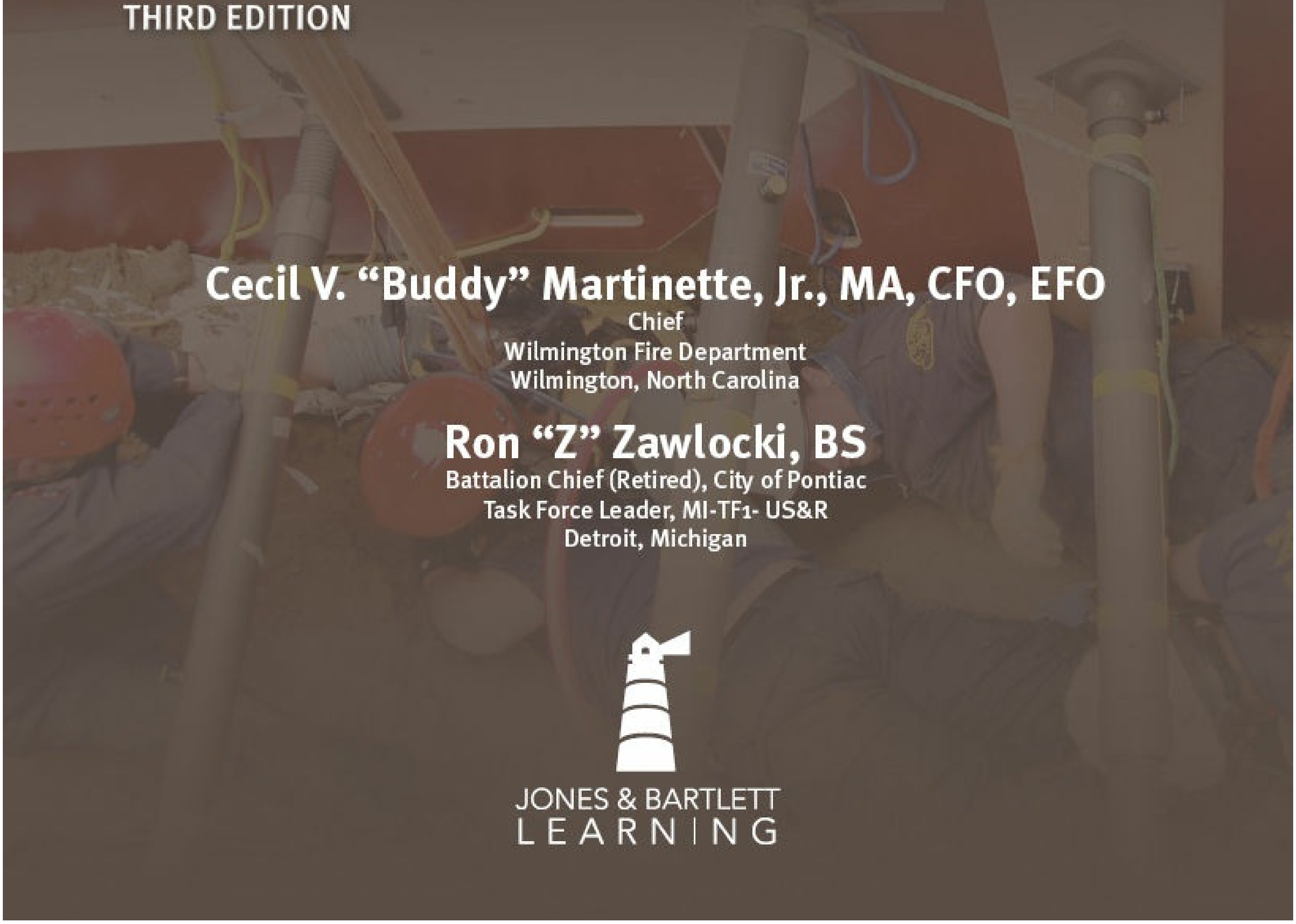
Trench Rescue

3rd Edition - I

Trench Rescue

Principles and Practice to NFPA 1006 and 1670

THIRD EDITION



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■ Instructor's Toolkit

Preparing for class is easy with the resources found in the Instructor's ToolKit. To meet your course delivery needs, the resources in the Instructor's ToolKit (ITK) are available for Trench Rescue Level I, Trench Rescue Level II, or Trench Rescue Levels I & II (combined). The ITK includes:

- **PowerPoint Presentations** provide you with a powerful way to make presentations that are educational and engaging to your students. These slides can be modified and edited to meet your needs.
- **Lesson Plans** provide you with complete, ready-to-use lesson plans that include all of the topics covered in the text. Offered in Word documents, the lesson plans can be modified and customized to fit your course.
- **Test Bank** contains multiple-choice questions, and allows you to create tailor-made classroom tests and quizzes quickly and easily by selecting, editing, organizing, and printing a test along with an answer key, including page references to the text.
- **Image and Table Bank** provide you with a selection of the most important images and tables found in the textbook. You can use them to incorporate more images into the PowerPoint presentations, make handouts, or enlarge a specific image for further discussion.
- **Skill Sheets** offer a detailed checklist to ensure students meet all the required skills.
- **Trench Rescuer in Action Answers** identify the correct answers to the end-of-chapter multiple-choice questions. The accessibility of these answers can facilitate class discussion or activity correction.
- **Practical Site and Equipment Requirements** provide guidelines for practical training and assessment.

Acknowledgments

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Cecil V. "Buddy" Martinette, Jr. is a career fire and rescue professional whose work experiences range from fire fighter to Chief to Assistant County Administrator. He is currently the fire chief in Wilmington, North Carolina. Chief Martinette started his career as a volunteer fire fighter in the Virginia Beach Fire Department, where he spent 25 years, leaving as a Battalion Chief and Chief Fire Marshal. He has also been the Chief of the Lynchburg Fire and EMS Department in Lynchburg, Virginia, and Assistant County Administrator in Hanover County, Virginia.

Mr. Martinette holds a Bachelor of Science Degree in Fire Administration from Hampton University and a Master's Degree in Public Administration from Troy State University. He is also a graduate of the National Fire Academy Executive Fire Officer Program where he received the 2003 Executive Leadership Outstanding Research Award. Chief Martinette has received the designation of "Chief Fire Officer" by the Commission on Chief Fire Officer Designation.

Previously, Buddy was an Instructor III with the Commonwealth of Virginia Department of Fire Programs and served as a part of the Virginia Heavy and Tactical Rescue Team. He also served as a FEMA Incident Support Team Operations Officer and Task Force Leader for Virginia Task Force II, of the Federal Emergency Management Agency's Urban Search and Rescue Program. His Urban Search and Rescue experience includes the Colonial Heights Wal-Mart Collapse; deployments for hurricanes Floyd, Fran, Francis, Charlie, Ivan, Katrina, and Rita; and also the Murrah Federal

Building Bombing and 9–11 Pentagon collapse.

■ Ron “Z” Zawlocki

Ron “Z” Zawlocki’s career in the fire and rescue service spans five decades. He began as a fire fighter with the City of Detroit in 1974 and retired as a Battalion Chief with the City of Pontiac in 2007. Mr. Zawlocki continues to serve as a Task Force Leader with Michigan’s Urban Search and Rescue Task Force (MI-TF1). During his career, he has responded to several thousand fire, emergency medical, and technical rescue incidents. The technical rescue discipline that has been his most frequent response is trench rescue. As a result, he has developed a passion for trench rescue shoring that has led him to new levels of testing, research, and development in that discipline. Including training, exercises, and actual rescue incidents, Mr. Zawlocki has shored more than 750 live trenches and has made a point to learn from every one of them.

Mr. Zawlocki has a Bachelor of Science Degree in Secondary Education from Eastern Michigan University. He has written the student manuals and instructor guides for trench rescue courses that were developed by Michigan State University and funded by the Michigan Occupational Safety and Health Administration. He is currently the lead trench rescue instructor for the MUSAR Training Foundation. Mr. Zawlocki has taught rescue programs across the United States and in Canada, Mexico, and the Persian Gulf. He has had rescue-related articles published in *Fire Engineering, Firehouse, Fire Chief* and *Fire and Rescue* magazines and has been both a classroom and a hands-on instructor at the Fire Department Instructor’s Conference (FDIC). Mr. Zawlocki would like to add the following acknowledgments:

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Christopher Blackwell (FDNY), Fire Chief Mike McGroarty (LaHabra FD), and the LODD death of FF Tracy Williamson (Pontiac FD) that prompted a change in rescue operations in Michigan. I hope this book helps transfer their dedication and passion to the next generation of fire fighters.

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Finally and most importantly, my family: my wife Jeri, daughters Erin and Lauren. Their love, patience, and support have enabled me to continue to pursue my dreams.

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Foreword

As I write this foreword it occurs to me that history is history. That may sound like something Confucius would have offered in a moment of reflection, however history is history unless we value how history got all of us to this point.

Now before I get all philosophical on you folks, you should realize that I am not referring to the history of the world, but rather the history and evolution of trench rescue. You see, I think it is important that we remember how we got here and, perhaps more importantly, who got us here, so as not to lose an appreciation for those efforts.

A good friend of mine was sharing with me the other day a film of the rescue workers who worked in England during the German Blitz on England in 1940. There was a small part of the film that dealt with the rescuers—miners recruited for their shoring skills—who tried to save persons in collapsed buildings and, more specifically, the tunneling techniques they used to shore unstable walls. Much of which I might add took place while bombs were still falling. As I watched these brave souls it occurred to me that many of the techniques we use today came from this modest beginning.

In the modern era, I say from the 1970s until now, there are many people who have built upon our expertise in trench rescue and shoring. Many of these instructors and pioneers have since passed away, but their value to us and the discipline of trench recue is immeasurable. Jim Gargan, with his first book in the 1970s, was the first to produce something the fire service could use to learn and practice trench rescue. Once published, many of us around the country gained an appreciation for both the dangers involved in trench rescue and also the challenges. Although I met Jim only once, a good friend of mine, Chase Sargent, developed and maintained a friendship with Jim over many years.

Chase, who retired as a District Chief and Chief of Special Operations in the Virginia Beach Fire Department, learned everything he could from Jim during the 1980s. Chase took that knowledge, developed classes, and then taught many of us in the Hampton Roads area about trench rescue. The problem for Chase was that in addition to be great a trench rescue guy, he was also an expert in confined space rescue. More on that in a minute.

On the west coast, there was a fellow named Mike McGroarty, who in addition to being an expert in just about every kind of rescue was *the* trench rescue expert. He developed many of the rescue systems classes in California, including trench rescue. Mike liked trench and subsequently, just like me, specialized in this area when it came to teaching and developing new and more modern shoring techniques. Mike retired as the Chief of La Habra Fire Department in 2001 and unfortunately passed away in 2013.

In order to spread the knowledge regarding technical rescue on the east coast, the Virginia Heavy & Tactical Rescue Team was formed in the mid-1980s. While there were many original team members back then, Dean Paderick, Mike Brown, and Chase Sargent were the backbone and driving influences in program development. These programs were rope rescue, confined space, and trench rescue. Dean was the team captain, Mike had an interest in rope rescue, and Chase was our trench and confined space rescue expert. Sometime a few years later I was accepted as a member of this very special group of instructors, even though I had no particular specialty.

Over the next few years, Mike, Chase, and I started to specialize in each of the three technical rescue disciplines. Mike wrote a book on rope rescue, Chase wrote a book on confined space rescue, and I wrote a book on trench rescue. To be perfectly honest about the situation, it wasn't that I knew more about trench rescue than either Mike or Chase, it just turned out that was the last discipline standing when the other two were picked and produced.

When Spec. Rescue International was formed in the early 1990s, Dean, Mike, Chase, and I were the principal partners. It was decided that Dean would run the business, Mike would concentrate on rope rescue, Chase would concentrate on confined space, and I would concentrate on trench rescue. It was a good plan and worked well for a few years. Over time, professional moves and subsequent retirements took a toll on the four of us and now Dean is last man standing in a very successful Spec. Rescue International training organization.

So now that I am in the twilight of my career, and for the most part not in the trenches anymore, I was considering how most folks might have forgotten about Jim Gargan, Chase Sargent, Mike McGroarty, and their contributions to trench rescue as it is presented today in this book. For some reason, that troubles me, and in that regard I want to ensure history and trench rescue is not lost and instead perpetuated by people who have the time, energy, and commitment to stay on top of professional advances in this area.

Some of you might have already noticed that there is a coauthor for this third edition of *Trench Rescue*. His name is Ron Zawlocki. I have known Ron for many years and we have taught many rescue classes together. He is passionate about trench rescue and I consider him to be the foremost person in our country to speak to its future. Ron not only has an interest in modern and more efficient shoring procedures, but also in testing and compliance of the systems we are already using.

I asked Ron to partner on this edition with the understanding that I will fade away when the next edition is published. He will then be responsible for bringing along another coauthor for the purpose of advancing this book and its subject. In that way, history will not be lost and our nation's fire fighters and rescue personnel will always have the most up-to-date trench rescue information available.

Make no mistake about it: I am still out there and still working. It is just time to step aside and move on to other things. To all the students, instructors, and professional acquaintances I have had the privilege to meet, instruct, and teach with, I say "Thank you" for being a part of my journey. It has been a great ride.

Stay Safe, Buddy.

Introduction to Trench Rescue

CHAPTER 1

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the importance of decision making in trench rescue. (p 4)
- Describe how to conduct a risk–benefit analysis NFPA 8.1.1 NFPA 8.1.2. (pp 4–5)
- Identify the most common reasons why rescues go wrong. (pp 5–6)
- Identify and describe common causes of trench collapse emergencies. (pp 7–8)

Skills Objectives

There are no Trench Rescue Level I skills objectives for this chapter.

Trench Rescue Levels I and II

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the importance of rules and regulations in trench rescue NFPA 8.1 NFPA 8.1.1 NFPA 8.2. (pp 11–14)

Skills Objectives

There are no Trench Rescue Levels I and II skills objectives for this chapter.

Additional Resources

- 29 CFR 1926 Subpart P, Excavations
- NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

Your trench rescue team arrives on the scene of a mutual aid request. You pull in about 25 minutes after the first-due fire companies have arrived. You begin assessing conditions and hazards as your crew walks to the end of the trench. Your first look at the trench reveals three construction workers in an unprotected trench attempting to dig out the buried victim. Additionally, two fire fighters from the first-due engine are in the trench placing oxygen on the buried victim. An excavator is positioned at the other end of the trench and is being directed to dig out the collapsed soil. The operator is the brother of the man trapped in the trench. The ladder company has positioned the aerial truck about 10 feet (3 m) from the side wall of the trench and is raising the stick (ladder truck) for use as a high directional. The digging has uncovered the victim's chest, and he is now buried to about his waist. The man is conscious, and the fire fighters are telling you that they will have him out in about 5 minutes.

The construction crew supervisor tells you that this is Class B soil and it has been stable since early this morning. The construction crew suspended work for approximately 2 hours this afternoon during a heavy thunderstorm. When they started work after the storm, the trench collapsed suddenly. The trench is 13 feet (4 m) deep and 5 feet (1.5 m) wide, with a cave-in from one side wall. Conditions are wet and muddy, with a couple of inches of water on the trench floor. As the first rescue technician on the scene, your responsibility will be to decide on a safe and effective rescue plan.

1. What is the risk–benefit analysis for either continuing the current rescue attempt or changing the rescue tactics?
2. Will your team's training, experience, and equipment be adequate to complete this rescue safely?
3. How will you justify your plan (decision) to the victim's brother and co-workers?
4. Based on the resources (level of training and equipment) available to you, which decisions need to be made immediately?

Trench Rescue Level I

Trench Rescue Decision Making

As professionals in the field of emergency services delivery, we often wonder what thoughts were going through someone's head at the time of a tragic mistake or critical error. Frequently, the conversation revolves around questions such as "What in the world caused him or her to do that?" In all fairness, it is always easier to surmise what you might have done, especially after the results of the decision are known. Nonetheless, our objective should be to avoid getting into dangerous or risky situations in the first place.

Risk–Benefit Analysis

Of the many factors we can examine that reduce rescuer deaths and injuries, the one that most often plays a critical role is training—the type of training that deals not with tactics, but with an internal process to decide how much risk to assume while performing our duties. We call this internal evaluation process risk–benefit analysis. Although you might not fully appreciate the principles underlying the weighing of risk versus benefit, you subconsciously do it each day without realizing the impact it has on your actions. When dealing with trench rescues, your struggle will be to focus on bringing risk–benefit analysis to the forefront of your strategic decision-making process.

Imagine that you are standing beside a trench with a rescue tool called a *risk–benefit scale*. This set of scales resembles the scales of justice, weighing risk on one side and benefit on the other side **FIGURE 1-1**. The tool works by considering all factors that deal with risk and comparing them with the factors that determine benefit. We can turn the situation in our favor if the benefit side is much heavier than the risk side. If the risk side seems heavier, there may be no advantage in continuing the operation.

Assess the following issues:

1. *Is this a rescue or a recovery?* Because we can never fully eliminate all of the risk associated with performing trench rescues, it is vitally important to understand the difference between a rescue and a recovery. A rescue involves a victim who can be saved by your intervention and constitutes a true emergency, whereas a recovery involves a dead body and should never be considered an emergency. As an incident commander, it is your first duty to determine a survivability profile for your victim. A low survivability profile should equate to low or no risk for your rescue personnel. You will have committed a terrible disservice to yourself and your team members if you kill or injure them during a recovery operation. Simply stated, it is your job to evaluate each collapse situation and determine the victim survivability profile before beginning rescue operations **FIGURE 1-2**.
2. *What is the risk to the rescuer?* Given all of the considerations under scrutiny, do the rescuers stand a fair chance of succeeding in the rescue without becoming fatalities or suffering injuries themselves? In addition, is the risk to rescuers proportional to the potential benefit of the attempted action? If you are questioning your judgment, then you should reconsider your response to the incident.
3. *What is the benefit to the situation?* If you can reduce the risk to the rescuers and the benefit is a savable victim, you are close to giving the situation the green light. No matter what anyone tells you, there is no benefit to recovering a body or property if that action requires undue risk to your personnel.

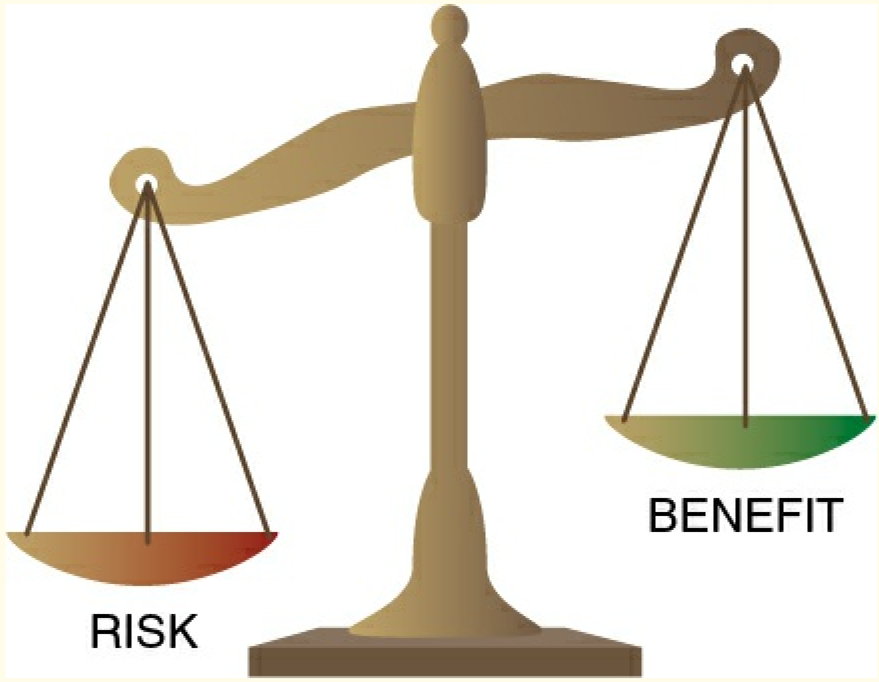

FIGURE 1-1 If risk outweighs benefit, caution is indicated.

FIGURE 1-2 Risk should be minimized when placing rescue personnel in danger to recover a deceased victim.
Courtesy of Larry Collins

4. *What is the difference between* head versus heart decision making? Remember that compassion kills. In every situation, ask yourself, "Am I thinking with my head or with my heart?" Hoping that you can effect a rescue in a hopeless situation is thinking with your heart. As much as you might wish that a victim under 10 feet (3 m) of soil in a trench

collapse is alive, without a protective mechanism in place, the victim will likely be dead. Nothing you do in that situation will reverse the misfortune of that victim. Your responsibility is to ensure that additional problems are not created by the actions of the response crew. The bottom line is that most completely buried victims do not survive a trench collapse.

If you take nothing else away from this text but the ability to act responsibly regarding your own and others' safety during each trench incident response, then we have accomplished our ultimate goal. As the rescuer, your mandate is clear: Do not become the second victim.

Safety Tip

If there is ever any doubt concerning risk, and the victim is known to be deceased, do not treat the incident as a rescue. Treat it as a recovery. That includes mitigating all hazards and completing the shoring system prior to entry.

The FAILURE Acronym

During the vast majority of emergency events that "go bad" or have major components go wrong, it is possible to identify specific aspects of the operation that contributed to the occurrence. Sometimes these failures result in death or injury to rescue personnel or add complications in the management of the rescue scene. When dealing with technical rescue operations, the FAILURE acronym is used to describe this process.

F: Failure to understand, or underestimating, the environment. In many instances, personnel simply lack the education (awareness) to make the proper decision based on the environment in which they are required to work. Ask any fire fighter whether he or she would wear a shower curtain as personal protective equipment (PPE) at a structural fire, and he or she will give you many reasons why this would not be a good idea. Ask any emergency medical services provider why he or she would not handle a bloody, virus-contaminated patient without proper PPE, and he or she will provide an informed answer.

So why do personnel routinely jump into open trenches without taking the necessary steps to ensure that action is safe? Do they fail to recognize the hazards of the environment they are in? Is it lack of education, hero syndrome, or heart versus head decision making? A thousand excuses can be offered—all of them unacceptable. Environmental factors that may not be considered include, but are not limited to, the following:

- Weight of soil
- Instability of the trench after the primary collapse
- Kinetic energy in wall movement
- Atmospheric conditions
- Wet or dry conditions

A: Additional medical implications not considered. We conduct rescue operations to rescue and take care of victims. If we fail to provide adequate patient care to the victim of a trench collapse, we may end up with a fatality, either immediately or after disentanglement and removal. A trench collapse victim has specific medical needs, such as those related to crush syndrome. (See the “Victim Access and Care” chapter for information on victim care considerations.)

I: Inadequate rescue skills. If you as a responder do not know your limitations and do not have the skills to perform at a certain level, doing nothing is better than doing something wrong. You should not let your ego cause you to attempt rescue operations for which you are not trained.

L: Lack of teamwork and experience. Teamwork is not “many people doing what I say.” Personnel who expect to integrate their skills into trench rescue operations must work together effectively if they are to be successful. This comes from understanding “team decision training” as opposed to simply training and experience. Excellent teamwork is not something that just happens because a group of personnel have been trained. Teams are living, breathing entities that have specific identities and capabilities. Individuals cannot perform as well as smoothly functioning, collective teams. Team integrity, team processes, and team efficiency concepts are all integral parts of being able to function at the high performance end, and not at the dysfunctional end, of the team scale.

U: Underestimating the logistical needs of the operation. From day one emergency services personnel have been taught, “Call for it. If you do not need it, turn it around.” Now add to that all the external resources that you may need, the need for trained teams, and the need for special resources that are not used very often. Locating these resources can be time consuming if not planned for up front in your standard operating procedure. Territorial egos may also get in the way of good sense, to the point that we may lose our focus on the victim. Logistics is not glorious, but it is very necessary in planning for any specialty rescue incidents. A trench rescue is not a weekend project where you can wait a few days before going to the hardware store to pick up what you need. You either have it or have access to it, or its absence affects your operation.

R: Rescue/recovery mode not considered. Put bluntly, deceased victims of trench collapse do not usually come back to life—so do not commit resources in a questionable situation to recover a body. In a recovery operation, you have as much time as you need. Very few completely buried patients will survive. Do not let compassion override your good sense. Compassion has no place in the special operations environment when the event is occurring **FIGURE 1-3**.

E: Equipment not mastered. How well do you think a new fire fighter would do if you were to completely disassemble your self-contained breathing apparatus or 12-lead defibrillator and then tell the individual to use it in a high-stress, emergency operation, having never seen it before? The equipment you will use in rescue operations falls within the same parameters. Most of it is specifically designed for the trench rescue operations, and it requires you, as the rescuer, to know it inside and out.

FIGURE 1-3 A viable rescue situation does not decrease the importance of a thorough risk–benefit analysis.
Courtesy of Larry Collins

Training Tip

Improve your abilities in using specialized equipment by following this system:

1. The instructor explains and demonstrates the equipment or tool.
2. Students then explain and demonstrate the equipment or tool back to the instructor.
3. Students perform the task in slow speed.
4. Students start timing themselves in decreasing increments to raise anxiety.
5. When students become proficient by time, start taking away sensory perceptions:

- Add gloves to restrict feeling.
- Put on a blindfold to eliminate sight.
- Introduce noise to reduce the ability to hear.

6. When students become proficient with gloves, while blindfolded, and with noise, start timing the evolution again.

Now *that's* creating a "top-gun" trench rescue technician.

Causes of Trench Collapse Emergencies

A contractor preparing to lay a pipe string has some decisions to make. Obviously, he or she should determine the soil profile and use an engineered system based on the soil's potential for collapse. The choices are as wide and varied as the different types of materials that can be used to construct the system. Steel interlocking piles, preformed steel or aluminum trench boxes, solid wood uprights, and hydraulic or air shores are just a few options. (More information on these types of systems is found in the "Protective Systems" chapter.)

Noncompliance

The one consistent factor that a contractor would closely evaluate regarding the type of trench protection used is the cost in time and money to use that system. It takes a long time to panel a 10-foot (3-m) long, 5-foot (1.5-m) deep trench just to lay one section of pipe. So why not take a chance and dig the trench, lay the pipe, and send someone down there to make the connection? You get the picture: The faster you lay the pipe, the more money you will make, and the faster you can get to another job site.

Another issue that no one is comfortable addressing is the socioeconomic makeup of trench collapse victims. Not many executives are rescued from trenches—the worker in the trench is probably making below-average wages and is more concerned with keeping his or her job than questioning the safety of the job site. The sad part of a rescuer's job is knowing that the victim rarely understands the hazards involved, and, even if he or she did, would not be in a position to question directions given by a contractor **FIGURE 1-4**.

Accidents Without a Cave-In

A collapse is not the only type of emergency that you will respond to involving trenches. In fact, many of the emergencies in trenches can deal with an occurrence other than a collapse.

FIGURE 1-4 There will always be workers who do not appreciate the hazards involved with trench work and are willing to take an ill-advised risk.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Tactical Tip

A common situation that leads to a trench incident is a normalization of deviance, in which contractors and site supervisors know it is wrong to send someone into the trench without protection, but take the risk on limited basis. The more times they get away with it, the more they convince themselves the practice is normal or acceptable. They justify this unsafe behavior with explanations like this often-heard refrain: "I have been doing this job for *x* years and have never had an incident. I know what I am doing."

A lot of work goes on after the trench is dug—for instance, the installation of a sewer lateral or storm water distribution box. This work takes place in both protected and unprotected trenches. The challenge for the rescuer is not to be lulled into complacency by protected trench situations or to assume that such rescues will be easily accomplished.

■ Equipment Failure and Load Management

One of the problems that you could have at the scene of a trench emergency that does not involve a collapse is the dreaded backhoe or excavator-caused problem. Being mechanical, these machines can cause terrible problems for workers operating on and around this equipment if they malfunction. Hydraulic failures during lifting operations as well as rigging that is improperly assembled or not appropriate for the load being moved result in numerous construction accidents **FIGURE 1-5**.

FIGURE 1-5 Heavy equipment operation and final placement can complicate rescue efforts at the scene of a trench collapse.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Think about all of the things that have to go right with just the equipment at a work site: The backhoe has to work properly. The load has to be rigged properly, and the rigging has to be substantial enough to carry the load. When problems occur in any one of these areas, you may find yourself in a trench rescuing a trapped or pinned worker.

FIGURE 1-6 There are many opportunities for mishaps when using heavy equipment for lifting operations.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

The machines operating at a trench site are powerful, and the loads being lifted are often heavy. To make matters worse, the backhoe or excavator is operated by humans in situations where the tolerance for maneuvering the load is small. Just like workers in other occupations, heavy equipment operators vary in experience. When responding to trench rescue incidents, you will likely encounter equipment operators with 30 years of experience, but you will also likely run into those who are just out of training.

Workers are sometimes pinned between steel panels that they are trying to set as sheeting or by pipe that is being placed. When this happens, you as the rescuer may be faced with a trench that is only partially protected, as well as a seriously injured victim.

Water and sewer pipes, as well as steel plates used as sheeting panels, have been known to crush workers while being moved into place. Commonly, these scenes call for a rapid size-up of the protective system being used and continuous evaluation of that system to determine whether your extrication methods might be compromising the in-place system.

Another problem is that the loads being moved in and around trenches are only as safe as the rigging and rigger that secure them. If a rigging strap breaks or an excavator's hydraulic system fails and a pipe falls on a worker, you could be faced with a seriously injured or dead worker. Even if the trench is protected, getting the victim out may pose a huge challenge **FIGURE 1-6**.

FIGURE 1-7 A hazardous material component should be a standard response for trench rescue incidents.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

■ Atmospheric Concerns

Atmospheric problems are another area of concern and a frequent cause of problems at trench sites. With today's stringent hazardous materials (hazmat) laws, it is not unusual to find hazardous waste products buried underground. If you happen to be a worker in or around a trench when one of these containers is broken, you could be confronted with an atmosphere that is within the explosive range, above permissible exposure limits for toxic atmospheres, or accompanied by a low oxygen profile.

Because it is impossible to determine what someone may have previously buried, extreme caution should be used when arriving at the scene with workers down in a trench. If you are confronted with a worker in a trench who is incapacitated for no apparent reason, remember that it is critical to monitor the atmosphere. If one worker is down, the cause may have been a heart attack or some other illness. If two or more workers are down and no accident is apparent, the culprit is most likely a hazardous atmosphere. Remember to monitor the environment, including the atmosphere. Also, have a hazardous materials team available as a part of your initial response to any trench collapse **FIGURE 1-7**. (Atmospheric monitoring is covered in greater detail in the "Hazard Control and Atmospheric Monitoring" chapter.)

VOICES OF EXPERIENCE

In April 2015, our team was dispatched to a trench rescue. The initial dispatch was a basic life support response for a fall. Upon hearing the short report of a worker in a hole at a construction site, the engine company officer requested a ladder company, medic unit, battalion chief, and a tech rescue unit. As it turned out, this request for additional resources was a good call and reduced the response time for specialized rescue units and personnel.

Upon arrival, we found an approximately 20-year-old male buried up to his chest. He and another worker had stepped into a void area that was not visible and both became trapped. One of the men was freed by his fellow workers; however, there were six construction workers in the trench with shovels attempting to remove the soil from around the remaining worker. While this was taking place, the trapped worker had his arms above his head and was using both arms to support himself from a cable attached to an excavator arm. The scene was filled with chaos, as the first-arriving officer attempted to control the workers and also deploy his crew to assist with digging. As engine company personnel dug to access the worker, the spoil pile grew and all personnel were now operating in a hazard zone without shoring or wearing any retrieval devices.

"While the victim was hanging on a cable attached to the excavator, it was decided a proper retrieval system needed to be rigged, and that, too, was then attached to the excavator arm."

Because this was a trench rescue call with an entrapment, the shoring trailer needed to respond to the scene. As it is not kept with a truck attached to it and there was not a crew to get it hooked up, a neighboring engine company needed to be dispatched to pick up the trailer with a utility truck and respond to the scene.

The incident took place in the parking lot of a large department store, where construction workers were in the process of excavating several large fuel storage tanks. As fire and rescue apparatus arrived on scene, they were not staged away from the rescue area and consequently access to the scene became more difficult. Because of the crowded situation, the tech rescue trucks and shoring trailer ended up being parked away from the scene and equipment was carried to the scene by hand.

The ladder company officer (a rescue technician) was assigned the role of rescue group supervisor by the incident commander (IC), who was a battalion chief. Other positions that were assigned were trench rescue (TR) safety, safety, rescue group supervisor aide, and a liaison for the excavator operator and crew. The aide kept track of the personnel who arrived and were assigned to work for the rescue group. Incident management system vests were not worn, so there was confusion as to who was responsible for specific functions.

The construction workers continued to operate in the trench after the assignment of a rescue group supervisor (RGS) and a TR safety officer. They refused to leave the trench and at one point took a rescue harness from a tech and applied it around the victim's chest (backward). The excavator remained running for quite some time until a rescue tech requested the key to the machine.

While the victim was hanging on a cable attached to the excavator, it was decided a proper retrieval system needed to be rigged. That, too, was then attached to the excavator arm. After this was completed, it was determined that the excavator would need to be moved to get the requested vacuum truck into position. The vacuum truck was to be an essential tool in removing dirt while not requiring rescuers to be in an unsafe area. As it turned out, the vacuum truck was able to get in a position to use extension tubing to reach the site.

Our response was in a very busy area on a weekday morning—and a slow news day. As a consequence, newspaper and television crews were quickly on the scene. The fire chief was the public information officer (PIO) and did an outstanding job in this role. The department training chief arrived on scene and was assigned as the safety officer, which is a role he fills on structure fires and other incidents. Upon my arrival, I was assigned by the IC to assist the RGS. I was then assigned the TR safety role.

The rescue trailer and two rescue trucks were parked, and one rescue tech was assigned to manage the distribution of equipment. As equipment left the trailers, very little documentation was done on what was being requested and who would be responsible for knowing the equipment's status. As the incident unfolded, various rescue equipment began to accumulate in and around the rescue area.

As the incident progressed, some things happened very fast and several key things did not happen. For instance, the number of tasks required outnumbered the number of people available to complete these tasks, so some people who were assigned specific functions had to complete functions that were outside of that position's responsibilities. As an example, rescue technicians who could have used their expertise to assist with victim removal were instead assigned duties such as atmospheric monitoring, utility support, and dewatering. In this situation, using laminated tactical worksheets would have helped identify overlooked functions and determine whether the incident required additional personnel.

As the victim needed to be supported, a victim harness was sent down to be placed on him. One problem was that the harness was grabbed by a construction worker. Another was that there was no access to the victim's legs at that point, so the harness did little to support the victim. As the victim was still partially buried, only one leg loop could be used. In addition, the buckles on the victim's harness were not threaded correctly, and neither the victim nor the other construction workers knew how to correct them.

As the victim was extricated, he grabbed a knife from a rescue tech and cut the single leg loop because he thought it was inhibiting his ability to be removed from the hole. Though there was a plan in place to place him on a backboard and slide him out of the trench, he instead scrambled up an unprotected slope, knocking soil and rocks on rescuers. He then climbed onto the trench box and finally self-exited the hazard area. The victim then refused medical treatment, signed a release, and left the scene.

Although the incident was ultimately a success, and no injuries to the victim or rescuers occurred, the team could have done some things better. For this reason, an incident critique was done with neighboring departments, rescue personnel, public works, and various city officials to review the incident and discuss any lessons learned, which included the following:

- Without a minimum of awareness-level training, personnel can find themselves in harm's way without fully understanding the hazards encountered. Rescue personnel should be trained to at least the operations level.
- All responders working at the site should be wearing class III harnesses so that anyone can be put to work as needed and will be easier to rescue if necessary.
- It is best to keep a vehicle hooked up to the rescue trailer. In addition, locating the trailer at a station with more than one staffed response unit will increase the chance that personnel will be immediately available to bring it to the scene. Because this is not always practical, several

vehicles should be identified that can pull the trailer and a written plan should be posted regarding which vehicles can pull the trailer and where the keys are located.

- After the initial response, a staging manager should be assigned a crew to move vehicles away from the scene to make room for the specialized rescue units. Trailers should be positioned so their back doors are facing the incident.
- Rescue scenes are dynamic events, and it is important that everyone working at the scene knows who is in charge and who they are working for. IMS vests (though often disliked) will help to provide that information.
- Maintaining a timeline during the incident is important both while on scene and for conducting an after-action report. The RGS can use the radio to report progress, and that information will be received by both the IC and the dispatcher. An aide can record the progress in a notebook as well as information for the confined space entry permit. The RGS can easily become overwhelmed at a busy incident site, so an aide may be considered an essential position to support the RGS.
- The scene needs to be secured. All heavy equipment needs to be shut down and, when appropriate, locked out. All nonessential personnel and personnel without personal protective equipment (PPE) should be removed from the site.
- The positioning of shoring, extraction systems, and the movement and placement needs to be coordinated so that everything works together smoothly.
- The TR safety position should be assigned to a rescue technician in that discipline.
- A good PIO is essential so that the IC can concentrate on running the incident.
- An equipment or quartermaster position is essential to ensure that you receive the correct equipment from the rescue truck and trailer. As equipment is sent to the scene, the equipment officer should record which items are being sent to the scene so the officer knows what is still available and when to request additional supplies
- Tactical worksheets are a great tool that can save you from missing something critical to the success of the operation.
- Assigning an engine or truck company to perform atmospheric monitoring, dewatering, and supporting utilities will free up rescue technician positions. Assign someone to be the primary point of contact with the victim.
- Do not allow nonrescue personnel to rig equipment or systems unless they are working under direct supervision of rescue techs.
- Do not let victims have access to cutting tools without a clear understanding of why they need to have access to that equipment.
- A formal incident review as an after-action report or a postincident analysis is important to prepare for the next incident. In the case of this trench incident, and given the number of rescue responders from various agencies on a multijurisdictional team, we are sending out a document to all team members for them to review.

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Rules and Regulations

The rules, regulations, and laws that govern our organizations are complex. Some of them are laws of the land that are enforced at local, state, and federal levels of government, whereas others are regulations that carry the weight of law. Still others are consensus standards that do not carry the weight of law but are considered best practices and are very frequently used to determine negligence in a court of law. If you are confused, you are not alone: Even experts can rarely tell you with 100 percent accuracy how all of these various standards and guidelines affect our individual organizations.

In most cases, the laws, regulations, and standards are in place to prevent trench incidents in the first place. In that regard, they can profoundly affect the way we do business. In fact, our organizations will be placed in a position of liability if we do not try to adhere to them on a consistent basis. The nice part of all of this is that these guidelines are written with our best interest and safety in mind.

Fire and rescue agency relationships with the Occupational Safety and Health Administration (OSHA) are unique among compliant organizations. Because the OSHA standard for excavations (29 CFR 1926 Subpart P) was created for the construction industry, how rescue organizations fit into the picture is usually up to a local OSHA enforcement officer. The standard may be applied quite differently from one jurisdiction to another. For rescue operations, it simply makes good sense to locate a standard that has been adequately researched, whether it is an OSHA, National Fire Protection Association (NFPA), or another standard, and to use it to the best of our ability.

From a rescue agency standpoint, OSHA requires compliance with the standard if the following conditions exist:

- An employee–employer relationship.
- Trench rescue operations are part of your job. Do you train for, acquire equipment for, or prepare to participate in trench rescue operations? Additionally, would you normally be dispatched to a trench collapse?

Career versus volunteer status issues may also arise. If you are a career rescuer and can answer “yes” to either of the previous questions, then you will probably be held accountable under the law. Volunteers are exempt from most OSHA regulations, so CFR 1926 may not apply in a given rescue situation. Even so, you should consider the following questions:

- Do volunteers have to comply with NFPA?
- Do volunteers have to comply with OSHA?
- Are you operating in an OSHA-covered state?

The answers to these questions are only as clear as your jurisdiction chooses to make them. Often, the authority having jurisdiction (AHJ) determines compliance with NFPA consensus standards; however, we assume that if you are reading this text to train your team, or if you are learning the discipline for yourself, then you are determined to do so in the safest, most efficient environment possible and, therefore, would not ignore the standards.

Whether you agree with this or any other legal or consensus standard, if something goes wrong, you can bet that the incident will end up in court. In the legal proceedings, an expert will appear in court quoting the law and waving nationally recognized consensus standards and, in effect, using them to the prosecution's/plaintiff's advantage. Consider the following issues when talking about the liability aspects of trench rescue operations:

- What is the current "standard of care" for a trench rescue?
- Which guidelines do similar teams follow?
- Do you comply with other OSHA or NFPA standards?

Safety Tip

The OSHA General Duty Clause (29 USC 654) can make it a criminal offense—rather than a civil offense—to violate a consensus standard. This clause describes employer and employee responsibilities as follows:

a. Each employer
   1. shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;
   2. shall comply with occupational safety and health standards promulgated under this Act.

b. Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct.

Source: OSHA; accessed from http://www.gpo.gov/fdsys/pkg/USCODE-2011-title29/pdf/USCODE-2011-title29-chap15-sec654.pdf.

OSHA CFR 1926 Subpart P, Excavations

Understanding the excavation standard is important to rescue personnel for several reasons. First, and most importantly, it will give you the data and information needed to decide on appropriate protective systems and safety requirements for trenches. This information can be universally applied to any given rescue operation by using the toolbox approach. Your toolbox should be full of ideas and techniques, even if not all of them will be appropriate for all situations. The goal here is to maintain a large and varied toolbox of information.

Second, knowledge of the standard, its requirements, protective systems, and soil classifications could qualify the user as a competent person according to the standard. While the competent person qualification does not eliminate any potential liability, it does help the user to make rational decisions based on a given standard during rescue operations.

The current OSHA standard, OSHA CFR 1926 Subpart P, Excavations, was originally a part of the Contract Work Hours Standard Act. When introduced, this act had requirements that were very confusing and led to inadvertent noncompliance and insufficient criteria for protective system design. Typically, the protective systems built to comply with the act were more expensive to put into place than the fine associated with non-compliance.

The current standard retains a lot of information from the original act; however, it has been clarified to ensure that the requirements can be better understood. Chief among the changes and additions to the existing standard are the following:

1. All criteria are performance-based standards. As a consequence, protective systems that are not outlined in the appendix may still be used if available data show that such systems are performance rated and oriented.
2. A consistent soil classification method is delineated, including the techniques used to test soil samples. This allows protective systems to be designed according to soil profiles.
3. Fines and penalties have been increased. Many fines are as much as seven times greater than the amounts specified in the original standard and may even provide for equipment seizure and impoundment during investigations.

The standard is divided into several key areas:

- Scope and definitions
- General requirements
- Protective systems
- Appendices

General Requirements

General requirements are those items required during construction operations that a competent person must consider and act on. From a rescue perspective, this offers an excellent safety guideline from which responders can determine the appropriate tactical direction.

Consider the following as rescue safety and operational guidelines and considerations:

- All trenches must be protected before entry, *except*:
  - Those made entirely of stable rock
  - Those less than 5 feet (1.5 m) in depth, previously inspected by a competent person, and found to have no indication of a potential cave-in
- Any trench more than 5 feet (1.5 m) deep, including the height of the spoil pile, must be protected.
- The spoil pile must have a 2-foot (0.6-m) setback from the lip (sometimes referred to as the *edge*).
- Trenches 4 feet (1.2 m) or greater in depth must have a means of egress—via stairway, ladder, or ramp—every 25 feet (7.6 m) **FIGURE 1-8**.
- Trenches 4 feet (1.2 m) or greater in depth must be tested before entry if an oxygen-deficient or other hazardous atmosphere could exist; however, all trenches should be tested for the following:
  - Oxygen deficiency or enrichment (less than 19.5 percent or greater than 23.5 percent, respectively)
  - Hazardous atmosphere (toxins in parts per million)
  - Flammable gases (greater than 10 percent of the lower explosive limit)

Testing must occur as often as necessary to ensure a safe atmosphere, and emergency rescue equipment must be readily available when a hazardous atmosphere could exist. A trench is an excavation but is not necessarily a confined space according to the OSHA 1910.146 standard. Voluntary compliance with 1910.146 requirements will provide additional life safety and liability protection. The crucial point is that workers and rescuers must be protected by either ventilation or respiratory protection if the potential for an atmospheric hazard exists. (See the "Hazard Control and Atmospheric Monitoring" chapter for more detailed information on trench rescue atmospheric monitoring requirements.) Additional considerations include the following:

- Water accumulation: Employees need to be protected from water by dewatering operations. Remember that dewatering must be monitored by a competent person and surface runoff must be diverted.
- Fall protection: Use a lifeline and harness when there is a risk of falling.
- Soil: A competent person must be able to determine the soil classification.

FIGURE 1-8 Always provide rescue personnel with two separate means of egress and ingress to the trench.

- Inspection: A competent person must inspect the trench (even during rescue operations) for the following:
  - Secondary cave-in potential
  - Protective systems failure
  - Atmospheric monitoring or control
  - Other hazardous conditions

■ OSHA's View of Trench Rescue Operations

During trench rescue operations, we tend to over-engineer our rescue systems to protect ourselves from the worst-case scenario. In almost all situations, the shoring components and panels recommended are far greater than the forces they are expected to hold. In effect, we usually overbuild our systems because we understand that the most important people on the scene are not the victims, but the rescuers.

Additionally, the time we are in the trench is limited. Usually, rescuers' time in the trench is measured in hours, not days, whereas the OSHA standard is designed to regulate protection systems engineered to last many days.

Finally, we are entering the environment for an entirely different reason than a utility worker. Rescuers are entering to do rescue operations, not commercial construction.

This is not to suggest that emergency services responders should be surprised or embarrassed if OSHA decides to get involved. Remember that the ball field belongs to this agency, even if the rescuers are playing the game. Generally, OSHA will get involved if one of the following occurs:

- A civilian or rescuer injury or death occurs as a result of the collapse (in fact, you are required to call OSHA whenever you have a civilian/rescuer injury or death).
- Any death occurs as a result of a construction accident.
- The authority having jurisdiction requests OSHA's involvement.

Tip

Emergency services personnel should not view OSHA as the enemy. We should keep OSHA abreast of our activities in a rescue situation. Also, consider taking time to meet and confer with your local OSHA representative. Together, you should work toward gaining an understanding of each other's roles. Often, OSHA personnel can provide a wealth of information and site support.

NFPA 1670 and 1006 Rescuer Levels

Two very important NFPA documents guide rescue operations in the fire service: NFPA 1670, Standard on Operations and Training for Technical Search and Rescue Incidents, and NFPA 1006, Standard for Technical Rescuer Professional Qualifications. The easiest way to distinguish between the two standards is to understand that NFPA 1670 applies to organizations and NFPA 1006 applies to the personnel who work in those organizations.

More specifically, NFPA 1006 prescribes the job performance requirements (JPRs) for individuals operating at either Level I or Level II. While not limited to trench rescue, this document provides a listing of JPRs, divided into levels by knowledge, skills, and abilities (KSAs), for fire service personnel who perform trench rescue operations. Level I trench rescuers must meet the JPRs in Sections 8.1.1 through 8.1.7, and Level II trench rescuers must meet the JPRs in Sections 8.1 and 8.2.1 through 8.2.6. (It is anticipated that the next edition of NFPA 1006 will reorganize JPRs into three levels: Awareness, Operations, and Technician.)

NFPA 1670, by comparison, prescribes various standards for organizations operating at the awareness, operations, or technician levels. For instance, it states various knowledge requirements that must be met organizationally to operate at the various levels. The delivery of technical rescue services, and in this case trench collapse operations, involves a layered or integrated system, which addresses the needs of all customers **FIGURE 1-9**. These levels are broken down into three specific areas:

- Awareness level: This provides information for the first responder to identify the hazards associated with collapse and its dangers. Awareness training provides a decision-making matrix that allows first responders to begin the process of incident stabilization, recognizing the need for rescue, identifying needed resources, initiating site control and scene management, recognizing hazards and collapse patterns, and initiating nonentry rescue. Awareness-level personnel are not intended to be actively involved in the rescue operation.

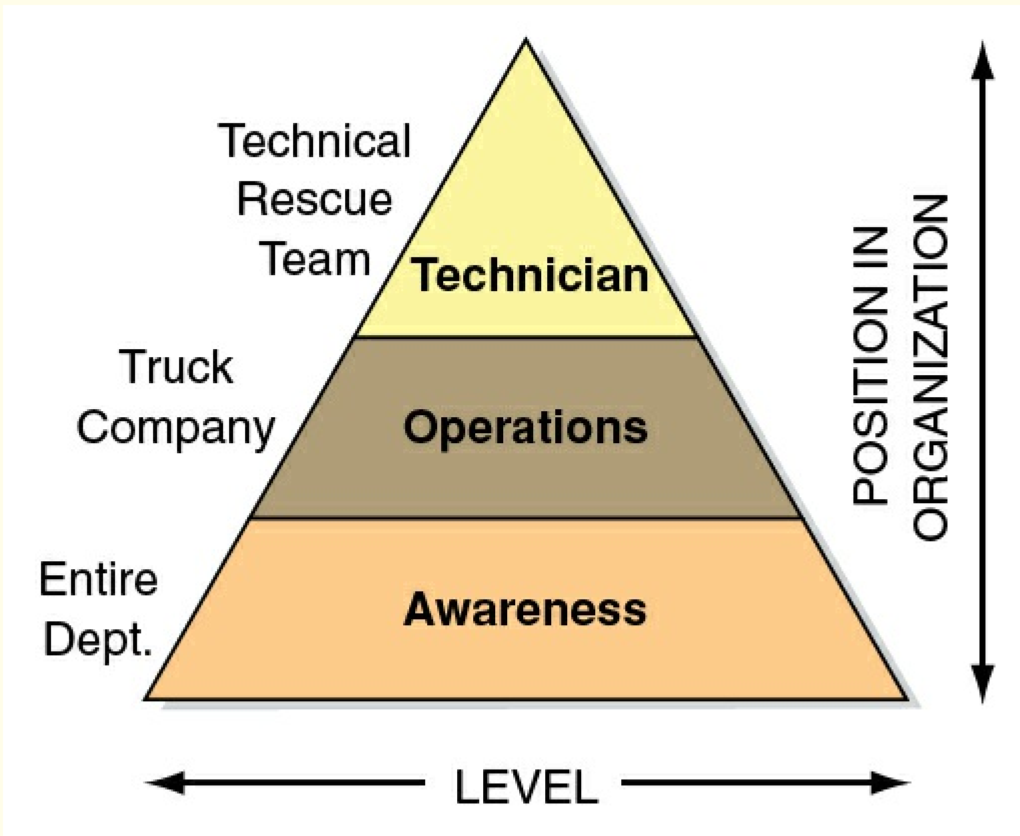

FIGURE 1-9 Departments need to train all members to levels of proficiency that are consistent with service level expectations.

- Operations level: Operations represents the first level at which personnel learn the necessary techniques to render certain types of collapse environments safe for subsequent rescue operations. In some systems, these personnel (sometimes called *support personnel*) may also be responsible for the initial or long-term rescue operations, such as size-up; victim location and survivability; sheeting, shoring, and ground pad usage; utility location; soil identification; ventilation; briefings; documentation; personnel duties; and extrication. Placement of traditional sheeting and shoring systems in all trenches that are not more than 8 feet (2.4 m) deep and do not intersect is within the operational scope of these personnel, provided that there are no severe environmental conditions and no supplemental shoring is needed. Personnel at this level may also function as group or division officers during the development of a trench rescue incident command system.

- Technician level: The technician level involves additional training associated with intersecting and deep-wall trench rescue operations or where additional conditions put the operation beyond the scope of the operations level. Personnel at this level are primarily responsible for overall operations, installation of protective systems, access, and disentanglement of victims in trench or excavation collapses. These personnel are typically technical rescue team personnel who have advanced training above the operations level, working with manufactured protective systems and isolation systems, supplemental sheeting and shoring, and atmospheric monitoring. Additionally, they will have technical rescue skills package training. Examples of this training include rope rescue, confined space rescue, and structural collapse rescue.

In addition to these specific requirements, NFPA 1670's Chapter 11, "Trench and Excavation Search and Rescue," requires organizations that operate at the awareness, operations, and technician levels to have additional training. TABLE 1-1 lists the requirements for each trench level.

Table 1-1 Additional Training Requirements by Level

Awareness	Operations	Technician
Chapter 4: General Requirements	Operations-level rope rescue	Technician-level confined space rescue
Awareness-level confined space rescue	Operations-level confined space rescue	Technician-level vehicle and machinery rescue
Chapter 4 of NFPA 472, *Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents*	Operationslevel vehicle and machinery rescue	
Competent person as defined in NFPA 1670 Section 3.3.20		

Wrap-Up

Review: Just the Dirt

- It is always easier to surmise what you might have done at a rescue incident, especially after the results of the decision are known.
- When dealing with trench rescues, your struggle will be to focus on bringing risk–benefit analysis to the forefront of your strategic decision-making process.
- The FAILURE acronym can be used to identify specific aspects of the operation that contributed to it going wrong.
- Common causes of trench collapse emergencies are noncompliance, accidents without a cave-in, equipment failure and load management, and atmospheric problems.
- The rules, regulations, and laws that govern our organizations are complex, with some being laws of the land, others being regulations that carry the weight of law, and still others being consensus standards that do not carry the weight of law but are considered best practices.

- Understanding OSHA CFR 1926 Subpart P, Excavations, will give you the information needed to decide on appropriate protective systems and safety requirements for trenches.
- Generally, OSHA will get involved at an incident if:
  - A death occurs as a result of the collapse.
  - A death occurs as a result of a construction accident.
  - The authority having jurisdiction requests its involvement.
- Two very important NFPA documents guide rescue operations in the fire service: NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, and NFPA 1006, *Standard for Technical Rescuer Professional Qualifications*.

Hot Terms

Authority having jurisdiction (AHJ) The local authority that draws on the power of law to make rules and regulations for the organization.

Awareness level The level of rescuer where the first responder can identify the hazards associated with collapse and its associated dangers.

Competent person The individual, usually the supervisor, who meets the OSHA standard for determining soil profiles, safety concerns, protective mechanisms, and other performance requirements.

Consensus standards Published standards, created by interested stakeholders, that act as a consensus of best practices for the industry.

Excavation Any human-made cut, cavity, trench, or depression in an earth surface formed by the earth's removal. In practical terms, when a hole is more than 15 feet (4.5 m) wide at its base, it is called an excavation. Overall, an excavation is wider than it is deep.

FAILURE Acronym used to describe the various reasons why technical rescue incidents are unsuccessful.

Head versus heart decision making Process of using cognitive ability to evaluate the essential risk–benefit factors instead of using compassion as the overriding factor.

Lip The area 360 degrees around the opening of the trench and extending down 2 feet (0.6 m). This area is very dangerous.

NFPA 1006, *Standard for Technical Rescuer Professional Qualifications* The National Fire Protection Association standard that addresses rescue technician professional qualifications.

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents* The National Fire Protection Association standard that addresses operations and training for technical rescue incidents.

Operations level The first level of rescuer at which personnel learn the necessary techniques to render trenches that are 8 feet (2.4 m) or less in depth, and that do not intersect, safe for rescue operations.

OSHA CFR 1926 Subpart P Occupational Safety and Health Administration Code of Federal Regulations 1926 is the general construction standard; Subpart P refers to the trenching and excavation section.

Risk–benefit analysis Decision-making process used to evaluate the level of risk involved in a situation versus the potential benefit that can be achieved based on the proposed intervention.

Spoil pile Excavated dirt removed from the trench.

Survivability profile Determination, based on a thorough risk–benefit analysis and other incident factors, that addresses the potential for a victim to survive or die with or without rescue intervention.

Technical rescue skills package training The complete package of training that includes confined space, vehicle rescue, rope rescue, structural collapse rescue, and trench rescue.

Technician level The level of rescuer that requires additional training associated with intersecting and deep wall trench rescue operations.

Trench A narrow excavation (in relationship to its length) made below the surface of the ground. In general, the depth is greater than the width, but its width measured at the bottom does not exceed 15 feet (4.5 m).

TRENCH RESCUER *in action*

Your station has been dispatched as the first-responding unit to a possible trench rescue. You are a fire fighter and the only member of your crew who has been trained up to the trench technician level. The other three members of your crew, including your captain, have had only trench awareness-level training.

Upon arrival at the scene, you find mass confusion and panic. A quick scene survey shows that a contractor was replacing a 24-inch (61-cm) sewer line in a trench without any protection system. The trench is approximately 6 feet (1.8 m) deep and 4 feet (1.2 m) wide and more than 50 feet (15.2 m) long. A 5-foot (1.5-m) long section of trench side wall has collapsed, trapping at least one worker up to his mid-chest.

Two workers and a police officer are trying to dig the trapped worker out with shovels. Several pieces of heavy equipment are located near the trench, including an excavator that is moving into position to remove soil from the collapse area.

Your captain looks at you and says, “Okay, kid, I’m putting you in charge. You have all the training.”

1. How do you know whether this is a rescue or a recovery?
   - **A.** Determine the victim’s survivability profile.
   - **B.** Determine which resources are already at the scene.
   - **C.** Ask the police officer.
   - **D.** Ask the site supervisor.
2. Your captain tells you he is taking the rest of your crew and going into the trench to help the police officer and two workers dig out the trapped worker. What do you do?
   - **A.** Tell him to go ahead.
   - **B.** Say nothing and worry about other issues facing you.
   - **C.** Tell him “no” and remind him of the risks and hazards of operating in an unprotected trench.

D. Await the arrival of the battalion chief and let him take charge.

3. Dispatch confirms that the trench rescue team is en route, 4 minutes from the scene. Several actions are required to stabilize the scene before they arrive. Which of the following actions is NOT an initial priority?
   A. Find the site supervisor.
   B. Shut down the excavator and other heavy equipment.
   C. Remove the workers and the police officer from the trench.
   D. Locate plywood to be used as ground pads.
4. What does the "F" in the acronym FAILURE stand for?
   A. Failure to utilize the correct techniques and equipment
   B. Failure to understand the environment
   C. Failure to utilize teamwork
   D. Failure to acquire adequate rescue skills

Preparing the Rescue System

CHAPTER 2

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Identify and describe the Big Three elements of technical rescue **NFPA 8.1.1**. (pp 20–21)
- Describe the evaluation cycle for the Big Three of technical rescue **NFPA 8.1.1**. (pp 21, 23)
- Identify and describe the most applicable types of fire service delivery systems for technical rescue. (pp 23–24)
- Discuss the qualities that make an effective technical rescue team **NFPA 8.1.1**. (pp 24–25)
- Discuss the options for getting specialized equipment to the rescue scene. (pp 25–27)

Skills Objectives

There are no Trench Rescue Level I skills objectives for this chapter.

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

Your day on the job starts like most days in the fire department—routine. But as we all know, routine days in emergency operations can turn out to be anything but routine. On this day, you are finishing up with your daily equipment checks and preparing to move along to your assigned house duties. As the last compartment door on the engine is shut and you initial the equipment check-off sheet, the special operations chief pulls up in the back yard. This visit is somewhat unusual, so you wonder what the "big wig" of special operations rescue could be doing at your station, especially this early in the morning.

To your surprise, the chief bypasses the front door and walks directly up to you, extends his hand as a matter of courtesy, and asks how you are doing. He goes on to say that he has been hearing good things about your skills as a fire fighter. In the back of your mind, you are thinking that the last time you heard this speech was right before the words, "We really need you to work at such-and-such a company."

To your surprise, the chief asks you if you have ever considered being on the rescue company as a special operations fire fighter. This is quite an honor, he says, as you have been on the job for only 5 years. As he leaves, he suggests that you talk with the other members of the rescue company, then let him know if this position is something you would be interested in pursuing at this point in your career.

As you watch the chief walk away, all sorts of things are running through your head. After you finish your house duties that day, you sit down with your captain and get help with the questions you will ask the rescue team members when you meet with them:

1. If I am assigned to the rescue company, how will my daily training and emergency scene responsibilities differ from those of an engine company fire fighter?
2. If I want to be the best rescue company fire fighter possible, on which areas of training should I concentrate?
3. Which additional certifications will I need to achieve the very highest level of competence in special operations rescue?

Trench Rescue Level I

The Big Three of Technical Rescue

Trench rescue is one of many disciplines associated with technical rescue. Technical rescue is the generic term for special rescue operations, which include trench rescue, rope rescue, vehicle and machinery rescue, swiftwater rescue, confined-space rescue, structural collapse rescue, and others.

Each of these very different disciplines has one thing in common: Each is a part of the Big Three—special people, special equipment, and special training **FIGURE 2-1**. Failure to integrate these elements into an active trench rescue program will result in a weak and potentially flawed system. Each one of these elements is critical to team success, and good teams have plans for how to evolve and maintain each element.

FIGURE 2-1 The rescue personnel who perform trench rescue are specially trained technicians.
Courtesy of Nigel Letherby

■ Special People

Personnel working in any nontraditional rescue team (e.g., trench, confined space, structural collapse, rope rescue) operate in exceptionally dangerous, unforgiving, and unpredictable environments with limited resources. Additionally, they are expected to maintain a positive attitude and to think clearly in situations that, from a victim survival standpoint, may ultimately be hopeless. They are also sometimes subjected to peer criticism because they elect to endure intense training to maintain proficiency in situations that do not occur very often. Moreover, technical rescuers must be tolerant of change, as new technology is introduced, evaluated, and integrated into training and response protocols. Ultimately, the foundation of your success in specialized rescue will be rooted in the people who make up the team.

■ Special Equipment

If the most important aspect of your team is its membership, then by far the second most important part of the Big Three is special equipment. It is vitally important to the rescue effort that the rescuer is provided with the equipment required to do the job safely and effectively. Specialized, highly technical equipment (the type of equipment used in technical rescue) is often complex and very expensive and requires frequent rescuer training to maintain proficiency **FIGURE 2-2**. (Trench rescue equipment is discussed in more detail in the "Equipment" chapter.)

If you are reading this text because you are interested in starting a trench rescue team but you are not willing to support that effort with the proper equipment, stop now. All the great people on your team are destined to fail without the right equipment. Make sure your team members have a reasonable chance at success. If you are going into the specialized rescue business, get the specialized rescue equipment required to be safe and effective.

FIGURE 2-2 A trench rescue team requires a cache of special equipment to be proficient.
Courtesy of Speed Shore Corporation

Training Tip

At a minimum, all personnel who may respond to a trench rescue should be trained to the Trench Rescue Level I General Requirements of NFPA 1006, *Technical Rescuer Professional Qualifications*, and the awareness level in NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, so that they have the basic skills to recognize hazards and not become victims.

■ Special Training

The third element in the Big Three is special training, which is necessary because all team members and their special equipment must function effectively together. This kind of preparation does not involve a run-of-the-mill training effort, but rather a training program that is solid, realistic, and practical. The special equipment involved will seem unfamiliar when it is needed if you have not taken the time to train with it. If there is any doubt about how challenging this can be, ask someone to set up the high-pressure air bags or extrication equipment as fast as possible, just like in an emergency. In most cases, people may think that they know their equipment, but when the pressure is on, they fumble around and look at it as if it came from outer space. To prevent this phenomenon, practice often and hard. Challenge yourself so that when all elements are working against you, a lack of training will not cause you to fail **FIGURE 2-3**.

The Specialized Training Cycle

The development of the Big Three as it applies to teams is subject to a constant circle of evaluation called the specialized training cycle **FIGURE 2-4**. The people selected as rescuers will be continually recruited and their skills developed and honed on an ongoing basis. The equipment that you purchase needs to be continuously evaluated and updated, so frequent training must be provided to support the system. This training should take place in a trench, using the equipment that you would use for a rescue, and trenches should be similar to those at which you would actually perform a rescue. Make sure you invest equally in all aspects of the specialized rescue cycle if you want to be successful.

FIGURE 2-3 Constant attention to training is necessary for all rescue team members to maintain proficiency.
Courtesy of Larry Collins

In this text, the focus will be on combining the Big Three to safely and effectively rescue individuals who may be trapped by collapses or any other form of medical/trauma emergency in a trench or excavation environment. In doing so, rescuers are expected to commit to providing the most effective customer service to both their internal (fire and emergency medical services [EMS] personnel) and external ("person in the trench") customers.

VOICES OF EXPERIENCE

A number of years ago, I had an experience that reinforced the lesson that no matter how many times you do something or how much you know about a subject, you must always expect the unexpected. An instructor's responsibility to the students is to pay constant attention to all of the conditions and be vigilant for how the changing conditions might have an adverse effect on them. It was during an operations-level rescue class that one of these "never take anything for granted" moments hit me right in the face.

"Whenever operating around an open trench, you are literally one step away from disaster."

I had just completed my lecture, and we headed out to the practical site for a long day of building protective systems. In all of my lectures, I constantly remind the students that open trenches are unsafe and should always be considered dangerous. This class was no different: Right before we ended the class, I told the students, "Whenever operating around an open trench, you are literally one step away from disaster."

As I made this statement, I happened to be making eye contact with a man named Jack Mickle, the father of soils and excavation science and the most respected man in the United States relative to trench excavations. It was an honor to have him as part of my class, although the thought of him listening to every word of my lecture was a bit intimidating.

As we were setting up the hands-on portion of the training, we dug an open trench that was approximately 6 to 8 feet deep. When the excavation was completed but before any students approached the trench, I started discussing the proper way to approach an open excavation as well as the use and placement of ground pads. As I was lecturing, Jack walked around the open trench to take a look at the soil profile. As he approached one side of the trench, he suddenly disappeared. The 70-plus-year-old gentleman had just taken a potentially serious fall and was now lying in the bottom of an 8-foot trench.

Our concerns at this point were twofold. First, Jack could be seriously hurt from the fall or buried at this point. Second, and even more disconcerting, he could now become a victim of a secondary collapse.

The students immediately recognized what had just occurred and in typical fire fighter fashion set about to mitigate the incident. First, however, they needed to panic, yelling at each other and running around the trench. I recognized that one of the fire fighters was about to jump in the trench in an attempt to assist Jack; thus, as loudly as I could, I yelled, "STOP! Everyone freeze!" I said, “Jack, are you okay?” He said “I think so, Tim.” His response was a first indication that he was not seriously hurt. We could see that he was not buried but instead rode the collapse down and was on top of the dirt that previously constituted the trench wall.

I asked him whether he could get up on his own. He replied, “Yes.” I told one of the students to grab the nearby ladder and put it in the trench next to Jack. He climbed out of the trench on his own, brushed himself off, and apologized for the problems created. We did a quick secondary survey and determined that he was not injured. He then told us that nothing like that had ever occurred to him in more than 50 years of working around trenches. We were lucky that Jack was uninjured and that he was able to continue with the course.

This story serves as a reminder that no matter how many times you do something, you can never let your guard down. This incident also confirms that the officer in charge must gain immediate control of a scene before emotions take over and cause greater harm to the victim(s) and rescuers. Complete a risk–benefit analysis and do not act out of pure emotion. Remember that your first consideration for any type of rescue situation should be victim self-rescue. A nonentry rescue is always better than putting your people in danger or taking the time to put all of that nice-looking sheeting and shoring in a trench.

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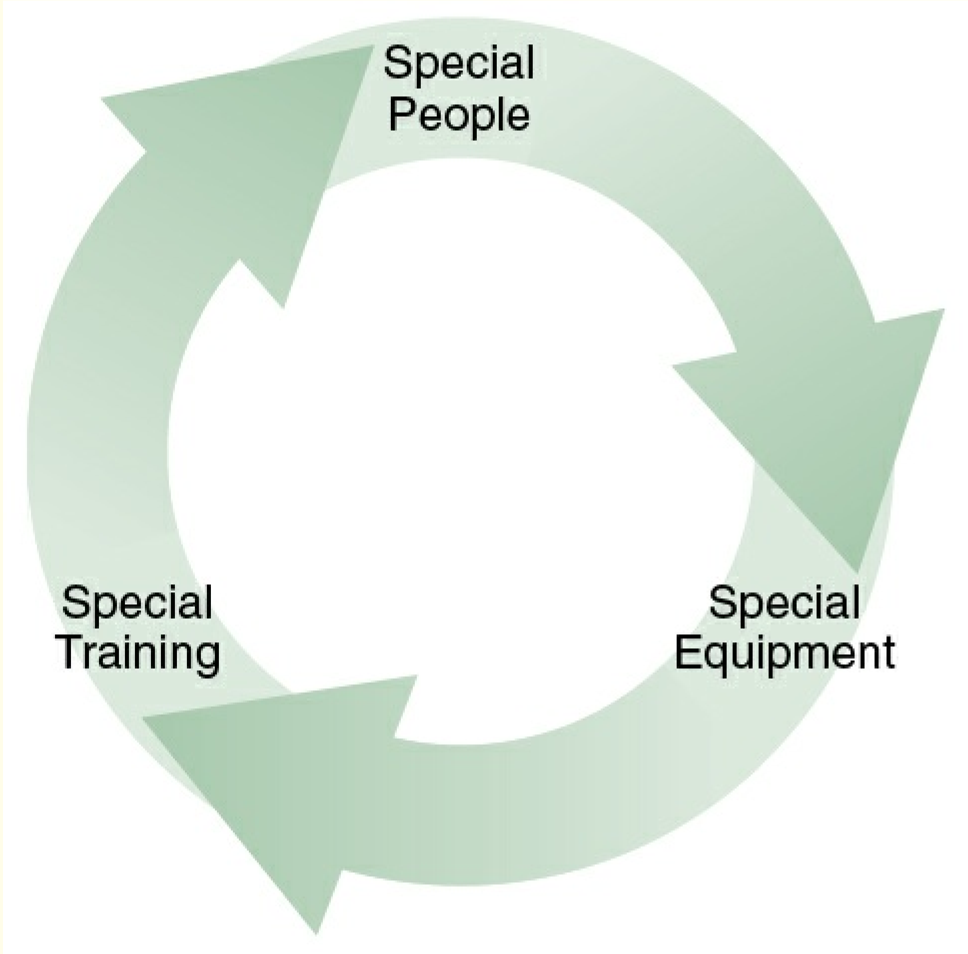

FIGURE 2-4 Attention must be paid to all aspects of the rescue training cycle for a team to maintain proficiency.

Service Delivery Systems

If you are charged with developing a rescue system for trench emergencies, you can pursue a number of different avenues. Each of these roads is littered with pitfalls and carries consequences in the form of time, money, training, and equipment. The road that you choose should reflect the expectations of your community for that type of service and your organization's level of commitment to providing the necessary resources to handle emergency responses safely.

The most difficult and time-consuming method for providing trench rescue services to your community is to be self-sufficient. This means that your agency has committed to many hours of training and practice for its personnel. To train effectively, you will need considerable specialized equipment and a means of transporting this equipment to emergency scenes **FIGURE 2-5**. The bottom line is that being self-sufficient is the best method to ensure that your community is prepared for a trench emergency. At the same time, it is the most expensive option. Remember the Big Three.

FIGURE 2-5 Medium-duty apparatus are very versatile and allow transport and storage of a wide variety of equipment, but are not very appropriate for trench rescue.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Trench Resource List

Name	Item	Contact #
Splinter's Lumber Yard	Panels, bracing	Joe (202) 555-1767
Gopher's Construction	Crane, back hoe, ventilation fan, ladders	Bob (202) 555-3347
Percy's Pumps	Wet/dry pump	Percy (202) 555-2578

FIGURE 2-6 Organizations that want to be community dependent need to spend time up front identifying community resources.

Many organizations recognize the expense involved, perhaps conduct a community risk assessment, and then based on the results elect to be community-dependent systems. This decision may be guided by a number of factors, including the infrequency of previous trench collapses or the fact that a trench collapse has never occurred in the service area. If your department decides to be community dependent, seek out those community members in your area who have construction and excavation experience, and put them on a resource call list **FIGURE 2-6**. It is also a good idea to predetermine necessary logistical needs and send a supply list to the specific vendors before an emergency occurs. For instance, a local hardware store may be more than willing to keep a cache of lumber and nails in a specific place for your immediate use if a trench collapse happens. Likewise, a contractor who has heavy equipment could be asked to sign a memorandum of agreement for providing this equipment if it were ever needed for a trench rescue. Being community dependent could possibly address logistical needs; however, personnel will still need to be adequately trained.

The most cost-effective method of providing trench rescue services to a community is the regional approach **FIGURE 2-7**. The key to this type of service delivery system is that it spreads the cost of development and operation over several jurisdictions. Such a practice reduces individual organizational costs but necessitates written mutual aid agreements to be effective. There also has to be a commitment on the part of each participating organization to train and keep its personnel proficient at trench rescue operations. The regional type of system can be more difficult to organize and maintain than the other systems because equipment and team members could be located in many jurisdictions.

The Team

If your organization has decided on the appropriate service delivery system and has committed to providing trench rescue services for your community, the next step is to put together a team. This is a very important step because the key to successful trench rescue operations will be more dependent on the makeup of the team than on the tools with which the team members operate.

Trench rescue activities are very demanding and necessitate the use of heavy, often cumbersome equipment. For that reason, the personnel on the team must be physically fit and capable of handling the demands inherent in conducting a long-term operation. Moving panels and digging dirt are hard work. Make sure you and the team are up to the physical challenges of such work.

In addition, team members need to be mentally fit and must work effectively under stress and when things are not going well. If personnel are capable of working around a half-buried deceased victim or a screaming, combative victim with two broken femurs, they are probably good candidates for the trench rescue team.

The most important abilities of team members involved in trench rescue operations are construction skills. At some point, a team member will have to cut a piece of wood or hammer a nail. Do not take a 100-pound rescuer, put a 22-ounce hammer in his or her hand, and expect miracles. Team proficiency in construction skills will make your operations safer, more efficient, and less time consuming **FIGURE 2-8**.

Another important part of the team package is the medical personnel. Put simply, medical personnel must be trained for the type(s) of rescue in which they will be involved. Special preparations, such as having protocols for crush syndrome, may be vital to your victim's survival. In addition, treating a victim in a partially collapsed trench can be a taxing experience **FIGURE 2-9**. Consider critical incident stress debriefing as a standard protocol.

FIGURE 2-7 Many organizations help control their start-up costs by sharing technical rescue responsibilities regionally.
Courtesy of Martin C. Grube

FIGURE 2-8 Incident scene success depends on getting the right people with the right skills in the right place at the right time.

FIGURE 2-9 Cross-training fire fighter medics in technical rescue is a first step in helping them understand the hazards of the trench environment.
Courtesy of Martin C. Grube

Not to be overlooked is the ability of personnel to think on their feet. Taking individual practical training components and applying them in a variety of unique situations is normally required during a trench rescue. Good training can prepare you for common collapse patterns and trench conditions, but real trench incidents will never look exactly like your training site.

Recognizing that everyone does some things better than others will also be critical to your team's success in a collapse situation. Put a hammer in some rescuers' hands, and one of two things will happen: They will get hurt themselves or they hurt will someone else. For these rescuers, their talents may lie elsewhere; for example, they may be great organizers and would be effective incident command officers. The point is to place the right person in the right job.

Training Tip

During training evolutions, practice activities that are less familiar to you. On a rescue scene, work in a position in which your skills are most likely to lead to success.

■ The Team Players

The most important attribute of your team members will be their ability to respond as team players. Not everyone on the scene will get a high-profile job FIGURE 2-10, and not every suggestion given to the incident commander will be implemented. Likewise, some people will be telling other members what to do, and other people will be required to follow directions. Once a risk–benefit analysis has been completed and a rescue plan developed, it is the duty of the team player to work as hard as possible to achieve a successful outcome in a given situation, regardless of who made the decision (or how wrong he or she may think that decision is).

FIGURE 2-10 Not everyone on the scene will get the high-profile jobs, but all jobs are important to team success.

The team-oriented rescuer can take direction and give it, and will succeed at whatever job you give him or her. It does not matter to the team player whether he or she has to hammer, dig, or direct. The outcome of the rescue is the most important consideration. One major consideration to remember is that the most talented person might not be the best team player. You will almost inevitably be better off with the team player.

Before you make another decision, call those who have done it before. Do not make the mistakes that someone else has already made. Be smart. Look for a successful "up and running" team. Learn from their mistakes, and then follow their example.

Getting Your Equipment to the Scene

There are many ways you can carry and store your trench rescue equipment. For the most part, these resources will not be sophisticated rescue equipment. Rather, they will consist of shores, panels, chains, shovels, buckets, and the like—construction equipment that is bulky and heavy.

The nice thing is that the possibilities for moving the equipment are endless because the truck that carries it does not have to be a fancy rescue rig.

The one type of truck that is *not* as appropriate for moving trench equipment, unless it has been specifically specified and designed for this purpose, is the prototypical vehicle extrication or squad truck **FIGURE 2-11**. These trucks are designed with outside compartments that are too small for the storage of trench rescue equipment like panels, long shores, and wales. Additionally, the inside is closed and narrow and better designed for people transportation than panel transportation.

FIGURE 2-11 The prototypical squad truck may be a good starting point for your trench rescue needs, but ultimately your rig will need more space.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

For this reason, many teams resort to use of a dump truck or flat-bed vehicle that they obtain from their city surplus department **FIGURE 2-12**. The back of such a unit is big enough and the chassis strong enough to handle the type of weight represented by shores and panels. The advantage to this arrangement is that the unit is self-contained, is relatively inexpensive, and can sit outside covered with a tarp when not in use.

Many different utility trailer or box truck configurations can be used for trench rescue purposes. As long as the wheel-base and chassis will support the load, the setup will work effectively. If the trailer or truck is large enough to hold the panels, it makes little difference if it is closed or open, although keeping panels and other equipment protected from the elements should always be a consideration. The disadvantages of trailers are that another motor-powered vehicle is needed to get it to the scene, and it can be more difficult to maneuver. The advantages include cost and low maintenance.

Custom vehicles and converted vehicles are usually designed and purchased by teams that will supply more than one technical rescue service **FIGURE 2-13**. For example, early in its team evolution, the Virginia Beach Fire Department took an old Seagrave pumper and put a Hackney body with roll-up doors on the chassis. It then purchased a trailer to carry the larger equipment. By splitting available storage space, the department was afforded the opportunity to provide confined-space, rope, and vehicle rescue with the engine, and trench and structural collapse with the trailer. This allowed the rescue team to leave the trailer at the station when it was not needed. The disadvantage of this arrangement was that the truck and trailer collectively were 56 feet (17 m) long. Of course, now the department has a rig and trailer specifically designed for rescue work.

FIGURE 2-12 Do not forget equipment transportation options like dump trucks that may already be available in your organization.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 2-13 Modifying older retired apparatus can provide a great low-cost method to initiate equipment acquisition.
Courtesy of Larry Collins

Another type of system that has gained popularity over the years is the pod system **FIGURE 2-14**. With this approach, a pod equipment storage system is designated for a specific purpose, and only that pod is taken to the scene. The truck just backs up and takes whichever pod is appropriate for the situation.

Much has changed over the years with regard to specialty vehicles for rescue. In the early years, no fire fighter could have imagined that departments would spend $500,000 to $1 million for a vehicle just to carry specialized rescue equipment. As the fire service became more versatile in the late 1980s and 1990s, however, citizens came to rely on departments for much more than just responding to fires. Emergency medical services came into the picture first, in the 1970s, followed in the 1990s by the first heavy specialized technical rescue units and teams. After the terrorist attacks on September 11, 2001, technical rescue gained significant attention and support. Fire departments that once had trouble finding money to perform routine fire responses suddenly found themselves with significant funding available through the Department of Homeland Security (DHS) for urban search and rescue (USAR) and technical rescue training and equipment. Many of these departments not only expanded their capabilities by purchasing equipment for specialized operations, but also spent thousands of dollars on training their people to provide these services safely.

Today, many departments provide specialized rescue functions and, in turn, have to come up with transportation alternatives so that the equipment and personnel can efficiently and effectively respond when required. As the fire service has refined its specifications for the equipment needed for each of the specialty functions, fire apparatus manufacturers have responded by designing and building apparatus specifically for that equipment and function. Thus, many departments have ended up with huge rescue trucks that carry everything from ropes and extrication equipment to shoring panels and concrete cutting saws. That is a long way from a cab over a Ford F-350 carrying a 500 gallon/minute single-stage pump **FIGURE 2-15**.

FIGURE 2-14 Pod systems are great for storing equipment by specialized discipline and for enabling quick transport of that equipment to the scene.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 2-15 Many departments special-order rigs big enough to carry all of their technical rescue equipment.
Courtesy of Larry Collins

Tactical Tip

Make sure that you figure out the total weight of the equipment before developing the specifications for the chassis and axle(s) on your apparatus. When the total is calculated, the weight will probably surprise you. A single homemade trench panel can weigh 200 pounds (91 kg). Also, make sure the apparatus fits in the station bay.

Wrap-Up

Review: Just the Dirt

- Failure to integrate the Big Three—special people, special equipment, and special training—into an active trench rescue program will result in a weak and potentially flawed system.
- Ultimately, success in specialized rescue is rooted in the people who make up the team.
- It is vitally important to the rescue effort that the rescuers be provided with the equipment required to do the job safely and effectively.
- Often, people think that they know their equipment, but when the pressure is on, they struggle with using it correctly and effectively. Sufficient training can prevent this problem.
- The development of the Big Three as it applies to teams takes place in a constant circle of evaluation called the specialized training cycle.
- Service delivery systems can be self-sufficient, community dependent, or regional, depending on the needs and resources of the rescue organization.
- Trench rescue personnel must be both physically and mentally fit to meet the demands of long-term or otherwise difficult operations.
- Once a risk–benefit analysis has been completed and a rescue plan developed, it is the duty of every team player to work as hard as possible to achieve a successful outcome in a given situation, regardless of who made the decision.
- Many teams use a dump truck, flat-bed vehicle, or box truck to transport specialized equipment. The back of such a unit is big enough and the chassis strong enough to handle the type of weight represented by shores and panels.

Hot Terms

Big Three The special people, special equipment, and special training that constitute a good rescue team.

Community-dependent systems Rescue systems in which rescue organizations work with specialty functions in the community that can assist when a specialized rescue event occurs.

Converted vehicles Vehicles that were originally intended for some other use but have been converted for trench rescue purposes.

Custom vehicles Vehicles specifically designed for the intended purpose and use.

Dump truck A vehicle with a hydraulic lift under the cargo bed that, when operated, allows cargo to be dumped.

Flat-bed vehicle A vehicle with a cargo area that is flat and has no sides or roof.

Pod system A self-contained unit that holds equipment specific to one type of specialized rescue function and that can be delivered to the scene as required when the incident occurs.

Regional approach Sharing specialized rescue functions among organizations to create less regional duplication of resources.

Rescue trucks Large, multipurpose vehicles that are specifically designed to transport specialized rescue equipment and rescue team members.

Self-sufficient Able to provide all levels of specialized rescue service and to maintain the special equipment and trained personnel for that purpose.

Specialized training cycle The constant circle of evaluation involving the Big Three.

Technical rescue Use of specialized rescue skills and tools to save life and property through actions not normally associated with traditional firefighting. These areas include rope rescue, swiftwater rescue, confined-space rescue, cave rescue, trench/excavation rescue, building collapse rescue, and other nontraditional specialized rescue functions.

Trench rescue A specialized rescue discipline that involves the shoring of a trench/excavation and subsequent removal of a victim who is trapped in soil or some other encapsulating form or implement.

TRENCH RESCUER *in action*

You are a fire fighter in a small city (20,000 population). You have been on the job for 15 years and have a lot of interest in technical rescue, having taken several classes on your own "dime and time." You have been attending regional and national fire service conferences on a somewhat regular basis for the past 10 years and have established a network of friends and contacts who are active in the technical rescue field in some of the busiest jurisdictions and who are well respected in their field of expertise. Because of this background, you have been assigned to your department's rescue company for the past 5 years. Your rescue company provides fire, extrication, high-angle, and confined-space rescue, but not trench rescue, although several members of the company have taken training on their own and all members have been trained to the awareness level of NFPA 1670 by the department.

Your city has experienced a steadily increasing number of trench rescue calls over the past 4 years due to a construction boom in an area of the city with soil conditions that are prone to collapse. Your rescue company has been involved in several trench rescues and recoveries. The chief of your department realizes that allowing the department to continue to respond to these calls without adequate training and equipment presents serious issues.

The chief has asked you to serve on a committee that is tasked with exploring whether your department should establish a self-sufficient trench rescue team or join in with two other jurisdictions in setting up a regional trench rescue team. He has asked the committee to provide the pros and cons of each of the two options as well as a detailed explanation of what will be required for the establishment of each option.

1. Your committee is discussing the various options of setting up a trench rescue team. What would the most cost-effective option be?
   - A. Community-dependent system
   - B. Self-sufficient system
   - C. Regional approach
   - D. Custom system
2. During several lectures at conferences you have heard the term “the Big Three” talked about many times. What are “the Big Three?”
   - A. Special people, special training, and special equipment
   - B. The three options of service delivery systems for trench rescue
   - C. The requirement for trench rescue personnel to be physically fit, mentally fit, and cognitively aware
   - D. Risk, benefit, and rescue plan
3. What are the benefits of the community-dependent approach for a trench rescue team?
   - A. Requires less equipment and specialized training
   - B. Requires fewer specialized personnel
   - C. Requires no specialized vehicle
   - D. Requires less equipment and fewer well-trained personnel
4. Your committee has learned that your city’s administrators believe that they have sufficient resources for the self-sufficient option. What are the pros of the self-sufficient option?
   - A. The city can set its own standard for levels of response, training, and equipment.
   - B. The option will be more economical in the long run.
   - C. With proper funding of training, and equipment, it is the best method to ensure that the local community is prepared for a trench emergency.
   - D. It requires minimal ongoing training of specialized personnel.
5. No matter which option your committee recommends, that decision should reflect:
   - A. the expectations of the community and the level of commitment of the department to provide what is necessary to do the job right.
   - B. concern for the costs and resources required from the local government.
   - C. that your department will be the one in charge.
   - D. a risk–benefit analysis.

Soil Classification and Testing

CHAPTER

3

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the purpose of trench soil classification. (p 32)
- Identify and describe the basic types of soil NFPA 8.1.1. (pp 32–34)
- Describe the soil testing procedures used by the underground construction industry NFPA 8.1.1. (pp 37–40)
- Describe the soil testing procedures used by trench rescuers NFPA 8.1.1. (pp 40–42)

Skills Objectives

After studying this chapter, you should be able to:

- Conduct a visual soil assessment NFPA 8.1.1. (p 41)
- Conduct a manual soil assessment NFPA 8.1.1. (p 41)

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

When you arrive at the scene of a trench cave-in, the incident commander assigns you the position of shoring officer. As you approach the trench to make your assessment, you see two laborers trapped in an unprotected trench that is 10 feet (3 m) deep and 4 feet (1.2 m) wide. A large section (about 3 cubic yards [2.3 m^3]) of one wall has collapsed. One worker is buried to his chest; only a boot of the other worker can be seen. During a quick interview with the backhoe operator, you find out that the "competent person" has assessed this soil as type A.

A trench rescue technician on your shoring team suggests skip shoring (two sets of strongbacks placed 8 feet [2.4 m] apart and supported by pneumatic struts). You know that skip shoring of type A soil is an acceptable practice for construction workers, but you have never used this technique with active soil and voids in the trench wall. Skip shoring and spot shoring techniques have shown to be effective when applied to type A soil (stable and lightweight) shortly after the digging process. This trench has been open for 3 days without support, however, and has already collapsed. Despite the soil analysis of a competent person, this soil cannot be considered stable.

1. Should you perform another Occupational Safety and Health Administration (OSHA) soil analysis (manual and visual test)?
2. Do you have the equipment and experience needed to properly perform an OSHA-compliant soil analysis?
3. Should shoring techniques approved for construction be relied on to shore trench walls that have collapsed?
4. Can you save time and still be safe by considering this to be unstable and heavy soil, making a rescue soil assessment, and shoring for worst-case (C-60) conditions?

Trench Rescue Level I

Soil Classification

The system of classifying soils used by underground construction workers is a hierarchical approach to determine the performance of a soil based on a decreasing order of stability. In a nutshell, some general assumptions are made about which products are in the soil and how they can be expected to behave when excavated. Soil assessment at a rescue incident must be a quick and simple process. The results of a rescue soil assessment are used to identify soil conditions and the level of danger associated with them.

The Occupational Safety and Health Administration (OSHA) requires all classifications to be determined based on one visual test and one manual test performed by a competent person. Many of the manual tests recognized by OSHA are not practical for use at rescue incidents because of the skills, experience, equipment, and time needed to obtain accurate results. Rescuers should use visual and manual assessments (discussed later in this chapter) to help them gauge the risk involved in any potential collapse situation.

Types of Soil

Each type of soil represents a varying degree of danger based on the characteristics that make it a part of that class **TABLE 3-1**. When multiple layers are present in the soil, the classification will be determined by the layer that is normally least stable **FIGURE 3-1**.

Stable Rock

The least dangerous soil type, from a collapse perspective, is stable rock **FIGURE 3-2**. This kind of soil is a natural solid material that can remain standing after excavation. The danger associated with stable rock excavations generally comes from anything except a collapse. This does not mean, however, that some excavated products cannot fall on a worker. Accidents in this environment usually involve worker falls or equipment failures that cause entrapments.

Type A

Type A soils are cohesive materials with an unconfined compressive strength of 1.5 tons per square foot (tsf) or greater. Examples of this type of soil include clay, silty clay, clay loam, and sandy clay loam **FIGURE 3-3**. Cemented soils are also considered type A. Soil is not considered type A if any of the following conditions is present:

- The soil is fissured.
- The soil is subject to vibration.
- The soil has been previously disturbed.
- The soil is part of a sloped soil layer that is steeper than 4 horizontal units to 1 vertical unit.
- The material is subject to other factors that would require it to be classified as a less stable material.

Table 3-1 Soil Types

Type	Characteristics	Concerns
Type A	• Soil is clay or a mix with mostly clay. Soil plasticity is present. Fissures and other signs of movement are not present. Spoil piles maintain steeper (greater than 56 degrees) angles of repose. • Unconfined compressive strength of 1.5 tons per square foot (tsf) or greater.	• Unusual conditions for a rescue response because the soil is stable and less likely to collapse. • If soil shows signs of movement (fissures, sloughing, raveling, or collapse), or if the trench has been subjected to vibrations, install a shoring system that is strong enough to support C-60 soil.
Type B	• Mixed soil with less clay. Includes granular soil with more than 15% clay. Fissures and other signs of active soil (sloughing or raveling) may be present. Includes	• The most common type of soil for a rescue response. Soil often looks fairly compact and stable when it is first dug, but becomes active with time. If soil shows signs of movement

	previously excavated soils that are not type C soils. Spoil pile angle of repose is 34–55 degrees. • Includes cohesive soil with unconfined compressive strength of 0.5–1.5 tsf.	(fissures, sloughing, raveling, or collapse), or if the trench has been subjected to vibrations, install a shoring system that is strong enough to support C-60 soil.
Type C	• Granular, sand and sandy loam (mix). Can include submerged soil. Spoil pile angle of repose less than 34 degrees. • Includes cohesive soils with unconfined compressive strength less than 0.5 tsf.	• Unstable and heavy soil that is further categorized as either C-60 or C-80. The numbers 60 and 80 represent the lateral pressure (per square foot of exposed wall) times depth.
C-60	• Includes weak/unstable soil types that will stand long enough to install shoring and have a water level at or below the bottom of the excavation.	• In type C soils and in all soils, whenever a cave-in has occurred, rescuers should install shoring systems that are strong enough to support C-60 soil unless the soil has C-80 characteristics.
C-80	• Soil that will not stand up long enough to install shoring. Water level above the bottom (floor) of the trench. Moving soil that looks like wet concrete, mud, or quicksand.	• Conventional trench rescue shoring (panels/struts and wales) is not effective in C-80 soils. Trench boxes, sloping, and sheet piling are commonly used techniques.

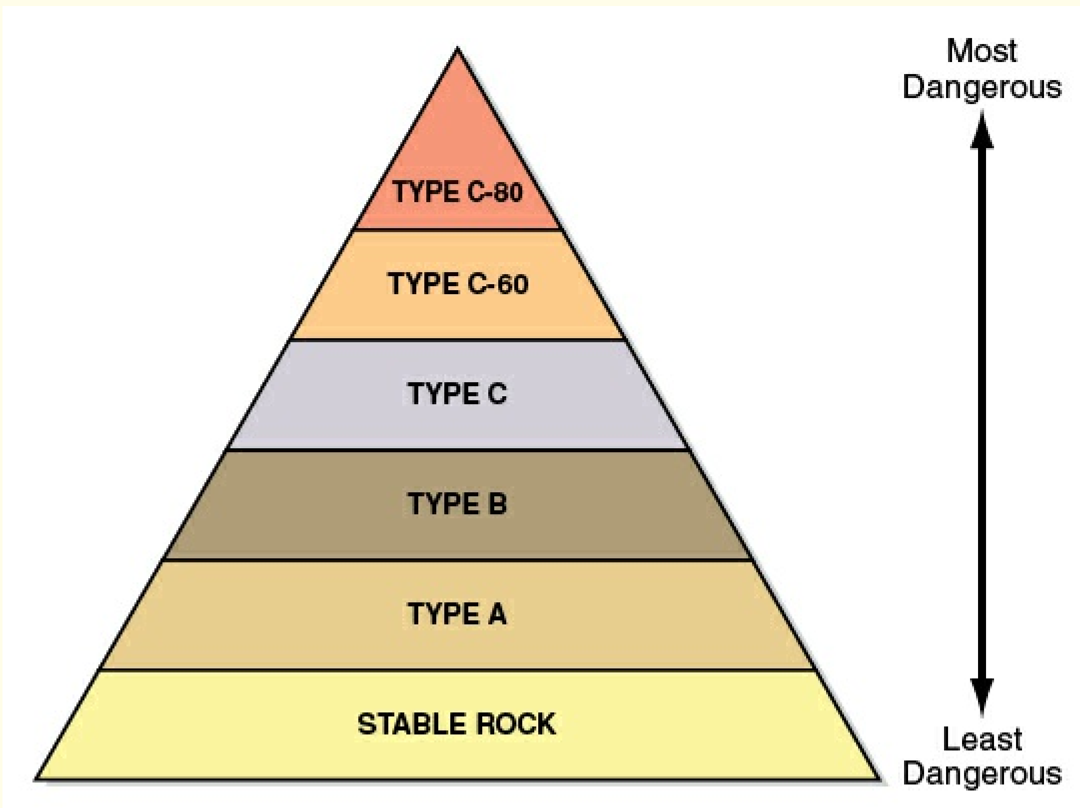

FIGURE 3-1 Stable rock is the least dangerous type of soil, with type C-80 being the most dangerous.

FIGURE 3-2 Stable rock.
Courtesy of Ron Zawlocki

FIGURE 3-3 Type A soil.
Courtesy of Ron Zawlocki

■ Type B

Type B soils are those cohesive materials with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf, or granular cohesionless materials, including angular gravel, silt, silt loam, sandy loam, and sandy clay loam **FIGURE 3-4**. Type B may also be a previously disturbed soil, unless it would otherwise be classified as type C. Alternatively, it may be a soil that, while meeting the unconfined compressive force requirements for type A, is fissured, or is subject to vibration from an external force, such as vehicles traveling on a roadway. In addition, it could be a material that is part of a sloped system steeper than 4 horizontal units to 1 vertical unit.

■ Type C

Type C soils are those cohesive materials with an unconfined compressive strength of 0.5 tsf or less. They include granular soils, sand, and sandy loam **FIGURE 3-5**. Type C soils also encompass submerged soils, soils from which water is freely flowing, and submerged rock that is not stable. Additionally, this type includes sloped or layered systems where the layers dip into the excavation at a slope of 4 horizontal units to 1 vertical unit, or steeper.

FIGURE 3-4 Type B soil.
Courtesy of Ron Zawlocki

FIGURE 3-5 Type C soil.
Courtesy of Ron Zawlocki

In underground construction, after a soil has been classified and conditions that determined the original classification change, a reclassification must be done by a competent person. This may necessitate a change in the type of protective system selected to accomplish the rescue or at least a change in the risk–benefit analysis of the rescue attempt.

■ Other Soil Classifications

During your education in trench rescue, you are likely to come upon other classifications of soil not listed in the OSHA standard, such as C-60 and C-80 soils. Type C-60 comprises soil that is either moist and cohesive or moist and granular, but that does not fit into the type A or type B classification and is not flowing or submerged. Type C-60 soil can be cut nearly vertical, and a trench in this soil will stand unsupported long enough to allow shoring to be installed. Type C-80 soil consists of moving or running soil that will not stand up long enough for shoring to be installed. It is often found below the water table line.

This exception for C-60 and C-80 is allowed because OSHA recognizes the use of classification tables other than those provided in the OSHA standard. The use of alternative classification tables is permitted only if the tabulated data are approved by a registered professional engineer for use in design and construction of the protective system. The key here is the term “registered professional engineer.” Based on this OSHA interpretation, you may encounter additional subcategories of recognized soil types.

Tactical Tip

OSHA requires a "competent person" to test and analyze soil. A competent person is trained and experienced and conducts visual and manual tests daily, if not several times each day. Rescuers, in contrast, usually receive an abbreviated version of soil analysis training and have little or no opportunity to practice those skills following the conclusion of their course. The soil testing procedures discussed in this chapter are included to give you an understanding and appreciation of what a competent person from the underground construction industry would do to test and analyze soil. It is understood that at a trench rescue scene you will not be performing this level of soil analysis and classification. The overwhelming majority of rescuers do not have the training and experience needed to accurately test and classify soil in this manner **FIGURE 3-6**. A simpler approach, discussed in the Rescue Soil Assessment section at the end of this chapter, should be used by rescuers.

FIGURE 3-6 Rescuers mistakenly considered this active soil to be type A. They used a construction-based shoring technique (spot shores) designed for stable and cohesive soil.
Courtesy of Marc Messier

VOICES OF EXPERIENCE

One of the more thought-provoking trench rescues we responded to recently occurred in a neighboring jurisdiction. This community of approximately 80,000 includes a mix of single-family residential homes and large retail commercial developments. The fire department that covers this area has limited technical rescue resources and called for our help immediately in the incident described here. We were dispatched to a report of a man trapped in a hole approximately 10 feet (3 m) deep. We responded with our heavy rescue unit and six trench rescue personnel, with an additional six technical rescue personnel responding from different parts of the city to rally at the incident.

"Because the soil was very sandy and active, it was obvious there would be a need for significant sheeting and shoring."

Upon arrival, we found one victim trapped in a wide U-shaped hole approximately 10 feet (3 m) long, 8 feet (2.4 m) wide, and 9 feet (2.7 m) deep, butted up against the foundation of a two-story home. All three of the soil walls were nearly vertical and unstable. The fourth wall was the concrete foundation wall of the house. The victim was the home owner, who had been using a small piece of excavating equipment to dig out the area to install new drain tiles. He became trapped when he went down into the trench to inspect his work. He was buried to his waist but was conscious and able to assist in his rescue. Because the soil was very sandy and active, it was obvious there would be a need for significant sheeting and shoring.

The first-arriving engine company had a trench rescue-trained fire fighter onboard and the initial actions were performed admirably, including cordoning off the area, making the correct notifications, and getting ground pads in place. As a result, the technical rescue team was able to hit the ground running and quickly installed panels on three sides of the trench, with the fourth side being the actual foundation of the house. Because the distance along the axis of the hole was so wide, it was necessary to use the Paratech Gold rescue struts, which were a new concept at the time. The larger-diameter struts provide more strength and can be used at longer lengths (length/diameter ratios). They proved to be the right call and were installed just above the dirt trapping the patient at about 6 feet (1.8 m) deep and again 2 feet (0.6 m) from the lip of the trench. Along the other axis, regular Paratech Gray rescue struts were installed from panels to the poured concrete foundation. Rescuers then entered the hole.

As rescue operations began in the hole, the victim started to go into shock. Thus it was necessary to have paramedics enter the hole to get an IV started and treat the victim while digging operations continued. The loose soil made it necessary to install supplemental shoring as the hole around the victim grew. However, because the soil was so loose, once the first set of supplemental shores was in place at about 18 inches (0.5 m), the patient was able to loosen his legs and help free himself.

Lessons learned included the following:

- The success of this incident depended on a strong incident command system (ICS), an established trench rescue response system (rescue specialists and equipment), and training at all levels (awareness, operations, and technician) of responders.
- Initial actions (site control, scene management, and activating the response system) are a key component to a successful technical rescue. The actions taken by the first-due fire/rescue companies have a profound effect on the success or failure of the entire rescue operation.
- Having a good understanding of shoring basics (collect the load, transfer the load, distribute the load, and resist the load) is critical to making decisions when the trench you need to

shore is different from the ones you have seen in training. Whenever soil is not cohesive, is active, or is running, shoring material that is strong enough to collect and resist the moving soil must be used. Three-quarter-inch FinnForm panels do a great job of collecting the load of active and noncohesive soil (running sand, in this case). It also works well in distributing the load to the opposing wall.

- Knowledge of your equipment capabilities and soil forces (load) provides for an informed decision on the selection and use of struts. In this incident, knowing that larger-diameter (length/diameter ratio) struts can significantly increase the safety factor for larger spans made the selection and placement of struts relatively simple. The smaller-diameter and more plentiful Paratech Gray struts were used to span the areas 8 feet (2.4 m) wide. The less available Paratech Gold struts were reserved for use for cross-shoring the spans that were 10 feet (3 m) and wider.
- When a tactically challenging rescue occurs, it is easy to get caught up in the moment and focus on making the correct tactical decisions. We must never forget that patient care must remain our utmost concern. We are not sent to a trench accident just to do a great job shoring a trench—we are sent there to save a life.

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Rescue Specialist, Michigan Urban Search and Rescue Task Force 1
Rescue Instructor, Michigan State University and the MUSAR Training Foundation

Soil Testing for the Competent Person

All of a soil's characteristics require proper evaluation to assume any degree of confidence in your protective system and thus the safety of your rescuers. To illustrate how critical testing and proper evaluation can be, you need look no further than the trench fatality statistics and the subsequent soil profiles developed for those incidents. An overwhelming majority of trench fatalities occur in clay and mud excavations, because these soils appear safe as compared to sand or gravel. You should not draw conclusions about a trench's safety based on its appearance; instead, rely on your knowledge of testing procedures. The soil testing procedures listed in this section are intended to enhance the rescuer's understanding of what OSHA requires workers to do before they install a shoring system and enter a trench.

■ Visual Test

The visual testing requirements to determine soil classification effectively are accomplished by inspecting the excavated material, the soil that forms the trench wall, and the excavation site in general. This overall site evaluation helps offset the fact that the layers in the soil may change as the excavation gets deeper. Remember—soil classification is based on the weakest soil in a layered system.

When the dirt is being excavated or when you first arrive on the scene, examine any soil that has been previously excavated. This will help you determine the initial cohesiveness of the soil. Soil made primarily of fine-grained material that remains in clumps is said to be cohesive. Soil that breaks up easily and is primarily composed of coarse-grained sand or gravel is considered granular **FIGURE 3-7**.

The trench particles can tell you a lot about the soil, but the most important area of the visual assessment will be the trench walls and the area surrounding the trench lip. On the trench walls, look for layered soil and any indication that the soil was previously disturbed **FIGURE 3-8**. The presence of utilities can indicate disturbed soil. As previously mentioned, a mixed soil will usually not be cohesive. In general, similar or identical particles of soil are the most likely to be attracted to each other and to remain attracted.

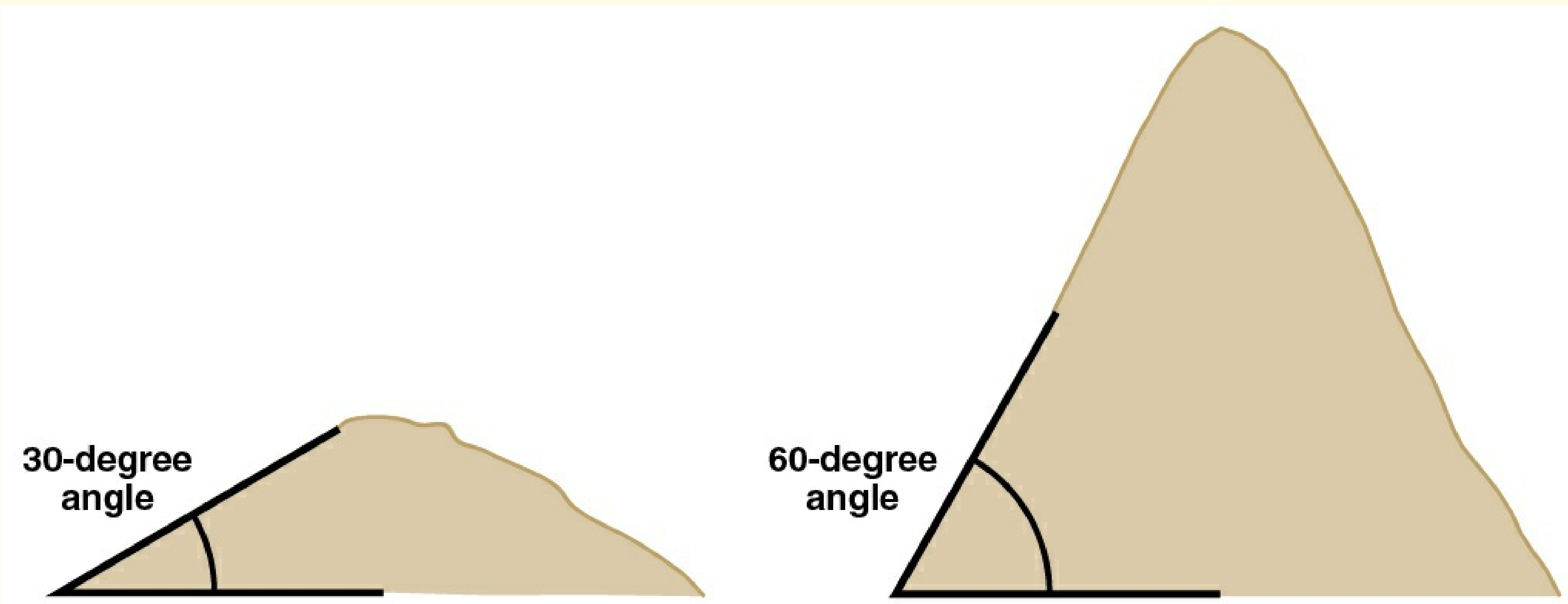

FIGURE 3-7 Spoil that cannot stand at steeper angles indicates less cohesive and less stable conditions.

FIGURE 3-8 Be very cautious of layered soils in an open trench.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

The visual evaluation should also determine whether the trench wall contains fissures or tension cracks that could suggest a potential collapse. Fissures, or cracks, in the exposed trench are indicators that the walls are under tension and subject to rapid release and subsequent collapse. Likewise, the area around the trench should be checked for cracks in the soil **FIGURE 3-9**.

The effect of water in soil can also be analyzed by looking for indications of standing, seeping, or running water **FIGURE 3-10**. Water adds weight, and weight adds pressure (force) to the trench walls. This pressure is called hydrostatic force. Standing, seeping, and running water are signs of hydrostatic forces. Look for surface water that has pooled (standing) or is running at the trench floor, as well as water seeping through the trench walls. As a clue to the anticipated hydrostatic forces, look for indications that the contractor has "well pointed" the area surrounding the excavation **FIGURE 3-11**. Well points are used to remove excess water from saturated soil before digging a trench.

FIGURE 3-9 Cracks in the soil indicate drying and can be the first sign of faults in and around the open trench.
Courtesy of Ron Zawlocki

FIGURE 3-10 When running or standing water is present in a trench, the site should always be considered type C soil.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 3-11 Look for indications that the area around the excavation has been well pointed.
Courtesy of Ron Zawlocki

■ Manual Test

A manual test is necessary to determine the various characteristics of the soil and to learn its relative strength when placed under force. These types of tests are used to formulate an assumption regarding the soil's stability.

■ Plasticity Test

Plasticity of the soil is the property that allows the soil to be deformed or molded without any appreciable change in its total volume; it is determined by the plasticity test. The test is done by molding a moist or wet sample into a ball and then attempting to roll it into threads as thin as ⅛ inch (0.3 cm) in diameter. A cohesive material can be rolled into threads without crumbling. As a rule, if a 2-inch (5-cm) length of ⅛-inch (0.3-cm) thread can be held on one end without it tearing, the soil is considered to be cohesive.

■ Ribbon Test

The ribbon test is used to determine how much clay or silt the soil contains. This test is done with a saturated, fine soil and fine sands that are rolled together between the palms of the hands until a cylinder approximately $^3/_4$ inch (1.9 cm) thick by 6 inches (15.2 cm) long is formed FIGURE 3-12. The cylinder is then placed across the palm of the hand and squeezed between the thumb and forefinger until it is approximately ⅛ inch (0.3 cm) thick. The squeezed portion is then allowed to hang over the side of the hand. If the cylinder forms six or more ribbon sections about 2 inches (5 cm) long, it is said to be clay. The longer the ribbon, the more clay the soil contains. If it forms shorter, broken ribbons, then the soil contains silt. A clay loam will barely form a ribbon of any length.

■ Dry Strength Test

A dry strength test is done to determine the propensity of the soil to fissure. If the soil is dry and crumbles on its own (or when subjected to moderate pressure) into individual grains or fine powder, it is considered granular. If the soil is dry and falls into clumps that in turn break into smaller clumps, but these smaller clumps can be broken only with difficulty, it may be clay in any combination with gravel, sand, or silt. If the dry soil breaks into clumps that do not subsequently break into smaller clumps, initial clumps can be broken only with difficulty, and there is no visual indication the soil is fissured, the soil may be considered unfissured.

FIGURE 3-12 The ribbon test is used to determine the clay and silt content of soil.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

■ Thumb Penetration Test

The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils. This type of test is accomplished by placing your extended thumb against the exposed material and attempting to push through the sample. Type A soils can be readily indented with the thumb but penetrated only with great effort. Type C soils can be easily penetrated several inches by the thumb and molded with little effort. This test should be completed as soon as is practical after excavation occurs to keep the drying influences of the environment from affecting the sample FIGURE 3-13.

■ Drying Test

The drying test is used to determine the difference between cohesive material with fissures, unfissured cohesive material, and granular material. This procedure involves drying a sample of soil that is approximately 6 inches (15.2 cm) in diameter and 1 inch (2.5 cm) thick until it is thoroughly dry. If the sample develops cracks as it dries, significant fissures are indicated. Samples that dry without cracking should be broken by hand. If considerable force is required to break a sample, the soil has significant cohesive material content. The soil should then be classified as an unfissured cohesive material, and the unconfined compressive strength should be determined. If a sample breaks easily by hand, it is either fissured cohesive material or a granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they pulverize easily into very small fragments, the material is granular.

■ Penetrometer and Shear Vane

Several types of field instruments can be used to determine the unconfined compressive strength of the soil sample. The most popular of these devices are the pocket penetrometer FIGURE 3-14 and the shear vane FIGURE 3-15. When used correctly, the amount of force required to insert these instruments into the trench wall correlates to the unconfined compressive strength of that section of sample. The soil must have some moisture content to extract an accurate reading, primarily because the instrument must be pushed into the wall and read numerically.

FIGURE 3-13 The degree to which your thumb penetrates a soil sample can indicate the soil's overall strength and its susceptibility to failure.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 3-14 The penetrometer is a field instrument that is used to determine soil strength.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 3-15 The shear vane is a type of field testing instrument used to determine soil strength.
Courtesy of Geotest Instrument Corp.

■ Laboratory Testing

Although these techniques are not very practical for on-scene testing at an emergency, engineers and other soil scientists use some very interesting methods to determine the various characteristics of soil. For the most part, many of these complicated procedures are very accurate laboratory tests in which mathematical calculations are performed so that engineers and architects can design and build bridges, roads, and other structures with a high degree of confidence they will not sink or fall down. As you can imagine, an architect or engineer needs something a little more substantial than the "stomping foot" testing method mentioned later in this chapter.

Laboratory soil testing begins with gathering surface soil as well as soil collected at varying depths using a hollow-stem auger. The sample is then put through a sieve to determine its coarseness **FIGURE 3-16**. For instance, a number 40 sieve would have 40 holes per square inch that the sample could pass through. By knowing the total volume of the sample size and then running the sample through a series of sieves, you can determine the total makeup of the sample by percentage.

Named for a Swedish engineer, the Atterberg test can be done in a laboratory to determine the liquid limit (the water content, in percent, of a soil at an arbitrarily defined boundary), the plasticity index (the range of water content over which a soil behaves plastically), and the plastic limit (water content, in percent, of a soil at the boundary between the plastic and semisolid states) **FIGURE 3-17**.

The direct shear strength of soil is determined by using a core sample and performing a triaxle shear test. This test, which uses a sample that is twice as high as it is wide, applies both a vertical load and a corresponding lateral load. The point at which the sample shears indicates its *shear* *strength*. A similar test, called an *unconfined compression test*, is basically the same as the triaxle shear test, except that no lateral force is applied.

A consolidation test can be done to determine the settling potential of soil. For instance, when an excavation is backfilled, the engineers need to determine how much overfill is needed and at what rate the soil will compact. This test is done by adding a predetermined load to a measured volume of material. Loads are then applied in sequence and measured for compaction density.

FIGURE 3-16 A soil sieve is used to determine the total makeup of a soil sample.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 3-17 The Atterberg testing instrument is primarily used to determine a soil's liquid limit and plasticity.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 3-18 A nuclear moisture density gauge is a field instrument used to determine soil density and moisture.
Courtesy of DOE and Fluor Fernald

The sedimentation test is used to determine the profile of the soil. In this test, a sample of soil is placed in a jar with water and shaken vigorously. The sample is then allowed to rest for 3 minutes. The individual elements of the sample are then measured for stratification. Basically, the sand will fall to the bottom. The silt will settle in the middle, and the clay will be suspended toward the top.

Another very common tool used in the field is a nuclear moisture density gauge **FIGURE 3-18**. This portable tool is handy for field use to measure soil density and soil moisture. The basic process involves using a probe to send gamma rays into the earth and then measuring the speed of the electrons as they reflect back to the probe. Such a gauge also contains an americium source that measures the hydrogen ions to determine soil moisture.

Rescue Soil Assessment

In reality, rescue personnel are not expected to analyze soil in the middle of an emergency. The bottom line is that these individuals have neither the time nor the skills necessary to conduct the analysis that construction workers are required to perform. Therefore, every type of protective system that rescuers build should be based on the worst-case scenario, which is type C soil. Ultimately, a rescuer's focus is not so much knowing the specific soil type as it is recognizing soil characteristics that can be used to determine the level of risk associated with the soil at each rescue incident.

This section presents a few real-world guidelines for determining soil type so that you will be able to determine a corresponding level of potential risk. The visual assessments are simple and do not require special equipment. Each manual assessment method is based on two very important aspects of soil strength: the breakability and moldability of soil.

■ Visual Assessment

To perform a visual assessment, first look at the trench wall and lip area. Are there signs that the soil is active (no longer stable)? Indications of unstable soil include a cave-in, fissures (cracks in the wall or on the lip), sloughing, raveling, and bulging areas (usually seen in the bottom one-third of the wall).

Second, look closely at the soil sample from the spoil pile. If the individual grains are readily apparent, it is sand or gravel base. Such a soil is not very cohesive and, therefore, has potential to become active or fail. Likewise, if you look at the sample and it is difficult to make out the individual grains, it is most likely cohesive. This may be a less dangerous soil **FIGURE 3-19**.

Third, look at the spoil pile itself and the angle at which the standing soil is resting under its own weight. This is the angle of repose. If the excavated material is lying at a somewhat steep angle, it is most likely much more cohesive than a soil for which the angle of repose is less steep. Of course, do not forget the effects that moisture can have on the spoil pile's angle. The free-standing time and the overall effects of drying can take what was once a cohesive and stable soil and turn it into a dangerous and active soil **FIGURE 3-20**. (For more information on the angle of repose and free-standing time, see the "Soil Physics and Trench Collapse" chapter.)

FIGURE 3-19 Sampling the soil and looking at its general characteristics can tell you much about the soil's strength. Note the dry and fine nature of the soil when it is compressed and/or broken.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 3-20 In some situations, moisture content will allow a running soil to have a steeper than normal angle of repose.
Courtesy of Scott Shahan

■ Manual Assessment

Moldability and breakability are the keys to a manual assessment. To assess moldability, a quick on-scene test is to simply grab a sample of soil and slowly add water. As the water is added, try to mold the sample into a ball. If it is moldable to any degree, it is most likely clay. If you cannot mold the sample, it is mostly sand.

To assess breakability, find a dirt clod and stomp on it with your foot. If the clod breaks, it is mostly silt—but if your foot breaks, it is mostly clay. If there are no clots, it is sand/gravel. Clay is generally more cohesive and more stable than silt and sand.

Interpreting the Assessment Results

TABLE 3-2 lists the information that you can obtain from the rescue soil assessment.

If all of the results from your rescue soil assessment point toward more stable soil conditions, the trench may not be in imminent danger of collapse. In this case, the standard shoring procedures should be followed:

1. Protect the lip area with ground pads.
2. Use panels and shores to create a safe zone around the victim (primary shoring).
3. Expand the safe zone (with panels and shores) to provide a safe working area (usually 12 feet [3.7 m] wide) for rescuers (secondary shoring).
4. Complete the shoring, making the safe zone at least as wide as it is deep, and adding supplemental shoring as needed. Your rescue shoring should be able to resist at least twice the force of C-60 soil.

If any of the results from your rescue soil assessment point toward more unstable soil conditions, the victim in the trench and rescuers working on the lip may be in imminent danger from collapse. This level of danger increases with each assessment result (visual or manual) that indicates unstable soil conditions. Rescue soil assessment information will help you make decisions about issues such as which type of lip protection to install or whether to implement temporary measures (e.g., spot shores, skip shores, excavator buckets) to initially protect the victim. The decision about when to attempt rescuer entry is made based both on hazards and on the victim's condition **FIGURE 3-21**.

Table 3-2 Signs of Stable and Unstable Soil

Unstable soils (higher risk)	• Signs of movement (active soil conditions) • Not cohesive (can see individual grains) • Not holding a steep angle of repose (spoil pile) • Cannot be molded (sand/silt) • No clots (sand) or clots that easily break apart (silt)
More stable soils (lower risk)	• No signs of movement (passive soil conditions) • Cohesive (cannot see individual grains) • Holding a steep angle of repose (spoil pile) • Can be molded (clay) • Clots that do not easily break apart (clay)

FIGURE 3-21 It is difficult to determine a soil type accurately using field tests (manual and visual). In this case, a registered professional engineer with years of experience underestimated this soil and was nearly killed by a collapse in soil that she evaluated as stable. After talking to the trapped engineer, fire fighters used shoring techniques designed for intact/stable soil instead of shoring for collapse conditions.
Courtesy of Marc Messier

Wrap-Up

Review: Just the Dirt

- The system that underground construction workers use to classify soils is a hierarchical approach to determine the performance of a soil based on a decreasing order of stability.
- Types of soil include the following:
  - Stable rock
  - Type A
  - Type B
  - Type C
  - Type C-60
  - Type C-80
- Do not draw conclusions about a trench's safety based on its appearance; instead, rely on your knowledge of testing procedures.
- Soil testing by a competent person includes the following tests:

- Visual test
- Manual test
- Plasticity test
- Ribbon test
- Dry strength test
- Thumb penetration test
- Drying test
- Penetrometer and shear vane tests
- Laboratory testing

- For trench rescue personnel, the focus is not so much knowing the specific soil type as it is recognizing soil characteristics that can be used to determine the level of risk associated with the soil at each rescue incident.

Hot Terms

Atterberg test Test done in a laboratory to determine the liquid limit (water content, in percent, of a soil at an arbitrarily defined boundary), the plasticity index (range of water content over which a soil behaves plastically), and plastic limit (water content, in percent, of a soil at the boundary between the plastic and semi-solid states).

Clay A fine-grained substance that is plastic when moist.

Consolidation test Test used to determine the settling potential of a soil.

Dry strength test Test used to determine the propensity of a soil to fissure.

Drying test Test used to determine the difference between cohesive material with fissures, unfissured cohesive material, and granular material.

Liquid limit Water content, in percent, of a soil at an arbitrarily defined boundary.

Nuclear moisture density gauge A portable device used to measure soil density and moisture.

Penetrometer A field instrument that can be used to determine the unconfined compressive strength of the soil sample.

Plastic limit Water content, in percent, of a soil at the boundary between the plastic and semisolid states.

Plasticity index The range of water content over which a soil behaves plastically.

Plasticity test Test used to determine the ability of the soil to be deformed or molded without an appreciable change in its total volume.

Rescue soil assessment A quick assessment (manual and visual) used by rescuers to identify soil conditions and assign levels of risk associated with those conditions.

Ribbon test Test used to determine how much clay or silt a soil contains.

Sedimentation test Test used to determine the profile of a soil based on stratification of its elements in water.

Shear vane A field instrument that can be used to determine the unconfined compressive strength of the soil sample.

Silt Loose soil made up mostly of fine rock.

Thumb penetration test Test used to estimate the unconfined compressive strength of cohesive soils.

Triaxle shear test Test used to determine the direct shear strength of a soil.

TRENCH RESCUER *in action*

You are a member of a trench rescue team that has been dispatched to a possible trench rescue incident in a residential housing development. It is early winter, with an inch or so of snow on the newly frozen ground. Upon arrival, you see a backhoe parked approximately 200 feet (61 m) off the roadway on top of a small hill in a green space in the middle of the housing development. There are obvious signs of excavation. The operator is frantically waving you over to his location.

When your crew arrives at the top of the hill, you find an approximately 30-year-old male pinned face-first against the wall of a 10 foot (3 m) deep by 6 foot (1.8 m) wide trench by a slough-in from the spoil pile side of the trench. The soil is midway up to his shoulders. The victim is conscious, communicating, and well aware of his predicament. The backhoe operator has placed his bucket against the collapsed wall of the trench in an attempt to prevent any further collapse. A quick visual test of the soil in the trench shows that it is predominantly clay but there is a layer of sand running through it. You also note that the spoil pile, which runs right to the edge of the trench, contains large chunks of clay mixed with some sand.

You are asked by your officer to establish face-to-face contact with the victim. You determine that other than being pinned to the wall of the trench and being very cold, he has no other apparent injuries at this point in time. You also discover that he is an engineer and that his crew was testing the soil to determine why the hill was "moving," as it was slated to become a park within the new housing development. The engineer tells you that he had tested the soil and determined it to be type A, which is why he got into the unsupported trench.

You report this information back to your officer and he assigns you to be the shoring officer.

1. There are several ways to test for soil type. What are the preferred methods to use for a rescue soil assessment?
   - **A.** Penetrometer and visual tests
   - **B.** Quick manual and visual tests
   - **C.** Sedimentation and shear vane tests
   - **D.** Thumb penetration test
2. Which classification of soil do you consider this to be?
   - **A.** Type A
   - **B.** Type B
   - **C.** Type C
   - **D.** The actual soil type is not important because for rescue purposes you treat all collapse situations as if it were the worst possible type of soil.
3. Based on your rescue soil assessment, you determine that the soil is inherently unstable and is at risk of secondary collapse. What should be your first action in this situation?
   - **A.** Establish a safe zone around the victim.

B. Place ground pads around the lip of the trench.
C. Remove the backhoe from the trench area.
D. Test the atmospheric conditions in the trench.

4. What does the presence of layered soil in the trench and loose sand mixed with such a large amount of clay indicate about this soil?
   A. It is a type B soil.
   B. The soil may be previously disturbed and more prone to collapse.
   C. It is a type A soil.
   D. Soil plasticity is present.
5. Which three things need to be looked at during a visual assessment?
   A. Depth, length, and width of the trench
   B. Location of the victim, amount of collapsed soil, and the area of the collapse
   C. Trench wall and lip area, soil from the spoil pile, and the spoil pile
   D. Location of the spoil pile, depth of the collapse, and size of the collapse
6. Which of the following is *not* a sign of stable soil (lower risk)?
   A. No sign of movement
   B. Cohesive
   C. Cannot be molded
   D. Clots that do not easily break apart

Soil Physics and Trench Collapse

CHAPTER 4

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss basic soil physics NFPA 8.1.1 NFPA 8.1.2. (pp 48–49)
- Describe the physical forces associated with collapse NFPA 8.1.1 NFPA 8.1.2 NFPA 8.1.5. (pp 49–51)
- Identify and describe factors that lead to trench collapse NFPA 8.1.1 NFPA 8.1.5. (pp 51, 54–56)
- Identify and describe types of trench collapse NFPA 8.1.1 NFPA 8.1.2 NFPA 8.1.5. (pp 56–58)

Skills Objectives

There are no Trench Rescue Level I skills objectives for this chapter.

Additional Resources

- 29 CFR 1926 Subpart P, *Excavations*
- NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*
- *OSHA Technical Manual (OTM)*, Section V, Chapter 2, Excavations: Hazard Recognition in Trenching and Shoring

You Are the Trench Rescuer

As you and your crew drive to the grocery store, you see a new trench being dug at the corner of Main Street and Second Avenue. You have your driver pull over to get a better look. An operator is digging between the sidewalk and the curb to repair a broken waterline. The digging has reached a depth of approximately 7 feet (2.1 m), and the soil looks stable and dry. A trench box is on a trailer that has one lane of Main Street blocked off to traffic. Things look good, so you head to the store.

Later that day, while returning to the firehouse from your sixth medical run, you notice that all work has stopped at the water line repair site. Upon closer inspection, you see that a large section of wall has caved in. A neighbor tells you that she heard some yelling and then saw the workers run up the ladder just before the cave-in occurred. The trench box remains on the trailer, serving as a good road barricade.

The soil in the bottom of the trench is heavy and wet. It looks like the crew reached a depth of approximately 10 feet (3 m) before the cave-in occurred. There are no pumps or dewatering equipment on the scene. Heavy traffic continues to travel on both Main and Second. You wonder what happened to that dry and stable trench you saw this morning; it now looks like about 2 cubic yards (1.5 m^3) of wet soil is on the floor of the trench. If the workers had not escaped in time, you would be shoring these walls and digging them out.

1. The water from the broken line has added to the weight of the soil. Estimate how much the cave-in pile (2 cubic yards [1.5 m^3]) weighs.
2. When soil gains weight, the lateral forces on the wall of a trench dug in that soil increase. What lateral force (pounds per cubic foot) would you assign to wet and unstable soil?
3. List several possible causes of this trench changing from passive soil to active soil.

Trench Rescue Level I

Soil Physics

To appreciate how to handle a trench collapse, a basic understanding of soil physics is necessary. If we strive to understand the concepts related to why a trench collapses, we will go a long way toward protecting the trench or keeping it from collapsing further.

One of the keys to success in trench rescue is recognition of how the various physical elements interact and then contribute to a collapse situation. Many of these factors, either by themselves or in conjunction with other physical factors, need to be evaluated before a trench rescue intervention is attempted.

One of the most important physical forces of nature that determines whether something stands or falls is the force that draws everything to the center of the earth—gravity. On a very basic scale, if we dig a hole and then leave, the hole will eventually fill itself back in. This tendency is simply nature's way of reaching the lowest energy state. In reality, a hole in the ground is preventing the earth from reaching the lowest gravitational energy state, which is an overall spherical planetary shape **FIGURE 4-1**. (Gravity is discussed in more depth in the "Lifting, Moving, and Stabilization" chapter.)

FIGURE 4-1 Mass, as it relates to other objects of mass, determines the effects of gravity.

Compounding the effects of gravity is the concept of hydrostatic pressure. Hydrostatic pressure is increased pressure caused by the addition of water to the soil profile. Dry soil can weigh between 80 and 120 pounds per cubic foot. When the weight of water is added to a very soluble soil, the resulting weight can be astounding. In fact, in some cases, water-saturated soil can weigh as much as 150 pounds per cubic foot **FIGURE 4-2**.

Going back to the "open hole in the ground" scenario, imagine the open walls of a trench as pressure outlets. The amount of resistance the soil has to internal pressure is a measurement of its unconfined compressive strength (UCS). At any level, the ground at rest is pushing in every direction with equal force; the adjacent soil, in turn, is pushing back with equal force. This balancing act explains why the ground stays stable. When one side of the ground is open, however, it is unconfined—that is, we have removed the section of earth that it was using for stability. When the UCS, caused by soil cohesion, is lower than the soil tension (the force of the trench wall trying to tip into the trench), the wall loses its ability to stand. A higher UCS suggests a more cohesive soil; a lower UCS indicates a less cohesive, or possibly water-saturated, soil. Thus UCS will vary with the water content of the soil. Notably, it will decrease as the cut trench face dries out, but can also decrease when too much water is present in the soil.

Another important concept related to the collapse potential of soil is its real or potential tendency to be active or passive. In general, an active soil has a tendency to move. This movement may result from the removal or failure of a protective system or simply from the soil's inability to hold its own weight.

A passive soil is just the opposite: It has no tendency to move. If you take a cubic yard of dirt and spread it on the ground over a circle with a 25-foot (7.6-m) radius, its potential would be passive at best. If you take that same volume of dirt and stand it up as a 25-foot (7.6-m) tall column resting on a 1-square-foot (9.3 cm^2) base, however, you will generate an active soil potential.

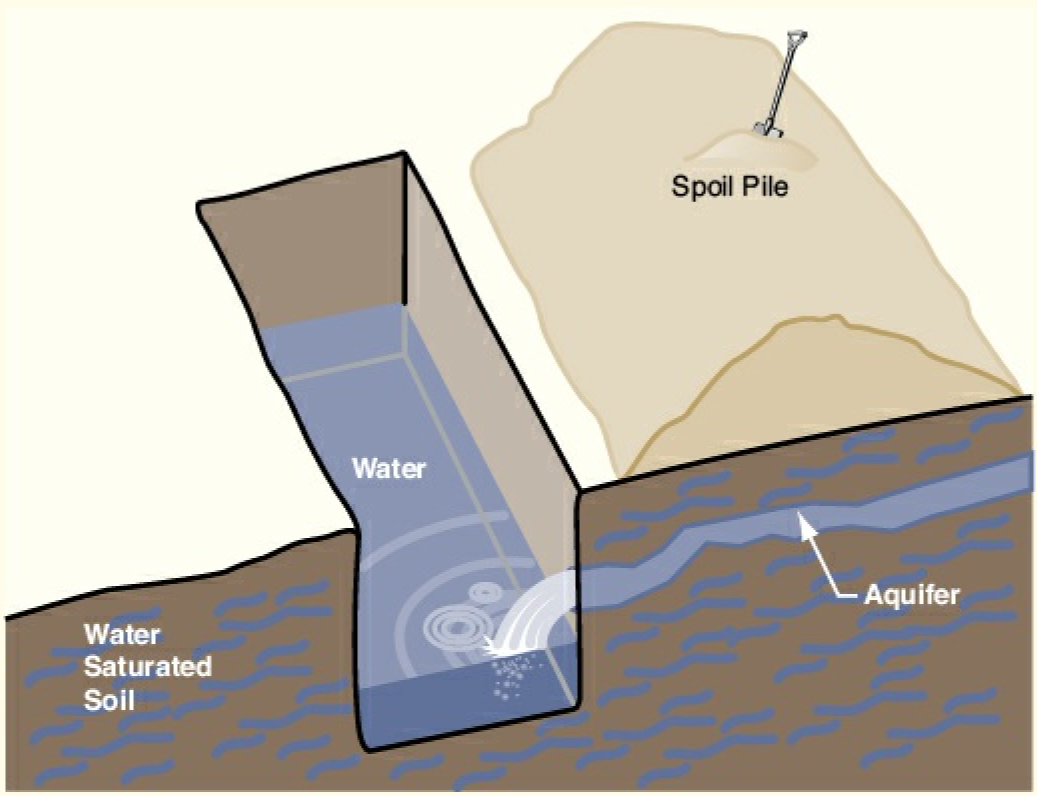

FIGURE 4-2 Water can change the dynamics of soil stability very quickly during rescue operations.

Let's apply these concepts to an imagined situation. Suppose you have just arrived on the scene where a worker has fallen off a ladder into a trench and broken his leg. The situation is certainly not life threatening, but the worker is in a significant amount of pain.

The spoil pile that is next to the trench consists of water-soaked sand and loam. It appears safe, but you realize that the height of the spoil pile has caused it to have an active potential. Compounding the problem is the proximity of the spoil pile to the trench lip.

The weight of the water in the spoil pile and the spoil pile's proximity to the trench lip are causing a higher than normal force on the open trench walls. Additionally, you determine that the very low unconfined compressive strength in the trench walls suggests the presence of a water-saturated soil that presents a very real collapse potential.

For all of these reasons you elect not to enter the trench but instead tell the unfortunate worker that he may become a victim of gravity if he does not pick himself up and crawl up the ladder. Using a rope to assist his climb, you pull him from the trench just as a major spoil pile slide occurs.

Great job! You just used the concept of soil physics to develop a trench collapse risk assessment that employed a non-entry rescue technique and very well may have saved the lives of both the rescuers and the victim. (Victim rescue is discussed further in the "Victim Access and Care" chapter.)

Training Tip

Recognition of hazards and procedures for non-entry rescue is an awareness-level activity that should be taught to all rescue personnel.

Physical Forces Associated with Collapse

Of all the physical factors associated with a trench collapse, probably none is as poorly understood as the weight of soil. Many people simply cannot relate to dirt as a volume that has mass and weight. To prove this point, think about this question: Have you ever seen someone stand under a piano being lifted to the upper floor in a building? No! If the piano were to fall, it would crush the individual. In contrast, people have no qualms about standing in a trench beside a volume of potentially collapsible soil, which can be just as dangerous as a falling piano **FIGURE 4-3**.

The weight of 1 cubic foot of most soil is approximately 100 pounds. That amounts to a 1 × 1 × 1-foot box of dirt. (That figure could be less or more depending on the type of soil and its moisture content.) Certainly, an even greater volume than 1 cubic foot of soil would fall on you in any significant trench collapse.

FIGURE 4-3 Workers in unprotected areas of a trench are not an uncommon sight in the construction industry.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

To determine the weight of soil scientifically, we can make a few observations. In very general terms, dry soil is one-half soil and one-half air. The specific gravity of rock is 2.65, which means that it is 2.65 times heavier than water. If water weighs 62.4 pounds per cubic foot, then rock would weigh 62.4 × 2.65 pounds, which equals 165.36 pounds (75.6 kg) per cubic foot.

If the soil you are dealing with is one-half rock and one-half air, it weighs 82.68 pounds (37.5 kg) per cubic foot. If the soil is one-half rock and one-half water (saturated), each cubic foot would weigh 113.88 pounds (51.7 kg). (We arrived at 113.88 pounds [51.7 kg] by adding together one-half cubic foot of water at 31.2 pounds [14.2] and one-half cubic foot of rock at 82.68 pounds [37.5 kg].) Generally, dirt weighs between 85 and 150 pounds (38.6 and 68.4 kg) per cubic foot, which in most situations can be averaged to 100 pounds (45.4 kg) per cubic foot.

To illustrate the seriousness of the problem, lie down on the floor, and have someone sit on your chest. Depending on the size and weight of your friend, that mass would amount to approximately 150 to 200 pounds (68.4 to 90.8 kg). Now imagine what just 10 cubic feet (1000 pounds [453.6 kg]) of soil on your chest would feel like. Clearly, it would be very hard to breathe.

There are specific reasons for how the earth falls in a certain manner. Some of these reasons relate to the manner in which the compressive forces are transmitted down and across a trench.

When the earth is in a stable state, it experiences no unbalanced pressures. That is, at any one point in the earth, the pressure is equally distributed. When we cut a hole in the ground, however, this balance is disrupted—more pressure is exerted on the remaining soil. When that pressure becomes too great because tension (active forces) overcomes cohesion (soil strength), you can guess what happens.

Training Tip

Make a clear 1 × 1 × 1-foot square Plexiglass box, and leave the top open. The box can then be filled with dirt and used as a tool to demonstrate the weight of soil.

For example, if normal soil weighs 100 pounds (45.4 kg) per cubic foot, then a column of dirt 1 × 1 × 6-feet tall would have a total force of 600 pounds per square foot (psf) (28.7 kPa) pressure at the bottom. One column over and 1 cubic foot up, that pressure would be 500 psf (23.9 kPa). This stepping process would continue upward as 400, 300, 200, 100, and then 0 psf when you got to the top of the column **FIGURE 4-4**.

The amount of lateral pressure exerted on the unshored wall is about one third of the total force as measured on the bottom of any cubic foot. In a 6-foot (1.8-m) deep trench, the force at the 4-foot (1.2-m) level would be approximately 400 psf (19.2 kPa) of vertical pressure. The lateral forces that could be expected would be approximately 132 psf (6.3 kPa). The distribution of lateral pressure occurs on about a 45-degree angle from the bottom of any given plane. When these lateral forces are released during a trench wall collapse, they result in rotational failure, which is the most prevalent type of collapse **FIGURE 4-5**.

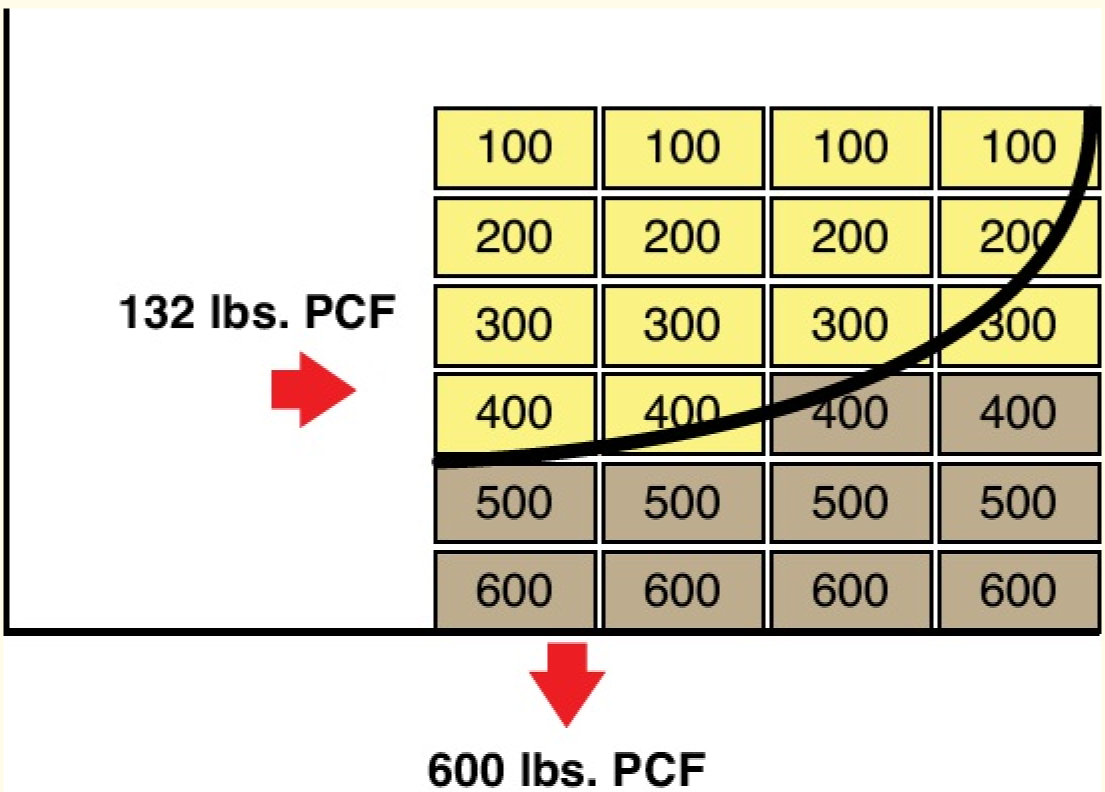

FIGURE 4-4 The distribution of force in a trench often causes the typical rotation failure in trench walls.

Actually, the most dangerous portion of the trench wall is the area about one fourth of the way up from the bottom. In a 6-foot (1.8-m) deep trench, the highest collapse potential would rest somewhere between the 4- and 5-foot (1.2- and 1.5-m) area (if the soil profile is the same throughout the trench wall and no other factor is involved). This concept may be difficult to understand until you realize that although the pressure is greater at the bottom, the approximate 90-degree angle present at the bottom at the trench wall provides a measure of stabilization. (Remember this theory because it is also discussed in the "Protective Systems" and "Trench Rescue Shoring Techniques" chapters, when we cover shoring installation procedures.)

Properly stabilizing a trench with shoring takes the pressure from one side of the trench and transmits it to the earth on the other side of the trench **FIGURE 4-6**. If the pressure is too great for the number or sizes of shores in place, however, they will bend, break, buckle, or otherwise collapse—reiterating Mother Nature's desire to bring stability to the world, one hole at a time.

Conditions and Factors That Lead to Collapse

Many conditions can ultimately lead to a trench collapse. While evaluating these factors, keep in mind that they can work synergistically to generate a very serious collapse situation. None of the factors by itself will always be the ultimate "straw that breaks the camel's back." Nevertheless, each can prove to be the tipping point, and therein lies part of the problem with a trench rescue. There is no definitive way to determine which one condition, or set of multiple conditions, will cause a collapse. Recognizing this complexity is key to success when evaluating the factors that could lead to trench failure.

■ Water

The addition of water can add tremendous weight to soil. As previously mentioned, water weighs 62.4 pounds per cubic foot (pcf), although the effect it has on soil is influenced by many factors. For instance, the absorption rate will ultimately determine the total weight for any given volume of soil. Additionally, the effect that water has on the soil's ability to maintain its strength is critical. Some soils initially gain strength with the introduction of water, but then at some point get saturated and become weak. Watch out for soils that look solid but are actually wet and unstable. For instance, consider clay soil: When dry, it can be powdery and loose. With the addition of water, it solidifies and becomes more stable and strong—but with the addition of even more water, it becomes fluid and loses strength.

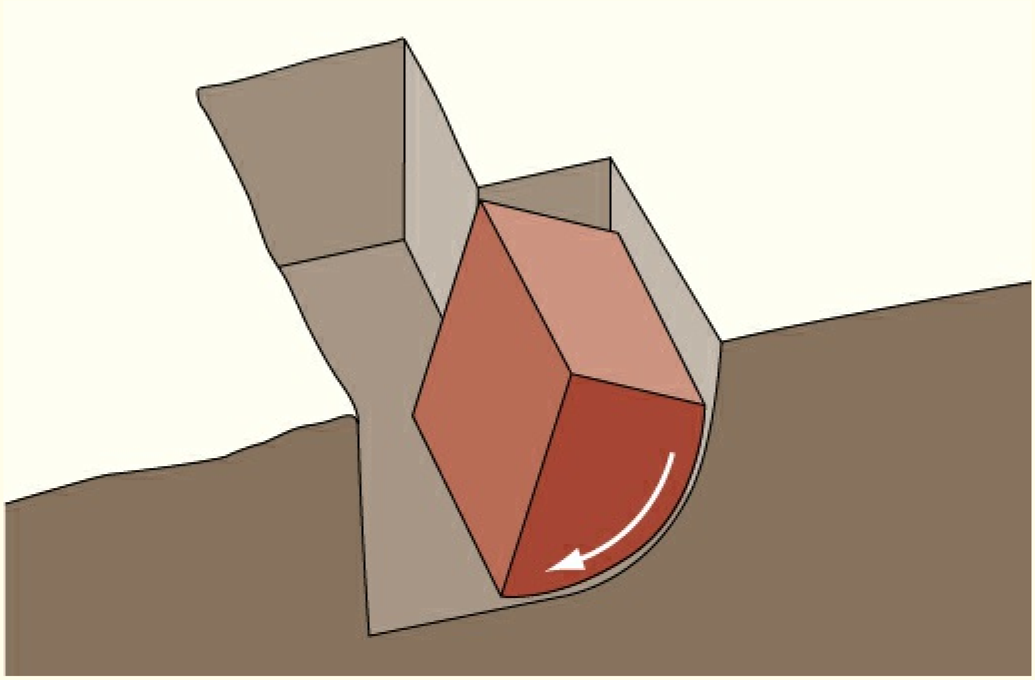

FIGURE 4-5 Rotational failure is by far the most common failure in nonintersecting trenches.

■ Freestanding Time

The freestanding time of a trench or open excavation can also be a factor that leads to collapse. After a trench is cut, it is subjected to environmental factors such as drying, wind, and water. The freestanding time also is a ticking bomb with respect to the compressive forces that the trench wall can withstand. The longer the trench is open, the closer you are to nature's attempt to fill it back in.

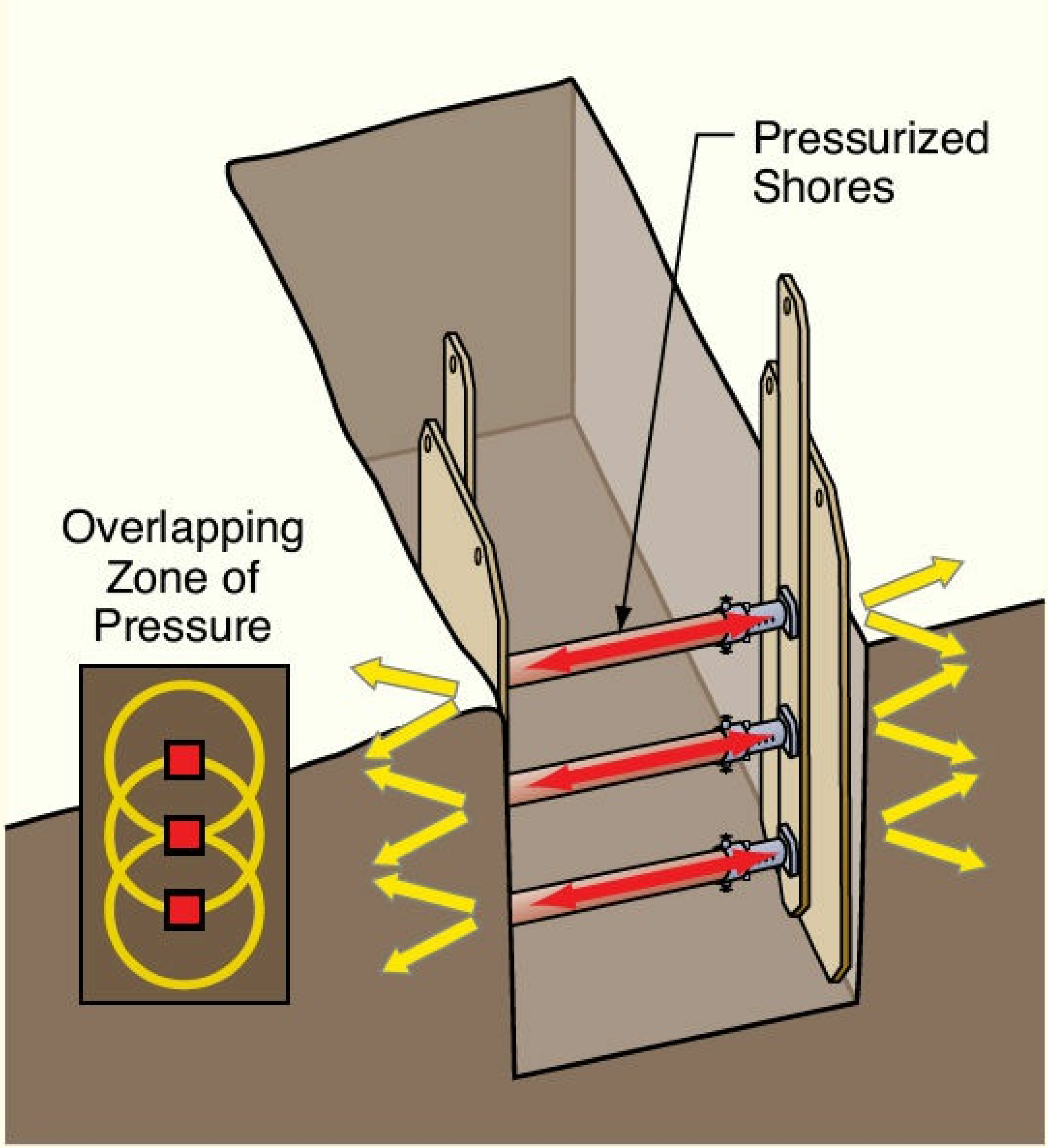

FIGURE 4-6 The practice of shoring transfers energy from one side of the trench to the other and stabilizes the unconfined forces associated with an open wall trench.

■ Varying Soil Profiles

Varying soil profiles within an excavation are a problem that rescuers face when determining the classification of the soil and its potential for collapse. Because multiple layers of different materials demonstrate different strengths and friction coefficients, it is often difficult to state with any reasonable certainty how they will react in a specific incident **FIGURE 4-7**. For example, how much of a fault is created when a layer of sand is sandwiched between two layers of clay? Certainly the sand creates a slip potential when the earth is not supported on one side of an excavation. Additionally, you need to determine just how much sand is contained in a certain clay sample and whether that sample represents a significant portion of the excavated material.

VOICES OF EXPERIENCE

At approximately 1000 hours on a sunny morning in May 2002, a report came in for a trench collapse in Harlem. In addition to the first alarm assignment of two engines, two trucks, and a battalion chief, other resources—Rescue 3, Squad 41, and the special operations command chief—responded. When the radio report confirmed that a victim was indeed pinned in the trench, the dispatcher also assigned Rescue 1 to the call.

"The north side panels were still in place and unsupported for several feet, which created a cantilever of concrete over the open trench."

When the first companies arrived, they discovered one man trapped and partially buried in a trench. The trench was approximately 25 feet (7.6 m) long and 8 feet (2.4 m) wide and was dug from the street directly to a building. The trench varied in depth from 6 feet (1.8 m) to 8 feet (2.4 m).

The north side of the trench wall had sloughed in the entire length of the trench. Above the trench on all sides were concrete sidewalk panels that were approximately 6 inches (15 cm) thick. The north side panels were still in place and unsupported for several feet, which created a cantilever of concrete over the open trench.

The construction workers had 2 × 12-inch shoring in place, although it was not sufficient to prevent a collapse. (Editor's note: This is an example of a trench collapse with shoring in place: 2 × 12-inch skip shoring is not safe on trench walls that are not compact and intact or that show any signs of movement [e.g., fissures, sloughing, raveling, collapsing].) When the north wall failed and the sheeting let go, it pinned the victim to the bottom of the trench under yards of soil and several pieces of lumber. He was buried up to his waist in soil, and his legs were pinned by two pieces of 2 × 12-inch shoring. His back was pinned up against the south wall of the trench.

When Rescue 3 arrived, we immediately started our assessment while the officer went directly to the chief to gather what information he had already obtained. At the time, there were two fire fighters and a police officer in the trench trying to ascertain the victim's condition and determine how badly he was pinned. Rescue 3 immediately started to shore the remaining trench walls. The protective system consisted of plywood sheeting that was placed on both the north and south walls of the trench and secured with walers and shores. This secured the trench and created a fairly open space in which to work.

As rescue personnel started digging around the victim, it became evident very quickly that this would be a difficult rescue. The effects of the collapse had pinned the worker's legs under the lumber originally used for sheeting and shoring. The lumber entrapping his legs was approximately 12 feet (3.7 m) long and completely buried; thus the decision was made to dig down along the worker's legs and under the buried lumber. This would allow minimum movement of soil while also accomplishing the objective of freeing his legs.

The area in the trench was tight, so entrenching shovels and buckets were used to remove the dirt. The digging operation continued until we had removed approximately 3 feet (0.9 m) of soil from around the worker's entrapped legs—although the deeper we dug, the less room there was to work in.

To enhance the digging operation, we called for Con Edison to respond with a vacuum truck. It is standard practice for two vacuum trucks to be on duty 24 hours a day in the city. One of the trucks arrived in less than 30 minutes and was immediately put to work. The vacuum truck operation made things tremendously easier. Even though the ground was hard clay with some rocks mixed in, fire fighters used tools to pry and loosen the dirt until it was of a size that could be vacuumed up through the hose and into the truck's debris tank.

When both of the worker's legs were finally freed, he was stabilized in the trench, splinted, spine stabilized, and lifted out of the hole in a Petzl harness/seat. He was then lowered onto a Stokes basket and transported to the hospital. During the extrication, operation personnel started an IV (intravenous line), and the victim was covered in blankets to help protect him and keep him warm. Oxygen was provided. He suffered only chest contusions and a broken leg and ultimately fully recovered.

In this situation, rescue personnel made a very good assessment and determined the worker had a strong chance of survival. For this reason, the primary objective was to establish a protective system suitable to allow the extrication to start and to prevent any type of secondary collapse. The use of the vacuum truck also strongly enhanced our ability to gain access to the worker's legs. It is always quicker to use these types of systems, although the dirt needs to be reduced to the proper size to be vacuumed. Finally, in addition to protecting the worker, we were able to provide advanced life support care that included precautions for crush syndrome, traumatic fracture injuries to the victim's legs, possible cervical spine injuries, and shock.

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Fire Fighter (Retired)
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Like sand between layers of clay, water can provide a slip fault in the earth. Frequently, excavated holes contain running water. Because the earth uses these underground streams as a method to move the water from one point to another, such flows present themselves as problems when we dig the hole. The running water may be either an aquifer or the result of the earth releasing the pressure of saturated soil. Both situations present a water-removal problem for rescuers involved in this type of collapse situation.

In one case, a plumber working on a broken sewer line nearly lost his life to the hydrostatic forces of saturated soil and running water. This worker got one of his legs stuck in the mud at the bottom of a 20-foot (6.1 m) hole. The suction created by the water and wet soil made it impossible for him to pull himself out: The more he struggled, the further entrapped he became. To make matters worse, water was running into the hole from the pipe that the plumber had disconnected at the bottom. Nothing is as heartbreaking as watching a man drown while you are trying desperately to free his submerged legs.

Luckily, the plumber avoided this dire fate. In this incident, the rescuers frantically assembled all of the available dewatering equipment to try to stay ahead of the impending water. Fortunately, someone had the presence of mind to place and open a self-contained breathing apparatus cylinder in the mud between his legs. The introduction of the air offset the suction created by the water just enough for the team to pull the plumber out of the trench with a rope.

Tactical Tip

Keep dewatering equipment on hand, and make sure that you have a backup in case the first mud, trash, or centrifugal pump fails. (Dewatering equipment is further described in the "Equipment" chapter.)

FIGURE 4-7 Layers of varying types of soil should be identified as having an increased collapse potential.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

■ Water Table

The water table also dictates which type of rescue situation you may confront at a trench collapse. If you live near the ocean or in another low-lying area, merely placing a shovel in the ground may create a hole for standing water. A high water table means a heavier, more unpredictable soil. Even the most experienced construction workers cannot determine the amount of time the trench can remain freestanding in such an environment **FIGURE 4-8**.

FIGURE 4-8 Minimize the effects of water in the trench by dewatering; however, be mindful that water-saturated soil may continue to present hazards to rescue personnel and increase the soil's lateral forces.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

In my own experience, I am reminded of a group of Phoenix fire fighters gazing into the bottom of a 6-foot (1.8-m) deep Virginia Beach trench that contained 2 feet (0.6 m) of water. "Perplexed" would only begin to describe their reaction to our native soil profile in Virginia. Know the types of soil in your response area, and preplan your protective system requirements based on this determination.

■ Disturbed Soils

Previously disturbed soils are another occurrence that is easy to spot but difficult to interpret. Disturbed soils lack cohesiveness because they are broken and/or mixed with other soil types—that is, unless the soil has been compacted back to its original condition or density. If the trench collapse occurs in a populated area, there is a very high probability that some type of utility has been placed in that location in the past. Rest assured that if you find a cross section of soil in an excavation that contains bricks, bottles, or other debris, it has been previously disturbed.

Nevertheless, not all previously disturbed soils are dangerous. For example, when using fill to build elevated roads, contractors are required to compact the soil to such a degree that it will not settle after the road is built. Engineers use mathematical calculations based on soil type and moisture content to determine maximum compaction. In these situations, previously disturbed soils are no more or less dangerous than undisturbed soils.

■ Heavy Equipment

Heavy equipment location represents another factor that can lead to a trench collapse. The same equipment that is digging the hole inevitably causes pressure to be exerted on the unsupported trench walls. The rule in this type of collapse is to turn off the piece of equipment and leave it in place. Generally, this will not be a problem: If the piece of equipment caused the collapse, it will probably be in the trench. If it is not already in the trench, leave it alone. An important point here is not to let your own heavy equipment become part of the problem. Keep it away from the rescue area or established hot zone **FIGURE 4-9**.

Safety Tip

No hard-and-fast rule exists concerning moving heavy equipment after you arrive on scene. Common sense will dictate whether it is better to move the equipment or work around it. In all cases, you should turn off the equipment after the operation starts and place the keys in a secure location.

■ Contractor Work

Contractors play an interesting role in trench collapse. Their consideration for digging a hole generally revolves around the concept of getting it dug, doing the work, and filling it in again. The contractor can expedite the work process by dropping the spoils right outside the trench to minimize swing time between scoops. While this practice makes sense from the contractor's perspective—the closer the spoil pile is to the trench, the faster it can be used to fill in the trench when the work is complete—it creates two problems for rescuers. First, the spoil pile adds additional weight to the unsupported trench wall. Second, part of the spoil pile may slide back into the hole. In any case, in a trench rescue scenario, the spoil pile must be moved far enough back to alleviate the weight concern and provide an area for placing the ground pads. When faced with this prospect, be sure to enlist the help of many people with shovels!

FIGURE 4-9 Rescue personnel need to consider the additional force that heavy equipment adds to the trench protective system requirements.
Courtesy of Nigel Letherby

■ Vibration

Another factor that can cause a trench collapse is vibration, which can result from road traffic near the collapse site, the machinery digging the trench, or other machinery being operated in the area. It can also be caused by directional drills and other machines used to force utilities under roadways **FIGURE 4-10**. The key here is to shut down the drilling equipment and limit the traffic not only in the rescue area, but also around the general area of the collapse.

Although less likely, events such as blasting, passing trains, and aircraft landings close to a trench rescue site can also cause vibrations that result in collapse. When effecting a rescue, efforts to control all source of vibrations within 300 feet (91.4 m) of the rescue area must be made.

Rescuers should become familiar with all of the factors that can lead to a collapse. Knowing what can cause a cave-in will help identify those areas of concern present when you arrive on the scene. Ultimately, you will need to eliminate or neutralize those concerns that could lead to rescuer injury or death.

FIGURE 4-10 Piston augers used to get utility lines under roads create vibration, which affects trench and spoil pile stability.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Types of Trench Collapses

Collapses can be somewhat predictable based on the soil profile, the type and size of the trench, and the conditions under which the trench was excavated. Familiarity with the types of collapse will help you determine the trench's potential for collapse and the proper protective system appropriate for making it safe.

■ Spoil Pile Slide

A spoil pile slide is the result of excavated earth placed too close to the lip of the trench. You may occasionally hear the term overburden pressure used to describe the effect of the weight of the spoil pile or other objects placed on the trench. This type of collapse is not as common as you might think, because most contractors are able to recognize and prevent this hazard **FIGURE 4-11**.

A spoil pile slide occurs when the soil's natural angle of repose—that is, the natural angle at which loose particulate products will support their own weight and can be expected not to flow from a standing position—is greater than the soil's cohesive tendency **FIGURE 4-12**. When this occurs, the soil flows back into the trench at the rate and volume necessary to bring the situation back into relative balance for the conditions. Remember that a hole in the ground wants to fill itself back in naturally; thus you should evaluate every pile of dirt around the trench for its potential to become active.

One factor contributing to this type of collapse is the presence of moisture in the newly excavated dirt, which may allow it to be piled at a steeper angle than would otherwise be possible. The moisture provides cohesion, holding the soil together. As the soil dries, it becomes less stable until its weight overcomes its cohesive properties. At this point, the spoil pile relieves the unbalanced pressure by flowing to a lower level.

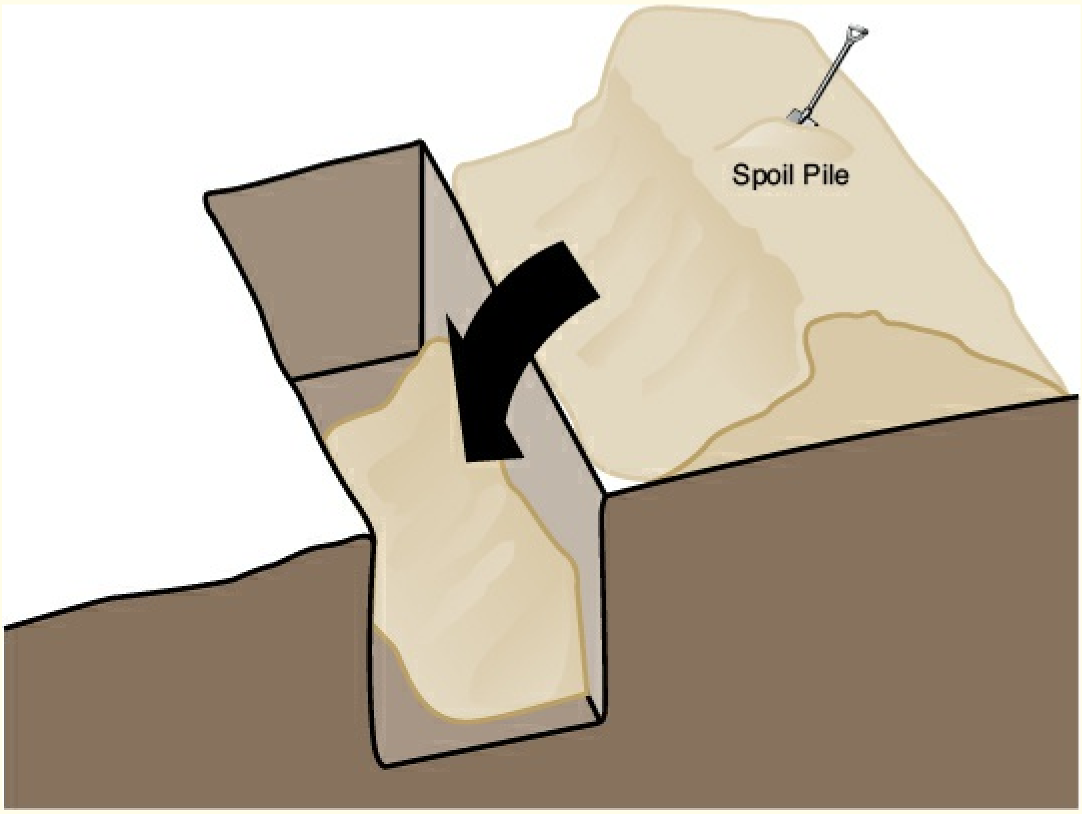

FIGURE 4-11 Spoil piles are frequently placed very close to the trench opening and must be considered as problematic in the rescue operation.

Tip

Angle of repose is a natural condition and should not be confused with maximum allowable slope, which is a human-made angle referenced in OSHA documents.

If the spoil pile maintains any potential to become active, it must be moved. This operation may require a few rescue personnel with shovels or, in a recovery operation, a heavy equipment operator and an excavator. The spoil pile must be moved to reduce the overburden pressure being transmitted to the open wall of the trench and to eliminate any possibility that it could flow back into the trench **FIGURE 4-13**.

■ Slough Failure

A slough failure involves the loss of part of the trench wall. It can be the result of several conditions. Frequently, the force associated with unconfined hydrostatic pressure becomes greater than the soil's ability to stand. Slough failure can also be caused by a spoil pile being placed too close to the trench lip. As extra earth is piled up, its weight is transmitted in a downward force communicated through the trench walls. When this pressure exceeds the soil's ability to support it, a failure will occur. Cracks in and around the excavated surface and multiple soil layers are key indicators that the potential for a slough collapse is present **FIGURE 4-14**.

Slough failure may also be referred to as rotational failure because it is characterized by a scoop-shaped collapse that starts back from the trench lip and transmits itself to the trench wall in a half-moon shape. Such a failure can result in the movement of large sections of soil to the trench floor. The outcome is a collapse that looks like someone took a spoon and carved out a chunk of earth. If the rotational failure is large enough, it creates a difficult protective system problem for rescuers, because the void will need to be filled at some point in the operation (see Figure 4-4 and Figure 4-5).

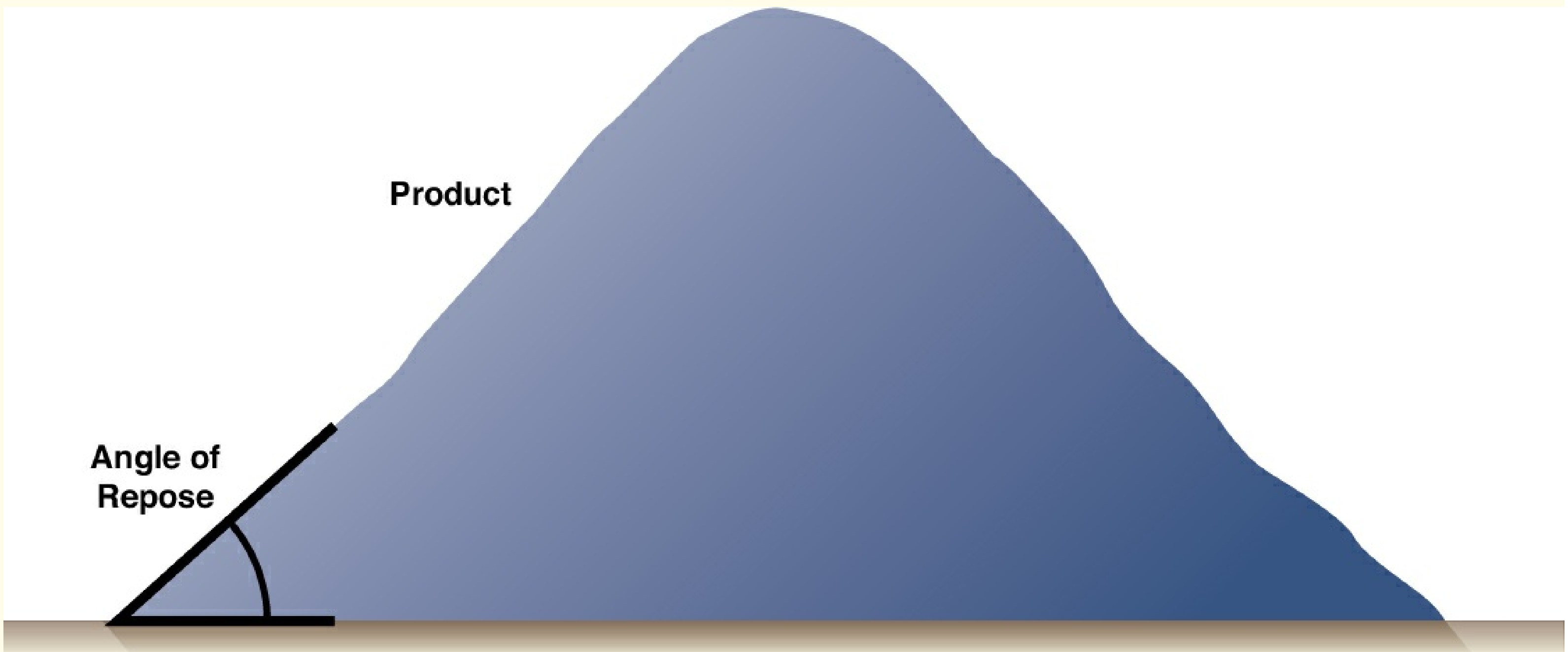

FIGURE 4-12 All materials settle at a specific angle that is based on their size, weight, and structural makeup.

FIGURE 4-13 Rescue personnel should always stand on ground pads while moving the spoil pile.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

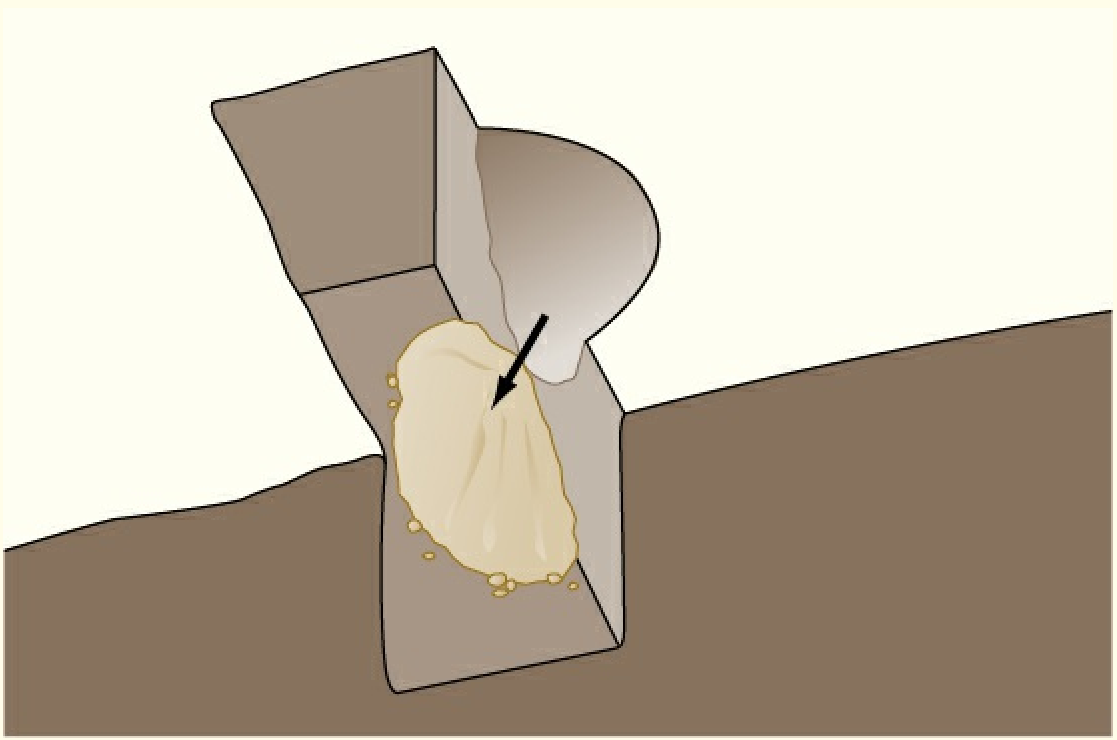

FIGURE 4-14 Slough failure is a type of rotational failure.

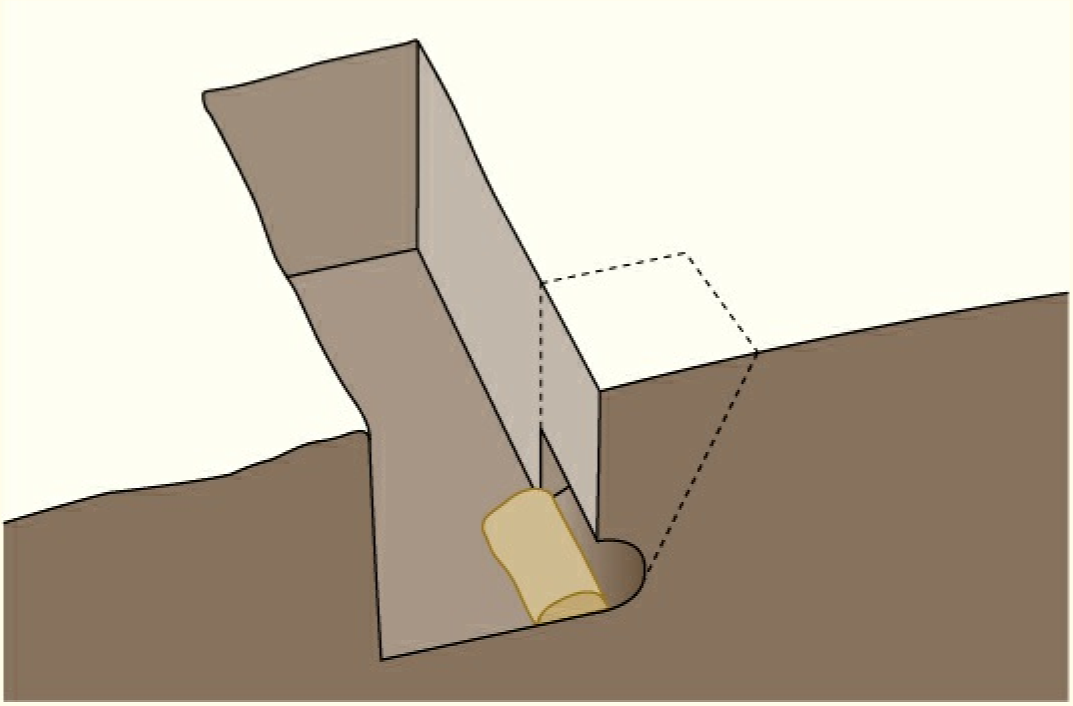

FIGURE 4-15 Wet conditions or a sandy soil profile can cause toe failure at the bottom of a trench.

■ Toe Failure

A toe failure is a slough failure that occurs at the bottom of the trench, where the floor meets the wall. As the soil falls into the trench, it creates an opening at the bottom that is characteristic of a cantilever. This type of collapse can be caused by a sand pocket or the effects of water at the bottom of the trench **FIGURE 4-15**.

Toe failure is a very dangerous type of failure for several different reasons. First, the rescuers might not notice the toe failure until they are standing on top of the cantilevered section of earth (and are therefore at risk of becoming part of a secondary collapse). Second, the situation is hard to correct until after a protective system is in place.

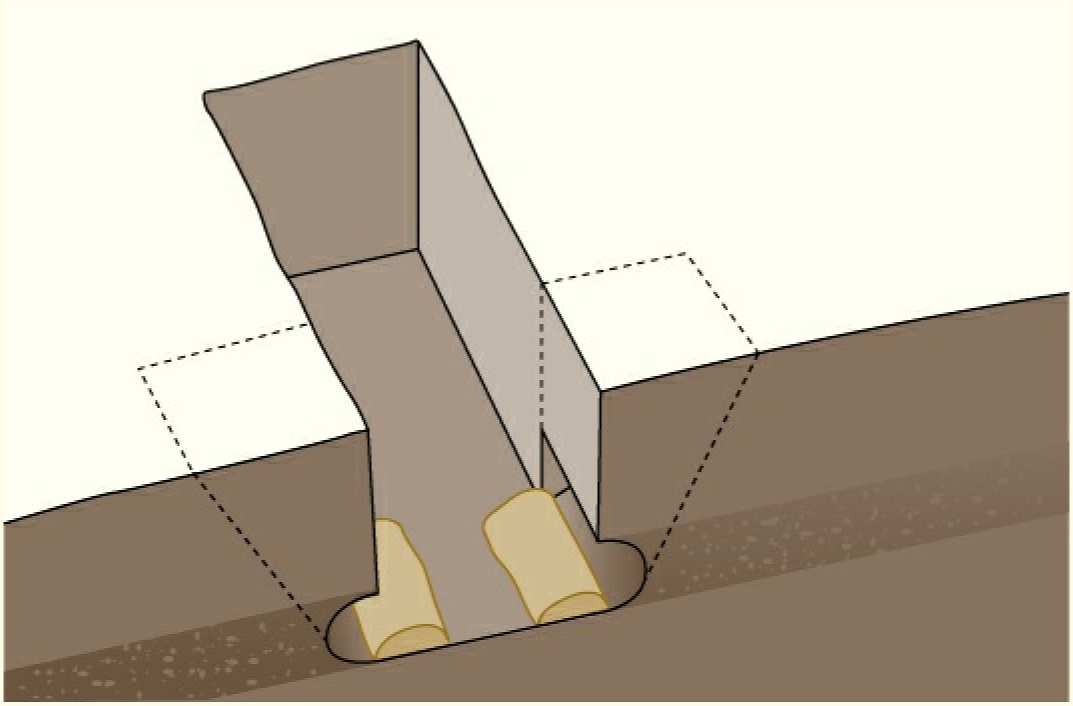

FIGURE 4-16 The failure of both sides of the toe in a trench can create a very difficult cantilever condition that is difficult to backfill during rescue operations.

The effects of water accumulation can also cause a bell pier condition. This type of situation does not usually occur suddenly, but more often is the result of a long-term toe failure on both sides of the trench floor FIGURE 4-16. The bell pier condition is also dangerous for the reasons previously discussed.

Shear Wall Collapse

A shear wall collapse occurs when a section of soil loses its ability to stand and collapses into the trench along a mostly vertical plane. This condition can occur when cracks in the earth's surface are exposed to the weather over time. As water runs into these openings, it washes out dirt and then dries. Over time, this washing and drying action causes a hole to become deeper and deeper, until it is not supported on two sides and a wall of dirt falls into the trench. Shear wall collapses are normally associated with fairly cohesive soils, a factor that makes them look safe. Big problem! As you might imagine, this type of failure can create a major collapse situation FIGURE 4-17.

Tactical Tip

Collapse potential and severity are proportional to how deep and wide the trench is and how long and difficult your rescue operation will be.

Wedge Failure

The last type of collapse that we discuss here is wedge failure. This type of failure normally occurs with intersecting trenches. It is characterized by an angled section of earth that falls from the corner of two intersecting trenches **FIGURE 4-18**. A wedge failure can be sudden and catastrophic. (The management of intersecting trenches is discussed in the "Trench Rescue Shoring Techniques" chapter.)

Although it may be relatively simple to determine which type of collapse has occurred, it is often quite difficult to understand why the collapse has taken place. Commit each of these types of collapse to memory; as we discuss the physical forces associated with various collapse scenarios, the reason each happens will become clear.

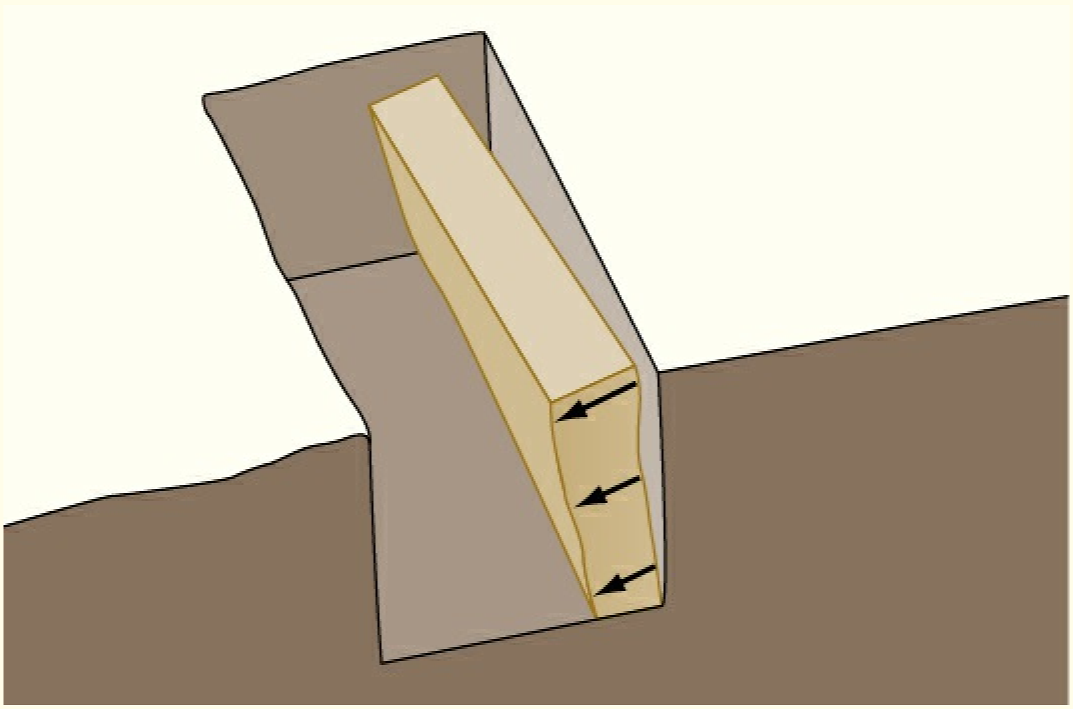

FIGURE 4-17 Shear failures can start with a fissure at the trench lip, but could also occur without warning.

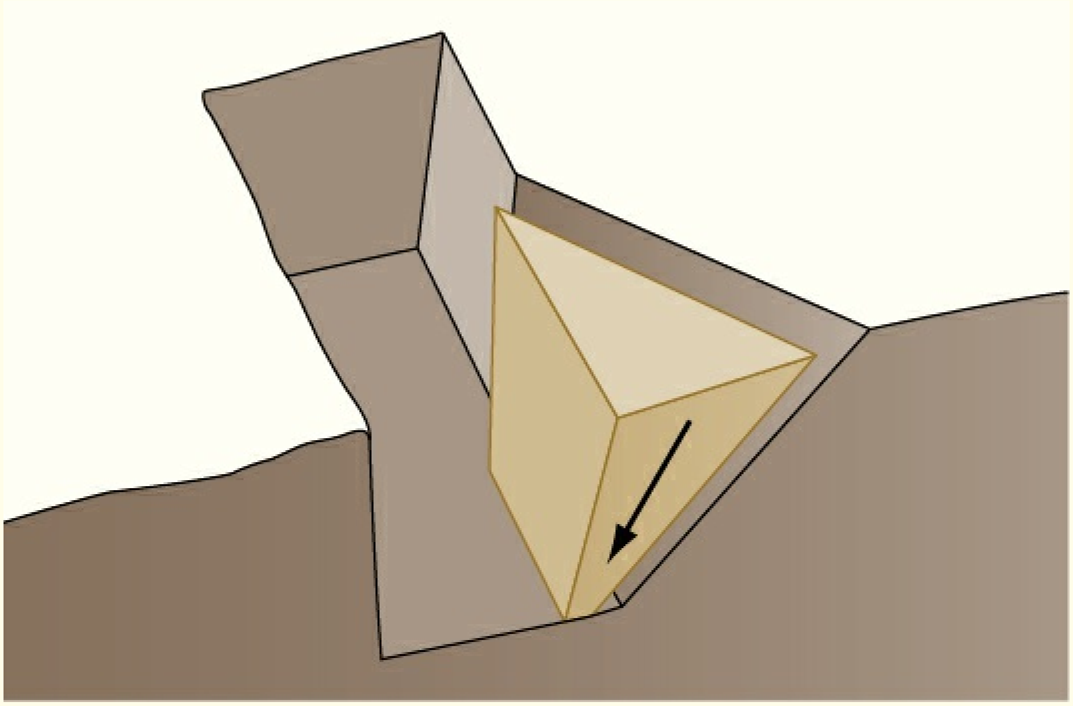

FIGURE 4-18 Wedge failure almost always occurs in intersecting trenches, which is why we try to secure the corners in these trenches first.

Wrap-Up

Review: Just the Dirt

- One of the keys to success in trench rescue is understanding how the various physical elements interact and contribute to a collapse situation.
- Of all of the physical factors associated with a trench collapse, probably none is as poorly understood as the weight of soil.
- There is no definitive way to determine which one condition, or set of multiple conditions, will cause a collapse. Recognizing this complexity is key to successfully evaluating the factors that could lead to trench failure.
- Some soils initially gain strength with the introduction of water, but then at some point get saturated and become weak. Watch out for soils that look solid but are actually wet and unstable.
- The longer the trench is open, the closer you are to nature's attempt to fill it back in.
- Because multiple layers of different materials demonstrate different strengths and friction coefficients, it is often difficult to state with any reasonable certainty how they will react in a specific scenario.
- A high water table means a heavier, more unpredictable soil.
- Disturbed soils lack cohesiveness because they are broken and/or mixed with other soil types—

that is, unless the soil has been compacted back to its original condition or density.

- The placement of heavy equipment represents another factor that can lead to a trench collapse. The same equipment that is digging the hole causes pressure to be exerted on the unsupported trench walls. For rescuers, it is important not to let their own heavy equipment become part of the problem.
- A contractor can expedite trench work by dropping the spoils right outside the trench to minimize swing time between scoops. The closer the spoil pile is to the trench, the faster it can be used to fill in the trench when the work is complete; however, the spoil pile adds weight to the unsupported trench wall, and part of the spoil pile may slide back into the hole.
- Vibration can be caused by road traffic near the collapse site, the machinery digging the trench, or other machinery being operated in the area. When effecting a rescue, it is critical to limit mechanical activity in the area of a trench collapse as much as possible.
- Familiarity with the types of collapse will help you determine the trench's potential for collapse and the proper protective system appropriate for making it safe.
- A spoil pile slide is the result of excavated earth placed too close to the lip of the trench.
- Slough failure is the loss of part of the trench wall.
- A shear wall collapse occurs when a section of soil loses its ability to stand and collapses into the trench along a mostly vertical plane.
- Wedge failure normally occurs with intersecting trenches and is characterized by an angled section of earth falling from the corner of two intersecting trenches.

Hot Terms

Active soil Soil containing energy as it relates to movement.

Angle of repose The natural angle at which loose particulate products will support their own weight and can be expected not to flow from a standing position.

Bell pier condition A toe failure that occurs on both sides of the trench.

Freestanding time The amount of time an excavation is open to the elements.

Gravity The force of attraction between two bodies that have mass.

Hydrostatic pressure Pressure caused by the addition of water to a soil profile.

Overburden pressure The pressure that the weight of the spoil pile or other object exerts on the trench.

Passive soil Soil with no potential for movement.

Previously disturbed soils Soils that lack cohesiveness because they are broken and/or mixed with other soil types.

Rotational failure A scoop-shaped collapse that starts back from the trench lip and transmits itself to the trench wall in a half-moon shape; also called slough failure.

Shear wall collapse A collapse that occurs when a section of soil loses its ability to stand and falls into the trench along a mostly vertical plane.

Slough failure The loss of part of the trench wall starting at an area back from the trench lip and extending down into the trench wall.

Spoil pile slide The result of excavated earth that is placed too close to the lip and subsequently falls into the trench.

Toe failure A slough failure that occurs at the bottom of the trench where the floor meets the wall.

Unconfined compressive strength (UCS) The force or load per unit area, as calculated with a penetrometer or other device and stated numerically in tons per square foot, that determines the point at which a soil will fail in compression.

Varying soil profiles Multiple layers of different soils found at various levels in the trench or excavation wall.

Water table The top of the water surface in the saturated part of an aquifer.

Wedge failure A failure that usually occurs in intersecting trenches, in which an angled section of earth falls from the corner of two intersecting trenches.

TRENCH RESCUER *in action*

As part of your rescue company's ongoing training and preplanning, you regularly stop at excavation sites to check out what is going on. Typically your captain will check with the site supervisor and request permission to take a quick look around, then take the crew and conduct a walk-around and visual inspection of the conditions and activities at the site. Once back at the station, a discussion is held around the kitchen table about the different aspects of the site and how your crew would respond to a trench incident there. The captain also asks each member if he or she noticed anything unusual about that particular site.

Today you are returning from your training academy when your captain notices some excavation activity on a side street and stops to check it out. With permission from the site supervisor, he takes you and the crew over to a trench in the shape of a "T" where workers have been preparing to replace a large valve on two intersecting pipes. The trenches are approximately 8 feet (2.4 m) deep, 4 feet (1.2 m) wide, and 10 feet (3 m) long. The spoil piles are approximately 6 feet (1.8 m) high and are the required distance from the trench lip. The trench walls are supported with wooden skip shoring and everything seems to be in a dry, safe condition other than a few spots where a little bit of soil has fallen from the trench wall between the skip shores. Overall, the trench appears dry and safe. The site supervisor mentions that the trench has been open for 2 days, as there has been a delay in receiving the new valve, which is not scheduled to arrive for another 2 or 3 days. Your crew concludes the visit, thanks the site supervisor for his time, and returns to the station.

The captain asks you to draw a diagram of the trench on the blackboard in the kitchen and then calls all members in for a discussion over a cup of coffee.

1. What should your main concern be regarding a possible incident with this trench?
   - **A.** The type of protective system in use
   - **B.** The fact that it is an intersecting trench
   - **C.** The soil that has fallen from between the shoring
   - **D.** The length of time the trench has been open
2. While doing a visual survey of the trench, you noticed several cracks in the area where the

trenches intersect. Which type of collapse is most likely to occur in this area?

A. Wedge failure
B. Slough failure
C. Spoil slide
D. Shear wall collapse

3. What is the approximate amount of vertical pressure being exerted by the soil at the bottom of this trench?

A. 300 lb
B. 500 lb
C. 800 lb
D. 1000 lb

4. The weather service is predicting thunderstorms with some periods of heavy rain over the next 24 hours. Which possible concern does this forecast raise?

A. Flooding in the trench
B. Movement of earth due to thunder vibrations
C. No concern
D. Change in soil weight and profile due to absorbed moisture

5. What is the most important force at work in this trench?

A. Active soil
B. Gravity
C. Hydrostatic pressure
D. Overburden pressure

6. What is the best definition of unconfined compressive strength (UCS)?

A. The force that determines the point at which a soil will fail in compression
B. The force created by unconfined overburden pressure
C. The force caused by the addition of water to the soil profile
D. The force between two bodies that have mass

Incident Management and Support Operations

CHAPTER 5

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the importance of incident management at a trench rescue NFPA 8.1.1 NFPA 8.1.2. (pp 64–65)
- Describe the personnel roles at a trench rescue at the strategic level NFPA 8.1.1 NFPA 8.1.2. (pp 65–66)
- Describe the personnel roles at a trench rescue at the tactical level NFPA 8.1.1 NFPA 8.1.2. (p 66)
- Describe the personnel roles at a trench rescue at the task level NFPA 8.1.1 NFPA 8.1.2. (p 66)
- Identify and describe the support functions at a trench rescue NFPA 8.1.1 NFPA 8.1.2 NFPA 8.1.3. (pp 66–69)
- Describe the incident termination and postincident considerations for a trench rescue NFPA 8.1.7. (p 72)

Skills Objectives

There are no Trench Rescue Level I skills objectives for this chapter.

Additional Resources

- National Incident Management System, Federal Emergency Management Agency
- NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*
- NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

You are a trench rescue technician with considerable training. As you are en route to a call, your memory takes you back to the only actual trench rescue incident you have under your belt. In that incident, a small construction company had excavated ground around a house to install waterproofing material on the basement walls. The straight trench was 2 feet (0.6 m) wide and 8 feet (2.4 m) deep, and the worker was buried to his waist.

Your fire department initially protected the victim with panels and a couple of pneumatic struts. While a second set of panels and struts was being installed, a shovel was lowered to the victim and he began digging himself out. After the second set of panels was shored, a rescuer entered the trench with another shovel and completed digging the victim out before a third set of panels was installed.

Twelve fire/rescue personnel completed the rescue in less than 50 minutes. The uninjured worker was transported (via basic life support [BLS] transport) to the hospital for observation and was later released. The incident command structure at this incident was minimal and appropriate for this very basic operational-level incident.

Now you come back to the reality of the current incident. This intersecting trench is 16 feet (4.9 m) deep, and three workers are trapped. Two of the workers are buried to their chests but are conscious and communicating with rescue personnel. The third worker is buried with only his left hand visible. One corner of the T-trench has collapsed and presents a huge void. The other corner is still in place but shows signs of impending collapse (fissures and sloughing). Your fire department's trench trailer is not equipped to shore a deep intersecting trench with a large collapsed corner. Your 12-member team may be able to give some protection (primary shoring) to the victims but will not be able to stabilize this trench for rescuer entry and victim extrication. This scenario is clearly not the "golden hour" rescue that you responded to the last time. The current incident will require more equipment, more personnel, outside resources, and a much more robust command structure.

1. Which additional fire, rescue, and medical resources would be appropriate for this situation?
2. Which outside resources should be called in?
3. Which branches, groups, or divisions should be utilized at this incident?

Trench Rescue Level I

Incident Management

The incident command system (ICS) is used by most fire departments to handle local emergency incidents. ICS was developed in the 1970s to deal with interagency responses to large-scale fire incidents. The incident management system (IMS) was later developed as part of the National Incident Management System (NIMS) of FEMA's National Response Plan. Regardless of the term you hear referenced, these systems were all developed to provide a coordinated interagency response to emergency incidents. With any command system, there will always be strategic, tactical, and task levels. Someone will need to be in charge, and other personnel will need to follow directions. Having a clearly defined approach to incident scene responsibilities and authority is critical to the safety of both victims and rescuers.

Dividing trench scene duties and responsibilities allows the incident commander (IC) to implement a systematic method to handle a problem that can quickly overwhelm even the most effective and experienced officers. It also decreases the organizational span of control and provides a measure of on-scene accountability **FIGURE 5-1**.

Ultimately, the level to which you develop your ICS will depend on the magnitude of the problem and the number of resources that are present on the scene. For example, if the rescue team comprises yourself and three others, it makes no sense to try to fill all of the job functions in the ICS. For obvious reasons, each person will fulfill multiple roles. In effect, you are the system.

FIGURE 5-1 A strong emphasis on incident management is critical to success in trench rescue incidents.

A common saying goes like this: "A good house starts with a good foundation." Applying this concept to trench rescue implies that a little time spent planning and organizing your efforts at the beginning of the incident will save time and maybe lives at the end. A well-developed and expanded ICS will be crucial to your success at a trench emergency. Just remember to develop a system only as large as is necessary to handle the incident. **FIGURE 5-2** provides an example of an incident management chart. (It is also necessary to have clear standard operating guidelines for these incidents; see Appendix A.)

Because trench emergencies rarely necessitate the use of a finance or planning officer, we will leave the explanation of those functions to a class on ICS, and instead concentrate on those roles that are almost always filled at a trench rescue.

The Strategic Level

The strategic level of the ICS is more about deciding *what* needs to be done and less about determining *how* those actions will be carried out. Strong strategic management is necessary to ensure that tactical personnel have an overall plan for achieving the mission and the necessary equipment and human resources to ensure operations run smoothly and efficiently. The strategic level of the ICS generally includes an incident commander, safety officer, liaison officer, and public information officer.

■ Incident Commander

The IC is responsible for developing the strategic goals for the operation based on the initial scene size-up and subsequent incident developments. This person is ultimately responsible for determining the need for and arranging the acquisition of all resources necessary to handle the incident. For example, the IC may develop a strategy specifying that the victim of a major collapse will be recovered using commercial techniques, as provided by John Doe Construction Company. He or she would then call for the resources necessary to actually fulfill the strategic goals. The fulfillment of those goals will rest with the operations officer (discussed later in the chapter).

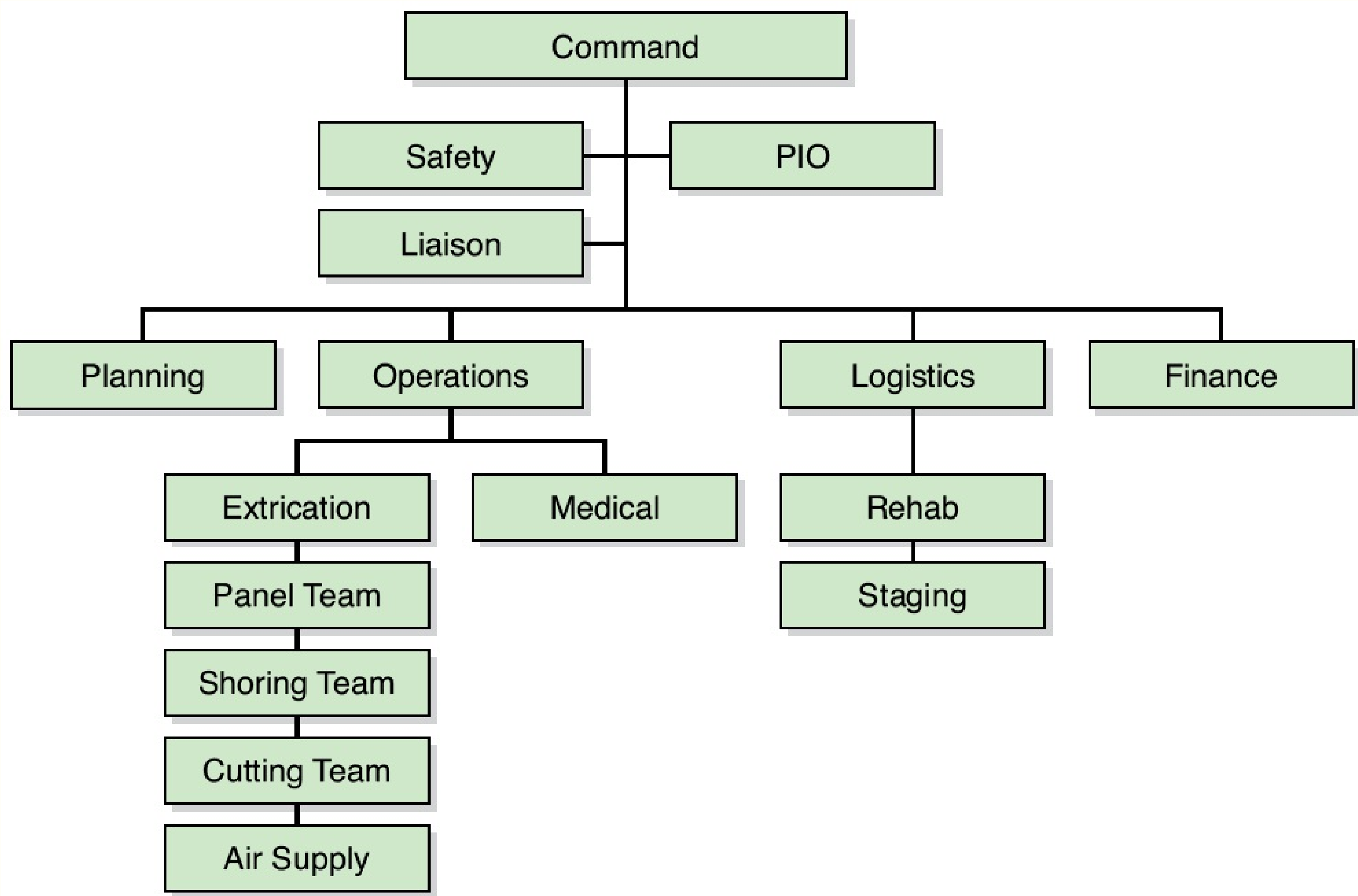

FIGURE 5-2 Trench rescue incident management chart.

■ Safety Officer

Directly under the IC is the safety officer. This function needs to be filled with someone who not only can spot unsafe acts, but also has the ability to anticipate activities that might lead to an accident. Although everyone on the scene is responsible for his or her own safety, it is necessary for someone to control the "big picture." It is critical that the safety officer be familiar with the environment and its potential hazards. This is a very important position when addressing a trench emergency, and consequently the safety officer can halt the rescue effort for any safety-related reason at any time.

Another very important function of the safety officer is to conduct a safety briefing, which should be included as part of the preoperational briefing. The kinds of items covered in this briefing should include, but not be limited to, emergency signals for evacuation or stopping all operations, rehabilitation cycles, the personnel accountability system, environmental concerns such as heat or cold, and dangers specific to the type of rescue effort. For those members already engaged in rescue operations, these short but very important briefings can be done during rescuer rotations and rehabilitation. All rescue personnel operating on the scene should recognize that safety is important, so a special pause in the operation to communicate that message is certainly warranted.

■ Liaison Officer

The liaison officer position will often have to be assigned for a trench collapse operation, because many agencies other than your own are likely to be involved in the rescue effort. When multiple resources respond to an incident, someone has to gather critical interagency information from all parties involved and at the same time buffer the IC from being overwhelmed with information that is not critical to the decision-making process. Examples of other agencies that might respond to a trench emergency include the police department, the utility contractor, the electric company, the water department, the Red Cross, and the Occupational Safety and Health Administration (OSHA), just to name a few.

■ Public Information Officer

The public information officer, if that position is established, provides the media with a direct point of contact for on-scene information. This person can give frequent updates to the media on the progress of the rescue effort and, more importantly, educate them regarding the rescue methods and any difficulties encountered. Keep in mind that these events do not happen every day. For that reason, you will need to get as much positive coverage out of each occurrence as possible. The public information officer can also help your department obtain the equipment you need if a previous lack of trench incidents has left your locality short on enthusiasm for purchasing equipment that is used infrequently. Picture the public information officer on your first collapse informing the media that the rescuers are doing all that they can, but that they lack the specialized equipment necessary to speed up the operation. With public support, equipment purchase requisitions will be more easily filled.

The Tactical Level

The tactical level of the ICS takes the strategic plan developed by the IC and implements the tactics necessary to achieve success. In particular, this level decides on the actual techniques that are required. For instance, does the situation call for commercial shoring that might include a trench box or sheet piling, or could it be handled with generally available rescue sheeting and shoring? The functions at this level encompass the operations, logistics, finance, and planning sections. Tactical-level personnel include the operations officer and the logistics officer.

■ Operations Officer

The individual assigned to the operations officer position is responsible for overall coordination of the rescue effort and the implementation of the tactics that will make the IC’s strategy successful. Included in the operations officer’s chain of responsibility are all of the individual groups that provide direct emergency support to the trench rescue effort, including the extrication officer, the panel team, the cutting team, and the shoring team.

■ Logistics Officer

The logistics officer is responsible for obtaining the appropriate equipment and personnel for deployment by the operations officer. The logistics officer tracks the use and depletion of on-scene resources and makes recommendations to the IC that will prevent shortages in needed equipment, materials, and personnel throughout the operation.

The Task Level

The task level of the ICS consists of the personnel who will implement the tactical objectives. In general, they are the "boots on the ground" personnel who will work together to accomplish a safe operation. Personnel at the task level include the medical officer and the extrication officer.

■ Medical Officer

The medical officer normally works at the direction of the operations officer. This member is responsible for establishing a medical control area to treat any on-scene rescuer injury and to provide for patient care as necessary. He or she may also establish a transportation section in the case of mass-casualty disasters. Additional duties may include assisting the rehabilitation section with monitoring of rescuers' vital signs.

■ Extrication Officer

The extrication officer is responsible for the actual extrication of the victim and for all those activities required to facilitate the rescue. This position coordinates the various support functions and ensures that rescuers follow the proper steps in the recovery effort. This officer is also responsible for the pre-entry or preoperation briefing, which communicates to all involved rescue personnel the plan for mitigating the incident.

Support Functions

Not all personnel at a trench collapse will get "glory jobs," nor do all people want them. Nevertheless, the trench support activities are an integral part of the trench rescue operation and cannot be neglected if the rescue effort is to be successful. It takes a tremendous number of personnel to handle a trench collapse situation, and most of them will be performing auxiliary functions.

■ Air Supply Operations

Air supply operations will be necessary if you are considering using pneumatic air shores or air bags. The people assigned to this task will need to ensure proper operation of the equipment and to gather and secure the necessary air supply.

■ Cutting Team

The cutting team is responsible for all cutting and manufacturing of systems that contain wood.

Examples of cutting jobs include creation of wedges, strongbacks, and shores. For this function, the rescuer team needs competent people who can handle a saw. Whenever placement of timber shores or cutting of wood will be a large part of the operation, you should consider setting up a cutting station. The time devoted to setting up this station will pay huge dividends in time saved during the operation **FIGURE 5-3**. (See also the skill drill for setting up a cutting station in the "Equipment" chapter.)

■ Panel Team

The panel team is required to set up, carry, and install all shields or panels. Being on the panel team is hard work. The panel team needs to be a group of at least four people dedicated to this task. Their job goes quickly when panels are called for, but then has slack time until termination. Given this reality, you should consider reassignment of the panel team members after the inside panels are set **FIGURE 5-4**.

FIGURE 5-3 Building a cutting station on timber trench incidents will save time later in the operation and provide a safer work space for rescue personnel.

Courtesy of John O'Connell

FIGURE 5-4 Panel teams and the techniques they use to set panels are very important to building a functional protective system.

FIGURE 5-5 Make sure that the shoring team members understand the type of protective system desired and are well versed in how to operate your specific type of shores.

■ Shoring Team

The shoring team assembles and installs all shores and wales required to make the protective system. This work may involve the installation of wood, pneumatic, or another type of shores. The individuals assigned to this role need to have a great deal of manual dexterity and be skilled with hammers, nails, and other hand tools **FIGURE 5-5**. (Shoring is covered in much more detail in the "Protective Systems" and "Trench Rescue Shoring Techniques" chapters.)

■ Rigging Team

The rigging team—or "riggers," as they are also known—establishes the systems by which any person or object will be lifted or moved during the incident. It is very important for the extrication officer to communicate with the rigging team regarding the method and timing of the victim removal or lifting operation. The bottom line is that rigging team members need to set up a system that will work with the victim movement plan, and that will be ready when you are.

■ Heavy Equipment Operations

In some cases, trench and excavation incidents may require the talents of a heavy equipment operator. Perhaps the area needs to be sloped or benched or, in the case of a large failure, perhaps lots of dirt needs to be moved before the responders can gain access to the victim. In other cases, it may be necessary to finish collapsing the remaining trench wall to take away the potential of a secondary collapse or even dig in from the unaffected side of the excavation.

Regardless of the reason you elect to use heavy equipment, careful consideration should be given to its proximity to the incident, because its sheer weight presents an overburden pressure on the remaining trench or extrication walls. Such equipment also causes vibration, which could be the "last straw" that triggers a secondary collapse.

Before you allow heavy equipment to be operated at the incident site, you should consider several pertinent issues. First, you must know with absolute certainty the capabilities of the operator. Do not let anyone who claims to be an excavator or backhoe operator jump into the rig and start working. You may find that this person is an overzealous backhoe operator who does not understand the complexities of victim extrication and removal.

Second, make sure you have a method to communicate by hand signals or radio (discussed in the "Lifting, Moving, and Stabilization" chapter). During the work, maintain visual contact with both the actual digging operation and the operator at all times.

Finally, make certain each and every move is evaluated before the actual operation. This may not be a major issue if you are digging; conversely, if the equipment is being used to lift anything in the trench, the shifting of the object could cause secondary problems in another area of the trench **FIGURE 5-6**.

■ Rapid Intervention Crew

In every trench rescue situation, a rapid intervention crew (RIC) should be ready to go before any trench stabilization activity begins. This team should be equipped for and prepared to handle everything from intervention if a secondary collapse occurs to a medical emergency involving a member of the rescue team. Careful thought should be given to making sure these personnel are located far enough away from the scene not to get caught up in incident activities, yet close enough that they will be immediately available should their services be needed. Additionally, because trench rescue incidents do not happen every day, you should give consideration to rotating the RIC responsibilities among members so all personnel can get experience in the rescue.

FIGURE 5-6 The high noise levels of heavy equipment and the safe distance requirements require rescue team members to use hand signals for coordinating rescue scene operations, in the same manner as construction workers do in their routine jobs.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

■ Logistics Team Manager

Equipment and logistical support functions entail all areas of equipment storage and dissemination that take place on the scene. Most trench rescue units carry only enough rescue shoring (panels, struts, wales, and associated support equipment) to stabilize a Level I trench incident. With deeper, wider, and more complex trench configurations, additional rescue shoring equipment will be needed. Level II trench incidents often take hours to resolve. This creates the need for food, water, shelter, and work relief (i.e., more rescuers). Some body recoveries at trenches that are deeper, wider, and with extreme soil conditions (e.g., C-80) will require the use of construction shoring techniques (e.g., trench boxes, sheet piling, sloping). Additionally, scene lighting and power sources may be needed depending on incident conditions and duration. The logistics team manager must forecast these additional requirements long before the resources are actually needed to provide for their timely delivery.

In addition, it is vitally important to keep all equipment not currently in use at a predetermined location. That way, the logistics team can keep track of it and determine its availability at any given time during the emergency.

Success in a trench incident is most often determined by how the scene is organized and controlled. Consider setting up your scene based on the complexity and danger involved in the activities associated with that area. For instance, place complex and dangerous activities in the hot zone, less dangerous activities in the warm zone, and nondangerous incident management activities outside the dangerous areas in the cold zone **FIGURE 5-7**.

■ Staging Officer

The staging officer is responsible for tracking, requesting, and maintaining adequate resources at the scene. This would include establishing an area to stage personnel for future deployment and to maintain and store equipment.

■ Rehabilitation Officer

For trench work, rehabilitation is an absolute necessity. Rescuers will be working very hard for long periods of time and will need rest. This function should provide for rescue personnel rotation to address medical monitoring and fluid replacement needs. Rehabilitation may take place under the direction of the medical officer.

Tip

If you are an IC, make an effort to thank the support personnel and recognize their contributions. The overall success of the incident will be directly related to the success of trench rescue support functions.

FIGURE 5-7 The expanded ICS should be considered on equipment-intensive and personnel-intensive operations that will last many hours.

VOICES OF EXPERIENCE

On August 19, 2005, the Detroit Fire Department (DFD) responded to a trench cave-in near I-94 and Addison Street. I was the battalion chief at the time and was attending a funeral for a line-of-duty death when the fifth battalion companies were dispatched. As it turned out, this was my old neighborhood and the incident was actually taking place on the street where I had lived. I had to respond from across town, but knowing the neighborhood helped me take some shortcuts to avoid traffic and reduce my response time.

"Seeing that one of the men was alive but in peril ... he devised a plan to implement a high-risk rescue operation."

Squad 4 was the first to arrive and was confronted with the chaos that is typically associated with trench collapse incidents. A large number of friends and neighbors of the two workers trapped in the trench were standing on the unstable trench lip. The workers were neighborhood handymen who were trying to repair a broken sewer line. Sergeant Sean Neary, a Trench Rescue Technician and skilled construction worker, was the officer on Squad 4, and quickly began initial actions, which included removing the people from the dangerous trench lip area. Seeing that one of the men was alive but in peril, and recognizing that the man had to be removed rapidly (before trench shoring equipment would arrive on the scene), he devised a plan to implement a high-risk rescue operation. The plan included rigging a ladder A-frame with a rope-based mechanical advantage system that would lower Sergeant Neary into the trench and bring both him and the injured man to safety. The plan was successful, and the first victim was removed and sent to the hospital before I arrived. (Sergeant Neary was awarded the prestigious "Ray Downy Courage and Valor Award" for this rescue at the 2006 Fire Department Instructors Conference).

When I arrived at the scene, we were faced with the daunting task of finding and removing the second victim, who was completely buried. The trench was 15 feet deep with an intersection (L-trench). With no signs of life in the trench, I gathered the troops and conducted a briefing on the strategic and tactical changes that were about to take place. We implemented zoning and moved bystanders farther away from the trench (cold zone). I set up a command post and established a staging area. Due to an enormous number of structure fires over the years, Detroit is full of vacant lots and abandoned buildings. I was able to utilize one of those vacant lots to set up a command post adjacent to the residence that had experienced the trench collapse. I selected another nearby vacant lot, right off the interstate exit, for the staging area.

Our primary shoring plan (protect the victim) was to use the limited trench panels and pneumatic struts that are carried on Detroit's trench rescue trailer to stabilize the trench enough to prevent a secondary collapse. Although we believed the second victim was deceased, we certainly did not want to subject his body to the impact of another collapse. Additionally, a more extensive collapse would affect the time and methods needed to make the trench safe for rescuers to enter. I believed that if we could prevent another collapse, the secondary shoring (a safe area for the rescue entry team) could be provided through the use of the shoring equipment on the Oakland County Technical Rescue Team's (OCTRT) collapse unit. Unfortunately, this plan had to be modified when I was notified that the truck that pulls Detroit's trench trailer was out of service. With this news, our goal of preventing a secondary collapse became much more challenging.

During my drive to the scene, I had noticed a construction crew working on a garage about a half-block away from the incident. I had also spotted a neighborhood hardware store that was near the incident site. When dispatch informed me that the DFD trench collapse trailer would not be responding, I began to develop a backup plan for shoring equipment. I sent a crew to the garage construction site to explain the rescue operation that was taking place down the street. The construction crew was willing to let us borrow several sheets of plywood. Another crew spoke with the owner of the hardware store and he provided some construction equipment. Several off-duty DFD personnel with trench rescue training had reported to the scene, and they were assigned to work with the on-duty trench technicians. The construction skills that many of our squad company members have, combined with their trench rescue training, allowed us to improvise a timber shoring system. The timber cross braces were made from posts (4 × 4 inches) taken from a nearby wood fence.

As a Trench Rescue Technician myself, I understood that this improvised shoring system did not provide the safety factor needed for entry operations on a body recovery. I was sure, however, that it would provide enough supplemental resistance to prevent a secondary collapse. A secondary collapse was averted, and the FinnForm panels and pneumatic struts provided by OCTRT enhanced our shoring effort and added an adequate secondary shoring system that kept the entry team safe during the long digging process that was needed to remove the victim. Supplemental shoring was installed in 2-foot (0.6-m) increments as the extrication progressed. The victim was packaged and removed from the trench using the same ladder A-frame and rope system that had been used during the initial rescue operation. The operating engineer, who is trained in rescue operations and is a member of MI-TF1 (USAR Task Force), used the backhoe that was on the scene to close the trench before the last fire company departed.

During my career, I have responded to a number of trench rescue incidents. This incident was more complex (intersecting/deep trench) and required many more internal and external resources than my previous experiences. As a result, the incident command structure had to expand to match the needs of this incident, including an incident commander, operations chief, planning, safety/accountability (Detroit Fire Academy officers), and a public information officer (PIO). Tactical- and task-level assignments included air monitoring (DFD Hazardous Materials unit), shoring team, panel team, extrication (entry) team, rigging team, and heavy equipment. Resources brought to the scene included all DFD squad companies, additional engine and truck companies, emergency medical services (EMS), the OCTRT (Pontiac, Southfield, and Independence Township), and an operating engineer (IUOE Local #324). Logistics included a staging officer and a rehabilitation section. Additional organizations that needed to be included in the incident management system were the Detroit Police Department/Michigan State Police (traffic control and force protection), Michigan OSHA (MI-OSHA), City of Detroit Community Relations, local news media, and a minister from the neighborhood church.

Lessons learned include the following:

1. *Daily Manpower Sheet*: Like many fire departments, Detroit does not have a designated technical rescue station, but it does have several highly trained and experienced rescue technicians. Shift commanders should identify the locations of these personnel at the beginning of each shift. At the time of this incident, that information was part of the daily manpower sheets.
2. *Internal and External Resources*: A tiered resource list that includes both internal resources (within your municipality) and external resources (mutual aid, agencies/organizations outside of your municipality) is essential to successful trench rescue operations. The incident

commander must have a thorough understanding of the list and its resource capabilities, and the dispatch center must have 24/7 points of contact for each resource listed.

3. *Improvise, Adapt, and Overcome*: To improvise safely, you must have a thorough understanding of trench shoring fundamentals. You must know the strength of each component and the strength of the overall shoring system. You must also know the minimum acceptable safety factors for rescue versus recovery operations.
4. *Training*: Trench collapse incidents rarely turn out exactly the way you practiced (trained) for them. You will not learn to improvise, adapt, and overcome by always practicing with the same or very similar trenches. Be sure to train for all of the common types of trench collapses. Do not waste your training time shoring trenches that do not include missing sections (collapse) of trench walls. Also, do not spend all of your training time in trench simulators—get out in the dirt.
5. *Exercise*: Most trench rescue teams train a few times a year. This training is usually geared toward rescue technicians and does not involve fire department command officers or the resources needed at a technician-level trench incident. Setting up a full-scale trench exercise will test your response system and will challenge the command staff.

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Termination and Postincident Considerations

No part of termination procedures should begin, nor should you leave the scene, before you conduct a modified postincident briefing. This is the first step in the debriefing process and will give you an indication as to the well-being of your rescue personnel. If nothing else, such a briefing offers the chance for the incident leaders to express their appreciation to the rescuers.

By far the most dangerous phase of a rescue operation is the termination. It is at this point in the process that the adrenaline is gone and the personnel are tired. Special care needs to be taken to ensure that rescuers are rested and alert before breakdown begins. You may well have to call in fresh crews to facilitate the termination and breakdown of the equipment. At any rate, do not rush through this phase. Make sure personnel get frequent breaks, and keep in mind that the emergency is not over until breakdown is complete.

As a rule, the termination and breakdown of the protective system happen in the reverse order from how the system was built. This process begins with breaking down shores and ends with removing the fire-line tape that was put up to control access to the scene. In every case, while personnel are removing the protective system, they must operate from within a safe area of the protective system or remove component parts from outside the trench area, and they should continue to use any necessary personal protective equipment.

A word of caution is necessary, because this stage of the event is when you really have to keep an eye on personnel. Rescuers have a tendency to work fast at all costs. Keep them focused on the fact that the job is not successfully completed until the incident is terminated and no personnel have been hurt. Consideration may also need to be given to rotating crew assignments; e.g., personnel who had outside-of-trench assignments during the operation might be given inside-of-trench assignments during termination and breakdown.

The issue of clean-up must also be addressed. You will be confronted with the dirtiest, nastiest bunch of equipment you have ever seen, and all of it has to be spotlessly clean before the incident is considered closed. You must also take care to document any issues with lost or broken equipment, as well as any rescuer injury.

The last part of your operation will involve after-action meetings, such as a critique and possibly a critical incident stress debriefing (CISD). The after-incident critique, which involves all the rescuers who participated in the rescue and sometimes occurs days after the incident, is important because it gives everyone on the team an opportunity to evaluate system performance and make adjustments so that the service delivery system continually improves. The key is to conduct the critique soon enough after the event so that specific aspects of the rescue are still fresh in rescuers' minds, and before rescuers have moved onto another incident.

The incident is never over until the critique and evaluation of the team's performance are complete. During these after-action meetings, take time to praise your team's efforts, but also have them discuss how they could have completed the rescue in a safer, quicker, and more efficient way.

CISD is the part of the event that allows rescuers to defuse and gear up for the next response. Just remember that the way something affects you is not always the way it affects someone else. Everyone's tolerance for critical events is different. With a significant trench collapse event, CISD should be offered to all who participated in the rescue.

Wrap-Up

Review: Just the Dirt

- Having a clearly defined approach to incident scene responsibilities and authority is critical to the safety of both victims and rescuers.
- The strategic level of the incident management organization is more about deciding *what* needs to be done and less about determining *how* those actions will be carried out.
- The strategic level of the organization generally includes an incident commander, safety officer, liaison officer, and public information officer.
- The tactical level of the incident management structure takes the strategic plan developed by the incident commander and implements the tactics necessary to achieve success.
- Tactical-level personnel include the operations officer and the logistics officer.
- The task level of the incident management structure consists of the personnel who will implement the tactical objectives.
- Personnel at the task level include the medical officer and the extrication officer.

- Emergency support functions at a trench incident include the following:
  - Air supply operations
  - Cutting team
  - Panel team
  - Shoring team
  - Rigging team
  - Heavy equipment operations
  - Rapid intervention crew
  - Logistics team manager
  - Staging officer
  - Rehabilitation officer
- No part of termination procedures should begin, nor should you leave the scene, before you conduct a modified postincident briefing.

Hot Terms

Air supply operations Activities to ensure proper operation of the air equipment and to gather and secure the necessary air supply.

Critical incident stress debriefing (CISD) Process used to debrief rescue personnel after an emotionally charged incident.

Cutting team Personnel responsible for all cutting and manufacturing of systems that contain wood.

Extrication officer Individual responsible for the actual extrication of the victim and for all activities that are required to facilitate the rescue.

Incident commander (IC) Individual responsible for developing the strategic goals for the operation.

Incident command system (ICS) Management system by which emergency personnel are assigned specific responsibilities and areas of supervision.

Liaison officer Individual responsible for providing information and gathering information from organizations and people outside of the immediate rescue effort.

Logistics officer Individual responsible for obtaining the appropriate equipment and personnel for deployment by the operations officer.

Medical officer Individual responsible for establishing a medical control area to treat any on-scene rescuer injury and to provide for victim care as necessary.

Operations officer Individual responsible for overall coordination of the rescue effort and the implementation of the tactical decisions that will make the incident commander's strategy successful.

Panel team Personnel responsible for setup, carrying, and installation of all shields or panels.

Preoperational briefing Briefing given to all personnel prior to entering the immediate rescue area or participating in the rescue effort.

Public information officer Individual who provides information to the media regarding incident activities.

Rapid intervention crew (RIC) Team established and equipped to handle everything from intervention for a secondary collapse or a medical emergency involving a member of the rescue team.

Rehabilitation An area that provides for rescue personnel rotation to address medical monitoring and fluid replacement needs.

Rigging team Personnel responsible for establishing the systems by which any person or object will be lifted and or moved during the trench emergency incident.

Safety officer Individual responsible for all aspects of the operations that deal with safety and health of the rescue personnel.

Shoring team Personnel who assemble and install all shores and walers required to make the protective system in a trench collapse.

Span of control The number of workers whom a supervisor can manage based on the type of work being performed.

Staging officer Individual responsible for ordering and maintaining adequate resources at the scene to handle additional requests for equipment and personnel.

Strategic level Level of the incident management structure that decides *what* needs to be done; it includes the incident commander, safety officer, liaison officer, and public information officer.

Tactical level Level of the incident management structure that takes the strategic plan developed by the incident commander and implements the tactics necessary to achieve success.

Task level Level of the incident management structure that includes the personnel who are responsible for implementing the tactical objectives.

TRENCH RESCUER *in action*

You and your crew are returning to quarters after doing some public education and are picking up groceries for the evening meal. While your company is at the store, dispatch requests that you respond to a trench collapse in a neighboring district. Upon your arrival, you discover that the first-due station and battalion chief are already on scene. The chief has established a command post at his vehicle, and you and your crew report to him for assignment. Because of your training as a trench rescue technician, he orders you to assume the role of operations officer and to attempt to stabilize both the scene and the trench until the arrival of the trench rescue team, which is expected in approximately 15 minutes.

You instruct your crew to stand by; meanwhile, you proceed to the trench area to conduct your initial survey. The trench is approximately 10 feet (3 m) deep, 8 feet (2.4 m) wide, and 20 feet (6.1 m) long, and a section about 10 feet (3 m) long and 2 feet (0.6 m) wide has sheared off the far side of the trench. Several large cracks are visible in the soil along the uncollapsed side of the trench.

The first-due engine company crew is treating an injured worker who was pulled from the trench by his co-workers, while the truck company crew is in the process of moving bystanders back from around the trench. The captain of the engine has located the site supervisor, and the lieutenant of the ladder is attempting to get the workers, who are frantically digging around another worker who is trapped by collapsed soil up to his neck, out of the trench. The trapped worker is conscious but in obvious respiratory distress. You meet with the engine captain, and he informs you that there are a total of three workers trapped in the trench: the one who is visible and two more who were working about 5 feet (1.5 m) behind him.

The rescue company has just arrived on scene and carries four 4 × 8-inch trench panels, a small assortment of pneumatic shores, and a number of 10-foot (3-m) 4 × 4s, as well as the usual tools and equipment for basic carpentry. The rescue company has a crew of four, all trained to the operations level of trench rescue. Now there are 3 officers and 12 fire fighters available at the scene, not including yourself and the battalion chief.

1. Based on your risk–benefit analysis, you decide to attempt to stabilize the trench and create a safe zone around the visible victim using the equipment from the rescue truck. Which level of operation would this be considered?
   - **A.** Strategic level
   - **B.** Tactical level
   - **C.** Operational level
   - **D.** Task level
2. Which of the following positions would NOT be present at this trench rescue?
   - **A.** Safety officer
   - **B.** Logistics officer
   - **C.** Planning officer
   - **D.** Liaison officer
3. Which phase of the trench rescue operation is considered the most dangerous?
   - **A.** Postincident
   - **B.** Termination
   - **C.** Initial survey
   - **D.** Extrication
4. The overall success of a trench rescue incident is directly related to which functions?
   - **A.** Safety
   - **B.** Tactical
   - **C.** Command
   - **D.** Support
5. Which support function is responsible for ensuring that adequate equipment, food, water, shelter, and work relief are ordered for the scene of a long, involved Level II trench rescue incident?
   - **A.** Incident commander
   - **B.** Staging officer
   - **C.** Logistics officer
   - **D.** Liaison officer

Equipment

CHAPTER 6

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the importance of having the proper equipment at a trench rescue. (p 78)
- Describe how to develop a safety culture. (pp 78–79)

Skills Objectives

There are no Trench Rescue Level I skills objectives for this chapter.

Trench Rescue Levels I and II

Knowledge Objectives

After studying this chapter, you should be able to:

- Identify and describe the personal protective equipment used at a trench rescue **NFPA 8.1.4** **NFPA 8.1.5** **NFPA 8.1.6** **NFPA 8.1.7** **NFPA 8.2.1** **NFPA 8.2.2** **NFPA 8.2.3** **NFPA 8.2.5** **NFPA 8.2.6**. (pp 79–81)
- Identify and describe the equipment used in trench rescue operations **NFPA 8.1.2** **NFPA 8.1.3** **NFPA 8.1.4** **NFPA 8.1.5** **NFPA 8.1.7** **NFPA 8.2.3** **NFPA 8.2.6**. (pp 81–86, 88–93)

Skills Objectives

After studying this chapter, you should be able to:

- Rope panels **NFPA 8.1.4**. (p 84)
- Set up a cutting station **NFPA 8.1.3**. (pp 91–93)

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

It is one of those days when you really do not want to get a run. It is as hot outside as it has ever been in your area. On top of that, there is no wind blowing, so heat levels are in the dangerous zone. You hope to spend the day relaxing at the station.

As you are cleaning up the lunch dishes, the inevitable happens: Your crew gets banged out for a "smells and bells" call for odor of smoke in a residence. You have made this kind of run many times in your career, so the thought crosses your mind that you might wait and put on your gear when you see what the real situation is on arrival at the scene. Of course, your captain is one of those "by the book" guys, and you appreciate that he looks out for you. For that reason, you dutifully don your full protective clothing.

Just as you suspected, the call is canceled by dispatch because the smoke was caused by a potholder placed in the dishwasher. It seems the drying cycle is not really meant for things other than dishes.

Just as the dispatcher cancels the structure fire run, she comes back and advises that she is getting reports of a man trapped; however, the details of the situation are not clear. The caller states that the victim is trapped in a trench but also says he does not think it is the result of a collapse.

Your engine is the first to arrive at the scene. You rush to the edge of the trench, where you see a worker frantically trying to remove a victim who is trapped under one end of a trench box. The victim has an obvious tib/fib injury. The box is lying across one of his lower legs, and there is an angulated open fracture of both bones.

The underground environment is deemed safe, and your captain orders you into the trench to evaluate what will be needed to extricate the victim. Upon examination, you decide that a set of air bags and some cribbing should be enough to free the victim; however, special consideration is needed for which type of patient packaging device should be used due to the limited access, which is complicated by the presence of the backhoe, trench box, and victim.

At about the 10-minute mark of the rescue, you start feeling lightheaded and have difficulty swallowing. In addition, your vision becomes fuzzy and it seems that people are talking slowly and not directly to you. The last thing you remember is the captain asking if you are okay. It is obvious to everyone at this point that you have suffered some type of heat-related emergency—and you are now a second victim.

1. Should you have remained in your structural firefighting gear while trying to effect this type of rescue?
2. What are the advantages of appropriate rescue gear as compared to turnout gear that is used for structural firefighting?
3. If the situation was cold as opposed to hot, would the choice of protective clothing have been a better one? Why or why not?

4. Which type of shoring, cribbing, and other trench protection do you think will be required to handle this incident properly?

Trench Rescue Level I

The Importance of Proper Equipment

At every incident, the safety of personnel depends on their level of skill, as developed during both training and real-time incidents. This training and experience may give personnel an initial advantage in the rescue effort; however, if they do not have the proper personal protective equipment (PPE) or operational equipment and are subsequently injured in the rescue attempt, overall the operation will not be considered a success. In other words, all training and experience can be rendered ineffective if personnel do not have the proper personal protective clothing and equipment to give them reasonable protection during the rescue.

Development of a Safety Culture

Selecting and using the proper PPE is just one component in providing a safe way for rescue personnel to operate on the scene of a trench collapse. More important may be instilling a safety mindset into the culture of your team—something that does not happen overnight. Rather, development of a safety culture is the result of many hours of training and the discipline that comes from everyone on the team being accountable. Such a culture is established because individual team members demand it from each other.

When an injury brings down a team member, everyone suffers the loss. Nothing is wrong with being safe or demanding that the team maintain a positive attitude about being safe. Ultimately, a safety culture is something to be proud of, and it should be emulated by other teams that deliver specialized rescue services.

Trench Rescue Levels I and II

Personal Protective Equipment

PPE can be classified into two main categories: the clothing that rescuers wear to protect themselves (e.g., gloves) and the equipment provided that would not be considered standard issue items (e.g., a breathing apparatus). PPE is not rocket science; it is more like common sense. The rescue personnel on the scene of a trench collapse need a variety of protective clothing to minimize the effects of the weather and any related trauma caused by working in and around machinery and tools. At a minimum, rescuers need a jumpsuit or other long-sleeve and pants combination, gloves, steel-toed boots, helmet, and eye protection. Other items, depending on the environment expected, could include hearing protection and safety vests for visibility concerns.

■ Clothing

In all cases, rescuers need to have some level of protection from skin abrasions from contact with on-scene objects. If it is very cold outside, this PPE might consist of fire-suppression turnout gear. Firefighting gear is very bulky and not recommended as standard protection for trench rescue, but when someone is cold and miserable, it is difficult for him or her to concentrate on the task at hand. Turnout gear is certainly appropriate in some circumstances, and if that is all you have, make sure that you have it on. In colder weather, however, it may be a good call to wear multiple layers of thinner outer clothing. The key is to evaluate the advantages of the warmth the gear provides as compared with the disadvantages of not having as much manual dexterity.

The standard fire-resistant jumpsuit is more than adequate skin protection for most trench emergencies **FIGURE 6-1**. It covers the arms and legs and can be ordered with the name of your organization and reflective tape for visibility purposes. One disadvantage of the jumpsuit is that it retains heat because of its one-piece design. Also, a suit that is too large or too small, or just in the wrong proportions, can cause discomfort and limit ease of movement. Ideally, rescuers should be as comfortable as possible so that they concentrate on the efforts at hand and not their clothing. This consideration alone makes a case for providing each member of the rescue team with his or her own standard set of protective clothing.

In any case, the minimum level of protective clothing should be long pants and long-sleeve shirts. Short pants or short-sleeve shirts should not be considered. If it is hot, provide for frequent rehabilitation breaks and set up misting and other ventilation fans to cool the area. If the outside temperature is a major consideration, set a tarp over the trench to shield the rescue area from the sun. Make sure that you wear the proper protection for the environment in which you are working.

FIGURE 6-1 Rescue personnel's PPE should be appropriate for the type of mission and the hazards present.

■ Gloves

The glove is often the undoing of the rescuer. We know that gloves have to be worn, but performing any rescue-related function is difficult when wearing them. When rescue personnel are standing around talking, they may have their gloves on—but all too often, the first time they are required to do something, off come the gloves. In my own work, I frequently remind rescue personnel that gloves will afford only limited protection when stored in their back pockets.

Comfort is the key to success when wearing gloves. Firefighting gloves are designed for fighting fires and, therefore, are not comfortable when trying to use tools or operate equipment. Conversely, if your sole task is to move lumber, the firefighting glove may be appropriate.

The best kind of glove for trench rescue personnel is the standard leather glove. These gloves are sturdy enough to keep abrasions and splinters to a minimum and still comfortable enough that rescuers will generally keep them on while working FIGURE 6-2.

Nicer still are the specialty-type vehicle-extrication gloves. These gloves are thin and flexible enough to be comfortable while also providing excellent abrasion protection. Most of these gloves also have slip-resistant palms.

FIGURE 6-2 Standard leather gloves are sturdy enough to keep abrasions and splinters to a minimum and still comfortable enough to wear while working.

If your department has plenty of money or there is a military installation in your area, you might want to try a pair of Nomex flight gloves. These gloves are very pliable and have a thin layer of leather in the palm. They are by far the most comfortable of all gloves to wear, and you can still accomplish just about any function with them on. They are expensive compared to the regular leather gloves; however, they can also be used for other specialized rescue functions, such as when working in a confined space.

Head Protection

The most critical piece of protective clothing that you will wear during a trench rescue is the helmet. Unlike with gloves, the occurrence of a splinter or abrasion is not the issue if you do not wear your helmet. Rather, the risk you run is head trauma from a hammer, shore, or piece of lumber—an injury from which you may not easily rebound and, in fact, could prove to be a career- or life-ending mishap.

As with firefighting clothing, most rescue/fire personnel will have a fire helmet issued to them. When you request special gear for your rescue team, however, appropriate helmets must be included. The problem with fire helmets is the same as with fire gloves: If they are heavy and uncomfortable, the rescuers will take them off. This is not what we want.

Taking into account the most likely sources of injury, the best helmet to wear at a trench emergency is the heavy-duty construction helmet. It provides limited impact protection (compared to a firefighting helmet), is lightweight, and for the most part is balanced. Many varieties of this type of helmet are available both commercially for general industry and through rescue gear manufacturers. Be sure that the helmet selected is American National Standards Institute (ANSI) approved for the task and has a chinstrap to keep it from falling off when the wearer bends over.

Safety Tip

Rescuers frequently need to remind each other to wear their helmets while on the rescue scene. When you need to issue this type of warning, tell rescuers that you know a great place to store their helmets. When they ask where, tell them, "On your heads." A little embarrassment plus some humor goes a long way toward reinforcing safe practices.

FIGURE 6-3 Standard safety glasses work well for trench rescue.

Eye Protection

Eye protection is essential for trench rescue work. Something needs to provide a barrier from the flying nails and other debris that can be expected in a construction environment. The only rule for eye protection is that it needs to encompass the entire front of the eye and not change positions when the head is moved; therefore, helmet-mounted eye protection is not recommended.

Full-face goggles, while providing the most protection, will usually fog when the rescuer gets hot. When that happens, what do you think comes next? That's right: The goggles end up hanging around the neck and not over the eyes—again providing you with an excellent opportunity to tell someone the proper place to store the goggles.

The standard pair of safety glasses is more than satisfactory for trench rescue FIGURE 6-3. Most can be purchased with or without the sun or glare protection, and they will stay in position when the rescuer's head moves. In addition, they will rarely fog because ventilation is allowed around the outside of the lenses. As with the helmet, make sure that any safety glasses you use for trench rescue are ANSI approved for that purpose.

One last point about eyewear: Rescue personnel should never wear reflective sunglasses. It is frequently very important for rescue personnel to confirm movement by eye contact. Do not let "looking cool" get in the way of providing the best and safest rescue for your victim and fellow rescue personnel. Leave the shades on the rig!

Foot Protection

All personnel should wear steel-toed, steel-shanked boots **FIGURE 6-4**. Not only are there many opportunities to drop something on your foot, but nails and other sharp debris are also typically found all around the trench site. In addition, it is a good idea to have a high-top boot. This will provide a measure of support in the event you step on a piece of lumber or other equipment and turn your ankle.

FIGURE 6-4 Rescue-quality boots will help protect your feet from incident hazards.

Specialty Items

Respiratory protection should always be considered at the scene of a trench collapse. Rescue personnel will be subjected to, at the very least, flying dust and dirt while working in and around the trench. At a minimum, you may want to consider the use of a dust mask because it is readily available in the medical supplies of most emergency apparatus. In any case, if there is any indication that an atmospheric problem might exist, you will want to use an atmospheric monitor, self-contained breathing apparatus (SCBA), or supplied air breathing apparatus (SABA) before entry into the environment **FIGURE 6-5**. A much more comprehensive look at atmospheric monitoring and related equipment is provided in the "Hazard Control and Atmospheric Monitoring" chapter.

Hearing protection is a good idea for anyone who is working around compressors or saws. Choose a level of protection that will shield the rescuer's ears from high noise frequencies but will not block out all communication. It is more dangerous for the rescuer to be unable to hear anything than it is for him or her to be exposed to loud noises.

Welders wear skullcaps to keep their heads cool under their helmets while welding. Rescue personnel wear them for the same purpose. As the heat from your head causes perspiration, it wets the skullcap, which in turn keeps the head cooler. You can also wet the skullcap before you put it on to get a head start on the process.

Leather chaps are good leg protection and a great idea for anyone who will be doing much cutting with a chainsaw. Although they will not keep someone from sawing a leg off, chaps might be enough to stop or deflect a chain that bounces off the wood and inadvertently hits a rescuer's lower body.

Equipment for Trench Rescue Operations

Many different types of tools and equipment may be required on the trench collapse scene. Most individuals are already familiar with much of this equipment. Consequently, the majority of this section focuses on less familiar items that are specifically related to trench rescue work.

FIGURE 6-5 SABA is compact and can be used as a constant supply of air for trapped victims if SCBA cannot be used.

■ Lip Protection

The area around the trench lip is a very unstable area. Any additional weight on the soil could cause a secondary collapse of the trench. For this reason, ground pads or lip bridges are used to line the area around the trench either before or after the removal of the excess dirt from the spoil pile. Ground pads distribute the rescuer's weight over a larger area. To get a greater understanding of the pressure per square inch concept, have someone stand on your foot. Now have that person put on a high-heeled shoe and do the same thing. Ouch! The effects of concentrated pressure are painfully apparent. The same principle is involved when you stand in one place on the lip of a trench without the benefit of a ground pad to spread out your weight.

Several types of ground pads can be used to accomplish the same purpose. The most commonly used is a 4 × 8-foot sheet of ½-inch plywood **FIGURE 6-6**. This type of ground pad provides a large area over which to distribute weight and provides a fairly nice platform from which to work. The major drawback of this type of ground pad is that it covers a significant portion of the ground around the trench, which makes it difficult to inspect for deteriorating conditions. In addition, if a large spoil pile is present at the site, it can take a long time to move enough dirt to get the ground pad flat.

Safety Tip

When covering up cracks on the trench lip with ground pads, mark the area on top of the ground pad with paint. This will remind people not to stand on that area, and you can also check for worsening conditions FIGURE 6-7.

In some cases, a 2 × 12-inch piece of lumber, usually 10 or 12 feet (3 or 3.7 m) long, can be used as a ground pad FIGURE 6-8. The 2-inch material does the same thing as a piece of plywood, but the weight is distributed over a smaller area. A disadvantage of this type of ground pad is that it is small and difficult to maintain your balance on. Frequently, you get the feeling of tiptoeing around the trench, which can create a trip or fall hazard. The main advantage of the 2 × 12-inch ground pad is that less spoil pile has to be moved to facilitate its use. Remember that the thicker the board, the heavier the board.

FIGURE 6-6 Ground pads that are 4 × 8 feet in area should be your first choice for trench lip protection.

FIGURE 6-7 Marking ground pads communicates to rescue personnel potential cracks or dangerous areas that should be monitored or avoided.

As you can see, each type of ground pad has both good and bad points. Whichever ground pad you decide to use, place it in service by staying on the safe side of the pad and not venturing between it and the trench. Clear a small area, and then push the ground pad in front of you until you can get to another area. Always stay on the ground pad. Be aware, however, that ground pads help distribute the weight of rescuers on the lip but do not eliminate the load above weakened walls. In the event of a secondary collapse, the ground pad and everything on it (including rescuers) can fall into the trench. (Ground pads and their proper installation are covered in more detail in the "Protective Systems" chapter.)

FIGURE 6-8 Used on the spoil side of the trench, the 2 × 12-inch ground pad works well.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 6-9 This lip bridge is used to work directly over a large lip shear collapse. It keeps the rescuer's weight off the missing or damaged wall.

Lip bridges provide an alternative to ground pads **FIGURE 6-9**. A lip bridge is built with girders (timbers), beams (ladders or timbers), decking (plywood or lumber), and supports (sections of timbers placed away from the compromised wall and used to elevate the bridge above the lip). A properly installed lip bridge will prevent rescuers from riding the wall into the trench in the event of a secondary collapse. Lip bridges require more material to be carried on your response rig. Although they add a few minutes to your setup time, once they are properly installed they offer a higher level of safety to the rescuers. (Lip bridges and their proper installation are covered in more detail in the "Protective Systems" chapter.)

A good rule of thumb is to use ground pads when the trench walls are stable and lip bridges when the walls are unstable or have collapsed, resulting in significant voids in the walls.

■ Sheeting

For the underground construction industry, sheeting material consists of interconnected steel uprights, sheets of plywood/timber, or manufactured panels that are used to contact the walls of the trench. The combination of sheeting and uprights functions as a shield system, holding back running soil and debris **FIGURE 6-10A**. In hard-packed soil that has not collapsed, sheeting is not required as a part of the protective system. However, if the soil has caved in or is showing signs of becoming active (sloughing, raveling, or cracking), sheeting should be used.

In trench rescue, sheeting will consist of ShorForm, FinnForm, or homemade plywood panels. The function of sheeting used for trench rescue shoring is to collect the load (unstable soil wall) and distribute the load to the wall across the trench. Panels also have a beneficial effect on the distribution of strut pressure. The ShorForm panel offers the rescuer a viable and safe sheeting panel for efficiently shoring trenches. This high-strength, relatively lightweight, and nonconductive material is made entirely of arctic white birch. The exterior of the ShorForm panel is highly durable because of resins impregnated into the hardwood surface that provide for maximum reuse and ease of cleaning **FIGURE 6-10B**.

Whatever type of sheeting you choose, there are several steps you can take to facilitate ease of use and storage. Cutting all of the corners off at 90 degrees reduces the possibility of splintering if the panel is dropped on the corner or edge **FIGURE 6-11**. Hand holes or holes for ropes can also be drilled to aid with the placement and adjustment of the panels in the trench.

Rescue panels should be used with strongbacks or specially designed aluminum spot shore rails. Wooden strongbacks have traditionally been made from 2 × 12-inch or 2 × 10-inch nominal lumber. LVL lumber (1.75 × 10 inches or 1.75 × 12 inches) appears to be a longer lasting alternative for wooden strongbacks. Historically, rescue teams have used bolts to connect the panels to the strongbacks. Recent tests conducted by the Michigan Urban Search & Rescue Training Foundation have shown that significant increases in strength of both the panel and the strongback can be achieved by gluing (construction-grade adhesive) and screwing (1⅝-inch deck screws) the strongback to the FinnForm **FIGURE 6-12**.

In a study conducted in 2009 by Dr. Marie LaBaw, it was concluded that FinnForm panels attached to strongbacks provide the most beneficial distribution of strut pressure to the trench walls. The thicker the panels, the better—but a good compromise of pressure distribution and ease of installation is a ¾-inch, 4 × 8-foot FinnForm panel. Paying careful attention to make sure that the panels are set tight against the walls of the trench will ensure that the strongback/panel can transfer the necessary force from the shore to the trench wall.

FIGURE 6-10 **A.** The ShorForm panel is a concrete form used as sheeting material for trench rescue operations. Although very strong, its primary purpose is to hold back running material. **B.** The resin-impregnated exterior of the ShorForm panel makes cleaning and upkeep easier.

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FIGURE 6-11 Cutting panel corners is a method to reduce hazards to rescue personnel; it also helps reduce panel damage.

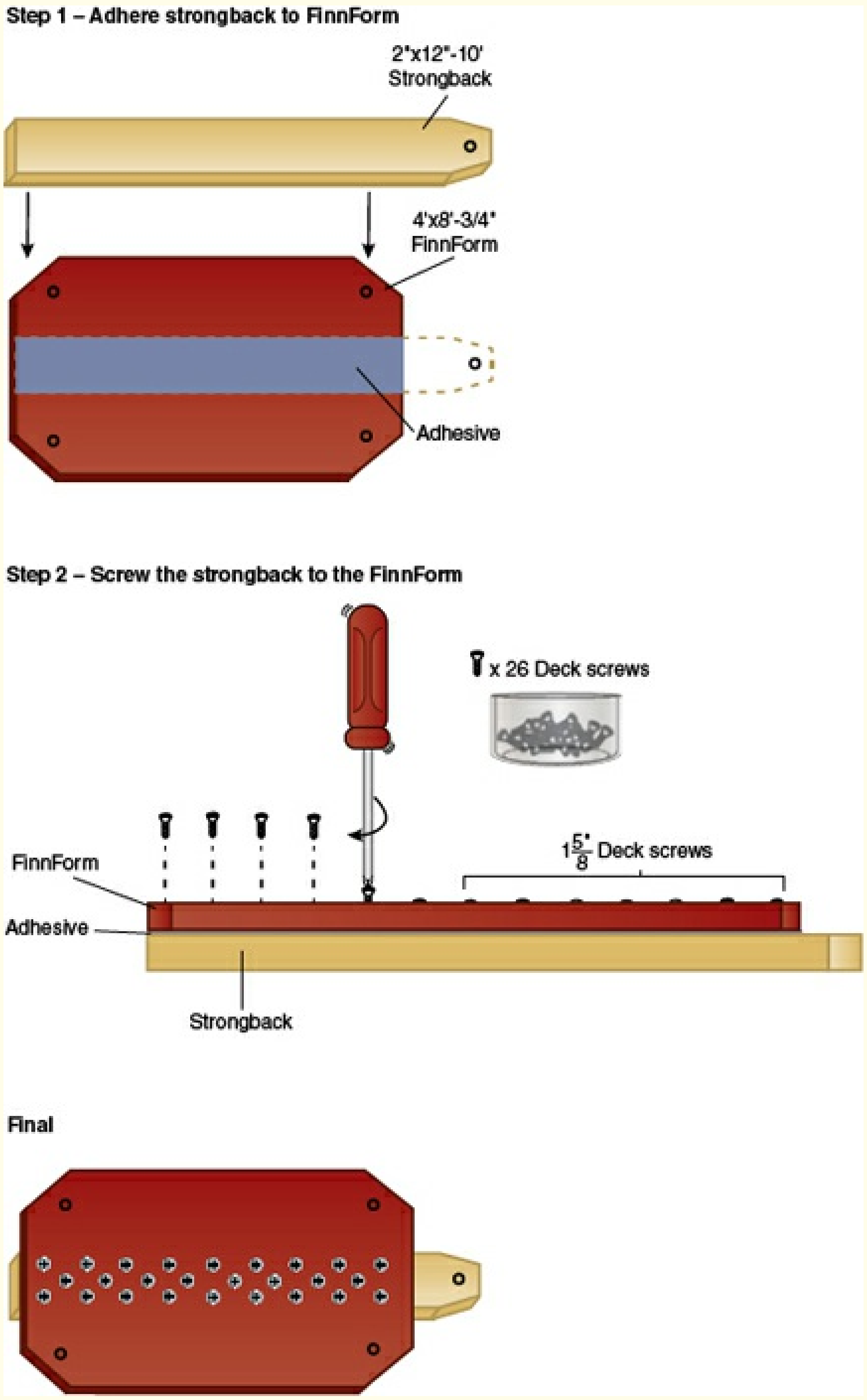

FIGURE 6-12 Use construction-grade adhesive and deck screws to secure strongbacks to FinnForm panels.

Roping the Panels

To rope the panels, follow the steps in **SKILL DRILL 6-1**:

1. Take a section of rope and place the end through a hole in the strongback side of the panel on the bottom. Tie a knot in it so that it will not pull back through, and then do the same for the other side **STEP 1**. Lower the panel into the trench while pulling back on the ropes—a technique that that ensures the panel will get a very nice vertical set against the trench wall.
2. If you have limited ropes, you can accomplish the same objective by wrapping the closed end of a rope around the strongback and holding the terminal ends **STEP 2**. After the panel

is lowered and placed in the proper position, the rope can be pulled up and used again. (Panel setting is discussed in more detail in the "Protective Systems" chapter.)

■ Shores

Shores (or struts) are the component in the protective system that transfers the force from one side of the trench to the other. They may comprise a number of different materials and forms, each having its own strengths and limitations.

Timber Shores

The most common (and oldest) type of shore is the timber shore. Timber shores usually are 4 × 4-inch, 4 × 6-inch, and 6 × 6-inch sections of Douglas fir with a bending strength of not less than 1500 pounds per square inch (105.5 kg/cm). The construction standard allows timber to be used in all trenches that do not exceed 20 feet (6.1 m) in width so as to maintain a relatively high strength-to-length ratio. This rule, however, is not practical for rescue operations. Keep in mind that the shorter the shore is cut, the stronger it is. Timber shores have the advantage of low cost when compared with other shores; in addition, they can be cut to varying lengths with little difficulty. The disadvantage of timber shores is that they are very time consuming to cut and install and have only limited effectiveness in rescue work **FIGURE 6-13**.

SKILL DRILL 6-1

Roping the Panels

(Trench Rescue Level I: 8.1.4)

1 Take a section of rope and place the end through a hole in the strongback side of the panel on the bottom. Tie a knot in it so that it will not pull back through, and then do the same for the other side.

2 If you have limited ropes, you can accomplish the same objective by wrapping the closed end of a rope around the strongback and holding the terminal ends.

The size and length of the timber shore selected is based on the depth and width of the trench as determined by the type of soil. Appendix C of the Occupational Safety and Health Administration (OSHA) standard CFR 1926, Subpart P contains information that can be used when timber is selected as the type of shoring material for use in a protective system. A word of caution is necessary, however: In any trench that is greater than 10 feet (3 m) in depth and 4 feet (1.2 m) in width, with any kind of soil, the minimum timber shore size is 4 × 6 inches, and in the case of type C soil, it is 8 × 8 inches. That is a big piece of wood, which most lumber yards will need to special order. Do not take for granted that an 8 × 8-inch timber of suitable length will be readily available at the lumberyard when a trench collapse occurs.

A screw jack is a tool commonly used in conjunction with timber shoring to form a tight wall-to-wall shore. This type of shore has a boot end, which fits over a piece of wood and then can be tightened by a thread and yoke assembly. Screw jacks are also sometimes referred to as pipe jacks when used in conjunction with varying lengths of pipe. Screw jacks are relatively inexpensive, although not very strong when compared to other types of shoring **FIGURE 6-14**. Particular care must be taken not to overextend this type of shore.

Hydraulic Shores

Hydraulic shores are a type of protective system that combines the shore and the upright into a single unit. The entire system is lowered in the trench from the top and then expanded by using a reservoir of nonflammable and biodegradable fluid. After the shore is expanded, the fluid is cut off at the cylinder, and the hose is taken off the shore. The advantage of a hydraulic system is that it can be set entirely from above the trench and the strongback portion of the shore is already attached. The disadvantage for rescue use is that it does not work well if the walls of the trench are not vertical or near vertical, as when a trench has caved in FIGURE 6-15.

FIGURE 6-13 Wood can be cut to various lengths and used as shores. Wood is also relatively inexpensive and widely available in most communities.

FIGURE 6-14 Screw jacks are very versatile and relatively inexpensive.

FIGURE 6-15 Hydraulic shores are very popular but are limited in use to walls that are mostly vertical.

Pneumatic Air Shores

Pneumatic air shores, like those manufactured by Hurst, Paratech, and Prospan, come in a wide variety of lengths. Made from lightweight tubular aluminum, the pneumatic shore is quick, strong, and dependable **FIGURE 6-16**. In general, these materials are available in lengths from 3 to 12 feet (0.9 to 3.7 m) and come with a multitude of extensions and attachments. For example, swivel base attachments allow the shore to be extended at an angle less than horizontal and still be effective.

Pneumatic shores all operate under the same principle. The shore is extended by using compressed air at pressures recommended by the manufacturer. After extension, the shore either locks by itself or is manually locked to prevent a collapse under load **FIGURE 6-17**. The main disadvantage associated with pneumatic shores is the number of shores required to maintain an effective cache and the cost of their acquisition.

Safety Tip

Most shores are rated for only 400 pounds (181.4 kg) of shear force when installed. The bottom line is this: Do not stand on them. They are not steps—use the ladder.

Wales

Wales are used to span large areas of trench walls (without intermediate struts). The large area needing to be spanned may be a result of the voids created by the cave-in, the trench shape, or an obstruction at the wall. Wales are also used to create room for extrication work and victim removal. Timbers are commonly carried by rescue teams for use as wales. In "worst-case" soil conditions, 6 × 6-inch wales do not have the strength needed to give rescuers an adequate safety factor. Instead, 8 × 8-inch timbers are a better choice. A best practice for wale use at trench rescues is use of 7 × 7-inch laminated beams. Laminated wood beams, such as laminated veneer lumber (LVL) or Microlam, have higher and more consistent strengths than timbers. The multiple layers within the laminated beams offer internal redundancy to overcome the deficiencies (e.g., knots, cracks, checks) often found in wood. It should be noted that the strength of cantilevered wales is only about 25 percent of that of wales supported at two points. (For more information on inside and outside wales, see the "Protective Systems" chapter.)

FIGURE 6-16 Pneumatic shores use air from a remote source to expand and then are locked manually.

FIGURE 6-17 The manual system used to lock shores varies according to shore manufacturer.

■ Backfill

Backfill is a generic term given to several common methods used to fill in the soil that has left the trench wall as a result of a collapse. Filling in voids that have been created from cave-ins is an essential skill for trench rescue shoring. Backfilling void areas helps minimize soil movement and distribute the load from the opposite wall. Backfilling voids in trench walls is done by placing equipment and materials in the voids to replace the missing soil. Such materials and equipment should have compressive strength equal to or greater than the soil pressures at the area of application. Commonly used backfill equipment and materials include air bags, wood, and soil. When backfill is installed at angles, as at a lip shear collapse, shear forces will need to be resolved to prevent the backfill from being forced out of the void area. In those instances, the system strength will not be solely dependent on the compressive strength of the equipment or material installed. Advanced shoring techniques include the use of struts (back-shores) to fill in voids **FIGURE 6-18**.

FIGURE 6-18 Advanced shoring techniques include the use of struts to fill in voids.

Safety Tip

Too much pressure in air bags used to fill voids can create problems. The pressure in the bag should be very close to the pressure from the soil it is replacing. In C-60 soil, the appropriate pressure is just under ½ psi times the depth of the bag (60 psf = 0.416 psi × 144 square inches).

VOICES OF EXPERIENCE

What was a typical day at the firehouse turned out to be anything but typical when the tones went off for a mutual aid call to a neighboring community for a trench rescue. In addition to its own technical rescue assignment, the local department called for Naperville's and North Aurora's Technical Rescue Teams. Both teams responded with semi-trucks of equipment. In addition, North Aurora brought its new Rescue Vac tool—a special nozzle that fits on a standard soil vacuum truck's hose and is used to evacuate dirt from a trench.

Our initial assessment determined that the trench had two victims in it at the time of collapse. One victim was injured but not buried; the other was substantially buried and not moving. The trench was approximately 14 feet (4.3 m) wide and 13 feet (4 m) deep and turned out to be two trenches side by side with a center wall that had collapsed on the victims. There was no protective system in place at the time of the collapse.

A Stokes basket was lowered to the younger victim; because he was not buried, he was told to crawl into it so that we could remove him. Because he had sustained leg injuries, however, this victim had to be assisted into the basket by a rescuer who was sent into a minimally protected area to assist. This victim was then removed using non-entry techniques.

"The Rescue Vac, used in conjunction with a municipal vacuum truck, along with an air knife, was used to break up the soil and vacuum it away from the victim."

The second victim was buried up to his head. Rescue personnel were able to access his position from the open end of a newly installed 36-inch (0.9-m) sewer pipe. Using confined-space standard operating procedures, an entry was made to do the initial patient assessment. Through the pipe, rescue personnel were able to reach the victim and found that he had no pulse. While in the pipe, rescue personnel placed webbing around the victim for use in removing him after he was uncovered from above. The rescue was then reclassified as a recovery.

With a 13-foot wide trench and a 25- by 35-foot diameter spoil pile, it was determined that shoring or sloping the trench would put rescue personnel in unnecessary danger. Instead, the tactic we would use to uncover the victim would be to employ the Rescue Vac.

The Rescue Vac, used in conjunction with a municipal vacuum truck from the local public works department, along with an air knife, was used to break up the soil and vacuum it away from the victim. The vacuum truck was placed approximately 150 feet (45.7 m) away, and an air compressor, used for the air knife, was located 200 feet (61 m) away.

A tower ladder was set up to be used as a high anchor point for the vacuum kit, and tag lines were placed on the vacuum tip so that it would be easier to maneuver it from the lip of the trench. The entire vacuum process was completed from above the trench, and the victim was retrieved in about 1.5 hours. The victim was transported to the hospital, where he was pronounced dead. The scene was well organized and followed all incident management protocols.

This trench incident was a success primarily because a good risk–benefit analysis was completed before committing rescuers. The initial victim was rescued using non-entry trench rescue techniques, and no unacceptable risks were taken by rescue personnel to access the fatality. Using the associated technical rescue discipline of confined-space rescue, the deceased victim was located and accessed, and then to facilitate a non-entry rescue later in the operation, he was attached to a piece of webbing.

In addition, the Rescue Vac technology allowed rescue personnel to uncover the victim in a timely manner when you consider the alternative of putting in place a protective system and then evacuating the dirt by hand.

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Naperville, Illinois

■ Tools and Appliances

The variations in tools and appliances required to complete a trench rescue successfully are as all-encompassing as "Give me whatever you have." If you would normally find it on a construction site, you can bet it will be needed on a trench rescue. TABLE 6-1 provides a general list of suggested tools for trench rescue.

Shovels

Ultimately, when you are dealing with the movement of dirt, the shovel becomes one of the most important tools employed during a trench rescue. In the initial stages of a collapse operation, shovels will be needed to move the spoil pile and flatten the area around the trench lip. This work allows the ground pads to lay flat so that they do not create an additional trip hazard on the scene. In addition, if a worker is partially buried, perhaps the shovel can be given to the worker to begin his or her own self-rescue efforts. In my experience, most victims who are conscious and trapped in a trench have no problem with self-rescue.

Although the shovel might work well at the top of a trench, it has very little value down at the bottom of the trench. The entrenching tool is a small, collapsible version of the larger shovel that is designed to be used in situations where room is limited and a shovel is too big. It also gives rescuers a better feel if they are digging in or around a victim.

Digging operations to remove trapped persons should begin as soon as possible after the protective system is in place—which means you will be working around shoring systems and other tight, congested places. Here the entrenching tool earns its money. It will not carry a lot of dirt but it is a great option when you cannot use a larger shovel and still have to move dirt FIGURE 6-19.

Hammers and Nails

The next most important item to have on the trench collapse site is the hammer. Here, the hammers that you might find in a discount store are not the appropriate tools—rather, you need 20-, 22-, and 24-ounce framing hammers that will drive a 16-penny duplex nail in three hits. Make sure that you not only have the right size hammer, but also give consideration to who is swinging the working end of it. Now is when having the right person for the right job starts to pay off. Remember this rule: Always make sure you have the right person with the right skills in the right place at the right time.

FIGURE 6-19 The entrenching tool is a must for digging in the limited space of a trench.

Because trench rescue operations typically involve temporary protective systems, the duplex nails used to connect wood components are designed to be easily removed. A duplex nail can be taken out because it has two shoulders, which are not supposed to be driven completely flush with the wood **FIGURE 6-20**. This affords the claw end of the hammer a place to get a bite for removing the nail after the operation is over. Wood is not inexpensive, and you should try to reuse it as much as you can.

Table 6-1 Suggested Hand and Miscellaneous Tools List for Trench Rescue

Shovels	Hammers	Saws
Flat Pointed "D" handled Post hole Entrenching tool	Nailing Large sledge Small sledge	Chain(s) Circular Hand Extra blades Repair kits Saw horses
Tools	**Miscellaneous**	**Cribbing**
Squares Pencils Paper Tool ropes (lots) Tool belts Nail pouches Nails (duplex) Nail bars Tape measures Road cones Barricade tape	Pickets Can of paint Buckets Ventilation fans Fan duct Power cords Generators Pike poles Air monitor Hydraulic rams Screw gun and long screws	2 × 4 inches 4 × 4 inches 4 × 6 inches 6 × 6 inches 8 × 8 inches Wedges, 6 inches and 4 inches

Chainsaw

The chainsaw is a very versatile saw for rescue operations involving timber shoring. Keep in mind that you and your fellow rescuers are not building furniture for sale; rather, you are putting together a protective system with an emphasis on function and safety, not keeping the structure level and straight. Stay alert when a chainsaw is in use, regardless of whether you are the one using it. Big chainsaws will cut off your leg in half a second. You do not get too many second chances with this type of cutting tool **FIGURE 6-21**.

FIGURE 6-20 Duplex nails are two-shoulder nails designed for easy removal after use.

FIGURE 6-21 Extreme caution should be used when cutting shores or other material with a chainsaw.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Ventilation Equipment

The electric-powered ventilation equipment used in trench rescue is normally the tried-and-true fire department smoke ejector. Used on the windward side, blowing in the trench, it affords an adequate flow of fresh air into the trench. When it is hot, this equipment also provides some relief to the rescuers in the hole. Remember that ventilation is not always called for unless an atmospheric problem is present. If it is cold outside, ventilation may simply make the rescuer and victim even colder. It would be disappointing to spend 6 hours rescuing a trapped worker, only to have him suffer from rescuer-induced hypothermia. Use ventilation only when appropriate.

Tactical Tip

Tie a few pieces of 12-inch (0.3-m) fire line tape to the exhaust side of the fan **FIGURE 6-22**. The blowing tape will provide a visual indicator that the fan is working. Frequently, the noise level on a trench rescue is too loud to notice if the fan is not operating.

FIGURE 6-22 Placing a piece of tape on a ventilation fan can provide a visual indication of when it is working.

Ladders

Ladders are another form of equipment that can be used for a multitude of purposes during a trench collapse. First, you can place a ladder in the trench and ask the victim to crawl out by himself or herself. Some people can get out of a trench quickly when you explain to them the complex protective system that has to be established before rescuers can enter. I have seen people with broken legs crawl up a ladder when they were frightened enough.

Secondary to victim escape is the requirement for ladder egress in trenches more than 4 feet (1.2 m) deep. Egress ladders need to be placed so that workers do not have to travel more than 25 feet (7.6 m) to get out of the trench, regardless of their location. More importantly, you want to provide two points of egress and ingress in the trench for rescuer safety.

Ladders can also be used to span the trench opening and to provide a base for lifting operations over the trench. In addition, ladders can be used as wales when assembled with a 2 × 12-inch board. Although this is not the preferred method to span a trench opening, it will work in a pinch FIGURE 6-23.

Scene Lighting

Proper incident management includes determining the logistical needs of the current operation and also forecasting the needs of the operation should it extend over many operational periods. In trench rescue, it is not unusual for operation periods to extend many hours, and thus rescue events that start in the daylight could be resolved at night time. Just as you should not wait for a rainstorm before finding dewatering equipment, dusk is not the time to realize you need lights. If external lighting, either separately carried or apparatus mounted, is not a part of your equipment cache, you will need to secure these tools for events that continue into the night. Also keep in mind that external lighting may need to be powered by an external source, meaning that in addition to the lights you will need a power plant (usually an apparatus-mounted or portable generator) to run them.

FIGURE 6-23 Although not the preferred method, ladders can be used as wales when 6 × 6-inch or 8 × 8-inch material is not available or access is difficult.
Courtesy of Larry Collins

Tactical Tip

Use only fire-service–grade ground ladders for makeshift wales. Household ladders cannot withstand the lateral pressures exerted by the shores. Even when a sturdier ladder is used, however, it may still be damaged. A much better alternative is to use an appropriately sized timber or laminated beam.

Dewatering Devices

Dewatering devices are absolutely necessary for the control of water from both ground seepage and rainwater runoff. Excess water in the trench not only creates an uncomfortable environment in which to work, but also deteriorates the trench floor and toe if it is allowed to stand.

FIGURE 6-24 Mud pumps are very versatile, although they sometimes require extensive priming to pull the vacuum.
Courtesy of Bob Schilp

Large diaphragm pumps, affectionately called *mud pumps*, are great low-volume dewatering devices that will hold up to the rigors of even the worst trench scene **FIGURE 6-24**. These pumps can be gas, air, or battery operated, with each model having its own advantages and disadvantages.

Additional dewatering devices are the municipal vacuum truck and the Rescue Vac system. We discuss these units in more detail in the "Victim Access and Care" chapter.

Tactical Tip

Do not wait for rain to begin before you look for a dewatering device. In addition, have two of these devices on site because one of them will inevitably break down and not work.

■ Setting up a Cutting Station

When a trench rescue incident requires several pieces of lumber to be cut, you should consider building a cutting station table. It takes just a few minutes for a few rescue personnel who are handy with a saw and nail gun to put such a table together, and the time spent setting up the cutting station can save you considerable time over the course of the incident.

The table itself is designed with a standard 4 × 8-inch sheet of ¾-inch plywood. Using a standard piece of plywood means you do not have to cut the table top and, in fact, can use it to square up the table when it is being nailed to the frame. Once the table is put together, the top can be railed with 2 × 4-inch runners that can be spaced and also marked at designated positions so standard cuts do not need to be measured each time. To build a cutting station table, follow the steps in **SKILL DRILL 6-2**:

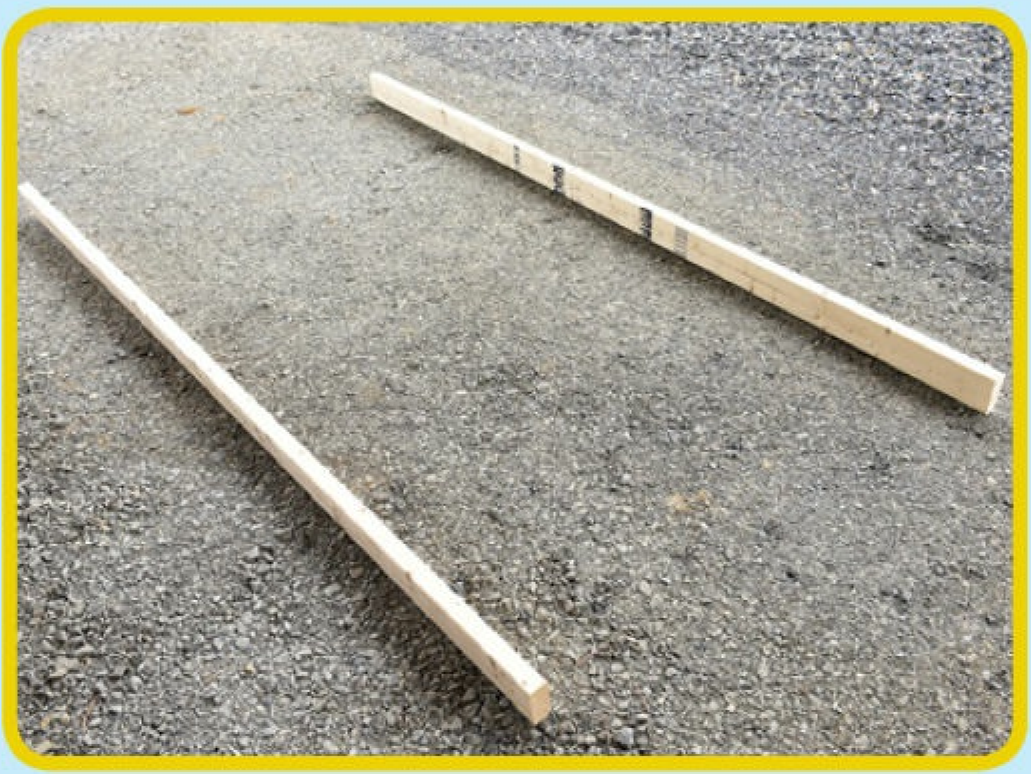
1. Cut four 4 × 4-inch pieces of wood all the same lengths that are between 32 and 36 inches (0.8 and 0.9 m) long **STEP 1**.
2. Lay out two 2 × 4 × 96-inch side rails **STEP 2**.
3. Cut seven 2 × 4 × 45-inch cross braces **STEP 3**.
4. Starting at one end, measure and mark the rails on 16-inch centers **STEP 4**.
5. Line up the seven cross braces with the marked rails and nail them together **STEP 5**.
6. Place the plywood top on the assembled frame and nail one corner **STEP 6**.
7. Adjust the plywood by using it to square up the frame. Nail the top on all sides and cross braces **STEP 7**.
8. Turn over the table and install the legs on the corners of each side of the table. Use a framing square to make sure the legs are square with the table frame when nailed to it **STEP 8**.
9. Pull a chalk line across the table top that lines up with the 2 × 4-inch pieces that make up the table frame **STEP 9**.
10. Nail the table top to the frame using the chalk lines as a guide **STEP 10**.
11. Stand the table on its legs and install 2-inch × 4-inch × 6-foot runners on the top that are spaced at widths of 1 ¾, 3 ¾ and 5 ¾ inches. Note: Each measurement is ¼ inch larger than standard lumber widths to account for swollen or slightly warped wood **STEP 11**.
12. Mark the 2 × 4-inch runners at 12-, 18-, 24-, 30-, and 39-inch intervals **STEP 12**.
13. For long-term operations, cut and install braces that are cut at opposite 45-degree angles from the table legs to the bottom of the table frame **STEP 13**.
14. The cutting station table is now complete **STEP 14**.

SKILL DRILL 6-2

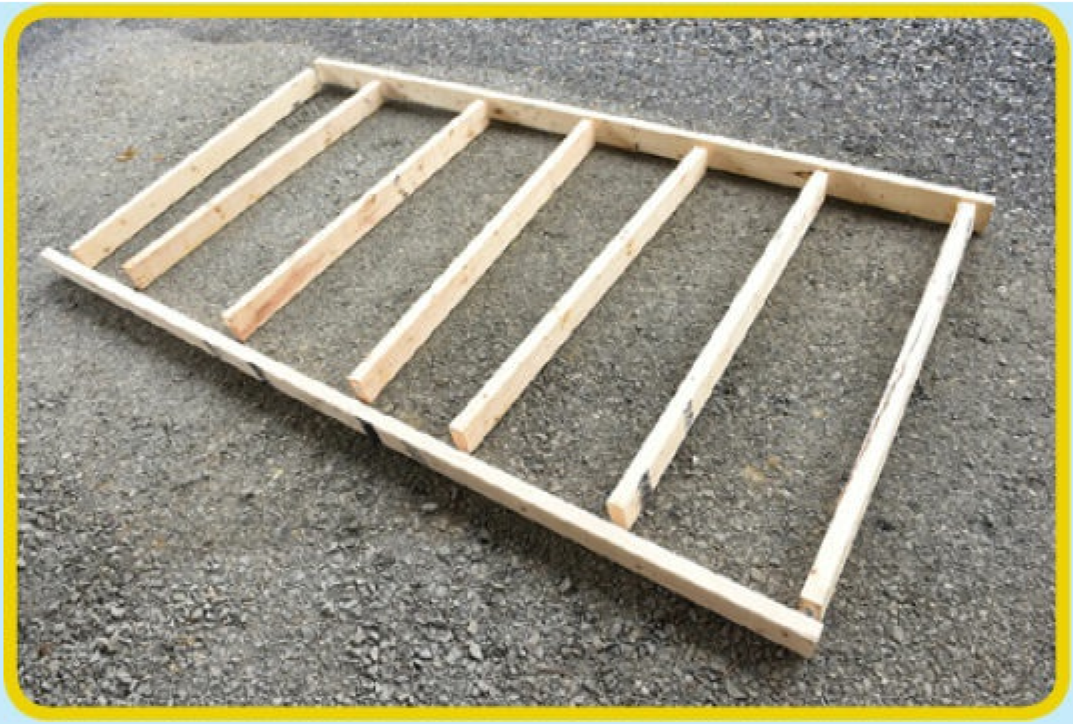
Setting Up a Cutting Station Table

(Trench Rescue Level I: 8.1.3)

1 Cut four 4 × 4-inch pieces of wood all the same lengths that are between 32 and 36 inches (0.8 and 0.9 m) long.



2 Lay out two 2 × 4 × 96-inch side rails.



3 Cut seven 2 × 4 × 45-inch cross braces.

4 Starting at one end, measure and mark the rails on 16-inch centers.

5 Line up the seven cross braces with the marked rails and nail them together.

6 Place the plywood top on the assembled frame and nail one corner.

7 Adjust the plywood by using it to square up the frame. Nail the top on all sides and cross braces.

8 Turn over the table and install the legs on the corners of each side of the table. Use a framing square to make sure the legs are square with the table frame when nailed to it.

9 Pull a chalk line across the table top that lines up with the 2 × 4-inch pieces that make up the table frame.

10 Nail the table top to the frame using the chalk lines as a guide.

11 Stand the table on its legs and install 2-inch × 4-inch × 6-foot runners on the top that are spaced at widths of 1 ¾, 3 ¾, and 5 ¾ inches. Note: Each measurement is ¼ inch larger than standard lumber widths to account for swollen or slightly warped wood.

12 Mark the 2 × 4-inch runners at 12-, 18-, 24-, 30-, and 39-inch intervals.

13 For long-term operations, cut and install braces that are cut at opposite 45-degree angles from the table legs to the bottom of the table frame.

14 The cutting station table is now complete.

Wrap-Up

Review: Just the Dirt

- In every case, the safety of personnel depends on their level of skill, as developed during both training and real-time incidents.
- Instilling a safety mindset into the culture of your team does not happen overnight, but rather is the result of many hours of training and the discipline that comes from everyone on the team being accountable.
- PPE can be divided into two main categories: the clothing that rescuers wear to protect themselves and the equipment provided that would not be considered standard issue items.
- In all cases, rescuers need to have some level of protection from skin abrasions from contact with on-scene objects. Other PPE includes gloves, head protection, eye protection, foot protection, and specialty items.
- Many different types of tools and equipment may be required at the trench collapse scene, most of which will already be familiar to rescuers.
- Equipment specific to trench rescue operations includes lip protection, sheeting, shores, and wales.
- Backfilling—filling in voids that have been created from cave-ins—is an essential skill for trench rescue shoring.
- The variations in tools and appliances required to complete a trench rescue successfully are all-encompassing, consisting of any tools you could find at a construction site.

Hot Terms

Dewatering devices Devices that control water from both ground seepage and rainwater runoff.

Duplex nail Nail that has two shoulders, which allows it to be removed easily.

Entrenching tool A small, collapsible version of the larger shovel, designed to be used in situations where space is limited and a regular shovel is too big.

Ground pads Wooden material used to line the trench lip for the purpose of distributing rescuer and equipment weight.

Hydraulic shores Type of shore that is lowered into the trench from the top and then expanded by using a 5-gallon reservoir of nonflammable and biodegradable fluid.

Lip bridges A type of lip protection built with girders (timbers), beams (ladders or timbers), decking (plywood or lumber), and supports (small pieces of timbers), which is placed away from the compromised wall and used to elevate the bridge above the lip.

Pneumatic air shores Type of shore that is extended by using compressed air. After extension, the shore either locks by itself or is manually locked to prevent a collapse under load.

Screw jack Type of shore that is tightened by a thread and yoke assembly. It is also sometimes referred to as a pipe jack when used in conjunction with varying lengths of pipe.

Self-contained breathing apparatus (SCBA) A respirator that supplies air to the user from a breathing air source that is independent of the environment. It is designed to be carried by the user.

Sheeting The portion of the protective system designed to hold back running debris.

Shores The component in the protective system that carries the force from one side of the trench to the other.

Strongbacks The 2-inch × 12-inch × 12-foot components in the protective system that transmit forces along the vertical plane of the trench wall.

Struts *See* Shores.

Supplied air breathing apparatus (SABA) A respirator that supplies breathing air to the user from an air source that is independent of the environment, supplied from a remote source. It is not designed to be carried by the user.

Timber shore Type of shore with a bending strength of not less than 1500 psi (105.5 kg/cm).

TRENCH RESCUER *in action*

You are enrolled in a 2-day trench rescue technician refresher class being given at a neighboring fire training academy. Day one was mostly classroom lectures, with updates on new standards, regulations, equipment innovations, and techniques. But today you are out in the dirt, putting to practical use some of the new things you saw and learned the day before. It is a beautiful spring day, sunny, dry, and about 65°F.

The instructor is running a scenario that involves an intersecting “T” trench that is approximately 9 feet (2.7 m) deep, 4–6 feet (1.2–1.8 m) wide, and 20 feet (6.1 m) long in each section. There has been a wedge collapse of one corner where the trench intersects. The goal in this scenario is to use the techniques learned in the classroom to shore up the collapsed corner. You are assigned to the Logistics section for this scenario, along with two assistants.

The main tool cache for the class is located approximately 300 feet (91.4 m) from the site of the trench, although trench panels, ground pads, and wales are cached 50 feet (15.2 m) away.

1. What would your first priority be as the scenario is getting under way?
   - A. Check with the IC as to where you should locate the tool and equipment cache.
   - B. Set up the tool and equipment cache where you think it should be.
   - C. Wait to be told where to set up the tool and equipment cache.
   - D. Set up several small caches where tools will likely be required.
2. Which item of PPE would you and the other logisticians NOT require for your tasks?
   - A. Gloves
   - B. Bunker gear
   - C. Helmet
   - D. Safety glasses
3. You notice that some students assigned to the paneling team are not wearing their gloves. What should you do?
   - A. Ignore it, because they are not your responsibility
   - B. Order them to put on their gloves in front of the other students
   - C. Tell their "officer"
   - D. Pull them aside and discretely mention that you know a good place to store their gloves—on their hands
4. Which equipment would you NOT likely use in this scenario?
   - A. Pneumatic air shores
   - B. Dewatering device
   - C. Air bags
   - D. Ventilation equipment
5. Why is it recommended to cut off all corners of trench panels at 90 degrees?
   - A. To facilitate handling
   - B. For ease of storage
   - C. To reduce the possibility of splintering if the panels are dropped
   - D. To replace the need for hand holes
6. What is a lip bridge used for?
   - A. To bridge across the trench from lip to lip
   - B. As an addition to shores to prevent the lip from collapsing
   - C. Lip bridges should not be used
   - D. As an alternative to ground pads around the lip of a trench

Incident Assessment

CHAPTER

7

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the purpose of a trench rescue assessment NFPA 8.1.1 NFPA 8.1.2. (p 98)
- Describe the assessment activities conducted at the time of the alarm NFPA 8.1.1 NFPA 8.1.2. (pp 98–99)
- Describe the assessment activities conducted on arrival at the scene NFPA 8.1.1 NFPA 8.1.2. (pp 99–100)
- Describe the assessment activities conducted during the emergency NFPA 8.1.1 NFPA 8.1.2. (pp 100–101, 104–105)

Skills Objectives

After studying this chapter, you should be able to:

- Assess a trench rescue scene NFPA 8.1.1 NFPA 8.1.2. (pp 98–105)

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

You arrive on the scene of a massive cave-in, only to find a collapsed trench with no protection. In addition to this complication, you find that the only workers left on the scene are Spanish speaking. It is obvious to everyone that people are trapped; however, you do not speak Spanish, and the only word you can make out is *dos*.

As you try to figure out the extent of the incident, you start making hand gestures to the workers in hopes that they can tell you where the victims might be located. The workers' response is to shrug their shoulders and make a hand gesture that moves their hands toward their mouth. From this, you can only assume that they were not here when the collapse occurred but rather left to eat lunch while some stayed at the site to continue working.

As there is no visible sign of anyone in the collapse area, and the workers on scene did not witness the collapse, you are a little unsure that you even have a problem. That said, you are in no position not to take action, but instead start working from the assumption that people are indeed trapped.

1. Since no one witnessed this incident, what are some things in and around the trench that could indicate a possible location of any victims?
2. Do you think this incident will be easily resolved, or will it be a long-term rescue situation? Which factors make you feel one way or the other?
3. If it turns out to be a long-term incident, which kind of environmental factors would you need to consider?

Trench Rescue Level I

Scene Assessment

In trench rescue, assessment is the foundation on which you build your decision-making platform. When completed, it helps you determine a set of guidelines for action.

The assessment is nothing more than a tried-and-true situational size-up. A size-up involves taking the time to figure out what has happened, analyzing the information, and developing an incident action plan to provide a coordinated plan to address the situation.

Assessment can be broken into three time periods: from the time of alarm until you arrive on scene, your arrival on scene, and continuously during the operation. If you are an emergency services provider, most of these considerations will come as a natural part of the emergency response; however, this chapter adds a few considerations specific to trench rescue operations.

Time of Alarm

At the time of the alarm, you should begin the process of gathering information. The initial information will come from the alarm data that are supplied to the dispatcher at the time the call is received. The typical call will reference a collapse of some sort, but information may be very vague. Usually you will get very little detailed information. Because trench rescue is a specialty call that does not happen very often, the initial questioning of the caller by the dispatcher may be less than adequate. It will then be up to you to question and prompt the dispatcher for additional information while you are en route. Some of the questions that may be appropriate are covered here.

■ What happened?

Have the dispatcher call back and keep the caller on the line. Having the caller available will be critical if you are having trouble finding the accident scene, but it is also helpful for someone to be available if you have additional questions, such as which type of collapse has occurred or how many people might be buried or trapped.

■ Why was the excavation work being done?

If the trench is for a small utility line, that is one thing. If the trench was dug for a large storm drain pipe, it is quite another **FIGURE 7-1**. This type of information will suggest how large the excavation was before it collapsed. Consideration may be given to acquiring additional resources when the type of excavation is pinpointed.

■ Is/are the victim(s) completely buried?

This step in the information process allows you to begin risk assessment. Although you cannot discount the possibility that a completely buried victim could be alive, the reality of the situation is that very few completely buried victims survive. Remember, all rescue actions and protocols should be based on weighing risk versus benefit. If the victim is completely buried, your risk profile should be very limited because the benefit profile is also very limited. Lastly, if the incident involves buried victims, you know that the rescue event is likely to be long and complex.

FIGURE 7-1 Large pipes mean deep and wide trenches.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

■ Is the situation a trench collapse or some other form of injury in the trench?

Trench emergencies may involve something other than a collapse. If the victim is injured but not buried, you are dealing with a very different type of call than if the victim were buried.

■ Will access be difficult for equipment and rescue personnel?

Generally, new construction areas do not have an established road network. This lack of access could mean a delay in getting resources to the scene. All of the equipment needed may have to be carried to the site if you cannot get your apparatus close to the collapse.

■ How is the weather, and is it expected to change during the operation?

The collapse itself may have been weather induced, but in any case, consideration may have to be given to changing weather conditions. For instance, you may need dewatering equipment if it is raining or if a storm is expected. If it will be hot during the rescue, you may need more personnel than would normally be necessary. If it is very cold, there can be devastating effects on the victim, but over time rescue personnel may also face the risk of hypothermia. In the case of cold weather, you should consider using a warm-air ventilator. In the case of hot weather, you should consider cooling the area using ventilation or even misting fans that use air and water droplets to lower the air temperature. You may want to consider the need for lighting during overcast conditions or if the situation is likely to extend into the night.

Tactical Tip

Have all resources that are responding to the scene stage at a remote location until your assessment is complete. A good assessment is hard to do with a wealth of action-oriented folks on the scene. Trust me: Rescuers are not a patient bunch!

Arrival at the Scene

Upon arrival at the scene, you will be expected to finish gathering your information and develop a plan for mitigating the incident. This means taking the basic information that you have gathered, adding to it what you can subsequently glean from witnesses, and assimilating all of those data with what you can actually see with your own eyes. (See the "Hazard Control and Atmospheric Monitoring" chapter for discussion of hazard assessment and the "Trench Rescue Shoring Techniques" chapter for general considerations for all trenches.) Some additional on-scene considerations are covered here.

■ Who is in charge, and what has happened?

Seek out and question the competent person or person in charge on the site. This person will give you information as to the original depth and width of the trench and the type of protective system that was or is in place (if any). You will also want to find out what the victim was doing at the time of collapse and where he or she was last seen.

■ Is there a language barrier?

Nothing can be as frustrating as trying to handle an emergency and not being able to communicate with the person who can give you the necessary information. If there is a language barrier, find someone to interpret.

■ Based on equipment limitations, is the collapse within your scope of operations?

Remember that your equipment has limitations. If the trench is deeper than 20 feet (6 m), cuts through C-80 soil, or is a massive cave-in, commercial techniques for stabilization will be necessary. (These techniques are discussed in the "Protective Systems" chapter.)

■ What are the injuries?

How serious are the victim's injuries, and is there enough time to provide treatment? For instance, will the extrication process take so long that the victim may die, or can the victim be hooked with a pike pole and pulled out? Although we always want to maintain good cervical spine immobilization for our victim, it is better to risk paralysis if the alternative is certain death because extrication took too long.

■ What is the victim's survivability profile?

If your victim is buried and there is no chance he or she jumped in the end of a pipe for protection, you are most likely dealing with a recovery. A recovery is no longer an emergency: Do not get your people hurt!

■ Which type of protective system is or was in place?

The kind of protective system in place is important because if the original protective system failed, rescuers face a big problem. In such a case, you may have to remove what was in place and then start over or, alternatively, figure out a method to stabilize the existing system. At this point, if you are dealing with a fatality, call the Occupational Safety and Health Administration (OSHA) or other professional engineers for help. OSHA is required to investigate such an incident and will be able to do so more easily if the scene is less disturbed.

■ Do you have the resources to accomplish this mission successfully?

The success of any rescue operation relies on having trained personnel who have the proper equipment to get the job done. If you are currently missing any of these elements, or know that you will be missing them, you will fall victim to one or more elements of the FAILURE acronym mentioned in the "Introduction to Trench Rescue" chapter.

■ Can you mitigate this incident with a rapid non-entry rescue technique?

Non-entry rescue techniques may be appropriate in many situations. Foremost among them is the case in which the victim is already deceased. Rescue entry will not provide any benefit in this circumstance. In such a situation, the best solution may be as simple as using a vacuum system to excavate the entrapping product and then getting some sort of retrieval line on the victim.

In other cases, you may be faced with an uninjured victim who has fallen into the trench and can climb a ladder to safety. A minimally injured victim can do amazing things when faced with a dire situation. Always consider non-entry options before other more risky techniques when evaluating your rescue options.

Tip

The trench rescue tactical worksheet is necessary for rescue personnel involved in the rescue operation. Using predefined boxes and questions helps guide rescue decision making and alerts incident commanders to potential rescue scene considerations. This can sometimes mean the difference between a successful rescue and a tragic recovery situation. **FIGURE 7-2** is a tactical worksheet with situation size-up questions that you can modify for your department's use.

During the Emergency

Keep in mind that everything done at a trench collapse scene makes it a new scene. These situations are so dynamic that constant evaluation for changing conditions is of paramount importance. Constant evaluation will help you anticipate potential problems and be proactive rather than reactive.

All of these factors, and many others, will need to be addressed if the rescue team is to be successful at a trench collapse. Take your time when completing this phase of the operation. Recognize that good information will lead to a good plan of attack: Do not make a move until you have fully assessed the situation or you may find yourself looking at the FAILURE acronym to see where you went wrong.

■ What is in your incident action plan?

The main way to ensure success in trench rescue operations is to have a plan. A trench rescue action plan is the key to communicating expectations to all levels of your team. From a strategic perspective, clearly articulated goals help personnel understand the broader scope of operations. For instance, in a trench rescue you could have somewhat generic goals like "Provide resources and personnel to rescue trapped persons in a safe and efficient manner." Although very broad in scope, take a look at what is actually stated. You have indicated you will determine necessary resources and personnel, use those resources to rescue a trapped person, and all of this will be conducted in a safe and efficient manner.

The point to having a clearly identified strategy is not so people know you are going to rescue someone from the trench—hopefully everyone will know why they are participating in the rescue event. Rather, it helps develop tactical objectives. The tactics are the nuts and bolts to how you will accomplish your strategic goal. What area will you designate as the rescue area? What area will be designated the general area? How many personnel will you need, and what must the scope of their training be for you to be successful? In addition, you would want to specify the techniques you will employ to rescue the victim in a safe and efficient manner.

■ What is the operational period?

You will also want to establish an operational planning period that can serve as a reminder to stop and take note of your progress at achieving the tactical objectives. Trench rescue action plans are dynamic plans because trench rescues are dynamic situations. Current conditions will not be the same as the conditions that may arise in mere minutes or hours. For example, the potential for changing weather conditions should be considered and planned for when developing tactical objectives, and the collapse zones and rescue areas may change as the incident progresses. Keep in mind that everything done at a trench collapse scene makes it a new scene. These situations are so dynamic that constant evaluation for changing conditions is of paramount importance. Constant evaluation will also help you anticipate potential problems and be proactive rather than reactive.

DATE	SHIFT
ADDRESS TIME	TIME
OWNER	WIND SPEED
RESPONSIBLE PARTY DIRECTION	DIRECTION
RESPONDING COMPANIES	
BACKFILL COMPANIES RIT	

Side C

Side B

Side D

Side A

What type of collapse has taken place?	What has occurred before my arrival?
Do I have sufficient manpower?	Is the IMS flow chart expanded sufficiently to handle the incident?
Are all necessary IMS positions filled?	Are rescue and/or EMS transport units on scene or en route?
Do I have sufficient specialized equipment on scene or en route?	Do I need to call for specialized civilian personnel (e.g., engineer or rigger)?
Is this a rescue or recovery?	Is the victim completely buried, or is this a partial entrapment?
What is the long-term weather forecast, and will it affect my operation?	Have I eliminated all hazards in the general and rescue area?
Are there any hazardous materials involved?	Have I monitored the atmosphere in and around the trench?
Is ventilation needed and in place?	Have I determined the correct protective system to make rescue attempt?
Do I need to consider commercial techniques?	Have I assigned a public information officer to handle the media?

Notes:

FIGURE 7-2 Trench rescue tactical worksheet.

VOICES OF EXPERIENCE

On January 20, 1999, the alarm sounded for Los Angeles County USAR-1 to respond with Los Angeles Fire Department (LAFD) to a trench rescue. The first sight of the victim led me to believe that this was likely to be a body-recovery operation. The only thing visible was the top of his yellow hard hat and one hand, which was raised above his head. The hand was clamped around a manila rope, and the other end of the rope was draped over the trench plate and held now by an LAFD fire fighter. Considering the likelihood that dirt had compacted directly around his face and possibly into his mouth and nose, the forces that were possibly being applied to the man's chest and torso, and the time that had elapsed since he became trapped, the event did not look very survivable.

"As rescue personnel kept bumping the victim's hands, the victim's fingers moved. Rescue personnel signaled and yelled to all of us that the victim was still alive."

While interviewing the site supervisor, we found that the worker and several colleagues had been standing on what they *thought* was solid ground, on the outside (north) perimeter of three main large trench plates that supported the walls of a 30-foot deep excavation during the installation of a public-works storm drain system. At the end of the shift, the ground collapsed, without warning, beneath the victim's feet. Apparently, a large void space (possibly from rain compacting and/or washing away loose soil and leaving a narrow "bridge" beneath the blacktop) gave way. The victim was sinking feet first into the fast-subsiding soil.

When everything stopped moving, the victim was buried with his head 8 feet (2.4 m) below grade and 2 feet (0.6 m) below the hanging trench plate. His hat was on his head, tilted forward to create a sort of brim over his forehead. He was buried in an upright position, with his face positioned several inches from one of the large steel I-beams that held the middle trench plate in place.

The potential for secondary collapse of the excavation walls was evident from the many growing stress cracks, and dirt was sloughing in spontaneously from the irregularly shaped walls over the victim. We agreed that the following tasks were required without delay to keep the victim alive until he could be rescued:

1. Expedite shoring operations to provide a "safe zone" for the victim.
2. Expedite the placement of edge protection to prevent "point loading."
3. Shut down local traffic and heavy equipment.
4. Have the truck company extend its heavy duty LTI (Ladder Towers Inc.) aerial ladder over the hole to a point directly over the victim, and rig it for a "suspended rescuer" operation.
5. Get at least one primary rescuer into the hole to begin using a dirt vacuum and air knife to

uncover the victim's face and secure his airway.

6. Provide at least one backup rescuer for every primary rescuer.

With an incident action plan established and provisions in place for the initial rescuer entry, we proceeded with the digging operation. The working conditions were restrictive because rescuers had to maintain a constant vigil to avoid kicking against the shoring or the side walls, which might lead to secondary collapse. As a result, each of the rescuers would be left without the normal leverage that one would have while standing on solid ground and/or bracing against a wall. They were reliant on the tag line teams to secure their suspended bodies in place while they directed the dirt vacuum against the soil and worked it around the victim.

After approximately 30 minutes, the decision was made to rotate personnel. Despite several more slough-ins, the victim was uncovered to the bridge of his nose. This was excruciatingly slow progress.

Meanwhile, the shoring team continued to shore up the irregular side walls, a task that proved extremely problematic. At one point, a sheet of plywood was lowered against the north wall, and an attempt was made to pressurize it with lateral struts braced to the south against the main trench plate; however, the increasing strut pressure caused an adjacent portion of the north wall to collapse and another layer of dirt to spill over the victim.

This was an example of the frustrating conditions faced by the shoring team: Shoring and pressurizing one area of the collapse zone sometimes caused dirt in other parts of the pit to fail and "slough in." From the beginning, there was limited room in which to place lateral struts while maintaining sufficient clearance to move the primary rescuers in and out of the pit, and the shoring options were becoming ever more limited because the dimensions of the pit forced rescuers to dig a V-shaped hole with the dirt vacuum as they worked to unbury the victim. Rescue personnel had discussed the option of placing a pipe or some other barrier protection over the victim. Consequently, workers on the scene had already fabricated several pipes and even one large steel pan with a section cut out for facial access, as part of this effort. However, there simply was not enough room in the pit beneath the hanging trench plate for such a measure. Also, we were still struggling to remove dirt from directly around the victim's face and head.

We went with an alternate plan to place a supplied air breathing apparatus (SABA) umbilical air mask on the victim, with an air supply officer assigned to ensure a constant supply of air throughout the rescue at the instant his face and head were cleared sufficiently to allow donning of the mask.

At this point, rescue personnel attached a strap unit to the end of Truck 39's rope via carabiner, and it was lowered to the victim. He was then instructed how to apply the straps to his own wrists, while his head was still buried in dirt! It was a blind application of the straps, but it worked. The victim deserves credit for keeping cool and calm enough to assist in this portion of his own rescue.

Now, with the victim captured by the wrist straps, it seemed safe to try another tactic that might expedite the process of extracting him. The decision was made to carefully and slowly begin hand digging the soil pile at the bottom of the center trench plate. The thought was that it might slough away from the victim, allowing us to uncover him faster, but this was a mistake on our part.

As soon as a couple of fire fighters began digging with shovels at the base of the plate, the victim and the soil that had engulfed him began to sink farther below grade in equal measure to the soil that was being removed from beneath the trench plate. We immediately called a halt to the digging operation, but the sinking continued. Within seconds, the victim was reburied in a layer of dirt about 2 feet deeper than the top of his head.

Rescue personnel had been working in the hole for nearly 30 minutes at the point when the victim was reburied. We had planned a rotation in rescue personnel, but the rescuer in the trench insisted on staying in the hole to attempt to uncover the victim's head and face. Time was clearly critical at this point; thus, we elected to keep the rescuer in the trench as the next rescuer got ready for a fast insertion at the moment it became necessary.

After another 10 minutes, the rescuer in the hole was nearing the point of exhaustion. Then the dirt vacuum became clogged with soil and had to be removed from the hole to be cleared.

We were now about 15 minutes into this particular burial sequence, and there was absolutely no sign of the victim. Worse, there was no movement whatsoever beneath the soil. The victim's survival seemed to be in extreme doubt. According to our estimate, this was the fourth or fifth time that we observed the victim completely buried by a secondary collapse.

A moment later, as rescue personnel kept bumping the victim's hands, the victim's fingers moved. Rescue personnel signaled and yelled to all of us that the victim was still alive. It was a true roller-coaster ride of emotion, but now we seemed to be back nearly to square one, with the victim mostly buried.

Rescue personnel worked feverishly to unbury the victim's face enough to finally apply the SABA mask. After it was secured on his head, the victim had a constant supply of breathing air.

The first hydro-vac truck then arrived on the scene. As the big vacuum truck was being positioned and its vacuum hose was being snaked toward the edge of the collapse zone, the rescuers continued to work with the smaller dirt vacuum. Finally, we were able to uncover the victim to the top of his shoulders, and with continued dirt removal and shoring free the victim.

The last hurdle was to cut the victim's belt, which was hung on a beam. After several more pulls, we "popped" the victim right out of his pants and boots, which remained lodged in the soil. Now suspended via the Cearley strap (with the wrist straps as backup), the victim was free of his entrapment. He was then raised from the trench and lowered directly onto a gurney for transport to the hospital.

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■ Which factors must be considered when looking for buried victims?

The first place you would look for, or expect to find, a victim of a trench collapse is at the end of the pipe string. This area represents the last location where work was taking place. Other information, such as the depth of the trench, may be determined by looking at the engineer's flagstick. Normally, the flagstick will be marked with the trench depth and grade information. You may also be able to look at the orientation of laser targets if they have not been moved **FIGURE 7-3**. More than likely, when you get the call for a collapse, the spot will be noticeable, and the competent person will have a good idea of the general area in which the victim was last seen

FIGURE 7-4.

FIGURE 7-3 The orientation of laser targets can be an indication of victim location.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 7-4 Most trench work takes place in limited-size openings, and a small area means that you do not have to look long to find the victim.

If the collapse has occurred at the end of a pipe string, you should definitely listen for sound in the pipes. The victim may have been able to get his or her head and chest in the exposed pipe before the collapse. Go back to the point of origination or nearest entry point for the pipe, and listen for sounds from the victim. If you enter the pipe for rescue purposes, be aware that it is a confined space and that additional considerations for this type of rescue are necessary **FIGURE 7-5**.

More difficult is actually finding a buried victim when his or her location is in question. One of the things that you can do in such a case is use some of the information that you gathered during the assessment. Consider what the victim was doing at the time of the collapse. For example, if he or she was sighting the hole for depth, you may find the victim at the bottom of a grade pole **FIGURE 7-6**. In addition, paint and grease buckets may have been located on top of the trench within reach of the worker. The same can be said for tools and other equipment.

FIGURE 7-5 When conducting size-up, you must consider which type of work was being done at the time of the collapse. Open pipes can provide refuge for victims in a collapse.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

FIGURE 7-6 Grade poles can yield information about trench depth before collapse.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Exposed limbs are obviously a good indication of victim location. Use caution, however, when assuming victim location based on exposed body parts. The exposed limb may not be in the normal orientation for the human body. Be careful when digging around victims until you are sure of the head and chest location.

Almost everyone these days carries a cellular phone that can be activated and, if on a ring notification mode, can help locate your victim. Getting positive results may be as easy as calling the victim's number and triangulating the location based on the sound. Other methods include use of listening devices or seismic indicators that are carried as part of a structural collapse tool cache.

■ Do you have a solid rescue plan, and have you given a preoperational briefing to rescue personnel?

Before any operation takes place, all rescue personnel should be informed of at least the "big picture" elements of the rescue plan. Sharing this plan includes holding a safety briefing as well as giving more detailed information about the method and type of protective system that you will build for those rescue personnel involved in constructing the system, along with all known hazards, command structure, radio frequencies, and tactical objectives. Additional components of the plan that should be covered include the stop work/evacuation notification procedure and personnel accountability system to track the locations and activities of all personnel on the scene.

Tactical Tip

By far, the best indicators of victim location are on-scene resources; however, when such credible information is lacking, nearby drink containers and refreshment items could provide clues to the last known location because they may have been within reach of workers.

Wrap-Up

Review: Just the Dirt

- In trench rescue, assessment is the foundation on which you build your decision-making platform.
- At the time of the alarm, you will begin the process of gathering information. Key questions include the following;
  - What happened?
  - Why was the excavation work being done?
  - Is the victim completely buried?
  - Is the situation a trench collapse or some other form of injury in the trench?
  - Will access be difficult for equipment and rescue personnel?
  - How is the weather, and is it expected to change during the operation?
- Upon arrival at the scene, you will be expected to finish gathering your information and develop a plan for mitigating the incident. Key questions include the following:
  - Who is in charge, and what has happened?
  - Is there a language barrier?
  - Based on equipment limitations, is the collapse within your scope of operations?
  - What are the injuries?
  - What is the victim's survivability profile?
  - Which type of protective system is/was in place?
  - Do you have the resources to accomplish this mission successfully?
  - Can you mitigate this incident with a rapid non-entry rescue technique?
- Trench rescue situations are so dynamic that constant evaluation for changing conditions is of paramount importance. Key questions include the following:
  - Which factors must be considered when looking for buried victims?
  - Do you have a solid rescue plan, and have you given a preoperational briefing to rescue personnel?

Hot Terms

Personnel accountability system System used by command to track personnel resources on the scene of an emergency.

Size-up Determination and analysis of information used to develop a rescue plan of action for an incident.

Stop work/evacuation notification procedure A predetermined signal or sound that indicates an unsafe condition.

TRENCH RESCUER *in action*

It is late in the afternoon when your trench rescue team is dispatched to a residential area for a reported trench cave-in. You are the senior officer on duty and respond in your command vehicle. You have to take care while responding because the roads are slick from the rain that has been falling all day.

You are the first member of your crew to arrive at the scene. There, you find a worker trapped in a very narrow excavation that has been dug alongside a bungalow. The trench extends along the fill side of the house, has collapsed around 15 feet (4.6 m) of its approximately 40-foot (12.2-m) length, and seems to go down to the footings, approximately 9 feet (2.7 m) deep. There is about 1 foot (0.3 m) of water in the uncollapsed portions of the trench. The trapped worker is near the end of the collapse zone, buried up to his chest, and is unresponsive due to a head injury caused by a stone that hit him as the trench collapsed. You notice that small amounts of soil are continuously sloughing into the trench all along the excavation.

You notice three lunch buckets and two backpacks sitting out of the rain on the porch of the house. There are no witnesses to the cave-in, but the resident who called 911 says that the contractor had dropped off four workers in the morning, but had been by several times during the day and had been coming and going with various workers. You obtain the phone number for the contractor but there is no answer when you call.

1. What would NOT be part of your size-up while responding to this call?
   - A. Location of the incident
   - B. Weather considerations
   - C. What has happened?
   - D. Which type of soil is it?
2. You establish command and await the arrival of your crews. Where should your initial staging area be located?
   - A. In the church parking lot, a half block up the street
   - B. Across the street from the scene
   - C. In the driveway of the bungalow
   - D. Just before and after the house, leaving the street in front clear of vehicles
3. Based on the information available, how many possible victims are there?
   - A. One
   - B. Five
   - C. One confirmed, possibly five more

D. One confirmed, possibly four or more

4. What is a major concern for this incident?
   A. Number of victims
   B. Time of day
   C. Weather conditions
   D. Type of collapse
5. Which is NOT an indicator of the location of possible victims?
   A. Lunch buckets and backpacks on the porch
   B. Water bottles on the edge of the excavation
   C. Anything indicating the work zone—tools, end of pipe, and so on
   D. Exposed limbs
6. Which of the following is NOT a component of a preoperational briefing?
   A. Safety briefing
   B. Known hazards
   C. Tactical objectives
   D. Individual assignments

Hazard Control and Atmospheric Monitoring

CHAPTER 8

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Describe the areas of a rescue scene in terms of hazard level NFPA 8.1.2. (p 115)
- Describe the use of atmospheric monitoring in trench rescue NFPA 8.1.2 NFPA 8.1.3. (pp 115–119)
- Describe hazard control using ventilation NFPA 8.1.2 NFPA 8.1.3. (p 119)

Skills Objectives

After studying this chapter, you should be able to:

- Use atmospheric monitoring in trench rescue NFPA 8.1.2 NFPA 8.1.3. (pp 115–119)
- Use ventilation for hazard control NFPA 8.1.2 NFPA 8.1.3. (p 119)

Trench Rescue Levels I and II

Knowledge Objectives

After studying this chapter, you should be able to:

- Identify and describe the five categories of hazards NFPA 8.1.1 NFPA 8.1.2 NFPA 8.1.3 NFPA 8.1.4 NFPA 8.2.1. (pp 110–112)

Skills Objectives

There are no Trench Rescue Levels I and II combined skills objectives for this chapter.

Additional Resources

- 29 CFR 1926 Subpart P, *Excavations*
- NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*
- OSHA 1910.146, *Permit-Required Confined Spaces*

You Are the Trench Rescuer

You are the "Haz Matician" on the technical rescue team. You are not only a rescue technician, but a hazardous materials technician as well. The technical rescue team officer asks you to lead next month's training on hazard assessment and control at trench rescue incidents. You could spend hours on atmospheric monitors alone, but this lesson needs to be a practical review that includes the assessment of probable hazards found at a trench site. You have contacted the city's Department of Public Utilities (DPU), and it will allow you to use a trench site on your training day.

You plan to set up the trench with mechanical, chemical, human-made, electrical, and water hazards. Your teammates will be evaluated on their ability to identify and mitigate these hazards. Your lesson on monitoring the atmosphere at trench rescue sites will include an operational review of your team's four-function monitor, identification of hazardous atmospheric indicators at trench sites, procedures for monitoring where atmospheric hazards are present, and procedures for monitoring when atmospheric hazards are not present.

Before starting the class, you quiz the students by asking them the following questions:

1. At a trench site, which conditions would likely cause CO build-up?
2. At a trench site, which conditions would likely cause H_2S build-up?
3. At a trench site, which conditions would likely cause O_2 deficiency?
4. At a trench site, which conditions would likely cause a flammable atmosphere?

Trench Rescue Levels I and II

Hazard Control

Your plan to handle a trench emergency is now at the point where real and potential hazards will need to be addressed. Hazard control is really the last phase of assessment, although it is so important that it warrants consideration as its own phase.

Of the many different hazards that can affect your operation, all of them can be categorized into one of two types: the hazards that you are able to control and the hazards that you should leave alone.

Hazards that can easily be controlled and that are within the expertise of the rescuer need attention before any deployment of your personnel occurs. These types of hazards could relate to the locations of vehicles, trip hazards, spoil pile movement, and supporting existing utilities. Examples of hazards that should be addressed by specialized personnel are electricity and gas. In general, if a professional discipline has been established for the hazard, it is a good indication that you are not qualified to handle it. Call a utility representative if there is any question or if the situation is beyond your training and abilities.

Hazards can be classified into five categories: mechanical, chemical, human made, electrical, and water.

Tactical Tip

Support all known utilities that cross the excavation before or during the process of building your protective system. Having an unsupported water line break in the middle of your operation could create significant problems **FIGURE 8-1**.

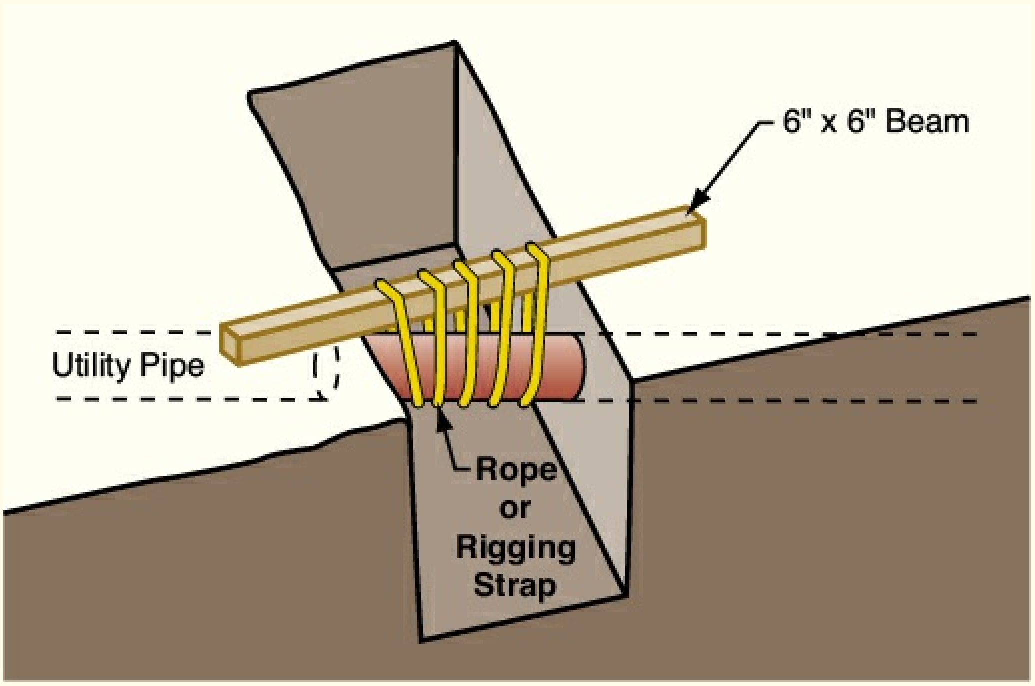

FIGURE 8-1 All exposed utilities need to be supported when they are run through the trench and exposed on all surfaces.

■ Mechanical Hazards

Machines and other entrapping mechanisms could be a danger to rescuers. Just as in confined-space lockout/tagout procedures, make sure you bring everything to a zero mechanical state. Bringing something to a zero mechanical state means eliminating any possibility that any activation could occur. Examples include taking the keys out of machinery, locking out electrical devices, and removing machines that are in the collapse zone **FIGURE 8-2**.

■ Chemical Hazards

You should always assume that something hazardous could have been unearthed during digging operations **FIGURE 8-3**. In addition, a worker may have carried a chemical in the trench for use during intended work activities. Examples include gasoline for saws, solvents for cleaning, and glue for making pipe connections. The lessons here are clear: Never assume anything is safe and always monitor the atmosphere. If any concerns about chemical hazards arise, call a hazardous materials team.

■ Human-Created Hazards

Human-created hazards are usually the reason why you are at a trench in the first place. They include all of the things that workers do as a part of their normal work but that either do not go according to plan or prove to be hazardous at some point in the operation. Examples of human-created hazards include the positioning of the spoil pile and trench equipment relative to the trench opening, inadequate trench protective systems, and installation procedures **FIGURE 8-4**.

FIGURE 8-2 When a decision is made regarding the status of a piece of heavy equipment, you should always secure the keys.

Courtesy of Chuck Wehrli

FIGURE 8-3 Always consider the potential that hazardous materials could have been exposed during a digging operation.
© Jones and Bartlett Publishers. Courtesy of MIEMSS.

FIGURE 8-4 The spoil pile is frequently placed right next to the trench lip, which creates tremendous forces on the exposed trench walls.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Safety Tip

When shutting down heavy equipment that is running, consider whether it is attached to anything. For instance, if the machine was lowering a trench box in place and is under a load, it may be necessary either to remove the box or to keep the machine running to maintain lifting pressure in the hydraulic lifting system. Always consider moving heavy equipment that is positioned on the "long wall" area of the trench. Heavy equipment creates a surcharged load, rendering the long walls more susceptible to collapse. Move equipment that is within the "effective area" (a distance from the lip that is equal to the depth of the trench) and that is on the long wall side. If you elect not to move the equipment positioned at the end wall, keep the operator on scene, but in all cases, take the key.

Electrical Hazards

A fire fighter should not get involved with electricity—that is, with pole, cable, and transmission box hazards. Control of electricity other than shutting off breakers is best left to the people who do it for a living, not to part-time hazard control experts **FIGURE 8-5**. Concerns should also be noted in regard to static electricity and its potential impact with exposed natural gas lines. By wrapping a wet towel around the pipe and stretching the towel to contact the ground (which may require tying towels together), you can ground the pipe and eliminate the static electricity.

FIGURE 8-5 Electrical hazards should be secured in both the general area and the rescue area.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Also be alert when operating around exposed telephone lines: They carry a voltage that can cause injury or even death with contact. Be cautious as well with electrical items you bring to the scene, such as lighting equipment, fans, and supplemental power.

As a routine practice, determine the locations of all utilities before digging in a collapsed area. This identification process can be as simple as calling the local utility service company. If the location of utilities is ever a hazard control issue, you should not hesitate to call the local utility location service. Sometimes called "Ms. Utility," "One Call," or 811, these services are paid for by the utility companies, and their purpose is to mark existing utilities before any type of digging operation begins. In a trench collapse, you would need such a service to confirm the locations of any utilities that are not already known but that may have an effect on your rescue operation. The standard color markings for utility locations noted in **FIGURE 8-6**.

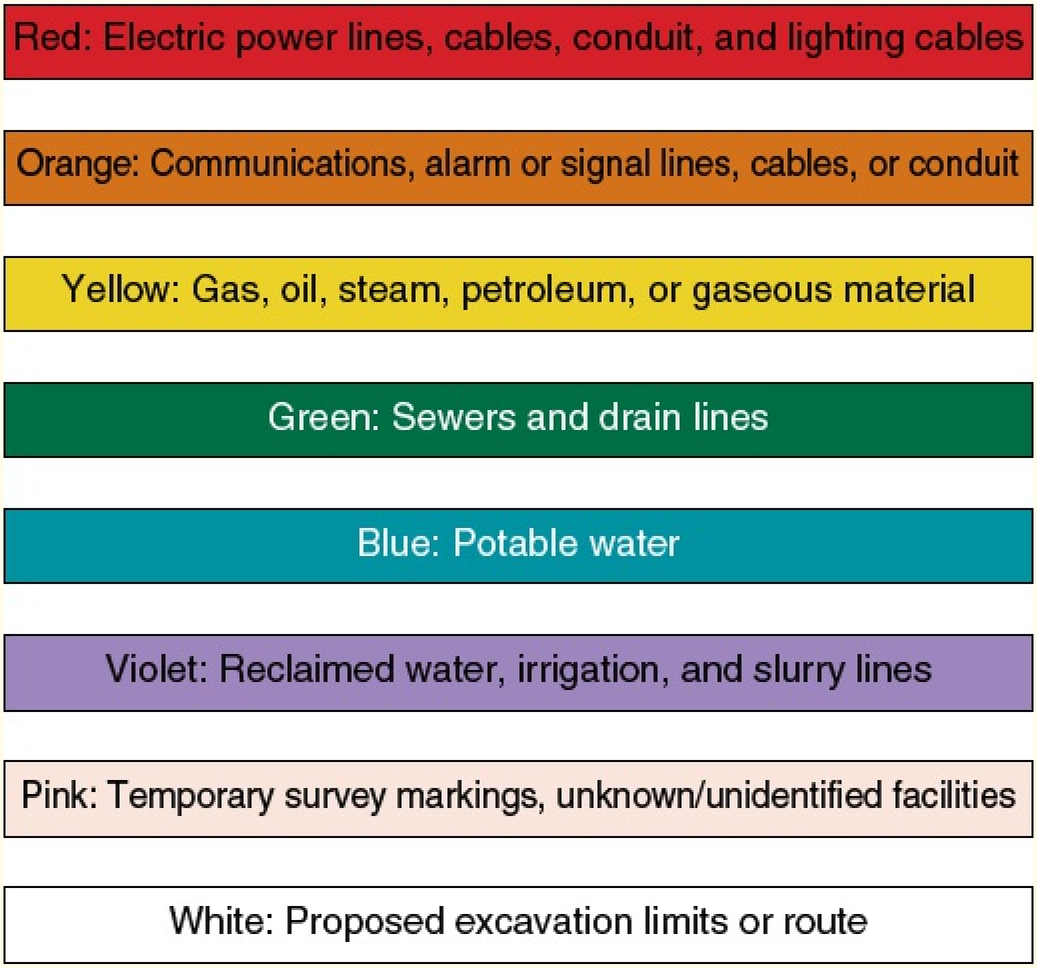

FIGURE 8-6 Utility color markings.

■ Water Hazards

Water can be a hazard at the scene of a trench collapse, whether in the form of groundwater or rain **FIGURE 8-7**. If rain is imminent, start thinking about building a cover for the trench and establishing a method to divert incoming rain. The bottom line is to get existing water out of the trench, and do your best to see that no additional water gets in it. Have dewatering equipment on site.

An additional option is to cover the trench with an inflatable tent and divert the water to an unaffected area. Most hazardous materials teams, mass-casualty teams, decontamination (decon) teams, and mobile command units have these types of tents, and many such tents have heating, cooling, and general ventilation capabilities.

FIGURE 8-7 Water creates extreme forces on trenches that can compromise already poor conditions.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Safety Tip

Include a hazardous materials team in your initial response matrix for atmospheric monitoring purposes. In addition, have personal contact numbers for each professional discipline—such as telephone, gas, and electricity companies—that might be involved in responding to a collapse scene hazard.

VOICES OF EXPERIENCE

Growing up in a "plumbing and heating" family exposed me to a lot of different trenching experiences. House perimeters, parking lots, new construction, roadways, and swimming pools were among job sites I worked in. It was not until I became a fire fighter, however, that I understood the dangers I had exposed myself to. Working with lead, Portland cement, hydrochloric acid, glue, solvents, tar, gas power tools, pumps, and torches poses significant dangers to any worker in the trench. Naturally, ventilation was provided most of the time, but there was that one time—just one time—that we opted to forego ventilation.

"We were using an atmospheric monitor but no one was assigned to it. As a result of the noise from the power saw, the monitor alarm could not be heard."

It was a warm June morning when we were replacing the main drain line on an in-ground pool. PVC and black poly pipe were the norm for this climate. At the bottom of the 8-foot (2.8-m) trench was the cracked pipe needing replacement. We cut out the old pipe, glued on a black poly adapter, and attempted to hook up the poly pipe. Not realizing the primer had been knocked over, I fired up the torch to soften the poly. The primer "flashed" and I suffered first- and second-degree burns on my hands, arms, and face. Conditions were right for this mishap, and it could have been worse. The only major injury was to my pride.

Another close call occurred when I was cutting storm sewer pipe with a gas-powered saw. The trench pit was only 7 × 7 × 7 feet (2.1 × 2.1 × 2.1 m) and filled with IDLH (immediately dangerous to life and health) carbon monoxide (CO) in about 5 minutes. We were using an atmospheric monitor but no one was assigned to it. As a result of the noise from the power saw, the monitor alarm could not be heard. When the saw shut down, I climbed out of the pit a little light-headed and dizzy, only to find the air monitor alarming. The lessons learned in my plumbing career have been invaluable to my fire career.

Underground construction workers are required to monitor the air when hazardous substances are stored near the trench site, whenever the area may be oxygen deficient, and when digging in landfills. Absent those conditions, freshly dug trenches rarely contain hazardous atmospheres. Underground construction workers enter thousands of trenches every day without monitoring the atmospheres. It is usually humans (construction workers and rescuers) who bring hazardous atmospheric conditions into trenches. Rescuers must look for the "tell-tale signs" (indicators) of hazards, which include but are not limited to the following: gasoline/diesel-powered equipment/machinery, fuel cans, torches, broken utility lines, chemical storage, and geological data (radon). Construction workers "down" in a trench with no apparent trauma, or workers feeling ill, are indicators of possible hazardous atmospheric conditions. We need to recognize and prepare for all of these possibilities. When a cave-in occurs, the chance of hazardous atmospheric conditions (e.g., broken gas/sewer lines, fuel or solvents on the lip now spilled into the trench) increases. Initial air readings should be part of every rescue safety plan. At a trench rescue, a complete hazard assessment is always necessary.

Which type of air monitoring is necessary? Most trench rescue operations will simply need a four-gas monitor to evaluate atmospheric conditions. That situation changes if a specific toxic substance is stored near the trench site, in which case a monitor for that toxin would be required. In most cases, a photo ionization detector (PID) is the monitor of choice. The PID will measure O_2, flammability, CO, hydrogen sulfide, and volatile organic compounds (VOCs). Equally important are the questions of how long and how frequently to monitor. The time and frequency will depend on the findings from your initial hazard assessment. If toxins are indicated, continuous monitoring becomes a requirement. A qualified person should be assigned to the air monitor, with results being recorded every 5 to 10 minutes. This assignment uses manpower that could be used for other needed rescue functions, but when atmospheric hazards are identified, this function is required. It is simply a function of risk–benefit analysis.

When a trench is initially monitored and nothing is noted, I look at the probability of types of toxins that might enter the trench. Are they lighter or heavier than air? Are they flammable? Then I choose a location in which to place a (manned or unmanned) monitor. If there is a lot of noise in and around the trench, make sure the monitor is where someone can hear the audible alarm.

Lessons I've learned include the following:

- Always conduct a complete hazard assessment that includes use of a four-gas monitor.
- Obtain an appropriate monitor for specific hazardous substances that are stored near the trench site.
- When possible, have a support group (such as a hazardous materials team) automatically respond to trench rescue incidents to provide continuous air monitoring.
- Develop action guidelines that spell out how your team will engage when (1) hazardous substances are identified, (2) indicators of hazardous substances are present but initial monitoring does not identify current hazards, and (3) both the initial monitor reading and the assessment of hazardous substance indicators demonstrate safe conditions.

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Trench Rescue Level I

Hazard Control Phases

After identifying all hazards on the scene of the collapse, you will want to turn your attention to addressing them in some sort of logical order. For obvious reasons, the most hazardous might warrant first consideration; however, do not blindly address what appears to be the most hazardous element without consideration for those hazards that may not be as readily apparent.

Just as in other rescue training in which you may have participated, a standard nomenclature is used to describe the various areas of the emergency scene. When hazardous materials are involved, you are dealing with "hot," "warm," and "cold" zones. In vehicle rescue, one learns about the "inner" and "outer" circles. These terms are used to describe areas of hazard in relation to the scene. For instance, the hot zone at a hazardous materials scene would be in the immediate area of the incident, and the cold zone would be away from or remote from the incident. Trench rescue incident scene management could use these terms or the terms general area and rescue area to define and establish boundaries of operation.

The general area is the surrounding area not in the immediate vicinity of the extrication effort. Hazard control in this area would entail a large overview of the scene and, under normal circumstances, should begin first. The activities that would normally take place in this area are staging, cutting, logistical support, rehabilitation, and vehicle parking.

The rescue area is located immediately surrounding the rescue site. This is a very small area around the rescue effort, and hazard control here would be considered only after hazard control of the general area was completed. Extrication efforts such as air supply, panel team, shoring personnel, and the safety officer are established within this area.

The "Incident Management and Support Operations" chapter includes a trench incident management chart that uses the hot, warm, and cold zone terminology.

Safety Tip

Personnel can become a hazard if too many of them end up in the rescue area. Keep all personnel not actively involved in the rescue effort in the staging area.

Atmospheric Monitoring for Trench Rescue

At any given time, it would be appropriate to ask yourself, "Why do I need to know about atmospheric monitoring to handle a trench rescue?" I would have probably asked this same question some years ago. These days, however, our thought process from a hazard recognition perspective needs to be much broader.

A note of caution: This is not a text on confined space entry and rescue. For that reason, the amount of atmospheric monitoring material covered here is not as comprehensive as it could be. This is a trench rescue text—not an all-inclusive guide to atmospheric monitoring or hazards associated with atmospheres. The information presented here is simply intended to make you aware of potential problems and the actions you should take with regard to hazardous atmospheres.

In past years, hazardous materials legislation has created a liability for anyone who has disposed of or is trying to dispose of a hazardous substance. This has generated an entirely new set of problems for rescuers, who may unknowingly get involved with the improper disposal of materials. Keep in mind that it normally costs a lot less money to bury something than to dispose of it properly.

■ Confined Space or Trench

By definition, there are hundreds of thousands of confined spaces—many of them permit-required confined spaces—in U.S. workplaces; many millions of workers are employed at these locations. Although a trench is not exactly a confined space under the definition established by the

Occupational Safety and Health Administration (OSHA), let us examine the definition of a confined space to see if any similarities exist. A confined space has the following characteristics:

- Is large enough and configured so that an employee can bodily enter the space
- Has limited means of egress for entry or exit
- Is not designed for continual employee occupancy
- Has an actual or potential hazardous atmosphere
- May also have any of the following:
  - Material with the potential of engulfing the entrant
  - An internal configuration that could trap or asphyxiate an entrant due to converging walls or sloping and tapered floors
  - Any other recognized serious safety hazard

As you can see, many similarities exist between a trench and a confined space. Because atmospheric problems are responsible for the overwhelming majority of deaths in confined spaces, it is probably a good idea to take a hard look at the subject as it applies to trench rescue.

The use of air monitoring and sampling equipment is one of the most important aspects of a confined-space or trench rescue operation. During your rescue effort, someone on your team (usually hazardous materials or support function personnel) should be providing periodic monitoring in and around the trench **FIGURE 8-8**. Monitoring is used not only to detect the presence of immediately dangerous to life and health (IDLH) atmospheres, but also as a tactical guide to ventilation of the trench **FIGURE 8-9**.

FIGURE 8-8 Atmospheric monitoring should take place on all trench and excavation rescues.

■ Monitoring Considerations

Before you can actually monitor a space, there are several questions you should consider regarding the atmosphere or potential hazards that exist at a trench rescue operation.

1. *What is the nature of the hazard I am monitoring?* You should know something about the product you are testing for from your previous evaluation, Safety Data Sheet (SDS), or intelligence that you gather at the scene. Do you know the upper and lower explosive limits (UEL and LEL) for the particular product? Is the atmosphere oxygen deficient, which might create interference with instrument response? What is the vapor pressure of the product,

and what is the outside temperature? Is it likely that this combination will create enough vapors to support ignition? Remember that if a product is producing vapors, then the product is "coming after you"—this is a very dangerous situation if not controlled. Finally, is the vapor a health hazard, and is the material lighter or heavier than air? This knowledge provides a clue regarding where the product might lie and how it might move.

2. *Are there sources of electrical interference nearby?* Electromagnetic fields, high voltage, static electricity, portable radios, cellular phones, and similar items can interfere with your meter readings. Many current instruments offer radio frequency (RF) shielding as a feature. Consider this factor when you operate.
3. *What are the environmental site conditions in which you are operating?* Conditions such as temperature, humidity, barometric pressure, elevation, particulates, and oxygen concentration must be considered.
4. *Are any gases and vapors interfering with the monitor?* The lead in leaded gasoline, for example, permanently desensitizes the filament of the combustible gas indicator, leaving it unable to detect anything. Certain acids and corrosives will eat away at the monitor and the sensors, rendering the meter useless. Manufacturers supply information about their particular meters, and you should be familiar with yours.

FIGURE 8-9 Rescue personnel should monitor for oxygen, flammability, and toxicity.
Courtesy of Cecil V. "Buddy" Martinette, Jr. and Industrial Scientific

■ Action Guidelines

To use monitored information tactically, you must have established action guidelines. In most instances, these guidelines are outlined in OSHA 1910.146, *Permit-Required Confined Spaces*, and should be incorporated into your standard operating procedures.

Action guidelines indicate which specific action(s) you should take when monitor readings reach certain levels. As you begin to look at action or alarm guidelines established by different agencies, such as the Environmental Protection Agency (EPA), OSHA, and others, you will find that these guidelines differ. Some are specific for hazardous materials events, some deal with hazardous waste sites, and, of course, some relate to confined spaces. The action guidelines presented in TABLE 8-1 are specific to confined-space and trench rescue operations and should not be confused with other operations. Action guidelines are exactly that—guidelines. In most cases, preset alarms on your monitors will alert you when a certain level, parameter, or product is detected.

■ General Monitoring Guidelines

The following are my friend Chase Sargent's *Ten Rules for Atmospheric Monitoring*.

Rule 1: Monitor in order. There is an order or hierarchy used in atmospheric monitoring and detection for rescue operations. This differs from the process used in hazardous materials incidents in some ways, because we do not monitor for radiological hazards unless there is a high suspicion that such materials are present. Typically, the order of monitoring will be as follows:

1. Oxygen
2. Flammability/combustibility
3. Toxicity

As we discuss specific monitoring considerations further, you will understand why this order has been established. This process should be followed each time you monitor. Hazardous materials technicians might say that pH (the measure on a scale from 0 to 14 of the acidity or alkalinity of a solution) should have been listed first: They are correct, and this is the preferred procedure, but the effect of pH on monitoring is beyond the scope of this text.

Rule 2: Always monitor at multiple levels in the trench. Any flammable vapor or gas, even below the LEL, can be hazardous to rescue personnel. Mixtures of gases can accumulate at different locations in the trench, depending on individual gas/vapor densities. Vapor density is nothing more than the tendency of a gas to rise or fall. Air has a vapor density of 1.0; gases and vapors with a vapor density of less than 1.0 will rise, whereas those with a vapor density greater than 1.0 will sink.

Always monitor at three levels within any space. Different products have different vapor densities, meaning that they will be found in a trench at different levels. If for some reason you measure only the bottom one-third of the trench, you may miss at least two or three different products that might be present.

As an example, methane is typically lighter than air and will leave the trench. Carbon monoxide is about the same density as air, and it will tend to locate mid-trench or diffuse within the air. Hydrogen sulfide is heavier than air and will tend to find its way to the bottom of the trench. The sampling technique is important.

Rule 3: Know your monitor's limitations. Monitors have limitations—not just technological limitations, but limitations on their accuracy when detecting certain substances. You must know the limitations on your monitoring capabilities and recognize how certain readings on your monitor will affect other readings that you might obtain.

Rule 4: Understand the relationship between flammability and toxicity. Understanding the relationship between toxicity and flammability when measuring is very important. Flammable range is a measurement (usually given as a percentage of the total volume of air/ignitable vapor mixture as shown on your monitor) of the amount of a substance that will ignite when mixed with air. When a substance is present in sufficient quantity to be measured as an ignitable mixture, it can also be measured in relation to its total volume in the mixture, represented in parts per million (PPM). This is the most frequently used method to measure toxicity, whereas percentage is the most frequently used method to measure flammability levels.

Rule 5: A substance (vapor) that comes after you is much more dangerous than one that expects you to come to it. These types of products require great caution because the product or its vapor (which may be toxic or flammable) can spread toward you and potentially cause problems over a greater area.

Table 8-1 Action Guidelines for Confined-Space and Trench Rescue Operations

Atmosphere	Level	Action	Monitor
Combustible/ flammable gas	10% of the LEL	If outside the space, correct the atmosphere. If inside the space, begin to exit.	Alarms both visually and audibly
Oxygen	Less than 19.5% or greater than 23.5%	If outside the space, determine the problem and correct it. If inside the space, begin to exit.	Alarms both visually and audibly
Toxicity	Carbon monoxide: 35 ppm Hydrogen sulfide: 10 ppm	If outside the space, determine the cause of the problem and correct it. If inside the space, begin to exit.	Alarms both visually and audibly

Rule 6: Know your monitor's operational parameters. This includes issues such as the following:

1. How long are the sensors in your monitor expected to last (e.g., 1 year, 2 years)?
2. Is the monitor radio frequency shielded to cut down on potential interference from electrical and radio sources?
3. If using a hand aspirator, how many pumps are necessary for each foot of tubing to bring the product into the sensor housing?
4. Do you use a water filter on the end to prevent liquid from being pulled up the tube and subsequently ruining your monitor?

The answers to all of these questions should be found in the technical manual that came with the monitor you use. Remember that you should specify training as part of the purchasing package.

Rule 7: Battery-operated monitors will not work if the batteries are dead. Checking the batteries at the incident is a novice approach to problem solving and not very smart. Batteries should be checked regularly (each shift).

Rule 8: Zero and field calibrate (bump check) your instrument in clean air. Before using any monitoring equipment, first check it to ensure it is reading 0 percent for flammability and toxicity and 20.9 percent for oxygen. Follow the manufacturer's recommendations for your monitor on field calibrations. Make sure that you are in clean air when you do this or your readings will be inaccurate.

Rule 9: Sample from upwind. Standing upwind will allow you to approach the potentially hazardous atmosphere at your own pace. Never let the wind bring it to you!

Rule 10: Never conduct atmospheric monitoring unless you have been thoroughly trained and are capable of providing that function.

■ Specific Monitoring Measurements

Oxygen

Monitors usually measure oxygen concentrations between 0 percent and 25 percent in air. Your monitor should be set up (because it is designed for use in confined spaces) to alarm at 19.5 percent, which is the minimum adequate percentage of oxygen concentration established by OSHA. It should also be set to alarm at levels of oxygen greater than 23.5 percent in air. Normally, air consists of approximately 20.9 percent oxygen. Oxygen-deficient atmospheres are those with oxygen levels that are 19.5 percent or less of the total air. Oxygen-enriched atmospheres are those with concentrations greater than 23.5 percent.

The reason that you check oxygen at this juncture is because at certain oxygen-deficient levels (look at the device manufacturer's data) the flammability readings you are about to take will be invalid or altered. Also, at oxygen levels greater than 23.5 percent, the measurement of flammability will not be accurate and will render false readings.

Flammable and Combustible Readings

Combustible gas indicators (CGI) in the air monitoring device determine the presence of flammable vapors of hydrocarbon products within the trench. Some instruments are designed to measure a single product (e.g., methane) only; they measure the flammable vapors as a percentage of the LEL. The air monitor that you use at trench incidents is calibrated for a certain flammable gas, such as methane, pentane, butane, or hexane. You should test for flammability during the following potential scenarios:

1. Any suspected contaminated trench
2. As part of the process of leak detection
3. If you are investigating an unknown material

The air monitor used in trench rescue scenarios has a preset alarm level for 10 percent of the LEL. Thus, when the level of the product you are testing (actually the level of the product the monitor is calibrated for) reaches 10 percent of its lower flammable limit, the CGI monitor will both sound an audible alarm and provide a visual signal. There is a 10 to 1 safety factor built into the alarm system—in other words, when the CGI "alarms," the atmosphere is at only 10 percent of the LEL. For the atmosphere to actually ignite, it must reach 100 percent of the LEL, which is still more than 90 percent away at this point. The alarm signals your action level—the level at which you need to make a decision, but not the level at which you need to panic.

Recall that we tested oxygen first: A certain percentage of oxygen is required for the CGI to function properly. Most instruments require a minimum of 10 percent oxygen to operate, but they may be inaccurate at levels even higher than that. For many of these devices, as much as 16 percent oxygen in the atmosphere is required to give an accurate reading. (Look at the device manufacturer's literature for limitations.) Thus, if you assess oxygen first, that measurement provides the information you need to determine whether the flammability readings will be accurate and usable as a tactical tool.

Measuring Toxicity

The air monitor you are using will have either one or two toxicity sensors, most likely set up to measure hydrogen sulfide or carbon monoxide (the two most common toxic vapors). The action limits or alarm settings on such devices are at 35 ppm for carbon monoxide and 10 ppm for hydrogen sulfide. Again, these levels do not constitute an emergency; rather, they are OSHA's time-weighted averages for an 8-hour exposure. They indicate that breathing apparatus must be worn and that a problem—which you will attempt to control or eliminate—exists in the trench.

Training Tip

1. Read the monitor's instruction manual. Be very familiar with it, and become the expert with that monitor.
2. Practice, practice, practice. Using the monitors must become second nature to you. You should be able to scroll through their displays with ease, understand their idiosyncrasies, and operate them effectively in all types of conditions.
3. If you need more help understanding the equipment, contact an individual in your organization who is adept at atmospheric monitoring—usually a member of the hazardous materials team—and ask him or her for help.

■ Consistent and Effective Monitoring

Imagine you are standing at the trench with the monitor in your hand. You have read the device manufacturer's literature, and you know exactly how the monitor works. You have calibrated, bump tested, and used your monitor appropriately as you lowered the sampling probe into the trench. The question now is this: What do you do with the data you are capturing?

Monitoring should take place before entry and at least every 5 minutes during trench operations. This is not a hard-and-fast time frame, but rather one that should be adjusted based on the severity of the atmosphere you are dealing with. Concerns about changing atmospheres should prompt you to monitor more frequently. Consider the following guidelines when monitoring:

1. One person should collect and record monitor readings throughout the entry and rescue/recovery operation. This should be his or her sole assignment.
2. All readings should be captured on the trench rescue tactical worksheet.
3. Readings should be reported to the extrication officer or the operations officer on a continual basis.
4. Any fluctuations or changes in readings should be reported immediately.
5. Any alarm levels should be reported immediately and action taken.
6. Never leave the monitor unattended. It could get kicked into the trench, stepped on, or ignored.
7. Always use a hazardous materials team to your best advantage.

Hazard Control Using Ventilation

Ventilation is the hazard control method of choice during rescue operations because it is fast and easily monitored. You cannot expect ventilation to work in every situation, however. You must use the readings from your monitor as a guide and be prepared to make hard decisions based on facts.

Ventilation is only as good as the technique you employ and, of course, is based on the nature of the product. If a flammable reading at an action (alarm) level occurs and you begin to ventilate, do the readings drop to acceptable levels? If not, why? Is that failure occurring because your ventilation is not working, or is there a liquid product that continues to give off vapors despite your best efforts?

When using ventilation as a hazard control method in trench rescue, you must consider the outside temperature and the effect ventilation will have on both victims and rescuers **FIGURE 8-10**. In addition, multiple fans may be needed on intersecting trenches.

FIGURE 8-10 Ventilation should be considered an option based on environmental conditions.

Safety Tip

Leave it alone: If it is a hazardous materials call, let the hazardous materials team deal with the problem. After hazards associated with atmosphere or contamination have been eliminated, go to work.

Wrap-Up

Review: Just the Dirt

- The many different hazards that may potentially affect your operation can be categorized into one of two types: the hazards that you are able to control and the hazards that you should leave alone.
- Hazards can be classified into five categories: mechanical, chemical, human made, electrical, and water.
- After identifying all hazards on the scene of the collapse, you should next turn your attention to addressing them in some sort of logical order.
- Hazardous materials legislation has created a liability for anyone who has disposed of or is trying to dispose of a hazardous substance. This has generated an entirely new set of problems for rescuers who unknowingly get involved with the improper disposal of materials.
- Atmospheric problems are responsible for the overwhelming majority of deaths in confined spaces.
- To use monitored information tactically, you must have established action guidelines.
- Specific monitoring measurements include oxygen, flammability and combustibility, and toxicity.
- Monitoring should take place before entry and at least every 5 minutes during trench operations (adjusted based on the severity of the atmospheric problems).
- Ventilation is the hazard control method of choice during rescue operations because it is fast and easily monitored.

Hot Terms

Action guidelines A list of guidelines indicating which specific action(s) you should take when monitor readings reach certain levels.

Alarm settings The preset levels within a monitor at which the monitor will display a visual alert and sound an audible alarm. These settings are established by the manufacturer and are based on Occupational Safety and Health Administration and National Institute of Occupational Safety and Health standards for a given product. For confined spaces, they are referred to as *action guidelines*.

Combustible gas indicator (CGI) A device used to determine the presence of flammable vapors and hydrocarbon products that might be present in a trench.

Detection The act of discovering the presence of a contaminant in a given atmosphere.

Explosive limits The percentage of a gas in an air mixture, as noted through atmospheric monitoring, that indicates the explosiveness of the gas. Readings indicate the upper explosive limit (UEL) or lower explosive limit (LEL).

Flammable range The percentage of vapor in air that must be present to sustain combustion should an ignition source be present.

General area The area that is not in the immediate vicinity of the extrication effort.

Immediately dangerous to life and health (IDLH) Maximum concentration of a substance from which a person could escape (in the event of respirator failure) within 30 minutes without permanent or escape-impairing effects.

Lockout/tagout Part of a procedure used to bring an object into a zero mechanical state; it involves shutting down and locking or tagging equipment so it cannot be used.

Rescue area The area located immediately surrounding the rescue site.

Zero mechanical state A situation in which there is no possibility that any mechanical activation could take place.

TRENCH RESCUER *in action*

You arrive on scene at a trench incident as a member of a truck company and are assigned to check for environmental hazards and set up ventilation, if required. A quick size-up shows that the trench is approximately 10 feet (3 m) deep and 8 feet (2.4 m) wide, and runs about 30 feet (9.1 m). It is obvious from the smell and the effluent in the bottom of the trench that the contractor was replacing a section of sewer pipe when the incident occurred. A worker was seriously injured and became trapped in the trench when a section of concrete pipe rolled off the lip and into the trench.

The trench rescue team is preparing to install additional protection on the trench walls before entering the trench to start the extrication of the injured worker. The hazardous materials team is responding, but due to traffic its ETA is approximately 30 minutes. You have received awareness/operations-level training in hazardous materials and trench rescue and are familiar and comfortable with the operation of the four-gas detector that the trench rescue team carries on its truck.

1. What is the first thing you need to do before starting to monitor the atmosphere in the trench?
   - **A.** Check that the batteries are good in the monitor
   - **B.** Zero and calibrate (bump check) the monitor in clean air
   - **C.** Approach the trench from the upwind side
   - **D.** Check for the monitor's limitations
2. Where do you take samples when testing the atmosphere in a trench?
   - **A.** Top area of the trench
   - **B.** Middle area of the trench
   - **C.** Bottom area of the trench
   - **D.** All three: top, middle, and bottom areas of the trench
3. When and how often should samples of the trench atmosphere be taken?
   - **A.** Upon entry and at least every 5 minutes during trench operations
   - **B.** Every 10 minutes while rescuers are in the trench
   - **C.** Before entry and every 5 minutes during trench operations
   - **D.** As conditions require
4. Your initial sampling of the trench indicates an elevated level of CO near the bottom of the trench and a slightly diminished level of O_2 as well. You notice two gas-powered concrete saws in the trench and can see where workers had attempted to cut the pipe away from the

trapped victim before your arrival. Which method of ventilation would be preferred to mitigate this situation?

A. A gas-powered ventilation fan
B. An electrical ventilation fan
C. A water fog spray from an 1½-inch nozzle
D. None; let the wind dissipate the vapors

5. Which of the following is NOT one of the five categories of hazards that could be found at a trench incident?
   A. Mechanical
   B. Chemical
   C. Biological
   D. Electrical
6. Specific monitoring measurements include oxygen, flammability and combustibility, and:
   A. toxicity.
   B. ventilation.
   C. combustible gas indicators (CGI).
   D. flammable range.

Lifting, Moving, and Stabilization

CHAPTER 9

Trench Rescue Levels I and II

Knowledge Objectives

After studying this chapter, you should be able to:

- Describe the basic physics involved in lifting and moving NFPA 8.2.3 NFPA 8.2.4. (pp 124–126)
- Describe the theory of mechanics and explain how it impacts a trench rescue NFPA 8.1.2 NFPA 8.1.6 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.3 NFPA 8.2.4. (pp 126–128)
- Describe the purpose and construction of rope raising and lowering systems NFPA 8.1.4 NFPA 8.1.6 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.3. (pp 128–129)
- Discuss the use of air bags in trench rescue NFPA 8.1.4 NFPA 8.1.5 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.3 NFPA 8.2.4 (pp 129, 132–133)
- Discuss the use of cribbing in trench rescue NFPA 8.1.4 NFPA 8.1.5 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.3 NFPA 8.2.4. (pp 133–135)
- Discuss the use of wedges in trench rescue NFPA 8.1.4 NFPA 8.1.5 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.3 NFPA 8.2.4. (p 135)

Skills Objectives

After studying this chapter, you should be able to:

- Calculate moment of force NFPA 8.1.2 NFPA 8.1.6 NFPA 8.2.2 NFPA 8.2.3 NFPA 8.2.4. (p 126)
- Calculate mechanical advantage NFPA 8.1.2 NFPA 8.1.6 NFPA 8.2.2 NFPA 8.2.3 NFPA 8.2.4. (pp 127–128)
- Calculate the lifting capacity of an airbag NFPA 8.1.4 NFPA 8.1.5 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.3 NFPA 8.2.4. (pp 132–133)

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

The rescue company and engine company have been dispatched to a report of an unknown type of accident with a report of trapped victims. You understand from dispatch that the rescue company will be delayed a few minutes because its members are just clearing from a house fire.

Upon arrival, you find that a concrete column being lifted by a crane has fallen into an excavation site beside a building under construction and trapped two workers. It appears that the rigging strap broke on a 10-foot- (3-m-) long and 12-inch- (0.9-m-) square monolithic column, which then fell about 20 feet (6.1 m) into a working excavation. The beam landed in the trench at an angle and is resting on some of the shoring that has been installed. Further size-up reveals that one worker is dead; however, the other worker is only partially trapped because the beam is being supported by a pipe that was being installed in the excavation.

1. When you report your size-up information to the rescue company officer, he inquires as to the estimated weight of the column, whether the high- or low-pressure air bags can be used, and whether another crane will be necessary. How do you reply?
2. How will you estimate the weight of the column?
3. Based on the column weight, do you think high- or low-pressure air bags would be the most appropriate?
4. Do you think it will be necessary to lift the entire weight of the column to gain access to the trapped worker? Why or why not?
5. Which size of cribbing material do you feel would be the most appropriate for this type of event?

Trench Rescue Levels I and II

Lifting, Moving, and Stabilization

Those of us who teach technical rescuers or fill command positions at rescue incidents are routinely frustrated with personnel who learned techniques by rote training. That is, they have watched and used specific techniques, and although they know the steps involved, they do not understand the underlying reasons why the techniques work.

All rescue personnel can benefit from an understanding of the basic concepts of lifting and moving. Fundamental information on the physics associated with lifting and moving should be taught in one of the first training classes offered to rescue personnel, rather than in one of the last.

Basic Physics of Lifting and Moving

Ultimately, when you find yourself on a trench rescue scene, much of what you do to either rescue or recover a victim involves displacing materials or lifting and lowering objects or people to gain access or move them from one place to another. This chapter focuses on often-overlooked but basic principles that allow rescuers to overcome the effects of gravity. As discussed in the "Soil Physics and Trench Collapse" chapter, the fundamental reason for a trench collapse is the effect of gravity on unconfined and potentially active soil. We can further use the basic concept of gravity to discuss movement of objects in the trench rescue environment. These situations can involve anything from stabilization of current conditions to lifting and moving objects that hinder victim extrication.

To move something, we must understand how gravity works and its effect on objects. To provide that understanding, we first cover the basic physics associated with lifting and moving objects, including gravity and its effects on mass, friction and resistance to force, center of gravity, moment of force considerations, mechanics, and energy and work concepts.

Before learning specific techniques, however, we should understand the theory behind why the techniques work. Archimedes once said, "Give me a lever long enough, and a prop strong enough, and I can single-handedly move the world." This was a bold statement for his time, but one that is still worth thinking about. The effectiveness of a lever is generally gauged by its efficiency in overcoming gravity.

■ Calculating the Weight of an Object

Before any consideration is given to lifting or moving an object, some thought should be put into calculating how much the object weighs. This information will help you decide the most appropriate lifting method to carry out the operation.

The first thing to consider is the type of material. Imagine that you need to move a concrete beam that has fallen onto a construction worker. The incident commander says the responding technical rescue truck has a set of low-pressure air bags, and he needs you to advise him as to whether they will be sufficient to perform the lift.

You start by determining the number of cubic feet in the beam. First, you measure the beam: It is 4 feet (1.2 m) in width and 2 feet (0.6 m) in depth and 20 feet (6.1 m) long. You multiply 20 × 4 × 2 (1.2 × 0.6 × 6.1) and get 160 cubic feet (4.4 m^3). You then take the 160 cubic feet and multiply it by the estimated value of 150 pounds per cubic foot of concrete to determine the beam's weight: 24,000 pounds **FIGURE 9-1**. The boss had better call for the high-pressure bags.

■ Gravity

To understand the concept of gravity, you must understand what causes it in the first place. Let us do a little experiment. Drop a pencil; it falls to the ground. The pencil just demonstrated part of the answer to the question. In effect, the earth's mass is partially responsible for the way gravity works.

Mass influences gravitational pull. Every object has mass, and an object's total mass determines the amount of attraction it has for another object. The more mass it has, the stronger its attraction for other objects. The pencil fell to the ground because of the strong attraction of the earth, a planet with a large mass.

Now consider the critical aspects of rescue operations and how gravity plays its part:

- Lifting: The action necessary to raise anything
- Lowering: Controlling the descent of an object
- Moving: Exerting enough force on an object to move it
- Stabilizing: Keeping the object from moving by applying a counterforce

Gravity is not the only factor that we need to consider before we plan to move an object—some additional obstacles are associated with the effects of gravity.

Friction

Friction is a measure of the amount of force it takes to move an object across the surface of another object. In other words, friction is how hard it is to push something when its surface is in contact with the surface of something else. The smoother the two surfaces, the easier an object will be to push; the rougher the two surfaces, the more difficult it will be to push the object.

We can reduce the amount of friction between two surfaces, however. The first and probably easiest way is by reducing the surface area that connects the two objects. Think of this as the "movement of the filing cabinet" trick. When you cannot push a filing cabinet across the floor, how would you move it? You could rock it back and forth. Generally, reducing the amount of surface area between the two objects lessens the contact area, thereby decreasing the friction between two objects.

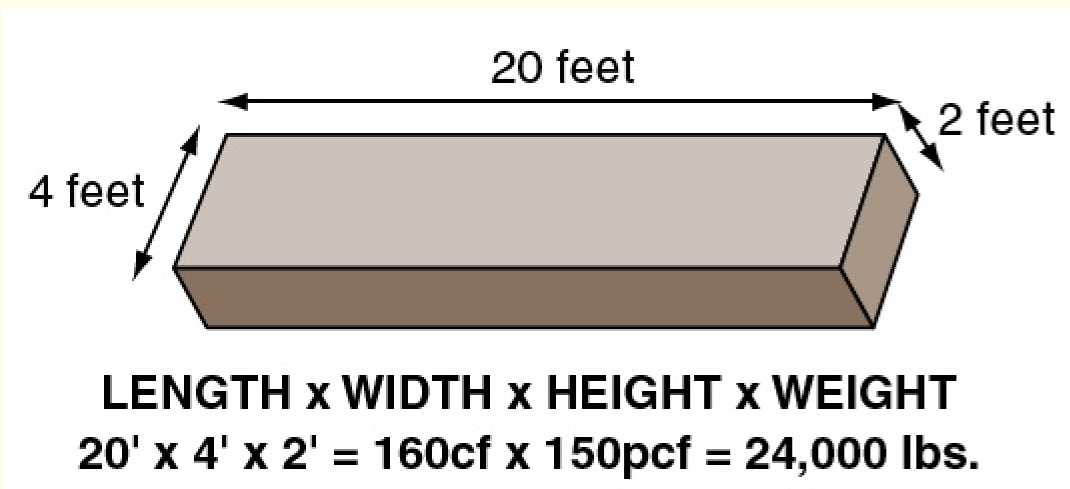

FIGURE 9-1 Calculating the weight of an object.

You might also put the stubborn filing cabinet on a large piece of smooth cardboard or a piece of cloth and then pull on it. This step also reduces the friction between the cabinet and the floor. Alternatively, you might place rollers or ball bearings under an object to move it with less effort. Less friction means it takes less force to initiate movement **FIGURE 9-2**.

Center of Gravity

Now that we have a general idea about how to deal with gravity, mass, and friction, let us turn our attention to the center of gravity. Have you ever seen a person with a big upper body and really skinny legs perform rope rescue work? Invariably, this person will flip upside down because the connection point of the harness is below his or her center of gravity **FIGURE 9-3**.

Simply defined, the center of gravity is the point on a body around which the body's mass is evenly distributed. Consider the center of gravity as the point on a body where all forces of the earth's gravitational pull are equal.

Determining an object's center of gravity is critical to any stabilization effort involving vehicle accidents, structural collapse, or trench rescue lifting operations. The center of gravity of an object is always at the junction of three axes **FIGURE 9-4**. The horizontal, vertical, and diagonal axes of an object will meet at a certain point that represents its absolute center; therefore, if you could attach to this point, you could lift the object straight up without a left/right correction.

FIGURE 9-2 Rollers reduce surface area and friction and allow heavier objects to be moved with less force.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

The center of gravity has enormous implications. Think of the crane operator who has to pick up an object. It is important to lift the load straight up to avoid hitting anything or shocking the crane boom. At the Murrah Building bombing site in Oklahoma City and at the collapsed area of the Pentagon in the wake of the September 2001 terrorist attack, I witnessed expert crane work. The crane operators used the center of gravity to remove and lift portions of the buildings effectively; however, they frequently could not position themselves directly over the top of the object's center of gravity to lift it. As a result, they had to predetermine the amount of correction that would occur at the point the object broke free from the rubble. To do so, they had to be able to estimate the object's center of gravity.

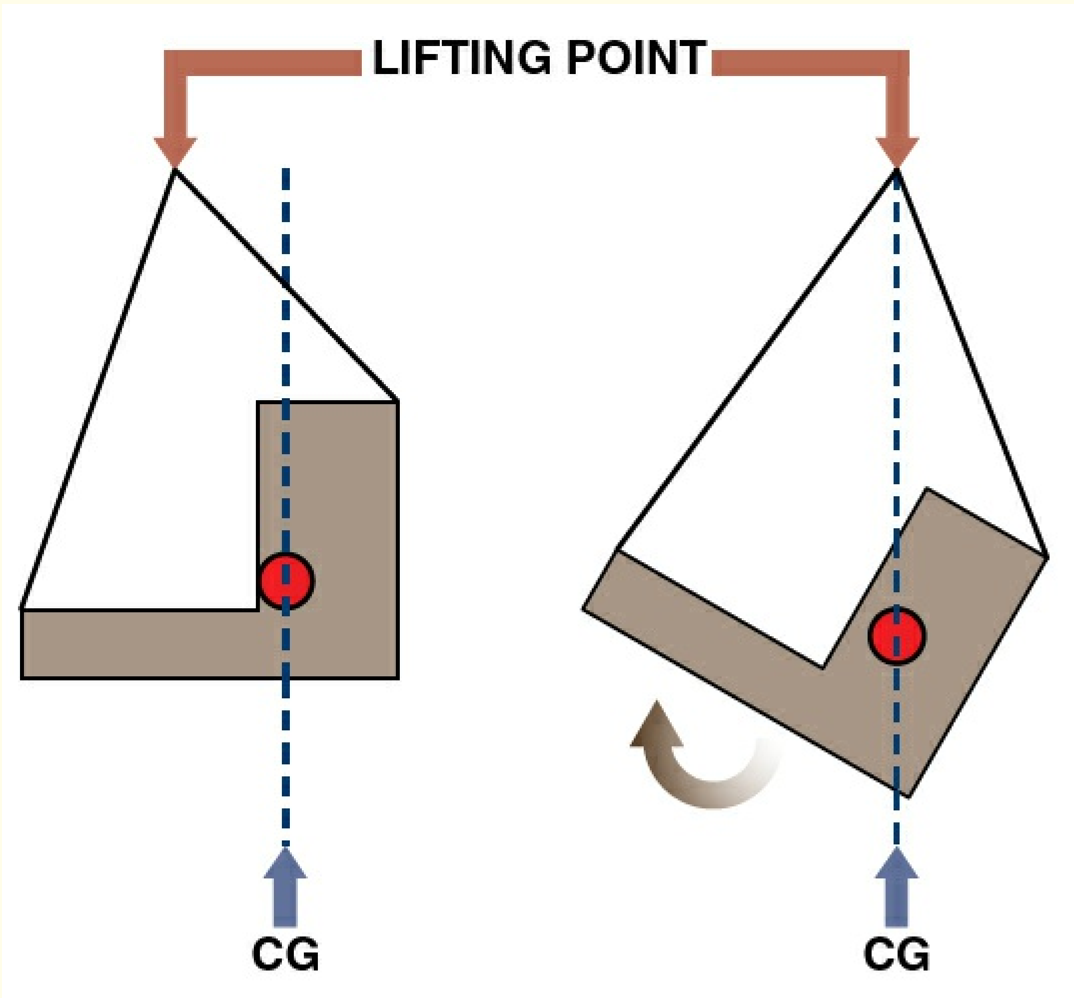

FIGURE 9-3 Even irregularly shaped objects have a center of gravity.

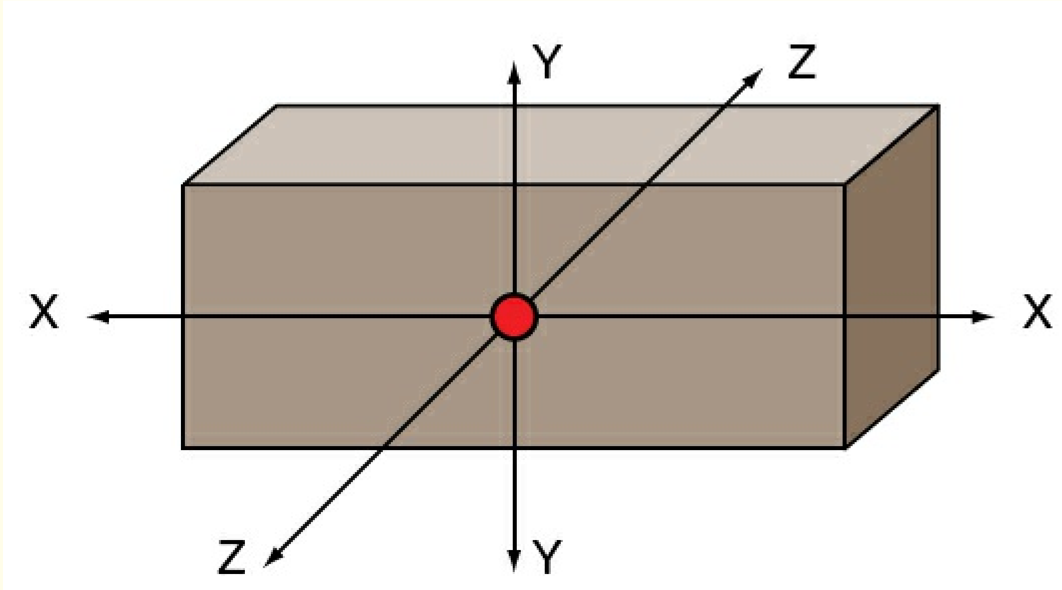

FIGURE 9-4 Center of gravity is always at the intersection of three axes.

An object on a sloped surface, from a gravity standpoint, is pulled toward the center of the earth. The friction coefficient of the two surfaces will determine how fast it arrives at that point. Moreover, the object's center of gravity will be a factor in determining how and in which position the object will come to rest.

These concepts can be added to the basic concept of percentage of a load based on the slope. When an object is on a 45-degree incline, you should be prepared to support 100 percent of the object's weight. The smaller the angle, the less weight by percentage you should have to support **FIGURE 9-5**.

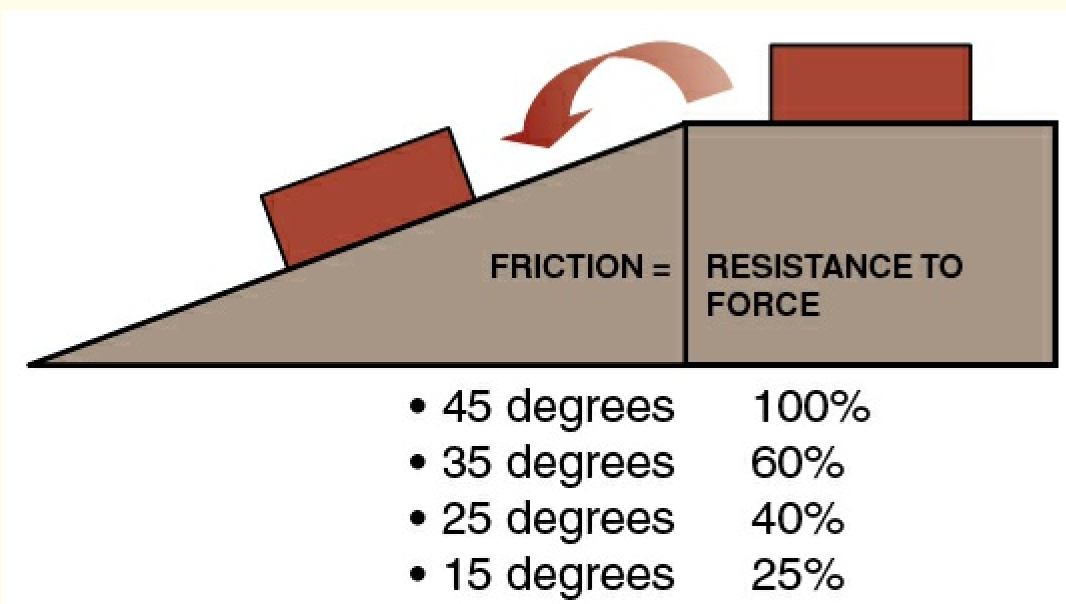

FIGURE 9-5 Lower angles mean less weight but greater friction.

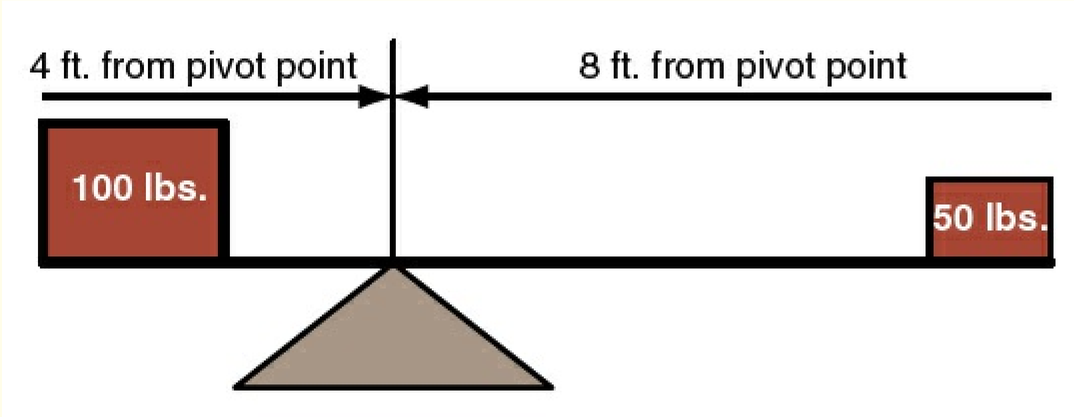

FIGURE 9-6 Moment of force equals mass times the distance it is away from turning point.

Movement

Another concept that plays an important role in the theory of movement is the moment of force: the mass multiplied by the distance away from the turning point, or fulcrum. It is calculated as the amount of force rotating around the fulcrum times the distance from the fulcrum—that is, force times distance is equal to the amount of force **FIGURE 9-6**. Moment of force is discussed in more detail later in this chapter.

Imagine a teeter-totter on the neighborhood playground. If a big kid and a little kid get on opposite ends of the teeter-totter, it is out of balance. If, however, the bigger kid moves closer to the center, at some point the two of them become balanced, and they can teeter-totter easily.

We can approach this scenario from a more scientific perspective by determining how much each of the children weighs and how far each is from the connection point of the teeter-totter (fulcrum). The balance point can be determined by multiplying the bigger kid's weight (e.g., 100 pounds [45.4 kg]) by the distance he is from the fulcrum (e.g., 4 feet [1.2 m]). In this example, the product is 400 pounds. For the small kid to have any fun, we must divide his weight into 400 pounds to determine the number of feet that he should sit from the fulcrum. If the small kid weighs 50 pounds (22.7 kg), then he would have to sit 8 feet (2.4 m) from the connection point. In effect, the small kid offsets the big kid's weight by moving away from the fulcrum.

Mechanics

The last concept for you to understand in lifting and moving is mechanics. The theory of mechanics is subdivided into two areas: energy and work. The effective use of rescue tools is often determined by a thorough understanding of these concepts and their application in a given situation.

Mechanics deals with energy and forces in relation to bodies. Something that creates a positive output in a given situation is called mechanical advantage. The efficiency, or advantage, is a measurement of the distance traveled compared with the force used to effect the movement.

Energy is the capacity for doing work and overcoming resistance. In other words, it deals with how hard it is to push or pull something over a distance. Energy is measured in feet/pounds, as either kinetic (in motion) or potential (at rest) energy; therefore, energy is what it takes to accomplish work.

Work is distance times force, or force as it is applied to set a body in motion. If you climb a mountain, the climbing is work, and the rate at which you climb is power. The total work performed is equal to the amount of energy expended.

Our challenge as rescuers is to take all of these theoretical concepts and put them to use. To explore our options, we must first understand that what makes a machine efficient is its potential advantage. A mechanical advantage is the ratio of the output force that a machine exerts compared with the input force furnished to that machine to do work **FIGURE 9-7**. A simple machine is measured in terms of its efficiency and effectiveness when doing work. For example, if you get five units of work out of a machine by putting in one unit of work, the machine has a five-to-one (5:1) ratio of efficiency.

How does this theory apply to rescue? Suppose you are operating at a fire on the roof of a 10-story building and see a 400-pound (181.4-kg) man in the window of the seventh floor. To make matters worse, there are no anchors, and the only tools you have available are 150 feet (45.7 m) of static kernmantle rope, a 10-foot (3-m) service ladder, a change of direction pulley, and your personal eight plate. Realizing that this person does not have rope-rappelling training, you decide that a standard lower is the best and safest rescue method; it would not be safe to hook the man into your eight plate.

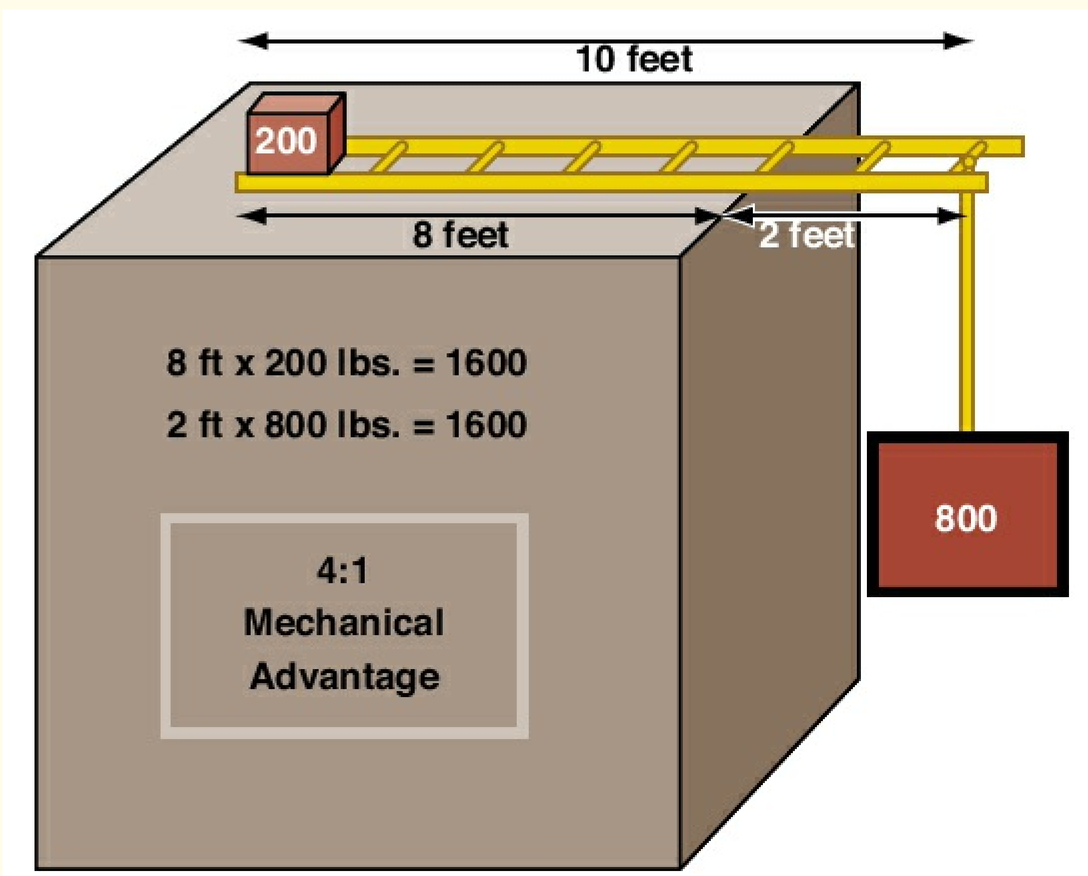

FIGURE 9-7 In this case, the efficiency of the lever is based on the distance that the load is from the fulcrum or turning point.

To overcome the problem, you take the 10-foot ladder and place it so that a 2-foot (0.6-m) length hangs over the edge of the building and the remaining 8 feet (2.4 m) lies on the roof. You then attach the rope to the eight plate and reeve it through the change-of-direction pulley that you attach at the end of the ladder that hangs over the end of the building. Next, you talk the victim into tying the rope around his upper body and climbing out the window.

By using the mechanical advantage of the lever (a simple machine) and the moment of force, we offset the disparity in the weight between you and the victim; you can theoretically effect this rescue with a little effort. As illustrated in Figure 9-7, the ladder used as a lever becomes your mechanical advantage. By leaving 8 feet (2.4 m) of the ladder on the building with 2 feet (0.6 m) hanging over, the ladder actually becomes a 4:1 mechanical advantage.

To see whether this plan will work, let us do the math. If you weigh 200 pounds (90.7 kg), multiply that times 8 feet (2.4 m) (the length of the ladder that remains on the building); the product is 1600 (217.7). The other side of the equation is the 400-pound (181.4-kg) person multiplied by 2 feet (0.6 m), which is the length of the ladder hanging over the building. This equals 800 (108.8). In effect, you used a lever to create a 2:1 advantage. Theoretically, your 200 pounds (90.7 kg) can now lower this 400-pound (181.4-kg) person safely to the ground.

A word of caution at this point: The person still weighs 400 pounds (181.4 kg), so you would have to use a friction control device such as a double-wrapped eight plate or a closed-end rigging rack for the lower. Also note that this discussion is a theoretical example only: I do not recommend that you actually try it without taking the necessary and proper safety precautions.

Two kinds of simple machines exist: those made up of levers (most efficient/least friction) and those made up of inclined planes (least efficient/most friction). Let us now take a look at the application of levers and leverage.

■ Levers

A lever is categorized as class I, class II, or class III. Levers can be used to move, haul, pull, or raise a load. Every lever has a fulcrum, which serves as a pivot point for the lever; force, which provides the power; and a load. The position of the fulcrum in relationship to the load determines the classification of the lever.

To understand the application of a lever, let us look first at the class I lever. The best example of this type of lever is a pry bar. If you have to lift a concrete slab to effect a rescue, the pry bar can give you a purchase point under the edge of the concrete. In this example, the concrete represents the load. If you place a block of wood under the pry bar, the wood becomes a fulcrum. The force, applied by the rescuer in a downward motion, will effectively manage the lift. The fulcrum is located between the force and the load **FIGURE 9-8**.

You can easily calculate the advantage that the class I lever has provided in this situation. The distance from the fulcrum to the force divided by the distance of the fulcrum from the load determines the amount of advantage. Here is an example: If you have a 6-foot (1.8-m) pry bar (lever) and you place the fulcrum at the lever's 5-foot (1.5-m) mark, the ratio can be represented as 5:1. Thus, to lift a 500-pound (226.8-kg) load, you would have to create only a 100-pound (45.4-kg) force. The way we used the ladder on the roof in the previous example fits the same concept.

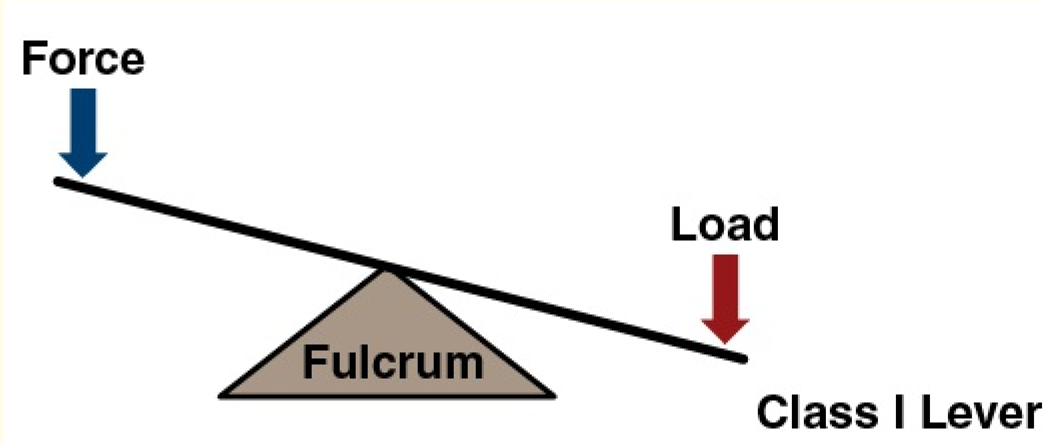

FIGURE 9-8 The fulcrum is between the force and the load.

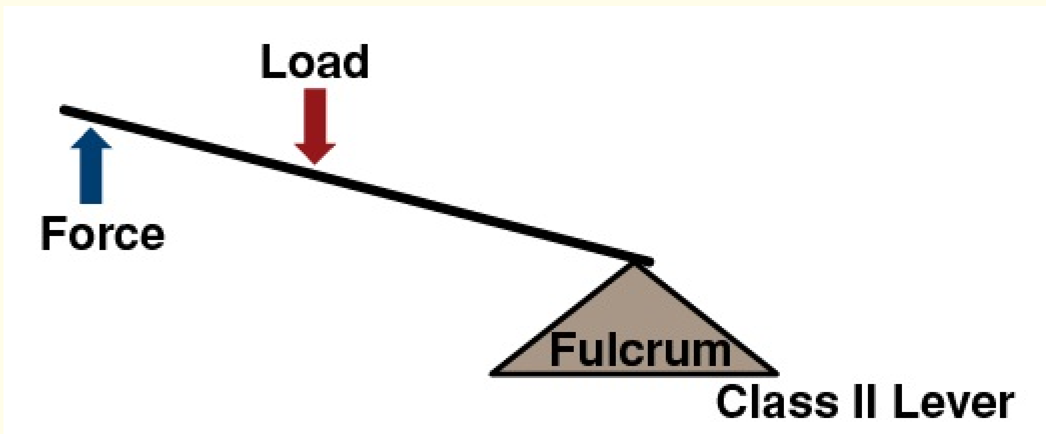

FIGURE 9-9 The load is between the force and the fulcrum.

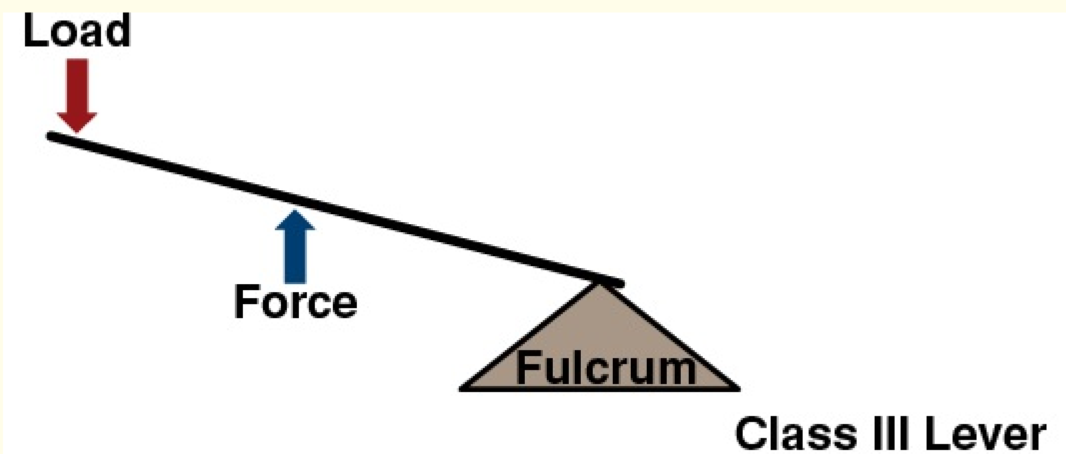

FIGURE 9-10 The force is between the fulcrum and the load.

The class II lever is best applied for moving objects on a horizontal or near horizontal plane. In this application, the load is between the fulcrum and the force **FIGURE 9-9**. A good example of this type of lever is the wheelbarrow. In this case, the force is applied in the lifting action of the handles. The load is in the hopper, with the fulcrum at the wheel. Using the formula, you can see that, up to a certain point, the longer the wheelbarrow handles are, the greater the advantage you will have when moving objects.

The class III lever is the hardest to understand because the primary example of it is the shovel, which can also be used as a class I or class II lever in some situations. This type of lever has the force located between the load and the fulcrum **FIGURE 9-10**. Imagine the action of moving a shovel full of sand. The sand is the load. The force is the hand that is used to lift and throw the sand, and the fulcrum is the hand on the end of the shovel that directs it to another location.

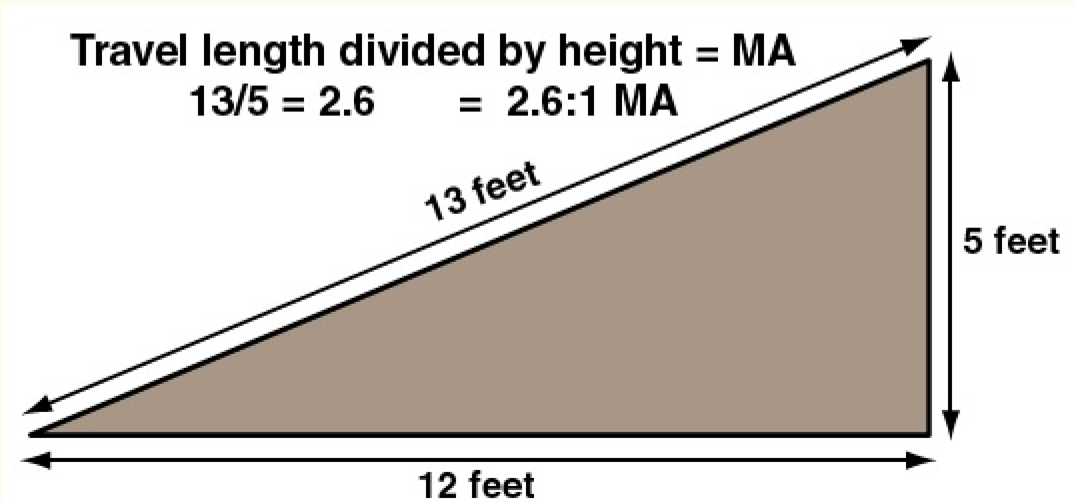

FIGURE 9-11 Advantage is calculated as travel distance divided by height.

Various actions of the shovel can represent all three classes of levers, depending on your desired outcome. When the shovel is first pushed into the ground and bent back, it is a class I lever. If you break the shovel forward to gain a better bite, it is a class II lever. The action of throwing the dirt makes it a class III lever.

■ Inclined Planes

The last simple machine that will help you gain advantage is the inclined plane. An inclined plane gains efficiency by reducing required force over time **FIGURE 9-11**. Inclined planes can be seen in all aspects of life, from interstate ramps to the steps of a house. In rescue operations, we use these tools to cut, saw, and raise objects. Such gradual increases in height let you reduce the amount of energy required at any given time by spreading out the effort over time.

When we place a ladder in a trench and then use the angle of the ladder to facilitate victim removal, we use the inclined plane concept. Using the angle of the ladder to decrease the slope divides the energy over a period of time. If you want to figure the advantage gained by using the ladder, divide the height of the trench into the ladder's height at the point it contacts the ground. In this case, if the base of the ladder is 4 feet (1.2 m) from the wall and the trench is 8 feet (2.4 m) deep, you would divide 8/4 (2.4/1.2), giving a theoretical 2:1 mechanical advantage **FIGURE 9-12**.

The concepts of mass, gravity, friction, center of gravity, moment of force, work, energy, inclined planes, levers, and pulleys can be applied in myriad ways to the trench rescue environment. Although you should always consider using modern equipment to effect positive rescue results, you should never forget that some tried and true basic techniques can be applied when the more modern tools are not available.

Rope Raising and Lowering Systems

In the course of a trench rescue, it is almost always the case that rescue personnel will need to use rope rescue skills, especially in raising and lowering objects and people. The very nature of a trench dictates that you will at some time during the rescue be physically at a point that is higher than the victim you are trying to extricate.

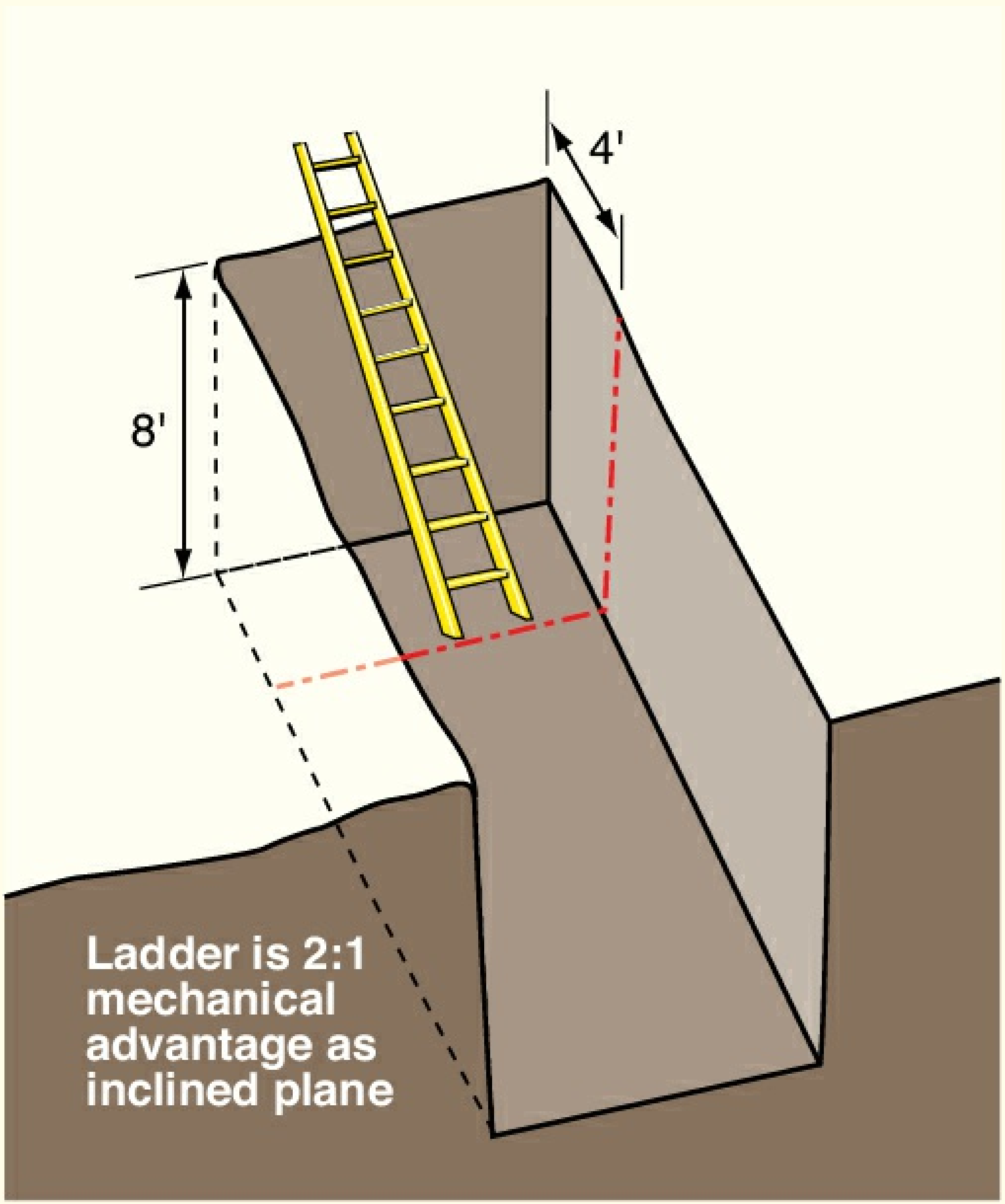

FIGURE 9-12 The advantage of the trench ladder is figured as distance of the ladder base from the trench wall, divided by the height of the trench where the wall meets the ladder.

While the preferred rescue method is a non-entry rescue, in many cases this is not possible. That means that someone will need to enter the environment, physically remove the entrapping mechanism, package a victim, and then remove them from the trench. This requires victim packaging skills and an understanding of rope rescue as it applies to mechanical advantage systems and their use in lowering and raising operations.

Rope rescue is a discipline that requires many hours of training and is beyond the scope of this text. The intent of introducing the topic here is to provide an understanding of the importance of rope rescue raising and lowering systems and, more specifically, how they help effect a trench rescue.

Understanding mechanical advantage systems and how they are used to raise and lower objects is a matter of understanding gravity and how pulleys can be used to make lifting easier. If you tie a rope to something to raise or lower it, you need to consider the object's entire weight. If the object weighs 200 pounds (90.7 kg), the system you create needs to be able to lift 200 pounds (90.7 kg). This is certainly easier over short distances but becomes more challenging when the load must be moved over considerable distance.

To make this job easier, pulleys can be used. The effect of anchoring one end of the rope and then having the pulley travel with the load divides the work in half, making it a 2:1 mechanical advantage. (Be sure the rope is anchored above the load, is threaded through the pulley, and is then brought back up.) In our example, the 200 pounds (90.7 kg) becomes 100 pounds (45.4 kg) because the anchored rope and pulley are supporting half the load. If you take that same system, disconnect the rope from the anchor, add a stationary pulley on the anchor (in addition to the travelling pulley), and then reattach the rope to the load, you will have created a 3:1 mechanical advantage system. In general, the number of ropes that are connected to the load pulley are an indicator of the mechanical advantage provided.

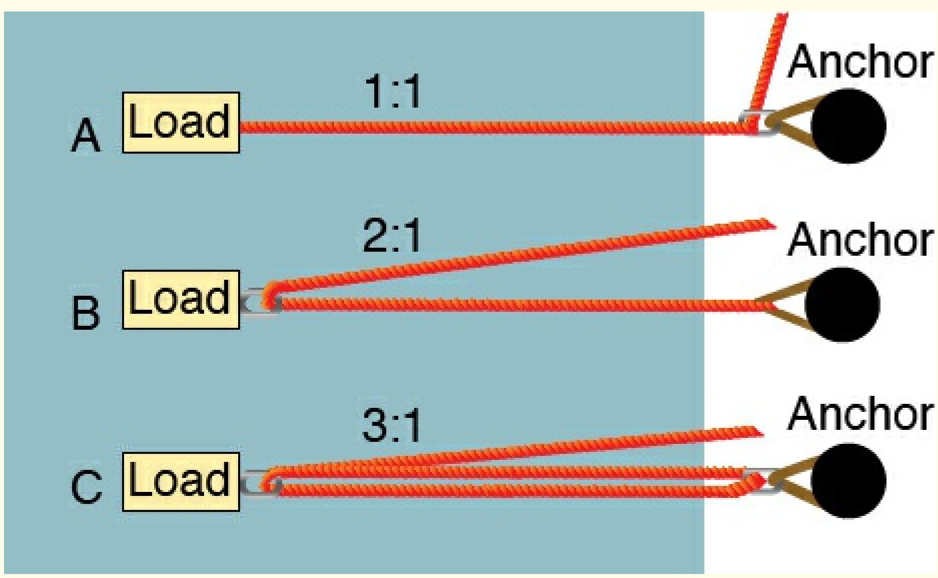

FIGURE 9-13 Mechanical advantage. **A.** 1:1. **B.** 2:1. **C.** 3:1.

There is a difference, however, between a change of direction pulley and a pulley that is part of a system that will provide an advantage. The best way to understand this concept is to recognize that only traveling pulleys provide an advantage. Any pulley that does not travel when the load is moved is just a change of direction device and does not provide a mechanical advantage **FIGURE 9-**

13.

Note that all systems need to be backed up and all systems need a method to control the load. In most cases, this will mean that it will be necessary to provide a second line to the load that can be anchored and run through a belay device. The belay device could be mechanical or rescue cordage (Prusik) that is of the correct size for the rope being used.

Air Bags for Trench Rescue

The air bag, as used for lifting objects, was introduced in the 1970s and is one of the very best tools developed and adapted for the rescue business. Using air supplied to a balloon-like vessel, the pneumatic air bag can perform many functions at a trench rescue. Some of these uses involve lifting heavy objects like pipes, excavators, steel panels, and concrete distribution boxes—objects that workers seem to sometimes find themselves under, instead of beside. In addition, air bags can be used to fill voids created by sloughs and other types of trench collapses FIGURE 9-14.

Keep in mind that this text is not a comprehensive guide to pneumatic air bags. Our task here is simply to explain their construction, operating principles, and specific applications for trench rescue activities. With this being said, it is a plus that no matter what the specific application of air bags, the principles of operation always remain the same.

About Air Bags

Air bags can be purchased as low-, medium-, or high-pressure systems. The amount of air pressure supplied to perform the lift determines the classification of the bag. Low-pressure bags use 7 pounds per square inch (psi) (0.5 kg/cm). Medium-pressure bags use 22 psi (1.5 kg/cm), and high-pressure bags use 80 to 120 psi (5.6 to 8.4 kg/cm). Medium-pressure air bags are not as popular as they once were; for that reason, the discussion here will concentrate on low- and high-pressure systems.

VOICES OF EXPERIENCE

It was an early fall day in Virginia Beach, Virginia, and all over the city people were outside enjoying the nice weather. In southern Virginia Beach, a rural area of the city, a teenage horseback rider was walking her horse to cool down after an afternoon ride, when the horse suddenly fell into an old septic tank in the middle of the horse pasture. The horse ended up in the bottom of the tank with her legs pinned.

I began to evaluate how the plan was going and to devise additional strategies to resolve the incident.

Immediately after falling, the horse began to buck and struggle in an effort to free herself from the entrapment. The teenage rider realized this was a true emergency and called her father, who then contacted a veterinarian specializing in large animal care. After arriving on scene, the father and the vet called 911 for assistance. The call was dispatched as a technical rescue incident with units from several stations, including Rescue Company 1, being sent to the scene. The Captain of Rescue 1 also requested Rescue 2 to respond for assistance with the collapse element of this incident.

The first-arriving unit was an engine company who were all trained to the awareness levels in all disciplines of technical rescue. The Virginia Beach Fire Department uses a tiered system for response to technical rescue incidents: Engine company personnel are trained at the awareness level, truck company personnel are trained at the operations level, and rescue company personnel are trained at the technician level. Of course, this does not mean that someone riding on either an engine or a truck would not be trained to the technician level in technical rescue, but as a rule they would all have at least awareness-level skills.

As appropriate, the first engine company established command and advised all incoming units that this was a working technical rescue incident. Their initial plan was to use fire hose placed under the horse and available manpower to muscle the horse from the tank and to safety. This effort was quickly abandoned over concerns with the horse's weight and the difficulty of getting the hose under the horse because of the way she was pinned.

The horse would became very agitated when people were near her. The initial crew did a good job of keeping bystanders away, and the veterinarian established a large-bore IV in the horse to administer sedatives.

I arrived on scene as the Captain of Rescue 2 and was assigned Operations. Since the rescue was already underway, I began to evaluate how the plan was going and to devise additional strategies to resolve the incident. In consultation with the vet, a lifting plan was established. The plan was to first stabilize the ground around the tank with ground pads. The ground pads would provide a firm platform from which an overhead anchor point could be established. At this point, and in consult with the veterinarian, we placed a wide sling under the horse in an area deemed safe by the vet. We then used an Airshore tripod as an artificial high directional along with a resultant force rope system to lift the horse from the tank.

One of the things that made this rescue different than others was that the vet asked that we limit all noise around the horse. This meant that the entire scene needed to be kept quiet, so we could not use radios or even talk to each other. Rather, we communicated using hand signals for all rope commands.

The estimated weight of the horse was 600 pounds, so the rope system we designed was a 6:1 mechanical advantage system. Basically we used a 2:1 system that was rigged to the tripod with a 3:1 "Z" rig anchored to a brush truck and then connected to the 2:1 system. Making certain the system anchor and overhead attachment could withstand the forces needed to lift the 600 pound horse, the lifting process was completed.

After the horse was extricated, it was too weak to stand. Wood panels were placed under her so there would not be any chance she could fall back in the tank. After several minutes and lots of coaching by all involved, the horse was able to stand and move on her own. In this incident, the outcome for the horse was good. She suffered only minor injuries, and no emergency responders were injured.

During this unusual incident, several lessons were learned. First was that people are not the only issue we deal with when responding to trench or excavation rescues. Second, our fire department had very limited experience and training on large animal rescue situations. This has now been corrected with several of our more rural engine companies attending a large animal rescue training session. Also, the incident required everyone to be quiet; therefore, we had to rely on hand signals for all communications. The VBFD does utilize hand signals during our rope and collapse training; however, those skills are normally taught and used by the rescue company fire fighters. We now know there is a need to train all our fire fighters in basic hand signals.

Jon Rigolo
Captain, Rescue Company 2
Virginia Beach Fire Department
Virginia Task Force Two
Virginia Beach, Virginia

FIGURE 9-14 Air bags have many applications in trench rescue. In this photo, they are used to fill a void in a trench slough.

Generally speaking, low-pressure air bags can lift only limited capacities, as compared with high-pressure bags, but will lift the objects higher. High-pressure air bags will lift a greater weight than low-pressure bags, but will not lift the object nearly as high. Using the proper tool for the job is the key to successful air bag operations at a trench rescue.

■ How Air Bags Work

All air bags are supplied with a volume of air and pressure from a remote air source. This source usually consists of a self-contained breathing apparatus bottle, but could be an air compressor or even a hand pump. In most applications, the air source will send air to a regulator that decreases the pressure and supplies a controller. The controller is the distribution point for multiple air lines and dictates the rate of flow to the individual bags.

All air bags use the same principle to effect the lift of an object. The effectiveness of air bags is tied to the compressibility of air, as divided over the inside surface of the air bag. Basically, the lifting capacity of any air bag is limited to the amount of bag surface area that can contact the object, multiplied by the operating pressure supplied to the bag **FIGURE 9-15**.

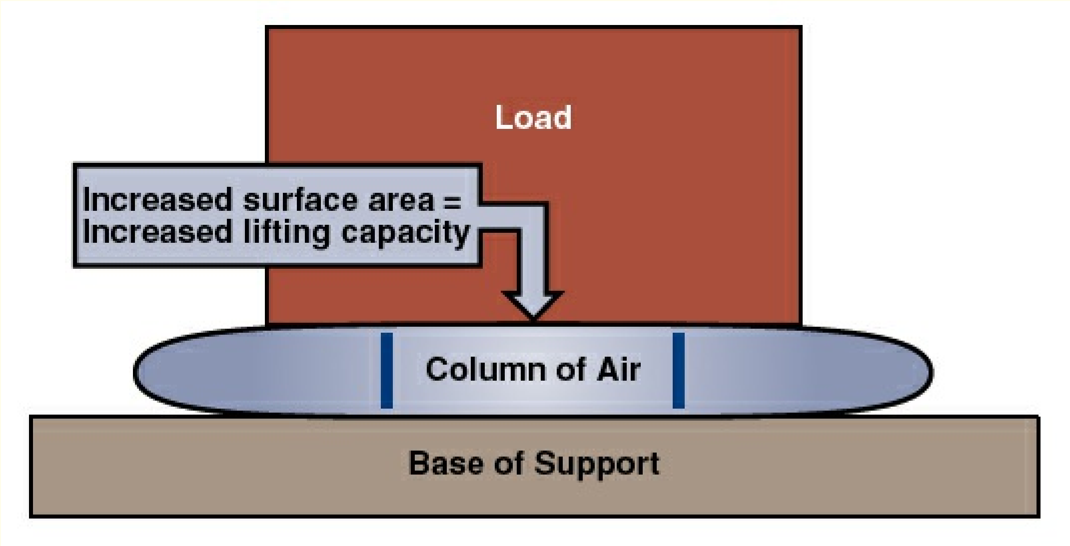

FIGURE 9-15 The lifting capacity of an air bag is calculated by multiplying the operating pressure by the surface area of the bag in contact with the object.

Air bags are rated as having a maximum and a minimum lift. This rating takes into consideration the surface area of the bag that is in contact with the object. As the bag inflates, it becomes oblong shaped and loses surface contact with the object. As this occurs, the lifting capacity of the bag diminishes proportionally.

■ Using Air Bags

As an experiment, pull out a set of high-pressure air bags and measure the length and width of one of the bags. Take these measurements and multiply them together, and then multiply the result by the operating pressure as recommended by the manufacturer. Now compare your figure with the maximum lifting capacity indicated on the bag. Your figure and the manufacturer's rating should be about the same.

Now that you have a handle on this concept, let us apply it to a rescue-lifting scenario. Suppose the object you want to lift has a surface area of 6 × 6 inches (15 × 15 cm) and weighs 6000 pounds (2721.6 kg). You have selected a 40-ton (36.3-metric ton) air bag to manage the lift. The 6 × 6-inch (15 × 15-cm) surface area of the object to be lifted equals 36 square inches (232.3 cm^2), and the operating pressure of the air bag is 120 psi (8.4 kg/cm). By multiplying the 36 square inches (232.3 cm^2) by the 120 psi (8.4 kg/cm) operating pressure, you obtain a lifting capacity of 4320 pounds (1960 kg). Because 4320 (1960) does not equal 6000 (2721.6), you have a problem.

At this point, it does not matter if your bag can lift 1 trillion pounds: You simply do not have the surface area necessary to effect the lift. In this scenario, you need to find a lifting point on the object that has more surface area or create more surface area by using a sturdy plate or other object that will not bend under the load.

■ High-Pressure Air Bags

High-pressure air bags consist of rubber or neoprene material reinforced with steel bands or Kevlar, and usually have a coarse surface to increase the friction between the bag and the lifting surface. They are operated with an air system that can supply between 80 and 120 psi (5.6 to 8.4 kg/cm).

As stated earlier, the drawback to high-pressure bags is that they do not lift objects very high. To offset this limitation, you can stack them. The rule of thumb for stacking high-pressure air bags is to stack only two and to always put the largest-capacity bag on the bottom. Keep in mind that the total capacity of your lift is limited to the lowest capacity of the stacked bags—the lowest-rated bag will not be able to lift more weight than the higher-rated bag has already lifted **FIGURE 9-16**.

FIGURE 9-16 High-pressure bags lift heavy objects, but only to limited heights.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Tactical Tip

Although stacking bags will increase the height that an object can be lifted, it will not increase the capacity of the lift. To achieve a higher-capacity lift, put the air bags beside each other (i.e., use more surface area of the object to be lifted) and inflate them simultaneously.

High-pressure bags, although very durable, cannot be repaired in the field if they should develop a hole. Remember this point and protect the bag from sharp objects.

■ Low-Pressure Air Bags

Low-pressure air bags are flexible rubber bags and are used primarily in trench rescue to fill voids in trench walls, although they can be used to lift some objects **FIGURE 9-17**. Operated at 7 to 12 psi (0.5 to 0.8 kg/cm), low-pressure bags will lift objects higher than high-pressure air bags will, but they will not lift nearly as much weight. Unlike high-pressure bags, if low-pressure bags get a hole in them, the hole can be plugged easily, making these bags fairly field repairable. Additionally, consider that the average 16-ton (14.5-metric ton) air bag may require as much as 250 cubic feet (7.1 m^3) of air to effect a lift.

Low-pressure bags can also be used to lift objects by placing them on a platform outside the trench and above the object that needs to be lifted. If you take a rigging strap and wrap it around the bag, then around the object to be lifted, the object will be lifted as the bag is inflated **FIGURE 9-18**. In this scenario, make sure your lifting platform is substantial enough to hold the weight of the load until it can be cribbed.

In a different type of application, the low-pressure bag can be used to fill a void. For example, with a slough failure, a section of the wall falls into the trench. To transfer the forces from one side of the trench to the other, this void must be filled. A large low-pressure air bag can be inflated between the wale that spans the opening and the existing wall **FIGURE 9-19**.

FIGURE 9-17 Low-pressure bags lift limited weight but to a much greater height than high-pressure bags.
Courtesy of Bob Schilp

FIGURE 9-18 Low-pressure bag being used to lift an object in the trench.
Courtesy of Bob Schilp

Tactical Tip

The higher any bag lifts, the more unstable the lifted object may become. For this reason, you must constantly evaluate the lifted object's center of gravity against its stability. Remember this rule of thumb: Lift an inch–crib an inch!

Cribbing

No section on the lifting of objects would be complete without a description of the proper use of cribbing. During each lift, the object being lifted should never be more than an inch from a substantial cribbing system.

FIGURE 9-19 Low-pressure air bag being used to fill a slough void.

Cribbing material for trench rescue is usually cut out of 2 × 4-inch and 4 × 4-inch pieces of lumber. The latter is what the boxes are usually constructed from, with the former used to take up odd spaces. It is generally recommended to cut cribbing from a softer type of wood (e.g., pine) rather than from a harder wood (e.g., oak). Softer woods will tend to bend and crack when they are being stressed, whereas hardwoods in this type of application can and do fail without notice.

Generally, cribbing is cut to standard 12-, 18-, or 24-inch (30.5-, 45.7-, or 61-cm) lengths. Do not spend all of your funds buying wood for cribbing. This is not the place to invest your money, because almost any construction-grade lumber will work. Over time, the wood will inevitably lose its natural moisture content; it can then become brittle or split under a load. Even if no damage is visible, consider removing wood from response status every 12 to 18 months.

Many types and sizes of synthetic cribbing are also available for rescue use. While these products are durable and will last for a very long time, they are expensive compared to wood cribbing and can easily slide under a load when wet.

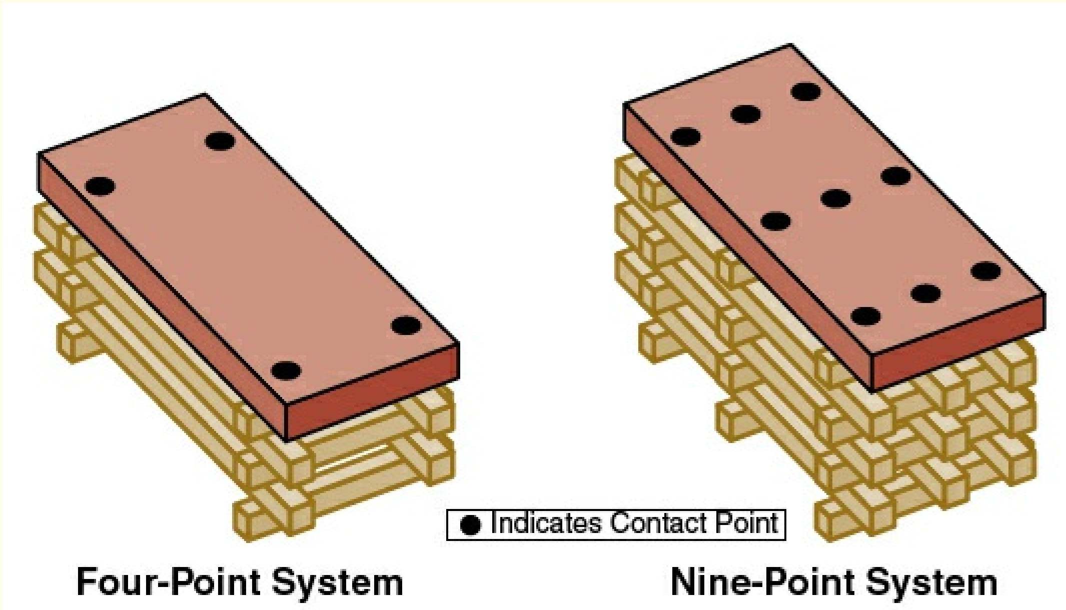

FIGURE 9-20 Four-point and nine-point box crib systems.

The Box Crib System

There are three variations of the box crib system—the four-point, the nine-point, and the full-box crib. Each system is named based on the number of contact points in the cribbing system. Thus, a four-point box crib system has two timbers for each layer, but a total of four places that each piece of lumber crosses. A nine-point box crib has nine contact points and three pieces of cribbing on each layer of the system **FIGURE 9-20**. A full-box crib system would be solid on all layers—a very strong system, but certainly lumber intensive, and rarely required in trench operations.

The general rule for box cribbing is that each point of contact will support a standard amount of weight, depending on the size of the lumber. A 4 × 4-inch crib will support approximately 6000 pounds (2721.6 kg) per contact point, and a 6 × 6-inch crib approximately 15,000 pounds (6803.9 kg) per contact point. By adding the number of points together, you can determine the total capacity of the box crib. Because the weight supported may be more concentrated when on the box crib (less surface area), you should also consider whether the ground on which the box crib rests is substantial enough to hold the load. This is especially true in the bottom of a wet trench.

All box crib systems are made by stacking the timbers in alternating rows, each row at a right angle to the previous row. When using the box crib as a lifting platform, the top layer should always be solid. Each row should be stacked and placed at a distance somewhat less than the total length of the piece of timber, thereby not creating too much overhang, but always situated past the outside edge of the piece directly under it. The height to which the box crib should be built is no more than three times the diameter of the base. Therefore, a 2 × 2-foot box crib should be no higher than 6 feet (1.8 m) tall; however, it may be less depending on the lifted object's center of gravity and the stability of the ground supporting the box crib FIGURE 9-21.

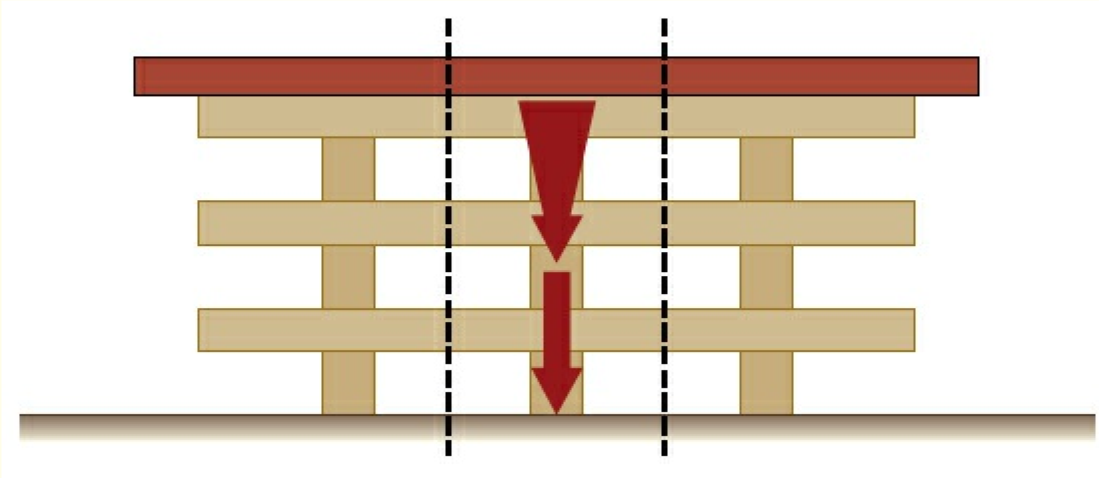

FIGURE 9-21 The object being stabilized should be as close to the center of the box crib as possible.

Wedges

Wedges are cut pieces of lumber that form an inclined plane. The plane of the wedge makes it adjustable depending on the space it needs to occupy. When used in this fashion, the wedge takes up the space between the object being lifted and the box crib, until a full piece of timber will fit under the object FIGURE 9-22. Thus, if something happens during the lift, the object can fall only the limited space between the wedge and the object.

Wedges have a variety of uses at a trench rescue. Functioning as inclined planes, they can be used to tighten objects and take up spaces between wales and uprights FIGURE 9-23. In the timber trench, wedges can be used to tighten the shores to the uprights.

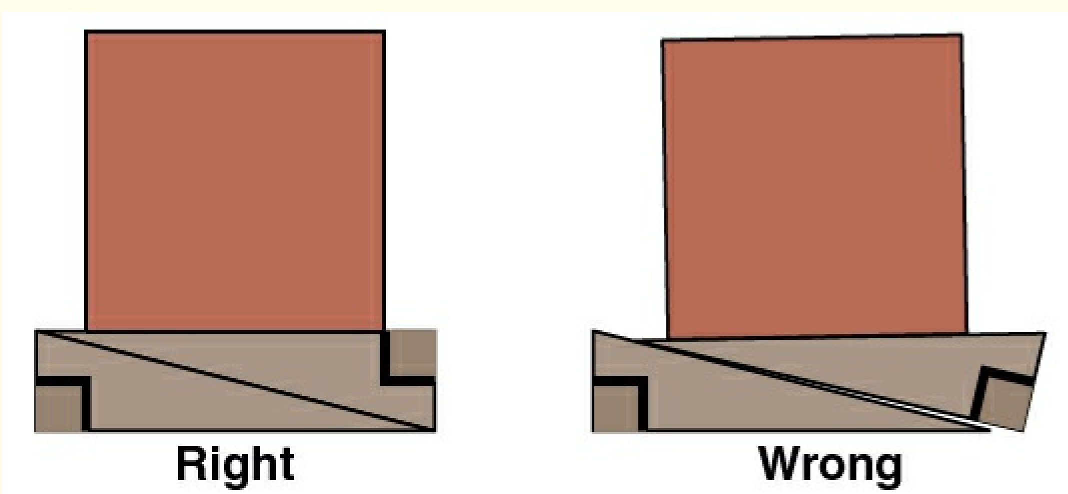

FIGURE 9-22 Cut wedges are married properly when the cut sides are in contact with each other.

FIGURE 9-23 Wedges being used to fill a void between the wale and the strongback.

Wrap-Up

Review: Just the Dirt

- All rescue personnel can benefit from an understanding of the basic concepts of lifting and moving.
- Ultimately, when you find yourself on a trench rescue scene, much of what you do to either rescue or recover a victim involves displacing materials or solid objects to gain access.
- Before any consideration is given to lifting or moving an object, some effort should be devoted to calculating how much the object weighs.
- The basic physics associated with lifting and moving objects include the concepts of gravity and its effects on mass, friction and resistance to force, center of gravity, moment of force considerations, and mechanics.
- The theory of mechanics is divided into two areas called energy and work. The effective use of rescue tools is often determined by a thorough understanding of these concepts and their application in a given situation.
- Levers can be used to move, haul, pull, or raise a load. Every lever has a fulcrum, which serves as a pivot point for the lever; force, which provides the power; and a load.
- An inclined plane uses gradual increases in height to gain efficiency by reducing required force over time.

- Air bags can be used to lift heavy objects like pipes, excavators, steel panels, and concrete distribution boxes. Low-pressure and high-pressure bags are most commonly employed in trench incidents.
- The lifting capacity of any air bag is limited to the amount of bag surface area that can contact the object, multiplied by the operating pressure supplied to the bag.
- The drawback to high-pressure bags is that they do not lift objects very high.
- Low-pressure bags will lift objects higher than high-pressure air bags will, but they will not lift nearly as much weight.
- During each lift, the object being lifted should never be more than an inch from a substantial cribbing system.
- There are three variations of the box crib system—the four-point, the nine-point, and the full-box crib. Each system is named based on the number of contact points in the cribbing system.
- Wedges are cut pieces of lumber that form an inclined plane. The plane of the wedge makes it adjustable depending on the space it needs to occupy.

Hot Terms

Center of gravity The point on a body around which the body's mass is evenly distributed.

Class I lever Lever in which the fulcrum is located between the force and the load.

Class II lever Lever in which the load is located between the fulcrum and the force.

Class III lever Lever in which the force is located between the load and the fulcrum.

Energy The capacity for doing work and overcoming resistance.

Friction Measure of the amount of force it takes to move an object across the surface of another object.

High-pressure air bags Rubber or neoprene bags with a coarse surface to increase the friction between the bag and the lifting surface.

Inclined planes Angled planes that gain efficiency by reducing required force over time.

Lever A simple machine used to move a load. It includes a fulcrum (pivot point), a force, and a load.

Low-pressure air bags Flexible rubber bags used primarily in trench rescue to fill voids in trench walls.

Mechanical advantage The force achieved using a tool, mechanical device, or other equipment.

Mechanics A branch of physics that deals with motion and the forces that cause it.

Moment of force The amount of force rotating around the fulcrum times the distance from the fulcrum.

Work Distance times force.

TRENCH RESCUER *in action*

It is a quiet Friday afternoon in the firehouse. You and other members of the rescue company are sitting around the kitchen table enjoying a coffee after having returned from doing some public education at a local park. You are discussing plans for the annual company picnic coming up on Sunday, when suddenly the tones go off and the house watch announces over the PA system that you are responding to a construction accident in a new residential housing development two districts away.

While your team is responding, dispatch announces more information over the radio. An excavator has fallen into a trench, with three to four workers injured and possibly trapped in the trench. As you are still approximately 10 minutes from the scene, your captain starts preplanning based on the information received. He makes a guess that the workers could be trapped by the excavator, which is in the trench, buried due to the collapse of a trench wall, or both. He thinks that the job will require some shoring of the trench, a lot of cribbing, and probably a lot of lifting to free the workers. All members agree that the situation could be a tough rescue job.

Upon arrival at the scene, you find that the incident is at the end of a dead-end street. The captain tells you and the other members to start offloading the cribbing and lifting equipment while he checks in with command. A few minutes later he is back with an update. The workers were installing the storm sewer system and the excavator has indeed fallen into the trench due to the collapse of the trench. The operator is injured, but because of the way his machine is situated in the trench, no stabilization or shoring will be required, and the engine company, along with paramedics, is in the process of removing him.

When the trench collapsed, however, the excavator was in the process of lowering a large, concrete, end-of-line sewer junction box into an area of the trench that is protected by a trench box system. When the excavator fell into the trench, it dumped the junction box into the trench box, injuring and trapping two workers. The junction box is 6 feet by 6 feet (1.8 m × 1.8 m) square with six solid walls, and the walls are all 6 inches (15.2 cm) thick. There are 36-inch (0.9-m) "knockouts" on five of the six sides of the box, but only two have been removed—one on the top and the other opposite the side trapping the workers.

Both workers are conscious and appear stable, but are pinned by the junction box in somewhat soft soil from mid-thigh down to their feet. The junction box will have to be stabilized and lifted to be able to extricate the two injured workers. It looks like this might turn into a simple lift-and-stabilize operation.

1. What is the first thing that needs to be done before giving any consideration to lifting and stabilizing the junction box?
   A. Determine how much cribbing the operation will require
   B. Determine how much the junction box weighs
   C. Determine how high a lift will be required to extricate the trapped workers
   D. Determine how many air bags the lift will require
2. Based on concrete weighing an estimated 150 lb (68 kg) per cubic foot (0.03 m^3), what is the approximate weight of the junction box?
   A. 8200 lb (3719.5 kg)
   B. 12,600 lb (5715.3 kg)
   C. 16,200 lb (7348.2 kg)

D. 20,500 lb (9298.6 kg)

3. Your captain decides that he would like the junction box lifted approximately 18 to 24 inches (0.5 to 0.6 m) to allow for the most efficient extrication of the injured workers. He tells you to get the air bags. Which air bags will you bring back?
   A. High-pressure air bags
   B. Medium-pressure air bags
   C. Low-pressure air bags
   D. A combination of high- and low-pressure air bags

4. Cribbing will be required to support the air bags and stabilize the load while it is lifted. Your captain tells the crew that he wants a full box crib base for the air bags and a nine-point box to support the junction box as it is lifted. What does he mean?
   A. A full box of 4 × 4s for the base layer and a box crib with three 4 × 4s on each layer
   B. A base layer of four 4 × 4s to support the air bags and a box crib with nine 4 × 4s on each layer
   C. A base layer of four 4 × 4s laid out in a box and a box crib with three 4 × 4s on each layer
   D. A base layer of four 4 × 4s to support the air bags and a box crib with three 4 × 4s on each layer

5. Your captain assigns two crew members to dig under the junction box on each side of the workers to allow the full box base and air bags to be installed. How big an area is required for this lift?
   A. Enough to allow at least half of the full box crib and the air bags to be installed under the junction box
   B. Enough to allow at least three-fourths of the full box crib and the air bags to be installed under the junction box
   C. Enough to allow the full box crib and the air bags to be installed under the junction box
   D. Enough to allow the full box crib and the air bags to be installed 1 foot (3 m) under the junction box

6. What is the center of gravity?
   A. The point on an object that is equidistant measured from all sides of an object
   B. The point on an object around which the object's mass is evenly distributed
   C. The point on an object that determines the amount of force required to move that object
   D. The point on an object that determines the capacity for overcoming gravity

Protective Systems

CHAPTER 10

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the protective systems used for trench rescue operations NFPA 8.1.2. (p 142)
- Identify the fundamentals of trench rescue shoring and the equipment that is commonly used for this purpose NFPA 8.1.2 NFPA 8.1.4. (pp 142–143)
- Explain the benefits of having a default trench rescue shoring method NFPA 8.1.2. (p 143)
- Describe how to install lip protection NFPA 8.1.2 NFPA 8.1.4. (pp 143–145)
- Describe the use of panels in trench rescue shoring NFPA 8.1.2 NFPA 8.1.4. (pp 145–150)
- Describe the use of struts in trench rescue shoring NFPA 8.1.2 NFPA 8.1.4. (pp 151–159)
- Describe the use of timber shores in trench rescue shoring NFPA 8.1.2 NFPA 8.1.4. (pp 159–161)
- Describe the use of wales in trench rescue shoring NFPA 8.1.2 NFPA 8.1.4. (p 161)
- Explain when and how to use isolation devices NFPA 8.1.2. (p 164)
- Describe the use of engineered systems in trench rescue shoring. (pp 164–166)
- Explain how to remove trench rescue shoring equipment at the termination of an incident NFPA 8.1.7. (pp 166–167)
- Discuss when commercial shoring techniques may be necessary at a trench rescue incident. (pp 167–169)

Skills Objectives

After studying this chapter, you should be able to:

- Demonstrate how to install ground pads NFPA 8.1.2 NFPA 8.1.4. (pp 143–144)
- Demonstrate how to install a lip bridge NFPA 8.1.2 NFPA 8.1.4. (pp 144–145)
- Demonstrate same-side panel installation NFPA 8.1.2 NFPA 8.1.4. (pp 148–149)
- Demonstrate opposite-side panel installation NFPA 8.1.2 NFPA 8.1.4. (PP 148, 150)
- Demonstrate how to install pneumatic shores from outside the trench NFPA 8.1.2 NFPA 8.1.4. (pp 155–156)
- Demonstrate how to install pneumatic shores with entry operations NFPA 8.1.2 NFPA 8.1.4. (pp 155, 157-158)
- Demonstrate timber shore installation NFPA 8.1.2 NFPA 8.1.4. (pp 159–160)

- Implement an isolation device **NFPA 8.1.2**. (p 164)
- Demonstrate machine removal of a pneumatic shoring system **NFPA 8.1.7**. (p 166)
- Demonstrate manual removal of a pneumatic shoring system **NFPA 8.1.7**. (p 166)
- Demonstrate manual removal of a timber shoring system **NFPA 8.1.7**. (pp 166–167)

Trench Rescue Level II

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss considerations when using heavy equipment at a rescue scene **NFPA 8.2.5**. (pp 169–171)

Skills Objectives

After studying this chapter, you should be able to:

- Use hand signals to direct heavy equipment rescue operations **NFPA 8.2.5**. (pp 170–171)

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

Your trench rescue team is rolling out to another emergency. This is the third such dispatch for you and, thanks to all of your training and drills, you are starting to feel comfortable with shoring. When you get off the truck and walk to the end of the trench for an assessment, you see a large cave-in at the bottom third of a 16-foot (5-m) deep trench wall. The walls are showing two distinct layers of soil. The top layer (from the lip down about 10 feet [3 m]) is a sand/clay mix. The bottom 6 feet [1.8 m] is saturated soil (mud) that looks like wet concrete. The ground water table is at the intersection of the two soil types. You notice that the construction workers are moving the spoil pile with shovels. They are dipping the shovel heads into buckets of diesel fuel to keep the wet soil from sticking to their shovels. They have also spread sawdust on the trench lip to keep the sticky mud from attaching to their boots. In all of the trenches you have encountered previously in training, drills, and incidents, you have not seen soil like this.

After about an hour's work, you are completing your "deep trench" shoring system when you notice that the trench floor seems to be rising up between the shored panels. When the first rescuer into the trench steps off the ladder onto the trench floor, he sinks almost to his knees. Before a shovel can be lowered to him, he sinks farther. This soil is acting like quicksand. A ground pad is lowered into the trench so that the next rescuer can have something to kneel on while he digs out his fellow rescuer. While climbing onto the pad, the second rescuer places his hand on one of the pneumatic struts (shot at 250 psi) and notices that it is loose and about to fall out. Other struts below the 8-foot (2.4-m) level also appear to be loose.

The chief of operations wants to get both rescuers out of this trench as soon as possible. The trapped construction worker has been completely buried in this mud for more than an hour now, and the incident commander has moved to a recovery mode. He is asking you for advice on how to reduce risks during the body recovery operation.

1. Is this soil beyond the capability of traditional trench rescue shoring?
2. Which alternative commercial methods could be used?
3. How will the transition from the rescue shoring that is in place to the commercial techniques take place?

Trench Rescue Level I

Protective Systems Used for Trench Rescue

In this chapter, you will learn about the fundamentals and installation practices used for trench rescue shoring. You will discover the differences between rescue shoring and construction shoring and learn to recognize the components of a default trench rescue shoring system. You will also learn about commercial trench protection techniques and their application to trench rescue and recovery operations.

The protective systems used at the majority of trench rescue incidents across the United States consist of panels, struts, wales, and support equipment. The method used to install that equipment at a collapsed trench with victims trapped is called trench rescue shoring. The basic set of rescue shoring equipment can be applied in many different ways; mastering its use and understanding its limitations are paramount to your success as a trench rescuer.

Trench rescue shoring is similar to underground construction shoring, but has some key differences. Rescue technicians need to know when the incident scene requirements have exceeded their ability to manage the situation safely. To achieve this goal, they need a comprehensive understanding of not only their own techniques and equipment, but also the techniques and equipment that contractors use in less serious but equally dangerous situations (commercial methods). The elements of those alternative methods include commercial trench protection techniques, isolation devices, and engineered designs.

Fundamentals of Trench Rescue Shoring

The sheeting and shoring techniques used by rescuers evolved over time from the underground construction industry. While these two shoring disciplines share some similarities, several significant differences exist as well. In the only study ever published on the subject of trench rescue shoring, author Dr. Marie LaBaw concluded that “Underground construction shoring and trench rescue shoring are significantly different. Many of the theories and field observations that have been done for construction shoring may not be applicable to trench rescue shoring.” (LaBaw 2009)

Dr. LaBaw’s study discusses several differences between construction shoring and rescue shoring. Level II Trench Rescue Technicians are encouraged to read that study because successful trench rescue shoring requires knowledge of those differences as well as understanding of the proper use and application of trench rescue shoring fundamentals.

Rescue Shoring Is Not Construction Shoring

Shoring in the underground construction world (large construction projects and utility installation and repair) differs from shoring of a trench for rescue in several ways:

- Rescue shoring must focus on the needs of a trapped victim. It must begin with techniques that will provide the victim with immediate protection from additional collapse. That immediate need, coupled with the active soil that has collapsed and created voids in the wall(s), often requires a departure from traditional construction shoring methods and Occupational Safety and Health Administration (OSHA)–mandated practices such as, but not limited to, always shoring from the top down. (See Appendix E for OSHA 1926, Subpart P, Excavations.)

- Sheeting/shoring used for construction purposes is designed to be installed before the soil becomes active. That is accomplished by installing the shoring during, soon after, or in some cases even before the excavation takes place. In those cases, the OSHA shoring charts, manufacturer's tabulated data, and construction shoring techniques are valuable guidelines. Rescuers, in contrast, are often confronted with soil conditions that have already become active and have usually collapsed. As a result, OSHA shoring charts, strut manufacturers' tabulated data, and construction techniques may not be the best practices for rescue shoring. In reality, OSHA shoring charts and "tab data" are often talked about but seldom used at rescue incidents.

A vast variety of methods, techniques, and equipment are used for underground construction shoring, whereas the methods, techniques, and equipment used for rescue shoring are fairly limited. While it is common to see sloping, benching, sheeting, soldier piling/lagging, and trench boxes used by construction workers, these techniques require a large assortment of material and heavy equipment for installation. Rescuers, by comparison, are constrained to a small assortment of shoring equipment that must be manually installed.

Trench rescue shoring is a unique discipline; however, the methods, techniques, and equipment are subject to limitations. Rescue technicians must understand both the application and the limitations of trench rescue shoring. More importantly, they must know when and how to transition into commercial shoring methods used by the underground construction industry.

Trench Rescue Shoring

Trench rescue shoring is defined in this text as the use and application of shoring techniques designed to resolve the majority of trench cave-in situations. It is limited to type A, type B, and some type C soil conditions in trenches up to 20 feet (6 m) deep.

For this reason, successful trench rescue teams develop a default rescue shoring method, which they use as their go-to method. The benefits of having a default rescue shoring method are that it is well practiced and that placement of equipment should enable rapid deployment of primary and secondary shoring techniques. In this regard, a default rescue shoring method is similar to a preconnected handline used for firefighting. Although it will not solve the problem in every situation, if you are good at it, that approach will suffice for most of the trench rescue incidents you will encounter. When establishing your default method, make sure it meets the following criteria:

- Can be accomplished with the shoring equipment carried on your trench rescue unit
- Is built upon best practices with adequate strength to resist the forces of C-60 soil
- Can be rapidly deployed to protect the victim from additional collapse
- Can be implemented in phases—first to protect the victim, and second to create a safe zone for rescuers to work

Most default trench rescue shoring systems include lip protection, panels, struts, and wales.

Lip Protection

In the "Equipment" chapter, we discuss the use of ground pads to distribute rescuer and equipment weight around the trench lip and the use of lip bridges to distribute the weight even farther away from the lip. At this point, we need to discuss the proper installation of the lip protection.

At each trench, you will need to decide which kind of lip protection is best suited for the situation. For example, at a trench with stable walls, you might decide to use 2 × 12-inch boards on the spoil pile side of the trench and a 4 × 8-foot piece of ¾-inch plywood on the other side (ground pads). Conversely, if a trench wall has collapsed or looks unstable, you might decide to use lip bridges instead of ground pads **FIGURE 10-1**. To install ground pads, follow the steps in **SKILL DRILL 10-1**:

1. Regardless of the type of lip protection used, approach the trench first from the corner **STEP 1**. The corner has the greatest stability.

FIGURE 10-1 This four-sided lip bridge was needed to install shoring over a repair hole where three walls collapsed on a city worker.
Courtesy of Ron Zawlocki

2. To clear an area for the lip protection, start by placing a ground pad on the ground at the corner; then while standing on the ground pad, level the ground in front of you **STEP 2**.
3. After the ground is level, step back and move the lip protection forward **STEP 3**.
4. Repeat this process until all of the lip protection is in the proper position **STEP 4**. In no case should you be in front of or off the lip protection while you are preparing the area next to the trench lip.

A lip bridge is built with girders (timbers), beams (ladders or timbers), decking (plywood or lumber), and supports (sections of timbers placed away from the compromised wall and used to elevate the bridge above the lip) **FIGURE 10-2**. To install lip bridges, follow the steps in **SKILL DRILL 10-2**:

1. Place ground pads starting from the trench corner to create a safe area for installing the lip bridges.
2. Place two bridge supports (6-inch × 6-inch × 4-foot) on each side of trench **STEP 1**.
3. Use a 6 × 6-inch timber to span across the trench from support to support **STEP 2**. The victim position in the trench should be in the middle of the two girders. The girders should be at least 12 feet (3.7 m) apart whenever possible.
4. Place beams with decking on the girders, and slide the decking to the edge of the trench **STEP 3**. Lip bridges are helpful over large wall shears **STEP 4**.

SKILL DRILL 10-1

Installing Ground Pads

(Trench Rescue Level I: 8.1.2, 8.1.4)

1 For size-up and ground pad installation, always approach the trench from the corners.

2 Place the ground pad at the corner and clear the ground in front.

3 Step back off the ground pad, and move it to the area just cleared.

4 Place additional ground pads into position.
© Jones and Bartlett Publishers. Courtesy of MIEMSS

FIGURE 10-2 Fire service ladders with 2 × 12-inch lumber can be used as lip bridge beams and decking.
Courtesy of Ron Zawlocki

Tactical Tip

The beams/decking can be pre-built or can be fire service ladders (beams) with 2-inch × 12-inch × 12-foot lumber (decking) placed on the rungs. Using 2 × 12-inch lumber alone (without beams) allows too much sag when rescuers with equipment (panels/wales) work in the center of the decking.

SKILL DRILL 10-2

Installing Lip Bridges

(Trench Rescue Level I: 8.1.2, 8.1.4)

1 Place ground pads starting from the trench corner and place two lip bridge supports (6 × 6 inches) on the pads.
Courtesy of Ron Zawlocki

2 Place girders across the trench on the supports.
Courtesy of Ron Zawlocki

3 Place decking on the girders and slide the decking to the edge of the trench.
Courtesy of Ron Zawlocki

4 Lip bridge over a large wall shear.
Courtesy of Ron Zawlocki

Panels

Of all of the equipment in a trench rescue cache that can be used to make a trench safe, panels (sheeting) along with struts (shores) are used the most often. Panels help to both collect the loads and distribute them. They are very effective when unstable soil and collapsed wall conditions are encountered.

The recommended panels at rescue incidents are ¾-inch or 1-inch thick, 4 × 8-foot sheets of Shorform or FinnForm, with a 2 × 12-inch strongback already attached. Having the strongback attached to the panel is not necessary; however, it is highly recommended because it enhances both panel strength and the speed of shoring installation. In fact, it is recommended that strongbacks be permanently connected (screwed, not bolted) to the panels, as this structure offers a greater system strength and, therefore, greater system safety.

Tactical Tip

Trench rescuers must recognize that a trench training class produces much straighter and more vertical walls than will be found at a real-world trench rescue incident. For example, at real-world events, panels and shores often do not line up. Panels may need to be cut, shaped, and overlapped to make the equipment work. At that point, you should not worry about making the shores pretty. Concentrate instead on covering the unstable walls with panels and preventing additional collapse with shoring.

A strongback of adequate size for the soil conditions is the vertical shoring component required by OSHA whenever you are shoring with strut methods. Approved exceptions to the commonly used timber strongback include rails and specially designed bases with manufacturer's tabulated data. When engineered aluminum rails or specially designed bases are used, struts can be installed directly on the panels without timber strongbacks (**FIGURE 10-3** and **FIGURE 10-4**).

There has been much discussion among rescuers about the need for panels. The construction industry does not consider the panel itself to be part of the protective system. Recent tests, however, have shown that in rescue shoring conditions, the panel (¾-inch arctic birch laminated plywood) is actually stronger than the strongback. The controversy related to panel use traces back to construction shoring. For construction shoring in some classes of soil, it is acceptable to use only the strongback and struts (no panel). For instance, in many parts of the United States, excavations are performed in a class of soil that enables the walls to stand in a mostly vertical manner unless disrupted by some external force. In such a case, it would be acceptable to use just the strongbacks **FIGURE 10-5**. That shoring option is valid for the construction industry and could be considered for use at a trench rescue where the soil has not collapsed and has been deemed to be stable (type A or type B) by a competent person. However, tabulated data from strut manufacturers always require the use of panels (minimum ¾-inch FinnForm) when the soil shows signs of becoming active (e.g., sloughing, raveling, cracking). When a collapse has occurred, the soil has already proven to be unstable and should be considered active. In that case, the use of panels to collect and distribute soil and its forces is not just a best practice—it is a necessity.

FIGURE 10-3 The Speed Shore has the strongback portion of the protective system already installed as part of the shore. This type of skip shoring is not recommended when soil has collapsed or is active.
Courtesy of Speed Shore Corporation

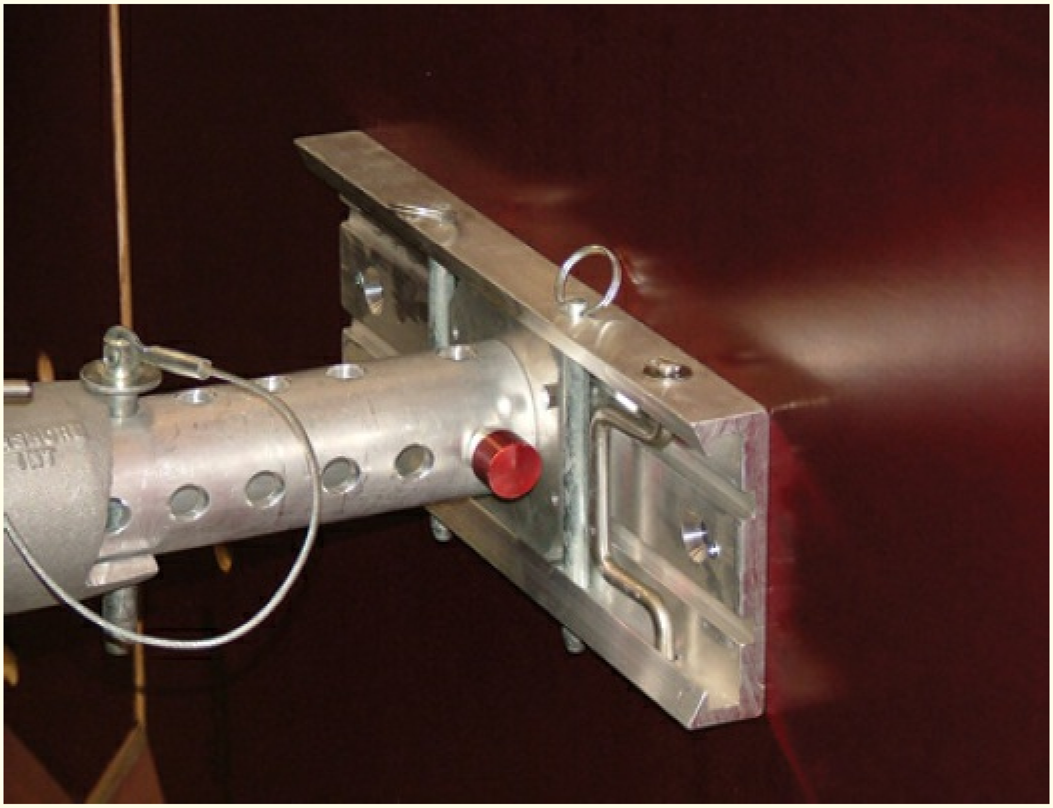

FIGURE 10-4 Some pneumatic struts now have spot shore rail bases that can be used on panels without strongbacks.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Some rescuers may want to classify soil as type B or even type A soil under the assumption that a less hazardous soil would reduce the amount of shoring required to make the trench safe. In theory, less shoring should mean less time required to install the protective system. In reality, trench teams that have a default shoring system set up for rapid deployment (i.e., a default for worst-case soil conditions) can usually shore a trench more quickly than teams that conduct proper visual and manual soil tests and then change their shoring procedures. In all cases, keep in mind that the testing procedures needed to classify soil (visual and manual tests) take time to perform and require substantial practice to complete with any reasonable degree of accuracy.

FIGURE 10-5 In hard-packed soils, the strongback can be used without the panel. This type of skip shoring is not recommended when soil has collapsed or is active.

Safety Tip

If you arrive at a trench accident (not a cave-in) where the soil appears to be stable and you choose not to install panels, you will need a competent person (per OSHA) to conduct a visual and manual test on the soil to determine its classification. Few rescuers are actually experienced and trained enough to be considered competent persons.

Most trench rescue teams rely on default shoring methods that include the use of 4-foot (1.2-m) wide panels with strongbacks positioned in the center. Placing panels right next to each other and installing struts on the strongbacks provides horizontal spacing at 4 feet (1.2 m) on center.

Horizontal and vertical spacing of 4 feet (1.2 m) or less will safely shore the majority of soil conditions found at trench emergency incidents. Application of this method need not wait for the soil to be tested (analyzed). It also does not complicate the issue by asking a rescuer, who may be unfamiliar with soil testing, to make a critical decision based on his or her analysis. Testing and decision making done by people who are not experienced and are not very familiar with the process will slow down the shoring process. Rescuers are encouraged to check with their engineer and/or strut manufacturer to validate the use of this method for unstable (cave-in) soil conditions.

Additionally, depending on where you live, it may be difficult to find a class of soil in which the panels are not necessary. For instance, in Virginia Beach, Virginia, you cannot dig a hole anywhere that will not be either moisture saturated or sand based; therefore, the Virginia Beach Fire Department teaches and utilizes panels with the strongbacks attached as its shoring method of choice.

Although most tabulated data state that panels should not be given any structural value, recent tests conducted by the MUSAR Training Foundation provided the following results:

- The ¾-inch FinnForm is more ductile than 2 × 12-inch strongbacks (both treated and untreated white pine were tested). This provides more warning before panels fail.
- The ¾-inch FinnForm is significantly stronger than 2 × 12-inch strongbacks (both treated and untreated white pine).
- When glued and screwed together, ¾-inch FinnForm and 2 × 12-inch strongbacks are significantly stronger than FinnForm and strongbacks that are bolted together. Screwing and gluing help the two components react to force together instead of separately (see the "Equipment" chapter).

The bottom line is that panels should be used whenever possible to shore collapsed walls, because shoring that includes panels provides strength and redundancy to the system. The effects of strut pressure on soil pressure (stability) using ¾-inch FinnForm panels with strongbacks greatly improves the distribution of forces. In turn, strut pressures that are well distributed are less likely to cause collapse and are more likely to stabilize soil walls.

Setting panels in a trench is accomplished using several different methods (explained later in this chapter). The method used depends on the condition of the trench and the location of the victim.

■ Skip Shoring and Spot Shoring

There is a time and place in rescue shoring for skip shoring and spot shoring. Skip shoring is shoring done with strongbacks only (no panels). Spot shoring is shoring that does not use either traditional strongbacks or panels, but instead uses specially designed rail bases installed directly on the trench walls. The time to use these methods is when you first arrive and identify a section of trench wall that is in danger of imminent collapse. Although these techniques lack many of the benefits of panels and strongbacks, their use may save valuable time, especially when staffing is limited. In active soil conditions, data (test results) are lacking that would show how soil properties such as cohesive strength are correlated with the ability of the soils to stand in the interval between the spaced supports without collapsing or spalling. Construction-based theories ("arching" and "strut pressurization zone") that are predicated on the presence of passive soil with mostly intact trench wall conditions are questionable, at best, in unstable soil with voids. Given the uncertainties, it is recommended that spot shores and skip shores, when placed to prevent trench collapse, be enhanced by creating safe zones built with panels, strongbacks, and struts.

■ Panel Installation

When setting panels, you will have the option of doing a "same side" set or an "opposite side" set. A "same side" panel set is accomplished by lowering a panel into the trench from the same side where it will be positioned. An "opposite side" panel set involves positioning a panel on the wall that is across (opposite) from the side used to lower it.

To perform a same-side panel installation, follow the steps in **SKILL DRILL 10-3**:

1. Tie the ropes on the panel and move the panel into place on the lip protection.
2. Hold the ropes **STEP 1** while the top of the panel is pushed out and over the trench **STEP 2**.
3. Use the ropes to slowly lower the panel, keeping it tight to the wall **STEP 3**.
4. If adjustments of the panel are necessary after setting, just pull up the ropes and move the panel.
5. Repeat this procedure to install a panel directly across the trench. As a rule, same-side sets are the easiest and fastest but require more room to maneuver your panel team. This ultimately could involve the moving of a substantial amount of the spoil pile.

Safety Tip

As a rule, strive to create a minimum safe area of 12 linear feet (3.7 m) in the trench.

When it is not possible to set the panel from the same side of the trench, you can use the opposite-side technique to set the panels using two 4 × 4-inch runners. To perform an opposite-side panel installation, follow the steps in **SKILL DRILL 10-4**:

1. Place two 4 × 4-inch rails in the trench so the bottoms of the rails create a target for the strongback on the panel **STEP 1**. Note: For easy panel installation, use a chainsaw to cut off the rail just above the lip protection.
2. Turn over the panel, place it on the rail, and then lower it into place using ropes **STEP 2**.
3. The panel can then be pushed or pulled to the opposite side using ropes or a pike pole **STEP 3**.

Tactical Tip

The opposite-side panel set is also a good technique when a victim is present in the trench and additional care must be taken with panel placement.

When placing panels for a rescue, the first two panels are set on each side of the victim, and then two more are set on each side. This creates a working area for the rescue team if immediate digging or victim care is needed. Not all panels necessarily need to be set before beginning victim care. Every situation is different—that is what makes the trench rescuer's job so challenging. When a live victim is in need of immediate life-saving measures, rescuers often enter the trench before shoring is completed. In such a scenario, care may start with one set of panels and some combination of shores that you deem a safe environment, based on all of the conditions present, in place. Your risk–benefit analysis should enable you to make this call. In most cases, you should try to complete the first two panels and shores on each side of the victim. Always follow your agency's policies and procedures on entering trenches.

For nonintersecting trenches up to 8 feet (2.4 m) deep, the recommended number of panels is six. Of course, this setup is not possible if the trench is less than 12 feet (3.7 m) long. In the latter case, after installing the primary shores, be sure to have panels set at both ends of the trench that will facilitate the installation of struts that are within 2 feet (0.6 m) of the end wall. This may require panels to overlap or to be cut to fit. If the end walls are not sloped or benched, shoring will have to be added to support the end walls.

Safety Tip

Secondary collapse is a very real possibility, especially after dirt removal. Make sure that the victim is protected from harm from such an event by setting panels and shores over the victim first.

SKILL DRILL 10-3 Same-Side Panel Installation

(Trench Rescue Level I: 8.1.2, 8.1.4)

1 Place ropes on the panel and prepare it for installation.

2 Place the panel on the trench lip protection and push out on the top while lowering the panel with ropes.

3 When the panel is vertical against the trench wall, continue to lower the ropes so that the panel is set tightly against the trench wall in the desired location. Repeat this procedure from the lip protection on the wall across the trench.

SKILL DRILL 10-4

Opposite-Side Panel Installation

(Trench Rescue Level I: 8.1.2, 8.1.4)

1 Place two 4 × 4-inch rails in the trench so the bottoms of the rails create a target for the strongback on the panel.

2 Turn over the panel, place it on the rail, and then lower it into place using ropes.

3 The panel can then be pushed or pulled to the opposite side using ropes or a pike pole.

Struts

Trench rescue shoring includes the use of struts. Struts are the horizontal braces that extend across the trench and transfer the forces from one trench wall, through the strongback/panels, and into the opposite wall. Struts are also known as shores or cross-braces. The terms *struts, cross-braces*, and *shores* are used interchangeably throughout this text.

Pneumatic, hydraulic, timber, and screw jacks are common types of struts used by trench rescue teams. Each has advantages and disadvantages. The use of each of those types of struts is discussed in this chapter, but step-by-step instructions are provided for only pneumatic and timber struts. Rescuers using hydraulic and screw jack–style struts for rescue operations are encouraged to review the installation protocols established by these devices' manufacturers and by their rescue team's authority having jurisdiction.

Strut activation forces create pressure on the soil behind the strut and panels. When properly used (controlled, measured, and distributed), strut activation forces can help stabilize the soil. Additionally, correct strut pressure can actually increase the strength and performance of the strongbacks, panels, and wales.

A best practice for trench rescue shoring is to use struts that meet the following criteria:

- Can be installed with controllable and measurable strut pressure
- Can be installed and removed without entering the trench
- Have full strength with activation forces of between 1000 and 1500 pounds (453.6 and 680.4 kg) of force

The group of rescuers who install struts is called the shoring team. The recommended minimum number of personnel on a shoring team is four. The duties of those members differ slightly based on the type and style of strut being used and will be addressed in the skill drills found in this chapter.

Tactical Tip

Strut strength, regardless of the type, reflects the strut's length-to-diameter ratio. All other things being equal, as the length of a strut increases, its strength decreases.

Pneumatic Struts

Pneumatic struts use air pressure to extend the piston inside the cylinders to create pressure against the strongbacks, panels, and wales positioned on the trench walls. With pneumatic struts, once the desired air pressure is achieved, the struts must be mechanically locked. Depending on the strut being used, the mechanical lock can be accomplished by (1) twisting a collar that rotates on the cylinder and inserting pins through the piston into holes, (2) spinning a collar that moves on the piston, or (3) utilizing a built-in automatic (one directional) locking mechanism. Automatic locking struts do not require a rescuer to enter the trench to lock the collar. Collars that spin can be locked from outside the trench with a strut-locking tool but are sometimes locked by a rescuer inside the trench. Collars that are twisted and pinned require a rescuer to enter the trench to lock them.

Each of these pneumatic strut styles has advantages and disadvantages. In any case, whenever a rescuer is in a trench that has not been completely shored, he or she is exposed to potential collapse. The strut installation procedures that you use must minimize that exposure time.

Pneumatic Strut Pressure

Pneumatic systems allow you to measure (gauge) and control (vary) strut pressure. When using such struts, the pressures can be varied to accomplish different tasks. For example, when a collapse has created a void in the trench wall, a panel set can be held in place with a strut shot at 75–100 psi (5.3–7 kg/cm). If the strut were shot at 200–250 psi (14.1–17.6 kg/cm) on a panel that is directly over a void, it would bend the panel/strongback. By temporarily using reduced strut pressure, the panel can be held in place while backfill is installed or completed behind the panel. After the backfill is complete, the struts can be increased to the manufacturer's recommended pressure. Knowing how to adjust the air pressure, based on the situation presented, is an important part of strut installation.

Safety Tip

Reduced strut pressure should be only temporary. Ultimately, every strut in your shoring system needs to be brought up to the pressure recommendations found in the manufacturer's tabulated data. If the pneumatic pressure of a strut causes a shoring system to slide, bend, or move (after backfill is in place), that system is inherently weak and would have no chance of resisting the forces of an active trench wall.

Throughout this text, you have encountered the terms *strut pressure* and *activation force*, which are related but different measurements. *Strut pressure* refers to the amount of air pressure that the air system is sending to the strut. It is measured in pounds per square inch (psi) (or kilograms per centimeter [kg/cm]) and can be seen on the air system's gauge.

By comparison, the activation force is a measurement of the total force that the strut exerts. The total force is the pressure (psi or kg/cm) multiplied by the number of square inches of the strut's surface area. A typical 2.5-inch diameter strut has a surface area of about 5 square inches. If the air pressure used to shoot the strut is 200 psi (14.1 kg/cm), you would simply multiply the pressure by the surface area (in this case, 200 × 5 = 1000) to calculate the activation force. That is, the total force exerted by the strut is 1000 pounds (of force).

Strut testing, as conducted by MUSAR, indicated that a strut activation force of between 1000 and 1500 pounds of force enhances soil distribution pressure behind the panels, strongback and wale strength, and overall system performance. The primary purpose of struts, however, is to transfer energy, not create it. While some energy is created from the activation pressures of struts, the amount of pressure should be regulated and distributed (not concentrated) on the trench walls. Excessive strut pressure creates unwanted energy and can result in dangerous soil pressure behind the shoring system.

Tactical Tip

Tightening the collars on pneumatic struts can create additional forces. The collars are tightened using a built-in mechanical advantage (inclined plane). When a lever like a hammer or a specially designed tool is used to twist the collar, two mechanical advantages are applied. Using two mechanical advantages can allow a rescuer to exert a force that greatly exceeds the recommended activation forces for strut use at trench rescue incidents. Excessive strut pressure, in turn, can cause unstable soil to collapse. Another reason not to overpressure the struts when installing them is that when the incident is over, you will have to pressurize them to an equal or greater pressure to unlock and remove them from the trench.

Pneumatic Strut Placement

The placement and sequence of strut installation is very important to ensure safe and efficient rescue shoring. The proper strut placement and installation sequence at a rescue incident depends on several factors, including how deep the trench is, what is likely to collapse next, and whether a rescuer has to enter the trench to lock the collar manually.

A common practice for primary shoring (discussed in the "Trench Rescue Shoring Techniques" chapter), where the goal is to rapidly protect the area directly above the victim, is to install three struts in the first panel set. When three struts will be installed on a panel set, it is often practical to install the middle shore first due to the strength of the shore and the compressive forces that it is transferring from wall to wall **FIGURE 10-6**. A strut shot at the middle of a properly constructed rescue panel will provide stability at the site of the strut and marginal protection toward both the top and the bottom of the wall. If the victim's condition warrants a rapid rescue effort, a single shore may provide enough protection to save a life. If you elect to follow this path, you need to be confident that no potential for the soil to become active remains. If the soil has already collapsed, the risk of the soil becoming active again increases dramatically. The kinetic energy in active soil can snap panels and strongbacks, causing a collapse even with one shore in place. When a rescuer enters the trench to initiate a high-risk operation, the rescue team must focus on immediately reducing those risks—including through the rapid deployment of additional shoring equipment.

Safety Tip

When using struts that require a person to enter the trench to install them, the only person who should call for the shore to be shot is the installer. This will help keep him or her from getting hurt if the shore is accidentally activated.

FIGURE 10-6 Middle shore installed on the first set of panels.

In most situations, after installing the (first) middle shore, you will likely move your efforts to installing the bottom shore **FIGURE 10-7**. On a trench wall that has not collapsed, the bottom section is predictably the next most dangerous and unstable area. Following the same procedure as with the middle shore, the rescuer climbs down a ladder beside the panel and installs the shore. Care should always be taken not to allow the rescuer to get farther into the trench than waist high to an installed shore. As an example, the person shooting the bottom shore would be allowed to enter the trench between the panels until his or her waist is even with the previously installed middle shore. It is easy then to lean over and secure the shore according to the manufacturer's recommendations. When using shores that cannot be shot and locked remotely, the rescuer should never enter an area of the trench that is not protected with a locked strut.

FIGURE 10-7 The bottom shore being installed.

The top shore would follow, with care being taken not to shoot it too close to the trench lip **FIGURE 10-8**. The proper depth is 18 to 24 inches [46 to 61 cm] below the lip.

After the first set of panels and struts is in place, rescue personnel can begin a continuous rescue effort by working from within the safe area created by the first set of panels and struts. Rescuers inside the protected area can provide patient care and help with installing struts positioned on outside panels. If three shores will be used for each panel set, the sequence of installation should remain middle, bottom, and top.

Strut Placement Options

The initial goal of trench rescue shoring should be to protect the victim(s) from subsequent collapse. Pneumatic struts that can be installed and locked from outside the trench (automatic locking and spinning collars) allow rescuers to place struts where they are needed so as to prevent collapse, while also minimizing the risks to rescuers. (Strategies and tactics for the shoring option of placing struts where they are needed to stop collapse can be found in the "Trench Rescue Shoring Techniques" chapter.)

FIGURE 10-8 The top shore completes the installation of the first set of panels.

A significant disadvantage of struts that require entry for installation is that rescuers entering a trench during the shoring installation process are exposed if a secondary collapse occurs. Because the installer must climb down a ladder to put the struts in place, these types of struts are better suited to a top-to-bottom installation procedure. Shoring from the top down provides the installer with some protection as he or she descends deeper into the trench. However, when the first strut is needed near the bottom of the trench (to protect the victim from impending collapse), rescuers using struts that require entry to install would need to climb into the trench, passing through areas unprotected with shores.

When the walls around the victim are still intact (not yet collapsed), the middle, bottom, and top shoring sequence is a logical way to protect the victim. Experience tells us that if we can get a middle strut shot on a panel with a strongback, it will likely prevent further collapse. This is one of those risk–benefit situations where rescuers must weigh the risk of a further collapse against the likelihood of saving someone's life.

That said, when a portion of the wall has collapsed, the sequence and placement of struts may change and should be dictated by the section of wall that is most likely to fall on the victim. In that case, the initial strut(s) must be placed in a position that will address the next most likely site of a cave-in.

For example, **FIGURE 10-9A** shows a 9-foot (2.7-m) deep trench in which the bottom portion of a wall has sloughed in, leaving a void 4 feet (1.2 m) wide, 5 feet (1.5 m) high, and 3 feet (0.9 m) deep. More than a cubic yard (1 m^3) of unsupported wall (overhang) sits 6 feet (1.8 m) above the victim's head. Your assessment tells you that the next most likely section to collapse is the unsupported overhang. The second most likely section to collapse is a slough-in at the bottom of the opposing wall. Your goal is to protect the victim(s) from subsequent collapse by (1) preventing the overhang from dropping and (2) preventing the bottom section of the opposite side wall from sloughing. Your primary shoring plan would be the following:

1. Lower and suspend (tie back) a 4-foot (1.2-m) diameter low-pressure air bag into the void at the bottom.
2. Place a panel on each wall to protect the victim from the next most likely cave-ins.
3. Lower the first strut (with ropes) and position it 2 feet (0.6 m) below the lip **FIGURE 10-9B**. Shoot it at 100 psi (7 kg/cm), or just enough pressure to keep safely in place, to pin the overhang and keep it from moving. Lock the collar and release the air pressure.
4. Lower the second strut (with ropes) and position it 2 feet (0.6 m) above the floor **FIGURE 10-9C** (this will be near the center of the air bag). Shoot it at 75–100 psi (5.3–7 kg/cm). Lock the collar and release the air pressure.
5. Inflate the air bag to 4–5 psi (0.3–0.4 kg/cm) to equalize the soil pressure at that depth.
6. Increase both strut pressures to 200–250 psi (14.1–17.6 kg/cm). Lock the collars and release the air pressure.
7. Lower the third strut (with ropes) and position it in between the top and bottom struts **FIGURE 10-9D**. Shoot it at 200–250 psi (14.1–17.6 kg/cm). Lock the collar and release the air pressure.
8. Nail the struts to the strongback and install secondary shoring.

In the case of a collapse leaving an unsupported overhanging wall, the sequence for shoring with pneumatic struts is top, bottom, middle.

Following the OSHA requirement (shore from the top down) or a standard operating guideline (middle, bottom, top), however, may not always be in the best interest of the victim trapped in the trench. Lives have been saved at trench rescue incidents by installing shoring in a sequence designed to stop the wall(s) from collapsing. That concept should be the cornerstone of rescue shoring operations.

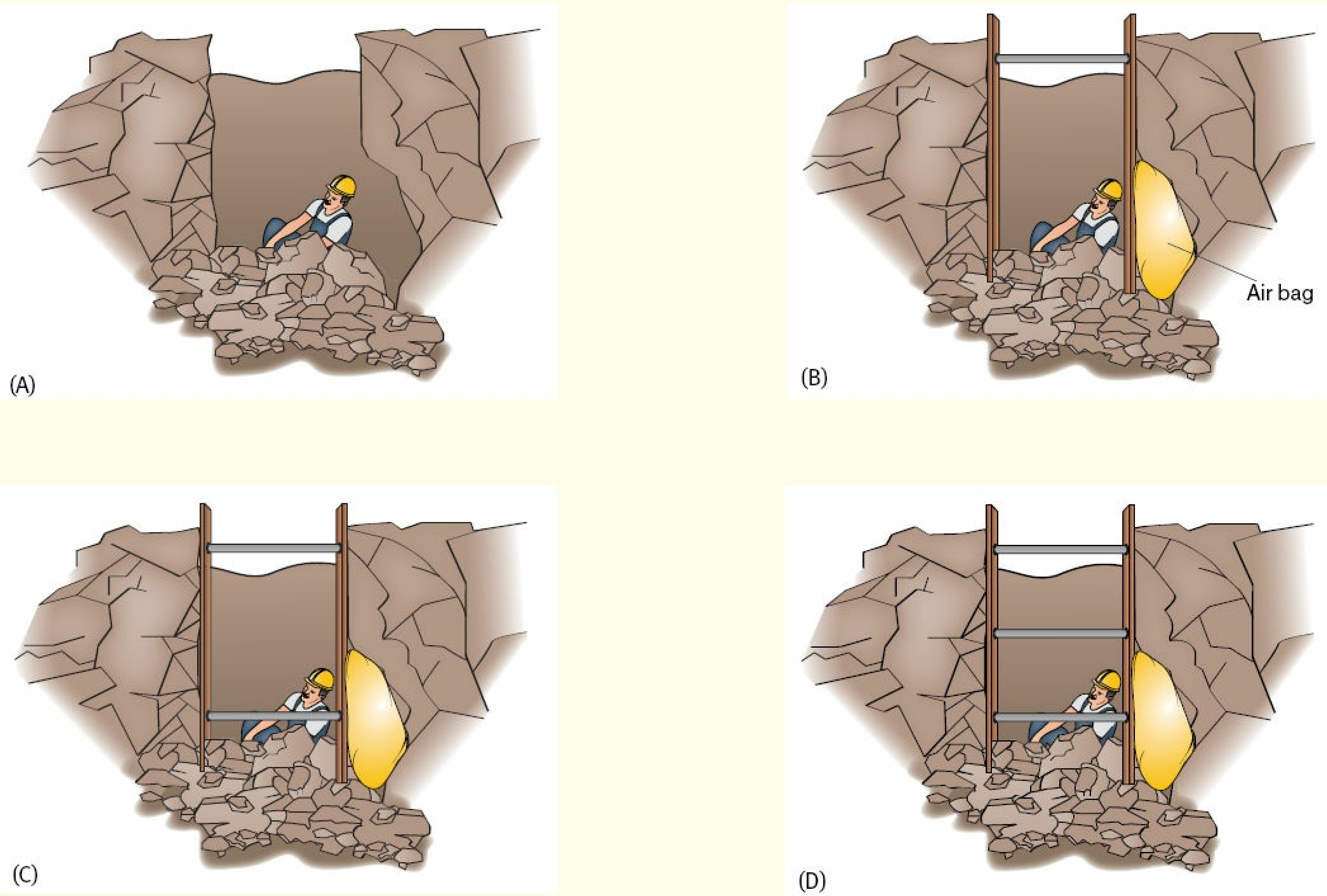

FIGURE 10-9 **A.** Position of a victim in a cave-in. **B.** Position of the first strut. **C.** Position of the second strut. **D.** Position of the third strut.

Tactical Tip

Rescue organizations are advised to get written approval from strut manufacturers for installation practices (spacing and sequence) not specified in the tabulated data.

Pneumatic Strut Spacing

The need for tight sheeting at cave-in incidents and the design of rescue panels provide an apparent answer to most strut spacing questions. The 4-foot (1.2-m) rule—no space greater than 4 feet (1.2 m) between any horizontal or vertical shoring point—is a great rule of thumb and the cornerstone of most trench rescue protective systems. If the top strut can be installed 18 to 24 inches (0.5 to 0.6 m) from the trench lip, with the bottom strut installed within 24 inches (0.6 m) of the trench floor, and the resulting distance between the top and bottom shore is not more than 4 feet (1.2 m), then only two shores would be necessary. If the distance exceeds 4 feet (1.2 m), simply install another strut midway between the struts already in place.

Tip

As a rule, the best rescue systems are those in which the maximum distance between both horizontal and vertical shores never exceeds 4 feet (1.2 m).

By placing the panels right next to each other and shoring to the strongbacks, you automatically maintain the 4-foot (1.2-m) horizontal spacing. While the "4-foot rule" is a good rule of thumb, it is not considered in the tabulated data developed for most strut manufacturers. You should request a written approval from the manufacturer of the struts you use before applying the 4-foot rule at rescue operations.

To install pneumatic shores from outside the trench, follow the steps in **SKILL DRILL 10-5**:

1. The officer takes a position at the end of the trench. The controller (shooter) works on lip protection near the primary panel set. Two strut handlers work on lip protection from both sides of the trench.
2. The controller connects the air hose to the strut and adjusts the regulator to the desired pressure **STEP 1**.
3. Each strut handler attaches a rope to the strut. The strut handlers position themselves across the trench from each other at the primary panel set and use the ropes to lower the strut to the proper position **STEP 2**.
4. The officer acts as a spotter at the end of the trench to determine whether the shore is level and in the correct location (depth). The handlers determine when the strut is aligned across the trench. The officer asks the handlers if they have aligned the strut: "Handlers ready?"
5. After telling the controller the desired pressure of the strut, the officer gives the command, "Shoot and hold" **STEP 3**.
6. After the strut has been shot and is in proper position, the strut collars are locked. If not using automatic locking struts (Paratech LockStroke), the strut handler on the collar side of the trench locks the collar with the collar locking tool. When the collar has been locked, the strut handler tells the officer, "Strut locked." With the collar locked, the strut is at its strongest point. Air pressure is no longer needed and the officer tells the controller "Down on air" **STEP 4**.
7. The process is repeated to install all needed struts on the primary panel set. Using struts with collars that can be locked without entering the trench can allow an entire rescue shoring system to be installed without exposing rescuers to collapse **STEP 5**.
8. A rescuer, equipped with a hammer and nails, enters the trench on a ladder placed within the shored panel area and nails all strut bases to the strongbacks **STEP 6**.

9 Strut bases are nailed to the strongbacks (from top to bottom) by a rescuer climbing down a ladder. Using the same procedures, additional shoring (panels and struts) can be added to expand the safe area in the trench.

Organizations that use struts that can be locked from outside the trench should use a shoring team consisting of a minimum of four members. Those positions and job descriptions are as follows:

- Officer: Develops the shoring plan; assigns team positions; determines strut length, placement, sequence, and pressures; and manages and supervises the shoring team operations
- Controller (shooter): Sets up the air system, "shoots" the struts at the pressure designated by the officer, and releases the strut pressure as ordered
- Two strut handlers: Assemble the struts and ropes, carry the struts to the trench wall, position the struts for shooting, and lock the collar from outside the trench

To install pneumatic shores with rescuer entry, follow the steps in **SKILL DRILL 10-6**:

1 Connect the air system to the strut and set the regulator to the desired air pressure **STEP 1**.
2 The installer and strut handler work on lip protection on opposite sides of the trench behind the primary panels. They lower the shore into place using ropes attached to either end **STEP 2**.
3 When the strut is lined up in the proper place (usually determined best by a spotter at the end of the trench) **STEP 3**, the installer gives the signal to "shoot and hold" the shore **STEP 4**.
4 The shooter activates the air at the pressure recommended by the manufacturer. This extends the strut and creates pressure on the trench wall.
5 An installer enters the trench on a ladder and manually locks the strut. With the collar locked, the strut is at its strongest point. After the shores are locked in place, they continue to create a zone of pressure on the trench wall **STEP 5**.

SKILL DRILL 10-5

Installing Pneumatic Struts Without Entering the Trench

(Trench Rescue Level I: 8.1.2, 8.1.4)

1 Connect the air hose to the shore and adjust the regulator to the desired pressure.

2 Using ropes, lower the strut into position.

3 From the end of the trench, the officer determines the correct position and alignment of the strut and tells the controller to "Shoot and hold."

4 The strut handler spins the collar from the trench lip (protection) using a collar-locking tool and tells the officer "Collar locked." The controller releases the air pressure and says, "Down on air."

5 Using struts with collars that can be locked from outside the trench allows an entire rescue shoring system to be installed without exposing rescuers to collapse.

6 After all struts are installed in the panel set, a rescuer enters the trench and nails all strut bases to the strongbacks.

SKILL DRILL 10-6 Installing Pneumatic Shores with Entry Operations

(Trench Rescue Level I: 8.1.2, 8.1.4)

1 Connect the air hose to the shore and adjust the regulator to the desired pressure.

2 Lower the strut into place using ropes.

3 Use a spotter at the end of the trench to determine whether the strut is level and in the correct location.

4 The installer initiates installation by saying, “Shoot and hold.”

5A Lock the strut collar manually as determined by the type and the manufacturer. The collar on this type spins toward the strut cylinder to lock.

5B This type may be locked from either inside or outside (spinning collar) the trench.

6 All strut bases should be nailed before the installer says, "Release."

6 After securing the shore manually, the installer nails the strut bases to the strongbacks and then says, "Release" (to release the pressure). The air hose is then removed and placed on another shore **STEP 6**.

Tactical Tip

When installing more than two struts on a strongback, use a wye adapter to pressurize all struts at the same time.

Training Tip

When possible, three struts should be shot for all trenches between 6 and 12 feet (1.8 and 3.7 m) deep, regardless of the type of soil. The reasons for this are twofold. First, when in a training environment, we want our students to install as many shores as possible. This helps to reinforce learning because trench rescues do not happen every day. Second, whenever possible, the team should make the shoring system stronger than the minimum requirement. As always, this decision is based on a risk–benefit analysis. Be mindful of keeping rescue personnel safe; every precaution should be taken not to compromise their safety.

Organizations that use struts that must be locked from inside the trench should also use a shoring team consisting of a minimum of four members. Those positions and job descriptions are as follows:

- Officer: Develops the shoring plan; assigns team positions; determines strut length, placement, sequence, and pressures; and manages and supervises the shoring team operations

- Controller (shooter): Sets up the air system, "shoots" the struts at the pressure designated by the officer, and releases the strut pressure as ordered
- Strut handler: Assembles the struts and attaches ropes, carries the struts to the trench wall, and assists the installer with positioning and supporting the struts during installation
- Installer: Helps lower the first strut into the trench, climbs the ladder into the trench, aligns the struts, calls for the struts to be shot, locks the collar, and nails the bases

Shore installation comes down to this simple fact: Rescue and training are different. If you are trying to save someone's life, one shore may suffice for patient care to begin; if you are trying to satisfy a standard operating guideline, two shores with less than 4 feet (1.2 m) of spacing between them may be enough. If the situation is a recovery or training, it may be best to install three shores to ensure rescue personnel are as safe as possible. In all cases, rescuers should use the safe trench entry protocols developed by their rescue organization **FIGURE 10-10**.

Tactical Tip

Remember to always toe nail the end of all shores to the strongbacks. With this technique, if subsequent shores cause the system to become loose, previously installed shores will not fall out.

FIGURE 10-10 This style of pneumatic strut has a collar that twists and uses pins to obtain it full strength. Rescuers must minimize their exposure time during installation.

Timber Shores

Timber shores have a long history in both construction and rescue shoring. In either application, they are very time consuming and create additional risks because they expose installers to the trench before it is safe. The minimum recommended size of timber shores for active soil is 4 × 6 inches and larger. OSHA provides a comprehensive guide for timber shoring. Rescue teams that deviate from that standard should have tabulated data for rescue timber shoring approved (stamped) by a registered professional engineer.

In some communities, the fire department rescue and truck companies carry enough timbers to start initial shoring at a trench rescue incident. Using timber shores as a "stop gap" method to protect a trapped victim is a legitimate technique that all rescuers should have in their tool box. However, timber shores have limited application at technician-level (Level II) trenches and at scenes where time is of the essence (rescues). A review of the strut use, and the limitations of various types of struts, can be found in the "Equipment" chapter.

Installing timber shores begins by measuring the distance between panels and cutting the timber to fit. Timber shores are then set from the top down as illustrated in Skill Drill 10-5. Working from the top down on a ladder allows the rescuer to install the shores without being more than waist deep in the unprotected part of the trench. If a secondary collapse does occur, the rescuer will most likely be buried only up to the waist, which normally is a survivable incident.

Pre-nailed bottom scabs can help the rescuer properly hold and position the shore for installation. In some cases, the shore needs to be forced into place using a maul or hammer. Another technique to make installation and adjustment of timber shores easier is to rail the panels with 2 × 4-inch stringers. Individual shores can then be moved up and down. The rescuer has to put only two scabs in place to finish the installation (See Figure 10-11).

The top shore is installed between 12 and 18 inches (0.3 and 0.5 m) below the trench lip. The middle and bottom shores would follow, in that order. The number of shores necessary to protect the trench is based on the depth of the trench. Again, if the bottom shore can be placed between 12 and 24 inches (0.3 and 0.6 m) from the bottom and results in less than 4 feet (1.2 m) of space between the bottom and top shores, then a middle shore would not be necessary. You can never go wrong by placing too many shores, however. If you are not comfortable with the environment or the conditions, add more shores than you would otherwise use.

In any case, the shoring sequence for the first set of panels is top, middle, and then bottom. This sequence is the safest application for timber shore use; however, it often does not provide for the most efficient method of protecting the victim from impending collapse.

Installing Timber Shores

Timber shores require a somewhat different procedure for their installation than do pneumatic shores. To install timber shores, follow the steps in SKILL DRILL 10-7:

1. After the timber shore has been measured and cut, the top shore is installed first STEP 1 and STEP 2.
2. Minimize the time the installer spends on the ladder. Strut handlers can assist the installer by lowering the timber (with ropes) to the designated depth.

3. After the shore is installed (compressed), it must be secured to the strongback with nails. This usually involves the use of scabs (short 2 × 4s).
4. Subsequently, the middle shore is installed **STEP 3**, and then the bottom **STEP 4**.

With each installation, the rescuer is allowed to enter the trench only at waist level to the last secured shore.

Organizations that use timber struts that must be installed by rescuers entering the trench should have a shoring team consisting of a minimum of four members. Those positions and job descriptions are as follows:

- Officer: Develops the shoring plan; assigns team positions; determines strut length, placement, sequence, and pressures; and manages and supervises the shoring team operations
- Two strut handlers: Build (cut) the struts and attach ropes, carry the struts to the trench wall, and assist the installer with positioning and supporting the struts during installation
- Installer: Climbs the ladder into the trench, aligns the struts, tightens (compresses) the struts, and nails the struts in place

Because accurately cutting the timbers for shoring is difficult at best, scabs are used to hold the shores in place. It is usually easier to nail the bottom part of both scabs to the strongbacks and to use this as a shelf on which to rest the shore while installing the top scab. Timber shores are usually tightened (put into compression) by using wedges or timber screw jacks or by oversizing the length of the shore and driving it in with hammers. In unstable soil conditions, the oversizing method is the least desirable. Keep in mind that the minimum-sized Douglas fir shore that is approved for type A and type B soil trenches up to 10 feet (3 m) in depth is 4 × 6 inches.

SKILL DRILL 10-7

Installing Timber Shores

(Trench Rescue Level I: 8.1.2, 8.1.4)

1 Install the top timber shore.

2 Use scabs to secure all timber shores.

3 Install the middle timber shore.

4 Install the bottom timber shore.

Rails that are 2 × 4 inches can be installed on the strongback prior to setting the panels. This technique, which is referred to as "railing the strongback," will make shore adjustment easier for the installer **FIGURE 10-11**.

■ Screw Jack Shoring

Screw jacks are used with pipes or timbers. The screw allows the strut to be tightened (compression) against the trench walls. The activation pressure created by turning the screw, however, is not measurable. Attempting to create an equalized soil pressure distribution across the shoring system is difficult and is based on the installer's "touch" rather than gauges. Because the installer must spend time in a trench before the struts have reached their full strength, it is critical to minimize exposure time to the shoring team during installation. Many of the screw jack struts used by rescue teams have a significantly lower breaking (buckling) strength than pneumatic and hydraulic struts. This is due in part to the smaller diameter of the screw jack struts (length–diameter ratio). Users of these struts should request a shoring chart (tab data) from the manufacturer that is specific to cave-in soil conditions.

FIGURE 10-11 Railing (stringers) the strongback can make the installation and adjustment of timber shores easier for the shore installer.

■ Hydraulic Shoring

Hydraulic struts have been successfully used to shore trenches for many years. The rescue service borrowed this technique from construction workers. The activation pressure is created by pumping hydraulic fluid from a reservoir through hoses and into the strut cylinders, which house the moving pistons. Hydraulic struts do not have collars that (mechanically) prevent the movement of the pistons and cylinders. Instead, the (compressive) strength of the strut remains dependent on the hydraulic pressure throughout the entire duration of their use in the trench. As a result, the pressures used for hydraulic shores are much higher than the pressures needed for pneumatic, timber, and screw jack struts. These higher pressures are very effective on trench walls that are intact and have stable soil conditions. Users of these struts should request a shoring chart (tab data) from the manufacturer that is specific to cave-in soil conditions.

Wales

Wales are horizontal members that are used to span openings along the trench walls. These elements can be of the inside or outside variety. They can be made of timber, laminated beams, metal, or makeshift ladders. (See the "Equipment" chapter for more information on wales.)

Inside wales are used to span a trench panel to create a safe area in a "T" trench or to create an open space in the middle of a trench **FIGURE 10-12**. The wales are lowered into the trench on the inside of the panels and placed up against the strongback. The shores are then shot to the wales.

Outside wales are placed against the trench wall before the panels are put into position. They are used to span an opening that may have been created by a slough of the trench wall **FIGURE 10-13**. After installation of the wales, panels, and initial struts, it is necessary to backfill the area between the panels and the trench wall. This method allows the forces to be transferred effectively when the protective system is complete. (More information about installation procedures is found in the "Trench Rescue Shoring Techniques" chapter.)

FIGURE 10-12 Inside wales are used to span a trench panel.

FIGURE 10-13 Outside wales are used to span a slough in the trench wall.

Tactical Tip

All areas of the trench need to be backfilled when there is an open space between the protective system and the trench wall. If a void is present, no transfer of forces can take place.

Tip

If you are concerned with the stability of your protective system, you can always add more strongbacks or wales, shorten the shoring zone, or call an engineer for advice.

VOICES OF EXPERIENCE

On a late October morning, a contractor was attempting to tap into a sewer line in a quiet neighborhood in Grosse Pointe, Michigan, just east of Detroit. The existing line was located 22 feet (6.7 m) below the roadway. The neighborhood had recently experienced heavy rainfall, and the area was located near a river and known for its high water table. Prior to the start of the excavation, a small portion of the road pavement was removed. An initial trench was dug 14 feet (4.3 m) deep, 9 feet (2.7 m) wide, and 12 feet (3.7 m) long, perpendicular to the roadway. The contractor utilized a large excavator to cut the trench and positioned it on what would later be designated as the "C" side. A secondary trench one bucket wide was also dug. The second trench, within the first, went down to 22 feet (6.7 m) below the road. At that point, a 5-foot (1.5-m) diameter sanitary sewer was exposed. The contractor's intent was to tap into that sewer line. He got out of the excavator, placed a straight-beam ladder into the trench, and climbed in to perform the tap. No OSHA-recommended safety measures or protective systems were in place. The contractor was on the ladder, with his head about 1 foot (0.3 m) below the initial trench floor, when the first collapse occurred. That first collapse completely buried the victim. His lower body was pinned by compacted soil and his upper body was buried by loose clay.

"His lower body was pinned by compacted soil and his upper body was buried by loose clay."

Co-workers activated the 911 system. First responders and nearby Department of Public Works (DPW) personnel arrived, and upon hearing muffled moans and shouts for help, entered the collapsed trench and began uncovering the victim's head and chest. Initial efforts successfully removed enough soil from around the victim to allow him to breathe. However, the trench conditions continued to deteriorate, with more and more soil falling on the victim and the first responders in the trench. I arrived on scene to find first responders still attempting to uncover the victim in spite of the continually collapsing walls. There had already been a secondary collapse that injured a public safety officer. Despite some strong opposition from the well-intentioned first responders and DPW workers, I was able to convince them to leave the trench. Within minutes of their exit, a third collapse occurred, completely covering the victim again.

As initial rescue equipment and personnel arrived, I was still operating in a rescue mode. My plan was to quickly install primary shoring to prevent an additional collapse from further burying the victim. Our biggest concern was that the front wall (A side), which had already significantly collapsed, still had visibly active soil. The concrete road, approximately 9 feet (2.7 m) thick, was now undermined on that wall, creating an overhang of about 3 feet (0.9 m). Two of the four corners of the trench were also visibly moving and were continually caving in. The cave-ins had created large voids and angled walls. A variety of rescue shoring techniques were used to protect the victim area.

With the victim completely buried for this extended period, and with secondary shoring still not completed, the decision was made to transition into recovery-mode operations. We initiated an "all stop," pulled everyone back from the hazard zone, took a deep breath, and organized the scene. We worked with the local incident commander to control the scene, move bystanders and nonessential personnel outside a perimeter, and develop a tactical action plan (TAP).

Supplemental shoring was attempted, but the extremely saturated and moving soil prevented us from attaining normal strut installation pressures. We also noticed that the pressure on many of our struts was changing. As the soil continued to move downward, the pressure on the upper struts would decrease and the struts would loosen.

After almost 8 hours of continuous work in the trench, crews were finally able to reach the victim and began to expose his head and arm. Unfortunately, the soil flowed over the victim as fast as it could be removed. We eventually tied a rope to his arm, attached the rope to the arm of the excavator, and attempted to secure him in place. It seemed that he was sinking farther from his original location as we worked. First-operational-period personnel were removed from the trench, and the oncoming shift took over.

We reevaluated the soil conditions, which were the biggest concern. Type C soil was at the upper levels of the trench and became increasingly wetter and heavier the deeper we went. At and below the water table, the soil was saturated, continually moving, and extremely heavy Traditional rescue shoring down to the water line was difficult but effective. Below the water line (C-80), the soil was heavy and continuously moving, preventing us from maintaining recommended strut pressure and stability. As the soil slumped behind the panels, it caused struts to loosen. These conditions exceeded the capabilities of the shoring methods and tactics being used.

Additional hazards included the 20-ton excavator positioned on the trench lip (side C), the overhanging concrete on the front wall (side A), and an active and exposed natural gas line underneath the excavator. Despite the shoring, the soil continued to move, exposing more of the gas line and expanding the void under the pavement. Additional concerns included cracks in the overhanging concrete and insufficient scene lighting.

Based on the expanded assessments and briefings from the first operational teams, and recognizing the fact that this was clearly a recovery, it was decided to discontinue the use of rescue shoring. The incident commander set a meeting for 0800 hours the next morning to develop strategies and tactics to complete the body recovery. The meeting, led by the incident commander, included city officials, USAR Strike Team managers (STMs), a city engineer, and representatives from an underground construction company experienced with deep excavations and moving soil conditions. In retrospect, the plan that evolved included many of the steps that should have been taken by the contractor who dug the trench and attempted to tap the sewer line.

At 0800 hours, all three STMs, the incident commander, city officials, and a licensed contractor met back on-site for the third operational period and began to discuss our previous recovery efforts and the development of "plan B," utilizing an engineered system that would allow us to safely complete the recovery operations. We collectively developed a new incident action plan (IAP) and TAP, listing out tasks for the contractor, the city DPW, and our Strike Team personnel.

A structures specialist (registered professional engineer) experienced with both underground construction shoring and trench rescue reviewed the plan, as did representatives from Michigan-OSHA. The transition from "trench rescue" shoring to "commercial" soil stabilization techniques required a coordinated effort from rescuers and underground construction workers. After the overhead electric wires and the gas line that passed through the trench were de-energized and locked out, the rescuers removed selected shoring to allow for the following commercial techniques:

- Installing a rated trench box
- Using sheets of 1-inch (2.5-cm) thick steel road plate piled into the trench floor as sheeting
- Cutting and removing street pavement so that the top sections of the trench walls could be sloped to a safe angle

Over the next 10 hours, rescuers worked with the contractor to safely remove the soil, working their way down toward the victim. The removal was aided by dropping down a "mud bucket" by the excavator, which would be filled up, one shovel-full at a time, then raised and dumped on a spoil pile.

At approximately 0530 hours, nearly 42 hours after the operation began, the victim was lifted out of the trench with a rope-based mechanical advantage system and lowered onto an awaiting gurney. Rescue personnel and the excavation contractor crews formed a double line from the trench to the ambulance. Everyone on the scene displayed a somber respect for the victim and his family.

Lessons learned included that every method of trench protection has limitations, and trench rescue teams should be prepared to implement alternative measures when the depth or width of the trench exceeds the capacity of the shoring equipment or when extreme soil exists. Rescuers need to have a hands-on understanding of the use and limitations of alternative methods like sloping, trench boxes, and sheet piling for atypical trench incidents.

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Isolation Devices

The term isolation device is specific to rescue operations. The use of concrete manhole rings, pre-cast concrete catch basins, steel or concrete pipe, and concrete vaults to provide a measure of protection in a trench is not an OSHA-compliant technique for keeping construction workers safe. Their use can, however, provide a protective barrier for a victim involved in a trench accident. Experienced Level II trench rescue personnel working in conjunction with heavy equipment operators may find it necessary to develop isolation devices improvised from material and equipment found at the construction site.

The use of an isolation device is a temporary or last-resort option. These devices are typically not rated for worker protection. In the case of a coal mine worker who was trapped in running debris, a 55-gallon barrel with both ends cut out was used. Keep in mind that objects such as a barrel can withstand most lateral forces but could easily fail under horizontal forces created by the weight of soil.

Improper installation of an isolation device can cause additional collapse and/or injury to the victim(s). Placement of an isolation device requires a cool, calm, and collected equipment operator. If the device is placed on a victim, it may injure buried (unseen) extremities.

Implementation of an isolation device should follow this procedure:

1. The rescue squad officer meets with and briefs the heavy equipment operator on the procedure. The operation will be directed by the rescue officer.
2. The operator performs a pre-lift to check rigging and stability.

3. Attach tag lines and assign personnel to manage them.
4. Use a signal person to give directional orders to the operator.
5. When the isolation device is not moving or swaying, direct the operator to slowly lower it over the victim.
6. If using a manhole ring, ensure that the fixed ladder does not contact the victim.
7. If the isolation device extends over the top of the trench wall and is large enough, a rescuer may be lowered into the device to begin assisting and freeing the victim.
8. If a rescuer cannot safely enter the isolation device, the trench walls may be cut to the maximum allowable angle or sheeted and shored as resources become available.

Additional considerations include the following:

- The added surcharge and vibrations from the heavy equipment may cause additional collapse.
- If a manhole ring is used, the fixed ladder rungs inside the ring may hit and injure the victim during installation.
- The device selected for isolation must be large enough to fit over the victim with room to spare, yet small enough to fit into the excavation area. If the top of the isolation device is below the trench lip, a collapse may turn the device into a coffin.
- The rescuers must have training and procedures for installing an isolation device over a trapped victim.

Modular Shields

Modular shields are aluminum trench boxes that are assembled at the scene and are rated for human safety **FIGURE 10-14**. They are often present on trailers at the trench site. Modular aluminum or steel shoring is available in a variety of shapes and configurations based on the size of the excavation and the type of soil in which they will be installed. In addition to coming in fixed sizes, some of these units are air or hydraulically adjustable.

The modular systems can be quickly assembled and lowered into the trench for use as rescue isolation devices or safe zones for rescuers. Once the shield is built, it can be lowered into the trench with an excavator.

Rescuers with access to modular shields are encouraged to train with them and to develop alternative methods for installing them. Ladder A-frames, gantries, and rope-based mechanical advantage systems, for example, are all viable installation alternatives.

Engineered Systems

A pre-engineered rescue shoring system that can resist the forces of extreme soil conditions and can be built with the shoring equipment carried on your rescue apparatus is a great addition to your tactical options. Having a practical and tested design for those conditions could save someone's life.

FIGURE 10-14 Modular shield.
Courtesy of Ron Zawlocki

An example of an engineered design that was developed to address the problems of running and very heavy type C soil can be seen in **FIGURE 10-15**. In this type of shoring system, each 4 × 8-foot sheet of panel has three strongbacks. These additional strongbacks are screwed to the sheeting and held in place using wales. The shores are then shot to the point where the wale crosses the center strongback of each. The goal with this type of system is to increase the stiffness and strength of the panels by adding strongbacks and to improve the performance of the wales by adding contact points that help distribute the load. While such a design is likely to increase the overall strength of the shoring system, a few questions should come to mind when an engineer creates a design for your organization:

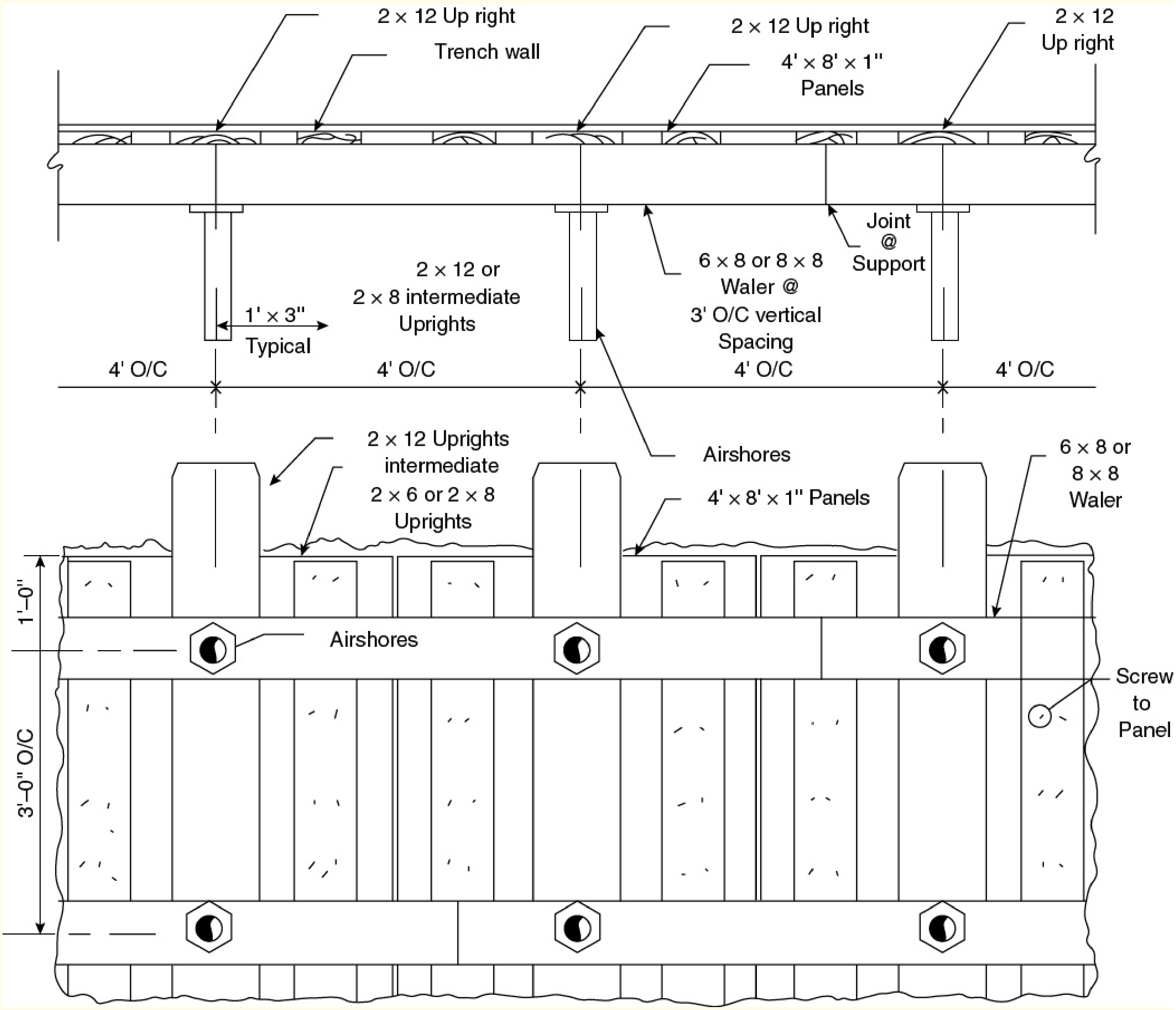


FIGURE 10-15 In very hazardous soils, you should at least consider the use of an engineered system like this one, which has additional strongbacks that create multiple contact points for energy transfer. How many additional contact points are created when compared with a normal trench with wales?

- How did the engineer calculate the soil forces for this design? Engineers commonly use several formulas for calculating soil forces. Not all of them are applicable to shallow, braced trenches with collapsed wall conditions.
- Is an accurate soil analysis required to use this design? Engineers often rely on accurate soil borings and analysis to create soil retention systems. It is common for structural engineers to work with geotechnical engineers to ensure a safe design.
- Does the engineer have field experience with trench rescue teams? Has the engineer who designed your rescue shoring system spent much time in trenches with your team? Does the engineer understand the skills and equipment limitations of your trench rescue team?

- How long would it take your trench rescue team to install this system? Before you add an engineered system design to your tactical options, make sure that your team tries it out. Engineers are used to designing systems that often take weeks or longer to install.
- Does this system meet the scope (i.e., collapsed trenches containing injured or trapped people in them) and purposes (i.e., to immediately protect the victims from additional soil collapse, to provide a safe area for rescuers working in the trench, and to support patient care and extrication operations) of the trench rescue operation? Very few engineers have designed shoring for those reasons.
- Has the system been tested? What is the breaking strength of this system in its position of function (i.e., in a trench with collapsed walls and active soil)?
- How many times stronger is the system than the forces that the soil could create? What is the safety factor of this system?

In all cases, to create a protective system that is different from the OSHA standard, the system must be certified and approved by a registered engineer.

When you seek the help of an engineer, you must be able to tell him or her exactly what you need. You should also ask him or her about the issues mentioned previously. Having an engineer's stamp on a system does not automatically mean that it is the best design for trench rescue operations. It also does not mean that other engineers will support the design, nor does it indicate that the system has actually been tested (absent computer modeling). Rather, it means that, based on the information that you have provided and the assumptions that have been made (check the disclaimers on the tab data closely), your engineer believes this system will work.

Having an engineer who is willing to work with your team and design safe shoring systems is a huge benefit. Hiring an engineer to design something solely on a computer, without any practical testing, is a different story.

Trench Rescue Shoring Equipment Removal

Part of the termination phase of an incident includes the removal of trench rescue shoring equipment. Equipment removal needs to be carefully planned and executed to avoid mistakes and injuries. When possible, it is best to use fresh crews to perform equipment removal. The person in charge of the equipment removal operation must create a plan that includes specific assignments and a clear sequence of events. A detailed briefing should also be held before the removal operation begins. At this point, there are no lives to be saved, so the operation must slow down and all risks must be eliminated.

The preferred equipment removal method includes the use of heavy equipment and trained equipment operators. If heavy equipment and operators are unavailable or their use is not feasible, manual removal techniques can be used. Procedures for both machine and manual removal are presented in this section.

Follow these steps to prepare for equipment removal:

1. Examine the lip conditions under each ground pad and/or lip bridge. Look for signs of soil movement (e.g., fissures, sliding, or shifting).

2. Evaluate the condition of the walls around the sheeting and shoring (e.g., for fissures, bulging, or sloughing).
3. If cracks, fissures, sloughing, and other indicators of active soil are present, do not attempt manual removal. Instead, have heavy equipment brought to the scene to remove rescue equipment.

The procedure for machine removal of a pneumatic strut shoring system should follow the steps presented here, starting from the bottom of the trench and working up:

1. Bring the middle panel rope up and tie a knot 3 feet (0.9 m) above the top of the panel. This helps lift the load higher (gain).
2. Attach the panel ropes to a lifting beam that is connected to the lifting eye on the excavator bucket. Raise the bucket to take out the slack on the ropes.
3. Enter the trench and connect air hoses to the struts in that panel set.
4. Add nails to achieve four nails in each strut base, then have all personnel exit the trench.
5. Working from the lip protection, decrease the pressure on air bags or backshores that are opposing the struts being removed.
6. Loosen the collars with air pressure and spin the collars back 3–4 inches (7.6–10.2 cm).
7. Slowly decrease the air pressure in the struts and look for any wall movement. If any wall movement occurs, remove all personnel from the trench lip.
8. Relieve all air pressure from the struts, and then remove the struts with ropes. Signal the heavy equipment operator to lift the shoring equipment out of the trench and swing and land it in a designated (safe) area away from the trench.
9. Assign personnel to remove struts from the panels and restore equipment.
10. Repeat these steps for the remaining panels and struts.

The procedure for manual removal of a pneumatic strut shoring system includes the following steps, starting from the bottom of the trench and working up:

1. Connect hoses and ropes to the struts.
2. Remove the nails from the strut bases.
3. Decrease the pressure on the air bags or backshores that are opposing the struts being removed.
4. Loosen the collars with air pressure and spin the collars from a safe zone.
5. Slowly decrease the air pressure in the struts and look for any wall movement. If any wall movement occurs, remove all personnel from the trench and wait for heavy equipment to remove the sheeting and shoring.
6. Relieve all air pressure from the struts, and remove the struts with ropes.
7. Repeat these steps for each tier of struts, moving from bottom to top.
8. Remove the panels last.

The procedure to manually remove a timber strut shoring system, starting from the bottom of the trench and working up, is as follows:

1. Connect ropes to both ends of the strut.
2. A rescuer climbs down the ladder to manually remove the timber struts. The rescuer should work from the ladder and keep his or her head and chest in a safe area above the next highest strut.
3. Decrease pressure on the air bags or backshores that are opposing the struts being removed.
4. Slowly decrease the compression (e.g., opposing wedges, screw jacks) on the strut and look for any wall movement. If any wall movement occurs, remove all personnel from the trench.
5. Remove the nails from the scabs supporting the strut ends. The rescuer on the ladder should climb up to a safe area, and when the strut is loose, the handlers on the lip can use the ropes to lift and remove the shore.
6. Working from a safe area, the rescuer on the ladder repeats steps 3 and 4 until all shores in that panel set have been removed.
7. Repeat steps 1–5 for equipment removal in subsequent panel sets.

Commercial Shoring Techniques

On some occasions, trench rescue shoring equipment and techniques may not suffice to meet the needs of the incident. Deep trenches and extreme soil conditions (running soils), for example, are beyond the scope of conventional rescue shoring operations. In these cases, professional engineers and construction workers should be called to assist with the extrication effort. This does not mean that the trench rescue technicians pack their bags and leave the scene; rather, it means that they recognize the situation as being beyond their shoring equipment and abilities. Keep in mind that trench rescuers do not dig and shore holes for a living. Likewise, construction workers do not rescue people for a living. Combining rescue and commercial shoring techniques, then, requires planning and coordination.

Consider using commercial techniques and professional help if any of the following factors is present:

- Type C-80 soil conditions
- Soil below the water table
- A trench deeper than 20 feet (6.1 m)
- A massive cave-in
- Workers trapped in running soil, grain, or product
- Environmental conditions that prohibit the use of rescue shoring

Any protective system that is put in place for either rescue or commercial operations must be capable of withstanding all intended and reasonably expected loads. Predesigned systems are engineered to withstand certain forces. The decision regarding the type of protective system to use may vary based on the type of rescue operation or, in the case of a commercial situation, the type of job, location of adjacent structures, and time.

Regardless of the parameters, selection of protective systems is based on a set of factors that are evaluated during each operation. These factors may include, but are not limited to, the following:

- Adjacent structures

- Existing hazards
- Soil type
- Water profile and hydraulic table
- Depth and width of the trench
- Purpose of operation (rescue versus utility installations)

Commercial shoring techniques include the use of a trench box (rabbit box/shield system), soldier pile and lag shoring, sheet piling, modular shoring, and sloping the trench banks to a safe angle. Rescuers should consider the following issues when using commercial shoring techniques:

- They are usually very time consuming.
- The application of these techniques may cause additional collapses in the area of the victim.
- Utilities (e.g., overhead electric lines, underground gas and water lines) may have to be shut down or removed.
- Commercial shoring techniques require tabulated data and/or engineered designs.
- They require a cool, calm, and collected equipment operator working under an experienced rescue officer's direction.

Use of Commercial Systems at Rescue Scenes

Commercial systems require the use of heavy equipment and highly skilled operators. Heavy equipment is common at every construction site. When the decision is made to utilize construction techniques to make the trench safe for rescue or recovery operations, rescuers must work hand in hand with heavy equipment operators.

Sloping and Benching Systems

Sloping and benching are two methods used to protect underground construction workers (**FIGURE 10-16** and **FIGURE 10-17**). Both techniques utilize the same principle that removes or minimizes the dangerous vertical sections of the trench walls. The walls are angled to a point where the material will support its own weight and will no longer collapse or flow—the so-called angle of repose or maximum allowable angle. Each soil type has its own angle of repose. Determination of the maximum allowable angle for a specific soil type is based on soil analysis and engineered data (angle chart).

The angle must be flattened when an excavation has water conditions; silty materials; loose boulders; or areas where erosion, deep frost action, or slide planes appear. When benching the side of an excavation, the vertical rise should not be more than 5 feet (1.5 m) and the step back should extend at least to the required angle of repose. Personnel are not permitted to work on sloped or benched excavations at levels above another employee, except when protection from falling, rolling, or sliding material (or equipment) is provided for the employee(s) working on the lower level.

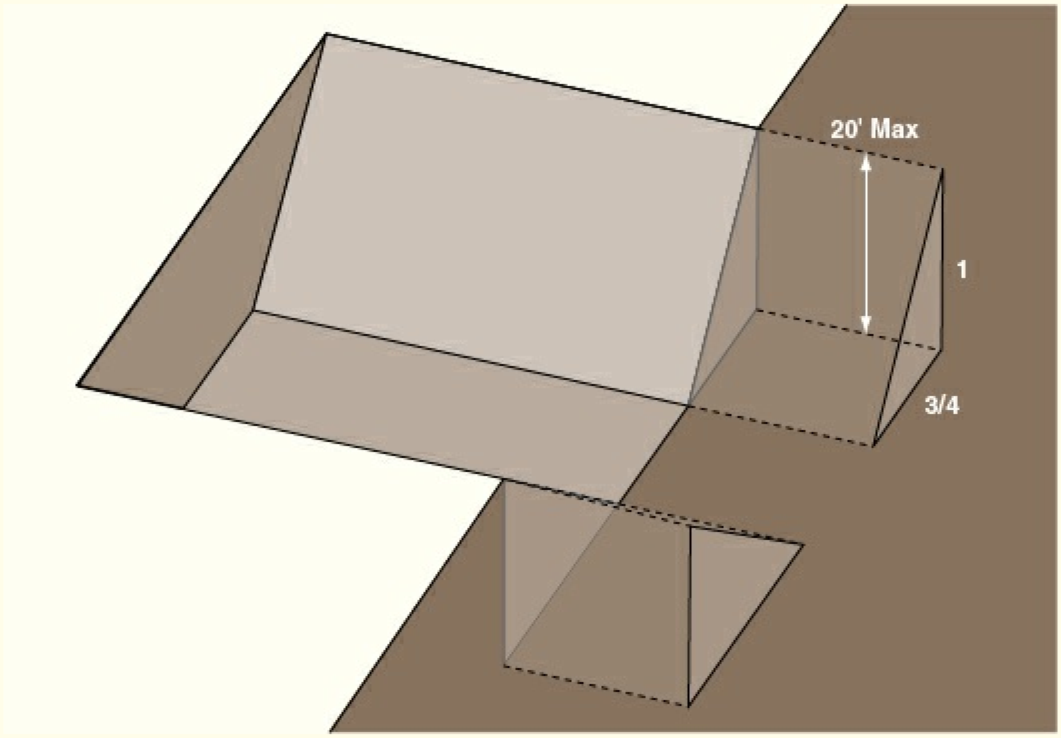


FIGURE 10-16 After the sloping is completed, it reduces the angle of the trench wall to eliminate collapse potential.

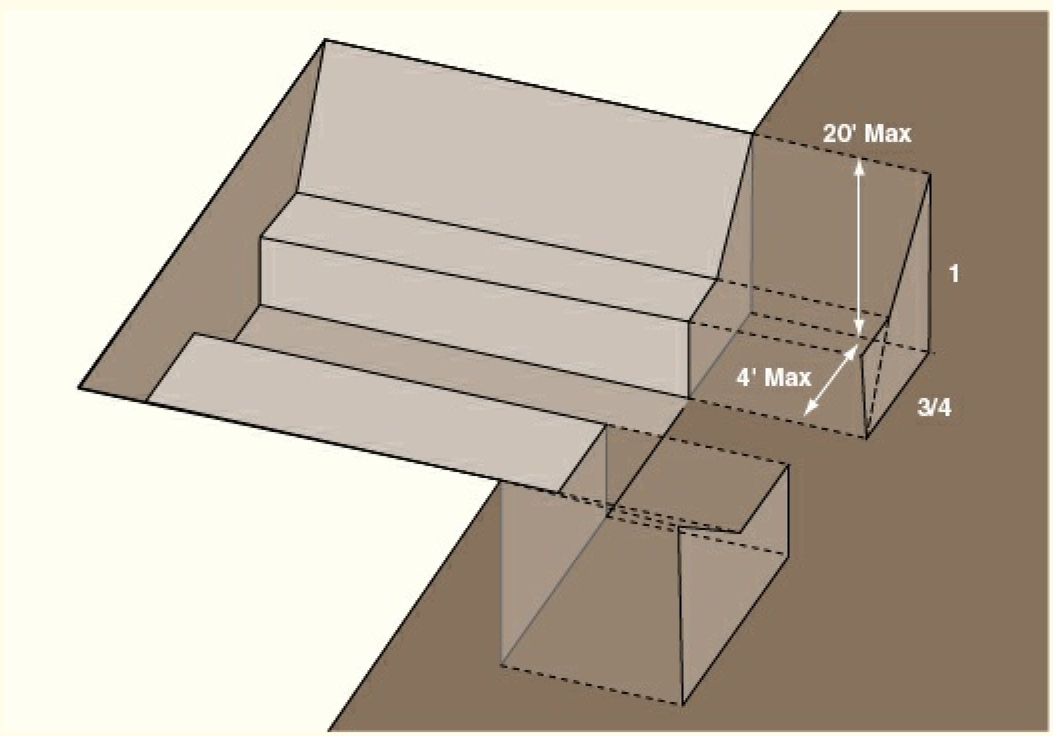


FIGURE 10-17 Benching is another technique that reduces collapse potential.

Sloping and benching are not typically used during rescue operations, but rather may be more appropriate for body recovery. Because of the risks to which sloping and benching expose a live victim, owing to the potential for additional collapse, their proper role in rescue operations must be determined by completing a risk–benefit analysis. If the use of the sloping or benching is deemed necessary, the following issues must be considered:

- A complete soil assessment, including determination of the maximum allowable angle, will require the use of a pocket penetrometer or shear to determine soil type.
- The added surcharge and vibrations from the heavy equipment needed to slope or bench may cause additional collapse.
- Sloping and benching are both very time-consuming operations.
- Sloping and benching take a lot of room.
- Sloping or benching during rescue operations should be used in conjunction with an isolation device whenever possible.

Sloping and benching can be used in any soil that is not sand or running mud and implemented to just about any depth. The limitations on their use are based on the soil type and the amount of room around the trench needed to obtain the necessary slope.

Tip

Sloping is referred to as "cutting back to the maximum allowable slope"—that is, the point where the material can support its own weight and is not expected to flow. Keep in mind that any sloping at the scene of a trench collapse should follow a pattern of at least 1.5-foot (0.5-m) horizontal to 1-foot (0.3-m) vertical for soils that are not running (sand or mud).

■ Trench Box

Trench boxes are commonly found at trenching sites **FIGURE 10-18**. This equipment usually contains steel or aluminum side walls and spreaders. Trench boxes come in a variety of lengths, heights, widths, side wall thickness, and weights. Unfortunately, quite often they spend more time above grade than below grade during underground construction work.

FIGURE 10-18 The trench box is a very stable commercial piece of equipment used to provide worker protection.

The selection and use of a trench box is based on soil type and trench width and depth. The criteria for use are based on the manufacturer's data and the analysis of a competent person. A trench box is a safe and effective method for protecting construction workers in a trench. Using one at a rescue scene, however, requires a well-developed plan. If the use of a trench box is deemed necessary, the following issues should be considered:

- Installation of a trench box may cause additional collapse. The issues of surcharged (backhoe/crane) loads, vibrations (heavy equipment), and collision of the trench box with the trench wall must be considered and resolved.
- Lowering or dragging a trench box, which can weigh several tons, into the area of a trench containing a victim may cause additional victim trauma. The rescue team must have strong indications that the trench box insertion will stay clear of the victim's position and location.
- The gap between the trench wall and trench box sides should be 6 inches (15.2 cm) or less. Backfill (e.g., air bags, backshores, timber/soil) may be required to resolve larger gaps.
- The top of the box must either extend above the lip of the trench or any soils above the trench box must be cut back to their angle of repose (or otherwise be protected).
- The bottom of the trench box may be a maximum of 2 feet (0.6 m) from the bottom of the trench, and only if a competent person determines the soil will stand with no possible loss from behind or below the shield.
- The trench box height may not be extended with steel plates unless approved sheet piling techniques are used.
- The box must be 4 feet (1.2 m) longer than the rescue work area.
- Rescuers may never be outside the protection of the trench box or other protected area of

the trench.

■ Soldier and Sheet Piling

Soldier piling and sheet piling are fixed shoring systems that support trench walls. They include sheet piles that can be cantilevered, braced, or tied back to provide ground support **FIGURE 10-19**. Using uprights made of steel plates or timber, the piles can be pushed into the ground at a depth that is appropriate for the type of soil and depth of the excavation. Piling is installed by pushing it in with a backhoe; drilling a hole to fit the pile; or using an impact, vibrating, or hydraulic hammer. The main advantage of this type of shoring system is that it can easily be maneuvered around existing utilities **FIGURE 10-20**. The use of soldier piling with lagging at rescue scenes is unusual. A modified version of sheet piling, using road plate in combination with trench boxes, is occasionally used in the transition from rescue shoring to commercial shoring techniques.

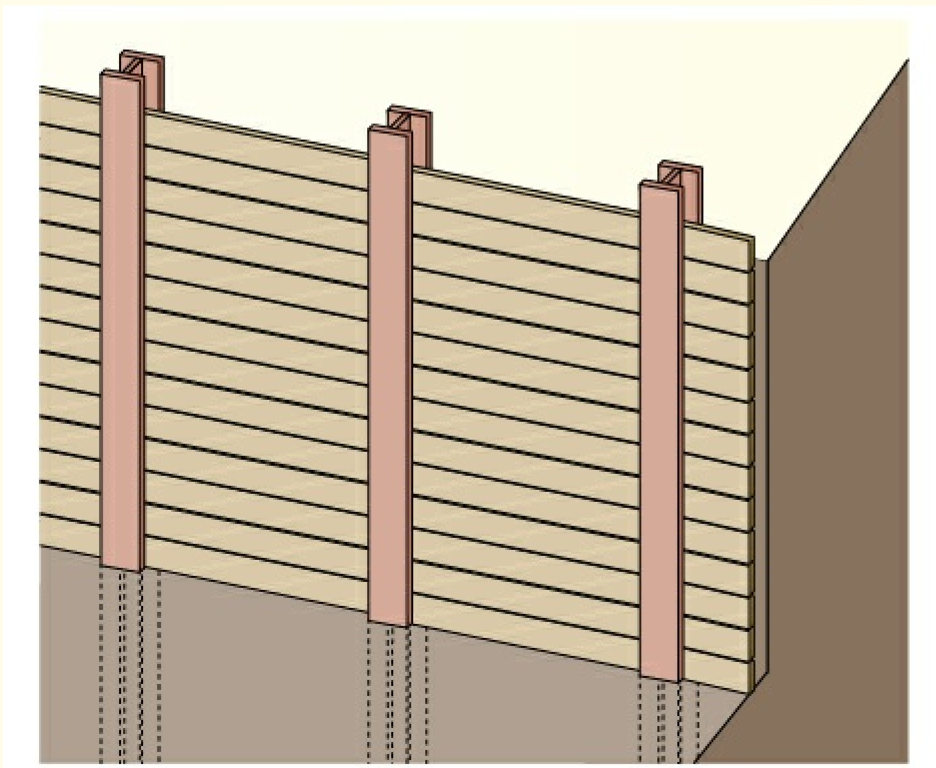


FIGURE 10-19 Soldier pile shoring consists of a set of horizontally installed wales held in place by a set of vertically installed piles.

FIGURE 10-20 Interlocking steel sheet pile shoring is a commercial technique typically used in deep trenches subject to tremendous compressive forces. These are seldom used at rescue incidents.
Courtesy of Chuck Wehrli

Trench Rescue Level II

Use of Heavy Equipment at Rescue Scenes

As a trench rescuer you must be capable of coordinating the use of heavy equipment at a rescue or recovery incident, which includes evaluating the capabilities and limitations of the operator and the equipment and establishing and maintaining communication with the equipment operator. Once these components are in place, you can establish tactical objectives for the use of the equipment and for recognizing and avoiding related hazards, such as the pivot or swing areas, which are the radius around which a rotating cab can reach.

■ Capabilities and Limitations

The heavy equipment that will be used most often to enhance rescue/recovery operations are the backhoe and the excavator. To evaluate these pieces of equipment, the trench rescuer should be able to recognize the differences between a backhoe and an excavator, to identify the operating components of both type of diggers, and to determine the capabilities of the equipment and the operator.

A backhoe is a piece of excavating equipment consisting of a digging bucket on the end of a two-part articulated arm FIGURE 10-21. It is typically mounted on the back of a tractor or front loader. The boom is attached to the vehicle through a pivot known as the kingpost, which allows the arm to swing left and right, usually through a total of approximately 200 degrees. An excavator is an engineering vehicle consisting of an articulated arm (boom, stick), bucket, and cab mounted on a pivot (rotating platform) fastened to tracks or wheels **FIGURE 10-22**.

The rescue specialist must know the name, location, size, and capacities of the following operational components:

- Boom: The section of the arm closest to the vehicle
- Stick: The section of the arm that carries the bucket
- Bucket: A specialized container attachment with teeth to facilitate digging. Buckets are attached to the second arm (stick) of excavators and backhoes and come in a variety of sizes and volumes.
- Lifting eye: The factory-installed rigging point on a bucket
- Outriggers: Stabilizers
- Center pin: The center of the rotating platform on an excavator

Equipment capabilities and limitations are objective and easy to determine based on the size and design of the machine. You can find this information by checking with the operator, looking at the chart in the cab, reviewing the operator's manual (if it is on site), or measuring the components to determine the length (reach) of the boom/stick and the capacity (amount of dirt) of the bucket.

FIGURE 10-21 A backhoe consists of a digging bucket on the end of a two-part articulated arm.

Determining the ability and limitations of the operator is much more subjective. Start by discussing the rescue plan with the operator. Determine the operator's emotional state and mental sharpness by giving him or her a chance to talk. If the operator is emotional (angry, fearful, etc.), cannot stay focused, or does not offer constructive suggestions to the plan, he or she should not be used. If the operator is calm and helpful, ask how many years of experience he or she has on that piece of equipment and how many times he or she has performed the objective (sloping, installing a trench box of sheeting, etc.) at hand.

■ Establish and Maintain Communications

Operations around a construction site are often noisy and hectic. When you add to that an emergency situation where people are often yelling and excited, the scene becomes especially challenging, noisy, and stressful.

Imagine arriving on the scene of a trench rescue where workers are frantically trying to extricate a victim who is buried in a collapse. Several workers are in the trench and still others are trying to communicate with the excavator operator who is trying to position his bucket to prevent a secondary collapse. If you are the first-arriving emergency provider, you will have your hands full getting people's attention and gaining control.

Situations like this are common, where the various construction and rescue equipment we use, along with normal emergency radio traffic, can make it difficult to communicate on scene. This is especially true when you are dealing with construction workers who are operating equipment at a distance, making face-to-face communications impossible or impractical. In such situations, you must either establish radio communications and verify that there is no language barrier, or communicate through well-established hand signals.

FIGURE 10-22 An excavator consists of an articulated arm, bucket, and cab mounted on a pivot.

With radio communications, it is imperative that you speak plainly rather than in ten codes or department slang. Plain talk with explicit directions is always preferable when communicating in situations where face-to-face communication is not achievable. It is also a good practice to have the person with whom you are communicating repeat back to you what they heard. This step is important because even experienced rescue technicians can have a picture in their mind of what needs to be done and may think what you are saying matches that vision.

Hand signals are another skill that every rescue technician should have. Construction workers often communicate using hand signals when operating large machinery like an excavator or crane on a construction site. Hand signals are a preferred communication tool both to convey messages over the noise of the machines and because frequently the operator cannot visually see the end of the piece of equipment and therefore relies on a spotter to guide him or her in where and how the bucket interacts with the material.

To maintain proficiency at communicating on a rescue scene, spend some time learning the various hand signals that equipment operators use. At the very least, learn the emergency stop, stop, and stop engine hand signals so you can quickly stop any unsafe operation. Your knowledge and confidence will put the operators at ease in the rescue operation. Common backhoe and excavator hand signals are shown in **FIGURE 10-23**.

Hand Signals

To communicate via hand signals, first establish verbal communications with the operating engineer and agree on hand signals that will facilitate digging, rigging, lifting, and moving. The essential hand signals include the following:

- Boom (up/down)
- Stick or arm (in/out)
- Bucket (in/out)
- Swing (left/right)

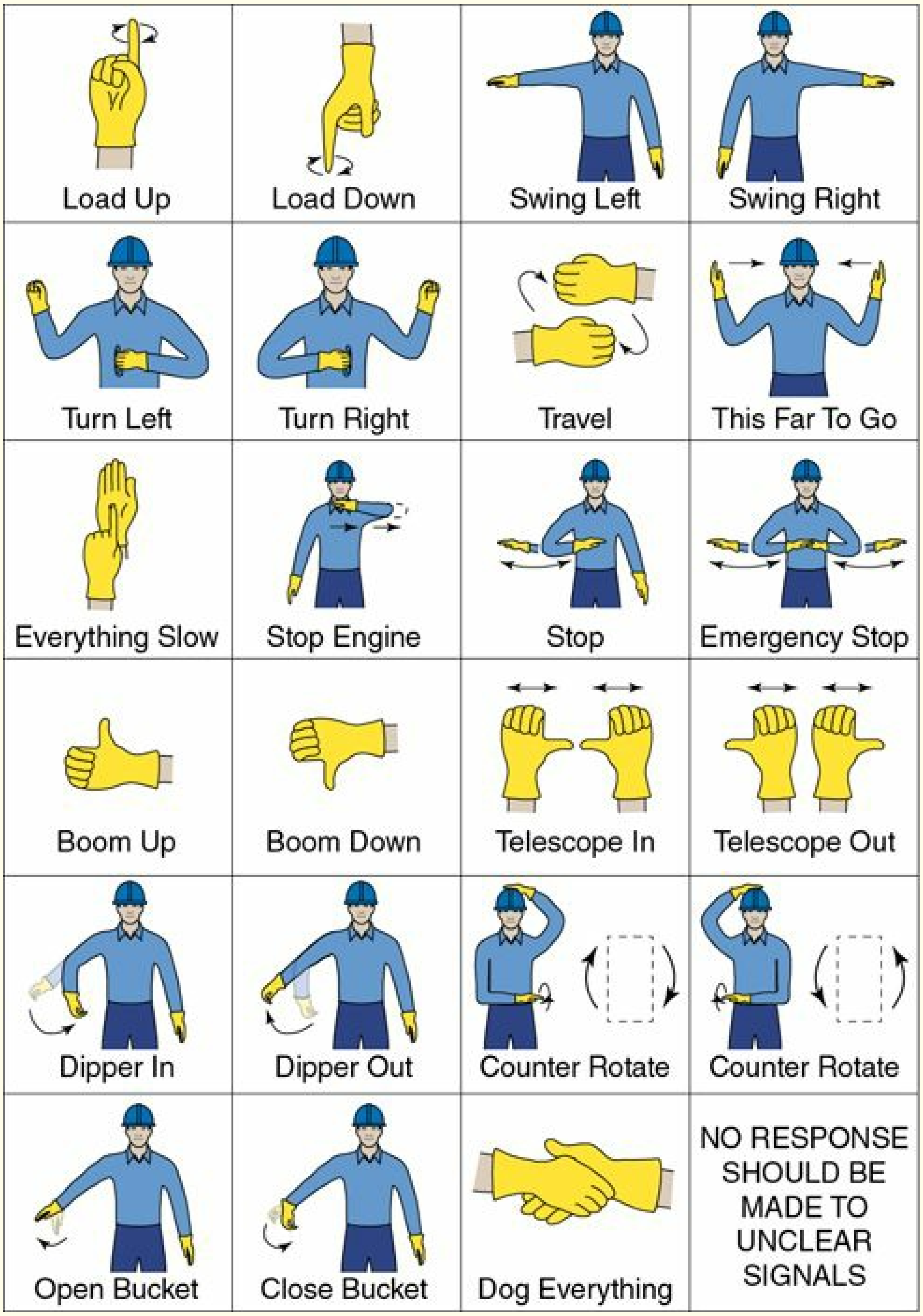


FIGURE 10-23 Common backhoe and excavator hand signals.

Tactical Tip

Always try to give hand signals using a non-gloved hand. Hand signals with a bare hand are more easily visible.

To lift and move an object you need to know the following signals:

- Load (in/out)
- Load (up/down)
- Slow

- Travel (ahead/back)
- Stop and emergency stop

Wrap-Up

Review: Just the Dirt

- The protective systems used at the majority of trench rescue incidents across the United States consist of panels, struts, wales, and support equipment.
- The sheeting and shoring techniques used by rescuers have evolved from the underground construction industry.
- The benefits of having a default rescue shoring method are that it is well practiced and that placement of equipment should enable rapid deployment of primary and secondary shoring techniques.
- At each trench, you will need to decide which kind of lip protection is best suited for the specific situation.
- Of all of the equipment in a trench rescue cache that can be used to make a trench safe, panels (sheeting), in combination with struts (shores), are used the most often.
- Pneumatic, hydraulic, timber, and screw jacks are common types of struts used by trench rescue teams. Each has advantages and disadvantages.
- Timber shores have a long history in both construction and rescue shoring. In either application, they are very time consuming to install and create additional risks because they expose installers to the trench before it is safe.
- Wales are horizontal members used to span openings along the trench walls. They can be of the inside or outside variety, and can be made of timber, laminated beams, metal, or makeshift ladders.
- The use of concrete manhole rings, pre-cast concrete catch basins, steel or concrete pipe, and concrete vaults to provide a measure of protection in a trench is not an OSHA-compliant technique for keeping construction workers safe. Their use can, however, provide a protective barrier for a victim involved in a trench accident.
- A pre-engineered rescue shoring system that can resist the forces of extreme soil conditions and can be built with the shoring equipment carried on your rescue apparatus is a great addition to your tactical options.
- Equipment removal needs to be carefully planned and executed to avoid mistakes and injuries.
- Deep trenches and extreme soil conditions (running soils) are beyond the scope of conventional rescue shoring operations. In these cases, professional engineers and construction workers should be called to assist with the extrication effort.

Hot Terms

Activation force A measurement of the total force that the strut exerts. The total force is calculated by multiplying the strut surface area (square inches) by the pressure (pounds per square inch). Using the formula radius squared (r^2) times pi (3.14), find the surface area of a cylinder ($r^2 \times 3.14$); then multiply the surface area by the strut pressure to get the activation force.

Backhoe A piece of excavating equipment consisting of a digging bucket on the end of a two-part articulated arm. It is typically mounted on the back of a tractor or front loader.

Benching Cutting back soil in benches of an appropriate height and width to meet the specifications as determined by the soil profile.

Engineered system Shoring or shielding system designed by registered professional engineers. Safety factors in such systems are calculated ratios of the system strength divided by soil force.

Excavator An engineering vehicle consisting of an articulated arm, bucket, and cab mounted on a pivot fastened to tracks or wheels.

Isolation device A concrete manhole ring, pre-cast concrete catch basin, concrete vault, or steel or concrete pipe that is placed over a victim in a trench to provide a degree of protection. Typically, such a cylinder-shaped object is placed over a victim while running or loose material is being excavated.

Rabbit box Portable (modular) trench box made from aluminum or other material that can be built and adjusted on-site.

Scabs Small pieces of lumber, usually 2 × 4 inches, that are used to hold shores and other connective devices in place.

Skip shoring Shoring done with strongbacks only (no panels).

Sloping Cutting soil back to a predetermined angle based on the soil's profile.

Soldier piling A system in which Z-shaped or H-sheet interlocking piles are driven into the ground and then held in place with vertical connections at a spacing that is appropriate for the depth of the excavation and class of soil.

Spot shoring Shoring that does not use traditional strongbacks or panels, but instead uses specially designed rail bases installed directly on the trench walls.

Strut pressure The amount of air pressure that the air system sends to the strut. It is measured in pounds per square inch (psi) and can be seen on the air system's gauge.

Trench boxes A premade shielding system that can be placed and lowered as digging operations continue.

Trench rescue shoring The method used to install protective systems at a collapsed trench with victims trapped.

TRENCH RESCUER *in action*

Tomorrow is a scheduled training day for your rescue company. The subject of the day will be trench rescue. Two engine companies as well as a truck company will be joining you, but the members of these companies are not familiar with the techniques used for trench rescue. Your captain will be giving several lectures on the topic during the morning and has asked you to lead the companies through several drills in the afternoon to familiarize them with what is required to help out at a trench incident.

In preparation, you do a quick review of the departmental SOPs relating to trench rescue and sketch out a basic teaching plan for the day. You will show the company members how to install lip protection and trench panels and will give them a brief introduction to shoring techniques so that they will be aware of what is required and able to assist the rescue company during an actual emergency.

While the captain is conducting his lecture, you and your fellow rescue company members will be installing both a timber-shored trench and a pneumatic-shored trench for practice and demonstration purposes as well as practicing "T" trench shoring techniques. You will use the timber and pneumatic demonstration trenches to explain the components of trench protective systems, then lead the members through several drills in which they will install the various components of the systems with the assistance of rescue company members.

1. The basic components of a protective system in trench rescue include lip protection, sheeting, shores, and:
   - A. engineered systems.
   - B. a trench box.
   - C. supplemental sheeting and shoring.
   - D. wales.
2. When approaching an unsupported trench or installing lip protection, the trench should always be approached:
   - A. from the uncollapsed side.
   - B. from the corners.
   - C. from the collapsed side.
   - D. from whichever side appears safest.
3. Which technique of installing a 2 × 12-inch strongback to a trench panel is strongest and offers the greatest safety factor?
   - A. Nailing the strongback to the shoring panel
   - B. Bolting the strongback to the shoring panel
   - C. Gluing the strongback to the shoring panel
   - D. Screwing and gluing the strongback to the shoring panel
4. It is always ideal to have trench panels "pre-rigged" before an incident. In reality, however, that is often not the case. Where should the ropes be attached to the trench panel for the purpose of lowering the panel into a trench?
   - A. Top
   - B. Middle
   - C. Bottom
   - D. Sides
5. For a basic straight trench, how many panels are required to be set and installed in place to

create a safe working area?

A. Two

B. Four

C. Six

D. Eight

6. In most situations, in which order are pneumatic shores installed?

A. Middle, bottom, top

B. Top, middle, bottom

C. Bottom, middle, top

D. Middle, top, bottom

7. In which order are timber shores installed?

A. Middle, bottom, top

B. Top, middle, bottom

C. Bottom, middle, top

D. Middle, top, bottom

Trench Rescue Shoring Techniques

CHAPTER 11

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Explain the shoring techniques for a straight-wall trench NFPA 8.1.2 NFPA 8.1.4. (pp 178–180)
- Describe when and how to use an outside wale NFPA 8.1.2 NFPA 8.1.4. (pp 180–184)
- Describe when and how to use an inside wale NFPA 8.1.2 NFPA 8.1.4. (pp 182, 184–187)

Skills Objectives

After studying this chapter, you should be able to:

- Shore a straight-wall trench NFPA 8.1.2 NFPA 8.1.4. (pp 178–180)
- Install an outside wale NFPA 8.1.2 NFPA 8.1.4. (180–184)
- Install an inside wale NFPA 8.1.2 NFPA 8.1.4. (pp 182, 184–187)

Trench Rescue Levels I and II

Knowledge Objectives

After studying this chapter, you should be able to:

- Identify the basic considerations for trench rescue shoring NFPA 8.1.2 NFPA 8.1.4 NFPA 8.2.1. (pp 176–177)
- Identify the fundamental trench rescue shoring strategy NFPA 8.1.4 NFPA 8.2.1. (pp 177–178)

Skills Objectives

There are no Trench Rescue Levels I and II combined skills objectives in this chapter. See the Trench Rescue Level I Skills Objectives for Level I-specific skills and the Trench Rescue Level II Skills Objectives for Level II-specific skills.

Trench Rescue Level II

Knowledge Objectives

After studying this chapter, you should be able to:

- Explain when and how to use supplemental shoring NFPA 8.2.2. (pp 190–192)
- Describe how to install rescue shoring in a T-trench NFPA 8.2.1. (pp 191–197)
- Describe how to install rescue shoring in an L-trench NFPA 8.2.1. (pp 197–207)
- Describe how to install rescue shoring in a deep-wall trench NFPA 8.2.2. (pp 208–212)
- Describe how to install rescue shoring in an excavation. (pp 212–216)

Skills Objectives

After studying this chapter, you should be able to:

- Install supplemental shoring NFPA 8.2.2. (pp 191–192)
- Shore a T-trench NFPA 8.2.1. (pp 193–197)
- Shore an L-trench with thrust blocks NFPA 8.2.1. (pp 199–202)
- Shore an L-trench with corner brackets NFPA 8.2.1. (pp 203–207)
- Shore a deep trench NFPA 8.2.1 NFPA 8.2.2. (pp 208–212)
- Build and install an excavation raker. (pp 213–216)

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

Your department recently completed a trench rescue training program. During the "technician" (Level II) course, you shored three trenches: a 12-foot (3.7-m) deep trench, an 8-foot (2.4-m) deep T-trench, and an 8-foot (2.4-m) deep L-trench. All of the trenches were dug in stable soil, and the lips and walls remained intact during the shoring lesson. During the training, your chief brought the media out to cover the events. In a television interview, the chief explained the purpose of the trench rescue team and described how it will serve the city and the neighboring communities.

Only a few weeks after the training, your department receives a mutual aid request for a man buried in a trench. When you arrive at the scene, you see a trench that looks nothing like your training experiences. This 17-foot (5.2-m) deep trench is 8 feet (2.4 m) wide where it intersects with another trench. At the intersection, a partially built concrete catch basin will clearly create an obstruction for conventional shoring. The inside corner of the L-trench has a wedge collapse and has resulted in a large void.

In your training, the instructor had mentioned that the course met the requirements found in the NFPA standards. Now you are wondering if that 3-day class really provided the knowledge, skills, and abilities needed to conduct rescue operations at the types of trenches you have seen being dug in your response district.

Today your chief is on the scene along with the chief of the neighboring fire department. The TV cameras are on the ground and are circling above in their helicopters. The spotlight is on you and your team of "trench rescue experts."

If your previous training provided you with a clear understanding of shoring fundamentals, you should be able to confidently answer these technician-level questions.

1. Which shoring practices could rapidly protect a victim and be easily expanded to create a safe working area for rescuers to enter this trench?
2. How can the strength of each component (e.g., panels, struts, wales) of your trench shoring equipment cache be used to establish a minimum 2:1 safety factor for the shoring system to be used at this site?
3. Which type of equipment and procedures are needed to install rescue shoring in a 17-foot (5.2-m) deep trench?
4. Which equipment and procedures can be used to resolve the shear forces for struts that contact trench walls at angles (inside corner of the L-trench)?
5. Which equipment and procedures can be used to shore an area with an obstruction that cannot be removed?

Basic Considerations in Trench Protection

The shoring procedures found in this chapter should be used in conjunction with the equipment best practices found in the "Equipment" chapter and the shoring fundamentals found in the "Protective Systems" chapter. Trench rescue shoring designs and procedures vary among jurisdictions, so if the designs and procedures found in this chapter differ from those used by your jurisdiction, please be sure to evaluate the strength of the systems you are using. At a minimum, all systems being installed should be capable of resisting at least twice the potential load of the soil you are dealing with.

Trench rescue shoring, as described in this text, has specific uses and limitations. The equipment and techniques available to most trench rescue response teams are capable of shoring collapsed trench walls that are less than 20 feet (6.1 m) deep and are for the most part still standing in a nearly vertical position. The trenches can be either non-intersecting (straight-wall) or intersecting, and are commonly dug to install or repair underground utilities. Trenches dug next to buildings (for basement-wall waterproofing or repair) also can be safely shored with rescue shoring equipment and techniques.

The aforementioned trenches are the source of the majority of trench emergencies and, therefore, should be the type you consider when developing trench rescue shoring systems. That said, the typical shoring equipment and techniques used by rescue teams are not designed for extreme soil (C-80 and soil below the water table) or extreme trench depths (deeper than 20 feet [6.1 m]). When extreme conditions exist, rescuers should implement a transitional shoring strategy that begins with protecting the victim with on-scene equipment and moves to the use of commercial shoring methods. (See the "Protective Systems" chapter for details.)

Certain steps need to be taken at all trench incidents. For the sake of organization and explanation, they are listed here as applicable to trenches of all types and will not be mentioned again under the specific techniques and drills found in this chapter.

- Establish an incident command system that assigns accountability and responsibility for specific job functions to specific individuals. This will help organize the scene and provide for the necessary accountability of personnel.
- Provide hazard control to eliminate any existing or potential hazards that could jeopardize the rescue operation.
- Monitor the area around and in the trench before and during the extrication effort. Remember to monitor for oxygen, flammability, and toxicity before taking any actions. (Refer to the "Hazard Control and Atmospheric Monitoring" chapter for action levels and parameters for entry.)
- Consider ventilation at all trench rescues, even if you do not use it. Remember that ventilation has both advantages and disadvantages. If it is not needed, do not use it!
- Install ground pads or lip bridges based on the soil conditions and depth of the trench whenever rescuers are working in and around the trench.
- Ladder placement needs to be one of the first steps, in case one of the rescuers or a

bystander falls into the trench before the protective system is built. Place the first ladder in the trench where the work is being done (near the victim). Ultimately, provide at least two points of egress and ingress for all persons in the trench. The Occupational Safety and Health Administration (OSHA) requires a means of egress to be no more than 25 feet (7.6 m) from every construction worker in a trench. A best practice for rescuers is to have ladders spaced no more than 15 feet (4.6 m) apart.

- Provide all personnel with a preoperational briefing that at a minimum includes information on the overall goal of the operation, specific protective system design, assignments, safety requirements, accountability system, and emergency evacuation procedures.
- Event documentation is critically important from a cost-recovery standpoint. From a legal perspective, you can assume that someone will get sued if a significant injury or a fatality is incurred. Keep good records.
- Every incident should be followed by a postincident critique. Trench rescues do not happen very often. Critique them, and resolve all safety and performance discrepancies.

It is only after careful consideration and risk–benefit analysis that you should ever enter a trench before the complete protective system is in place. Check your organization's policies and procedures on entry criteria. In a recovery situation, never enter the trench until the entire protective system is in place. Follow the manufacturer's recommendations for shoring installation.

Rescue Shoring Strategy

Trench shoring is commonly taught by instructing rescue personnel through the installation of shoring systems that are specifically designed for selected trench sizes, shapes, and conditions—in other words, absent a full understanding of the strategy associated with the system and how it functions. Consequently, the sequence of assigned shoring tasks (procedures) is geared toward how the system will function when the entire shoring system is in place. These practices are fine for workers shoring trenches dug for utility repair or installation because they have the luxury of waiting until all system components are in place before entering the trench.

Unfortunately, this type of construction-based shoring mentality has permeated trench rescue operations. The major problem is that procedures used for underground construction shoring fail to address the most important element of shoring for rescue: protecting the victim. The practice of installing the entire shoring system before addressing the issue at hand must sometimes be sacrificed to keep the victim alive.

A fundamental trench rescue shoring strategy should always start with what is required to immediately protect the victim. The strategy (and corresponding tactics) must be easily expanded from that point to create a safe working area for rescuers. The shoring system strategy is then completed with a continuation of efforts that are necessary to maximize rescuer and victim safety during the extrication process.

A three-phase strategic approach can take what appears to be an overwhelming task and divide it into manageable pieces. By dividing the shoring into phases, we create separate but linked goals for each phase. These goals must be recognizable and attainable even at complex trench rescue situations. The fundamental trench rescue shoring strategy consists of the following steps:

1. Primary shoring to quickly protect the victim
2. Secondary shoring to create a safe working area for rescuers
3. Complete shoring to maximize safety during the extrication and patient removal process

Tactics and procedures specific to each of the three phases must be learned and practiced often.

■ Primary Shoring

The purpose of primary shoring is to rapidly provide protection to the victim(s) by stabilizing the area(s) of the trench that is (are) most likely to collapse. The scope of primary shoring includes the use of strategically placed panels and struts, spot shores, and skip shores. Strut pressures are sometimes temporarily set lower than the manufacturer's specifications and are used to temporarily hold the soil in place until backfill can be added and the initial shoring can be expanded into a full system. Primary shoring is usually concluded with the placement of one or two struts. A good primary shoring plan must allow for future installation of secondary shoring.

■ Secondary Shoring

The purpose of secondary shoring is to provide a safe zone for rescuers working inside the trench. The scope of secondary shoring includes expanding and enhancing the area shored during primary shoring. A common goal of secondary shoring is the development of a safe zone that is 12 feet (3.7 m) wide (three-panel set). Appropriate vertical and horizontal strut spacing must be achieved within the shored area. During secondary shoring, backfill is put in place and all struts are activated to the manufacturer's recommended pressures.

■ Complete Shoring

The purpose of the third phase—complete shoring—is to maximize the safety of the rescuers and the victim during extrication and victim removal operations. The scope includes the creation of a safe zone that is at least as wide as it is deep (e.g., a 15-foot [4.6-m] deep trench with three panels set and with rescuers working inside would be expanded to a four-panel [16-foot; 4.9-m] set). In complete shoring, all struts are pressurized to the manufacturer's specification, all strut bases are nailed, and supplemental shoring (when needed) is in place.

In the shoring drills in this chapter, these three phases will be explicitly identified. Rescuers should practice completing the steps in each phase before venturing into the steps listed under subsequent phases.

Trench Rescue Level I

Straight-Wall Trench

The straight-wall trench is the first shoring system presented in this chapter because it clearly shows the basis of the fundamental rescue shoring strategy **FIGURE 11-1**. A straight-wall trench that is at least 12 feet (3.7 m) long requires the rescuer to use a minimum of three sets of panels.

■ Straight-Wall Shoring

To shore a straight-wall trench, follow the steps in SKILL DRILL 11-1:

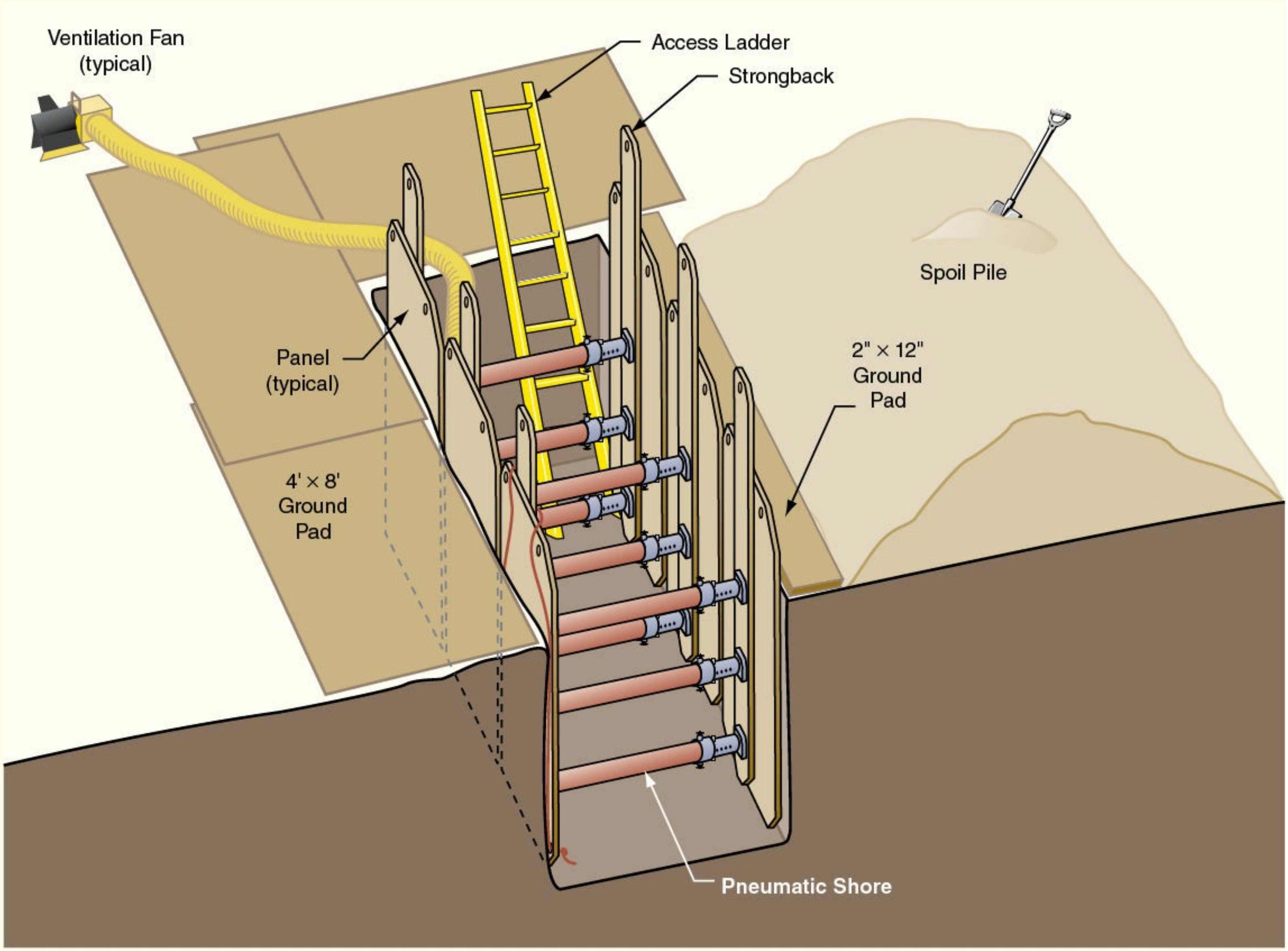


FIGURE 11-1 The straight-wall trench.

1 Using either a same-side or opposite-side technique, align the first (primary) set of panels to cover the walls on each side of the victim's head and chest STEP 1. Primary panels and a single strut can often provide protection to the victim if the soil becomes active (starts moving) before the team gets more shores in place. Procedures for installing struts will vary depending on the type of shore being used. (See the "Protective Systems" chapter for details.)

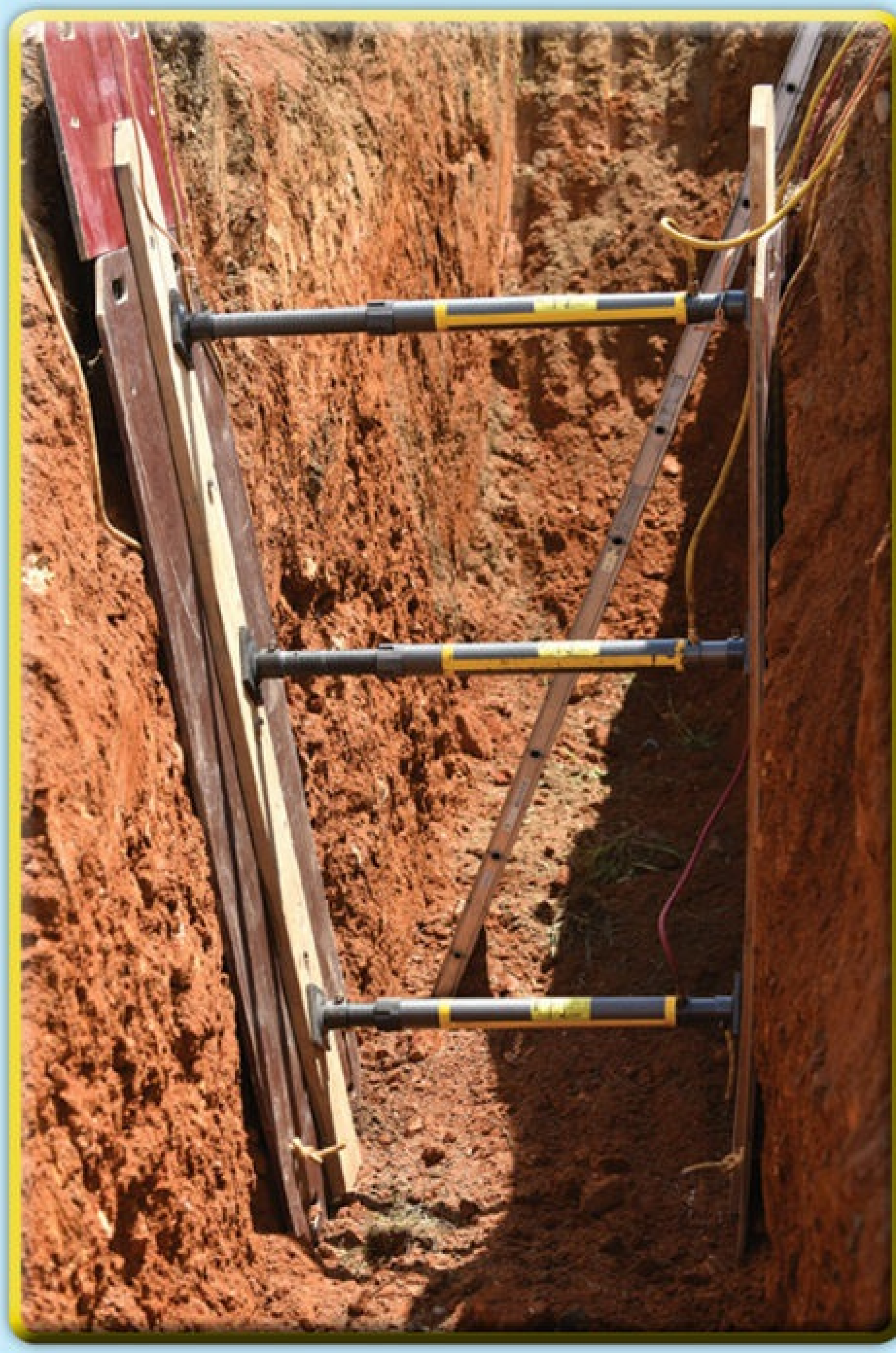
SKILL DRILL 11-1 Shoring a Straight-Wall Trench

Primary Shoring

1 Using either a same-side or opposite-side panel set, position the first set of panels to protect the victim.

2 For this drill, install the first strut (200 psi) about halfway between the trench floor and the lip.

Secondary Shoring



3 Add struts to the primary panel set, typically the middle, bottom, then top struts.

4 Create a safe area for the rescuers by placing two additional sets of panels on either side of the first set of panels.

5 Install the struts to the secondary panel sets. Complete backfill and bring strut pressures to the manufacturer's recommendations.

Complete Shoring

6 Nail all strut bases, expand the safe zone, and install supplemental shoring as needed.

2 Install the first strut in the panel set in a position where it will best prevent additional collapse. If this strut is installed on solid wall surfaces (no voids or impending signs of collapse), it can be shot at 200 psi **STEP 2**. (See the "Protective Systems" chapter for strut pressure options.)

3 Add struts to the primary panel sets to comply with vertical spacing requirements. The typical sequence of middle, bottom, top will apply unless otherwise indicated by impending collapse conditions **STEP 3**.

4 Begin to expand the safe zone by adding panels to both sides of the primary panel set. These are called secondary panels **STEP 4**.

5 Install struts in all three panel sets using horizontal and vertical spacing as determined by the strut manufacturer or a registered professional engineer **STEP 5**. Complete backfill and bring all strut pressures to the manufacturer's recommendations.

6 To complete the shoring, expand the safe zone with panels and shores as needed. The panels need to make the rescuer work area at least as long as the trench is deep. Nail all strut bases with 16d nails **STEP 6**. This prevents the struts from falling if the system shifts or becomes loose. Install supplemental shoring as needed during extrication operations.

Outside Wales

An outside wale is used to span a large void in a trench wall. The void created in this collapse situation is usually larger than a void that can be filled with soil, timber, or single air bag backfill techniques. Rather, it requires that sets of outside wales (usually at least two sets) be installed to span the void created by the cave-in. The wales provide a backing or foundation that supports the panels. They also provide a temporary point of resistance for the struts and any subsequent forces (soil pressure) being transferred from the opposing wall **FIGURE 11-2**.

To install outside wales, follow the steps in **SKILL DRILL 11-2**:

1. When using the outside wale technique, it is helpful to install pickets to hold the wales in place while the panels are being set **STEP 1**. To use this method of supporting the wales, find a location with sturdy ground that will hold the weight of the wales. Make certain that the pickets are installed far enough away (at least 4 feet [1.2 m]) from the trench lip so that any vibration caused by the driving of the stake will not trigger a secondary collapse.
2. After the pickets are in place, lower and tie off the bottom wale; then do the same for the top wale **STEP 2**. In most cases, the best location for each wale is a position that maximizes the function of spanning the void. If the lip has collapsed, the top wale must be a maximum of 2 feet (0.6 m) below the trench lip. This provides support for the top strut and the forces that could be transferred through it from the opposite wall. The placement of the next wale can be determined by splitting the distance between the top wale and the bottom of the void opening and placing the wale at that location. The larger the void, the greater the number of wales that will be needed to span the opening.

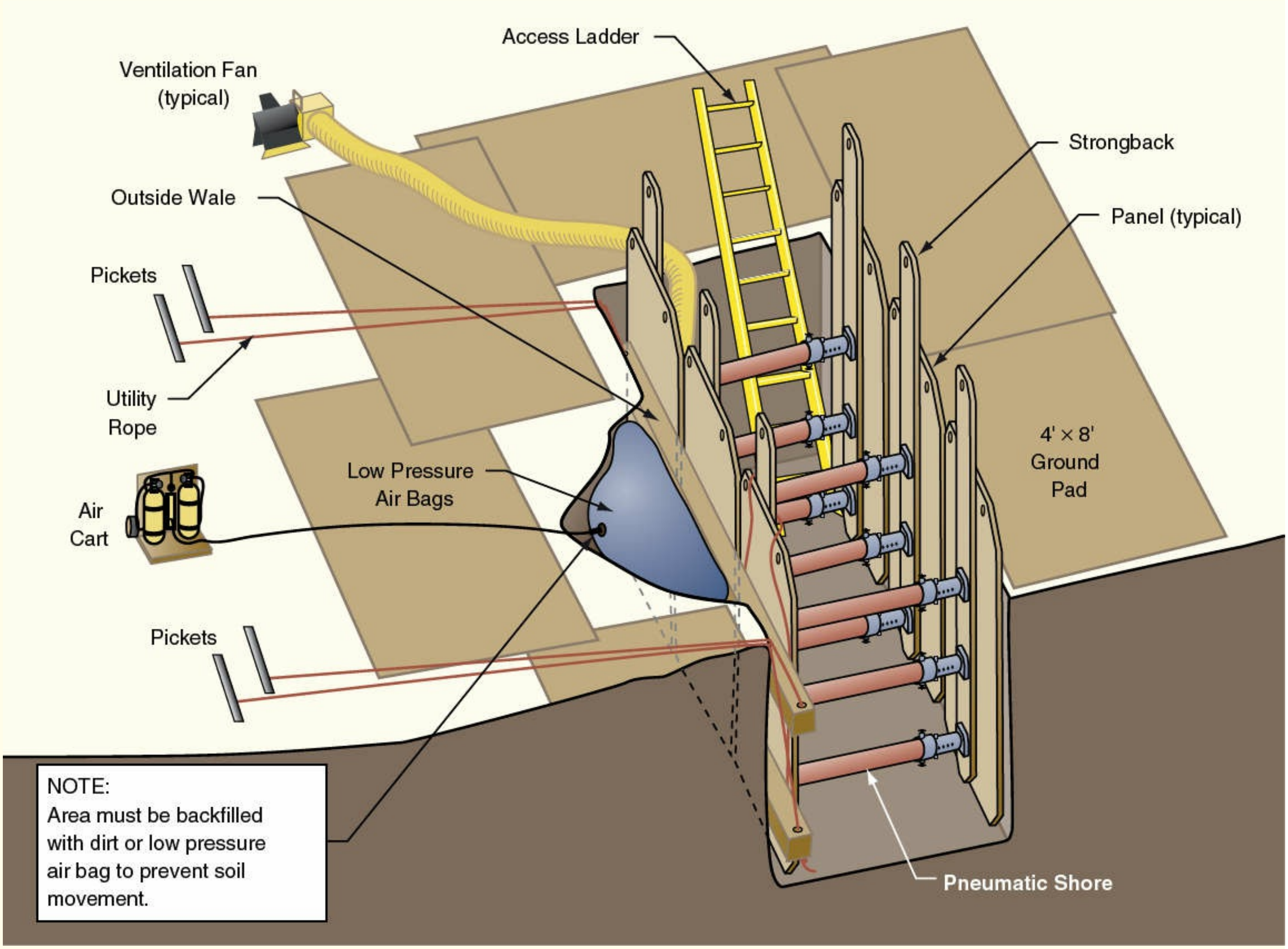


FIGURE 11-2 Outside wale (single-wall collapse).

Safety Tip

Wales must have the capacity (minimum 2:1 safety factor) to resist the soil pressure at the depth and type of soil where they are being used. See the "Equipment" chapter for wale best-practice recommendations.

3 Position the first set of panels to protect the victim(s) from collapse. Next, install the primary strut in a position that will support the section of wall that is most likely to collapse **STEP 3**. If you are using pneumatic or hydraulic struts, you will need to temporarily reduce the strut pressure (maximum 100 psi) until adequate backfill is in place behind the panel. If the struts that you are using require a rescuer to enter the trench, you must take the rescuer's safety into account when placing the primary strut.

Tactical Tip

When possible, backfill the opening behind the wale with appropriately sized low-pressure air bags, timbers, and/or soil after the strut is installed. Inflate the bag to fill the void, but only to the point where the expansion of the air bag starts to move the wales and panels. More than one low-pressure air bag may be required to fill the void, depending on the size of bags available and the size of the void being filled.

Tactical Tip

Secondary shoring a straight-wall trench normally means setting a minimum of three sets of panels **FIGURE 11-3**. One set of panels is placed directly over the victim, and the other sets of panels are positioned on either side of the victim. However, the trench size (length, width, depth) may not be conducive to use of a three-panel set. Additionally, obstructions (e.g., pipes, underground wires, heavy equipment) in the trench may make it difficult to install full panels. Rescuers must be capable of overlapping and cutting panels to fit.

FIGURE 11-3 The three-panel set in a straight-wall trench.

4 Expand the safe working zone by installing secondary panels and shores on both sides of the primary panel sets STEP 4. When necessary, rescuers can enter the trench and help set the outside panels and struts from within the safe zone created by the primary shores. Minimize exposure time for rescuers working in trenches prior to completing shoring.

5 After all of the secondary panels and shores are set and a safe area around the victim is secured, personnel should complete the backfill of existing voids behind every panel and bring all strut pressure to the manufacturer's recommendations STEP 5. The potential for active soil should be eliminated before team members enter the trench for rescue or recovery of the victim. Air bags (previously positioned but not filled) used for backfill can minimize soil movement by matching the bag pressure to the soil pressure. (See the "Equipment" chapter for more information on air bag backfill.) If air bags will not work or

are unavailable, dirt can be used to backfill voids **FIGURE 11-4**.

6 To complete the shoring, expand the safe zone with panels and shores as needed. The panels should make the rescuer work area at least as long as the trench is deep. Nail all strut bases with 16d nails to prevent the struts from falling if the system shifts or loosens **STEP 6**. Install supplemental shoring as needed during extrication operations.

Completed outside wale shoring is shown in **FIGURE 11-5**.

Tactical Tip

In some situations (e.g., lip shears), panels will need to be held in place by struts shot at reduced pressures. These temporary strut pressures should be 100 psi or less while backfilling is being conducted. When backfill is completed, all strut pressures need to be increased to the manufacturer's specifications.

Safety Tip

Entering a trench before the voids are backfilled and shored is not advisable because the unsupported soil left by the void may become active.

Inside Wales

Inside wales are commonly used to span a set of panels to create an open space **FIGURE 11-6**. (Minimum 8 × 8-inch timber or 7 × 7-inch LVLs should be considered for use as wales.) The open space may be required to provide room for digging or extrication operations or to shore around an obstruction that cannot be moved.

Whenever a rescue or recovery will require significant digging activity, using inside wales to create an open work area is a preferred technique. The open space created around the victim facilitates rescuer movement and eliminates strut-related obstructions as a concern for victim packaging and extrication.

To use inside wales, follow the steps in **SKILL DRILL 11-3**:

1 Install pickets to hold the wales in place while the panels are being set **STEP 1**. To use this method of supporting the wales, find a location with sturdy ground that will hold the weight of the wales. Make certain that the pickets are installed far enough away (at least 4 feet [1.2 m]) from the trench lip so that any vibration caused by the driving of the stake will not trigger a secondary collapse.

SKILL DRILL 11-2

Outside Wale Shoring

(Trench Rescue Level I: 8.1.2, 8.1.4)

Primary Shoring

1 Install pickets to hold the wales in place.

2 Lower the wales (bottom first, then top) and tie them off at the desired depths.

3 Set the primary panels in place and install the first strut (up to 100 psi) where it is needed to prevent the next collapse.

Secondary Shoring

4 Expand the safe zone by lowering secondary panels into place and installing struts to the secondary panels.

5 Backfill voids behind all panels and increase strut pressure to the manufacturer's recommendations.

Complete Shoring

6 Nail all strut bases, expand the safe zone, and install supplemental shoring as needed.

FIGURE 11-4 Voids can be filled with dirt when air bags will not work or are not available.
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FIGURE 11-5 Completed outside wale trench shoring.

2 Lower two wales to the bottom of the trench **STEP 2**. Position the wales slightly away from the trench walls so that panels can be placed between the wales and the trench walls. Tie off the wale ropes so that they do not get kicked into the trench. If a wall is in danger of imminent collapse, skip this step and go to Step 3. The bottom wale can be positioned after the primary shore is in place, but it is a bit more difficult to do.

3 Place the primary panel set to protect the victim from collapse. Install a strut where it is needed to prevent collapse **STEP 3**. (See the "Protective Systems" chapter for strut placement options.) For this drill, that position will be in between the floor and the lip on the primary panel set. Strut pressure should be 200 psi if no voids are behind the panels. Strut pressure should be up to 100 psi if voids exist behind the panels. This step concludes primary shoring and should protect the victim from subsequent collapse while shoring is completed.

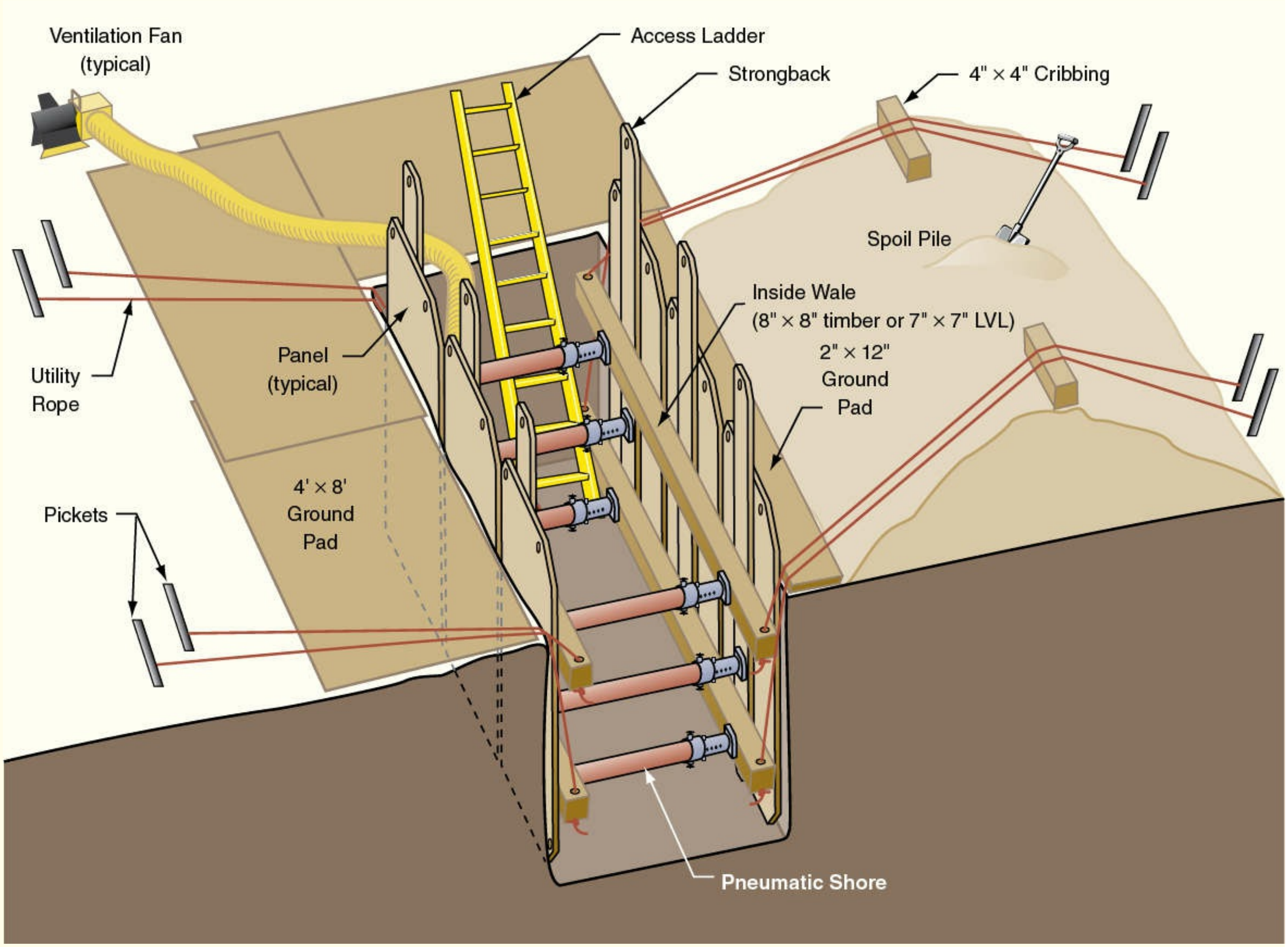


FIGURE 11-6 Inside wale trench.

4 After the primary shore is in place, position both sets of secondary panels, one set on each side of the primary panels **STEP 4**.

5 Tack-boards or panel ropes (tied back to pickets) may be used to hold three panels on each side of the trench in place while struts are being installed **STEP 5**. To use tack-boards (2 × 4 inches × 10 feet), simply nail the tackboard to each of the three panels' strongbacks.

6 Install struts halfway between the floor and the lip on both secondary (outside) sets of panels **STEP 6**. If struts are being installed by rescuers in the trench, it is critical to minimize rescuer exposure to partially shored areas of the trench.

7 Raise the bottom wales (maximum of 2 feet [0.6 m] above the trench floor) on both sides. Install struts on the bottom wales at the point where the wale crosses the strongbacks of each outside (secondary) panel **STEP 7**.

8 Position the top wales within 2 feet (0.6 m) of the trench lip and secure them with struts, as performed in the previous step **STEP 8**.

9 The strut on the middle (primary) panel can now be removed **STEP 9**. The wales will span and support the center set of panels, creating a fully open space to continue rescue or

recovery operations.

10 To complete the shoring, expand the safe zone with panels and shores as needed. Placement of the panels should make the rescuer work area at least as long as the trench is deep. Install supplemental shoring as needed during extrication operations. If using wooden wales, nail all strut bases with 16d nails. This prevents the struts from falling if the system shifts or loosens STEP 10.

SKILL DRILL 11-3

Inside Wales

(Trench Rescue Level I: 8.1.2, 8.1.4)

Photos show use of aluminum wales. Prior to using aluminum wales in your locality, tabulated data should be obtained from a registered professional engineer.

Primary Shoring

1 Install pickets on both sides of the trench to tie off wales and/or panels as needed.

2 Lower the wales to the trench floor.

3 Position the primary panels and strut to protect the victim.

4 Install secondary panels on both sides of the primary shores.

5 Use tack-boards or ropes to hold panels in place.

6 Install the middle shores on the outside panels.

7 Raise the bottom wales and tie them off no more than 2 feet (0.6 m) above the trench floor. Install struts on the wales at the outside panels/strongbacks.

8 Position the top wales no more than 2 feet (0.6 m) below the trench lip and install the struts.

9 Remove the first strut (primary) to open up the area.

Complete Shoring

10 Expand the safe zone with panels and shores as needed. Placement of the panels should make the rescuer work area at least as long as the trench is deep. Install supplemental shoring as needed during extrication operations.

VOICES OF EXPERIENCE

On July 30, 2014, at 1505 hours, a call was received for a person trapped in a trench at 6550 North Maple Road in Pittsfield Township. Pittsfield Township Fire Department (PTFD) initially responded with three engines and seven personnel. An ALS ambulance was also dispatched.

Engine 3 arrived at 1515 hours and established command. The engine company conducted the initial assessment and found one person alive, standing upright in a 2-foot (0.6-m) wide by 12-foot (3.7-m) long trench immediately adjacent to a single-family residence. The trench was initially 8 feet (2.4 m) deep, but was now 4 feet (2.1 m) deep as the lip had collapsed around the victim. The victim was buried up to his chest, but had used a shovel to remove dirt from around himself. The workers had been digging a trench along the house to expose the basement wall to apply tar seal for water proofing.

Command requested the Washtenaw County Technical Rescue Team (WCTRT) at 1509 hrs. First-arriving companies evacuated the coworker and resident from around the trench and finished a hazard assessment. Fire fighters placed a ladder into the trench and moved the spoil pile away from the trench lip. A fire fighter and paramedic were also assigned to monitor the victim from the porch of the house.

"Once an area was secured around the victim, rescuers entered the trench, both in front of and behind the victim, and started to remove dirt by hand."

Rescue 17-1 (WCTRT) arrived with the county's main trench equipment cache. Technical rescue team officers were placed in charge of operations and team management. Using both PTFD and WCTRT personnel, ground pads were placed along the trench lip and shoring equipment was staged.

An automatic response from the Washtenaw County Hazardous Materials Response Team is activated when the WCTRT is dispatched to a confined space, trench, or structural collapse incident. At this incident, they assisted with continuous air monitoring in and around the trench, as well as documentation. Air quality readings were initially normal but dropped at some points during the rescue, demonstrating the importance of continuous monitoring.

The panel team managed the placement of shoring panels and back-fill, and a shoring team installed pneumatic struts. Another team was assigned to make entry into the trench to finish removing the soil from around the victim.

A vacuum truck was requested from the Pittsfield Township Utilities Department. The WCTRT carries vacuum hose and all the clamps and adapters necessary to extend off of a vacuum truck. The team had trained twice with the Pittsfield Township operators during the previous year. Prior to its arrival, equipment was moved to allow the vac truck to approach within approximately 50 feet (15.2 m) of the work site.

A shoring panel was placed horizontally into the trench, covering the exposed wall over the victim down to the existing level of the collapse. Two medium-pressure air bags were used to fill the area behind the shoring panel that had fallen in on the victim. Pre-cut pieces of 2 × 12-inch lumber, each approximately 2 feet (0.6 m) long, were secured to the Paratech swivel bases that were placed against the exposed basement concrete block wall, as the struts were placed in the trench. Once an area was secured around the victim, rescuers entered the trench, both in front of and behind the victim, and started to remove dirt by hand.

When the vacuum truck arrived, a crew was assigned to extend the 8-inch (20.3-cm) vacuum hose up to the trench. An air knife was fed by an industrial compressor mounted on R 17-2. Because the soil was very sandy, the air knife and vacuum system worked well for removing dirt from around the victim's legs. The 8-inch (20.3-cm) hose was then reduced to 4-inch (10.2-cm) hose, allowing for easier movement around the victim. As the amount of entrapment was reduced, the shoring crew inserted additional spot shores to prevent the loose soil from raveling down into the hole.

Because the vacuum truck was dispatched while they were out performing other routine maintenance, they arrived on site with their tank approximately two-thirds full. This became an issue before the victim was completely free because the tank filled quickly. The township utilities superintendent was on-site and authorized the truck to dump a portion of its contents on the lawn to allow more dirt to be vacuumed from the trench. This prevented the need to back the vacuum truck out and replace it with another truck from another jurisdiction.

The weather became a concern approximately 1 hour into the incident. Several small storms were moving through lower Michigan at the time. The county emergency manager was consulted and advised that no severe storms were forecasted for the immediate area around the incident. The safety officer used his phone to monitor radar images throughout the afternoon. As a line of rain showers approached the area, the safety officer advised the rescue team manager of the potential hazard and the rescue team manager assigned a group to prepare a tarp for shelter. They secured a large tarp to the roof of the house directly above the trench and were prepared to deploy the tarp over the trench and secure it to poles in the yard to keep rain from compromising the trench. Fortunately, the series of showers split and went around the incident several times during the afternoon.

As the dirt was removed to the victim's knee level, a team was assembled to prepare a removal system. A ground ladder was placed over the victim, supported by the house's roof line. A life safety rope was run through a pulley at the top of the ladder and down into the trench. The victim was placed in a LSP Halfback device and supported on the rope system as the disentanglement was completed.

Several television, radio, and other news personnel had begun to arrive and fly over the scene. The WCTRT Team Director was assigned as the Press Information Officer. The media was assembled approximately 100 feet (30.5 m) from the trench and kept updated on the incident's progress.

The victim was freed at 1750 hours, lifted from the trench, and placed on a cot at the edge of the trench. He was in stable condition, but due to the length of entrapment and the transport time by ground, he was flown to University of Michigan Hospital, the closest Level I trauma center.

In total, eight Pittsfield Township Fire Department members, 28 WCTRT members, seven medical personnel, three utilities personnel, four fire apparatus, three technical rescue trucks, and one technical rescue trailer responded to the scene.

Because the initial arriving officer and overall incident commander was trained to the technician level in trench rescue, he was able to assess the incident properly, initiate appropriate initial actions, and request appropriate resources. Additionally, because almost all the fire fighters from the initial responding fire department were trained to the operations level, they understood the rescue process and were able to assist the TRT in many aspects.

One TRT member was assigned as an accountability officer early in the incident and could provide an accurate account of "who did what and when" throughout the incident. Assigning someone to this seemingly mundane task proved to be extremely important during the post-incident analysis and for writing an accurate report.

Although joint operations between the county technical rescue team and the county haz mat team had been tested several times during training evolutions, a few issues arose during this incident. Site access, need for awareness-level training, demarcation of responsibility, and the importance of ongoing air monitoring documentation were brought up during the post-incident analysis.

The vacuum truck was a great resource, and because the TRT had trained with the operator of the vacuum truck during the previous year, the on-site briefing was short and sweet. In fact, the operator exited the truck smiling, being excited about being able to use his previous training during an actual rescue so quickly. This demonstrates that training with the local resources is extremely valuable.

A continual assessment of PPE is important. Hazards had been routine for most of the incident.

However, when the air knife was used, respiratory and eye protection for the victim as well as the rescuers in the trench became very important.

Calm and cooperative attitudes among team members were also key. In this setting, the house occupied one side of the trench, which limited the access. The rigging, digging, shoring, and panel teams were all vying for the same real estate, slowing operations at times.

Carl Hein
Lieutenant, Ann Arbor Fire Department
Strike Team Manager, Washtenaw County USAR Strike Team
Ann Arbor, Michigan

Trench Rescue Level II

Supplemental Shoring

After secondary shoring has been installed, rescuers may need to add modified (cut-down) sheeting and shoring to complete the shoring task. This process, which is called supplemental shoring, can be used to extend shoring either between (vertical) or under existing shoring systems FIGURE 11-7.

The need to extend under existing shoring usually stems from removal of soil while digging to extricate a buried victim. As a result of digging, the trench wall becomes increasingly exposed. The soil can be removed using a variety of techniques, including entrenching shovels, buckets, air-knives, and vacuum systems. Exposed portions of a trench wall are subject to collapse and must be shored. Whenever 2 vertical feet (0.6 m) of wall is exposed, additional (supplemental) shoring must be added.

Supplemental shoring is a Trench Rescue Technician (Level II) skill required to improve safety during advanced trench rescue operations. In addition to the extra struts required, supplemental sheeting commonly involves 2 × 4-foot (0.6 × 1.2-m) sections of shoring panels and 4-foot (1.2-m) long sections of 2 × 12-inch lumber. A strut and supplemental panels must be installed for every 2 feet (0.6 m) vertical and 4 feet (1.2 m) horizontal area of trench wall that is exposed as a result of digging.

Options for the supplemental sheeting that will be used under secondary shoring panels include ¾-inch FinnForm cut into 2 × 4-foot (0.6 × 1.2-m) sections or 2 × 12-inch lumber cut 4 feet (1.2 m) long. Strongbacks (2 × 12 inches at 36 inches [0.9 m]) can be bolted or screwed to the supplemental sheeting, or can be nailed together at the scene. Some strut manufacturers now offer spot shore rail bases that can be installed directly to the sheeting and eliminate the need for strongbacks for supplemental shoring.

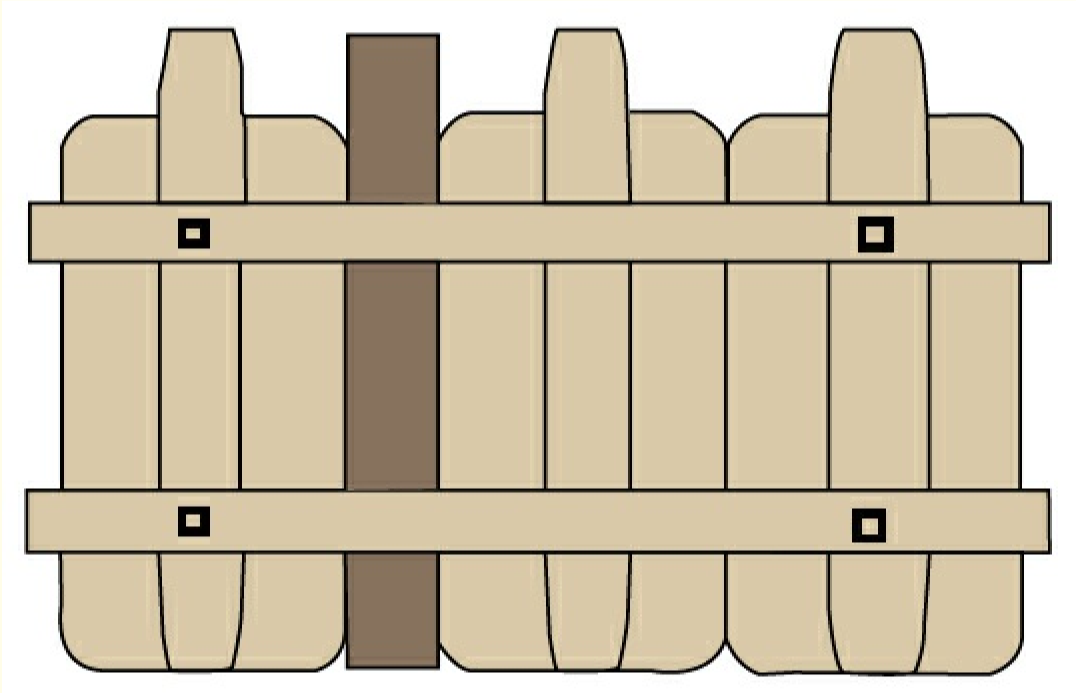


FIGURE 11-7 Vertical supplemental sheeting.

Tactical Tip

Traditional trench rescue panels consist of 4 × 8-foot panels and 12-foot (3.7-m) long 2 × 12-inch lumber strongbacks. The strongback usually extends 2 feet (0.6 m) past the panel on both ends FIGURE 11-8. Attempting to install supplemental sheeting behind these extended strongbacks can be both frustrating and time consuming. Using rescue panels, which are built with strongbacks that are flush with the bottom of the FinnForm on one end, provides for much quicker installation of supplemental shoring. This panel design also allows you to remove a full 2 feet (0.6 m) of soil from the floor before you need to shore the wall FIGURE 11-9.

Another option is to extend the strongback only FIGURE 11-10.

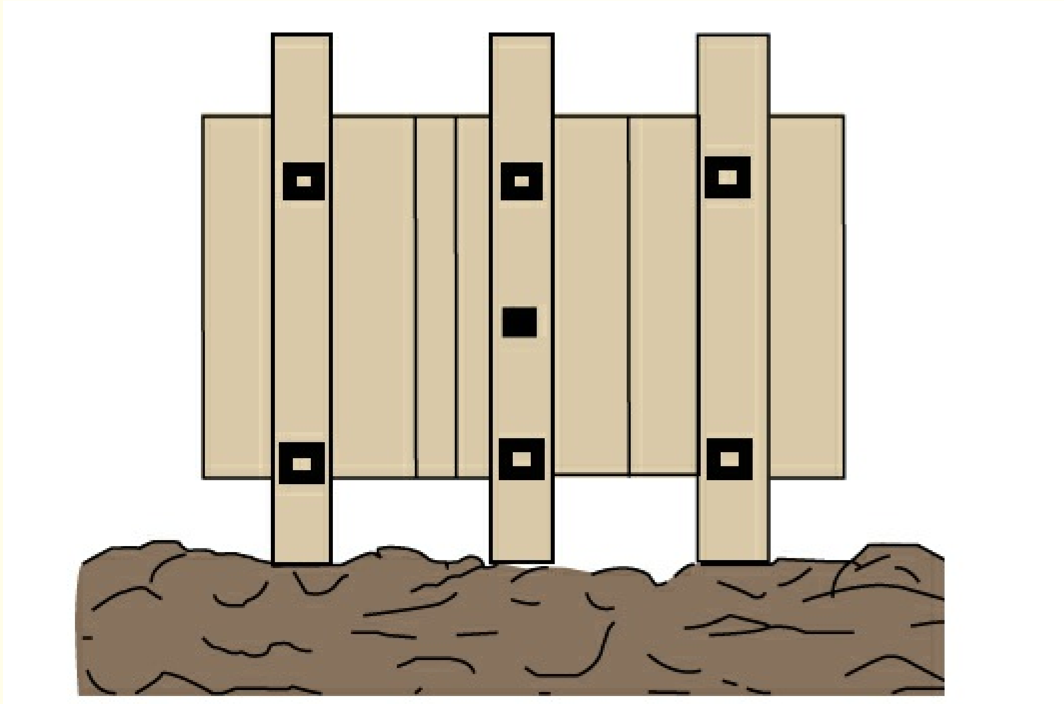


FIGURE 11-8 With this panel/strongback design, there is 2 feet (0.6 m) of exposed wall before digging starts. Installation of supplemental sheeting behind the strongbacks (extending below the panel) is difficult and time consuming.

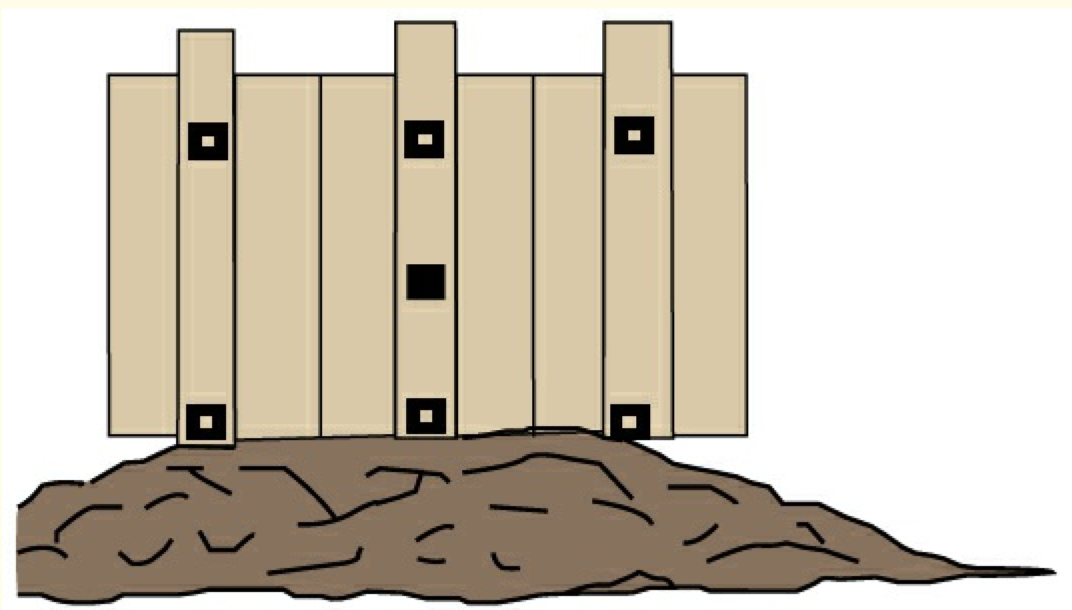


FIGURE 11-9 With this panel/strongback design, you can remove 2 feet (0.6 m) of soil from around the victim before 2 feet (0.6 m) of wall is exposed.

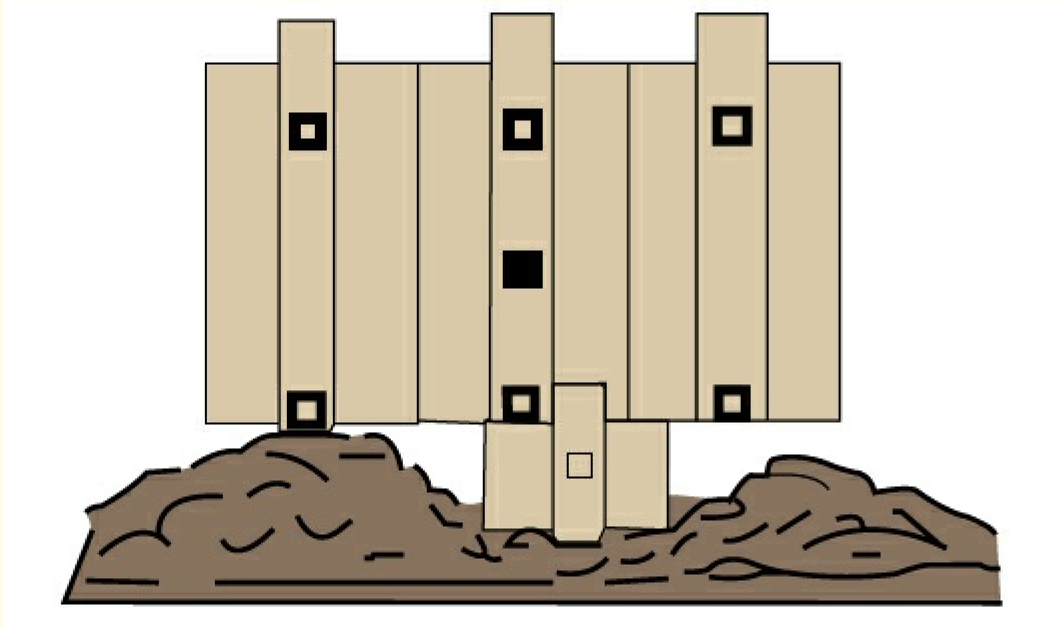


FIGURE 11-10 Eliminating the need to fit the supplemental sheeting between the wall and an extending strongback saves significant time and effort.

To install supplemental shoring, follow the steps in **SKILL DRILL 11-4**:

1. Staging supplemental sheeting/strongback and struts near the trench prior to beginning soil removal operations provides for a timely transition into the supplemental shoring operation **STEP 1**.
2. Stop soil removal (digging) when 2 feet (0.6 m) of trench wall is exposed below the strongbacks on opposite sides of the trench **STEP 2**. Install backfill if a void is present.
3. Insert supplemental (2 × 4-foot) sheeting sections directly below the existing panels. If using supplemental panels without attached strongbacks, place a 3-foot (0.9-m) long 2 × 12-inch strongback or a spot shore rail base closely in line with the strongback on the panel above **STEP 3**.
4. Install a strut on the supplemental panel/strongback at the manufacturer's recommended pressure **STEP 4**.
5. Continue soil removal as needed until another 2 feet (0.6 m) of wall is exposed, then repeat the supplemental shoring procedure.

T-Trench

All things being equal (considering the same soil conditions), intersecting trenches are significantly less stable than straight trenches. One reason for this difference is that intersecting trenches have more exposed (wall) surface areas. More unsupported surface area means a higher probability for collapse. Straight trenches have exposed walls running in only one direction, whereas intersecting trenches have exposed walls running in two directions. The area where the two unsupported wall surfaces meet (corners) is the most susceptible to collapse. A T-trench has two such (corner) areas.

The key to successful rescue shoring at intersecting trenches is to capture (support) the inside corners as quickly as possible. In this section, we discuss how to shore a T-trench that has not yet collapsed. This procedure represents an introduction to T-trench shoring and provides the reader with the basic elements of a T-trench shoring design. Given that most intersecting trench rescue incidents will include the collapse of inside corners, you will need additional training and equipment to resolve those issues.

SKILL DRILL 11-4

Installing Supplemental Shoring

(Trench Rescue Level II: 8.2.2)

1 Stage supplemental sheeting/strongback and struts near the trench lip.

2 Stop soil removal (digging) when 2 feet (0.6 m) of trench wall is exposed below a strongback. Install backfill if a void is present.

3 Insert supplemental (2 × 4 foot) sheeting sections directly below the existing panels on both sides of the trench.

4 Install a strut on the supplemental panel/strongbacks.

A typical shallow (less than 10 feet [3 m] deep) T-trench requires the use of inside wales and a minimum of seven panels. Inside wales are necessary to support the center panel(s) on the long wall of the trench because there is no wall across from that panel to which to shore. The inside wales act as headers or simply supported beams and carry the load (soil forces) between the struts. Be sure that the wales you are using have the capacity (minimum 2:1 safety factor) to resist the soil pressure at the depth and type of soil where they are being used. The main objective is to immediately protect the victim and then create a shoring system that supports both the corners and the area of the wall (long leg) that is directly across from the opening made by the intersecting trench (short leg) **FIGURE 11-11**.

When shoring a T-trench, you should limit the number of personnel and the amount of equipment placed at the corners of the intersecting trench. Because these intersections are the least stable, always try to capture the corners first before moving to other areas of the trench. Intersecting trenches require more knowledge, more skills, more equipment, and more personnel to effect a rescue or recovery. Managing operations at these complex incidents can be a challenge, even to very experienced rescue technicians. During the briefing, designating names for key areas of the rescue scene can reduce mistakes and help personnel understand their assignments and locations. A simple sketch of the shoring plan will present a clear concept of the goal for each phase. **FIGURE 11-12A**, for example, shows area designations and the primary shoring plan for an incident; **FIGURE 11-12B** shows the secondary shoring plan.

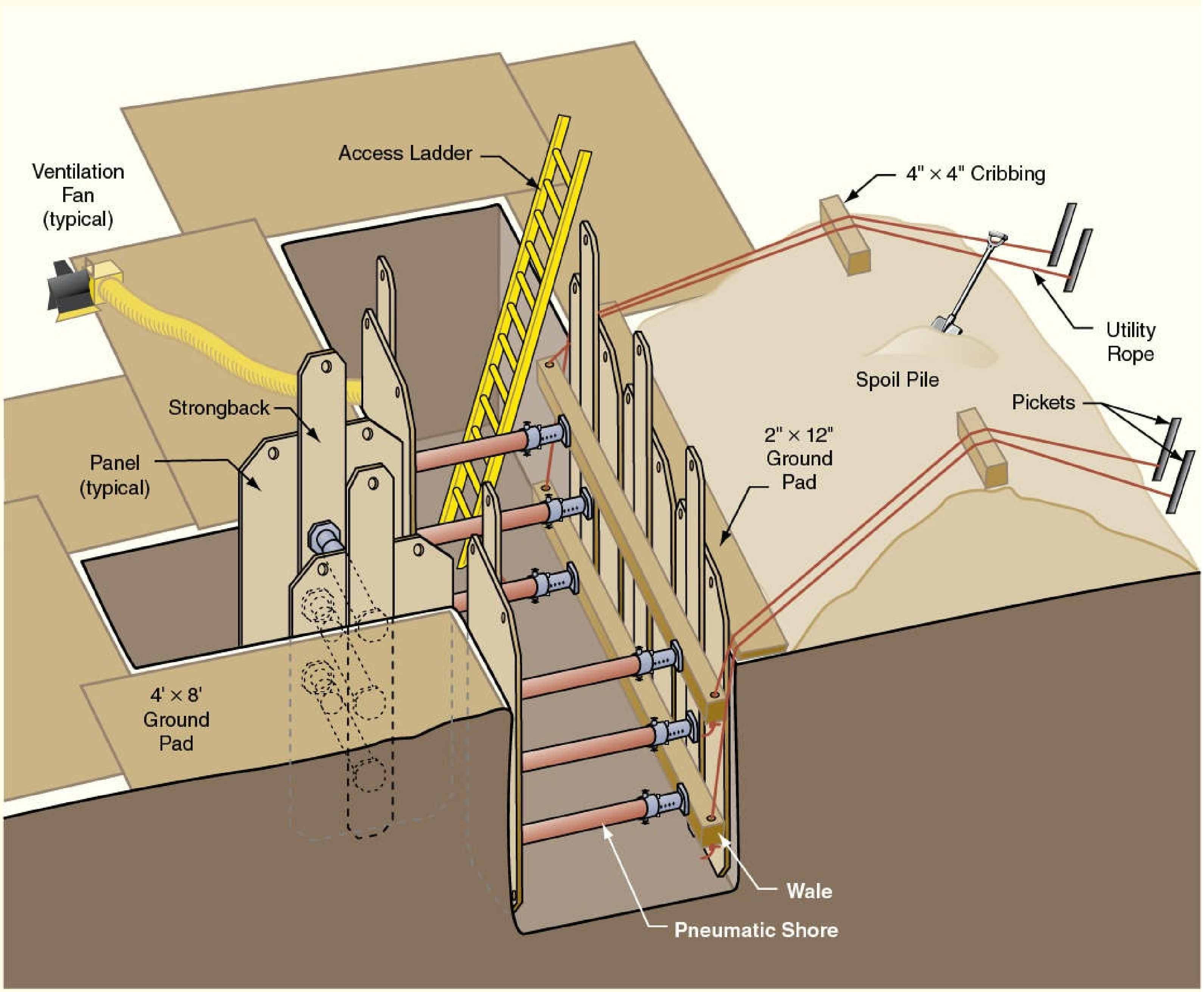


FIGURE 11-11 T-trench.

To shore a T-trench, follow the steps in **SKILL DRILL 11-5**:

1 Begin the operation by setting panels at both corners of the T-trench's short leg **STEP 1**. After these panels are in place, install the first strut in a position where it will best prevent collapse. In a trench that has not collapsed, a middle strut is usually a good choice for strut placement. Strut pressures of 100–150 psi can be used if there is no void behind the panel and strut. This pressure is kept on the low end to reduce forces on the exposed wall around the corner. When a void is present behind the panel where the strut is placed, use strut pressures of up to 100 psi until backfill is completed.

2 After capturing the short-leg side of the trench corners, lower a wale to the bottom of the trench on the long wall **STEP 2**. Make sure that the ropes attached to the wale are tied off to pickets. If a wall is in danger of imminent collapse, skip this step and go to Step 3. The bottom wale can be positioned after the primary shore is in place, but it is a bit more difficult to do.)

FIGURE 11-12 **A.** Example of area designations and a primary shoring plan. **B.** Example of a secondary shoring plan.

3 Install a panel on the corner of the long leg where the victim is located (see Figure 11–12A). Place a panel directly across the trench (on the long wall) from that panel. Install middle struts on the panels just set **STEP 3**. Complete backfill behind the strut location if needed.

4 Repeat the panel and strut installation process on the opposite corner **STEP 4**. Working with one corner at a time, simultaneously increase the pressure on both the short-leg and long-leg struts. Bringing these strut pressures up to the manufacturer's specifications captures the corners and helps prevent a wedge failure of the trench. This step concludes primary shoring and should protect the victim(s) from subsequent collapse.

5 Install additional struts (bottom and top) in the primary panel set (short leg) **STEP 5**.

6 To begin secondary shoring, place a panel between the two shored panels on the long wall **STEP 6**. Strut pressure should be not more than 150 psi.

7 Install pickets to hold the wales in place while the panels are being set **STEP 7**. To use this method of supporting the wales, find a location with sturdy ground that will hold the

weight of the wales. Make certain that the pickets are installed far enough away (at least 4 feet [1.2 m]) from the trench lip so that any vibration caused by the driving of the stake will not trigger a secondary collapse.

8 Raise the (bottom) wale into position (no more than 2 feet [0.6 m] above the floor) and secure it to the pickets. After the wale is in position and the center panels on the long wall are in place, install the bottom struts **STEP 8**. These struts are positioned on the strongbacks of the corner panels and extend over to the wale on the long wall (see Figure 11–12B). The struts on the wale should be positioned where the strongbacks and wale intersect. Pressurizing these struts simultaneously is preferred.

9 Lower the top wale into position (within 2 feet [0.6 m] of the lip) and install struts using the same strut installation procedure as in the previous step **STEP 9**. After all secondary panels, wales, and struts are in place, systematically increase all strut pressures to the manufacturer's recommendations.

10 To complete the shoring, nail all strut bases and expand the safe zone with panels and shores as needed **STEP 10**. The panels should make the rescuer work area at least as long as the trench is deep. Install supplemental shoring as needed during extrication operations.

Complete T-trench shoring is shown in **FIGURE 11-13**.

FIGURE 11-13 Complete T-trench rescue shoring.

SKILL DRILL 11-5

Shoring the T-Trench

(Trench Rescue Level II: 8.2.1)

This drill assumes the victim to be in the short-leg corner of the T-trench. This shoring plan directs the efforts to protect that area first.

Primary Shoring

1 Install primary panels and the first strut to protect the victim.

2 Lower a wale to the trench floor on the long wall.

3 Place a panel on the long-leg corner and a panel directly across from it, and install a middle strut.

4 Repeat the panel set and strut procedure on the opposite corner.

5 Install a bottom and top strut in the primary panel set (short leg).

Secondary Shoring

6 Place a panel on the long wall between the two shored panels.

7 Install two pickets behind the lip on the long wall side.

8 Raise the bottom wale (not more than 2 feet [0.6 m] above the trench floor) and install struts.

9 Position the top wale (not more than 2 feet [0.6 m] below the lip) and install struts.

Complete Shoring

10 Nail all strut bases, expand the safe zone, and install supplemental shoring as needed.

L-Trench

The L-trench consists of two trench cuts or legs that converge at a single point, commonly forming a right angle. This type of trench presents a difficult scenario for rescuers because the inside and outside corners formed by the intersection are difficult to shore with standard trench rescue equipment and techniques **FIGURE 11-14**. The L-trench requires some specialized equipment and advanced shoring methods.

This section provides two methods for shoring an L-trench. One method uses thrust blocks to shore an L-trench that has not yet collapsed. The other method uses corner brackets to shore an L-trench with a moderate-sized inside corner collapse. Details are provided later in this section. Note that both methods—thrust block and corner bracket—are effective for shoring either of these two conditions (collapsed or not). The method that rescue teams choose to implement must be predetermined so that the correct specialty equipment is purchased and its use mastered before it is needed at a rescue incident.

The techniques described in this section are useful for shoring L-trenches that are up to 8 feet (2.4 m) deep. By adding a third tier of shoring, these techniques could be used in L-trenches up to 10 feet (3 m) deep. Shoring a deep-wall L-trench or one with a large collapsed inside corner is beyond the scope of this text and exceeds the requirements of NFPA 1006. However, both of those situations are likely to occur with L-trenches and should be part of your advanced trench rescue shoring training program.

The L-trench requires several panels and wales. Consider setting tie-back pickets for panels and wales immediately after the primary shoring is in place. As with any intersecting trench, it is necessary to limit the number of personnel and the amount of equipment staged at the inside corner of the L-trench. Rescuers near the lip must ensure that they always work on appropriate lip protection. Simple sketches of the primary and secondary shoring designs are an extremely helpful visual aid during team briefings **FIGURE 11-15**.

■ Shoring with Thrust Blocks

The thrust blocks fit over the strongbacks and have both an angled surface and a flat surface from which struts can be shot. The number of wales, corner blocks, and thrust blocks needed is determined by the depth of the trench. For each tier of shoring, you will need two wales, two thrust blocks, and corner blocks **FIGURE 11-16**.

Wooden thrust blocks can be installed on the strongback by toe-nailing them to the strongback or by using a joist hanger. If you are considering placing them on the strongback before installing the panel, keep in mind that the final position of the thrust block will need to meet the maximum vertical strut spacing requirements (2 feet [0.6 m] below the lip, 2 feet [0.6 m] above the floor, and not more than 4 feet [1.2 m] apart).

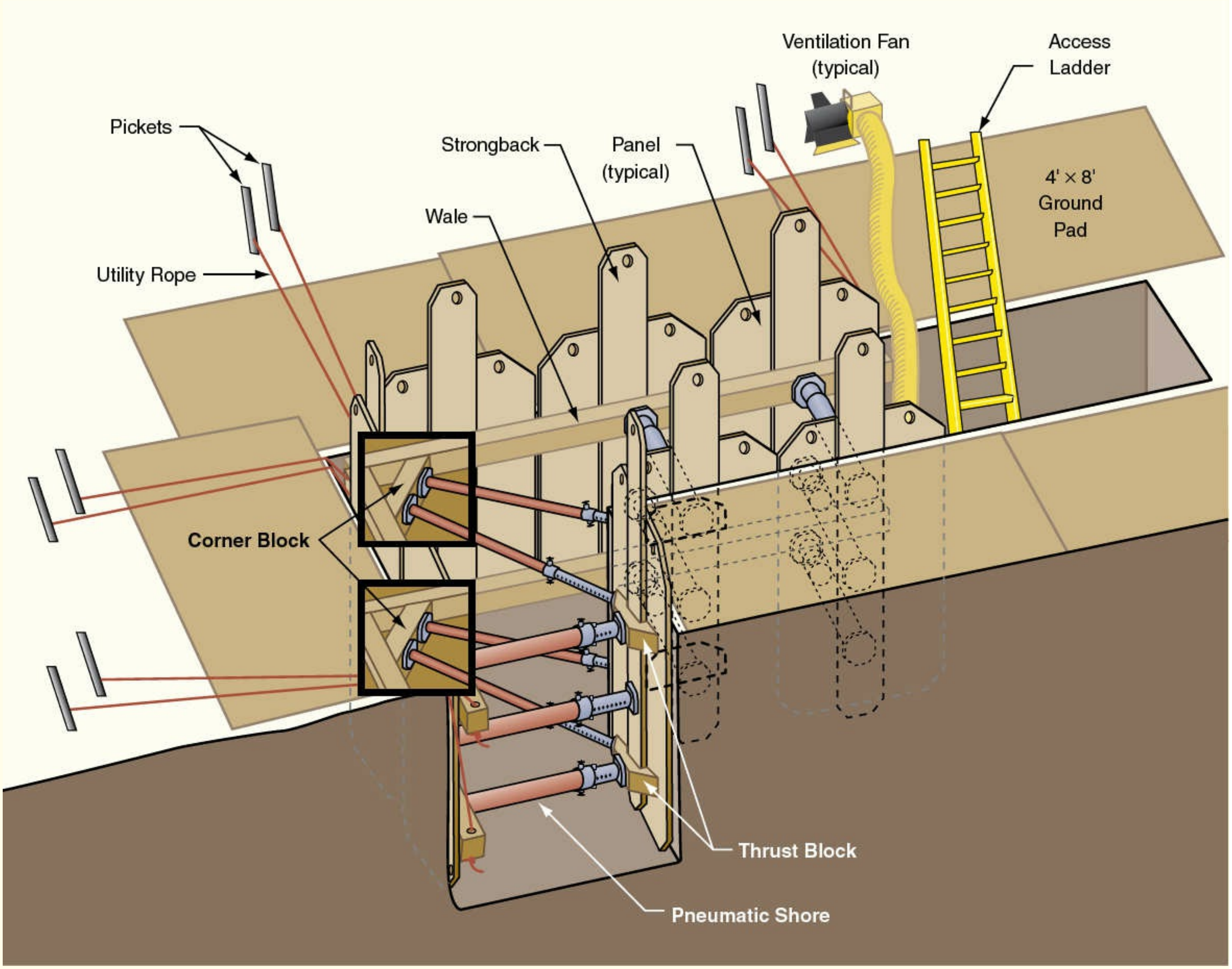
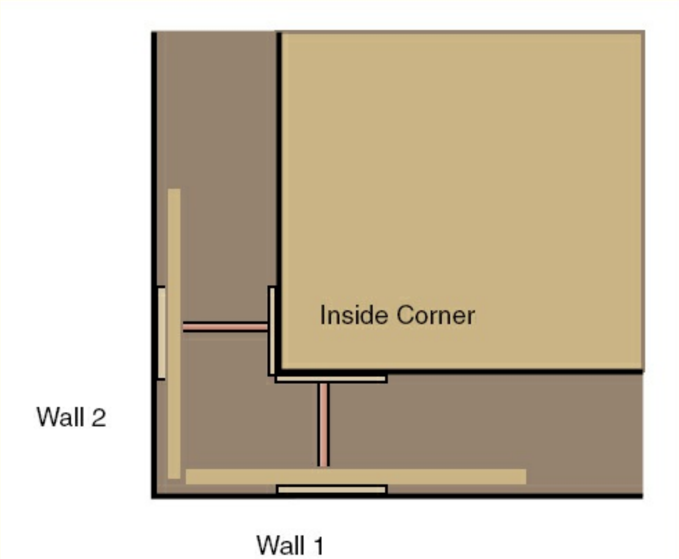


FIGURE 11-14 L-trench.



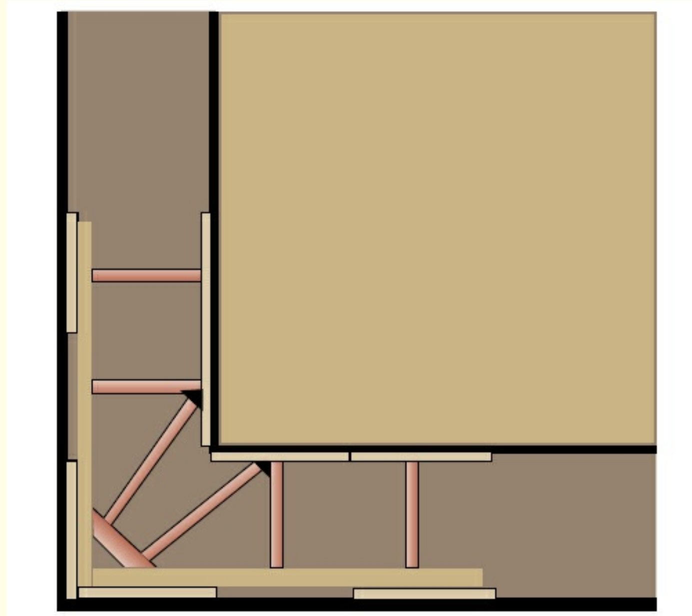


FIGURE 11-15 **A.** Primary shoring sketch (wales on trench floor). **B.** Secondary shoring sketch (one tier of shoring shown).

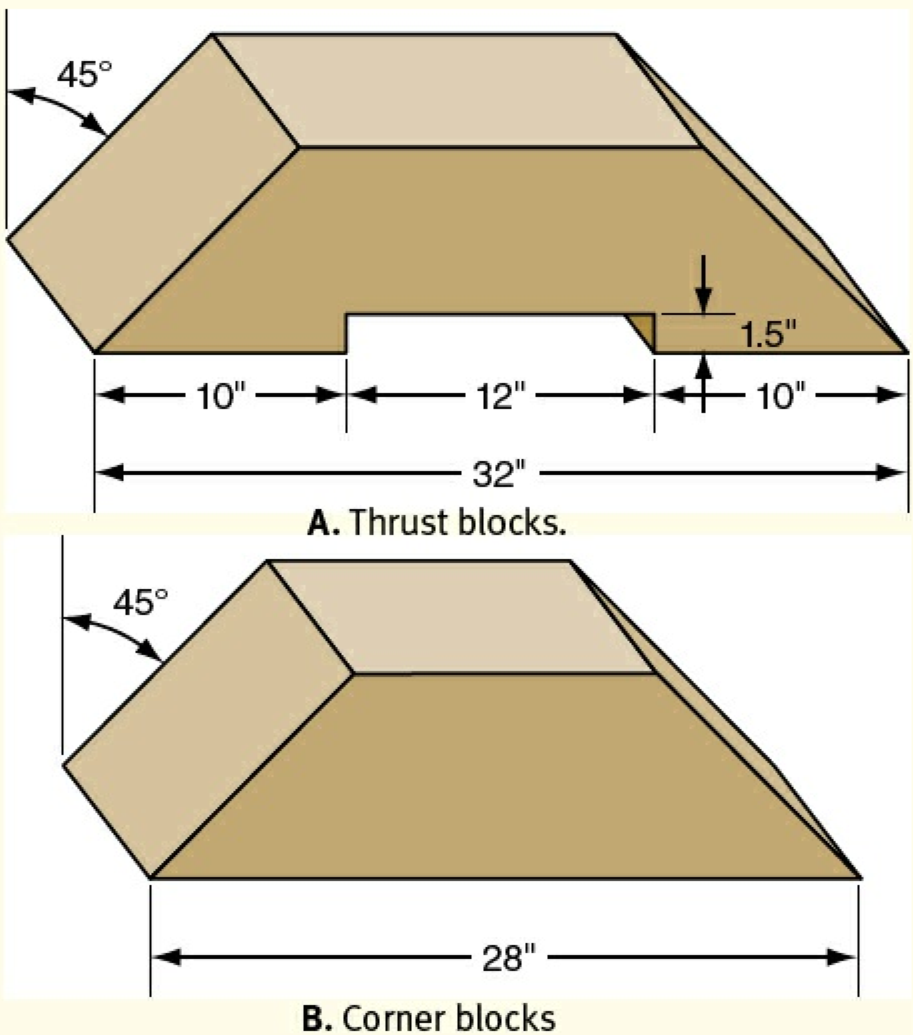


FIGURE 11-16 Corner blocks When using timbers or LVL lumber to create thrust blocks and corner blocks, the angles and dimensions shown in these illustrations work well when the trench legs are at right angles.

To shore an L-trench using thrust blocks, follow the steps in **SKILL DRILL 11-6**

1. Use ropes to lower the wales to the trench floor on both legs of the L-trench **STEP 1**. Secure the ropes to the pickets to keep the ropes from falling into the trench. (If a wall is in danger of imminent collapse, skip this step and go to Step 2. The bottom wale can be positioned after the primary shore is in place, but it is a bit more difficult to do.)
2. The unsupported inside corner is the major concern. Place the primary panels to protect the victim on the inside "L" corners with panel sets directly across the trench from them on the outside walls. Install struts in the middle of each primary panel set. Using a wye adapter or a double outlet controller, shoot these struts simultaneously with up to 100 psi of pressure to capture the corners **STEP 2**.

Tactical Tip

Because of the high potential for inside-corner collapse, the inside corner panel placement is usually accomplished using the opposite-side panel set technique (described in the "Protective Systems" chapter) from a position on the outside wall. The panel ropes may be tied back to pickets or held in place, depending on the number of personnel available.

3. Secondary shoring will create a safe working area at the corner and in both legs of the intersecting trench. To support the corner of an L-trench, this shoring system will consist of thrust blocks on the inside corner panels and wales/corner blocks on the outside corner panels. Install pickets at least 4 feet (1.2 m) behind the lip of both outside corner walls to support wales and outside wall panels **STEP 3**.

Tactical Tip

Thrust blocks can be attached before or after the inside corner panels are installed. The recommended method is to attach them beforehand. When doing so, keep in mind that the final position of the thrust block will need to meet the maximum vertical strut spacing requirements (2 feet [0.6 m] below the lip, 2 feet [0.6 m] above the floor, and not more than 4 feet [1.2 m] apart).

4. Set two panels at the outside corner so that they form a clean corner **STEP 4**. If soil is showing between the panels on the outside walls, you can install lumber or cut-down sections of panel to cover the open wall spaces.
5. Raise and secure the bottom wales, ensuring that they form a clean corner at the outside intersection of the corner panels and line up with the thrust blocks **STEP 5**. The wales on the outside wall should be positioned and tied off at exactly the same depth as the thrust blocks. They can be held in place by tying them back to pickets.
6. Install struts from the bottom wales to the flat surface of the thrust block at temporarily reduced pressures (100–150 psi for pneumatic struts) **STEP 6**. Whenever possible (using dual strut controllers, two air systems, or a wye), install and pressurize both struts (one on

each side of the inside corner wall) simultaneously.

7. Lower and position the top wale at a maximum of 2 feet (0.6 m) below the trench lip **STEP 7**.
8. Repeat Step 7 to install struts from top wales to the flat surface of thrust blocks **STEP 8**.
9. Place the corner blocks on the wales (bottom and top), making sure that they line up with the thrust blocks **STEP 9**.
10. Install two bottom diagonal struts (corner block to angled surface on the thrust blocks) at temporarily reduced pressures (75–100 psi for pneumatic struts) **STEP 10**. Use wye adapters or double outlet (dual) controllers to pressurize both diagonal struts simultaneously. Attach and tighten ratchet straps.
11. Repeat the procedure in Step 9 to install the two top diagonal struts **STEP 11**. After the ratchet straps are tightened, increase the pressure of all struts to the manufacturer's recommendations. First bring all perpendicular struts to the manufacturer's recommended pressures. Next, bring diagonal struts to the manufacturer's recommended pressure simultaneously by using wye adapters or dual controllers. Ratchet straps need a minimum breaking strength of 10,000 pounds (4536 kg).

SKILL DRILL 11-6

Shoring the L-Trench Using the Thrust Block Method

(Trench Rescue Level II: 8.2.1)

The placement of primary shores in this drill assumes that the victim is at or near the corner area. If that is not the case, primary shoring must always be installed first to protect the victim.

Primary Shoring

1 Lower two wales to the trench floor, one in each leg.

2 Position the primary panel sets on the inside corners with panels directly across from them on the outside walls, and install middle struts.

3 Install two pickets behind the lip protection on both outside wales.

4 Place two panels at the outside corner.

5 Raise and position the bottom wale within 2 feet (0.6 m) of the floor.

6 Install struts on both inside corner panels from thrust blocks (flat surface) to the bottom wales.

7 Lower and position the top wale at a maximum of 2 feet (0.6 m) below the trench lip.

8 Install struts on both inside corner panels from the thrust blocks (flat surface) to the top wales.

9 Install corner blocks in the bottom and top wales.

10 Install diagonal struts from the bottom corner block to the bottom thrust blocks and connect ratchet straps.

11 Install diagonal struts from the top corner blocks to the top thrust blocks, and connect and tighten the ratchet straps. Bring all struts to the manufacturer's recommended pressure.

Complete Shoring

12 Nail all strut bases, expand the safe zone, and install supplemental shoring as needed.

12 Complete shoring by nailing all strut bases and expanding the safe zone with panels and shores as needed **STEP 12**. Install supplemental shoring as needed during extrication operations

■ Shoring with Corner Brackets

Corner brackets are metal (high-strength aluminum is preferred) brackets that bolt on to pre-drilled panels. These brackets hold the two panels together at a 90-degree angle and allow both panels to be installed at the same time.

Corner brackets replace thrust blocks and ratchet straps. The time needed to bolt them onto the strongbacks is more than made up for by the time saved during the remaining system installation period. The corner bracket shoring system is especially safe and efficient when dealing with inside corner collapse conditions. It is important to install the bolted corner panels using the opposite-side technique from the outside wall. To minimize panel adjustments, slide the panels in on the high side of the cave-in pile (i.e., on the trench floor).

Tactical Tip

The diagonal struts used in L-trench shoring designs have vectors that create shear forces on the inside corner walls. Resisting that shear force is probably the most important—yet often the most neglected—part of shoring an L-trench. Contrary to a pervasive myth, the shear forces are not resolved by simply installing perpendicular struts (farther down the wall) shot at pressures higher than the angled struts. Installing the shores this way may allow you to set up the system in the trench, but it does not provide enough strength to hold back the potential soil forces associated with unstable soil.

The shear forces of active soil from the outside walls that will push the inside corner panels (and thrust blocks) down the wall can be resolved by using engineered or rated equipment such as corner brackets or heavy-duty ratchet straps. Prior to installing the ratchet straps (thrust block method), it is necessary to temporarily shoot the perpendicular struts at 50 percent more pressure than the diagonal struts (e.g., 150 psi on perpendicular struts and 100 psi on diagonal struts). Shoring is not complete until all shores are pressurized to the manufacturer's specifications.

Tactical Tip

Additional system integrity can be achieved by installing gusset plates, hanger plates, or toe nails at the connection points of the corner blocks and wales. Keep in mind that none of these methods should be initiated before shooting the shores to the corner blocks.

To shore an L-trench using corner brackets, follow the steps in **SKILL DRILL 11-7**:

1. The corner panels are assembled on the lip protection placed at the outside wall. Evaluate the cave-in pile and choose the outside wall with the highest level of cave-in material (on the floor) for the set-up and installation point. Place two 6 × 6-inch 6-foot (1.8-m) runners on lip protection on the outside wall. This will make it easier to bolt the brackets to the panels and will assist with sliding the assembled corner panels over the edge. Lay a pre-drilled panel on the runners. Line up the edge of the panel with the inside corner of the trench. Bolt the corner brackets onto the panel. Stand a second pre-drilled panel vertically and bolt it to the vertical sections of the brackets. Attach ropes to both panels **STEP 1**.
2. Insert 4 × 4-inch rails into the trench. Cut the rails just above the lip. Using rails and the opposite-side panel technique, slide the corner panels into the trench. A rescuer working on lip protection at the inside corner will use a pike pole to hook the panel ropes and stand up the panels **STEP 2**.
3. Lower the wales to the trench floor at both outside corner walls **STEP 3**. (Note: If a wall is in danger of imminent collapse, skip this step and go to Step 7. The bottom wale can be positioned after the primary shore is in place, but it is a bit more difficult to do.)
4. Set two additional primary panels on both outside walls directly across from the corner panels. The strongbacks on these two panels must line up with the strongbacks on the assembled corner panels **STEP 4**.
5. Install a strut from the inside corner panels to the primary panels on each side of the inside corner **STEP 5**. Position these struts at points that will prevent a secondary collapse. Shoot these struts (simultaneously if possible) at 100–150 psi. The lower strut pressures and the simultaneous installation are needed to prevent additional collapse that can be caused by excessive or unequal strut pressure on one side of the inside corner. The installation of these panels and struts give the victim some protection and accomplish primary shoring goals.
6. Begin secondary shoring by installing two panels at the intersection of the outside corner **STEP 6**. Install sheeting (fillers or cut-down panels) to fill in gaps between these panels and

the primary panels if needed.

7 Raise and position the bottom wales (both trench legs) within 2 feet (0.6 m) of the floor STEP 7. The wales must line up directly across from the corner brackets and must meet at the outside corner. Install perpendicular struts from the wales (outside walls) to both panels/strongbacks (inside walls) at 150 psi.

8 Install corner blocks on the bottom wales STEP 8. They provide a platform for the base of the diagonal struts.

9 Install a diagonal strut from the corner block to the corner bracket at a pressure of 100 psi STEP 9. This strut and the struts installed in Step 7 will stabilize the bottom section of the L-trench corner.

10 Place an appropriately sized air bag into the void at the inside corner. Do not inflate it at this time. Backfill the lip areas behind all shored panels to prepare for the installation of the top tier of struts STEP 10.

11 Position the top wales between 18 inches (0.5 m) and 2 feet (0.6 m) below the trench lip. The wales must line up directly across from the corner brackets and must meet at the outside corner STEP 11.

12 Repeat the strut placement process (Steps 7, 8, and 9) to shore the top wale, but reduce strut pressures to 100 psi until back-fill is completed. Inflate the air bag to 1-2 psi and bring all strut pressures up to the manufacturer's recommended pressures STEP 12.

13 Complete shoring by nailing all strut bases. Expand the safe zone with additional shoring and install supplemental shoring as needed during extrication operations STEP 13.

For deeper trenches, add additional tiers of struts following the same procedures FIGURE 11-17.

Tactical Tip

When installing more than two struts on a vertical column (strongback) or a horizontal row (wale), attach all strut hoses (from the row or column of struts) to the controller using wyes and pressurize them simultaneously. This will keep the struts from loosening and falling out.

FIGURE 11-17 Deeper L-trenches require additional tiers of struts.
Courtesy of Ron Zawlocki

SKILL DRILL 11-7

Shoring the L-Trench Using Corner Brackets

(Trench Rescue Level II: 8.2.1)

Primary Shoring

1 Assemble the inside corner panels (bolt on corner brackets) while working on lip protection.
Courtesy of Ron Zawlocki

2 Using rails and the opposite-side panel technique, slide the corner panels into the trench. Line up the vertical panel with the edge of the corner wall.

Courtesy of Ron Zawlocki

3 Lower the wales to the floor of both trench legs. Postpone this step if a collapse is imminent.
Courtesy of Ron Zawlocki

4 Place panels on both outside walls directly across from the inside corner panels. These create two primary panel sets.
Courtesy of Ron Zawlocki

5 Install struts on both primary panel sets (primary shores).
Courtesy of Ron Zawlocki

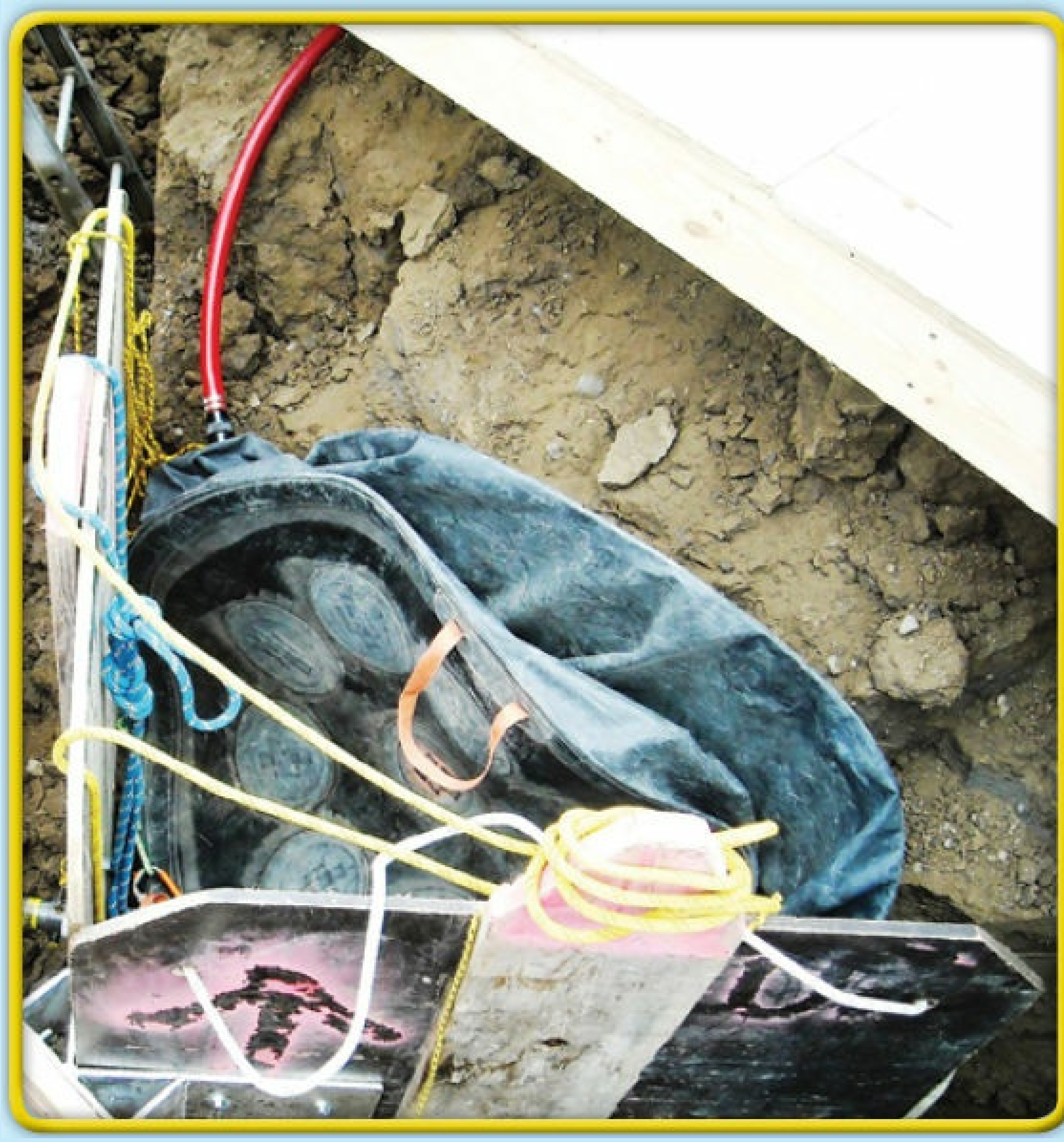
Secondary Shoring

6 Position two panels at the outside corner.

7 Raise and position the bottom wales in each leg of the trench. Install perpendicular struts from both wales to the corner panels.

8 Position corner blocks on the bottom wales. The wales and corner block will establish the bottom shoring tier.

9 Install a diagonal strut from the corner block to the corner bracket.



10 Place an air bag in the inside corner void, but do not inflate it at this time.

11 Lower and position the top wales on the outside wall directly across from the top corner bracket. This will establish the top shoring tier.

12 Shore the top tier following the same steps used for the bottom. Inflate the air bag and complete backfill. Bring all struts to the manufacturer's recommended pressures.

Complete Shoring

13 To complete shoring of the L-trench, nail all strut bases. Expand the safe zone and install supplemental shoring as needed.

Deep-Wall Trench

Since the last edition of this text was published, a great deal of research has been done on both the equipment and the techniques used to shore trenches. This research has led us to change our procedures regarding the shoring of deep trenches. In fact, we now have enough data to support rescue shoring systems in soils other than C-80 for trenches that do not exceed 20 feet (6.1 m) in depth.

The new 20-foot (6.1-m) depth recommendation is not the only change noted, as we now have data to suggest that wales are not always needed when building rescue systems in trenches deeper than 10 feet (3 m). Keep in mind that the wales requirement previously suggested was recommended because it was articulated in the OSHA shoring tables for timber shoring. There were few data that supported shoring deep trenches without wales.

Recent testing conducted by rescuers and directed by a registered engineer suggests a significant increase in panel strength is achieved by using ¾-inch or 1-inch FinnForm panels with strongbacks screwed and glued (rather than bolted) on the panels. The panels, as constructed using these techniques, have shown a breaking strength of more than 30,000 pounds (13,608 kg) of force (per 16 square feet of panel). That additional panel/strongback strength, along with approved strut use (tab data or engineered design), can eliminate the need for wales when shoring some soil conditions for trenches up to 20 feet (6.1 m) deep. When using panel and strongback construction methods that have not been tested, the use of wales is required to strengthen the shoring system in deep trenches.

As explained in the “Protective Systems” chapter, extreme soil conditions and trenches deeper than 20 feet (6.1 m) are beyond the capability of this and other rescue shoring techniques described in this text. If you are not sure of the capacity (strength) of the panels/strongbacks in your equipment cache, you may want to consider using alternative methods to strengthen your shoring system.

Deep-trench shoring procedures apply in situations when shores are placed at depths of more than 10 feet (3 m) below the trench lip. Shoring below this point requires rescue panels to be stacked because the depth of the trench will exceed the vertical dimension of a standard 8-foot (2.4-m) panel. Additionally, the deep trench requires procedures that account for the width of the shored area being equal to or exceeding the depth of the trench, because excessive lateral forces resulting from deep vertical or near-vertical walls can cause sudden and often catastrophic collapse.

OSHA allows construction workers to shore trenches up to 20 feet (6.1 m) deep, provided that they follow the manufacturer's tabulated data or a shoring plan designed by a registered professional engineer (RPE). For rescue purposes, the deep-trench shoring procedure recommended in this section uses a maximum vertical and horizontal spacing of 4 feet (1.2 m). This spacing assumes that your trench rescue team has either an RPE plan or written approval from the strut manufacturer for the use of 4 × 4-foot spacing at these depths. If that is not the case, you must adjust the strut spacing to comply with the shoring charts used by your organization. Regardless, shoring equipment used in deep trenches must have adequate strength to resist the additional soil forces associated with the greater depth, and in that regard it should be tested and approved for breaking strengths that meet at least a 2:1 safety factor.

Deep trenches that can be shored with the techniques found in this chapter are those defined as more than 10 feet (3 m) deep but not more than 20 feet (6.1 m) deep **FIGURE 11-18**. When confronted with extreme conditions (e.g., trenches deeper than 20 feet [6.1 m], type C-80 soil, or moving soil below the ground water table), rescuers may be able to initially protect the victim with rescue shoring but should immediately request an RPE and a contractor with expertise in using specialized shoring equipment and techniques designed for these conditions. Well-prepared trench rescue teams should always have a prearranged response plan and have trained with both of those important resources.

■ Deep-Wall Trench Shoring

In preparation for shoring a deep trench, consider using lip bridges. When ground pads are deemed appropriate, make sure that personnel remain attached (class III harness) to an anchored retrieval line/edge limiters and that they never operate off the ground pads. A secondary collapse of a deep trench can be catastrophic for both the victim and the rescue personnel. To ward against such a disaster, make certain that rescuers working near the lip are protected from a wall collapse below them.

An important step in this type of operation is to set the pickets and prepare the panels and shores. While the lip team is setting up lip protection, the panel team should be installing pickets and moving roped panels off the rescue unit and close to the trench.

To support a deep trench, follow the steps in **SKILL DRILL 11-8**

1 Deep trenches can yield rapid and catastrophic wall collapse. It is therefore important for rescue team members working around the trench lip to take extra precautions. When placing or working on ground pads, rescuers should be in harnesses and tied off to edge limiter anchors STEP 1.

2 Shoring equipment installation should be accomplished while working on lip bridges whenever possible STEP 2.

3 Install pickets to hold the wales in place while the panels are being set STEP 3. To use this method of supporting the wales, find a location with sturdy ground that will hold the weight of the wales. Make certain that the pickets are installed far enough away (at least 4 feet [1.2 m]) from the trench lip so that any vibration caused by the driving of the stake will not trigger a secondary collapse.

4 Position the primary panels to shelter the victim(s) from collapse. If voids are present in this area, low-pressure air bags should be positioned (suspended on ropes) in the voids, but not inflated at this point. Install a strut in the middle of the primary panel set STEP 4.

5 Place a set of panels next to the first set and install a strut in the middle STEP 5.

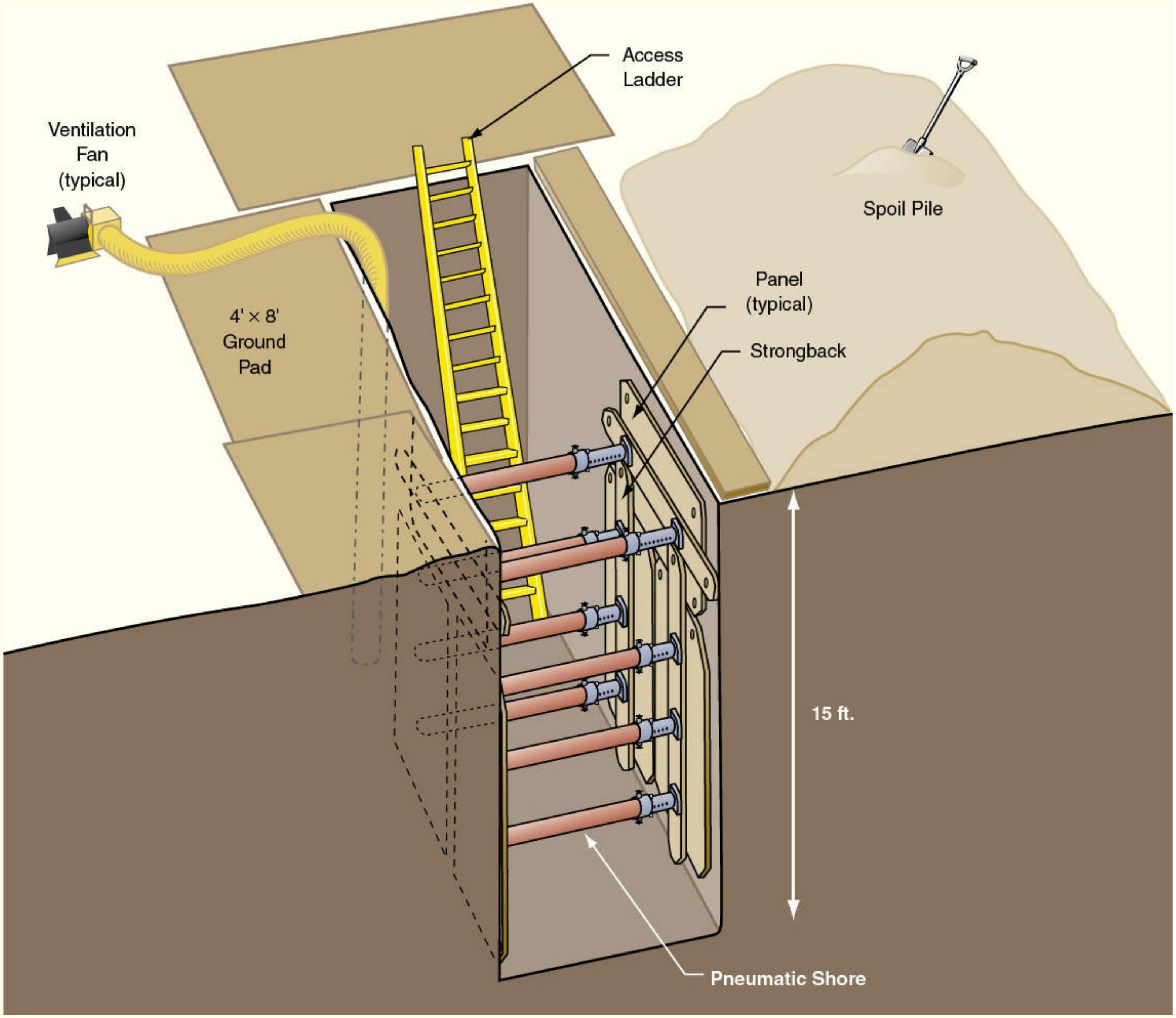


FIGURE 11-18 The deep trench. Panel placement is shown for a 15-foot deep trench.

Tactical Tip

Install the first strut in the middle of the first primary panels at 200 psi if the walls behind them are intact (no voids), and at reduced pressure (100 psi) if voids are present. This set of panels and single strut will provide the first level of protection to the victim and will help hold the panels installed above them.

6. Place panels on top of the initial two-panel set **STEP 6**. (For trenches 12 feet (3.6 m) deep or less, these top panels can be set horizontally.)
7. Install two struts on the top panel set **STEP 7**.

8 Install additional struts to these primary panel sets following the horizontal and vertical strut spacing requirements set by your agency **STEP 8**.

9 Install secondary shoring (panels and struts) to create a safe zone that is 12 feet (3.6 m) wide (3 panel sets) and covers the trench wall from top to bottom **STEP 9**.

10 To complete the shoring, nail all strut bases and expand the safe zone with panels and shores as needed. The panels should make the rescuer work area at least as long as the trench is deep. Install supplemental shoring as needed during extrication operations **STEP 10**.

SKILL DRILL 11-8

Shoring a Deep Trench

Primary Shoring

1 Set ground pads. Be sure to wear fall protection.

2 Install lip bridges, which should always be considered for deep trench shoring operations.
Courtesy of Ron Zawlocki

3 Set pickets to hold all panels and wales in place.

4 Position panels to protect the victim, and install a middle strut.

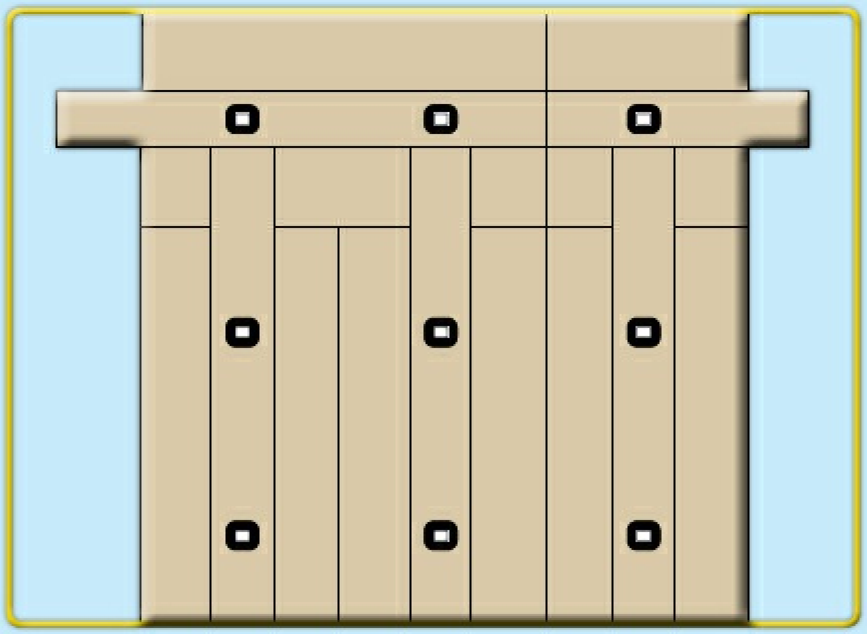
5 Place two panels next to the first set and install a middle strut.

6 Position the top panels (horizontal for a 12-foot [3.7-m] deep trench).

7 Install two struts on the horizontal panels.

Secondary Shoring

8 Install additional struts on all panels to meet horizontal and vertical strut spacing requirements.



9 Install additional panels and struts to create a 12-foot (3.6 m) wide safe zone.

Complete Shoring

10 Nail all strut bases, expand the safe zone, and install supplemental shoring as needed.

Tactical Tip

Shoring with struts that can be installed without entering the trench is a best practice for deep trench rescue shoring.

Excavation Shoring

Rescuers have distinguished between trenches and excavations for many years. A trench is defined as a narrow (in relationship to its depth), human-made cut in the earth's surface formed by the removal of soil. What we call excavations are human-made cuts in the earth's surface that are wide (in relationship to their depth). Excavation shoring situations occur whenever horizontal struts cannot reach from one soil wall to another.

Excavation shoring, in this sense, is not included as a NFPA trench rescue requirement. We have decided to include it in this text because of an apparent increase in the frequency of rescue events involving these settings and because fire fighters are using unproven (not tested) techniques to shore them. Excavation rescue shoring requires preparation, specialized equipment, and new skill sets to be successful.

The basic mechanics behind trench rescue shoring involve supporting the sections of the trench walls that remain standing and reducing the potential movement of soil behind the shoring system. The same mechanics apply to excavation rescue shoring, but the struts need to be installed at angles, which requires additional shear force resistance (in this case, pickets). The shores used to resolve these issues are called excavation raker shores.

The first attempts at shoring excavations were done with rakers built from timbers and lumber braces. The raker designs were borrowed from building collapse rescue shoring guidelines. Recent tests conducted by the MUSAR Training Foundation concluded that the building collapse raker designs perform poorly and do not provide the desired safety factors in excavations. The destructive tests that were conducted in this investigation created more forces on the bottom of the shore than at the top. This was done to replicate soil force distribution, which increases with depth. Building collapse rakers are designed to support more forces at the top of the shore and are strong in the application, but they did not provide a 2:1 safety factor (for C-60 soil pressures) when supporting loads increased from top to bottom.

As a result of the poor performance of the timber raker shores, the focus of subsequent research switched to the use of pneumatic raker systems in excavations. The initial tests on pneumatic raker shoring systems revealed that the weak point is the shore climbing the wall as lateral pressures increase. That design failure was resolved by bolting the aluminum Paratech wales to the FinnForm panels and then anchoring the panel/raker assembly to the wall with pickets. High-shear-strength, ½-inch bolts that thread into T-nuts that are pre-drilled and set into the panel are used in this case, allowing the panels and wales to act as one unit. After the assembled system is lowered into the excavation, it is secured (pinned) into the wall with pickets (1-inch [2.5-cm] diameter by 36 inches [91 cm] long). Pre-drilled (1.25-inch [3.2-cm] diameter) holes in the panels allow for quick installation of the pickets. These pre-drilled holes are spaced across the panels to provide room for personnel to use powered hammers or sledge hammers.

With the wall climbing issue resolved, the next set of tests on the pneumatic rakers showed a failure point at the base that holds the raker junction. The raker junction is the point where the upper and the lower struts come together and meet in an aluminum base at the ground anchor. Based on the conclusion that the distribution of forces on a soil wall differs from the distribution of forces on a structure wall, test designs that created more forces on the bottom of the shore were retained. Unfortunately, this effect caused repeated failures of the base connector attached to the raker junction.

In an attempt to overcome that component failure, a modified angled ground anchor base was fabricated and has been tested. Test results have shown that with the addition of an angled ground base, the pneumatic strut-based excavation shoring systems can resist twice (2:1 safety factor) the anticipated soil forces of C-60 soil. The angled ground base and adequate resistance to shear forces on both the excavation wall and floor are essential to the safe use of pneumatic raker shores at excavation raker incidents. After continued tests and discussions with shoring manufacturers, an improved version of the excavation ground base is now available from Paratech Rescue.

Tactical Tip

A wood "foot" is required under the intersection (raker junction) of the top and bottom struts of the excavation raker shore.

Tactical Tip

The hinged base used for building collapse raker shores should not be used in an excavation. Angled excavation bases are needed to resolve the soil force vectors. (See the angled base in Skill Drill 11–9, step 7.)

Installing a raker system on an excavation wall takes preparation, coordination, and practice. Because the installation of a raker in an excavation environment is different than the installation of traditional trench rescue shoring, the following drill details the task assignments for both the panel team and the shoring team. A minimum of six rescuers on each team is recommended. An achievable goal for a practiced panel and shoring team would be to build and install an excavation raker (primary and secondary shoring) in less than 20 minutes. With advanced training and additional equipment, deep excavation can be shored safely.

The shoring system used in the following procedure is specific to Paratech rescue struts. That choice was made not because we think that this method is the only one capable of adequately supporting an excavation wall, but rather because it is the only equipment and method that we have had an opportunity to test. To build and install the excavation raker, follow the steps in **SKILL DRILL 11-9**:

1. Place the lip protection (ground pads or lip bridges, depending on the stability of the wall) on the lip directly above the victim **STEP 1**.
2. Assemble the excavation raker shore on the lip protection **STEP 2**. To provide rescuers with an 8-foot (2.4-m) safe zone in a typical (8–10 feet [2.4–3.0 m] deep) excavation, you will need two FinnForm panels (4 × 8 foot), two 8-foot aluminum wales, a Paratech 610 raker kit, nailing blocks, 2 × 6-inch braces (pre-cut), 16 steel pickets (1-inch [2.5-cm] diameter, 36 inches [91 cm] long) a 6 × 6-inch sole plate ground anchor with a wood foot **FIGURE 11-19**, and sledge hammers or powered hammers. The entire excavation raker shore system is assembled on ground pads or lip bridges.
3. After the two rakers are built and attached to the panels, nail 2 × 6-inch lumber to create

horizontal and diagonal (X) bracing. This bracing can be pre-cut and stored as a kit on your trench rescue truck or trailer STEP 3.

4 Next, tie a lowering (rope) system to an anchor point (usually a couple of pickets) well behind the excavation lip STEP 4. Use six rescuers (three on each side) to slide the raker shore over the lip.

5 As the shoring unit crosses the edge it will start to tip into the excavation. At that point, the ropes will become tensioned and the lowering system will control the load. The rescuers on the sides will only need to guide (steer) the shore into the hole. The panel/raker assembly is lowered into the hole using ropes controlled by two rescuers using descent control devices attached to the anchors STEP 5.

6 After the raker system is lowered and in position, a wall anchor team climbs down into the excavation with pickets and hammers to drive pickets into the wall STEP 6.

7 Simultaneously, a ground anchor team enters to place a foot under the angled (excavation) bases and to install sole plate anchors to the rakers STEP 7. After four ground anchor pickets and two wall pickets have been installed, use air pressure (100 psi) on all four struts to push the raker system tight against the wall.

8 With all wall anchors and ground anchors in place, increase all strut pressures to 150–175 psi STEP 8.

9 Complete shoring by expanding the safe zone (adding more rakers) and/or installing supplemental shoring as needed STEP 9.

Tactical Tip

Ladder gins are useful high directionals at excavation rescues.

Safety Tip

Because the entire excavation raker system is built and installed (lowered) from the lip of the excavation, the picket installation is the only exposure time that the rescuers experience. Their exposure risk becomes less with each picket (wall and floor) that is placed.

SKILL DRILL 11-9

Installing an Excavation Raker

(Trench Rescue Level II: 8.2)

Primary Shoring

1 Place lip protection over the victim area.

Courtesy of Ron Zawlocki

2 Assemble the excavation raker system while working on the lip protection.
Courtesy of Ron Zawlocki

3 Nail 2 × 6-inch bracing to the rakers.
Courtesy of Ron Zawlocki

4 Attach a lowering system to the raker and anchors (pickets). Position three rescuers on each side of the shore to help slide it off the lip.

Photo by Ron

5 After the shore is over the edge, the ropes (lowering system) control the descent.

Courtesy of Ron Zawlocki

6 A wall anchor team enters the excavation with pickets and hammers to place the sole footing and pin the shoring system in place.

Courtesy of Ron Zawlocki

7 A ground anchor team enters the excavation with hammers to install sole footings, sole anchors, and pickets.
Courtesy of Ron Zawlocki

Secondary Shoring

8 After all wall and ground anchor pickets are in place, bring the strut pressures up to the manufacturer's recommendations. Increase the top strut pressure first and then the bottom strut pressure. This secondary shoring creates an 8-foot (2.4-m) wide safe zone for rescuers.

Complete Shoring

9 Complete shoring by expanding the safe zone and/or installing supplemental shoring as needed.
Courtesy of Ron Zawlocki

Additional considerations with excavation rakers include the following:

- To minimize exposure time, rescuers must assemble the raker, attach it to the wales/panels, and lower the system into the excavation from a safe position on the lip.
- The excavation rescue shoring system that is used at an incident must have been tested using vectors that closely replicate the pressures of a damaged soil wall. Test forces of at least two times greater than the "worst case" soil forces must be imposed and resisted during the testing process.
- Equipment modifications must be made (such as the angled anchor base) when a system fails to resist at least two times the potential soil pressure. Tremendous safety and efficiency improvements can be achieved when rescuers and manufacturers of shoring and rescue equipment develop close working relationships.
- A wall anchor team and a ground anchor team should enter the excavation simultaneously with all needed equipment and materials.
- Use of hydraulic, pneumatic, or electric hammer tools with picket driving bits significantly reduces the time needed to anchor the system.

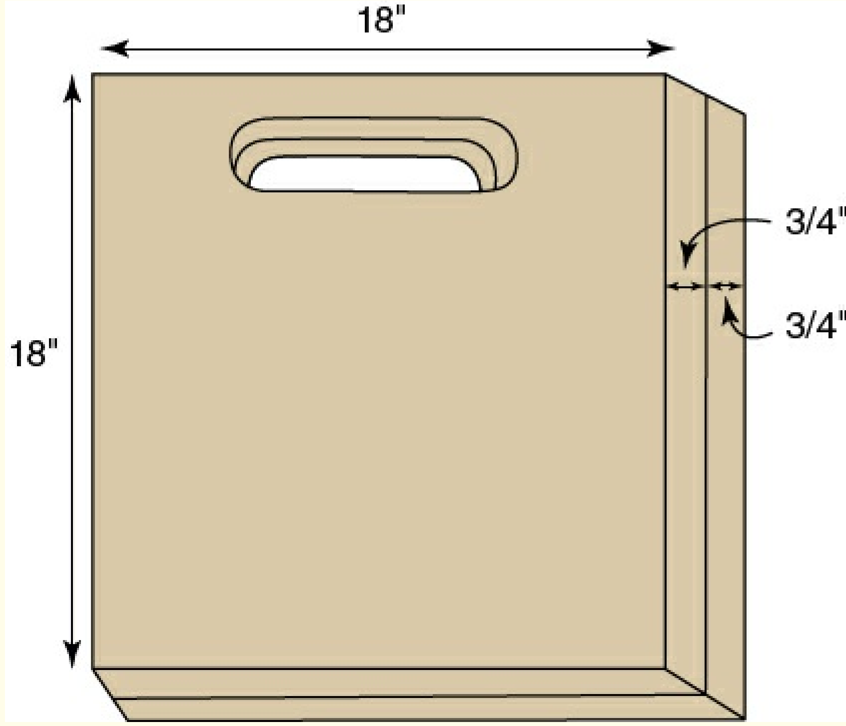


FIGURE 11-19 Sole footings are formed from two stacked 18 × 18-inch pieces of 3/4-inch plywood.

Equipment used by shoring and panel teams is listed in **TABLE 11-1**

Table 11-1 Equipment Lists

Shoring Team Equipment	Panel Team Equipment
Paratech excavation raker shore Four 610 struts (Gold) Two 235 extensions (Gold) Two B-23 struts Two raker junctions Two rail junctions Two rail latches Four angled (excavation) bases Six nail blocks Paratech wale Paratech air system Air bottle Regulator Controller Five hoses Four hammers and 16d nails Two raker tie-off ropes	Wood brace kit (pre-cut 2 × 6-inch lumber) Excavation panels (pre-drilled with T-nuts) Lowering system • ½-inch main line with two steel pickets (42 inches) • Two tag lines • Three carabiners Wall anchor kit • Six steel pickets (42 inches) • Two sledge hammers or air hammer Sole anchor kit • 6-inch × 6-inch × 8-foot timber • Eight steel pickets (42 inches) • Two sledge hammers Two sole feet Two 4 × 4-inch × 8-foot timbers (rails) Back-fill (as needed)

Wrap-Up

Review: Just the Dirt

- At a minimum, all systems being installed should be capable of resisting at least twice the potential load of the soil at the trench rescue site.
- Procedures used for underground construction shoring fail to address the most important element of shoring for rescue: protecting the victim.
- A straight-wall trench that is at least 12 feet (3.7 m) long requires the rescuer to use a minimum of three sets of panels.
- An outside wale is used to span a large void in a trench wall that cannot be filled with soil, timber, or single air bag backfill techniques.
- Inside wales are commonly used to span a set of panels to create an open space (e.g., to provide room for digging or extrication operations or to shore around an obstruction that cannot be moved).
- After secondary shoring has been installed, rescuers may need to add modified (cut-down) sheeting and shoring to complete the shoring task—a process called supplemental shoring.
- All things being equal (considering the same soil conditions), intersecting trenches are significantly less stable than straight trenches.
- The L-trench consists of two trench cuts or legs that converge at a single point, commonly forming a right angle.
- If you are not sure of the capacity (strength) of the panels/strongbacks in your equipment cache, you may want to consider using alternative methods to strengthen your shoring system.
- Excavation shoring situations occur whenever horizontal struts cannot reach from one soil wall to another.

Hot Terms

Corner blocks Specially designed and cut wale pieces that fit in the corner of the outside L wales and provide a platform for angle shores to be installed from the thrust blocks.

Corner brackets Metal (preferably high-strength aluminum) brackets that bolt on to pre-drilled panels. They can be used on the inside corner of any trench that intersects at a 90-degree angle. Such brackets hold the inside corner panels together, providing shear force resistance and allowing both panels to be installed at one time.

Excavation rescue shoring Specially designed raker shoring system made with pneumatic struts, FinnForm panels, and aluminum wales.

Inside wales Wales used to span a set of panels to create an open space in a trench. They are used in most intersecting trench shoring designs.

Thrust blocks Specially designed and cut 6 × 6-inch pieces that fit over the strongback and provide both a flat surface and an angled surface for use as a platform for installed shores.

TRENCH RESCUER *in action*

You and your rescue company are at the scene of a trench incident. A contractor is replacing sewer pipes as part of a large infrastructure upgrade project. It is early afternoon and the weather is warm—in the mid-70s with a moderate breeze. The trench is open for several blocks with short intersecting trenches at each street. The trench has collapsed at one of these intersections, where it forms a T-trench.

There are trench boxes on either side of the intersection along the long walls. Where the pipes were to join an 8-foot (2.4-m) gap between the trench boxes, however, a section of the long wall has sloughed into the trench, leaving a 5-foot (1.5-m) long section of the lip overhanging the collapse by about 3 feet (0.9 m). There are numerous cracks in the two corners opposite the cave-in. The trench is approximately 10 feet (3 m) deep. The 4-foot (1.2-m) concrete sewer pipe is in the hole along with the intersection chamber. One worker is totally buried and two others are pinned against the pipe.

1. What is your first priority?
   - **A.** Establish a safe zone around the pinned workers.
   - **B.** Install panels along the long wall and fill the void with air bags.
   - **C.** Establish ventilation in the trench.
   - **D.** Eliminate any existing or potential hazards.
2. One of the workers is pinned up to his mid-thighs and is about 3 feet (0.9 m) from the end of the trench box. What is a possible option for this victim?
   - **A.** Hand the worker a shovel and encourage him to dig himself out and get into the trench box.
   - **B.** Hand the worker a shovel and place a rescuer into the trench box to assist the worker from the safety of the trench box.
   - **C.** Place a rescuer in the trench to dig him out as long as he stays within a few feet of the trench box.
   - **D.** Place a ladder into the trench alongside the end of the trench box closest to the worker and have a rescuer dig from this point.
3. What is the minimum number of trench panels required to safely shore this trench before starting rescue operations within the trench?
   - **A.** 3
   - **B.** 5
   - **C.** 7
   - **D.** 9
4. What is the best definition of complete shoring?
   - **A.** A safe zone that is at least as wide as it is deep, with at least a three-panel set that will be expanded to a four-panel set
   - **B.** A shoring system usually completed with one or two struts
   - **C.** Struts that are pressurized below the manufacturer's specification, with all bases nailed and supplemental shoring in place
   - **D.** Establishment of a complete safe zone 12 feet (3.7 m) wide
5. What would be a good method to shore the sloughed-in section of trench?
   - **A.** Place high-pressure air bags sufficient to fill the void after placing the panels and shoring

B. Place low-pressure air bags sufficient to fill the void before placing the panels and shoring
C. Place high-pressure air bags sufficient to fill the void before placing the panels and shoring
D. Place low-pressure air bags sufficient to fill the void after placing the panels and shoring

6. Where is the use of a thrust block required?
   A. When installing wales in a T-trench
   B. When installing trench panels in any straight-wall trench
   C. When installing wales in an L-trench
   D. Wherever extra strength is needed on a strongback

Victim Access and Care

CHAPTER 12

Trench Rescue Levels I and II

Knowledge Objectives

After studying this chapter, you should be able to:

- Describe how to assist in non-entry and victim self-rescue NFPA 8.1.1 NFPA 8.1.2 NFPA 8.1.5 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.6. (pp 222–223)
- Describe the purpose of a pre-entry briefing NFPA 8.1.2 NFPA 8.1.5 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.6. (pp 223–224)
- Describe how to gain access to a victim NFPA 8.1.3 NFPA 8.1.5 NFPA 8.1.6 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.6. (pp 224–229)
- Identify and describe victim care considerations NFPA 8.1.1 NFPA 8.1.3 NFPA 8.1.4 NFPA 8.1.5 NFPA 8.1.6 NFPA 8.2.1 NFPA 8.2.2 NFPA 8.2.6. (pp 229–232)

Skills Objectives

After studying this chapter, you should be able to:

- Facilitate non-entry rescue NFPA 8.1.2 NFPA 8.2.6. (pp 222–223)
- Facilitate victim self-rescue NFPA 8.1.2 NFPA 8.2.6. (pp 222–223)
- Assess a victim in a trench NFPA 8.1.5 NFPA 8.2.6. (pp 229–230)
- Extricate a victim from a trench NFPA 8.1.3 NFPA 8.1.4 NFPA 8.1.5 NFPA 8.2.6. (pp 231–232)

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

As the department training officer, you have been tasked with developing a class on risk–benefit analysis as it pertains to specialized rescue and fire-ground operations. As you try to determine the main objectives for the presentation, you reflect on situations in your career where you felt the risk of intervention was not worth the benefit of what was achieved as an incident outcome. There was the time your crew was ordered to do an interior attack on an abandoned house that was for the most part fully involved. There was also the time at 0300 hours when you arrived at a restaurant that someone had tried to burn down using gasoline. The fire never vented and, in fact, burned itself out. Nonetheless, you were ordered to force the door and search the building. There was also the time when you were a captain and arrived on scene of a trench collapse and found one of your colleagues in an unstable trench trying to uncover an obvious fatality. In each of these incidents, you were left wondering, "What the heck were they thinking?"

Based on your recollections, you decide to develop scenarios around each of these incidents and then get your students to think about the pros and cons for each intervention strategy. You decide that the easiest scenario to develop first would be the trench incident, because the victim's outcome was already known upon arrival.

1. In the case of an obvious fatality at a trench rescue, what would be your most important priority?
2. Other than rescuer entry into an unstable environment, what are some additional techniques that can be used to uncover buried and trapped victims?
3. Explain how risk–benefit analysis and the time necessary to rescue victims are sometimes conflicting values at scenes where there is a savable victim.
4. How can a postincident debriefing help rescuers develop the skills needed to make proper risk–benefit determinations at future incidents?

Trench Rescue Levels I and II

Approaching Victim Access

To be successful in trench rescue, you need to mitigate the incident in a manner that brings no further harm to the victim and absolutely no harm to the rescue personnel. To accomplish this, you must use all of the information at your disposal to make a decision about the most appropriate method of gaining access to the victim and then provide the appropriate level of care.

For example, if the incident involves a fatality, the methods that you employ to get the victim out of the trench are not nearly as important as if you are dealing with a viable patient. This caveat extends to the speed at which you need to carry out the rescue to do the most good for the victim. If the victim is dead, in most circumstances it does not make much difference how you package to extricate him or her, as long as the process is done with dignity and respect. By comparison, a live victim may require additional considerations for patient packaging.

Non-entry Rescue and Victim Self-Rescue

Before considering gaining access to the victim, we need to discuss non-entry and victim self-rescue. Non-entry and victim self-rescue are always the preferred methods to reduce the risk to rescue personnel, and they should be considered in every incident. This approach may be as simple as a worker who is only partially buried being able to dig himself or herself out or a non-entry rescue where responders extricate the victim without ever going into the trench.

The best scenario is the one in which an individual just needs a ladder to get out of the trench. Keep in mind that even individuals with broken bones will climb a ladder if they think a potential for collapse exists. If they are hurt and only partially able to help themselves, pass down a modified packaging device such as the chest portion of a class 3 rope rescue harness **FIGURE 12-1**. If victims are able, you can instruct them on how to secure the harness and then pull them up the ladder to safety with the retrieval line.

In other cases, a non-entry rescue could take the form of a hauling device attached to an elevated platform that removes the victim vertically. Access to the scene and proximity of the safe operation of the platform device to the trench will need to be considered as a part of the operational plan in this situation. Most trench victims have not trained in how to put on a class 3 harness or other webbing configuration, so you will have to resist the temptation to send someone down in the trench to secure the packaging system **FIGURE 12-2**. Of course, in all cases, you should never attempt to pull a partially buried victim from the trench.

FIGURE 12-1 A modified packaging device like the LSP Cinch Collar can be passed down to a victim in a trench.
Courtesy of CMC Rescue, Inc

FIGURE 12-2 Class 3 harness.
Courtesy of CMC Rescue, Inc

Another, less glamorous method of performing non-entry rescue is to have the victim place a pair of wristlets on his or her wrists and then to haul the victim out by whatever method you have. At this point, the best way to remove the victim may be to get all of your strongest rescuers on the rope and let them go to work **FIGURE 12-3**.

Whether your victim can self-rescue or even partially assist in the removal process, mitigating the incident and not placing your personnel in harm's way is always the preferred method.

FIGURE 12-3 A rescued worker being pulled out vertically.
Courtesy of Captain David Jackson, Saginaw Township Fire Department

Pre-entry Briefing

If you have eliminated victim self-rescue or non-entry rescue as an option, you will need a much more comprehensive rescue plan. Many options must be considered, many of which are determined through risk–benefit analysis FIGURE 12-4.

At some point, though, you will have to move forward. Before you elect to begin building the protective system, all personnel involved must be briefed on the rescue plan. Conducting a pre-entry or preaction briefing allows the incident commander, operations chief, or rescue leader to think out loud one more time and also enables personnel to question openly the assumptions on which the incident commander devised the plan. Items to include in the pre-entry briefing include the overall goal of the operation; position assignments; protective system design; known, suspected, or possible hazards; safety requirements; accountability system; and emergency procedures.

Other than the normal scene setup activities, no action in the immediate rescue area should take place until the pre-entry briefing is conducted for required personnel and an equipment/systems safety check is completed. The pre-entry briefing is important because rescue personnel need to understand the desired outcome and the strategic steps that are part of the overall rescue plan. When such a briefing is implemented, the trained rescue professionals tend to achieve a positive outcome with limited problems or consequences and, more importantly, with limited direction on the leader's part. This very important aspect of leadership is covered more fully in the "Rescue Team Leadership" chapter.

FIGURE 12-4 Injured but conscious and alert workers can be difficult for rescue personnel to deal with from a risk–benefit perspective.

Courtesy of Captain David Jackson, Saginaw Township Fire Department

Gaining Access to the Victim

Consider the following case study: A worker was trapped under a pipe in a trench where the contractor's protective system was in place and functional at the time of the incident. When responders arrived at the scene, the victim was conscious but not alert and, therefore, was considered to be a true emergency victim. In fact, he appeared to be in some sort of trauma-related shock.

Following the initial victim assessment, a ladder was placed in the trench, and a paramedic entered to conduct a victim survey. The medic immediately became confused and disoriented; he was never able to reach the victim, but instead slumped over at the bottom of the ladder. Realizing that something was wrong, the incident commander ordered a fire fighter to enter the trench with a self-contained breathing apparatus (SCBA). This fire fighter, wearing full protective clothing and SCBA, climbed down the ladder and retrieved the medic. He also was able to place a supplied-air breathing apparatus (SABA) on the victim.

This story deserves a closer critique. As it turns out, the worker was trapped by the pipe but was not seriously hurt. He was never in danger of dying from a trauma-related injury because the pipe had trapped only his foot in the soft sand of the trench floor. He had actually fallen victim to the fumes from the solvent that he was using to clean the pipe. The incident commander assumed that the trench was safe because the contractor's protective system was in place. The victim's confusion and disorientation were taken as signs of shock, but he was really overcome by vapors.

This scenario serves as an example of the problems that may confront an incident commander at the scene of a trench incident without a collapse. As was discussed earlier, only two types of incidents can really occur at a trench site: incidents that involve a cave-in and incidents that do not involve a cave-in. It is imperative that each of these situations be evaluated from the same standpoint, regardless of the circumstances. Applying the same evaluation criteria to both types of incidents will keep you from making a mistake and operating in an unsafe area or a potentially hazardous environment.

Keep in mind that the types of materials that can entrap a worker are as numerous as the types of equipment found at the construction scene. Pipes and other heavy objects may have to be lifted off the victim using air bags or another type of mechanical lifting device. These lifts can be done from inside the trench or from above the trench using lifting straps.

Tactical Tip

The cardinal rule for gaining access to the victim is to remove any entrapment mechanism and uncover the victim's head and chest first.

■ Incidents Without a Cave-in

Trench accidents that do not involve a cave-in will almost always be more difficult to handle than those in which a cave-in has buried the victim. This difference arises because it is more stressful to deal with a situation when someone's life is hanging in the balance. If the person is deceased, as is more often the case when a cave-in has buried the victim, the extrication method will not affect the outcome for the victim. Just remember to protect your personnel.

To say that your skills will be tested in these situations would be an understatement. Whether the situation involves a pipe that has broken a rigging strap and fallen, an equipment failure, a toxic environment, or victim illness, your success will be determined by following a safe and logical plan—a plan that does not skip any steps!

■ Cave-in Incidents

Incidents with a cave-in can be organized into two different categories: those involving a partially buried victim and those in which the victim is completely buried. Both types will be challenging, because each may involve a substantial amount of work, depending on the entrapping mechanism **FIGURE 12-5**.

■ Excavation Techniques

Working with Existing Systems

Before responders start talking about extricating the victim, they need to consider what to do with the existing protective system, if one is in place. In many cases, responders will need to determine the functionality of the protective system and identify whether it is sufficient for rescue personnel to operate in. Understanding the system components and then making a recommendation concerning removal or replacement of the system may open up many options and consequently lead to many opportunities to make poor choices.

In some cases, rescue personnel may arrive on the scene of a trench emergency and be faced with sheeting and shoring that have already been installed but that have safety margins below the recognized rescue shoring standard. This substandard shoring typically consists of undersized lumber (2 × 4, 2 × 6, or 4 × 4 inches) and may include the use of plywood (½, ⅝, or ¾ inch) as a form of makeshift sheeting. The substandard sheeting and shoring may have been installed before the emergency by undertrained construction workers, or it may have been placed by first-arriving fire fighters without the benefit of training as a trench rescue unit. Sometimes, this shoring may actually be temporarily preventing additional cave-ins.

FIGURE 12-5 Deeply buried victims require significant rescue personnel and are always difficult rescue situations. The victim in this photo is trapped in running coal.
Courtesy of Chuck Wehrli

The technician-level trench rescue team needs to be able to recognize substandard shoring and to use the materials in place while reinforcing the safety margin to meet a suitable rescue standard. Because substandard shoring is typically "in the way" of rescue operations, the trench rescue technicians must be able to adapt and to overcome problems not usually associated with sheeting and shoring.

Replacing or enhancing substandard sheeting and shoring should be undertaken whenever the risk–benefit analysis concludes that the safety margin provided by the current sheeting and shoring system is inadequate for the entry of rescue personnel. This analysis would include, but is not limited to, the following issues:

- Wooden shores are of dimensions that are smaller than the rescue shoring standard.
- Shores are placed in a fashion that does not provide axial loading **FIGURE 12-6**.
- Shores are not adequately compressed.
- Sheeting is neither plywood (1-inch minimum) and strongback (2 × 12 inches) nor a rated panel.
- Gap management (voids created by cave-in areas) is inadequate to create pressurization zones.
- Vertical spacing is greater than 4 feet (1.2 m) on center.
- Horizontal spacing is greater than 4 feet (1.2 m) on center.

In all of these cases, replacement shoring may be necessary for rescue entry operations. Using replacement shoring techniques requires some additional understanding and precautions. Other hazards associated with removing existing or substandard shoring may include the following considerations:

- Removing substandard shores before the installation of replacement shoring may result in a trench cave-in.
- Installing and compressing replacement shoring may loosen up the substandard shores and cause them to drop into the trench, injuring the victim. These substandard shores must be supported before the installation of replacement shores.
- Ground pads and lip safety must be in place prior to replacement shoring operations.

If you have evaluated the in-place protective system and discovered that dirt or sand is the entrapping mechanism, then get out your entrenching tools and go to work. Your crew is in for a long couple of hours or even days. The magnitude of this type of situation is never more evident than the first time you have to use a rope to raise a 5-gallon bucket half-filled with dirt. In many cases, tons of dirt may have to be removed from the trench by hand **FIGURE 12-7**.

Regardless of the type of digging equipment used to remove a buried victim, there are a few rules you should follow:

1. Never use a mechanical device or backhoe to dig up or pull out a partially buried victim.
2. Never attempt to pull out a partially buried victim.
3. Dig by hand when you get near or around the victim. You do not want to cause further injury to the victim or cause physical damage to a body.

Resist the urge to pull or otherwise try to remove the victim before completely freeing him or her from the entrapment mechanism. Time and time again I have witnessed 15 minutes of digging that is then followed by 10 minutes of pulling. The cycle then repeats itself for several hours while someone stands over the trench and says, "You might as well keep digging; he is not going to come out."

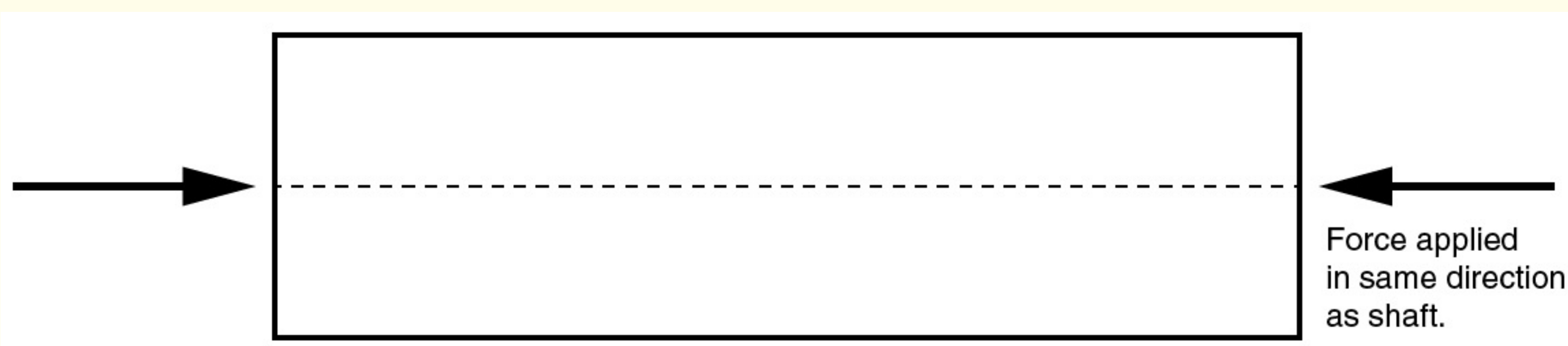


FIGURE 12-6 Axial loading.

FIGURE 12-7 Dirt bag being used to excavate spoil from a trench.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Tactical Tip

Resist the urge to try to pull out a partially buried victim until you can see the tops of his or her feet.

I have actually stood over the trench and said to a group of fire fighters, "I know you are not going to be able to resist pulling on the victim, but he is not going to come out until the last piece of dirt is removed from around his ankle." This was followed by repeated cycles of the "pull and dig" game until the very last piece of the victim's foot was uncovered. It gave me only limited pleasure for the fire fighters to exit the trench and say, "You know what? You were right about getting him completely free before we could get him out."

Vacuum Systems

In a more heavily populated area, there is a good possibility that one of the local utility companies has a vacuum truck. Municipal vacuum trucks have hose extensions that enable them to access and clear storm drains or clean up loose road debris such as leaves and dirt **FIGURE 12-8**.

A centrifugal vacuum truck uses a large fan to create suction in the intake line. Truck-mounted centrifugal vacuums average 5000 cubic feet (141.6 m^3) per minute airflow but have a relatively low vacuum pressure. In trench rescue applications, the low vacuum pressure means that such equipment is not very well suited for removing large pieces of soil. Instead, for this system to work effectively, the soil needs to be very granular or loose in consistency. If the soil is of a consistency that makes it easy to vacuum, the airflow picks up the debris and transports it through a flexible hose and deposits it in a debris tank. When this tank becomes full, it can be emptied through a dump hatch located at the rear of the vehicle **FIGURE 12-9**.

Because of the combination of low vacuum pressure and limited length of the intake hose, these trucks must be positioned very close to the actual trench to be effective. Such vacuum trucks usually weigh between 50,000 and 60,000 pounds (23,000 and 27,000 kg), so positioning them close enough to the trench to be effective when you have limited access or an unstable trench environment can be a real risk–benefit challenge.

FIGURE 12-8 Municipal vacuum trucks can expedite the removal of soil; however, the soil must be of the proper size and consistency that it can be picked up by the vacuum.
Courtesy of Larry Collins

FIGURE 12-9 Centrifugal vacuum truck.
Courtesy of Rescue Vac

Positive-displacement vacuum trucks may also be available. This type of vacuum truck, although not as popular or numerous as the centrifugal type, has a much greater vacuum pressure than centrifugal units and is generally used in instances that require a high lifting capacity. Because of the high vacuum pressure at the hose tip, using this type of vacuum around a victim can be very dangerous; therefore, rescue personnel should use extreme caution to avoid injury.

If getting a 60,000-pound (27,000-kg) truck close enough to the incident site to be effective is not enough, you could also elect to use a hydro vac truck to remove soil from the trench. With this technique, water is used as a reduction method to make the soil run so that it can be picked up and then vacuumed to the debris tank FIGURE 12-10. As mentioned earlier, water can be a very destabilizing element if not handled correctly. When using this type of evacuating equipment, apply only enough water to reduce the soil so that it can be successfully vacuumed from the trench.

Another soil removal tool is the vacuum system. It uses hose with couplings that allow it to be attached to most types of municipal vacuum trucks. At the end of the hose, one of several specially designed nozzles is used to vacuum the soil. These nozzles create enough vacuum pressure that the vacuum truck itself can be placed as far as 200 feet (60 m) above or 800 feet (240 m) away from your incident. Such positioning means that the truck's additional weight and the noise created by the truck's fan do not become additional hazards for rescue personnel or the victim FIGURE 12-11.

The vacuum system can also be operated from outside the trench using a combination of handles and guide ropes. Because the soil can be removed without rescue personnel entering in the trench, the process can start before the protective system is in place. Removing soil can create a more unsafe situation if it is done before a protective system is established. However, when done with consideration for rescuer safety, it could mean the difference between your operation being a rescue or a recovery FIGURE 12-12.

FIGURE 12-10 Hydro vac trucks reduce the soil to a product that can be picked up easily by the vacuum.
Courtesy of Badger Daylighting

FIGURE 12-11 Technology like the vacuum system combines older municipal vacuum technology with a product specifically designed for rescue personnel and dirt excavation.
Courtesy of Rescue Vac

If you elect to use any type of vacuum system, it will most likely have to be applied in tandem with some manner of soil reduction. Water, as mentioned earlier, may be used as the reduction method; however, far more prevalent is the use of air in the form of an air knife. In this situation, air is injected into the soil at approximately 100 pounds per square inch (7 kg/cm) to break the soil into smaller particles. The smaller particles can then effectively be picked up and moved through the vacuum system **FIGURE 12-13**.

FIGURE 12-12 Centrifugal vacuum truck.
Courtesy of Rescue Vac

FIGURE 12-13 The air knife uses compressed air to reduce the size and change the consistency of soil so that it can be vacuumed more easily.
Courtesy of Rescue Vac

All of these methods to remove soil accelerate the process of gaining access to the victim, and all of them are much better than using 5-gallon buckets and a rope. This can be very good news for your personnel who would have had to haul buckets, as well as for the victim who needs more room to expand his or her chest. This newfound speed in soil removal could, however, add risks to the situation if the soil evacuation process gets too far out in front of the protective system. Careful consideration should be given to ensuring all elements of the protective system are in place and to maintaining a proper balance among speed, efficiency, and the safety of all those involved in the incident.

VOICES OF EXPERIENCE

On Friday, October 19, 2012, the Spring Arbor Fire Department (Michigan) was called to the campus of Spring Arbor University for a man trapped in a trench cave-in. Upon arrival, members of Spring Arbor Rescue #1 assessed the scene as one person buried to his chest in a trench that was 12 feet (3.7 m) deep. The victim was conscious and trying to dig himself out with the help of his co-workers. The Spring Arbor Fire Department requested a trench rescue team from the nearby Summit Fire Department, which is part of Michigan's (Region 1) USAR Response System. Hearing the call from home was Summit Fire Department's Lieutenant Scott Stoker, who resided in Spring Arbor. The off-duty lieutenant recognized that the incident was only a few blocks away and responded to offer assistance. Upon arrival, he noted numerous workers and fire fighters in the trench attempting to dig out the victim. The trench was not shored, and soil conditions were extremely unstable. The entire length of the trench was marked by walls that had sloughed, raveled, and caved in. Other obvious hazards included exposed utilities and unsupported concrete slabs hanging over the rescue area. Lieutenant Stoker's immediate concern was to remove the workers and fire fighters from the trench. After some convincing, he was able to accomplish that life-saving goal. Site control measures included placing a ladder into the trench and eliminating vibrations by having all heavy equipment shut down. Heavy equipment still operating at the site included two excavators running at the trench lip.

"The immediate concern was to remove the workers and fire fighters from the trench."

When the Summit Fire Department trench rescue team arrived, they placed ground pads on the lip and took measurements for primary shoring operations. Shortly after that, the victim freed himself from the collapsed soil. The injuries that he suffered to both legs prevented him from being able to climb the ladder to safety. The focus of the tactical operations quickly changed from shoring to non-entry rescue. Rescuers repositioned the ladder (already in the trench) so the victim could support his body and hold onto a rung with both hands. From a safe area on the trench lip (ground pads), rescuers were able to utilize a "moving ladder slide" technique to extricate the victim from the trench. Within minutes of extricating the patient from the trench, a second cave-in occurred.

The patient was treated on the scene and transported to Allegiance Hospital in Jackson, Michigan. He was treated for a fractured lower leg and was expected to return to work following a rehabilitation period.

The Spring Arbor Trench Rescue was a good example of the "best" of all rescue opportunities (non-entry rescue). The fact that the stage was set for a successful non-entry rescue was a tribute to good training and command presence. Gaining control of the scene eliminated the potential for additional victims. Site control (ground pads and stopping vibrations) improved the window of opportunity for rescue by postponing the secondary collapse.

Quick and decisive initial actions were key to the success at this rescue. They saved the lives of first-arriving fire fighters and construction workers. The rapid change in tactical objectives allowed the rescuers to remove the patient from the trench just minutes before the impending cave-in occurred. Both training and experience can be credited with the lieutenant's ability to make those decisions and to implement the appropriate actions.

Recognizing the soil dynamics and the impending secondary collapse caused the rescuers to change tactics from a shoring-based entry rescue to a quicker and safer non-entry rescue operation. Shutting down the excavators may have delayed the secondary collapse those few extra minutes that allowed for the rescue to be completed.

Active soil creates very unsafe lip conditions, and ground pads are not always capable of preventing rescuers working on the lip from riding a secondary collapse into the trench. Lip bridges would have been a much safer method of lip protection at this scene. As a result of this incident, the Summit Fire Department now carries and trains with lip bridges.

Additionally, having equipment stored on your trench rescue unit in the order it needs to be applied to the rescue is paramount to efficient operations. We recommend at least one panel set (two panels) be completely assembled and rigged for quick placement of primary shores.

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Tactical Tip

Remove all dirt from the trench when you are digging to access a victim. Resist the temptation to just shove dirt to one side; otherwise, you will definitely be moving it again.

Victim Care Considerations

With the exception of command personnel, trench rescue involves responding professionals who are responsible for either protective system placement, extrication, or patient care. Technical rescue situations require difficult, personnel-intensive work and demand that all responders add as much value as possible to the rescue effort.

Those who have been involved in rescue work for any length of time understand that in a given situation, personnel can be called on to perform many different jobs. With specialized rescue situations such as trench collapses, the interaction between functions becomes more critical as the situation becomes more technical. In these situations, it is imperative that each rescuer, regardless of assignment, helps those performing other functions to improve the victim survivability profile—a determination based on a thorough risk–benefit analysis and other incident factors that address the potential for a victim to survive or die with or without rescue intervention. Under the incident command system, each person has a primary assignment to perform even though he or she may be cross-trained.

The information included here is not meant to take the place of any specific local medical protocols. Rather, it is provided so that trench rescuers, regardless of their specific function on the trench scene, will have an idea of the factors that they should consider when dealing with a viable patient.

■ Providing EMS Care

It is vital to consider who, exactly, will provide the patient care. The removal of a partially buried victim will likely take some time, and patient care typically starts before victim removal and continues during packaging. Consequently, you should always make certain you have the right people with the right medical skills as a part of any trench response **FIGURE 12-14**.

After the rescue team establishes a safe zone around the victim, the extrication officer should assign a paramedic in the trench to perform a primary assessment and begin patient care. Keep in mind that this person needs to be nimble and fit because there is usually limited room in which to provide patient care after rescue shoring is in place.

FIGURE 12-14 Emergency medical care providers should understand the trench environment and be comfortable operating in the special conditions they present.

Photo by Martin C. Grube

It is also suggested that the person sent to assist with patient care be comfortable with the environment. It is therefore important that this person has specialized training in trench rescue if he or she may potentially be asked to provide patient care in this very technical situation.

Training Tip

It is recommended that all the team doctors and paramedics be trained in structural collapse, trench, confined-space, and rope rescue. Such training provides patient care personnel with a sufficient understanding of the environment and the tools and, most importantly, helps create trust that rescue personnel have the skills and talent necessary to maintain their safety while they are providing patient care.

■ Concerns for All Patients

All providers of patient care should be aware of and practice local authority having jurisdiction (AHJ) requirements regarding universal and/or standard precautions. Such precautions cover protection of both the provider and the patient from exposure to blood, other body fluids, and/or airborne products that could pass from the rescuer to the victim or from the victim to the rescuer. Examples of these protections include hand washing, gloves, gowns, masks, eye protection, and respiratory protection.

Assuming you are properly protected, the trench has been made safe, and you are ready to enter and begin the assessment and treatment of the victim, remember the first rule of medicine: Do no harm. Always protect the victim from further injury and proceed with caution. Most trench rescue scenes will be cramped, and you will have limited room in which to work, making assessment and treatment a challenge. Often the trench will be muddy and contain water, creating a slippery, uncomfortable, and intimidating situation. Do your best to block out distractions and concentrate on patient care.

During scene size-up, determine whether the victim has suffered some type of injury or experienced a medical problem. If an injury has occurred or the patient has fallen, use C-spine precautions, if possible. Start the assessment with a primary survey, checking the ABCs (airway, breathing, and circulation). First, check for an open airway and secure it as necessary. If trained in advanced airway management, place an oral airway if the patient is unconscious and will tolerate it, but be prepared to intubate if required.

After you have secured the airway, assess the victim's breathing. If the patient is not breathing adequately, administer supplemental oxygen and assist with ventilations, if required. One trick when administering oxygen in a cramped space is to keep the oxygen bottle outside the space and add extension tubing to the delivery device on the patient via an inexpensive, double-male adapter. If the patient is having breathing difficulty for no apparent reason, reevaluate for the possibility of a toxic or oxygen-deficient atmosphere—you should have already checked the atmosphere at least once before accessing the victim. Confirm that the trench is well ventilated and constantly monitored, while also ensuring that airflow on or near the patient does not cause hypothermia.

Next, assess the victim's circulation. This can be accomplished by checking capillary refill and taking radial, brachial, or carotid pulses or a blood pressure by palpation. The trench environment may be noisy, making it difficult to auscultate blood pressures.

After the primary survey has been completed, proceed with the secondary survey, and check for any additional life-threatening injuries. If none is found, prepare to package the victim for removal. It will be much easier to continue patient care after the victim is out of the trench and in the medical unit **FIGURE 12-15**.

If additional life-threatening problems are found during the secondary survey, treat them as quickly as possible. Traumatic amputations and crush injuries tend to bleed moderately and can be stabilized with a bulky pressure dressing. If major extremity hemorrhage is present and cannot be controlled with a pressure dressing or direct manual pressure, use a blood-clotting product if allowed by your state and regional protocols. A blood pressure cuff applied over a dressing can be inflated to apply direct pressure when manual pressure cannot be achieved. You will have additional time to control bleeding after the victim has been removed from the trench. When compared to all other techniques used to control bleeding, the placement of a tourniquet should be the last resort.

FIGURE 12-15 When deciding on patient packaging devices, consider the limiting factor of the shoring system.
Courtesy of Brad Ferguson

Fractures that are not life threatening should be stabilized by securing the patient to a long backboard. Do not take the time to splint these injuries in the trench unless the victim is completely stable and the scene is safe. After the patient has been removed from the trench environment, treat the patient as you would any other victim of trauma or illness.

■ Victim Care Involving a Collapse

If the victim is completely covered, try to determine where the victim's head is, and uncover the head and chest first. Be aware that the victim's mouth and airway may be full of dirt and foreign matter. Clear the airway as quickly as possible by any means available. Use your fingers and suction from at least one portable suction device to remove the obstructing debris, and then attempt to ventilate the patient. If you do not succeed, look deeper in the patient's airway for additional debris.

After the airway is clear, check for adequate breathing. If the patient's chest and abdomen are covered by soil, breathing may be restricted and compromised. If the dirt in the trench is dry or sandy, it will easily move and flow around the victim and cause additional chest restriction. Each time the victim exhales and the chest deflates, dirt will flow in and fill the void, causing more restriction; therefore, it is essential to clear the dirt from around the victim's chest to allow proper lung expansion as soon as possible. If a rated sling or rescue-quality rope is placed on the victim to keep him or her from sliding down deeper into a hole, make sure that it is not restricting the patient's breathing or complicating his or her condition.

After the head and neck are clear, place a cervical collar to stabilize any possible C-spine injury. If the victim can communicate with you, ask whether he or she is aware of any injuries in the area still covered by dirt.

Uncovering a victim's buried limbs can be slow work, and you will need to provide emotional support to the victim during this process; however, you can also use this time to plan how to manage additional injuries. For example, if the victim tells you that he or she has a broken upper leg and it feels wet, be prepared to handle an open femur fracture and have the necessary equipment ready for when the injury is uncovered.

As soon as an extremity is uncovered and accessible, establish an intravenous (IV) line of normal saline with a 16- or 18-gauge catheter. This line can be used for fluid replacement or drug administration, if necessary. Remember to secure the IV well because there will be a lot of victim movement and many people working in the area.

If the victim's chest is uncovered and circumstances allow, place a cardiac monitor on the victim and check for abnormal heart rhythms. As the extrication proceeds, monitor the victim's condition, while constantly providing emotional support. Such support is important and will have a positive impact on the victim's outcome.

Tactical Tip

When administering medication via IV, consider drawing up the medications from the glass vials into plastic syringes before passing them down to the medical personnel in the trench. This will eliminate the possibility of the glass vial breaking and will save the medical rescuer some time.

■ Special Considerations

During a prolonged extrication, the trench environment will be cooler than the surrounding area, and hypothermia could be a concern—even in summer. The earth below grade remains at a constant temperature, usually in the low 50s (degrees Fahrenheit; 10s degrees Celsius), year round.

Prolonged contact with cool soil can lower the patient's core temperature, and because most trench environments are damp or contain water, the patient may be surrounded by water or mud, increasing the body's rate of heat loss. Inclement weather can also lower a patient's body temperature. Given these factors, you should consider the use of heated forced-air blowers or the administration of heated IV fluids as a method to prevent hypothermia when dealing with prolonged trench extrications in colder climates.

Try to keep the victim as dry as possible, and limit his or her contact with the ground if possible. Place some form of insulation, such as an isothermal blanket, under and around the victim to prevent heat loss. The use of a foam pad, extra turnout gear, or blankets will also help. Heated, humidified oxygen may be administered to warm the core body from within. Hot packs under the armpits or around the neck/head region will warm the victim. You can also direct portable quartz lights toward the area to add heat if the environment is safe.

A condition known as crush syndrome occurs in prolonged entrapments where the victim's body tissue is crushed and circulation to the tissue is restricted. Because the blood flow is reduced or absent, the affected tissue becomes acidotic, and lactic acid builds up. When the crushed tissue is relieved and circulation restored, blood dumping into central circulation causes such problems as cardiac arrhythmias and electrolyte imbalances. Although an exhaustive review of crush syndrome is beyond the scope of this chapter, you should be aware of the potential problems associated with it and monitor and treat entrapped victims for this condition.

When a victim is entrapped for an extended period of time, he or she may deteriorate to a point where defibrillation or cardiopulmonary resuscitation (CPR) is required. You must be prepared for this situation and its potential hazards. Remember that a victim trapped in a trench environment may be wet. If defibrillation must be attempted, make sure that the patient is dried off as much as possible, that defibrillation pads are securely in place, and that the area is as clear as you can make it.

If the patient's condition continues to deteriorate and he or she progresses to asystole (absence of electrical activity in the heart), carefully consider all factors before starting resuscitation efforts. Effective CPR will be difficult, if not impossible, when a victim is trapped in a trench environment. If removal of the victim is expected to be a lengthy process, you should reconsider the entire situation and your termination of care protocol before starting resuscitation efforts. If you have a question regarding whether you should begin CPR, contact medical control and seek advice.

■ Victim Packaging and Removal

Trench rescue victim packaging and removal techniques are not all that different from the other technical rescue (rope and confined-space rescue) victim packaging techniques that you have learned up to this point. Nevertheless, a few extra considerations warrant your attention.

While working to remove a victim from a trench, extreme care must be taken not to dislodge any of the shoring material. This can, and frequently does, happen during extended digging operations when many personnel are working at the same time. Someone on the scene should continuously monitor the integrity of the protective system **FIGURE 12-16**.

Essential to the successful removal of a buried victim is careful and comprehensive preplanning of activities leading up to that removal. It is not uncommon for rescuers to place their shoring material so close to the victim that it is impossible to remove him or her. Take the time to forecast your movement patterns and consider how the type of packaging device will affect the victim's removal. If planning reveals that adjustment or moving of the shores is necessary, start before victim packaging begins.

Another concern in victim extrication from a trench is an activity that is usually handled by the rigging group: The trapped victim will eventually have to be lifted out of the trench. If the victim is large or the packaging device is cumbersome, you may want to implement some sort of mechanical advantage system. To do so effectively, some kind of elevated (high directional) point of attachment will be necessary. (See the "Lifting, Moving, and Stabilization" chapter for more information on mechanical advantage.)

FIGURE 12-16 Constantly monitor the protective system, and never let your guard down or rush to remove the victim during the extrication process.
Courtesy of Captain David Jackson, Saginaw Township Fire Department

The method used to secure the victim during digging operations may be as simple as wristlets attached to an elevated platform **FIGURE 12-17**. This system may be all that is required until soil removal allows placement of a hasty harness around the victim's hips and legs. Ultimately, you may want to secure the victim in a full or partial body lifting system for final removal. Always keep in mind that the victim's condition and the risk–benefit considerations ultimately will determine the speed at which the victim needs to be removed and the mechanism employed to effect the removal.

By far, the best practice is to find an elevated attachment point and remove the victim vertically

FIGURE 12-18. The primary reason for this preference is the need for a method that can both support an unresponsive victim during the digging process and remove the victim once he or she is free. Generally, as the entrapping mechanism is removed from around the victim, he or she becomes flaccid and difficult to manage. Supporting the victim from an elevated attachment point keeps the victim in a mostly vertical position throughout the extrication process. Additionally, removing the victim vertically allows removal from the trench while staying entirely between the safe areas of the panels.

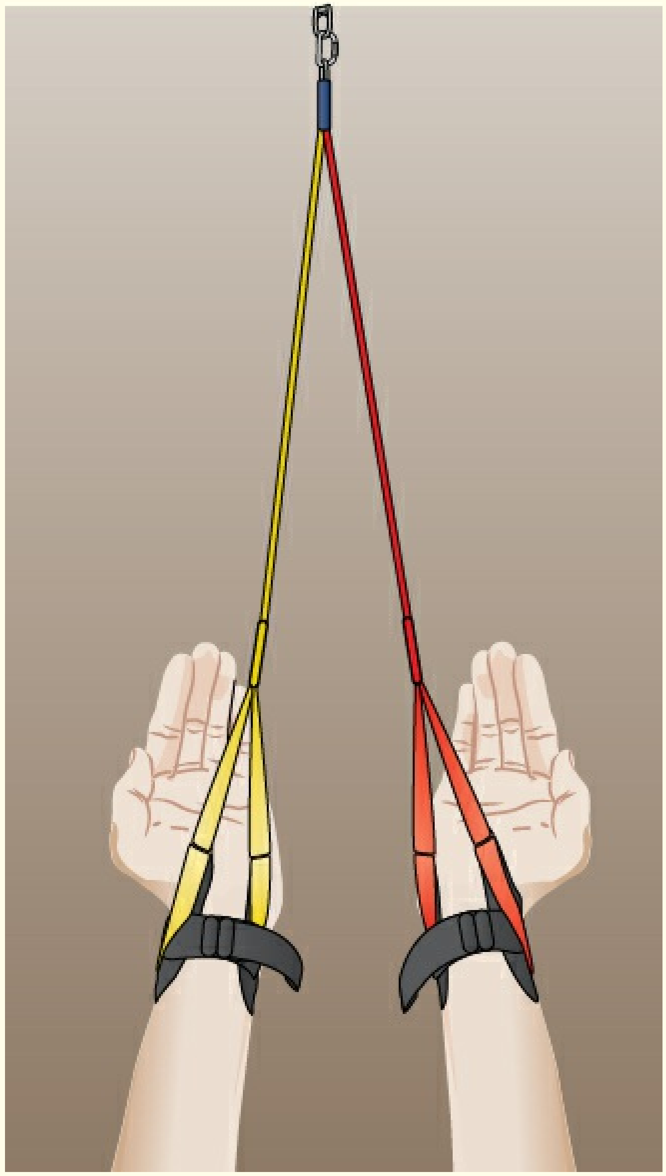


FIGURE 12-17 Wristlets are lowered to the victim to provide stabilization during digging operations.

FIGURE 12-18 The vertical lift is usually the preferred method for removing victims from a trench.
Courtesy of Lance Cpl. Angel J. Velasquez/U.S. Marines

Wrap-Up

Review: Just the Dirt

- To be successful in trench rescue, you need to mitigate the incident in a manner that brings no further harm to the victim and absolutely no harm to the rescue personnel.

- Non-entry and victim self-rescue are always the preferred rescue methods, as they reduce the risk to rescue personnel; they should be considered in every incident.
- Conducting a pre-entry or preaction briefing allows the incident commander, operations chief, or rescue leader to discuss the plan with personnel.
- Applying the same evaluation criteria to both cave-in and non-cave-in incidents will keep you from making a mistake and operating in an unsafe area or a potentially hazardous environment.
- Excavation techniques include working with existing systems and vacuum systems.
- It is imperative that each rescuer, regardless of assignment, helps those performing other functions to improve the victim survivability profile.
- After the rescue team establishes a safe zone around the patient, the extrication officer should assign a paramedic in the trench to perform a primary assessment and begin patient care.
- Always protect the victim from further injury and proceed with caution.
- Clear the victim's airway as quickly as possible by any means available.
- During a prolonged extrication, the trench environment will be cooler than the surrounding area, and hypothermia could be a concern—even in summer.
- Trench rescue victim packaging and removal techniques are not very different from other technical rescue victim packaging techniques.

Hot Terms

Air knife Tool that injects air into the soil at approximately 100 pounds per square inch (7 kg/cm) for the purpose of breaking the soil into smaller particles.

Axial loading A force that is applied in the same direction as the shaft.

Centrifugal vacuum truck Apparatus that uses a large fan to create suction in the intake line.

Class 3 harness Harness designed with lower body and upper body attachments.

Crush syndrome Medical condition that is the result of a prolonged entrapment where the victim's body tissue is crushed and circulation to the tissue is restricted.

Non-entry rescue Rescue techniques employed to eliminate the necessity of rescue personnel entering a hazardous area.

Vacuum system Equipment that uses a standard hose with couplings and specially designed nozzles to create vacuum pressure and that attaches to most types of municipal vacuum trucks.

Victim survivability profile Determination based on a thorough risk–benefit analysis and other incident factors that address the potential for a victim to survive or die with or without rescue intervention.

Wristlets Webbing or other material designed to wrap around the wrist for the purpose of providing a lifting or pulling attachment point.

TRENCH RESCUER *in action*

You are part of a trench rescue team that was called to a trench collapse incident in a neighboring town. Upon arrival, your officer reports to command, while you and the rest of the team begin opening your trench rescue trailer. Your officer returns to give you an overview of the situation. Three workers are trapped in the trench. One is almost completely buried, with just his hand sticking out of the soil, and the other two are buried to varying degrees. Your officer has been instructed by command to come up with a strategy for making the trench safe and removing the three workers.

Because you are the senior member of the team in attendance, your officer asks you to come with him to do the initial assessment of the trench. The trench is 6 feet (1.8 m) wide and approximately 10 feet (3 m) deep, and is open for a length of 30 feet (9.1 m). The collapse zone is about 6 feet (1.8 m) along the near end of the trench and involves a spoil pile slide into the trench. The first-arriving crews have laid ground pads on three sides of the trench and have placed a ladder on each end of the collapse area, about 10 feet (3 m) away from the workers. The two workers who are only partially buried are very aware and responsive. One is buried to above the diaphragm level of his chest, and the other is buried to just above his knees and is frantically digging with his hands to free himself. There is no sign of movement from the hand of the third worker. You and your officer realize that the lightly buried worker may actually free himself in the next couple of minutes.

1. Which steps would be most appropriate to assist the lightly buried worker in successfully self-rescuing?
   - **A.** Pass him a Class 3 harness and instruct him in how to don it
   - **B.** Pass him an entrenching tool and place a ladder as close as possible for him to climb up once he is free
   - **C.** Have him put on a pair of wristlets and pull him out
   - **D.** Have a rescuer enter to assist the worker in digging himself out
2. The worker has self-rescued, but there are still two victims to deal with. What should you do next?
   - **A.** Implement your rescue plan
   - **B.** Try to talk the second trapped worker through self-rescuing
   - **C.** Do a victim survivability profile for the two remaining trapped workers
   - **D.** Begin installing panels and shores
3. Your initial assessment is complete. Which step should be taken before proceeding with further rescue actions?
   - **A.** Create an action plan
   - **B.** Hold a safety briefing
   - **C.** Create a rescue plan
   - **D.** Conduct a pre-entry briefing
4. With only one viable trapped worker, all efforts are being directed to his rescue. The trench team has installed the first pair of panels to protect the viable worker. When is it safe to send in a medical person to begin assessment on the trapped worker?
   - **A.** As soon as the first strut is shot and secured
   - **B.** As soon as the middle strut is shot

C. After a safe zone has been established around the patient

D. As soon as all struts are shot

5. The worker has now been trapped for almost an hour. Which of the following injuries or conditions is least likely to be a concern for your medical team?

A. Hypothermia

B. Fractures

C. Heat stroke

D. Crush syndrome

6. The remaining trench panels have been installed, and the trapped worker is nearly free. He has possible fractures to his lower legs. Oxygen is being administered, and an IV has been started as a precaution. Which of the following techniques would be the best method of removing the worker from the trench?

A. Vertically with a high point lift, with the worker secured on a spine board in a Stokes basket

B. Vertically using wristlets on the worker's wrists

C. On an angle up a ladder, with the worker secured in a Stokes basket

D. Vertically with a high point lift, with the worker in a Class 3 harness

Rescue Team Leadership

CHAPTER 13

Trench Rescue Level I

Knowledge Objectives

After studying this chapter, you should be able to:

- Discuss the importance of rescue team leadership. (pp 238–239)
- Describe the role of frontline personnel in operating the rescue system. (pp 239–240)
- Describe the role of middle management in improving the rescue system. (pp 240–242)
- Describe the role of chief officers in creating the future. (pp 242, 245)

Skills Objectives

There are no Trench Rescue Level I skills objectives for this chapter.

Additional Resources

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*

You Are the Trench Rescuer

The chief is frustrated with succession planning in the department and, in particular, in the technical rescue team. It seems that while the team has been very efficient and effective over the years, only a small number of people have shared the honor of being department technical rescue team members.

Through a recent annexation of territory, your local department has taken over another area, which has opened up the opportunity for several unanticipated promotions. In reviewing the promotions list, you have come to realize that many of those promotions will come from the ranks of the technical rescue team.

As the new supervisor of the technical rescue team, this afternoon will be your first meeting with the chief to discuss team issues. You are certain that the issue of succession planning and team leadership will be foremost on the chief's mind. In preparation for this meeting, you sit down to discuss with current team members what they see as challenges to leading the technical rescue team in the future.

In the lively conversation with team members that ensues, some advocate that you, as the leader, need to take a more hands-on approach and practice with the team, which was the style of the former team leader. In a nutshell, those team members are comfortable with the old way, as many of them firmly believe that any effective leader needs to be as proficient in rescue operations as the people who provide the service.

Other team members profess the opposite view: They are frustrated that the previous supervisor did nothing to prepare the team for future challenges and in particular to ready new team members for the challenges of being proficient in such a high-risk, low-frequency event as technical rescue.

In advance of your meeting with the chief, you are organizing your thoughts concerning the team members' input and need to come to some resolution concerning your opinion on the following issues:

1. How important is it that the team leader be as proficient in rescue operations as the team members?
2. How much time should the team leader devote to planning for the future as opposed to operating in the present?
3. If the chief asks you how much time you plan to devote to improving the efficiency of the team, how will you answer the question?

Rescue Team Leadership

Building a great rescue team involves people in various job functions within the team understanding both their own roles and the expectations of others with regard to work outcomes. When these expectations have been clearly stated, accountability and responsibility are natural outcomes.

One cannot overstate the importance of leadership and management within rescue teams. Having a rigorously trained and well-equipped team does not happen by accident. Rather, it results from a very strategic and well-conceived plan that addresses every aspect of strong and competent team building.

Another, simpler way to state this idea is that some of us are in charge and some of us follow directions. This is not a chapter about incident command; rather, it deals with specific management and leadership considerations that help create successful rescue teams. As with most technical rescue operations, leadership from all levels of the team is essential to ensure team success. In other words, fire fighters, middle managers, and chief officers all have very important leadership roles in high-achieving, innovative, and progressive trench rescue teams.

Fire and rescue organizations, because of their paramilitary structure, are often depicted as a steeply pointed pyramid. Most personnel are located within the wide base of this pyramidal hierarchy, and far fewer are located within the narrow point at the top. As the pyramid becomes narrower at the top, there is typically a corresponding increase in the level of responsibility and accountability.

The pyramid, by its very nature, speaks to many of our problems in the rescue business because it embodies the idea that those at the top are more important than those at the bottom. It is also safe to assume that people come to understand this pyramid from the perspective that, as we continue toward the peak, our roles and functions completely change.

Although the pyramid is perhaps something we are stuck with in our paramilitary structures, the way we view the pyramid and act within its framework can and should be rethought. The pyramid represents a simple view of leadership in organizations, but we can operate to reduce the layers of separation in it that might otherwise create an “us versus them” mentality.

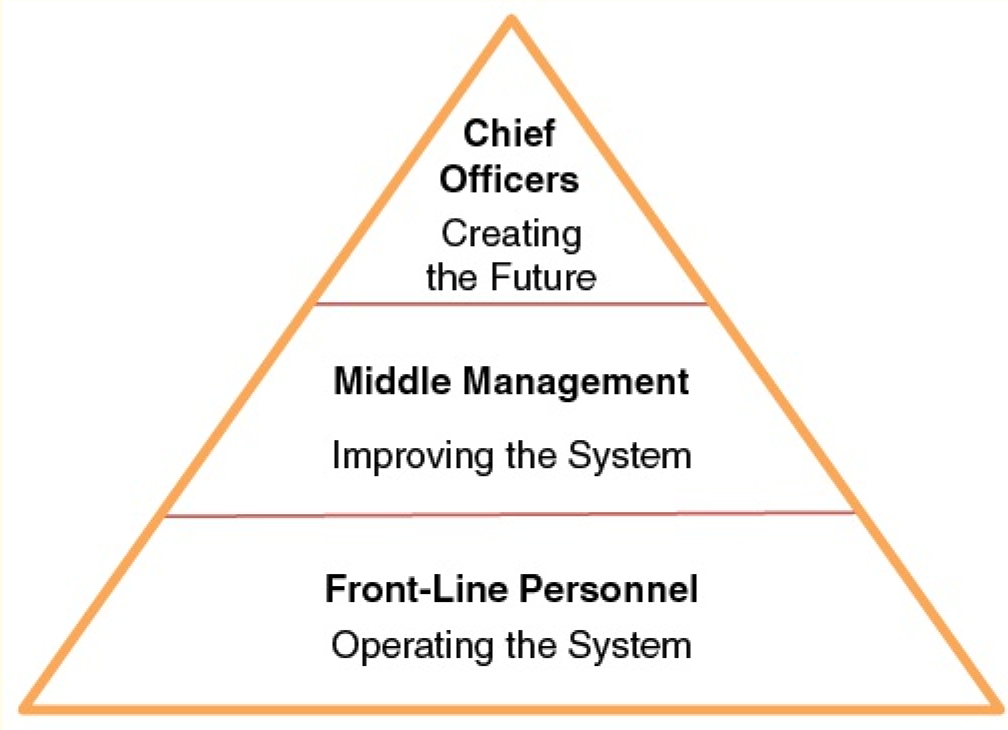


FIGURE 13-1 The organizational pyramid of a trench rescue organization.

The organizational pyramid of a trench rescue organization has three basic levels **FIGURE 13-1**. At the bottom of the pyramid are the frontline people who make up the organization's greatest numbers. These individuals provide direct service delivery to the public and actually operate the system. You count on them to provide rescue services when an emergency occurs and to help maintain the system under nonemergency conditions.

Just above these operations personnel in the pyramid are the middle managers. They are fewer in number and provide functional oversight and coordination during system operations. These managers also have the very important role of looking for ways to improve system operations and other management-related team activities. In most fire service systems, these personnel are called battalion or division chiefs.

The top level comprises the chief officers, those in command, who represent the fewest members and are charged with looking toward the future. These individuals conduct strategic planning and other organizational management tasks.

Essentially, rescue team members are responsible for either operating the system (rescuers), improving the system (middle-management officers), or creating the future (chief officers). All of us, regardless of rank, spend time in one of these areas, and in many cases, we are involved in all three areas at one time or another. In the strongest teams, all members address all three functions to some degree. It is the percentage of time that they spend in their primary area, however, that determines whether the team will find success.

Frontline Personnel: Operating the System

The largest component of any rescue team is made up of the personnel who perform rescue work, their first-line supervisors, and the officers who provide direct oversight **FIGURE 13-2**. These employees directly operate the system and, when given the proper tools and direction, function quite well without much intervention. Most of the individuals who work in specialized operations work very well and get the job done with minimal direction.

FIGURE 13-2 Most members of a rescue team are frontline personnel.
Courtesy of Tim Olk

The operations roles become much easier when leaders provide the necessary tools, empower the workers to make decisions, and trust that they will do what is necessary to get the job done. Things start getting a little cloudy when leaders at the "improving the system" and the "creating the future" levels start spending too much time directing the "operating the system" personnel. This practice is commonly referred to as micromanagement, and if you have ever worked under this type of leadership, you know that this situation is the least empowering, most uninspiring, and least progressive type of leadership.

■ Activities and Responsibilities

In operations, officers should give workers control to operate the system and, to some extent, accountability for the outcome of the operation. This process cannot begin, however, until the operations activities are defined.

Safety

Each member of the trench rescue team is responsible for his or her own safety. Frequently, this safety culture starts with each member having a good grasp of the standard operating procedures (SOPs) that determine emergency scene operations, and extends to a comprehensive understanding of Occupational Safety and Health Administration (OSHA) regulations and other state and local compliance considerations for incident site operations. It is never acceptable for rescuers to assume that they can do anything until told differently. Rescue operations are dangerous—and very unforgiving when performed incorrectly. The bottom line is that if you are hurt, it is always your fault.

Compliance

Rescuers' compliance with NFPA 1006, *Technical Rescuer Professional Qualifications*, and NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, must be documented. Whether the rescue team members are fully trained to NFPA 1670 Awareness, Operations, or Technician levels and to NFPA 1006 Levels I and II will ultimately determine the degree to which team members can participate in the rescue. Benchmarking team members against these well-thought-out consensus standards is the first step in the accountability part of your empowerment as a frontline member of the team.

Community Needs

Higher management staff should be kept informed of the special needs of the community. Do not assume that upper management is sitting around somewhere worrying about what you may face on your next shift. As a trench rescue team member, it is up to you to recognize and anticipate the needs of the community that you serve and then make specific recommendations to address directly the formalization of best practices for that situation. Doing so may require brainstorming new ideas with team members, recommending the proper equipment to handle an emerging type of rescue, or making sure you have requested adequate equipment and resources to do the job.

Environment

Individual team members also have a responsibility to understand the environment in which they will be required to operate. For instance, a trench rescue in sandy soil is a very different problem than a trench rescue in hard-packed and nonrunning soils. Understanding the limitations of your equipment and knowing how it will perform in a variety of circumstances are best achieved through training and practice.

Equipment

The people required to use the equipment in an emergency situation should be the same people who make sure that equipment is assembled, stored, and maintained so it is ready when needed. The set of rescue equipment is your tools, and the tools absolutely must work when they are needed to save a life.

Strengths and Abilities

Team members at the operations level also need to take responsibility for making sure that members are available at all times. Rescues do not take a day off, and you should always be prepared to respond to an incident. This extends to making sure associate team members are physically able to do their job. Do not wait for a team SOP on physical fitness to be issued: For members of a special operations team, being constantly proactive in striving to be the best is what makes you special.

The rescuers providing the direct service are the team members who provide the critical path to success for the team. This is accomplished instinctively by evaluating and understanding each team member's strengths and limitations. That way, members can be placed in the proper role when it counts the most.

To make the most of every member's talent, you should establish and maintain regular training cycles for team members so that they can learn one another's specific talents. In addition, you should continually recruit new team members and establish testing processes to ensure that all members have what it takes to be part of the specialized unit. Allow and encourage other department members to come to your team training sessions to observe and learn. What they learn today may be used tomorrow.

A final word regarding your role in team leadership and management: It is your job to create, monitor, and maintain team loyalty and focus. Maintaining member interest during the often long periods between calls is not the job of some officers that we affectionately refer to as "them"; rather, it is an "us" job.

Middle Management: Improving the System

Middle managers and battalion and division chiefs should concentrate on how alignment occurs at the rescue scene and consider how their efforts can be directed at improving the efficiency and effectiveness of operations **FIGURE 13-3**. These employees are seasoned veterans and the least removed of all officers from the frontline service providers. They are generally required to coordinate the personnel operating the system, and they should be in a position to make recommendations regarding the efficiency and effectiveness of operations. Collectively, these efforts are called "improving the system."

Perhaps the most important aspect of middle management and on-scene operations is the establishment of a strong and reliable incident command system. As a middle manager, your first responsibility and main objective is to organize and maintain accountability of personnel. The process of on-scene accountability is always best done through effective incident management.

FIGURE 13-3 Middle management is focused on improving efficiency and effectiveness of operations.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

Communication

Middle management personnel are just close enough to top leadership that they understand the limitations of the organization, yet near enough to the bottom that they can see how the limitations affect both the community and rescue personnel. They are, in effect, a conduit by which vital communications make it from the bottom to the top of the organizational pyramid, and then from the top back down again.

Without an effective communications flow, the organization can come to a standstill; therefore, good communication is one of the most critical elements in rescue team leadership. It becomes even more imperative when you consider that most trench rescuers are on specialized teams outside of a regular job of firefighting or emergency medical services delivery. Regardless of your background outside of trench rescue, gathering team input through effective communication is critical to building strong relationships among team members, and is the foundation on which great teams are built.

Not only does middle-management leadership need to be effective at communicating with existing and future team members, but it also needs to provide a platform for effective communication between government leadership and the community. The processes involved in making sure all stakeholders know what you do and understand the resources you need to be effective are keys to building a successful rescue team. The same criteria apply when serving as a liaison with other local and national teams to build a network of communications and information flow.

■ Evaluating Personnel, Training, and Equipment

Just as with the personnel "operating the system," a large part of the job for rescue middle managers is focused on evaluating people, training, and equipment. Middle management should be receiving a lot of information from frontline rescue personnel, and it is necessary to analyze the statistical data and then get them the appropriate resources to be effective. At the very least, if a true need exists, you should advocate for the needed resources if that is all you can do at your level.

Ideally, requests for additional resources should be based on data. These data can result from analyzing rescue techniques for efficiency and effectiveness and then using this information as a baseline for developing performance benchmarks. If you can demonstrate a true need within your community based on the measurement of an agreed-upon goal, then you are much more likely to be successful in your efforts to secure resources to meet that need.

Another very important function of middle management in rescue leadership and management is making certain the system that you are working so hard to build and support actually meets the needs of the community. Some teams have a wealth of equipment but not enough personnel trained at a high enough level to operate that equipment. In other cases, teams have very talented personnel but woefully limited equipment. As a middle manager, you should use your leadership position to advocate for a good balance between personnel and equipment, and make certain those in decision-making positions understand the entire picture when it comes to successful rescue operations.

At this level, you are also responsible for developing procedures for each team function so that individuals in those positions do the right things. In particular, you should look for common threads that link individual team components together and then align the specific functional areas so that they complement each other. In middle management, you are in a coordinating and improving position—which means you keep everything running in the same direction, even if you cannot keep it all together.

Because middle managers are close enough to the action to see problems in practical applications, they are in a unique position to recommend and even in some cases develop new training curricula. In this role, they assume the responsibility of advocating for continuing education and enhanced skills development opportunities for team members, with an emphasis on improving the overall team and individual work skills. Put simply, the middle manager recognizes problems and then recommends solutions to fix them—not waiting for the next shift to do it!

Another responsibility for middle management is to create and maintain a process to benchmark team members' skills. Not all team members need the same skills, because successful teams are created by making sure that each team member's skills complement those of the other team members, and that team members are then placed in situations in which they can best help ensure a positive rescue outcome.

The most successful leaders, regardless of their level in the organization, understand that the greatest asset team members bring to the team is the skills in which they are strongest to begin with. Do not spend your time looking for people's weaknesses, but rather devote your energy to getting the right members into the right positions—that is, into the positions where they can help the team in the things they are good at.

Organizations often rely on middle managers to recognize deficiencies in team operations because they are just far enough away from the frontlines to avoid tunnel vision. Detection of deficiencies may occur through observation of incidents and training and through postincident critiques. For example, after a somewhat difficult trench incident in running debris, a team might decide to explore and test new techniques for rescues in situations with loose running soil. As a middle manager, you need to make sure that the important lessons learned are not forgotten, but rather implemented following the review and critique of the incident. This extends to the lessons learned from other departments' successes and failures as well as through articles and other accounts of rescue incidents.

The process to improve rescue operations may also extend to recommending improved uses and functions for existing equipment and to evaluating new technology. In such cases, it is vital to make sure that the equipment is adequate for solving the problem and not just a "quick fix" that will compromise the safety of rescuers.

Tip

There may be some temptation to engage in "comshawing," in which one acquires equipment and tools in a manner inconsistent with department procedure. In this situation, an industrious rescuer comes into possession of a piece of equipment and then adds this suspiciously acquired asset to the team's inventory. This vital piece of equipment then breaks or becomes unserviceable, at which point it is presented to the organization's logistics officer as a needed replacement item. In this way, a piece of equipment that was never approved for purchase as part of the budget process may be replaced using the budget process. While this method of acquiring assets can be effective, it is not a very value-driven manner in which to operate your rescue team.

■ Mentoring, Coaching, and Team Building

While mentoring and coaching in healthy teams takes place at all levels, middle managers must ensure that it is happening. Leaders at this level frequently have valuable experience and can relay those tough lessons learned to less experienced team members. Such experience can also help bring a sense of calmness to team operations. This type of experience, as relayed through coaching and mentoring, is vital for newer team members.

One very important function for middle managers has to do with establishing new teams or bringing new members onto existing teams. Middle-management officers are frequently called upon to use their experience for the purpose of establishing testing benchmarks for new team members. In this role, they are responsible for developing policies regarding who can be on the team, how long they can stay, and how active they should be to maintain team affiliation. This function is performed by fully communicating written guidelines for team membership and then holding the team members accountable and responsible for abiding by those rules. In some cases, this is a "tough love" process, but specialized rescue teams are successful because members are proud to be associated with them. This kind of accountability is created by setting the bar high and then holding personnel accountable for reaching it.

Chief Officers: Creating the Future

Chiefs and other senior staff personnel should plan for and create outcomes that will help the organization adapt to the future **FIGURE 13-4**. This place in the time allocation model is called "creating the future." It is the responsibility of upper management to determine the course and provide adequate assets for frontline employees to operate the system and for middle managers to adjust and improve system operations. This top level of the organization has less to do with what we are doing now than with what we will be doing next.

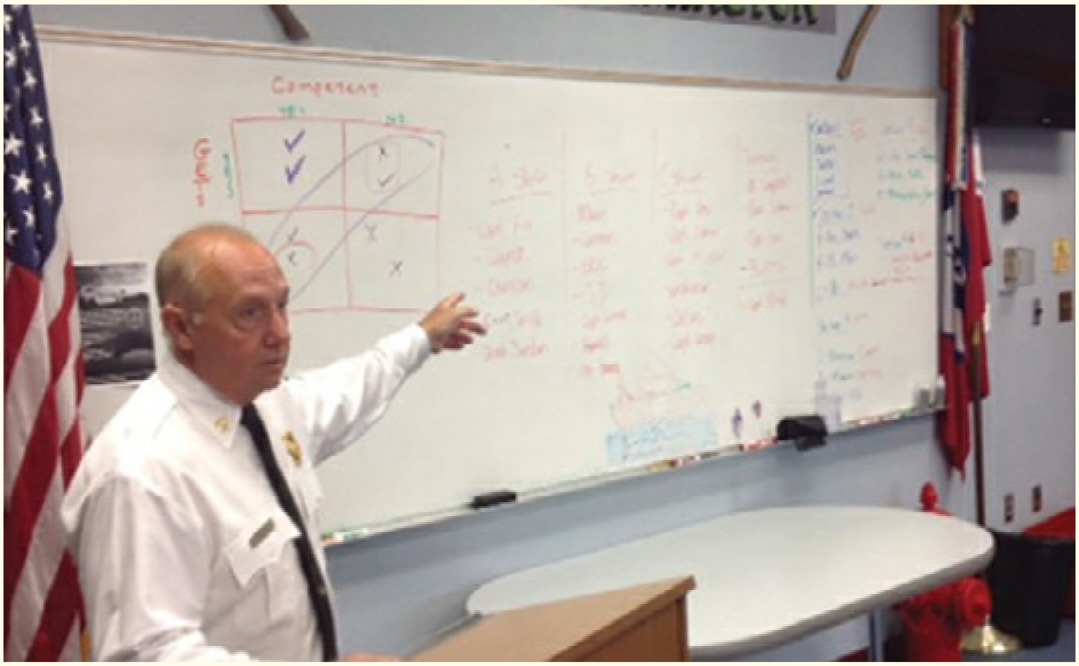


FIGURE 13-4 Chief officers are tasked with creating the future of the organization through strategic planning, recruitment, and other activities.
Courtesy of Cecil V. "Buddy" Martinette, Jr.

In addition to understanding each level's responsibility, it is imperative that senior management create open communications through all levels of the team's organization. It is never acceptable to withhold information or create a system where "power" is in the knowledge you withhold from your members. As with every good relationship, good teams are built on a foundation of trust and honesty.

Many resourceful chief officers spend much of their time developing innovative funding sources for equipment purchase and replacement. This activity is certainly critical in the rescue business, because specialized rescue incidents do not happen every day, yet they require specialized and somewhat expensive equipment to mitigate. These characteristics present quite a paradox for local government officials when they are divvying up a limited pool of tax dollars. Developing partnerships with local utility contractors or finding a sympathetic social organization in your community can be just the steps that your team needs to keep things running.

■ Values and Culture

When discussing leadership values, one does not have to look any further than team culture to see how good values produce great teams. The job of those at the highest levels of the organization is to ensure that the desired team values are ingrained into the culture of the team and permeate every aspect of its decision-making system. Open, honest communication is developed by "walking the talk" in your everyday actions. Mentoring, coaching, and developing the team's culture ensure that common goals are aligned and decision making is consistent through all levels of the team.

■ Strategic Planning

We expect our leaders to consider demand for future responses and the ever-changing political and societal aspects of the community. As a leader, you should never expect your people to pay close attention to what is happening at the street level and then hold them accountable when they are run over by a truck (i.e., changing environment) they did not know was coming. Looking out for the truck is your primary function at the chief officer level, not the team's.

VOICES OF EXPERIENCE

In 1994, Ray Downey, Buddy Martinette, and I taught a Rescue Specialist train-the-trainer class for the FEMA USAR [Federal Emergency Management Agency urban search and rescue] task forces. Ray was one of the main driving forces behind the creation of the FEMA system, and it was through his leadership that some 20 years later we have such a professional rescue system in the United States and, for that matter, the world.

Ray's rescue system influence began many years ago, when he was the captain of Rescue Company 2 in Brooklyn, New York. During this time, he was instrumental in developing much of the training curriculum in use today. More importantly, Ray was a mentor to all whom he met. He understood that being the best fire fighter or fire officer one can be is simply not enough. A truly great leader has a responsibility to prepare all around him or her for the day when the leader is not there, whether that absence is due to a day off-shift, retirement, or, as in Ray's case, an untimely death as a result of the terrorist attacks in New York on September 11, 2001.

"Having a deep bench is important, but having the ability to replicate that bench, creating additional high-quality personnel, is even more vital."

Chief Downey was an absolutely tremendous fire and rescue officer, as his numerous medals for valor will testify. As the company commander of Rescue 2, he took his responsibility for training the people assigned to his unit to heart. In fact, he was not only training his people, but was also an instructor at numerous technical rescue conferences, and he advocated to the city, state, and federal government for funding to bring about what eventually turned into the nation's 28 USAR task forces. In time, Ray realized that his mission in making Rescue 2 into the finest technical rescue unit possible was well in hand, and that his expertise would be more valuable at the strategic level, as the chief in charge of all of New York City's special operations units. It is there, perhaps, that he had the greatest impact. Certainly it had the greatest impact on me.

The role of the strategic leader is to exercise vision, imagining the threats and opportunities an organization will face in the future; to obtain the resources that will allow the people charged with achieving the mission to do their jobs; and then get out of the way and let the troops do their job. Ray was instrumental in building FDNY's Technical Rescue School, obtaining funding to better equip the field units, and making them aware of the future challenges the department was likely to face, including the growing threat of terrorism.

A key role for upper management is mentoring and succession planning—that is, preparing the organization for the inevitable day when a leadership transition occurs. In the case of FDNY SOC [Special Operations Command], there was a transition plan already under way. Ray Downey was approaching mandatory retirement. Ray's executive officer, Charlie Casper, was almost due to be promoted to deputy chief. The plan was that Charlie would work side-by-side with Ray for 6 months, and then Charlie would be promoted and Ray would retire. It was a good plan, but one good plan is not good enough. Accidents happen, and illnesses and other unforeseen events may impact plans, so the FDNY tries to have not just a "plan A," but a "plan B" and a "plan C" as well. In this case, two other battalion chiefs assigned to the SOC Battalion—John Paolillo and John Moran—were also on the deputy chief promotion list, although further down the list. In the unfortunate event that something happened to Charlie, either of the two Johns could have stepped in.

Unfortunately, even this depth of planning was not enough to deal with the scale of the tragedy of September 11, 2001. All four of the chiefs mentioned previously were lost that morning, along with Jack Fanning—a total of five of the seven senior leaders of SOC. The department had to fall back to "plan D," which points out the importance of the other aspects of good leadership—mentoring and creating a deep bench.

Having a deep bench is important, but having the ability to replicate that bench, thereby creating additional high-quality personnel, is even more vital. That is the role of training—in FDNY's case, its Technical Rescue School. During the September 11 attack, SOC lost 95 people, who had an average of 16½ years of experience. We lost another 25 members (out of approximately 400 total) in the next years as personnel began to retire. We had to quickly replace nearly 30 percent of our personnel. You cannot replace all the experience that was lost, but good training can help. When I was the captain of Rescue 1 in the mid-1990s, I used to tell new people that it would take at least 2 years to turn someone into a Rescue Specialist fire fighter. Captain Chris King and the rest of the staff at the Technical Rescue School did a tremendous job, implementing a training program that allowed us to get all the depleted units back up to workable personnel complements by Christmas Eve 2001, a little more than 3 months after the attack. Today, the training program that is in place achieves virtually the same goal of creating a rescue-trained fire fighter in less than a year. It does not replace the experience, but by recruiting highly motivated personnel who want to be the best they can be, it allows them to achieve great successes. That is crucial to preparing the organization for the challenges of the future.

FDNY has taken the concept of a deep bench even further, establishing 25 SOC support ladder companies. These units are trained and equipped to perform operations-level tasks at a variety of technical rescue and hazardous materials incidents. Primarily, they act as a pool of trained personnel at single-site events to augment the SOC personnel on scene, working with the rescue and squad personnel to achieve objectives more quickly. These ladder companies can also be used as single resource units during times of disaster or widespread problems, where there are not enough SOC units to go around. (They are equipped with a small "mechanic's truck"–type vehicle in addition to their normal ladder apparatus so that in crisis circumstances they can be split into 25 additional units for emergency response.) They are trained at the SOC Technical Rescue School and drill alongside SOC units regularly. Implementation of this system allowed the department to nearly triple the number of Rescue Specialist–trained personnel available at any moment.

Now, many years after the attack on the United States, after weathering many challenges and tests, from Hurricane Sandy to numerous building explosions and collapses, from terrorist attacks to subway and train crashes, the system has proved itself to be far better prepared than we could have imagined before September 11, 2001. Ray would be proud.

John Norman
Chief of Special Operations (Retired)
Fire Department of New York
New York, New York

Looking to the future and then creating systems to match expectations is most effective when data are used to support the future needs of the team. For example, the number of team members may have to be expanded over several years based on the future growth of the community or a call-volume trend analysis. These vital data can also be used to update your team's strategic objectives and goals, upgrade individual team member skills, or justify the addition of position functions.

It is also the leader's primary goal to evaluate the entire system constantly to ensure current service level goals and objectives are being met. This is accomplished through performance measurement, which is a great strategy for gaining additional equipment and personnel to do the job. If you have clearly established performance goals for your team and the ability to measure success in meeting those goals, then it will be easy to demonstrate team needs when the time is politically favorable to do so.

■ Recruitment

To maintain a functional and healthy team, the leader should continually recruit new team members. The leader should anticipate future requirements of the team along with the subsequent training versus real-time experience necessary to maintain team member competency. An example of this concept *not* being applied appropriately is having an all–advanced life support (ALS) system with a call volume that does not have enough activity to maintain the providers' skills. The chief officer's job in creating the future is recommending and preparing the organization so that balance is achieved between system needs and the organization's ability to meet that demand.

Many times we do not expect the "big chief" to have an intimate understanding of what rescuers do, but rather a conceptual understanding concerning the team's mission, purpose, and goals. That perspective is acceptable in a contextual sense, but in real life, the highest levels of the organization must be able to understand enough about the team's functions and goals to make competent and consistent decisions. If you must take a recommendation at face value from someone else in the pyramid, then you had better make sure that you can interpret the analysis and research you are provided. In many cases, this requires developing new and appropriate standards for expected future challenges.

■ Communication with Stakeholders

Another aspect of rescue team leadership is creating a system for communicating effectively with policy makers and other key stakeholders outside of the organization. Doing so may involve inviting local, state, and federal elected officials to witness actual calls or training evolutions. Keep in mind that money flows from citizens to trench rescue teams through elected officials. Do not spend all of your energy with the bureaucrats and ignore this very critical path to success.

■ Budgeting

Part of the "creating the future" responsibility includes budgeting for and securing the capital equipment the trench rescue team needs to do its job effectively and efficiently. For instance, it does little good to buy equipment yet have no means to transport it, or to have a nice piece of rolling equipment and no tools to operate. Securing the financial resources and then making sure they are distributed in an appropriate fashion to all of the system's component parts are vital leadership functions.

Money for specialized operations teams often comes from grants. Paying attention to the local, state, and federal grants available can mean the difference between having a fully functional rescue team or one that is only marginally capable.

■ Education

Because we look to our chief officers for guidance on the future, we expect them to provide a mechanism to ensure we are prepared for that future when it arrives. To perform this function adequately, the leader may need to challenge the team by expanding the educational requirements, or frequency of recertification requirements, of team members to meet the expected future challenges. It does not do any good for us to embrace technology in the rescue business and then have no one prepared to use it in an efficient manner.

■ Developing Partnerships

A very important function of upper management in rescue team leadership is that of maintaining partnerships with those customer groups that can help the team get resources and recognition—in other words, taking on the role of public relations liaison with the media and developing partnerships with the local business community.

A good example of the positive effects of such a partnership is when things do not go as well as planned, and instead of the media jumping to conclusions, they give you a chance to explain. Ideally, your story will be portrayed in the most positive light possible rather than in the most negative. Of course, people can tell when they are being taken advantage of; therefore, you should make sure the relationships you forge are always of mutual benefit to all involved.

The partnerships that you are expected to build at the highest levels of team leadership also extend to the business community. These partnerships can take the form of contractor outreach programs that allow full participation by the business community in the rescue team's effort.

Likewise, you will want to take every opportunity to publicly recognize these partners for the special attributes they bring to the table.

Mutual aid agreements should also be beneficial for both the participating stakeholders and the public you serve. Making good use of the taxpayers' dollars by trying your best not to duplicate the same resources in every community is a good business practice and is accomplished only through the cultivation of great jurisdictional relationships.

Wrap-Up

Review: Just the Dirt

- Building a great rescue team involves people in various job functions within the team understanding their own roles and recognizing the expectations of others with regard to work outcomes.
- The largest component of any rescue team is the personnel who perform rescue work, their first-line supervisors, and the officers who provide direct oversight.
- In operations, officers should give workers control to operate the system and also accountability for the outcome of the operation.
- Middle managers (battalion and division chiefs) should concentrate on how alignment occurs at the rescue scene and how their efforts can be directed toward improving the efficiency and effectiveness of operations.
- Middle management is the conduit by which vital communications make it from the bottom of the organizational pyramid to the top, and then from the top back down again.
- A large part of the middle manager's job is focused on evaluating people, training, and equipment.
- Middle managers frequently have valuable experience and can relay tough lessons learned to less experienced team members. Such experience can also help bring about a sense of calmness to team operations.
- Chiefs and other senior staff personnel should plan for and create outcomes that will help the organization adapt to the future.
- The job of those at the highest levels of the organization is to ensure that the desired values are ingrained into the culture of the team and used in every aspect of its decision-making system.
- Looking to the future and then creating systems to match those expectations are most effectively accomplished by using data to support the future needs of the team.
- To maintain a functional and healthy team, the leader should anticipate the future requirements of the team and consider the subsequent training versus real-time experience necessary to maintain team member competency.
- Communicating effectively with policy makers and other key stakeholders outside the organization may be accomplished by inviting local, state, and federal elected officials to witness

actual calls or training evolutions.

- Part of the "creating the future" responsibility includes budgeting for and securing the capital equipment the team needs to do its job effectively and efficiently.
- The leader may need to challenge the team by expanding the educational requirements, or frequency of recertification requirements, of team members to meet the expected future challenges.
- A critical function of upper management is maintaining partnerships with those customer groups that can help the team get resources and recognition.

Hot Terms

Creating the future Portion of the time allocation model that pertains to those members whose primary role is the organization's strategic direction.

Improving the system Portion of the time allocation model that pertains to coordinating the various levels of the organization to create greater efficiency and effectiveness.

Operating the system Portion of the time allocation model that speaks to direct service delivery to the public.

Organizational pyramid The hierarchal structure of organizations in which the lowest-ranking and largest number of members are located on the bottom and the highest-ranking and fewest members are at the top.

Time allocation model A model that describes leadership based on the individual's level in the organization and the kinds of activities that he or she should be spending the most time trying to accomplish.

TRENCH RESCUER *in action*

You have decided that you want to improve your knowledge and chance for promotion and have enrolled in a leadership and management program at your local community college. You have learned a lot of new information and concepts and have gained a better appreciation for how things run "upstairs" at fire department HQ.

It is now the end of the term and you are required to write a paper on leadership. In your paper, you have decided to take the point of view of your rescue company and fire department in general.

1. Leadership has been defined as the action of leading a group of people or an organization. Which of the following would be a better definition of leadership as it applies to your rescue company?
   A. The ability to provide oversight and coordination during rescue operations
   B. The ability to make safe, sound decisions and to inspire others to perform well

C. The ability to conduct strategic planning
D. The ability to manage organizational tasks

2. Which of the following is NOT a component of the organizational pyramid for trench rescue in the fire service?
A. Frontline personnel
B. Middle managers
C. Support staff
D. Chief officers

3. Each level of the organizational pyramid is responsible for a specific function. In a strong organization, which function is the middle manager level responsible for?
A. Operating the system
B. Improving the system
C. Creating the future
D. All of these functions to some degree

4. Higher management staff should be kept informed of the special needs of the community. From your perspective, this may include brainstorming new ideas with team members, recommending the proper equipment to handle an emerging type of rescue, or:
A. making sure that you have requested adequate equipment and resources to do the job.
B. creating new policy for the trench rescue team.
C. maintaining member interest.
D. coordinating members who are operating the system.

5. Middle management performs numerous functions. Which of the following is one of the most important?
A. On-scene accountability
B. Effective communications
C. Establishing a strong incident command system
D. Making recommendations regarding efficiency and effectiveness of operations

6. In the organizational pyramid leadership model, which level is ultimately responsible for recruitment to maintain a functional and healthy team?
A. Chief officers
B. Support staff
C. Middle managers
D. Front-line personnel

Appendix A: Sample Trench Rescue Standard Operating Procedure

Purpose

To address operations that involve the location, disentanglement, and removal of victims from underground collapses in trenches and excavations.

Scope

This policy is designed to provide guidelines to all fire and EMS units when presented with an incident involving the collapse of a trench or excavation where a victim(s) is(are) trapped or buried. This includes "protected" trenches where a victim(s) is(are) trapped or pinned by heavy equipment, pipe, or items other than soil.

Definition

As defined by the OSHA regulation 29 CFR Part 1926:

Trench: A narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

Excavation: A man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

General Guidelines

I. Any incident that involves a trench or excavation shall be the responsibility of the special operations/technical rescue team.

II. Any incident in which a victim is trapped, buried, or experiencing a medical emergency in a trench or excavation will require the response of the technical rescue team.

III. No fire fighter or EMS person shall enter an unprotected trench to render victim care or perform disentanglement operations. All trenches shall be "safe and protected" using approved methods before entry by any emergency personnel.

IV. All emergency vehicles shall park at least 100 feet from the collapse site. The only exception to this shall be the technical rescue team vehicle, which may park no closer than 50 feet.

V. All traffic within 300 feet of the collapse zone shall be stopped or detoured.

VI. A hazard zone shall be established to control at least 75 feet around the perimeter of the collapse zone. This should be done with fire line tape.

Operational Phases: First-Due Units

I. Assessment

A. First-due units should attempt to gather the following information:

1. What is the nature of the problem: collapse, medical, etc.?
2. How many victims are there?
3. What is their location?
4. What are the width, length, and depth of the trench?
5. Are there any on-scene hazards?
   a. Disrupted utilities
   b. Flowing water
   c. Secondary collapse potential
   d. Mechanical hazards/heavy equipment
   e. Exposed but nondisrupted utilities
   f. Hazardous materials/explosives

B. After these items are evaluated, the following should be completed:

1. Determine whether the incident involves a rescue or a recovery.
2. Ensure technical rescue team response and full assignment.
3. Ensure hazardous materials team response.
4. Establish visible command and control access to collapse area.

II. Making the Site Safe

A. General area safety

1. Protect the general area around the collapse zone for at least 300 feet in all directions. This includes:
   a. Traffic control
   b. Access control
   c. General hazard identification
   d. Shutting down all heavy equipment

B. Rescue area safety

1. "Perform" or "conduct" the initial steps needed to make the actual collapse zone around and in the trench as safe as possible using basic techniques. Sheeting and shoring operations, entry, and disentanglement operations are operational skills that should be carried out under the direction of the technical rescue team.
   a. Ground pad the trench site lip.
   b. Ventilate the trench with positive pressure ventilation if needed.

c. Support any unbroken utilities.
d. If medical conditions permit, provide a helmet and goggles for the victim (preferably not a fire service helmet).
e. Locate, mark, and monitor fissures.
f. Begin air monitoring.
g. Move the spoil pile back 2 feet from the trench lip.
h. Mark the location of the victim with chalk or paint at the lip and at the victim (in case of secondary collapse).
i. Take pictures of what you see, preferably digital so that the teams can see what the situation looked like when you got to it and before further collapse.
j. Supply a rope to the victim (preferably tied to him or her) to lead you back to him or her in case of a secondary collapse.
k. Supply oxygen or SABA to the victim as appropriate; however, never enter an unprotected trench.
l. Supply at least two ground ladders into the trench. This serves as a means of self-rescue/escape for the victim or if someone falls in.
m. Obtain GPS location for AirEvac unit.
n. Have utilities re-marked. Locations may have changed because of the collapse.
o. Do not allow any personnel into an unprotected trench.
p. Do not touch or lean on any heavy equipment until you have ensured it is not in contact with electrical utilities!

Stop: Await the arrival of technical rescue team personnel and equipment.

Technical Rescue Operations Phase

I. **Operational Responsibility**

A. All personnel shall report to and work through the incident command post.
B. It may be necessary to establish group officers associated with the trench or excavation collapse. These shall be in accordance with the incident command policy.
C. In some cases, the following group officers shall be established:
1. Operations: Responsible for coordination of the actual collapse site and the groups associated with all activity in the rescue area.
2. Extrication: Responsible for directing the actual sheeting and shoring, disentanglement, and removal operations associated with the trench or excavation. Operations personnel report directly to the operations officer.

II. **Collapse Zone Operations**

A. Different collapse scenarios will obviously require different sheeting and shoring techniques as the situation demands. Each scenario should be evaluated using the same evaluation mechanism and adaptations made to the current operation as required by the configuration of the trench or excavation.
B. The following are potential forms of collapse that may be encountered. They should be handled in accordance with accepted techniques previously taught.

1. Single wall collapse
2. Single or double wall slough
3. Sheer wall
4. Spoil pile slide
5. Intersecting trench collapse
6. Collapses in protected trenches
    a. Rabbit box slide or above level collapse
    b. Industrial shoring collapse
    c. Inadequate protection systems in place

C. The following are potential forms of victim entrapment scenarios that may be encountered:
1. Victim(s) buried to waist
2. Victim(s) buried to chest
3. Victim(s) not buried but injured or experiencing a medical problem in the trench environment
4. Victim(s) trapped or pinned by heavy equipment or pipe
5. Victim(s) trapped in running sand or material
6. Victim(s) completely buried
7. Victim(s) buried in the end of a large-diameter pipe

III. Operational Guidelines

A. Rescue Area Considerations
1. Ensure ventilation continues when needed, and monitor the atmosphere.
2. Ensure that dewatering systems are operational.
3. Ensure that utilities are controlled and identified.
4. Limit personnel at the lip and collapse zone.
5. Ensure communications with logistics area via department radio system or landline.
6. Ensure that the safety officer is in control of access and personnel.
7. Ensure that the media staging area is located away from the collapse zone.

B. General Considerations
1. Brief all personnel on plan of action and confer with appropriate groups.
2. Provide constant updates to incident command.
3. Plan at least two steps ahead of the operation and have a secondary plan ready in the event that the initial tactical plan proves unworkable.
4. Rotate personnel regularly.
5. Ensure that personnel involved in disentanglement and digging operations are rotated at least every 30 minutes.

C. Victim Considerations
1. Above all, treat the victim for crush syndrome in accordance with local protocols.
2. Consider and treat for hypothermia as necessary.
3. Never dig out a victim with heavy equipment.
4. Once you are close to the victim, dig by hand.

5. Consider the use of helicopter transport to a trauma center.

6. Ensure that technical rescue team paramedics coordinate and direct victim packaging operations.

7. Plan movement mechanism well ahead of time for the removal of the victim after disentanglement.

D. Community Resources

1. In the event that public utility resources are needed, advise the following:

a. Determine exactly what is needed.

i. Manpower

ii. Heavy equipment (what type)

iii. Pumps (what type)

iv. Vacuum truck

b. Ensure that all identified utilities have a representative present. Do not attempt to control utilities unless you are qualified.

c. Ensure a staging area for all incoming community resources requested.

Special Situations

I. **Running sand or material**

A. In these cases, it may be necessary to encase the victim(s) in interlocking drums used as an isolation tunnel. Remember that in all cases these drums should be used in the vertical position only. Using them horizontally may cause them to fail and crush under the weight of material.

II. **Other items that may be used for isolation tunnels in either the vertical or horizontal configurations are:**

A. Concrete or steel pipe

B. Corrugated pipe

III. **Pier holes or caissons**

A. These are bell-shaped excavations, which are used mainly as footers to pour support columns for concrete buildings. They represent extreme danger because of the difficulty in sheeting and shoring their bell-shaped bottoms. Extreme caution should be exercised when involved in these types of operations.

IV. **Trench and tunnel operations**

A. In certain cases, it may be necessary to dig a parallel trench or excavation to create a parallel shaft. If this becomes necessary, consider the following:

1. Any trench cut for a rescue operation should be properly protected by either conventional or industrial means.

2. Ensure that all utilities are identified before cutting the trench. This can be done by requesting the utility company(s) on an emergency basis.

3. Ensure adequate shaft material for construction of your parallel shaft.

4. If possible, request and retain a certified engineer to assist in the planning and

implementation.

5. Trench and tunneling operations should be used only as a last option.

Termination

I. Rehab all personnel before termination and removal operations.

II. Brief all personnel on the operation and its intended outcome.

III. Perform removal operations in the reverse order.

IV. Beware of secondary collapse zones. No equipment is worth risking an injury.

V. Stage, clean, and inventory all equipment. Report any lost or damaged equipment.

VI. Any parallel shaft construction, tunnels, or isolation tunnels should be left in place. Removing them may cause a collapse.

VII. Consider CISM/CISD.

VIII. Conduct a post-incident critique.

Appendix B: Pro Board Assessment Methodology Matrices for NFPA 1006

NFPA 1006 - Trench Rescue Technician - 2013 Edition						
IMPORTANT: The language from the standard on the AMMs is truncated. When completing the AMMs, the agency must refer to the NFPA standards for the complete text and a comprehensive statement of each Job Performance Requirement (JPR), Requisite Knowledge (RK), Requisite Skill (RS), and any applicable annex or explanatory information.						
INSTRUCTIONS: Please review the instructions for filling out this Assessment Methodology Matrix at http://theproboard.org/AMM.htm. The submission of this form by an agency is affirmation that it is filled out in accordance with the instructions listed above.						
Agency Name:					**Date Compiled:**	
Objective / JPR, RK, RS		**Cognitive Written Test**	**Manipulative Skills Station**	**Portfolio**	**Projects**	**Trench Rescue: Principles and Practice to NFPA 1006 and 1670**
Section	**Abbreviated Text**					
Level I						
8.1.1	Conduct a size-up of a collapsed trench.					Chapter 4 (pp 51, 54–58), Chapter 5 (p 65), Chapter 7 (pp 98–100), Chapter 8 (pp 110–112), Chapter 12 (pp 222–223)
8.1.1(A)	RK: Methods to distinguish soil types					Chapter 1 (pp 4–5, 11–14), Chapter 2 (pp 20–21, 24–25), Chapter 3 (pp 32–34, 37–42), Chapter 4 (pp 48–51), Chapter 5 (pp 64–69), Chapter 7 (pp 98–100, 105), Chapter 8 (pp 110–112)
8.1.1(B)	RS: Ability to measure dimensions of trench					Chapter 1 (pp 11–14), Chapter 3 (pp 32–34, 37–42), Chapter 4 (pp 56–58), Chapter 5 (pp 64–69), Chapter 7 (pp 99–100, 104–105), Chapter 8 (p 112), Chapter 12 (p 229)
8.1.2	Implement a trench emergency action plan.					Chapter 1 (pp 4–5), Chapter 4 (pp 48–51, 56–58), Chapter 5 (pp 65–69), Chapter 7 (pp 98–101, 104–105), Chapter 8 (pp 110–112, 115–119), Chapter 10 (pp 142–161, 164), Chapter 11 (pp 176–182, 184–187), Chapter 12 (pp 222–224)
8.1.2(A)	RK: Size-up information and documentation					Chapter 1 (pp 4–5), Chapter 4 (pp 56–58), Chapter 5 (pp 64–69), Chapter 6 (pp 81–86, 88–90), Chapter 7 (pp 98–101, 104–105), Chapter 8 (pp 110–112, 115–119), Chapter 10 (pp 142–161, 164), Chapter 11 (pp 176–182, 184–187), Chapter 12 (pp 222–224)
8.1.2(B)	RS: Ability to use and document tactical worksheets					Chapter 1 (pp 4–5), Chapter 5 (pp 64–69), Chapter 7 (pp 100–101, 104–105), Chapter 9 (pp 126–128), Chapter 10 (pp 142–161, 164), Chapter 11 (pp 176–182, 184–187), Chapter 12 (pp 222–223)
8.1.3	Implement support operations.					Chapter 5 (pp 66–69), Chapter 6 (pp 89–93), Chapter 8 (pp 110–112, 115–119), Chapter 12 (pp 224–227, 229–232)

8.1.3(A)	RK: Equipment organization and tracking methods					Chapter 5 (p 68), Chapter 6 (pp 88–93), Chapter 8 (pp 112, 115–119), Chapter 12 (pp 231–232)
8.1.3(B)	RS: Ability to track equipment inventory					Chapter 5 (p 68), Chapter 8 (pp 112, 115–119), Chapter 12 (pp 231–232)
8.1.4	Support a nonintersecting straight wall trench.					Chapter 6 (pp 79–81), Chapter 8 (pp 110–112), Chapter 9 (pp 128–129, 132–135), Chapter 10 (pp 142–161), Chapter 11 (pp 176–182, 184–187), Chapter 12 (pp 231–232)
8.1.4(A)	RK: Shoring and shielding					Chapter 6 (pp 79–81, 83–86), Chapter 9 (pp 132–135), Chapter 10 (142–161), Chapter 11 (176–182, 184–187)
8.1.4(B)	RS: Ability to interpret tabulated data information and tables					Chapter 6 (pp 79–81), Chapter 9 (pp 128–129, 132–135), Chapter 10 (pp 142–161), Chapter 11 (176–182, 184–187)
8.1.5	Release a victim from soil entrapment.					Chapter 6 (pp 79–81), Chapter 12 (pp 222–227, 229–232)
8.1.5(A)	RK: Identification, utilization, and required care of personal equipment					Chapter 4 (pp 49–51, 54–58), Chapter 6 (pp 79–86, 88–90), Chapter 12 (pp 222–227, 229–232)
8.1.5(B)	RS: Ability to select, use, and care for personal protective equipment					Chapter 6 (pp 79–86, 88–90), Chapter 9 (pp 132–135), Chapter 12 (pp 222–227, 229–232)
8.1.6	Remove a victim from a trench.					Chapter 12 (pp 224–227, 229–232)
8.1.6(A)	RK: Medical protocols					Chapter 9 (pp 126–129), Chapter 12 (pp 231–232)
8.1.6(B)	RS: Ability to select and use personal protective equipment					Chapter 6 (pp 79–81), Chapter 12 (pp 224–227, 229–232)
8.1.7	Disassemble support systems.					Chapter 5 (p 72), Chapter 6 (pp 79–81), Chapter 10 (pp 166–167)
8.1.7(A)	RK: Selection of personal protective equipment					Chapter 5 (p 72), Chapter 6 (pp 79–86, 88–90), Chapter 10 (pp 166–167)
8.1.7(B)	RS: Ability to use personal protective equipment					Chapter 5 (p 72), Chapter 6 (pp 79–81), Chapter 10 (pp 166–167)
Level II						
8.2.1	Support an intersecting trench.					Chapter 6 (pp 79–81), Chapter 8 (pp 110–112), Chapter 9 (pp 128–129), Chapter 11 (pp 176–178, 191–207), Chapter 12 (pp 222–227, 229–232)
8.2.1(A)	RK: Shoring and shielding					Chapter 6 (pp 79–81), Chapter 9 (pp 132–135), Chapter 11 (pp 176–178, 191–207)
8.2.1(B)	RS: Ability to interpret tabulated data information and tables					Chapter 6 (pp 79–81), Chapter 9 (pp 126–129, 132–135), Chapter 11 (pp 176–178, 191–207), Chapter 12 (pp 231–232)
8.2.2	Install supplemental sheeting and shoring.					Chapter 9 (pp 126–129), Chapter 11 (pp 190–192, 208–212), Chapter 12 (pp 222–227, 229–232)

8.2.2(A)	RK: Shoring and shielding					Chapter 6 (pp 79–81), Chapter 9 (pp 132–135), Chapter 11 (pp 190–192, 208–212)
8.2.2(B)	RS: Ability to interpret tabulated data					Chapter 6 (pp 79–81), Chapter 9 (pp 126–129, 132–135), Chapter 11 (pp 190–192, 208–212), Chapter 12 (pp 231–232)
8.2.3	Construct load stabilization systems.					Chapter 6 (pp 79–86, 88–91), Chapter 9 (pp 124–129, 132–135)
8.2.3(A)	RK: Different types of stabilization systems					Chapter 9 (pp 124–129, 132–135)
8.2.3(B)	RS: Ability to select and construct stabilization systems					Chapter 9 (pp 124–129, 132–135)
8.2.4	Lift a load.					Chapter 9 (pp 124–129, 132–135)
8.2.4(A)	RK: Applications of levers					Chapter 9 (pp 124–129, 132–135)
8.2.4(B)	RS: Ability to evaluate and estimate the weight of the load					Chapter 9 (pp 124–129, 132–135)
8.2.5	Coordinate the use of heavy equipment.					Chapter 6 (pp 79–81), Chapter 10 (pp 169–171)
8.2.5(A)	RK: Types of heavy equipment					Chapter 10 (pp 169–171)
8.2.5(B)	RS: Ability to use hand signals					Chapter 6 (pp 79–81), Chapter 10 (pp 169–171)
8.2.6	Release a victim from entrapment.					Chapter 6 (pp 79–86, 88–91), Chapter 12 (pp 224–227, 229, 231–232)
8.2.6(A)	RK: Identification, utilization, and required care of personal equipment					Chapter 6 (pp 79–86, 88–91), Chapter 12 (pp 224–227, 229, 231–232)
8.2.6(B)	RS: Ability to select, use, and care for personal protective equipment					Chapter 6 (pp 79–86, 88–91), Chapter 12 (pp 224–227, 229, 231–232)

Appendix C: Correlation to NFPA 1006, Standard for Technical Rescue Personnel Professional Qualifications, 2017 Edition, First Draft Ballot (May 18, 2015)

Chapter 6: Trench Rescue

Objectives	Corresponding Chapters	Corresponding Pages
6.1 Awareness Level		
6.1.1	7	98-101, 104-105
6.1.2	1-5, 7-8, 12	4-5, 11-14, 20-21, 24-25, 32-34, 37-42, 48-51, 54-58, 64-69, 98-100, 104-105, 110-112, 222-223, 229
6.1.3	1, 4-12	4-5, 48-51, 56-58, 64-69, 81-86, 88-90, 98-101, 104-105, 110-112, 115-119, 126-128, 142-161, 164, 176-182, 184-187, 222-224
6.1.4	5-6, 8, 12	66-69, 88-93, 110-112, 115-119, 224-227, 229-232
6.1.5	5	64-69, 72
6.2 Operations Level		
6.2.1	6, 8, 9-12	79-81, 83-86, 110-112, 128-129, 132-135, 142-161, 176-182, 184-187, 231-232
6.2.2	4, 6, 9, 12	49-51, 54-58, 79-86, 88-90, 132-135, 222-227, 229-232
6.2.3	6, 9, 12	79-81, 126-129, 224-227, 229-232
6.2.4	5-6, 10	72, 79-86, 88-90, 166-167
6.2.5	5	64-69, 72
6.3 Technician Level		
6.3.1	6, 8-9, 11-12	79-81, 110-112, 128-129, 132-135, 176-178, 191-207, 222-227, 229-232
6.3.2	6, 9, 11-12	79-81, 126-129, 132-135, 190-192, 208-212, 222-227, 229-232
6.3.3	6, 9	79-86, 88-91, 124-129, 132-135
6.3.4	9	124-129, 132-135
6.3.5	6, 10	79-81, 169-171
6.3.6	6, 12	79-86, 88-91, 224-227, 229, 231-232

Appendix D: Correlation to NFPA 1670, Standard on Operations and Training for Technical Search and Rescue Incidents, 2014 Edition

Chapter 11: Trench and Excavation Search and Rescue

Objectives	Corresponding Chapters	Corresponding Pages
11.1	1	14
11.2	1	13-14
11.2.1	1	14
11.2.2	1	14
11.2.3	1	13
11.2.3(1)	1, 5, 7	13, 65, 98-100
11.2.3(2)	1-2, 5-8, 11-12	13, 20-21, 25-27, 65-66, 79-86, 88-93, 100, 110-112, 115-119, 166-167, 222-227, 229-232
11.2.3(3)	1, 5	13, 64-66
11.2.3(4)	1, 5, 11	13, 65-66, 176-177
11.2.3(5)	1, 3, 6, 8	13, 32-34, 79-81, 110-112, 115-119
11.2.3(6)	1, 4, 11	13, 48-51, 54-58, 177, 180-185, 190-216
11.2.3(7)	1, 12	13, 222-223
11.2.3(8)	1, 4	13, 49-51
11.3	1	13-14
11.3.1	1	14
11.3.1(1)	1	14
11.3.1(2)	1	14
11.3.1(3)	1	14
11.3.2	1	13
11.3.2(1)	1	13
11.3.2(2)	1	13
11.3.2(3)	1	13
11.3.3	1	13
11.3.3(1)	1, 3, 7, 11	13, 41-42, 98-101, 103-104, 176-177
11.3.3(2)	1, 11	13, 176-177
11.3.3(3)	1, 4, 6, 11	13, 49-51, 54-58, 81-86, 176-187, 190-216
11.3.3(4)	1, 7, 12	13, 98-100, 104-105, 222-224, 229-231
11.3.3(5)	1, 9-11	13, 124-124, 142-161, 164-169, 176-187, 190-216
11.3.3(6)	1, 8	13, 112
11.3.3(7)	1, 3	13, 41-42
11.3.3(8)	1, 8	13, 119
11.3.3(9)	1, 4	13, 58

11.3.3(10)	1, 6, 10	13, 81-83, 143-145
11.3.3(11)	1, 11	13, 177
11.3.3(12)	1, 5, 7, 11-12	13, 65-66, 105, 177, 182, 223-224
11.3.3(13)	1	13
11.3.3(14)	1, 6, 11	13, 83, 177-187, 190-216
11.3.3(15)	1, 10	13, 167-168
11.3.3(16)	1, 5, 10-12	13, 66-69, 143-161, 164-167, 176-187, 190-216, 224-227, 230-232
11.3.3(17)	1, 7, 12	13, 104-105, 222-227, 229-232
11.3.3(18)	1, 12	13, 224-227, 229-232
11.4	1	13-14
ii.4.1	1	14
ii.4.i(i)	1	14
11.4.1(2)	1	14
11.4.2	1	13-14
11.4.3	1	14
11.4.3(1)	1, 3-5, 7	14, 41-42, 51, 54-58, 65, 98-101, 104-105
11.4.3(2)	1, 10-11	14, 143-161, 164-167, 178-187, 190-216
11.4.3(3)	1, 8	14, 115-119
11.4.3(4)	1, 11	14, 190-192
11.4.3(5)	1, 12	14, 224-226
11.4.3(6)	1, 10	14, 164

Appendix E: OSHA 1926, Subpart P, Excavations

Authority: Sec. 107, Contract Worker Hours and Safety Standards Act (Construction Safety Act) (40 U.S.C. 333); Secs. 4, 6, 8, Occupational Safety and Health Act of 1970 (29 U.S.C. 653, 655, 657); Secretary of Labor's Order No. 12-71 (36 FR 8754), 8-76 (41 FR 25059), or 9-83 (48 FR 35736), as applicable, and 29 CFR part 1911.

Source: 54 FR 45959, Oct. 31, 1989, unless otherwise noted.

§1926.650 Scope, application, and definitions applicable to this subpart

1926.650(a) Scope and application. This subpart applies to all open excavations made in the earth's surface. Excavations are defined to include trenches.

1926.650(b) Definitions applicable to this subpart.

"Accepted engineering practices" means those requirements which are compatible with standards of practice required by a registered professional engineer.

"Aluminum Hydraulic Shoring" means a pre-engineered shoring system comprised of aluminum hydraulic cylinders (crossbraces) used in conjunction with vertical rails (uprights) or horizontal rails (wales). Such system is designed specifically to support the sidewalls of an excavation and prevent cave-ins.

"Bell-bottom pier hole" means a type of shaft or footing excavation, the bottom of which is made larger than the cross section above to form a belled shape.

"Benching (Benching system)" means a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

"Cave-in" means the separation of a mass of soil or rock material from the side of an excavation, or the loss of soil from under a trench shield or support system, and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

"Competent person" means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

"Cross braces" mean the horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

"Excavation" means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

"Faces" or "sides" means the vertical or inclined earth surfaces formed as a result of excavation work.

"Failure" means the breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

"Hazardous atmosphere" means an atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

"Kickout" means the accidental release or failure of a cross brace.

"Protective system" means a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

"Ramp" means an inclined walking or working surface that is used to gain access to one point from another, and is constructed from earth or from structural materials such as steel or wood.

"Registered Professional Engineer" means a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state is deemed to be a "registered professional engineer" within the meaning of this standard when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

"Sheeting" means the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

"Shield (Shield system)" means a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either premanufactured or job-built in accordance with 1926.652(c)(3) or (c)(4). Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

"Shoring (Shoring system)" means a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent cave-ins.

"Sides." See "Faces."

"Sloping (Sloping system)" means a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation so as to prevent cave-ins. The angle of incline required to prevent a cave-in varies with differences in such factors as the soil type, environmental conditions of exposure, and application of surcharge loads.

"Stable rock" means natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed. Unstable rock is considered to be stable when the rock material on the side or sides of the excavation is secured against caving-in or movement by rock bolts or by another protective system that has been designed by a registered professional engineer.

"Structural ramp" means a ramp built of steel or wood, usually used for vehicle access. Ramps made of soil or rock are not considered structural ramps.

"Support system" means a structure such as underpinning, bracing, or shoring, which provides support to an adjacent structure, underground installation, or the sides of an excavation.

"Tabulated data" means tables and charts approved by a registered professional engineer and used to design and construct a protective system.

"Trench (Trench excavation)" means a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

"Trench box." See "Shield."

"Trench shield." See "Shield."

"Uprights" means the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not contact each other. Uprights placed so that individual members are closely spaced, in contact with or interconnected to each other, are often called "sheeting."

"Wales" means horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

§1926.651 Specific excavation requirements

1926.651(a) Surface encumbrances. All surface encumbrances that are located so as to create a hazard to employees shall be removed or supported, as necessary, to safeguard employees.

1926.651(b) Underground installations.

1926.651(b)(1) The estimated location of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered during excavation work, shall be determined prior to opening an excavation.

1926.651(b)(2) Utility companies or owners shall be contacted within established or customary local response times, advised of the proposed work, and asked to establish the location of the utility underground installations prior to the start of actual excavation. When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours (unless a longer period is required by state or local law), or cannot establish the exact location of these installations, the employer may proceed, provided the employer does so with caution, and provided detection equipment or other acceptable means to locate utility installations are used.

1926.651(b)(3) When excavation operations approach the estimated location of underground installations, the exact location of the installations shall be determined by safe and acceptable means.

1926.651(b)(4) While the excavation is open, underground installations shall be protected, supported or removed as necessary to safeguard employees.

1926.651(c) Access and egress.

1926.651(c)(1) Structural ramps.

1926.651(c)(1)(i) Structural ramps that are used solely by employees as a means of access or egress from excavations shall be designed by a competent person. Structural ramps used for access or egress of equipment shall be designed by a competent person qualified in structural design, and shall be constructed in accordance with the design.

1926.651(c)(1)(ii) Ramps and runways constructed of two or more structural members shall have the structural members connected together to prevent displacement.

1926.651(c)(1)(iii) Structural members used for ramps and runways shall be of uniform thickness.

1926.651(c)(1)(iv) Cleats or other appropriate means used to connect runway structural members shall be attached to the bottom of the runway or shall be attached in a manner to prevent tripping.

1926.651(c)(1)(v) Structural ramps used in lieu of steps shall be provided with cleats or other surface treatments on the top surface to prevent slipping.

1926.651(c)(2) Means of egress from trench excavations. A stairway, ladder, ramp or other safe means of egress shall be located in trench excavations that are 4 feet (1.22 m) or more in depth so as to require no more than 25 feet (7.62 m) of lateral travel for employees.

1926.651(d) Exposure to vehicular traffic. Employees exposed to public vehicular traffic shall be provided with, and shall wear, warning vests or other suitable garments marked with or made of reflectorized or high-visibility material.

1926.651(e) Exposure to falling loads. No employee shall be permitted underneath loads handled by lifting or digging equipment. Employees shall be required to stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials. Operators may remain in the cabs of vehicles being loaded or unloaded when the vehicles are equipped, in accordance with 1926.601(b)(6), to provide adequate protection for the operator during loading and unloading operations.

1926.651(f) Warning system for mobile equipment. When mobile equipment is operated adjacent to an excavation, or when such equipment is required to approach the edge of an excavation, and the operator does not have a clear and direct view of the edge of the excavation, a warning system shall be utilized such as barricades, hand or mechanical signals, or stop logs. If possible, the grade should be away from the excavation.

1926.651(g) Hazardous atmospheres.

1926.651(g)(1) Testing and controls. In addition to the requirements set forth in subparts D and E of this part (29 CFR 1926.50–1926.107) to prevent exposure to harmful levels of atmospheric contaminants and to assure acceptable atmospheric conditions, the following requirements shall apply:

1926.651(g)(1)(i) Where oxygen deficiency (atmospheres containing less than 19.5 percent oxygen) or a hazardous atmosphere exists or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby, the atmospheres in the excavation shall be tested before employees enter excavations greater than 4 feet (1.22 m) in depth.

1926.651(g)(1)(ii) Adequate precautions shall be taken to prevent employee exposure to atmospheres containing less than 19.5 percent oxygen and other hazardous atmospheres. These precautions include providing proper respiratory protection or ventilation in accordance with subparts D and E of this part respectively.

1926.651(g)(1)(iii) Adequate precaution shall be taken such as providing ventilation, to prevent employee exposure to an atmosphere containing a concentration of a flammable gas in excess of 20 percent of the lower flammable limit of the gas.

1926.651(g)(1)(iv) When controls are used that are intended to reduce the level of atmospheric contaminants to acceptable levels, testing shall be conducted as often as necessary to ensure that the atmosphere remains safe.

1926.651(g)(2) Emergency rescue equipment.

1926.651(g)(2)(i) Emergency rescue equipment, such as breathing apparatus, a safety harness and line, or a basket stretcher, shall be readily available where hazardous atmospheric conditions exist or may reasonably be expected to develop during work in an excavation. This equipment shall be attended when in use.

1926.651(g)(2)(ii) Employees entering bell-bottom pier holes, or other similar deep and confined footing excavations, shall wear a harness with a lifeline securely attached to it. The lifeline shall be separate from any line used to handle materials, and shall be individually attended at all times while the employee wearing the lifeline is in the excavation.

1926.651(h) Protection from hazards associated with water accumulation.

1926.651(h)(1) Employees shall not work in excavations in which there is accumulated water, or in excavations in which water is accumulating, unless adequate precautions have been taken to protect employees against the hazards posed by water accumulation. The precautions necessary to protect employees adequately vary with each situation, but could include special support or shield systems to protect from cave-ins, water removal to control the level of accumulating water, or use of a safety harness and lifeline.

1926.651(h)(2) If water is controlled or prevented from accumulating by the use of water removal equipment, the water removal equipment and operations shall be monitored by a competent person to ensure proper operation.

1926.651(h)(3) If excavation work interrupts the natural drainage of surface water (such as streams), diversion ditches, dikes, or other suitable means shall be used to prevent surface water from entering the excavation and to provide adequate drainage of the area adjacent to the excavation. Excavations subject to runoff from heavy rains will require an inspection by a competent person and compliance with paragraphs (h)(1) and (h)(2) of this section.

1926.651(i) Stability of adjacent structures.

1926.651(i)(1) Where the stability of adjoining buildings, walls, or other structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning shall be provided to ensure the stability of such structures for the protection of employees.

1926.651(i)(2) Excavation below the level of the base or footing of any foundation or retaining wall that could be reasonably expected to pose a hazard to employees shall not be permitted except when:

1926.651(i)(2)(i) A support system, such as underpinning, is provided to ensure the safety of employees and the stability of the structure; or

1926.651(i)(2)(ii) The excavation is in stable rock; or

1926.651(i)(2)(iii) A registered professional engineer has approved the determination that the structure is sufficiently removed from the excavation so as to be unaffected by the excavation activity; or

1926.651(i)(2)(iv) A registered professional engineer has approved the determination that such excavation work will not pose a hazard to employees.

1926.651(i)(3) Sidewalks, pavements and appurtenant structure shall not be undermined unless a support system or another method of protection is provided to protect employees from the possible collapse of such structures.

1926.651(j) Protection of employees from loose rock or soil.

1926.651(j)(1) Adequate protection shall be provided to protect employees from loose rock or soil that could pose a hazard by falling or rolling from an excavation face. Such protection shall consist of scaling to remove loose material; installation of protective barricades at intervals as necessary on the face to stop and contain falling material; or other means that provide equivalent protection.

1926.651(j)(2) Employees shall be protected from excavated or other materials or equipment that could pose a hazard by falling or rolling into excavations. Protection shall be provided by placing and keeping such materials or equipment at least 2 feet (0.61 m) from the edge of excavations, or by the use of retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations, or by a combination of both if necessary.

1926.651(k) Inspections.

1926.651(k)(1) Daily inspections of excavations, the adjacent areas, and protective systems shall be made by a competent person for evidence of a situation that could result in possible cave-ins, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions. An inspection shall be conducted by the competent person prior to the start of work and as needed throughout the shift. Inspections shall also be made after every rainstorm or other hazard increasing occurrence. These inspections are only required when employee exposure can be reasonably anticipated.

1926.651(k)(2) Where the competent person finds evidence of a situation that could result in a possible cave-in, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions, exposed employees shall be removed from the hazardous area until the necessary precautions have been taken to ensure their safety.

1926.651(l) Walkways shall be provided where employees or equipment are required or permitted to cross over excavations. Guardrails which comply with 1926.502(b) shall be provided where walkways are 6 feet (1.8 m) or more above lower levels. [59 FR 40730, Aug 9, 1994]

§1926.652 Requirements for protective systems

1926.652(a) Protection of employees in excavations.

1926.652(a)(1) Each employee in an excavation shall be protected from cave-ins by an adequate protective system designed in accordance with paragraph (b) or (c) of this section except when:

1926.652(a)(1)(i) Excavations are made entirely in stable rock; or

1926.652(a)(1)(ii) Excavations are less than 5 feet (1.52 m) in depth and examination of the ground by a competent person provides no indication of a potential cave-in.

1926.652(a)(2) Protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system.

1926.652(b) Design of sloping and benching systems. The slopes and configurations of sloping and benching systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (b)(1); or, in the alternative, paragraph (b)(2); or, in the alternative, paragraph (b)(3); or, in the alternative, paragraph (b)(4), as follows:

1926.652(b)(1) Option (1)—Allowable configurations and slopes.

1926.652(b)(1)(i) Excavations shall be sloped at an angle not steeper than one and one-half horizontal to one vertical (34 degrees measured from the horizontal), unless the employer uses one of the other options listed below.

1926.652(b)(1)(ii) Slopes specified in paragraph (b)(1)(i) of this section, shall be excavated to form configurations that are in accordance with the slopes shown for Type C soil in Appendix B to this subpart.

1926.652(b)(2) Option (2)—Determination of slopes and configurations using Appendices A and B. Maximum allowable slopes, and allowable configurations for sloping and benching systems, shall be determined in accordance with the conditions and requirements set forth in appendices A and B to this subpart.

1926.652(b)(3) Option (3)—Designs using other tabulated data.

1926.652(b)(3)(i) Designs of sloping or benching systems shall be selected from and in accordance with tabulated data, such as tables and charts.

1926.652(b)(3)(ii) The tabulated data shall be in written form and shall include all of the following:

1926.652(b)(3)(ii)(A) Identification of the parameters that affect the selection of a sloping or benching system drawn from such data;

1926.652(b)(3)(ii)(B) Identification of the limits of use of the data, to include the magnitude and configuration of slopes determined to be safe;

1926.652(b)(3)(ii)(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

1926.652(b)(3)(iii) At least one copy of the tabulated data which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

1926.652(b)(4) Option (4)—Design by a registered professional engineer.

1926.652(b)(4)(i) Sloping and benching systems not utilizing Option (1) or Option (2) or Option (3) under paragraph (b) of this section shall be approved by a registered professional engineer.

1926.652(b)(4)(ii) Designs shall be in written form and shall include at least the following:

1926.652(b)(4)(ii)(A) The magnitude of the slopes that were determined to be safe for the particular project;

1926.652(b)(4)(ii)(B) The configurations that were determined to be safe for the particular project;

1926.652(b)(4)(ii)(C) The identity of the registered professional engineer approving the design.

1926.652(b)(4)(iii) At least one copy of the design shall be maintained at the jobsite while the slope is being constructed. After that time the design need not be at the jobsite, but a copy shall be made available to the Secretary upon request.

1926.652(c) Design of support systems, shield systems, and other protective systems. Designs of support systems, shield systems, and other protective systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (c)(1); or, in the alternative, paragraph (c)(2); or, in the alternative, paragraph (c)(3); or, in the alternative, paragraph (c)(4) as follows:

1926.652(c)(1) Option (1)—Designs using appendices A, C and D. Designs for timber shoring in trenches shall be determined in accordance with the conditions and requirements set forth in appendices A and C to this subpart. Designs for aluminum hydraulic shoring shall be in accordance with paragraph (c)(2) of this section, but if manufacturer's tabulated data cannot be utilized, designs shall be in accordance with appendix D.

1926.652(c)(2) Option (2)—Designs Using Manufacturer's Tabulated Data.

1926.652(c)(2)(i) Design of support systems, shield systems, or other protective systems that are drawn from manufacturer's tabulated data shall be in accordance with all specifications, recommendations, and limitations issued or made by the manufacturer.

1926.652(c)(2)(ii) Deviation from the specifications, recommendations, and limitations issued or made by the manufacturer shall only be allowed after the manufacturer issues specific written approval.

1926.652(c)(2)(iii) Manufacturer's specifications, recommendations, and limitations, and manufacturer's approval to deviate from the specifications, recommendations, and limitations shall be in written form at the jobsite during construction of the protective system. After that time this data may be stored off the jobsite, but a copy shall be made available to the Secretary upon request.

1926.652(c)(3) Option (3)—Designs using other tabulated data.

1926.652(c)(3)(i) Designs of support systems, shield systems, or other protective systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

1926.652(c)(3)(ii) The tabulated data shall be in written form and include all of the following:

1926.652(c)(3)(ii)(A) Identification of the parameters that affect the selection of a protective system drawn from such data;

1926.652(c)(3)(ii)(B) Identification of the limits of use of the data;

1926.652(c)(3)(ii)(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

1926.652(c)(3)(iii) At least one copy of the tabulated data, which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

1926.652(c)(4) Option (4)—Design by a registered professional engineer.

1926.652(c)(4)(i) Support systems, shield systems, and other protective systems not utilizing Option 1, Option 2 or Option 3, above, shall be approved by a registered professional engineer.

1926.652(c)(4)(ii) Designs shall be in written form and shall include the following:

1926.652(c)(4)(ii)(A) A plan indicating the sizes, types, and configurations of the materials to be used in the protective system; and

1926.652(c)(4)(ii)(B) The identity of the registered professional engineer approving the design.

1926.652(c)(4)(iii) At least one copy of the design shall be maintained at the jobsite during construction of the protective system. After that time, the design may be stored off the jobsite, but a copy of the design shall be made available to the Secretary upon request.

1926.652(d) Materials and equipment.

1926.652(d)(1) Materials and equipment used for protective systems shall be free from damage or defects that might impair their proper function.

1926.652(d)(2) Manufactured materials and equipment used for protective systems shall be used and maintained in a manner that is consistent with the recommendations of the manufacturer, and in a manner that will prevent employee exposure to hazards.

1926.652(d)(3) When material or equipment that is used for protective systems is damaged, a competent person shall examine the material or equipment and evaluate its suitability for continued use. If the competent person cannot assure the material or equipment is able to support the intended loads or is otherwise suitable for safe use, then such material or equipment shall be removed from service, and shall be evaluated and approved by a registered professional engineer before being returned to service.

1926.652(e) Installation and removal of support.

1926.652(e)(1) General.

1926.652(e)(1)(i) Members of support systems shall be securely connected together to prevent sliding, falling, kickouts, or other predictable failure.

1926.652(e)(1)(ii) Support systems shall be installed and removed in a manner that protects employees from cave-ins, structural collapses, or from being struck by members of the support system.

1926.652(e)(1)(iii) Individual members of support systems shall not be subjected to loads exceeding those which those members were designed to withstand.

1926.652(e)(1)(iv) Before temporary removal of individual members begins, additional precautions shall be taken to ensure the safety of employees, such as installing other structural members to carry the loads imposed on the support system.

1926.652(e)(1)(v) Removal shall begin at, and progress from, the bottom of the excavation. Members shall be released slowly so as to note any indication of possible failure of the remaining members of the structure or possible cave-in of the sides of the excavation.

1926.652(e)(1)(vi) Backfilling shall progress together with the removal of support systems from excavations.

1926.652(e)(2) Additional requirements for support systems for trench excavations.

1926.652(e)(2)(i) Excavation of material to a level no greater than 2 feet (0.61 m) below the bottom of the members of a support system shall be permitted, but only if the system is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.

1926.652(e)(2)(ii) Installation of a support system shall be closely coordinated with the excavation of trenches.

1926.652(f) Sloping and benching systems. Employees shall not be permitted to work on the faces of sloped or benched excavations at levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling, or sliding material or equipment.

1926.652(g) Shield systems.

1926.652(g)(1) General.

1926.652(g)(1)(i) Shield systems shall not be subjected to loads exceeding those which the system was designed to withstand.

1926.652(g)(1)(ii) Shields shall be installed in a manner to restrict lateral or other hazardous movement of the shield in the event of the application of sudden lateral loads.

1926.652(g)(1)(iii) Employees shall be protected from the hazard of cave-ins when entering or exiting the areas protected by shields.

1926.652(g)(1)(iv) Employees shall not be allowed in shields when shields are being installed, removed, or moved vertically.

1926.652(g)(2) Additional requirement for shield systems used in trench excavations. Excavations of earth material to a level not greater than 2 feet (0.61 m) below the bottom of a shield shall be permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the shield.

■ Appendix A to Subpart P of Part 1926—Soil Classification

a. Scope and application.

1. Scope. This appendix describes a method of classifying soil and rock deposits based on site and environmental conditions, and on the structure and composition of the earth deposits. The appendix contains definitions, sets forth requirements, and describes acceptable visual and manual tests for use in classifying soils.
2. Application. This appendix applies when a sloping or benching system is designed in accordance with the requirements set forth in 1926.652(b)(2) as a method of protection for employees from cave-ins. This appendix also applies when timber shoring for excavations is designed as a method of protection from cave-ins in accordance with appendix C to subpart P of part 1926, and when aluminum hydraulic shoring is designed in accordance with appendix D. This Appendix also applies if other protective systems are designed and selected for use from data prepared in accordance with the requirements set forth in 1926.652(c), and the use of the data is predicated on the use of the soil classification system set forth in this appendix.

b. Definitions. The definitions and examples given below are based on, in whole or in part, the following; American Society for Testing Materials (ASTM) Standards D653-85 and D2488; The Unified Soils Classification System; The U.S. Department of Agriculture (USDA) Textural Classification Scheme; and The National Bureau of Standards Report BSS-121.

"Cemented soil" means a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

"Cohesive soil" means clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay.

"Dry soil" means soil that does not exhibit visible signs of moisture content.

"Fissured" means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

"Granular soil" means gravel, sand, or silt (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

"Layered system" means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

"Moist soil" means a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into small diameter threads before crumbling. Moist granular soil that contains some cohesive material will exhibit signs of cohesion between particles.

"Plastic" means a property of a soil which allows the soil to be deformed or molded without cracking, or appreciable volume change.

"Saturated soil" means a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or sheer vane.

"Soil classification system" means, for the purpose of this subpart, a method of categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the characteristics of the deposits and the environmental conditions of exposure.

"Stable rock" means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

"Submerged soil" means soil which is underwater or is free seeping.

"Type A" means cohesive soils with an unconfined, compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

- **i.** The soil is fissured; or
- **ii.** The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
- **iii.** The soil has been previously disturbed; or
- **iv.** The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or
- **v.** The material is subject to other factors that would require it to be classified as a less stable material.

"Type B" means:

- **i.** Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa); or
- **ii.** Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt

loam, sandy loam and, in some cases, silty clay loam and sandy clay loam.

iii. Previously disturbed soils except those which would otherwise be classed as Type C soil.

iv. Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

v. Dry rock that is not stable; or

vi. Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

"Type C" means:

i. Cohesive soil with an unconfined compressive strength of 0.5 tsf (48 kPa) or less; or

ii. Granular soils including gravel, sand, and loamy sand; or

iii. Submerged soil or soil from which water is freely seeping; or

iv. Submerged rock that is not stable, or

v. Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4H:1V) or steeper.

"Unconfined compressive strength" means the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing, or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.

"Wet soil" means soil that contains significantly more moisture than moist soil, but in such a range of values that cohesive material will slump or begin to flow when vibrated. Granular material that would exhibit cohesive properties when moist will lose those cohesive properties when wet.

c. Requirements.

1. Classification of soil and rock deposits. Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in paragraph (b) of this appendix.

2. Basis of classification. The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis. Such analyses shall be conducted by a competent person using tests described in paragraph (d) below, or in other recognized methods of soil classification and testing such as those adopted by the American Society for Testing Materials, or the U.S. Department of Agriculture textural classification system.

3. Visual and manual analyses. The visual and manual analyses, such as those noted as being acceptable in paragraph (d) of this appendix, shall be designed and conducted to provide sufficient quantitative and qualitative information as may be necessary to identify properly the properties, factors, and conditions affecting the classification of the deposits.

4. Layered systems. In a layered system, the system shall be classified in accordance with its weakest layer. However, each layer may be classified individually where a more stable layer lies under a less stable layer.

5. Reclassification. If, after classifying a deposit, the properties, factors, or conditions affecting its classification change in any way, the changes shall be evaluated by a competent person. The deposit shall be reclassified as necessary to reflect the changed circumstances.

d. Acceptable visual and manual tests.

1. Visual tests. Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material.

i. Observe samples of soil that are excavated and soil in the sides of the excavation. Estimate the range of particle sizes and the relative amounts of the particle sizes. Soil that is primarily composed of fine-grained material is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

ii. Observe soil as it is excavated. Soil that remains in clumps when excavated is cohesive. Soil that breaks up easily and does not stay in clumps is granular.

iii. Observe the side of the opened excavation and the surface area adjacent to the excavation. Crack-like openings such as tension cracks could indicate fissured material. If chunks of soil spall off a vertical side, the soil could be fissured. Small spalls are evidence of moving ground and are indications of potentially hazardous situations.

iv. Observe the area adjacent to the excavation and the excavation itself for evidence of existing utility and other underground structures, and to identify previously disturbed soil.

v. Observe the opened side of the excavation to identify layered systems. Examine layered systems to identify if the layers slope toward the excavation. Estimate the degree of slope of the layers.

vi. Observe the area adjacent to the excavation and the sides of the opened excavation for evidence of surface water, water seeping from the sides of the excavation, or the location of the level of the water table.

vii. Observe the area adjacent to the excavation and the area within the excavation for sources of vibration that may affect the stability of the excavation face.

2. Manual tests. Manual analysis of soil samples is conducted to determine quantitative as well as qualitative properties of soil and to provide more information in order to classify soil properly.

i. Plasticity. Mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as 1/8-inch in diameter. Cohesive material can be successfully rolled into threads without crumbling. For example, if at least a two inch (50 mm) length of 1/8-inch thread can be held on one end without tearing, the soil is cohesive.

ii. Dry strength. If the soil is dry and crumbles on its own or with moderate pressure into individual grains or fine powder, it is granular (any combination of gravel, sand, or silt). If the soil is dry and falls into clumps which break up into smaller clumps, but the smaller clumps can only be broken up with difficulty, it may be clay in any combination with gravel, sand or silt. If the dry soil breaks into clumps which do not break up into small clumps and which can only be broken with difficulty, and there is no visual indication the soil is fissured, the soil may be considered unfissured.

iii. Thumb penetration. The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils. (This test is based on the thumb penetration test described in American Society for Testing and Materials (ASTM) Standard designation

D2488—"Standard Recommended Practice for Description of Soils (Visual–Manual Procedure).") Type A soils with an unconfined compressive strength of 1.5 tsf can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort. Type C soils with an unconfined compressive strength of 0.5 tsf can be easily penetrated several inches by the thumb, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

iv. Other strength tests. Estimates of unconfined compressive strength of soils can also be obtained by use of a pocket penetrometer or by using a hand-operated shearvane.

v. Drying test. The basic purpose of the drying test is to differentiate between cohesive material with fissures, unfissured cohesive material, and granular material. The procedure for the drying test involves drying a sample of soil that is approximately one inch thick (2.54 cm) and six inches (15.24 cm) in diameter until it is thoroughly dry:

A. If the sample develops cracks as it dries, significant fissures are indicated.

B. Samples that dry without cracking are to be broken by hand. If considerable force is necessary to break a sample, the soil has significant cohesive material content. The soil can be classified as an unfissured cohesive material and the unconfined compressive strength should be determined.

C. If a sample breaks easily by hand, it is either a fissured cohesive material or a granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they pulverize easily into very small fragments, the material is granular.

■ Appendix B to Subpart P of Part 1926—Sloping and Benching

a. Scope and application. This appendix contains specifications for sloping and benching when used as methods of protecting employees working in excavations from cave-ins. The requirements of this appendix apply when the design of sloping and benching protective systems is to be performed in accordance with the requirements set forth in § 1926.652(b)(2).

b. Definitions.

Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation; and ravelling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short term exposure means a period of time less than or equal to 24 hours that an excavation is open.

c. Requirements

1. Soil classification. Soil and rock deposits shall be classified in accordance with appendix A to subpart P of part 1926.
2. Maximum allowable slope. The maximum allowable slope for a soil or rock deposit shall be determined from **TABLE B-1** of this appendix.
3. Actual slope.
   - **i.** The actual slope shall not be steeper than the maximum allowable slope.
   - **ii.** The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least ½ horizontal to one vertical (½H:1V) less steep than the maximum allowable slope.
   - **iii.** When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope, and shall assure that such reduction is achieved. Surcharge loads from adjacent structures shall be evaluated in accordance with § 1926.651(i).
4. Configurations. Configurations of sloping and benching systems shall be in accordance with **FIGURE B-1**.

Table B-1 Maximum Allowable Slopes

SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H:V)(1) FOR EXCAVATIONS LESS THAN 20 FEET DEEP(3)
STABLE ROCK	VERTICAL (90°)
TYPE A (2)	3/4:1 (53°)
TYPE B	1:1 (45°)
TYPE C	1½:1 (34°)

Footnote (1) Numbers shown in parentheses next to maximum allowable slopes are angles expressed in degrees from the horizontal. Angles have been rounded off.

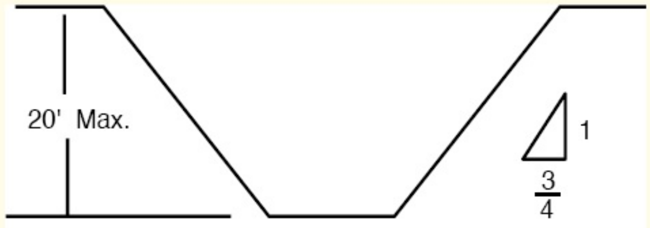
Footnote (2) A short-term maximum allowable slope of 1/2H:1V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67 m) or less in depth. Short-term maximum allowable slopes for excavations greater than 12 feet (3.67 m) in depth shall be 3/4H:1V (53°).

Footnote (3) Sloping or benching for excavations greater than 20 feet deep shall be designed by a registered professional engineer.

(All slopes stated below are in the horizontal to vertical ratio)

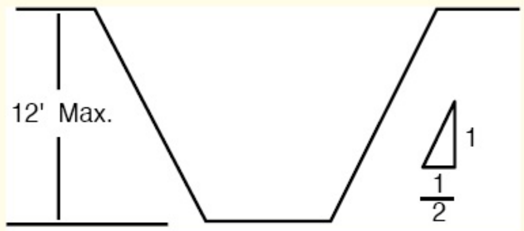
B-1.1 Excavations Made in Type A Soil.

1. All simple slope excavation 20 feet or less in depth shall have a maximum allowable slope of ¾:1.



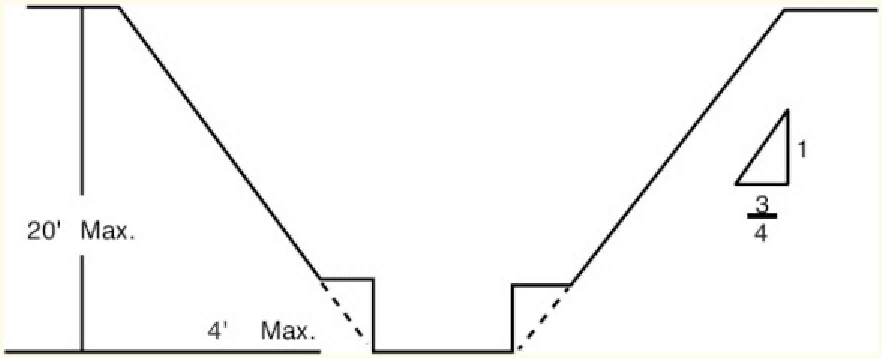
SIMPLE SLOPE—GENERAL

Exception: Simple slope excavations which are open 24 hours or less (short term) and which are 12 feet or less in depth shall have a maximum allowable slope of ½:1.

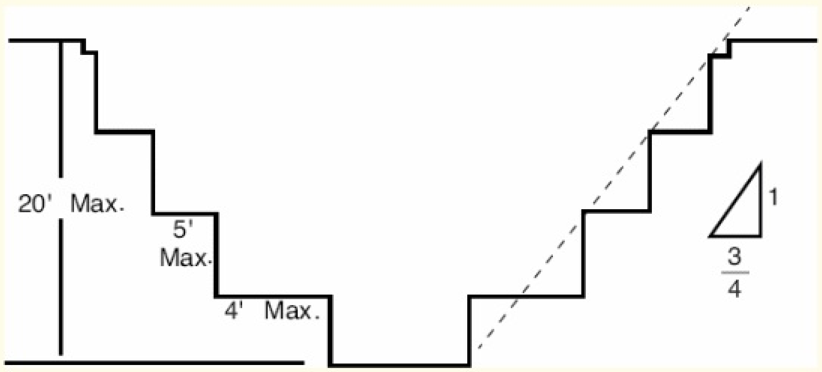


SIMPLE SLOPE—SHORT TERM

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of 3/4 to 1 and maximum bench dimensions as follows:

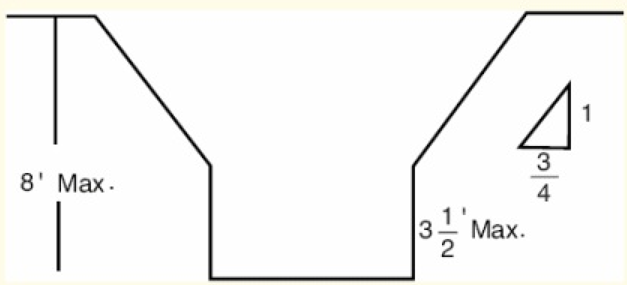


SIMPLE BENCH



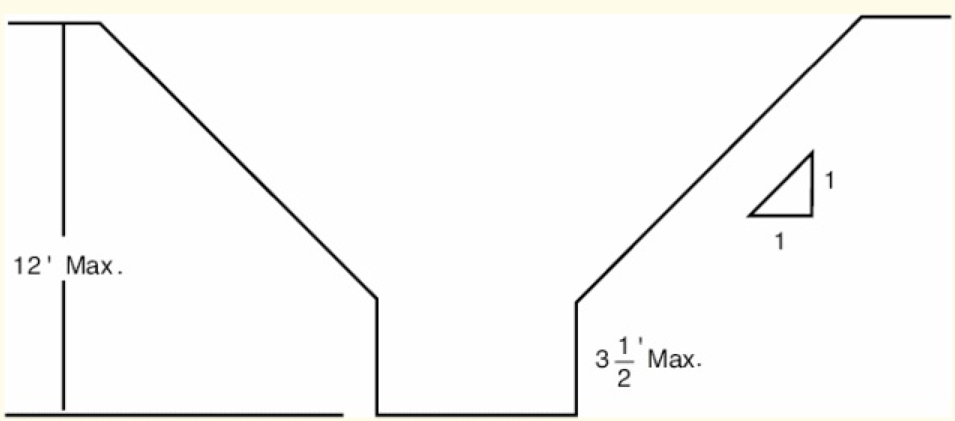
MULTIPLE BENCH

3. All excavations 8 feet or less in depth which have unsupported vertically sided lower portions shall have a maximum vertical side of 3½ feet.



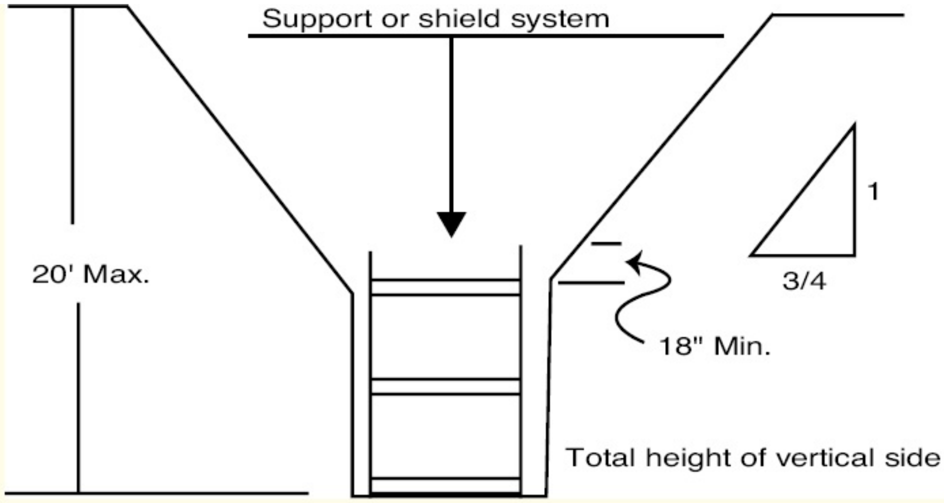
UNSUPPORTED VERTICALLY SIDED LOWER PORTION—MAXIMUM 8 FEET IN DEPTH

All excavations more than 8 feet but not more than 12 feet in depth with unsupported vertically sided lower portions shall have a maximum allowable slope of 1:1 and a maximum vertical side of 3½ feet.



UNSUPPORTED VERTICALLY SIDED LOWER PORTION—MAXIMUM 12 FEET IN DEPTH

All excavations 20 feet or less in depth which have vertically sided lower portions that are supported or shielded shall have a maximum allowable slope of ¾:1. The support or shield system must extend at least 18 inches above the top of the vertical side.



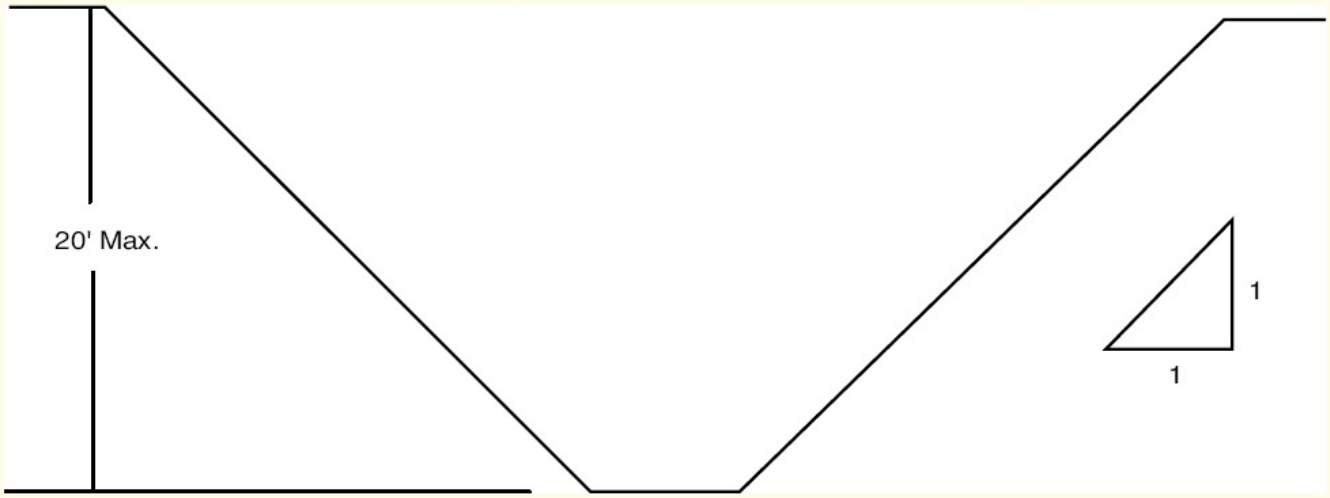
SUPPORTED OR SHIELDED VERTICALLY SIDED LOWER PORTION

4. All other simple slope, compound slope, and vertically sided lower portion excavations shall be in accordance with the other options permitted under § 1926.652(b).

FIGURE B-1-1 Slope Configurations. Excavations Made in Type A Soil.

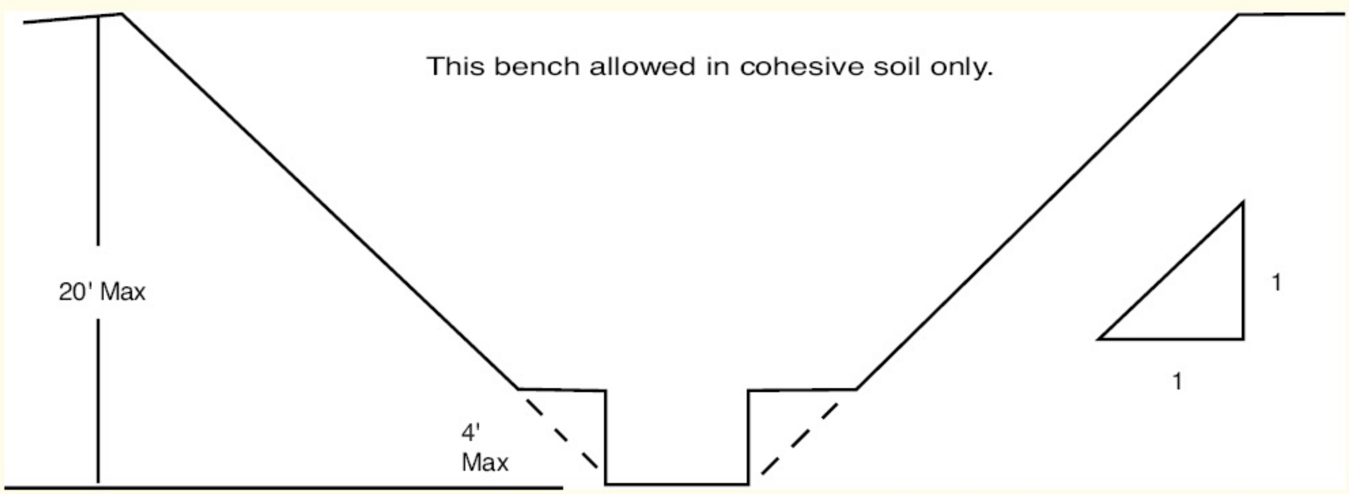
B-1.2 Excavations Made in Type B Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1.

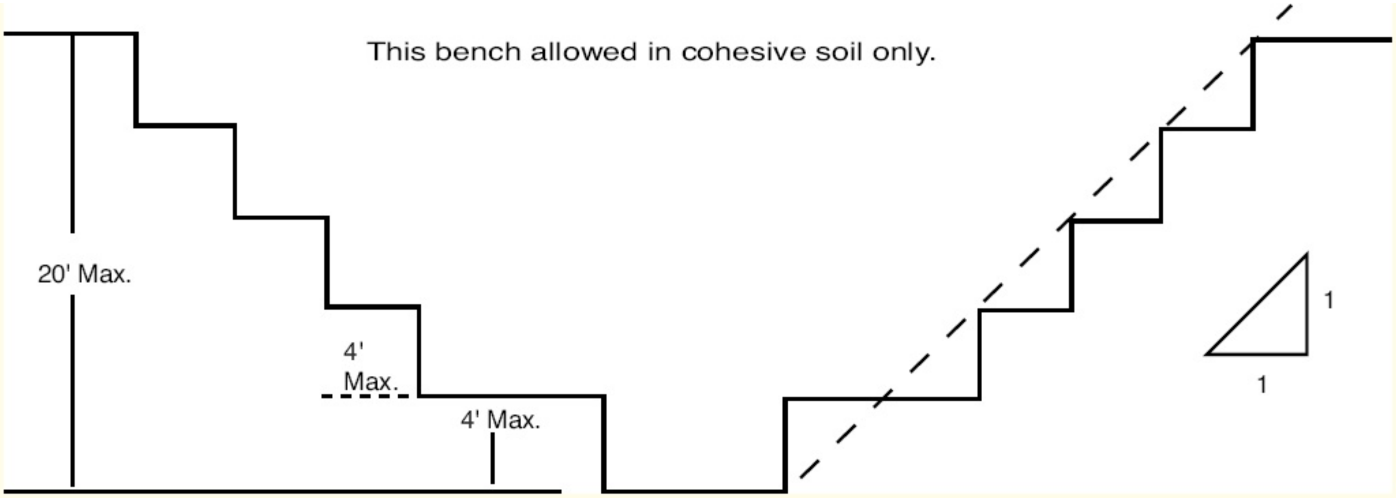


SIMPLE SLOPE

2. All benched excavations 20 feet or less in depth shall have a maximum allowable slope of 1:1 and maximum bench dimensions as follows:

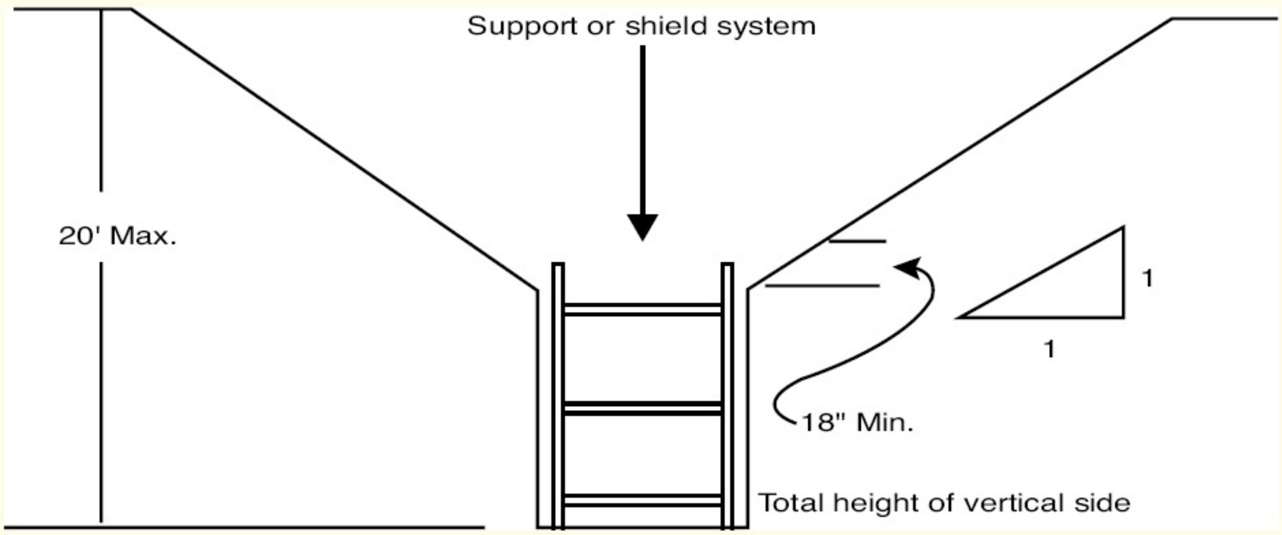


SINGLE BENCH



MULTIPLE BENCH

3. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1:1.



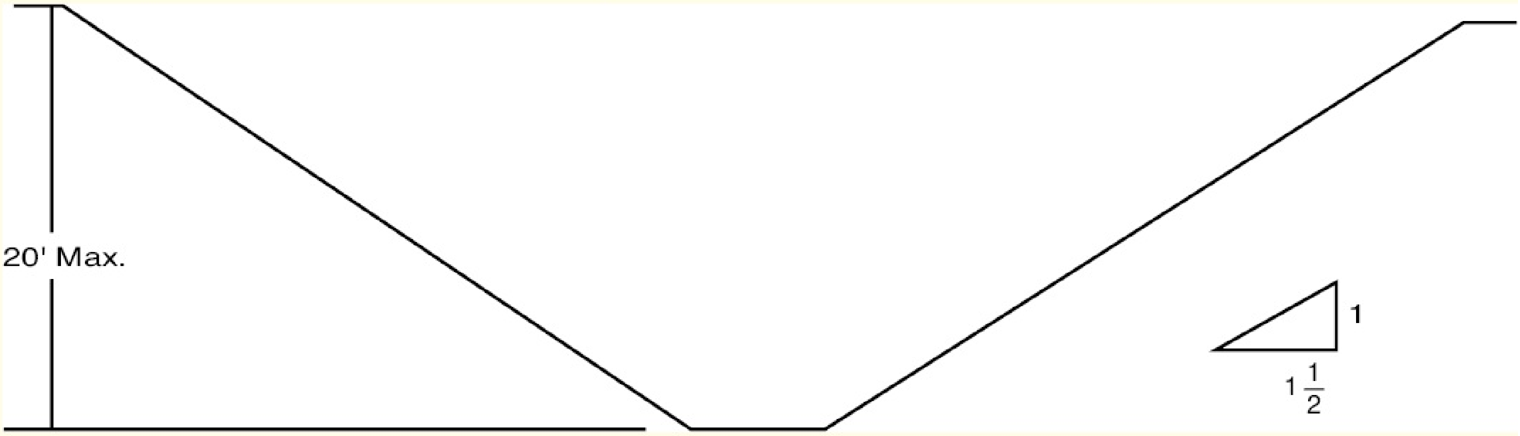
VERTICALLY SIDED LOWER PORTION

4. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

FIGURE B-1-2 Slope Configurations. Excavations Made in Type B Soil.

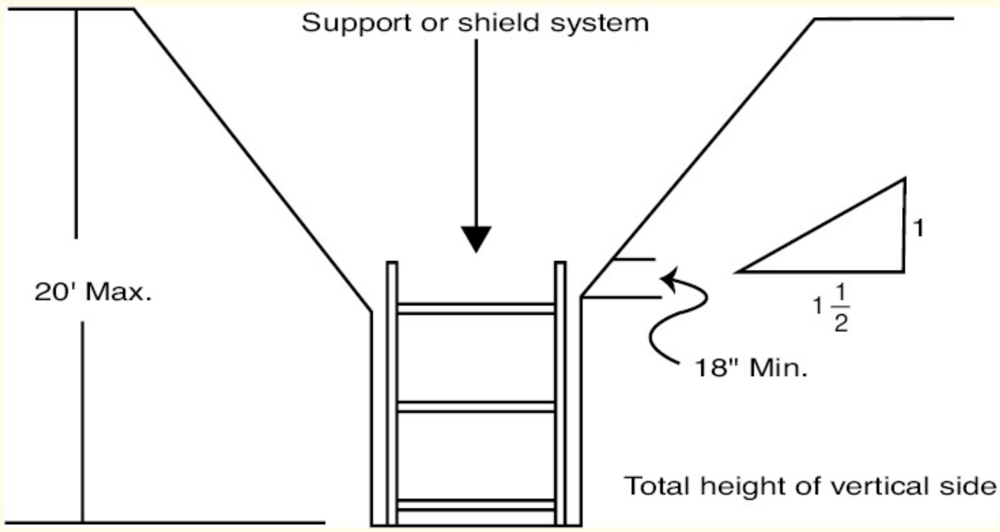
B-1.3 Excavations Made in Type C Soil

1. All simple slope excavations 20 feet or less in depth shall have a maximum allowable slope of 1½:1.



SIMPLE SLOPE

2. All excavations 20 feet or less in depth which have vertically sided lower portions shall be shielded or supported to a height at least 18 inches above the top of the vertical side. All such excavations shall have a maximum allowable slope of 1½:1.



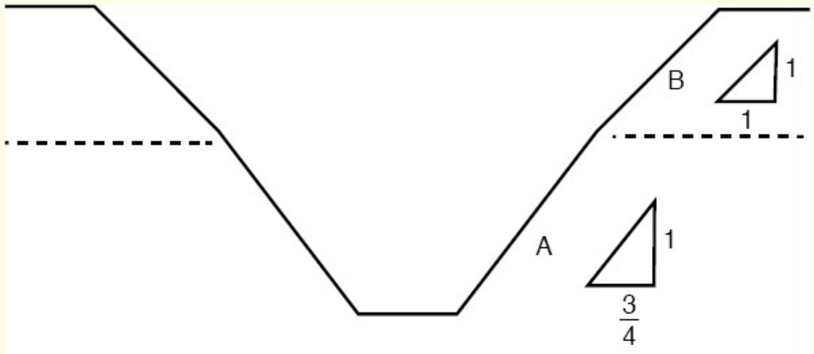
VERTICAL SIDED LOWER PORTION

3. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

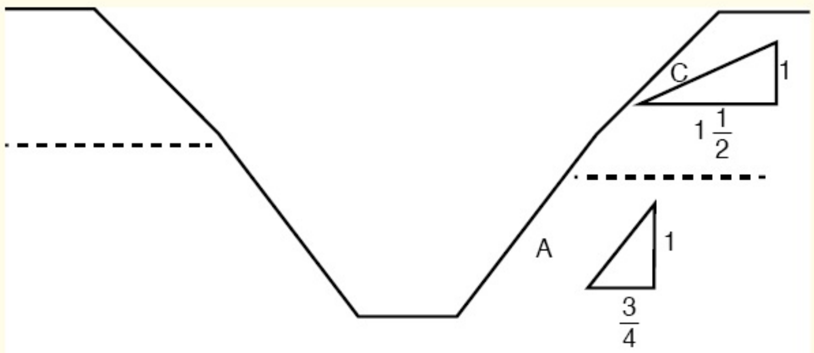
FIGURE B-1-3 Slope Configurations. Excavations Made in Type C Soil.

B-1.4 Excavations Made in Layered Soils

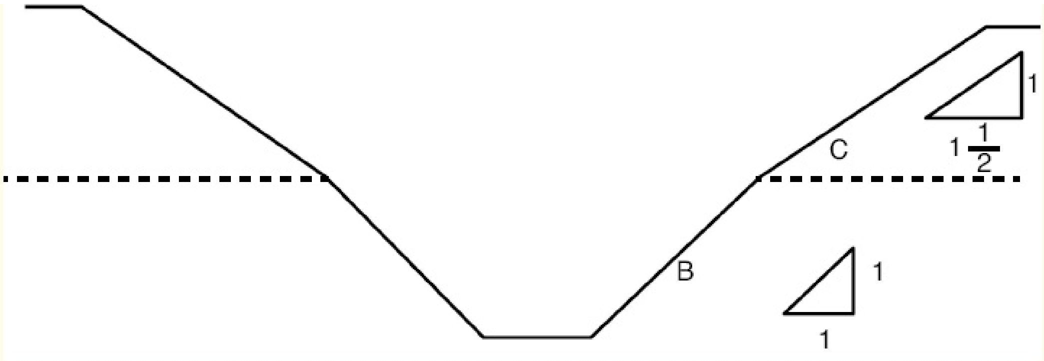
1. All excavations 20 feet or less in depth made in layered soils shall have a maximum allowable slope for each layer as set forth below.



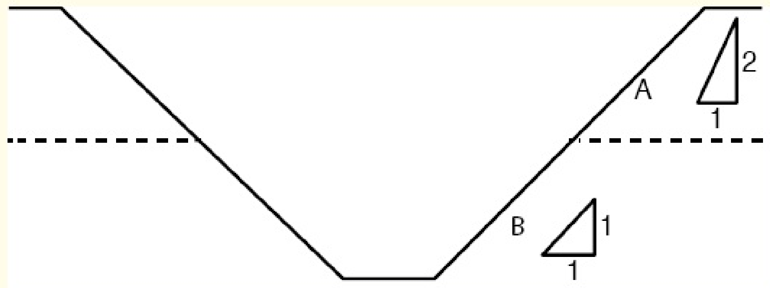
B OVER A



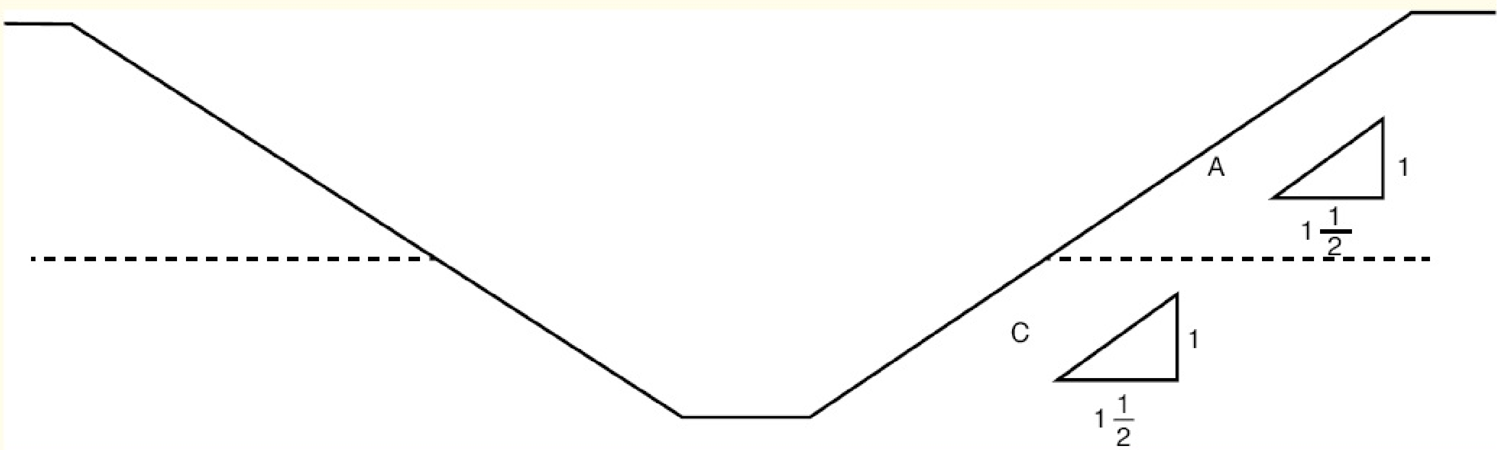
C OVER A



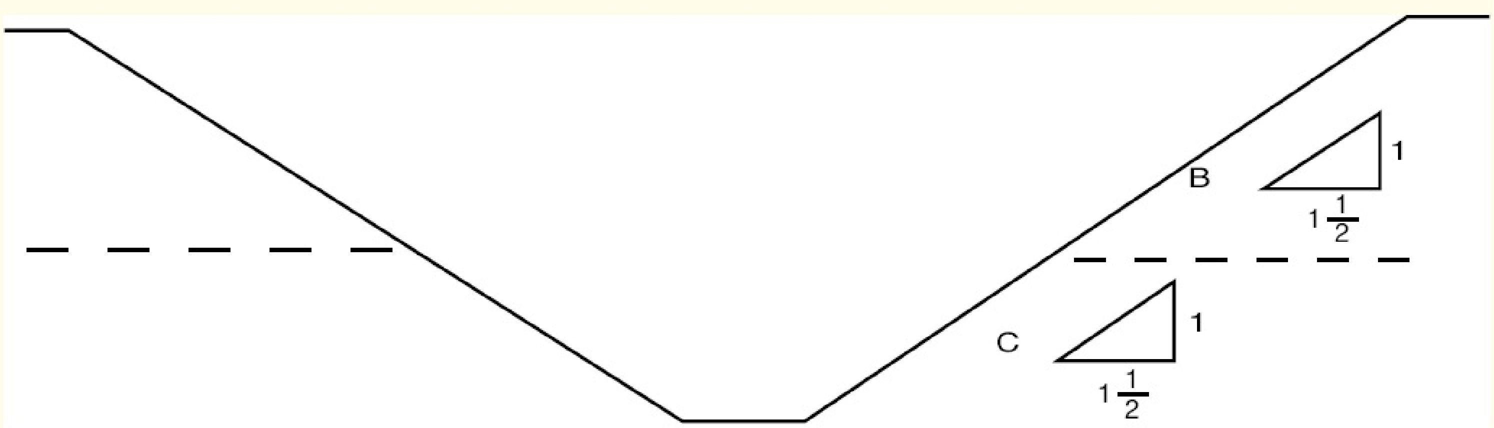
C OVER B



A OVER B



A OVER C



B OVER C

2. All other sloped excavations shall be in accordance with the other options permitted in § 1926.652(b).

FIGURE B-1-4 Slope Configurations. Excavations Made in Layered Soils.

■ Appendix C to Subpart P of Part 1926—Timber Shoring for Trenches

a. Scope. This appendix contains information that can be used when timber shoring is provided as a method of protection from cave-ins in trenches that do not exceed 20 feet (6.1 m) in depth. This appendix must be used when design of timber shoring protective systems is to be performed in accordance with 1926.652(c)(1). Other timber shoring configurations; other systems of support such as hydraulic and pneumatic systems; and other protective systems such as sloping, benching, shielding, and freezing systems must be designed in accordance with the requirements set forth in 1926.652(b) and 1926.652(c).

b. Soil Classification. In order to use the data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of this part.

c. Presentation of Information. Information is presented in several forms as follows:

1. Information is presented in tabular form in Tables C-1.1–C-1.3 and Tables C-2.1–C-2.3 following paragraph (g) of the appendix. Each table presents the minimum sizes of timber members to use in a shoring system, and each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. The data are arranged to allow the user the flexibility to select from among several acceptable configurations of members based on varying the horizontal spacing of the crossbraces. Stable rock is exempt from shoring requirements and therefore, no data are presented for this condition.
2. Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix, and on the tables themselves.
3. Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.
4. Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.
5. Miscellaneous notations regarding Tables C-1.1 through C-1.3 and Tables C-2.1 through C-2.3 are presented in paragraph (g) of this Appendix.

d. Basis and limitations of the data.

1. Dimensions of timber members.
   - **i.** The sizes of the timber members listed in Tables C-1.1 through C-1.3 are taken from the National Bureau of Standards (NBS) report, "Recommended Technical Provisions for Construction Practice in Shoring and Sloping of Trenches and Excavations." In addition, where NBS did not recommend specific sizes of members, member sizes are based on an analysis of the sizes required for use by existing codes and on empirical practice.
   - **ii.** The required dimensions of the members listed in Tables C-1.1 through C-1.3 refer to actual dimensions and not nominal dimensions of the timber. Employers wanting to use nominal size shoring are directed to Tables C-2.1 through C-2.3, or have this choice under 1926.652(c)(3), and are referred to The Corps of Engineers, The Bureau of Reclamation or data from other acceptable sources.

2. Limitation of application.

i. It is not intended that the timber shoring specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be designed as specified in 1926.652(c).

ii. When any of the following conditions are present, the members specified in the tables are not considered adequate. Either an alternate timber shoring system must be designed or another type of protective system designed in accordance with 1926.652.

A. When loads imposed by structures or by stored material adjacent to the trench weigh in excess of the load imposed by a two-foot soil surcharge. The term “adjacent” as used here means the area within a horizontal distance from the edge of the trench equal to the depth of the trench.

B. When vertical loads imposed on cross braces exceed a 240-pound gravity load distributed on a one-foot section of the center of the cross-brace.

C. When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

D. When only the lower portion of a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

e. Use of Tables. The members of the shoring system that are to be selected using this information are the cross braces, the uprights, and the wales, where wales are required. Minimum sizes of members are specified for use in different types of soil. There are six tables of information, two for each soil type. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is then made. The selection is based on the depth and width of the trench where the members are to be installed and, in most instances, the selection is also based on the horizontal spacing of the crossbraces. Instances where a choice of horizontal spacing of crossbracing is available, the horizontal spacing of the crossbraces must be chosen by the user before the size of any member can be determined. When the soil type, the width and depth of the trench, and the horizontal spacing of the crossbraces are known, the size and vertical spacing of the crossbraces are known, the size and vertical spacing of the crossbraces, the size and vertical spacing of the wales, and the size and horizontal spacing of the uprights can be read from the appropriate table.

Table C-1.1 | Timber Trench Shoring-Minimum Timber Requirements*

SOIL TYPE A P(a) = 25 X H + 72 psf (2 ft Surcharge)														
SIZE (ACTUAL) AND SPACING OF MEMBERS**														
	CROSS BRACES							WALES		UPRIGHTS				
DEPTH OF TRENCH (FEET)	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	4	5	6	8
5 TO 10	UP TO 6	4 × 4	4 × 4	Not Req'd	---	6 × 6	4	Not Req'd	---				2 × 6	
	UP TO 8	4 × 4	4 × 4	Not Req'd	---	6 × 6	4	Not Req'd	---					2 × 8
	UP TO 10	4 × 6	4 × 6	8 × 8	4	6 × 6	4	8 × 8	4			2 × 6		
	UP TO 12	4 × 6	4 × 6	8 × 8	4	6 × 6	4	8 × 8	4				2 × 6	
10 TO 15	UP TO 6	4 × 4	4 × 4	Not Req'd	---	6 × 6	4	Not Req'd	---				3 × 8	
	UP TO 8	4 × 6	4 × 6	8 × 8	4	6 × 6	4	8 × 8	4		2 × 6			
	UP TO 10	6 × 6	6 × 6	8 × 10	4	6 × 8	4	8 × 10	4			2 × 6		
	UP TO 12	6 × 6	6 × 6	10 × 10	4	6 × 8	4	10 × 10	4				3 × 8	
15 TO 20	UP TO 6	6 × 6	6 × 6	6 × 8	4	6 × 8	4	6 × 8	4	3 × 6				
	UP TO 8	6 × 6	6 × 6	8 × 8	4	6 × 8	4	8 × 8	4	3 × 6				
	UP TO 10	8 × 8	8 × 8	8 × 10	4	8 × 10	4	8 × 10	4	3 × 6				
	UP TO 12	8 × 8	8 × 8	10 × 10	4	8 × 10	4	10 × 10	4	3 × 6				
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.

** Manufactured members of equivalent strength may be substituted for wood.

Table C-1.2 Timber Trench Shoring-Minimum Timber Requirements*

SOIL TYPE B P(a) = 45 X H + 72 psf (2 ft Surcharge)														
SIZE (ACTUAL) AND SPACING OF MEMBERS**														
	CROSS BRACES							WALES		UPRIGHTS				
DEPTH OF TRENCH (FEET)	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	2	3		
5 TO 10	UP TO 6	4 × 6	4 × 6	6 × 6	6 × 6	6 × 6	5	6 × 8	5			2 × 6		
	UP TO 8	6 × 6	6 × 6	6 × 6	6 × 8	6 × 8	5	8 × 10	5			2 × 6		
	UP TO 10	6 × 6	6 × 6	6 × 6	6 × 8	6 × 8	5	10 × 10	5			2 × 6		
	SEE NOTE 1													
10 TO 15	UP TO 6	6 × 6	6 × 6	6 × 6	6 × 8	6 × 8	5	8 × 8	5		2 × 6			
	UP TO 8	6 × 8	6 × 8	6 × 8	8 × 8	8 × 8	5	10 × 10	5		2 × 6			
	UP TO 10	8 × 8	8 × 8	8 × 8	8 × 8	8 × 10	5	10 × 12	5		2 × 6			
	SEE NOTE 1													
15 TO 20	UP TO 6	6 × 8	6 × 8	6 × 8	8 × 8	8 × 8	5	8 × 10	5	3 × 6				
	UP TO 8	8 × 8	8 × 8	8 × 8	8 × 8	8 × 10	5	10 × 12	5	3 × 6				
	UP TO 10	8 × 10	8 × 10	8 × 10	8 × 10	10 × 10	5	12 × 12	5	3 × 6				
	SEE NOTE 1													
OVER 20	SEE NOTE 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.

** Manufactured members of equivalent strength may be substituted for wood.

Table C-1.3 Timber Trench Shoring-Minimum Timber Requirements*

SOIL TYPE C P(a) = 80 × H + 72 psf (2 ft Surcharge)														
SIZE (ACTUAL) AND SPACING OF MEMBERS**														
	CROSS BRACES							WALES		UPRIGHTS				
		WIDTH OF TRENCH (FEET)								MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) (See Note 2)				
DEPTH OF TRENCH (FEET)	HORIZ. SPACING (FEET)	UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15	VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	CLOSE				
5 TO 10	UP TO 6	6 × 8	6 × 8	6 × 8	8 × 8	8 × 8	5	8 × 10	5	2 × 6				
	UP TO 8	8 × 8	8 × 8	8 × 8	8 × 8	8 × 10	5	10 × 12	5	2 × 6				
	UP TO 10	8 × 10	8 × 10	8 × 10	8 × 10	10 × 10	5	12 × 12	5	2 × 6				
	SEE NOTE 1													
10 TO 15	UP TO 6	8 × 8	8 × 8	8 × 8	8 × 8	8 × 10	5	10 × 12	5	2 × 6				
	UP TO 8	8 × 10	8 × 10	8 × 10	8 × 10	10 × 10	5	10 × 10	5	2 × 6				
	See Note 1													
	See Note 1													
15 TO 20	UP TO 6	8 × 10	8 × 10	8 × 10	8 × 10	10 × 10	5	12 × 12	5	3 × 6				
	See Note 1													
	See Note 1													
	See Note 1													
OVER 20	See Note 1													

* Mixed oak or equivalent with a bending strength not less than 850 psi.

** Manufactured members of equivalent strength may be substituted for wood.

Table C-2.1 Timber Trench Shoring-Minimum Timber Requirements*

SOIL TYPE A P(a) = 25 $\times$ H + 72 psf (2 ft Surcharge)														
SIZE (S4S) AND SPACING OF MEMBERS**														
	CROSS BRACES							WALES		UPRIGHTS				
DEPTH OF TRENCH (FEET)	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)		VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) (See Note 2)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15		SIZE (IN)		CLOSE	4	5	6	8
5 TO 10	UP TO 6	4 $\times$ 4	4 $\times$ 4	4 $\times$ 4	4 $\times$ 4	4 $\times$ 6	4	Not Req'd	Not Req'd				4 $\times$ 6	
	UP TO 8	4 $\times$ 4	4 $\times$ 4	4 $\times$ 4	4 $\times$ 6	4 $\times$ 6	4	Not Req'd	Not Req'd					4 $\times$ 8
	UP TO 10	4 $\times$ 6	4 $\times$ 6	4 $\times$ 6	6 $\times$ 6	6 $\times$ 6	4	8 $\times$ 8	4			4 $\times$ 6		
	UP TO 12	4 $\times$ 6	4 $\times$ 6	4 $\times$ 6	6 $\times$ 6	6 $\times$ 6	4	8 $\times$ 8	4				4 $\times$ 6	
10 TO 15	UP TO 6	4 $\times$ 4	4 $\times$ 4	4 $\times$ 4	6 $\times$ 6	6 $\times$ 6	4	Not Req'd	Not Req'd				4 $\times$ 10	
	UP TO 8	4 $\times$ 6	4 $\times$ 6	4 $\times$ 6	6 $\times$ 6	6 $\times$ 6	4	6 $\times$ 8	4		4 $\times$ 6			
	UP TO 10	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	4	8 $\times$ 8	4			4 $\times$ 8		
	UP TO 12	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	4	8 $\times$ 10	4		4 $\times$ 6		4 $\times$ 10	
15 TO 20	UP TO 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	4	6 $\times$ 8	4	3 $\times$ 6				
	UP TO 8	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	4	8 $\times$ 8	4	3 $\times$ 6	4 $\times$ 12			
	UP TO 10	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 8	4	8 $\times$ 10	4	3 $\times$ 6				
	UP TO 12	6 $\times$ 6	6 $\times$ 6	6 $\times$ 6	6 $\times$ 8	6 $\times$ 8	4	8 $\times$ 12	4	3 $\times$ 6	4 $\times$ 12			
OVER 20	See Note 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.

** Manufactured members of equivalent strength may be substituted for wood.

Table C-2.2 Timber Trench Shoring-Minimum Timber Requirements*

SOIL TYPE B P(a) = 45 × H + 72 psf (2 ft Surcharge)														
SIZE (S4S) AND SPACING OF MEMBERS**														
	CROSS BRACES							WALES		UPRIGHTS				
DEPTH OF TRENCH (FEET)	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET) (See Note 2)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE	2	3	4	6
5 TO 10	UP TO 6	4 × 6	4 × 6	4 × 6	6 × 6	6 × 6	5		5			3 × 12 4 × 8		4 × 12
	UP TO 8	4 × 6	4 × 6	6 × 6	6 × 6	6 × 6	5		5		3 × 8		4 × 8	
	UP TO 10	4 × 6	4 × 6	6 × 6	6 × 6	6 × 8	5		5			4 × 8		
	See Note 1													
10 TO 15	UP TO 6	6 × 6	6 × 6	6 × 6	6 × 8	6 × 8	5	8 × 8	5	3 × 6	4 × 10			
	UP TO 8	6 × 8	6 × 8	6 × 8	8 × 8	8 × 8	5		5	3 × 6	4 × 10			
	UP TO 10	6 × 8	6 × 8	8 × 8	8 × 8	8 × 8	5		5	3 × 6	4 × 10			
	See Note 1													
15 TO 20	UP TO 6	6 × 8	6 × 8	6 × 8	6 × 8	8 × 8	5		5	4 × 6				
	UP TO 8	6 × 8	6 × 8	6 × 8	8 × 8	8 × 8	5		5	4 × 6				
	UP TO 10	8 × 8	8 × 8	8 × 8	8 × 8	8 × 8	5		5	4 × 6				
	See Note 1													
OVER 20	See Note 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.

** Manufactured members of equivalent strength may be substituted for wood.

Table C-2.3 Timber Trench Shoring-Minimum Timber Requirements*

SOIL TYPE C P(a) = 80 × H + 72 psf (2 ft Surcharge)														
SIZE (S4S) AND SPACING OF MEMBERS**														
	CROSS BRACES							WALES		UPRIGHTS				
DEPTH OF TRENCH (FEET)	HORIZ. SPACING (FEET)	WIDTH OF TRENCH (FEET)					VERT. SPACING (FEET)	SIZE (IN)	VERT. SPACING (FEET)	MAXIMUM ALLOWABLE HORIZONTAL SPACING (FEET)				
		UP TO 4	UP TO 6	UP TO 9	UP TO 12	UP TO 15				CLOSE				
5 TO 10	UP TO 6	6 × 6	6 × 6	6 × 6	6 × 6	8 × 8	5	8 × 8	5	3 × 6				
	UP TO 8	6 × 6	6 × 6	6 × 6	8 × 8	8 × 8	5		5	3 × 6				
	UP TO 10	6 × 6	6 × 6	8 × 8	8 × 8	8 × 8	5		5	3 × 6				
	See Note 1													
10 TO 15	UP TO 6	6 × 8	6 × 8	6 × 8	8 × 8	8 × 8	5	10 × 10	5	4 × 6				
	UP TO 8	8 × 8	8 × 8	8 × 8	8 × 8	8 × 8	5	12 × 12	5	4 × 6				
	See Note 1													
	See Note 1													
15 TO 20	UP TO 6	8 × 8	8 × 8	8 × 8	8 × 10	8 × 10	5	10 × 12	5	4 × 6				
	See Note 1													
	See Note 1													
	See Note 1													
OVER 20	See Note 1													

* Douglas fir or equivalent with a bending strength not less than 1500 psi.

** Manufactured members of equivalent strength may be substituted for wood.

f. Examples to Illustrate the Use of Tables C-1.1 through C-1.3.

1. Example 1.

A trench dug in Type A soil is 13 feet deep and five feet wide.

From TABLE C-1.1, four acceptable arrangements of timber can be used.

Arrangement #1

Space 4 × 4 crossbraces at six feet horizontally and four feet vertically.

Wales are not required.

Space 3 × 8 uprights at six feet horizontally. This arrangement is commonly called "skip shoring."

Arrangement #2

Space 4 × 6 crossbraces at eight feet horizontally and four feet vertically.

Space 8 × 8 wales at four feet vertically.

Space 2 × 6 uprights at four feet horizontally.

Arrangement #3

Space 6 × 6 crossbraces at 10 feet horizontally and four feet vertically.

Space 8 × 10 wales at four feet vertically.

Space 2 × 6 uprights at five feet horizontally.

Arrangement #4

Space 6 × 6 crossbraces at 12 feet horizontally and four feet vertically.

Space 10 × 10 wales at four feet vertically.

Space 3 × 8 uprights at six feet horizontally.

2. Example 2. A trench dug in Type B soil is 13 feet deep and five feet wide. From TABLE C-1.2 three acceptable arrangements of members are listed.

Arrangement #1

Space 6 × 6 crossbraces at six feet horizontally and five feet vertically.

Space 8 × 8 wales at five feet vertically.

Space 2 × 6 uprights at two feet horizontally.

Arrangement #2

Space 6 × 8 crossbraces at eight feet horizontally and five feet vertically.

Space 10 × 10 wales at five feet vertically.

Space 2 × 6 uprights at two feet horizontally.

Arrangement #3

Space 8 × 8 crossbraces at 10 feet horizontally and five feet vertically.

Space 10 × 12 wales at five feet vertically.

Space 2 × 6 uprights at two feet vertically.

3. Example 3. A trench dug in Type C soil is 13 feet deep and five feet wide. From TABLE C-1.3 two acceptable arrangements of members can be used.

Arrangement #1
Space 8 × 8 crossbraces at six feet horizontally and five feet vertically.
Space 10 × 12 wales at five feet vertically.
Position 2 × 6 uprights as closely together as possible.
If water must be retained use special tongue and groove uprights to form tight sheeting.

Arrangement #2
Space 8 × 10 crossbraces at eight feet horizontally and five feet vertically.
Space 12 × 12 wales at five feet vertically.
Position 2 × 6 uprights in a close sheeting configuration unless water pressure must be resisted. Tight sheeting must be used where water must be retained.

4. Example 4. A trench dug in Type C soil is 20 feet deep and 11 feet wide. The size and spacing of members for the section of trench that is over 15 feet in depth is determined using TABLE C-1.3. Only one arrangement of members is provided.

Space 8 × 10 crossbraces at six feet horizontally and five feet vertically.
Space 12 × 12 wales at five feet vertically.
Use 3 × 6 tight sheeting.
Use of TABLES C-2.1 through C-2.3 would follow the same procedures.

g. Notes for all Tables.

1. Member sizes at spacings other than indicated are to be determined as specified in 1926.652(c), “Design of Protective Systems.”
2. When conditions are saturated or submerged use Tight Sheeting. Tight Sheeting refers to the use of specially-edged timber planks (e.g., tongue and groove) at least three inches thick, steel sheet piling, or similar construction that when driven or placed in position provide a tight wall to resist the lateral pressure of water and to prevent the loss of backfill material. Close Sheeting refers to the placement of planks side-by-side allowing as little space as possible between them.
3. All spacing indicated is measured center to center.
4. Wales to be installed with greater dimension horizontal.
5. If the vertical distance from the center of the lowest crossbrace to the bottom of the trench exceeds two and one-half feet, uprights shall be firmly embedded or a mudsill shall be used. Where uprights are embedded, the vertical distance from the center of the lowest crossbrace to the bottom of the trench shall not exceed 36 inches. When mudsills are used, the vertical distance shall not exceed 42 inches. Mudsills are wales that are installed at the tow of the trench side.
6. Trench jacks may be used in lieu of or in combination with timber crossbraces.
7. Placement of crossbraces. When the vertical spacing of crossbraces is four feet, place the top

crossbrace no more than two feet below the top of the trench. When the vertical spacing of crossbraces is five feet, place the top crossbrace no more than 2.5 feet below the top of the trench.

Appendix D to Subpart P of Part 1926—Aluminum Hydraulic Shoring for Trenches

a. Scope. This appendix contains information that can be used when aluminum hydraulic shoring is provided as a method of protection against cave-ins in trenches that do not exceed 20 feet (6.1m) in depth. This appendix must be used when design of the aluminum hydraulic protective system cannot be performed in accordance with 1926.652(c)(2).

b. Soil Classification. In order to use data presented in this appendix, the soil type or types in which the excavation is made must first be determined using the soil classification method set forth in appendix A of subpart P of part 1926.

c. Presentation of Information. Information is presented in several forms as follows:

1. Information is presented in tabular form in Tables D-1.1–D-1.4. Each table presents the maximum vertical and horizontal spacings that may be used with various aluminum member sizes and various hydraulic cylinder sizes. Each table contains data only for the particular soil type in which the excavation or portion of the excavation is made. Tables D-1.1 and D-1.2 are for vertical shores in Types A and B soil. Tables D-1.3 and D-1.4 are for horizontal waler systems in Types B and C soil.
2. Information concerning the basis of the tabular data and the limitations of the data is presented in paragraph (d) of this appendix.
3. Information explaining the use of the tabular data is presented in paragraph (e) of this appendix.
4. Information illustrating the use of the tabular data is presented in paragraph (f) of this appendix.
5. Miscellaneous notations (Footnotes) regarding Tables D-1.1 through D-1.4 are presented in paragraph (g) of this appendix.
6. Figures, illustrating typical installations of hydraulic shoring, are included just prior to the Tables. The illustrations page is entitled “Aluminum Hydraulic Shoring: Typical Installations.”

d. Basis and limitations of the data.

1. Vertical shore rails and horizontal wales are those that meet the Section Modulus requirements in the D-1 Tables. Aluminum material is 6061-T6 or material of equivalent strength and properties.
2. Hydraulic cylinders specifications.
    i. 2-inch cylinders shall be a minimum 2-inch inside diameter with a minimum safe working capacity of no less than 18,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

ii. 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe working capacity of not less than 30,000 pounds axial compressive load at extensions as recommended by product manufacturer.

3. Limitation of application.

i. It is not intended that the aluminum hydraulic specification apply to every situation that may be experienced in the field. These data were developed to apply to the situations that are most commonly experienced in current trenching practice. Shoring systems for use in situations that are not covered by the data in this appendix must be otherwise designed as specified in 1926.652(c).

ii. When any of the following conditions are present, the members specified in the Tables are not considered adequate. In this case, an alternative aluminum hydraulic shoring system or other type of protective system must be designed in accordance with 1926.652.

A. When vertical loads imposed on cross braces exceed a 100 Pound gravity load distributed on a one foot section of the center of the hydraulic cylinder.

B. When surcharge loads are present from equipment weighing in excess of 20,000 pounds.

C. When only the lower portion of a trench is shored and the remaining portion of the trench is sloped or benched unless: The sloped portion is sloped at an angle less steep than three horizontal to one vertical; or the members are selected from the tables for use at a depth which is determined from the top of the overall trench, and not from the toe of the sloped portion.

e. Use of Tables D-1.1–D-1.4. The members of the shoring system that are to be selected using this information are the hydraulic cylinders, and either the vertical shores or the horizontal wales. When a waler system is used the vertical timber sheeting to be used is also selected from these tables. The Tables D-1.1 and D-1.2 for vertical shores are used in Type A and B soils that do not require sheeting. Type B soils that may require sheeting, and Type C soils that always require sheeting, are found in the horizontal wale Tables D-1.3 and D-1.4. The soil type must first be determined in accordance with the soil classification system described in appendix A to subpart P of part 1926. Using the appropriate table, the selection of the size and spacing of the members is made. The selection is based on the depth and width of the trench where the members are to be installed. In these tables the vertical spacing is held constant at four feet on center. The tables show the maximum horizontal spacing of cylinders allowed for each size of wale in the waler system tables, and in the vertical shore tables, the hydraulic cylinder horizontal spacing is the same as the vertical shore spacing.

f. Example to Illustrate the Use of the Tables:

1. Example 1:

A trench dug in Type A soil is 6 feet deep and 3 feet wide. From **TABLE D-1.1**: Find vertical shores and 2 inch diameter cylinders spaced 8 feet on center (o.c.) horizontally and 4 feet on center (o.c.) vertically. (See **FIGURES 1 & 3** for typical installations.)

2. Example 2:

A trench is dug in Type B soil that does not require sheeting, 13 feet deep and 5 feet wide. From TABLE D-1.2: Find vertical shores and 2 inch diameter cylinders spaced 6.5 feet o.c. horizontally and 4 feet o.c. vertically. (See Figures 1 & 3 for typical installations.)

3. A trench is dug in Type B soil that does not require sheeting, but does experience some minor raveling of the trench face. the trench is 16 feet deep and 9 feet wide. From Table D-1.2: Find vertical shores and 2 inch diameter cylinder (with special oversleeves as designated by Footnote #2) spaced 5.5 feet o.c. horizontally and 4 feet o.c. vertically. Plywood (per Footnote (g)(7) to the D-1 Table) should be used behind the shores. (See FIGURES 2 & 3 for typical installations.)

4. Example 4: A trench is dug in previously disturbed Type B soil, with characteristics of a Type C soil, and will require sheeting. The trench is 18 feet deep, and 12 feet wide 8 foot horizontal spacing between cylinders is desired for working space.v From TABLE D-1.3: Find horizontal wale with a section modulus of 14.0 spaced at 4 feet o.c. vertically and 3 inch diameter cylinder spaced at 9 feet maximum o.c. horizontally, 3 × 12 timber sheeting is required at close spacing vertically. (See FIGURE 4 for typical installation.)

5. Example 5: A trench is dug in Type C soil, 9 feet deep and 4 feet wide. Horizontal cylinder spacing in excess of 6 feet is desired for working space. From TABLE D-1.4: Find horizontal wale with a section modulus of 7.0 and 2 inch diameter cylinders spaced at 6.5 feet o.c. horizontally. Or, find horizontal wale with a 14.0 section modulus and 3 inch diameter cylinder spaced at 10 feet o.c. horizontally. Both wales are spaced 4 feet o.c. vertically, 3 × 12 timber sheeting is required at close spacing vertically. (See Figure 4 for typical installation.)

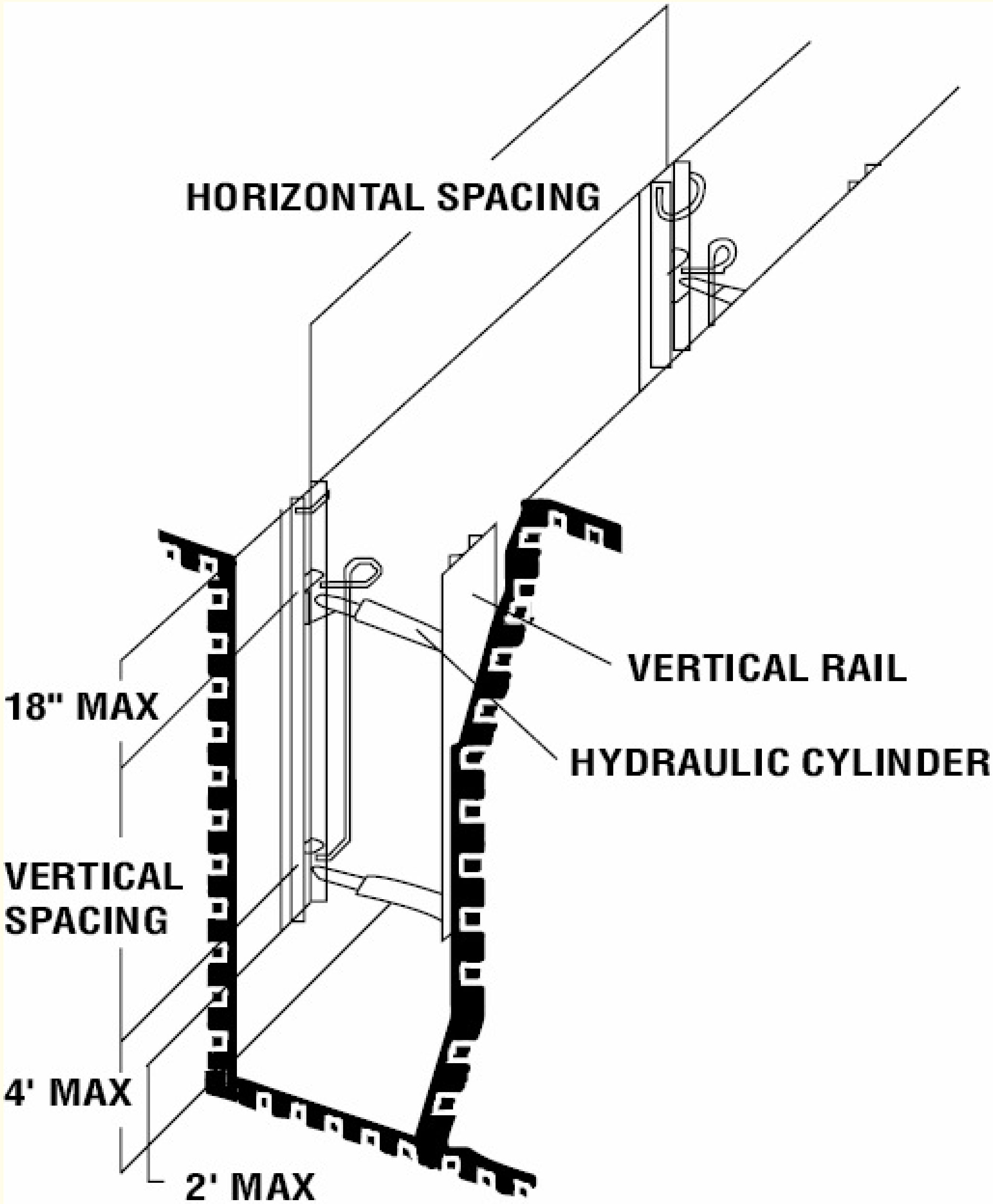


FIGURE D-1 Vertical aluminum hydraulic shoring (spot bracing).

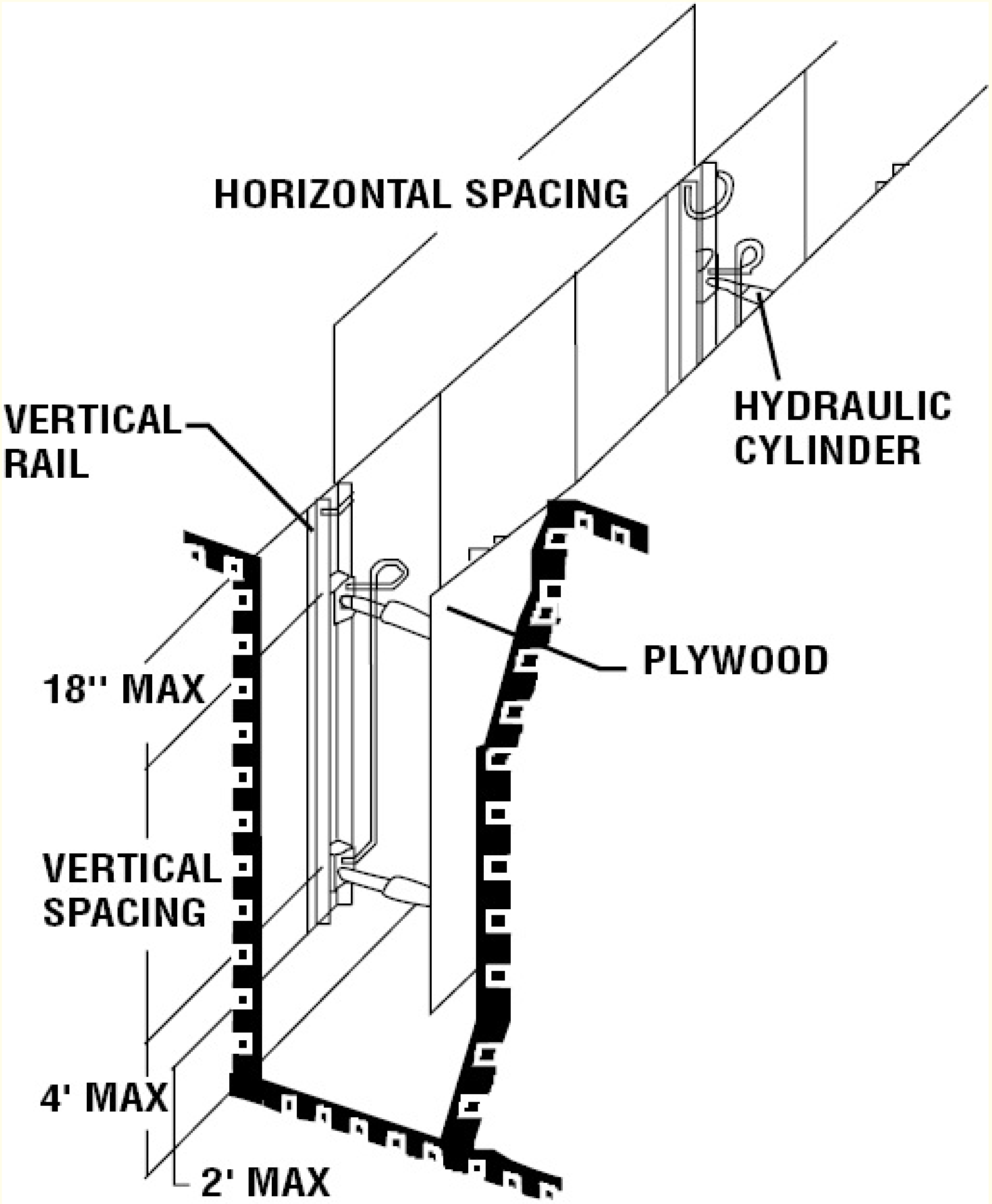


FIGURE D-2 Vertical aluminum hydraulic shoring (with plywood).

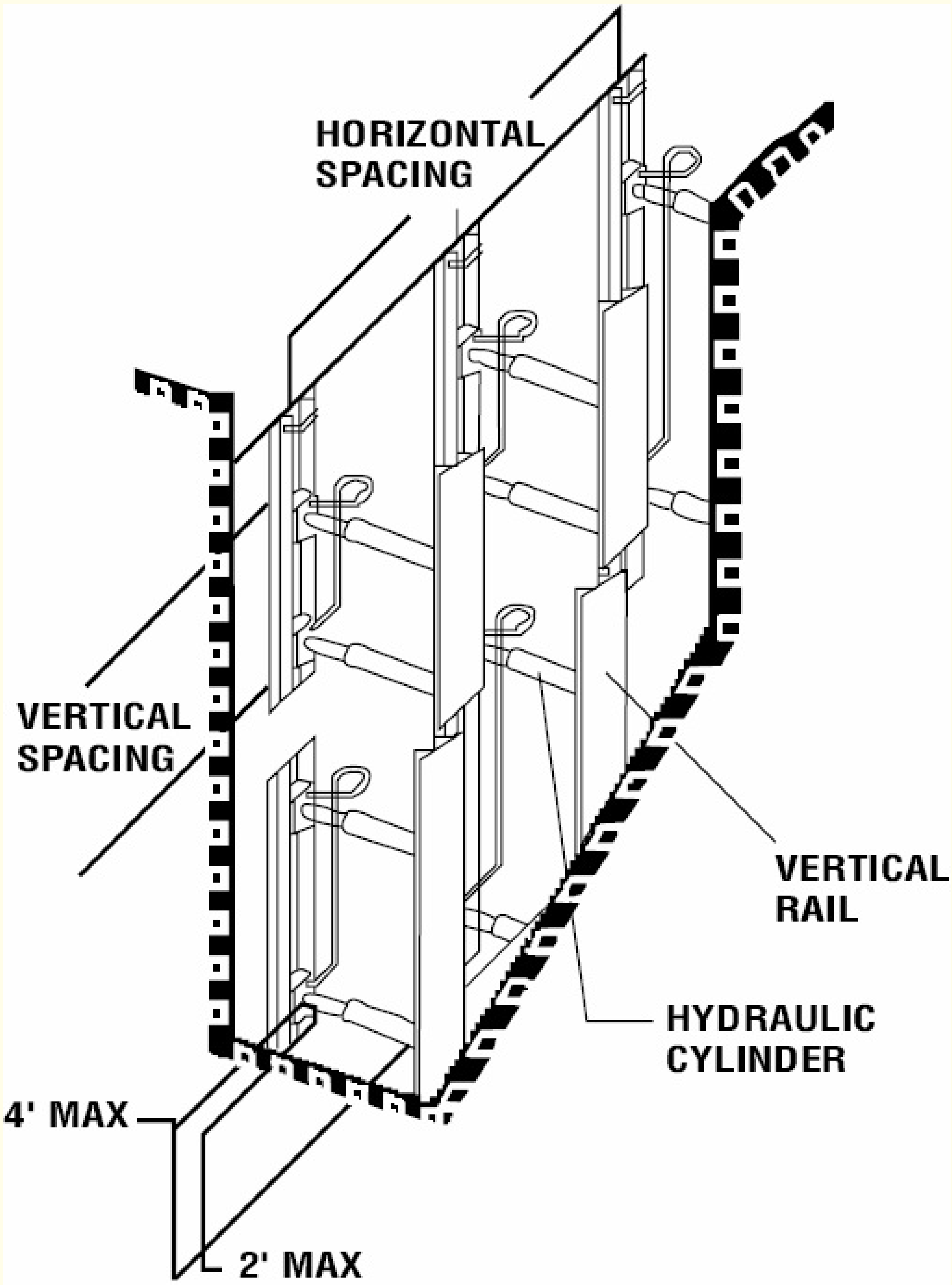


FIGURE D-3 Vertical aluminum hydraulic shoring (stacked).

g. Footnotes, and general notes, for Tables D-1.1 – D-1.4

1. For applications other than those listed in the tables, refer to 1926.652(c)(2) for use of manufacturer's tabulated data. For trench depths in excess of 20 feet, refer to 1926.652(c)(2) and 1926.652(c)(3).
2. 2 inch diameter cylinders, at this width, shall have structural steel tube (3.5 × 3.5 × 0.1875) oversleeves, or structural oversleeves of manufacturer's specification, extending the full, collapsed length.
3. Hydraulic cylinders capacities.
   i. 2-inch cylinders shall be a minimum 2-inch inside diameter with a safe working capacity of not less than 18,000 pounds axial compressive load at maximum extension.

Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

ii. 3-inch cylinders shall be a minimum 3-inch inside diameter with a safe work capacity of not less than 30,000 pounds axial compressive load at maximum extension. Maximum extension is to include full range of cylinder extensions as recommended by product manufacturer.

4. All spacing indicated is measured center to center.
5. Vertical shoring rails shall have a minimum section modulus of 0.40 inch.
6. When vertical shores are used, there must be a minimum of three shores spaced equally, horizontally, in a group.
7. Plywood shall be 1.125 inch thick softwood or 0.75 inch thick, 14 ply, arctic white birch (Finland form). Please note that plywood is not intended as a structural member, but only for prevention of local raveling (sloughing of the trench face) between shores.
8. See appendix C for timber specifications.
9. Wales are calculated for simple span conditions.
10. See appendix D, item (d), for basis and limitations of the data.

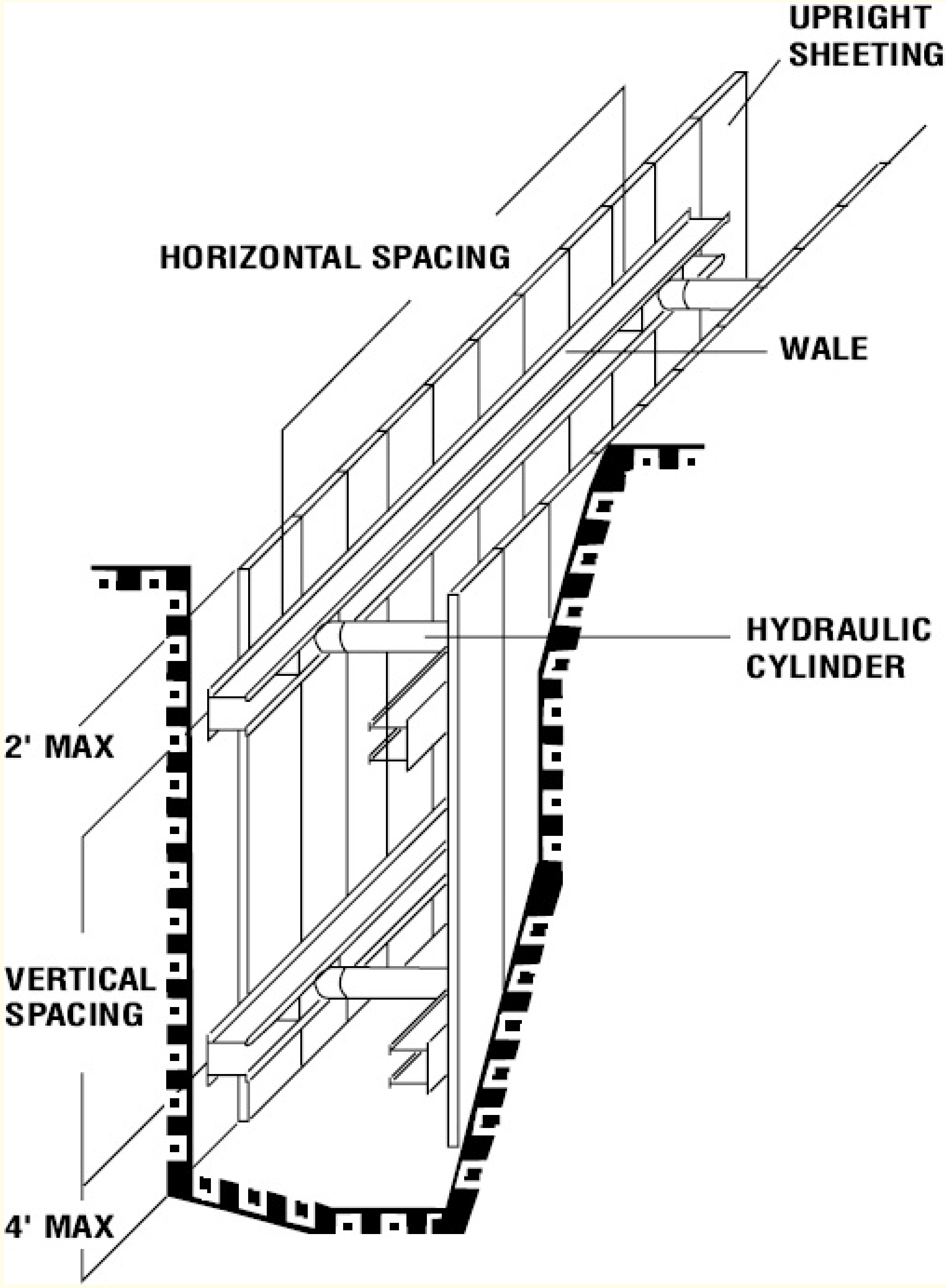


FIGURE D-4 Aluminum hydraulic shoring—Waler System (typical).

Table D-1.1 Aluminum Hydraulic Shoring: Vertical Shores for Soil Type A

DEPTH OF TRENCH (FEET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 UP TO 10	8	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
OVER 10 UP TO 15	8				
OVER 15 UP TO 20	7				
OVER 20	NOTE (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g)(1)
Note (2): See Appendix D, Item (g)(2)

Table D-1.2 Aluminum Hydraulic Shoring: Vertical Shores for Soil Type B

DEPTH OF TRENCH (FEET)	HYDRAULIC CYLINDERS				
	MAXIMUM HORIZONTAL SPACING (FEET)	MAXIMUM VERTICAL SPACING (FEET)	WIDTH OF TRENCH (FEET)		
			UP TO 8	OVER 8 UP TO 12	OVER 12 UP TO 15
OVER 5 UP TO 10	8	4	2 INCH DIAMETER	2 INCH DIAMETER NOTE (2)	3 INCH DIAMETER
OVER 10 UP TO 15	6.5				
OVER 15 UP TO 20	5.5				
OVER 20	NOTE (1)				

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g)(1)
Note (2): See Appendix D, Item (g)(2)

Table D-1.3 Aluminum Hydraulic Shoring: Waler Systems for Soil Type B

DEPTH OF TRENCH	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
			WIDTH OF TRENCH (FEET)						MAX. HORIZ. SPACING (ON CENTER)		
			UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO 15				
	VERTICAL SPACING (FEET)	SECTION MODULUS (IN^3)	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	SOLID SHEET	2 FT.	3 FT.
OVER 5 UP TO 10	4	3.5	8.0	2 IN	8.0	2 IN NOTE (2)	8.0	3 IN	—	—	3 × 12
		7.0	9.0	2 IN	9.0	2 IN NOTE (2)	9.0	3 IN			
		14.0	12.0	3 IN	12.0	3 IN	12.0	3 IN			
OVER 10 UP TO 15	4	3.5	6.0	2 IN	6.0	2 IN NOTE (2)	6.0	3 IN	—	3 × 12	—
		7.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 15 UP TO 20	4	3.5	5.5	2 IN	5.5	2 IN NOTE (2)	5.5	3 IN	3 × 12	—	—
		7.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
		14.0	9.0	3 IN	9.0	3 IN	9.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)
Note (1): See Appendix D, Item (g)(1)
Note (2): See Appendix D, Item (g)(2)
* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

Table D-1.4 Aluminum Hydraulic Shoring: Waler Systems for Soil Type C

DEPTH OF TRENCH	WALES		HYDRAULIC CYLINDERS						TIMBER UPRIGHTS		
			WIDTH OF TRENCH (FEET)						MAX. HORIZ. SPACING (ON CENTER)		
			UP TO 8		OVER 8 UP TO 12		OVER 12 UP TO 15				
	VERTICAL SPACING (FEET)	SECTION MODULUS (IN^3)	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	HORIZ. SPACING	CYLINDER DIAMETER	SOLID SHEET	2 FT.	3 FT.
OVER 5 UP TO 10	4	3.5	6.0	2 IN	6.0	2 IN NOTE (2)	6.0	3 IN	3 × 12	—	—
		7.0	6.5	2 IN	6.5	2 IN NOTE (2)	6.5	3 IN			
		14.0	10.0	3 IN	10.0	3 IN	10.0	3 IN			
OVER 10 UP TO 15	4	3.5	4.0	2 IN	4.0	2 IN NOTE (2)	4.0	3 IN	3 × 12	—	—
		7.0	5.5	3 IN	5.5	3 IN	5.5	3 IN			
		14.0	8.0	3 IN	8.0	3 IN	8.0	3 IN			
OVER 15 UP TO 20	4	3.5	3.5	2 IN	3.5	2 IN NOTE (2)	3.5	3 IN	3 × 12	—	—
		7.0	5.0	3 IN	5.0	3 IN	5.0	3 IN			
		14.0	6.0	3 IN	6.0	3 IN	6.0	3 IN			
OVER 20	NOTE (1)										

Footnotes to tables, and general notes on hydraulic shoring, are found in Appendix D, Item (g)

Note (1): See Appendix D, Item (g)(1)

Note (2): See Appendix D, Item (g)(2)

* Consult product manufacturer and/or qualified engineer for Section Modulus of available wales.

■ Appendix E to Subpart P of Part 1926—Alternatives to Timber Shoring

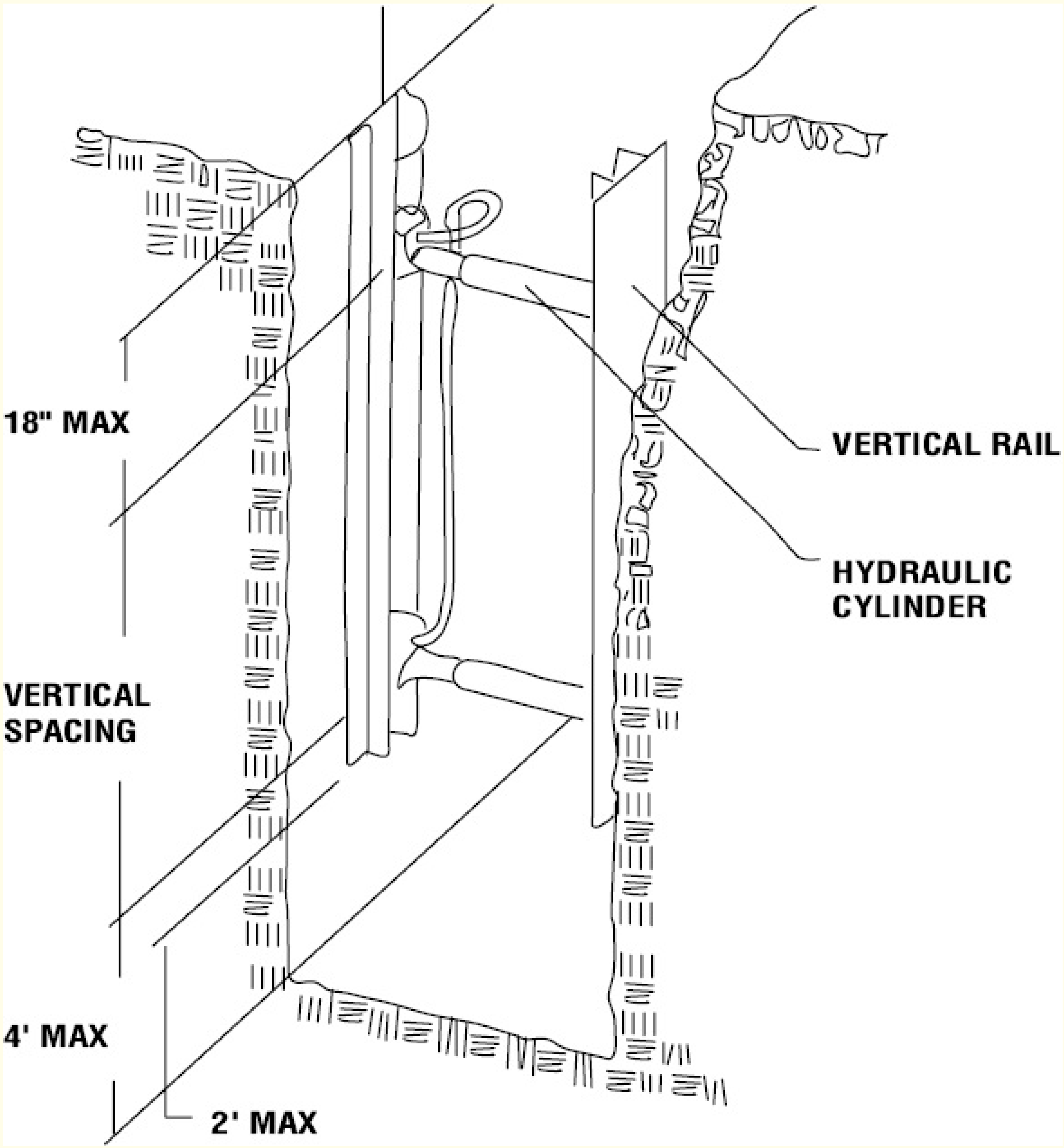


FIGURE E-1 Aluminum hydraulic shoring.

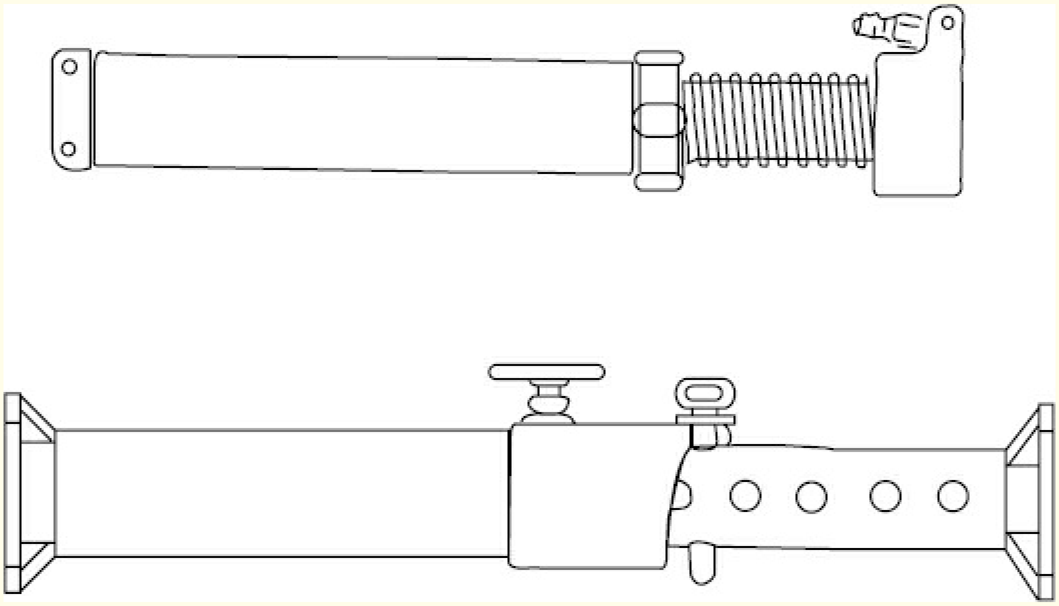


FIGURE E-2 Pneumatic/hydraulic shoring.

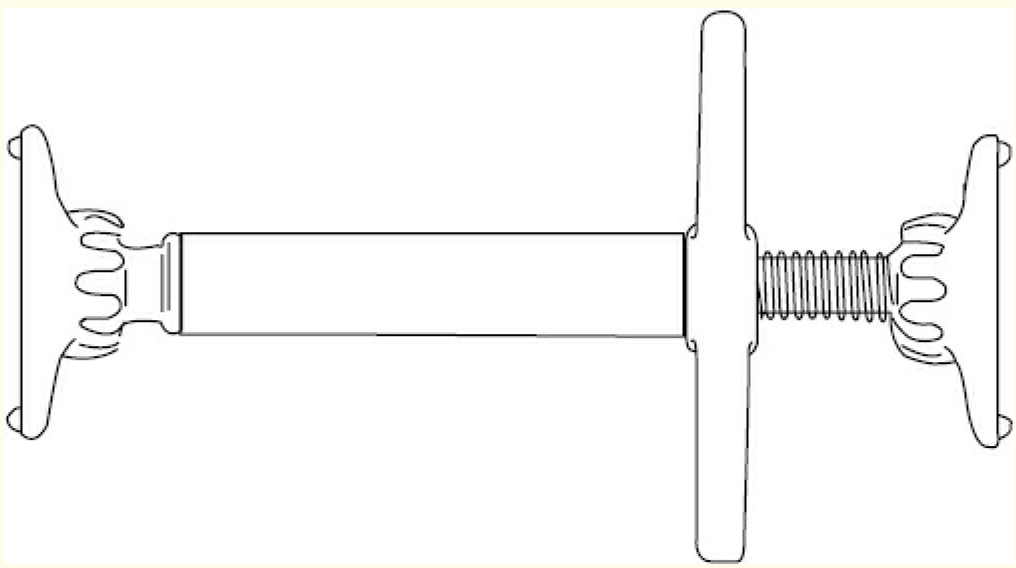


FIGURE E-3 Trench jacks (screw jacks).

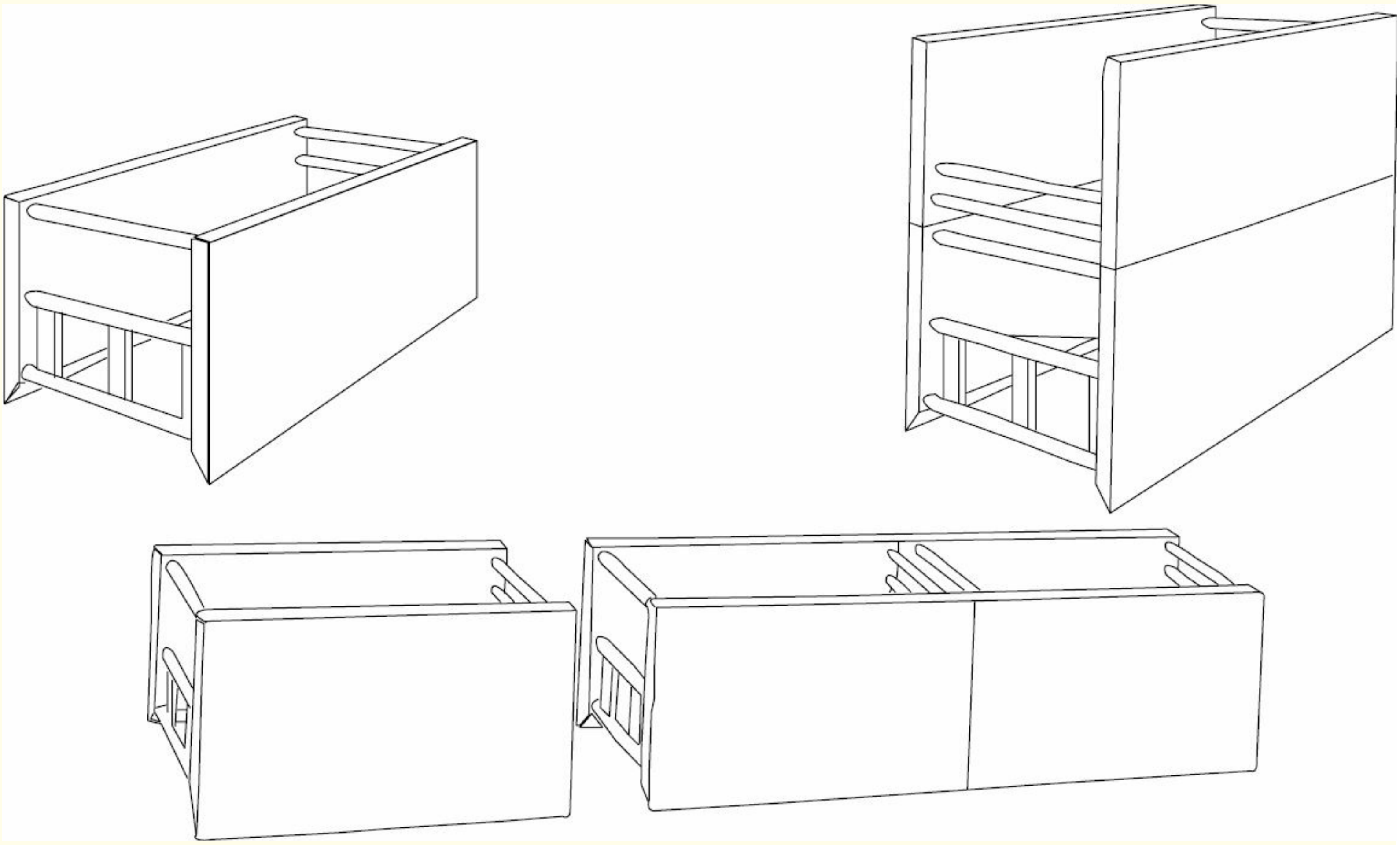


FIGURE E-4 Trench shields.

■ Appendix F to Subpart P of Part 1926—Selection of Protective Systems

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Protective systems for use in excavations more than 20 feet in depth must be designed by a registered professional engineer in accordance with 1926.652(b) and (c).

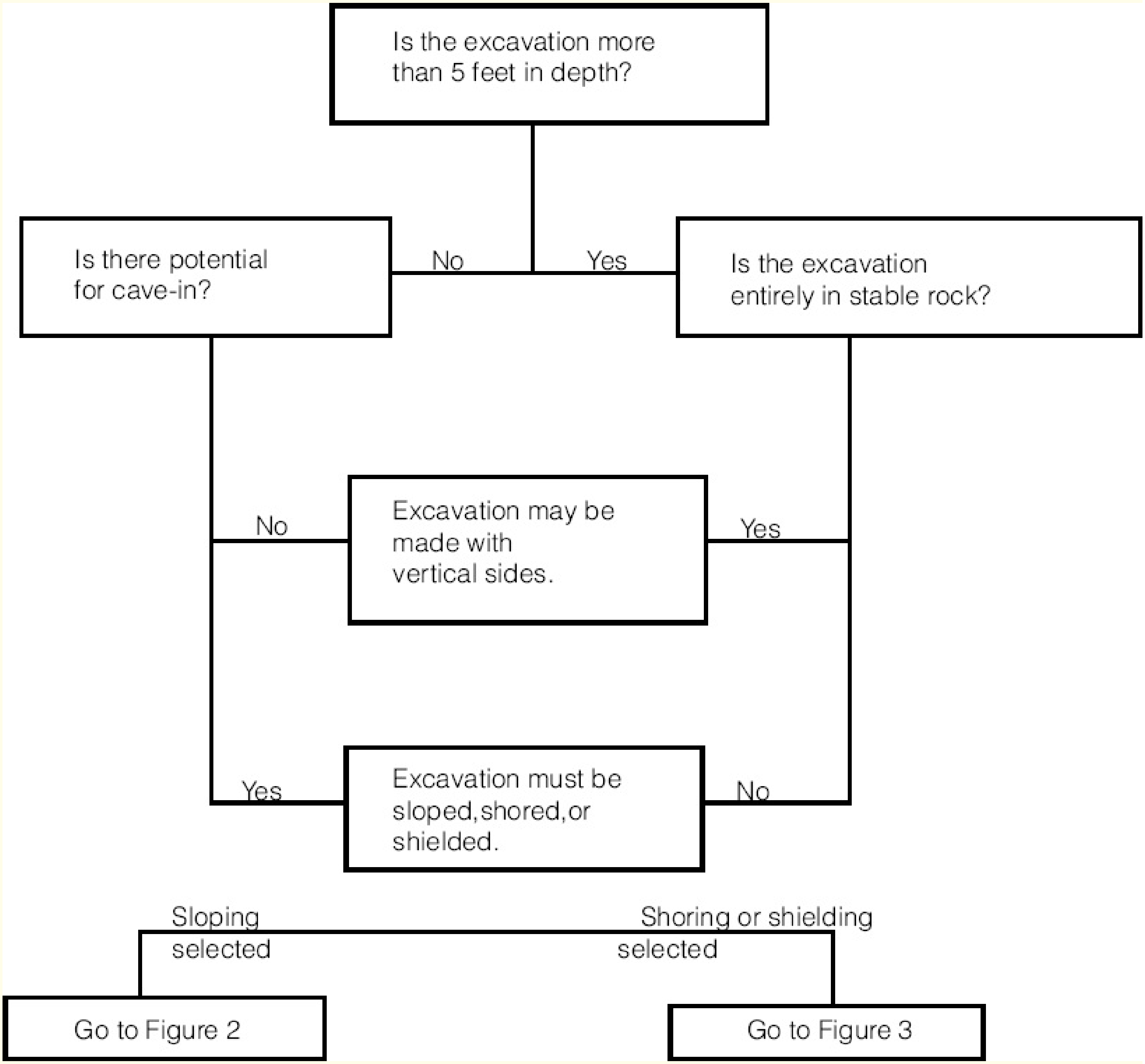


FIGURE F-1 Preliminary decisions.

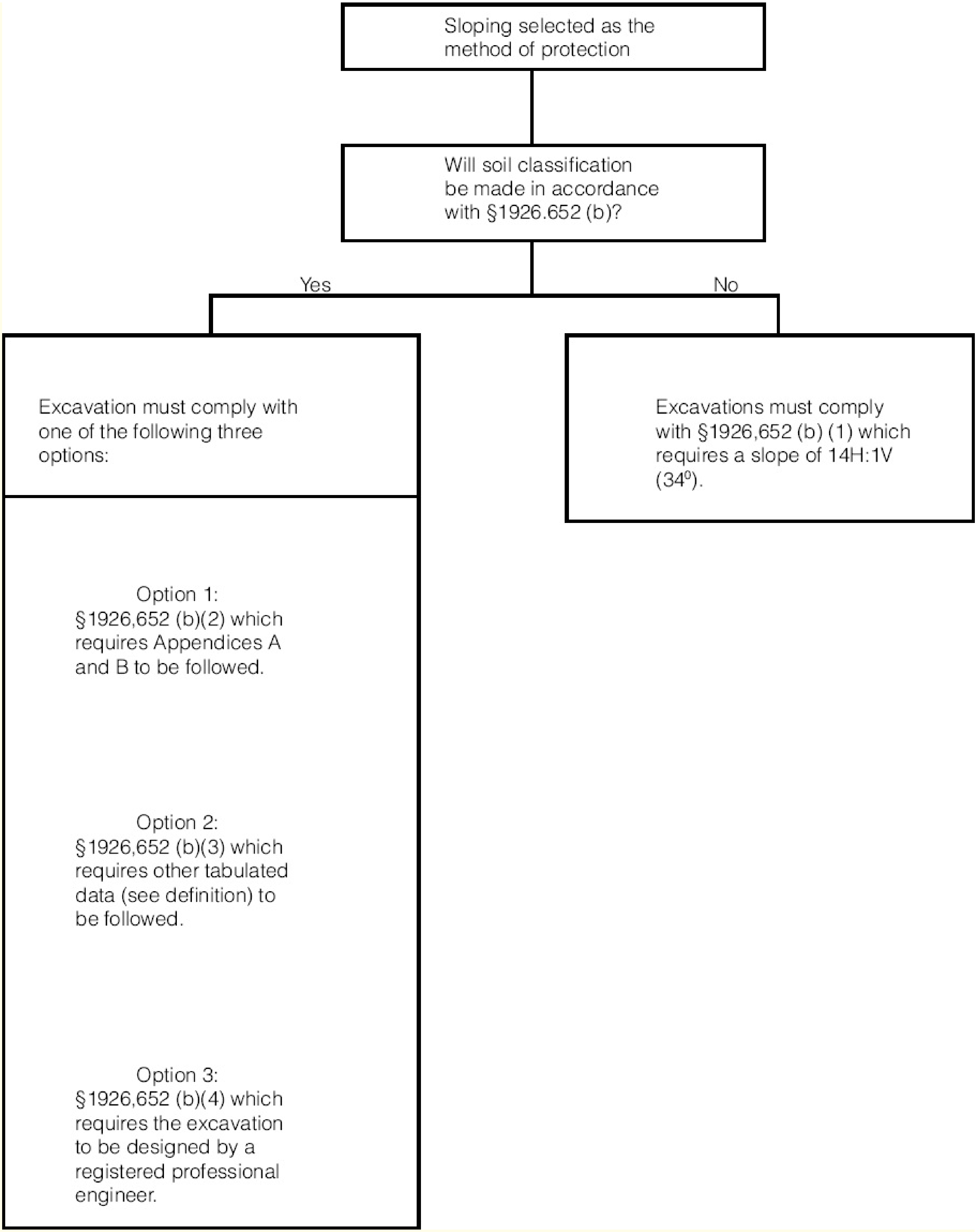


FIGURE F-2 Sloping options.

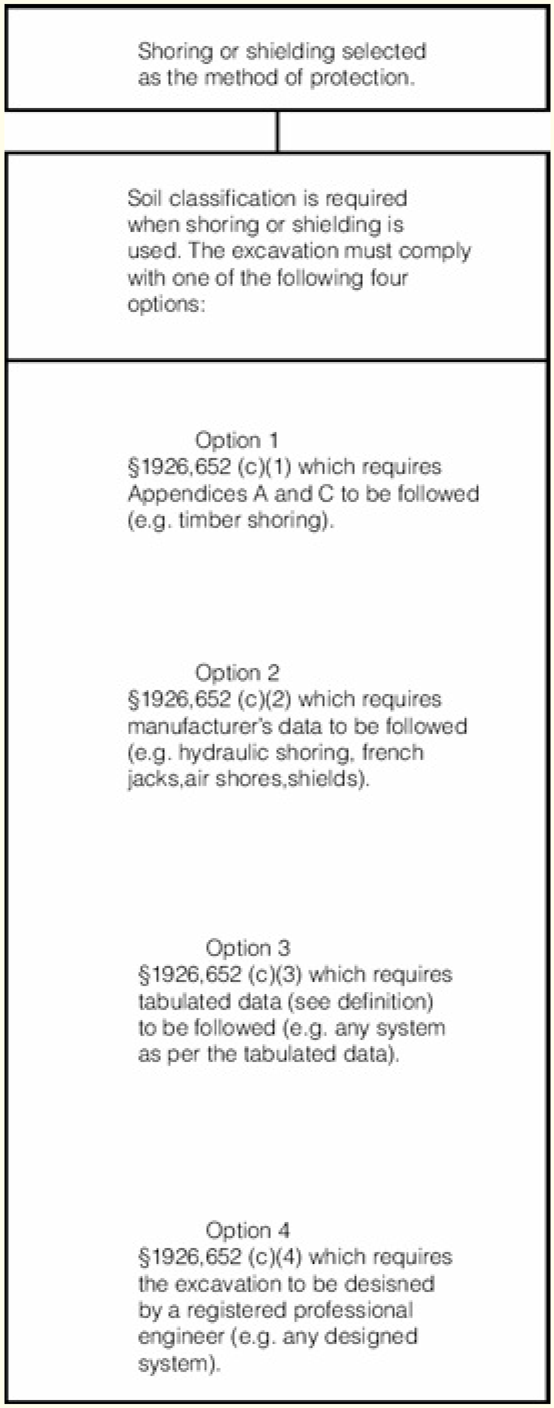


FIGURE F-3 Shoring and shielding options.

Glossary

Action guidelines A list of guidelines indicating which specific action(s) you should take when monitor readings reach certain levels.

Activation force A measurement of the total force that the strut exerts. The total force is calculated by multiplying the strut surface area (square inches) by the pressure (pounds per square inch). Using the formula radius squared (r^2) times pi (3.14), find the surface area of a cylinder ($r^2 \times 3.14$); then multiply the surface area by the strut pressure to get the activation force.

Active soil Soil containing energy as it relates to movement.

Air knife Tool that injects air into the soil at approximately 100 pounds per square inch (7 kg/cm) for the purpose of breaking the soil into smaller particles.

Air supply operations Activities to ensure proper operation of the air equipment and to gather and secure the necessary air supply.

Alarm settings The preset levels within a monitor at which the monitor will display a visual alert and sound an audible alarm. These settings are established by the manufacturer and are based on Occupational Safety and Health Administration and National Institute of Occupational Safety and Health standards for a given product. For confined spaces, they are referred to as action guidelines.

Angle of repose The natural angle at which loose particulate products will support their own weight and can be expected not to flow from a standing position.

Atterberg test Test done in a laboratory to determine the liquid limit (water content, in percent, of a soil at an arbitrarily defined boundary), the plasticity index (range of water content over which a soil behaves plastically), and plastic limit (water content, in percent, of a soil at the boundary between the plastic and semi-solid states).

Authority having jurisdiction (AHJ) The local authority that draws on the power of law to make rules and regulations for the organization.

Awareness level The level of rescuer where the first responder can identify the hazards associated with collapse and its associated dangers.

Axial loading A force that is applied in the same direction as the shaft.

Backhoe A piece of excavating equipment consisting of a digging bucket on the end of a two-part articulated arm. It is typically mounted on the back of a tractor or front loader.

Bell pier condition A toe failure that occurs on both sides of the trench.

Benching Cutting back soil in benches of an appropriate height and width to meet the specifications as determined by the soil profile.

Big Three The special people, special equipment, and special training that constitute a good rescue team.

Center of gravity The point on a body around which the body's mass is evenly distributed.

Centrifugal vacuum truck Apparatus that uses a large fan to create suction in the intake line.

Class 3 harness Harness designed with lower body and upper body attachments.

Class I lever Lever in which the fulcrum is located between the force and the load.

Class II lever Lever in which the load is located between the fulcrum and the force.

Class III lever Lever in which the force is located between the load and the fulcrum.

Clay A fine-grained substance that is plastic when moist.

Combustible gas indicator (CGI) A device used to determine the presence of flammable vapors and hydrocarbon products that might be present in a trench.

Community-dependent systems Rescue systems in which rescue organizations work with specialty functions in the community that can assist when a specialized rescue event occurs.

Competent person The individual, usually the supervisor, who meets the OSHA standard for determining soil profiles, safety concerns, protective mechanisms, and other performance requirements.

Consensus standards Published standards, created by interested stakeholders, that act as a consensus of best practices for the industry.

Consolidation test Test used to determine the settling potential of a soil.

Converted vehicles Vehicles that were originally intended for some other use but have been converted for trench rescue purposes.

Corner blocks Specially designed and cut wale pieces that fit in the corner of the outside L wales and provide a platform for angle shores to be installed from the thrust blocks.

Corner brackets Metal (preferably high-strength aluminum) brackets that bolt on to pre-drilled panels. They can be used on the inside corner of any trench that intersects at a 90-degree angle. Such brackets hold the inside corner panels together, providing shear force resistance and allowing both panels to be installed at one time.

Creating the future Portion of the time allocation model that pertains to those members whose primary role is the organization's strategic direction.

Critical incident stress debriefing (CISD) Process used to debrief rescue personnel after an emotionally charged incident.

Crush syndrome Medical condition that is the result of a prolonged entrapment where the victim's body tissue is crushed and circulation to the tissue is restricted.

Custom vehicles Vehicles specifically designed for the intended purpose and use.

Cutting team Personnel responsible for all cutting and manufacturing of systems that contain wood.

Detection The act of discovering the presence of a contaminant in a given atmosphere.

Dewatering devices Devices that control water from both ground seepage and rainwater runoff.

Dry strength test Test used to determine the propensity of a soil to fissure.

Drying test Test used to determine the difference between cohesive material with fissures, unfissured cohesive material, and granular material.

Dump truck A vehicle with a hydraulic lift under the cargo bed that, when operated, allows cargo to be dumped.

Duplex nail Nail that has two shoulders, which allows it to be removed easily.

Energy The capacity for doing work and overcoming resistance.

Engineered system Shoring or shielding system designed by registered professional engineers. Safety factors in such systems are calculated ratios of the system strength divided by soil force.

Entrenching tool A small, collapsible version of the larger shovel, designed to be used in situations where space is limited and a regular shovel is too big.

Excavation Any human-made cut, cavity, trench, or depression in an earth surface formed by the earth's removal. In practical terms, when a hole is more than 15 feet (4.5 m) wide at its base, it is called an excavation. Overall, an excavation is wider than it is deep.

Excavation rescue shoring Specially designed raker shoring system made with pneumatic struts, FinnForm panels, and aluminum wales.

Excavator An engineering vehicle consisting of an articulated arm, bucket, and cab mounted on a pivot fastened to tracks or wheels.

Explosive limits The percentage of a gas in an air mixture, as noted through atmospheric monitoring, that indicates the explosiveness of the gas. Readings indicate the upper explosive limit (UEL) or lower explosive limit (LEL).

Extrication officer Individual responsible for the actual extrication of the victim and for all activities that are required to facilitate the rescue.

FAILURE Acronym used to describe the various reasons why technical rescue incidents are unsuccessful.

Flammable range The percentage of vapor in air that must be present to sustain combustion should an ignition source be present.

Flat-bed vehicle A vehicle with a cargo area that is flat and has no sides or roof.

Freestanding time The amount of time an excavation is open to the elements.

Friction Measure of the amount of force it takes to move an object across the surface of another object.

General area The area that is not in the immediate vicinity of the extrication effort.

Gravity The force of attraction between two bodies that have mass.

Ground pads Wooden material used to line the trench lip for the purpose of distributing rescuer and equipment weight.

Head versus heart decision making Process of using cognitive ability to evaluate the essential risk–benefit factors instead of using compassion as the overriding factor.

High-pressure air bags Rubber or neoprene bags with a coarse surface to increase the friction between the bag and the lifting surface.

Hydraulic shores Type of shore that is lowered into the trench from the top and then expanded by using a 5-gallon reservoir of nonflammable and biodegradable fluid.

Hydrostatic pressure Pressure caused by the addition of water to a soil profile.

Immediately dangerous to life and health (IDLH) Maximum concentration of a substance from which a person could escape (in the event of respirator failure) within 30 minutes without permanent or escape-impairing effects.

Improving the system Portion of the time allocation model that pertains to coordinating the various levels of the organization to create greater efficiency and effectiveness.

Incident commander (IC) Individual responsible for developing the strategic goals for the operation.

Incident command system (ICS) Management system by which emergency personnel are assigned specific responsibilities and areas of supervision.

Inclined planes Angled planes that gain efficiency by reducing required force over time.

Inside wales Wales used to span a set of panels to create an open space in a trench. They are used in most intersecting trench shoring designs.

Isolation device A concrete manhole ring, pre-cast concrete catch basin, concrete vault, or steel or concrete pipe that is placed over a victim in a trench to provide a degree of protection. Typically, such a cylinder-shaped object is placed over a victim while running or loose material is being excavated.

Lever A simple machine used to move a load. It includes a fulcrum (pivot point), a force, and a load.

Liaison officer Individual responsible for providing information and gathering information from organizations and people outside of the immediate rescue effort.

Lip The area 360 degrees around the opening of the trench and extending down 2 feet (0.6 m). This area is very dangerous.

Lip bridges A type of lip protection built with girders (timbers), beams (ladders or timbers), decking (plywood or lumber), and supports (small pieces of timbers), which is placed away from the compromised wall and used to elevate the bridge above the lip.

Liquid limit Water content, in percent, of a soil at an arbitrarily defined boundary.

Lockout/tagout Part of a procedure used to bring an object into a zero mechanical state; it involves shutting down and locking or tagging equipment so it cannot be used.

Logistics officer Individual responsible for obtaining the appropriate equipment and personnel for deployment by the operations officer.

Low-pressure air bags Flexible rubber bags used primarily in trench rescue to fill voids in trench walls.

Mechanical advantage The force achieved using a tool, mechanical device, or other equipment.

Mechanics A branch of physics that deals with motion and the forces that cause it.

Medical officer Individual responsible for establishing a medical control area to treat any on-scene rescuer injury and to provide for victim care as necessary.

Moment of force The amount of force rotating around the fulcrum times the distance from the fulcrum.

NFPA 1006, *Standard for Technical Rescuer Professional Qualifications* The National Fire Protection Association standard that addresses rescue technician professional qualifications.

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents* The National Fire Protection Association standard that addresses operations and training for technical rescue incidents.

Non-entry rescue Rescue techniques employed to eliminate the necessity of rescue personnel entering a hazardous area.

Nuclear moisture density gauge A portable device used to measure soil density and moisture.

Operating the system Portion of the time allocation model that speaks to direct service delivery to the public.

Operations level The first level of rescuer at which personnel learn the necessary techniques to render trenches that are 8 feet (2.4 m) or less in depth, and that do not intersect, safe for rescue operations.

Operations officer Individual responsible for overall coordination of the rescue effort and the implementation of the tactical decisions that will make the incident commander's strategy successful.

Organizational pyramid The hierarchal structure of organizations in which the lowest-ranking and largest number of members are located on the bottom and the highest-ranking and fewest members are at the top.

OSHA CFR 1926 Subpart P Occupational Safety and Health Administration Code of Federal Regulations 1926 is the general construction standard; Subpart P refers to the trenching and excavation section.

Overburden pressure The pressure that the weight of the spoil pile or other object exerts on the trench.

Panel team Personnel responsible for setup, carrying, and installation of all shields or panels.

Passive soil Soil with no potential for movement.

Penetrometer A field instrument that can be used to determine the unconfined compressive strength of the soil sample.

Personnel accountability system System used by command to track personnel resources on the scene of an emergency.

Plastic limit Water content, in percent, of a soil at the boundary between the plastic and semisolid states.

Plasticity index The range of water content over which a soil behaves plastically.

Plasticity test Test used to determine the ability of the soil to be deformed or molded without an appreciable change in its total volume.

Pneumatic air shores Type of shore that is extended by using compressed air. After extension, the shore either locks by itself or is manually locked to prevent a collapse under load.

Pod system A self-contained unit that holds equipment specific to one type of specialized rescue function and that can be delivered to the scene as required when the incident occurs.

Preoperational briefing Briefing given to all personnel prior to entering the immediate rescue area or participating in the rescue effort.

Previously disturbed soils Soils that lack cohesiveness because they are broken and/or mixed with other soil types.

Public information officer Individual who provides information to the media regarding incident activities.

Rabbit box Portable (modular) trench box made from aluminum or other material that can be built and adjusted on-site.

Rapid intervention crew (RIC) Team established and equipped to handle everything from intervention for a secondary collapse or a medical emergency involving a member of the rescue team.

Regional approach Sharing specialized rescue functions among organizations to create less regional duplication of resources.

Rehabilitation An area that provides for rescue personnel rotation to address medical monitoring and fluid replacement needs.

Rescue area The area located immediately surrounding the rescue site.

Rescue soil assessment A quick assessment (manual and visual) used by rescuers to identify soil conditions and assign levels of risk associated with those conditions.

Rescue trucks Large, multipurpose vehicles that are specifically designed to transport specialized rescue equipment and rescue team members.

Ribbon test Test used to determine how much clay or silt a soil contains.

Rigging team Personnel responsible for establishing the systems by which any person or object will be lifted and/or moved during the trench emergency incident.

Risk–benefit analysis Decision-making process used to evaluate the level of risk involved in a situation versus the potential benefit that can be achieved based on the proposed intervention.

Rotational failure A scoop-shaped collapse that starts back from the trench lip and transmits itself to the trench wall in a half-moon shape; also called slough failure.

Safety officer Individual responsible for all aspects of the operations that deal with safety and health of the rescue personnel.

Scabs Small pieces of lumber, usually 2 × 4 inches, that are used to hold shores and other connective devices in place.

Screw jack Type of shore that is tightened by a thread and yoke assembly. It is also sometimes referred to as a pipe jack when used in conjunction with varying lengths of pipe.

Sedimentation test Test used to determine the profile of a soil based on stratification of its elements in water.

Self-contained breathing apparatus (SCBA) A respirator that supplies air to the user from a breathing air source that is independent of the environment. It is designed to be carried by the user.

Self-sufficient Able to provide all levels of specialized rescue service and to maintain the special equipment and trained personnel for that purpose.

Shear vane A field instrument that can be used to determine the unconfined compressive strength of the soil sample.

Shear wall collapse A collapse that occurs when a section of soil loses its ability to stand and falls into the trench along a mostly vertical plane.

Sheeting The portion of the protective system designed to hold back running debris.

Shores The component in the protective system that carries the force from one side of the trench to the other.

Shoring team Personnel who assemble and install all shores and wales required to make the protective system in a trench collapse.

Silt Loose soil made up mostly of fine rock.

Size-up Determination and analysis of information used to develop a rescue plan of action for an incident.

Skip shoring Shoring done with strongbacks only (no panels).

Sloping Cutting soil back to a predetermined angle based on the soil's profile.

Slough failure The loss of part of the trench wall starting at an area back from the trench lip and extending down into the trench wall.

Soldier piling A system in which Z-shaped or H-sheet interlocking piles are driven into the ground and then held in place with vertical connections at a spacing that is appropriate for the depth of the excavation and class of soil.

Span of control The number of workers whom a supervisor can manage based on the type of work being performed.

Specialized training cycle The constant circle of evaluation involving the Big Three.

Spoil pile Excavated dirt removed from the trench.

Spoil pile slide The result of excavated earth that is placed too close to the lip and subsequently falls into the trench.

Spot shoring Shoring that does not use traditional strongbacks or panels, but instead uses specially designed rail bases installed directly on the trench walls.

Staging officer Individual responsible for ordering and maintaining adequate resources at the scene to handle additional requests for equipment and personnel.

Stop work/evacuation notification procedure A predetermined signal or sound that indicates an unsafe condition.

Strategic level Level of the incident management structure that decides *what* needs to be done; it includes the incident commander, safety officer, liaison officer, and public information officer.

Strongbacks The 2-inch × 12-inch × 12-foot components in the protective system that transmit forces along the vertical plane of the trench wall.

Strut pressure The amount of air pressure that the air system sends to the strut. It is measured in pounds per square inch (psi) and can be seen on the air system's gauge.

Struts *See* Shores.

Supplied air breathing apparatus (SABA) A respirator that supplies breathing air to the user from an air source that is independent of the environment, supplied from a remote source. It is not designed to be carried by the user.

Survivability profile Determination, based on a thorough risk–benefit analysis and other incident factors, that addresses the potential for a victim to survive or die with or without rescue intervention.

Tactical level Level of the incident management structure that takes the strategic plan developed by the incident commander and implements the tactics necessary to achieve success.

Task level Level of the incident management structure that includes the personnel who are responsible for implementing the tactical objectives.

Technical rescue Use of specialized rescue skills and tools to save life and property through actions not normally associated with traditional firefighting. These areas include rope rescue, swiftwater rescue, confined-space rescue, cave rescue, trench/excavation rescue, building collapse rescue, and other nontraditional specialized rescue functions.

Technical rescue skills package training The complete package of training that includes confined space, vehicle rescue, rope rescue, structural collapse rescue, and trench rescue.

Technician level The level of rescuer that requires additional training associated with intersecting and deep wall trench rescue operations.

Thrust blocks Specially designed and cut 6 × 6-inch pieces that fit over the strongback and provide both a flat surface and an angled surface for use as a platform for installed shores.

Thumb penetration test Test used to estimate the unconfined compressive strength of cohesive soils.

Timber shore Type of shore with a bending strength of not less than 1500 psi (105.5 kg/cm).

Time allocation model A model that describes leadership based on the individual's level in the organization and the kinds of activities that he or she should be spending the most time trying to accomplish.

Toe failure A slough failure that occurs at the bottom of the trench where the floor meets the wall.

Trench A narrow excavation (in relationship to its length) made below the surface of the ground. In general, the depth is greater than the width, but its width measured at the bottom does not exceed 15 feet (4.5 m).

Trench boxes A premade shielding system that can be placed and lowered as digging operations continue.

Trench rescue A specialized rescue discipline that involves the shoring of a trench/excavation and subsequent removal of a victim who is trapped in soil or some other encapsulating form or implement.

Trench rescue shoring The method used to install protective systems at a collapse with victims trapped.

Triaxle shear test Test used to determine the direct shear strength of a soil.

Unconfined compressive strength (UCS) The force or load per unit area, as calculated with a penetrometer or other device and stated numerically in tons per square foot, that determines the point at which a soil will fail in compression.

Vacuum system Equipment that uses a standard hose with couplings and specially designed nozzles to create vacuum pressure and that attaches to most types of municipal vacuum trucks.

Varying soil profiles Multiple layers of different soils found at various levels in the trench or excavation wall.

Victim survivability profile Determination based on a thorough risk–benefit analysis and other incident factors that address the potential for a victim to survive or die with or without rescue intervention.

Water table The top of the water surface in the saturated part of an aquifer.

Wedge failure A failure that usually occurs in intersecting trenches, in which an angled section of earth falls from the corner of two intersecting trenches.

Work Distance times force.

Wristlets Webbing or other material designed to wrap around the wrist for the purpose of providing a lifting or pulling attachment point.

Zero mechanical state A situation in which there is no possibility that any mechanical activation could take place.

Index

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