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SRNL Emergency Response Capability for Atmospheric Contaminant Releases

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ABSTRACT. Emergency response to an atmospheric release of chemical or radiological contamination is enhanced when plume predictions, field measurements, and real-time weather information are integrated into a geospatial framework. The Weather Information and Display (WIND) System at Savannah River National Laboratory (SRNL) utilizes such an integrated framework. The rapid availability of predictions from a suite of atmospheric transport models within this geospatial framework has proven to be of great value to decision makers during an emergency involving an atmospheric contaminant release.

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INTRODUCTION

The release of toxic material into the atmosphere may result from industrial accidents, transportation accidents, natural disasters, or from acts of terrorism, such as explosion of a "dirty bomb" that releases radiological material. In responding to such an incident, prompt decisions regarding immediate action, such as the decision to evacuate or remain indoors, may be required. Decisions on what spatial area to evacuate as well as guidance for the direction of evacuation require knowledge of weather conditions, both current and predicted. Weather conditions can be further utilized in computational models to predict the transient plume spatial extent and toxicity level, providing decision makers with valuable additional information as the response evolves. Timely decisions are essential in such an emergency and the ability to provide weather conditions and plume predictions quickly is vastly improved if an operational system is in place that has automated measurement and predictive capability. Decision makers need the plume predictions in the form of maps so the computational modeling should be integrated within a geospatial framework that provides adequate mapping for the stage of the emergency.

The Savannah River Site (SRS) is a U. S. Department of Energy (DOE) nuclear facility about 30 kilometers southeast of Augusta, Georgia that produced radionuclides for national defense from the 1950's into the 1990's and is now engaged in waste processing and nuclear materials disposition. Emergency preparedness for an accidental atmospheric release of chemical or radiological contamination has been a key component of the SRS emergency response program. For more than 30 years the Savannah River National Laboratory (SRNL) has developed automated atmospheric transport and consequence assessment assets in support of the SRS emergency response program. The primary asset used in the initial and intermediate stages of a response is the Weather INformation and Display (WIND) System. This integrated system is comprised of real-time weather measurements at a number of local stations, access to regional weather data, advanced atmospheric modeling capabilities that provide operational numerical weather forecasts, and a suite of atmospheric transport models that utilize the weather forecasts to predict the transient evolution of the contaminant plume and the associated consequence assessment. For the atmospheric transport models, graphical user interfaces have been developed that make these applications very easy to use. The ease of use of these models combined with frequent user training ensures that these assets can be quickly deployed in an emergency.

Over the past 10 years the WIND System has been integrated into a geospatial framework that utilizes geographic information system (GIS) technology. The graphical user interfaces for the atmospheric transport models have their own internal mapping capabilities, which allows for maps to be generated quickly for decision makers in the initial stages of an emergency. Originally GIS was utilized for its ability to easily handle readily available geospatial data and to port that data into the user interfaces for the transport models, and it is still used for that purpose. As desktop GIS evolved with its own user friendly interface, the flexibility of utilizing GIS directly became desirable. Automated applications were developed to import the transport model results into GIS for display with various other geospatial data. An added benefit of importing the transport model results into GIS is that these results can be easily shared with other agencies that use GIS.

In conjunction with the development of this automated measurement and consequence assessment capability, SRNL established mutual aid agreements with emergency management agencies in five counties surrounding SRS (Hunter el al., 1999). Initiated in 1996, these agreements delineate three areas of technical support: assistance in establishing meteorological monitoring stations linked to the SRS monitoring network, delivery of easy-to-use custom software for consequence assessment, and technical support to the county's emergency managers during a real-time response. As will be discussed, the benefits of this local agreement became evident when a train wreck occurred in Aiken County that released toxic levels of chlorine gas.

SRNL WIND SYSTEM

The primary SRNL resource used to conduct consequence assessment for emergency response is the Weather INformation and Display (WIND) System. The backbone of the WIND System is a cluster of UNIX workstations, located in the SRS central computer facility, that gather data from a regional network of meteorological monitoring stations and archive these data in a relational database. Every 15 minutes, meteorological observations are extracted from the database and downloaded, along with forecast data from operational runs of an advanced weather prediction model, to desktop PCs. Consequence assessment models residing on the PCs can then be run with the current observations and forecasts to generate real-time predictions of downwind transport and associated hazards.

Meteorological Measurements. The network of meteorological monitoring stations currently incorporated into WIND System operations spans the 300 square mile SRS and extends into Augusta, Georgia. Towers located adjacent to each of the eight major operations areas at SRS are instrumented to measure winds, temperature, and moisture at an elevation of 61 meters above ground level. A ninth tower located near the center of the SRS collects similar data at four levels through a height of 61 meters. A TV tower located between SRS and Augusta, Georgia is instrumented to provide measurements of wind, temperature, and moisture at several levels through 330 meters. The mutual aid agreements led to installation of an additional four monitoring stations in Augusta/Richmond County, with measurements of wind and temperature at these towers collected at a single level with heights ranging from 10 to 60 meters above ground. Every 15 minutes, field measurements are transmitted to the UNIX workstation cluster and archived in a database. Measurements from this regional network are supplemented by Southeastern U.S. surface observations and upper-air soundings from the National Weather Service (NWS). The NWS information is integrated into the WIND System in real-time via satellite transmission from a private sector meteorological service. These archived real-time weather measurements provide SRNL meteorologists with immediate knowledge of local and regional wind conditions in the event of an emergency and the data are available for automatic use by transport and consequence assessment models.

Meteorological Forecasts. SRNL has configured a prognostic atmospheric model, the Regional Atmospheric Modeling System (RAMS), to generate routine three-dimensional forecasts of meteorological conditions throughout the Central Savannah River area and much of the Southeast U.S. Detailed 6-hour forecasts of wind speed, direction, turbulence and other meteorological variables are generated every 3 hours for a region encompassing the Central Savannah River area; 36-hour forecasts for an area that includes much of Georgia and South Carolina are produced every 12 hours. The operational nature of these calculations ensures that detailed numerical forecasts are always available for automatic use by transport and consequence assessment models in the event of an emergency.

Atmospheric Transport and Consequence Assessment Models. A suite of transport and diffusion models are available for assessing consequences of hazardous materials released to the environment. These models are tailored to support a broad range of assessment needs during mainly the early and intermediate phase of response.

Puff/Plume is a segmented trajectory Gaussian dispersion model that provides an initial, reasonably conservative estimate of potential downwind hazards from a chemical or radiological release. Puff or plume release trajectories are constructed for up to 12 hours of observed and forecast winds with results available in less than a minute. The model has a graphical user interface for input that makes it very easy to use. The model can automatically use the database of wind measurements and the numerical wind forecasts from the RAMS calculations, thus seamlessly integrating the operational measurements and numerical forecasts with the plume calculation for the user. At the click of a button the model outputs an image file of a map with the puff trajectories (see Figure 1) that can be provided quickly to decision makers.

The Lagrangian Particle Dispersion Model (LPDM) is a more advanced model that provides highly refined transport and dispersion analyses on local to regional scales. LPDM fully utilizes three-dimensional winds forecast by RAMS to account for complex wind patterns due to the effects of terrain or other mesoscale atmospheric phenomena. Although primarily configured to calculate dose and deposition for radiological releases, LPDM can be used to simulate dispersion of any passive contaminant. An easy-to-use graphical user interface for LPDM has been written using Interactive Data Language (IDL). The LPDM user interface seamlessly integrates the operational measurements and numerical forecasts into the calculation for the user (Buckley and Hunter, 2006). Easy-to-use post-processing routines automatically generate image files of maps showing the concentration level and extent at various times in the calculation.

WIND SYSTEM GEOSPATIAL FRAMEWORK

The utility of the WIND System for weather prediction and consequence assessment is a result of the use of automation and easy-to-use graphical user interfaces. Following this same strategy a geospatial framework has been developed that uses easy-to-use automated GIS applications for pre-processing and post-processing of geospatial data used with the WIND System.

The Puff/Plume Model has its own graphical user interface that uses a static image as a basemap and the calculated plume is overlaid on this static basemap (see Figure 1). The user interface allows the user to choose from a variety of basemaps that represent different geographic extent. An ArcView 3.2 extension has been developed that automates the creation of basemap images used in Puff/Plume. The user can bring any vector or raster data into the view and the application exports the view as an image file at the correct resolution for Puff/Plume and automatically generates the coordinate information needed for georeferencing the image in Puff/Plume. Since the process is automated, it is straightforward to create basemaps at any location, which allows custom versions of Puff/Plume to be developed at sites other than SRS.

For post-processing of Puff/Plume results, an ArcView 3.2 extension was developed that converts the circular puffs shown in Figure 1 into a polygon shapefile (Koffman, 2006). The extension has a simple user interface and is very easy to use, which is important during an emergency response. The extension classifies the shapefile using the same colors and ranges as Puff/Plume, so the result in ArcView looks identical to the result in Puff/Plume. An ArcGIS version of this application has been developed by SRNL and is used by the SRS Emergency Operations Center (EOC) with their ArcGIS system. The resulting puff shapefile can be shared with other agencies that use GIS.

The graphical user interface for LPDM is written using Interactive Data Language (IDL) and IDL is also used for output processing to create map images (Buckley and Hunter, 2002). Vector geospatial data is pre-processed into files in geographic coordinates that are accessed by the IDL routines to draw the maps. The IDL routines are preconfigured with symbology and labeling, but different view extents may be used depending on the simulation. An ArcView 3.2 application was written to export coordinates from vector geospatial data into the text file format used by LPDM. This ArcView application was used to pre-process the geospatial data used with LPDM and makes it relatively easy to add data to the LPDM user interface. The LPDM automated output generates a time series of maps with the plume results overlaid (see Figure 2) and the user has the option to automatically create a movie from these image files.

For post-processing of LPDM results, an ArcView 3.2 extension was developed that processes the LPDM output files into GIS format (Koffman, 2006). The LPDM results are typically more complicated than the Puff/Plume results and provide information on a regular grid of points. The ArcView application uses Spatial Analyst to import the LPDM results as grids. The grid may be contoured to create a shapefile, which can be shared with other agencies. The grid and the contour shapefile are automatically classified for the user. The easy-to-use interface allows a user to quickly import the LPDM results into ArcView.

One other feature of the geospatial framework is the ability to import field measurements into ArcView through two easy-to-use applications. The first ArcView extension has a form that can be filled in with field measurements collected at single points that are called in from a field team. A shapefile is created that contains a time stamp along with the location and the measurements. More sophisticated field measurements are available from the SRNL resource for mobile measurements of radiological contamination called the Tracking Radioactive Atmospheric Contaminants (TRAC) vehicle. The TRAC vehicle has onboard computers with a data acquisition system and a satellite connection for transmitting the collected data files. The second

ArcView extension has an easy-to-use interface that automatically imports the TRAC data files into shapefiles that show the path of the vehicle along with measurements.

GRANITEVILLE TRAIN ACCIDENT

Hunter et al. (2006) discuss the use of the WIND System to respond to a real emergency that occurred near SRS that was within the domain of the RAMS numerical forecasts. On January 6, 2005 at approximately 2:40 AM, two Norfolk Southern freight trains collided in the town of Graniteville, SC, resulting in the rupture of rail cars transporting liquefied chlorine and other industrial chemicals. The subsequent discharge of chlorine quickly produced a dense airborne cloud of toxic gas and aerosols that spread throughout property occupied by a textile mill and into adjacent areas of town, resulting in the deaths of nine individuals, mainly mill workers, and injuries to more than 500 others. The threat of a rupture to additional tankers of chlorine that were damaged in the accident resulted in closure of businesses and the relocation of more than 5000 residents for up to nine days, as crews worked to dispose of the remaining inventories. The town of Graniteville is located approximately 20 km north of SRS.

Through the SRNL mutual aid agreements with surrounding counties, consultations with Aiken County EMA began around 7 AM on the morning of January 6. Initially, the most significant challenge for the SRNL response team was development of a source term that would provide an adequate basis for reassessing protective action measures. The first Puff/Plume transport model calculation, shown as Figure 1, was posted to an external web site for access by officials at Aiken County's Unified Command Center around 8 AM. Results showed that predicted downwind concentrations greater than the protective action threshold of 3 parts per million (ppm) extended no more than 1 mile downwind of the accident site.

By 9AM, results were available from an LPDM simulation of downwind transport using RAMS forecasts of local winds. The RAMS forecasts for the Graniteville area showed winds that were consistent with the regional observations and indicated persistence of the south-southwest wind throughout the day (Figure 2). Wind observations during the day verified this RAMS forecast. Animation of LPDM results based on the RAMS forecast showed a corresponding north-northeast transport of the residual chlorine release that would remain west of more densely populated areas near the city of Aiken.

The SRNL team continued to provide ongoing support. Updates of Puff/Plume consequence assessment model results using current meteorological conditions were posted to the external web site approximately every 2 hours. Briefings were provided for local and state officials on consequence modeling results and forecasts of meteorological conditions expected for the upcoming 12-24 hour period.

By midday on January 7, responders began to plan recovery actions for the chlorine tankers. One disposition alternative was to physically lift the damaged tankers from the wreckage. Due to concern that such actions could result in an additional catastrophic rupture, Aiken County requested SRNL to estimate possible downwind consequences resulting from the postulated release of the entire contents of a tanker. Puff/Plume results for this scenario, using meteorological conditions anticipated for that afternoon, showed an area of potentially life threatening effects (concentration greater than 20 ppm) to a distance of 5 km from the crash site and potentially irreversible severe effects (concentration greater than 3 ppm) to a distance of more than 20 km from the site (see Figure 3). Furthermore, winds had shifted to a direction that would transport the contaminant more toward the city of Aiken and impact a nearby hospital and other sensitive receptors. Model results for this scenario were posted to the external web site and provided to Aiken County as a GIS layer for display on the Unified Command Center mapping system. These results led to a decision to defer recovery actions involving movement of the damaged tankers.

SUMMARY

SRNL has developed an operational emergency response capability for atmospheric contaminant releases that relies on automation and user friendly interfaces for models to ensure rapid deployment. The WIND System records real-time meteorological measurements from a network of towers and the RAMS model is run on a routine schedule to generate three-dimensional forecasts of meteorological conditions. Both measurements and numerical forecasts are always available for automatic use by transport and consequence assessment models in the event of an emergency. The Puff/Plume model is used for early assessment and has an easy-to-use interface that allows an analyst to generate plume predictions in a few minutes once a source term has been determined. The more sophisticated LPDM utilizes the full three-dimensional forecasts from RAMS to calculate deposition for radiological releases or to simulate dispersion of any passive contaminant and a user friendly interface has been developed for LPDM calculations. Both models export image files of the plume prediction overlaid on basemaps that are useful to decision makers.

The need to display results on maps for decision makers has led to development of a geospatial framework that uses easy-to-use automated GIS applications for pre-processing and post-processing of geospatial data used with the WIND System. Automated applications have been developed that pre-process geospatial data for use in the Puff/Plume and LPDM user interfaces. Automated applications have also been developed that post-process the results from

Puff/Plume and LPDM into GIS for interactive display with other geospatial data during an emergency. The import of field measurements into GIS from field teams and from the TRAC vehicle has also been automated.

The WIND System performed as designed to provide timely support to Aiken County and State of South Carolina officials responding to the Norfolk Southern train accident in Graniteville, SC. This real emergency response in Graniteville clearly demonstrates that local/regional consequence assessment assets can play a valuable role since many emergencies are coordinated at a local level.

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FIGURE 1: Initial Puff/Plume prediction provided to the Aiken County EMA for the ongoing residual release of chlorine from the Graniteville site.

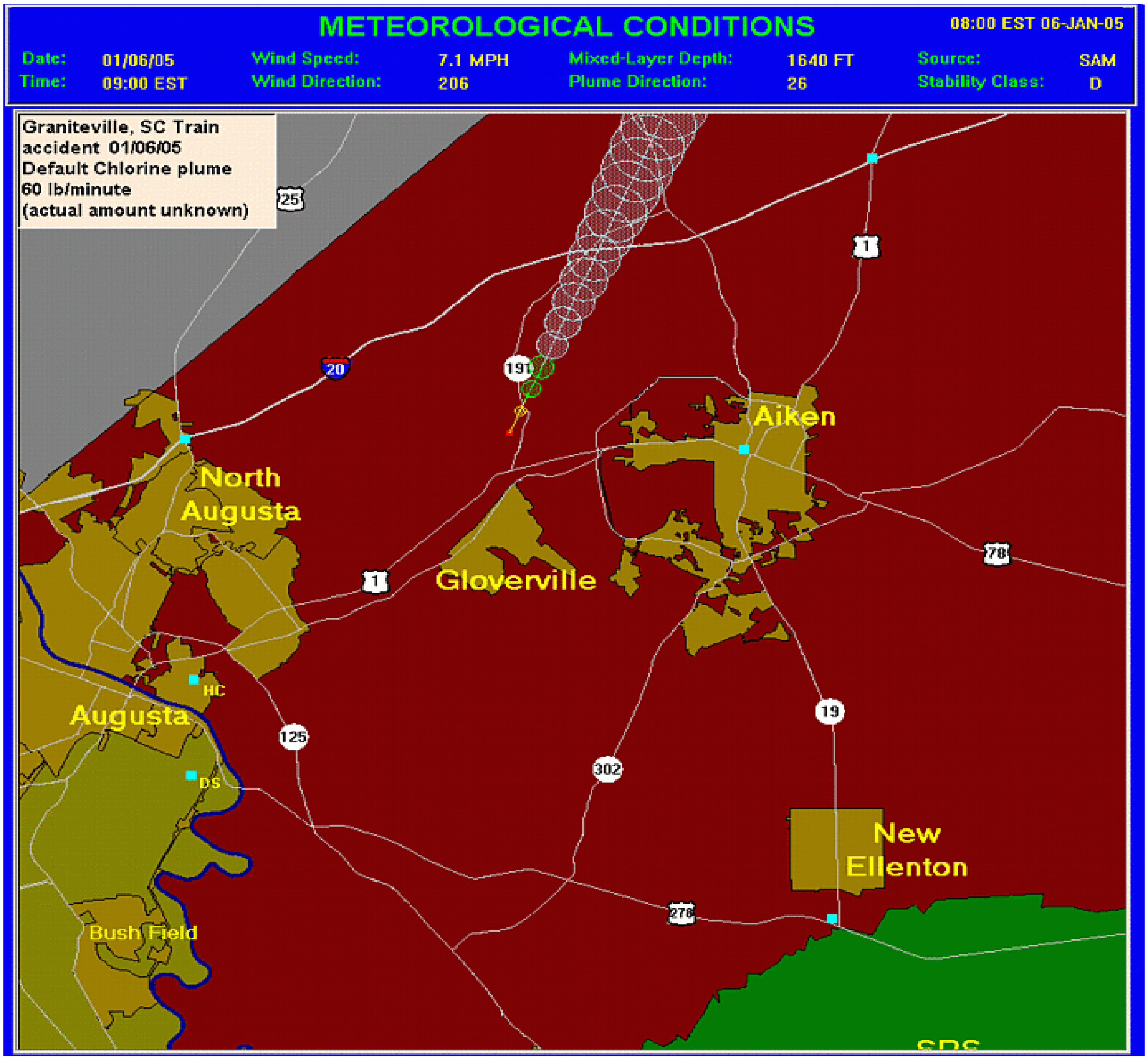

FIGURE 2: Forecasted concentration field from LPDM at 1200 PM where colors denote orders of magnitude assuming a continuous unit release.

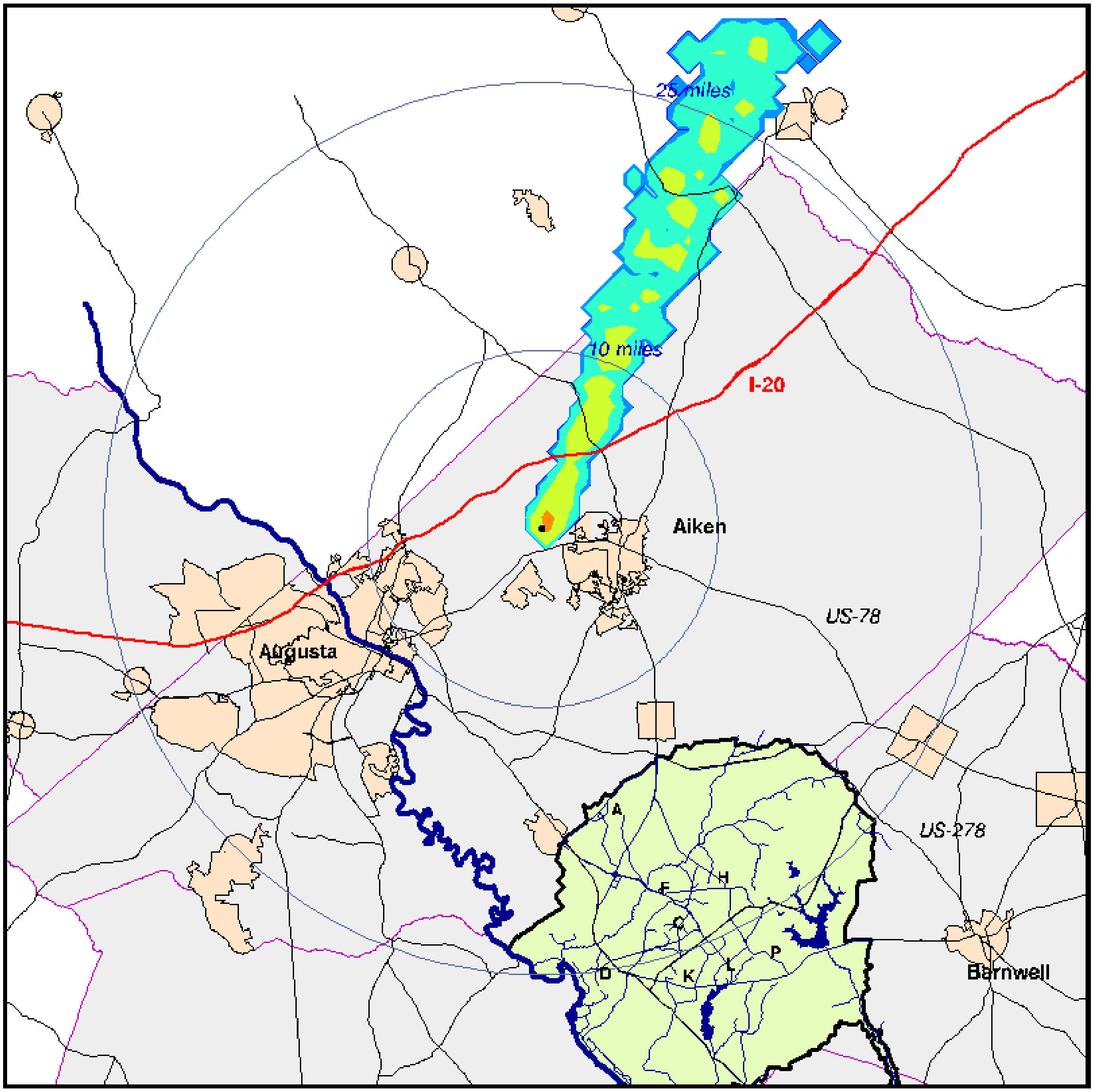

FIGURE 3: Puff/Plume prediction provided to the Aiken County EMA for catastrophic rupture of another tanker on January 7.