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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *June 10, 2002*

Volunteer Fire Fighter Drowns During Multi-Agency Dive-Rescue Exercise - Illinois

SUMMARY

On October 13, 2001, a 28-year-old male volunteer fire fighter (the victim) drowned during a multi-agency dive-rescue exercise. The dive exercise included a dive coordinator, an assistant dive coordinator, and seven divers. The site of the incident was a man-made lake that is owned and maintained by a private club. The dive coordinator and assistant dive coordinator had sunk a boat and two mannequins in the lake to simulate a boating incident. Four of the divers, including the victim, were on their second dive when the victim failed to surface. Dispatch was notified of the missing diver, and additional search-and-rescue crews responded to the scene with two rescue boats. The victim was found in the area of his last known location, approximately 1 hour and 15 minutes after he was last seen by his dive partner. He was transported to a local hospital where he was pronounced dead.

NIOSH investigators concluded that, to minimize the risk of similar occurrences, fire departments should

- ***develop, implement, and enforce standard operating procedures (SOPs) regarding diver training***
- ***ensure that each diver maintains continuous visual, verbal, or physical contact with his or her dive partner***
- ***ensure that a backup diver and a ninety-percent-ready diver are in position to render assistance***
- ***ensure that the dive coordinator stays informed about the rates of air consumption by divers***
- ***provide divers with refresher training on the hazards of lung overexpansion injuries and prevention measures***

INTRODUCTION

On October 13, 2001, a 28-year-old male volunteer fire fighter (the victim) drowned during a multi-agency dive-rescue exercise.

Aerial View of Incident Scene

The **Fire Fighter Fatality Investigation and Prevention Program** is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Website at

www.cdc.gov/niosh/firehome.html
or call toll free **1-800-35-NIOSH**

Volunteer Fire Fighter Drowns During Multi-Agency Dive-Rescue Exercise - Illinois

The National Institute for Occupational Safety and Health (NIOSH) was notified of this incident on October 16, 2001, by the fire department involved in this incident and the United States Fire Administration. On November 13, 2001, two safety and occupational health specialists from the NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated this incident. Meetings were conducted with the Chief of the department, the county coroner, the attorney representing various fire departments involved in this incident, and the administrative coordinator for the fire department. Officers and fire fighters directly involved in the exercise and the search-and-recovery operation were interviewed. The NIOSH investigators reviewed the county sheriff's police report, the emergency medical service (EMS) report, the medical examiner's report, the fire department's dive rescue standard operating guidelines (SOGs), an inventory of the victim's dive equipment, medical records, and his training records. A site visit was conducted and the incident scene was photographed. A review of the County Sheriff's police investigative report, health records, and the victim's autopsy report was performed by a U.S. Navy Diving Medical Officer (expert review) upon request by NIOSH investigators. Though medical findings were inconclusive, the medical examiner and the reviewing medical officer noted the possibility that an air embolism may have contributed to the drowning.

At the request of the victim's fire department, an evaluation of the victim's dive equipment was conducted by the U.S. Department of the Navy's, experimental diving unit. An evaluation of an air sample was taken from the air tank and found to be free of any contaminants. The buoyancy compensator (BC) was tested and found to work as designed. Tests of the regulator system showed that it did not meet manufacturer's specification for cracking pressure (pressure required in the second-stage regulator to initiate air flow), and delivered a large amount of air with minimal effort. It is inconclusive whether the poorly regulated air flow from the regulator contributed to the victim running out of air.

The site of the incident is a man-made lake that is owned and maintained by a private club. The lake has a controlled access gate on the road leading to the beach. The staging area for the dive-rescue exercise was a sandy beach with a paved parking area, a boat ramp, and a restroom facility. Records of the depths and size of the lake were not available at the time of the investigation. The area of the lake where the dives were conducted was approximately 50 feet deep. The width of the lake at the incident site is approximately 250 feet. Based on interviews, the water visibility on the day of the incident was approximately 5 to 10 feet and the temperature was approximately 50° F.

The fire department involved in this incident consists of two stations with a total of 45 uniformed fire fighters. The department serves a population of approximately 8,000 in a geographic area of about 38 square miles. The department requires all new fire fighters to complete the training requirements for NFPA fire fighter level I and II certification and to serve a 1-year probationary period. The fire department requires all new dive team members to be Professional Association Dive Instructor (PADI) open-water certified. The victim was certified NFPA fire fighter level I and II as well as PADI open-water certified. The victim's dive certifications included dry-suit diver, ice diver, surface ice rescue specialist, visual inspection procedures, and basic river rescue. The victim had 4 years of volunteer fire-fighting experience and 1 year of diving experience.

INVESTIGATION

A multi-agency dive-rescue exercise was organized by a dive coordinator and an assistant dive coordinator to familiarize area rescue divers with

search patterns and working together. The exercise included a dive coordinator, an assistant dive coordinator, and seven rescue divers (the victim and Divers #1 to #6) from four fire departments. Before a scheduled briefing, the dive coordinator had sunk a 14-foot john-boat at the dive site. After removing the seats and cushions from the john-boat, the dive coordinator punched numerous holes in the boat and wedged half a cement block at each end of the boat. After sinking the boat, the dive coordinator dropped an adolescent (young adult) mannequin and a child mannequin into the water near the boat to simulate a capsized boat with two victims.

The briefing began at 0730 hours at the dive coordinator's fire station with all present except Diver #1. The dive coordinator briefed everyone on the area and the scenario of the overturned boat and the two potential victims. He then described the search pattern to be used (a V-pattern). *Note: The V-pattern uses a ski rope (having a handle on one end) and a line tender on the surface of the water or from a boat. A diver (lead diver) descends to the bottom while holding on to the handle. Additional divers are then assigned to either the lead diver's left or right side by the line tender on the surface. Each diver descends along the ski rope, meets up with the lead diver, and proceeds to his or her assigned position on either the lead diver's left or right side (Diagram 1).* The coordinator then reviewed the hand signals to be used for communicating while underwater.

The group arrived at about 0830 hours at the dive site, where Diver #1 joined them. The divers were in dry-suits but did not have any underwater communications systems. The dive coordinator used his personal pontoon boat to monitor the divers while practicing search patterns.

The initial dive lasted approximately 40 minutes. After exiting the water, the divers and dive coordinators conducted a debriefing on shore lasting approximately 15 minutes. *Note: After completing the first dive, the victim did not change out his air tank. Diver #2 reported to NIOSH investigators that the victim had between 2000 and 2100 psi of air (a full tank would have 3000 psi of air) left in his air tank after the first dive.* For the second dive, the dive coordinator paired the divers so that each set of divers would have a partner from a different department. The victim was the partner of Diver #1. Diver #2 and Diver #3 were paired together. Diver #6 did not have a partner. Diver #4 (having difficulty staying warm) and Diver #5 (having problems clearing his ears) stayed near shore and did not participate in any additional dives. The victim, Diver #1, Diver #2, Diver #3, and Diver #6 deflated their buoyancy control devices (BCDs) and descended while being towed (at idling speed) away from the shore by the pontoon boat. The dive coordinator and the assistant dive coordinator were in the boat. The boat was heading west from the beach area with the divers in the V-pattern. When the divers were approximately 15 feet from the east shore, Diver #6 surfaced, signaled that he was alright, and swam back to the beach. *Note: Diver #6 was having problems with his pressure gauge giving him a false reading.* The dive coordinator continued driving the boat toward the west shore when the adolescent mannequin and boat were found (Diagram 2). All four divers then surfaced; Diver #1 surfaced with the adolescent mannequin. A surface marker was placed directly above the sunken boat with the pontoon boat (with the dive coordinator and assistant dive coordinator) positioned nearby. The assistant dive coordinator jumped into the water and assisted Diver #1 in getting the mannequin into the boat.

After getting the mannequin into the boat, Diver #1 and the victim descended to continue searching near the sunken boat. The victim and Diver #1 were to do circle patterns on the east and southeast side of the sunken boat. The victim tethered a rope to the sunken boat. The rope was used as a guide for the

victim and Diver #1. The victim held on to the rope bag while Diver #1 held on to his other hand. Diver #2 and Diver #3 descended to do circle patterns on the north side of the sunken boat. The divers continued with the search patterns trying to locate the child mannequin.

Diver #2 surfaced to get a lift bag to attach to the sunken boat to be used as an underwater marker. While Diver #2 was putting air into the lift bag, his regulator began free-flowing (a malfunction of the regulator results in a free flow of air rather than a termination of air), causing the lift bag to overinflate. The boat began to rise off the bottom at an angle. Diver #2 and Diver #3 surfaced and told the dive coordinator that the boat had begun to rise from the lake bottom but was lifting at an angle. Diver #2 corrected the problem with his regulator before the two divers descended to release air from the lift bag. The dive coordinator saw the rush of air that had been released from the lift bag. At approximately 1050 hours, the assistant dive coordinator saw two people surface at the shore and walk toward the vehicles. *Note: It was later determined that this was Diver #5 and Diver #6.* The dive coordinator also saw two sets of bubbles in the area that the victim and Diver #1 were searching. Diver #2 and Diver #3 surfaced (on the north side of the pontoon boat) at this time. After completing three to four sweeps near the sunken boat, the victim signaled to Diver #1 that he was going to surface. Approximately 2 to 3 minutes later, Diver #1 surfaced on the south side of the pontoon boat (Diagram 3). The victim was not seen again until he was located at approximately 1215 hours (Photo 1 and Diagram 2).

While the dive coordinator was talking to Divers #1, #2, and #3, he could see the truck with Divers #5 and #6 leaving the parking area. The dive coordinator then decided to end the exercise and head back to the beach. Diver #2 then asked about the victim's location. The dive coordinator and assistant dive coordinator began looking for bubbles on the water's surface (Photo 1). Not seeing any bubbles, they scanned the shoreline. Diver #1 then informed them that the victim had passed him the rope bag and had indicated that he was coming to the surface. They yelled to the diver on shore (Diver #4) to see if the victim was with him. He replied that he had not seen the victim. The dive coordinator then drove the pontoon boat to shore, dragging Diver #1 and Diver #2 behind the boat. Diver #3 stayed near the buoy of the sunken boat to search for the victim. When they reached the shore they searched the vehicles and the restrooms but did not find the victim. The dive coordinator then radioed Divers #5 and #6 to see if the victim had left with them. They replied that the victim was not with them. The dive coordinator and divers then realized that the victim must still be in the water. The dive coordinator called Central Dispatch to report that they might have a possible drowning. The dive coordinator set up command and assembled a team for the initial search (Photo 2). Diver #1 and Diver #2 changed out their air tanks and then swam back out to the buoy to conduct a search for the victim. They descended and searched near the sunken boat for approximately 15 to 20 minutes. They ascended and could see additional fire departments and dive crews arriving on the scene. They swam to shore where Diver #2 had his air tank refilled.

The dive teams that were dispatched had arrived on the scene with two dive-rescue boats (Dive-Rescue Boat #1 and Dive-Rescue Boat #2). The boats were deployed: Dive-Rescue Boat #2 searched along the shoreline, and Dive-Rescue Boat #1 worked near the dive buoy with divers searching the bottom. The dive coordinator had people searching up and down the road along the shore. He also had the search team in Dive-Rescue Boat #1 drag the sunken boat to the west shore to move it out of the way. Diver #2 replaced one of the search team's divers who was having equipment problems.

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The search team was using the V-pattern with Diver #1 as the tender on the surface. The divers searching along the bottom consisted of a lead diver, Diver #2 and another diver to his left, and two divers to his right. The search team had been searching the bottom for approximately 5 minutes when the diver to the left of Diver #2 tugged on his arm indicating that he had found the victim (at approximately 1215 hours). The two divers broke away from the group and moved toward the victim. The victim was located to the southeast of the sunken boat's original position at a depth of 50 feet. He was lying on his back, his mask and hood were off, his regulator was not in his mouth, and a couple of buckles were undone on his BCD. Diver #2 then attempted to fill the victim's BCD with air from the victim's air tank, but the air tank was empty. The two divers then grabbed underneath the victim's arms and inflated their own BCDs to bring the victim to the surface. The victim's weights (40 pounds) were still in place. When the victim was brought to the surface he had blood coming from his nose and mouth. The victim was transported by Dive-Rescue Boat #1 to the shore where he was loaded into the ambulance. The paramedics removed his dive gear and clothing. He did not have a pulse and was unresponsive to advanced life support interventions. He was then transported to an area hospital where he arrived at 1233 hours. The victim was pronounced dead at 1312 hours.

CAUSE OF DEATH

The death certificate listed the cause of death as drowning.

RECOMMENDATIONS AND DISCUSSION

Recommendation #1: Fire departments should develop, implement, and enforce standard operating procedures (SOPs) regarding diver training. [1]

Discussion: Operational protocol, minimum equipment, personnel requirements, qualifications for team membership, and issues of training, drills, health, and safety should all be addressed in the SOGs. Operational protocol should address the needs of beginning all dives with a full tank of air and remaining in constant contact with a dive buddy. SOGs should be reviewed in-house, at a minimum, on an annual basis to see whether any changes are necessary. Every team member should have a copy of the SOGs, and each member should sign a statement indicating that he has read, understands, and agrees to abide by them. The multi-agency dive-rescue exercise was not considered formal training. It was considered to be a scheduled monthly gathering of multiple-area dive-rescue teams, allowing dive members a chance to become more familiar with working together.

Recommendation #2: Fire departments should ensure that each diver maintains continuous visual, verbal, or physical contact with his or her dive partner. [2, 3]

Discussion: Effective underwater communication refers to the capability to communicate between divers and from a diver to the surface. The divers present at this incident were able to communicate by using recognized dive signals such as a "thumbs-up" to indicate they were okay. Fire departments should follow OSHA safety standard 29 CFR 1910.424(c)(2) by ensuring that a diver be line-tended from the surface or accompanied by another diver in the water who is in continuous visual contact during the diving operations. The victim was a volunteer fire fighter and was not covered by OSHA regulations. However, following OSHA standards would provide additional protection for fire fighters who face unique environments and hazards associated with technical rescue operations. Effective communication and continuous visual contact are two ways in which divers can convey any equipment or medical problems they may be experiencing.

Recommendation #3: Fire departments should ensure that a backup diver and ninety-percent-ready diver are in position to render assistance. [1]

Discussion: *Public Safety Diving* states that "in addition to having the normal duties of divers, a backup diver must be ready to act as a replacement if the primary is unable to perform for any mission, and he must be ready to render assistance if the primary runs into trouble. Because of the complex nature of diving, it's always possible that the backup diver will experience a problem when called. Following a policy of having contingency plans in place, it's best to have a second backup diver available, wearing an exposure suit and with his gear fully checked and functioning. If the backup diver is called on to make the descent, the ninety-percent-ready diver completes the dressing process so that he is fully ready to enter the water. With a ninety-percent-ready diver in place, the redundancy and safety of an operation increase dramatically."

Recommendation #4: Fire departments should ensure that the dive coordinator stays informed about the rates of air consumption by divers. [1]

Discussion: *Public Safety Diving* states that "The dive coordinator needs to stay informed about the rates of air consumption, since excessive consumption may indicate an equipment problem, fatigue, or an inexperienced diver." This information should be gathered by the tender. *Public Safety Diving* states that "the tender should note the diver's time of entry and their starting tank pressure. They should monitor the diver's air bubbles, recording their breathing rate every 5 minutes, and they should continuously assess the diver's status."

Recommendation #5: Fire departments should provide divers with refresher training on the hazards of lung overexpansion injuries and prevention measures. [1]

Discussion: *Public Safety Diving* states that "there are several different types of lung overexpansion injuries, including arterial gas embolism, pneumothorax, mediastinal emphysema, and subcutaneuos emphysema. Each of these are induced when the diver holds his or her breath for any reason during an ascent while on self-contained underwater breathing apparatus (SCUBA) or surface-supplied air. SCUBA divers are trained to breathe continuously and normally underwater, but there are many situations in which a diver may unwittingly, or unconsciously fail to follow this rule. Some of these situations occur while equalizing, dealing with mask-related problems, working hard or concentrating, while managing buoyancy, or when overweighted. If a diver is overweighted, there is an increased risk of making an uncontrolled rapid ascent. Divers who use their dry suits to control buoyancy may experience trouble with controlling their buoyancy, resulting in an uncontrolled ascent. This could result in a carotid sinus reflex and unconsciousness during ascent." In his review, the evaluating U.S. Navy Diving Medical Officer stated that "running out of air and diver inexperience are significant risk factors for air embolism" and that "a possible contributing cause may have been air embolism."

REFERENCES

1. Hendrick W, Zaferes A, Nelson C [2000]. Public safety diving. Saddle Brook, NJ: Fire Engineering Books & Videos.

2. NFPA [1999]. NFPA 1670, standard on operations and training for technical rescue incidents. Quincy, MA: National Fire Protection Association.

3. 29 Code of Federal Regulations 1910 Subpart T, Commercial Diving Operations. 1910.424, SCUBA diving.

INVESTIGATOR INFORMATION

This incident was investigated by Mark McFall and Jay Tarley, Safety and Occupational Health Specialists, Division of Safety Research, NIOSH.

EXPERT REVIEW

Expert review was provided by James L. Caruso, M.D., U.S. Navy Diving Medical Officer.

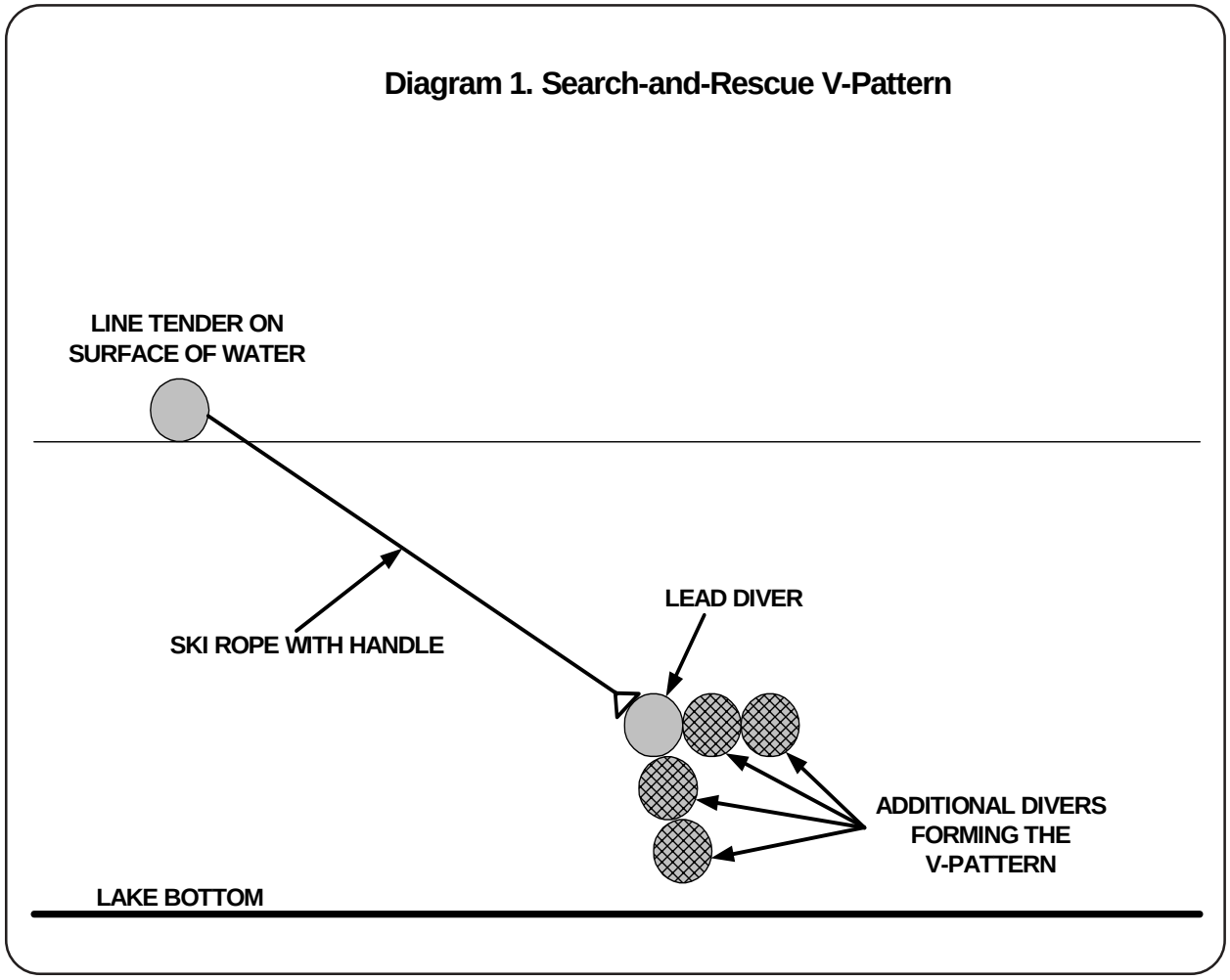

Diagram 1. Search-and-Rescue V-Pattern

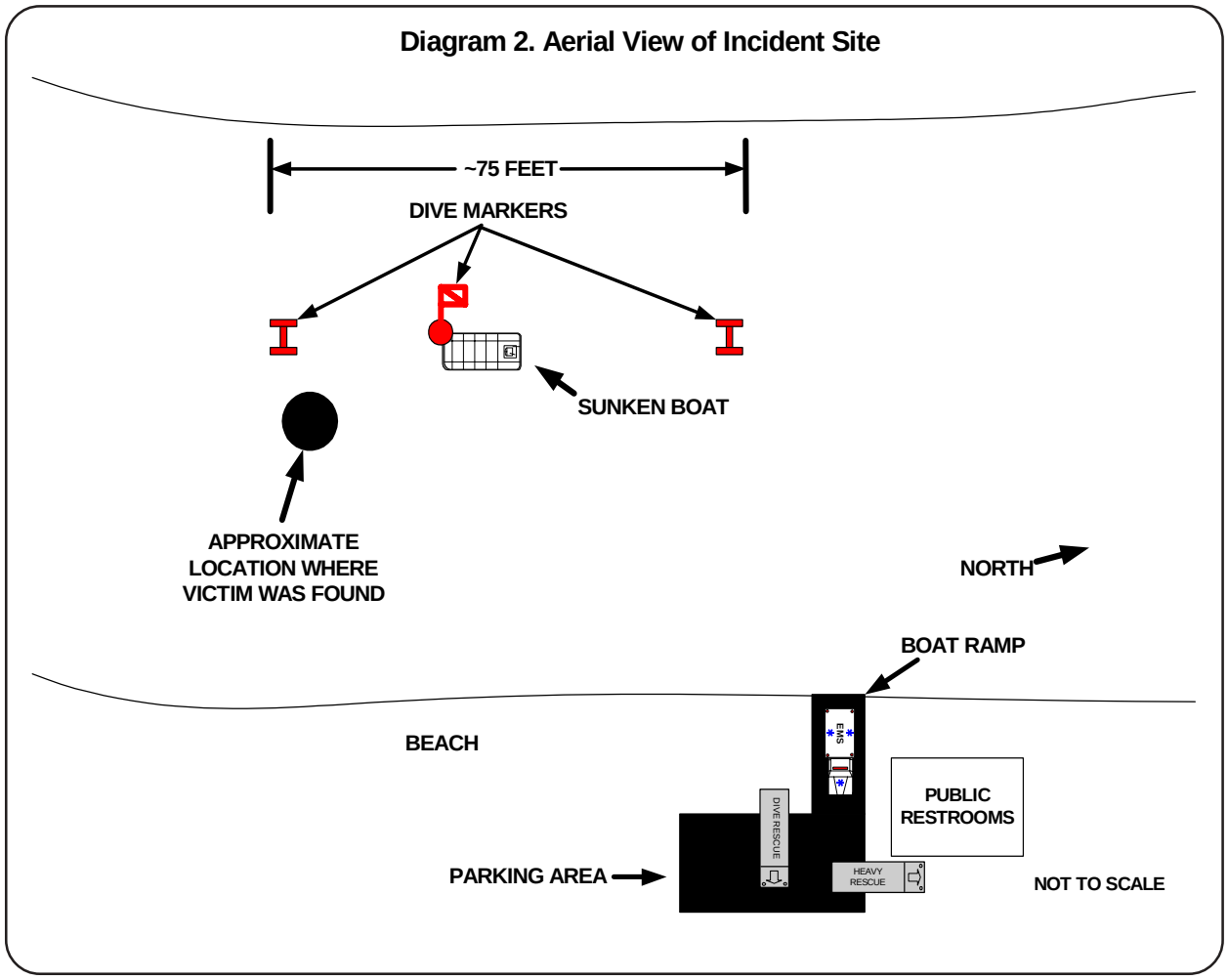

Diagram 2. Aerial View of Incident Site

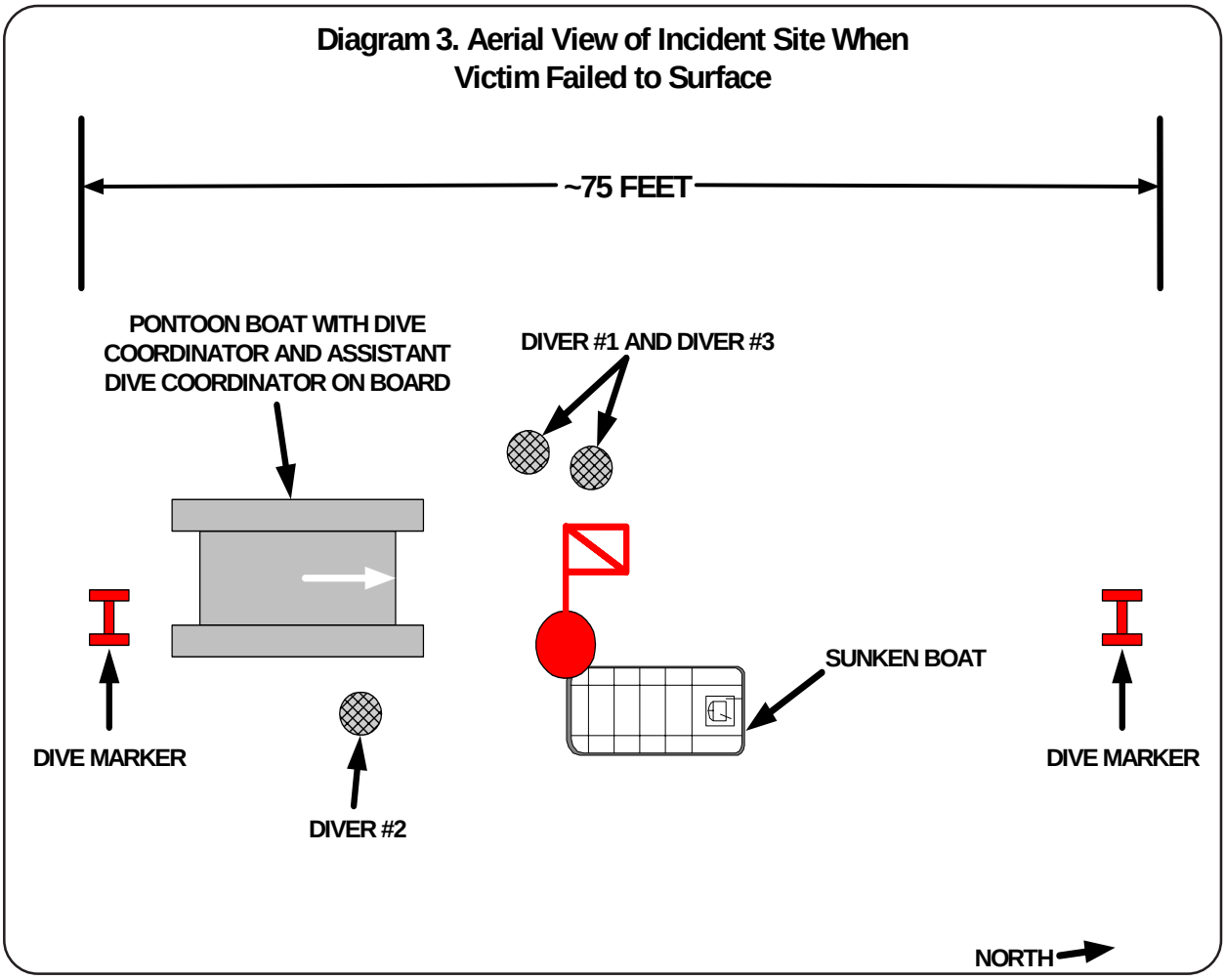

Diagram 3. Aerial View of Incident Site

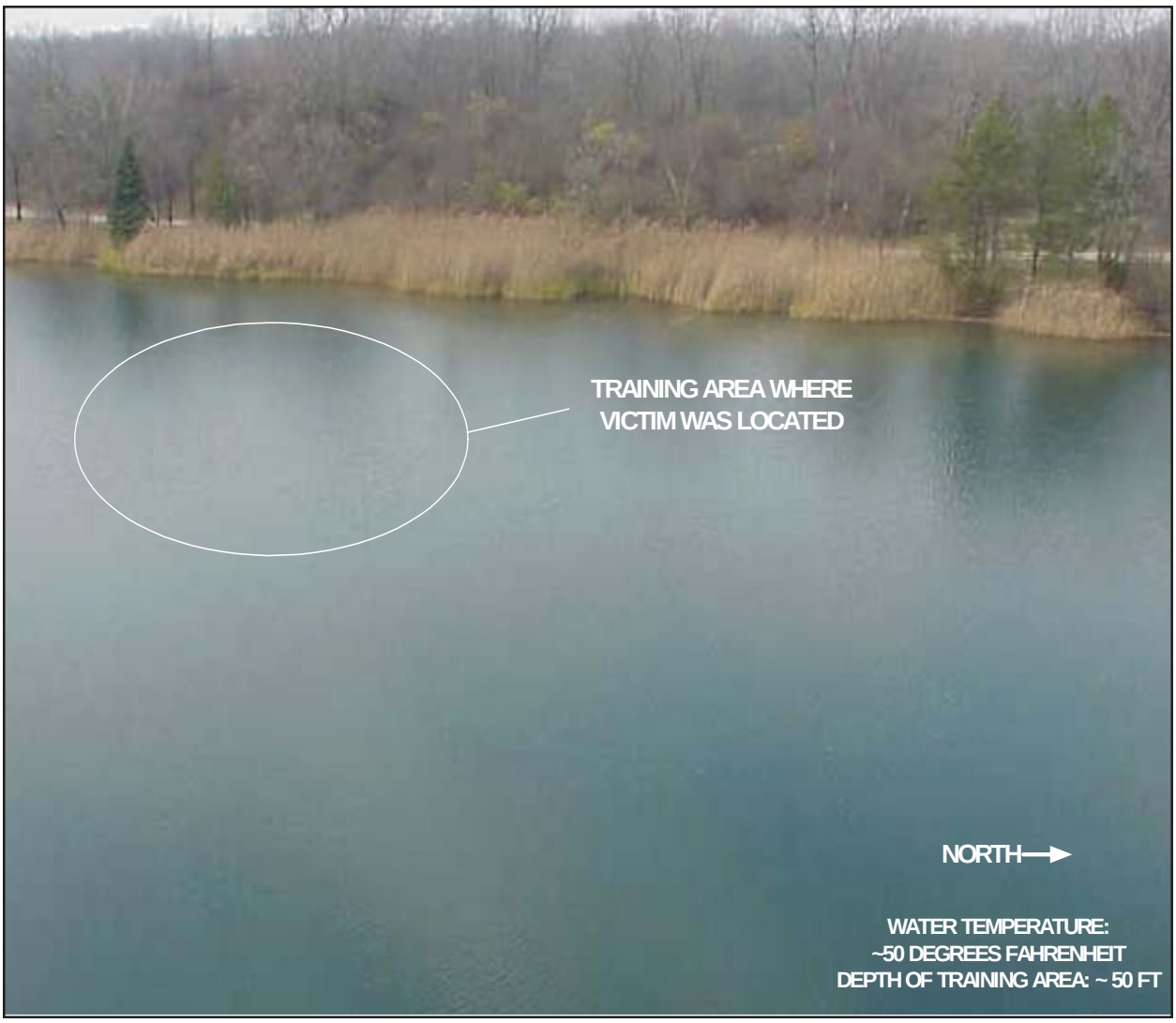

Photo 1. Aerial View of Incident Scene

Photo 2. View of Incident Scene from Beach

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