Train Wreck and Chlorine Spill in Graniteville, South Carolina

Transportation Effects and Lessons in Small-Town Capacity for No-Notice Evacuation

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The 2005 railroad chlorine spill in Graniteville, South Carolina, killed "only" nine people, but it illustrated the difficulties of achieving adequate capacity to handle no-notice evacuation for hazardous materials incidents. This research uses Graniteville as a case study to highlight needs for building capacity in evacuation capabilities and transportation recovery. Rail operational concepts emerged, such as the need for positive train control and automatic warning technology. The local community faced several challenges, including a lack of public understanding of how to react to a chlorine spill (even though chlorine traversed the town daily), public necessity for basic transportation to work after the evacuation, and a need for documentation of transportation infrastructure to facilitate recovery. Finally, evacuation issues arose, such as how to determine whether to shelter in place or evacuate, what routes would protect or harm people given different hazardous materials and how they behave in a spill, and the role of transportation professionals in working with emergency responders to manage evacuation. Experience and lessons learned from Graniteville can help define a national research agenda for the transportation requirements of no-notice and hazardous-materials evacuation.

The 2005 chlorine spill (Figure 1) in Graniteville, South Carolina, posed one of the greatest potential hazardous material disasters in recent American history. The accident occurred during the middle of the night in a small rural community just outside of Aiken, South Carolina. The accident displaced 5,400 people from their homes, killed nine people (*1*), and permanently changed a community. Even though the ultimate death toll remained remarkably low, the disaster response showed gaps in local preparedness and need to improve practices of major organizations. The objectives of this research are to raise research questions related to decision making for no-notice evacuations and to determine the long-term impacts of the Graniteville disaster on transportation organizations and their operations.

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Transportation Research Record: Journal of the Transportation Research Board, No. 2009, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 130–135.
DOI: 10.3141/2009-17

METHODOLOGY

This research examined the Graniteville disaster as a case study illuminating the issues of small-town capacity to handle no-notice evacuation and hazardous materials. Research included interaction in the community from May to August 2005, speaking with community members, Norfolk Southern officials and employees, South Carolina Department of Transportation (SCDOT) employees, and local officials. The case study involved observing and participating in rebuilding efforts to restore the town to its conditions before the wreck.

CHRONICLE OF EVENTS

Many trains traveled through the quiet mill town each day. A rail spur in the center of the town serviced the Avondale plant, which employed most of the town's citizens and received daily deliveries of chlorine gas via a Norfolk Southern train for mill operations. The switch connecting the spur to the main line had to be turned manually for deliveries. Contributing to the failure, no feature or mechanism existed to remind crewmembers of the switch position and prompt them to complete the switch before departing the work site. The investigative team of the National Transportation Safety Board (NTSB) concluded that "the distance required for the [moving] train['s] crew to perceive the banner of the misaligned switch, react to it, and brake the train to a safe stop was greater than the distance available" (*2*).

The chlorine spill occurred as the result of a train crash at 2:39 a.m. on January 6, 2005, after someone forgot to toggle the switch to disconnect a spur from the main line (Figure 2). The incorrectly toggled switch mistakenly diverted Freight Train 192 from the main line onto the spur at 47 mph (76 km/h). Train 192 subsequently collided into parked Train P22, derailing three engines and 18 cars (*3*). Roughly 60 tons of liquefied chlorine gas spilled out of the ninth of 42 freight cars. The liquefied gas rapidly vaporized, with volumetric expansion of 450:1 (*4*).

The engineers were unharmed in the crash; however, the deadly chlorine gas seeped through the air. The crash sound awakened local residents, and initial notification came through a 911 call within 1 min. The Aiken 911 call record indicated reports of a "bleach gas smell and smoke on the ground," and at least one caller identified chlorine (*5*). Fire and rescue services responded within 1 min of notification and were en route within one more minute; however, upon hearing a radio report of a "smell of chemicals," the fire department chief ordered

FIGURE 1 Graniteville accident displaced rail cars and spilled chlorine cargo. (Photo source: Environmental Protection Agency, Region 4, Southeast.)

responders to stand by. Within 6 min, the fire department chief stood 1,000 ft (305 m) from the crash and was forced to withdraw lest he be overcome by chlorine fumes, which were spreading rapidly and approaching critically toxic levels. Within 13 min, the chief recognized the need for a mass evacuation and relocated upwind. Emergency responders marshaled personnel and equipment, established incident command, requested mutual aid, activated Reverse 911 with instructions to shelter in place, and initiated a major evacuation (*6*). However, these actions did not take place with immediacy and efficiency.

About 5,400 residents were evacuated. The chlorine gas had already affected many people: 554 were treated at hospitals, 75 were admitted, and nine would eventually die from its poison (*2*): the train's engineer (who had survived the crash), three workers in the mill, a truck driver sleeping in his cab, a man in a shack one block from the wreckage, two workers who had evacuated the mill on foot into the woods, and one other person (*7*).

EVACUATION

The emergency response community has recognized a need to reduce the chaos of the type experienced in Graniteville. Poor communication between agencies and lack of clear decision-making authority exacerbated the disaster. Responders disagreed over how to evacuate the town, and this disagreement resulted in inaction.

While the Reverse 911 system worked, the timing and decision making of the evacuation actions rendered the system only marginally effective. Responders could not quickly and positively identify the hazardous material or the proper procedure. The wheel report faxed from Norfolk Southern Railway to the Bath Fire Department did not identify emergency response procedures for hazardous materials cargo (*6*). The fire department did not seek industry resources to learn procedures. The 911 record showed that callers received

FIGURE 2 Impact occurred after switching point between main line and Avondale Mills delivery spur. (Figure source: Google Earth, with modifications from the authors.)

little direction on how to evacuate beyond "get out of the area. We've got people on the way." Instructions to evacuate from low-lying areas might have been helpful, but such instructions would have required information on materials and knowledge of proper response. As callers reported people dying around them, 911 could do nothing but advise callers to stay inside. In the most extreme example, one mill worker stayed on hold with a 911 operator for 28 min. The operator advised him to stay inside and wait for help while the caller labored to breathe and screamed in agony. After those 28 min, that call ended with a disconnection. The caller followed instructions and waited in the mill for 4 h for help to arrive before he dragged himself out of the plant and drove himself to evacuate (*7*). Automated Reverse 911 called people and advised them to stay in their homes and turn off their air circulation; however, this system did not start until 4 h after the incident.

The 911 records suggested that pedestrian movement created concerns. Whether people worried about walking to their vehicles, felt they could not drive through the thick green cloud, or had no vehicle option available to them was not clear. Callers reported that they were stuck where they could not walk either way because they would "choke to death." The 911 operator advised them to go indoors.

Hazardous materials pose unique evacuation challenges because the type of material determines the appropriate response; however, many response plans do not account for this difference. A national hazardous materials response handbook states that, in the development of exercises for handling emergencies, "scenarios virtually always progress to an evacuation of some area," an event that "effectively limits the need to utilize the protective action decision making process" (*8*). Evacuation is sometimes inappropriate because sheltering in place will better protect the population. Chlorine gas sinks lower than air and concentrates in valleys; other gases rise to higher elevations. Advising people to run must account for the fact that running along a valley or up a hill will catalyze either life or death according to the type of hazard posed. Response plans and training exercises need to include decision paths that consider the effects of materials and the most appropriate responses to protect the population.

Timing and performance posed critical opportunities and challenges in Graniteville. The crash happened in the middle of the night. As a substantial benefit, the mill contained few workers at that hour and most residents were not moving through the town, posing the maximum threat to a minimum number of people. As a challenge, the late timing reduced visibility and made it difficult to contact people for information.

TRANSPORTATION STAKEHOLDERS

Because this accident touched thousands of people, much debate has risen. The accident affected four major institutions: Norfolk Southern Railway, the people of Graniteville, Avondale Mills, and SCDOT.

Norfolk Southern

The National Transportation Safety Board (NTSB) stated in its investigation findings that the cause of the crash "was the failure of the crew of Norfolk Southern Train P22P to return a main line switch to the normal position after the crew completed work at an industry track" (*2*). The railroad took action against the individuals responsible and is assuming all responsibility for the accident. Norfolk Southern is paying for the roads to be rebuilt, cleanup from the accident, compensation for displaced citizens, repairs to all the homes and businesses damaged by the chlorine gas, and damages to Avondale Mills. Norfolk Southern has announced that the total cost for the disaster will range from $30 million to $40 million (*1*). It will be a long time before the railroad sees an end to compensation for the Graniteville accident. Beyond paying monetarily, stigma now exists because people are aware of the threat railroads pose to communities and how deadly some railroad cargo is.

South Carolina Department of Transportation

The roads adjacent to the train tracks were heavily damaged during the accident. SCDOT had to remove and reconstruct them completely. It had to get the roads in working order immediately after the crash and permanently repair them in the months to follow.

This project presented exceptional challenges for SCDOT. First, funding had to be approved for the work through an emergency repair contract. Second, the cleanup posed substantial embedded debris. Two of the crashed cars were carrying scrap train parts, which were deposited in the road, dirt, bushes, trees, and other milieus around the accident site. Another car had 12-ton rolls of aluminum, and one disappeared. It reemerged when SCDOT accessed a failed drainage pipe that had been crushed by the aluminum and buried in dirt. The situation showed that even large objects or breaches in infrastructure can hide in the chaos of major disasters.

Finally, the proprietary nature of initial construction made reconstruction difficult. Avondale had built the town of Graniteville: Avondale built the roads, the mill, and many of the mill homes. The roads were given to the State of South Carolina and grandfathered into the agency's maintenance plans. SCDOT had no building plans and no documentation of existing conditions. There were no road plans and no drainage plans. No one knew where the pipes went, who maintained them, or what materials comprised them. Some of the replacements had to be special-ordered because standard configurations did not fit into the existing structures.

People of Graniteville

The town of Graniteville lost lives, jobs, infrastructure, time, and resources in the aftermath of the train wreck. The chlorine spill occurred centrally in populated areas (Figures 3 and 4), and the gas harmed everything it touched. It hurt wiring in buildings, ruined anything electronic, and killed trees, plants, shrubbery, birds, and insects. For months, Graniteville was silent. There were no birds singing, no insects flying, and no fire ants crawling. The citizens were surprised to see that some of the trees survived and sprouted anew with the spring. Evidence of the train wreck remains everywhere. There are scars in the trees from flying train parts, shrubbery that is dead from the chlorine gas, and a wooden cross that lies where the train engineer died.

The citizens who lived immediately in the affected area were evacuated and taken to shelters and hotels. Some would be allowed to return to their homes in a few days, more in a few weeks, and the people living nearest the impact point in a few months. Their homes had to be decontaminated and the damages repaired. Norfolk Southern paid the costs.

Avondale

Avondale Mills shut down its Graniteville plant for months following the accident. Without the rail line working, the company had no way

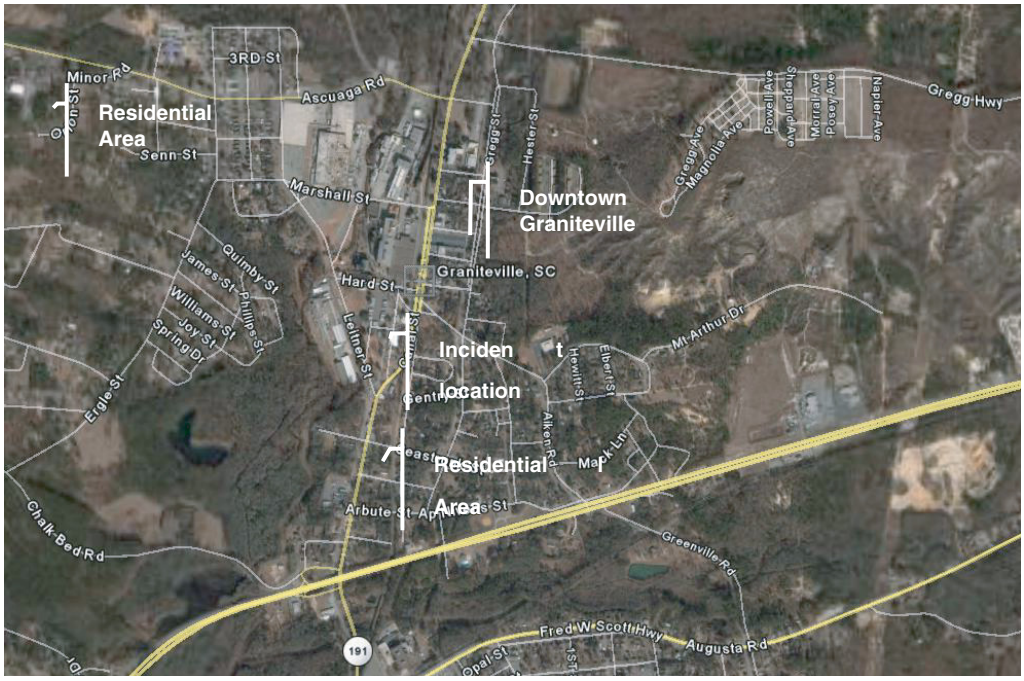

FIGURE 3 Chlorine spilled centrally to local population. (Figure source: Google Earth, with modifications from the authors.)

to get the materials needed to make products, and no adequate transportation infrastructure or operations could cost-effectively replace the impaired delivery mechanism. Evidently, the Mills had no business continuity plan to keep the plant functioning through other modes. Also, repairs had to be made from the damage that the chlorine gas caused. The accident left many employees homeless and displaced to shelter or hotels. These employees also faced individual transportation challenges because they had no way to get to work and could not reenter the contaminated area.

Avondale shutting down was a disaster in itself for the mill town of Graniteville. Most local residents were employed by the mill and fed their families with money earned there. The townspeople struggled through several months of temporary closure. Avondale Mills reopened its plant it 2005, but the Graniteville plant closed permanently in 2006 due to its economic situation (*9*).

FIGURE 4 Downtown businesses, church (now freshly painted), and local residences stood adjacent to switch and spill site.

RESULTS

Consideration for Train Disasters

The disaster could have been avoided if railroad employees had been alerted to their mistake with the switch. Electronic signals to alert dispatchers of switches' positions are commonly used but not fully placed. Roughly 40% of the 170,000 mi of main-line tracks in the United States do not have such signals; Norfolk Southern has an above-average record, with roughly only one-third of its 16,630 mi unsignalized (*10*). The NTSB has identified positive train control as an important national issue, partially based on the Graniteville incident and another train spill of chlorine in Macdona, Texas, on June 28, 2004 (*11*).

As another railroad safeguard, the NTSB investigation team for Graniteville recommended operational precautions. Hazardous materials should be located in the rear one-quarter of a train, operators should reduce speeds for hazardous materials, and the length of trains should be reduced (*4*). These recommendations run counter to the demands of the competitive freight-shipping industry. Competition encourages running as many cars as possible to maximize shipment while minimizing operational expense and moving freight quickly to free engines for the next shipment. The Graniteville disaster has increased the precariousness of the balance between private railroad safety and profitability.

A legal issue lies in the territory between state and private railroad responsibilities. The FRA sets guidelines and standards for private rail carriers and rail lines. In order for a state or private rail entity to receive federal funding, it must comply with FRA standards. In this case, those standards did not provide protection from disaster because the main line and rail siding located in Graniteville complied with the standards set by the FRA. Some people have argued that Norfolk Southern kept an unsafe environment that was accessible

to the public, but the company did comply with current standards (www.fra.dot.gov).

Community Considerations for Evacuation and Transportation System Recovery

Within the four-phase emergency management cycle (prevention, preparedness, response, and recovery), difficulties with preparedness created some of the most substantial problems. More local planning for emergency events would have greatly affected the chain of events following the wreck in Graniteville. All local communities can look to this situation to realize that a better warning system, more preparedness, and community involvement can prevent or mitigate such a catastrophe from happening again. These factors all contribute as components for a community emergency response plan, which Graniteville particularly should have had in light of the routine shipments of a known hazardous material.

Given that the accident occurred, the number one thing that would have most helped the crisis was for everyone to be aware of what the train was hauling. The need for information and communication cannot be overstated. If the engineers had known what they had crashed into, they could have fled the scene; possibly they would both be alive today. If the emergency response workers had known about the chlorine, they could have evacuated the area earlier. Further, if a warning system were in place, the citizens could have left earlier. Most citizens did not know what materials the daily trains carried. The hazardous material cars could be fitted with an external monitor to detect hazardous materials in the air and alert the proper authorities through an intelligent communication system connected to the 911 call center. A Reverse 911 call could have been put out to everyone in the immediate area to evacuate, and emergency response workers could have been prepared with information and equipment earlier.

The transportation challenges of a hazardous-materials evacuation continue long after the no-notice evacuation. Reentry posed logistical difficulties for residents to get to work. "How Graniteville will completely recover from the train wreck has yet to be seen," stated resident Will Gibbes. "How this will continue to affect the community and its citizens is up to much debate" (personal communication, August 8, 2005). He says that Graniteville residents have different opinions on how the train wreck affected their community. Some think that it has made them more aware of what materials are in their locale. Others are now adverse to Norfolk Southern working in the community. Most people just want things back to the way they were before the wreck.

Reconstruction and recovery difficulties typically continue for years. Accurate and thorough record keeping of public infrastructure would have helped long-term community recovery. Documented knowledge of infrastructure materials, characteristics, and locations can speed planning and reparations. Such documentation can facilitate claims made for insurance, government grants, and recovery planning.

Implications for Evacuation

Literature on the transportation aspects of decision-making and instructions is limited and needs to improve on national, state, and local levels. Recent efforts on no-notice evacuation research have included concepts of household decision making for no-notice evacuation (*12*), route choice (*13*), intelligent transportation systems (*14*), and signal timing (*15*).

Overall, the Graniteville disaster highlighted several research questions related to no-notice and hazardous-material evacuation for the transportation community to address. These research questions can help begin to define the national research agenda for no-notice evacuation:

- What is local capacity across the country to handle decision making for evacuation and sheltering in place according to the requirements of the diverse hazardous material incidents that might happen to them, especially in small rural towns?
- What is local capacity across the country to communicate instructions for evacuation or sheltering in place, especially in the middle of the night when few people are tuned into television, radio, the Internet, or other communication media?
- How should emergency responders prepare for evacuation or sheltering action based on time of day (or night)? Populations exist in different places and have different capacities to react based on whether they are working for employers, studying at school, staying in their homes for the evening, relaxing or recreating on the weekend, feeling obligated to report to work in the morning, or sleeping at night.
- How well can emergency centers instruct the public on best courses of action for evacuation? How well can incident managers analyze the interaction of hazardous materials with topography, infrastructure, vehicle availability, and evacuation routes? These responders need to give life-determining directions for evacuation or sheltering on a moment's notice.
- How can transportation expertise facilitate evacuation procedures in the context of the chain of command for disaster response? Typically emergency responders are making decisions, but might transportation professionals add some efficiency? If so, do they belong in the planning and preparation stages, at an incident management post, or at all stages of handling transportation for disasters?

Overall, public education and communication with the public underlay Graniteville's experience with the disaster. The 2004 tsunami brought a relevant example of the effectiveness of public education on evacuation: an 11-year-old British schoolgirl, Tilly Smith, recognized the characteristics of a tsunami from geography lessons and successfully evacuated 100 people from a beach in Phuket, Thailand (*16*). Information disseminated to the public saved lives. Transposing this example to Graniteville, Avondale Mills routinely received shipments of chlorine gas; therefore, local public education could have taught people how to react to chlorine spills. Such education might have resulted in residents recognizing the situation early and evacuating immediately based on best practices. Such public education on common hazardous material shipments would have eschewed the time spent waiting for emergency responders to hear of the incident, identify the problem, recognize best practices, and advise the public.

CONCLUSION

The Graniteville train wreck and chlorine spill resulted in relatively few fatalities, but illustrated a number of important lessons for disaster and evacuation planning that should be heeded before other incidents threaten larger death tolls. These lessons largely related to the need to extend safety and evacuation practices to the most remote parts of extensive systems: prevention through rail safety signal technology that only exists on 60% of infrastructure in the United States, preparedness through sophisticated public education on hazardous materials for even the most remote communities, and comprehensive

emergency response training for even small-town people working in the middle of the night. The need for planning of business continuity and long-term community recovery is still being revealed now as the town must redefine itself in the wake of the mill closure.

Expanding capacity to adequate levels in all of these areas will require substantial resources; however, the Graniteville incident offered a glimpse of the potential for far greater devastation. The first step toward building that capacity relates to defining the existing capacity and identifying the most efficient means of improving practices. This paper has identified questions to define a transportation research agenda on no-notice and hazardous-materials evacuation.

ACKNOWLEDGMENTS

On-site research occurred when one of the authors worked with the South Carolina Department of Transportation on recovery from the disaster. Special thanks go to Jeff Terry of SCDOT in Aiken County for the opportunity and to Chris Lybarker and Will Gibbes for their personal testimony and research contributions.

REFERENCES

1. Norfolk Southern Tallies Cost of Train Wreck. *New York Times*, Jan. 5, 2005.
2. Southworth, J. Accident Overview: Collision of Norfolk Southern Freight Train 192 with Standing Norfolk Southern Local Train P22 with Subsequent Hazardous Materials Release at Graniteville, South Carolina, January 6, 2005. NTSB meeting presentation to the NTSB. Accessed July 30, 2006. www.ntsb.gov/Events/2005/Graniteville/iic.pdf.
3. National Transportation Safety Board. *Collision of Norfolk Southern Freight Train 192 with Norfolk Southern Local Train P22 with Subsequent Hazardous Materials Release at Graniteville, South Carolina.* NTSB/RAR-05/04 (PB2005-916304). January 6, 2005. http://www.ntsb.gov/publictn/2005/RAR0504.pdf.
4. Henderson, J. Hazardous Materials: Collision of Norfolk Southern Freight Train 192 with Standing Norfolk Southern Local Train P22 with Subsequent Hazardous Materials Release at Graniteville, South Carolina, January 6, 2005. NTSB meeting presentation to the NTSB. Accessed July 30, 2006. www.ntsb.gov/Events/2005/Graniteville/hazmat.pdf.
5. Aiken County S.C. 911 archive telephone recordings, Jan. 6, 2005.
6. Downs, R. Survival Factors: Collision of Norfolk Southern Freight Train 192 with Standing Norfolk Southern Local Train P22 with Subsequent Hazardous Materials Release at Graniteville, South Carolina, Jan. 6, 2005. NTSB meeting presentation to the NTSB. Accessed July 30, 2006. www.ntsb.gov/Events/2005/Graniteville/hazmat.pdf.
7. Goad, B. Toxic Cargo: Desperate for Help. *Press Enterprise*, Nov. 20, 2005. Accessed July 28, 2006. www.pe.com/digitalextra/metro/trains/lamar.html.
8. National Response Team of the National Oil and Hazardous Substances Contingency Plan. *Developing a Hazardous Materials Exercise Program: A Handbook for State and Local Officials*. National Transportation Library, Washington D.C. Accessed July 30, 2006. ntl.bts.gov/DOCS/254.html.
9. Gilliland, B. Last Day Comes to Avondale Mills. *Augusta Chronicle*, July 25, 2006.
10. Noland, D. What Went Wrong: Toxic Train Wreck. *Popular Mechanics*, April 2005.
11. Chipkevich, R. J. Testimony of Director of Office of Railroad, Pipeline and Hazardous Materials Investigations for National Transportation Safety Board Before U.S. House of Representatives Committee on Transportation and Infrastructure, Subcommittee on Railroads, April 28, 2005.
12. Murray-Tuite, P. Modeling Household Level Decisions in a No-Notice Evacuation. Presented at Virginia Polytechnic Institute and State University, Blacksburg, March 29, 2006.
13. Chiu, Y.-C., J. Villalobos, B. Gautam, and H. Zheng. Modeling and Solving Optimal Evacuation Destination-Route-Flow-Staging Problem for No-Notice Extreme Events. Presented at 85th Annual Meeting of the Transportation Research Board, Washington, D.C., 2006.
14. Assessment of State of the Practice and State of the Art in Evacuation Transportation Management. FHWA, U.S. Department of Transportation. Accessed July 31, 2006. www.its.dot.gov/eto/eto_sopractice.htm.
15. Chen, M. *Traffic Signal Timing for Urban Evacuation*. MS thesis. University of Maryland, College Park, Aug. 2005.
16. Award for Tsunami Warning Pupil. BBC News, Sept. 9, 2005. Accessed July 27, 2006. news.bbc.co.uk/1/hi/uk/4229392.stm.

The Transportation Safety Management Committee sponsored publication of this paper.