted? Explain.
- What type of surveillance activities will you undertake at this time?
- Given what you learn, what actions would you take, if any?
- Who would you notify at this point?
- Are any additional resources needed at this time?
- Is a request for aid from other counties made at this point?
- What mutual aid agreements (MAAs) do you currently have in place that could be used for this response?
    - What aid is the county requesting?
    - If so, how is that letter of request drafted and sent?
    - What considerations are made for issues of liability, finance, workman compensation?

Day 2- Tuesday

The Schoharie County HD has contacted the Schenectady County HD to assist in the disease investigation, since the number of patients treated at the hospital ED for gastrointestinal symptoms has grown to a total of eighteen (18). A case history has been obtained on each patient and the hospital physician has ordered stool specimens for analysis for those patients in the hospital, and any new patients that present to the ED. Schoharie County public health authorities have issued a Health Alert to inform providers of the situation and stimulate reporting.

Surveillance activities have been expanded, with calls going to local pediatric and general practitioners

There has also been an increase in the number of gastrointestinal illnesses being reported through surveillance monitoring. Hospitals in Schenectady County are now reporting an abnormally high number of similar cases.

Questions

- What actions would you take?
- What local, state, or federal agencies would you notify?
- Should the Emergency Operations Center (EOC) be activated? If not, when would it be?
- Are any additional resources needed at this time?
- Would mutual aid be requested now?
    - What aid is the county requesting?
    - What types of personnel are being requested?
    - If so, how is that letter of request drafted and sent?
    - What considerations are made for issues of liability, finance, and workman compensation?
- How are enacted Mutual Aid Agreements handled?

Day 3- Wednesday

There have now been cases in hospitals in Albany and Rensselaer counties, with thirty-one (31) reported within the last 24 hours. Still more patients are being admitted to all Capital Region area hospitals, while other patients are being seen in the emergency rooms, urgent care and public health clinics. Private physicians have called in to tell of crowded waiting rooms with ill patients and multiple phone calls from the 'worried well'.

Patient interviews reveal a possible link to five (5) area fast food establishments of the same chain. The food histories reveal the cases appear to have eaten at the fast food establishments within 24-36 hours of the development of their symptoms. Environmental Health staff members have been dispatched to the affected food establishments for an investigation.

Questions

- What actions would you take?
- Who would you notify at this point?
- What, if any, additional resources are needed at this time?
- Would a request for aid from other counties be made at this point?
    - What aid is the county requesting?
    - What types of personnel are being requested?
    - If so, how is that letter of request drafted and sent?
    - What considerations are made for issues of liability, finance, and workman compensation?
- Will counties continue to support other counties now that the outbreak is in their county?
- What is the procedure to end an agreement?

Epilogue

A week has passed since the first cases in Schoharie County and laboratory results have confirmed that 16 patient samples grew out salmonella with the remaining cases suspected, but unconfirmed.

The source of the salmonella is believed to have come from milk that was sold at fast food establishments in the Capital Region. Environmental health staff have embargoed the suspect milk and contacted the distributor.

13 MA Players' Situation Manual

Capital District Urban Areas Security Initiative (UASI) Mutual Aid Tabletop Exercise

March 24, 2011

Developed by
The Urban Areas Security Initiative (UASI) Public Health Sub-committee and the NY●NJ Preparedness and Emergency Response Learning Center (PERLC)

Part I- Introduction

Exercise Name
Capital District UASI Mutual Aid Tabletop Exercise

Exercise Purpose and Design
The purpose of the Capital District UASI TTX exercise is to inform and test mutual aid protocols between the policy makers, planners and coordinators of four Capital District counties (Albany, Rensselaer, Schenectady, Schoharie) in the event of a public health emergency. The intent of the exercise is to develop processes and protocols to initiate, maintain, track and recover critical personnel resources during a public health emergency at the agency level. A combination of discussion oriented pre-event planning workshops and a tabletop exercise was developed and delivered for the goals of this exercise.

This exercise is funded by the Homeland Security (HS) Urban Areas Security Initiative (UASI) grant intended to address and assist multi-discipline preparedness and emergency operations for high-threat urban areas. The exercise planning was a collaborative initiative between the Albany, Rensselaer, Schenectady, and Schoharie County public health departments. The NY-NJ PERLC was requested as a coordinating and advising agency to help with exercise development, facilitation, and evaluation.

Exercise Objectives, Capabilities and Activities
Capabilities-based planning allows for exercise planning teams to develop exercise objectives and observe exercise outcomes through a framework of specific action items that were derived from the Target Capabilities List (TCL). The capabilities listed below form the foundation for the organization of all objectives and observations in this exercise. Additionally, each capability is linked to several corresponding activities and tasks to provide additional detail. The capability selected for this exercise is Critical Resource Logistics and Distribution under the Response Mission.

The following are the Capital District UASI Mutual Aid Tabletop Exercise objectives and the capabilities to be demonstrated during this exercise:

Objective 1:
Identify and define each county's mutual aid agreements as utilized for the request, release and recall of skilled personnel during public health emergencies.

- **Capability**: Critical Resource Logistics and Distribution:
  - Activity 1: Direct Critical Resource Logistics(CRL) and Distribution
  - Activity 2: Activate Critical Resource Logistics and Distribution
  - Activity 3: Respond to Needs Assessment and Inventory
  - Activity 4: Acquire Resources
  - Activity 5: Transport, Track and Manage Resources
  - Activity 6: Maintain and Recover Resources
  - Activity 7: Demobilize Critical Resource Logistics and Distribution

Objective 2:
Determine how mutual aid and continuity of operations planning and operations interact when allocating skilled personnel during a public health emergency.

- o **Capability**: Critical Resource Logistics and Distribution:
  - Activity 5: Transport, Track and Manage Resources
  - Activity 6: Maintain and Recover Resources

Objective 3:
Identify and define considerations informing the planning and allocation of skilled personnel during a regional public health emergency response effort in the Capital District counties. Factors included in this planning include:

a. Duration of the emergency.
b. Forms needed for resource sharing.
c. General guidance sheet for determining request, release and recall of skilled personnel.

- o **Capability**: Critical Resource Logistics and Distribution:
  - i. Activity 1: Direct Critical Resource Logistics(CRL) and Distribution
  - ii. Activity 3: Respond to Needs Assessment and Inventory
  - iii. Activity 5: Transport, Track and Manage Resources

Objective 4:
Practice protocols for requesting, releasing, tracking and recovering skilled personnel during a public health emergency driven scenario during the tabletop exercise.

- o **Capability**: Critical Resource Logistics and Distribution:
  - Activity 1: Direct Critical Resource Logistics(CRL) and Distribution
  - Activity 2: Activate Critical Resource Logistics and Distribution
  - Activity 3: Respond to Needs Assessment and Inventory
  - Activity 4: Acquire Resources
  - Activity 5: Transport, Track and Manage Resources
  - Activity 6: Maintain and Recover Resources
  - Activity 7: Demobilize Critical Resource Logistics and Distribution

Participants

- Players: Emergency Manager, BT Coordinator/DOH representatives from each of the participating counties
- Facilitators
- Evaluators
- Observers

Exercise Agenda

10:00 – 10:10	Welcome
10:10 – 10:15	Introduction to TTX
10:15 – 11:00	Scenario 1
11:00 – 11:15	Break
11:15 – 12:00	Scenario II
12:00 – 12:45	Lunch
12:45- 1:15	Scenario III
1:15 – 2:00	Hot Wash and Evaluation
2:00	Adjourn

Exercise Guidelines

This TTX will be held in an open, low-stress, no-fault environment. Varying viewpoints, even disagreements, are expected. Respond on the basis of your knowledge of current plans and capabilities (i.e., you may use only existing assets) and insights derived from your training. Decisions are not precedent setting and may not reflect your organization's final position on a given issue. This exercise is an opportunity to discuss and present multiple options and possible solutions. Issue identification is not as valuable as suggestions and recommended actions that could improve response and preparedness efforts. Problem-solving efforts should be the focus.

Assumptions and Artificialities

In any exercise, assumptions and artificialities may be necessary to complete play in the time allotted. During this exercise, the following apply:

- The scenario is plausible, and events occur as they are presented.
- There is no hidden agenda, and there are no trick questions.
- All players receive information at the same time.

Capital District UASI Mutual Aid Table Top

March 24, 2011

Purpose

The purpose of the Capital District UASI TTX exercise is to inform and test mutual aid protocols between the policy makers, planners and coordinators of four Capital District counties (Albany, Rensselaer, Schenectady, Schoharie) in the event of a public health emergency.

Table Top Exercise

- Informal group discussion stimulated by a scripted scenario
- Designed to promote exchange of ideas and stimulate thought
- Identifies issues to consider (e.g. policies, resources, communication, data, coordination
- Familiarizes participants with roles, functions, plans, and procedures

Objective #1

- Identify and define each county’s mutual aid agreements as utilized for the request, release and recall of skilled personnel during public health emergencies.

Objective #2

- Determine how mutual aid and continuity of operations planning and operations interact when allocating skilled personnel during a public health emergency.

Objective #3

- Identify and define considerations informing the planning and allocation of skilled personnel during a regional public health emergency response effort in the Capital District counties. Factors included in this planning include:
    a. Duration of the emergency.
    b. Forms needed for resource sharing.
    c. General guidance sheet for determining request, release and recall of skilled personnel.

Objective #4

- Practice protocols for requesting, releasing, tracking and recovering skilled personnel during a public health emergency driven scenario during the tabletop exercise.

Schedule

10:00 – 10:10	Welcome
10:10 – 10:15	Introduction to TTX
10:15 – 11:00	Scenario 1
11:00 – 11:15	Break
11:15 – 12:00	Scenario II
12:00 – 12:45	Lunch
12:45- 1:15	Scenario III
1:15 – 2:00	Hot Wash and Evaluation
2:00	Adjourn

Instructions□

- Players will be sitting by county.
- Discussion between counties is permitted and encouraged when appropriate in the scenario.
- The scenario is plausible, and events occur as they are presented.
- There is no hidden agenda, and there are no trick questions.
- All players receive information at the same time.

Day 1- Monday

It is the beginning of spring in the Capital Region of New York state and the snow is finally beginning to melt and the flu season is drawing to a close. However, there has been a mixture of Influenza A and gastrointestinal illnesses being reported.

Day 1- Monday continued

Within an eight hour period, twelve (12) patients, including a family of four (4), have been seen at the Cobleskill Regional Hospital emergency department; on a typical Monday, 1 or 2 might be seen in an entire 24 hour period. Symptoms included diarrhea, fever, nausea, headache, and cramping. The four family members have been admitted to the local hospital, with two of the four transferred to pediatrics. The hospital has notified the Schoharie County Health Department.

Discussion Period 1
Within County

Time: 15 minutes WITHIN County Discussion

Consider The Following Questions….

Questions

- Is further investigation warranted? Explain.
- What type of surveillance activities will you undertake at this time?
- Given what you learn, what actions would you take, if any?
- Who would you notify at this point?
- Are any additional resources needed at this time?
- Is a request for aid from other counties made at this point?
  - What mutual aid agreements (MAAs) do you currently have in place that could be used for this response?
  - What aid is the county requesting?
  - If so, how is that letter of request drafted and sent?
  - What considerations are made for issues of liability, finance, workman compensation?

Report Out 1
All Counties

Time: 20 Minutes

Report Out on the SAME questions….

Questions

- Is further investigation warranted? Explain.
- What type of surveillance activities will you undertake at this time?
- Given what you learn, what actions would you take, if any?
- Who would you notify at this point?
- Are any additional resources needed at this time?
- Is a request for aid from other counties made at this point?
  - What mutual aid agreements (MAAs) do you currently have in place that could be used for this response?
  - What aid is the county requesting?
  - If so, how is that letter of request drafted and sent?
  - What considerations are made for issues of liability, finance, workman compensation?

Day 2- Tuesday

The Schoharie County HD has contacted the Schenectady County HD to assist in the disease investigation, since the number of patients treated at the hospital ED for gastrointestinal symptoms has grown to a total of eighteen (18). A case history has been obtained on each patient and the hospital physician has ordered stool specimens for analysis for those patients in the hospital, and any new patients that present to the ED. Schoharie County public health authorities have issued a Health Alert to inform providers of the situation and stimulate reporting.

Day 2- Tuesday Continued

Surveillance activities have been expanded, with calls going to local pediatric and general practitioners

There has also been an increase in the number of gastrointestinal illnesses being reported through surveillance monitoring. Hospitals in Schenectady County are now reporting an abnormally high number of similar cases.

Discussion Period 2
Within County

Time: 15 minutes WITHIN County Discussion

Consider The Following Questions….

Questions

- What actions would you take?
- What local, state, or federal agencies would you notify?
- Should the Emergency Operations Center (EOC) be activated? If not, when would it be?
- Are any additional resources needed at this time?
- Would mutual aid be requested now?
  - What aid is the county requesting?
  - If so, how is that letter of request drafted and sent?
  - What considerations are made for issues of liability, finance, and workman compensation?
- How are enacted Mutual Aid Agreements handled?

Report Out 2
All Counties

Time: 20 Minutes

Report Out On The SAME Questions….

Questions

- What actions would you take?
- What local, state, or federal agencies would you notify?
- Should the Emergency Operations Center (EOC) be activated? If not, when would it be?
- Are any additional resources needed at this time?
- Would mutual aid be requested now?
  - What aid is the county requesting?
  - What types of personnel are being requested?
  - If so, how is that letter of request drafted and sent?
  - What considerations are made for issues of liability, finance, and workman compensation?
- How are enacted Mutual Aid Agreements handled?

Day 3- Wednesday

There have now been cases in hospitals in Albany and Rensselaer counties, with thirty-one (31) reported within the last 24 hours. Still more patients are being admitted to all Capital Region area hospitals, while other patients are being seen in the emergency rooms, urgent care and public health clinics. Private physicians have called in to tell of crowded waiting rooms with ill patients and multiple phone calls from the ‘worried well’.

Day 3- Wednesday Continued

Patient interviews reveal a possible link to five (5) area fast food establishments of the same chain. The food histories reveal the cases appear to have eaten at the fast food establishments within 24-36 hours of the development of their symptoms. Environmental Health staff members have been dispatched to the affected food establishments for an investigation.

Discussion Period 3
Within County

Time: 15 minutes WITHIN County Discussion

Consider The Following Questions….

Questions

- What actions would you take?
- Who would you notify at this point?
- What, if any, additional resources are needed at this time?
- Would a request for aid from other counties be made at this point?
  - What aid is the county requesting?
  - What types of personnel are being requested?
  - If so, how is that letter of request drafted and sent?
  - What considerations are made for issues of liability, finance, and workman compensation?
- Will counties continue to support other counties now that the outbreak is in their county?
- What is the procedure to end an agreement?

Report Out 3
All Counties

Time: 20 Minutes

Report Out On The SAME Questions….

Questions

- What actions would you take?
- Who would you notify at this point?
- What, if any, additional resources are needed at this time?
- Would a request for aid from other counties be made at this point?
  - What aid is the county requesting?
  - What types of personnel are being requested?
  - If so, how is that letter of request drafted and sent?
  - What considerations are made for issues of liability, finance, and workman compensation?
- Will counties continue to support other counties now that the outbreak is in their county?
- What is the procedure to end an agreement?

Epilogue

A week has passed since the first cases in Schoharie County and laboratory results have confirmed that 16 patient samples grew out salmonella with the remaining cases suspected, but unconfirmed.

The source of the salmonella is believed to have come from milk that was sold at fast food establishments in the Capital Region. Environmental health staff have embargoed the suspect milk and contacted the distributor.

Hot Wash

Acknowledgements

- Homeland Security (HS) Urban Areas Security Initiative (UASI)
- Albany, Rensselaer, Schenectady, and Schoharie County Public Health Departments
- New York-New Jersey Preparedness and Emergency Response Learning Center (NY-NJ PERLC)
- Heartland Center for Public Health Preparedness

15 MA Participant Feedback Form

Participant Feedback Form

Name: (optional) ______________________ **Title: (optional)** ______________

Agency: (optional) ______________________

Role: Player ☐ Facilitator ☐ Observer ☐ Evaluator ☐

Part I: Recommendations and Corrective Actions

1. List the top three demonstrated strengths after today's exercise.

2. List the top three areas that need improvement after today's exercise.

3. Identify the action steps that should be taken to address the issues you identified in questions 1. and 2.

4. List the policies, plans, and procedures that should be reviewed, revised, or developed for your agency.

Part II: Assessment of Training Session and Exercise Design and Conduct

Please rate, on a scale of 1 to 5, your overall assessment of the exercise relative to the statements provided below, with 1 indicating strong disagreement with the statement, 5 indicating strong agreement, and 7 indicating don't know or not applicable.

Assessment Factor		Strongly Disagree 1	2	3	4	Strongly Agree 5	Total	Mean
a. The exercise was well structured and organized.	N	0	4	4	5	12	25	
	%	0.0	16.0	16.0	20.0	48.0	100.0	4.0
b. The exercise scenario was plausible and realistic.	N	0	1	5	10	8	24	
	%	0.0	4.2	20.8	41.7	33.3	100.0	4.0
c. The facilitators were knowledgeable about the material, kept the exercise on target, and were sensitive to group dynamics.	N	0	1	4	9	9	23	
	%	0.0	4.3	17.5	39.1	39.1	100.0	4.1
d. The materials provided were valuable tools throughout the exercise.	N	1	1	9	9	4	24	
	%	4.2	4.2	37.5	37.5	16.6	100.0	3.6
e. Participation in the exercise was appropriate for someone in my position.	N	0	0	2	4	18	24	
	%	0.0	0.0	8.3	16.7	75.0	100.0	4.7
f. The participants included the right people in terms of level and mix of disciplines.	N	0	0	1	9	14	24	
	%	0.0	0.0	4.2	37.5	58.3	100.0	4.5
g. The arrangements (facility, location, food) were suitable.	N	0	0	2	2	20	24	
	%	0.0	0.0	8.3	8.3	83.4	100.0	4.8

Part III: Participant Feedback

What changes would you make to this exercise overall? Please provide any recommendations on how this exercise or future exercises could be improved or enhanced.
