This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

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WSRC-MS-2005-00612
October 2005

The Savannah River National Laboratory's Response to the Graniteville, SC Train Accident

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Abstract - *The Savannah River National Laboratory's (SRNL) Weather INformation and Display (WIND) System was used to provide meteorological and atmospheric modeling/consequence assessment support to state and local agencies following the collision of two Norfolk Southern freight trains on the morning of January 6, 2005. This collision resulted in the release of several toxic chemicals to the environment, including chlorine. The dense and highly toxic cloud of chlorine gas that formed in the vicinity of the accident was responsible for nine fatalities and injuries to more than five hundred others. Transport model results depicting the forecast path of the ongoing release were made available to emergency managers in the county's Unified Command Center shortly after SRNL received a request for assistance. Support continued over the ensuing two days of the active response. The SRNL also provided weather briefings and transport/consequence assessment model results to responders from South Carolina Department of Health and Environmental control (SCDHEC), the Savannah River Site's (SRS) Emergency Operations Center (EOC), DOE Headquarters, and hazmat teams dispatched from the SRS.*

I. INTRODUCTION

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. Hundreds of emergency workers from local volunteer fire departments, Aiken County sheriff and emergency management offices, the Department of Energy's Savannah River Site, and state and Federal agencies responded to the event. The town of Graniteville is located in west-central South Carolina a few kilometers (km) west of Aiken, SC and approximately 10 km north of DOE's Savannah River Site (SRS) and the SRNL.

II. BACKGROUND

The SRNL's Atmospheric Technologies Group has developed automated atmospheric transport and consequence assessment assets in support of the SRS emergency response program for more than 30 years. In 1996, the ATG initiated the establishment of mutual aid agreements with emergency management agencies in five counties surrounding the SRS, including Aiken County[1]. These agreements delineated three areas of technical support: (1) assistance in establishing meteorological monitoring stations, linked to the existing SRS meteorological monitoring network, in areas with potential for generating airborne hazards; (2) provide custom software for use by the county in real-time consequence assessment; and (3) provide technical assistance to the county's emergency managers during a real-time response.

II.A. Overview of Current SRS Resources for Consequence Assessment

The primary SRNL resource used to conduct consequence assessment for emergency response is the Weather INformation and Display (WIND)

System[2]. The backbone of the WIND System is a cluster of UNIX workstations, located in the SRS central computer facility, that gather data from the regional network of meteorological monitoring stations (mesonet) and archives 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 a prognostic mesoscale 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.

II.B. WIND System Components

Meteorological Measurements. The mesonet of meteorological monitoring stations currently incorporated into WIND System operations is illustrated in Fig. 1. Towers located adjacent to each of the SRS's eight major operations areas are instrumented to measure winds, temperature, and moisture at an elevation of 60 meters above ground level. A ninth tower located near the center of the SRS collects similar data at four levels through a height of 60 meters. The ATG also operates instrumentation on a TV tower facility located near the SRS which provides measurements of wind, temperature, and moisture at several levels through 330 meters. Every 15 minutes, field observations are transmitted to the UNIX workstation cluster and archived, as noted above. The mutual aid agreements led of 1996 to installation of an additional four monitoring stations in Augusta/Richmond Co. (GA). Measurements of wind and temperature at these four sites are collected at a single level with heights ranging from 10 to 60 meters above ground.

Measurements from the regional mesonet 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.

Meteorological Forecasts. The 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 8-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; 24-hour forecasts for an area that includes much of Georgia and South Carolina are produced every 12 hours.

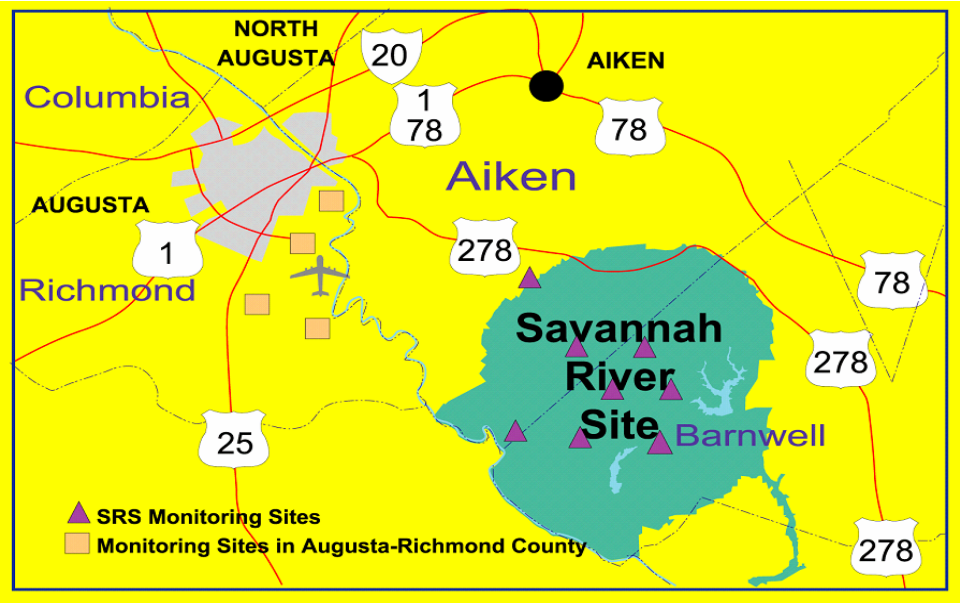

Fig. 1 SRS Regional Monitoring Network.

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. Two of these models were used during the Graniteville 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. Output can also be exported for use with geographic information system software.

- The ***Lagrangian Particle Dispersion Model (LPDM)*** 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.

III. SRNL SUPPORT DURING THE GRANITEVILLE RESPONSE

III.A. Summary of Prevailing Meteorological Conditions Affecting the Release

Table 1 provides a summary of meteorological conditions observed from the WIND System regional mesonet at the time of the accident. The south to southwest wind that was observed throughout the mesonet and at NWS stations across the region was the result of a clockwise flow around surface high pressure system centered off the southeast U. S. coast. Several aspects of the meteorological observations at the time of the accident through the remaining pre-dawn hours are believed to be significant:

(1) The uniform nature of observed wind direction and speed across all stations in the mesonet suggested that synoptic scale pressure gradients were, in general, sufficient to overcome possible microscale flows driven by local terrain. This provided the SRNL response team greater confidence that the regional wind observations were reasonably representative of conditions in the Graniteville area.

(2) Surface wind speeds and turbulence were more pronounced than is often observed in the early morning hours. In fact, measured values of turbulence intensity suggested an atmospheric stability that varied between neutral and weakly stable.

These conditions are believed to have been sufficient to cause some turbulent mixing and steady erosion of contaminant along the periphery of the dense cloud that formed immediately after the crash and tank rupture, with subsequent passive transport of chlorine gas toward less populated areas to the north-northeast of Graniteville. By dawn, visual reports from television broadcasts appeared to indicate that most of the initially compact dense cloud had been flushed from the shallow valley in which Graniteville is located.

TABLE I. Synopsis of Meteorological Conditions Observed from the SRNL Mesonet, between 3 AM and 6 AM, January 6, 2005

Wind Direction (from):	South-southwest
Wind speed:	7 to10 mph (at 60m) 2 to 4 mph (surface)
Temperature:	52^{o}F to 56^{o}F
Relative Humidity:	92% to 98%
Atmospheric Stability:	P-G Class E and D

III.B. Overview of SRNL Support Activities

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. Aiken County officials reported that the accident resulted in breaches to rail cars containing chlorine, sodium hydroxide, and cresol. All subsequent assessments then focused on chlorine as by far the most volatile, and hence, the most significant of the three substances with respect to

potential airborne hazards. Furthermore, based on reports of injuries and possible fatalities occurring during the pre-dawn hours, the breach to the chlorine tanker was believed to have resulted in a rapid initial discharge of most of the contents, followed by an ongoing residual release. These assumptions were supported by television reports from the scene in which no significant venting or notable reductions in visibility could be observed. The initial assessment was based on a modest, and believed reasonably conservative, ongoing release of 60 pounds per min (lbs/min)

The first Puff/Plume transport model calculation, shown as Fig. 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) (ERPG-2) extended no more than 1 mile downwind of the accident site. Discussions continued through the morning with Aiken County EMA and with representatives from SCDHEC to begin evaluating the appropriateness of the initial calculation and refine the initial assumptions on source term. Unsubstantiated reports indicated odors had been noted by motorists along Interstate 20, approximately 20 km north of the incident; however, SCDHEC reported no evidence of detectable levels of chlorine in areas downwind of the immediate incident scene after daylight. This provided the SRNL assessment team increased confidence that the chosen default release rate was reasonably bounding.

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 (Fig. 3). 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

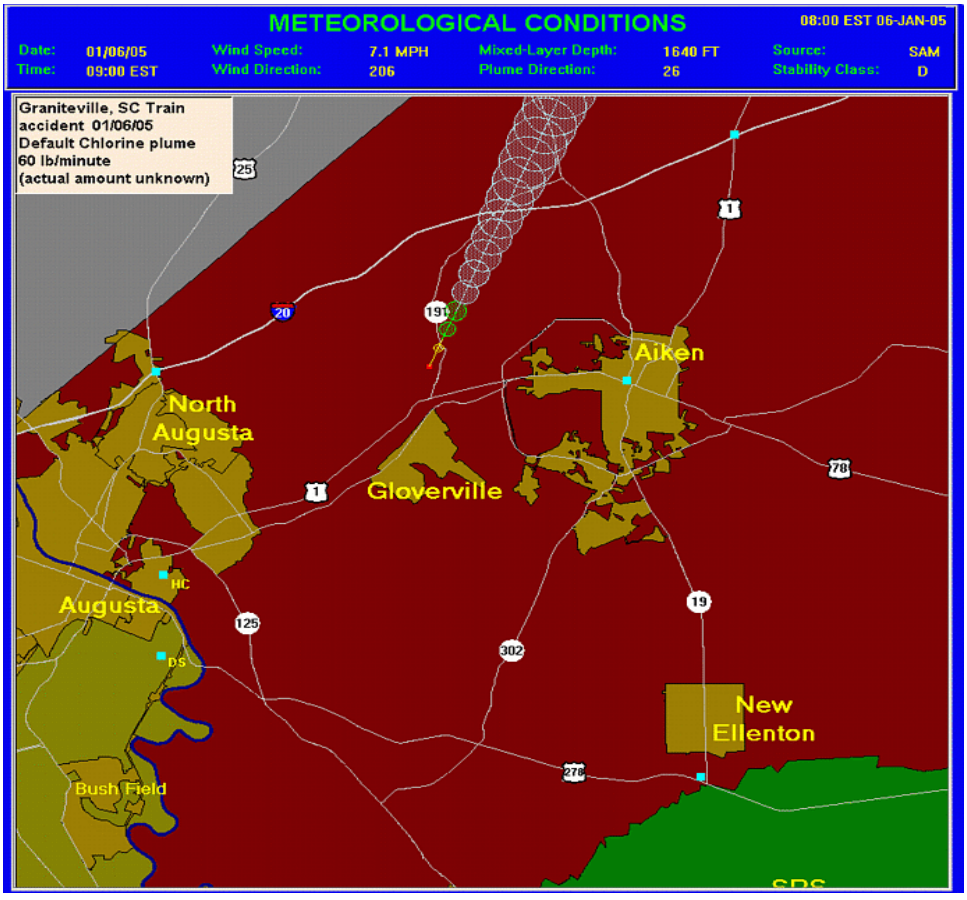

Fig. **2. Initial Puff/Plume prediction provided Aiken Co. EMA and South Carolina DHEC for the ongoing residual release of chlorine form the Graniteville site.**

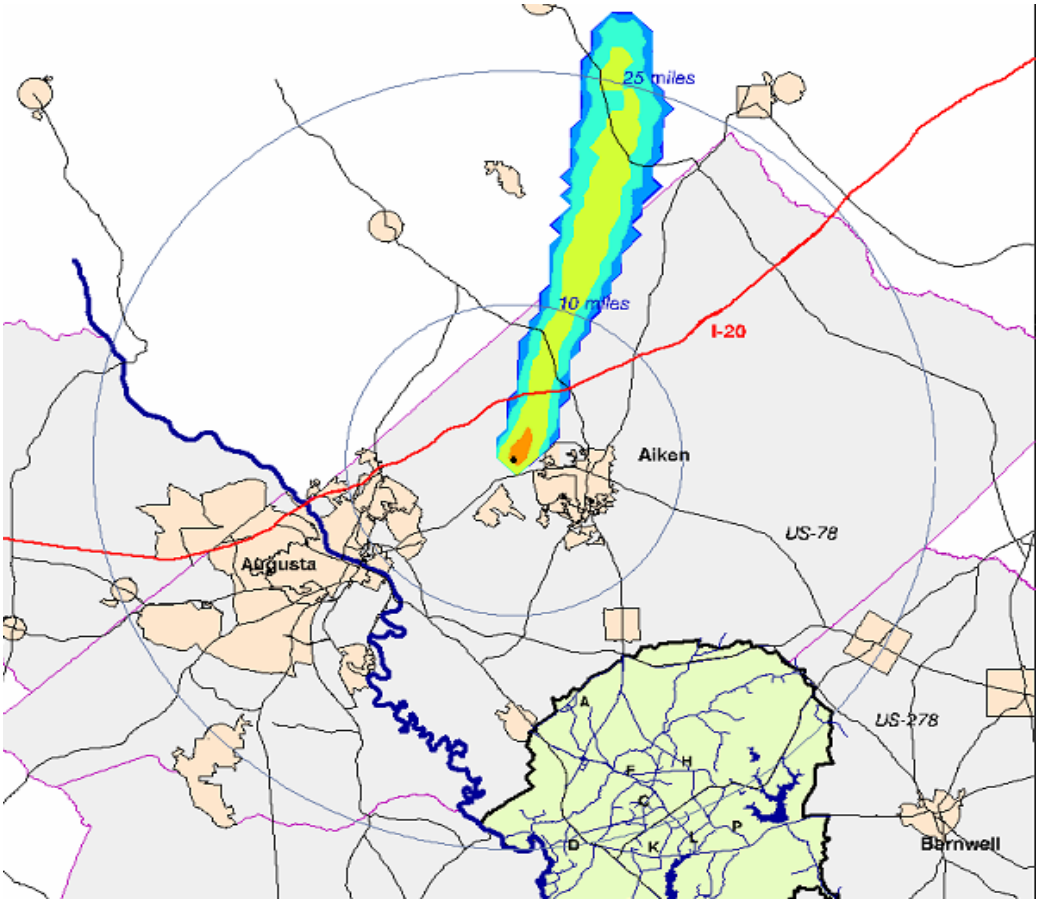

Fig. 3. Initial LPDM results indicating a forecast of persistent north-northeast transport from the Graniteville site.

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 as follows:

- Updates of Puff/Plume consequence assessment model output using current meteorological conditions, posted to the external web site for use by Aiken County and SCDHEC approximately every 2 hours.

- Briefings for local and state officials on consequence modeling results and forecasts of meteorological conditions expected for the upcoming 12-24 hour period.

Puff/Plume model results were also supplied to core staff in the SRS Emergency Operations Center (EOC), and subsequently forwarded to DOE Headquarters EOC and to the DOE liaison with the Department of Homeland Security.

By midday on January 7, responders at the incident scene began to plan recovery actions for the ruptured tanker as well as for at least one additional chlorine tanker that had been damaged but not believed to have been ruptured. One disposition alternative was to physically lift the damaged tankers from the wreckage and remove them from the scene. 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 the tanker.

Puff/Plume results for this scenario, using meteorological conditions anticipated for that afternoon, showed an area of potentially life threatening effects (greater than the ERPG-3 concentration of 20 ppm) to a distance of 5 km from

the crash site and potentially irreversible severe effects (greater than the ERPG-2 concentration of 3 ppm) to a distance of more than 20 km from the site. 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. Eventually, teams were able to reach the tanker in place and were able to siphon the remaining chlorine inventory onto undamaged tankers that were brought to the scene.

IV. CONCLUSIONS

The SRNL's WIND System, a real-time consequence assessment resource for emergency response, performed as designed to provide timely support to Aiken County and State of South Carolina officials responding the Norfolk Southern rail accident in Graniteville, SC. Results were used to reassess the appropriateness of initial protective actions for the surrounding community and to plan incident scene recovery actions. The value of SRNL's support to local emergency managers was noted in subsequent newspaper reports[3].

Furthermore, experience gained from the Graniteville response clearly demonstrates that local/regional consequence assessment assets can play a valuable role during hazardous material incidents of national significance by providing nearly full-time, customized support targeted directly to local decision makers.

REFERENCES

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