Career Fire Captain Drowns After Stepping Into Flooded Storm Drain During Floodwater Rescue – Oklahoma

Executive Summary

On May 23, 2015, a 46-year-old male career fire captain drowned after stepping into a flooded catch basin at the entrance of an unguarded underground storm drain. At approximately 2223 hours, the local fire department was dispatched to rescue civilians trapped in their residences by rising floodwater following heavy rain and thunderstorms in the local area. Fire fighters responded to find the city street and entrance to a small housing development flooded by storm water runoff flowing both under and over the street just west of the entrance to the housing development. Fire fighters worked for over an hour in floodwater ranging from a few inches deep to over 3 feet deep in some areas to evacuate 10 civilians including 6 children from three flooded single-family duplex units on the east side of the development. Other residents were sheltered in place while waiting for city-provided transportation. Throughout the incident, fire fighters experienced radio communication issues (both transmitting and receiving) due to the falling rain and working in wet conditions. At times, the Engine 2 captain was able to communicate over the radio with the incident commander. At other times, radio transmissions were garbled. After the civilian rescues were completed, the Engine 2 captain proceeded to walk along the west edge of the floodwater to speak with the incident commander face-to-face. As he approached the location of the incident commander's vehicle, he stepped into a flooded storm water catch basin and was pulled into the 36-inch unguarded opening that led to the underground storm drain. Fire fighters heard the struggling captain yell for help and rushed to assist him. The Engine 2 fire fighter 1 was pulled inside the drain while attempting to assist the struggling captain. Moments later, the captain was also pulled inside the drain. The Engine 2 fire fighter was propelled 276 feet through the storm drain, emerging where the drain emptied into the creek east of the development. The captain became entangled approximately 95 feet inside the drain and drowned. The Engine 2 fire fighter 1 was hospitalized following the incident.

Photo taken on June 10, 2015 during similar flood conditions at the site of drowning incident. Both fire and police departments had responded numerous times to this flood prone location.
(Photo courtesy of Police Department.)

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Contributing Factors

- *Housing development built in flood-prone area.*
- *Storm drain entrance not guarded, grated, or marked.*
- *Insufficient hazard identification and risk assessment analysis for flood prone areas.*
- *Operational level for technical rescue operations not established as defined in NFPA 1670.*
- *Lack of SOPs and training on water rescue operations.*
- *Incident safety officer not designated at technical rescue incident.*
- *Inoperable radios caused the captain to walk to command post.*
- *Floodwater obstructed view of the catch basin and storm drain.*

Catch basin and unguarded entrance to underground storm drain where 46-year-old fire captain drowned. *(NIOSH Photo.)*

Key Recommendations

- *Fire departments should ensure that fire fighters who engage in water rescue operations are properly trained and equipped for the assigned task as outlined by NFPA 1670 Standard on Operations and Training for Technical Search and Rescue Incidents.*
- *Fire departments and authorities having jurisdiction (AHJ) should conduct a hazard identification and risk assessment analysis of their response areas and incident scenes to determine what resources are needed to conduct technical search and rescue operations in accordance with NFPA 1670.*
- *Fire departments and fire fighters should be trained to understand the concept and hazards associated with differential pressure, especially those trained for water search and rescue operations.*
- *Fire departments should ensure that fire fighters are equipped with and use the appropriate personal protective clothing and equipment when engaged in water rescue operations.*

Additionally, authorities having jurisdiction (federal, state, regional, and local) should:

- *Consider enacting and enforcing requirements for identifying, marking and guarding underground storm drains.*

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Introduction

On May 23, 2015, a 46-year-old male career fire captain drowned after he stepped into a flooded storm drain and was pulled through the unguarded 36-inch diameter opening into the underground drain. On May 26, 2015, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On May 28, 2015, the fire department contacted NIOSH and requested that NIOSH conduct an independent investigation of this incident. On June 14-18, 2015, a safety engineer and an occupational health and safety specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to Oklahoma to investigate this incident. The NIOSH investigators met with representatives of the fire department, the International Association of Fire Fighters (IAFF) union local, the police department, the city's director of public infrastructure, the city's director of public works, and the county's chief medical examiner. The NIOSH investigators reviewed the fire department's standard operating procedures and training records. The NIOSH investigators also reviewed the dispatch audio and transcribed records for this incident.

Fire Department

At the time of this incident, this career fire department had 47 full-time employees including 42 uniformed fire fighters assigned to one of three shifts. The fire department operates from three stations located throughout the city and serves a population of 18,812 in a response area of approximately 26 miles, including 16 square miles within the city limits and 10 square miles outside the city limits. The department's administrative staff consists of a fire chief, deputy chief, fire marshal, training officer, and executive assistant.

Shift personnel work a rotation of 24 hours on-duty and 48 hours off-duty with a minimum daily staffing of 10 fire fighters per shift. Each shift is supervised by a battalion chief. Minimum staffing is three fire fighters (officer and two fire fighters) per apparatus. Station 1 is attached to city hall, and houses a fire engine, the Region 2 CBRNE (Chemical, Biological, Radiological, Nuclear, and Explosive) Unit, the command vehicle, and a wildland/brush unit. Station 2 is located on the city's west side and houses a fire engine, a medium rescue unit, and a wildland/brush unit. Station 3 houses two fire engines, one aerial apparatus and a 2000-gallon water tanker. The city is home to one of only five Oklahoma Office of Homeland Security Regional Response Units for the state of Oklahoma.

The fire department serves as an emergency medical response agency providing non-transport emergency medical services. The majority of the department's fire fighters are certified as registered emergency medical technicians (EMT), with the remainder being certified as state first responders, national registered intermediates and paramedics. A private ambulance company provides advanced life support services for the city.

The fire department is dispatched through the city's UHF dispatch system, which is responsible for dispatching both fire and police departments. At the time of this investigation, the police department was in the process of switching over to a digital UHF radio system, and the fire department could not communicate directly with the police department over the fire department's radio system. However, all fire department vehicles had the capability to switch from UHF to VHF so that the fire department could communicate with mutual aid responders.

The fire department has received a Class 3 rating from the Insurance Services Organization (ISO). In the ISO rating system, Class 1 represents exemplary fire protection, and Class 10 indicates that the area's fire-suppression program does not meet ISO's minimum criteria.

At the time of this investigation, the fire department had a number of written policies and procedures covering both administrative and operational functions, which are available to all department members within their stations. However, the fire department did not have any policies or procedures covering water rescue operations and had not had water rescue training.

Training and Experience

The only requirement in the state of Oklahoma to be a fire fighter is that the individual must be 18 years old. The fire department where this incident occurred requires a prospective fire fighter to be 21 years old and have valid emergency medical technician (EMT) certification. All recruits must successfully complete a background check and a candidate physical ability test (CPAT). All new recruits receive 160 hours of employee orientation and job awareness training (both classroom and hands-on skills training). This training is based upon the National Fire Protection Association (NFPA) 1001 *Standard for Fire Fighter Professional Qualifications* [NFPA 2013a].

After completing the 160-hour training program, the new recruit is assigned to an engine or ladder truck company. The new recruit works as a probationary fire fighter for the next year, with no restrictions on what the fire fighter can do. The probationary fire fighter is classified based upon their training level and could be classified as a Fire Fighter Rookie, Fire Fighter I, or Fire Fighter II. Live fire training is provided by the Oklahoma State University.

Each fire fighter receives relief driver training during their probationary year. Driver training is based upon NFPA 1002 *Standard for Fire Apparatus Driver/Operator Professional Qualifications* [NFPA 2014a]. Fire fighters can move up to the Fire Fighter II rank after testing to receive Fire Fighter II certification through an accredited program (The International Fire Service Accreditation Congress (IFSAC) or the Pro Board® Fire Service Professional Qualifications System) or after completing 1 year of service at the Fire Fighter 1 rank. This department also offers the rank of Fire Fighter III based upon 3 years of successful service with this fire department. The fire department also offers Fire Officer 1 and Instructor I training to fire fighters with at least 2 years of service.

NIOSH investigators reviewed extensive training records for the deceased fire captain and the incident commander. The Engine 2 captain had documented training in a number of subjects including Fire Fighter I, industrial fire bridge and fire fighting, rope rescue, haz mat awareness and operations, Firefighter II, vehicle extrication, emergency medical technician (EMT), fire service instructor, fire arson detection, fire arson investigation, and others. The Engine 2 captain was assigned to the A Shift and was working an overtime shift on B Shift at the time of the incident.

Equipment and Personnel

The incident involved the local career fire department being dispatched for the report of multiple phone calls from civilians trapped in a residential development by rising floodwaters. Engine 2 (captain [the victim] and two fire fighters) and the battalion chief were initially dispatched. Another engine company (Engine 1) had previously been dispatched to the scene of a vehicle stalled in floodwater. After the passengers were removed from the stalled vehicle, Engine 1 responded and staged west of the development. The deputy fire chief called dispatch to inquire about how the fire department was dealing with the flood. After hearing that two engines and the battalion chief were out on calls, the deputy chief drove to headquarters to pick up his gear and provide assistance.

Fire department units and crews dispatched on May 23, 2015 for the initial incident included:

- Engine 2: captain and two fire fighters
- Acting Battalion Chief: captain in rank
- Engine 1: captain and two fire fighters.

Timeline

Note: This timeline is provided to set out, to the extent possible, the sequence of events as the fire department responded. The times are approximate and were obtained from review of the dispatch audio records, police dispatch records, witness interviews, and other available information. In some cases the times may be rounded to the nearest minute, and not all events have been included. The timeline is not intended, nor should it be used, as a formal record of events.

- **2223 Hours**
  Engine 2 and acting Battalion Chief were dispatched for report of civilians needing assistance due to rising floodwaters threatening their residences.

- **2225 Hours**
  Engine 2 and acting Battalion Chief enroute to residential development in flood-prone are of town.

- **2228 Hours**
  Engine 2 on-scene.

- **2230 Hours**
  Acting Battalion Chief (incident commander) on-scene.

- **2335 Hours (approximate)**
  Engine 2 captain walks to meet incident commander face-to-face.

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- **2338–2342 Hours**
  Engine 2 fire fighter and captain pulled into underground storm drain. Radio reports to Dispatch announcing that a fire fighter went into the drain. Engine 2 fire fighter ejected at storm drain discharge.

- **2343 Hours**
  Incident commander radios Dispatch and asks for information on where storm drain discharge is located. Search in progress

- **0109 Hours**
  Search called off: location of missing Engine 2 captain has been determined.

- **0325 Hours**
  Extrication of Engine 2 captain complete.

Photo 1. Overhead view of the incident site.
(Adapted from Google Earth, image date 3/24/2015.)

Personal Protective Equipment

At the time of the incident, the Engine 2 captain was wearing his station uniform, work boots, and structural fire fighting pants. It is believed that he was carrying his turnout coat and helmet. He was also carrying his department issued personal radio. All fire fighters on scene reported that they initially wore boots, turnout pants, rain coats and helmets. NIOSH investigators inspected the captain's personal protective clothing and equipment as part of the field investigation. No further evaluation was conducted on the protective clothing and equipment by NIOSH.

Incident Scene

This incident occurred in a small residential housing development located west of the center of town. The development contained 12 single-story ranch-style duplex units. Six units were located on each side of the single north-south dead-end street (see Photo 1). Access to the development was via a single entrance located north of the two-lane city street (running east and west) at a T intersection (see Diagram 1). A small stream flowed from south to north and bisected the city street just west of the entrance to the development. This area was prone to flooding following heavy rainstorms. The duplex units on the east side of the development were constructed at a slightly lower elevation than the duplex units on the west side. The first three units on the east side of development were vulnerable to flooding (see Photo 2). The fire and police departments had responded to this location multiple times for floodwaters blocking the east-west city street and for floodwater entering the first residential units on the east side of the street.

According to city records, the development was permitted in the late 1970s. The area was not considered to be a flood plain. City ordinances at the time covered drainage. The catch basin and underground storm drain were included in the development plans. The development contractor installed the drainage system within the housing development while drainage along the city stream was the responsibility of the Oklahoma Department of Transportation. The city's master drainage plan designated the development as a problem area due to storm water runoff and local street flooding. In 2008, the city had attempted to purchase the first two duplex units on the east side of the street for demolition using Federal Emergency Management Agency (FEMA) funds. However the effort was not successful at that time. Photograph 2 and Diagrams 1 through 3 illustrate the incident location.

The vertical opening to the underground storm drain was a 36-inch diameter opening set in the middle of a concrete wall, 42 inches high, with angled walls on both sides (see Photo 3). During this incident, the Engine 2 captain was unable to travel past an 8-inch sewer drain pipe that bisected the underground storm drain approximately 95 feet from the drain entrance and became stuck inside the drain at this location. Following the incident, the city contracted to have a robotic camera travel through the underground drain to document the interior condition with video photography. The entire underground drain was documented (see Photo 4).

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Diagram 1. Overhead view showing location of incident scene west of center of town. The green arrow depicts the general path of natural drainage for storm water runoff following heavy rainfall.
NIOSH diagram adapted from Google Earth.

Photo 2. View of incident scene taken on June 10, 2015 during similar flood conditions. Note how duplex units on east side of street (right portion of photo) sit at a lower elevation than units on the west side of street (left side of photo). During the May 23, 2015, incident, the floodwater was reported to be up to the bottom window ledges on the duplex units on the east side of the street (right side of photo). Area surrounded by orange fence and caution tape is the location where the underground storm drain was opened to extricate the victim.
Photo adapted from scene video provided by police department.

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Photo 3. View of opening to underground storm drain looking north. Carport where fire fighters placed turnout gear is at the upper left corner of photo.
NIOSH Photo.

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Diagram 2. Overhead view showing location of underground storm drain.
NIOSH diagram adapted from Google Earth.

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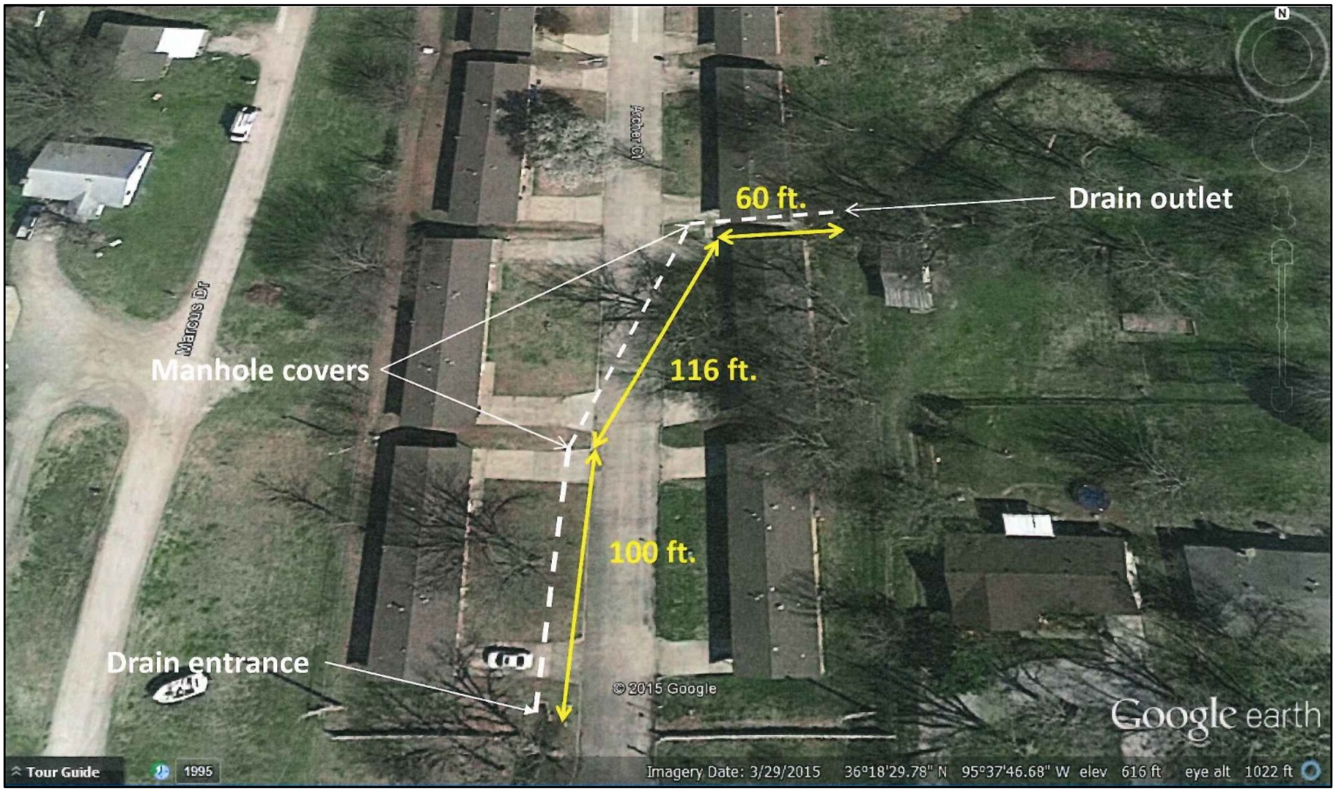

Diagram 3. Overhead view showing approximate dimensions of 276-foot-long underground storm drain.
NIOSH diagram adapted from Google Earth.

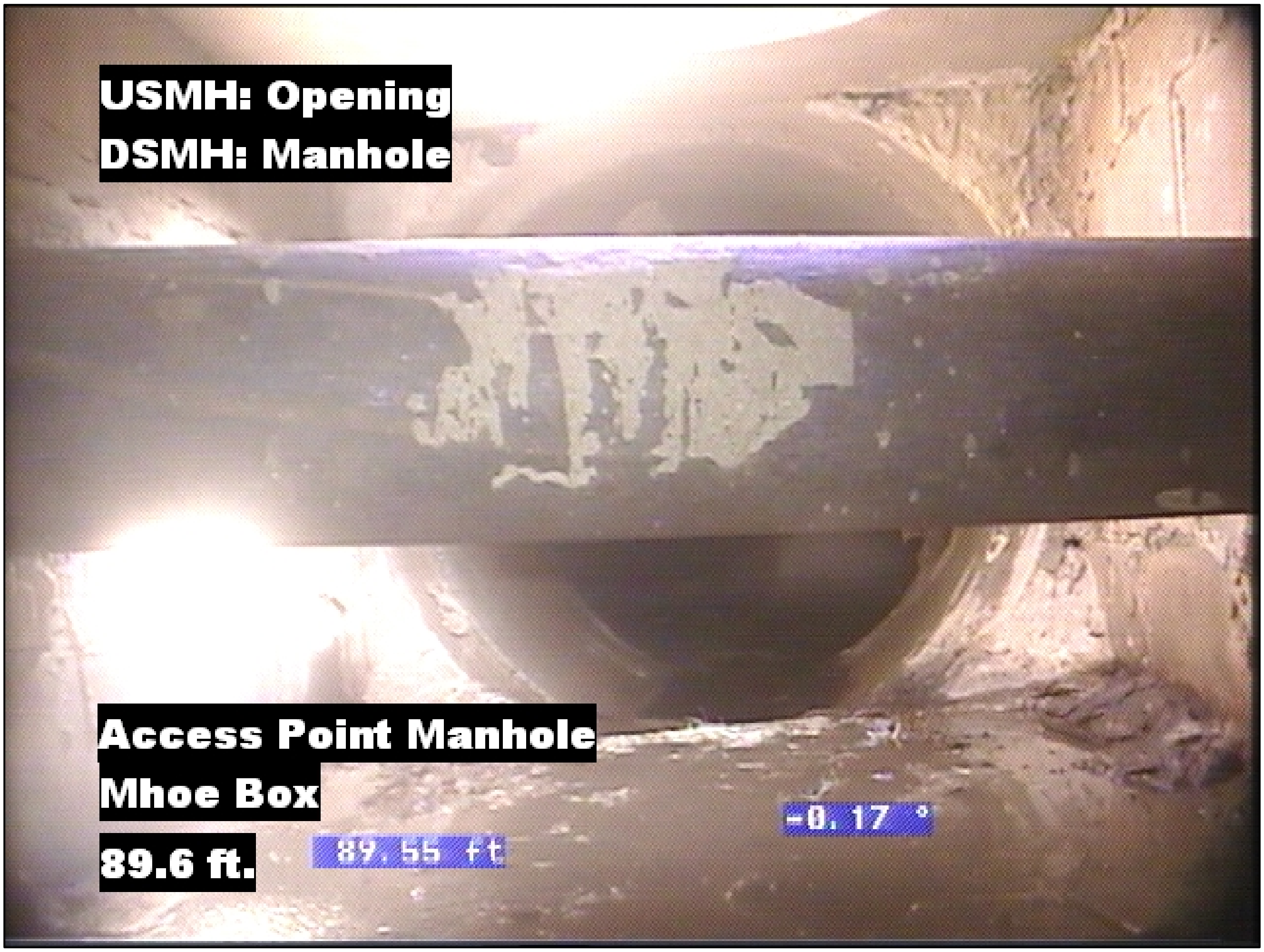

Photo 4. View of inside of underground storm drain taken by robotic camera after incident. View shows location where Engine 2 captain was recovered.
Photo courtesy of the fire department.

Weather Conditions

On May 23, 2015, at 2230 hours (time of dispatch), the weather was overcast with heavy thunderstorms and rain in the local area. The temperature was approximately 64.4 degrees Fahrenheit with 94 percent humidity. Periods of rain and thunderstorms had occurred over the previous 24 hours [Weather Underground, 2015]. Records indicated that the local area had received 8 to 11 inches of rain during the period May 1 through May 23, 2015, with over 3 inches of rain falling on May 23, 2015. The weather was considered to be a contributing factor to this line-of-duty death.

Investigation

On May 23, 2015, at approximately 2220 hours, the local city dispatch center received phone calls reporting localized flooding with floodwaters threatening a number of residential duplex units located in a small housing development west of the center of town. Rain and thunderstorms had passed through the local area over the previous 24 hours. Precipitation amounts ranging from 1.5 inches to over 3 inches of rain were recorded [Weather Underground, 2015]. Engine 1 had previously been dispatched for the report of a vehicle stalled in floodwater.

At 2223 hours, Engine 2 and the acting shift battalion chief were dispatched to the development to investigate the report of floodwaters trapping occupants within their residences. It was raining heavily at the time. Engine 2 approached from the west and encountered flooded streets and roads in a number of locations as they approached the development (see Photo 2). Engine 2 staged in the street east of the entrance into the development (see Diagram 4). The acting battalion chief staged his vehicle in the street just in front of Engine 2. He established Incident Command and stayed at his vehicle.

The duplex units on the east side of the development were at a slightly lower elevation than the units on the west side. The Engine 2 crew found the street leading into the development flooded with water over top of the curb on both sides of the street. As much as 3 feet of floodwater was running through the yards in front of the first three duplex units east of the street. The Engine 2 captain instructed his crew to walk in a single file behind him as they proceeded to each residence. The Engine 2 crew began knocking on doors on the east side of the development to determine the status of the occupants in each duplex. When the Engine 1 crew cleared the motor vehicle incident, the battalion chief immediately radioed for Engine 1 to come to the development for assistance. Engine 1 approached from the west and staged in an empty lot behind the duplex units on the west side of the street (see Diagram 4).

Engine 1 was assigned to assist the Engine 2 crew in checking the residences on the east side of the street. The residents of the first two units on the east side of the street were instructed to shelter in place since the floodwater had not yet entered these residences. The residences on the west side of the street were not affected by the floodwater.

The Engine 2 crew found an adult and six young children in the third duplex unit on the east side of the street. The Engine 2 crew carried the children across the flooded street to higher ground on the west side of the street where they were picked up by a family member who was called to the scene for assistance. The Engine 1 and Engine 2 captains met and discussed how many occupants needed to be moved out of their residences (see Diagram 5).

During this time, the deputy fire chief called Dispatch to get an update on the flood situation. When the deputy chief learned that the fire department had been dispatched for the civilian rescue he drove to headquarters to monitor the rescue operation. The incident commander called the deputy chief and requested that he obtain transportation to move the displaced residents from the flooded development. The deputy chief contacted the Red Cross and made arrangements for transportation to take the displaced residents to temporary shelter. Throughout the incident, fire fighters experienced problems

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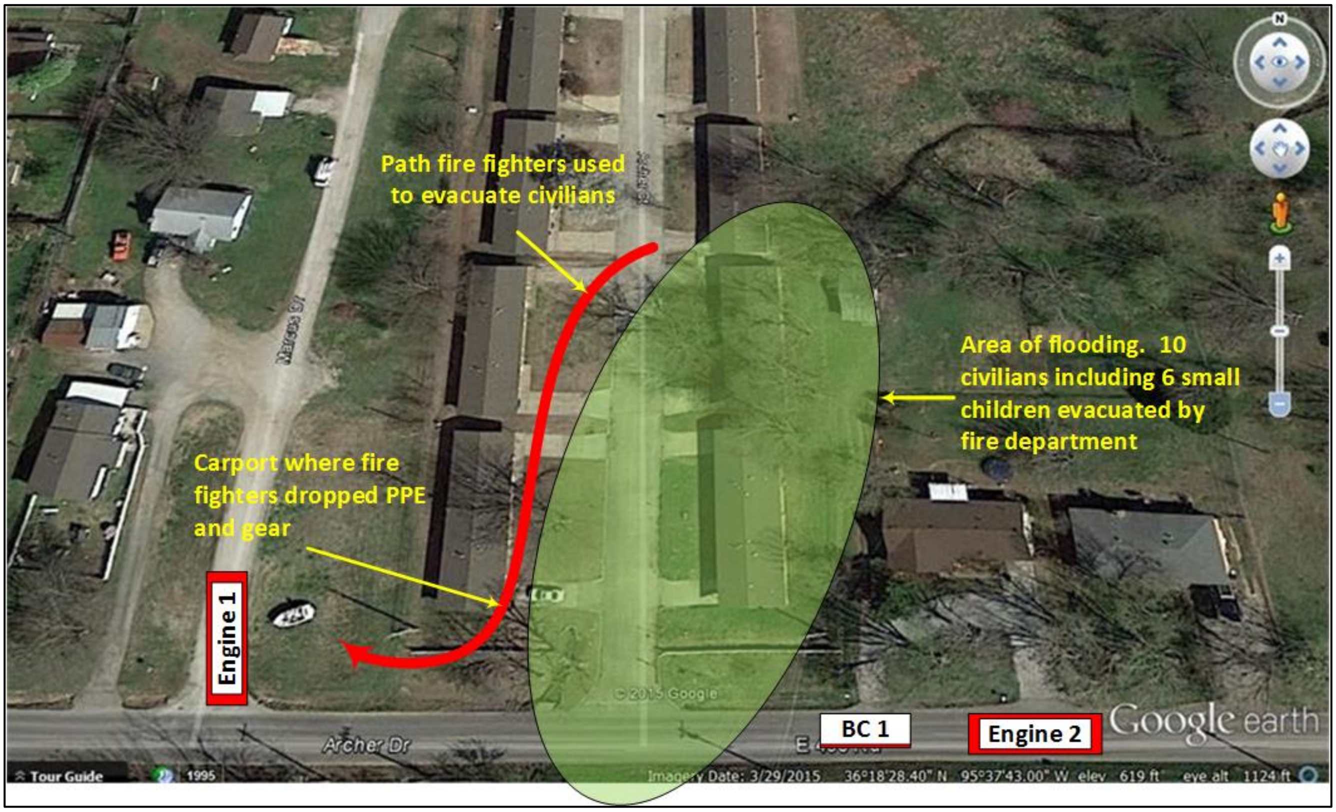

Diagram 4. Overhead view showing approximate area of most extensive flooding and travel path used by fire fighters to evacuate civilian residents. Floodwater was reported to be 3 to 4 feet deep in front of the duplex units in the area highlighted in green.
(NIOSH diagram adapted from Google Earth.)

with radios transmitting and receiving due to their portable radios becoming wet from the rain and working in the wet conditions.

After the children had been removed from the flooded duplex unit on the east side of the street, the Engine 1 and Engine 2 crews met in a yard on the west side of the street as they waited for the transportation to arrive for the remaining occupants who were sheltering in place. Throughout the incident, fire fighters reported experiencing intermittent radio transmission problems. The Engine 2 captain experienced issues with his radio and at different times borrowed both Fire Fighter 1 and Fire Fighter 2's radios. It was reported to NIOSH investigators that the radios appeared to work properly when dry but after the radios got wet there were problems with hearing transmissions and not being able to confirm whether transmissions were being received by the incident commander or other fire fighters. These problems were likely caused by the rain and working in wet conditions as none of the radios were reported to have been submerged up to this point. All three radios used by the Engine 2 crew experienced problems during this incident. As the crews waited, they heard a garbled transmission that could not be understood. After hearing the garbled transmission, the Engine 2 captain told the fire fighters he was going to meet with the incident commander face-to-face. He proceeded to walk through the yards on the west side of the street to stay out of the floodwater since this was the highest area in the development. *Note: All the fire fighters were wet and their turnout gear was saturated from the rain and working in the floodwaters. A number of fire fighters had dropped their coats and helmets in a dry area under the carport at the first duplex on the west side of the street (see Photo 3). The Engine 2 captain walked to this carport to retrieve his helmet and coat before proceeding to meet with the incident commander.*

After retrieving his coat and helmet from the carport at the first duplex on the west side of the street, the Engine 2 captain proceeded to go speak with the incident commander face-to-face. The floodwater was still over the top of the street curb and over the top of the storm drain entrance at this time. Fire fighters reported to NIOSH investigators that at this time, the water was still. Some described the floodwater as smooth as glass and mirror-like and did not appear to have any movement.

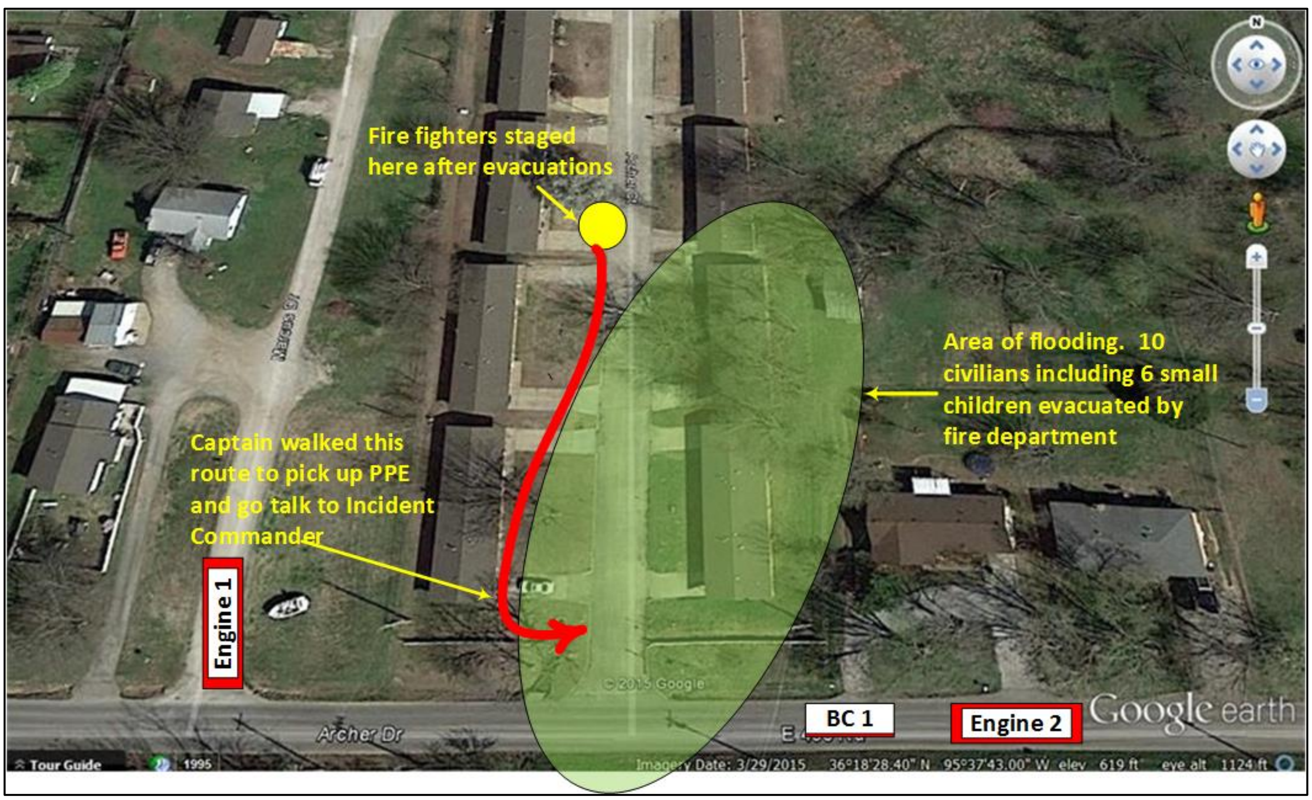

Diagram 5. Overhead view showing approximate area of most extensive flooding and travel path taken by Engine 2 captain to meet with the acting battalion chief (incident commander). The Engine 2 captain retrieved his turnout coat and helmet from the carport at the first duplex on the west side of the street, then walked through the floodwater to meet with the incident commander.
(NIOSH diagram adapted from Google Earth.)

The floodwater completely covered the vertical concrete wall above the storm drain opening. As he walked to meet the incident commander, the Engine 2 captain stepped into the flooded catch basin between the city street and the entrance to the underground storm drain (see Photo 2, Photo 3 and Diagram 5).

The Engine 1 crew and the Engine 2 fire fighters were still huddled together when they heard the Engine 2 captain yell for help. They immediately ran to where the Engine 2 captain was struggling to grasp onto the top of the concrete wall at the storm drain entrance. The incident commander realized the Engine 2 captain was in trouble and also ran to offer assistance. The Engine 1 fire fighter 2 got to the storm drain first and grabbed hold of the Engine 2 captain's right arm. The incident commander arrived and also reached into the water in an attempt to get a grasp on the struggling Engine 2 captain. The Engine 2 fire fighter 1 (Engine 2 driver) arrived and lost his footing and slid into the catch basin behind the Engine 2 captain. The Engine 2 fire fighter 1 was immediately pulled under the water by the force of the hydraulics created at the entrance to the storm drain. The Engine 2 fire fighter 1 kicked off the bottom when his feet hit the bottom of the catch basin and forced his way to the surface, took a quick breathe and then was pulled feet first into the storm drain. The Engine 1 captain reached the storm drain and quickly submerged his arms, head and upper body under the water while two other fire fighters (Engine 1 fire fighter 2 and Engine 2 fire fighter 2) held his legs as the Engine 1 captain attempted to reach the submerged Engine 2 fire fighter 1 but he could not reach the Engine 2 fire fighter in time. Movements later, the Engine 2 captain was pulled into the storm drain and disappeared. The Engine 1 fire fighter 2 began feeding his rescue rope into the storm drain in the hope that the fire fighters in the drain could grab onto it. The Engine 1 fire fighter 1 sprinted north to the end of the development thinking that the underground drain ran parallel to the street. The Engine 1 captain and fire fighters followed to look for the discharge end of the storm drain. They could not locate the drain discharge at the end of the street and asked civilians standing outside one of the residences if they knew where the discharge was located.

The Engine 1 captain initially thought that the Engine 2 captain must have gone into the flooded storm drain in an attempt to assist a civilian so he radioed Dispatch and reported that two fire fighters and a civilian had been pulled into the storm drain and disappeared at 2338 hours.

The Engine 2 fire fighter 1 was pulled feet first into the storm drain and was quickly propelled through the drain by the force of the moving water. He momentarily became stuck on an obstruction, then was propelled the rest of the way through the drain. He traveled a total distance of approximately 276 feet under water while struggling to hold his breath. He was discharged from the drain into the creek and was able to grab hold of a wire fence near the drain discharge. He was initially disoriented and had trouble catching his breath but was able to hang on the fence and keep his head above the water. He began to yell for the Engine 2 captain. The incident commander heard him yelling and directed him to walk south toward the command post at the chief's vehicle in the street (see Diagram 2 and Diagram 5).

The Fire Chief and Deputy Chief responded to the scene and helped organize the search operation. The floodwaters slowly began to recede over the next few hours. The rest of the fire fighters searched up and down the creek bank looking for the Engine 2 captain. They found his turnout coat near the storm drain discharge. Mutual aid fire departments were called for search and rescue support. His helmet was found some time later approximately ½ to ¾ miles downstream.

The city water department was called to begin opening manholes to inspect the inside of the still-flooded storm drain. A manhole cover approximately 100 feet from the storm drain entrance was opened and the Engine 2 captain was found inside the drain a few feet south of the manhole, entangled on an 8-inch sewer drain pipe set perpendicular to the storm drain. The search operation was called off at 0109 hours on May 24. Heavy equipment was brought in to cut through the top of the concrete storm drain to gain access to the Engine 2 captain's body. The captain was recovered at approximately 0325 hours.

Contributing Factors

Occupational injuries and fatalities are often the result of one or more contributing factors or key events in a larger sequence of events that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatality:

- Housing development built in flood-prone area.
- Storm drain entrance not guarded, grated, or marked.
- Insufficient hazard identification and risk assessment analysis for flood prone areas.
- Operational level for technical rescue operations not established as defined in NFPA 1670.
- Lack of SOPs and training on water rescue operations.
- Incident safety officer not designated at technical rescue incident.
- Inoperable radios caused the captain to walk to command post.
- Floodwater obstructed view of the catch basin and storm drain.

Cause of Death

According to the medical examiner, cause of death was drowning and the manner was accidental.

Hazards of Differential Pressures

The hazards associated with water differential pressure or "Delta P" are generally well known in the commercial diving industry but may not be generally well known or understood in the fire service community. Differential pressure is created when water flows from an area of higher pressure to an area of lower pressure. Differential pressure can be caused by water flowing downhill or by water flowing through a pipe, an opening in a wall, a dam, a levee, or similar objects. Standing water does not produce differential pressure but the potential is there. Once water starts to flow, the force generated by differential pressure can be quite large [HSE 2010].

Differential pressure is explained by the YouTube video https://www.youtube.com/watch?v=AEtbFm_CjE0&feature=youtu.be. This video illustrates the hazards of differential pressure and provides a number of case studies from commercial diving incidents.

The force generated by water flowing between two bodies of water at different elevations or levels is dependent upon the difference in height between the two bodies of water and the size of the opening in the barrier between the two bodies. When the water levels are significantly different, the forces generated can be quite significant. What is often not recognized is the very significant suction forces that can be generated by even small differences in water levels combined with relatively large openings [HSE 2010]. Water flowing through a drain pipe can create substantial differential pressure at the drain inlet as seen during this incident. Differential pressure can be calculated by multiplying the area of the opening by the difference in water depth by the factor 0.432, which represents the pressure in pounds per square inch (psi) exerted by 1 foot of water depth. Assuming that the floodwater was 4 feet deep at the entrance to the 36 inch diameter storm drain, the floodwater flowing through the storm drain to the stream east of the housing development created a differential pressure (sucking force) at the drain entrance that likely exceeded 800 to 1600 psi. Fire fighters engaged in water rescue operations need to be aware of this hazard.

Relevant NFPA Standards

National Fire Protection Association (NFPA) 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, is an organizational training document that determines the organizational capability of a response organization [NFPA 2014b]. NFPA 1670 was developed to define levels of preparation and operational capability that should be achieved by any authority having jurisdiction (AHJ) who has the responsibility for conducting technical rescue operations. It does not apply to individuals.

NFPA 1006 *Standard for Technical Rescuer Professional Qualifications* was designed to establish the minimum job performance requirements necessary for fire service and other emergency response personnel who perform technical rescue operations [NFPA 2013b].

Recommendations

Recommendation #1: Fire departments should ensure that fire fighters who engage in water rescue operations are properly trained and equipped for the assigned task as outlined by NFPA 1670 Standard on Operations and Training for Technical Search and Rescue Incidents.

Discussion: Virtually every jurisdiction in North America has the potential for water rescue and recovery operations. These situations can occur in swimming pools, ponds, lakes, rivers, streams, drainage canals and other bodies of water [Dodson 2007, IFSTA 2008]. Water, the very ingredient that fire fighters regularly use to extinguish fires has caused numerous fire fighter injuries and deaths [Dodson 2007, NIOSH 2002, NIOSH 2010, NIOSH 2011].

National Fire Protection Association (NFPA) 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents* was developed to define specific levels of preparation and operational capability that should be achieved by any authority having jurisdiction (AHJ) who has the responsibility for conducting technical rescue operations. The purpose of this standard is to assist the

AHJ in accessing technical search and rescue hazards within the response area, to identify the level of operational capability, and to establish operational criteria [NFPA 2014b].

NFPA 1670, Chapter 4.1.1, states, "The authority having jurisdiction (AHJ) shall establish levels of operational capability needed to conduct operations at technical search and rescue incidents, based on hazard identification, risk assessment, training level of personnel, and availability of internal and external resources." Chapter 4.1.2 states "At a minimum, all technical search and rescue organizations shall meet the awareness level for each type of search and rescue incident for which the AHJ has identified a potential hazard. Chapter 4.1.4 of NFPA 1670 identifies the following operational levels for technical search and rescue and as noted, requires that standard operating procedures be established. Quoting NFPA 1670, Chapter 4.1.4:

> "The AHJ shall establish written standard operating procedures (SOPs) consistent with one of the following operational levels for each of the disciplines defined in this document.
>
> (1) ****Awareness Level***. This level represents the minimum capability of organizations that provide response to technical search and rescue incidents.
>
> (2) ****Operations Level***. This level represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply limited techniques specified in this standard to support and participate in technical search and rescue incidents.
>
> (3) ***Technician Level***. This level represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply advanced techniques specified in this standard necessary to coordinate, perform, and supervise technical search and rescue incidents." [NFPA 2014b].

Chapter 4.1.5 states that it is not the intent of this document to have an organization deem itself capable of an advanced skill level in any of the disciplines defined herein simply by training or adhering to the requirements set forth. Maintaining an operations- or technician-level capability in any discipline shall require a combination of study, training, skill, and frequency of operations in that discipline [NFPA 2014b].

Chapter 4.1.6 states that the AHJ shall establish operational procedures consistent with the identified level of operational capability to ensure that technical search and rescue operations are performed in a manner that minimizes threats to rescuers and others [NFPA 2014b].

Chapter 4.1.8 states that operational procedures shall not exceed the identified level of capability established in 4.1.4. Annex A of NFPA 1670 contains additional information to clarify this point. According to Annex A4.1.4(1), the "awareness level" can involve search, rescue, and recovery operations. Members of a team at this level are generally not considered rescuers. Annex A4.1.4(2) states the "operations level" can involve search, rescue, and recovery operations, but usually operations are carried out under the supervision of technician-level personnel [NFPA 2014b].

Chapter 4.1.10 contains information that fire departments and authorities having jurisdiction can use to develop training programs for technical search and rescue operations. This chapter requires that the training be commensurate with the operational capability of the organization. Chapter 4.1.10.4 states, "The AHJ shall evaluate its training program to determine whether the current training has prepared the organization to function at the established operational level under abnormal weather conditions, extremely hazardous operational conditions, and other difficult situations" [NFPA 2014b].

NFPA 1670 covers technical search and rescue operations involving rope rescue (Chapter 5), structural collapse search and rescue (Chapter 6), confined space search and rescue (Chapter 7), vehicle search and rescue (Chapter 8), water search and rescue (Chapter 9), wilderness search and rescue (Chapter 10), trench and excavation search and rescue (Chapter 11), machinery search and rescue (Chapter 12), cave search and rescue (Chapter 13), mine and tunnel search and rescue (Chapter 14), helicopter search and rescue (Chapter 15), tower rescue (Chapter 16), and animal technical rescue (Chapter 17) [NFPA 2014b].

NFPA 1670 Chapter 9 focuses on water search and rescue and includes six separate water-related disciplines at both the operations level and technician level for dive, ice, surf, surface, swift water, and flood [NFPA 2014b]. Chapter 9 includes detailed requirements for the standard operating procedures to be developed and implemented and the type of personal protective equipment and clothing to be worn during all levels of water search and rescue [NFPA 2014b].

At the time this incident occurred, the fire department did not have any policies or procedures covering water rescue operations and had not had swift water rescue training.

Recommendation #2*: *Fire departments and authorities having jurisdiction (AHJ) should conduct a hazard identification and risk assessment analysis of their response areas and incident scenes to determine what resources are needed to conduct technical search and rescue operations in accordance with NFPA 1670.

Discussion: Technical rescue incidents are "low frequency/high risk" events. The primary purpose of risk assessment is to focus on incidents that might not occur very often (low frequency) but that could have severe consequences associated with them (high risk). The reason for the focus on low frequency/high risk incidents is that since they do not occur on a frequent basis, responders might not be as prepared to deal with them, and the outcomes can be harmful or detrimental to fire fighters.

According to NFPA 1670 *Standard on Operations and Training for Technical Search and Rescue Incidents*, Chapter 4.2.1, states, "The AHJ shall conduct a hazard identification and risk assessment of the response area and shall determine the feasibility of conducting technical search and rescue operations." Chapter 4.2.2 states, "The hazard identification and risk assessment shall include an evaluation of the environmental, physical, social, and cultural factors influencing the scope, frequency and magnitude of a potential technical search and rescue incident and the impact they might have on the ability of the AHJ to respond to and to operate while minimizing threats to rescuers at those incidents" [NFPA 2014b].

The hazard identification and risk assessment determines "what" can occur, "when" (how often) it is likely to occur, and "how bad" the effects could be. In other words, the hazard identification and risk assessment is necessary in order for fire departments and AHJs to determine what the hazard is, how often it is likely to occur, the location it is likely to occur, and what actions are necessary to mitigate the threats.

Fire departments and authorities having jurisdiction at the local, state and federal level can help ensure the safety of emergency responders who must respond in areas that include flood prone areas by conducting hazard identification and risk assessment surveys within their response areas. These surveys should include both existing water hazards (lakes, rivers, streams, reservoirs, and standing bodies of water) and anticipated flood-prone areas based upon historical data. The survey should also include flood maps and identify other site-specific hazards. These survey plans should also identify the specific personal protective clothing and equipment necessary to respond to the different hazards identified by the survey.

Once the hazard identification and risk assessment is developed, fire departments and AHJs can use this information to ensure that all fire fighters and emergency responders are trained and properly equipped to address all potentially dangerous areas of concern during a water rescue, following the requirements outlined in NFPA 1670.

In this incident, the city had a master drainage plan, and the residential development had previously been designated as an area of concern due to a history of localized flooding. The fire and police departments had previously responded to the location on a number of calls involving flooding and trapped residents. In 2008, the city had attempted to purchase the two duplex units most prone to flooding but the attempt was unsuccessful. While the fire department had responded to the development for previous flood events, the fire department and city had not conducted a detailed hazard identification and risk assessment. As noted, the fire department did not have standard operating procedures in place at the time of the incident that covered water rescue operations. This resulted in the fire department being improperly equipped for water search and rescue technical operations. Any time a rescue operation involves physically entering the medium (e.g., in the water or on ice) the rescue becomes a "go" situation, requiring knowledge, skills, and abilities at the "technician level" of operation.

In this instance, a site survey or pre-plan that identified the location of the storm drain could have aided the fire department in avoiding the flooded catch basin and also by identifying the drain's discharge location. Whenever possible, this information should be input into computer-aided dispatch systems so that the information is readily available to first responders and the incident commander. Such information is useful when developing the incident action plan. Shortly after this incident, the city installed a fence around the catch basin where this incident occurred (see Photo 5).

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Photo 5. Note guard rail installed by city around entrance to storm drain inlet.
(Photo courtesy of the fire department.)

Recommendation #3: Fire departments and authorities having jurisdiction should ensure that they identify the operational level for technical search and rescue they are capable of providing.

Discussion: As previously noted, fire departments and authorities having jurisdiction are required by NFPA 1670 to identify the operational level for technical search and rescue that they are capable of providing, based upon hazard identification, risk assessment, training level of personnel, and availability of internal and external resources. Fire fighters should be trained to the appropriate operational level based upon the requirements of NFPA 1006 *Standard for Technical Rescuer Professional Qualifications* [NFPA 2013b]. NFPA 1006, Chapter 11, covers surface water rescue when water is moving at less than 1 knot. NFPA 1006, Chapter 12, covers swiftwater rescue when water is moving at a rate greater than 1 knot as defined by NFPA 1006, Chapter 3.3.207. Fire fighters encountered both situations during this incident. Water flowed down the street and through the yards on the east side of the street to enter the stream behind the houses on the east side of the street. The floodwater in the area around the submerged catch basin and storm drain entrance was reported by several fire fighters to have a smooth and mirrored appearance that did not give any indication of the location of the storm drain entrance.

As noted previously, the ***Awareness Level*** represents the minimum capability of organizations that provide response to technical search and rescue incidents. ***Operations Level*** represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply limited techniques specified in this standard to support and participate in technical search and rescue incidents. The ***Technician Level*** represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply advanced techniques specified in this standard necessary to coordinate, perform, and supervise technical search and rescue incidents" [NFPA 2014b]. NFPA 1670, Chapter 4.1.3, states, "In jurisdictions where identified hazards might require a search and rescue capability at a level higher than awareness, a plan to address this situation shall be written." Chapter 4.1.3.2 further states, "Where an advanced level of search and rescue capability is required in a given area, organizations shall have a system in place to utilize the most appropriate resource(s) available, through the use of local experts, agreements with specialized resources, and mutual aid."

During this incident, the fire department responded for a civilian rescue operation from a residential housing development. The housing development was located in a flood prone area and the local fire and police departments had responded to the immediate area for flood-related issues in the past. The single street within the development was flooded with water over top of the concrete curbs on both sides of the street. The floodwater hid the location of the catch basin and underground storm drain. NFPA 1670 requires that rescuers expected to enter water for search and rescue operations operate at the technician level and be trained to the requirements of NFPA 1006 *Standard for Technical Rescuer Professional Qualifications*.

Recommendation #4: Fire departments and fire fighters should be trained to understand the concept and hazards associated with differential pressure, especially those trained for water search and rescue operations.

Discussion: Virtually every jurisdiction in North America has the potential for water rescue and recovery operations. The hazards associated with water differential pressure or "Delta P" are generally well known in the commercial diving industry but may not be generally well known or understood in the fire service community. Differential pressure is created when water flows from an area of higher pressure to an area of lower pressure. Differential pressure can be caused by water flowing downhill or by water flowing through a pipe or an opening in a wall, a dam, a levee, or similar objects. Standing water does not produce differential pressure but the potential is there. Once water starts to flow, the force generated by differential pressure can be quite large [HSE 2009, HSE 2010]. Many commercial diving accidents have been caused by differential pressure. Arms or legs can be severed by the force of differential pressure pulling a victim against an opening such as a pipe or valve opening [Barsky and Neuman 2003].

Differential pressure is explained by the YouTube video https://www.youtube.com/watch?v=AEtbFm_CjE0&feature=youtu.be . This video illustrates the hazards of differential pressure and provides a number of case studies from commercial diving incidents.

The force generated by water flowing between two bodies of water at different elevations or levels is dependent upon the difference in height between the two bodies of water and the size of the opening in the barrier between the two bodies. When the water levels are significantly different, the forces generated can be quite significant. What is often not recognized is the very significant suction forces (differential pressure) that can be generated by even small differences in water levels combined with relatively large openings [HSE 2009, HSE 2010]. Water flowing through a drain pipe can create substantial differential pressure at the drain inlet as seen during this incident. Differential pressure can be calculated by multiplying the area of the opening by the difference in water depth by the factor 0.432, which represents the pressure in pounds per square inch (psi) exerted by 1 foot of water depth.

Assuming that the floodwater in this incident was 4 feet deep at the entrance to the 36 inch diameter storm drain, the floodwater flowing through the storm drain to the stream east of the housing development created a differential pressure (sucking force) at the drain entrance that likely exceeded 800 to 1600 psi. Fire fighters engaged in water rescue operations need to be aware of this hazard.

Identifying areas that present the potential for creating differential pressure is an important concept for fire fighters engaged in water rescue operations. Fire fighters who engage in water search and rescue operations need to be trained to identify storm drains, culverts, and other underwater openings where differential pressure may be a hazard. Authorities having jurisdiction can help ensure the safety of emergency responders by identifying and marking underground storm drains. This information should be incorporated into pre-plan information and computer-aided dispatch systems.

Recommendation #5: Fire departments should develop, implement, and enforce standard operating procedures for water search and rescue operations.

Discussion: NFPA 1670 *Standard on Operations and Training for Technical Search and Rescue Incidents*, Chapter 4.1.4, requires the authority having jurisdiction (AHJ) to establish standard operating procedures that are consistent with each of the awareness, operational, and technician operational levels. Chapter 4.1.6 states that the AHJ shall establish operational procedures consistent with the identified level of operational capability to ensure that technical search and rescue operations are performed in a manner that minimizes threats to rescuers and others. Chapter 4.1.8 states, "Operational procedures shall not exceed the identified level of capability established in 4.1.4" [NFPA 2014b].

In addition to other fireground operations, standard operating procedures (SOPs) pertaining to water rescues should be developed to standardize practices and techniques used by fire departments. These SOPs should also be tailored to meet the specific needs and conditions within a response jurisdiction. SOPs should outline, at a minimum, the following: mandatory appropriate PPE, equipment or apparel likely to endanger personnel if they fall into the water or attempt a rescue, upstream safety spotters, personnel staged at downstream points, only properly trained personnel staged in the danger area, standard communications, waterway rescue preplans, and safety consideration for rescuers.

Water rescue operations can be very dangerous for the rescuers. In many cases, the victim in need of rescue can be seen, which results in the emotions of the victim(s) and bystanders running high. They may expect the rescuer to immediately jump into the water to rescue the person in trouble. That is the last thing the rescuer should do and it should never be done without a personal flotation device (PFD) being worn by the rescuer [Delmar Thompson Learning 2000].

Some commonly employed water rescue methods used by fire departments to aid victims in water include:

- **Reach. –** If the victim can be reached without the rescuer entering the water, extend a long handled tool to the victim.
- **Throw. –** If the victim cannot be reached directly but is within throwing distance, throw a rope or flotation device with an attached rope to the victim.
- **Row. –** If the victim cannot be reached by extending a long handled tool or by throwing a rope or flotation device, use a suitable boat to retrieve the victim.
- **Go. –** If no other option is readily available, the absolute last method is for the rescuer to enter the water to reach the victim and pull him or her to safety [Delmar Thompson Learning 2000, IFSTA 2008].

Fire departments and fire fighters need to understand that all SOPs - including those for technical search and rescue operations such as the Reach, Throw, Row and Go concept - should only be used up to the limits of their operational level.

Another example of an SOP that could be used to help protect fire fighters during water search and rescue operations is to use hand tools to sound the area underneath the floodwater's surface to identify the location of holes, tripping hazards and submerged objects in areas where they must walk through standing floodwater. Just like sounding the roof, it is very important that fire fighters walking through floodwater check the surface beneath the water to identify the location of holes, tripping hazards, and submerged objects that could threaten the fire fighter's ability to walk safely. The use of a long-handled tool such as a pike pool or roof hook allows the fire fighter to probe the area to their front and on both sides. Other tools such as axes and pry bars can also be used. These tools can also be used as a walking stick to provide additional stability in swift or moving water or if the fire fighter should slip or trip. Long-handled tools can also be extended from a safe location to reach victims in need of rescue. However, this procedure also presents a safety challenge because fire fighters must understand the concept of differential pressure and the hazards associated with stepping into a submerged storm drain, culvert, or underwater opening.

In this incident, the fire department did not have SOPs for water rescue or working in floodwaters at the time the fatality occurred. Fire fighters on-scene at this incident reported the standing floodwater in the area of the storm drain to be "smooth as glass" and "mirror like" in appearance. The standing water hid the entrance to the underground storm drain so that the responding fire fighters were not aware of its location. The Engine 2 captain stepped into the flooded catch basin and was pulled into the underground storm drain by the differential pressure at the storm drain entrance. The Engine 2 fire fighter was also pulled into the storm drain while attempting to assist the Engine 2 captain. Five other fire fighters were endangered during the efforts to assist the Engine 2 captain and fire fighter.

Recommendation #6: Fire departments should ensure that fire fighters are equipped with and use the appropriate personal protective clothing and equipment when engaged in water rescue operations.

Discussion: All fire departments who are subject to water rescue should ensure that all rescuers are trained in water rescue and that they don the proper personal protective clothing and equipment consistent with the operational level at which they are expected to operate. Standard fire fighter turnout clothing is not acceptable for water rescue operations [IFSTA 2008]. Fire fighters who are required to work in cold water or on ice should also wear thermal protective suits [IFSTA 2008].

NFPA 1670, Chapter 4.4.2 and Chapter 9.3.5, cover the minimum level of personal protective equipment and clothing necessary during water rescue operations. NFPA 1670, Chapter 9.3.5, lists a personal floatation device (PFD), thermal protection, a helmet appropriate for water rescue operations, a cutting device, a whistle, and contamination protection (where necessary) as the minimum personal protective equipment for personnel operating in the hazard zone. All personal protective equipment should be used in accordance with the manufacturer's recommendations and limitations for use.

In this incident, all fire fighters reported wearing structural fire fighting pants. Some fire fighters did wear protective rain coats instead of their turnout coats. The Engine 2 captain initially wore his full set of structural turnout pants and coat, but at some point the captain and other fire fighters removed their coats and helmets after it stopped raining. Turnout clothing, when saturated with water can add a considerable amount of weight (approximately 60 pounds) to the amount of weight already carried by fire fighters, making it very difficult to swim. The heavy turnout clothing may have impeded the captain's efforts to escape from the flooded catch basin before he was pulled into the storm drain.

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Recommendation #7: Fire departments should ensure that an incident safety officer is designated at all technical search and rescue operations and that the safety officer is properly trained in the technical rescue discipline utilized at the incident.

Discussion: NFFPA 1670, Chapter 4.5.2, states that "at technical search and rescue training exercises and in actual operations, the incident commander shall assign a safety officer with the specific knowledge and responsibility for the identification, evaluation, and where possible, correction of hazardous conditions and unsafe practices. [NFPA 2014b]. The assigned safety officer should meet the requirements specified in NFPA 1521 *Standard for Fire Department Safety Officer* [NFPA 2015]. Safety officers assigned to special operations incidents need to have the expertise in the specific technical rescue field to effectively evaluate hazards and provide direction with respect to the safety of all personnel. A qualified fireground safety officer might not possess the necessary expertise in water rescue and, therefore, might not recognize or understand capabilities of the team members, limitations and hazards to rescue workers, the need for specialized equipment appropriate for water rescue operations problems with equipment, or performance issues of personnel (i.e. under-trained for the mission at hand). NFPA 1521 *Standard for Fire Department Safety Officer*, notes, in cases where the designated incident safety officer does not possess the technician-level training, appointing a technician-level trained assistant or technical specialist with the necessary training will help satisfy the safety needs of the technician-level members. A fire department safety officer properly trained in the technical rescue field being performed can also help prevent a fire fighter from attempting a skill beyond their level of training. The incident safety officer should be integrated into the incident command structure [NFPA 2015].

In this incident, the event escalated from a non-routine emergency dispatch to assist civilians trapped in their homes due to rising floodwaters to an urgent search for a missing fire fighter. A fire department safety officer qualified in water search and rescue operations could have assisted the incident commander in evaluating the potential hazards presented during the operation.

Recommendation #8: Fire departments should consider upgrading portable radios to ensure enhanced protection from moisture and heat exposure.

Discussion: Several recent incidents involving fire fighter fatalities demonstrate that despite technological advances in two-way radio communications, important information is not always adequately communicated on the fireground or emergency incident scene. Inadequate fireground or emergency scene communication has a definite negative impact on the safety of emergency personnel and may contribute to injuries or deaths of fire fighters, rescue workers, and civilians [USFA 1999]. Fire fighters operate in extreme environments that are markedly different from those of any other radio users. Fire fighters operate lying on the floor, in zero visibility, in high heat, in high moisture, and while wearing bulky safety equipment, protective clothing, and particularly, gloves. The size and construction type of the building have a direct impact on the ability of the radio wave to penetrate the structure [USFA 2008, USFA 2016].

Ideally, radios used for fire fighting should be highly water-resistant, shock-resistant and designed for easy operation by fire fighters wearing heavy gloves in a hostile environment. Despite fire service limitations with the current types of portable radios available, it is highly recommended that ***every*** fire fighter entering a fire situation be equipped with a portable radio [USFA 1999].

During this incident, the fire department reported to NIOSH investigators that several radios became inoperable due to moisture from working in the floodwater. The fire department also reported experiencing similar problems with moisture causing radios to malfunction during previous responses. During this incident, the three radios used by the Engine 2 captain and both Engine 2 fire fighters became inoperable. The Engine 2 captain experienced issues with his radio and at different times had to borrow both fire fighter 1 and fire fighter 2's radios to communicate with others including the incident commander. Some transmissions were recorded and others were garbled to the point of being unintelligible. It was reported to NIOSH investigators that the radios appeared to work properly when dry but after the radios got wet there were problems with hearing transmissions and not being able to confirm whether transmissions were being received by the incident commander or other fire fighters on-scene. These problems were likely caused by the rain and working in damp, wet conditions as none of the radios were reported to have been submerged up to this point where the Engine 2 captain stepped into the flooded catch basin. It was reported to NIOSH investigators that after the civilian rescues were completed, fire fighters gathered to await further assignments. As the crews waited, they heard a garbled radio transmission that could not be understood. After hearing the garbled transmission, the Engine 2 captain told the fire fighters he was going to meet with the incident commander face-to-face. His travel path led him to step into the flooded storm drain catch basin.

Radio system manufacturers have designed and developed radio systems that meet the needs of the majority of the users in the marketplace. The fire service is a small part of the public safety communications market and an even smaller part of the overall communications market [USFA 2008, USFA 2016]. The National Fire Protection Association NFPA is currently working on a new standard – *NFPA 1802: Standard on Two-Way Portable Voice Communication Devices for use by Emergency Services Personnel in the Hazard Zone* - for fire service portable radios and electronic devices. This new standard is intended to help ensure that fire service radios are resistant to water, heat, shock, and vibration exposures commonly experienced on the fire ground. Fire service input is encouraged to help develop this new standard.

Recommendation #9: Authorities having jurisdiction (federal, state, regional, and local) should consider enacting and enforcing requirements for identifying, marking, and guarding underground storm drains

Discussion: Requirements for identifying, marking, and guarding underground and enclosed storm drains vary from state to state. Drainage systems constructed in many densely populated areas to collect stormwater feature wide drain openings at the bottom of open culverts or ditches that feed into long pipes. During floods, the drainage channels create powerful currents that can sweep people in, along with those trying to rescue them [The Associated Press 2015].

Guarding storm drain entrance and exit points could potentially prevent incidents like this from happening. However, grating and other types of guarding can become clogged with debris carried by floodwaters, which reduces the effectiveness of the storm drain and could increase floodwater damage, block roadways, lead to localized erosion, and produce other unintended results. Another unintended problem that can result from guarding storm drains is the localized vandalism and theft of metal storm drain covers which are sold for scrap. It can cost hundreds of dollars per cover to replace missing storm drain covers, while the hazard of an uncovered or unguarded storm drain remains [FETI 2015].

Some local officials fear that covering the drains with grates might worsen flood damage to homes and property if they get clogged with debris [The Associated Press 2015]. Marking and guarding storm drains can be expensive and many localities are forced to evaluate corrective measures on a case-by-case basis. National public works and engineering groups say the grates can be kept clear with routine maintenance and innovative designs. Fences, guardrails, and warning signs are other safety options [The Associated Press 2015].

According to the National Association of Flood and Stormwater Management Agencies, new drainage systems are generally safer but cities need to upgrade many older structures that "can get a lot of water depth at the inlet of a pipe" and create dangerous situations [The Associated Press 2015].

In this incident, the opening to the storm drain was unmarked and unguarded. The catch basin and surrounding streets were covered with standing floodwater. Fire fighters on-scene described the standing floodwater as mirror-like with little or no movement in the area of the storm drain entrance. The standing floodwater obscured the storm drain opening from the emergency responders working in the area. The incident also occurred at night with overcast skies and rain, which further reduced visibility in the area. Shortly after this incident, the city installed a fence around the catch basin where this incident occurred (see Photo 5).

References

Barsky S, Neuman T [2003]. Investigating recreational and commercial diving accidents. Ojai, CA: Ojai Printing, Hammerhead Press.

Delmar Thompson Learning [2000]. Firefighter’s handbook: essentials of firefighting and emergency response. Stamford CT: Delmar Thompson Learning.

Dodson D [2007]. Fire department incident safety officer. 2nd ed. Clifton Park, NY: Thompson Delmar Learning.

FETI [2015]. Storm drain hazards—don’t get stuck! Baton Rouge, LA: Louisiana State University, Fire Emergency Training Institute, Safety Bulletin 20, http://www.lsu.edu/feti/municipal/safety_brief/SB-20.pdf . Date accessed: Oct. 4, 2016.

HSE [2009]. Differential pressure hazards in diving. Liverpool, England: Health and Safety Executive, RR761, http://www.hse.gov.uk/research/rrhtm/rr761.htm. Date accessed: Oct 4, 2016.

HSE [2010]. Differential pressure hazards in diving. Liverpool, England: Health and Safety Executive, Diving information sheet no. 13, http://www.hse.gov.uk/pubns/dvis13.pdf. Date accessed: Oct 4, 2016.

IFSTA [2008]. Essentials of fire fighting. 5th ed. Stillwater, OK: Oklahoma State University. International Fire Service Training Association.

NFPA [2013a]. NFPA 1001 Standard for fire fighter professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2013b]. NFPA 1006 Standard for technical rescuer professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2014a]. NFPA 1002 Standard for fire apparatus driver/operator professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2014b]. NFPA 1670 Standard on operations and training for technical search and rescue incidents. Quincy, MA: National Fire Protection Association.

NFPA [2015]. NFPA 1521 Standard for fire department safety officer professional qualifications. Quincy, MA: National Fire Protection Association.

NIOSH [2002]. A fire fighter drowns after attempting to rescue a civilian stranded in flood water—Colorado. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2001-02, http://www.cdc.gov/niosh/fire/reports/face200102.html.

NIOSH [2010]. Two career fire fighters seriously injured during swiftwater rescue training at a low-head dam—Ohio. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2007-11, http://www.cdc.gov/niosh/fire/reports/face200711.html.

NIOSH [2011]. Volunteer fire fighter drowns after being thrown from his swiftwater rescue boat—West Virginia. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2010-09, http://www.cdc.gov/niosh/fire/reports/face201009.html.

The Associated Press [2015]. Firefighter's death highlights municipal storm drain dangers. Firerescue1, May 28, http://www.firerescue1.com/Firefighter-Training/articles/2179500-Firefighters-death-highlights-municipal-storm-drain-dangers/. Date accessed: Oct 4, 2016.

USFA [1999]. Special report: improving firefighter communications. Emmitsburg, MD: Department of Homeland Security; United States Fire Administration, USFA-TR-099.

USFA [2008]. Voice radio communications guide for the fire service. Emmitsburg, MD: Department of Homeland Security, United States Fire Administration.

USFA [2016]. Voice radio communications guide for the fire service. Emmitsburg, MD: Department of Homeland Security, Unites States Fire Administration.

Weatherunderground [2015]. Weather history for KGCM, May 23. Atlanta, GA: The Weather Channel Interactive, Inc., http://www.wunderground.com/history/airport/KGCM/2015/5/23/DailyHistory.html?req_city=Claremore&req_state=OK&req_statename=&reqdb.zip=74017&reqdb.magic=1&reqdb.wmo=99999&MR=1. Date accessed: Oct 4, 2016.

Investigator Information

This incident was investigated by Timothy Merinar, Safety Engineer and Steve Miles, Safety and Occupational Health Specialist, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, West Virginia. An expert technical review was provided by Chief Steven Orusa, Fishers, Indiana, Fire Department. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

Additional Information

IAFC Rules of Engagement for Firefighter Survival

The international Association of Fire Chiefs (IAFC) is committed to reducing fire fighter fatalities and injuries. As part of that effort, the nearly 1,000 member IAFC Safety, Health and Survival Section has developed the DRAFT "*Rules of Engagement for Structural Firefighting*" to provide guidance to individual fire fighters and incident commanders, regarding risk and safety issues when operating on the fireground. The intent is to provide a set of "modern procedures" for structural firefighting to be made available by the IAFC to fire departments as a guide for developing their own standard operating procedures (http://www.iafcsafety.org/downloads/Rules_of_Engagement).

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